Armidale Regional Landfill
Armidale Dumaresq Council
15-Jun-2017

Water Quality Monitoring Plan

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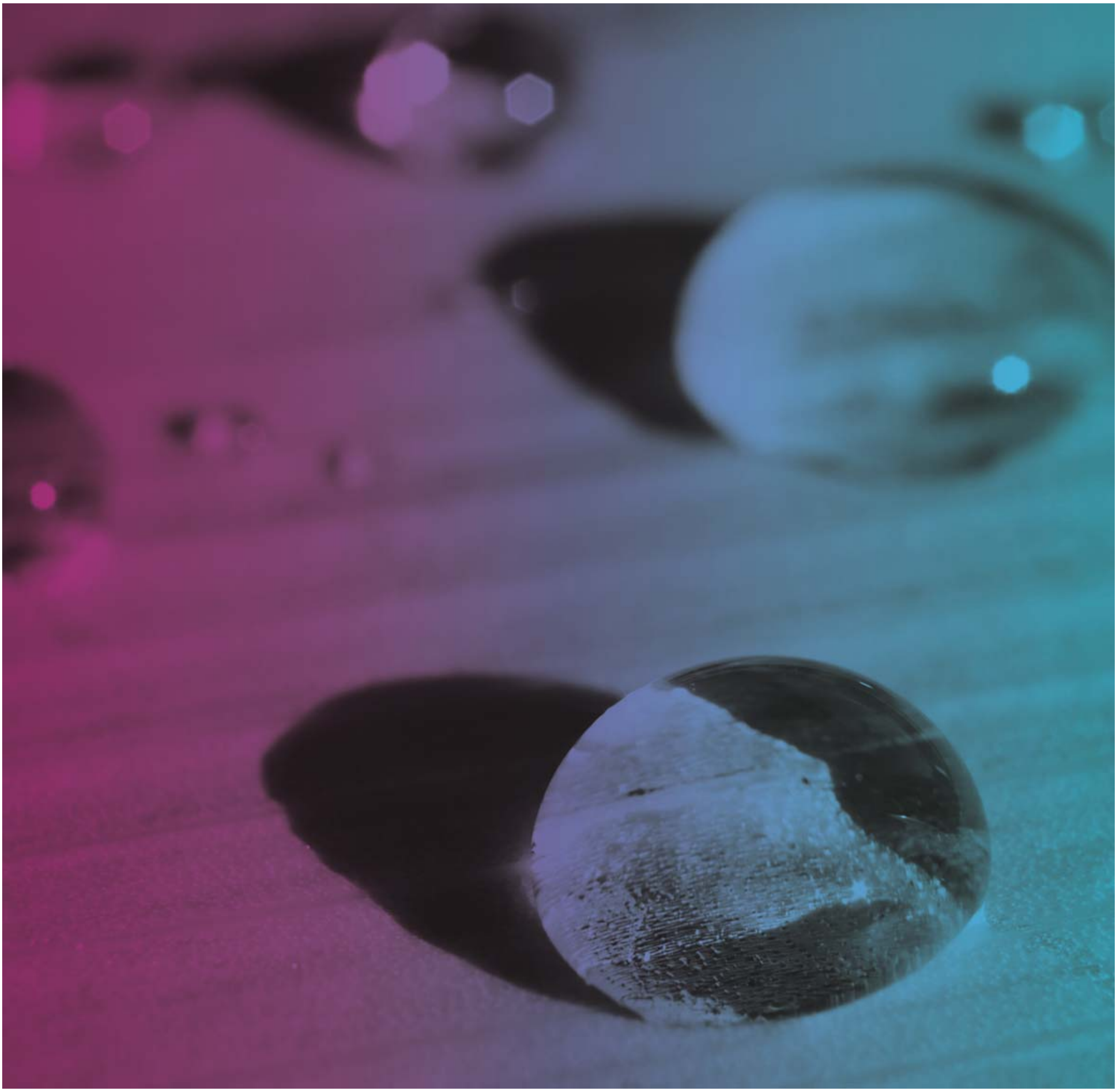

Water Quality Monitoring Plan

Armidale Regional Landfill

Client: Armidale Dumaresq Council

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15-Jun-2017

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Quality Information

Document	Water Quality Monitoring Plan
Ref	ARLF-LEMP-RP-0010-WQMP-G
Date	15-Jun-2017
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Reviewed by	Graham Hawkes and Danielle Poirier

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
1	18-Jan-2010	Issued with Environmental Assessment	Chris Carloss EA Project Manager	On original
A	18-May-2015	Updated draft for Council review	Danielle Poirier, Associate Director - Environment	
A1	25-May-2015	Council review	James Turnell, Waste Manager & CodyHart Environmental	
B	29-May-2015	Final draft for review	Danielle Poirier, Associate Director - Environment	
C	21-Oct-2015	Issue to EPA and DPI Water	Danielle Poirier, Associate Director - Environment	
D	26-Feb-2016	Issue to DP&E for approval	Danielle Poirier, Associate Director - Environment	
E	6-Sept-2016	Revised following consultation with DPI Water and issued to DP&E for approval	Danielle Poirier, Associate Director – Environment	DPoirier
F	3-May-2017	Revised to incorporate comments from DotEE	Alexandra Frolich Principal Environmental Scientist	
G	3-Jun-2017	Revised to incorporate comments from DotEE	Alexandra Frolich Principal Environmental Scientist	

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Abbreviations

ANZECC	The Australian and New Zealand Environment Conservation Council
BOD	Biochemical Oxygen Demand
COC	Chain of Custody
DEWHA	(former) Department of Environment, Water, Heritage and the Arts (Commonwealth)
DO	Dissolved Oxygen
DotEE	Department of the Environment and Energy (Commonwealth)
DP&E	Department of Environment
DQOs	Data Quality Objectives
EC	Electrical Conductivity
EPA	Environment Protection Authority
FRP	Filterable Reactive Phosphate
GRAWHA	Gondwana Rainforests of Australia World Heritage Area
LEMP	Landfill Environmental Management Plan
NEPM	National Environment Protection Measure
NHNRC	National Health and Nutrition Research Council
NRMMC	National Resource Management Ministerial Council
OC	Organochlorin
OEH	Office of Environment and Heritage
ORP	Oxidation Reduction Potential
STP	Sewage Treatment Plan
SWL	Standing Water Levels
SVOC	Semi Volatile Organic Compound
SWMS	Safe Work Method Statement
TDS	Total Dissolved Salts
TKN	Total Kijedahl Nitrogen
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
VOCs	Volatile organic compounds
WLMP	Water and Leachate Management Plan
WQMP	Water Quality Monitoring Plan

1.0 Introduction

1.1 Project Background

Armidale Dumaresq Council (Council) has approval for the construction and operation of a new regional landfill to service the Armidale region. The landfill site is located on Waterfall Way, approximately 12 km east of Armidale.

The Planning Assessment Commission, as delegate for the then NSW Minister for Planning and Infrastructure, granted approval for the project under Section 75J of the *Environmental Planning and Assessment Act 1979*, subject to conditions, on 4 July 2012. The project involves construction and operation of a landfill comprising five cells, each cell with a maximum volume of 211,000 m^3.

AECOM has prepared this Water Quality Monitoring Plan (WQMP) on behalf of Council to identify water monitoring requirements for the new regional landfill.

1.1.1 Consultation

1.1.1.1 Commonwealth Department of Environment and Energy

A copy of this plan was provided to the Commonwealth Department of Environment and Energy (Department of Environment and Energy) in accordance with consultation requirements under Condition 9 of Schedule 4 of the Project Approval.

Comments were received from the Department of Environment and Energy on 22/02/2017 and 09/05/2017 providing some recommendations for updates and inclusions to the plan. AECOM, on behalf of Council responded to the comments and issued an updated plan to the Department of Environment and Energy.

1.1.1.2 NSW State Government agencies

A copy of this Plan was provided to the NSW Environment Protection Authority (EPA) and NSW Department of Primary Industries (DPI) Water (formerly NSW Office of Water) on 23 October 2015 in accordance with consultation requirements under Condition 9 of Schedule 4 of the Project Approval. Additional information (second round of groundwater monitoring results) was also provided to DPI Water on 2 November 2015.

Comments were received from DPI Water on 23 November providing feedback and recommendations for the plan. AECOM, on behalf of Council, responded to the comments raised by DPI Water who responded in further correspondence dated 16 February 2016.

A meeting was held with DPI Water on 23 August 2016 at the Department of Planning and Environment (DP&E). DPI Water advised that prior to endorsing this WQMP, additional monitoring wells targeting shallow and deep aquifers are required to detect potential leachate contamination. In response, Council, to the satisfaction of DPI Water, provides a commitment to:

- Construct and screen additional monitoring wells at a location that would appropriately detect leachate downstream from active cells
- Confirm the location and screening of the additional monitoring wells in consultation with DPI Water prior to their construction
- Ensure the revised monitoring network is operational prior to any landfill waste emplacement.

Further comments were received from DPI Water on 27 September 2016, providing feedback and recommendations for the plan. Comments were provided in regard to the following:

- The location and number of proposed monitoring wells to be installed
- requirements associated with the construction of the monitoring wells
- request for further information on the existing groundwater conditions, particularly the provision of updated groundwater contour maps.

A number of recommendations made by DPI Water throughout the consultation process have been incorporated into a revision of this plan. No comments were received from EPA. No formal consultation is required with the local community under this condition.

1.2 Purpose and Scope

1.2.1 Approval Conditions under the NSW Environmental Planning and Assessment Act 1979

Condition 9f / Schedule 4 of the Conditions of Approval requires the preparation of a ground and surface water monitoring plan for the project in consultation with, and endorsed by, DPI Water and submitted to the Secretary of the DP&E for approval.

The purpose of this document is to respond to the approval condition, ensuring the adequate monitoring and management of water quality. This document, the Water Quality Monitoring Plan, satisfies *Condition 9f*.

This WQMP has been developed to ensure that water quality is both successfully monitored and managed prior to construction and throughout the life of the landfill. The potential impacts on heritage values of the downstream Gondwana Rainforests of Australia World Heritage Area (GRAWHA) are also addressed.

1.2.2 Approval Conditions under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999

Condition 2 of the Conditions of Approval requires the preparation of a Leachate Management Plan to be submitted to the Minister for approval. The plan is to include a surface and ground water monitoring plan in accordance with **Condition 9f/Schedule 4** of the Approval Conditions under the NSW *Environmental Planning and Assessment Act 1979* (refer to Section 1.2.1 above).

Table 1 outlines where each component of the EPBC Act conditions is addressed in this plan.

Table 1 Conditions of Approval

Project Approval Condition	Plan Section
Condition 1	
The person taking the action must ensure that all surface water discharges from the sites comply with the discharge limits (both volume and quality) set for the development in any NSW Environmental Protection Licence issued for the proposed action or relevant provisions of the NSW *Protection of the Environment Operations Act 1997*.	Section 2.0 and Section 6.2
Condition 2	
Prior to commencement of the action, the person taking the action must prepare a Leachate Management Plan for the Ministers approval. The plan must include a ground and surface water monitoring plan for the site, a remedial action plan to provide contingencies in the event that leachate escapes the leachate containment system and include details on: a) the number, design and location of the monitoring bores, including upstream groundwater bore/s for baseline data collection;	Section 6.4.3
b) timelines for establishment and sampling regime(s) for the monitoring bores;	Section 6.4.5
c) monitoring frequency, including monitoring during rainfall;	Sections 6.3.4, 6.4.5 and 6.5.3
d) a schedule of contaminants to be monitored;	Sections 6.3.4, 6.4.5, 6.5.3, and Appendix A
e) triggers for increased monitoring and remedial action; and	Section 8.3.2 and Appendix A
f) reporting requirements for the sampling results	Section 6.7
The person taking the action must install the baseline monitoring bore and implement the baseline monitoring sampling program before commencing construction of the landfill.	Section 6.4 and Appendix C
Condition 3	
The person taking the action must ensure that the leachate storage dam: a) is designed to address dispersive soil in the A2 and B horizon;	Sections 5.3 and 6 of the Detailed Design Report and Section 6 of the main report
b) allow for the level of leachate in the storage dam to be maintained such as there is no overflow;	Section 3.2 to 8 of the Detailed Design Report
c) is designed to contain a 100-year ARI 3 day rainfall event and provides at least 150mm freeboard for waste action, providing a total storage capacity of at least 14.6ML;	Sections 5.5, 5.8, and 6.4 of the Detailed Design Report

Project Approval Condition	Plan Section
d) includes a leachate barrier comprising: i. a re-compacted clay or similar material at least 90 centimetres thick with an in situ coefficient of permeability of less than 10^{-9} metres per second covering the entire floor and walls of the dam/s; ii. a flexible membrane liner stabilised against or protected from ultra violet light with a minimum co-efficient of permeability of less than 10^{-14} metres per second covering the entire floor and walls of the dam/s.	Sections 4.3, 5.3, 5.5, 6.2, and 6.4 of the Detailed Design Report
Condition 4	
The person taking the action must ensure that the stormwater infrastructure design: a) direct all sediment laden water in overland flow: i. away from the leachate containment system; and ii. to a sediment basin with capacity for a 5 day 95th percentile storm with a minimum storage capacity of 5250m^3.	Sections 5.6-5.8, and 6.5-6.7 of the Detailed Design Report
b) Includes a dry detention basin below the operational part of the site with a capacity for a 100 year ARI 3 day rainfall event with a minimum storage capacity of 30ML;	Sections 5.7 and 6.6 of the Detailed Design Report
The person taking the action must manage the sediment basin so that it maintains capacity to store run-off from 5 day 95th percentile storm.	Sections 5.6-5.8, and 6.5-6.7 of the Detailed Design Report
Condition 5	
The person taking the action must comply with the provisions of the Armidale Regional Landfill Facility Water Quality Monitoring Program and Management Plan	This plan has been prepared with consideration of the measures outlined in the WQMPMP to comply with this condition.
Condition 7	
Within 10 days after the commencement of the action, the person taking the action must advice the Department in writing of the actual date of commencement.	Section 9.2 of the Leachate Management Plan
Condition 8	
The person taking the action must maintain accurate records substantiating all activities associated with or relevant to the conditions of approval, and make them available upon request to the Department. Such records may be subject to audit by the Department or an independent auditor in accordance with section 458 of the EPBC Act, or used to verify compliance with the conditions of approval. Summaries of audits will be posted on the Department's website. The results of audits may also be publicised through the general media.	Section 9.1 of the Leachate Management Plan

Project Approval Condition	Plan Section
Condition 9	
By 31 December of each year after the commencement of the action, the person taking the action must publish a report on their addressing compliance with the conditions of this approval over the previous 12 months, including implementation of any management plans as specified in the conditions. Non-compliance with any of the of this approval must be reported to the Department at the same time as the compliance report is published.	Section 9.2 of the Leachate Management Plan
Condition 10	
Upon the direction of the Minister, the person taking the action must ensure that an independent audit of compliance with the conditions of approvals is conducted and a report submitted to the Minister. The independent auditor must be approved by the Minister prior to the commencement of the audit. Audit criteria must be agreed to by the Minister and the audit report must address the criteria to the satisfaction of the Minister.	Section 9.3 of the Leachate Management Plan
Condition 11	
If the person taking the action wishes to carry out any activity otherwise than in accordance with the plans as specified in the conditions, the person taking the action must submit to the Department for the Minister’s writing approval a revised version of that plan. The varied activity shall not commence until the Minister has approved the varied plan in writing. The Minister will not approve a varied plan unless the revised plan would result in an equivalent or improved environmental outcome over time. If the minister approves the revised plan, that plan must be implemented in place of the plan originally approved.	Section 9.1 of this plan and Section 9.3 of the Leachate Management Plan
Condition 12	
If the Minister believes that it is necessary or convenient for the better protection of the World Heritage properties or national heritage places to do so, the Minister may request that the person taking the action make specified revisions to the plans specified in the conditions and submit the revised plans for the Minister’s writing approval	Section 9.1 of this plan and Section 9.3 of the Leachate Management Plan

1.3 Structure of this Plan

This Management Plan is structured as follows:

- **Section 1.0** – Introduction
- **Section 2.0** – Statutory Requirements
- **Section 3.0** – Existing Conditions
- **Section 4.0** – Water Quality Criteria
- **Section 5.0** – Roles and Responsibilities
- **Section 6.0** – Monitoring Program
- **Section 7.0** – Quality Assurance/Quality Control
- **Section 8.0** – Contingency Plan
- **Section 9.0** – Review and Continual Improvement
- **Section 10.0** – References

This plan forms part of the project's Landfill Environmental Management Plan (LEMP) as shown in Figure 1.

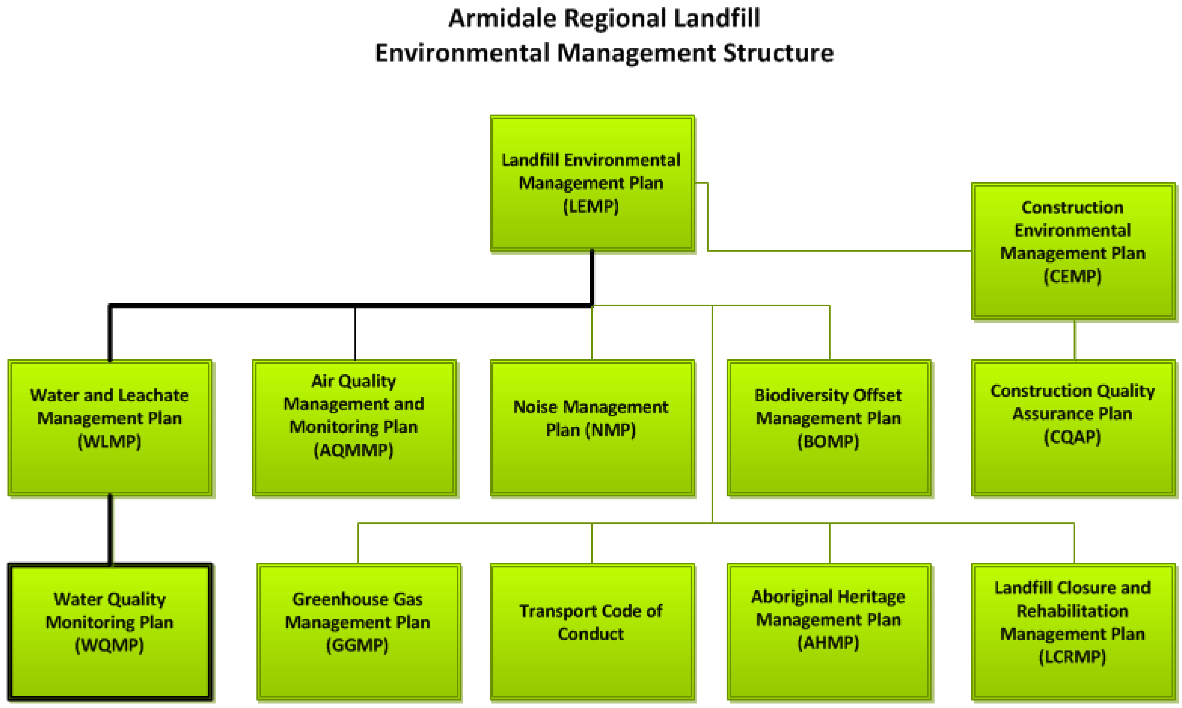

Figure 1 Environmental Management Structure

2.0 Statutory Requirements

2.1 Approval Requirements

Condition 9f / Schedule 4 of the Conditions of Approval requires the preparation of a Water Quality Monitoring Plan for the project as shown in Table 2.

Table 2 Management Plan Requirements

Project Approval Condition	Plan Section
Condition 9f/Schedule 4	
Include a ground and surface water monitoring plan for the site in consultation with Department of Primary Industries - Water. The plan shall include details on: • the number, design and location for the monitoring bores, including upstream	Section 6.4.3
• groundwater bore/s for baseline data collection;	Section 6.4.3. Sampling methodology is outlined in Section 6.4.2.
• timelines for establishment and sampling regime(s) for the monitoring bores;	Section 6.4.5
• monitoring frequency, including monitoring during rainfall;	Sections 6.3.4 and 6.4.5
• a schedule of contaminants to be monitored; and	Sections 6.3.4, 6.4.5, 6.5.3, and Appendix A
• reporting requirements for the sampling results.	Section 6.7
The plan must be submitted to the Secretary prior to commencement of construction and be endorsed by Department of Primary Industries - Water before submission.	Section 1.1.1
The Proponent shall install the baseline monitoring bore and implement the baseline monitoring sampling program obtaining a minimum of two bi-monthly baseline sampling events before commencing construction of the landfill.	Section 6.0 Appendix C
The Proponent shall implement the approved ground and surface water monitoring plan to the satisfaction of the Secretary.	Section 6.0

2.2 Licenses and Permits

The operation of the landfill will require an Environment Protection Licence from the NSW EPA as prescribed under the *Protection of the Environment Operations Act 1997*.

2.3 Relevant Legislation

- The *Protection of the Environment Operations Act (POEO) 1997*
- Project Approval (06_0220) and other relevant project information provided by Council
- *Water Act 1912*
- *Water Management Act 2000*

3.0 Existing Conditions

3.1 Overview

A background review has been conducted to establish the appropriateness of baseline data available for current surface and ground water quality. The review assessed both current surface and ground water monitoring program and available historical data, including:

- Historical data and information obtained during the environmental assessment.
- Currently established ground water monitoring network and surface water sampling locations;
- Local hydrogeological conditions; and
- Available surface and ground water data.

The findings of this review are summarised in this section, and are explained in detail in the appended Surface Water and Groundwater Monitoring Reports (refer Appendix B and Appendix C).

3.2 Oxley Wild Rivers National Park (GRAWHA)

The proposed landfill facility is located approximately 4 km north north-west of Oxley Wild Rivers National Park and 1 km (at its closest point) west of the Gara River which flows into the park. Oxley Wild Rivers National Park forms part of the Gondwana Rainforests of Australia World Heritage Area (GRAWHA).

Pursuant to the EPBC Act, the proximity of the World Heritage Area (Oxley Wild Rivers National Park) to the landfill required that an assessment of matters of National Environmental Significance (NES) be undertaken. This assessment was completed as part of the environmental assessment for the project. The assessment included an assessment of flora and fauna, water quality and consultation with the then Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA; now Department of the Environment). The results of the assessment have informed the selection of groundwater monitoring well locations and surface water sampling locations incorporated into this WQMP.

3.2.1 Water Quality

The quality of water is the second most existing concern that impacts on the ecological integrity of Oxley Wild Rivers National Park. Water quality monitoring reported by (NSW NPWS, 2005) has found poor water quality to be characteristic of streams such as the Gara River on the tablelands upstream of Oxley Wild Rivers National Park. These same rivers, however, were much cleaner downstream of the Park, indicating that the relatively undisturbed environments of the Park contributed to removal of excess nutrients (NSW NPWS, 2005).

Additional issues identified include the following:

- The New England Highway, Oxley Highway and Waterfall Way cross the headwaters of most of the major streams that flow into Oxley Wild Rivers National Park at points close to the park boundaries. A vehicle accident involving a chemical or fuel spill would also pose a major threat to water quality.
- Armidale’s Sewage Treatment Plant discharges to Commissioners Waters with high concentrations of Phosphates continuously detected in water quality monitoring.
- Algal blooms in the vicinity of Blue Hole are a common occurrence during periods of low flows (pers.comm. Matt Ryan and George Monroe, NWPS, Armidale, 2009).

A review of water quality data in proximity to the landfill site is provided in Section 3.3.2.

3.2.2 Flooding

Concern has been raised in relation to potential contaminants entering the waterways of Oxley Wild Rivers National Park during flood events.

Runoff from the proposed landfill site falls to the north towards a tributary of the Gara River. The proposed landfill is located within the upper reaches of the catchment. No flood studies have been conducted in this area. Instead, calculations using Manning's equation were used to estimate the 100 year Average Recurrence Interval (ARI) flow and the 100 year flood level in these creeks. The results of these calculations indicate that the proposed landfill site is well outside the extent of the 100 year floodplain.

The design for the landfill, leachate pond, sedimentation basin and dry basin incorporates adequate freeboard to contain a 100 year ARI, 3 day rainfall event on site, without further containment or storage actions needing to be implemented.

Events larger than the 100 year event would be relatively catastrophic for the local area. Washing out of leachate water from the landfill site during events larger than this are likely to be undetectable in comparison to widespread erosion, sediment and debris mobilisation, and influx of contaminants from other point sources (e.g. Armidale STP, and toilet facilities within the Gara Gorge's day facilities).

3.3 Existing Surface Water Environment

3.3.1 Catchment Areas

The proposed landfill site is situated within the Gara River catchment, a major catchment within the local region that covers an area of 41,486 ha, and a sub-catchment of the Macleay River. The Gara River originates approximately 45 km north of the proposed landfill site and flows from north to south, to the east of the proposed landfill site. The minimum or straight line distance between the Gara River and the proposed landfill site is 1.06 km. The River descends into a Gara Gorge approximately 4 km south-south-east of the proposed landfill site, within the Oxley Wild Rivers National Park. The riverbed distance between the closest point to the proposed landfill site and the Oxley Wild Rivers National Park is 8.8 km.

Tributaries of the Gara River (upstream of the Oxley Wild Rivers National Park) include Commissioners Waters, Burying Ground Creek, and a number of minor drainage lines (Figure 2).

Commissioners Waters is located approximately 1.6 km south of the proposed landfill site, and flows into the Gara River approximately 800 m upstream of the Oxley Wild Rivers National Park. Burying Ground Creek enters Commissioners Waters approximately 2 km west of the site. Runoff from the proposed landfill site does not flow to Commissioners Waters or its tributary Burying Ground Creek.

Runoff from the proposed landfill site runs into the Gara River via two unnamed intermittent creeks which have a combined catchment area of 370 ha. These creeks flow onto the site from the west and south west for approximately 200 m before merging to form a single gully that intermittently flows a further 1300 m to the east before joining the Gara River at the north-western corner of the proposed landfill site.

Both drainage lines are regulated by several farm dams, two of which are located within the boundaries of the proposed landfill site and its associated buffer zones.

Land use within the region is predominantly agricultural, with some residential, commercial and industrial areas concentrated around the major urban centres of Guyra and Armidale.

The *Southern New England Tablelands Region State of the Environment Report 2004* (and *Supplementary Report*, 2004/05) identifies the Gara River as a "stressed sub-catchment", exhibiting signs of poor water quality. It also shows signs of "high hydrologic and environmental stress", including:

- Eutrophication (due to high nutrient content); and
- Poor river structure (stream bank erosion and poor riparian habitat).

The *Stressed Rivers Assessment Report 1998*, produced by the former Department of Land and Water Conservation (DLWC), gave the Gara River the highest overall stress classification, indicating that water extraction within the region contributes to the River's environmental stress. Flows within the river are impacted both by the Guyra Shire Council Dams and the Malpas Dam, all of which are close to Guyra. It is noted that a Water Sharing Plan (WSP) is being developed for this catchment, and the final WSP will be reviewed for its applicability to the landfill once available.

The Gara River is a water source regulated by the *Draft Water Sharing Plan for the Macleay Unregulated and Alluvial Water Sources* (2015). Department of Primary Industries –Water prepared Water Source Report Cards to assist in the consultation process for developing the WSP. The Report Card for the Gara River Water Source (prepared October 2014) characterised the Gara River as having medium in-steam value (catchment contains threatened frog species and significant area of National Park), low risk to instream value from extraction and medium economic dependence of the local community on water extracted for irrigation. In addition, the report card characterised the Gara River water source as under high cumulative hydrologic stress as a result of the town water supply extractions from the water source upstream.

3.3.2 Existing Baseline Data

3.3.3 Gara River

A range of baseline surface water sampling has been undertaken at five sites since 2008. Three of these sites are located on the Gara River (GARA1, GARA2 [upstream of the landfill] and GARA4 [downstream of the landfill]) and two sites on the gully running through the proposed landfill site (GARA3 and GARA5) Figure 2 shows the locations of these sites. A total of 14 samples were collected from these sites over the following dates:

- 17 December 2008
- 28 January 2009
- 10 March 2009
- 18 May 2010
- 9 June 2010
- 7 September 2010
- 7 December 2010
- 31 May 2011
- 16 August 2011
- 22 November 2011
- 10 April 2012
- 27 August 2012
- 27 November 2012
- 5 June 2013.

Armidale Sewage Treatment Plant (STP) discharges treated effluent into Commissioners Waters which flows into the Gara River. GARA4 sampling point at Blue Hole is downstream of the confluence of Commissioners Waters and the Gara River. Therefore a sixth sampling site (Gara6) was included in the May 2015 sampling as an additional non-STP influenced Gara River sampling location for comparison purposes. Microbial testing was also added to the analyte list for all ambient surface water sampling points.

An Ambient Surface Water Monitoring Report (CodyHart, 2015a) summarises the results of baseline monitoring conducted between 2007 and 2013 (refer to Appendix B). The report also summarises the results of the most recent round of baseline surface water monitoring conducted in May 2015 at six surface water sampling points. All sampling results to date are tabled in the report to allow comparison of each parameter and analyte's historical results over time. A summary of basic trend observations relevant to analytical results are provided below.

- GARA5 (gully) has on occasion been dry at the time of sampling.
- GARA3 (gully) has often had low flow with resulting elevated salinity and degraded water quality parameters.

- GARA3 and GARA5 show similar water quality characteristics. Both these sites have exhibited elevated levels of trace elements likely due to adjacent land use activities. Some observations include:
    - Elevated Zinc and Copper levels exceeded criteria for most of the sample events, with higher levels of Zinc noted at GARA5.
    - Elevated levels of Nickel at both sampling sites
    - Elevated Chromium levels recorded on some occasions at both sampling sites however was more prevalent at GARA5.
    - Elevated Lead levels recorded on some occasions at both sampling sites however was more prevalent at GARA5.
- The river sites GARA1, GARA2 and GARA4 share similar results for water quality parameters and elevated nutrient concentrations reflecting the nature of the surrounding land use. Some observations include:
    - GARA4, located downstream of the confluence of Commissioners Waters at Blue Water Hole has consistently shown higher total phosphorous (TP) concentrations mainly in the form of filterable reactive phosphate (FRP).
    - A spike in Zinc levels was consistently detected in the sampling events for 7-Sep-10 and 7-Dec-10 for all three river sites.
    - It can be ascertained that concentrations of higher levels of elements upstream (GARA1), dilute downstream as detected downstream (GARA2 and GARA4).
    - GARA4 exhibited elevated levels of Chromium and Copper during some sampling events that were inconsistent with data for GARA1 and GARA2. It can be ascertained that these elements are attributed to inflow from the Commissioners Waters.

3.3.4 Influence of Armidale Sewage Treatment Plant on baseline surface water quality

Armidale STP discharges effluent into Commissioners Waters, which is a tributary of the Gara River. The confluence of Commissioners Waters and the Gara River is approximately 3 km south and downstream of the landfill site.

Monitoring of three creeks, Dumaresq Creek, Tilbuster Creek and Commissioners Waters, in the vicinity of the Council's sewage treatment plant (STP) was undertaken on a three monthly basis from July 2005 to April 2009. Dumaresq Creek and Tilbuster Creek were monitored upstream while Commissioners Waters was monitored downstream of the STP discharge point.

A review of the STP monitoring data identified a significant increase in nutrients in Commissioners Waters downstream from the STP discharge point (EPA Point No. 1). Mean total nitrogen (TN) concentrations of 0.25 mg/L and 0.44 mg/L were recorded in Dumaresq and Tilbuster Creeks respectively, while downstream of the discharge, in Commissioners Waters, mean TN concentration was 1.32 mg/L. Similarly, mean TP concentrations of 0.17 mg/L and 0.20 mg/L were recorded in Dumaresq and Tilbuster Creeks respectively, while downstream of the discharge, in Commissioners Waters, mean TP concentration was 1.65 mg/L.

Baseline surface water quality sampling is continuing to be undertaken prior to construction of the landfill. Surface water sampling will also be undertaken during construction and operation of the landfill. The Surface Water Monitoring Program is detailed in Section 6.

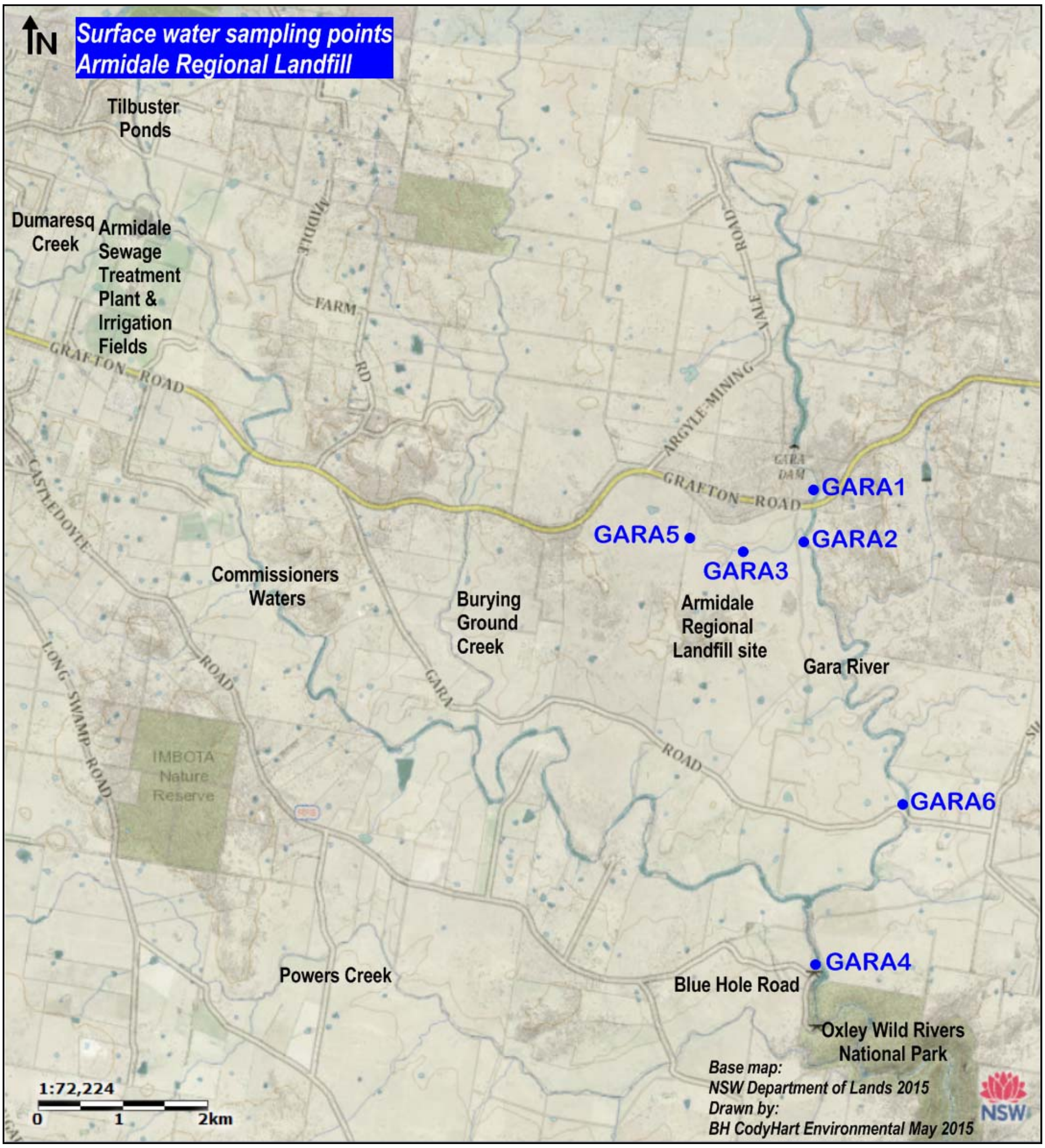

Figure 2. Surface Waters and Location of Surface Water Quality Monitoring

3.4 Existing Groundwater Environment

3.4.1 Previous Groundwater Investigations

Hydrogeological investigations were conducted by EA Systems (2005) and RCA (2006-2007) to:

- Establish the current hydro-geological conditions across the site; and
- Determine the potential impact from the project.

EA Systems drilled and logged five bore holes, into which five piezometers were installed to monitor groundwater level fluctuations. Groundwater monitoring was then carried out from November through to December 2005. While no standing groundwater was detected during the shallow soil drilling investigation, the soil profile had evidence of transient sub-surface flow within the shallower soils. No groundwater was detected in any of the bore holes during the piezometer monitoring period.

Subsequent to the above investigation, RCA conducted hydrogeological studies in October 2006, which included the drilling of 10 bores in depths ranging from 1.0 m to18.0 m, with groundwater monitoring wells installed in 5 bores (two in rock, and three in soil) (Figure 3).

Groundwater samples were collected from the wells in rock (BH4 and BH5) as well as from an existing groundwater bore on a neighbouring property to the west of the landfill site. No groundwater was encountered in any of the bores in soil.

During March 2007, RCA conducted further groundwater investigation in the study site, installing seven groundwater monitoring wells into the bedrock aquifer, including BH4 and BH5 from earlier investigations. Groundwater was encountered in all bores as shown in Table 3.

Table 3 Gauged groundwater depths (RCA, 2007)

Bore No.	RL (m AHD)	Stickup (m)	GW Depth from top of pipe (m)	Screen depth (m) below ground level	GW RL (m, AHD)
4	954.11	0.74	6.35	6.0-18.0	947.76
5	953.13	0.75	5.27	3.6-9.5	947.86
9	1014.03	0.95	46.7	53.5-59.5	967.33
10	993.78	0.67	37.0	41.0-47.0	956.78
11	977.58	0.72	28.0	30.0-36.0	949.58
12	969.79	0.62	21.3	34.0-40.0	948.49
13	961.70	0.60	13.3	16.0-22.0	948.40

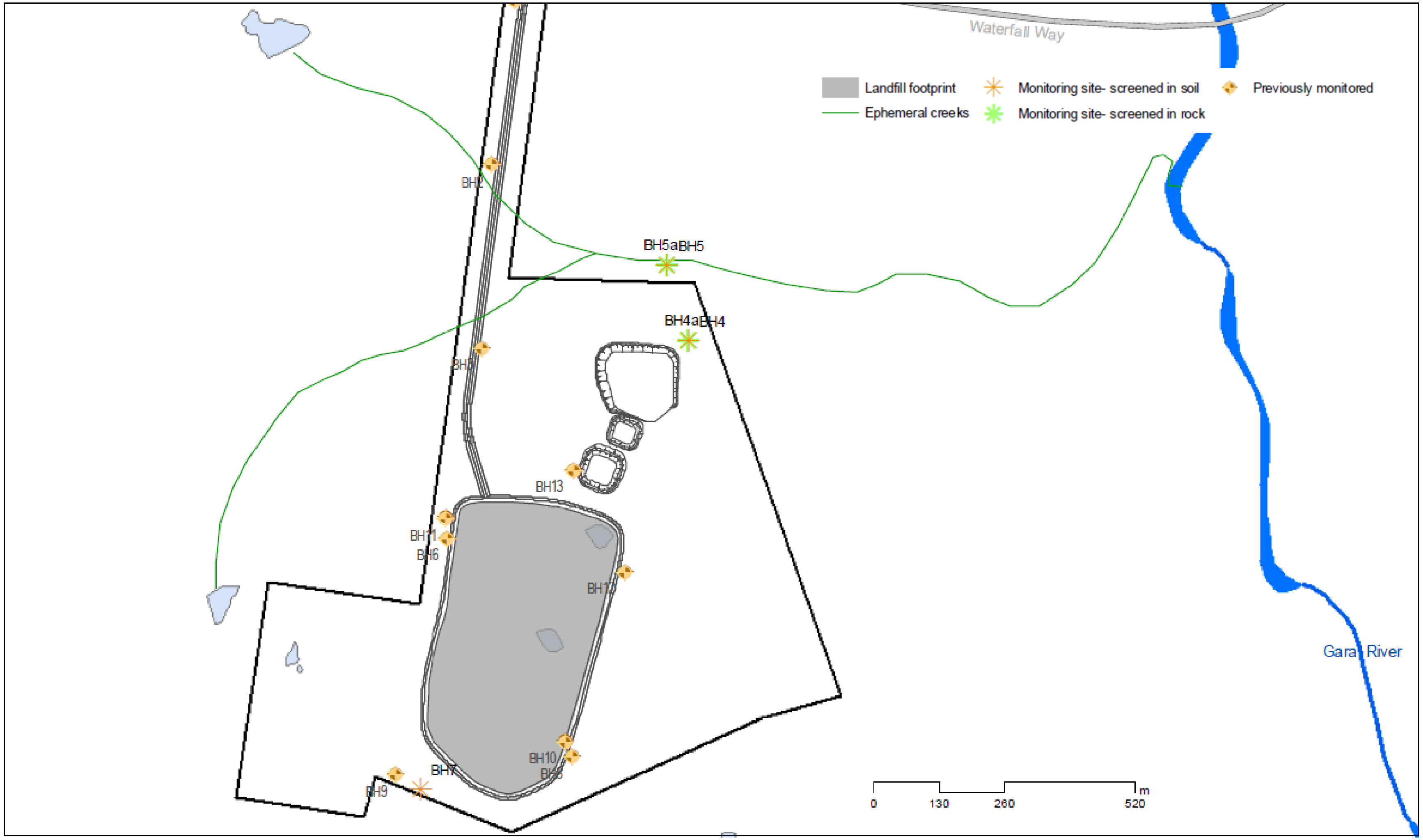

Figure 3. Location of previously monitored groundwater wells

Hydrogeological Conditions

RCA (2007) divided the Sites topography into two distinct sections:

- The southern or upper section which is steep and heavily vegetated, and
- The northern or lower section which is more gently sloping and consists of open paddock and defined by a ridge running east-west at the northern extremity.

Groundwater in the upper or southern section of the site was generally assumed to be toward the north-north east, whereas in the lower or northern section of the site flow was assumed to be more directly north-east. Collectively groundwater is considered to be leaving the site in a predominantly north easterly flow direction, towards the Gara River (refer Figure 4). Summer extraction demand in the Gara River is reported as regularly exceeding available flows in November (DNR 2006), indicating that minimal recharge from groundwater inflows is likely to be occurring.

Hydraulic gradient

The gauging of the groundwater levels (as previously shown in Table 3) allowed the gradient of the groundwater in each section of the site. Table 4 summarises the groundwater hydraulic gradient results.

Table 4 Groundwater hydraulic gradient results (RCA, 2007)

Site section	GW RL (high)	GW RL (low)	Distance	Gradient (m/m)
Upper	967.33 (BH9)	948.49 (BH12)	600m	3.14×10^{-2}
Lower	948.49 (BH12)	947.76 (BH4)	485m	1.51×10^{-3}

Hydraulic conductivity

Tests for hydraulic conductivity (permeability) were previously undertaken at two bore locations (RCA, 2007). Due to the conditions encountered and project constraints, only one test was undertaken in each bore. Hydraulic conductivity test results are summarised in Table 5.

Table 5 Hydraulic conductivity/Permeability test result summary (RCA, 2007)

Bore number	Test method	Permeability
BH11	Falling Head Piezometer Test (Hvorslev method)	3.8×10^{-6}
BH5	Rising Head Test (Hvorslev method)	4.4×10^{-8}

* Note: The falling head test was conducted over a relatively short period and has required extrapolation to interpret the permeability.

The aquifer in the well BH11 was encountered and screened in sandstone. The permeability recorded is considered to be consistent with that expected in a highly fractured, sandstone strata.

The aquifer in the well BH5 was encountered and screened in argillite bedrock. The permeability recorded is considered to be consistent with that expected in a slightly fractured, argillite strata.

Given the limitations associated with the permeability data collected to date, it is recommended that the above permeability results be used as indicative values only.

Aquifer characterisation

Groundwater sampling results indicate that the aquifer in the southern or upper section of the site, which is contained within the ridgeline, is predominantly a chloride water type. In the lower or northern section of the site, the flatter topography means that the water is more likely to be influenced by influx of other water types from up gradient or south-west of the site. All groundwater sampled in this section of the site was predominantly a bicarbonate water type, except for the water in well BH5, which was a sulphate water type.

BH5 well is closest to the toe of the ridge at the northern extremity of the site. RCA (2007) observed a significantly lower recovery rate in BH5 than the other wells on the site following purging, and purged groundwater appeared more turbid. This was attributed to a layer of mudstone found immediately above the level of the argillite in BH5, which was not identified in the other bores. The topography in the well's vicinity also suggests that groundwater flows in the opposite direction to the general groundwater.

As a result, RCA (2007) considers it likely that the water sampled from BH5 is representative of, or is being impacted upon, by a separate aquifer to that of the majority of the site, flowing from the north back toward the low point of the site in the vicinity of BH4. Based on the limited number of wells in this section of the site, groundwater flow direction could not be accurately interpolated. However, the estimation of groundwater flow direction, based on the available data and the observed topography, is considered to give a valid representation of the flow direction in the northern section of the site.

Groundwater geochemistry

Groundwater passing through the argillite bedrock is expected to have higher dissolved solids than water discharging from the sandstone or highly weathered argillite layers. Results from analysis of groundwater sampling for ammonia, chloride, sulphate, chloroform, phenols, and total organic carbon are summarised below:

- The ammonia concentration in BH5 was slightly greater (<109%) than the National Health and Nutrition Research Council (NHNRC) and National Resource Management Ministerial Council (NRMMC) 2004 drinking water guidelines. The overall concentration of ammonia across the aquifers encountered could be considered as low, given the high potential for solubility.
- The relatively high concentrations of major ions (chloride and sulphate) detected in groundwater on the site is considered likely to be as a result of the long residence time of the groundwater within the predominantly argillite bedrock, and the solubility of the chemical constituents of the rock.
- Chloroform was detected in very low concentrations in two (2) wells, BH9 and BH11. The wells are on opposite sides of the site and do not have the same geochemical characterisation. Despite the potential source of the chloroform being unknown, the chloroform detected is not considered significant given the low concentrations.
- Phenols have been detected in BH5. However, the concentrations detected do not exceed the site guidelines and are falling. No likely source of phenols was observed in the vicinity of BH5. Contamination of the well due to drilling is not considered to be a likely source as the phenols were detected over several months and the bore has been subjected to repeated rigorous development.
- The Total Organic Carbon concentrations detected in all wells is considered relatively low except for BH5. The TOC concentration in BH5 has risen markedly (740%) from 2006 to 2007 with no apparent reason for this rise observed.

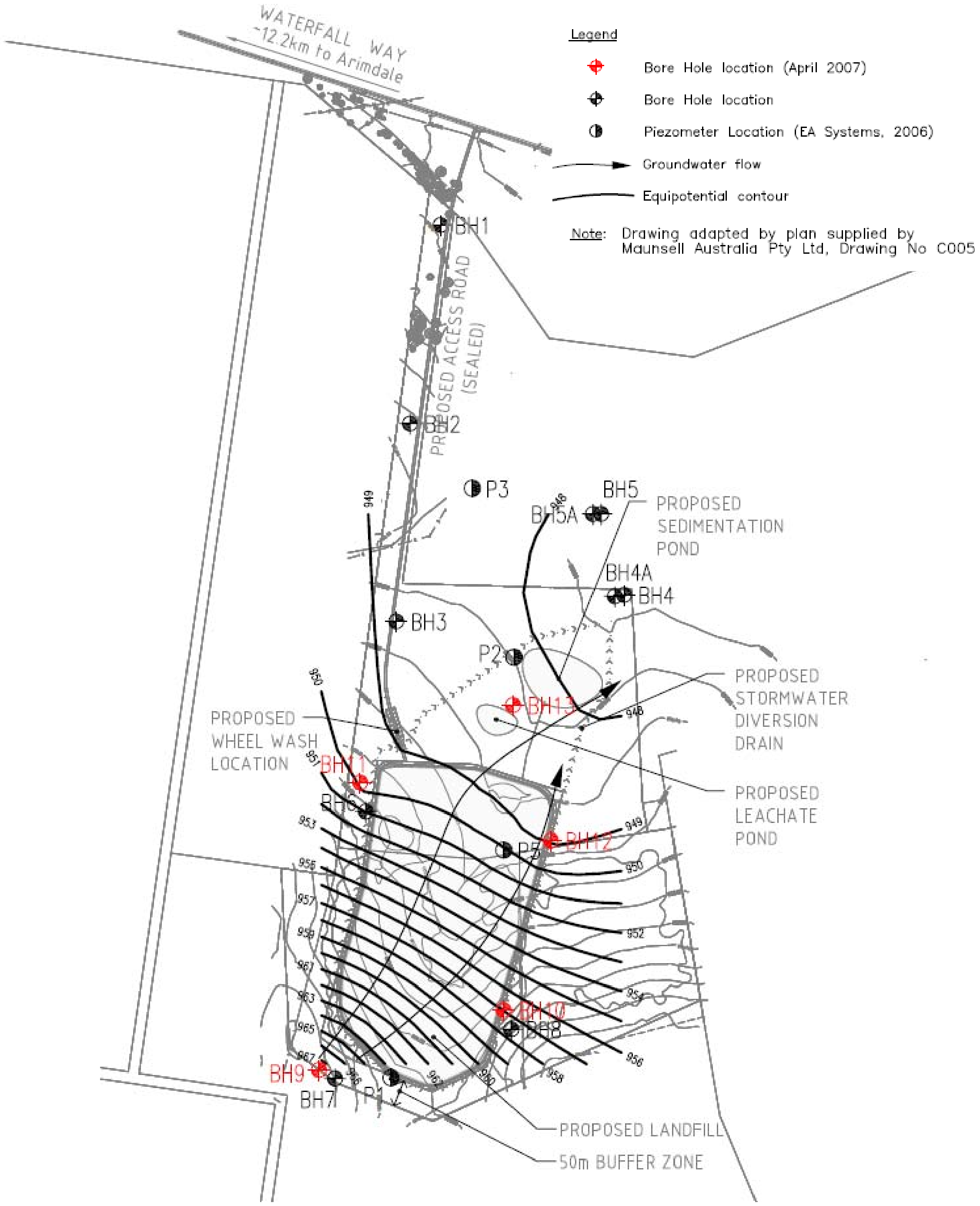

Figure 4 Borehole Locations and Inferred Groundwater Direction (RCA, 2007)

3.4.2 Recent Geotechnical Investigation and Monitoring Well Installation

AECOM undertook a geotechnical investigation of the landfill site in October 2014 (AECOM, 2015). The investigation involved:

- Drilling of eight boreholes
- Installation of four additional groundwater monitoring wells
- Excavation of 32 test pits.

Information obtained from the 2014 investigations was combined with geotechnical and hydrological data sourced from previous investigations carried out at the site (refer section 4.4.1 and 4.4.2).

Monitoring wells (piezometers) were installed in four boreholes between the depths of 5.0m and 29.6m to monitor groundwater conditions that may be influential and/or impacted during construction, assess natural seasonal variation, and to regularly assess the groundwater depth and changes to groundwater quality over the life of the proposed landfill. A summary of the wells installed during this investigation is provided in Table 6.

Table 6 Summary of Geotechnical Investigation – Boreholes installed for groundwater monitoring (AECOM, 2015)

BH ID	Date Completed	Easting	Northing	Elevation	Final Depth (m)	Monitoring Well
				RL (m AHD)		
BH02	7/10/14	383744	6619550	955	11.0	YES
BH02A	10/11/14	383748	6619551	955	30.1	YES
BH04	11/11/14	383644	6619659	953	28.3	YES
BH04A	12/11/14	383636	6619659	953	8.0	YES

In addition to the monitoring well installations, approximately 20L of groundwater was extracted from existing groundwater monitoring wells to assess their response and suitability for long term monitoring purposes. Measured groundwater levels before and after extraction, together with corresponding monitoring well depths are provided in Table 7.

Extraction of groundwater from the existing monitoring wells was undertaken during the investigation, and the subsequent limited water level decline shows that the screened sections of the monitoring wells are hydraulically connected to the aquifer. As such, it is considered that these wells are suitable to form part of a groundwater monitoring network to monitor groundwater level fluctuations across the site. It should also be noted that groundwater extracted from the monitoring wells is assessed as being representative of the aquifer intersected, and suitable for groundwater quality analyses. The groundwater monitoring wells selected for long term monitoring are further detailed in the Groundwater Monitoring Program outlined in Section 6.2.

Table 7 **Summary of Groundwater Monitoring Results**

Borehole Location	Date Installed	Piezometer Depth (m)	Screen Depth (m)	Groundwater Depth (m)[1]	Groundwater Depth (m)[2]	Date Measured
BH4	Oct 2006	18.1	6.0 – 18.0	4.1	4.2[3]	Oct 2014
BH4A	Oct 2006	2.8	1.0 – 2.8	DRY	-	Oct 2014
BH5	Oct 2006	9.6	3.6 – 9.6	3.1	7.0	Oct 2014
BH5A	Oct 2006	2.5	0.7 – 2.5	DRY	-	Oct 2014
BH7	Oct 2006	1.5	0.5 – 1.5	0.9	DRY[4]	Oct 2014
BH9	Apr 2007	59.5	53.5 – 59.5	43.8	43.8	Oct 2014
BH10	Apr 2007	47.0	41.0 – 47.0	32.5	33.0	Oct 2014
BH11	Apr 2007	36.0	30.0 – 36.0	24.6	24.6	Oct 2014
BH12	Apr 2007	40.0	34.0 – 40.0	18.9	18.9	Oct 2014
BH13	Apr 2007	22.0	16.0 – 22.0	10.9	10.9	Oct 2014
P1	Oct 2005	2.3	0.5 – 2.0	1.9	NA	Oct 2014
BH02	Oct 2014	11.0	5.0 – 11.0	6.9	NA	Nov 2014
BH02A	Nov 2014	29.6	23.6 – 29.6	6.8	NA	Nov 2014
BH04	Nov 2014	28.0	22.0 – 28.0	3.8	NA	Nov 2014
BH04A	Nov 2014	8.0	5.0 – 8.0	6.7	NA	Nov 2014

Notes: 1 - Groundwater level measured before 20L extraction. 2 - Groundwater level measured following 20L extraction. 3 - Groundwater level measured at 3.4m (approx. 6 hours after initial extraction). 4 - Groundwater level measured at 1.2m (approx. 5 hours after initial extraction). NA - No groundwater was extracted at this test location.

3.4.3 Current Groundwater Monitoring and Preliminary Results

Aquifers present

The hydrogeological conceptual model has been updated to include three aquifers as follows:

- Shallow aquifer (perched within soil profile above volcanics);
- Intermediate aquifer (within the weathered fractured rock aquifer)
- Deep aquifer (within the fresh non weathered volcanics)

The thickness of each aquifer is variable across the site and influenced by local conditions. The shallow aquifer is expected to be deepest higher in the profile thinning down gradient as the perched water becomes closer to ground surface. The shallow aquifer extends from approximately two to ten metres below ground level. The intermediate aquifer occurs within the weathered volcanics and based on previous drilling extends to a depth of around 30 to 35 m below ground level. The deep aquifer is below the weathered volcanics, within the fresh fractured rock and expected to occur at around 60 m below ground level.

Groundwater flow direction

The direction of groundwater flow was revisited by CodyHart in 2015 (Appendix C) to verify previous findings. The groundwater contours were later redrawn based on the completion of groundwater gauging results measured by Cody Hart Environmental (Appendix C). The contours confirm groundwater flow is to the north east then turns to the east down gradient of the proposed landfill cells.

Overall, the groundwater flow direction is in sympathy with topographical fall to the Gara River. It flows in a north-northeast direction on the southern, elevated section of the site, then turns easterly on the northern, lower levels of the site to follow the ephemeral stream direction to the Gara River.

Baseline Groundwater Quality

Groundwater quality sampling was undertaken from July 2015 to February 2016 as part of bi-monthly pre-construction ground water quality sampling program (refer to Section 6.2). Baseline groundwater monitoring reports have been prepared by Council's water quality consultant, which also reviewed the previous RCA results to determine the suitability of baseline data and recommend an appropriate monitoring regime moving forward. These reports are provided in Appendix C.

Overall it was determined that results were typical of slightly saline groundwater in the Armidale Dumaresq area. Metal concentrations were low. Total nitrogen compounds and total organic carbon concentrations were also low.

An anomalous analyte detected from the two rounds of groundwater monitoring conducted to date was trace chloroform in wells ABH9, ABH11 and ABH12, which in July 2015 were respectively 0.005 mg/L, 0.006 mg/L, and 0.001 mg/L. It was also detected in Year 2007 in trace concentrations in wells ABH9 and ABH11. Chloroform is not a naturally occurring substance but is often attributed to chlorinated potable water supplies.

Possible sources of chloroform at the sampling locations could include:

- Introduction of potable water while drilling to reduce dust and facilitate hammer head penetration, or introduction during earlier slug tests
- Use of bleach to decontaminate groundwater sampling pumps or to disinfect wells with iron bacteria.
- A combination of chlorine bleach and acetone. Acetone is a substance that can be naturally occurring from plants, trees, volcanic gases, forest fires (ATDRS 2015) but it is also present in blue 'plumber's glue' sometimes used to glue well casings together.

It is noted that this detection of chloroform prior to the acceptance of solid waste means that the source is not landfill leachate. It is also noted that such prior trace contaminants often dissipate over time.

3.5 Summary

Surface water

Water quality of surface water bodies upstream and downstream of the landfill site has been characterised through baseline monitoring undertaken at 5 locations since 2007. Two of the sampling locations (GARA3 and GARA5) are located in an ephemeral stream characterised by low and intermittent flows. Cattle grazing upgradient of the site also influences surface water quality in the ephemeral stream as well as the Gara River, evidenced by the presence of elevated organic nitrogen in background samples.

The available surface water data for the Gara River and Commissioners Waters identifies the likely impact of the Council STP discharge on the water quality at Blue Hole (GARA4). In order to better quantify the impact of the STP discharge on the water quality of the Gara River an additional sampling site (GARA6) upstream of the confluence of the Gara River and Commissioners Waters has been included in the monitoring program.

Analytical parameters that will be used to monitor the impacts of the landfill construction and operation, and the contribution of the catchment environment, include:

- Total suspended solids (TSS)
- Heavy metals (As, Cr, Cd, Cu, Hg, Pb, Ni, Se, Zn)
- Volatile organic compounds (VOC) and semi-volatile organic compound (sVOC).
- Organochlorine (OC) and organophosphorous (OP) pesticides.
- Nutrients - total nitrogen (TN), total kjledahl nitrogen (TKN), nitrite (NO_2), nitrate (NO_3), total phosphorous (TP) and filterable reactive phosphorous (TRP).
- Major cations and anions

Groundwater

Groundwater within the deep aquifer is inferred to flow north, towards the Gara River. Based on previous hydrogeological investigations carried out at the site, it is understood groundwater is present as both a series of shallow perched aquifers and within a deeper regional aquifer. The perched aquifer is located at the interface of the gravelly - clayey residual soils and/or weathered bedrock, typically within the upper 5.0m. The presence of perched groundwater is likely to be intermittent following rainfall until the water either discharges to the Gara River or infiltrates into the deeper regional aquifer, and is likely to form isolated pockets of groundwater above the regional water table.

Groundwater measured in the deeper regional aquifer ranges at depths in excess of 40.0m in the higher southern elevations to around 10.0m in the flatter central region. The area of elevated topography towards the southern site boundary is likely a local source of groundwater recharge.

It is important to note, however, that groundwater levels and flows are transient, and are affected by such factors as soil and rock permeability, geological structure, earth moving operations, land use practices and preceding climatic conditions.

Limited background data is available with respect to potential landfill contaminants in groundwater. A series of monitoring wells have been installed for this purpose at select locations across the site to supplement the existing monitoring well installed during previous investigations.

Chloroform and phenols have been detected in the groundwater beneath the site, albeit in concentrations only marginally above detection limits. Continued monitoring of VOCs and SVOCs will provide a baseline to assess impacts from the proposed landfill construction and operation. Ammonia (NH3) has been identified at concentrations close to nominated regulatory guidelines. Monitoring of total nitrogen (TN) and ammonia (NH3) is recommended along with a suite of heavy metals (refers Section 6 Monitoring Program).

4.0 Roles and Responsibilities

Roles are responsibilities are consistent with those described in the overarching Landfill Environmental Management Plan. Responsibilities for the implementation of the WQMP are summarised in Table 8.

Table 8 Summary of Responsibilities

Responsibility within Council	Action
Waste Manager	• Overall implementation of the Water Quality Monitoring and Management Plan • Implement methodology for avoiding water quality criteria exceedance. • Authorise and confirm the implementation of remedial measures • Reporting any pollution incidents to the EPA • Engaging suitable Personnel required to undertake monitoring activities
Site Environmental Officer / Superintendant	• Coordinate monitoring and compile reports • Maintain internal records of monitoring • Collate and maintain records of complaints, respond to complainant • Identify Non Conformances and notify Waste Manager • Supervise monitoring activities implemented by this Plan
Personnel / Contractors	• Carrying out activities in accordance with the requirements of this Plan • Notifying the Superintendant of any non-conformances or pollution incidents that occur on the site or during monitoring

4.1 Training and Induction

All Personnel undertaking work on the site are to be inducted in accordance with the LEMP.

All Personnel undertaking sampling work for the landfill will be suitably qualified and have passed the NSW Workcover General Construction Induction or its equivalent. Copies of the cards are to be provided to Council as part of the Safe Work Method Statement.

5.0 Water Quality Criteria

5.1 Surface Water

Surface water analytical results will generally be compared to and assessed against the ANZECC (2000) *Guidelines for Fresh and Marine Water Quality (Appendix A)*.

ANZECC (2000) provides comprehensive information and procedures for setting more specific water quality targets tailored for unique conditions for a range of pollutants or indicators and may be used to further customise water quality targets for local conditions. Once defined, water quality criteria become indicators of management performance and progress towards management goals or attainment of environmental values.

Indicators for water quality include:

- Nutrients (nitrogen and phosphorus).
- Salinity.
- Turbidity and suspended solids.
- River condition, including biological indicators (when established).

Gara River is an ephemeral waterway and subject to significant periodic flows. These flows result in high erosion, sediment transport and disturbance to the creek and surrounding area. Given the dynamic nature of the receiving waters, the 95% level of species protection will be adopted for the WQMP (where laboratory techniques can be quantified to these limits). The 99% species protection criteria will be used for chemicals that bioaccumulate (e.g. PCBs, OC pesticides and some heavy metals including mercury).

The ANZECC guidelines were developed in a manner cognisant that ecosystems may have been modified to various degrees and that different levels of protection are required depending on the ecosystem condition. For the Gara River, trigger values for “slightly to moderately disturbed systems” will be applied. **Table T1** in Appendix A presents the ANZECC (2000) water quality trigger values for protection of environmental values of upland rivers.

The trigger values for ‘freshwater aquatic ecosystem’ were chosen for comparison to the baseline results because they are designed to protect the most immediate and the most sensitive environmental value. Irrigation and stock uses are also important for the Gara River but the applicable trigger values are less stringent than those for freshwater aquatic ecosystems. Considering the sensitivity of the downstream catchment (Oxley Wild Rivers National Park), the more stringent trigger values for freshwater aquatic ecosystem protection will be applied for the Armidale Regional Landfill surface water monitoring program.

For some analytes, the analytical program may not be able to achieve the ANZECC (2000) 95% criteria, as the criteria are significantly below laboratory limits of reporting. Notwithstanding, the proposed analytical program is sufficient to achieve the nominated Data Quality Objectives (DQOs, refer to Section 7.1), which are focused on the monitoring of groundwater and surface water quality against background data and appropriate trigger levels.

It is also noted that the baseline water quality monitoring results on many occasions show exceedences of the ANZECC (2000) trigger values for the protection of freshwater aquatic ecosystems. The maximum baseline results will therefore supersede the ANZECC (2000) trigger values for these analytes where regular exceedences have been recorded, to reflect the local conditions at the site and to provide a tailored water quality target specific for the site.

Table T2 in Appendix A of this document provides ANZECC (2000) trigger levels / criteria for all analytes. Section 6.3 presents the analytes selected as suitable for inclusion in the monitoring program for a general solid waste landfill as part of the Armidale Regional Landfill surface water monitoring program.

5.2 Groundwater

The ANZECC (2000) guidelines relate to receiving surface water bodies, and not to groundwater. The NSW Office of Environment and Heritage (OEH) *Guidelines for Assessment and Management of Groundwater Contamination* OEH, 2007) provides the framework for best practice management of contaminated groundwater. The OEH guidelines indicate that ANZECC (2000) guidelines can be used as groundwater investigation levels (GILs). The OEH guidelines also recommend that the GILs be used as trigger levels for further investigation. Therefore, ANZECC (2000) 95% values for protection of aquatic ecosystems will be applied for the Armidale groundwater monitoring.

Table T2 in Appendix A of this document provides ANZECC (2000) trigger levels / criteria to be applied to the selected indicators for the surface and groundwater monitoring program. If ANZECC (2000) or other suitable criteria are not available for an analyte, background concentrations (where available) will be used as a guide for identifying the relevant criteria for groundwater monitoring. The detection monitoring parameters / analytes and the ones chosen as ‘detection monitoring indicators’ will be finalised once eight rounds of baseline monitoring are complete (this will be undertaken prior to the commencement of landfill operation - refer to Section 6.0).

6.0 Monitoring Program

6.1 General Requirements

The general requirement of monitoring procedures described by this program is to maintain the integrity of the monitoring program over time. The procedures and approaches, described in the following sections are required to:

- Conduct a technically defendable water quality monitoring program that complies with established standards, scientific monitoring protocols and reporting frameworks, in accordance with the data quality objectives detailed in Section 7.1 of this document;
- Establish baseline physical, chemical and biological properties of groundwater and surface water at the Site;
- Establish baseline hydraulic characteristics of surface water and groundwater at the Site
- Monitor representative physical, chemical and biological parameters, which will provide an indication of trends in ecosystem health and assist with identifying the causes and effects of pollution;
- Efficiently manage surface water and groundwater sampling data, so as to provide easy access and interpretation for future analysis and reporting, establishing trends and reporting anomalies; and
- Ensure Workplace Health and Safety risks, associated with implementation of the program, are identified and mitigated.

6.1.1 Standard Operating Procedures

The WQMP is intended to be used as a guidance document for the surface and groundwater monitoring across the site. It is understood that monitoring will be undertaken by a contractor engaged by Council. The contractor is required to prepare their own Standard Operating Procedure (SOP) that is consistent with the requirements of this Plan. The SOP will generally detail the following:

i. Preliminary review of regulatory requirements, Council requirements and historical data
ii. Sampling locations
iii. Preliminary preparations before sampling event (include decontamination of equipment, form preparation - field parameter, chain of custody)
iv. Preceding 24 hour preparations (include calibration of field lab/s within 24 hours of sampling)
v. Site safety
vi. Groundwater sampling methodology (Make suitable for particular wells and note interface probe measurement of piezometric level, purge method etc. Methodologies are to be justified through reference to documents such as
    - *Schedule B2 Guideline on Site Characterisation* NEPM (2013), *Section 8 - Groundwater assessment*
    - ASTM 2001 *Standard guide for the selection of purging and sampling devices for ground-water monitoring well, D6634*
    - ASTM 2001 *Standard guide for planning and preparing for a groundwater sampling event*, D5903 - 96(2012)
    - ASTM 2002 *Standard practices for decontamination of field equipment used at waste sites*, D5608-10
    - ASTM 2002 *Standard practice for low-flow purging and sampling for wells and devices used for ground-water quality investigations*, D6771-02 as WK46668

- ASTM 2004, *Standard guide for documenting a ground-water sampling event*, D7069-04(2010)
- ASTM 2005, *Standard guide for purging method for wells used for groundwater quality investigations*, D6452-00(2012)
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- ISO 5667-1:2009*, Water quality — Sampling — Part 11: Guidance on sampling of groundwaters*, 2nd edition, www.iso.org
- New South Wales Environment Protection Authority (2015) *DRAFT Environmental Guidelines: Solid Waste Landfills*, Second Edition, published March 2015.
- Nielsen, DM 2005, *Practical handbook of environmental site characterisation and ground-water monitoring,* 2nd edition
- Puls, RW & Barcelona, MJ 1996*, Low flow (minimal drawdown) ground-water sampling procedures,* Ground water issue*,* EPA/540/S-95/504

vii. Surface water and leachate sampling methodology. Methodologies are to be justified through reference to documents such as

- ANZECC and ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand) 2000, *Australian and New Zealand guidelines for fresh and marine water quality 2000*
- Csuros, M 1994, *Environmental sampling for technicians*
- ISO 5667-1:2006, *Water quality – Sampling – Part 1: Guidance on the design of sampling programmes and sampling techniques*, 2nd edition
- New South Wales Environment Protection Authority (2015) DRAFT Environmental Guidelines: Solid Waste Landfills, Second Edition, published March 2015.

viii. Site work completion tasks

ix. Water sample despatch methodology

x. Field alkalinity and free carbon dioxide analysis methodology

xi. Procedure to check on sample arrival at lab

xii. Style of quarterly monitoring report

xiii. Procedures to input results into the report's historical tables, to double check and review them, and to discuss any perceived anomalies with the field and laboratory staff

xiv. Types of calibration certificates and laboratory results for report (include laboratory: sign off of chain of custody form; sample receipt notification (SRN); certificate of analysis; quality control report; and a QA/QC Compliance Assessment for DQO Reporting that summarises the laboratory quality assurance findings

xv. Style of monitoring data pdf file for Council website as required under the future landfill licence.

xvi. Completion method for the monitoring section of the landfill's Environment Protection Licence Annual Return

xvii. Bibliography/Reference List

6.2 Approach

The monitoring program for the Armidale Regional Landfill has been prepared to align with the three phases of monitoring for surface water and groundwater:

1. Site characterisation (baseline monitoring) prior to landfill construction, and initial leachate quality once the landfill is constructed and operating, to serve as a baseline against which to compare future water quality data.
2. Detection monitoring during construction and landfill operation to determine whether or not there has been an impact on surface water and/or groundwater quality from landfill leachate or sediment runoff.
3. Assessment monitoring in the event of detection monitoring criteria being exceeded, to characterise possible contamination (nature, extent, possible future extent and source); and if required, to evaluate and recommend mitigation techniques.

Site characterisation has been completed for surface water and the baseline data collected has been used to inform the criteria for detection monitoring as specified in Section 6.3(and detailed in Appendix B). A review of the baseline data identified that the geochemical parameters and analytes likely to have at least a 20% immediate increase on the baseline maximum due to landfill leachate intrusion are EC, pH, alkalinity, TOC, total nitrogen, chloride. These were selected due to their early and noticeable response to leachate intrusion in surface water.

Statistically derived trigger values will be calculated for these indicators for the GARA2 sampling point only. The GARA2 indicator statistical trigger values will be calculated using the methodology devised by Hart (2000) in conjunction with a statistician and approved by NSW EPA for the landfill. If GARA2 statistical trigger values, for three or more indicators, are exceeded by 20% or more, then the assessment monitoring program will commence within five working days or sooner.

The data at GARA3 and GARA5 are too variable to devise meaningful trigger values. This is due to their location in the ephemeral stream where sample volumes are limited and often colloidal. Judicious review of each round's results by a water monitoring specialist is advisable.

In summary, trigger values for assessment monitoring as presented in Appendix A include:

- If any three of more of the selected geochemical indicators for GARA2 exceed their statistical trigger value/s by more than 20%
- If either GARA3 and/or GARA5 are determined to be in need of assessment monitoring by a person experienced in water quality review
- If inspection of any other water body in the landfill environs is noted as needing water quality review.

Site characterisation has also been completed for groundwater and the results of eight rounds of monitoring are presented in Appendix C. A review of the baseline data has identified a number of indicator analytes for detection monitoring, namely total nitrogen, total organic carbon, EC, alkalinity, free carbon dioxide (CO_2), chloride, sulphate, iron and manganese.

In the eighth round of monitoring, six observations for select detection monitoring analytes were taken in each well to add a 'within-event' variation to the maximum baseline value. This maximum baseline value, added to the within-event variation forms the detection monitoring criteria value for assessment monitoring to be undertaken. Assessment monitoring would be required if any individual well has three parameters/analytes exceed their trigger value, or are outside their range for three consecutive monitoring rounds.

The monitoring criteria will be finalised in conjunction with the EPA as part of the EPL process. This WQMP will be updated to include the detection monitoring criteria once they have been developed. A copy of the updated WQMP, inclusive of detection monitoring criteria, will be submitted to the Department of Environment and Energy before implementation.

6.3 Surface Water Monitoring

6.3.1 Purpose

The purpose of the surface water monitoring program is to capture an accurate snapshot of surface water quality as well as environmental factors influencing or associated with the surface water quality at the time of sampling.

6.3.2 Sampling Methodology

The surface water samples will be collected using a grab sampler or by direct filling into the sample bottle. Measures will be taken to minimise potential volatile loss i.e. using a dedicated secondary container to collect samples and fill into VOC sample bottles. Care will be taken to minimise aeration. Surface water samples to be analysed for dissolved metals will be filtered in the field prior to filling appropriate containers.

During sampling, field parameters, such as pH, dissolved oxygen (DO), electrical conductivity (EC), oxidation-reduction potential (ORP), turbidity and water temperature will be measured using calibrated equipment. Each sample will be visually observed and a description of the colour, turbidity, odour and any visible sheen will be recorded in the field notes (Table 9).

Field parameter measuring equipment will be calibrated as required and calibration certificates and records retained.

Table 9 Surface water monitoring field parameters

Type	Parameter
Field Observation	Unique sample location identifier
	GPS coordinates (WGS 84, decimal degrees)
	Photographic Record
	Water body description
	Weather conditions
	Flood level indicator reading (if applicable)
	Estimated flow rate
	Substrate type
	Water colour, light penetration, odour, presence of scum or sheen etc.
	Fish and aquatic flora and fauna observations
	Evidence of bank stability/erosion and feral animal activity
Field Measurement	Time and date
	pH
	Oxidation Reduction Potential
	Electrical Conductivity
	Dissolved Oxygen
	Turbidity
	Water Temperature
	Depth of water sample taken from

Sampling will be undertaken in accordance with the Data Quality Objectives (DQOs) outlined in Section 7.1. Demonstration of the DQOs will require the collection of:

- One field duplicate sample for every ten primary samples collected;
- One rinsate blank for each day of sampling; and
- A trip blank for each esky dispatched to the laboratory.

6.3.3 Sampling Locations

The surface water monitoring program will be conducted at the locations detailed in Table 10, and as shown in Figure 2.

Table 10 Surface water sampling locations

Site	Sample Site Description	GPS Position	
		Easting	Northing
GARA1	Located on Gara River, upstream of the confluence of the ephemeral creek (which flows to the north of the landfill site) and the Gara River, north of the Waterfall Way/Gara River road bridge. This site is not influenced by run-off originating from the landfill.	384741.0	6620301.0
GARA2	Located on the Gara River immediately downstream of the confluence of the ephemeral creek (which flows to the north of the landfill site) and the Gara River. This site is 1.2 km from the landfill and represents a monitoring location on the Gara River where potential impact from the landfill facilities might be detected.	384635.0	6619865.0
GARA3	Located on the landfill site gully (ephemeral stream) immediately downstream of the landfill.	383826.0	6619708.0
GARA4	Located on the Gara River, at the Blue Hole (Oxley Wild Rivers National Park) 10 km downstream of the landfill and 21km downstream of Commissioners Water (including potential influences from the Armidale STP).	384915.0	6614748.0
GARA5	Located on the landfill site gully (ephemeral stream) upstream of the landfill site.	383279.0	6619897.0
GARA6	Located on the Gara River, immediately upstream of the confluence of Commissioners Waters and the Gara River, approximately 7.5 km downstream of the landfill site.	385915.0	6616606.0

6.3.4 Sample Frequency and Analytical Regime

Table 11 describes the sampling frequency and the laboratory analytical suite for the surface water monitoring program at the Site.

Table 11 Surface Water Monitoring Program (CodyHart Environmental, 2015)

	Baseline monitoring program	Detection monitoring	Assessment monitoring
Sampling points	GARA1 GARA2 (GARA3 GARA4 GARA5 GARA6	GARA5 (upstream from landfill) GARA3 (downstream from landfill) GARA2 (1.2 km farther downstream from landfill than GARA3)	For impacted sampling point : GARA5, GARA3 and/or GARA2 If GARA2 impacted, add GARA1 and GARA6, or more appropriate upstream and downstream substitutes.
Sampling frequency	Two to six months apart depending if there was flow at GARA3 and GARA5	Bi-monthly during major construction works, quarterly thereafter	Determine by review of need
Parameters & analytes	Field: Depth, volumetric flow, DO, EC, pH, Eh, temp, turbidity, alkalinity, free CO2 Laboratory: SS, Cl, SO4, Ca, Mg, Na, K, Hardness, Nutrients (NH4+ as N, TKN as N, NOx as N, Total Phosphorus), Total metals not filtered [Al, As, Cd, Cr, Cu, Ni, Pb, Zn, Mn, Fe, Se, Hg, Fe (II)-GARA6, Br, B, TOC (filtered), UT PAH, OC&OP pesticides, TPH/TRH, speciated phenolics. Notes: Some extra tests by ADC are not noted above. Highlighted ones added by CodyHart.	Field: Depth, volumetric flow, DO, EC, pH, Eh, temp, turbidity, alkalinity, free CO2 Laboratory: SS, Cl, Nutrients (NH4+ as N, TKN as N, NOx as N, Total Phosphorus), Dissolved metals filtered on site with 0.45 µm filter [Al, As, Cd, Cr, Cu, Ni, Pb, Zn, Mn, Fe, Fe (II)], TOC (filtered).	Field: Depth, volumetric flow, DO, EC, pH, Eh, temp, turbidity, alkalinity, free CO2 Laboratory: SS, Cl, SO4, Ca, Mg, Na, K, Hardness, Nutrients (NH4+ as N, TKN as N, NOx as N, Total Phosphorus), Dissolved metals filtered on site with 0.45 µm filter [Al, As, Cd, Cr, Cu, Ni, Pb, Zn, Mn, Fe, Fe (II)], TOC (filtered), and if sheen, colour, odour indicates it is warranted – test for VOCs, UT PAHs, speciated phenolics.
QA samples to laboratory	1 intra-lab duplicate per 10 sampling points/wells	1 intra-lab duplicate per 10 sampling points/wells	1 intra-lab duplicate per 10 sampling points/wells

6.4 Groundwater Monitoring Program

6.4.1 Purpose

Routine groundwater sampling is required at the landfill site to monitor existing groundwater contamination, identify new groundwater contamination and to demonstrate continuing groundwater quality.

6.4.2 Groundwater Monitoring Well Sampling Methodology

Prior to the sampling of groundwater, standing water levels (SWL) should be measured. Where phase separated hydrocarbon PSH is suspected, an interface probe should be used to measure the apparent thickness of the layer.

Low flow sampling or micro-purge sampling should be used to sample all groundwater monitoring wells. The technique generally utilises an air driven bladder pump, but other methods may be used provided effective decontamination can be achieved. Bladder pumps and low-flow sampling are preferable because this style of pump and methodology are suitable for sampling all water quality analytes including volatile organic compounds.

Low flow sampling is a technique designed to minimise the hydraulic stress on the aquifer during purging and sampling. This is done by using an adjustable rate pump to remove water from the screened zone at a rate that will cause minimal drawdown of the water level in the well. Drawdown is measured in the well concurrent with pumping using a water level meter. Low flow sampling does not require a specific flow rate or purge volume.

In practical terms, allowable drawdown should never exceed the distance between the top of the well screen and the pump intake, which is normally positioned near the mid-point of the screen. To provide a safety factor, drawdown should generally not exceed 25 % of this distance to ensure that no water stored in the casing prior to purging is drawn down into the pump intake and collected as part of the sample. Typically, flow rates during purging in the order of 0.1 to 0.5 L/min are used; however, this is dependent on site-specific and well-specific factors.

Pumping water levels in the monitoring well and water-quality indicator parameters should be monitored during pumping. Water quality parameters including pH, temperature, electrical conductivity (EC), dissolved oxygen (DO) and oxidation-reduction potential (ORP) will be measured using calibrated equipment. Stabilising water quality parameters indicate that purging is complete and sampling can begin. Field parameter measuring equipment will be calibrated as required and calibration certificates and records retained.

Table 12 Criteria for Defining Stabilisation of Water Quality Parameters

Parameter	Stabilisation Criterion
pH	± 0.2 pH units
Electrical Conductivity	± 3% of reading
Dissolved Oxygen	± 10% of reading or ± 0.2 mg/L, whichever is greater
Eh	± 20 mV

All wells have individual characteristics that need to be taken into account when devising their purging and sampling regime. It is important to use the same methodology from sampling round to sampling round to minimise variation in the water quality results that can be caused by variation in purging and sampling methodology.

A sample can be collected after the water level and measured field parameters stabilise over three consecutive readings taken three to five minutes apart. For in-line flow-through cells, the frequency of the measurements should be based on the time required to completely evacuate one volume of the cell to ensure that independent measurements are made. It is important to know the manufacturer’s recommendations for the amount of time required to completely evacuate the cell to allow individual sensors being used to measure field parameters (e.g. dissolved oxygen) to stabilize and to ensure that representative data is collected.

Though not a chemical parameter, turbidity can be indicative of stress and disturbance resulting from pumping. Turbidity should be as low as possible when sampling is undertaken. The stabilisation criterion for turbidity is ± 10 % of the preceding reading or ± 1.0 NTU, whichever is greater.

The flow cell should be disconnected or bypassed during sample collection. Sampling should be completed at a rate where aeration and turbulent filling is minimised, typically less than 0.5 L/min. Generally samples for the most sensitive parameters (e.g. VOCs) and those of greatest interest at the site should be collected first. Samples for analytes that require filtration should be collected last (e.g. heavy metals).
Low-flow purging and sampling can be used to collect samples for all aqueous-phase contaminants and naturally occurring analytes, including volatile and semivolatile organic compounds (VOCs and SVOCs), metals and other inorganics, pesticides, PCBs, other organic compounds, radionuclides and microbiological constituents.

Further detail on low-flow sampling can be obtained from:

- The US EPA publication “Low-flow (minimal draw down) groundwater sampling procedures” (Puls & Barcelona, 1996); and
- The ASTM standard D 6771-02 “Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations” (ASTM 2002).

During the groundwater sampling, field observations, field parameters (when stabilisation parameters as specified in Table 12 are met) and photographs should be recorded. Table 13 lists the parameters to be recorded.

Table 13 Groundwater monitoring field paramaters

Type	Parameter
Bore Description	Unique sample location identifier
	GPS coordinates (WGS 84, decimal degrees)
	Photographic Record
	Sample appearance (colour/odour/clarity/visible sheen – if any)
	Bore details (Total Depth, Screen level)
Field Measurement	Time and date
	pH
	Oxidation Reduction Potential
	Electrical Conductivity
	Dissolved Oxygen
	Turbidity, colour and opacity
	Water Temperature
	Standing Water Level

6.4.3 Sampling Locations

The groundwater monitoring program will be conducted at the locations detailed in Table 14 and as shown in Figure 5. Following recommendations from DPI Water, an additional two dual purpose, monitoring wells will be considered post landfill construction. These two locations include:

- One up gradient of the landfill to measure piezometric levels and methane; and
- One in between ABH11 and ABH12 at least 50 metres downgradient from the wall of the final landfill cell and upgradient of the leachate pond.

Establishment of these additional locations would be confirmed with EPA, DPI Water and/or DP&E.

In addition, a nested well consisting of monitoring wells ABH13a, ABH13b and ABH13c is to be added to the monitoring network replacing ABH04a and ABH04, the northern most monitoring wells (refer ABH13 shown in Figure 6). The nested well will be sampled for the same analytes in the current analytical suite.

Table 14 Groundwater monitoring locations

Monitoring Well ID	Description	Position (MGA94 Zone 56)		RL (m, AHD)		Final Depth (m)
		Easting	Northing			
ABH02	Screened in soil	383744	6619550	955	5.0 – 11.0	11.0
ABH02A	Screened in rock	383748	6619551	955	23.6 – 29.6	30.1
ABH4	Screened in rock	383691	6619577	954	6.0 – 18.0	18.1
ABH4a	Screened in soil	383693	6619577	954	1.0 – 2.8	2.8
ABH9	Screened in soil	383129	6618698	1014	53.5 – 59.5	59.5
ABH11	Screened in rock	383205	6619230	978	30.0 – 36.0	36.0
ABH12	Screened in rock	383558	6619123	970	34.0 – 40.0	40.0
ABH13a	Screened in soil	TBC	TBC	TBC	TBC	TBC
ABH13b	Screened in rock	TBC	TBC	TBC	TBC	TBC
ABH13c	Screened in rock	TBC	TBC	TBC	TBC	TBC

RL = reduced level
AHD = Australian Height Datum

Following recommendations from DPI Water (refer to Section 1.1.1) additional monitoring wells are to be included in this existing network to ensure its adequacy to detect potential leachate contamination. At a minimum, the monitoring well location proposed in Figure 6 (ABH13) will be constructed and operational prior to fill emplacement. The final location of ABH13 will be confirmed in consultation with DPI Water. Shallow and deep wells will be installed at this location in order to monitor the shallow and deep aquifers.

As part of the groundwater monitoring network and environmental management commitments made by this WQMP, Council is committed to ensuring:

- all additional monitoring works are constructed and screened;
- the location and screening are to the satisfaction of DPI Water; and
- the additional monitoring works are operational prior to any landfill emplacement activities.

Establishment of additional monitoring locations would be confirmed with EPA, DPI Water and/or DP&E.

A barometric pressure logger and water loggers will also be installed at key representative monitoring bores, in consultation with DPI Water.

Sampling should be undertaken in accordance with the DQOs outlined in Section 7.1. Demonstration of the DQOs will require the collection of:

- One field duplicate sample for every ten primary samples collected;
- One rinsate blank for each day of sampling; and
- A trip blank for each esky dispatched to the laboratory.

Non-routine sampling may be required in response to environmental incidents or as a result of subsequent environmental investigations at the site. Figure 5 provides the locations that should be monitored as part of the program. This list should be reviewed and updated if additional monitoring wells are installed.

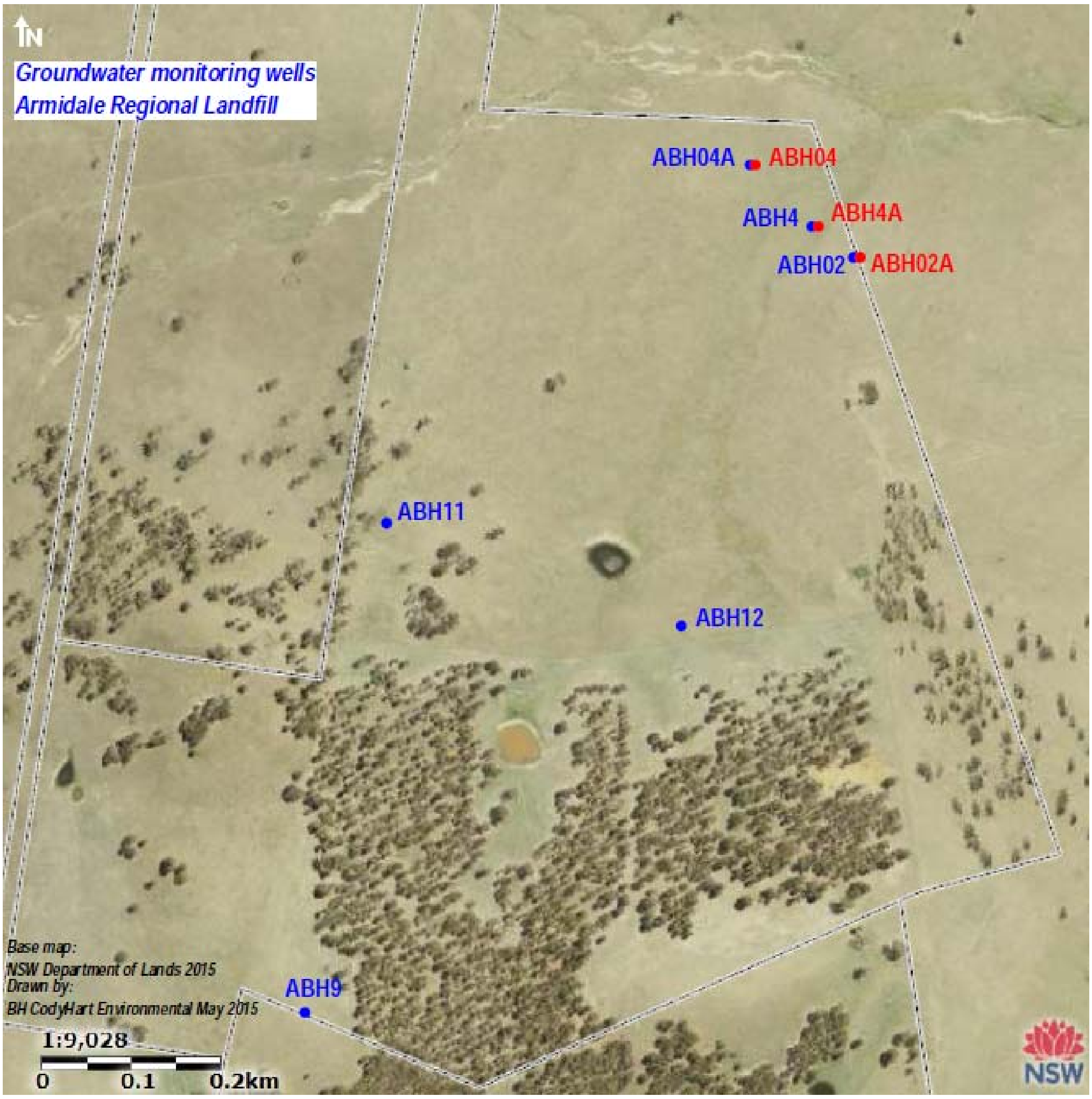
Construction of additional monitoring well ABH13

Drilling of nested monitoring well ABH13 will consist of drilling three separate monitoring wells approximately five metres apart. The monitoring wells are designed to measure standing water levels and extract groundwater from the shallow perched zone, weathered fractured volcanic rock aquifer and fresh fractured rock aquifer. The borehole design will be determined on site during the drilling program and will be dependent on the lithology intersected, groundwater intersected and the distribution of saturated aquifers. It is proposed to drill the deepest bore first to gain an understanding of the geology and hydrogeology intersected, after which the construction details for the intermediate and shallow wells could be designed.

All monitoring wells will be constructed by a licenced drilling contractor. Once drilling is complete, the drilling contractor will be responsible for completing the bore completion report (Form A).

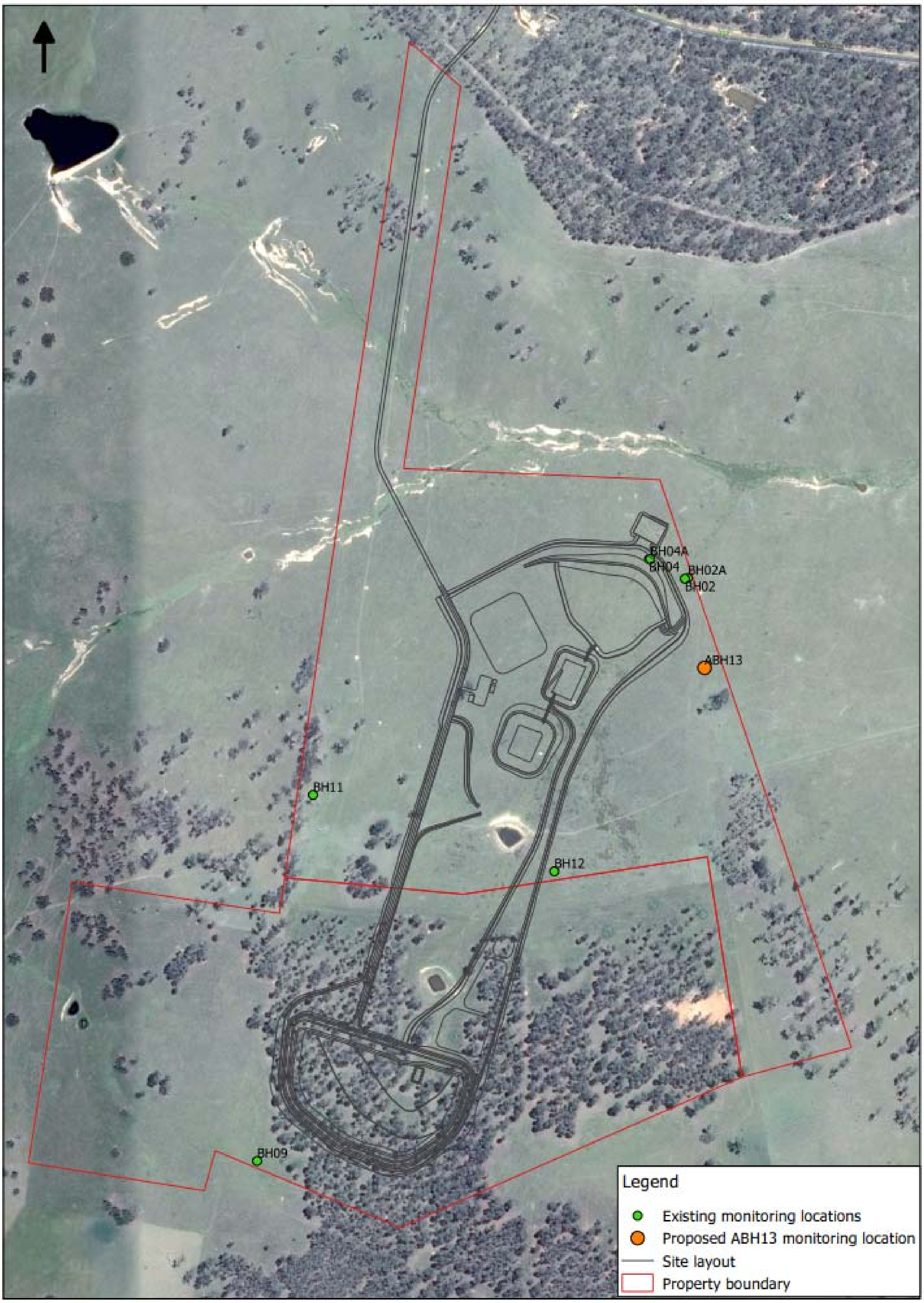
The drilling method, depending on the drilling contractors capabilities is likely to be rotary percussion with down hole hammer. An experienced hydrogeologist or environmental scientist will provide input into the location and design of the monitoring well. During the drilling program the hydrologist will monitor the drilling progress logging the geology and water intersections to assist in designing the monitoring well. Once groundwater is intersected the hole would be airlifted at the change of each drilling rod to estimate the groundwater yield and if pumping the groundwater is sustainable.

Figure 5 Groundwater Monitoring Program - Groundwater Monitoring Locations



Note: Installation of monitoring wells at an additional location is proposed and is highlighted in Figure 6.

Figure 6 Groundwater Monitoring Program – Proposed Additional Groundwater Monitoring Location ABH13



6.4.4 Hydraulic testing

Monitoring of existing wells

Falling Head Tests

The average linear groundwater velocity requires calculating to assist in recommending sampling frequencies during the detection monitoring phase. Calculation of the linear velocity is conducted by the following equation:

The linear or true velocity is calculated by the following equation:

$$\mathrm{V} = \frac{Ki}{\Phi}$$ (Carey et al, 2006)

where V= groundwater velocity (m/day)

K = hydraulic conductivity (m/day)
i = hydraulic gradient
Φ = effective porosity (%)

The hydraulic gradient is known and the porosity can be reasonably estimated, however the hydraulic conductivity is unknown at a number of boreholes and it is recommended that falling head tests are conducted to obtain values of hydraulic conductivity. It is recommended at least three falling head tests are conducted as follows:

- Review monitoring well construction details to determine the borehole diameter, screen interval and borehole depth;
- Review site operations to ensure the aquifer is at equilibrium and is not impacted by recent drilling or localised pumping or the water is not impacted by drilling muds;
- Measure the standing water level;
- Suspend the pressure transducer within the monitoring well, position it towards the base of the hole and check that the data logger is monitoring.
- Pour potable water into the borehole with a bucket or pre-constructed slug as quickly as possible and monitor the water level response automatically with the data logger. A maximum of 20 litres of water is sufficient to induce a suitable response in a 50 mm diameter well.
- At the completion of the test, manually monitor the water level in the monitoring well to compare with the datalogger water levels.
- Repeat the test if the data logger data is of poor quality
- Analyse the data using the Bouwer and Rice (1976), Hvorslev (1951) or Cooper, Bredehoeft, Papadopulos (1967) techniques to calculate hydraulic conductivity.

Construction of additional wells

It has been suggested that the previous slug tests undertaken at the site may be unreliable and an additional method of measuring hydraulic conductivity may be more reliable. Test pumping is an option however it is reliant on there being sufficient water within the aquifer to extract so drawdown in the pumping bore and any observation bores can be measured. During any drilling for monitoring wells, airlifting the hole at the end of each rod will provide an indication if there is sufficient groundwater present in the aquifer to conduct a pump test. If there is more than a “spray” lifted from the hole then the water can be captured in a bund and the yield measured by passing the water over a ‘V’ Notch Weir. Should airlift yields be low (less than 1L/sec) and not sustainable then test pumping would not be recommended and the existing rising head test results would be considered acceptable.

Rising head tests could be conducted on the three additional monitoring wells during the next monitoring program to obtain values of hydraulic conductivity. This will be assessed based on the findings of the drilling program.

Pump tests will be undertaken on all additional monitoring wells at the time of bore construction if it is determined that suitable water volume is available to do so.

6.4.5 Frequency and Analytical Regime

Table 15 describes the groundwater sample frequency and laboratory analytical suite for ongoing groundwater monitoring at the Site. It is noted that groundwater sampling will be undertaken bi-monthly prior to construction.

Table 15 Groundwater Monitoring Program (CodyHart Environmental, 2015)

	Baseline monitoring program	Detection monitoring	Assessment monitoring
Monitoring wells	ABH02, ABH02A, ABH4, ABH4A (dry), ABH04, ABH04A, ABH11, ABH12 (downgradient of landfill), ABH9 (upgradient of landfill) ABHD (duplicate sample taken at one of the above wells)	ABH02, ABH02A, ABH4, ABH4A (dry), ABH04, ABH04A, ABH11, ABH12 (unless redundancies noted in baseline monitoring) ABH9 (upgradient of landfill) ABHD (duplicate sample taken at one of the above wells) ABH13	Wells in which detection monitoring indicates exceedance of three indicator parameter / analytes for three consecutive monitoring rounds.
Sampling frequency	Bi-monthly for eight rounds to be undertaken in any weather condition (i.e. during rainfall, dry conditions, etc.)	Determined from the groundwater average linear velocities for the site based on in-situ hydraulic conductivity estimates. • Moderate groundwater movement – quarterly (mid-gradient wells ABH11 & ABH12); • slow groundwater movement – six monthly (lower gradient ABH02, ABH02A, ABH4, ABH04, ABH04A); • upgradient ABH9 – six monthly - located higher than the landfill cells.	Determine by review of need
Parameters & analytes	Field: Depth, DO, EC, pH, Eh, temp, turbidity, alkalinity, free CO2 Laboratory: Every round: Cl, SO4, Alk, Ca, Mg, Na, K, Nitrogen compounds (NH4+ as N, TKN as N, NOx as N), Filtered [Al, As, Cd, Cr, Cu, Ni, Pb, Zn, Mn, Fe, Se, Hg, Sb, Fe (II)]; TOC (filtered). Every second round: UT VOCs, OC&OP pesticides, UT PAH.	Field: Depth, DO, EC, pH, Eh, temp, turbidity, alkalinity, free CO2 Possible Laboratory: Every round: Cl, SO4, Nitrogen compounds (NH4+ as N, TKN as N, NOx as N), Filtered [Al, As, Cd, Cr, Cu, Ni, Pb, Zn, Mn, Fe, Fe (II)]; TOC (filtered).	Field: Depth, DO, EC, pH, Eh, temp, turbidity, alkalinity, free CO2 Possible Laboratory: Every round: Cl, SO4, Nitrogen compounds (NH4+ as N, TKN as N, NOx as N), Filtered [Al, As, Cd, Cr, Cu, Ni, Pb, Zn, Mn, Fe, Se, Hg, Sb, Fe (II); TOC (filtered). If sheen, colour, odour indicates it is warranted – test UT VOCs, UT PAHs.
QA samples to laboratory	1 intra-lab duplicate per 10 sampling points/wells	1 intra-lab duplicate per 10 sampling points/wells	1 intra-lab duplicate per 10 sampling points/wells

6.5 Leachate Monitoring Program

The monitoring points for the landfill will be the same as the GARA sites for surface water monitoring identified previously in this WQMP.

Onsite leachate monitoring points:

- Leachate Pond stored water (water to be tested for leachate contamination concentrations);
- Sedimentation Basin (water will need to be tested for total suspended solids prior to discharge);
- Dry Basin stored water (water to be tested prior to release to downstream watercourse off-site, water to be tested for potential suspended solids and leachate contamination).

Further details regarding the leachate monitoring program are contained in the Leachate and Water Management Plan (AECOM, 2015), however a brief summary is provided in the following sub-sections.

6.5.1 Purpose

The objectives of the leachate monitoring program are to enable the leachate produced by the landfill to be characterised so that the status of the landfill can be determined (i.e. active landfill) and the storage/use options of the leachate can be assessed.

Leachate will be collected from the leachate collection sump and/or leachate pond. The level of leachate in the pond and leachate collection sump will be recorded at the time the representative samples are taken. The level of leachate in the pond will be monitored to ensure the integrity of the pond’s lining.

6.5.2 Performance Indicators

The results of the Leachate Monitoring Program will be analysed to determine if the landfill is producing leachate with characteristics typical of a General Solid Waste (putrescibles) landfill. Leachate in putrescible waste landfills is generally characterised by high nutrient concentrations (in particular nitrogen compounds), high Total Organic Carbon (TOC), elevated Total Dissolved Salts (TDS) and relatively low pH when compared to fresh unpolluted waters. However, the composition of landfill leachate also varies depending on:

- The age of the landfill.
- Phase of decomposition that the landfill is experiencing at the time.
- Type of waste disposed in the landfill.
- Landfill gas generation, in particular the concentration of carbon dioxide.

6.5.3 Sample Frequency and Analytical Regime

Table 16 describes the sampling frequency and the laboratory analytical suite for ongoing leachate monitoring program at the Site.

Table 16 Leachate Sampling Frequency and Analytical Regime

Location	Frequency	Laboratory Analytical Regime
Leachate collection sump and/or leachate pond	Six monthly for four rounds when leachate becomes available, then annually during any weather condition (i.e. during rainfall, dry conditions, etc.).	Field analytes: - pH - electrical conductivity (EC) - temperature - dissolved oxygen (DO) - redox potential (Eh) - alkalinity - free CO2 (titrations by the end of the sampling day) Laboratory analytes: - 13 metals (As Cd Cr Cu Pb Ni Zn Al Fe Se Hg Mn Sb) - Nitrogen family analytes (NH_4, TKN, NO_x) - Total phosphorus - TOC - Cl and SO_4 (anions) - TPH/TRH(C6-C36 or 40)/BTEX plus VOC - TPH/TRH (C6-C36 or 40)/BTEXN, F1 & F2 (Silica Gel cleanup) - OC&OP Pesticides - PAH

6.6 Additional Requirements

6.6.1 Sample Preservation, Packaging and Shipping

Procedures for containing and preserving groundwater, leachate and surface water samples are as follows.

- The type and size of containers and preservatives used for water samples varies based on the type of analysis to be performed. Samples will be placed and stored in laboratory-supplied sample containers.
- Filtering of groundwater and extraction bore samples to 0.45 m for metals analysis will be conducted using disposable filters prior to preservation (i.e. placement within the preserved laboratory supplied sample bottle).
- All water samples will be placed in a cooler with ice to maintain samples at <6^{o}C prior to analysis.
- Holding times for water samples vary according to the type of analysis that is to be performed. In general, holding times for common types of analyses are as follows:
  - samples to be analysed for *E. Coli* and enterococci can be held a maximum of 1day.
  - samples to be analysed for VOCs can be held a maximum of 14 days.
  - samples to be analysed for other organic chemicals (including TRH, PAHs and phenols) can be held a maximum of 7 days until extraction, and then for 40 days until analysis.
  - samples to be analysed for metals (except mercury) can be held a maximum of 6 months.

- Samples will be labelled with specific details including:
    - date and time of sample collection.
    - project number.
    - name(s) of sampler.
    - sample identification number.
    - sample preservatives used.

6.6.2 Chain of Custody (COC) Protocols

Samples collected in the field must be able to be tracked from the time of collection until the analytical laboratory receives them. To document sample possession, Chain of Custody (COC) procedures shall be followed.

COC records shall include the following information:

- Project number.
- Name(s) of sampler.
- Time and date of sample collection.
- Sample type (i.e. water, soil or sediment).
- Number and type of sample containers (including preservatives used).
- Sample identification number.
- Receiving analytical laboratory.
- Required analyses.
- Contact details for questions regarding sample analysis.
- Names, dates, times and signatures documenting all changes in sample possession from:
    - the person collecting the samples in the field; to the –
    - courier transporting the samples to the laboratory; to the -
    - analytical laboratory.

COC records will accompany samples at all times once the samples are collected.

6.6.3 Decontamination

Field personnel are responsible for ensuring that all field equipment is decontaminated prior to use for the collection of samples as required by the WQMP. Decontamination is performed to eliminate the possibility of cross-contamination from previous projects or between sampling locations. In general, decontamination consists of either: a high pressure, hot water wash (steam-cleaning); or, a non-phosphate detergent solution (Decon 90, or Alconox) wash followed by deionized, distilled, or clean water rinse(s).

The decontamination procedures must be performed before initial use of any equipment for sample collection and after each subsequent use.

Decontamination procedures that must be utilised during sampling are as follows:

- Prior to collection of each sample, all sampling and measurement field equipment (e.g. water quality meters etc) will be hand washed with a mixture of water and phosphate free detergent. This will be followed by a double dioinised water rinse. Where possible, equipment will be wiped with disposable paper towel prior to, and after, decontamination as above.
- The air discharge line, fluid line and internal air bladder used in the low flow purging and sampling system will be dedicated (i.e. re-used for subsequent rounds in dedicated location) or replaced between groundwater monitoring wells.

6.7 Data Management and Reporting

Reporting will be required at the completion of each monitoring program. The objectives of the report will be to: interpret the analytical results received; identify any compliance issues; trigger implementation of contingency plan (as described by **Section 6.7**); and, recommend any additional or modified management measures that might be required.

The specific reporting requirements for the WQMP are as follows.

- Verbally report to the Waste Manager any criteria exceedances of the contaminants of concern within 24 hours of obtaining results from the laboratory.
- Provide an environmental monitoring report (EMR) from each sampling event (ie. Quarterly, annually).

6.7.1 Verbal Reporting

All trigger level exceedances will be reported verbally to the Waste Manager. The purpose of the verbal reporting is to enable identification of and proactive management of any changed conditions (for example a leaking pipe or tank) which might have contributed to the trigger level exceedance.

All verbal reporting, including any agreed actions, shall be confirmed in writing by e-mail.

6.7.2 Progress Reporting

Progress reports will be prepared upon completion of each sampling event. Progress reports will include, as minimum requirements:

- The locations of all groundwater monitoring wells and surface water sample sites sampled as part of the sampling event;
- A description of the sampling methodology used and, in particular, any departures from the requirements of this WQMMP;
- Descriptions of all samples collected, including measured field parameters, in accordance with the WQMMP;
- Tabulated comparison of analytical results from the subject sampling event with the trigger levels recommended by the WQMP and with historical sampling results;
- Identification of any trigger level exceedances, sample data anomalies or sample data trends and provision of an explanation (for example changed conditions such as a leaking pipe or a spill event);
- Assessment of the quality of data obtained and achievement of the Data Quality Objectives recommended by the WQMP;
- Recommendation of management actions, including but not limited to triggering of the Contingency Plan described by **Section 8.0**; and
- Recommendations (if any) for modification of the WQMP.

6.7.3 Annual Summary Reporting

Annual summary reports will be prepared upon the conclusion of each calendar year. Annual summary reports will include, as minimum requirements:

- A summary of all groundwater and surface water samples collected during the preceding year;
- Tabulated comparison of analytical results from the subject sampling event with the trigger levels recommended by the WQMP and with historical sampling results;
- Summary of any trigger level exceedances, sample data anomolies or sample data trends and provision of an explanation (for example changed conditions such as a leaking pipe or a spill event);
- Summary of recommended management actions, including but not limited to triggering of the Contingency Plan described by **Section 8.0**;

- Summary of Contingency measures implemented in accordance with **Section 8.0** (if any); and
- Summary of recommendations (if any) for modification of the WQMP.

7.0 Quality Assurance/Quality Control

7.1 Data Quality Objectives

The National Environmental Protection Measure (NEPM, Schedule B[2]) *Guideline on Data Collection, Sample Design and Reporting* (1999), specifies that the nature and quality of the data produced in an investigation will be determined by the Data Quality Objectives (DQOs). As referenced by the NEPM, the DQO process is detailed in the US EPA *Guidance for the Data Quality Objectives Process* (1994), EPA QA/G-4 (EPA 600R96055). The US EPA defines the process as:

> *'a strategic planning approach based on the Scientific Method that is used to prepare for a data collection activity. It provides a systematic procedure for defining the criteria that a data collection design should satisfy, including when to collect samples, where to collect samples, the tolerable level of decision errors for the study, and how many samples to collect'.*

The process of establishing appropriate DQOs is defined by the USEPA according to the following seven steps (Table 17).

Table 17 DQO Steps

Step	Data Quality Objective
1	**State the problem** – define the problem to be addressed, identify the planning team, examine budget and schedule.
2	**Identify the decision** – outline the decision, the study question and alternative actions.
3	**Identify inputs to the decision** – present parameters and inputs for decision, including information sources, basis for trigger/guideline levels, sampling and analysis methodology, etc.
4	**Define the study boundaries** – present spatial and temporal limits for study, sample characteristics and decision making units.
5	**Develop a decision rule** – define a statistical parameter, specify trigger/guideline levels and develop argument for action.
6	**Specify limits on decision errors** – set acceptable limits for decision errors relative to potential consequences such as health, budget, social or environmental impacts.
7	**Optimise the design for obtaining data** – develop an effective sampling and analysis plan that meets resource and performance criteria.

In the context of the WQMP adoption of the DQO process is considered critical to obtaining relevant data for interpretation and development and implementation of associated management or mitigation measures. The DQO process was considered in the development of the WQMP and to address QA/QC measures to be adopted during the program.

The approach adopted relative to the seven steps presented above is discussed below.

7.1.1 Step 1 - State the Problem to be Resolved

The problems to be addressed are whether:

- Any potential groundwater or surface water contamination issues are present.
- Any contamination or performance issues can be effectively managed and what measures can be taken to reduce associated impacts.

7.1.2 Step 2 - Identify the Decision to be Made

The decision identification component of the DQO process represents the key issues that need to be reviewed / considered in order to resolve the problems identified in Step 1. These issues include:

- Are contaminant concentrations above background levels?

- Do the concentrations identified exceed the relevant regulatory guidelines levels?
- Has the extent of any groundwater/surface water contamination been identified?
- Are the current groundwater surface/water monitoring results representative of historical results?
- Do the contaminant concentrations adversely impact upon human health or the environment for the identified receptors of concern?
- Is the investigation approach scientifically suitable and defensible?

7.1.3 Step 3 - Identify Inputs to the Decision

To allow assessment of the data against the objectives listed above, various inputs are considered. The following list presents various inputs considered.

- Relevant regulatory guidelines / trigger levels;
- Landfill performance criteria;
- Aesthetic impacts (odours, sheen, etc);
- Identification of the contaminants of interest for each area, based on previous investigation data;
- The known distribution of surface water / groundwater contamination at and surrounding the site; and
- The previously recorded concentrations of contaminants relative to the guidance levels.

7.1.4 Step 4 - Define the Boundaries of the Investigation

The spatial boundaries (geographical limits) applied for data collection and decision making in the investigations are defined as follows:

- The extent of the sampling locations surrounding the site; and
- The groundwater aquifer to a depth of approximately 60 mBGL

7.1.5 Step 5 - Develop a Decision Rule

Based upon the relevance of all of the data collected, the decision rule for the program is to assess:

- The representativeness of current and historic analytical data;
- Whether the current groundwater and/or surface water controls (if any) are adequate; and
- Whether previous conclusions regarding risk to the environment are still accurate/relevant.

7.1.6 Step 6 - Specify Limits on Decision Errors

A decision error in the context of the decision rule presented above would lead to either underestimation or overestimation of the risk level associated with a particular area. Decision errors may include:

- Limitations based on inaccurate/inadequate data from previous investigations;
- Errors in the WQMP;
- Data not representative of site conditions; and
- Inadequate data quality (refer to Section 7.3).

7.1.7 Step 7 - Optimise the Design for Obtaining Data

The methodology presented represents a program which is designed to meet the objectives of the WQMP and also to achieve the nominated DQOs. Optimisation of the data collection process will be achieved by:

- Targeted sampling based on historical and anecdotal evidence.

7.2 QA/QC Data Assessment

7.2.1 Field QA/QC

All work completed on the site will be conducted in accordance with standard environmental sampling protocols. The essential elements of the QA/QC program are presented in Table 18.

Table 18 Essential elements of the field QA/QC program

Action	Description
Use of Experienced Personnel	Field work will be undertaken by people well trained in surface water and groundwater sampling and workplace health and safety issues, or supervised by someone who is.
Record Keeping	Full records of all field activities including water monitoring data and sample collection will be maintained on standard field logging sheets.
Sample Collection	New nitrile gloves will be worn during water sampling, and replaced between each sample collection.
Sample Labelling	A unique sample number will be used for each sample to clearly specify the sample origin (site/well number and date), preservation standards and analytical requirements.
Chain of Custody	Chain of Custody procedures are required for all sample transfers. Custody sheets should list sample numbers; date of collection and analyses required and be signed by each person transferring and accepting custody.
Sample Storage	The collected water samples will be transferred to approved sampling containers with appropriate preservation as required and then placed in cool storage prior to transfer to a NATA accredited laboratory.
Decontamination	All equipment used in the sampling process will be decontaminated using a phosphate free detergent, followed by rinsing with de-ionised water, prior to mobilisation and between sampling locations to reduce the risks of cross contamination.

Field Duplicates

In addition to the primary samples, quality control field duplicate (inter-laboratory duplicates) samples will be collected to assess aspects of field protocols and laboratory performance and to classify the validity of the laboratory data. Field duplicates will be collected in general accordance with AS 4482.1-2005 guidelines (Standards Australia 2005).

A relative percentage difference (RPD) analysis of primary and duplicate / triplicate samples is used to measure the representativeness and/or precision of duplicate samples. The RPD is calculated from the absolute difference between results of the duplicate pair divided by the mean value of the duplicate pair.

$\text{RPD}(\%) = 100 \times (D1-D2) / ((D1+D2) / 2)$

where: $D1$ = primary sample analysis
$D2$ = duplicate sample analysis

Laboratory quality assurance reports present relevant RPD for each analyte and medium and should be adopted.

7.2.2 Laboratory QA/QC

The laboratory used in the investigations will be National Association of Testing Authorities (NATA) approved for the analyses required. Quality assurance procedures adopted by the analytical laboratory will include analysis of blanks, duplicates, laboratory control samples, matrix spikes and surrogate spikes (for organics).

A description of the laboratory's minimum quality assurance procedures is presented in Table 19.

Table 19 Description of laboratory quality assurance procedures

QA Procedure	Description
Laboratory Blanks and Controls	The quality control term Method/Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC type is to monitor potential laboratory contamination. The quality control term Laboratory Control Sample (LCS) refers to a known, interference free matrix spiked with target analytes or certified reference material. The purpose of this QC type is to monitor method precision and accuracy independent of sample matrix. Frequency of QC samples 1 in 20.
Laboratory Duplicates	The quality control term Laboratory Duplicate refers to an intra laboratory split sample randomly selected from the sample batch. Laboratory duplicates provide information on method precision and sample heterogeneity. Relative percentage differences (RPDs) are used to assess precision. Frequency of QC samples 1 in 10.
Matrix Spikes	The quality control term Matrix Spike (MS) refers to an intra laboratory split sample spiked with a representative set of target analytes. The purpose of this QC type is to monitor potential matrix effects on analyte recoveries. The samples undergo the same extraction and analysis procedures and the results are used to assess the method precision and bias. Spike recoveries are reported as a percent recovery. Frequency of QC samples 1 in 20.
Surrogate Spikes	The quality control term Surrogate Spike refers to a compound added to a sample aliquot in known amounts before extraction and analysis. The compound should be similar in composition and behaviour to the target analyte but not naturally occurring in the sample. A surrogate is used to monitor the method performance for analysis of organic compounds. Spike recoveries are reported as a percent recovery.

All samples will be received by the laboratory in appropriately pre-treated and preserved containers and within specified holding times.

7.3 Assessment of Data Quality

Based on the outcomes of the DQO process the quality of the data collected in accordance with the WQMP should be assessed according to a range of factors including:

- documentation and data completeness
- data comparability, representativeness and precision and accuracy for sampling and analysis.

The relevant evaluation criteria for each of these issues are presented in Table 20.

Table 20 DQO Evaluation

DQO	Evaluation Criteria
Documentation Completeness	Site conditions properly described
	Investigation area properly described
	Understanding of site history and chemicals of interest presented
	Sampling locations properly described and accurately located
Data Completeness	Samples tested for appropriate chemicals of interest
	Completion of field records, chain of custody forms, laboratory sample receipt and test certificates from NATA registered laboratories.
	Consideration of key receptors of interest
	Monitoring strategies assessed and preferred selection based upon site specific factors
Data Comparability	Appropriate sampling techniques, sample storage and transportation of samples used
	Selection of NATA certified laboratory using NEPM testing procedures
	Inter-laboratory duplicate samples
Data Representativeness	Collection of representative samples (and adequate numbers) from each location
	Use of properly trained field personnel
	Assessment of the RPD for laboratory and field duplicate samples
	Assessment of the analytical results for laboratory quality control samples

Table 21 Acceptance criteria for data quality indicators water analysis

Data Quality Indicator	Acceptance Criteria
Intra laboratory field duplicates (1) (3)	RPD presented in laboratory quality assurance reports.
Laboratory duplicates (2) (3)	RPD less than: 20% for high level laboratory duplicates (i.e. >20 x LOR) 50% for medium level laboratory duplicates (i.e. 10 to 20 x LOR)
Matrix spikes (3) (4)	Recoveries between 70-130% of the theoretical recovery
Method blanks	Less than the laboratory LOR
Laboratory control samples (5)	Recoveries between 70-130%.
Surrogate spikes	See Note 6

1. Potential exceptions to these criteria may occur where sample variation or heterogeneity, rather than poor laboratory performance, is accountable for the poor reproducibility, or where the results are close to the LOR. This typical RPD range is obtained from AS 4482.1-2005 *Guide to the investigation and sampling of sites with potentially contaminated soil*.

2. If the results are close to the LOR, then higher results will be accepted.

3. Criteria for sample duplicate and matrix spike results assume no sample heterogeneity. If samples are found to be heterogeneous with respect to a particular analyte the above criteria does not apply.

4. Assumes that samples are homogeneous and the background analyte level is less than 20% of the spike level (refer to USEPA Method 8000B). Note that there is no requirement for matrix spikes to pass as certain matrices may preclude recovery of spiked compounds. In this case data will be accepted if LCS data meets the acceptance criteria.

5. 80% of the compounds tested must fall within the control limits. Control limits are dynamic and vary for individual tests as per USEPA Method 8000B.

6. Recoveries for surrogates are test dependent and are based on USEPA Method SW846. Control limits are dynamic and vary for individual tests but are within the criteria described in USEPA Method SW846.

8.0 Contingency Plan

The Site's Pollution Incident Response Management Plan (PIRMP) will identify procedures for incidents and immediate response actions. Where appropriate the PIRMP will articulate the Triggers, Actions, and Response in place for the landfill with reference the trigger values and actions within this WQMP.

This contingency plan outlines the measures to be taken in response to:

- An exceedance of the specified guidance levels described in Table T1 and Table T2 in Appendix A (only where those values are not already naturally exceeding as described in Section 3.0); and/or
- An exceedance or change in concentration compared to the baseline data.

The contingency outlines measures, including assessment monitoring, to be taken in the event groundwater and/or surface water detection monitoring results exceed either the guidance levels or historically reported results (as applicable) are described following.

If surface or groundwater pollution is detected, the Waste Manager will take immediate action to contain the pollution, and prepare a report to the EPA detailing the nature and source of the contamination, any actions taken, and future actions that will be carried out to prevent recurrence. The process for groundwater monitoring, assessment and remediation is shown in Figure 7.

8.1 Contingency Measures

8.1.1 Repeat Sampling

A repeat sample will be collected from the same location at which the exceedance was reported. The sample will be collected as soon as possible following receipt of the elevated result to minimise differences in site conditions which might occur over time.

In addition, repeat samples will also be collected upstream / hydraulic gradient and downstream / hydraulic gradient of the subject sample location.

The objectives of the repeat sampling event are to:

- Validate the reported result and demonstrate that the result, and the observed exceedance(s), can be replicated;
- Define the spatial extent of the observed impact; and
- Assist in defining the source of the observed impact.

In the event that repeat sampling does not validate the original result, consideration will be given to:

- Whether the original result was anomalous; or
- Whether a further repeat sample is warranted;
- Whether the monitoring frequency should be increased to provide for detection of temporal variations not otherwise detected by the current program.
- Whether a program of assessment monitoring is required.

In the event that repeat sampling does validate the original result, a detailed conceptual site model and risk assessment will be undertaken.

8.2 Conceptual Site Model and Risk Assessment

A preliminary conceptual site model has been developed (Figure 4 of WLMP) and considers:

- Potential sources of the identified contamination – including changes in site conditions and activities which could have resulted in the observed impact;
- Potential pathways from the potential source to the observed impact and from the observed impact to potential receptors; and
- Potential receptors of the observed impact.

A risk assessment considering the above pathways will be able to further quantify potential impacts to human and environmental health. Should an increase in risk to Armidale Dumaresq Council be identified (i.e. where contamination is likely to result in unacceptable impacts to human or environmental health), consideration will be given in initiation of corrective action as described by Section 8.3.

Should no increase in risk to Armidale Dumaresq Council be identified, consideration will be given to increasing the frequency of monitoring at the subject location such that any future changes are detected in a timely fashion and proactively managed.

8.3 Corrective Action

Depending on the outcomes of the preceding repeat sampling and risk assessment, corrective actions may be warranted. Corrective actions may include:

- Modification of the existing monitoring program
- Implementation of management or remediation strategies (refer Section 8.2 of the WLMP), as appropriate.

The requirement of corrective action will take into consideration: the degree of trigger value exceedance; nature of the contaminant; and, available historical data. In the case of significant exceedances, potentially resulting from spills or leaking infrastructure, immediate management or remediation responses to mitigate the impacts would be considered.

The selected response is particularly important to surface water exceedances at a site boundary sampling location because of the potential to impact off-site receptors.

8.3.1 Monitoring Program Modification

The purpose of any modification to the monitoring program would be to:

- Refine the conceptual site model prepared in respect of the identified impact, including identification of the contamination source;
- Refine the assessment of risk to Armidale Dumaresq Council related to the identified impact;
- Enable design of appropriate management or remediation measures (determined in consultation with EPA); and
- Identify what parameters may be affecting the analytical results (e.g. an increasing water table that encounters soil contamination not previously affecting groundwater quality).

Modifications to the monitoring program might include:

- Inclusion of additional monitoring well/sampling locations,
- Amending the analytes being assessed,
- Lowering the laboratory detection limits (through collection of additional sample, modification of analysis methodology),
- Increasing the frequency of sample collection.
- Implementation of assessment monitoring.

8.3.2 Management Strategies

In the event that surface water detection monitoring results exceed the monitoring criteria, the EPA would be notified and an action plan implemented.

Remedial actions would be undertaken to contain the contaminants. These may include identifying the cause of the exceedance and taking measures to prevent further pollution (e.g. inspection and repair of the leachate pond liner to prevent further leaks). Depending on the extent and nature of the exceedance, water and sediments downstream may also need to be treated in order to return them to their original condition.

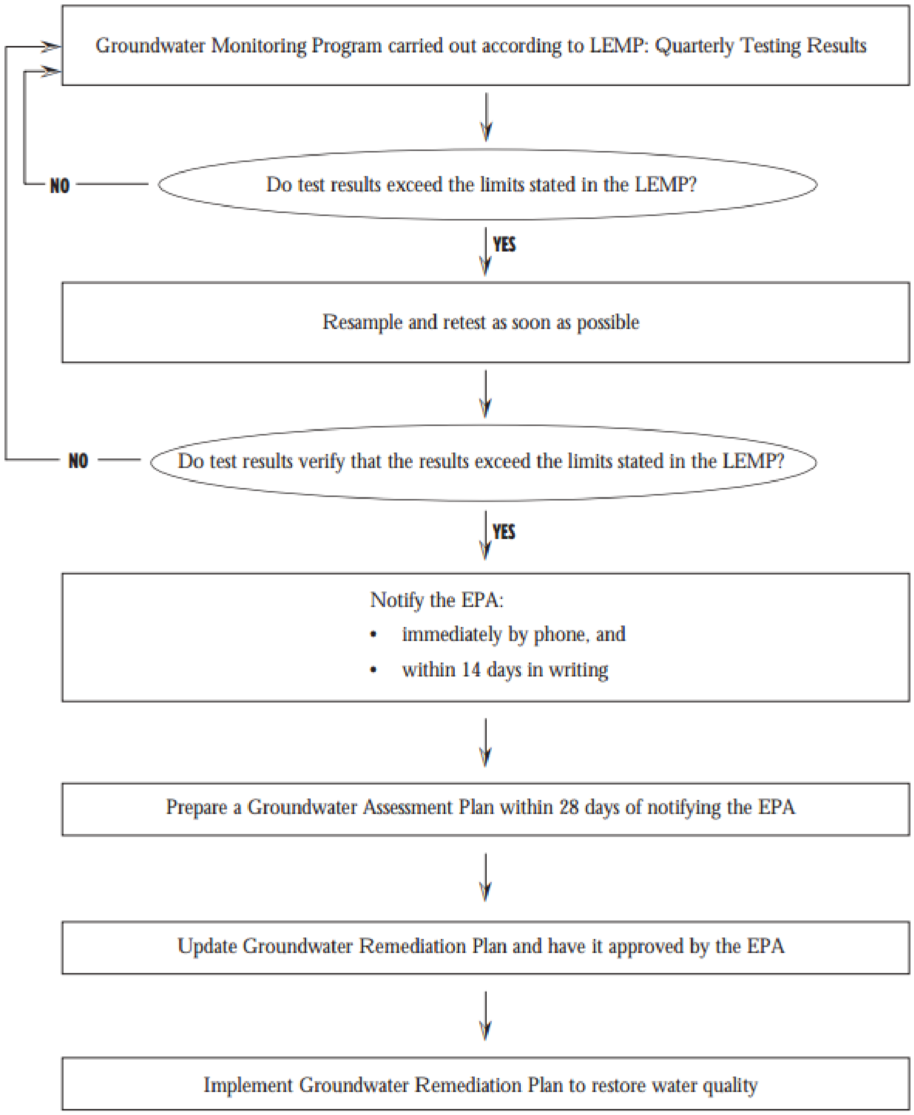
Measures may need to be undertaken to prevent re-occurrence of pollution incidences, which may include re-design of the leachate storage system as outlined in the EPA Landfill Guidelines.

If groundwater or subsoil contamination is confirmed, a detailed Groundwater Contamination Remediation Plan would be developed in accordance with the Benchmark Technique Number 9.

Procedures to deal with a contamination incident could include techniques such as:

- Modification of current work practices or provision of improved waste management facilities to minimise the future risk of spills and impact to surface water or groundwater.
- Active remediation, such as removal of the primary contaminant source (for example a leaking cell liner) and secondary source (for example impacted soil surrounding the cell liner). Measures may include:
    - Isolation of the source of the contaminant.
    - Immobilisation of the contaminant.
    - Installation of cut-off bunds, barrier walls or cut-off trenches.
    - Excavation and repair of capping/liner.
    - Groundwater extraction, treatment and reinjection.
- Institutional controls, such as fencing, establishment of a groundwater exclusion zone, or implementation of a site management plan, to limit access to identified impact.
- Preparation of a report to the EPA detailing the nature and source of the contamination, any actions taken, and future actions that will be carried out to prevent recurrence.

Techniques implemented will dependent upon the extent and nature of any contamination incident. Consultation on management techniques is to be undertaken with EPA and DPI Water where required to ensure the best environmental outcome. Where appropriate, DPI Water should be issued a copy of the Groundwater Assessment and Remediation Plans.



Source: EPA Landfill Guidelines

Figure 7 Process for Groundwater Monitoring, Assessment and Remediation

9.0 Review and Continual Improvement

9.1 Frequency of Review

In accordance with Condition 5 / Schedule 5 of the Conditions of Approval, within three months of a report submission to the Secretary, including the annual report, incident report and independent environmental audit, this WQMP shall be reviewed, and if necessary revised to the satisfaction of the Secretary.

The review would assess all information relevant to the WQMP including but not limited to:

- Historical analytical data
- Changes in land use
- Changes in extraction water use (where applicable)
- Changes in water use (e.g. for recreational activities)
- Changes in guideline criteria
- Outcomes of new environmental assessments
- New contamination issues.

The WQMP would need to be modified to reflect any variation in sampling frequency, addition of new sampling locations or variation in the analytical regime for example, from a new contamination issue being identified on site).

In accordance with Conditions 11 and 12 of the EPBC approval, the WQMP would be updated to reflect any additional activities not covered by this plan, or under the direction of the Minister to protect world heritage properties or national heritage places. The revised plan would then be submitted to the Department of Environment and Energy to be approved in writing by the Minister.

The WQMP would be viewed as a live document and updated as necessary, noting that revision of the WQMP may result in the monitoring regime increasing or decreasing.

In accordance with Condition 8 of the Conditions of Approval under the *Environment Protection and Biodiversity Conservation Act 1999*, records of all monitoring activities would be kept including:

- full records of all field activities including water monitoring data and sample collection (in the form of field logging sheets)
- QA/QC information including field records, chain of custody forms, laboratory sample receipt and test certificates from NATA registered laboratories
- Environmental monitoring reports (EMR).

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Appendix A

Water Quality Environmental Value Criteria

Appendix A Water Quality Environmental Value Criteria

Table T1: Water Quality Targets - New South Wales / Rivers Upland (µg/L)

Indicator (µg/L)	Environmental Value					
	Aquatic Ecosystem Protection	Recreation	Drinking Water	Livestock Drinking Water	Irrigation (long term targets)	Aquaculture
Total Nitrogen (µg/L as N)	250				5,000	
Nitrogen Oxides (NO_x) (µg/L as N)	15					
Nitrate (µg/L as N)		5,000 *	50,000** (health)	400,000 (health)		50,000
Nitrite (µg/L as N)		300** (primary contact)	3,000** (health)	30,000 (health)		100
Ammonia (µg/L as N)		50 (primary contact)	500 (aesthetic)			20 (pH>8.0)
Total Phosphorus (µg/L as P)	20				50	
Filterable Reactive Phosphate (FRP) (µg/L as P)	15					
Phosphates (µg/L as P)						100
Turbidity (NTU)	2-25***	>1.6 m Secchi depth (primary contact)	5 (aesthetic)	6,000^^^		40 mg/L TSS^
Salinity (µS/cm)	30-350^^					4,500
Sodium (µg/L)		18,000 (primary contact)	180,000 (aesthetic)		115,000#	
Chloride (µg/L)		25,000 (primary contact)	250,000 (aesthetic)		175,000#	
Dissolved Oxygen	<80%					
pH	6 – 8.5					

Notes:

Nitrogen (total nitrogen, ammonia, NOx, nitrate, nitrate) values as µg/L N, except:

* Nitrate as µg/L $N0_3$

** Nitrite as µg/L $N0_2$

*** High turbidity values apply to high flows

^ TSS – Total Suspended Solids
^^ Low values in Highlands; High values in NSW
^^^ Beef cattle, No effect (see Water Quality Targets On-line for other receptors)
# Prevention of foliar Injury – most sensitive species

Table T2: ANZECC trigger values for freshwater aquatic ecosystems 95% level of protection for slight to moderately disturbed systems (µg/L)

Chemical	Trigger values for freshwater (μ g/L)
METALS & METALLOIDS	
Aluminium (pH>6.5)	55
Aluminium (pH<6.5)	0.8
Antimony	9
Arsenic (As III)	24
Arsenic (As V)	13
Beryllium	0.13
Bismuth	0.7
Boron	370
Cadmium	0.2
Chromium (Cr III)	3.3
Chromium (Cr VI)	1
Cobalt	2.8
Copper	1.4
Gallium	18
Iron	300
Lanthanum	0.04
Lead	3.4
Manganese	1900
Mercury (inorganic)	0.06
Mercury (methyl)	ID
Molybdenum	34
Nickel	11
Selenium (Total)	5
Selenium (Se IV)	11
Silver	0.05
Thallium	0.03
Tin (inorganic,Sn IV)	3
Tributyltin (as µg/L Sn)	0.002
Uranium	0.5
Vanadium	6
Zinc	8
NON-METALLIC INORGANICS	
Ammonia	900
Chlorine	3

Chemical	Trigger values for freshwater (μ g/L)
Cyanide	7
Nitrate	700
Hydrogen sulfide	1
ORGANIC ALCOHOLS	
Ethanol	1400
Ethylene glycol	330
Isopropyl alcohol	4200
CHLORINATED ALKANES	
Chloromethanes	
Dichloromethane	4000
Chloroform	370
Carbon tetrachloride	240
Chloroethanes	
1,2-dichloroethane	1900
1,1,1-trichloroethane	270
1,1,2-trichloroethane	6500
1,1,2,2-tetrachloroethane	400
Pentachloroethane	80
Hexachloroethane	290
Chloropropanes	
1,1-dichloropropane	500
1,2-dichloropropane	900
1,3-dichloropropane	1100
CHLORINATED ALKENES	
Chloroethylene	100
1,1-dichloroethylene	700
1,1,2-trichloroethylene	330
1,1,2,2-tetrachloroethylene	70
3-chloropropene	3
1,3-dichloropropene	0.1
ANILINES	
Aniline	8
2,4-dichloroaniline	7
2,5-dichloroaniline	3
3,4-dichloroaniline	3
3,5-dichloroaniline	1

Chemical	Trigger values for freshwater (μg/L)
Benzidine	2.5
Dichlorobenzidine	0.5
AROMATIC HYDROCARBONS	
Benzene	950
Toluene	180
Ethylbenzene	80
o-xylene	350
m-xylene	75
p-xylene	200
m+p-xylene	ID
Cumene (*i*-propyl benzene)	30
Polycyclic Aromatic Hydrocarbons	
Naphthalene	16
Anthracene	0.4
Phenanthrene	2
Fluoranthene	1.4
Benzo(a)pyrene	0.2
Nitrobenzenes	
Nitrobenzene	550
1,2-dinitrobenzene	0.6
1,3-dinitrobenzene	13
1,4-dinitrobenzene	0.6
1,3,5-trinitrobenzene	4
1-methoxy-2-nitrobenzene	130
1-methoxy-4-nitrobenzene	16
1-chloro-2-nitrobenzene	15
1-chloro-3-nitrobenzene	12
1-chloro-4-nitrobenzene	1
1-chloro-2,4-dinitrobenzene	4
1,2-dichloro-3-nitrobenzene	15
1,3-dichloro-5-nitrobenzene	3
1,4-dichloro-2-nitrobenzene	10
2,4-dichloro-2-nitrobenzene	12
1,2,4,5-tetrachloro-3-nitrobenzene	0.3
1,5-dichloro-2,4-dinitrobenzene	0.03
1,3,5-trichloro-2,4-dinitrobenzene	0.2

Chemical	Trigger values for freshwater (μ g/L)
1-fluoro-4-nitrobenzene	28
Nitrotoluenes	
2-nitrotoluene	110
3-nitrotoluene	75
4-nitrotoluene	120
2,3-dinitrotoluene	0.3
2,4-dinitrotoluene	16
2,4,6-trinitrotoluene	140
1,2-dimethyl-3-nitrobenzene	4
1,2-dimethyl-4-nitrobenzene	16
4-chloro-3-nitrotoluene	1.5
Chlorobenzenes and Chloronaphthalenes	
Monochlorobenzene	55
1,2-dichlorobenzene	160
1,3-dichlorobenzene	260
1,4-dichlorobenzene	60
1,2,3-trichlorobenzene	3
1,2,4-trichlorobenzene	85
1,3,5-trichlorobenzene	8
1,2,3,4-tetrachlorobenzene	2
1,2,3,5-tetrachlorobenzene	3
1,2,4,5-tetrachlorobenzene	5
Pentachlorobenzene	1.5
Hexachlorobenzene	0.05
1-chloronaphthalene	1.6
Polychlorinated Biphenyls (PCBs) & Dioxins	
Capacitor 21	0.002
Aroclor 1016	0.001
Aroclor 1221	1
Aroclor 1232	0.3
Aroclor 1242	0.3
Aroclor 1248	0.03
Aroclor 1254	0.01
Aroclor 1260	25
Aroclor 1262	50
Aroclor 1268	50

Chemical	Trigger values for freshwater (μ g/L)
2,3,4’-trichlorobiphenyl	0.07
4,4’-dichlorobiphenyl	0.1
2,2’,4,5,5’-pentachloro-1,1’-biphenylB	0.2
2,4,6,2’,4’,6’-hexachlorobiphenyl	0.15
Total PCBs	ID
2,3,7,8-TCDD	0.00001
PHENOLS and XYLENOLS	
Phenol	320
2,4-dimethylphenol	2
Nonylphenol	0.1
2-chlorophenol	340
3-chlorophenol	4.5
4-chlorophenol	220
2,3-dichlorophenol	31
2,4-dichlorophenol	120
2,5-dichlorophenol	3
2,6-dichlorophenol	34
3,4-dichlorophenol	2
3,5-dichlorophenol	4
2,3,4-trichlorophenol	1
2,3,5-trichlorophenol	2
2,3,6-trichlorophenol	2
2,4,5-trichlorophenol	0.5
2,4,6-trichlorophenol	3
2,3,4,5-tetrachlorophenol	0.2
2,3,4,6-tetrachlorophenol	10
2,3,5,6-tetrachlorophenol	0.2
Pentachlorophenol	3.6
Nitrophenols	
2-nitrophenol	2
3-nitrophenol	1
4-nitrophenol	58
2,4-dinitrophenol	45
2,4,6-trinitrophenol	250
ORGANIC SULFUR COMPOUNDS	
Carbon disulfide	20

Chemical	Trigger values for freshwater (μ g/L)
Isopropyl disulfide	8
n-propyl sulfide	20
Propyl disulfide	3
Tert-butyl sulfide	30
Phenyl disulfide	0.1
Bis(dimethylthiocarbamyl)sulfide	10
Bis(diethylthiocarbamyl)disulfide	1
2-methoxy-4H-1,3,2-benzodioxaphosphorium-2-sulfide	2
Xanthates	
Potassium amyl xanthate	0.5
Potassium ethyl xanthate	0.05
Potassium hexyl xanthate	500
Potassium isopropyl xanthate	15
Sodium ethyl xanthate	0.05
Sodium isobutyl xanthate	5
Sodium isopropyl xanthate	0.05
Sodium sec-butyl xanthate	5
PHTHALATES	
Dimethylphthalate	3700
Diethylphthalate	1000
Dibutylphthalate	9.9
Di(2-ethylhexyl)phthalate	1
MISCELLANEOUS INDUSTRIAL CHEMICALS	
Acetonitrile	160
Acrylonitrile	8
Poly(acrylonitrile-co-butadiene-costyrene)	530
Dimethylformamide	1000
1,2-diphenylhydrazine	2
Diphenylnitrosamine	6
Hexachlorobutadiene	0.04
Hexachlorocyclopentadiene	0.05
Isophorone	120
ORGANOCHLORINE PESTICIDES	
Aldrin	0.001
Chlordane	0.03

Chemical	Trigger values for freshwater (μg/L)
DDE	0.03
DDT	0.006
Dicofol	0.5
Dieldrin	0.01
Endosulfan	0.03
Endosulfan alpha	0.0002
Endosulfan beta	0.007
Endrin	0.01
Heptachlor	0.01
Lindane	0.2
Methoxychlor	0.005
Mirex	0.04
Toxaphene	0.1
ORGANOPHOSPHORUS PESTICIDES	
Azinphos methyl	0.01
Chlorpyrifos	0.01
Demeton	0.04
Demeton-S-methyl	4
Diazinon	0.01
Dimethoate	0.15
Fenitrothion	0.2
Malathion	0.05
Parathion	0.004
Profenofos	0.02
Temephos	0.05
CARBAMATE & OTHER PESTICIDES	
Carbofuran	0.06
Methomyl	3.5
S-methoprene	0.2
PYRETHROIDS	
Deltamethrin	0.0001
Esfenvalerate	0.001
HERBICIDES & FUNGICIDES	
Bypyridilium herbicides	
Diquat	1.4
Paraquat	0.5

Chemical	Trigger values for freshwater (μ g/L)
Phenoxyacetic acid herbicides	
MCPA	1.4
2,4-D	280
2,4,5-T	36
Sulfonylurea herbicides	
Bensulfuron	800
Metsulfuron	8
Thiocarbamate herbicides	
Molinate	3.4
Thiobencarb	2.8
Thiram	0.01
Triazine herbicides	
Amitrole	22
Atrazine	13
Hexazinone	75
Simazine	3.2
Urea herbicides	
Diuron	0.2
Tebuthiuron	2.2
Miscellaneous herbicides	
Acrolein	0.01
Bromacil	180
Glyphosate	370
Imazethapyr	240
Ioxynil	0.4
Metolachlor	0.02
Sethoxydim	2
Trifluralin	2.6
GENERIC GROUPS OF CHEMICALS	
Surfactants	
Linear alkylbenzene sulfonates (LAS)	280
Alcohol ethoxyolated sulfate (AES)	650
Alcohol ethoxylated surfactants (AE)	140
Oils & Petroleum Hydrocarbons	ID
Oil Spill Dispersants	
BP 1100X	25

Chemical	Trigger values for freshwater (μ g/L)
Corexit 7664	16
Corexit 8667	1200
Corexit 9527	1100
Corexit 9550	140

Trigger values are for the 95% level of protection for slight to moderately disturbed systems where available, exceptions are highlighted as below:

▨	99% level of protection (recommended where chemical may bioaccumulate or 95% provides inadequate protection for test species).
🟨	low reliability trigger value (due to insufficient data), to be used only as an indicative interim working level
🟧	Environmental Concern Level (ECL), to be used only as an indicative interim working level, see ANZECC (2000) 8.3.4.5
🟩	other source
ID	insufficient data

Appendix B

Ambient Surface Water Monitoring Reports

Appendix B Ambient Surface Water Monitoring Reports

Helping You Protect Your Environment

AMBIENT
SURFACE WATER MONITORING REPORT

ARMIDALE REGIONAL LANDFILL

May 2015

Revision 1

for Armidale Dumaresq Council

CodyHart Consulting Pty Ltd ACN: 076 662 989 ABN: 23 809 060 895
Trading as CodyHart Environmental
Groundwater and Landfill Environmental Monitoring Specialists

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Presented by: Barbara Hart
Hydrogeologist & Environmental Scientist
Master of Environmental and Community Health
Master of Science in Hydrogeology and Groundwater Management

Date: 25 May 2015
Report: CodyHart 15.2119.1

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1. INTRODUCTION

The focus of this first initial environmental monitoring report (EMR) for the Armidale Regional Landfill site has been:

- A round of baseline ambient surface water monitoring conducted in May 2015 by CodyHart Environmental. Analyses were performed by Australian Laboratory Services (ALS) at their Brisbane laboratory.
- Fourteen earlier baseline monitoring rounds conducted by Armidale Dumaresq Council. The water was analysed by Lanfax Laboratory, Armidale, and the Australian Government National Measurement Institute, Sydney.

The baseline ambient surface water monitoring results are summarised in tables of this report so that their concentrations and values over time can be easily reviewed.

Interpretation of the results to date and recommendations for future ambient surface water monitoring are provided.

2. OBJECTIVE

The objective of the baseline ambient surface water monitoring program for the Armidale Regional Landfill is

> *to detect any pollution of off-site surface water bodies by leachate or by sediment-laden stormwater from the landfill.* (NSW EPA, 2015, p. 25)

3. SAMPLING LOCATIONS

Two maps and one satellite composite are provided to show the six (6) locations of the ambient surface water sampling points for baseline monitoring (GARA1, GARA2, GARA3, GARA4, GARA5, GARA6).

- Figure 1 is an expansive view to show where the surface water sampling points are located in relation to the water courses that flow into the Gara River.
- Figure 2 is a closer view that frames the six surface water sampling points, GARA1 to GARA6.
- Figure 3 is a composite of close satellite clips for each location.

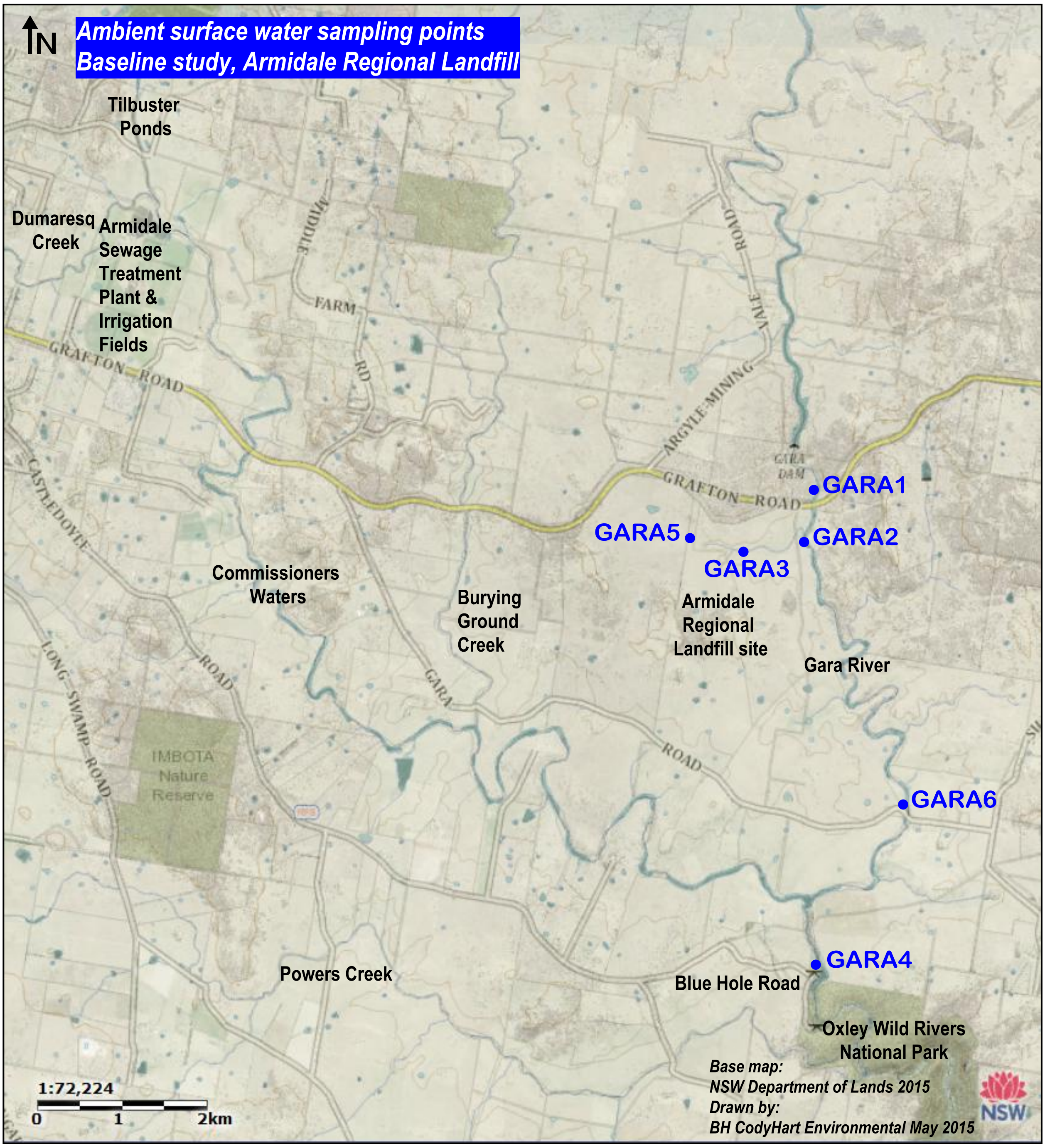
The base maps and the satellite images are from the NSW Department of Land Spatial Information eXchange (SIX) mapping program.

The sampling points going forward to the detection monitoring phase will be:

- GARA5 upstream from the landfill in the landfill site ephemeral stream
- GARA3 immediately downstream from the landfill in the landfill site ephemeral stream, and
- GARA2 in the Gara River, just downstream of the confluence of the Gara River and the ephemeral stream that passes through the landfill site. (Figure 4, p. 36)

The other ambient surface water sampling points, GARA1, GARA4 and GARA6, all on the Gara River, were included as precautionary measures for the baseline monitoring phase. GARA1 and GARA6, or upstream and downstream substitutes, will be reinstated if contamination is suspected at GARA2.

Figure 1: Baseline study, ambient surface water sampling locations - expansive view



Coordinates of the surface water sampling points were ascertained using a Sunnto X9 GPS wrist watch which is accurate to one metre. The UTM readings obtained were then matched with GDA94 coordinates on the NSW Department of Lands spatial information exchange (SIX) map.

Figure 2: Baseline study, ambient surface water sampling locations – closer view

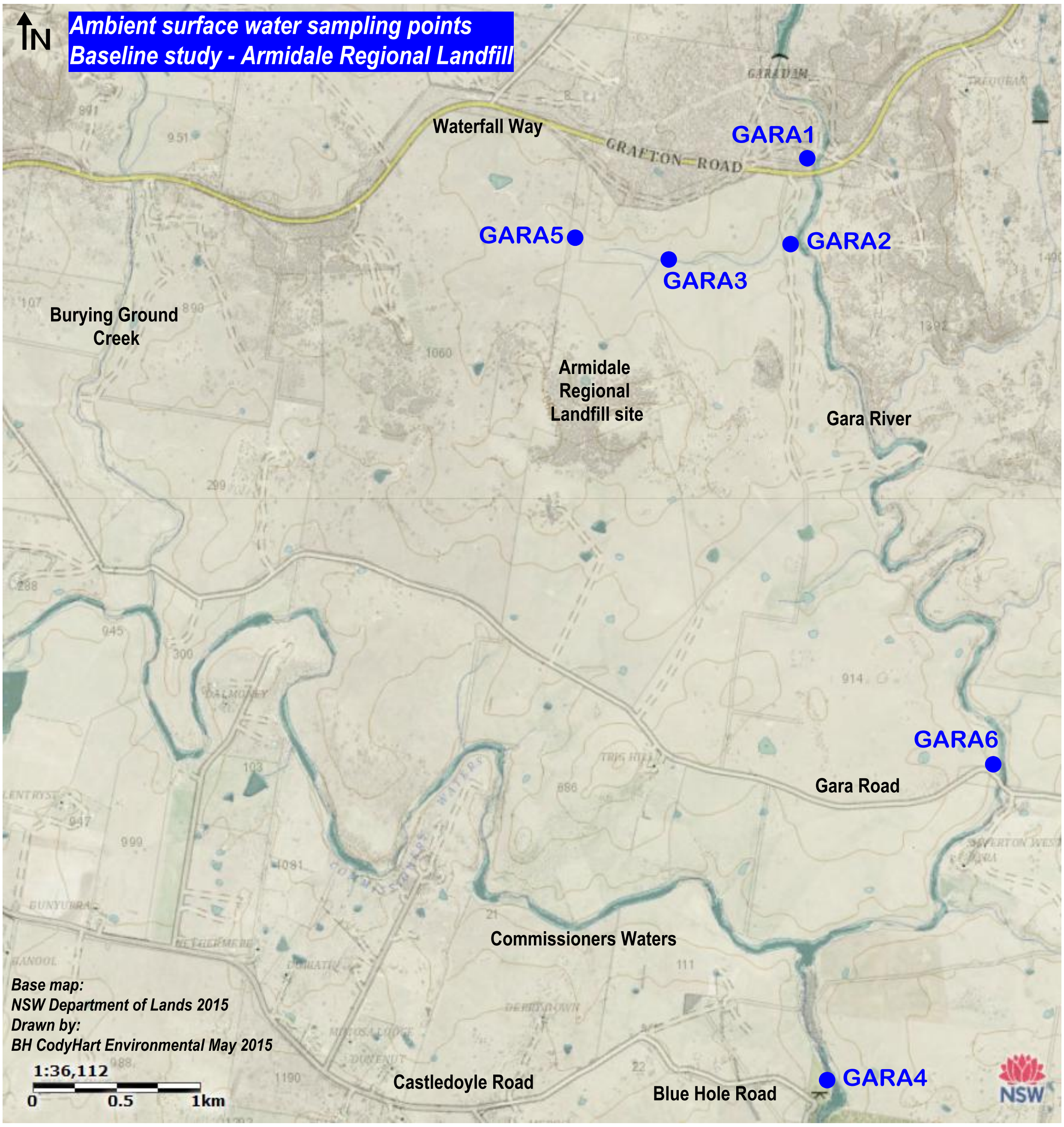


Figure 3: Baseline study ambient surface water sampling points – SIX satellite views

Base satellite views – SIX, NSW Dept of Lands 2015

4. WATER SAMPLING FIELD WORK – MAY 2015

Sampling was conducted on 4 May 2015 at all six ambient surface water sampling points: GARA1, GARA2, GARA3, GARA4, GARA5 and GARA6 according to the standard operating procedure (SOP) devised by CodyHart Environmental using Australian and international standards and guidelines.

The TPS 90FLT field lab used by CodyHart Environmental to take field dissolved oxygen (DO), electrical conductivity (EC), pH, redox potential (Eh), temperature and turbidity readings was calibrated so that sampling was conducted within a few hours of calibration.

Sampling point locations are displayed on Figures 1 to 3.

Samples were collected in a decontaminated beaker on the end of a three metre extension pole. Using an extension pole means that a more representative sample can be reached.

Two field parameter samples were taken, and the values noted on the field parameter form (Appendix A). Sample bottles were filled in order from the most volatile analyte being sampled to the least volatile.

After collection, the samples were immediately put on ice in a chilled esky. The samples were transported in an iced esky to reach the ALS laboratory well within holding times.

An anemometer, thermometer and compass were used to determine air temperature, wind speed and wind direction and their values were noted on each field parameter form (Appendix A).

5. WATER MONITORING QUALITY ASSURANCE – MAY 2015

A number of techniques are used in an endeavour to assure a high quality of sampling and analyses.

- Calibration of the TPS 90FLT field lab was documented. A certificate is provided in Appendix B.
- Sampling procedures documented by in the CodyHart Environmental SOP were followed. These included tests of deionised water and field blanks to assure proper decontamination of equipment.
- Relative percentage differences (RPDs) of field parameters were reviewed. None exceeded a RPD of 20%. (RPD is a standard method of assessing the variability of duplicate samples, in this case the two separate surface water samples. It quantifies the precision and reproducibility of the data.)
- Lack of tampering with the samples on their way to the laboratory is documented through Chain of custody (COC) forms, the transport company’s consignment note system, and through the laboratory’s sample receipt notification (SRN). The COCs and SRNs are provided in Appendix B. The COC was sealed within the cooler. Security seals, the courier company’s consignment notes, and the laboratory’s sample receipt notification suffice as evidence of non-tampering with samples. Two courier companies were used: TNT overnight express for the microbial samples to meet the 24 hour holding time requirements by reaching the laboratory by 10:00 am the next morning; and Tamex for next afternoon delivery by road transport for the bulk of the samples whose holding times were not as urgent. Unfortunately, TNT Express did not transit the samples through their

Sydney depot that evening as contracted. SRN for EB1518177 shows the holding time breach. Transport is problematic from regional towns to larger city laboratories that are capable of conducting all the analyses.

- Australian Laboratory Services (ALS), Stafford, Brisbane, conducted the majority of laboratory analyses. They are a global, Australian company who analyses a broad range of analytes and provide good service. In addition to the certificate of analysis and analytical results, ALS provide quality control reports for laboratory duplicates, method blank and laboratory control samples, and matrix spikes; and a QA/QC Compliance Assessment for a data quality objective (DQO) report that summarises the quality assurance findings (Appendix C). The recovery of a laboratory control spike for an organophosphorus pesticide was less than its lower control value. Then there was the holding time breach for the microbial samples. There were no other untoward quality control issues.
- CodyHart conducted laboratory analyses (yellow sheet, Appendix C) that are best conducted on fresh samples – using an APHA (1998) titration method for alkalinity and free carbon dioxide (CO_2).
- The CodyHart sampling team took duplicate samples (GARA-DUP) as split samples (both duplicate and original from one container) at GARA2. Analyses were conducted for all the inorganic analytes tested at GARA2 and for organics TPH and BTEX. The values were within the ALS quality control duplicate criteria values, that is:

  Result < 10 times LOR: No Value; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%. (LOR = Value of reporting)

6. WATER QUALITY RESULTS TO DATE

All results to date are tabled on portrait tables which allow a quick comparison of each parameter and analyte's historical results over time by looking down each column. Maximum historical results are coloured red and highlighted yellow; and minimum historical results are green and underlined. This makes it easier on the eye to review the latest result against historical results.

Some results have been converted from µg/L to mg/L so that all results are in mg/L. This minimises confusion in regard to the concentrations. In addition, some concentrations from the Lanfax Laboratory have been rounded off so that they match the ongoing number of decimal places used by ALS Laboratory, Brisbane.

Appendix C has a copy of the detailed laboratory results for this monitoring round, which include the laboratory QC and DQO assessment reports. The CodyHart field analysis results for alkalinity and free CO_2 follow the QC reports.

Photograph 1: Ambient surface water sampling point GARA1 looking south

GARA1 E 56 384741.0 N 6620301.0

Table 1: Field parameters, water level, flow, sediment, carbon, nutrients – Surface water GARA1

GARA1	*Field parameters*					*Depth, flow & sediment*				*Carbon*				*Nutrients*				
	DO	EC	pH	Eh	Temp	D	VFR	Turb	SS	Alk	Free CO$_2$	CO$_2$ + Alk	TOC	NH$_3$	NO$_3$ / NO$_x$	TKN	TotN	TotP
Measure	mg/L	µS/cm	1-14	mV	°C	m	kL/day	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L as N	mg/L as N	mg/L as N	mg/L	mg/L
Reporting Value	0.01	1	0.01	1	0.1	0.01	1	0.1	1-2	1	1	1	1	0.01 -0.2	0.001-0.01	0.01 -0.1	0.01 -0.1	0.001-0.01
17/12/08	8.51	280	7.13	+267	25.9	NT	NT	NT	3	145	NT	NT	NT	<0.20	0.06	0.6	0.6	0.04
28/01/09	7.64	305	7.62	+267	24.9	NT	NT	NT	5	153	NT	NT	NT	<0.20	0.22	0.6	0.8	0.14
10/03/09	5.77	215	<u>6.19</u>	+266	22.6	NT	NT	NT	10	87	NT	NT	NT	<0.20	0.16	0.6	0.7	0.15
18/05/10	7.01	355	7.57	NT	<u>6.4</u>	NT	NT	NT	4	154	NT	NT	NT	0.13	0.10	0.3	0.4	0.09
09/06/10	6.50	337	7.54	NT	8.8	NT	NT	NT	<u><2</u>	180	NT	NT	NT	0.13	0.12	<0.2	<u>0.1</u>	0.09
07/09/10	5.92	295	7.54	NT	13.3	NT	NT	NT	2	150	NT	NT	NT	0.08	0.07	0.3	0.4	0.02
07/12/10	5.32	240	7.74	NT	20.0	NT	NT	NT	10	118	NT	NT	NT	<u><0.02</u>	<u>0.01</u>	1.7	1.7	0.09
31/05/11	<u>3.85</u>	368	7.77	NT	9.5	NT	NT	NT	5	190	NT	NT	NT	0.12	0.22	<0.2	0.2	0.37
16/08/11	5.20	325	8.05	NT	9.3	NT	NT	NT	3	157	NT	NT	NT	<0.02	0.11	0.6	0.7	0.49
22/11/11	5.45	223	7.47	NT	22.0	NT	NT	NT	3	101	NT	NT	NT	<0.20	0.19	0.3	0.5	0.09
10/04/12	5.70	320	7.72	NT	15.8	NT	NT	NT	3	167	NT	NT	NT	<0.01	0.42	0.5	0.9	<u><0.01</u>
27/08/12	8.57	305	7.95	NT	10.9	NT	NT	NT	<u><2</u>	170	NT	NT	NT	0.01	0.32	0.3	0.6	0.17
27/11/12	5.84	<u>144</u>	6.92	NT	19.2	NT	NT	NT	20	<u>35</u>	NT	NT	NT	<0.10	0.36	<u><0.1</u>	0.4	0.28
05/06/13	7.57	685	7.70	NT	7.9	NT	NT	NT	5	180	NT	NT	NT	<0.20	0.17	0.6	0.7	0.26
04/05/15	6.61	300	7.94	<u>+172</u>	16.3	0.35	37800	26.9	13	117	15	27	15	0.06	0.02	1.7	1.7	0.08

Abbreviations: DO = Dissolved Oxygen; EC = Electrical Conductivity also called specific conductance; Eh = Redox Potential; Temp = Temperature; D = Approximate depth of water at sampling point; VFR = Volumetric Flow Rate; Turb = Turbidity; SS = Suspended Solids; Alk = Alkalinity measured as mg/L $CaCO_3$ equivalent; Free CO_2 = Free carbon dioxide; Unfiltered C of (CO_2 + Alk) = 12/44 CO_2 + 12/61 Alk; TOC = Total Organic Carbon; NH_3 = Ammonia as a measure of ammonium ions; NO_3 = Nitrate; NO_x = Nitrite + Nitrate; TKN = Total Kjeldahl Nitrogen (organic nitrogen and ammonia); Tot N = Total Nitrogen; Tot P = Total Phosphorus; NT = Not tested.
Note. From May 2015 onwards, CodyHart and ALS results, and NO_x rather than NO_3.

Table 2: Metals & metalloids – Surface water GARA1

GARA1	**Al**	**Sb**	**As**	**Cd**	**Cr**	**Cu**	**Ni**	**Pb**	**Se**	**Zn**	**Mn**	**Fe**	**Hg**
Measure	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Reporting Value	0.005-0.01	0.001	0.001	0.001-0.0001	0.001	0.001	0.001	0.001	0.001-0.01	0.001-005	0.001-0.005	0.005-0.01	0.0001
17/12/08	**0.025**	NT	**0.004**	**<0.001**	**<0.001**	**<0.001**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**0.001**	**0.188**	**<0.0001**
28/01/09	**<0.005**	NT	**0.004**	**<0.001**	**<0.001**	**<0.001**	**0.003**	**<0.001**	**<0.001**	**<0.001**	**<0.005**	**0.096**	**<0.0001**
10/03/09	**0.192**	NT	**0.005**	**<0.001**	**<0.001**	**0.001**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**<0.005**	**0.252**	**<0.0001**
18/05/10	**1.300**	NT	**0.001**	**<0.0001**	**<0.001**	**<0.001**	**0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.005**	**4.480**	**<0.0001**
09/06/10	**<0.005**	NT	**0.002**	**<0.0001**	**<0.001**	**<0.001**	**0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.005**	**0.024**	**<0.0001**
07/09/10	**<0.005**	NT	**0.002**	**<0.0001**	**<0.001**	**0.002**	**0.003**	**<0.001**	**<0.001**	**0.014**	**0.021**	**0.099**	**<0.0001**
07/12/10	**<0.005**	NT	**0.004**	**<0.0001**	**<0.001**	**0.006**	**0.003**	**<0.001**	**<0.001**	**0.010**	**0.015**	**0.199**	**<0.0001**
31/05/11	**0.040**	NT	**0.001**	**<0.0001**	**0.026**	**0.001**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**<0.005**	**<0.005**	**<0.0001**
16/08/11	**<0.005**	NT	**0.002**	**<0.0001**	**<0.001**	**0.001**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**0.019**	**0.173**	**<0.0001**
22/11/11	**0.411**	NT	**0.003**	**<0.0001**	**0.001**	**0.002**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**<0.005**	**0.346**	**<0.0001**
10/04/12	**<0.005**	NT	**0.002**	**<0.0001**	**<0.001**	**0.001**	**0.002**	**<0.001**	**<0.001**	**0.002**	**0.040**	**0.060**	**<0.0001**
27/08/12	**0.014**	NT	**0.001**	**<0.0001**	**<0.001**	**0.001**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**0.011**	**0.015**	**<0.0001**
27/11/12	**1.490**	NT	**0.002**	**<0.0001**	**<0.001**	**0.003**	**0.002**	**<0.001**	**<0.001**	**0.004**	**0.055**	**<0.010**	**<0.0001**
05/06/13	**<0.005**	NT	**0.002**	**<0.0001**	**<0.001**	**<0.001**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**0.050**	**0.161**	**<0.0001**
04/05/15	0.020	<0.001	0.002	<0.0001	<0.001	0.001	0.001	<0.001	<0.010	<0.005	0.046	0.230	<0.0001

Abbreviations: Al = Aluminium; Sb = Antimony; As = Arsenic; Cd = Cadmium; Cr = Chromium; Cu = Copper; Ni = Nickel; Pb = Lead; Se = Selenium; Zn = Zinc; Mn = Manganese; Fe = Iron; Hg = Mercury; NT = Not tested; Bold result = unfiltered.
Notes. CodyHart and ALS results from May 2015 onwards. Metals not filtered and analysed for total metals until May 2015.

Table 3: Extra laboratory analytes and parameters A – baseline only – Surface water GARA1

GARA1	***TDS, anions & cations, boron, reactive phosphorus, microbial***														
	TDS	**Ca**	**Mg**	**Na**	**K**	**SAR**	**Hard**	**Fl**	**Cl**	**S**	**Br**	**B**	**RP**	***E.Coli***	**Enterococci**
Measure	mg/L	mg/L	mg/L	mg/L	mg/L	ratio	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	CFU/100mL	CFU/100mL
Reporting Value	1	0.1	0.1	0.1	0.01-0.1	0.1	1	0.001	0.01	0.01	0.005-0.01	0.005-0.01	0.005-0.01	1	1
17/12/08	188	22.0	19.8	11.2	2.6	0.4	136	0.159	9.1	1.43	<0.010	<0.005	0.035	NT	NT
28/01/09	205	20.2	11.9	12.9	1.9	0.6	99	0.226	10.8	1.34	<0.005	<0.005	0.028	NT	NT
10/03/09	144	13.0	10.7	12.5	4.3	0.6	77	0.128	14.0	3.82	<0.005	0.026	<0.010	NT	NT
18/05/10	238	26.8	21.4	9.6	3.5	0.3	166	0.105	14.3	1.76	<0.005	<0.005	<0.010	NT	NT
09/06/10	226	29.4	26.2	21.8	1.0	0.7	181	0.114	15.2	0.69	<0.005	<0.005	<0.020	NT	NT
07/09/10	198	22.4	18.7	11.4	3.3	0.4	133	0.102	11.4	2.31	<0.005	0.087	<0.005	NT	NT
07/12/10	161	18.9	15.3	9.1	1.6	0.4	110	0.040	5.5	1.69	<0.005	<0.005	0.061	NT	NT
31/05/11	247	23.8	22.6	16.0	1.3	0.6	153	0.164	14.9	2.96	<0.005	<0.005	<0.020	NT	NT
16/08/11	218	25.6	20.8	13.7	1.3	0.5	149	0.104	12.4	3.30	0.840	0.038	0.028	NT	NT
22/11/11	152	14.6	12.8	11.6	0.8	0.5	89	0.165	7.9	3.79	0.671	0.411	<0.005	NT	NT
10/04/12	214	25.5	22.3	13.6	1.3	0.5	155	0.122	10.1	1.52	1.508	0.010	<0.005	NT	NT
27/08/12	204	23.8	20.0	12.8	1.6	0.5	142	0.074	11.8	2.99	0.554	<0.005	0.067	NT	NT
27/11/12	96	8.1	6.4	9.8	0.2	0.6	46	0.084	9.6	6.75	0.108	0.010	0.185	NT	NT
05/06/13	459	26.7	23.1	18.6	2.8	0.6	162	0.113	26.5	3.83	0.010	<0.005	0.037	NT	NT
04/05/15	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	18	22

Abbreviations: TDS = Total Dissolved Solids; Ca = Calcium; Mg = Magnesium; Na = Sodium; K = Potassium; SAR = Sodium Absorption Ratio; Hard = Hardness; Fl = Fluoride; Cl = Chloride; S = Sulphide; Br = Bromine; B = Boron; RP = Reactive Phosphorus; *E. Coli* = Escherichia coli; NT = Not tested; NC = Not continuing. Note. CodyHart and ALS results from May 2015 onwards.

Table 4: Extra laboratory analytes B – baseline only – Surface water GARA1

GARA1	***Organics***							
	PAH	**OC & OP**	**BTEX**	**TPH** C6-C9	**TPH** C10-C14	**TPH** C15-C28	**TPH** C29-C36	Phenols
Measure	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Reporting Value	0.00005-0.0001	0.0005-0.002	0.001-0.002	0.025	0.025	0.1	0.1	various
17/12/08	ND	ND	ND	ND	ND	ND	ND	ND
28/01/09	ND	ND	ND	ND	ND	ND	ND	ND
10/03/09	ND	ND	ND	ND	ND	ND	ND	ND
18/05/10	ND	ND	ND	ND	ND	ND	ND	ND
09/06/10	ND	ND	ND	ND	ND	ND	ND	ND
07/09/10	ND	ND	ND	ND	ND	ND	ND	ND
07/12/10	ND	ND	ND	ND	ND	ND	ND	ND
31/05/11	ND	ND	ND	ND	ND	ND	ND	ND
16/08/11	ND	ND	ND	ND	ND	ND	ND	ND
22/11/11	ND	ND	ND	ND	ND	0.240	ND	ND
10/04/12	ND	ND	ND	ND	ND	ND	ND	ND
27/08/12	ND	ND	ND	ND	ND	ND	ND	ND
27/11/12	ND	ND	ND	ND	ND	0.270	0.100	ND
05/06/13	ND	ND	ND	ND	ND	ND	ND	ND
04/05/15	ND (UT)	ND	ND	ND	ND	ND	ND	NC
	NC	NC	NC	NC	NC	NC	NC	NC

Abbreviations:
PAHs = Polynuclear Aromatic Hydrocarbons; BTEX = Benzene, Tolulene, Ethylbenzene, Xylene compounds; TPH = Total Petroleum Hydrocarbons; ND = Nil detected; UT = Ultra trace; NC = Not continuing. Note. CodyHart and ALS results from May 2015 onwards.

Photograph 2: Ambient surface water sampling point GARA2 looking east

GARA2 E 56 384635.0 N 6619865.0

Table 5: Field parameters, water level, flow, sediment, carbon, nutrients – Surface water GARA2

GARA2	Field parameters					Depth, flow & sediment				Carbon				Nutrients				
	DO	EC	pH	Eh	Temp	D	VFR	Turb	SS	Alk	Free CO_2	CO_2 + Alk	TOC	NH_3	NO_3 / NO_x	TKN	TotN	TotP
Measure	mg/L	µS/cm	1-14	mV	°C	m	kL/day	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L as N	mg/L as N	mg/L as N	mg/L	mg/L
Reporting Value	0.01	1	0.01	1	0.1	0.01	1	0.1	1-5	1	1	1	1	0.01 -0.2	0.001-0.01	0.01 -0.1	0.01 -0.1	0.001-0.01
17/12/08	8.54	290	6.59	+262	21.2	NT	NT	NT	3	160	NT	NT	NT	<0.20	0.01	0.6	0.6	0.05
28/01/09	7.27	305	6.80	+277	25.5	NT	NT	NT	3	162	NT	NT	NT	<0.20	0.21	0.6	0.8	0.15
10/03/09	5.52	222	6.27	+271	23.2	NT	NT	NT	10	90	NT	NT	NT	<0.20	0.14	1.1	1.3	0.13
18/05/10	7.25	355	7.76	NT	9.5	NT	NT	NT	8	179	NT	NT	NT	0.24	0.11	0.6	0.7	0.23
09/06/10	6.52	330	7.62	NT	9.1	NT	NT	NT	2	177	NT	NT	NT	0.24	0.12	0.3	0.4	0.05
07/09/10	5.15	295	7.62	NT	13.3	NT	NT	NT	4	151	NT	NT	NT	0.26	0.26	0.8	0.9	0.02
07/12/10	5.07	237	7.56	NT	19.7	NT	NT	NT	10	118	NT	NT	NT	<0.02	0.06	1.7	1.7	0.09
31/05/11	3.32	365	7.74	NT	9.3	NT	NT	NT	3	185	NT	NT	NT	<0.01	0.22	<0.2	0.2	0.34
16/08/11	3.88	325	7.80	NT	8.8	NT	NT	NT	5	159	NT	NT	NT	<0.02	0.12	0.8	1.0	0.45
22/11/11	5.09	222	7.30	NT	22.5	NT	NT	NT	5	103	NT	NT	NT	<0.20	0.20	0.6	0.8	0.10
10/04/12	4.10	325	7.96	NT	16.8	NT	NT	NT	3	180	NT	NT	NT	<0.01	0.54	0.5	1.0	<0.01
27/08/12	7.10	315	7.45	NT	11.6	NT	NT	NT	5	160	NT	NT	NT	0.07	0.33	0.3	0.6	0.20
27/11/12	4.79	140	6.90	NT	19.0	NT	NT	NT	20	32	NT	NT	NT	<0.10	0.35	<0.1	0.3	0.28
05/06/13	7.79	710	7.75	NT	8.4	NT	NT	NT	5	177	NT	NT	NT	<0.20	0.22	0.6	0.8	0.25
04/05/15	6.88	386	8.24	+168	18.1	~≥2.5	16941	3.6	<5	140	12	31	13	0.03	<0.01	0.9	0.9	0.03

Abbreviations: DO = Dissolved Oxygen; EC = Electrical Conductivity also called specific conductance; Eh = Redox Potential; Temp = Temperature; D = Approximate depth of water at sampling point; VFR = Volumetric Flow Rate; Turb = Turbidity; SS = Suspended Solids; Alk = Alkalinity measured as mg/L $CaCO_3$ equivalent; Free CO_2 = Free carbon dioxide; Unfiltered C of (CO_2 + Alk) = 12/44 CO_2 + 12/61 Alk; TOC = Total Organic Carbon; NH_3 = Ammonia as a measure of ammonium ions; NO_3 = Nitrate; NO_x = Nitrite + Nitrate; TKN = Total Kjeldahl Nitrogen (organic nitrogen and ammonia); Tot N = Total Nitrogen; Tot P = Total Phosphorus; NT = Not tested.
Note. From May 2015 onwards, CodyHart and ALS results, and NO_x rather than NO_3.

Table 6: Metals & metalloids – Surface water GARA2

GARA2	**Al**	**Sb**	**As**	**Cd**	**Cr**	**Cu**	**Ni**	**Pb**	**Se**	**Zn**	**Mn**	**Fe**	**Hg**
Measure	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Reporting Value	0.005-0.01	0.001	0.001	0.001-0.0001	0.001	0.001	0.001	0.001	0.001-0.01	0.001-005	0.001-0.005	0.005-0.01	0.0001
17/12/08	**<0.005**	NT	**0.003**	**<0.001**	**<0.001**	**<0.001**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**0.001**	**0.188**	**<0.0001**
28/01/09	**<0.005**	NT	**0.004**	**<0.001**	**<0.001**	**<0.001**	**0.003**	**<0.001**	**<0.001**	**<0.001**	**<0.005**	**0.096**	**<0.0001**
10/03/09	**0.288**	NT	**0.006**	**<0.001**	**0.001**	**0.001**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**<0.005**	**0.252**	**<0.0001**
18/05/10	**<0.005**	NT	**0.002**	**<0.0001**	**<0.001**	**<0.001**	**0.021**	**<0.001**	**<0.001**	**<0.001**	**<0.005**	**4.480**	**<0.0001**
09/06/10	**<0.005**	NT	**0.002**	**<0.0001**	**<0.001**	**<0.001**	**0.001**	**<0.001**	**<0.001**	**0.002**	**<0.005**	**0.024**	**<0.0001**
07/09/10	**0.005**	NT	**0.002**	**<0.0001**	**<0.001**	**0.002**	**0.003**	**<0.001**	**<0.001**	**0.014**	**0.021**	**0.099**	**<0.0001**
07/12/10	**0.068**	NT	**0.004**	**<0.0001**	**0.001**	**0.002**	**0.003**	**<0.001**	**<0.001**	**0.010**	**0.015**	**0.199**	**<0.0001**
31/05/11	**<0.005**	NT	**0.001**	**<0.0001**	**<0.001**	**<0.001**	**0.002**	**<0.001**	**<0.001**	**0.001**	**<0.005**	**<0.005**	**<0.0001**
16/08/11	**<0.005**	NT	**0.002**	**<0.0001**	**<0.001**	**0.001**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**0.019**	**0.173**	**<0.0001**
22/11/11	**0.236**	NT	**0.003**	**<0.0001**	**<0.001**	**0.002**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**<0.005**	**0.346**	**<0.0001**
10/04/12	**0.174**	NT	**0.002**	**<0.0001**	**<0.001**	**0.001**	**0.002**	**<0.001**	**<0.001**	**0.002**	**0.040**	**0.060**	**<0.0001**
27/08/12	**<0.005**	NT	**0.001**	**<0.0001**	**<0.001**	**0.001**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**0.011**	**0.015**	**<0.0001**
27/11/12	**1.130**	NT	**0.002**	**<0.0001**	**<0.001**	**0.003**	**0.002**	**<0.001**	**<0.001**	**0.003**	**0.055**	**<0.010**	**<0.0001**
05/06/13	**<0.005**	NT	**0.001**	**<0.0001**	**<0.001**	**<0.001**	**0.002**	**<0.001**	**<0.001**	**0.001**	**0.050**	**0.161**	**<0.0001**
04/05/15	<0.010	<0.001	0.002	<0.0001	<0.001	0.001	0.001	<0.001	<0.010	<0.005	0.044	0.090	<0.0001

Abbreviations: Al = Aluminium; Sb = Antimony; As = Arsenic; Cd = Cadmium; Cr = Chromium; Cu = Copper; Ni = Nickel; Pb = Lead; Se = Selenium; Zn = Zinc; Mn = Manganese; Fe = Iron; Hg = Mercury; NT = Not tested; Bold result = unfiltered.

Notes. CodyHart and ALS results from May 2015 onwards. Metals not filtered and analysed for total metals until May 2015.

Table 7: *Extra laboratory analytes and parameters A – baseline only – Surface water GARA2*

GARA2	*TDS, anions & cations, boron, reactive phosphorus, microbial*														
	TDS	Ca	Mg	Na	K	SAR	Hard	Fl	Cl	S	Br	B	RP	*E.Coli*	Enterococci
Measure	mg/L	mg/L	mg/L	mg/L	mg/L	ratio	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	CFU/100mL	CFU/100mL
Reporting Value	1	0.1	0.1	0.1	0.01-0.1	0.1	1	0.001	0.01	0.01	0.005-0.01	0.005-0.01	0.005-0.01	1	1
17/12/08	194	22.0	20.0	11.9	2.6	0.4	138	0.162	10.5	1.40	<0.010	<0.005	0.017	NT	NT
28/01/09	205	20.5	23.1	12.8	1.8	0.5	146	0.181	11.0	1.29	<0.005	<0.005	<0.010	NT	NT
10/03/09	149	13.2	11.1	13.2	4.3	0.6	79	0.114	14.2	3.76	<0.005	10.000	<0.010	NT	NT
18/05/10	238	27.7	23.1	17.6	2.5	0.6	164	0.202	20.3	1.70	<0.005	<0.005	<0.010	NT	NT
09/06/10	221	29.7	25.9	21.4	0.8	0.7	181	0.114	15.6	0.94	<0.005	<0.005	<0.020	NT	NT
07/09/10	198	22.3	18.5	11.4	3.2	0.4	132	0.102	11.7	2.25	<0.005	0.043	<0.005	NT	NT
07/12/10	157	19.0	15.3	8.7	1.5	0.4	110	0.146	5.7	1.71	<0.005	<0.005	0.035	NT	NT
31/05/11	245	24.0	22.9	16.8	1.2	0.6	154	0.187	16.5	3.11	<0.005	<0.005	<0.020	NT	NT
16/08/11	218	26.1	20.7	14.2	1.4	0.5	150	0.103	12.7	3.37	0.850	0.011	0.028	NT	NT
22/11/11	151	15.0	13.1	11.8	0.8	0.5	92	0.172	7.5	3.82	0.792	0.007	0.021	NT	NT
10/04/12	218	26.2	22.8	14.4	1.3	0.5	159	0.120	10.9	1.59	0.005	<0.005	<0.005	NT	NT
27/08/12	211	24.4	20.2	13.8	1.5	0.5	144	0.121	13.8	3.12	0.567	<0.005	0.023	NT	NT
27/11/12	94	7.9	6.3	8.5	0.2	0.6	45	0.081	9.4	6.51	0.121	<0.010	0.164	NT	NT
05/06/13	476	27.4	23.1	21.9	3.0	0.7	163	0.106	21.8	4.24	0.013	0.010	0.027	NT	NT
04/05/15	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	20	16

Abbreviations: TDS = Total Dissolved Solids; Ca = Calcium; Mg = Magnesium; Na = Sodium; K = Potassium; SAR = Sodium Absorption Ratio; Hard = Hardness; Fl = Fluoride; Cl = Chloride; S = Sulphide; Br = Bromine; B = Boron; RP = Reactive Phosphorus; *E. Coli* = Escherichia coli; NT = Not tested; NC = Not continuing.

Table 8: *Extra laboratory analytes B – baseline only – Surface water GARA2*

GARA2	*Organics*							
	PAH	OC & OP	BTEX	TPH C6-C9	TPH C10-C14	TPH C15-C28	TPH C29-C36	Phenols
Measure	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Reporting Value	0.00005-0.0001	0.0005-0.002	0.001-0.002	0.025	0.025	0.1	0.1	various
17/12/08	ND	ND	ND	ND	ND	ND	ND	ND
28/01/09	ND	ND	ND	ND	ND	ND	ND	ND
10/03/09	ND	ND	ND	ND	ND	ND	ND	ND
18/05/10	ND	ND	ND	ND	ND	ND	ND	ND
09/06/10	ND	ND	ND	ND	ND	ND	ND	ND
07/09/10	ND	ND	ND	ND	ND	ND	ND	ND
07/12/10	ND	ND	ND	ND	ND	ND	ND	ND
31/05/11	ND	ND	ND	ND	ND	ND	ND	ND
16/08/11	ND	ND	ND	ND	ND	0.400	ND	ND
22/11/11	ND	ND	ND	ND	ND	ND	ND	ND
10/04/12	ND	ND	ND	ND	ND	ND	ND	ND
27/08/12	ND	ND	ND	ND	0.120	ND	ND	ND
27/11/12	ND	ND	ND	ND	0.470	0.420	0.180	ND
05/06/13	ND	ND	ND	ND	ND	ND	ND	ND
04/05/15	ND (UT)	ND	ND	ND	ND	ND	ND	NC
	NC	NC	NC	NC	NC	NC	NC	NC

Abbreviations:
PAHs = Polynuclear Aromatic Hydrocarbons; BTEX = Benzene, Tolulene, Ethylbenzene, Xylene compounds; TPH = Total Petroleum Hydrocarbons; ND = Nil detected; UT = Ultra trace; NC = Not continuing. Note. CodyHart and ALS results from May 2015 onwards.

Photograph 3: Ambient surface water sampling point GARA3 looking west

GARA3 E 56 383826.0 N 6619708.0

Table 9: Field parameters, water level, flow, sediment, carbon, nutrients – Surface water GARA3

GARA3	Field parameters					Depth, flow & sediment				Carbon				Nutrients				
	DO	EC	pH	Eh	Temp	D	VFR	Turb	SS	Alk	Free CO_2	CO_2 + Alk	TOC	NH_3	NO_3 / NO_x	TKN	TotN	TotP
Measure	mg/L	µS/cm	1-14	mV	°C	m	kL/day	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L as N	mg/L as N	mg/L as N	mg/L	mg/L
Reporting Value	0.01	1	0.01	1	0.1	0.01	0.1	0.1	1-5	1	1	1	1	0.01 -0.2	0.001- 0.01	0.01 -0.1	0.01 -0.1	0.001- 0.01
17/12/08	6.54	145	6.27	+317	21.2	NT	NT	NT	135	64	NT	NT	NT	<0.20	0.01	2.0	2.0	0.28
28/01/09	9.72	1360	6.95	+272	26.1	NT	NT	NT	40	287	NT	NT	NT	<0.20	0.62	1.1	1.8	0.14
10/03/09	6.11	188	6.11	+264	25.8	NT	NT	NT	70	65	NT	NT	NT	<0.20	0.12	2.0	2.1	0.19
18/05/10	5.66	150	6.36	NT	7.1	NT	NT	NT	85	24	NT	NT	NT	0.31	0.04	0.8	0.9	0.19
09/06/10	6.19	184	6.84	NT	4.6	NT	NT	NT	180	58	NT	NT	NT	0.31	0.05	1.4	1.5	0.57
07/09/10	4.88	92	6.84	NT	8.3	NT	NT	NT	24	29	NT	NT	NT	0.11	0.11	2.0	2.0	0.11
07/12/10	2.47	77	6.32	NT	17.0	NT	NT	NT	22	35	NT	NT	NT	<0.02	0.01	3.1	3.1	0.10
31/05/11	4.00	215	6.97	NT	7.9	NT	NT	NT	43	52	NT	NT	NT	0.15	<0.02	<0.2	0.2	0.31
16/08/11	3.88	325	6.70	NT	11.4	NT	NT	NT	5	159	NT	NT	NT	<0.02	0.12	0.8	1.0	0.45
22/11/11	2.18	107	6.42	NT	23.1	NT	NT	NT	20	43	NT	NT	NT	<0.20	0.14	1.1	1.3	0.05
10/04/12	4.30	170	6.98	NT	11.4	NT	NT	NT	67	59	NT	NT	NT	0.10	0.36	1.6	2.0	<0.01
27/08/12	7.64	660	6.64	NT	13.7	NT	NT	NT	85	40	NT	NT	NT	0.03	0.15	0.9	1.1	0.28
27/11/12	4.08	660	7.20	NT	19.5	NT	NT	NT	440	113	NT	NT	NT	0.21	0.23	7.0	7.2	0.74
05/06/13	4.34	1180	6.52	NT	5.1	NT	NT	NT	87	29	NT	NT	NT	0.50	0.04	2.2	2.3	0.50
04/05/15	6.35	94	7.58	+209	17.9	0.05	259.2	281	65	20	12	7	16	0.04	<0.01	3.4	3.4	0.36

Abbreviations: DO = Dissolved Oxygen; EC = Electrical Conductivity also called specific conductance; Eh = Redox Potential; Temp = Temperature; D = Approximate depth of water at sampling point; VFR = Volumetric Flow Rate; Turb = Turbidity; SS = Suspended Solids; Alk = Alkalinity measured as mg/L $CaCO_3$ equivalent; Free CO_2 = Free carbon dioxide; Unfiltered C of (CO_2 + Alk) = 12/44 CO_2 + 12/61 Alk; TOC = Total Organic Carbon; NH_3 = Ammonia as a measure of ammonium ions; NO_3 = Nitrate; NO_x = Nitrite + Nitrate; TKN = Total Kjeldahl Nitrogen (organic nitrogen and ammonia); Tot N = Total Nitrogen; Tot P = Total Phosphorus; NT = Not tested.
Note. From May 2015 onwards, CodyHart and ALS results, and NO_x rather than NO_3.

Table 10: Metals & metalloids – Surface water GARA3

GARA3	Al	Sb	As	Cd	Cr	Cu	Ni	Pb	Se	Zn	Mn	Fe	Hg
Measure	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Reporting Value	0.005-0.01	0.001	0.001	0.001-0.0001	0.001	0.001	0.001	0.001	0.001-0.01	0.001-005	0.001-0.005	0.005-0.01	0.0001
17/12/08	**8.740**	NT	**0.003**	**<0.001**	**0.007**	**0.008**	**0.006**	**0.009**	**<0.001**	**0.019**	**0.216**	**5.370**	**<0.0001**
28/01/09	**0.055**	NT	**0.002**	**<0.001**	**<0.001**	**0.001**	**0.002**	**<0.001**	**<0.001**	**0.001**	**<0.005**	**0.058**	**<0.0001**
10/03/09	**16.400**	NT	**0.002**	**<0.001**	**0.005**	**0.007**	**0.004**	**0.003**	**<0.001**	**0.011**	**0.028**	**7.180**	**<0.0001**
18/05/10	**2.720**	NT	**0.002**	**<0.0001**	**0.003**	**0.003**	**0.003**	**0.002**	**<0.001**	**0.006**	**0.015**	**2.900**	**<0.0001**
09/06/10	**41.200**	NT	**0.003**	**<0.0001**	**0.029**	**0.021**	**0.018**	**0.013**	**<0.001**	**0.069**	**<0.005**	**17.500**	**<0.0001**
07/09/10	**3.012**	NT	**<0.001**	**<0.0001**	**0.002**	**0.004**	**0.003**	**<0.001**	**<0.001**	**0.020**	**<0.005**	**2.046**	**<0.0001**
07/12/10	**1.800**	NT	**0.003**	**<0.0001**	**0.002**	**0.007**	**0.004**	**0.003**	**<0.001**	**0.015**	**0.021**	**5.040**	**<0.0001**
31/05/11	**2.610**	NT	**<0.001**	**<0.0001**	**0.002**	**0.003**	**0.002**	**0.001**	**<0.001**	**0.006**	**0.020**	**1.240**	**<0.0001**
16/08/11	**0.012**	NT	**<0.001**	**<0.0001**	**<0.001**	**0.001**	**0.001**	**<0.001**	**<0.001**	**<0.001**	**0.045**	**0.181**	**<0.0001**
22/11/11	**1.294**	NT	**0.002**	**<0.0001**	**0.001**	**0.003**	**0.004**	**<0.001**	**<0.001**	**0.004**	**<0.005**	**2.478**	**<0.0001**
10/04/12	**5.760**	NT	**0.002**	**<0.0001**	**0.006**	**0.008**	**0.006**	**0.005**	**0.001**	**0.014**	**0.070**	**3.820**	**<0.0001**
27/08/12	**0.287**	NT	**0.002**	**<0.0001**	**0.005**	**0.004**	**0.004**	**0.002**	**<0.001**	**0.012**	**0.112**	**0.058**	**<0.0001**
27/11/12	**0.375**	NT	**0.005**	**<0.0001**	**0.006**	**0.011**	**0.012**	**0.008**	**0.002**	**0.021**	**3.420**	**0.870**	**<0.0001**
05/06/13	**1.370**	NT	**0.002**	**<0.0001**	**0.005**	**0.007**	**0.006**	**0.003**	**0.004**	**0.021**	**0.243**	**0.827**	**<0.0001**
04/05/15	0.720	<0.001	<0.001	<0.0001	<0.001	0.004	0.002	<0.001	<0.010	0.006	0.013	0.840	<0.0001

Abbreviations: Al = Aluminium; Sb = Antimony; As = Arsenic; Cd = Cadmium; Cr = Chromium; Cu = Copper; Ni = Nickel; Pb = Lead; Se = Selenium; Zn = Zinc; Mn = Manganese; Fe = Iron; Hg = Mercury; NT = Not tested; Bold result = unfiltered.
Notes. CodyHart and ALS results from May 2015 onwards. Metals not filtered and analysed for total metals until May 2015.

Table 11: Extra laboratory analytes and parameters A – baseline only – Surface water GARA3

GARA3	*TDS, anions & cations, boron, reactive phosphorus, microbial*														
	TDS	Ca	Mg	Na	K	SAR	Hard	Fl	Cl	S	Br	B	RP	*E.Coli*	Enterococci
Measure	mg/L	mg/L	mg/L	mg/L	mg/L	ratio	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	CFU/100mL	CFU/100mL
Reporting Value	1	0.1	0.1	0.1	0.01-0.1	0.1	1	0.001	0.01	0.01	0.005-0.01	0.005-0.01	0.005-0.01	1	1
17/12/08	98	9.7	5.7	11.5	3.8	0.7	48	0.218	9.0	0.61	<0.01	<0.005	0.047	NT	NT
28/01/09	910	53.4	57.5	147.0	7.6	3.3	370	0.474	56.0	34.40	0.524	<0.005	<0.010	NT	NT
10/03/09	126	7.9	5.7	21.4	5.4	1.4	43	0.209	23.6	1.73	0.524	<0.005	<0.010	NT	NT
18/05/10	100	4.9	4.7	14.3	4.6	1.1	32	0.115	40.6	0.22	<0.005	<0.005	<0.010	NT	NT
09/06/10	123	8.7	7.8	32.2	5.1	1.9	54	0.156	31.7	1.21	0.672	<0.005	0.123	NT	NT
07/09/10	62	4.9	3.1	8.6	3.1	0.7	25	0.078	10.6	0.34	<0.005	0.016	0.080	NT	NT
07/12/10	52	2.8	3.7	9.5	0.5	0.9	22	0.212	0.9	0.56	<0.005	<0.005	0.070	NT	NT
31/05/11	144	6.9	4.6	27.9	0.6	2.0	36	0.227	45.6	1.09	<0.005	<0.005	<0.020	NT	NT
16/08/11	218	26.1	20.7	14.2	1.4	0.5	150	0.065	77.4	3.37	0.046	0.049	0.028	NT	NT
22/11/11	73	5.9	4.1	7.7	1.1	0.6	32	0.213	6.8	0.59	0.659	<0.005	0.040	NT	NT
10/04/12	114	7.8	7.8	23.0	1.1	1.5	43	0.190	21.9	0.35	0.005	0.010	<0.005	NT	NT
27/08/12	442	31.6	21.1	68.2	1.7	2.3	166	0.137	202.0	11.10	0.603	<0.005	<0.01	NT	NT
27/11/12	442	38.6	23.0	60.2	0.3	1.9	191	0.275	180.0	6.13	1.310	<0.010	0.210	NT	NT
05/06/13	791	24.6	16.4	62.0	9.4	2.4	129	0.117	182.0	9.35	0.329	0.040	0.137	NT	NT
04/05/15	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	85	190

Abbreviations: TDS = Total Dissolved Solids; Ca = Calcium; Mg = Magnesium; Na = Sodium; K = Potassium; SAR = Sodium Absorption Ratio; Hard = Hardness; Fl = Fluoride; Cl = Chloride; S = Sulphide; Br = Bromine; B = Boron; RP = Reactive Phosphorus; *E. Coli* = Escherichia coli; NT = Not tested; NC = Not continuing.

Table 12: Extra laboratory analytes B – baseline only – Surface water GARA3

GARA3	***Organics***							
	PAH	**OC & OP**	**BTEX**	**TPH** C6-C9	**TPH** C10-C14	**TPH** C15-C28	**TPH** C29-C36	Phenols
Measure	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Reporting Value	0.00005-0.0001	0.0005-0.002	0.001-0.002	0.025	0.025	0.1	0.1	various
17/12/08	**0.00069** (Phenanthrene)	**0.00029** (trans-Chlordane)	ND	ND	**0.260**	**0.990**	**0.200**	**ND**
28/01/09	**ND**	**ND**	ND	ND	**ND**	**ND**	**ND**	ND
10/03/09	ND	ND	ND	ND	ND	ND	ND	ND
18/05/10	ND	ND	ND	ND	ND	ND	ND	ND
09/06/10	ND	ND	ND	ND	ND	ND	ND	ND
07/09/10	ND	ND	ND	ND	ND	ND	ND	ND
07/12/10	ND	ND	ND	ND	ND	ND	ND	ND
31/05/11	ND	ND	ND	ND	ND	ND	ND	ND
16/08/11	ND	ND	ND	ND	ND	0.440	0.110	ND
22/11/11	ND	ND	ND	ND	ND	0.120	ND	**0.025** 3-&4-Methylphenols
10/04/12	ND	ND	ND	ND	ND	ND	ND	ND
27/08/12	ND	ND	ND	ND	ND	ND	ND	ND
27/11/12	ND	ND	ND	ND	0.034	0.340	0.140	ND
05/06/13	ND	ND	ND	ND	ND	ND	ND	ND
04/05/15	ND (UT)	ND	ND	ND	ND	ND	ND	NC
	NC	NC	NC	NC	NC	NC	NC	NC

Abbreviations:
PAHs = Polynuclear Aromatic Hydrocarbons; BTEX = Benzene, Tolulene, Ethylbenzene, Xylene compounds; TPH = Total Petroleum Hydrocarbons; ND = Nil detected; UT = Ultra trace; NC = Not continuing. Note. CodyHart and ALS results from May 2015 onwards.

Photograph 4: *Ambient surface water sampling point GARA4 looking south*

GARA4 E 56 384915.0 N 6614748.0

Table 13: Field parameters, water level, flow, sediment, carbon, nutrients – Surface water GARA4

GARA4	*Field parameters*					*Depth, flow & sediment*				*Carbon*				*Nutrients*				
	DO	**EC**	**pH**	**Eh**	**Temp**	**D**	**VFR**	**Turb**	**SS**	**Alk**	**Free CO_2**	**CO_2 + Alk**	**TOC**	**NH_3**	**NO_3 / NO_x**	**TKN**	**TotN**	**TotP**
Measure	mg/L	µS/cm	1-14	mV	°C	m	kL/day	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L as N	mg/L as N	mg/L as N	mg/L	mg/L
Reporting Value	0.01	1	0.01	1	0.1	0.01	1	0.1	1-5	1	1	1	1	0.01 -0.2	0.001-0.01	0.01 -0.1	0.01 -0.1	0.001-0.01
17/12/08	7.95	335	7.27	+247	24.1	NT	NT	NT	18	142	NT	NT	NT	<0.20	0.05	1.1	1.2	0.82
28/01/09	8.23	325	7.60	**+260**	**27.9**	NT	NT	NT	5	160	NT	NT	NT	<0.20	0.26	0.6	0.8	0.44
10/03/09	8.47	272	**6.80**	**+215**	23.4	NT	NT	NT	8	106	NT	NT	NT	<0.20	0.12	1.1	1.2	**1.49**
18/05/10	**9.45**	420	8.02	NT	9.6	NT	NT	NT	8	**178**	NT	NT	NT	0.08	0.11	0.3	0.4	0.55
09/06/10	6.75	390	7.82	NT	10.2	NT	NT	NT	15	170	NT	NT	NT	0.08	0.11	<0.2	**0.1**	0.52
07/09/10	5.89	290	7.82	NT	12.8	NT	NT	NT	**<2**	137	NT	NT	NT	**<0.01**	0.01	1.1	1.4	0.27
07/12/10	**4.63**	245	7.61	NT	20.5	NT	NT	NT	15	115	NT	NT	NT	**0.83**	0.04	1.7	1.7	0.23
31/05/11	4.68	335	8.48	NT	9.9	NT	NT	NT	8	155	NT	NT	NT	<0.10	<0.02	<0.2	<0.2	0.77
16/08/11	4.91	360	8.13	NT	10.4	NT	NT	NT	5	128	NT	NT	NT	<0.02	0.29	**2.5**	**2.8**	0.63
22/11/11	4.77	284	7.84	NT	23.6	NT	NT	NT	3	121	NT	NT	NT	<0.20	0.26	0.6	0.5	0.40
10/04/12	5.40	340	7.92	NT	15.3	NT	NT	NT	5	160	NT	NT	NT	0.03	0.40	0.7	1.1	**0.07**
27/08/12	8.79	365	**9.17**	NT	11.4	NT	NT	NT	8	147	NT	NT	NT	0.02	0.39	0.3	0.7	0.42
27/11/12	6.34	**131**	6.93	NT	18.3	NT	NT	NT	**52**	**42**	NT	NT	NT	<0.10	0.33	**<0.1**	0.3	0.25
05/06/13	8.15	**790**	7.84	NT	**9.5**	NT	NT	NT	5	161	NT	NT	NT	<0.20	**0.50**	0.6	1.1	0.24
04/05/15	7.24	413	7.78	+228	14.6	1.0	80000	5.0	<5	117	9	25	10	0.06	**<0.01**	2.0	2.0	0.54

Abbreviations: DO = Dissolved Oxygen; EC = Electrical Conductivity also called specific conductance; Eh = Redox Potential; Temp = Temperature; D = Approximate depth of water at sampling point; VFR = Volumetric Flow Rate; Turb = Turbidity; SS = Suspended Solids; Alk = Alkalinity measured as mg/L $CaCO_3$ equivalent; Free CO_2 = Free carbon dioxide; Unfiltered C of (CO_2 + Alk) = 12/44 CO_2 + 12/61 Alk; TOC = Total Organic Carbon;NH_3 = Ammonia as a measure of ammonium ions; NO_3 = Nitrate; NO_x = Nitrite + Nitrate; TKN = Total Kjeldahl Nitrogen (organic nitrogen and ammonia); Tot N = Total Nitrogen; Tot P = Total Phosphorus; NT = Not tested.
Note. From May 2015 onwards, CodyHart and ALS results, and NO_x rather than NO_3.

Table 14: *Metals & metalloids – Surface water GARA4*

GARA4	**Al**	**Sb**	**As**	**Cd**	**Cr**	**Cu**	**Ni**	**Pb**	**Se**	**Zn**	**Mn**	**Fe**	**Hg**
Measure	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Reporting Value	0.005-0.01	0.001	0.001	0.001-0.0001	0.001	0.001	0.001	0.001	0.001-0.01	0.001-005	0.001-0.005	0.005-0.01	0.0001
17/12/08	**<0.005**	NT	**0.008**	**<0.001**	**0.001**	**0.002**	**0.003**	**<0.001**	**<0.001**	**0.003**	**0.001**	**0.061**	**<0.0001**
28/01/09	**<0.005**	NT	**0.008**	**<0.001**	**<0.001**	**0.003**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**0.008**	**0.054**	**<0.0001**
10/03/09	**0.019**	NT	**0.007**	**<0.001**	**0.002**	**0.003**	**0.003**	**<0.001**	**<0.001**	**0.004**	**0.008**	**0.243**	**<0.0001**
18/05/10	**0.012**	NT	**0.006**	**<0.0001**	**<0.001**	**0.001**	**0.001**	**<0.001**	**<0.001**	**0.007**	**<0.005**	**0.108**	**<0.0001**
09/06/10	**1.050**	NT	**0.005**	**<0.0001**	**0.002**	**0.002**	**0.002**	**<0.001**	**<0.001**	**0.003**	**<0.005**	**2.820**	**<0.0001**
07/09/10	**<0.005**	NT	**0.003**	**<0.0001**	**<0.001**	**0.002**	**0.002**	**<0.001**	**<0.001**	**0.013**	**<0.005**	**0.130**	**<0.0001**
07/12/10	**0.032**	NT	**0.005**	**<0.0001**	**<0.001**	**0.002**	**0.003**	**<0.001**	**<0.001**	**0.010**	**0.009**	**0.153**	**<0.0001**
31/05/11	**0.220**	NT	**0.002**	**<0.0001**	**<0.001**	**0.001**	**0.002**	**<0.001**	**<0.001**	**0.001**	**<0.005**	**0.100**	**<0.0001**
16/08/11	**0.034**	NT	**0.002**	**<0.0001**	**<0.001**	**0.002**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**0.009**	**0.055**	**<0.0001**
22/11/11	**0.048**	NT	**0.003**	**<0.0001**	**<0.001**	**0.001**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**<0.005**	**0.057**	**<0.0001**
10/04/12	**<0.005**	NT	**0.004**	**<0.0001**	**<0.001**	**0.001**	**0.002**	**<0.001**	**<0.001**	**0.002**	**0.030**	**0.080**	**<0.0001**
27/08/12	**<0.005**	NT	**0.003**	**<0.0001**	**<0.001**	**0.002**	**0.002**	**<0.001**	**<0.001**	**0.005**	**0.030**	**<0.005**	**<0.0001**
27/11/12	**0.477**	NT	**0.002**	**<0.0001**	**0.002**	**0.003**	**0.004**	**0.001**	**<0.001**	**0.005**	**0.010**	**0.470**	**<0.0001**
05/06/13	**<0.005**	NT	**0.002**	**<0.0001**	**<0.001**	**0.002**	**0.002**	**<0.001**	**<0.001**	**0.003**	**0.040**	**<0.005**	**<0.0001**
04/05/15	<0.010	<0.001	0.006	<0.0001	<0.001	0.002	<0.001	<0.001	<0.010	<0.005	0.016	<0.005	<0.0001

Abbreviations: Al = Aluminium; Sb = Antimony; As = Arsenic; Cd = Cadmium; Cr = Chromium; Cu = Copper; Ni = Nickel; Pb = Lead; Se = Selenium; Zn = Zinc; Mn = Manganese; Fe = Iron; Hg = Mercury; NT = Not tested; Bold result = unfiltered.
Notes. CodyHart and ALS results from May 2015 onwards. Metals not filtered and analysed for total metals until May 2015.

Table 15: *Extra laboratory analytes and parameters A – baseline only – Surface water GARA4*

GARA4	***TDS, anions & cations, boron, reactive phosphorus, microbial***														
	TDS	**Ca**	**Mg**	**Na**	**K**	**SAR**	**Hard**	**Fl**	**Cl**	**S**	**Br**	**B**	**RP**	***E.Coli***	**Enterococci**
Measure	mg/L	mg/L	mg/L	mg/L	mg/L	ratio	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	CFU/100mL	CFU/100mL
Reporting Value	1	0.1	0.1	0.1	0.01-0.1	0.1	1	0.001	0.01	0.01	0.005-0.01	0.005-0.01	0.005-0.01	1	1
17/12/08	224	20.3	16.3	29.3	4.7	1.2	118	0.292	23.2	4.29	0.045	<0.005	0.664	NT	NT
28/01/09	220	18.1	21.1	21.3	4.0	0.8	132	0.285	24.3	2.35	<0.005	<0.005	0.305	NT	NT
10/03/09	182	14.5	11.7	21.0	5.6	1.0	84	0.215	24.7	4.91	<0.005	<0.005	1.245	NT	NT
18/05/10	280	26.5	17.8	38.8	6.8	1.4	139	0.260	45.6	0.61	<0.005	<0.005	0.211	NT	NT
09/06/10	261	30.4	21.9	42.1	6.6	1.4	166	0.241	39.8	7.22	<0.005	<0.005	0.500	NT	NT
07/09/10	194	20.0	16.0	16.8	3.4	0.7	116	0.134	21.3	3.40	<0.005	0.045	0.260	NT	NT
07/12/10	164	18.5	13.9	12.9	1.5	0.6	106	0.167	11.6	2.45	<0.005	<0.005	0.079	NT	NT
31/05/11	224	20.3	17.1	20.9	1.8	0.8	121	0.239	21.8	9.94	<0.005	<0.005	0.227	NT	NT
16/08/11	241	25.9	18.7	22.0	1.7	0.8	142	0.139	25.2	4.85	0.490	0.029	0.078	NT	NT
22/11/11	193	16.6	14.6	16.2	1.0	0.7	102	0.123	18.6	0.31	1.174	0.026	0.060	NT	NT
10/04/12	228	24.5	24.5	23.7	1.5	0.9	145	0.164	24.9	3.58	1.407	<0.005	0.068	NT	NT
27/08/12	245	24.8	18.5	29.2	2.0	1.1	138	0.200	39.7	7.02	0.373	<0.005	0.100	NT	NT
27/11/12	88	8.2	6.4	8.2	0.1	0.5	47	0.070	12.7	2.71	0.135	<0.010	0.060	NT	NT
05/06/13	529	29.5	20.3	29.5	3.7	1.0	157	0.172	38.1	7.27	0.022	<0.005	0.030	NT	NT
04/05/15	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	45	52

Abbreviations: TDS = Total Dissolved Solids; Ca = Calcium; Mg = Magnesium; Na = Sodium; K = Potassium; SAR = Sodium Absorption Ratio; Hard = Hardness; Fl = Fluoride; Cl = Chloride; S = Sulphide; Br = Bromine; B = Boron; RP = Reactive Phosphorus; *E. Coli* = Escherichia coli; NT = Not tested; NC = Not continuing.

Table 16: Extra laboratory analytes B – baseline only – Surface water GARA4

GARA4	Organics							
	PAH	**OC & OP**	**BTEX**	**TPH** C6-C9	**TPH** C10-C14	**TPH** C15-C28	**TPH** C29-C36	Phenols
Measure	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Reporting Value	0.00005-0.0001	0.0005-0.002	0.001-0.002	0.025	0.025	0.1	0.1	various
17/12/08	ND	ND	ND	ND	ND	ND	ND	ND
28/01/09	ND	ND	ND	ND	ND	ND	ND	ND
10/03/09	ND	ND	ND	ND	ND	ND	ND	ND
18/05/10	ND	ND	ND	ND	ND	ND	ND	ND
09/06/10	ND	ND	ND	ND	ND	ND	ND	ND
07/09/10	ND	ND	ND	ND	ND	ND	ND	ND
07/12/10	ND	ND	ND	ND	ND	ND	ND	ND
31/05/11	ND	ND	ND	ND	ND	ND	ND	ND
16/08/11	ND	ND	ND	ND	ND	0.240	0.110	ND
22/11/11	ND	ND	ND	ND	ND	0.110	ND	ND
10/04/12	ND	ND	ND	ND	ND	ND	ND	ND
27/08/12	ND	ND	ND	ND	ND	0.110	ND	ND
27/11/12	ND	ND	ND	ND	ND	**0.330**	**0.120**	ND
05/06/13	ND	ND	ND	ND	ND	ND	ND	ND
04/05/15	ND (UT)	ND	ND	ND	ND	ND	ND	NC
	NC	NC	NC	NC	NC	NC	NC	NC

Abbreviations:
PAHs = Polynuclear Aromatic Hydrocarbons; BTEX = Benzene, Tolulene, Ethylbenzene, Xylene compounds; TPH = Total Petroleum Hydrocarbons; ND = Nil detected; UT = Ultra trace; NC = Not continuing. Note. CodyHart and ALS results from May 2015 onwards.

Photograph 5: Ambient surface water sampling point GARA5 looking west

GARA5 E 56 383279.0 N 6619897.0

Table 17: Field parameters, water level, flow, sediment, carbon, nutrients – Surface water GARA5

GARA5	Field parameters					Depth, flow & sediment				Carbon				Nutrients				
	DO	EC	pH	Eh	Temp	D	VFR	Turb	SS	Alk	Free CO_2	CO_2 + Alk	TOC	NH_3	NO_3 / NO_x	TKN	TotN	TotP
Measure	mg/L	µS/cm	1-14	mV	°C	m	kL/day	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L as N	mg/L as N	mg/L as N	mg/L	mg/L
Reporting Value	0.01	1	0.01	1	0.1	0.01	1	0.1	1-5	1	1	1	1	0.01 -0.2	0.001-0.01	0.01 -0.1	0.01 -0.1	0.001 -0.01
17/12/08	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
28/01/09	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
10/03/09	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
18/05/10	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
09/06/10	6.35	115	7.07	NT	5.6	NT	NT	NT	307	47	NT	NT	NT	0.08	0.04	0.6	0.6	0.21
07/09/10	4.04	81	7.07	NT	9.2	NT	NT	NT	8	25	NT	NT	NT	0.09	0.09	1.7	1.7	0.05
07/12/10	5.58	184	6.83	NT	17.5	NT	NT	NT	12	94	NT	NT	NT	0.05	0.04	3.6	3.7	0.19
31/05/11	2.24	94	6.10	NT	7.1	NT	NT	NT	83	20	NT	NT	NT	0.19	<0.02	1.2	1.2	0.45
16/08/11	4.55	118	6.88	NT	10.4	NT	NT	NT	130	40	NT	NT	NT	<0.02	0.01	0.6	0.6	0.61
22/11/11	2.27	120	6.56	NT	23.7	NT	NT	NT	23	50	NT	NT	NT	<0.20	0.13	1.4	1.5	0.06
10/04/12	1.80	110	6.57	NT	9.2	NT	NT	NT	360	49	NT	NT	NT	0.30	0.55	2.6	2.9	0.05
27/08/12	6.78	100	6.34	NT	8.2	NT	NT	NT	145	24	NT	NT	NT	0.13	0.21	0.8	1.1	0.38
27/11/12	4.07	265	7.04	NT	19.5	NT	NT	NT	145	94	NT	NT	NT	<0.10	0.38	2.0	2.3	0.35
05/06/13	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
04/05/15	5.61	45	8.17	+206	20.4	0.25	270	63.8	17	13	9	5	21	0.03	<0.01	4.6	4.6	0.11

Abbreviations: DO = Dissolved Oxygen; EC = Electrical Conductivity also called specific conductance; Eh = Redox Potential; Temp = Temperature; D = Approximate depth of water at sampling point; VFR = Volumetric Flow Rate; Turb = Turbidity; SS = Suspended Solids; Alk = Alkalinity measured as mg/L $CaCO_3$ equivalent; Free CO_2 = Free carbon dioxide; Unfiltered C of (CO_2 + Alk) = 12/44 CO_2 + 12/61 Alk; TOC = Total Organic Carbon; NH_3 = Ammonia as a measure of ammonium ions; NO_3 = Nitrate; NO_x = Nitrite + Nitrate; TKN = Total Kjeldahl Nitrogen (organic nitrogen and ammonia); Tot N = Total Nitrogen; Tot P = Total Phosphorus; NT = Not tested.
Note. From May 2015 onwards, CodyHart and ALS results, and NO_x rather than NO_3.

Table 18: Metals & metalloids – Surface water GARA5

GARA5	Al	Sb	As	Cd	Cr	Cu	Ni	Pb	Se	Zn	Mn	Fe	Hg
Measure	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Reporting Value	0.005-0.01	0.001	0.001	0.001-0.0001	0.001	0.001	0.001	0.001	0.001-0.01	0.001-005	0.001-0.005	0.005-0.01	0.0001
17/12/08	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
28/01/09	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
10/03/09	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
18/05/10	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
09/06/10	**5.170**	**NT**	**0.002**	**<0.0001**	**0.014**	**0.009**	**0.006**	**0.008**	**<0.001**	**0.033**	**<0.005**	**2.200**	**<0.0001**
07/09/10	**1.060**	**NT**	**<0.001**	**<0.0001**	**<0.001**	**0.003**	**0.002**	**<0.001**	**<0.001**	**0.018**	**<0.005**	**0.978**	**<0.0001**
07/12/10	**0.555**	**NT**	**0.005**	**<0.0001**	**0.002**	**0.004**	**0.005**	**0.002**	**<0.001**	**0.015**	**0.305**	**6.590**	**<0.0001**
31/05/11	**3.480**	**NT**	**<0.001**	**<0.0001**	**0.003**	**0.005**	**0.002**	**0.002**	**<0.001**	**0.013**	**0.020**	**1.980**	**<0.0001**
16/08/11	**12.100**	**NT**	**0.002**	**<0.0001**	**0.009**	**0.007**	**0.005**	**0.005**	**<0.001**	**0.023**	**0.027**	**6.497**	**<0.0001**
22/11/11	**0.398**	**NT**	**0.002**	**<0.0001**	**0.001**	**0.003**	**0.003**	**<0.001**	**<0.001**	**0.004**	**<0.005**	**1.189**	**<0.0001**
10/04/12	**14.100**	**NT**	**0.005**	**<0.0001**	**0.012**	**0.013**	**0.010**	**0.013**	**<0.001**	**0.035**	**0.690**	**9.660**	**<0.0001**
27/08/12	**0.514**	**NT**	**0.003**	**<0.0001**	**0.008**	**0.011**	**0.006**	**0.006**	**<0.001**	**0.024**	**0.030**	**0.460**	**0.0002**
27/11/12	**1.810**	**NT**	**0.003**	**<0.0001**	**0.004**	**0.007**	**0.006**	**0.003**	**0.002**	**0.015**	**0.500**	**0.770**	**<0.0001**
05/06/13	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
04/05/15	0.410	<0.001	<0.001	<0.0001	<0.001	0.004	0.001	<0.001	<0.010	0.011	0.004	0.320	<0.0001

Abbreviations: Al = Aluminium; Sb = Antimony; As = Arsenic; Cd = Cadmium; Cr = Chromium; Cu = Copper; Ni = Nickel; Pb = Lead; Se = Selenium; Zn = Zinc; Mn = Manganese; Fe = Iron; Hg = Mercury; NT = Not tested; Bold result = unfiltered.
Notes. CodyHart and ALS results from May 2015 onwards. Metals not filtered and analysed for total metals until May 2015.

Table 19: Extra laboratory parameters and analytes A – baseline only – Surface water GARA5

GARA5	TDS, anions & cations, boron, reactive phosphorus, microbial													
	TDS	Ca	Mg	Na	K	SAR	Hard	Fl	Cl	S	Br	B	RP	*E.Coli*	Enterococci
Measure	mg/L	mg/L	mg/L	mg/L	mg/L	ratio	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	CFU/100mL	CFU/100mL
Reporting Value	1	0.1	0.1	0.1	0.01-0.1	0.1	1	0.001	0.01	0.01	0.005-0.01	0.005-0.01	0.005-0.01	1	1
17/12/08	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
28/01/09	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
10/03/09	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
18/05/10	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
09/06/10	77	2.3	4.0	18.5	2.3	1.7	22	0.157	12.7	0.14	0.532	<0.005	<0.020	NT	NT
07/09/10	54	3.7	2.3	8.3	2.5	0.8	19	0.077	9.5	0.41	<0.005	<0.005	0.037	NT	NT
07/12/10	123	14.8	9.2	9.6	2.3	0.5	75	0.188	4.5	0.55	<0.005	<0.005	0.165	NT	NT
31/05/11	63	2.7	2.7	6.9	4.0	0.8	15	0.069	15.7	0.22	<0.005	<0.005	0.030	NT	NT
16/08/11	79	5.3	3.8	14.6	1.5	1.2	29	0.122	13.4	0.25	0.260	0.037	0.002	NT	NT
22/11/11	82	7.5	4.8	8.3	1.5	0.6	39	0.225	5.9	0.71	0.569	<0.005	<0.005	NT	NT
10/04/12	74	7.2	5.2	10.8	2.0	0.8	39	0.141	6.2	0.16	0.005	<0.005	<0.005	NT	NT
27/08/12	67	4.2	2.6	10.5	1.7	1.0	21	0.090	19.3	0.36	0.216	<0.005	<0.010	NT	NT
27/11/12	178	18.4	12.0	25.0	0.1	1.1	95	0.280	39.9	0.89	1.020	<0.010	0.140	NT	NT
05/06/13	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
04/05/15	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	2800	1300

Abbreviations: TDS = Total Dissolved Solids; Ca = Calcium; Mg = Magnesium; Na = Sodium; K = Potassium; SAR = Sodium Absorption Ratio; Hard = Hardness; Fl = Fluoride; Cl = Chloride; S = Sulphide; Br = Bromine; B = Boron; RP = Reactive Phosphorus; *E. Coli* = Escherichia coli; NT = Not tested; NC = Not continuing.

Table 20: Extra laboratory analytes B – baseline only – Surface water GARA5

GARA5	***Organics***							
	PAH	**OC & OP**	**BTEX**	**TPH** C6-C9	**TPH** C10-C14	**TPH** C15-C28	**TPH** C29-C36	Phenols
Measure	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Reporting Value	0.00005-0.0001	0.0005-0.002	0.001-0.002	0.025	0.025	0.1	0.1	various
17/12/08	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
28/01/09	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
10/03/09	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
18/05/10	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
09/06/10	ND	ND	ND	ND	ND	**ND**	ND	ND
07/09/10	ND	ND	ND	ND	ND	ND	ND	ND
07/12/10	ND	ND	ND	ND	ND	ND	ND	ND
31/05/11	ND	ND	ND	ND	ND	ND	ND	ND
16/08/11	ND	ND	ND	ND	ND	**0.320**	ND	ND
22/11/11	ND	ND	ND	ND	ND	ND	ND	ND
10/04/12	ND	ND	ND	ND	ND	ND	ND	ND
27/08/12	ND	ND	ND	ND	ND	ND	ND	ND
27/11/12	ND	ND	ND	ND	ND	0.270	ND	ND
05/06/13	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
04/05/15	ND (UT)	ND	ND	ND	ND	ND	ND	NC
	NC	NC	NC	NC	NC	NC	NC	NC

Abbreviations:
PAHs = Polynuclear Aromatic Hydrocarbons; BTEX = Benzene, Tolulene, Ethylbenzene, Xylene compounds; TPH = Total Petroleum Hydrocarbons; ND = Nil detected; UT = Ultra trace; NC = Not continuing. Note. CodyHart and ALS results from May 2015 onwards.

Photograph 6: Ambient surface water sampling point GARA6

GARA6 E 56 385915.0 N 6616606.0

Table 21: Field parameters, water level, flow, sediment, carbon, nutrients – Surface water GARA6

GARA6	Field parameters					Depth, flow & sediment				Carbon				Nutrients				
	DO	EC	pH	Eh	Temp	D	VFR	Turb	SS	Alk	Free CO_2	CO_2 + Alk	TOC	NH_3	NO_x	TKN	TotN	TotP
Measure	mg/L	µS/cm	1-14	mV	°C	m	kL/day	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L as N	mg/L as N	mg/L as N	mg/L	mg/L
Reporting Value	0.01	1	0.01	1	0.1	0.01	1	0.1	1-5	1	1	1	1	0.01	0.01	0.1	0.1	0.01
04/05/15	7.05	396	8.12	+208	15.2	0.45	2304	7.2	<5	150	6	31	13	0.04	0.01	2.0	2.0	0.05

Abbreviations: DO = Dissolved Oxygen; EC = Electrical Conductivity also called specific conductance; Eh = Redox Potential; Temp = Temperature; D = Approximate depth of water at sampling point; VFR = Volumetric Flow Rate; Turb = Turbidity; SS = Suspended Solids; Alk = Alkalinity measured as mg/L $CaCO_3$ equivalent; Free CO_2 = Free carbon dioxide; Unfiltered C of (CO_2 + Alk) = 12/44 CO_2 + 12/61 Alk; TOC = Total Organic Carbon; NH_3 = Ammonia as a measure of ammonium ions; NO_x = Nitrite + Nitrate; TKN = Total Kjeldahl Nitrogen (organic nitrogen and ammonia); Tot N = Total Nitrogen; Tot P = Total Phosphorus. Note. No sampling prior to May 2015.

Table 22: Metals & metalloids – Surface water GARA6

GARA6	Al	Sb	As	Cd	Cr	Cu	Ni	Pb	Se	Zn	Mn	Fe	Hg
Measure	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Reporting Value	0.01	0.001	0.001	0.0001	0.001	0.001	0.001	0.001	0.01	0.005	0.001	0.05	0.0001
04/05/15	<0.01	<0.001	0.002	<0.0001	<0.001	0.001	0.002	<0.001	<0.01	<0.005	0.013	0.12	<0.0001

Abbreviations: Al = Aluminium; Sb = Antimony; As = Arsenic; Cd = Cadmium; Cr = Chromium; Cu = Copper; Ni = Nickel; Pb = Lead; Se = Selenium; Zn = Zinc; Mn = Manganese; Fe = Iron; Hg = Mercury; NT = Not tested. Notes. Metals filtered. No sampling prior to May 2015.

Table 23: Extra laboratory parameters and analytes A – baseline only – Surface water GARA6

GARA6	Organics							Microbial	
	PAH	OC & OP	BTEX	TPH C6-C9	TPH C10-C14	TPH C15-C28	TPH C29-C36	*E.Coli*	Enterococci
Measure	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	CFU/100mL	CFU/100mL
Reporting Value	0.00005-0.0001	0.0005-0.002	0.001-0.002	0.025	0.025	0.1	0.1	1	1
04/05/15	ND (UT)	ND	ND	ND	ND	ND	ND	~10	~8

Abbreviations:
PAHs = Polynuclear Aromatic Hydrocarbons; BTEX = Benzene, Tolulene, Ethylbenzene, Xylene compounds; TPH = Total Petroleum Hydrocarbons; *E. Coli* = Escherichia coli; ND = Nil detected; UT = Ultra trace. Note. No sampling prior to May 2015.

7. WATER QUALITY COMPARISONS

Table 24 devised by CodyHart is provided to aid review of environmental health risks.

Table 24: Environmental health warning values **surface water** *- some landfill parameters & analytes*

Parameter	***Reason for Inclusion***	***Aquatic*** 1	***Human*** 2	***Irrigation*** 3	***Livestock*** 4
Temperature	Biodegradation of waste increases temperature. Temp + EC have successfully defined a leachate plume (Scrudato & Pagano, 1994).	>80%ile <20%ile	NR	NR	NR
pH	varies from acidic to alkaline as waste decomposition progresses (Andreottola & Cannas, 1992:72). But pH levels in groundwater are often naturally low.	6.5 to 8.0 (2000); 6.5 – 9.0 (1992)	6.5 to 8.5 (A)	>6 values corrosion of pipes	NR
Electric Conductivity (EC)	a general indicator that summarises the general trend of major cation and anion concentrations.	30 -350 μS/cm (2000); ≤1500 μS/cm (1992)	≤938 μS/cm (A) >1875 μS/cm (unpalatable)	varies, e.g., ≤1,000μS/cm carrots	≥3582 μS/cm analyse for specific ions which may affect
Analyte	***Reason for Inclusion***	***Aquatic*** 1	***Human*** 2	***Irrigation*** 3	***Livestock*** 4
Alkalinity	Measures acid-neutralising capacity, a solution's ability to buffer, that is stop pH changing. Often high in leachate, but some groundwaters can also have high alkalinity.	NR	NR	NR	NR
Boron	High mobility in clay. Good tracer. Found in leachate (Bagchi, 1994:52). Found in fireproofing agents, preservatives, antiseptics, glass, enamels, cosmetics, cements, carpets, soaps, powders and ointments. Some crops are intolerant to boron (ANZECC, 1992:5-13). However, low in northern NSW leachate (Hart, 2015)	≤0.37 mg/L	≤4.0 mg/L	≤0.5 mg/L (long term)	≤5mg/L
Bromide	Leachate indicator if leachate high in sea salt (Baker1993; Hart 1994). Used in bleaches; dyes; pharmaceuticals; pesticides; solvents for waxes, greases & oils; additives for motor oil & fuels; used in photograph development. Bromate generated from bromides in water (Wikipedia). Bromate is carcinogenic. Relatively low in northern NSW leachates (Hart, 2015)	NR	Bromate ≤0.02 mg/L forms bromide as a by-product	NR	NR
Ammonium ions	From decaying plants and animals. May be high in leachate (Hancock & Phillips, 1992:22). Toxic to fish (ANZECC, 1992:2-30).	Table 8.3.7 ≤0.18 mg/L as N for pH 9.0; ≤0.9 mg/L as N pH 8.0; ≤2.18 mg/L pH 7.0; ≤2.57 mg/L pH 6.	≤0.04 mg/L as N (A – corrosion of copper pipes)	Nitrogen ≤5 mg/L (long term; 25-125 mg/L (short term – up to 20 years)	NR
Nitrate	From final stage of plant and animal decomposition or fertilisers. May be high in leachate (Canter, 1997:6). Toxic to infants and livestock (ANZECC, 1992:4-10, 5-23).	(Table 3.3.2 eutro - NO_x as N ≤0.015 mg/L; TN ≤0.25 mg/L; Table 3.4.1 Toxic ≤0.158 NO_x as N	≤11.3 mg/L as N for up to 3 month bottle fed babies. Others ≤22.6 mg/L as N.	As for ammonia	≤ 90 mg/L as N; Nitrite ≤9 mg/L as N
Phosphorus	Csuros (1994:228-229) explains that phosphorus occurs in animal, plant and mineral kingdoms. Its discharge to streams may stimulate growth of photosynthetic organisms especially if it is the nutrient whose low values are valueing the primary productivity of the water.	Total P ≤0.02 mg/L	NR	≤0.05 mg/L (long term to prevent clogging irrig equipment; ≤0.8-12 mg/L (short term)	NR
VOCs / BTEX	Good indicators of man-made pollutants found in landfill leachate (USEPA, 1991:51075). Toxic and carcinogenic to animals and humans.	varies for different compounds	varies for different compounds	NR	NR
PAH	In old coal gasification plant coal tar waste. From incomplete burning of oil, wood, gas, garbage, meat. Rarely detected in northern NSW landfills.	e.g., Naphthalene ≤0.016 mg/L	Benzo-(a)-pyrene ≤0.00001 mg/L	NR	as per human
Phenolics	Rarely detected in landfill leachate in northern NSW. If they are detected, they are at trace levels (NSW EPA, 2015, p. 78)	Total phenols ≤0.32 mg/L	e.g., Pentachloro phenol ≤0.01 mg/L	NR	as per human

Table 24 continued:

Analyte	***Reason for Inclusion***	***Aquatic*** 1	***Human*** 2	***Irrigation*** 3	***Livestock*** 4
Iron and manganese	High iron concentrations affect plant growth and high manganese concentrations clog irrigation equipment and are toxic to plants (ANZECC, 1992:5-15, 5-16).	Fe NR (2000), ≤1 mg/L (1992), Mn≤1.9mg/L	Fe 0.3 mg/L (A) Mn 0.1 mg/L (A), Health 0.5 mg/L	Fe & Mn 0.2 mg/L long term, 10 mg/L short term	not sufficiently toxic (2000); ≤17 mg/L for dairy cattle (1992)
Aluminium for pH>6.5	Aluminium (and iron) >1mg/L indicates the presence of suspended clay minerals (Thorbjornsen & Myers 2007:26) that are naturally occurring. Aluminium results therefore assist review of metal results to determine if source is natural due to clay presence (Hart 2011).	≤0.055 mg/L	≤0.2 (A)	≤5 mg/L long term; ≤20mg/L short term	≤5 mg/L
Arsenic	Found naturally in soils & in cattle dip soils; toxic, possibly carcinogenic (Manahan, 1990:150), toxic to livestock in high concentrations (ANZECC, 1992:5-25)	≤0.024 mg/L (III) form; ≤0.05 aquaculture	≤0.01 mg/L	≤0.1 mg/L long term; ≤2 mg/L short term	0.5 to 5 mg/L tolerated
Cadmium	Causes high blood pressure, kidney damage, destroys testicular tissue and red blood cells, toxic to aquatic biota (Manahan, 1990:150), toxic and carcinogenic to livestock (ANZECC, 1992:5-26)	≤0.0002 mg/L – if 'hard' water ≤0.00084 mg/L	≤0.002 mg/L	≤0.01 mg/L long term; ≤0.05 mg/L short term	≤0.01 mg/L
Chromium	Cr^{+6} is possibly carcinogenic and is toxic to humans (anaemia, kidney disease, nervous system) (Manahan, 1990:150), reduces crop yield (ANZECC, 1992:5-14).	≤0.001 mg/L for Cr^{+6}	≤0.05 mg/L (Cr^{+6})	≤0.1 mg/L long term; ≤1 mg/L short term	≤1 mg/L
Copper	Essential in small concentrations for plant growth and animals (ANZECC, 1992:5-15&5-27). Toxic to sensitive plants and animals and bioaccumulated.	0.0014 mg/L – if 'hard' water ≤0.00546 mg/L	≤2 mg/L (Health) ≤1 mg/L (A)	≤0.2 mg/L long term; ≤5 mg/L short term	<0.4 mg/L sheep, <1 mg/L cattle; <5 mg/L pigs & poultry
Lead	Wildlife destruction (Manahan, 1990:151). Reduces plant growth (ANZECC, 1992:5-16). Decreases human intelligence, growth (Csuros, 1994:210).	≤0.0034 mg/L – if 'hard' water ≤0.02584 mg/L	≤0.01 mg/L	≤2 mg/L long term; ≤5 mg/L short term	≤0.1 mg/L
Mercury	Very toxic to humans - numbness, deafness, loss of muscle control (Csuros, 1994:212); toxic to fish (ANZECC, 1992:2-38).	NR (2000); ≤0.0001 mg/L (1992)	≤0.001 mg/L	≤0.002 mg/L	≤0.002mg/L
Nickel	Commonly on metal analyte suite lists. Occurs naturally and is ubiquitous in soils. Found in foods: cocoa, soy beans and some cereals (NHMRC 2015:861).	≤0.011 mg/L – if 'hard' water ≤0.0429 mg/L	≤0.02 mg/L	≤0.2 mg/L long term; ≤2.0mg/L short term	≤1 mg/L
Selenium	Toxic to cattle, fish and humans (Manahan, 1990:151) Used in electronics, glass, ceramics, pigments, rubber (Csuros, 1994:213).	≤0.005 mg/L	≤0.01 mg/L	≤0.02 mg/L long term; ≤0.05 mg/L short term	≤0.02 mg/L
Zinc	Found both naturally (weathering & erosion) and from anthropogenic sources (ANZECC, 1992:2-42). Zinc coating used to protect iron, steel and brass; used in dry batteries, construction materials, printing processes (Csuros, 1994:215). One of seven analytes with greatest percentage increase from 71 unlined landfills in North Carolina, USA (Borden and Yanoschak, 1990:269).	≤0.008 mg/L – if 'hard' water ≤0.0312 mg/L	≤3 mg/L (A)	≤2 mg/L long term; ≤5 mg/L short term	≤20 mg/L

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1. from Tables 3.3.1, 3.3.2, 3.3.3 - Default trigger values for aquatic ecosystems in upland rivers of south-east Australia which are slightly-moderately disturbed; Tables 3.4.1 trigger values for toxicants 95% level of aquatic ecosystem protection; and Table 3.4.4 Hardness factors for select metals in *'Australian and New Zealand Guidelines for Fresh and Marine Water Quality',* ANZECC & ARMCANZ 2000.
2. from *'Australian Drinking Water Guidelines 6'* NHMRC & NRMMC 2011, updated March 2015. <http://www.nhmrc.gov.au/guidelines/publications/eh52/>.
3. from Tables 4.2.5, 4.2.10, 4.2.11, 4.2.14 and 4.2.15 *'Australian and New Zealand Guidelines for Fresh and Marine Water Quality',* ANZECC & ARMCANZ 2000.
4. from page 4.3-3 – 4.3-5 *'Australian and New Zealand Guidelines for Fresh and Marine Water Quality',* ANZECC & ARMCANZ 2000.

NR - No recommendation; (A) aesthetic guideline rather than an environmental health guideline; (1992) refers to the 1992 edition of the *'Australian and New Zealand Guidelines for Fresh and Marine Water Quality'*.

8. REVIEW OF BASELINE AMBIENT SURFACE WATER MONITORING

Armidale Dumaresq Council commenced the baseline ambient surface water monitoring program in December 2008. They conducted 14 sampling rounds at sampling points GARA1, GARA2, GARA3, GARA4 and GARA5. Two of these sampling points (GARA3 and GARA5) are on the ephemeral stream on the Armidale Regional Landfill site. The other sampling points are on the Gara River (Figures 1 & 2).

CodyHart conducted the latest round, the fifteenth round, in May 2015. A new sampling point, GARA6, and microbial testing had been added to the program. The CodyHart hands-on field work allowed field assessment, as well as a desktop review of the baseline ambient surface water monitoring program to date. From this it has been possible to:

- Note field practicalities.
- Review the baseline monitoring for completeness.
- Detail any further monitoring that is needed to complete the baseline monitoring.
- Recommend detection monitoring sampling points, sampling frequencies, parameters and analytes, and quality assurance.
- Recommend assessment monitoring parameters and analytes in case they are ever required.

Council has tested for a very full suite of water quality analytes and parameters. The list included ones applicable to landfill leachate as well as others which generally assess surface water quality.

Before the last round in May 2015, it was decided to add an additional sampling point, GARA6, and microbial testing at all sampling points. So there has been only one round of testing at GARA6, and only one round of microbial testing at all sampling points.

8.1 Field practicalities

8.1.1 Photographic records and GPS noted for each sampling point

Craig Smith of Armidale Dumaresq Council took CodyHart personnel on a guided tour to point out the ambient surface water sampling locations sampled by Armidale Dumaresq Council personnel. To assure that future sampling is conducted at the same locations, CodyHart photographed the sampling points, measured their northings and eastings with GPS, and then noted them on Spatial Information eXchange (SIX) satellite images. This sampling location information is provided in this report as Figures 1, 2, 3 and 4.

8.1.2 Low flows in ephemeral stream – low risk of leachate impacts

A major observation is the low flow volumes of the ephemeral stream just downgradient of the landfill site in comparison to that of the Gara River. At GARA5, upstream on the landfill site ephemeral stream, and the downstream GARA3, the rough estimate of flow volumes was 260-270 kL/day. In comparison, the rough estimate of the flow volume was 19,940 kL/day at GARA2, which is situated on the Gara River approximately 45 metres downstream of the confluence of the landfill site ephemeral creek and the Gara River. After rain, the flows in the Gara River are therefore approximately 75 times greater than in the landfill site ephemeral stream. Remember too that most times there is no flow in the ephemeral stream.

Pollution dilution is not the focus of the preceding flow comparison. It merely illustrates that the degree of risk to the Gara River from landfill leachate is very low due to the small flows from the landfill site ephemeral stream into the far greater flows of the Gara River.

Couple this low risk due to small flow volumes with considered design, construction and operation of the Armidale Regional Landfill, and then the likelihood of a landfill leachate discharge occurrence to the Gara River becomes very unlikely. Construction works will improve the ephemeral stream erosion control. The landfill will be operated to minimise the open working face and therefore the likelihood of rainfall ingress to create leachate. Rain resistant cover will be applied to the small operating cell at the end of each working day. Leachate will be reinjected into the landfill to reduce the volume of concentrated leachate being held in the leachate sump and pond.

The on-site ponds have been designed so that overflows will rarely occur. If they do occur, the volumes and concentrations will be minimal due to the leachate management process planned. Let’s be pessimistic and say that a leachate discharge did occur during an extreme rainfall event. Nitrogen compounds in landfill leachate are the greatest risk to surrounding water quality. The dilution effect of rain onto the ephemeral stream catchment would reduce an original 28.8 mg/L total nitrogen concentration typical in a leachate dam affected by rainfall, two thousand fold to 0.014 mg/L by the time it reaches the Gara River. Given the baseline minimum concentration of total nitrogen of 0.2 mg/L at GARA2, there would be no consequences for the Gara River water quality. Very low likelihood of leachate escape and no consequences to the Gara River, means the overall risk from leachate discharge is very low.

8.1.3 Cattle dung and urine increase on-site total nitrogen concentrations

Following on from the low flows is the observation that cattle graze both on the landfill site itself, and on the upgradient property from which rainfall flows overland to the landfill ephemeral stream (Photograph 7).

Photograph 7: Looking northwest to cattle grazing on landfill site May 2015

The catchment of the landfill ephemeral stream is the valley that passes through the background of Photograph 7. Cattle will continue to graze on the upgradient property post landfill development.

Cattle grazing effects on the ephemeral stream are indicated in the baseline results. Of all the ambient surface water sampling points, the maximum total nitrogen results were at GARA3 (7.2 mg/L) and GARA5 (4.6 mg/L) – both on the landfill site ephemeral stream. The predominant nitrogen compound in the total nitrogen was organic nitrogen. When a plant or animal dies or an animal expels waste, the initial form of nitrogen is organic nitrogen. Cattle dung and urine were the sources of organic nitrogen at GARA3 and GARA5. This will remain the case because cattle grazing will continue upgradient of the ephemeral stream's catchment.

The principle forms of dissolved organic nitrogen are urea, uric acid and amino acids (Allan 1996, p. 286). Bacteria or fungi convert the organic nitrogen into ammonium (NH_4^+), a process called ammonification or mineralization (Wikipedia). NH_4 is then converted by bacteria into nitrite which is then transformed into nitrate, a process called nitrification. Nitrification occurs when the environment is aerobic. When the environment is anaerobic the nitrate undergoes denitrification in which nitrate is reduced to nitrogen gas. In nitrification and denitrification '*bacteria obtain energy by using ammonia as a fuel or nitrate as an oxidising agent'* (Allan 1996, p. 288).

Due to the nitrogen cycle detailed above, it is best to test for a full range of nitrogen compounds; otherwise the full potential environmental impact over time cannot be quantified.

- NH_4^+ as ammonia (NH_3 as N)
- Total kjeldahl nitrogen (TKN as N) because TKN - NH_4^+ = organic nitrogen
- NO_x as N which equals nitrite (NO_2^- as N) + nitrate (NO_3^- as N). (Nitrite is typically only a trace, so NO_x is sufficient and is more practical because it has a 28 day holding time rather than the 2 day holding time of nitrite and nitrate as separate entities.)

8.1.4 Faecal coliforms testing unwarranted

Some concern was raised that the new Armidale Regional Landfill may be noted as a cause of faecal contamination when the source may be the Armidale sewage treatment plant (STP). The Armidale STP discharges treated effluent into Commissioners Waters which flows into the Gara River. GARA4 sampling point at *Blue Hole* is downstream of the confluence of Commissioners Waters and the Gara River. It was thought that any contaminated water here in the mixed waters may lead to the new landfill being blamed as the source of contamination. Hence in the last sampling round of May 2015, GARA6 was inserted as another, non-STP affected sampling point and microbial testing was added to the parameter/analyte list for all ambient surface water sampling points.

E. Coli and enterococci were the microbial tests chosen as evidence of faecal contamination. *E. Coli* is the recommended test for Australian drinking water (NHMRC 2015, p. 264). *E. Coli* is an indicator microorganism for other pathogens that may be present in faeces. The Australian recreational water guidelines (NHMRC 2008, Table 5.7, p. 72) prefer the use of intestinal enterococci as a screening level because dose-response relationships are available in the literature. No *E. Coli* or enterococci should be present in drinking water. However, NHMRC (2015, p. 265, 269) cautions that neither *E. Coli* nor enterococci are '*effective indicators for the presence of enteric protozoa or viruses'*.

E. Coli is a subgroup that forms 97% of thermotolerant coliforms commonly called faecal coliforms (ANZECC & ARMCANZ 2000, p. 5-4). The Australian National Health and Medical Research Council (NHMRC) (2015, p. 264) explains that coliforms

> *are found in large numbers in the faeces of humans and other warm-blooded animals.... Thermotolerant coliforms are a sub-group of coliforms that are able to grow at 44.5 ± 0.2°C. E. coli is the most common thermotolerant coliform present in faeces and is regarded as the most specific indicator of recent faecal contamination because generally it is not capable of growth in the environment.... E. coli is considered a superior indicator for detecting faecal contamination.... E. coli is a normal inhabitant of the intestine, generally present in high numbers in human and animal faeces, and it generally does not grow in natural waters.*

The NHMRC (2015, p. 268) describes intestinal enterococci as

> *a functional group of organisms from the Enterococcus and Streptococcus genera that are excreted in human and animal waste.*

There are flaws in the argument that microbial tests should be undertaken as part of the baseline monitoring or during detection monitoring at ambient surface water sampling points, in case the landfill is construed as the source of the faecal contamination rather than the Armidale STP:

- Sources of faecal contamination are multiple. The best parameters available for indicating faecal contamination apply to any warm blooded animal - treated human waste from the STP, cattle, sheep, kangaroos or birds etc. Even at the Armidale STP discharge point the source may be confused. There are hundreds of cattle grazing at the Armidale STP and upstream along the banks of Commissioners Waters. The source of *Blue Hole* water microbial content may be from a close-by source such as the many ducks that frolic in the waterbody, or the cattle grazing upstream. So any positive microbial results at *Blue Hole* cannot be directly attributed to the Armidale STP.
- The considerable distances and variety of catchments between the Armidale STP and *Blue Hole* multiplies the faecal coliform source confusion and the futility in monitoring for faecal coliforms long term. For example, the watercourse distance from the STP to *Blue Hole* GARA4 sampling point is 21 km (SIX measurement). By the time the treated effluent reaches *Blue Hole* it would have undergone natural water treatment and have had more faecal inputs from animals and birds. Another example is the watercourse distance from GARA2 to the new sampling point GARA6 of 6.3 km, and from GARA2 to *Blue Hole* of 9.2 km. The same distance and variety of catchments problem of not being able to directly attribute the faecal contamination source to particularly the landfill, animals or birds recurs on the Gara River.

There are flaws with the argument that microbial tests should be undertaken as part of stormwater or ambient surface water monitoring during construction and operational stages of the landfill.

- Positive faecal coliform counts from the landfill ephemeral stream may be construed as a landfill management problem when a positive result is highly likely to be simply due to cattle, sheep, kangaroos or birds etc. The first baseline faecal coliform results for the landfill ephemeral stream in May 2015 are relatively high, not due to the landfill which is not constructed yet, but definitely due to cattle dung and urine. The worst was GARA5, the upstream sampling point on the landfill ephemeral stream. The *E. Coli* count was 2,800 CFU/100mL. This is 4.4 times greater than the maximum result at the Armidale STP discharge point from monthly sampling over the last four years. [Faecal coliform (E Coli ~97% subset) Armidale STP discharge point maximum of 640 CFU/100mL and a minimum of 8 CFU/100mL.]
- The days have long gone since 'nightsoil' was deposited in trenches at landfills.
- No biosolids are received at the current landfill for Armidale, the Long Swamp Road Landfill, and will not be received at the Armidale Regional Landfill.
- Armidale Dumaresq Council actively promotes that residents place their animal manures in their organic bins for the Council's *City to Soil* composting program. This capturing of pet manures rather than landfilling them is working well (Turnell, 2015).
- Faecal coliforms desiccate in dry conditions and biodegrade in moist conditions (Redlinger et al. 2001). Ware (1980, p.55-59) cited a number of studies concerning the decline of faecal coliform counts in municipal solid waste and landfill leachate. An example was the study by Engelbrecht (1974) who found that faecal coliforms persisted for 40 to 60 days, and then rapidly disappeared. Therefore, any faecal coliforms in the municipal solid waste, such as in nappies, will be treated in the landfill environment.

- The new NSW EPA *Draft Environmental Guidelines: Solid Waste Landfills* (March 2015) discuss thermotolerant (faecal) coliforms testing to meet a ≤600 cfu/100mL criteria for discharges from sediment basins '*where required*', and suggest their testing for ambient surface water monitoring. Faecal coliform testing as referenced in their source, *Managing Urban Stormwater: Harvesting and Reuse* (NSW DEC, 2006) is applicable to urban settings or irrigation of food crops. Landfill settings are quite different. There are no urban pets, no sewer pipes or septic tanks that may overflow into stormwater pipes or drains, and no above ground food crops such as lettuce or cauliflower being irrigated. The faecal contamination from cattle, kangaroos and birds has been proven to be present before landfill construction and nothing can be done or should be done to stop it in this normal rural setting. There is therefore no point in microbial testing at the Armidale Regional Landfill site.
- In addition, microbial tests for faecal coliforms in regional areas are problematic due to the 24 hour holding time before they should be counted at a lab NATA registered to count them. The problem with TNT Express not on-sending the Armidale Regional Landfill samples from Sydney to Brisbane overnight as contracted in this May 2015 sampling round is a good example of these problems.

8.2 Baseline ambient surface water monitoring completeness

To review the completeness of the baseline ambient surface water monitoring, three questions are asked:

1. Are the ambient surface water sampling points sufficient?
2. Have there been a sufficient number of sampling rounds at adequate frequency?
3. Do the parameters and analytes tested give a good indication of the general surface water quality, and in particular are parameters and analytes included whose concentrations will increase due to landfill leachate intrusion?

8.2.1 Number and locations of sampling points

The NSW EPA *Draft Environmental Waste Guidelines: Solid Waste Landfills* (2015, p. 26) recommend at least one upstream and one downstream ambient surface water sampling point.

In comparison, six ambient surface water sampling points have been included in the Armidale Regional Landfill baseline ambient surface water monitoring program (Figures 1, 2, 3).

The sampling points in close proximity to the landfill are the most applicable:

GARA5 – upstream of the yet to be constructed landfill
GARA3 – downstream of the yet to be constructed landfill
GARA2 – just downstream of the confluence of the landfill site ephemeral stream and the Gara River.

To be thorough and precautionary, upstream and downstream sampling points on the Gara River have been included in the baseline study due to the Gara River flowing into the Oxley Wild Rivers National Park:

GARA1 – upstream of the confluence of the landfill site ephemeral stream and the Gara River
GARA6 – the first downstream sampling point after GARA2
GARA4 – the second downstream sampling point after GARA2 and located in the northern end of the Oxley Wild Rivers National Park at *Blue Hole*.

The number and locations of the baseline ambient surface water sampling points are sufficient due to the mix of sampling points. The most applicable sampling points during the detection monitoring phase are GARA5, GARA3 and GARA2 due to their close proximity to the future landfill. GARA1, GARA6 and GARA4 were precautionary ones during the baseline monitoring due to conservation concerns for the Gara River. There is a very low likelihood of landfill leachate entering the Gara River. There are no consequences to the water quality due to dilution by rainwater before it reaches the Gara River. So overall the risk to the Gara River is extremely low. Consequently, results from GARA1, GARA6 and GARA4 sampling during the detection monitoring phase would be of no use. One is upstream of the confluence of the landfill site ephemeral stream and the Gara River, and the other two are too distant for landfill leachate to be detected.

8.2.2 Sampling rounds and frequency

Fifteen sampling rounds have been conducted at GARA1 to GARA5. Sampling frequencies between December 2008 and June 2013 were predominately 2 to 3 months apart with a few 5 to 7 months apart. This range of frequencies is common when waiting for water flows in ephemeral streams. There has been a two year gap between Council's fourteen rounds and sampling and the last sampling round in May 2015 conducted by CodyHart.

GARA6 has only been sampled once (May 2015).

It is common to suggest 8 rounds of baseline sampling over two years before the construction of a landfill. It can therefore be said that there has been a sufficient number of sampling rounds at an adequate frequency for sampling points GARA1 to GARA5.

A further seven baseline monitoring rounds at GARA6 are recommended to gain an understanding of its quality over time.

8.2.3 Parameter and analyte results review

'An analyte is a substance whose chemical constituents are being identified and measured' (Oxford Dictionary). 'Parameter' is an applicable term when not referring to chemical analysis. The term 'parameter' in water quality monitoring refers to a measure taken either with a probe, measured manually with a tape measure or scales, or counted visually. Parameters include dissolved oxygen (DO), electrical conductivity (EC), pH, redox potential (Eh), temperature, turbidity, water depth, water flow rate for volumetric flow estimation, suspended solids or microbial counts.

Parameters and analytes used in the baseline program thoroughly tested the general surface water quality at the ambient surface water sampling sites:

- A range of field parameters allowed review of general water quality health: DO, EC, pH, Eh, temperature, and the analyte, alkalinity. All these parameters and one analyte are useful in detecting landfill leachate ingress into surface water (Table 24).

  Dissolved oxygen readings were predominantly above the 'rule of thumb' 5 mg/L, which indicates reasonably oxygenated waters.

  Two EC values at GARA3 exceeded 1,000 µS/cm. These values were probably due to low-flow conditions in this relatively low lying area that is frequented by cattle that disturb the clays. In addition, there were many instances when Gara River EC values exceeded the ≤350 µS/cm recommended as the salt level value for upland NSW rivers

(ANZECC & ARMCANZ 2000, Table 3.3.3, p. 3.3-11). The pH upper value of 7.5 (ANZECC & ARMCANZ 2000, Table 3.3.2, p. 3.3-10) was exceeded on many occasions at all sampling points. This is common in New England surface water bodies.

- Individual anions and cations gave a full overview of the salts present. These are useful to have for baseline in case they need to be tested again during the assessment monitoring phase as a comparison. In the detection monitoring phase, they are made redundant by EC which gives a general, and sufficient indication of the salts present.
- A full suite of nitrogen compounds was needed so that organic nitrogen was not excluded. Nitrogen compounds are the major indication of landfill leachate contamination of surface water and groundwater. Their analyses need to continue into the detection monitoring phase.

  The maximum total nitrogen concentrations (due to cattle dung and urine) of 7.2 mg/L at GARA3 and 4.6 mg/L at GARA5 far exceeded the recommended 0.25 mg/L toxicity concentration by ANZECC & ARMCANZ 2000 (Table 3.4.1, p. 3.4-5). Most nitrate concentrations from GARA1 to GARA5 exceeded the recommended eutrophication safeguard of 0.015 mg/L nitrate as N (ANZECC & ARMCANZ 2000, Table 3.3.2, p. 3.3-10).
- Total phosphorus is a basis for detection monitoring eutrophication review. This analyte assists understanding of eutrophication, a process where water bodies receive excess nutrients that stimulate excessive plant growth. Phosphorus values the effect of nitrogen inputs in the eutrophication process and therefore stimulation of algae and plant growth.

  All total phosphorus concentrations, except three concentrations, at all the GARA1 to GARA6 sampling points, exceeded the ≤0.02 mg/L trigger value recommended for NSW upland rivers (ANZECC & ARMCANZ 2000, p. 8.2-42).
- Sediment load was tested by measuring total suspended solids (SS). ANZECC & ARMCANZ (2000, p. 8.2-13), explain that while in suspension, suspended solids '*reduce light penetration and thus affect primary production'*. Fish gills may be impaired. Benthic organisms and their habitats can be smothered when the suspended solids settle. Sediment load in a water body needs to be monitored in both baseline and detection phases of ambient surface water monitoring as a means of assessing erosion controls.

  SS was excessive (≥50 mg/L) at only the landfill site ephemeral stream locations, GARA3 and GARA5, and were so on many sampling occasions.

  Turbidity is an alternative indicator for quantifying sediment load and is particularly effective when there are clays in suspension as colloids. It is measured in the field with a nephelometer that measures '*the cloudiness of a water sample due to light deflection by the suspended particles'* (NSW EPA 2015, p. 22). It gives an immediate indication in the field rather than having to wait for a suspended solids result from the laboratory. This assists decision-making especially if water needs to be released from a sedimentation dam into receiving waters.

  Turbidity was measured for the first time in May 2015. A 2-25 NTU range is normal for an upland NSW river (ANZECC & ARMCANZ 2000, Table 3.3.3, p. 3.3-11). All the Gara River sampling points except GARA1 were within this range. Both landfill site sampling point waters (GARA3 and GARA5) exceeded the recommended range.
- Metals were tested by using a range of metals commonly used in water quality testing. Comments on the importance of the metals tested are found in Table 24.

  In a number of instances, the naturally occurring metal concentrations of the baseline study exceeded the 95% protection of aquatic ecosystem trigger values. Let's take GARA2, the sampling point that needs the most protection from the landfill perspective. It has only two metals (aluminium and iron) with concentrations that exceed the ANZECC & ARMCANZ (2000, Table 3.4.1, p. 3.4-5) trigger values for 95% protection of freshwater aquatic ecosystems. [Copper at GARA2 is not an exceedance. The water is classified as “hard” which reduces the metal’s bioavailability and allows the 0.0014 mg/L trigger value to be multiplied by 3.9 (Table 3.4.3, p. 3.4-21)]. In contrast, the worst overall results were at the landfill site GARA3 where five metals (Al, Cu, Zn, Mn and Fe) exceeded the trigger values for 95% protection.

Antimony was sampled in May 2015 due to it being mined in the area. None was detected at any sampling point so its testing will be discontinued.

Metal samples for the first 14 rounds were not filtered and were tested for total metals. Filtering the metal samples in the field in the May 2015 sampling round and testing for dissolved metals has reduced the number of exceedances. For example, GARA3 metals only had one exceedance, aluminium.

Whether or not metal samples and TOC are filtered needs to be defined for the ambient surface water monitoring plan going forward. There are arguments for and against filtering. If a surface water sample is laden with sediment, it is difficult to filter. The easiest choice is not to filter metals or TOC in the baseline monitoring phase. If the concentrations exceed the ANZECC & ARMCANZ (2000) trigger values, then filtering can be undertaken in the detection monitoring phase. Dissolved metals results are admissible for comparisons against ANZECC & ARMCANZ (2000) trigger values for freshwater aquatic ecosystems because ‘*the major toxic effect of metals comes from the dissolved fraction’* (ANZECC & ARMCANZ, 2000, p. 3.4-15).

The foremost comment in regard to the preceding review is that the baseline results on many occasions exceed the ANZECC & ARMCANZ (2000) trigger values for the protection of freshwater aquatic ecosystems. The maximum baseline results therefore supersede the ANZECC & ARMCANZ (2000) trigger values. However, it needs to be taken into account that the baseline study provides just a snapshot of results that may not have revealed the true maximum natural concentrations or values. [The freshwater aquatic ecosystem trigger values were chosen as a comparison to the baseline results because it is the most immediate beneficial use (environmental value) to be protected and the most sensitive. Irrigation and stock uses are also important for the Gara River but the applicable concentrations are less stringent than those for freshwater aquatic ecosystems.]

The analytes and parameters tested included those whose values may show substantial variation due to landfill leachate intrusion or sediment load from site soil runoff. These were:

- Field: DO, EC, pH, Eh, alkalinity
- Nitrogen compounds
- Metals, especially iron (Fe) and manganese (Mn)
- Suspended solids and turbidity.

There were some extraneous inclusions in the parameter and analyte list. They were tested as a precaution and to broaden the understanding of the ambient surface water quality. Examples include:

- Sodium absorption ratio (SAR) is relevant to irrigation effects on soil. It indicates if soil may be affected by sodicity, that is, the presence of a high proportion of sodium (Na^+) ions relative to calcium (Ca_2^+) and magnesium (Mg_2^+) ions in soil or water. Sodicity degrades soil structure by breaking down clay aggregates.

  All SAR results in the baseline testing were reasonable for irrigation. Of particular note is the very low maximum 0.7 SAR at GARA2, which is protective of this most critical ambient surface water sampling point.

- Reactive phosphorus (RP) is the available portion of phosphorus to plants. Concentrations at GARA1 to GARA5 exceeded the ANZECC & ARMCANZ (2000, Table 3.3.2, p. 3.3-10) recommended 0.015 mg/L for NSW upland rivers. So RP is contributing to the plant growth in the Gara River. However, RP testing will not be carried out in the detection monitoring phase due to its holding time of only two (2) days before it must be analysed by the laboratory. Total phosphorus analysis suffices because RP is a subset of total phosphorus, which has a 28 day holding time.
- Fluoride is a secondary ion and a component of an anion cation balance used in laboratory quality control. Like some other major anions and cations, it is not needed in the detection monitoring phase because EC makes them redundant.
- Hardness is often tested for home purposes. It is applicable to suds in washing water and calcification build up on home appliances such as kettles, dishwashers, and water heaters and the installation of water softeners. Its use in stream water quality monitoring is valueed due to insufficient research data, but there are algorithms available to modify the trigger values for the protection of freshwater aquatic ecosystems of some metals [Cd, Cr(III), Cu, Pb Ni and Zn].

  The hardness results for the Gara River sampling points (GARA1, GARA2, GARA4) are classified as 'hard' because they are in the 120-179 mg/L as $CaCO_3$ range. Table 3.4.3 of ANZECC & ARMCANZ (2000, p. 3.4-21) indicates that the ANZECC & ARMCANZ (2000, Table 3.4.1, p. 3.4-5) trigger values can be increased for: Cd X 4.2; Cr (III) X 3.7; Cu X 3.9' Pb X 7.6; Ni X 3.9; and Zn X 3.9. The resulting trigger value concentrations for these metals are provided in Table 24.

  Sufficient information for varying metals trigger values has been obtained in the baseline study. Hardness testing will be discontinued in the detection monitoring phase.
- Total dissolved solids are the solids that remain after a sample is placed in a dish to evaporate. Electrical conductivity (EC) is commonly used to estimate an approximation. As EC is measured in the field it gives immediate answers concerning changes that may indicate landfill leachate contamination of surface water. TDS is therefore redundant and not needed in detection monitoring.
- Organochlorine (OC) and Organophosphorus (OP) pesticides were checked in case there are residuals from farming practices.

  The only pesticide detected was trans-Chlordane at GARA3 on the landfill site. At 0.00029 mg/L it was only a very low trace. Pesticides are very rarely detected in landfill leachate. Testing for pesticides should only be conducted in landfill leachate. There is no point in testing for OC & OP pesticides in groundwater or surface water if they are not present in high concentrations in leachate – which they are not. Only two, low trace OC & OP pesticides have been detected in concentrated landfill leachate results from four northern NSW landfills over the past 15 years (Hart 2015).
- Total petroleum hydrocarbons (TPH) can result from naturally occurring oils as well as petroleum products. Their inclusion in the baseline monitoring list was precautionary.

  A few traces were detected but not retested with silica gel cleanup to identify if they were natural or man-made. TPH or total recoverable hydrocarbons (TRH) are general tests that do not identify individual compounds.

  It is better to review specific hydrocarbon compounds which are landfill leachate contaminants of concern, for example, BTEX and PAH compounds.
- Phenols are usually not detected in rural landfill leachate. If they are, they are at trace levels (NSW EPA, 2015, p. 78). The ubiquity of phenols use and their trace levels in landfill leachate means that the phenols detected in surface water can never be directly attributed to landfill leachate.

The only phenol detected throughout the baseline ambient surface water monitoring was 3-&4-Methylphenols (a cresol) at GARA3 on the landfill site. This cresol could have been naturally occurring or evident due to its use in the manufacture of many compounds and materials including plastics, pesticides, pharmaceuticals and dyes (Wikipedia).

- Polynuclear aromatic compounds (PAHs) are rarely found in landfill leachate. PAHs are found in coal tar, crude oil, creosote, and roofing tar, but a few are used in medicines or to make dyes, plastics, and pesticides. They can also be due to incomplete burning, e.g., car exhaust fumes, burning wood, or even grilled meat.

  Only one was detected, and only once at GARA3 on the landfill site. Phenathrene was detected as a trace 0.00069 mg/L. Phenathrene is used to make dyes, plastics and pesticides, explosives and drugs. It has also been used to make bile acids, cholesterol and steroids. It is also found in cigarette smoke and occurs naturally in the mineral, ravatite (Wikipedia). (U.S. EPA fact sheet, http://www.epa.gov/osw/hazard/wastemin/minimize/factshts/phenanth.pdf)

There were some omissions that will assist interpretation of water quality if they are included in the detection monitoring program:

- Depth estimate of the water at the point at which the sample is taken.
- An estimate of the daily flow volume at each sampling point.
- Free carbon dioxide (CO_2) which is a field titration. Added to alkalinity, free CO_2 allows quantification of the major forms of inorganic carbon in the water sample. High free carbon dioxide in surface water provides an indication of a possible contamination problem on the day of sampling.
- Total organic carbon (TOC) is typically far less in surface water than in landfill leachate.

The above parameters and analytes were included for the first time in the May 2015 sampling round.

The preceding review indicates that the analytes and parameters used for the baseline monitoring were thorough. They provided:

- A full spectrum of understanding of the general ambient surface water quality; and
- A basis against which detection monitoring phase parameter and analyte values can be compared to note changes in water quality that may be due to landfill leachate or sediment load ingress.

8.3 Baseline ambient surface water monitoring to complete

It is concluded from the review in Sections 8.1 and 8.2 that sufficient baseline ambient surface water monitoring has been conducted at sampling points GARA1 to GARA5.

It is recommended that:

- Ambient surface water monitoring at GARA1 and GARA4 cease. A full baseline study is complete for these sampling points. Their monitoring was included in the baseline study as a precautionary measure. These sampling points are not directly relevant to the landfill site.
  - GARA2 is the sampling point whose water quality needs the most protection. There is now a full baseline study available to act as a comparison for its detection monitoring results. GARA1 is not needed as a comparison. It would only be necessary to retest GARA1 if assessment monitoring is triggered, when it would be needed to eliminate upstream water as the source of suspect results at GARA2.

    - GARA4 is approximately 10.4 km watercourse distance from the landfill site and therefore cannot be affected by landfill site events.
- Seven more quarterly baseline ambient surface water sampling rounds are conducted at GARA6 to gain an understanding of its quality over time.
- Detection monitoring commences at GARA2, GARA3 and GARA5. This should include the collection of two (2) more microbial data sets in the initial detection monitoring rounds to validate that faecal contamination is present from cattle dung and urine. These additional tests are to endorse the discontinuation of microbial testing in future site monitoring.

9. DETECTION MONITORING RECOMMENDATIONS

There are three phases to water monitoring at landfill sites:

1. ***Site characterisation*** of surface water and groundwater prior to landfill construction, and initial leachate quality once the landfill is constructed and operating, to serve as a ***baseline*** against which to compare future water quality data
2. ***Detection monitoring*** to determine whether or not there has been an impact on surface water and/or groundwater quality from landfill leachate or sediment runoff
3. ***Assessment monitoring*** in the event of impacts, to characterize possible surface water or groundwater contamination (nature, extent, possible future extent and source); and if required, to evaluate and recommend mitigation techniques.

(in keeping with Sara & Gibbons 2006)

The first two are essential for the operation of an environmentally responsible landfill. The third is undertaken after suspected impact.

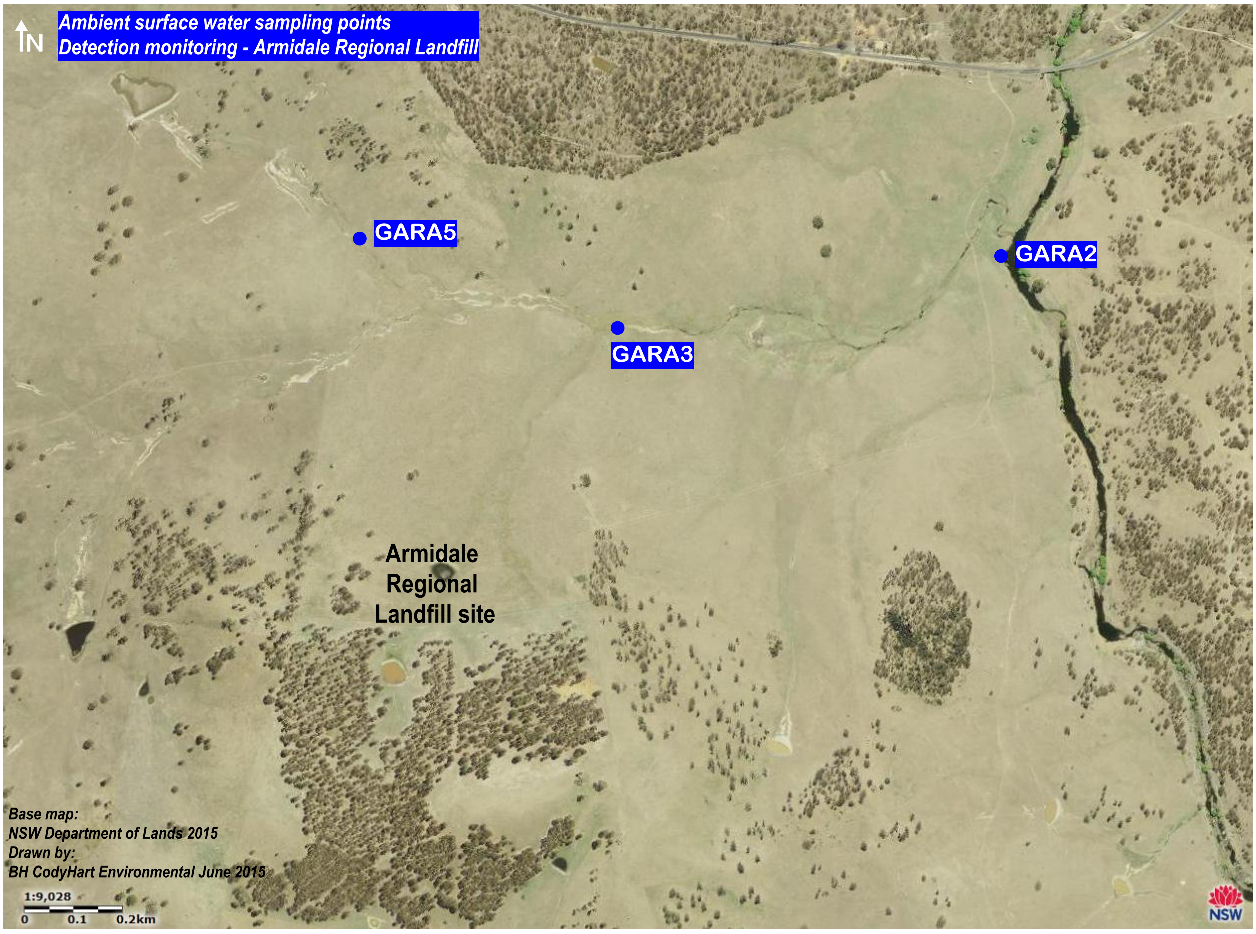
The baseline ambient surface water monitoring already conducted for the Armidale Regional Landfill has given a thorough overview of the ambient surface water quality in the area surrounding the landfill and on the landfill site. Continuing the ambient water quality monitoring at GARA6 for seven more quarterly rounds will complete the baseline sampling.

The detection monitoring phase for ambient surface water quality monitoring extends through the construction and operational phases of the landfill.

9.1 Detection monitoring ambient surface water sampling points

The on-site sampling points (GARA3 and GARA5) are the most relevant during the operational and post-operational stages of the landfill. These are the closest sampling points at which to detect sediment or landfill leachate problems affecting the ephemeral stream. The closest downstream sampling point on the Gara River, GARA2, is also of importance, not only due to its location as a detection point for impacts, but also due to this reach of the river being a platypus habitat. Figure 4 shows the three ambient surface water sampling points recommended for detection monitoring.

Figure 4: Detection monitoring ambient surface water sampling points – recommended



These locations are in keeping with the recommendations in the NSW EPA *Draft Environmental Waste Guidelines: Solid Waste Landfills* (2015, p. 26) for ambient surface water sampling points.

> *For each potentially affected surface water body, there should be at least one monitoring point downstream of the landfill (for flowing or perennial waters such as rivers and creeks) or near the landfill (for still waters such as lakes and dams).*
>
> *There should also be one monitoring point upstream of the landfill (for flowing waters) or distant from the landfill (for still waters) to establish the background, or unimpacted, surface water quality in the locality.*

Rather than one sampling point downstream of the landfill, two are proposed: GARA3 and GARA2.

9.2 Detection monitoring ambient surface water sampling frequency

Bi-monthly ambient surface water quality monitoring is proposed while major earthworks are ongoing, and thereafter, quarterly. Weather forecasts will be watched to ascertain when ephemeral stream water flow is likely at GARA5 and GARA3 and the sampling times adjusted accordingly. They will be sampled even if only isolated pools of water remain.

9.3 Detection monitoring ambient surface water parameters and analytes

The review of the baseline water quality analytes and parameters in Sections 8.1 and 8.2 was a precursor to the following selection of parameters and analytes for detection monitoring.

- Field parameters: Depth, volumetric flow, DO, EC, pH, Eh, temperature, turbidity
- Field analytes: Alkalinity, free CO_2
- Chloride
- Nutrients (NH_4^+ as N, TKN as N, NO_x as N, Total Phosphorus)
- Total organic carbon (TOC) (Filter on-site)
- Metals [Al, As, Cd, Cr, Cu, Ni, Pb, Zn, Mn, Fe, Fe (II)] (Filter on-site)
- Suspended solids

The metals tested are reduced from those in the baseline study to:

- those found in higher concentrations in a number of northern NSW landfills and Brisbane Landfill concentrated leachate samples over the past 20 years, with
- the addition of aluminium due to its presence in clays, and
- ferrous iron [Fe (II)]because it is a soluble by-product of iron reduction as biodegradation progresses (Dinicola, Simonds & Defawe 2005, p. 15; Wiedemeier et al. 2006, p. 582).

From the above parameters and analytes, the following are chosen as the geochemical parameters and analytes likely to have at least a 20% immediate increase on the baseline maximum due to landfill leachate intrusion: EC, pH, alkalinity, TOC, total nitrogen, chloride.

In many instances these geochemical indicators would increase GARA2 concentrations between 1.5 and 4.8 times if landfill leachate intruded, and the increases would occur in relative unison. Exceedances would be very obvious. This conclusion has been reached by reviewing data from landfill ponds that receive minimal and diluted landfill leachate at other northern NSW landfills, and comparing that data to GARA2 baseline results (Hart 2015). In many instances there was at least 15 years data for a thorough review.

9.4 Detection monitoring quality assurance

The Armidale Regional Landfill is not a contaminated site. The extensive number and type of quality assurance tests used during contaminated site assessment are not appropriate or warranted.

A range of methodologies and tests assure that the data being obtained is representative of the ambient surface water quality. These have already been explained in Section 5 of this report.

9.5 Detection monitoring water quality comparisons

Comparing results as they come to hand with historical results is essential to complete the objective of landfill detection monitoring - to determine whether or not there has been an impact on surface water and/or groundwater quality by landfill leachate or sediment runoff.

The following process will be followed:

1. Prepare statistical trigger values for GARA2 geochemical indicator parameters or analytes (EC, pH, alkalinity, TOC, total nitrogen, chloride). Take 6 samples of each geochemical analyte or parameter in the next round of sampling at GARA2. Use these

samples to add an estimate of within-event variation that is possible at each sampling event. (Taking only one sample per round does not reveal the maximum or minimum value possible for that round. A far higher maximum than that detected may actually be the fact. Variation in results is normal and should be taken into account). Use Chebyshev's Theorem theory to estimate and add-on an estimate of the within-event variation to the maximum, or subtract from the minimum pH, of each selected geochemical indicator for GARA2.

The preceding methodology was devised with the assistance of a statistician and implemented by Hart (2000) and accepted by EPA Grafton office. It is the basis of the statistical trigger values detailed in Environment Protection Licence L7186 for the Grafton Regional Landfill.

GARA2 is the aquatic habitat to be protected. Concentrating on knowing its water quality characteristics and quickly taking action if there are any concerns is paramount. Note that the parameter and analyte values at the ephemeral stream sampling points GARA3 and GARA5 during the baseline study show considerable variation. This is probably due to the sample volume being valued on some sampling occasions, and exposed clay being entrained in turbid samples. Clay in samples increases EC values and total metal concentrations. There would be little confidence in trigger values based on these variable results.

GARA3 and GARA5 results are to be reviewed by a person experienced in water quality review, such as a landfill hydrogeologist who is aware of the site conditions and possible sediment load and leachate ingress scenarios.

2. When field and laboratory results become available, input them into the historical tables on that day, or the day after.
3. Compare the latest results through a vertical scan of each parameter and analyte in the tables and note if any are greater than the baseline maximum value or statistical trigger value for GARA2 - or in the case of pH if also less than the minimum value. (Remember to review pH from a logarithmic scale perspective.)
4. If anomalies may be a clerical or laboratory mistake, have the results double checked.
5. If any three or more of the selected geochemical indicators for GARA2 exceed their statistical trigger values/s by more than 20%, then commence assessment monitoring within 5 business days or sooner.
6. If suspended solids ≥50 mg/L at any sampling point, review if upstream erosion remediation is warranted, or if the results at GARA3 and GARA5 are simply due to low sample depth and exposed clay in a colloidal sample.

10. ASSESSMENT MONIITORING RECOMMENDATIONS

Assessment monitoring will come into play:

- If any three or more of the selected geochemical indicators for GARA2 exceed their statistical trigger value/s by more than 20%
- If either GARA3 and/or GARA5 are determined to be in need of assessment monitoring by a person experienced in water quality review
- If inspection of any other water body in the landfill environs is noted as needing water quality review.

The watercourse upstream and downstream of the suspected contamination will be inspected to decide the most appropriate sampling points for investigating the nature, extent, possible future extent and source of the contamination. In the process, possible mitigation techniques will be identified for evaluation with Council personnel.

If GARA2 is the impacted sampling point, then assessment monitoring will include GARA1 and GARA6, or more appropriate upstream and downstream substitutes, as well as GARA2.

The parameters and analytes to be tested are similar but slightly varied from those used in baseline monitoring.

- Field: Depth, volumetric flow, DO, EC, pH, Eh, temp, turbidity, alkalinity, free CO_2
- Laboratory:
    - SS
    - Cl, SO_4, Ca, Mg, Na, K, Hardness
    - Nutrients (NH_4^+ as N, TKN as N, NO_x as N, Total Phosphorus)
    - Dissolved metals filtered on site with 0.45 µm filter [Al, As, Cd, Cr, Cu, Ni, Pb, Zn, Mn, Fe, Fe (II)]
    - TOC (filtered)
    - Organics – VOCs, ultra trace (UT) PAHs, speciated phenols – only if sheen, colour, odour indicates that testing for these is worthwhile.

The sampling frequency will be determined by a person experienced in water quality review.

Desktop review will involve:

- Assessment of results against the baseline values of parameters and analytes for each of the sampling points or nearby sampling points
- Assessment of geochemical results for GARA2 against the statistical trigger values derived from baseline data
- Assessment of all results against trigger values for metals and organics as detailed in ANZECC & ARMCANZ (2000) tables – metals & organic compounds against the toxicity table 3.4.1, with the metal trigger values adjusted for hardness as detailed on Table 3.4.4.

Armidale Dumaresq Council management will be informed throughout the assessment process and advised of the surface water contamination nature, extent, possible future extent, and source. Mitigation techniques will be discussed with and evaluated by Council.

11. AMBIENT SURFACE WATER MONITORING PROGRAM OVERVIEW

The following table provides an overview of the Armidale Regional Landfill ambient surface water monitoring program as detailed in the preceding sections of this report.

Table 25: Ambient surface water monitoring program - Armidale Regional Landfill

Baseline monitoring *(GARA1-GARA6)*	**Detection monitoring** *(GARA2, GARA3, GARA5)*	**Assessment monitoring** *(GARA2, GARA3, GARA5 + appropriate)*
Sampling points (Figures 1, 2, 3) ***GARA1*** (upstream Gara River) ***GARA2*** (on Gara River, 1.2 km downstream from landfill) ***GARA3*** (on landfill site ephemeral stream, just downstream from the landfill) **GARA4** ("Blue Hole", Oxley Wild Rivers National Park, 10.4 km downstream from landfill, 21.0 km downstream from Armidale STP) ***GARA5*** (on landfill site ephemeral stream, upstream from landfill) ***GARA6*** (6.3km downstream from GARA2, 7.5 km downstream from the landfill)	***Sampling points*** (Figure 4) ***GARA5*** (upstream from landfill) ***GARA3*** (downstream from landfill) ***GARA2*** (1.2 km farther downstream from landfill than GARA3)	***Sampling points*** (Figures 1, 2, 3) **For impacted sampling point : GARA5, GARA3 and/or GARA2** If GARA2 impacted, add GARA1 and GARA6, or more appropriate upstream and downstream substitutes.
Sampling frequency Two to six months apart depending if there was flow at GARA3 and GARA5	***Sampling frequency*** Bi-monthly during major construction works, quarterly thereafter	***Sampling frequency*** Determine by review of need
Parameters & analytes Field: Depth, volumetric flow, DO, EC, pH, Eh, temp, turbidity, alkalinity, free CO_2 Laboratory: SS, Cl, SO_4, Ca, Mg, Na, K, Hardness, Nutrients (NH_4^+ as N, TKN as N, NO_x as N, Total Phosphorus), Total metals not filtered [Al, As, Cd, Cr, Cu, Ni, Pb, Zn, Mn, Fe, Se, Hg, Fe (II)-GARA6, Br, B, TOC (filtered), UT PAH, OC&OP pesticides, TPH/TRH, speciated phenolics. Notes: Some extra tests by ADC are not noted above. Highlighted ones added by CodyHart.	***Parameters & analytes*** Field: Depth, volumetric flow, DO, EC, pH, Eh, temp, turbidity, alkalinity, free CO_2 Laboratory: SS, Cl, Nutrients (NH_4^+ as N, TKN as N, NO_x as N, Total Phosphorus), Dissolved metals filtered on site with 0.45 µm filter [Al, As, Cd, Cr, Cu, Ni, Pb, Zn, Mn, Fe, Fe (II)], TOC (filtered).	***Parameters & analytes*** Field: Depth, volumetric flow, DO, EC, pH, Eh, temp, turbidity, alkalinity, free CO_2 Laboratory: SS, Cl, SO_4, Ca, Mg, Na, K, Hardness, Nutrients (NH_4^+ as N, TKN as N, NO_x as N, Total Phosphorus), Dissolved metals filtered on site with 0.45 µm filter [Al, As, Cd, Cr, Cu, Ni, Pb, Zn, Mn, Fe, Fe (II)], TOC (filtered), and if sheen, colour, odour indicates it is warranted – test for VOCs, UT PAHs, speciated phenolics.
QA samples to laboratory 1 intra-lab duplicate per 10 sampling points	***QA samples to laboratory*** 1 intra-lab duplicate per 10 sampling points	***QA samples to laboratory*** 1 intra-lab duplicate per 10 sampling points
Comparisons Baseline results against 95% protection of freshwater aquatic ecosystems (ANZECC & ARMCANZ 2000, Table 3.4.1, p. 3.4-5) and other tables 3.3.2, 3.4.4 and 8.3.7. If two baseline values greater than ANZECC & ARMCANZ (2000), then devise new comparison method based on review of landfill leachate values at other sites. **Note** (June 2015): To complete the baseline monitoring, conduct 7 more quarterly rounds at GARA6; and *E Coli & enterococci* two more times at GARA5, GARA3 and GARA2.	***Comparisons*** GARA3 & GARA5 – review by water monitoring specialist GARA2 – If any three or more of the geochemical indicators exceed their statistical trigger value/s by 20% or more, then commence assessment monitoring within 5 working days or sooner. [Selected indicators: EC, pH, alkalinity, TOC, total nitrogen, chloride.] If any sampling point SS ≥50 mg/L then review upstream erosion & sediment control measures.	***Comparisons*** GARA2 - Review against statistical trigger values of selected geochemical indicators and acceptable values for metals & organic compounds ANZECC & ARMCANZ (2000) toxicity Table 3.4.1, and combine with Hardness Table 3.4.4 for metals. *© CodyHart Environmental 2015*

12. CONCLUSION

This report has detailed and interpreted the baseline ambient surface water results for the Armidale Regional Landfill.

There are six baseline ambient surface sampling as displayed on Figures 1, 2 and 3: GARA1, GARA2, GARA3, GARA4, GARA5, GARA6.

GARA1, GARA4 and GARA6 were included as precautionary sampling points to ascertain the water quality state of the Gara River, which flows through the Oxley Wild Rivers National Park.

A recent baseline sampling round was conducted by CodyHart in May 2015 and has been described in this report. Prior to that, fourteen rounds of baseline monitoring, which commenced in December 2008, were undertaken by Armidale Dumaresq Council at all sampling points - except for GARA6, which was sampled for the first time in May 2015.

Results from all sampling rounds have been input into historical tables in this report.

It is concluded that baseline monitoring is complete for GARA1 to GARA5.

It is recommended that seven (7) more quarterly baseline monitoring rounds be conducted at GARA6.

It is also recommended that *E. Coli* and enterococci be sampled twice more at GARA3 and GARA5 located on the landfill site ephemeral stream. These faecal coliform indicators were sampled only once at all sampling points - in May 2015. The results were high at GARA3 and GARA5 due to cattle dung and urine. The extra samples are recommended prior to landfill operation to validate the high results and endorse their removal from both the ambient and stormwater surface water monitoring program. The high faecal coliforms are due to cattle dung and urine from both on-site grazing which will cease, and from grazing on the upgradient property which will continue post landfill installation. The faecal coliforms will never be attributable to landfill site works or landfill leachate.

It is recommended that the detection monitoring program commence when major works on the site begins.

A quarterly detection monitoring program is recommended for GARA2, GARA3 and GARA5 (Figure 4). Two of these sampling points (GARA3 and GARA2) are downstream of the landfill. This is one more downstream ambient surface water sampling point than required in the NSW EPA *Draft Environmental Guidelines: Solid Waste Landfills* (March 2015).

Data from landfill ponds that receive minimal and diluted landfill leachate at other northern NSW landfills were compared to GARA2 baseline results by Hart (2015). This review resulted in a succinct list of parameters and analytes for the detection monitoring program.

From within this list, six traditional, geochemical parameters and analytes (EC, pH, alkalinity, TOC, total nitrogen and chloride) were selected due to their early and noticeable response to leachate intrusion in surface water. Statistically derived trigger values will be calculated for these indicators for the GARA2 sampling point only. The GARA2 indicator statistical trigger values will be calculated using the methodology devised by Hart (2000) in conjunction with a statistician and approved by NSW EPA Grafton for the Grafton Regional Landfill. If GARA2 statistical trigger values, for three or more indicators, are exceeded by 20% or more, then the assessment monitoring program will commence within five working days or sooner.

The data at GARA3 and GARA5 are too variable to devise meaningful trigger values. This is due to their location in the ephemeral stream where sample volumes are limited and often colloidal. Judicious review of each round's results by a water monitoring specialist is advisable.

For the ambient surface water assessment monitoring program, additional parameters and analytes are added to those tested in the detection monitoring program: major anions and cations, hardness, and if sheen, colour or odour indicates it is warranted – tests for VOCs, UT PAHs, and speciated phenolics. Appropriate sampling points will be sampled to determine the nature, extent, possible future extent, and source of the contamination.

Table 25 summarises the three phases of the ambient surface water monitoring program for the Armidale Regional Landfill: baseline monitoring, detection monitoring and assessment monitoring.

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Appendix C

Baseline Groundwater Monitoring Reports

Appendix C Baseline Groundwater Monitoring Reports

Baseline groundwater monitoing reports available as elecontric copy on request.