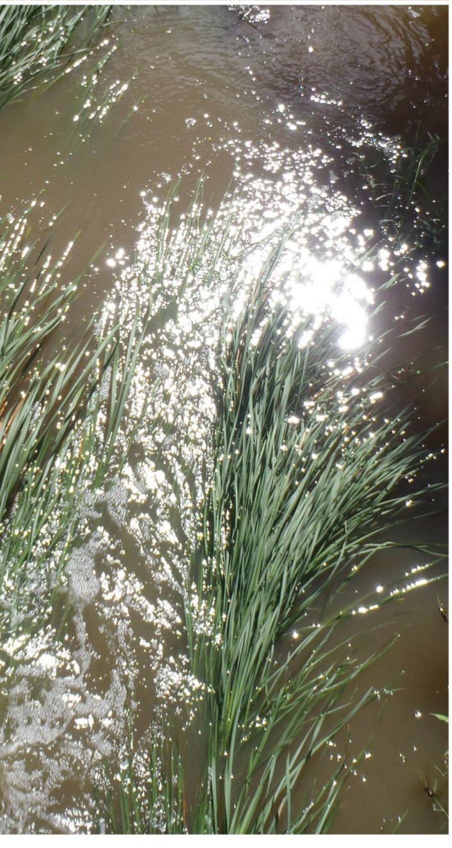
Rooty Hill Regional Distribution Centre

Annual Environmental Monitoring Report 2012 - 2013

HOLCIM

Final



JACOBS® Holcim

Holcim Regional Distribution Centre Environmental Monitoring Program

Document title:	Annual environmental monitoring report 2012-13
Document no.	EN03250 170914
Revision:	Rev 2
Date:	14/04/2015
Prepared by:	John Hutchison
Approved by:	John Wall
File name:	I:\ENVR\Projects\EN03250\Technical\Annual reports\2012-13\EN03250 Annual Environmental Monitoring Report 2012 - 2013 Rev 2.docx

Jacobs Group (Australia) Pty Limited
ABN 37 001 024 095
100 Christie Street,
St Leonards
NSW 2065
T +61 8 8424 3800
www.jacobs.com

Contents

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to summarise environmental monitoring data recorded between September 2012 and August 2013 at the Rooty Hill Regional Distribution Centre construction site in accordance with the scope of services set out in the contract between Jacobs and the Client. That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Client (if any) and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

This report has been prepared on behalf of, and for the exclusive use of, Jacobs's Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

1. Introduction

1.1 Project overview

The Rooty Hill Regional Distribution Centre (RDC), located at Kellogg Road, Rooty Hill, within the Blacktown Local Government Area (LGA), will allow Holcim to receive construction material by rail from quarries located outside of the Sydney Basin, blend the materials to meet customer specifications and distribute these by road to the Sydney market.

The Project involves construction of a rail siding with aggregate unloading facility, on-ground concrete storage bins and truck load out facility, a conveyor system linking the unloading station to the storage and truck facilities, site offices, bridges over Angus Creek, truck wash down, refuelling, weighbridge and parking facilities, a radial stacker, a blending plant/pug mill, a concrete batching plant, a regional office building and quarry and concrete testing laboratory.

The site is 15 hectares, bound by the Main Western Railway Line to the south, the Nurragingy Reserve to the East, the OneSteel Mini Mill and the Humes and other industrial facilities to the north. Angus Creek, a tributary of Eastern Creek, flows through the southern portion of the site (Figure 1-1).

Construction is being undertaken in accordance with the requirements of the Environmental Assessment Report (EAR), Submissions Report, Modification Report, final Statement of Commitments (SoC) and the final Minister's Conditions of Approval (MCoA 05-0051).

- **Figure 1-1 Site Layout Plan**

Source: Holcim and Google Earth 2010

0 100 200 250m
1:5000

1.2 Monitoring program

Environmental monitoring involves collecting and interpreting data to quantify the effectiveness of Holcim's Environmental Management System. The monitoring programs will assist in the auditing of safeguard measures to ensure they achieve their objectives and to facilitate modification where necessary.

A number of parameters have been included in the monitoring program, in line with requirements of the Construction Environmental Management Plan (CEMP), its sub-plans and relevant conditions of project approval and statement of commitments. The monitoring parameters included in the program and references to relevant sections within this report are summarised in Table 1-1.

Table 1-1 Monitoring parameters

Description		Frequency	Requirement			Where to find in this report
			Conditions of approval	Statement of commitments	CEMP	
Meteorology		Monthly	-	3.3, 10.4, 15.3	✓	Section 2
Aquatic ecology	Macro invertebrates	6 monthly	2.28A	7.5, 10.4, 15.2	✓	Section 3
	Fish	6 monthly	2.28A	7.5, 10.4, 15.2	✓	
	Habitat condition and aquatic vegetation	Quarterly	2.28A	7.5, 10.4, 15.3	✓	Section 4
Terrestrial ecology	Flora and fauna	Quarterly	2.24, 2.25, 2.26	7.4	✓	Section 4
Water quality		Quarterly	2.28A	7.5, 10.4, 15.3	✓	Section 5
Air quality	Depositional dust	Monthly	2.8, 5.3 c)	4.1, 10.4, 15.3	✓	Section 6
	PM_{10}	Weekly	2.8, 5.3 d)	4.1, 10.4, 15.3	✓	Section 6
Noise		Monthly	5.3 b)	10.4, 15.3	✓	Section 7
Groundwater		Quarterly	-	-	✓	Section 8

1.3 Scope of this report

The monitoring program of 2012-13 commenced in September 2012, and followed from previous monitoring completed by GHD up to this time. This report incorporates all monitoring results from September 2012 to August 2013 inclusive.

This report describes the methods and the results of conducting environmental monitoring. Environmental assessment criteria are presented, where relevant, for ready comparison with results; however this report does not represent a review of environmental performance over the monitoring period and hence, does not represent an Annual Environmental Management Review.

Monitoring methodologies, including dates, instrumentation, calibration details and measurement locations, and results for each parameter described in Table 1-1 are presented individually in the sections listed in the table.

2. Meteorology

Summary

Meteorological monitoring indicated that a large proportion of winds are from the south and south east and are generally light. During all but the spring months, south to south-easterly breezes dominated, but in September, the breeze came largely from the north-west.

Temperatures at the RDC generally reach mid to high 20's in the summer with several days exceeding 30 degrees. The maximum observed temperature was 46 degrees. Winter temperatures are generally in the mid-teens with many days dropping below 10 degrees. The lowest recorded temperature was 0.5 degrees.

Total rainfall in the period was 395 mm over 125 rain days. Major rainfalls were observed in October 2012 and January 2013. Not all rainfall events may have been captured, with a data gap between 21 November and 19 December.

The highest UV exposure is during the summer months, with several days exceeding the "Extreme" classification. During winter, most days presented low to moderate UV exposure. Average daily solar radiation follows the UV index, with highest levels experienced in summer.

2.1 Methodology

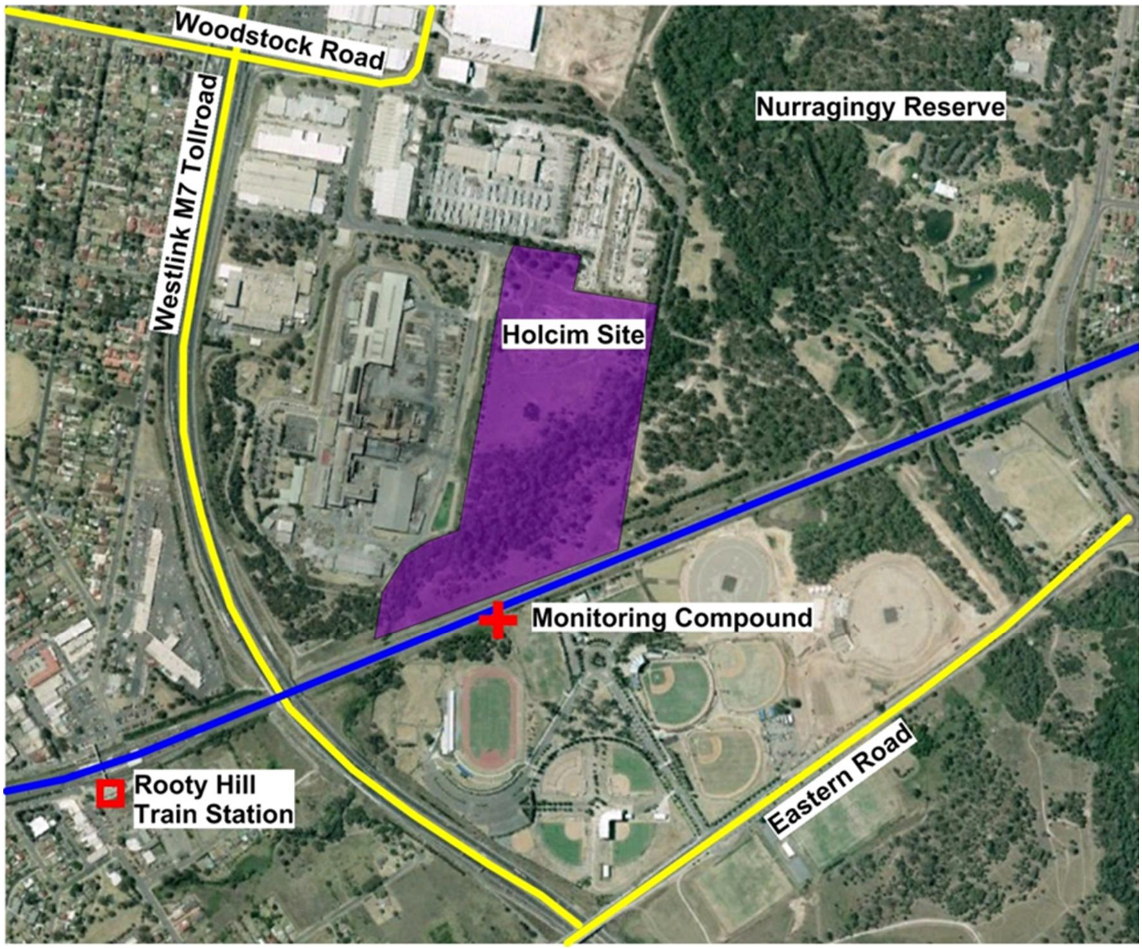
Meteorological conditions were monitored using a Davis Vantage Pro2 Plus monitoring unit. This unit was positioned in accordance with AS2923-1987 *Ambient air – Guide for measurement of horizontal wind for air quality applications* and the location is illustrated in Figure 2-1.

Meteorological parameters monitored included:

- Wind speed and direction
- Temperature
- Humidity
- Rainfall
- Barometric pressure
- Solar radiation

The meteorological station does not satisfy the accuracy requirements of AS 3580.14-2011 for wind speed and direction measurements. However, no monitoring standards are specified in the Project Approval and the accuracy of the proposed unit is sufficient for the purposes of construction impact management. The integrity of the meteorological monitoring station is checked every six days and data collected on a monthly basis.

Figure 2-1 Meteorological monitoring station location



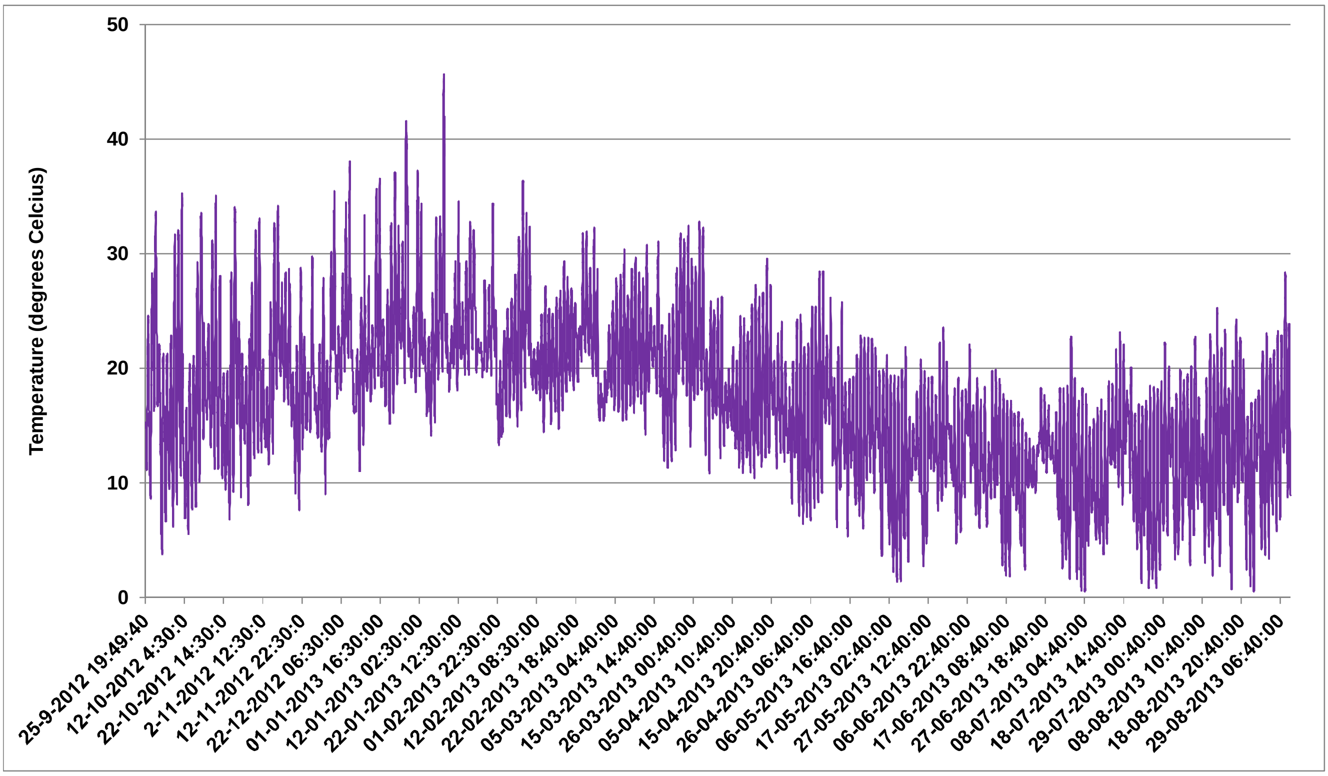
2.2 Wind speed and direction

Available wind speed and direction data have been summarised for each month in Figure 2-3. It can be seen that a large proportion of winds are from the south and south east and are generally light. During all but the spring months, south to south-easterly breezes dominated but in September, the breeze came largely from the north-west.

2.3 Temperature

Temperature data are summarised in Figure 2-2. A clear distinction between summer and winter months is evident, with maximum temperatures generally reaching mid to high 20's in the summer and several days exceeding 30 degrees. The maximum observed temperature was 46 degrees in January. Winter temperatures are generally in the mid-teens with many days dropping below 10 degrees. The lowest recorded temperature was 0.5 degrees in July.

Figure 2-2 Summary of temperature data



2.4 Rainfall

Results of rainfall observations are summarised in Figure 2-4. Total rainfall in the period was 395 mm over 125 rain days, slightly less than other locations within the vicinity of the RDC (Quakers Hill 528 mm). Major rainfalls were observed in October 2012 and January 2013. Not all rainfall events may have been captured, with a data gap existed between 21 November and 19 December 2012.

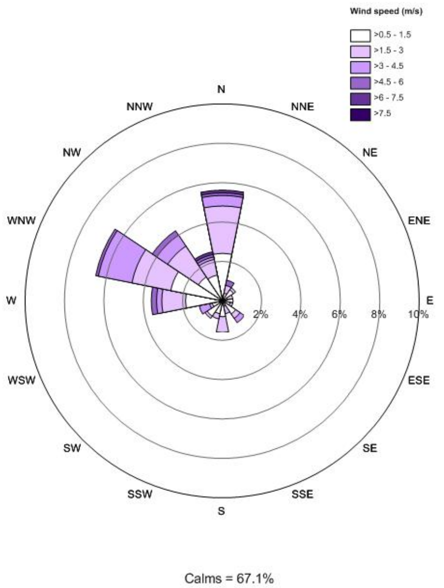
Rainfall from the nearby (5 km to north east) Quackers Hills monitoring site is overlayed in the graph for reference. The timing and rainfall for the majority of observed rain days are similar for each site; however; Quakers Hill is reported as having received around 130 mm additional rainfall. This difference is relatively large and may indicate localised storm activity or that the Rooty Hill monitoring station is less sensitive to some rainfall events.

2.5 Solar exposure

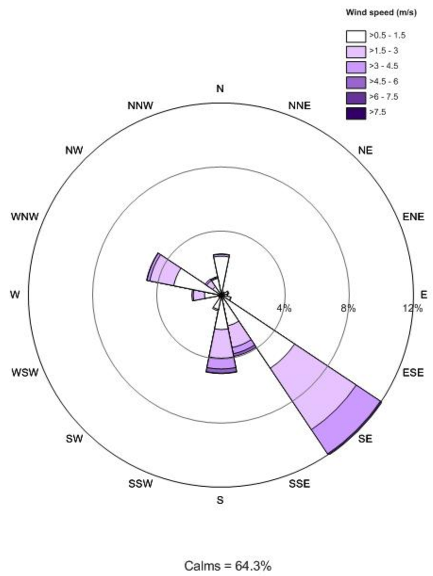
Solar radiation and UV index were recorded from December 2012. A summary of the UV index is presented in Figure 2-5. It can be seen that the highest UV exposure is during the summer months, with several days exceeding the "Extreme" classification. During winter, most days presented low to moderate UV exposure.

Average daily solar radiation is summarised in Figure 2-6. The trend in solar radiation follows the UV index, with highest levels experienced in summer.

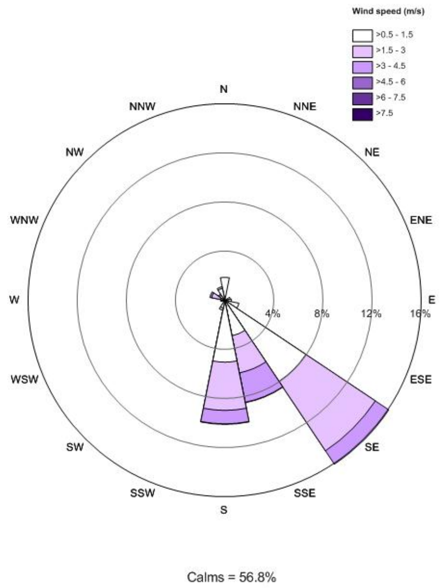
Figure 2-3 Monthly wind roses – October 2012 to June 2013



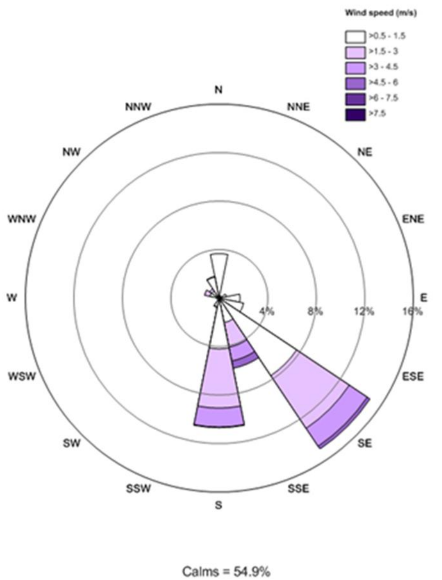
September 2012



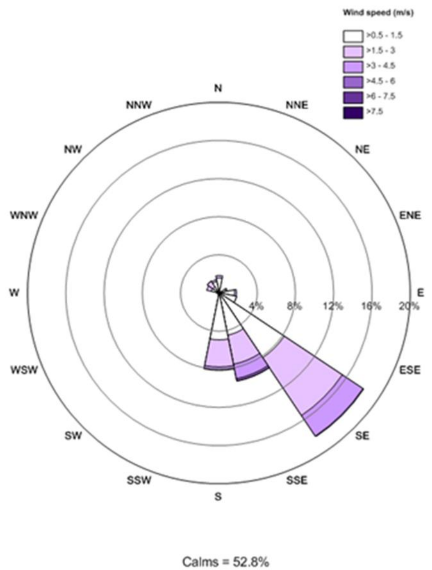
October 2012



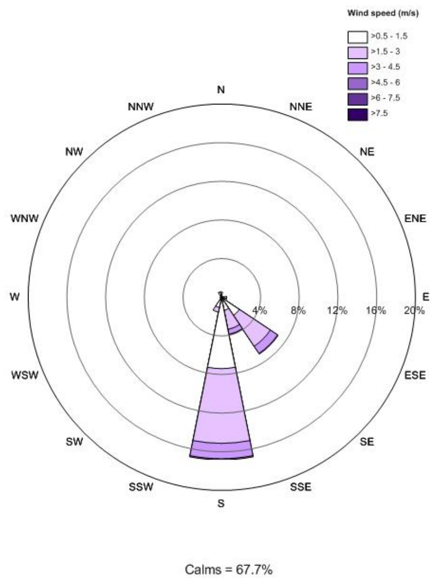
November 2012



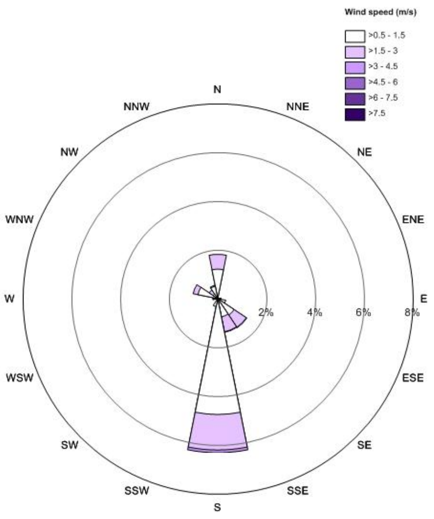
December 2012



January 2013

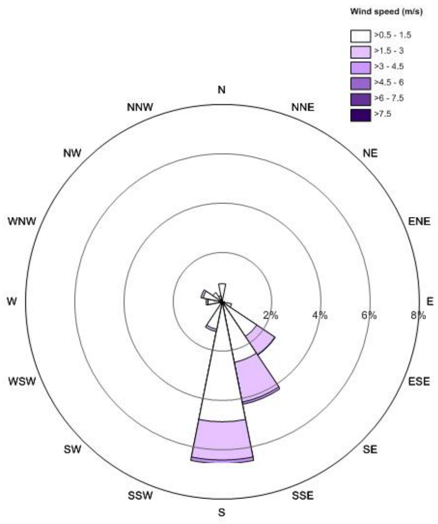


February 2013



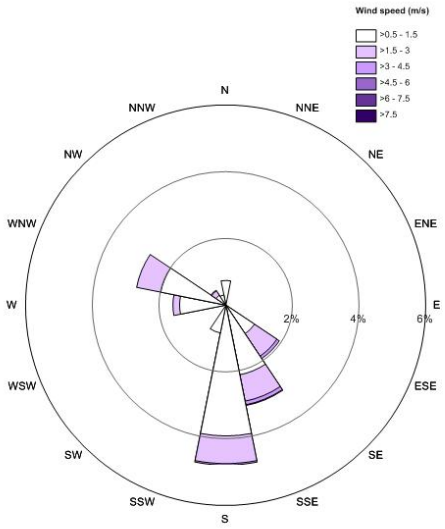
Calms = 85.9%

March 2013



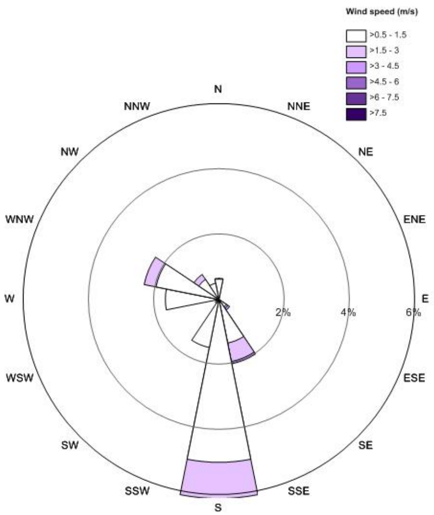
Calms = 81.7%

April 2013



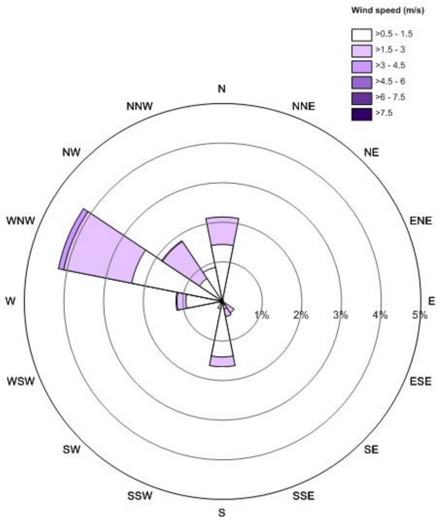
Calms = 83.4%

May 2013



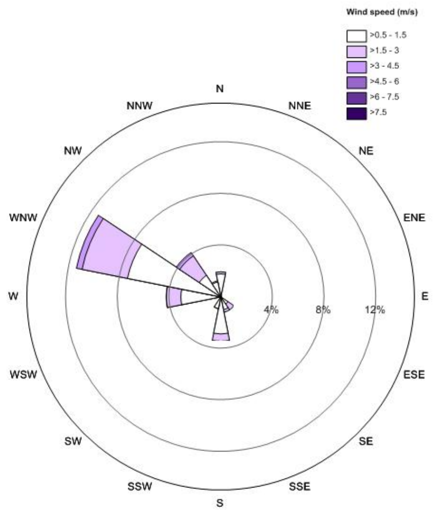
Calms = 83.7%

June 2013



Calms = 87.0%

July 2013



Calms = 69.9%

August 2013

Figure 2-4 Daily rainfall

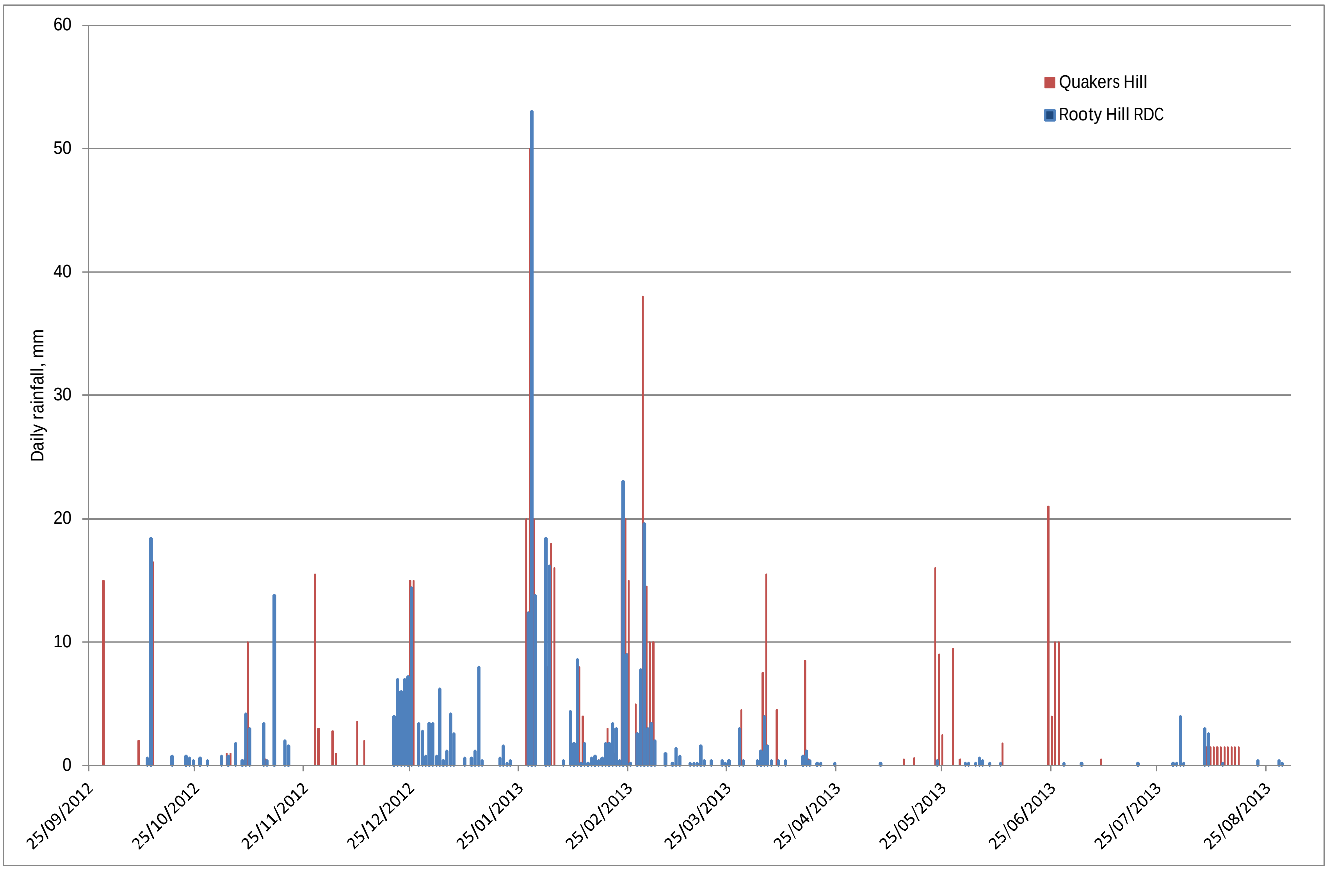


Figure 2-5 UV index

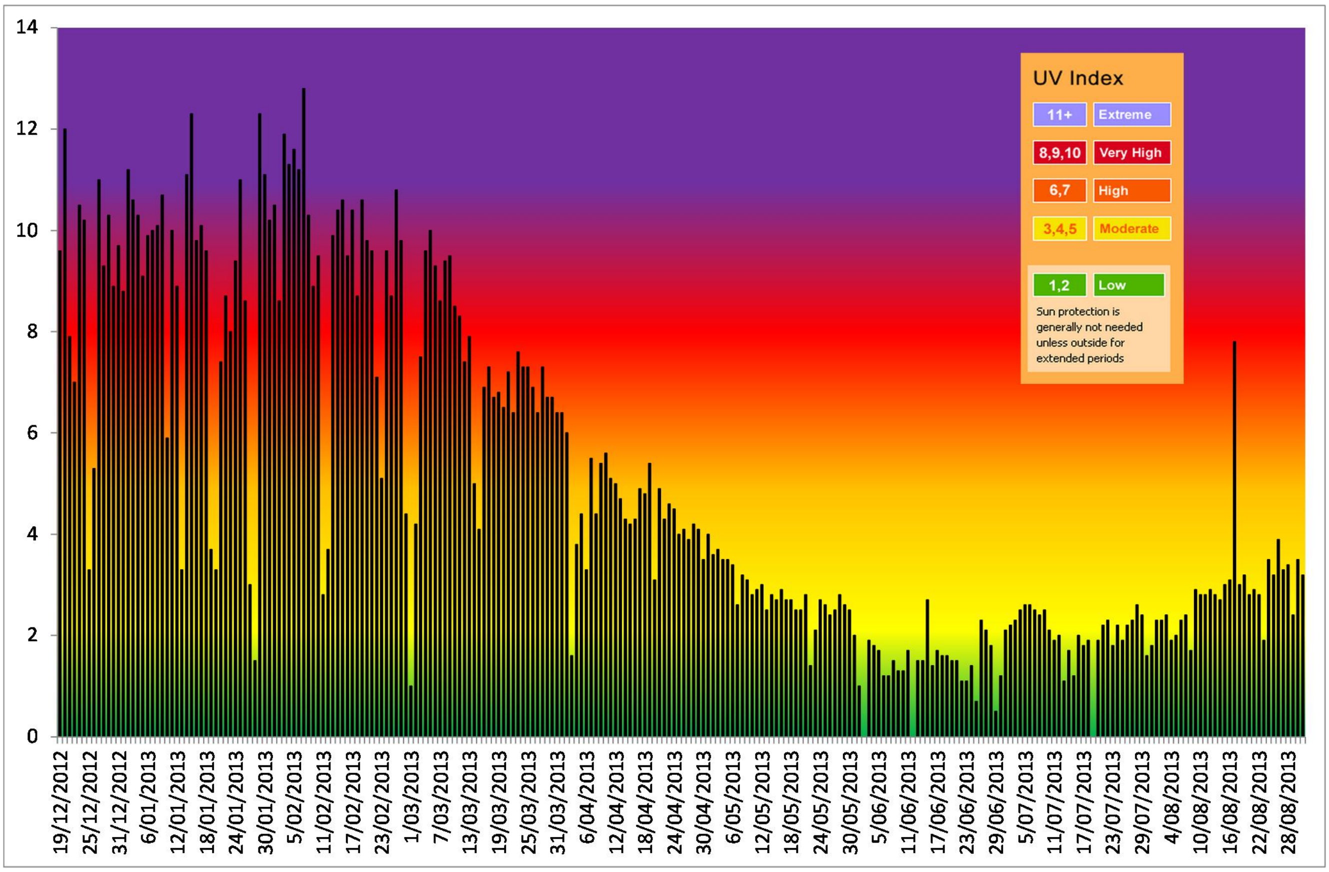
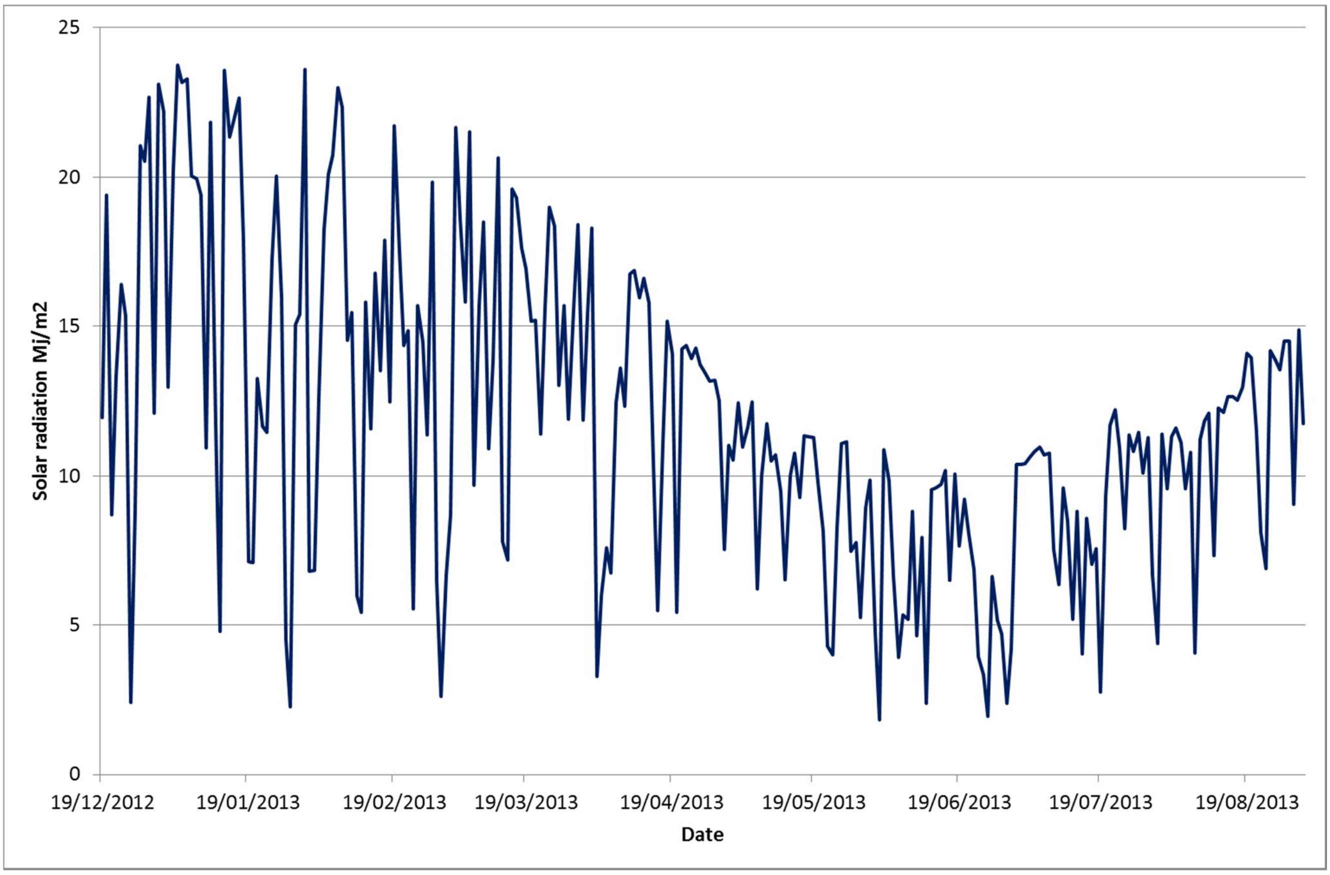


Figure 2-6 Solar radiation



3. Aquatic ecology

Summary

While there are significant localised land use disturbances, the Holcim site is not a major contributor to the currently impaired macroinvertebrate and fish communities in Angus and Eastern Creeks.

Fish and macroinvertebrates monitoring indicated that Angus and Eastern Creeks are impaired and representative of a degraded catchment influenced by mixed rural and urban land uses.

Sites generally had low diversity of macroinvertebrates and fish species. Large numbers of the introduced species Gambusia were observed at all sites and are hardier in degraded conditions compared to most native fish species.

Following the first sampling event, the control site (AE6) became part of an unrelated construction facility which resulted in poor water quality that was noticeably poorer than downstream during dry weather. Shallow, stagnant and muddy pools were observed at site AE6 following the commencement of construction. This may have contributed to an increase in more tolerant macroinvertebrate taxa and a reduction in abundances from AE6 downstream to AE4.

Historically there has been a consistent trend of decreasing biological impairment (measured through AUSRIVAS bands and OE50 scores) moving downstream from AE6 to AE4, with the best performing site being AE5 above the confluence with Angus Creek. Water quality of Angus Creek shows no noticeable deterioration downstream of the Holcim Compound (AE1) and is not reflected by a change in the fish community or historical macroinvertebrate data.

3.1 Sampling methodology

3.1.1 Macroinvertebrate

Aquatic macroinvertebrate sampling followed Rapid Bio-assessment (RBA) protocols, in accordance with the NSW AUSRIVAS Sampling and Processing Manual (Turak *et al* 2004). The AUSRIVAS program is a nationally recognised, standardised sampling protocol used to assess the health of Australian Rivers and developed for the Australia's National River Health Program (NRHP). This method is consistent with the recommended method in the Environmental Assessment Report (EAR) (Umwelt 2006) for monitoring macroinvertebrates.

Samples were collected within the Spring AUSRIVAS sampling period (15th September – 15th December 2012) and Autumn AUSRIVAS sampling period (15th March – 15th June 2013). Chemical and physical variables (environmental data) were recorded at each site to be used as predictor variables in the AUSRIVAS model.

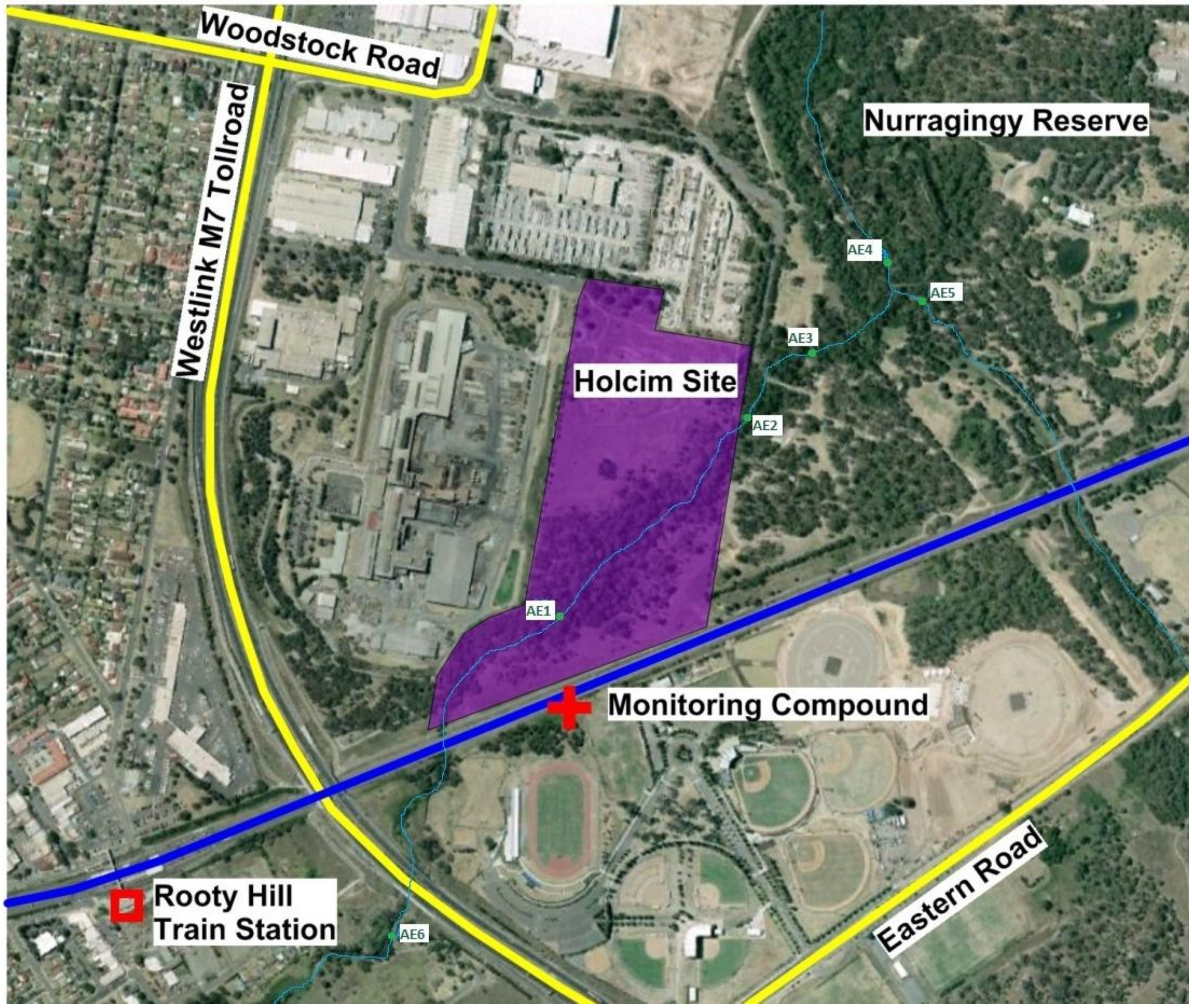
Aquatic ecology (fish and macroinvertebrate) sampling was conducted at six sites, four of which were located on Angus Creek and two on Eastern Creek (Figure 3-1). Table 3-1 provides a list of the sites.

Table 3-1 Site Location

Site Code	Location
AE6	Angus Creek, 500m upstream RDC^
AE1	Angus Creek at upstream boundary of RDC
AE2	Angus Creek at downstream boundary of RDC
AE3	Angus Creek 150m downstream of RDC culvert
AE4	Eastern Creek downstream of Angus Creek confluence
AE5	Eastern Creek upstream of Angus Creek confluence^

^These sites will be adopted as control sites (MCoA 2.28A)

Figure 3-1 Aquatic ecology monitoring locations



Jacobs ecologists are licensed to conduct field surveys under the National Parks and Wildlife Service Scientific Research Permit SL100044, Fisheries Permit P06/0066.4 and the Department of Primary Industries Animal Research Authority (09/1895).

The AUSRIVAS sampling site at each location was 100m in length. At each of the six locations macroinvertebrates were collected from edge habitats. Edge habitats are defined as the creek bank in areas of little or no flow, including alcoves and backwaters, with abundant leaf litter, fine sediment deposits, macrophyte beds and overhanging bank vegetation (Turak et al 2004). Edge samples were collected from 10m of representative edge sub-habitats using a 0.25mm mesh size kick net to dislodge macroinvertebrates, whilst noting physical habitat conditions of the sampled locations. Care was taken to ensure all sub-habitats within the site were represented within the sample.

Riffle habitats, areas of broken water with rapid current, were not sampled at any location due to a lack of suitable riffle habitat.

Macroinvertebrate samples were live-sorted in the field for a minimum of 40 minutes. If new taxa were collected between the 30 to 40 minute period, picking continued for an additional 10 minutes. If no new taxa were found after the additional 10 minutes, sorting stopped. The maximum sorting time was 60 minutes. All picked animals were preserved in ethanol and transferred to the laboratory for identification. Specific care was taken to ensure cryptic, fast moving or micro-crustacean taxa were represented.

3.1.2 Fish

Fish surveys were conducted at the six sites (AE1 - AE6) using passive fish sampling techniques. The variety of these sampling methodologies increases the probability of sampling a wider range of species and size classes. A description of the fish sampling methodologies is provided below.

Fyke nets were used to trap mobile, large bodied fish. Depending upon habitat availability between two to four fyke nets were set for a minimum of two hours. Large single-wing fyke nets with 4m leaders were set with the cod-end on one bank with the wing attached midstream. The cod-end of each fyke was always suspended out of the water to avoid the mortality of captured air breathing vertebrates.

Bait traps were used to trap mobile, small bodied fish. At each site, 10 bait traps (unbaited 45 × 25 × 25 cm traps) were set in shallow habitats for a minimum of two hours. Where possible, traps were set in stands of emergent vegetation, areas with submerged vegetation, or snag piles, as these areas are likely to have a greater diversity and abundance of small bodied fish.

Seine nets were not used due to the large abundance of woody snags throughout the channel, preventing the seine net from being pulled through the water. Backpack electrofishing was also not conducted due to the elevated conductivities within the study area and associated health hazards.

All fish captured were identified and measured to the nearest 1mm. Fork length was measured for fork-tailed species and total length for all other fish species. Before release each fish was examined on both sides for any injuries, diseases, parasites, or abnormalities. Eels can occur in large numbers at some sites and can be difficult to handle, so to minimise handling stress and the risk of injury to the eels they were netted and whilst in the net identified and examined. Eel lengths were estimated to the nearest 20mm. Any fish seen but not captured were identified and listed as an observed individual where possible.

Total fish abundance (number of individuals), richness (number of taxa) and the ratio of native to alien fish diversity were recorded and reported.

3.2 Data analysis

All macroinvertebrates were identified to the family level of taxonomic resolution, with the exception of Oligochaeta (class), Ostracoda (subclass), Acarina (order), Nematoda (Phylum) and Chironomidae (subfamily) as per the AUSRIVAS model requirements.

The total abundance (number of individuals collected), richness (number of taxonomic groups) and EPT richness were calculated for both seasons. EPT richness is the sum of the number of families from the orders Ephemeroptera, Plecoptera and Trichoptera. EPT families are typically sensitive to disturbance so their presence or absence can provide information about stream health. Values less than 1 indicate poor ecological conditions; values between 2 and 5 indicate moderate ecological conditions and anything greater indicate good ecological conditions.

The AUSRIVAS program uses mathematical models to compare observed macroinvertebrate taxa against a modelled reference condition. These comparisons provide a measure of biological impairment. Predictor variables (including physical habitat variables, latitude, longitude, altitude, slope and distance from source) are used to model the predicted reference condition for each sampling site. Latitude, longitude, altitude, slope and distance from source were determined from 1:25,000 topographic maps. Physical habitat variables were qualitatively assessed or directly measured at each site during the field surveys.

The AUSRIVAS model software outputs specify the 'Observed' (macroinvertebrates collected during sampling) and 'Expected Ratios' (macroinvertebrates which are predicted to occur in reference conditions). Both measures relate to macroinvertebrates that have a predicted probability greater than 50% of occurring at the site if it is in reference condition. The 'Observed' value is the number of these macroinvertebrate families that were actually collected at the site. Each observed family contributes a score of 1 to the 'Observed' value. The 'Expected' value is the sum of the probabilities for all taxa that are predicted to occur at that site with a probability greater than 50%. Families that have a 50% probability of occurring at the site contribute a score of 0.5 to the 'Expected' value, while families that have a 90% probability of occurrence contribute a score of 0.9. An Observed to Expected ratio (O/E50 score) close to 1 indicates that the macroinvertebrate fauna are similar to those of the modelled reference condition. A ratio close to zero, indicates severe impairment compared to reference condition. Based upon these O/E50 scores, a band ranking indicating the ecological health of the river can be assigned (Table 3-2).

Table 3-2 AUSRIVAS OE50 upper limits and associated band categories

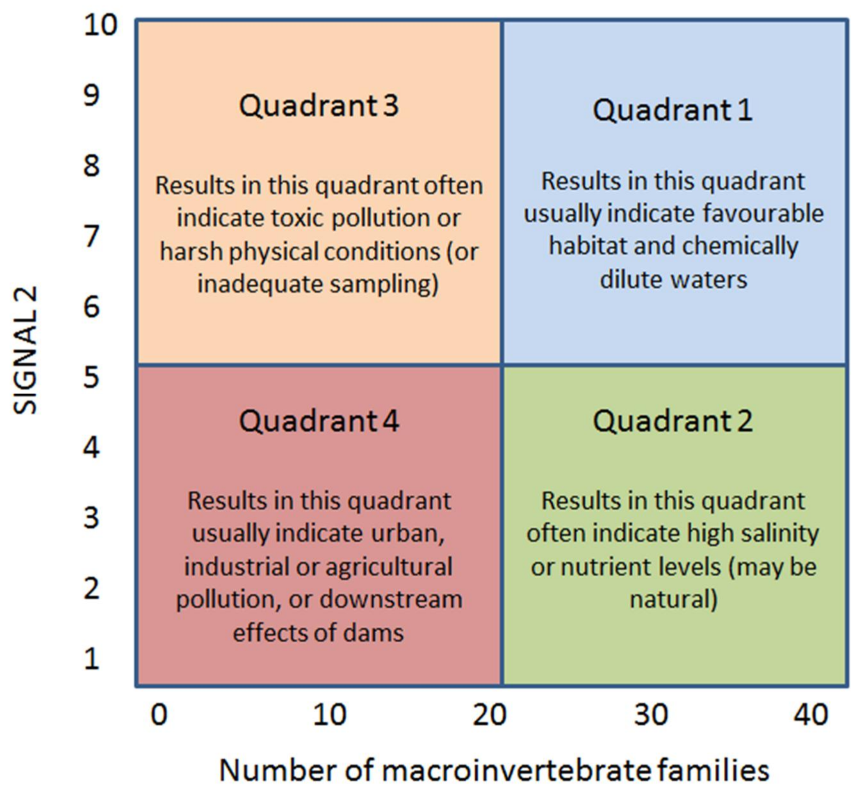
OE50 upper limit (Autumn)	OE50 upper limit (Spring)	Band		Interpretation
-	-	X	More biologically diverse than reference sites	Possible organic enrichment or a biodiversity hotspot as more taxa occur compared to reference site
1.17	1.16	A	Reference condition	Families collected are the same or similar to reference sites
0.81	0.83	B	Significantly impaired	Some taxa missing, possibly from impacts to water quality or habitat
0.46	0.51	C	Severely impaired	Several taxa missing. Impacts to water quality and/or habitat are more severe
0.11	0.19	D	Extremely impaired	Few of the taxa expected at reference sites were collected. Water quality and habitat are poor and highly degraded

SIGNAL (Stream Invertebrate Grade Number - Average Level) scoring gives an indication of water quality of the water body from which a sample was collected. High SIGNAL scores are likely to be of low salinity, turbidity and nutrients such as phosphorous and nitrogen and high in dissolved oxygen.

SIGNAL scores for each site were calculated using the method outlined in Chessman (2004), based on the sensitivity grades of the macroinvertebrates collected, scaled from 1 to 10, where 1 are taxa very tolerant to pollution and 10 are very sensitive. These scores are weighted by the abundance of the taxa collected and provides an overall indication of site impairment. Sites where sensitive taxa are present are less likely to have been affected by disturbance.

Signal scores were plotted against the number of taxa collected (richness). The biplot is divided into four quadrants (see Figure 3-2), and where the data point falls is indicative of the type of disturbance. The lines of division on the biplot are adjustable and are determined based on knowledge of the sites and reference conditions.

Figure 3-2 Signal 2 versus richness biplot (Chessman 2004).



3.3 Results

3.3.1 Macroinvertebrates

Macroinvertebrate assemblages suggest biological impairment at all sites, including reference (AE6 Angus Creek upstream of RDC and AE5 Eastern Creek, upstream of the confluence with Angus Creek) and impact sites. Although seasonal differences existed between Spring and Autumn, overall macroinvertebrate diversity was low and mostly consisted of taxa more tolerant to changing environmental conditions.

Generally over 70% of taxa were from the SIGNAL grades 4 and below, indicating that all sites contained taxa that were tolerant and moderately tolerant to a range of environmental conditions (Table 3-3). Taxa sensitive to most forms of pollution or disturbance were not found at any of the sites in either season, with one exception; a single individual from the dragonfly family Telephlebiidae which was collected at site AE3 (SIGNAL grade 9).

Table 3-3 Summary of macroinvertebrate results, spring 2012 and autumn 2013

Site	Spring 2012						Autumn 2013					
	Richness	Abundance	EPT	% Tolerant (≤4)	SIGNAL	AUSRIVAS band	Richness	Abundance	EPT	% Tolerant (≤4)	SIGNAL	AUSRIVAS band
AE6	10	366	0	93.7	2.6	D	19	122	0	84.8	2.09	C
AE1	12	238	0	88.5	3.03	C	14	112	0	95.3	2.17	C
AE2	10	174	0	93.6	3.41	C	20	254	0	89.4	2.24	C
AE3	18	485	0	91.7	3.06	C	20	283	2	77.1	2.29	C
AE4	8	24	1	88.9	2.6	D	21	96	2	72.7	2.89	C
AE5	16	54	0	97.5	2.28	C	21	139	0	95.9	2.48	B

Generally taxa richness was higher in Autumn while SIGNAL scores were lower. Two reasons may explain this. The first is that more taxa were collected in Autumn but these taxa were less sensitive to disturbance and the second is that the abundance weighting contributed less to the SIGNAL calculations because taxa occurred in lower abundances.

Total abundance was greater in Spring, with an additional 335 individuals collected. The taxon primarily responsible for the difference in abundance was the gastropod Hydrobiidae. Over 700 individuals were collected from Sites AE1, AE2, AE3 and AE6. They were observed at the same sites in Autumn but in smaller numbers (333).

Site AE4 on Eastern Creek (downstream of the confluence with Angus Creek) had the lowest abundances during both seasons but the highest richness in Autumn (Table 3-3). This is again explained by the Hydrobiidae gastropod which accounted for much of the abundance at the other sites (thereby contributing a larger proportion to the SIGNAL score calculations due to the abundance weighting). However, taxa at site AE4 occurred in smaller numbers thereby contributing less to the SIGNAL score calculations. The reference sites AE5 and AE6 did not show greater abundance or diversity compared to impact sites downstream of the construction works.

The presence of families from the orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) were very low. These are sensitive taxa which are a good indicator of impairment when missing. In Spring, only one family was collected at site AE4 while two were collected at sites AE3 and AE4 in Autumn.

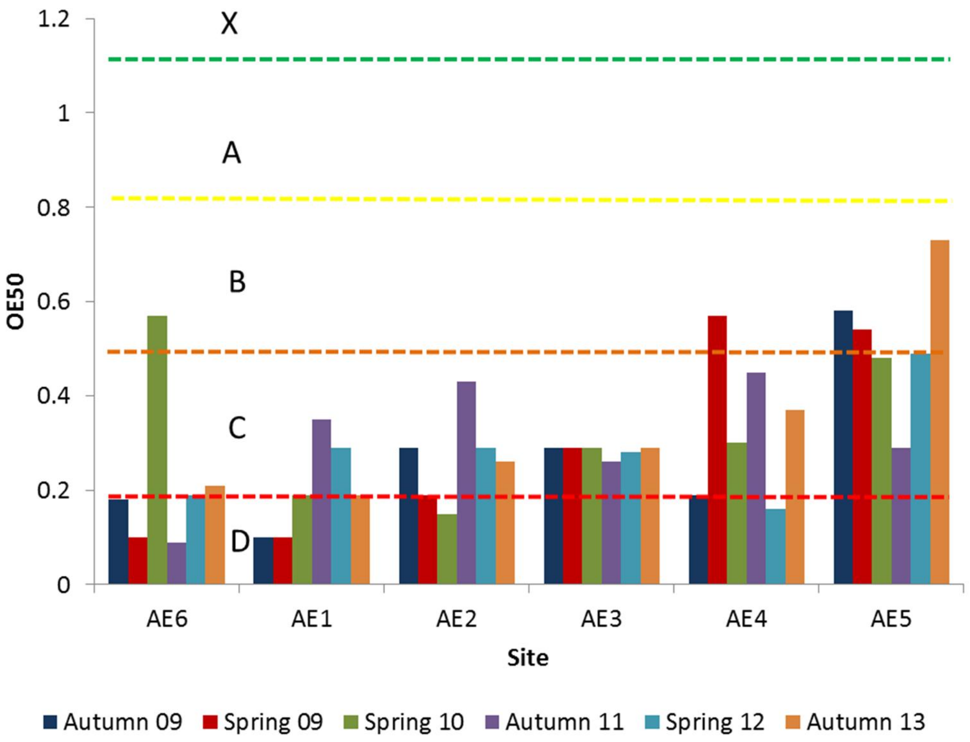
Generally over 70% of taxa were from the SIGNAL grades 4 and below, indicating that all sites contained taxa that were tolerant and moderately tolerant to a range of environmental conditions (Table 3-3). Taxa sensitive to most forms of pollution or disturbance were not found at any of the sites in either season, with one exception; a single individual from the dragonfly family Telephlebiidae which was collected at site AE3 (SIGNAL grade 9).

Table 3-3 Summary of macroinvertebrate results, spring 2012 and autumn 2013

Site	Spring 2012						Autumn 2013					
	Richness	Abundance	EPT	% Tolerant (≤4)	SIGNAL	AUSRIVAS band	Richness	Abundance	EPT	% Tolerant (≤4)	SIGNAL	AUSRIVAS band
AE6	10	366	0	93.7	2.6	D	19	122	0	84.8	2.09	C
AE1	12	238	0	88.5	3.03	C	14	112	0	95.3	2.17	C
AE2	10	174	0	93.6	3.41	C	20	254	0	89.4	2.24	C
AE3	18	485	0	91.7	3.06	C	20	283	2	77.1	2.29	C
AE4	8	24	1	88.9	2.6	D	21	96	2	72.7	2.89	C
AE5	16	54	0	97.5	2.28	C	21	139	0	95.9	2.48	B

AUSRIVAS OE50 scores and resulting Bands also indicated that sites were severely (band C) or extremely impaired (band D), except AE5 in Spring which was significantly impaired (band B).

Figure 3-3 AUSRIVAS bands



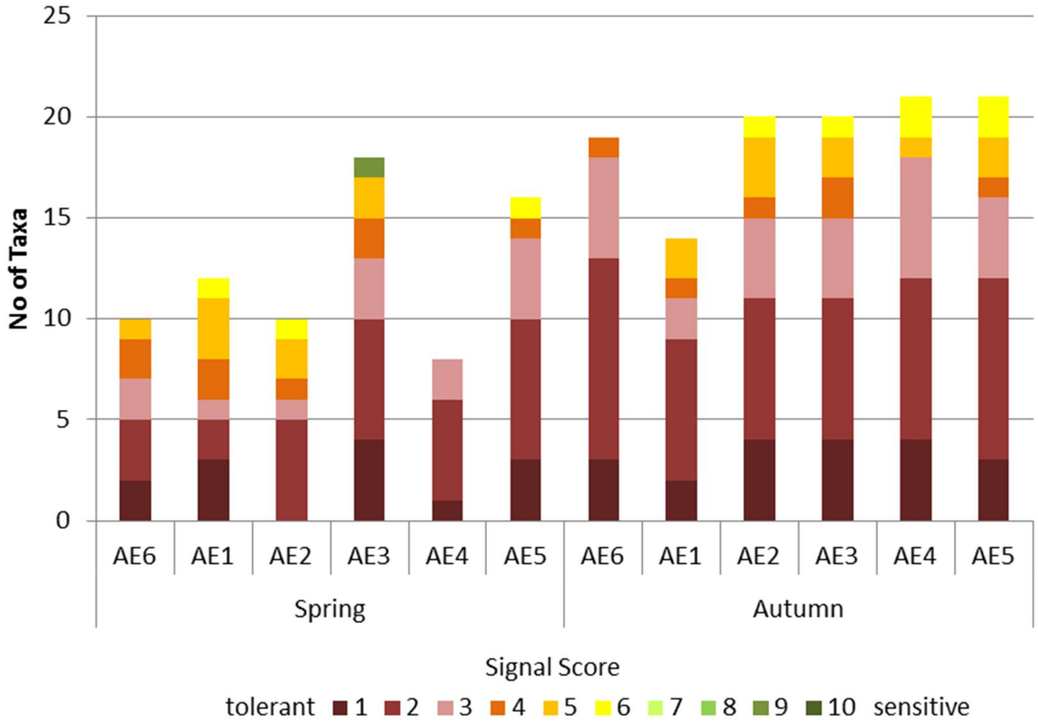
Several taxa expected to occur at the sites under reference conditions were absent. The most notable, and with ~90% chance of being collected, were the caddisfly Leptoceridae (only collected at AE4 and AE5), the Gerridae (not collected) and Veliidae (collected at AE1, AE2 and AE5), the mayfly Leptophlebiidae (not collected) and the mite Acarina (collected at AE2, AE3 and AE5).

The absence of Leptophlebiidae may be explained by its sensitivity to changing environmental conditions (SIGNAL grade 8). However other absent taxa were moderately tolerant (SIGNAL grades 3-6). Different macroinvertebrates are sensitive to certain types of disturbances which may explain their absence despite taxa with similar SIGNAL scores being present.

SIGNAL scores and AUSRIVAS bands indicated that the reference and impact sites were at a similar level of impairment with respect to the macroinvertebrate community. Furthermore, AE6 had the lowest SIGNAL score in autumn (Table 3-3). This may be explained by construction works undertaken by Blacktown City Council which commenced at site AE6 after the Spring sampling event and subsequently affected the Autumn sampling. These works may also have affected the downstream sites which displayed lower OE50 scores in autumn.

The number of taxa in each SIGNAL grade contributing to overall site SIGNAL scores are displayed Figure 3-4. A large proportion of taxa were tolerant and moderately tolerant taxa from SIGNAL grades 1, 2 and 3. Figure 3-4 also reiterates the lower taxa richness in Spring and highlights the consistent increase in richness in Autumn across all sites. Seasonal effects are probably responsible for the increase in richness as the pattern was evident at both reference and impact sites.

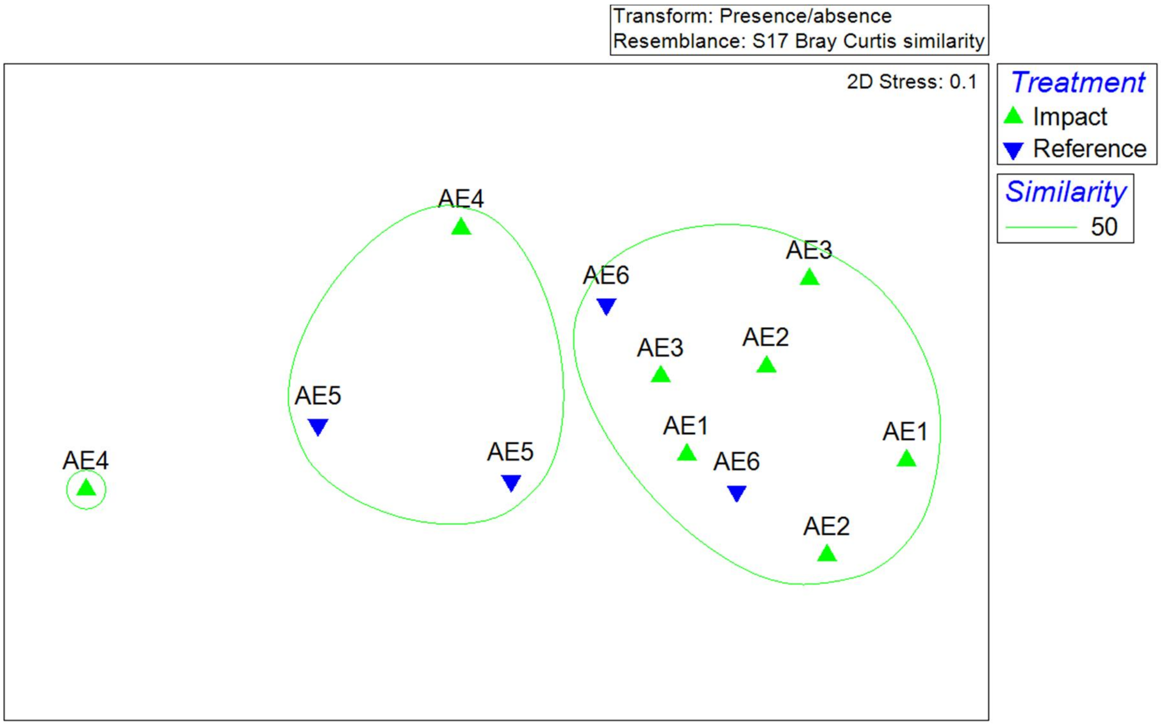
Figure 3-4 Contribution of macroinvertebrate taxa to SIGNAL scores in 2012-2013.



Note: The stacked bars represent the number of taxa which contribute to each SIGNAL score grade, where red bars represent the more tolerant species and yellow and green bars represent the more sensitive species. Sites are listed in order from upstream (AE6) on Angus Creek to downstream. Sites AE4 and AE5 are downstream on Eastern Creek.

Hierarchical cluster analysis (Primer V6) separated sites into three main groupings; (1) AE4 Spring, (2) AE4 Autumn, AE5 Spring and Autumn, and (3) AE1, AE2, AE3 and AE6 Spring and Autumn. An MDS plot where sites closest to each other are most similar is displayed in (Figure 3-5). The results from the cluster analysis indicate the three groupings (green circles). Clearly, the sites on Eastern Creek (AE4 and AE5) are different to the sites on Angus Creek.

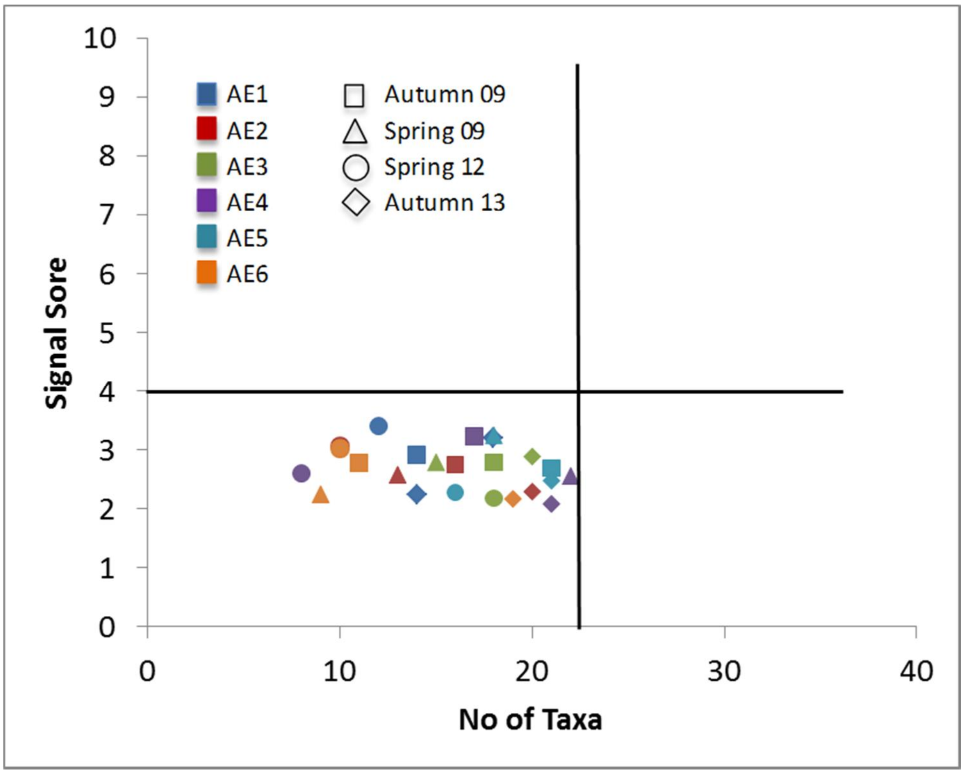
Figure 3-5 Nonmetric multidimensional scaling plot of macroinvertebrate sites in Spring and Autumn. Note: Blue are reference sites and Green are impact sites. Green circles represent similarity (at 50%) determined by the cluster analysis.



3.3.2 Macroinvertebrate Historical Comparison

The 2012-13 macroinvertebrate SIGNAL scores were compared to the available data from 2009. A bi-plot of site SIGNAL scores against the number of taxa (richness) was used to identify any temporal changes in the sites (Figure 3-6). No consistent pattern emerged between sites and seasons (refer to legend; sites represented by different colours and seasons represented by different shapes) although sites AE1 (dark blue) and the reference site AE6 (orange) tended to have fewer taxa. SIGNAL scores were relatively consistent across sites although Autumn 2013 (diamond shape) showed overall lower SIGNAL scores but higher number of taxa compared to other seasons.

Figure 3-6 Biplot of macroinvertebrate sites over four sampling seasons from 2009 and 2012-13. Note: Reference sites (AE6:orange and AE5:light blue) did not plot differently to other sites.



AUSRIVAS OE50 scores and the associated condition bands from 2009 to 2013 indicate an overall increasing trend in AUSRIVAS OE50 scores from the upstream (AE6) reference site downstream along Angus Creek (AE1, AE2 and AE3 respectively) and to Eastern Creek (AE4 and AE5). Site AE4 is downstream of the confluence with Angus creek while AE5 is upstream of the confluence. The data suggests that the inflow from Angus Creek may be reducing water quality at site AE4, although localised disturbance at this site, as shown by the water quality data, cannot be ruled out. Inter-seasonal variability is also quite high, with some sites fluctuating between AUSRIVAS bands D and B (e.g. Site AE6). The best performing site is AE5 on Eastern Creek, which displayed its highest AUSRIVAS band of all sites (band B) in August 2013.

3.4 Fish ecology

Seven fish taxa were collected over the two sampling seasons (Table 3-4) and were dominated by the invasive species Gambusia (*Gambusia holbrooki)* which was collected at all sites and was the only taxon collected at sites AE2 and AE3. Other single indivduals were collected including:

- Short Finned Eel (Anguilla australis; sites AE1 and AE6),
- Australian Water Dragon (Physignathus lesueuriiI; AE1),
- Eastern Snake-necked turtle (Chelodina longicollis; AE6),
- Striped Gudgeon (Gobiomorphus australis; AE1 and AE5),
- Flathead Gudgeon (Philypnodon grandiceps; AE4)
- Australian Bass (Macquaria novemaculeata; AE5).

The total abundance of fish was at least 132 (noting that where large numbers of Gambusia were collected, counting ceased after 40). The ratio of native to alien species was 1:32. A large number of juvenile Gambusia (<30mm) were collected suggesting on-going recruitment in both Angus and Eastern Creeks. The high number of Gambusia and the low diversity is indicative of a degraded waterway.

Table 3-4 Fish survey data (spring and autumn combined)

Site	Common Name	Scientific Name	No.	Length (mm)	Method
AE1	Short Finned Eel	*Anguilla australis*	1	600	Fyke Net
	Australian Water Dragon	*Physignathus lesueurii*	1	300	Fyke Net
	Gambusia	*Gambusia holbrooki*	6	All<30	Dip
	Gambusia	*Gambusia holbrooki*	1	32	Bait
	Striped Gudgeon	*Gobiomorphus australis*	1	49	Bait
AE2	Gambusia	*Gambusia holbrooki*	11	<30, 37, <30, 29, 36, 29, 32, 36,32,39,27	Bait
	Gambusia	*Gambusia holbrooki*	3	29, 37, 28, 33, <50, <50, <50	Dip
AE3	Gambusia	*Gambusia holbrooki*	4	32, 32, 34, <30,	Bait
	Gambusia	*Gambusia holbrooki*	8	47, 32, rest <30	Dip
AE4	Gambusia	*Gambusia holbrooki*	4	37,40,26,19	Bait
	Flathead Gudgeon	*Philypnodon grandiceps*	1	49	Bait
	Gambusia	*Gambusia holbrooki*	>40	All < 30	Dip
AE5	Australian Bass	*Macquaria novemaculeata*	1	150	Fyke
	Striped Gudgeon	*Gobiomorphus australis*	2	37, 44	Bait
	Gambusia	*Gambusia holbrooki*	1	26	Bait
	Gambusia	*Gambusia holbrooki*	4	31, 30, 27, 31	Dip
AE6	Gambusia	*Gambusia holbrooki*	30	23, 29, 37	Bait
	Gambusia	*Gambusia holbrooki*	16	27,32,36,40,25,20,16,19,21, rest <30	Dip
	Eastern Snake-necked turtle	*Chelodina longicollis*	1	200	Fyke
	Short Finned Eel	*Anguilla australis*	1	300	Fyke

4. Terrestrial ecology

Summary

Quarterly monitoring has been successful in identifying trends in ecological health of natural site values at the Rooty Hill RDC site and off-site reference points in the 2012 to 2013 monitoring period. Declines in ecological condition have been noted and are likely due to rain and localised flooding (in the case of riparian environments) and a summer wildfire event (in the case of the southern grevillea population and one Cumberland Plain Woodland monitoring site) rather than works associated with the development of the Rooty Hill RDC site.

This is a reasonable conclusion given the impact of flooding has been demonstrated across all riparian monitoring sites (including those off-site) as has the impact of psyllid infestation across all sites with native overstorey species. In all instances, and in alignment with the baseline surveys for these sites, the Rooty Hill RDC monitoring locations include sites of value which exceed the conditions of adjacent reference monitoring sites.

Given the general success of natural recruitment observed in the spring 2012 monitoring round, it was previously recommended that efforts to enhance the species be delayed. Given that there has only been slow natural regeneration from the soil seedbank in the southern population since the January 2013 wildfire, it was recommended preparations are made for the mechanical disturbance of the site to encourage soil seedbank germination in Spring 2013. While mature adults in the northern population are also senescing, the reproductive potential of the juveniles at that site (which represent the greatest proportion of individuals) remains high, and decisions to intervene at this site should only be made where a decline of juveniles is demonstrated over two successive survey periods.

4.1 Overview

Terrestrial ecology was monitored on a quarterly basis between Spring 2012 and Winter 2013. The report provides an assessment of the trends in condition of ecological variables required to determine whether the project is having an impact on the natural environmental values at the site. This includes monitoring of two populations of threatened Juniper-leaved Grevillea (Grevillea juniperina subsp. Juniperina), as well as value and condition assessments for riparian environments (listed as River-flat Eucalypt Forest endangered ecological community under NSW threatened species legislation) and the commonwealth and state listed Cumberland Plain Woodland critically endangered/endangered ecological community.

It also includes an assessment of the integrity of the riparian channel of Angus Creek, and monitoring of a number of reference sites in proximity to the Rooty Hill RDC site to confirm whether trends in condition are as a result of site development or natural stochastic events.

4.2 Monitoring timing and locations

Table 4-1 identifies the dates monitoring was undertaken at the Rooty Hill RDC site in relation to the project construction program.

Table 4-1 Monitoring dates between spring 2012 and winter 2013

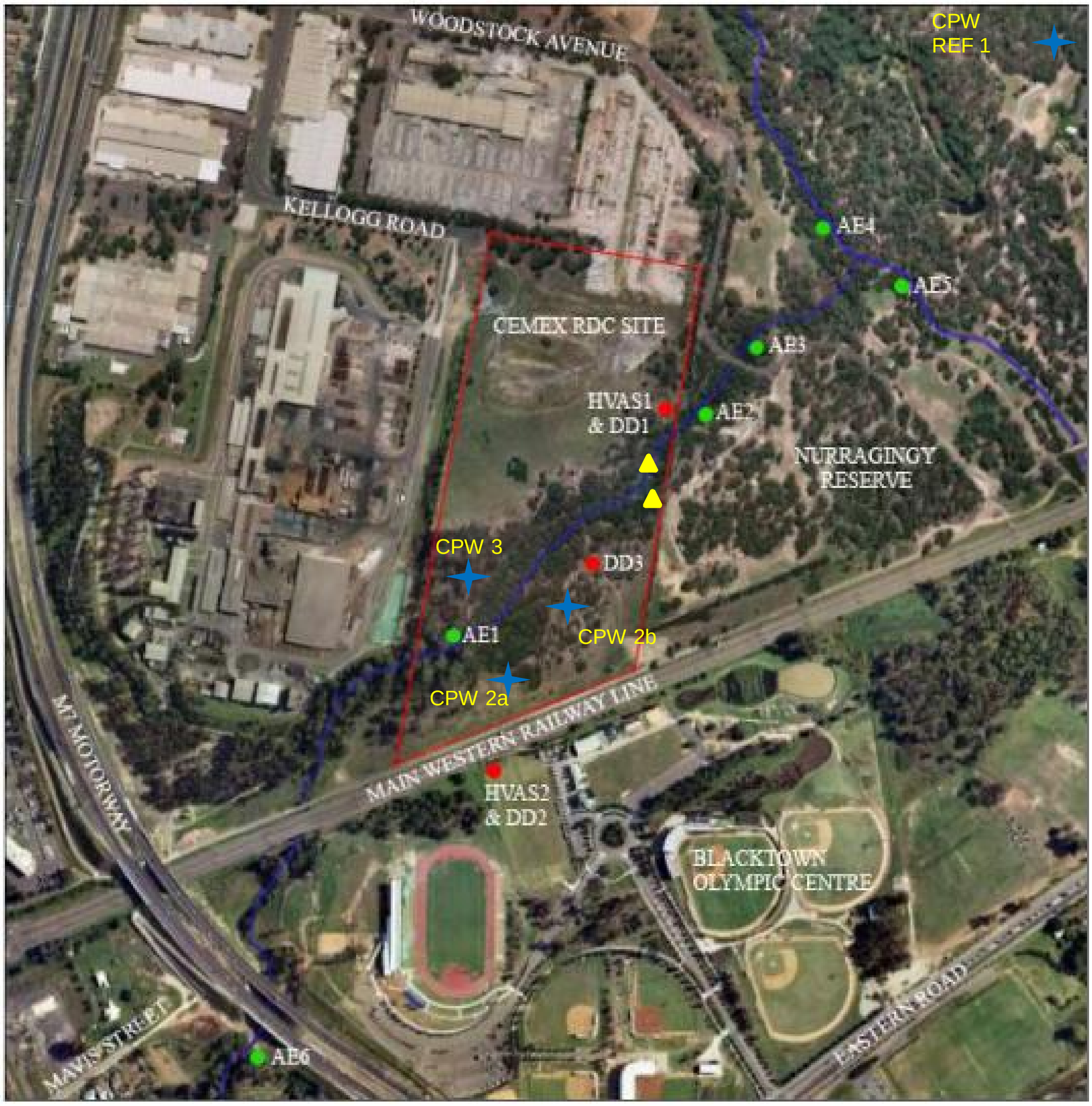
Date	Pre-construction (early works)	Construction (Stage 2 weeks)
Spring 2012	9 - 11 October 2012	
Summer 2013		16 - 17 January 2013
Autumn 2013		25 - 26 March 2013
Winter 2013		24-25 July 2013

Monitoring locations included the following, which are illustrated in Figure 4-1.

- AE1 - Angus Creek at upstream boundary of Rooty Hill RDC (Holcim site)
- AE2 -Angus Creek at downstream boundary of Rooty Hill RDC (Nurragingy Reserve)
- AE3 -Angus Creek 150 m downstream of Rooty Hill RDC culvert (Nurragingy Reserve)
- AE4 -Eastern Creek downstream of Angus Creek confluence (Nurragingy Reserve)
- AE5 - Eastern Creek upstream of Angus Creek confluence^ (Nurragingy Reserve)
- AE6 - Angus Creek, 500 m upstream Rooty Hill RDC^

(^These sites will be adopted as control sites.)

Figure 4-1 Monitoring locations



Legend:

- ▲ Juniper-leaved Grevillea populations - North and South of Angus Creek
- ● Riparian health assessment - AE1 to AE6
- ✦ Cumberland Plain Woodland CEEC- Rooty Hill RDC site and Nurragingy Nature Reserve (CPW 2a, CPW 2b, CPW 3, CPW Ref)

4.3 Monitoring methodology

4.3.1 Juniper-leaved Grevillea

Across the RDC, the Juniper-leaved Grevillea has been recorded in very small densities at two locations either side of Angus Creek. In 2005, Biosis recorded fewer than 4 mature individuals in total across the site, with several additional juveniles successfully recruiting in the location north of Angus Creek.

Pre-construction counts of the species, provide baseline information for the quarterly monitoring required in the Vegetation Management Plan (VMP). The intention of quarterly monitoring is to monitor the health of individuals of the grevillea to ensure works across the site are not having a negative impact on the population.

Once bushland regeneration works commence at the site, quarterly monitoring will also report on the active management of the species. Absolute counts of individuals of the species were undertaken at sites quarterly, as well as an assessment of growth rates, records of vigour, photopoint monitoring and a fixed quadrat assessment of groundcover diversity and abundance.

4.3.2 Riparian health assessment

Riparian health and condition monitoring was conducted at the six established monitoring sites quarterly during dry weather (refer Figure 4-1).

4.3.3 Riparian site value assessments – NSW Biobanking framework

ALS previously monitored riparian health at six sites – one on the Rooty Hill RDC site and five sites on other properties both upstream and downstream of the project site; however, it is not clear from the Annual Environmental Reports which parameters were measured. As a result, the current monitoring program builds upon the ALS methodology and includes assessments for general riparian health and condition using the NSW Biometric vegetation condition as a benchmark and the Biobanking methodology to record condition. These benchmarks are specified for a suite of vegetation and fauna habitat condition variables for each Biometric vegetation type and can be readily used to assess the current and predicted condition of native vegetation.

The riparian environments across the six sampling sites were characteristic of River-flat Eucalypt Forest (RFEF) being a Threatened Ecological Community (TEC) listed as Endangered under the NSW Threatened Species Conservation Act 1995. A Site Value assessment under the NSW Biobanking framework (DECC 2009) was undertaken for each sampling site to quantify the overall condition of the vegetation against established benchmarks for the Biometric vegetation types present in the study area. Survey effort (that is, the number of sites monitored) and monitoring method followed the NSW Biobanking Assessment Methodology (DECC 2009).

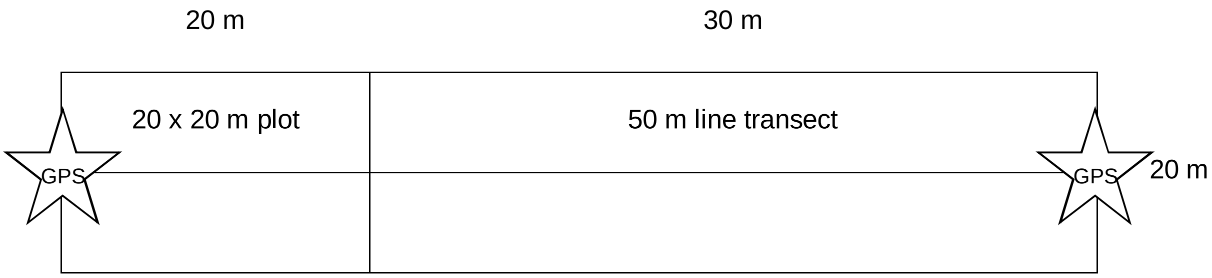
The intention of monitoring these sites prior to construction was to develop a baseline of vegetation condition, from which ongoing monitoring could determine whether the project is having an impact upon the vegetation communities present. The program also includes surveys to monitor change in reference sites of similar vegetation condition situated in close proximity to the property but not subjected to potential impacts from the project. For example, if the study area is subject to a natural event which results in a decline in vegetation condition (such as wildfire, flooding or psyllid infestation), reference sites may also be influenced by this event, demonstrating that any decline in condition is a result of natural events rather than as a result of the project.

The following parameters were recorded at the six sampling sites:

- Native plant species richness
- Native mid-storey cover
- Number of trees with hollows
- Exotic plant cover
- Native over-storey cover
- Native ground cover
- Total length of fallen logs
- Over-storey regeneration

The site value assessment was recorded on BioBanking field data sheets using the recommended BioBanking plot layout which consists of a 20 x 20 m plot (0.04 ha) and a 50 m line transect (Figure 4-2.) Native canopy and mid-storey cover were visually estimated at 10 points along the 50 m line transect and divided by 10 to provide an estimated project foliage cover for the plot. The projected foliage cover (%) of ground covers (native grasses, shrubs, other and exotic species), was calculated by recording their presence/absence at 50 points along the 50 m line transect and dividing the total number of hits by 50.

Figure 4-2 Transect / plot layout



The plot data for each site attribute was compared against the relevant benchmark for the vegetation type, scored and then ranked using the matrix in Seidel and Briggs 2008. The final score for each vegetation plot was then assigned an arbitrary condition rating based on this assessment:

- low = 0 to 16
- low-moderate = 17 to 33
- moderate = 34 to 50
- moderate-high = 51 to 67
- high = 68 to 84
- very high = 85 to 100

Trends in site value for each of the sites AE1 to AE6 across the four seasons is presented in Section 4.4.2.

4.3.4 Riparian Channel and Environmental Inventory

The Riparian, Channel and Environmental (RCE) Inventory was developed to provide a consistent framework for assessing biophysical conditions of small streams in modified agricultural landscapes (Petersen and Robert, 1992). It uses rapid assessment parameters to characterise biological structure and function of streams in order to provide a relative value of stream health against established indicators. At each of the six sites in the monitoring program and 50 m upstream and downstream of the site the following parameters were recorded within the stream channel and riparian zone:

- Land-use pattern beyond immediate riparian zone
- Completeness of riparian zone
- Width of riparian zone from stream edge to field
- Aquatic vegetation
- Stream-bank structure
- Riffles and pools or meanders
- Stony substrate; feel and appearance
- Stream bottom
- Retention devices
- Detritus
- Channel sediments
- Bank undercutting
- Channel structure

Vegetation of riparian zone within 10m of channel RCE scores range from 16-36 and are divided into the following categories:

- 4-21 Poor
- 22-38 Fair
- 39-56 Good
- 57-73 Very Good
- 74-90 Excellent

4.3.5 Cumberland Plain Woodland Critically Endangered Ecological Community

Cumberland Plain Woodland (CPW) was monitored as a baseline assessment (pre-Stage 2 construction) of the three zones (or conditions) of the woodland on the Rooty Hill RDC site and an assessment of one external reference CPW site in close proximity to the site (refer Figure 4-1). The field methodology aligns with current industry best practice for describing vegetation condition in relation to biodiversity offsets. This methodology will provide a useful baseline upon which to describe improvements resulting from bushland regeneration efforts that are required at the site as part of the conditions of approval for the project as well as identifying any condition changes as a result of the project.

A site value assessment using the NSW Biobanking framework was undertaken in the woodland at each of the four sites to describe the overall condition of the vegetation against formally established benchmarks for CPW. This methodology follows that described in Sections 4.2 for the riparian assessment. These sites are being monitored prior to significant construction works to develop a baseline of condition to demonstrate whether the project is having an impact upon the woodland. The use of control sites on adjacent properties not subject to the potential impacts of the project will assist in determining whether any trend in vegetation condition decline is attributable to the project or natural environmental events. This is particularly important as current infestations of the lace lerp have resulted in the defoliation of Grey Box (*Eucalyptus moluccana*) across the region, although without including a control site in the monitoring program, this defoliation may have been incorrectly attributed to project impacts. Applying the site value assessment of the NSW Biobanking framework will achieve repeatable, comparable monitoring assessments which will provide a valuable framework for determining improvements in vegetation condition once bushland regeneration takes place at the site.

4.4 RESULTS

4.4.1 Juniper-leaved Grevillea

Southern population

The southern population of the Juniper-leaved Grevillea is the smaller of the two populations at the RDC site originally comprising two mature individuals and more than 10 juveniles. The individuals occupied an area of more than 20 m^2 and generally occurred in small clumps with juveniles usually between one and three metres from mature adults. Seedling germination at the site was low and in the summer of 2013 a wildfire swept through the area that has resulted in 100% loss of individuals from that site. In autumn 2013 monitoring, less than five individuals remained, but by the winter monitoring these had died off completely.

Figure 4-3 illustrates the population dynamic of the southern population highlighting that juvenile plants dominated the population profile. The winter 2013 data point represents the new growth at the site post-fire which represents 5 seedlings observed during that survey.

Figure 4-3 Population dynamics of the northern and southern populations of the Juniper-leaved Grevillea since the baseline survey

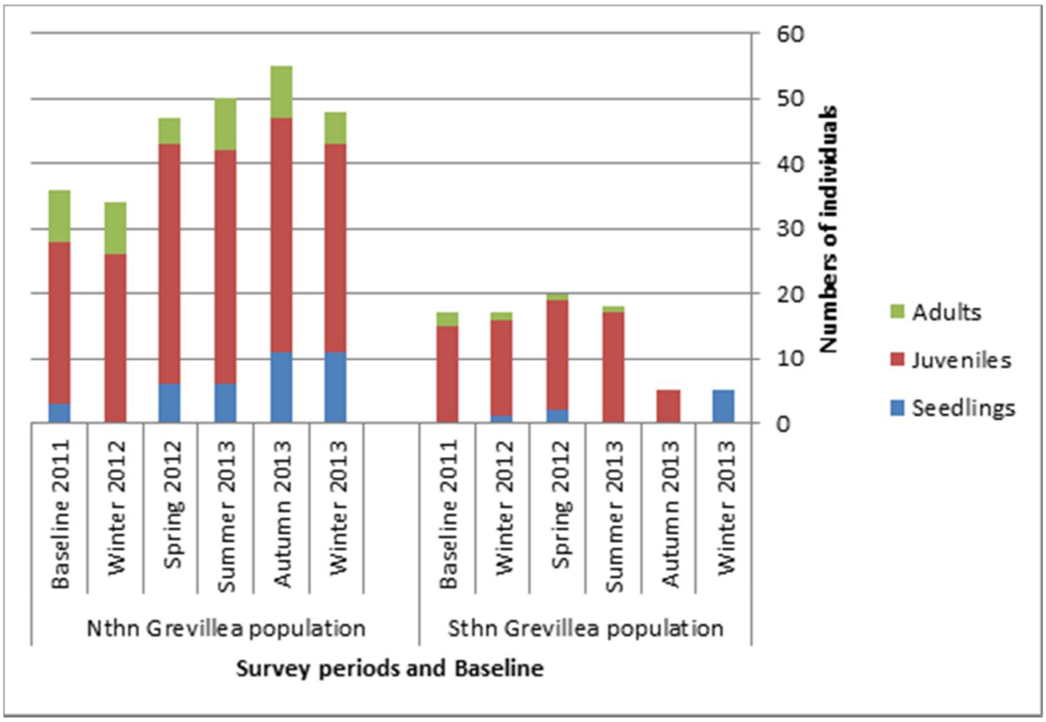


Figure 4-4 illustrates the reasonably stable but lower proportion of individuals surviving at the site since the baseline survey in comparison with the northern population which exhibited high juvenile recruitment over the spring and summer period (2012). The reproductive potential of the southern population (demonstrated by the proportion of individuals with evidence of fruiting or flowering) was also lower than the northern population as illustrated in Figure 4-5.

Figure 4-4 The proportion of the northern and southern populations of the Juniper-leaved Grevillea surviving since baseline

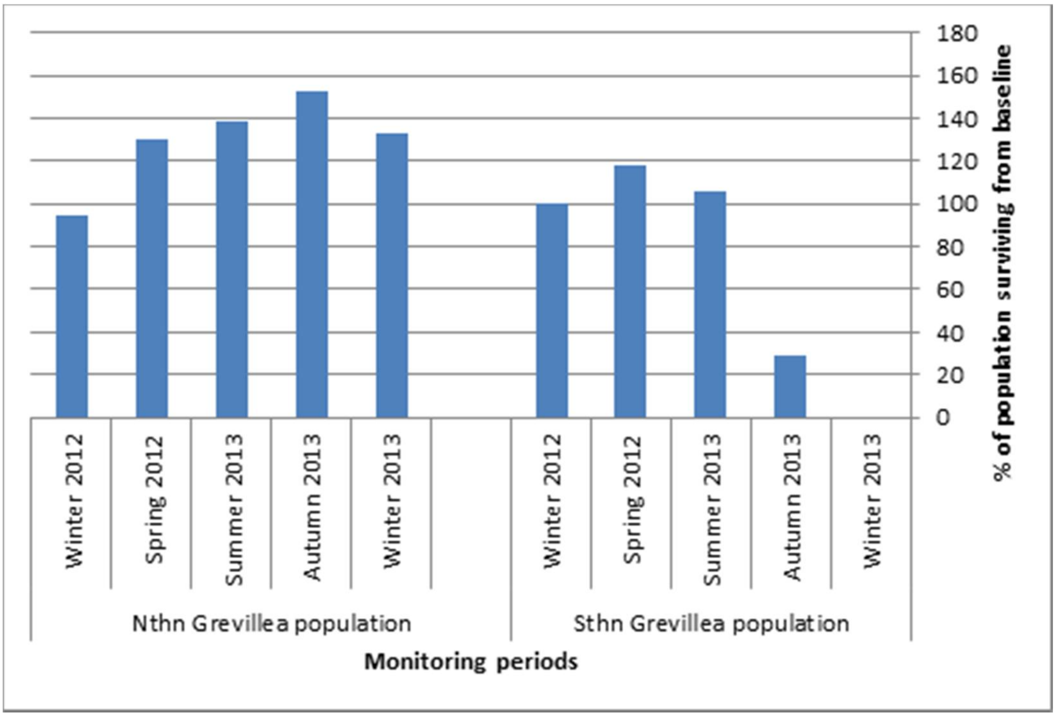
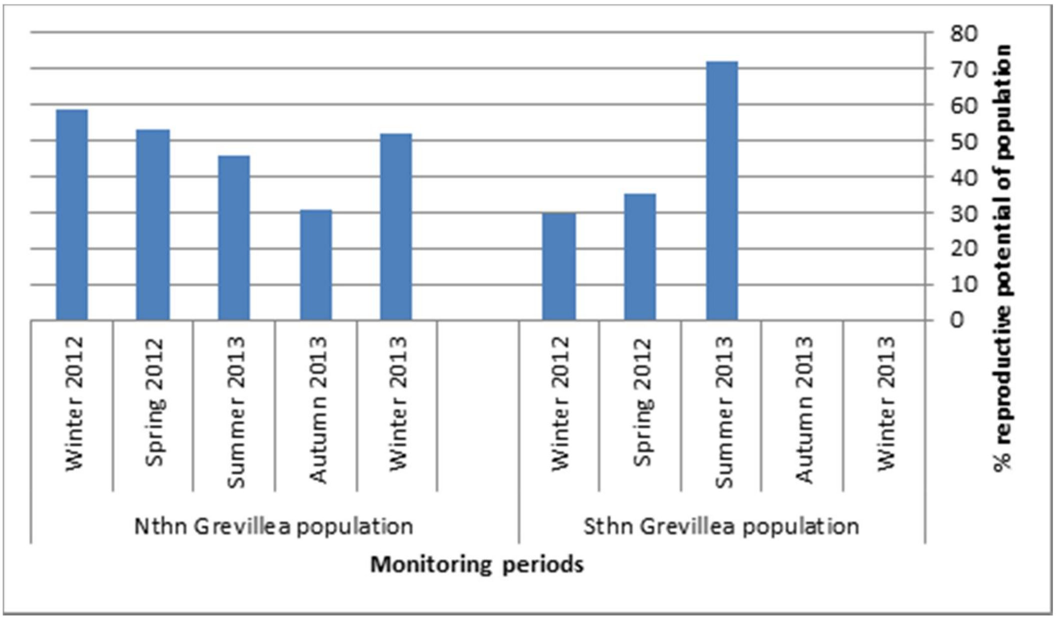


Figure 4-5 Reproductive potential of each population of the Juniper-leaved Grevillea over four seasons



Previous research on the species suggests that plants are generally killed by fire with regeneration occurring from soil-stored seed enhanced by heat and smoke (Makinson, 2000; Morris, 2000). Regeneration of the species from any seed stored in the soil at the southern site has been slower than expected with only five seedlings recorded across the site in the winter survey despite the heavy and frequent summer rainfall events experienced in the region and the mild winter. This may in part be explained by the population exhibiting less vigour in terms of survivability and reproductive potential than the northern population; however there is no published research on the expected vigour of the species upon which to make a comparison.

Bare patches of soil are being quickly recolonised by grasses with some juvenile eucalypts (13 individuals) resprouting from surviving individuals or from the soil seedbank.

It would be worthwhile to actively intervene at the site to increase the rate of germination of the species, before the site becomes shaded out by regenerating eucalypts and acacias, rendering the habitat unsuitable for the species. At the direction of the NSW Office of Environment and Heritage, and as detailed in the VMP for the Rooty Hill RDC, this should take the form of mechanical disturbance of soil at the site.

Northern population

The northern population of the Juniper-leaved Grevillea is the larger of the two populations at the RDC site comprising four mature individuals and more than 20 juveniles at baseline. The population occupies an area of approximately 30 m^2 with juveniles aggregating in small clumps usually between one and three metres from mature adults. Seedling germination at the site was prolific in the summer and autumn of 2013 with more than 80% of seedlings surviving into the winter. The northern population of the grevillea remains generally healthy, although two mature individuals were in the advanced stages of senescence in autumn 2013 and were subsequently lost from the population in winter along with one other individual at the site. Four other mature plants are also exhibiting some branch senescence. This does not appear to be as a result of any human-induced disturbance as most juveniles in this area continue to appear to thrive. Figure 4-3 illustrates the population dynamic of the northern population highlighting that juvenile plants dominate the population profile with a healthy cohort of seedlings likely to develop into juveniles in the spring and summer of 2013.

Figure 4-5 illustrates the strong and stable reproductive potential of the northern population which should maintain its viability even if the mature individuals are lost from the population. Half of the juvenile individuals were observed to have recently flowered or produced fruit, which will assist with ongoing recruitment of individuals at the site as plants greater than one metre in height are generally the most prolific seeders (NSW NPWS, 2000).

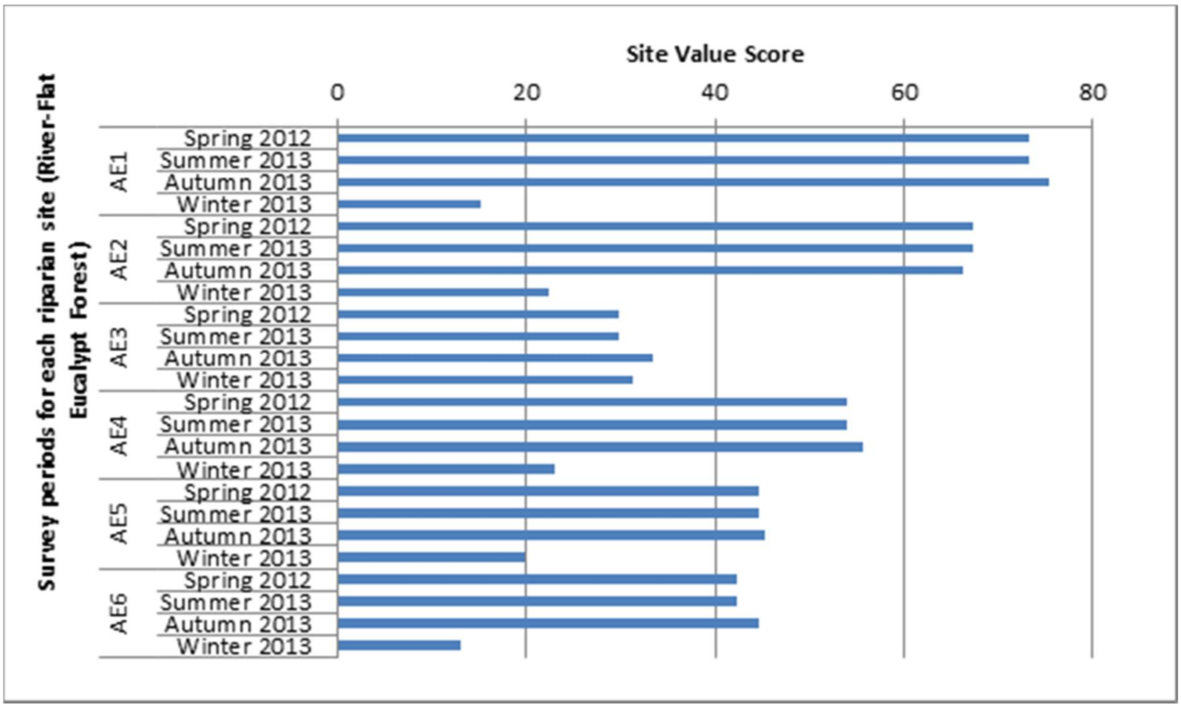
The loss of mature individuals at this site is difficult to attribute directly to any development north of Angus Creek as native plant diversity, structure and abundance does not seem to have altered significantly since Early Works, however the lifespan of the species remains unknown. Given that so many juvenile individuals are exhibiting reproductive potential through flowering and fruiting, the potential demise of the northern population as a result of the mortality of more than 30% of the adult individuals at the site seems unlikely. At this stage it is not considered necessary to intervene with the natural succession of the site through mechanical soil disturbance in an attempt to trigger further germination.

4.4.2 Riparian site value and condition assessments

Figure 4-6 illustrates the trend in site value for each riparian site (AE1 to AE6) across the four seasonal survey periods, taking the baseline survey as Spring 2012. Note the significant decrease in site value across all sites AE1 - AE6 for the Winter 2013 survey (except for AE3). This marked decrease in the conditions of the riparian monitoring sites is likely to be the result of heavy rain in June and July causing localised flooding and subsequent topsoil removal and transport of fallen logs downstream (see Figure 2-4). This decline across the survey sites is not evident at site AE3; however this site has been recently maintained (grassy areas mown and weeds removed) which may have resulted in a flush of native species regeneration in the groundcover at that site. Figure 4-6 also shows that AE1 on the Rooty Hill RDC site consistently has the highest site value score, but with the greatest decline in condition across all sites between autumn and winter 2013 as a result of localised flooding from rainfall events.

Reductions in groundcover abundance of native grasses have also contributed to the decline in site values in winter as many species brown off during the cooler temperatures of winter. A reduction in native overstorey cover was also observed across most sites, and this was observed to be attributed to the ongoing defoliation of eucalypts as a result of the infestation of the psyllid insect across the Cumberland Plain.

Figure 4-6 Site value scores for each riparian monitoring site across 4 seasonal survey periods



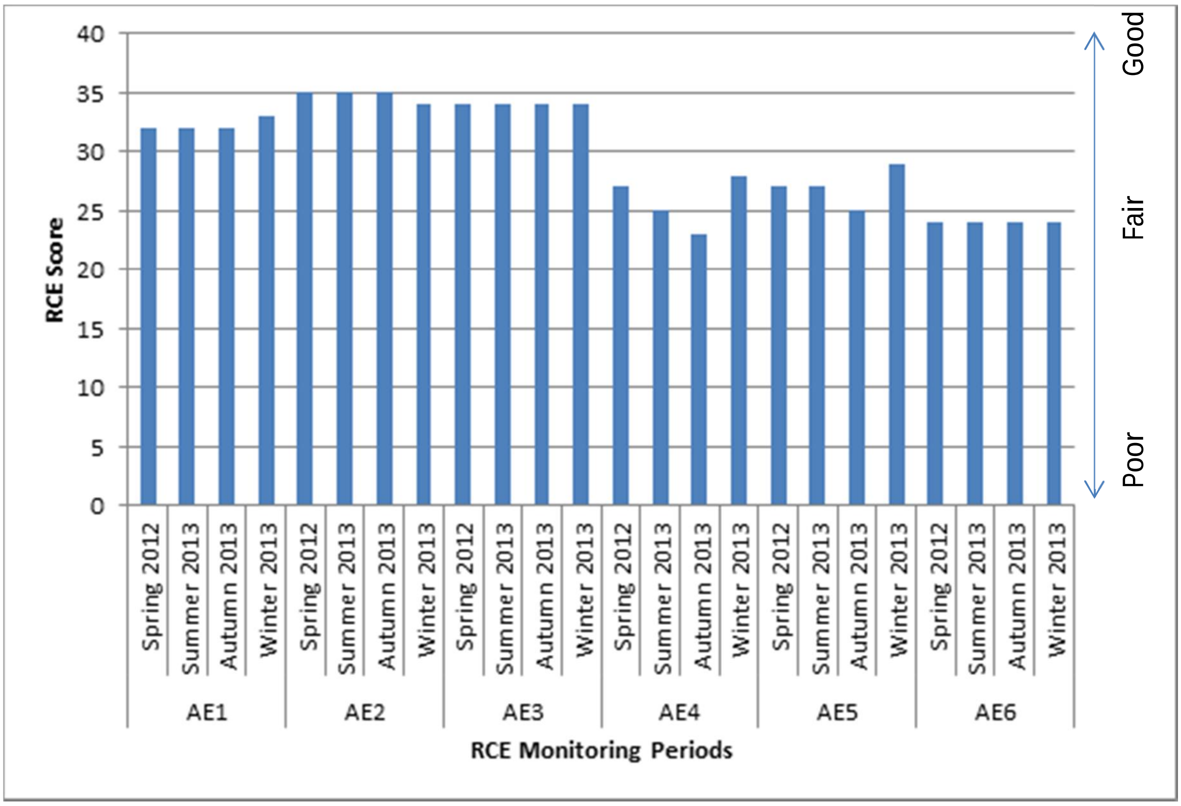
4.4.3 Riparian Channel and Environmental Inventory

Figure 4-7 illustrates the seasonal trends in the riparian channel and environment attributes monitored at AE1 to AE6. All monitoring locations have consistently maintained a Fair condition over the four seasonal survey periods. The Rooty Hill RDC monitoring site (AE1) showed more intact riparian channel characteristics than either reference site for almost all parameters.

Slightly higher scores in winter 2013 for sites AE1, AE2, AE4 and AE5 were most likely as a result of periods of heavy rain in June and July which has caused some channel sediment accumulation (topsoil moved from banks as a result of localised flooding), greater retention devices in-stream (logs moved from banks during localised flooding) and increases in stream detritus.

A small change in stream bank structure was observed at AE1 and AE2; however this was not significant enough to alter the score. These results suggest that major alterations are required to the stability of both Eastern Creek and its tributary both upstream and downstream of the Rooty Hill RDC site.

Figure 4-7 Seasonal trends in riparian channel and environment attributes



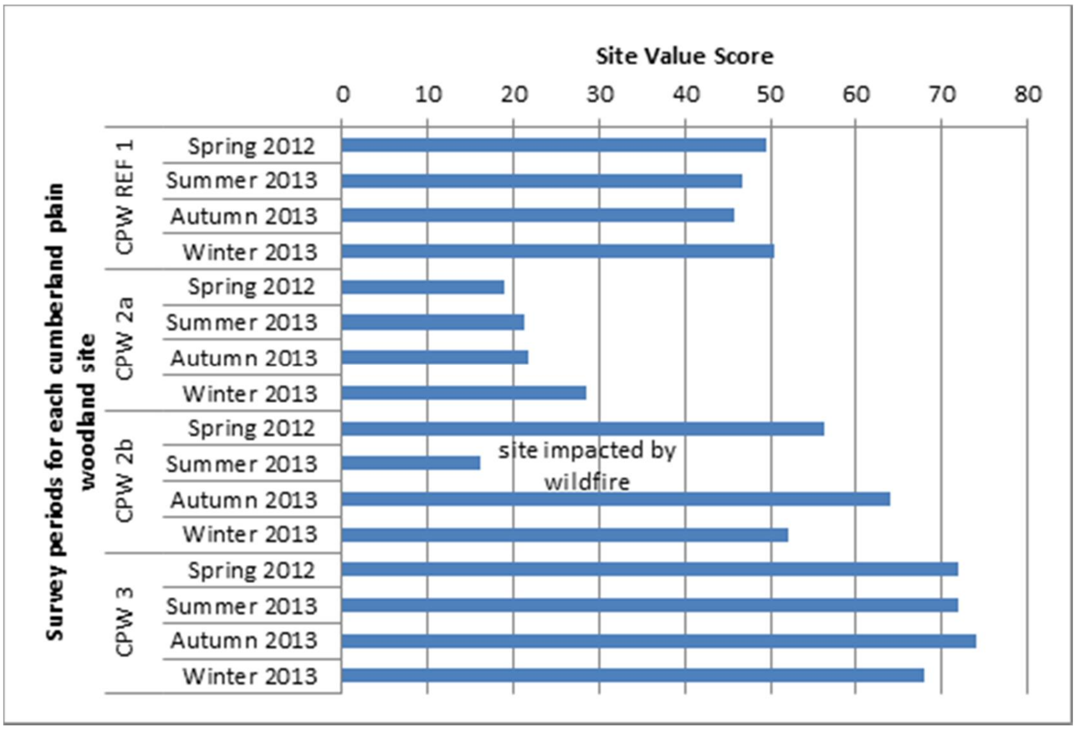
Riparian health and condition have been previously reported both by ALS in Annual Environment Reports and Biosis in the Rooty Hill RDC Aquatic Ecology – Environmental Assessment. Monitoring of riparian health and condition during 2012/2013 concurs with previous assessments that suggest both the aquatic and terrestrial components of the riparian corridor both at the Rooty Hill RDC site and upstream and downstream references sites are highly modified and representative of streams in peri-urban landscapes. The site value assessment (NSW Biobanking methodology) and the RCE methodology applied in the current monitoring program have allowed for a quantitative evaluation and comparison of the health and condition of development (AE1 Rooty Hill RDC site) and reference (AE5 and AE6) sites as well as determination of the condition of these sites against established benchmarks.

4.4.4 Cumberland Plain Woodland Critically Endangered Ecological Community

Vegetation condition of Cumberland Plain Woodland varied considerably across all four monitoring sites (three of these are on the RDC site and the reference site is in Nurragingy Reserve), and this variation is consistent across all four monitoring seasons as illustrated in Figure 4-8.

Despite this variation, conditions remained reasonably stable at each site across the seasons, and small reductions in site values are likely to be reflective of seasonal changes as plants become dormant or slow their growth. Native plant species richness across all sites was considered moderate and ground cover condition was directly related to density of exotic (weed) species at the sites and where weed density was highest, condition values were lowest. Regenerative potential of overstorey species at all sites was reasonable; however psyllid infestations across all monitoring locations have contributed to a decrease in overstorey cover, although at some sites there is evidence of partial recovery with flushes of epicormic regrowth on higher limbs. At all sites, weed infestations persist in the groundcover predominantly as grass weeds.

Figure 4-8 Site value scores for Cumberland Plain Woodland monitoring locations for the four seasonal survey periods



Despite variability in the condition of Cumberland Plain Woodland at the RDC site, resilience is considered to be moderately good across all sites and equivalent to the control site in the adjacent Nurragingy Reserve. Weed infestations persist across all sites including the control site, outcompeting native vegetation particularly in the groundcovers and lessening the condition of each site. Site resilience suggests the sites have good natural regenerative capacity where weeds can be controlled. The most intact remnant of woodland on the RDC site (north of Angus Creek) has maintained its site value despite construction works and is consistently monitored as a higher value than the woodland reference site on Nurragingy Reserve.

5. Water quality

Summary

Water quality indicates that Angus and Eastern Creeks are impaired and representative of a degraded catchment influenced by mixed rural and urban landuses. However, it would appear that, while there are significant localised land use disturbances, the Holcim site is not a major contributor to poor water quality.

Poor water quality was mainly due to low flows, high turbidity, low dissolved oxygen and high conductivity. Many of these parameters were often outside the ANZECC/ARMCANZ (2000) water quality guidelines for the protection of lowland river aquatic ecosystem. Oily films and odours were also observed. Such conditions can only sustain the most tolerant aquatic biota.

Wet weather increased turbidity and nutrients in the waters, primarily from runoff and continued bank erosion of the clay based sediment.

Sites along Eastern Creek (AE4 and AE5) showed high nutrient concentrations and occasional algal blooms. This indicates eutrophication of the waterway. The reduced water quality of the inflow from Angus Creek on the water quality in Eastern Creek downstream of the confluence (AE4) was possibly responsible for the poorer conditions compared to the site upstream of the confluence (AE5) although localised disturbance at site AE4 cannot be ruled out.

Following the first sampling event, the control site (AE6) became part of an unrelated construction facility which resulted in poor water quality that was noticeably poorer than downstream during dry weather. Shallow, stagnant and muddy pools were observed at site AE6 following the commencement of construction.

Following wet weather, water quality appeared poorer downstream from AE6; however, deterioration could not be directly attributed to the Holcim site. Water quality of Angus Creek shows no noticeable deterioration downstream of the Holcim Compound (AE1).

5.1 Sampling methodology

Surface water quality was monitored on a quarterly basis in six locations. Sampling was undertaken on:

- 7 November 2012
- 29 January 2013
- 26-27 March 2013
- 3 June 2013

Sampling locations are summarised in Table 5-1.

Table 5-1 Sampling locations

Site Code	Location
AE6	Angus Creek, 500m upstream RDC^
AE1	Angus Creek at upstream boundary of RDC
AE2	Angus Creek at downstream boundary of RDC
AE3	Angus Creek 150m downstream of RDC culvert
AE4	Eastern Creek downstream of Angus Creek confluence
AE5	Eastern Creek upstream of Angus Creek confluence^

^These sites will be adopted as control sites (MCoA 2.28A)

Water quality sampling was undertaken both *in situ* and via grab samples. In situ sampling was undertaken using a calibrated Hydrolab Quanta Water Quality Probe. The following indicators were measured:

- pH (pH Units)
- Turbidity (NTU)
- Temperature (°C)
- Dissolved Oxygen (% saturation and mg/L)
- Electrical conductivity (µS/cm and ms/cm).

Three replicate readings of each indicator were taken within a 50m radius from approximately 30cm below the surface at each site. Readings were recorded onto a field data sheet together with additional information including: site code, site name, location and coordinates, date and time of sampling, details of team members collecting samples, weather conditions, water surface conditions, presence of nuisance organisms, presence of oily films, odour etc.

Grab samples were collected concurrently with *in situ* water monitoring at each site for analysis of total nitrogen and total phosphorus concentrations. Sampling was conducted in accordance with the Australian/New Zealand standards for water quality sampling (AS/NZS 5667.1:1998). Samples were collected in the appropriate bottles and stored on ice as per the preservation techniques appropriate for analysis. Samples were then transported to Envirolab in Chatswood for ex-situ analysis.

5.2 Sampling results

Water quality results for each site during both dry and wet weather are presented in Table 5-2 together with the ANZECC/ARMCANZ (2000) default trigger values. Highlighted text indicates values that exceed the water quality guidelines.

The sites are displayed in a downstream order with AE6, AE1, AE2 and AE3 located on Angus Creek, AE6 being the most upstream. AE5 and AE4 are on Eastern Creek. All sites are located upstream of wastewater treatment plant discharges and are representative of mixed rural and urban land uses.

Overall, water quality was poor across the study area. During dry weather sampling, water levels were low at all sites with little or no flow. All sites presented oily films and odours which are a reflection of low flow. During wet weather sampling, flow increased with highly turbid waters due to the scouring of banks and underlying geology which was largely clay based.

Table 5-2 Average dry and wet weather water quality results (2012/13)

Site	Dry/Wet	Temp (°C)	Turbidity (NTU)	DO (% sat)	Conductivity (µS/cm)	TDS (g/L)	pH	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
AE6	Dry	19.95	91.17	44.00	5773	3.08	7.43	1.00	0.15
	Wet	17.70	225.52	77.08	724	0.36	8.37	3.45	0.10
AE1	Dry	19.99	18.12	31.47	3465	3.40	7.19	0.4	0.15
	Wet	17.42	417.83	80.50	601	0.29	8.10	2.80	0.20
AE2	Dry	20.30	8.4	25.87	4137	2.18	7.28	0.4	0.15
	Wet	17.79	648.33	74.63	635	0.31	8.32	2.45	0.15
AE3	Dry	19.83	10.6	31.97	4218	2.22	7.11	0.50	0.10
	Wet	17.82	801.83	78.08	613	0.29	8.32	7.00	0.20
AE4	Dry	21.90	33.00	40.05	1531	0.76	6.85	3.35	0.25
	Wet	17.24	608.17	70.15	548	0.26	8.20	5.75	0.30
AE5	Dry	22.04	40.60	34.02	1394	0.7	6.88	1.35	0.10
	Wet	17.29	565.33	66.12	556	0.27	8.14	5.90	0.30
ANZECC/ARMCANZ Guidelines		**N/A**	**6-50**	**85-110**	**125-2200**	**N/A**	**6.5-8.5**	**0.5**	**0.05**

Shaded cells exceed ANZECC/ARMCANZ (2000) Guidelines

Turbidity results during dry weather were compliant across all sites with the exception of the control site, AE6. This was largely due to local unrelated construction works which commenced at the site following the first sampling event. Part of the construction process was to 'dam' the creek at the site and release water weekly. This resulted in a shallow stagnant and muddy pool, which at times exhibited algal growth. Following wet weather, turbidity levels exceeded the guidelines at all sites in both Angus and Eastern Creeks, with turbidity increasing with distance downstream. The increased turbidity is likely due to the addition of suspended solids from runoff and channel erosion.

Dissolved oxygen levels were low across all sites, particularly during dry weather when mean concentrations were less than half the minimum required level for protection of aquatic ecosystems. The low dissolved oxygen levels are attributable to the stagnant low flow conditions across all sites. Following wet weather, dissolved oxygen levels increased (generally two-fold) as a result of aeration due to increased water flow, however levels still fell below the lower guideline limit of 85% saturation.

Angus Creek has elevated electrical conductivity during dry weather, which was more than 1.5 to 2 times the recommended upper limit for the protection of aquatic ecosystems. These saline conditions are likely a result of both the inherent low flow conditions during dry weather and the discharge of saline groundwater. Following wet weather, increased flow provided dilution of salts and therefore conductivity levels fell within the recommended limit of 125 to 2200µS/cm. In Eastern Creek, conductivity complied during both dry and wet weather, and similar to Angus Creek, electrical conductivity was lower during wet weather.

pH levels in Angus Creek were higher overall than Eastern Creek, although average pH levels were within the recommended limits of 6.5-8.5 mg/L for protection of lowland river aquatic ecosystems at all sites. During wet weather, pH levels were generally higher by one pH unit due to runoff from the surrounding catchment which may contain fertilizers and detergents that are known to increase pH.

Nutrient concentrations were elevated in both Angus and Eastern Creeks. Total phosphorus concentrations were elevated at all sites during both dry and wet weather, particularly in Eastern Creek. In high concentrations this nutrient can result in the algal blooms which were evident during dry weather at both AE4 and AE5. During dry weather, total nitrogen only complied at sites AE1 and AE2 in Angus Creek downstream of the control site AE6. The elevated TN concentrations at AE6 are likely attributable to the local construction activities at this site. Dry weather total nitrogen concentrations at the upstream control site AE5 in Eastern Creek were more than double the recommended guideline. Further downstream at AE4, average dry weather TN concentrations were twice that of upstream and more than 6 times the recommended guideline limit. Clearly there are localised sources of these elevated nutrients. Following wet weather, concentrations increased dramatically at all sites, particularly at AE3, which is downstream of a culvert. The dramatic increase in total nitrogen (and to a lesser extent total phosphorus) at all sites following wet weather is due in part to the increase in suspended solids (as indicated by increased turbidity) that enter the creek from runoff from disturbed land and eroded banks. Nutrients bind to soil particles leading to high concentrations during high flow events.

6. Air quality

Summary

Ambient dust sampling included PM_{10}, TSP and depositional dust. While measured directly between October and December 2012, TSP was calculated based on PM_{10} concentrations (a factor of 2.5 was applied) from December to August once the High Volume Air sampling head was changed to a size selective model.

Annual limits for PM_{10} and TSP were complied with over the reporting period.

The 24-hour limit for PM_{10} was exceeded on one occasion. However this occurred on a Sunday when no construction work was underway. As such, it is unlikely that this exceedance is attributable to activities under Holcim's control.

Depositional dust was sampled from February to August 2013; however rain interfered with February's result. Results for the six valid months of sampling demonstrate depositional dust levels were less than half the annual limit. However, the higher and more variable recorded concentrations were from the southern end of the construction site where works were concentrated.

6.1 Sampling methodology

Air quality monitoring included the measurement of depositional dust and particulate matter (PM). The monitoring study commenced with total suspended particulate (TSP) due to the equipment available at this time. By December 2012, equipment was modified to collect PM_{10} (Particulate Matter smaller than 10 micrometres) in accordance with the construction dust management plan.

Particulate Matter, as PM_{10}, was monitored during construction at a single location, as shown in Table 6-1, using a high volume sampler (HVAS) with size selective head. TSP was conservatively estimated from the PM_{10} results at 2.5 times the measured PM_{10} level.

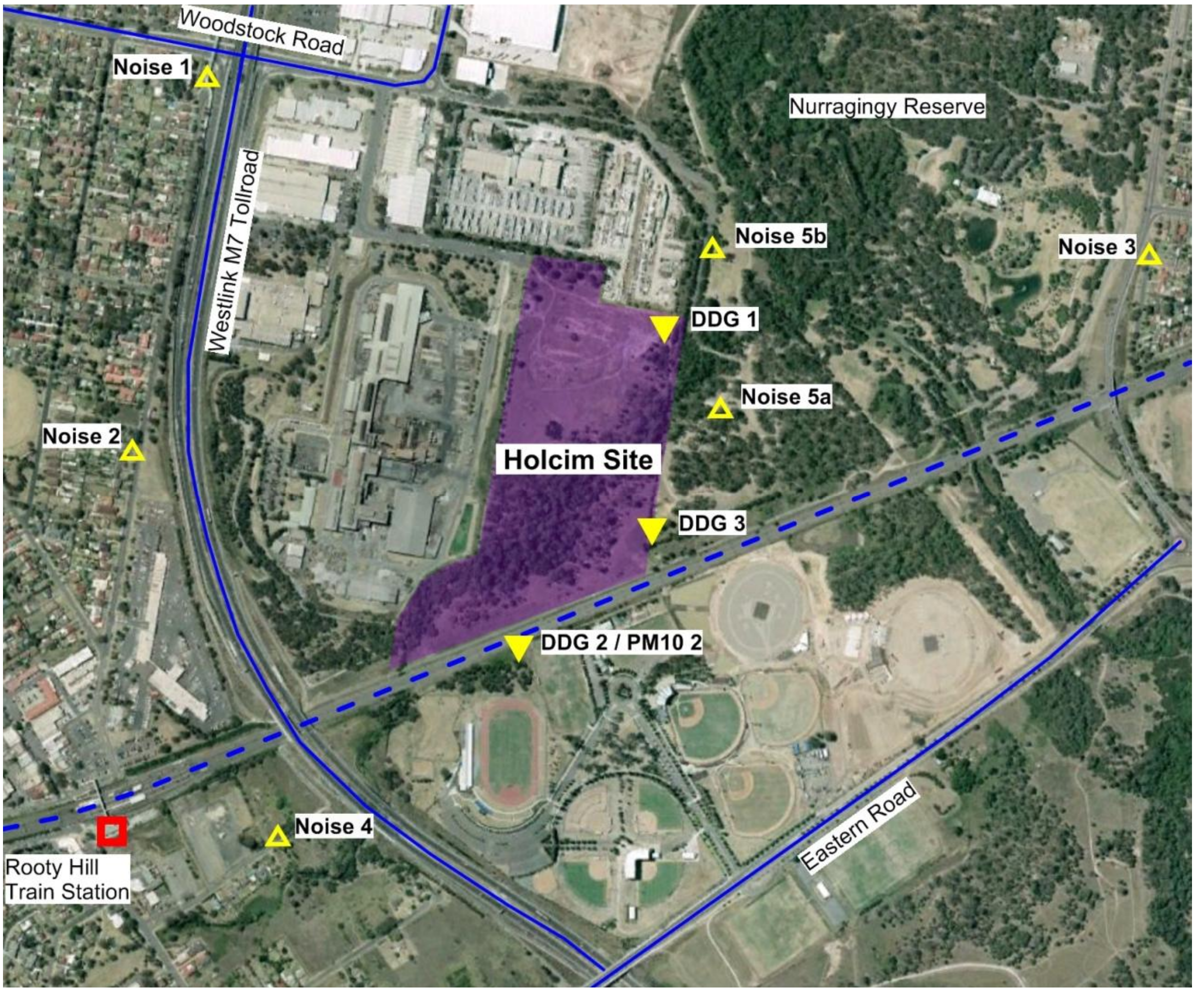
The HVAS was operated on one-day-in-six in accordance with AS/NZS 3580.9.6:2003 *Methods for sampling and analysis or ambient air, Method 9.6: Determination of suspended particulate matter (PM10) – High volume sampler with size selective inlet - Gravimetric method*. Calibration of the unit is checked on a monthly basis, in accordance with operating instructions for the unit and AS/NZS 3580.9.6:2003.

Depositional dust monitoring did not commence until February 2013. Depositional dust monitoring consisted of three depositional dust gauges (DDGs), which are collected and replaced approximately every 30 days in accordance with AS/NZS 3580.10.1:2003 *Methods for sampling and analysis of ambient air Method 10.1: Determination of particulate matter – Deposited matter – Gravimetric method* and are analysed for total insoluble solids. The depositional dust monitoring locations provided in Table 6-1 have been selected to be representative of sensitive receptors. Figure 6-1 is a site plan showing indicative monitoring locations.

Table 6-1 Dust monitoring locations

Reference	Description	Type of dust measured	
		Depositional dust	TSP / PM_{10}
D1	Adjacent to eastern boundary in northern section of construction site, abutting Nurragingy Reserve	✓	
D2	Adjacent to southern boundary abutting Blacktown Olympic Centre	✓	✓
D3	Adjacent to south eastern boundary abutting Nurragingy Reserve	✓	

Figure 6-1 Air quality monitoring locations



6.2 Dust guidelines

Air quality (dust) criteria within the Project Conditions of Approval and the CDMP mirror those in the NSW EPA document A*pproved methods for the modelling and assessment of air pollutants in New South Wales* (DEC 2005). The air quality assessment criteria are outlined in Table 6-2, which apply cumulatively (that is, due to all sources of emissions and not just the contribution from the project).

Table 6-2 Dust concentration guidelines

Pollutant	Averaging period	Concentration
TSP	Annual	90µg/m^3
PM_{10}	24 hours	50µg/m^3
	Annual	30µg/m^3
Deposited dust	Annual	4g/m^2/month

6.3 Results

6.3.1 PM_{10} and TSP

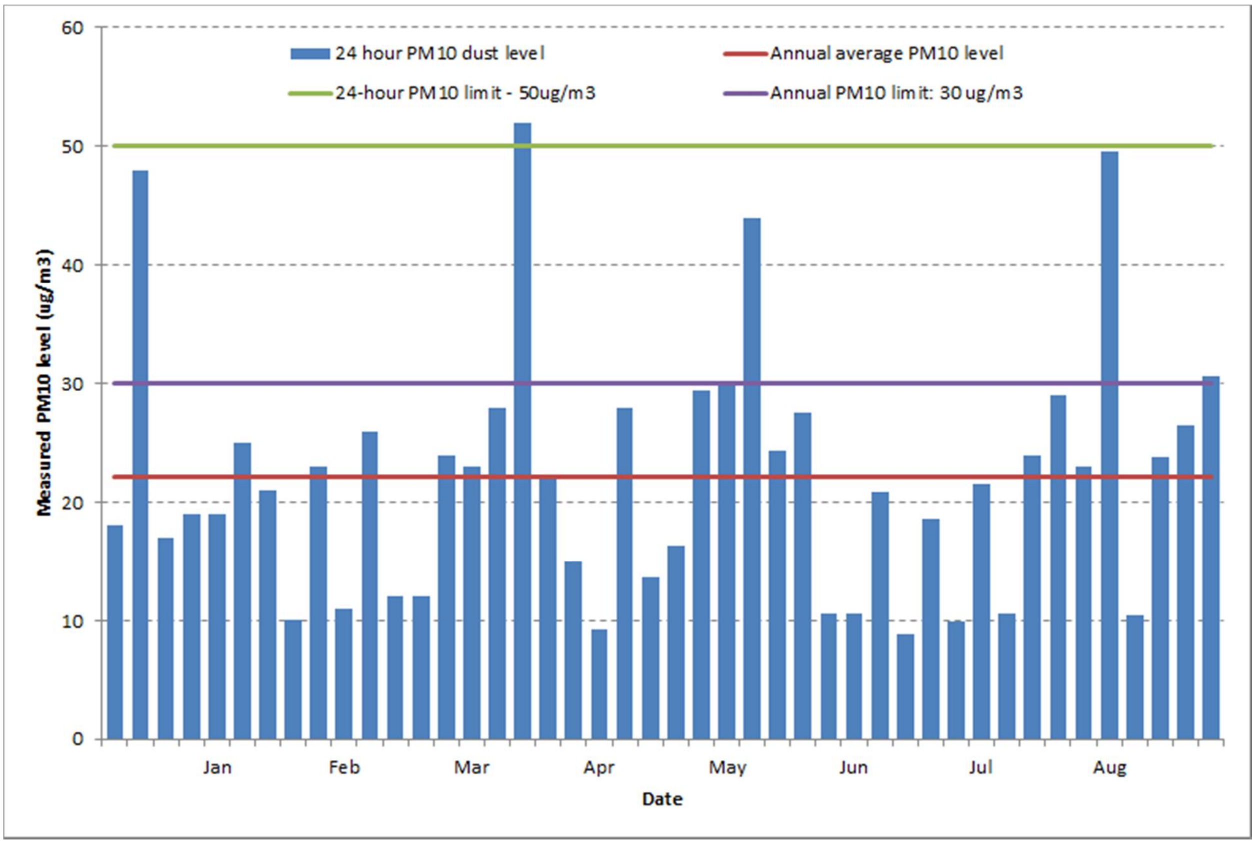
Measured concentrations of PM_{10} and TSP are summarised graphically in Figure 6-2 and Figure 6-3.

PM_{10} concentrations are generally within the 24-hour limit of 50 µg/m^3, with the exception of one sample period where a minor exceedance of the limit was observed. This dust concentration was measured on 17 March 2013, which was a Sunday and no RDC construction work was being carried out at the time. As such, it is unlikely that this exceedance is attributable to activities under Holcim's control.

Soccer fields adjacent to the air monitoring location were treated with topdressing material immediately prior to the 17 December 2012 sampling period. This is reflected in elevated PM_{10} dust concentrations on this day.

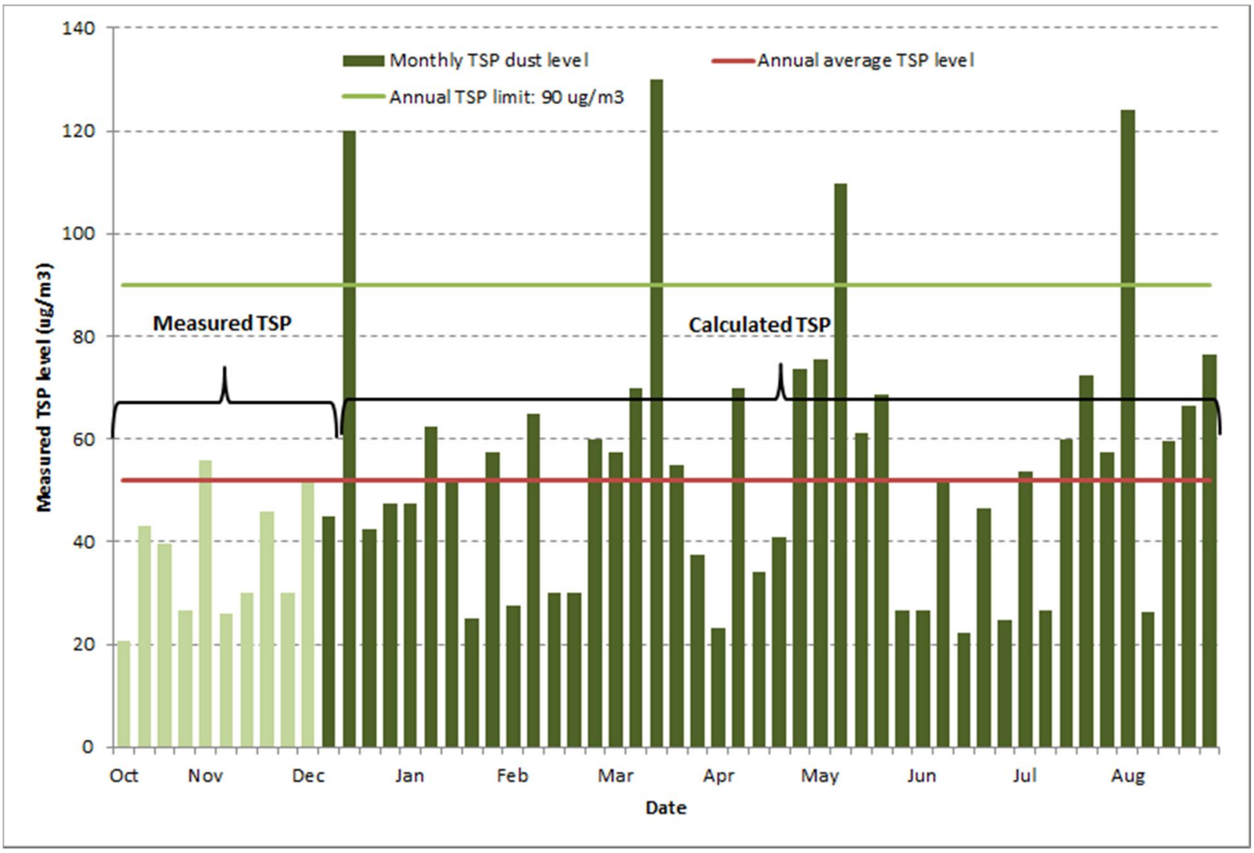
Annual PM_{10} dust concentrations, at 22 µg/m^3 represented by the red line, were well below the limit of 30 µg/m^3.

Figure 6-2 Measured PM_{10} concentrations



The annual average of measured and calculated (2.5 x PM_{10} concentration) TSP concentrations was 52 µg/m^3. This value is well below the annual limit of 90 µg/m^3 despite several outstanding results. These higher results align with the higher measured PM_{10}. Of note is the conservative assumption that TSP concentrations would be around 2.5 times those of PM_{10}. Comparison of measured TSP *versus* the estimated values indicates a lower average level for measured values.

Figure 6-3 Measured and calculated TSP concentrations



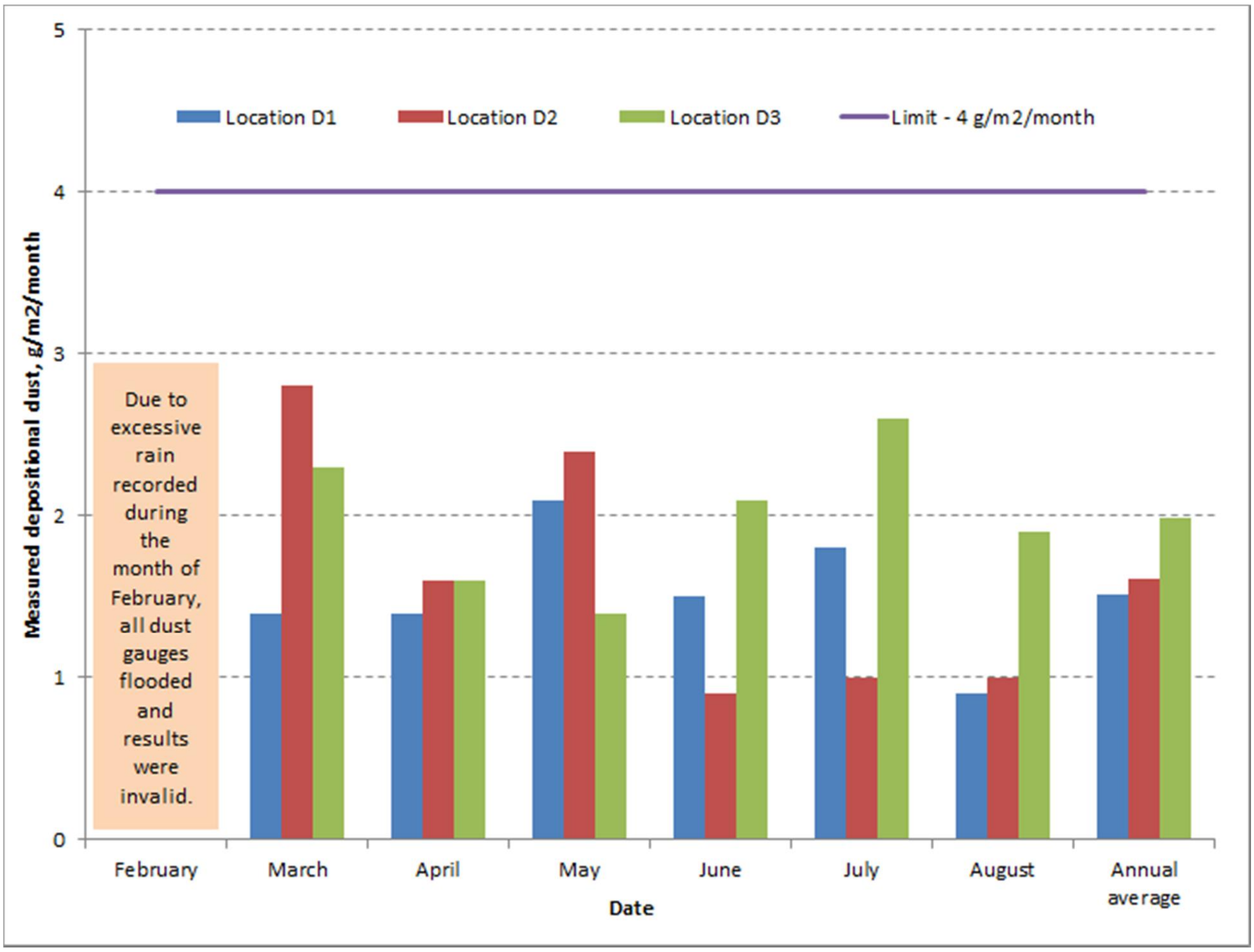
6.3.2 Depositional dust

Results for monthly depositional dust sampling are summarised graphically in Figure 6-4. It is evident that the annual average values for each of the three monitoring locations are less than half the annual limit of 4 g/m^2/month.

Location 1 recorded relatively steady dust concentrations. This location is in the northern section of the site and construction works were minimal here during the reporting period.

Location 2 and location 3 are in the southern section of the site where construction was more concentrated. Location 2 recorded the highest concentrations of depositional dust between March and May 2013, whilst being lowest from June to August 2013. Results for location 3 increased in the second half of the year.

Figure 6-4 Depositional dust results



7. Noise

Summary

Noise was measured in six locations around the construction site from January to August 2013. Monthly monitoring indicated that noise from RDC construction at the nearest residential receivers was generally inaudible, with traffic noise making up the majority of noise at any single location.

In the adjacent Nurragingy Reserve, noise from construction was audible for several months, with comments noting the contribution of construction noise as being approximately equal to the noise management level (NML); however exceedance of the NML was minor and included contributions from rail and road traffic.

It is unlikely that construction noise is having a significant impact on nearby sensitive receivers.

7.1 Monitoring methodology

Monthly noise monitoring has been undertaken by a qualified acoustic consultant in six locations since January 2013. Monitoring was conducted for a minimum of 15 minutes in each location and in accordance with the requirements set out in the EPA (2000) *Industrial Noise Policy* and the DECC (2009) *Interim Construction Noise Guidelines*.

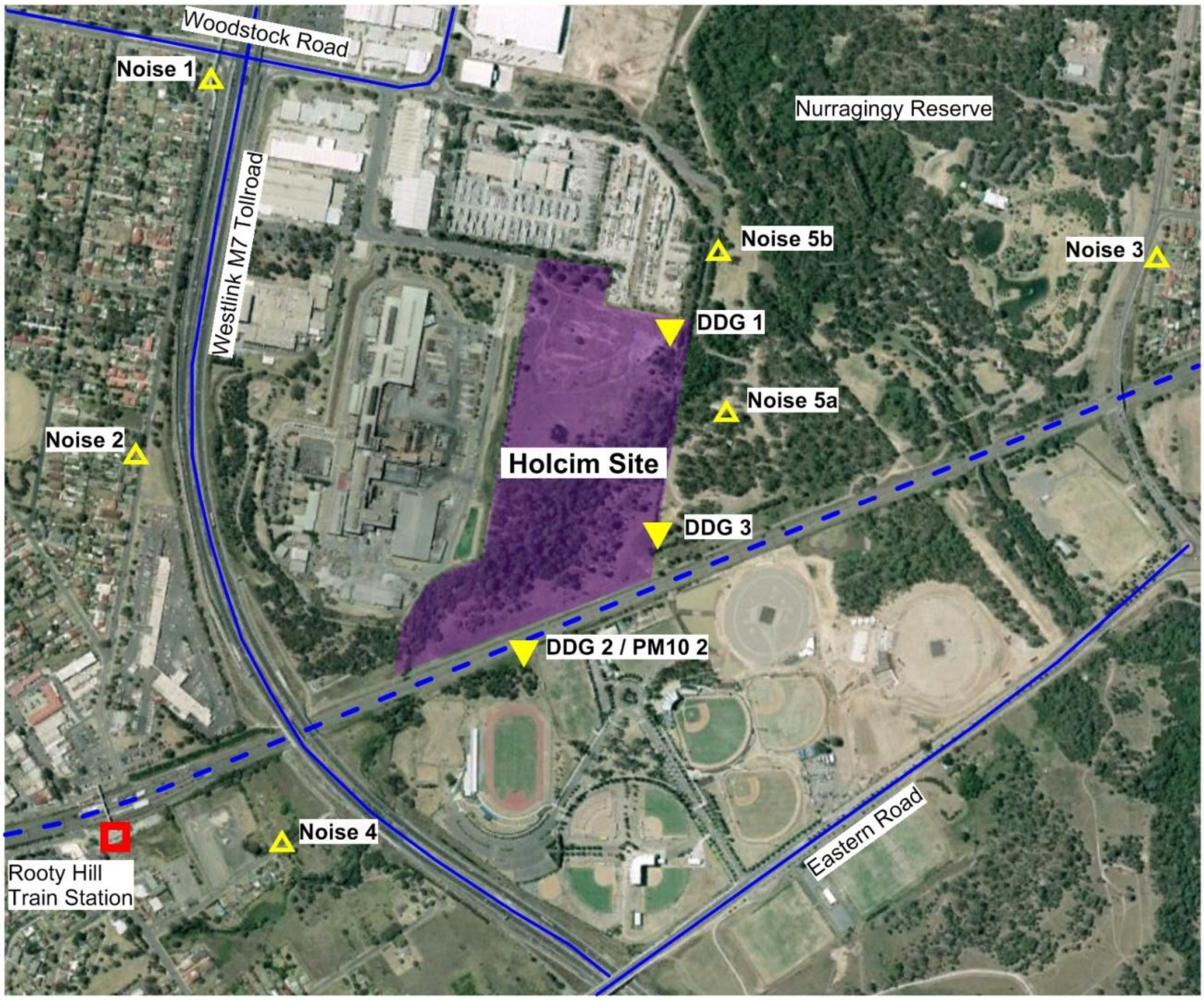
Monitoring was carried out using a Brűel and Kjær Type 1 2260 Sound Level Meter by appropriately qualified personnel. Calibration of the unit was checked before and after each monitoring period, and the drift was less than 0.5dB.

Monitoring locations are listed in Table 7-1 and are illustrated in Figure 7-1. Not all location with assessment criteria were used as monitoring locations. The monitoring locations selected are sufficient to demonstrate compliance with noise criteria in all locations. Assessment criteria are based on the requirements of the ICNG, Ministers Condition of Approval (MCoA) 2.2 and the measured background levels.

Table 7-1 Monitoring locations and assessment criteria

Receiver		**Receiver Type**	Approximate Distance and Orientation from RDC boundary	**NML $L_{Aeq,15min}$ dB(A)**
1	132 Station Street	Residential	650m west	58
2	54 Station Street	Residential	650m west	58
3	63 Coghlan Street	Residential	850m east	58
4	16 Mavis Street	Residential	650m west	63
5a	Lomandra Shelter Shed (Nurragingy Reserve)	Recreational	<100m east	60
5b	Boronia Shelter Shed (Nurragingy Reserve)	Recreational	<100m east	60

Figure 7-1 Noise monitoring locations



7.2 Monitoring results

Monitoring results for each location are summarised individually from Table 7-1 to Table 7-7.

Results and observations recorded for each monitoring period demonstrate that construction noise was rarely audible and did not contribute substantially to total noise levels measured at sensitive receiver locations. The existing noise environment is relatively noisy, with the M7 Motorway and other busy generating the majority of noise in the area.

At locations 1 – 4 and 5b, construction noise was consistently inaudible, with some distant reverse beepers recorded in February as the only audible construction source at receiver 4.

The exception to this was receiver 5a in Nurragingy Reserve where, for several months, construction noise was audible with sound pressure levels approximately equal to the noise criterion. However, the predominant noise source again was traffic.

Based on observations and recorded noise levels, traffic noise is the dominant noise source in the area and construction of the RDC is unlikely to result in adverse impacts on sensitive receivers.

Table 7-2 Summary of monthly monitoring – Location 1

Month	$L_{Aeq(15min)}$ sound pressure level, dB(A)			Observations
	NML	L_{Aeq}	L_{A90}	
Jan	58	54	45	Holcim inaudible, M7 (constant 55, Woodstock avenue traffic (frequent 55-65), local residential noise
Feb		57	53	Holcim inaudible, M7 (constant 60-65, Woodstock avenue traffic (frequent 50-60)
March		-	-	Monitoring not carried out due to lawn mowing which was being carried out at the monitoring location. Holcim inaudible
April		56	51	Holcim inaudible, M7 (constant 45-55), Woodstock avenue traffic (freq 50-55)
May		59	53	Holcim inaudible, M7 (constant 60-70), Woodstock avenue traffic (freq 50-60)
July		56	54	Holcim inaudible, M7 (constant 50-60), Woodstock avenue traffic (freq 50-60), wind (40-60)
August		57	55	Holcim inaudible, M7 (constant 50-60), Woodstock avenue traffic (freq 55-60)

Table 7-3 Summary of monthly monitoring – Location 2

Month	$L_{Aeq(15min)}$ sound pressure level, dB(A)			Observations
	NML	L_{Aeq}	L_{A90}	
Jan	58	57	53	Holcim inaudible, M7 (constant 50-60), local traffic (regular 60-80)
Feb		59	53	Holcim inaudible, M7 (constant 55-65), local traffic (regular 60-70)
March		58	55	Holcim inaudible, M7 (constant 55-60), local traffic (regular 60-65), One Steel reversing beepers, cicadas
April		55	51	Holcim inaudible, M7 (constant 50-60), local traffic (reg 55-60)
May		60	52	Holcim inaudible, M7 (constant 50-60), local traffic (reg 60-70)
July		57	54	Holcim inaudible, M7 (constant 50-60), wind (40-60), local traffic (60)
August		57	53	Holcim inaudible, M7 (constant 50-60), local traffic (60-65)

Table 7-4 Summary of monthly monitoring – Location 3

Month	$L_{Aeq(15min)}$ sound pressure level, dB(A)			Observations
	NML	L_{Aeq}	L_{A90}	
Jan	58	61	51	Holcim inaudible, Knox Rd traffic (constant 50-55, infrequent 63-67)
Feb		60	52	Holcim inaudible, Knox Rd traffic (constant 55-60), bridge construction (not measureable), residential noise / dog (infrequent 60-65)
March		59	49	Holcim inaudible, Knox Rd traffic (constant 55-70), bridge construction (55)
April		59	56	Holcim inaudible, Knox Rd traffic (constant 50-65)
May		61	53	Holcim inaudible, Knox Rd traffic (constant 50-65)
July		61	54	Holcim inaudible, Knox Rd traffic (constant 50-75), sports carnival at Knox Road oval
August		56	54	Holcim inaudible, Knox Rd traffic (constant 55-70)

Table 7-5 Summary of monthly monitoring – Location 4

Month	$L_{Aeq(15min)}$ sound pressure level, dB(A)			Observations
	NML	L_{Aeq}	L_{A90}	
Jan	63	56	51	Holcim inaudible, M7 (constant 55-60), occasional max to 65, birds, cicadas
Feb		57	51	Holcim occasional reversing beeper (not measureable), M7 (constant 55-60), birds, cicadas, frogs
March		55	53	Holcim inaudible, M7 (constant 50-60), birds
April		57	53	Holcim inaudible, M7 (constant 50-60), birds and frogs (40-60)
May		57	53	Holcim inaudible, M7 (constant 50-60), birds (60-70)
July		54	52	Holcim inaudible, M7 (constant 45-55), wind (40-50), train (70)
August		58	52	Holcim inaudible, M7 (constant 45-55)

Table 7-6 Summary of monthly monitoring – Location 5a

Month	$L_{Aeq(15min)}$ sound pressure level, dB(A)			Observations
	NML	L_{Aeq}	L_{A90}	
Jan	60	58	55	Holcim - excavator near SE corner (infrequent 50 LAeq, bucket bangs frequent 73 - 5 minutes only), train 60-65, Industrial area (continuous 40), construction on bridge Knox Rd (Not measureable), cicadas, birds
Feb		52	48	Holcim – pumps, occasional bucket bangs (45), Knox Rd traffic (55-60), cicadas (65)
March		50	46	Holcim – occasional beepers (Not measureable), single concrete truck passby (55) Knox Road construction (Not measureable), M7, Blacktown Sports Centre announcements
April		52	45	Holcim - continuous excavator loading (50-55), birds (50), occasional train (55-60), local traffic (60-70)
May		51	47	Holcim - continuous excavator loading (40-55), birds (50-60), occasional train (65-70), local traffic (60-70)
July		58	48	Holcim inaudible, occasional train (75), wind (35-55), local traffic (40-50), birds (50-55)
August		55	47	Holcim inaudible, infrequent local traffic (40-50), birds (50-55)

Table 7-7 Summary of monthly monitoring – Location 5b

Month	$L_{Aeq(15min)}$ sound pressure level, dB(A)			Observations
	NML	L_{Aeq}	L_{A90}	
Jan	60	54	45	Holcim inaudible, M7 (constant 55, Woodstock avenue traffic (frequent 55-65), local residential noise
Feb		57	53	Holcim inaudible, M7 (constant 60-65, Woodstock avenue traffic (frequent 50-60)
March		-	-	Monitoring not carried out due to lawn mowing which was being carried out at the monitoring location. Holcim inaudible
April		56	51	Holcim inaudible, M7 (constant 45-55), Woodstock avenue traffic (freq 50-55)
May		59	53	Holcim inaudible, M7 (constant 60-70), Woodstock avenue traffic (freq 50-60)
July		56	54	Holcim inaudible, M7 (constant 50-60), Woodstock avenue traffic (freq 50-60), wind (40-60)
August		57	55	Holcim inaudible, M7 (constant 50-60), Woodstock avenue traffic (freq 55-60)

8. Groundwater

Summary

Data collected in Spring 2012 and Autumn 2013 support the following conclusions in terms of groundwater quality:

- With exception of the TSS, groundwater monitoring undertaken in March 2013 indicated that the parameters assessed remain consistent with pre-construction baseline data collected in September 2012.
- The consistent EC and salinity levels reported across the site are likely to indicate high background salinity.
- TSS concentrations varied significantly across the site and between monitoring rounds.

  It is probable that the variation in TSS concentrations is not directly related to construction activities at the site, but more likely associated with residual fines which may be present within the gravel pack associated with well construction. The low yield of the monitoring wells has meant that significant volumes of water and fines could not be removed during well development. It is anticipated that the TSS levels will reduce with ongoing monitoring as more water and fines are removed from these wells during purging and sampling. The TSS results will be scrutinised during future monitoring rounds.

8.1 Methodology

Two rounds of the six-monthly groundwater monitoring were completed in September 2012 and March 2013 at four groundwater monitoring locations, GW1 - GW4, as illustrated in Figure 8-1.

The depth to water and total well depth were measured using a decontaminated multi-phase probe to record water levels and the presence of any non-aqueous phase liquids (NAPLs). No measurable indications of NAPL were recorded within any of the groundwater monitoring wells.

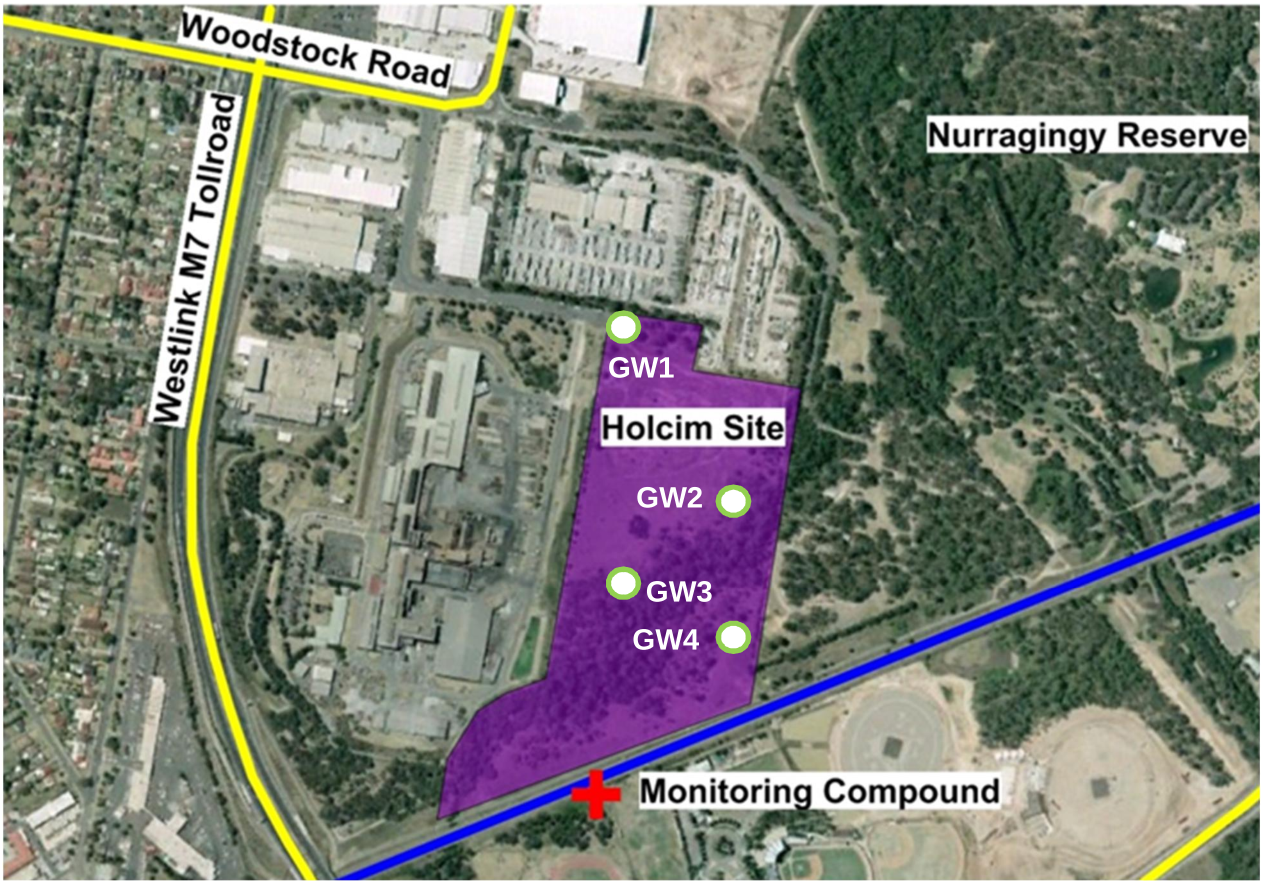
Monitoring wells were purged and sampled using dedicated disposable bailers. A Quanta Hydrolab water quality meter was used to measure the physico-chemical water quality parameters *in situ* including dissolved oxygen, total dissolved solids, conductivity, pH, redox, temperature and pH. Unfortunately, some water parameters were not able to be recorded in the autumn monitoring period for all four wells due to a fault with the water quality meter. The laboratory analysed these parameters.

Once each well had been purged (by removing three well volumes of water) groundwater was decanted into appropriately labelled sample containers provided by the laboratory. Following completion of sampling, all sample containers were transferred to ice chilled eskies for transport to the laboratory. All samples were received by the analytical laboratory in correctly preserved and chilled containers with no reported breakages.

Groundwater sample collection, handling and preservation were undertaken in accordance with documented Jacobs procedures, as summarised below:

- Label sample containers with unique sample identification, project details, date and sampling personnel.
- Collect groundwater samples using a single use/disposable bailer. New latex gloves were worn during the collection of each sample.
- Collect samples in laboratory supplied, pre-preserved containers. Samples were collected in the order of volatility to minimise the effects of oxygen on the water sampled. Samples for heavy metal analysis were filtered by the laboratory.
- Place samples in coolers containing ice.
- Seal coolers with custody seal at the conclusion of sampling.
- Complete record of samples collected and Chain of Custody (CoC) form.
- Transport samples to the analytical laboratory under CoC.

Figure 8-1 Groundwater monitoring locations



8.2 Analytical Plan

Groundwater samples were analysed by Envirolab Services using National Association of Testing Authorities (NATA) accredited methods. Groundwater samples were analysed for:

- Total Suspended Solids (TSS)
- Salinity
- Electrical Conductivity (EC)
- pH

8.3 Quality Assurance/Quality Control

All groundwater samples were collected by experienced environmental scientists in line with established protocols and all analysis undertaken by a NATA accredited laboratory using NATA accredited analytical methods. The laboratory quality control safeguards summarised in Table 8-1 were followed during sampling, transport and analysis.

Table 8-1 Quality control procedures for groundwater sampling

Parameter	Description
Laboratory Duplicates	Relative percentage differences (RPD) for laboratory duplicate samples conformed to the laboratory acceptance criteria.
Laboratory Control Samples	Recoveries for laboratory control samples conformed to the laboratory acceptance criteria.
Surrogates	Recoveries for laboratory surrogate samples conformed to the laboratory acceptance criteria.
Matrix Spikes	All matrix spike data conformed to the laboratory acceptance criteria.
Method Blanks	All method blanks reported analyte concentration below the laboratory level of reporting (LOR) and therefore conformed to the laboratory acceptance criteria.
Sample Holding Times	All samples were extracted and analysed within the specified holding times.

8.4 Results

8.4.1 *In situ* groundwater quality

In situ water quality parameters are summarised in Table 8-2. It is evident that there were no dramatic changes in groundwater depth between measurement periods. Unfortunately, trends in *in situ* results were not possible for most parameters. Trends are discussed for analytical results.

- **Table 8-2 - Summary of intrinsic groundwater quality**

Location	Date	Depth to Water (m)	Well Depth (m)	Dissolved Oxygen (% sat)	Electric Conductivity (µS/cm)	Salinity (mg/L)	Redox Potential (mV)	pH	Temp. (^{0}C)
GW01	14/09/12	6.61	9.59	47.2	22,523	16,040	86.6	6.78	18.6
	26/03/13	6.36	9.59	ND					
GW02	14/09/12	3.23	6.61	48.6	24,519	18,010	109.6	6.63	16.9
	26/03/13	3.24	6.61	ND					
GW03	14/09/12	3.30	9.60	38.7	23,206	16,640	33.8	6.65	17.6
	26/03/13	3.35	9.60	ND					
GW04	14/09/12	2.83	7.67	43	21,797	16,390	97.1	6.57	15.4
	26/03/13	3.2	7.67	ND					

ND - Intrinsic water quality parameters not recorded during this monitoring event due to a fault with the water quality meter.

8.4.2 Analytical results

Groundwater samples analysed by the laboratory are summarised in Table 8-3. Salinity values were consistent within the wells across the site as measured both in the field and in the laboratory. Salinity concentrations ranged between 16 and 18 g/L.

EC values were relatively consistent across the site as measured both in the field and in the laboratory, ranging between 22,000 µS/cm and 27,000 µS/cm.

TSS concentrations varied spatially and temporally, with 37,000 mg/L and 160 mg/L reported in GW01 between September and March. Increases were observed in GW02 and GW04, while a reduction was recorded in GW03. This may be a result of sampling techniques, well recharge rates and well construction. In future sampling, it is likely that TSS will reduce as fines associated with the gravel pack used in construction are flushed through the system. TSS will be scrutinised in future sampling.

- **Table 8-3 - Analytical Results (unless stated all results expressed as mg/L)**

Location	Date	TSS (@103-105c)	Salinity (mg/L)	Electrical conductivity (µS/cm)	pH*
GW01	14/09/12	37,000	16,000	24,000	
	26/03/13	160	16,000	24,000	6.8
GW02	14/09/12	5,300	17,000	27,000	
	26/03/13	13,000	12,000	18,000	6.9
GW03	14/09/12	13,000	16,000	25,000	
	26/03/13	7,200	14,000	22,000	6.8
GW04	14/09/12	2,000	16,000	25,000	
	26/03/13	38,000	16,000	26,000	6.9

* Analysis of pH performed by lab in lieu of successful *in situ* measurement