Holcim (Australia) Pty Limited

Lynwood Quarry
Groundwater Monitoring Program
Revision 2

June 2011

Umwelt
Environmental Consultants

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Groundwater Monitoring Program
Revision 2

Prepared by

Umwelt (Australia) Pty Limited

on behalf of

Holcim (Australia) Pty Limited

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Report No.	2238/R25/Final	Date:	June 2011

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1.0 Scope

This Groundwater Monitoring Program outlines the groundwater monitoring required to be undertaken by Holcim (Australia) Pty Limited (Holcim) to ensure compliance with statutory requirements at Lynwood Quarry. The program addresses the requirements contained in Lynwood Quarry's Development Consent (DA-128-5-2005).

The Groundwater Monitoring Program is included as part of the Water Management Plan for Lynwood Quarry, in accordance with *Part d* of Condition 20, Schedule 3 of the Lynwood Quarry Development Consent. This is the second revision of the monitoring program. Revision one of the Groundwater Monitoring Program was prepared in consultation with the Department of Planning and Infrastructure (DP&I), NSW Office of Water (NOW), NSW Office of Environment and Heritage (OEH) and the Sydney Catchment Authority, and was approved by the Director-General on 31 August 2007.

Condition 24, Schedule 3 of the Development Consent specifies the requirements for the Groundwater Monitoring Program. These requirements are summarised in **Table 1.1** below.

Table 1.1 - DA-128-5-2005 Condition 24 - Requirements for the Groundwater Monitoring Program

Condition	Requirements	Relevant Section of Program
24.	***The Groundwater Monitoring Program shall include:***	
24a)	*detailed baseline data on groundwater levels, flows, and quality, based on statistical analysis*	**Section 2.0**
24b)	*groundwater impact assessment criteria for monitoring bores*	**Section 3.0**
24c)	*a program to monitor regional groundwater levels and quality*	**Section 4.0**
24d)	*a protocol for the investigation of identified exceedances of the groundwater impact assessment criteria*	**Section 5.0**

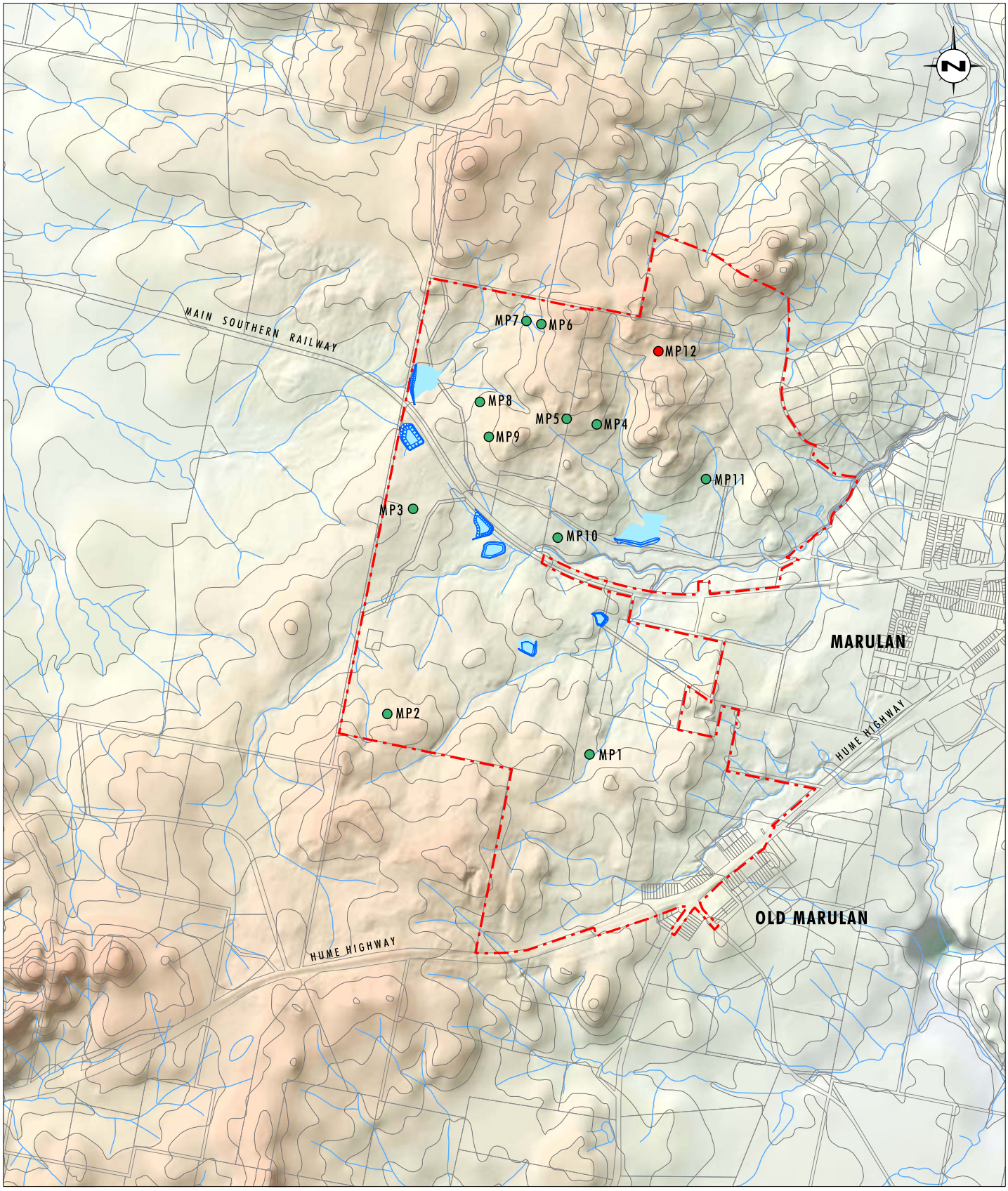
Note: The groundwater monitoring program must be consistent with the current version of Approved Methods for the Sampling and analysis of Water Pollutants in New South Wales (DEC).

2.0 Baseline Data

Holcim (formerly Readymix Holdings Pty Limited) established a groundwater monitoring program in the project area in 2004 to provide baseline groundwater data, with a network of 11 piezometers installed (refer to **Figure 2.1**). The piezometers have been tested quarterly for water quality and monthly for groundwater level (refer to Figure A1 of **Appendix A**).

Construction of Lynwood Quarry commenced on site in November 2010. However, as no works to date have intercepted groundwater the full data set has been used in the baseline data analysis.

Consent Condition 24 a) of DA 128-5-2005 requires that this Program include detailed baseline data on groundwater levels, flows and quality, based on statistical analysis. This baseline data is analysed and described in **Sections 2.1** to **2.3** below.



Base Source: LPI 2004

0 0.5 1 1.5km
1:36 000

Legend

- Project Area
- Groundwater Monitoring Location
- Approximate Future Monitoring Location

FIGURE 2.1

Groundwater Monitoring Locations

2.1 Groundwater Levels

Groundwater levels have been monitored in all piezometers approximately monthly since July 2004. Hydrographs of bore water levels are shown in Figure A1 of **Appendix A**. Most bores have shown a fluctuation in water level over a one metre to two metre range throughout the monitoring period. The historical raw monitoring data has been found to have some anomalies in the data set for bores MP-5, MP-9 and MP-11 which are believed to be a result of monitoring practice (Holcim has commenced a process of reviewing the monitoring practice for these bores). These points have been removed in the data presented in **Appendix A**. As described in **Section 4.0**, rainfall data will be recorded during monitoring to allow consideration during assessment of groundwater fluctuations.

The water table is generally well below the ground surface (refer to Figure A1 of **Appendix A**). MP-1 recorded the water level closest to the surface, with a depth of 2.1 metres recorded in August 2004, November 2005 and February 2008. MP-5 recorded the water level furthest from the ground surface with the level measured at 33.2 metres below the surface in October 2005.

2.2 Groundwater Flows

The groundwater contours on **Figure 2.2** are based on groundwater levels measured in all bores on 2 July 2004. Groundwater monitoring results from July 2004 to July 2010 indicate that minor fluctuations in groundwater levels have occurred in that period (refer to **Section 2.1**). The groundwater contours are generally sympathetic to the topography, with the highest water table elevations being recorded in the elevated regions near the northern and southern boundaries of the project area, and the lowest in the central zone close to Joarimin Creek. Groundwater flows southwards or northwards towards the vicinity of Joarimin Creek, then flows eastwards in the same general direction as surface flow.

2.3 Groundwater Quality

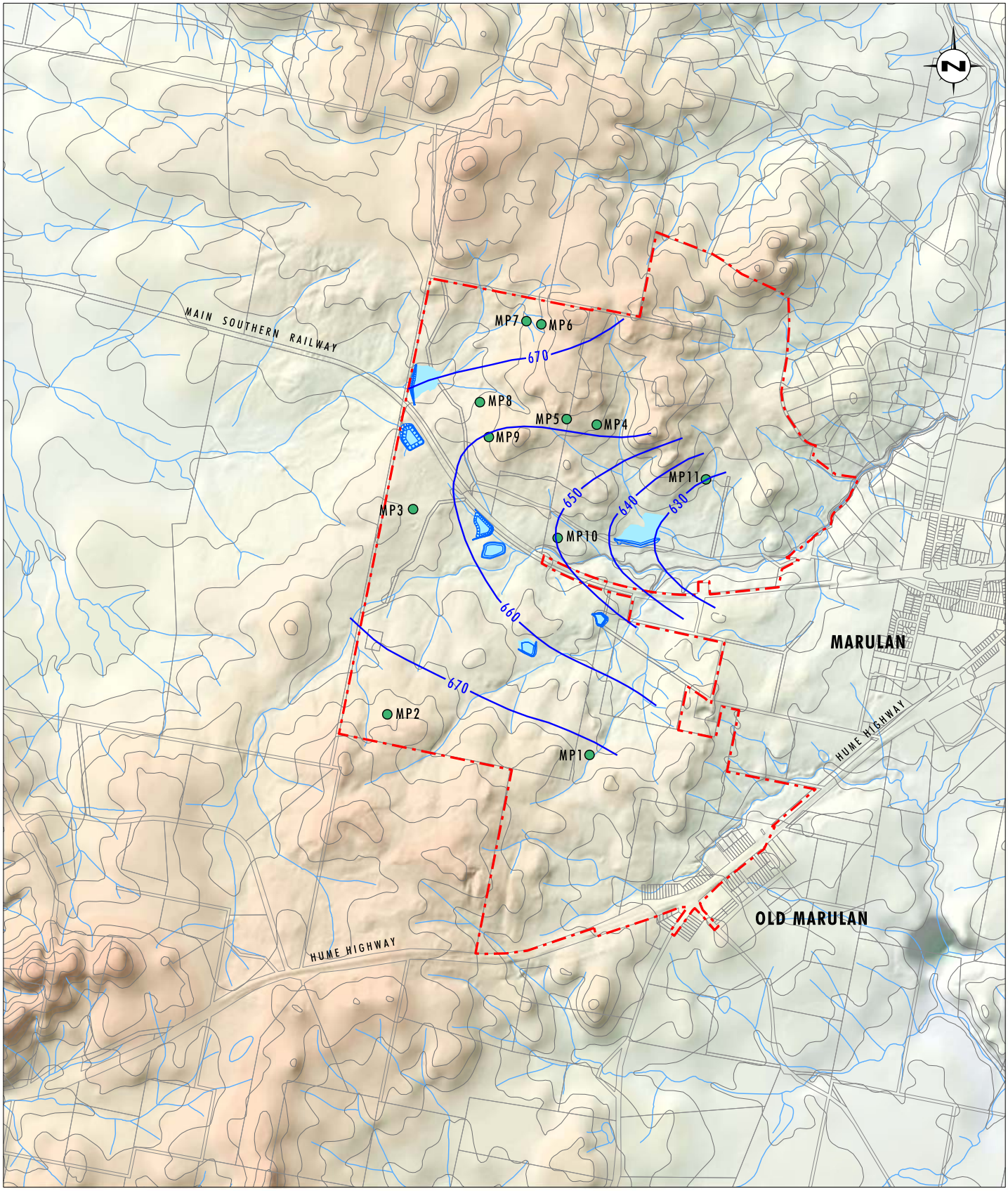
Baseline groundwater quality in the area has been established by quarterly water quality sampling of the 11 piezometers (refer to **Figure 2.1**).

Five different water quality aspects of groundwater have been monitored:

- electrical conductivity (refer to **Section 2.3.1**);
- pH (refer to **Section 2.3.2**);
- trace elements (refer to **Section 2.3.3**);
- nutrients (refer to **Section 2.3.4**); and
- total petroleum hydrocarbons (refer to **Section 2.3.5**).

The baseline data for each of these groundwater quality aspects is discussed in **Sections 2.3.1** to **Section 2.3.5**.

Each of the groundwater quality parameters has been compared to Australian and New Zealand Environment and Conversation Council (ANZECC) Guidelines (2000) and to the National Health and Medical Research Council (NHMRC) Guidelines (2004). ANZECC Guidelines (2000) were chosen using values for slightly disturbed Freshwater Ecosystems in



Base Source: LPI 2004, Groundwater Contours: Peter Dundon & Associates Pty Limited 2005

0 0.5 1 1.5km
1:36 000

Legend

- Project Area
- Groundwater Monitoring Location
- Groundwater Contour (mAHD)

FIGURE 2.2

Groundwater Contours

upland rivers in NSW to represent the moderately disturbed condition of the existing surface water system within the project area (i.e. the system into which groundwater contributes to base flows) as these are the default, low-risk trigger values recommended by ANZECC (2000).

2.3.1 Electrical Conductivity

The ranges electrical conductivity for the monitoring piezometers from July 2004 to April 2011 are outlined in Table B1 of **Appendix B.** The monitoring results indicate that groundwater electrical conductivity (EC) is quite variable across the project area. Measured EC ranges from 489 µS/cm (MP-2 in April 2011) to 11,521 µS/cm (MP-3 in October 2004). **Table 2.1** shows the statistics for the EC results for the monitoring piezometers from July 2004 to April 2011.

Table 2.1 - Groundwater Monitoring Summary for Electrical Conductivity

Water Quality Parameter	Minimum Concentration	10th percentile Concentration	Average Concentration	90th percentile Concentration	Maximum Concentration
EC (µS/cm)	489	603	3,844	10,488	11,521

This high degree of variability in EC is considered to indicate a generally low hydraulic conductivity and poor lateral continuity within the bedrock formation.

The EC monitoring results have been compared with ANZECC Guidelines (2000) as outlined in **Table 2.2**.

Table 2.2 - ANZECC Guideline Values for Electrical Conductivity (µS/cm)

Guideline	Minimum	Maximum
ANZECC	30	350

Source: ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

All samples at all the monitoring locations had recorded EC values higher than the ANZECC value (refer to **Table 2.2**).

2.3.2 pH

The ranges for pH for the monitoring piezometers from July 2004 to April 2011 are outlined in Table B1 **of Appendix B**. Generally the groundwater had near neutral pH, with values ranging from 4.2 (MP-3 in February 2009) to 9.5 (MP-10 in April 2006), and the average over all bores being 6.6 (refer to **Table 2.3**). **Table 2.3** summarises a statistical analysis for pH for the monitoring piezometers from July 2004 to April 2011.

Table 2.3 - Groundwater Monitoring Summary for pH

Water Quality Parameter	Minimum Concentration	10th percentile Concentration	Average Concentration	90th percentile Concentration	Maximum Concentration
pH	4.2	6.1	6.6	7.3	9.5

The measurements taken were compared with ANZECC Guidelines (2000) and NHMRC Guidelines (2004) as outlined in **Table 2.4**.

Table 2.4 - ANZECC and NHMRC Guideline Values for pH

Guideline	Guideline Value	
ANZECC	Lower limit	Upper Limit
	6.5	7.5
NHMRC	6.5	8.5

Sources: ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. NHMRC (2004) Australian Drinking Water Guidelines

Most of the monitoring locations recorded pH values outside the limits of ANZECC Guidelines, with 1 sample of pH 9.5 at MP-10 in April 2006 exceeding the upper limit for the NHMRC guideline and 106 samples recording pH values below the lower limit.

2.3.3 Trace Elements

Baseline monitoring has also included analysis of dissolved trace element concentrations. The monitoring result ranges for dissolved trace elements for the monitoring piezometers from July 2004 to April 2011 are outlined below in Table C1 of **Appendix C**. Table C2 of **Appendix C** includes a statistical analysis of the range of results for dissolved metals.

The results for dissolved trace elements have been compared with ANZECC guideline values for freshwater ecosystem protection and NHMRC Guidelines (2004) and are outlined in Table C2 of **Appendix C**. The analysis indicates that the majority of piezometers recorded concentrations that comply with ANZECC and NHMRC guidelines, however, some elevated concentrations were recorded as discussed below:

- several piezometers recorded aluminium concentrations in exceedance of ANZECC guidelines, but only MP-9 exceeded the NHMRC Guidelines;
- all piezometer locations recorded chromium and zinc concentrations in excess of ANZECC guidelines, however all were below the NHMRC Guidelines;
- nickel concentrations were recorded at levels in excess of NHMRC guideline concentrations in all piezometers, with some also exceeding the ANZECC guidelines;
- lead concentrations exceeded the ANZECC guideline at MP-5, MP-6 and MP-9. MP-5 and MP-6 recorded lead concentrations that also exceeded the NHMRC guideline;
- piezometers MP-5 and MP-10 recorded cadmium concentrations in exceedance of both the ANZECC and NHMRC guidelines;
- manganese was recorded at levels in excess of NHMRC guidelines in all piezometers; and
- copper was recorded in excess of ANZECC guidelines in all piezometers.

2.3.4 Nutrients

The ranges for nutrients (including sulphate, nitrate and phosphate concentrations measured in mg/L) for the monitoring piezometers from July 2004 to April 2011 are outlined in Table B1 of **Appendix B**. Monitoring results indicate that nitrate levels throughout the project area are

consistently very low, with only one piezometer exceeding the limit of reading for the analysis. Measured nitrate values ranged from <0.01 mg/L to 0.04 mg/L.

Sulphate levels throughout the project area vary considerably (refer to Table B1 of **Appendix B**). Measured sulphate concentrations ranged from 1.2 mg/L to 110 mg/L.

The monitoring results indicate that phosphate levels vary significantly throughout the project area (refer to Table B1 of **Appendix B**), with measured phosphate values ranging from 0.01 mg/L to 1.23 mg/L).

Table 2.5 summarises the statistical range for nutrients for the monitoring piezometers from July 2004 to April 2011.

Table 2.5 - Groundwater Monitoring Summary for Nutrients (mg/L)

Water Quality Parameter	Minimum Concentration	10th percentile Concentration	Average Concentration	90th percentile Concentration	Maximum Concentration
Sulphate	<1.2	8.9	27.0	49.7	110.0
Nitrate	<0.01	0.10	0.15	0.20	0.30
Phosphate	0.01	0.03	0.09	0.20	1.23

The variability in sulphate measurements indicates high variability in nutrient activity around the project area.

The measurements taken were compared with ANZECC Guidelines (2000) and NHMRC Guidelines (2004) as outlined in **Table 2.6**.

Table 2.6 - ANZECC and NHMRC Guideline Values for Nutrients (mg/L)

Guideline	Guideline for Nitrate	Guideline for Sulphate	Guideline for Phosphate
ANZECC	0.7	#	0.015
NHMRC	50	500	#

#No guideline listed

Source: ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. NHMRC (2004) Australian Drinking Water Guidelines

All monitoring locations complied with the ANZECC (2000) and NHMRC (2004) guidelines for nitrate (refer to Table B1 of **Appendix B**). No guideline was listed for sulphate values for ANZECC (2000) however all sites recorded sulphate concentrations significantly lower than the NHMRC (2004) guideline for sulphate (refer to Table B1 of **Appendix B**). All sites recorded phosphate levels in exceedance of the ANZECC (2000) guideline (refer to Table B1 of **Appendix B**).

2.3.5 Total Petroleum Hydrocarbons

The following Total Petroleum Hydrocarbons (TPH) have been monitored as part of the baseline groundwater monitoring:

- C6-9;
- C10-14;

- C15-28;
- C29-36;
- Benzene;
- Toluene;
- Ethyl Benzene; and
- Xylene.

The ranges for TPH for the monitoring piezometers from July 2004 to April 2011 are outlined in Table B2 of **Appendix B**. **Table 2.7** summarises the statistical range of results for TPH. Samples were analysed for TPH and the concentrations compared with ANZECC (2000) and NHMRC Guidelines (2004) as outlined in **Table 2.7**.

Table 2.7 - Groundwater Monitoring Summary for Total Petroleum Hydrocarbons (µg/L)

TPH	Minimum Concentration	10th percentile Concentration	Average Concentration	90th percentile Concentration	Maximum Concentration	ANZECC Guideline Values	NHMRC Guideline Values
C6-9	20.0	25.0	25.8	25.0	90.0	-	-
C10-14	25.0	25.0	68.8	52.5	5870.0	-	-
C15-28	25.0	100.0	183.5	300.0	6450.0	-	-
C29-36	50.0	100.0	126.4	100.0	3220.0	-	-
Benzene	1.0	1.0	1.1	1.0	21.0	950	1
Toluene	1.0	1.0	1.7	1.0	52.0	-	800
Ethyl Benzene	1.0	1.0	1.0	1.0	2.0	-	300
Xylene	1.0	2.0	2.0	2.0	2.4	o-Xylene: 350 p-Xylene: 200	600

Source: ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. NHMRC (2004) Australian Drinking Water Guidelines

Analysis of the TPH monitoring results indicates that all piezometers recorded TPH concentrations that comply with ANZECC and NHMRC guideline values (Note: the limit of analysis for Benzene was above the NHMRC guidelines but complied with ANZECC guidelines).

3.0 Groundwater Impact Assessment Criteria

The baseline groundwater monitoring program has indicated that the baseline concentrations of the various water quality parameters throughout the project area are in exceedance of ANZECC guidelines. Salinity and dissolved metals concentrations exceed ANZECC values at many monitoring locations, and phosphate concentrations at all monitoring locations. This indicates that the groundwater throughout the monitoring area has naturally high background concentrations of the water quality parameters investigated, and that consideration of baseline concentrations is necessary to appropriately assess groundwater quality impacts.

As such, the baseline values to be used in monitoring of groundwater at Lynwood Quarry have been determined from the range of baseline data available to date. The key parameters to be assessed to indicate any potential negative impacts on groundwater quality include pH, electrical conductivity and dissolved iron.

Where ongoing monitoring during the operation of the quarry indicates that the water quality is varying significantly from the baseline trends identified through baseline monitoring, the Environmental Officer will trigger an investigation to identify the cause of the exceedance as discussed in **Section 5.0**.

The other key groundwater parameter to be measured is groundwater level. Monitoring of groundwater levels will involve continuing to measure depth to groundwater and comparing these values to the drawdown predictions outlined in the Groundwater Impact Assessment contained in the Lynwood Quarry EIS (Umwelt, 2005). If the results of this monitoring indicate that changes in water levels deviate significantly from the trends predicted, an investigation of potential cause shall be undertaken. Should an investigation be required it will be triggered by the Environmental Officer as discussed in **Section 5.0**. If required, corrective action will be undertaken in accordance with **Section 8.2**.

4.0 Program to Monitor Regional Groundwater Levels and Quality

Monitoring of groundwater piezometers will be continued throughout the life of the project, with water levels in all piezometers measured on a three monthly basis and water samples from all piezometers tested for groundwater quality for a wide suite of parameters on a six monthly basis. The parameters to be monitored as part of the six monthly groundwater testing are outlined in Table D1 of **Appendix D**. Rainfall data will be collected on site, and will be considered during analysis of groundwater fluctuations.

As the quarry pit progresses, a number of existing piezometers will be removed and a replacement piezometer will be established near the north-eastern boundary of the project area. Replacement piezometers will be installed 12 months before decommissioning of the piezometer that is being replaced.

5.0 Investigation Protocol

If water quality monitoring results are outside of the pre-quarrying range on four consecutive occasions, an investigation will be undertaken to determine if operations at Lynwood Quarry are the cause of this trend. The investigation will be triggered by the Environmental Officer and will be undertaken by an appropriately qualified hydrogeologist. The investigation will include an analysis of the following variables to identify potential causes of adverse trends:

- climate (including rainfall);
- changes to project operations (e.g. quarrying areas, equipment etc.); and
- changes in geology of the area being quarried.

The investigation may include more frequent monitoring to determine the cause of the adverse trend. If required, this additional monitoring it will be undertaken for a period determined by the hydrogeologist.

The findings of the investigation will be reported in the Annual Environmental Management Report.

Should the comparison of groundwater level monitoring results to predicted drawdowns contained in the EIS (Umwelt, 2005) identify impacts greater than predicted, an investigation will be triggered. The investigation will be triggered by the Environmental Officer and will be undertaken by an appropriately qualified hydrogeologist to determine if the impacts are due to operations at Lynwood Quarry and if so, is there any potential for impacts on private bores. If the investigation identifies that Lynwood Quarry may be the source of the impacts, a program of regional monitoring will be implemented for a period of three months to determine impacts on regional groundwater levels and quality. More regular monitoring will be undertaken if recommended by the hydrogeologist. The findings of the above investigations will be reported in the Annual Environmental Management Report.

Remedial action will be required if, following the investigation, it is found that the monitoring results indicate that the negative trend is occurring due to failure or ineffectiveness of the site environmental management strategies. If required, corrective action will be undertaken in accordance with **Section 8.2**.

6.0 Monitoring Standards

Groundwater monitoring at Lynwood Quarry will be undertaken in accordance with relevant Australian Standards, legislation and NSW OEH approved methods for sampling. The Australian Standards and OEH approved methods relevant to the Groundwater Monitoring Program are listed below:

- NSW DEC, 2004, Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales.
- AS/NZS 5667.1:1998 Water Quality – Sampling – Guidance on the Design of Sampling Programs, Sampling Techniques, and the Preservation and Handling of Samples.
- AS/NZS 5667.11:1998 Water Quality - Sampling - Guidance on Sampling of Groundwaters.

7.0 Reporting and Review of Results

Monitoring results will be reviewed on a quarterly basis by the Lynwood Quarry Environmental Officer to assess compliance with limits outlined in **Section 2.0**. Should any exceedances of the limits be identified the Environmental Officer will report the exceedance to the DP&I, OEH and any other relevant agencies within seven days. Monitoring results will also be reported as required in the Annual Environmental Management Report (AEMR) and, as required, in the EPL Annual Return.

All groundwater monitoring results will be made publicly available on the Lynwood Quarry website in accordance with Schedule 5, Condition 12 of the Development Consent. Holcim will update these results on a quarterly basis.

7.1 Complaints Response

In accordance with the Environmental Management Strategy, the Environmental Officer will maintain a centralised location to record communication records with relevant external stakeholders.

As described in the Environmental Management Strategy, Lynwood Quarry will utilise a Community Contact Line, which will be maintained and advertised regularly for the duration of the project. Complaints including those related to groundwater will be recorded and investigated by the Environmental Officer. All other complaints, via letter, in person or by fax, will also be recorded and investigated by the Environmental Officer. The Environmental Officer will ensure that complaints are responded to in a timely and efficient manner.

Follow up correspondence with the complainant will be made explaining the outcome of complaint investigations.

7.2 Corrective Action

Table 7.1 summarises the potential groundwater related issues that may arise and the appropriate corrective action to be taken.

Table 7.1 - Corrective Actions

Problem	Corrective Action
Exceedance of Development Consent conditions for groundwater criteria	Investigation of exceedance, undertaking mitigating measures where applicable. Report exceedance to DP&I and senior management, as required.
Community complaints	Investigation of complaint, undertaking mitigating measures where applicable and provide feedback to complainant. Report complaint to senior management. Provide feedback to quarry planning and production personnel, where relevant.

8.0 Responsibility

The Lynwood Quarry Environmental Officer will be responsible for managing the Groundwater Monitoring Program. This duty includes assessing Lynwood Quarry's compliance with the conditions listed in the Development Consent.

If a contractor is engaged to undertake groundwater monitoring on behalf of Holcim, all monitoring undertaken by the contractor must be in accordance with this Groundwater Monitoring Program and all relevant monitoring standards (as outlined in **Section 6.0**).

9.0 Program Review

The Environmental Officer shall review this program annually or more often as the need arises. If any significant changes to the program are required as an outcome of the review, NOW, OEH and the Sydney Catchment Authority will be consulted and the revised program submitted to the DP&I for approval. If any significant changes to the program are required as an outcome of the review, the OEH and NOW will be consulted and the revised program submitted to the DP&I.

10.0 References

Australian and New Zealand Environment and Conservation Council (2000), *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*.

Umwelt (2005), *Environmental Impact Statement Readymix Holdings Pty Ltd Proposed Lynwood Quarry, Marulan.*

National Health and Medical Research Council (2004), *Australian Drinking Water Guidelines*.

APPENDIX A

Groundwater Levels

APPENDIX A

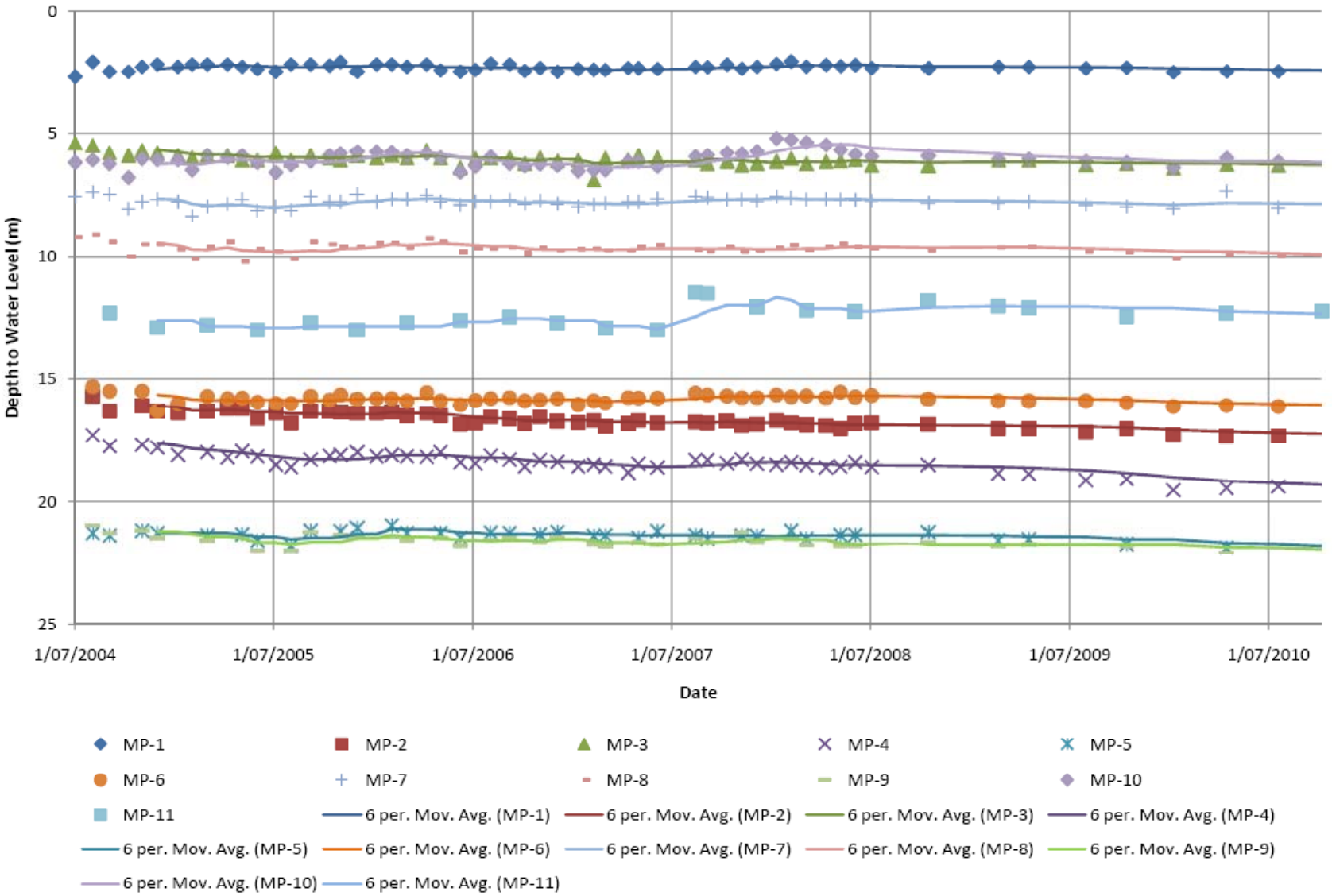


Figure A1 - Groundwater Hydrographs for the Sampling Period

APPENDIX B

Groundwater Monitoring Results for Water Quality and Total Petroleum Hydrocarbons

APPENDIX B

Table B1 - Ranges for Selected Water Quality Parameters

Monitoring Piezometer	pH	Conductivity µS/cm	Iron mg/L	Sulphate mg/L	Nitrate mg/L	Total Phosphate mg/L
MP-1	6.4 - 7.2	1057 - 10930	0.09 - 5.3	18 - 29	<0.01 - <0.2	0.07 - 0.29
MP-2	5.8 - 6.5	1008 - 10780	1.6 - 26	11 - 40	<0.01 - <0.2	0.02 - 0.33
MP-3	6.3 - 7.2	10388 - 11521	0.13 - 3.5	50 - 110	<0.01 - <0.3	0.02 - 0.08
MP-4	6.4 - 7.2	496 - 561	0.15 - 1.1	5.9 - 17	<0.01 - <0.2	0.04 - 0.17
MP-5	6.9 - 7.9	601 - 11410	0.65 - 5.1	4 - 4	<0.01 - <0.2	0.15 - 0.66
MP-6	6.9 - 7.8	2499 - 4670	0.33 - 2.45	1.6 - 24	<0.01 - <0.2	0.02 - 0.11
MP-7	6.5 - 7.3	5560 - 6320	0.37 - 11	19 - 31	<0.01 - <0.2	0.01 - 0.07
MP-8	6.3 - 7.0	2900 - 4471	0.93 - 11.2	14 - 38	<0.01 - <0.2	0.03 - 0.08
MP-9	6.8 - 7.8	742 - 3653	0.27 - 9.2	3 - 13	<0.01 - <0.2	0.05 - 0.49
MP-10	6.4 - 9.5	6120 - 7210	0.04 - 2.4	22 - 68	<0.01 - <0.2	0.02 - 1.23
MP-11	7.1 - 7.8	610 - 766	0.02 - 2.4	1.2 - 35	0.04 - <0.2	0.03 - 0.13

Table B2 – Ranges for Total Petroleum Hydrocarbons (µg/L)

Monitoring Piezometer	C6-C9	C10-C14	C15-C28	C29-C36	Benzene	Toluene	Ethyl Benzer	Xylene
MP-1	<20 - <25	<25 - 38	<100 - 350	<50 - 400	<1 - <1	<1 - 2	<1 - <2	<1 - <2
MP-2	<25 - 26	<25 - 34	<100 - 130	<50 - 100	<1 - <1	<1 - 12	<1 - <2	<2 - <2
MP-3	<21 - <25	<25 - 140	<100 - 640	<50 - 2600	<1 - <1	<1 - 11	<1 - <2	<2 - <2
MP-4	<25 - <25	<25 - 53	<100 - 300	<50 - 100	<1 - <2	<1 - 10	<1 - <2	<2 - <2
MP-5	<25 - 70	<25 - 180	<100 - 1550	<100 - 100	<1 - <1	<1 - 45	<1 - <2	<2 - <2
MP-6	<20 - 60	<25 - 568	<100 - 1300	<100 - 294	<1 - 21	<1 - 3	<1 - <2	<2 - <2
MP-7	<20 - <25	<25 - 63	<100 - 330	<50 - 100	<1 - <1	<1 - <2	<1 - <2	<2 - <2
MP-8	<20 - <25	<25 - 280	<25 - 170	<50 - 100	<1 - <1	<1 - 4	<1 - <2	<2 - <2
MP-9	<25 - 90	<25 - 5870	<100 - 6450	<100 - 3220	<1 - <1	<1 - 52	<1 - <2	<1 - 2.4
MP-10	<25 - 51	<25 - 114	<100 - 532	<100 - 206	<1 - <1	<1 - 28	<1 - <2	<2 - <2
MP-11	<25 - 33	<25 - 360	<100 - 1430	<100 - 420	<1 - <1	<1 - 22	<1 - <2	<2 - <2

APPENDIX C

Groundwater Monitoring Results for Dissolved Metals

APPENDIX C

Table C1 - Ranges for Dissolved Metals and Comparison with ANZECC Guidelines

Analyte	ANZECC Guideline	Monitoring Piezometer										
		MP-1	MP-2	MP-3	MP-4	MP-5	MP-6	MP-7	MP-8	MP-9	MP-10	MP-11
Arsenic (µg/L)	13	<1 - 5	<1 - 2	<1 - 10	<1 - 3	<1 - 4	<1 - 5	<1 - 7	<1 - 4	<1 - 3	<1 - 7	<1 - 3
Selenium (µg/L)	5	<1 - <10	<1 - <10	<1 - <10	<1 - <10	<1 - <10	<1 - <10	<1 - <10	<1 - <10	<1 - <10	<1 - <10	<1 - <10
Silver (µg/L)	0.05	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1
Aluminium (µg/L)	55	5 - 10	5 - 43	5 - 13	5 - 12	5 - **90**	5 - **120**	5 - 15	5 - 10	5 - **1200**	5 - **78**	5 - 24
Barium (µg/L)	-	180 - 240	79 - 180	280 - 390	100 - 130	67 - 310	18 - 59	350 - 460	280 - 450	46 - 250	240 - 460	200 - 650
Berylium (µg/L)	-	<0.1 - 0.4	<0.1 - 0.7	<0.1 - 0.3	<0.1 - 0.8	<0.1 - 0.1	<0.1 - 0.1	<0.1 - 0.4	<0.1 - 0.2	<0.1 - 0.1	<0.1 - 0.2	<0.1 - 0.1
Cadmium (µg/L)	0.2	<0.05 - 0.24	<0.05 - **0.4**	<0.05 - **1**	<0.05 - 0.2	<0.05 - **5**	<0.05 - 0.1	<0.05 - 0.1	<0.05 - 0.1	<0.05 - 0.**34**	<0.05 - **5.1**	<0.05 - 0.2
Cobalt (µg/L)	-	<0.2 - 0.8	<5 - 11	<0.8 - 19	<0.4 - 1.1	<0.8 - 3.4	<0.5 - 1.1	<1 - 2.9	<0.8 - 2.5	<0.3 - 1.5	<1.1 - 4.7	<0.2 - 3.4
Chromium (µg/L)	1	<1 - **8**	<1 - **5**	<1 - **22**	<1 - **10**	<1 - **7**	<1 - **24**	<1 - **31**	<1 - **16**	<2 - **22**	<1 - **33**	<1 - **10**
Copper (µg/L)	1.4	<0.5 - **3.5**	<0.5 - **3.8**	<1.1 - **5.5**	<0.5 - **2.1**	<0.5 - **4.2**	<0.5 - **3.7**	<0.8 - **32**	<0.5 - **2.3**	<0.5 - **11**	<0.7 - **5.9**	<0.5 - **5**
Manganese (µg/L)	1900	490 - 908	1200 - **4000**	1600 - **5600**	243 - 620	470 - 1400	280 - 810	**2800 - 3900**	1000 - 1600	155 - **2800**	1300 - **2300**	390 - **2200**
Molybdenum (µg/L)	-	<0.5 - 0.7	<0.5 - 2.9	<0.5 - 12	<0.5 - 4.8	<3.5 - 89	<0.5 - 14	<0.5 - 2.6	<0.5 - 3.5	<0.8 - 810	<0.5 - 8.1	<1.4 - 34
Nickel (µg/L)	11	<1 - 3	<1 - **20**	<6 - **35**	<1 - 3	<1 - 10	<1 - **25**	<1 - **32**	<1 - 9	<1 - 10	<1 - **40**	<1 - **44**
Lead (µg/L)	3.4	<0.05 - 1	<0.05 - 1	<0.05 - 1	<0.05 - 1.1	<0.05 - **11**	<0.05 - **13**	<0.05 - 1	<0.05 - 1	<0.05 - **8.5**	<0.05 - 1.5	<0.05 - 2.1
Antimony (µg/L)	-	<3 - 3	<3 - 3	<3 - 7	<3 - 3	<3 - 3	<3 - 3	<3 - 3	<3 - 3	<3 - 3	<3 - 3	<3 - 3
Zinc (µg/L)	8	<5 - **53**	<5 - **380**	<7 - **85**	<5 - **40**	<9 - **69**	<5 - **85**	<5 - **88**	<5 - **54**	<10 - **85**	<5 - **90**	<5 - **164**
Boron (µg/L)	370	<0.01 - <0.02	<0.01 - <0.04	<0.01 - <0.02	<0.01 - <0.03	<0.02 - <0.06	<0.01 - <0.06	<0.01 - <0.03	<0.01 - <0.02	<0.02 - <0.05	<0.01 - <0.07	<0.01 - <0.02
Calcium (µg/L)	-	30 - 41	9.8 - 25	240 - 310	15 - 20	28 - 100	200 - 440	446 - 520	85 - 120	18 - 130	302 - 410	79 - 110
Iron (µg/L)	-	0.03 - 6.3	0.01 - 28	0.01 - 3.5	0.03 - 1.1	0.02 - 10	0.03 - 2.45	0.01 - 11	0.19 - 11.2	0.04 - 13	0.01 - 4.5	0.01 - 2.4
Potassium (mg/L)	-	2 - 3.7	3.4 - 7.3	17 - 28	1 - 2.8	9.8 - 45	2.8 - 13	3 - 7.6	7 - 11	14 - 43	10 - 14	1.8 - 3.7
Magnesium (mg/L)	-	30 - 36	13 - 40	530 - 660	11 - 13	11 - 22	30 - 58	150 - 200	149 - 370	14 - 170	208 - 290	6 - 11
Sodium (mg/L)	-	99 - 167	60 - 189	520 - 1330	59 - 76	47 - 110	260 - 452	310 - 610	200 - 420	95 - 410	400 - 808	25 - 53
Ammonia as N (mg/L)	900	<0.01 - 0.04	<0.01 - 0.13	<0.01 - 0.12	<0.01 - 0.03	<0.21 - 2.5	<0.01 - 0.42	<0.01 - 0.24	<0.01 - 0.11	<0.19 - 0.9	<0.01 - 0.07	<0.01 - 0.17
OrthPhosphate as P (mg/L)	-	<0.01 - 0.03	<0.01 - 0.05	<0.01 - 0.02	<0.01 - 0.03	<0.02 - 0.14	<0.01 - 0.04	<0.01 - 0.03	<0.01 - 0.03	<0.02 - 0.11	<0.01 - 0.04	<0.01 - 0.03

Table C2 –Summary for Dissolved Metals and Comparison with ANZECC and NHMRC Guidelines

Analyte	ANZECC Criteria	NHMRC	Minimum	10th percentile	Mean	90th percentile	Maximum
Arsenic (µg/L)	13	7	1.0	1.0	1.6	3.0	10.0
Selenium (µg/L)	5	10	1.0	1.0	1.4	2.0	10.0
Silver (µg/L)	0.05	100	1.0	1.0	1.0	1.0	1.0
Aluminium (µg/L)	55	200[1]	5.0	5.0	20.8	14.0	1200.0
Barium (µg/L)	-	700	18	58.4	263.8	450.0	650.0
Berylium (µg/L)	-	-	0.1	0.1	0.2	0.5	0.8
Cadmium (µg/L)	0.2	2	0.1	0.1	0.1	0.3	5.1
Cobalt (µg/L)	-	-	0.2	0.3	2.8	9.3	19.0
Chromium (µg/L)	1	50	1.0	2.0	3.2	5.0	33.0
Copper (µg/L)	1.4	2000	0.5	0.5	1.6	2.8	32.0
Manganese (µg/L)	1900	500	155	465.0	1764.4	3500.0	5600.0
Molybdenum (µg/L)	-	50	0.5	0.5	18.5	15.0	810.0
Nickel (µg/L)	11	20	1.0	1.0	7.7	17.0	44.0
Lead (µg/L)	3.4	10	0.1	0.1	0.8	1.1	13.0
Antimony (µg/L)	-	3	3	3.0	3.0	3.0	7.0
Zinc (µg/L)	8	3000[1]	5	6.0	29.0	58.0	380.0
Boron (µg/L)	370	4000	0.01	0.0	0.0	0.0	1.0
Calcium (µg/L)	-	-	9.8	20.0	172.7	410.0	520.0
Iron (µg/L)	-	300[1]	0.0	0.1	3.3	9.8	28.0
Potassium (mg/L)	-	-	1.0	2.2	10.4	24.5	45.0
Magnesium (mg/L)	-	-	6	11.0	136.8	290.0	660.0
Sodium (mg/L)	-	180,000[1]	25	52.5	317.8	750.0	1330.0
Ammonia as N (mg/L)	0.09	0.05[1]	0.01	0.0	0.2	0.6	2.5
OrthPhosphate as P (mg/L)	-	-	0.01	0.0	0.0	0.0	0.1

Note 1: NHMRC (2004) aesthetic guideline
Source: ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality.
NHMRC (2004) Australian Drinking Water Guidelines

APPENDIX D

Groundwater Monitoring Analytes to be Tested 6 Monthly

APPENDIX D

Table D1 – Analytes to be Tested as Part of 6-Monthly Monitoring

Parameter	Units
pH Value	
Conductivity @ 25'C	µS/cm
Total Dissolved Solids (TDS)	mg/L
Hardness as CaCO3	mg/L
Calcium - Filtered	mg/L
Magnesium - Filtered	mg/L
Sodium - Filtered	mg/L
Potassium - Filtered	mg/L
Carbonate as CaCO3	mg/L
Bicarbonate as CaCO3	mg/L
Sulphate - Filtered	mg/L
Chloride	mg/L
DISSOLVED METALS	
Iron - Filtered	µg/L
Silver - Filtered	µg/L
Aluminium - Filtered	µg/L
Antimony - Filtered	µg/L
Barium - Filtered	µg/L
Beryllium -Filtered	µg/L
Boron - Filtered	µg/L
Cadmium - Filtered	µg/L
Chromium - Filtered	µg/L
Cobalt - Filtered	µg/L
Copper - Filtered	µg/L
Manganese - Filtered	µg/L
Molybdenum - Filtered	µg/L
Nickel - Filtered	µg/L
Lead - Filtered	µg/L
Selenium - Filtered	µg/L
Zinc - Filtered	µg/L
Mercury - Filtered	µg/L

Parameter	Units
WAD Cyanide	µg/L
Ammonia as N	mg/L
Nitrate as N	mg/L
Total Kjeldahl Nitrogen as N	mg/L
Total Phosphorus as P	mg/L
Reactive Phosphorus as P	mg/L
Total Cations	me/L
Total Anions	me/L
Actual (Anion / Cation) Difference	me/L
Allowed (Anion / Cation) Difference	me/L
TOTAL PETROLEUM HYDROCARBONS	
C6-C9 Fraction	µg/L
C10-C14 Fraction	µg/L
C15-C28 Fraction	µg/L
C29-C36 Fraction	µg/L
Total C10 - C36	µg/L
BTEX	
Benzene	µg/L
Toluene	µg/L
Chlorobenzene	µg/L
Ethylbenzene	µg/L
meta- & para-Xylene	µg/L
ortho-Xylene	µg/L

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