Appendix 4

Australian Groundwater Technologies Report

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Groundwater Assessment for Dixon Sands Operation on Lot 1 and 2 - Groundwater Monitoring and Management

Prepared for Dixon Sands (Penrith) Pty Ltd

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Dixon Sands (Penrith) Pty Ltd

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1 Introduction

1.1 Background

Dixon Sand (Penrith) Pty Ltd owns and operates a sand quarry comprising four separate parcels of land which include the current pits Lots 1 and 2 DP 547255. These lots were approved for a maximum permissible mining depth of 2 metres above the wet weather groundwater level (under the development consent condition 5.2.5).

A groundwater assessment was recently undertaken by RPS Aquaterra (2012) to determine the elevation of the wet weather groundwater level, such that the depth of mining can be established. The report also addressed the potential groundwater related impacts of the development.

This groundwater assessment follows on from the RPS Aquaterra assessment and addresses the following objectives.

1.2 Scope of work

This report is prepared as a supporting document for the overall EA and addresses the following Director Generals Requirements (DGR's):

- A description of the existing environment, using sufficient baseline data (addressed under Section 2 of this report).
- A detailed description of the proposed water management system, water monitoring program and other measures to mitigate surface and groundwater impacts; and a statement of commitments, outlining all the proposed environmental management and monitoring measures (addressed under Section 3 of this report).
- A description of the measures that would be implemented to avoid, minimise, (and if necessary), offset the potential impacts of the proposed modification, including proposals for adaptive management and/or contingency plans to manage any significant risks to the environment (addressed under Sections 3 and 4 of this report).
- A detailed assessment of potential impacts on the quality and quantity of existing surface and ground water resources in accordance with the NSW Aquifer Interference Policy (AIP) (DPI, 2012) (addressed under Section 5 of this report).

1.3 Previous Work

This report follows on from the groundwater impact assessment which was undertaken by RPS Aquaterra in August 2012. The overall aim of the RPS Aquaterra study was to define the elevation of the regional water table, characterise the extent of perched water table and the Maroota Sand Groundwater Source, and to assess the potential groundwater impacts of the project in accordance with the rules of the Water Sharing Plan (WSP).

The study, which included drilling and review of available information, concluded that the only gazetted groundwater source found to be underlying the Lot 1 and 2 development areas was the Sydney Basin Central Groundwater Source. Previous

investigations involving the installation of shallow groundwater monitoring bores incorrectly identified small perched groundwater levels in the upper unsaturated part of this aquifer as the regional groundwater level. These perched layers are within the sandstone and are associated with thin shale, clay or ironstone bands that are of limited spatial extent and are not hydraulically connected to the regional groundwater level or the Maroota Tertiary Sands Groundwater Source, which was shown to be absent from the area.

Following detailed site specific investigations the regional groundwater table level was determined to be about 171 mAHD in the east and 151 mAHD in the west. Therefore, sand extraction in Lot 1 and 2 could extend to a depth of 173 mAHD in the east grading to 153 mAHD in the west.

The deepening of the quarry pit will not involve contact with, or removal of groundwater from either of the two gazetted groundwater sources in the region (Maroota Tertiary Sands Groundwater Source and the Sydney Basin Central Groundwater Source) and therefore will not impact users abstracting from these sources.

2 Baseline Groundwater Conditions

2.1 Groundwater Levels

Groundwater levels for the deep and shallow bores in the project area range from 106 to 200 mAHD and generally follow the topography, with an inferred regional groundwater flow direction to the east. The shallow bore water levels indicate a difference in head of at least 16 m (Figure 1). The higher groundwater level in the shallow piezometers represents a perched water table above the ironstone or shale band(s), within the upper unsaturated zone of the Hawkesbury Sandstone.

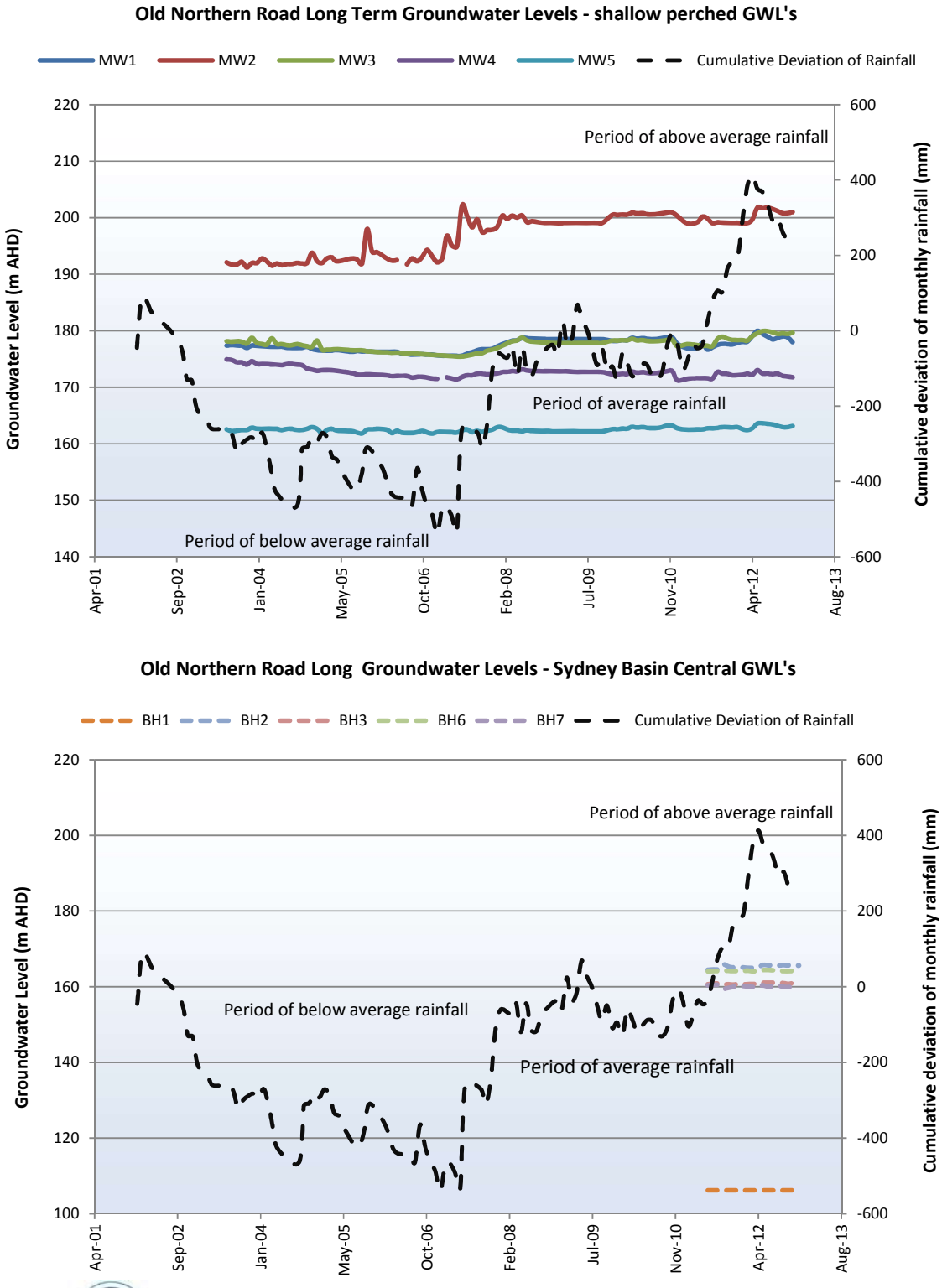
Groundwater monitoring has been undertaken in the shallow bores since 2003, and in the deep bores since 2010, over a range of different climatic conditions.

The cumulative deviation of monthly rainfall is plotted on hydrographs to help explain the groundwater level (water table) trends observed in the perched and deep water tables. The cumulative deviation curve (shown as a black dashed line on Figure 1) shows how far the monthly rainfall deviates from the long-term average. These deviations are cumulatively added to produce the cumulative deviation curve. Positive slopes represent periods of above average rainfall (i.e. 2010 to 2012), whilst negative slopes indicate periods of below average rainfall (i.e. 2002 to 2007).

The hydrographs from the shallow bores (MW1 to MW5) have been responding slightly to climatic variability, decreasing slightly during periods of below average rainfall, and increasing slightly over periods of above average rainfall. Figure 1 shows that the most shallow (perched) groundwater levels (MW2) can fluctuate by up to 5 m, draining rapidly following high rainfall events, whilst the deeper regional groundwater levels do not respond directly to rainfall events, remaining relatively stable through the period of monitoring (showing only small fluctuations of between 0.3 and 0.6 m over the past 2 years).

Baseline groundwater levels recorded onsite over the preceding two years are considered to be representative of the ‘wet weather’ elevation, as these have been recorded during a period of above average rainfall.

Figure 1: Hydrographs of Sydney Basin Central Groundwater Source and the shallow perched water tables.



2.2 Groundwater Quality

In accordance with the current development consent conditions, groundwater samples have been collected from each bore for analysis of the following parameters: Electrical Conductivity (EC), pH, Totals Suspended Solids (TSS) and Turbidity. A summary of the natural variation of groundwater quality is provided in Table 1.

- Groundwater salinity of the shallow and deep aquifers is very low, ranging from 120 to 560 µS/cm (66 to 307 mg/L).
- pH ranges from 3.8 to 7.8, with deeper bores revealing higher average pH values (6.4) in comparison to the shallower bores (4.8).
- Groundwater turbidity and TSS was generally higher in the shallow bores than in the deeper bores.

As the groundwater salinity is <1,500 mg/L, the source is classified as a highly productive groundwater source under the criteria of the AIP.

Table 1: Baseline groundwater quality

Bore	MW1	MW2	MW3	MW4	MW5	BH1	BH2	BH3	BH6	BH7
Electrical Conductivity (µS/cm)										
Nov 10	357	560	173	144	151					
Jul 11	234	267	120	161	220		292	288	226	164
Jan 12	211	135	137	203	129		289	287	161	289
Jun 12	131	198	155	133		156	234			136
Dec 12	274	270	269	267	274		235	263	258	256
pH										
Nov 10	3.92	3.8	5.9	5.99	4					
Jul 11	4.4	4	6.2	6.2	4.4		7.2	7	6.2	6.5
Jan 12	5.4	6	6	4.6	4.4		7.6	7.8	6.3	6.2
Jun 12	5.3	4.2	6.7	5.9		6.3	5.4			6.3
Dec 12	3.9	3.9	3.9	3.9	3.9		4.7	6.8	6.2	6.3
Turbidity (NTU)										
Nov 10	109	70	28	80.5	24					
Jul 11	10	23	14	27	20		33	6	5.8	4.5
Jan 12	21	9.2	2.1	140	40		16	1.5	1	0.8
Jun 12	33	15	3.4	19	n/a	220	9.7	n/a	11	3.7
Dec 12	3.7	19	20	25	29	n/a	0.6	5.2	5	1.5
TSS										
Nov 10	120	66	30	32	13					
Jul 11	10	27	21	43	13		32	6	8	10
Jan 12	10	9	<1.0	121	34		15	2	<1.0	1
Jun 12	34	14	4	10	n/a	166	16	n/a	11	4
Dec 12	4	17	21	30	28	n/a	3	9	6	2

3 Groundwater Monitoring

3.1 Existing Groundwater Monitoring Program

The locations of the groundwater monitoring bores are shown in Figure 1 of the RPS Aquaterra, 2012 report and are summarised in Table 2.

A baseline groundwater monitoring programme for Lots 1 and 2 has been active since 2003 and is ongoing. The monitoring network was expanded in 2010 and again in 2011, which involved the installation of deeper piezometers (BH1 to BH7).

The Dixon Sands monitoring network includes 10 piezometers. Six of the piezometers are located around the periphery of the proposed pit on Lot 1 and 2, whilst the remaining piezometers are located further away on adjacent properties. All piezometers are located outside of the mining foot print, and will not be mined out.

The piezometers are standpipes which target the Hawkesbury Sandstone and allow monitoring for both groundwater levels and groundwater quality.

BH1 to 7 monitor the deeper regional water level of the Sydney Basin Central Groundwater Source, whilst MW1 to 5 monitor a perched water table that has been found to exists above some ironstone or shale bands, within the upper part of the Hawkesbury Sandstone. This perched water table has limited lateral extent (RPS Aquaterra, 2012).

Table 2: Summary of existing groundwater monitoring program

Property	Bore	Monitoring	Installed	Monitoring data since	Water level frequency	Water quality frequency
Lot 1 and 2 DP547255	BH6	Sydney Basin Central GW Source	2011	Feb 2011	monthly	biannual
	BH7					
	MW2	Perched groundwater above the deep regional aquifer	2003	July 2003	monthly	biannual
	MW3					
	MW4					
	MW5					
Lot 196 DP752025	BH1	Sydney Basin Central GW Source	2010	Oct 2010	monthly	biannual
	MW5	Perched groundwater above the deep regional aquifer	2003	July 2003	monthly	biannual
Lot 1 DP204159	BH2	Sydney Basin Central GW Source	2010	Oct 2010	monthly	biannual
	BH3					

3.2 Proposed Groundwater Monitoring Program

Although mining on Lots 1 and 2 will not intercept the regional groundwater level of the Sydney Basin Central Groundwater Source, monitoring will be continued for the life of the project to detect any unforseen groundwater level or quality impacts, including any impacts to existing users.

Monitoring on Lots 1 and 2 has also been integrated with monitoring that is being undertaken on neighbouring allotments, such that any unforseen impacts that may occur off site to neighbouring users can also be detected.

The ongoing monitoring program is summarised in Table 2 and has been designed to detect changes in groundwater levels, groundwater quality and pit inflow, or to indicate that an abnormal condition relating to mining has developed. Key aspects include:

- Water quality sampling from groundwater across the project area on a biannual basis.
- Monitoring and assessment of groundwater inflows and quality to the open cut mining operations, in the unlikely event that groundwater inflows occur.
- Monitoring groundwater levels in the:
    - Sydney Basin Central Groundwater Source (Hawkesbury Sandstone)
    - Shallow perched groundwater within unsaturated zone of the Hawkesbury Sandstone.

It is important to note that the Maroota Tertiary Sand Groundwater Source is absent from the area and is therefore not monitored. Whilst some of the bores (MW2, BH2 and BH3) plot inside the inferred boundary of the Maroota Tertiary Sand Groundwater Source, drilling results from these bores and registered bores in the greater area indicate that this Maroota Sands Groundwater Source is actually absent from the area and it is in fact located much further (at least 2 km) away than shown in the WSP. Therefore no bores (observation or private) target the Maroota Sands Groundwater Source, despite them being shown to exist within the source boundary.

The locations of the groundwater monitoring bores are shown in Figure 1 of the RPS Aquaterra, 2012 report and a description of the location and monitoring frequency is summarised below in Table 2.

No bores are anticipated to be damaged during mining as all lie outside of the disturbance footprint.

Table 3: Proposed groundwater monitoring program

Pre mining	Purpose	Weekly	Fortnightly	Monthly	Bi-annual
BH1, BH2, BH3, BH6, BH7, MW1–5	To obtain baseline, pre mining conditions for Lot 1 and 2 and surrounding area			Water level	
	Provide the foundation for establishing trigger values for investigation				Field Parameters EC,TSS, pH, Turbidity
	Obtain natural variation of regional groundwater level, such that depth of mining can be determined				
During mining					
BH1, BH2, BH3, BH6, BH7, MW1–5	Ensure mining is maintained above the regional groundwater level			Water level	
	Monitor any unforseen water quality impacts, ensuring that there is no change in overall beneficial use category >40 m from site				Field Parameters EC,TSS, pH, Turbidity
	Monitor unforseen regional impacts, ensure there are no WL/WQ impacts to neighbouring private bores				
	Ongoing compliance with the WSP and AIP	No pit seepages are expected, but undertake measurements in the unlikely event that measurable volumes occur		No pit seepages are expected, but take sample in the unlikely event that measurable volumes occur	
Post mining					
BH6, BH7, MW2–5	Monitoring of post mining water level and quality impacts and ensuring ongoing compliance with the WSP and AIP				Water level & Field Parameters

4 Management of Groundwater Impacts

4.1 Groundwater Management Strategy

The strategy for groundwater management is to minimise groundwater inflows from the Sydney Basin Central Groundwater Source to the open cut and preservation of groundwater quality. It involves maintaining the depth of mining to an elevation which is at least 2 m above the 'wet weather' elevation.

Aspects assessed to be at risk have been previously assessed by RPS Aquaterra (2012) and are presented in Table 4 along with mitigation measures for each. These include both predicted and unpredicted impacts, and as such the groundwater monitoring program specifically deals with:

- A mechanism for ensuring project is compliant with the rules of the WSP and AIP (DPI, 2012).
- Unforseen impacts on groundwater levels on neighbouring properties and on any users of groundwater.
- Unforseen impacts of the development on groundwater quality such as around storages.
- Periodical monitoring for changes and local and regional impacts of the quarry on groundwater levels and quality during the project and on a reduced basis for at least five years post mining.

Information gained from the monitoring program has been used to determine the pit extraction depth, which will remain 2 m above the 'wet weather' groundwater level, thereby mitigating any drawdown impact to the Sydney Basin Central Groundwater Source.

Ongoing groundwater monitoring serves to notify changes to the groundwater, quality or unforeseen discharges into the pit (interference with groundwater flow). Monitoring is necessary to indicate that an abnormal condition relating mining has developed as well as compliance with the rules of the WSP and AIP.

A Trigger Action Response Plan (TARP) for groundwater will be developed to focus upon appropriate trigger and response actions for the management or mitigation of impacts to the natural environment as a result of mining. An example is provided in Table 4 but this will be refined following consultation with NSW Office of Water. To ensure compliance with the AIP, triggers will be developed based on the baseline groundwater data and the minimal impact considerations outlined for fractured rock aquifers in Table 1 of the AIP (DPI, 2012) (reproduced in Table 5 of this report).

The baseline monitoring program that is in place will have established triggers, which will be used to indicate levels of impact and trigger an appropriate response. The fundamental means of determining the magnitude of any impact and the need for further monitoring and/or remedial actions is based upon the impact assessment criteria detailed in Table 3. The responses (actions) documented in the table are proposed to ensure the timely and adequate management of impacts outside of the established trigger levels.

The TARP has been designed to allow reference to identified risks of impact from mining to environmental aspects identified within the mining area and surrounds. These may be either predicted or unpredicted.

4.2 Dixon Sands Responsible Impacts Procedure

Where investigations detailed in the TARP determine that groundwater impacts are the result of Dixon Sands operations or may potentially impact on adjacent bores, the following procedure is actioned:

- Inform landholders adjacent to streams and/or private bore owners, and the NSW Office of Water of preliminary investigation outcomes, as appropriate.
- Undertake a detailed investigation and assess possible mitigation measures in consultation with the landowner and the NSW Office of Water, as appropriate.
- If deemed necessary prepare and implement a site mitigation/action plan to the satisfaction of DPI, in consultation with the landowner and the NSW Office of Water, as appropriate.
- Conduct a review of results from the follow up investigation.
- Further, the timing of the above includes, but is not limited to:
- Results of preliminary investigation reported within one week of completion.
- Commence preparation of detailed investigation including assessment of possible mitigation measures immediately.
- Commence preparation of mitigation/action within one week of the need being identified.

4.3 Notification of Significant Impact

Where a significant, confirmed impact to the environment or private landowner has occurred according to the TARPs, relevant agencies will be contacted immediately.

Table 4: Trigger Action and Response Plan

Impact	Observation	Strategy for Mitigation	Monitoring	Monitoring Action	Response
Groundwater level	Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the water sharing plan.	Baseline GWL data has been used to ensure depth of mining remains above the Sydney Basin Central Groundwater Source. Regular review of monitoring data to ensure mining is maintained above the elevation of the regional water table.	BH 6 and BH7	**Water level**: Increase monitoring frequency to weekly to establish trend	Investigate potential contributing factors: • Confirm trends or anomalies by repeating water level sampling as required • Compare exceedance with climatic conditions • Engage a hydrogeologist to undertake a preliminary investigation and report on any identified changes. Where investigations determine that impacts are the result of Dixon Sands operations or may potentially impact on adjacent bores or surface water users, implement Section 4.2 of this report, which may include: Modify mine plan, increase or obtain groundwater licence to offset impact
Groundwater quality	Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.	Ensure all spillages are contained, diversion of dirty water into settling ponds, maintenance of machinery to be undertaken in work shop areas. Monitoring of pit sumps will be undertaken as a first line of defence to detect & control the risk of groundwater contamination	MW1 to 5, BH 6 and BH7	**Water Quality**: Repeat sampling of bore to confirm. If so obtain samples for comprehensive analysis from all bores	
Groundwater users	Reported decrease in yield or GWL outside of climatic variations. Reported decrease in water quality parameter outside of baseline variation	Baseline GWL data has been used to ensure depth of mining remains above the Sydney Basin Groundwater source. Regular review of monitoring data to ensure mining is maintained above the elevation of the regional water table.	BH1, 2, 3, 6 and 7	**Water level**: Increase monitoring frequency to weekly to establish trend	
Mine inflows	Observed seepages from pit wall	Regular review of monitoring data to ensure mining is maintained above the elevation of the regional water table. Monitoring of water quality in pit sumps will be undertaken as a first line of defence to control the risk of groundwater contamination	Pit seepages, BH1 to 3 BH6 and 7 and MW1 to 5	**Water level**: Increase monitoring of bores to weekly to establish trend. **Water quality:** obtain comprehensive analysis of seepages. **Volume:** weekly record of pit seepages	

5 Aquifer Interference Policy

As discussed above, the depth of the development will not extend to the depth of the groundwater level in this aquifer and the risk of aquifer interference will be mitigated through measures described under Section 4.1 of this report.

The outcomes from the RPS Aquaterra 2012 study show that the project is compliant with the rules of the AIP, however, for clarity all of the rules and requirements stipulated in the AIP (Table 1 and Section 3.2 of the AIP) have been summarised in the following tables.

Table 5: Minimal impact considerations for aquifer interference activities

	Highly Productive Groundwater Sources					
	Water Table	**Summary of impact and monitoring**	**Water Pressure**	**Summary of impact and monitoring**	**Water Quality**	**Summary of impact and monitoring**
4. Fractured Rock Water Sources	1. Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan. A maximum of a 2 m decline cumulatively at any water supply work. 2. If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan then appropriate studies(6) will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than 2 m decline cumulatively at any water supply work then make good provisions should apply.	**Mitigation Measure:** Mining will be undertaken a great distance from the Maroota Tertiary Sands Groundwater Source and will be maintained 2 m above the wet weather regional groundwater level for the underling Sydney Basin Groundwater Resource, thereby mitigating any groundwater drawdown impact to these groundwater sources. There are no GDE or Water supply works identified in the greater area that could be impacted. **Monitoring**: Extensive monitoring bores will be maintained both on site and off site, to detect any unforseen groundwater impacts, including detection of impacts > 40 m away from the site	1. A cumulative pressure head decline of not more than a 2 m decline, at any water supply work. 2. If the predicted pressure head decline is greater than requirement 1.(a) above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	**Mitigation Measure:** Mining will be undertaken a great distance from the Maroota Tertiary Sands Groundwater Source and will be maintained 2 m above the wet weather regional groundwater level for the underling Sydney Basin Groundwater Resource, thereby mitigating any groundwater drawdown impact to these groundwater sources. **Monitoring**: Extensive monitoring bores will be maintained both on site and off site, to detect any unforseen groundwater impacts, including detection of impacts > 40 m away from the site	1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity. 2. If condition 1 is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.	**Mitigation Measure:** Mining will be undertaken a great distance from the Maroota Tertiary Sands Groundwater Source and will be maintained 2m above the wet weather regional groundwater level for the underling Sydney Basin Central Groundwater Source. There are no water quality impacts as a result of the project. Mitigation measures such as those listed in Table 4 will be implemented to prevent contamination to the groundwater source. There are no GDE or Water supply works identified in the greater area that could be impacted. **Monitoring**: Extensive monitoring bores will be maintained both on site and off site, to detect any un foreseen groundwater quality impacts, including detection of impacts > 40 m away from the site.

Table 6: Summary of AIP requirements

Requirement	Summary of compliance	Reference of compliance
Establishment of baseline groundwater conditions including groundwater depth, quality and flow based on sampling of all existing bores in the area potentially affected by the activity, any existing monitoring bores and any new monitoring bores that may be required under an authorisation issued under the Mining Act 1992 or the Petroleum (Onshore) Act 1991	Baseline groundwater and quality data has been captured since 2003 for shallow bores and 2010 for deep bores, over a range of climatic variations	Section 2 of this report and Section 6 or the RPS Aquaterra 2012 report (Table 6.1)
A strategy for complying with any water access rules applying to relevant categories of water access licences, as specified in relevant water sharing plans. For example, returning water of an acceptable quality to the affected water source during periods when flows are at levels below which water users are not permitted to pump	Project is in accordance with the rules of the WSP, in particular meets the criteria stipulated for both the Maroota Tertiary Sands Groundwater Source and the Sydney Basin Central Groundwater Source	Section 7 of the RPS Aquaterra 2012 report
Details of potential water level, quality or pressure drawdown impacts on nearby water users who are exercising their right to take water under a basic landholder right. Consideration will need to be given to any relevant distance restriction requirements that may be specified in any relevant water sharing plan or any remediation measures to address these impacts	No impact to existing users as the regional water level will not be intercepted by mining. The Maroota Tertiary Sands Groundwater Source is absent from the greater study area	Section 6 of the RPS Aquaterra 2012 report
Details of potential water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources	There will be no impact to existing users as the regional water level will not be intercepted by mining. The Maroota Tertiary Sands Groundwater Source is absent from the greater study area.	Section 6 of the RPS Aquaterra 2012 report
Details of potential water level, quality or pressure drawdown impacts on groundwater dependent ecosystems	No GDE's identified in the study area	Section 6 of the RPS Aquaterra 2012 report
Details of potential for increased saline or contaminated water inflows to aquifers and highly connected river systems	Mitigation measures for contamination are in place	Section 4, Table 4 of this report
Details of the potential to cause or enhance hydraulic connection between aquifers	There is only one aquifer in the study area, the Sydney Basin Central Groundwater Source. There will be no enhance connection between other aquifers, such as the Maroota Tertiary Sands Groundwater Source, as this aquifer is absent from the area and mining will be maintained above the elevation of the Sydney Basin Central Groundwater Source	Sections 5 and 6 of the RPS Aquaterra 2012 report
Details of the potential for river bank instability, or high wall instability or failure to occur	Mining will not be carried out near any creek or river	Section 6 of the RPS Aquaterra 2012 report
Details of the method for disposing of extracted water (in the case of coal seam gas activities)	N/A	N/A

6 References

RPS Aquaterra, 2012. Groundwater Assessment for Dixon Sand Operation, Lot 1 and 2 DP547255, Maroota NSW. Prepared for Dixon Sands, July 2012.

DPI, 2012. NSW Aquifer Interference Policy: NSW Government policy for the licensing and assessment of aquifer interference activities. September 2012. ISBN 978 1 74256 338 1