Narrabri Mine

EXTRACTION PLAN
WATER MANAGEMENT PLAN LW101 to LW106

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Abbreviations

AEMR	**Annual Environmental Management Report**
AHD	**Australian Height Datum**
ALS	**Aerial Laser Scanning**
ANZECC	**Australian and New Zealand Environment Control Council**
ARI	**Average Recurrence Interval**
CHPP	**Coal Handling and Processing Plant**
DGS	**Ditton Geotechnical Services Pty Ltd**
DP&E	**Department of Planning and Environment**
DPI Water	**Department of Primary Industries – Water**
EA	**Environmental Assessment**
EC	**Electrical Conductivity**
EPL	**Environment Protection Licence**
EP-WMP	**Extraction Plan Water Management Plan**
ESCP	**Erosion and Sediment Control Plan**
LW	**Longwall**
NCMA	**Namoi Catchment Management Authority**
NCOPL	**Narrabri Coal Operations Pty Ltd**
OEH	**Office of Environment and Heritage**
Raffinate	Treated Process Water from the Water Conditioning Plant
ROM	**Run-of-mine Coal**. Raw coal delivered to the Processing Facility with varying particle size and moisture content. ROM coal often contains contaminates introduced by the mining process.
SoC	**Statement of Commitments** from Section 5 of Surface Water Management Plan for the Narrabri Coal Mine Stage 2 Longwall Project Stage 2 Environmental Assessment.
TDS	**Total Dissolved Solids**
TSS	**Total Suspended Solids**
TOC	**Total Organic Content**
WMP	Stage 2 **Water Management Plan**

1 INTRODUCTION

1.1 Project Background

Narrabri Coal Operations Pty Ltd (NCOPL) (formerly Narrabri Coal Pty Ltd) was granted consent for Stage 1 of the development in 2007 (PA 05_0102). The Water Management Plan for the construction phase was subsequently replaced with an operational plan prior to the commencement of active mining.

Stage 2 of the development has been approved subject to the conditions listed in the modified approval document; PA 08_0144 (as modified), Narrabri Mine Stage 2 Project Approval. Stage 2 will result in the mine achieving full production by longwall mining techniques. The Stage 2 approval will enable ROM production to increase to 11 million tonnes per annum once the longwall is fully operational.

A number of documents are required to satisfy the conditions of approval of which an Extraction Plan is one. The Extraction Plan is required to contain a Water Management Plan (EP-WMP) that covers the operations involved in the longwall process. Specifically, this EP-WMP must consider the impacts of subsidence on the surface and ground water flows across the mine lease and beyond. This is in addition to the existing Water Management Plan (WMP) (URS, 2011) which covers the whole site and consequently significant overlaps exist.

This EP-WMP has been prepared to address secondary extraction (longwall mining) of Longwalls (LW) 101 to 106 only. The original plan was developed by URS and related to the extraction of LW101 to LW105. This revision has been developed to incorporate LW106 into this EP-WMP.

1.2 Application Area

The Narrabri Mine is located approximately 30km southeast of Narrabri and approximately 10km northwest of Baan Baa in north-western New South Wales. Surface operations are located adjacent to, and accessed by, the Kamilaroi Highway across Lot 151-152 DP816020; Lot 60 &115 DP757124; and Lot 381-382 DP1028753.

The land above the proposed LW 101–106 (i.e. the application area) comprises private land holdings (project related) used primarily for livestock grazing with some cereal crop farming. NCOPL owns the private land holdings above the proposed longwalls. The land to the west of the proposed longwalls is overlain by native woodlands and the Jacks Creek and Pilliga East State Forests.

The terrain is generally flat to gently undulating (2° - 5°) with moderate 10° - 15° slopes along Pine Creek and its tributaries. The creeks are ephemeral watercourses that drain the mine site towards the north-east. Topographic relief above the proposed longwalls ranges from 270 m AHD in the east to 305 m AHD in the west.

1.3 Management Plan Requirements

Schedule 3, Condition 4 of PA 08_0144, as modified, requires that Narrabri Mine prepare and implement a Water Management Plan, as part of an Extraction Plan. This is in addition to other subsidence related conditions within Schedule 3 which are considered by this report. Table 1-1 shows sections from Condition 4 that relate to the requirements of the EP-WMP.

Table 1-1 Requirements of the EP-WMP

Condition	Refer to Sections
Schedule 3, Subsidence Impact Performance Measures	
1. The Proponent shall ensure that mine subsidence does not cause any exceedances of the performance measures in Table 1. *Table 1: Subsidence Impact Performance Measures* Water Resources Great Artesian Basin — The Proponent shall ensure that, within 5 years of the date of this approval, any loss of water flow into the Great Artesian Basin aquifers (equal to the maximum predicted impact, or the measured impact of the project, whichever is greater), is managed, licensed or offset (including the possibility of injection of raffinate) to the satisfaction of DPI Water.	Section 6.2
Schedule 3, Extraction Plan	
4. The Proponent shall prepare and implement Extraction Plans for any second workings to be mined to the satisfaction of the Secretary. Each Extraction Plan must: (h) include a: • Water Management Plan, which has been prepared in consultation with OEH and DPI Water, which provides for the management of the potential impacts and/or environmental consequences of the proposed second workings on surface water resources, groundwater resources and flooding, and which includes:	
o surface and groundwater impact assessment including trigger levels for investigating any potentially adverse impacts on water resources or water quality;	Sections 3.3, 5.3 and 6.2
o a program to monitor and report groundwater inflows to underground workings; and	Section 6.3
o a program to manage and monitor impacts on groundwater bores on privately owned land;	Section 6.4.3
5. The Proponent shall ensure that the management plans required under condition 4(h) above include:	
(a) an assessment of the potential environmental consequences of the Extraction Plan, incorporating any relevant information that has been obtained since this approval;	Section 5.1 and 6.2.3
(b) a detailed description of the measures that would be implemented to remediate predicted impacts; and	Section 8.1and 8.2

(c) a contingency plan that expressly provides for adaptive management.	Section 8.4
Schedule 6, Condition 2, Management Plan Requirements	
2. The Proponent shall ensure that the management plans required under this approval are prepared in accordance with any relevant guidelines, and include:	
(a) detailed baseline data;	Section 5.2 6.2.3
(b) a description of: • the relevant statutory requirements (including any relevant approval, licence or lease conditions);	
• any relevant limits or performance measures/criteria;	Section 5.2.2 and 6.3
• the specific performance indicators that are proposed to be used to judge the performance of, or guide the implementation of, the project or any management measures;	Section 8.1 and 8.2
(c) a description of the measures that would be implemented to comply with the relevant statutory requirements, limits, or performance measures/criteria;	Section 5.4and 6.4
(d) a program to monitor and report on the • impacts and environmental performance of the project; • effectiveness of any management measures (see (c) above);	Section 7
(e) a contingency plan to manage any unpredicted impacts and their consequences;	Section 8
(f) a program to investigate and implement ways to improve the environmental performance of the project over time;	Section 7
(g) a protocol for managing and reporting any: • incidents; • complaints; • non-compliances with statutory requirements; and • exceedances of the impact assessment criteria and/or performance criteria; and	Section 7
(h) a protocol for periodic review of the plan.	Section 7

This EP-WMP is based on the Stage 2 WMP (URS, 2011), but focuses on the impact of longwall mining, especially subsidence. The WMP is based on the Statement of Commitments (SoC) and the Environmental Assessment (EA) (R.W. Corkery & Co. Pty. Limited, 2009) for Stage 2 of the mining operations, including the following specialist technical reports:

- Narrabri Coal Mine Stage 2 Longwall Hydrogeological Assessment, Aquaterra Consulting Pty Ltd, November 2009
- Narrabri Coal Mine Stage 2 Longwall Project Surface Water Assessment, WRM Water & Environmental Pty Ltd, November 2009
- Narrabri Mine Modification 5 Environmental Assessment, Resource Strategies, September 2015

Any future refinements to water management or monitoring requirements will result in subsequent revisions of the WMP which will be submitted to the Secretary for endorsement. This may in turn require a possible review and update of this document.

1.4 Extraction Plan Water Management Plan Objectives

The EP-WMP aims to provide management approaches for the potential impacts from the longwall mining process (LW 101–106). These impacts may be on surface water resources, groundwater resources or flooding. Where there are overlaps with the existing WMP, those sections have been reproduced in this report.

It should be noted that this revision of the report took place at a time when LWs 101-103 were complete and the mining of LW104 was underway. The revision includes LW106 in the assessment and also presents some initial findings post mining in LWs 101-103.

1.5 Responsibilities

During the operational phase of mine development, the Narrabri Mine is managed by the General Manager who has overall responsibility for ensuring contractors, employees and service providers comply with all laws, regulations, licences, approvals and conditions of the project approval. Table 1-2 below outlines the responsibilities of personnel at Narrabri Mine under this Management plan.

Table 1-2 Roles and Responsibilities

Role	Accountability
General Manager	Responsible for providing adequate resources to undertake the activities required by this plan.
Technical Services Manager	Responsible for ensuring that monitoring, periodic environmental inspections and inspections following high rainfall events are undertaken. WMP and EP-WMP review.
Environment Officer	Implementing this EP-WMP on a day to day basis. WMP and EP-WMP review. Carrying out monitoring program

As part of his duty, the General Manager has the power to delegate resources and responsibility. The General Manager acts on the behalf of the mine and must fulfil the requirements of the Project Approval and commitments outlined in the Environmental Assessment. Implementation of these commitments is a requirement of the Project Approval and they contain a number of statements concerning the effects of subsidence.

2 MINESITE WATER MANAGEMENT

2.1 Water Management Approach

The WMP (URS 2011) sets out the overall principles for the management of water at Narrabri Mine.

For the purposes of water management, the water generated at the Narrabri Mine is divided into four types based on water quality, as detailed below:

'Clean' – surface runoff from the mine site areas where water quality is unaffected by mining operations. Clean water includes runoff from undisturbed areas and any fully rehabilitated areas;

'Dirty' – surface runoff water from the mine site areas that are disturbed by mining operations. This runoff may contain silt and sediment, but does not contain contaminated material. However, this runoff must be of sufficient quality prior to discharge into natural water courses, if required;

'Contaminated' – surface water from areas affected by mining operations and potentially containing chemicals of various types used in the mining operations. There are restrictions on the use and release of this water. Contaminated water areas include sumps, stockpile areas, service ponds and fuel storage areas. Rainfall and resulting runoff from these areas are also potentially contaminated and therefore must be managed to avoid discharge of potentially contaminated water into the natural water courses; and

'Saline' – water pumped from the underground workings containing concentrations of total dissolved solids (TDS) above that considered fresh water by ANZECC & ARMCANZ (2000) criteria. For the purpose of clarity, this water is referred to as 'dirty' in this document.

Catchment runoff from land overlying LW101 – 106 is generally considered 'clean', however would generally contain a background level of silt and sediment due to natural erosion processes and current agricultural activity. This runoff has the potential to be indirectly impacted by subsidence and become 'dirty' in that elevated levels of sediment or salinity result in comparison to the background water quality of the catchment runoff. The mechanisms for these impacts and proposed monitoring and mitigation measures are outlined in this EP-WMP.

There should be no contaminated water produced by the longwall, however groundwater inflows into the mine are typically saline and are pumped to the surface as part of normal operations. These flows are managed by the surface infrastructure on site. Monitoring of these mine inflow rates are documented in this EP-WMP as an indicator of subsidence behaviour in the overlying strata and associated consequences to the overlying groundwater and surface water resources.

A description of the strategies for monitoring and management of water impacts relating to secondary extraction of LW101 – 106 are given below.

2.1.1 Clean Water Management

Pine Creek and its catchment is not located near the surface operations area of the mine; however it does pass over LW101 – 106, as does Pine Creek Tributary No. 1. The channel of Kurrajong Creek does not pass over LW101 – 105, however a small area of land overlying LW101 drains south to this watercourse and therefore forms a small part of its catchment.

These are clean water catchments and will be potentially affected by the mine through subsidence and limited surface activities (i.e. installation of gas drainage and other associated infrastructure). Data gathered through the monitoring program documented in this EP-WMP will be used to assess the quality of these flows during mining and to regularly compare these values to the performance indicators, which include both the baseline water quality and ANZECC criteria. A Trigger Action Response Plan (TARP) has been developed to investigate and remedy issues, should a degradation of water quality be identified as a result of mining activities.

2.1.2 Saline Water Management

During the early years of operation, when the groundwater inflows are expected to be low, the saline ground water pumped out mine water will be used on site for dust suppression or will be evaporated.

As part of the SoC for Stage 2 the reverse osmosis water conditioning plant has been commissioned. It is used to remove excess salts from the pumped out mine water resulting in clean water and brine (high salt content water). The resulting clean water is used for; dust suppression in the underground operations; longwall operational requirements; or potentially for off-site use. The brine is stored in onsite evaporation ponds.

Any excesses in the concentrated brine by-product of the water conditioning plant will be evaporated in storage dams on site without releasing it to the environment. Salt accumulation predictions and management will be based on the EA, specifically the supporting specialist consultant study; Surface Water Assessment, Section 6.3.3 (WRM Water & Environment Pty Ltd, 2009).

Further detail for this system is given in the WMP (URS, 2011).

2.1.2.1 Saline Water Contingency Plan

Narrabri Mine monitors the volume of pumped out mine water as mining progresses. This allows the mine to anticipate when the current measures may not be sufficient for the volume being extracted from the underground works. Options to manage any excess water, should this occur, are currently being investigated. These options include:

- Increasing the area of the planned evaporation basins (BR1 to BR5);
- Treating the water to a quality sufficient to release it to the Namoi River; and

- Transferring the treated water to a third party for agricultural use.

The most appropriate option will be determined when an issue arises. In addition to the measurement of extracted water, there will also be re-calibrations of the groundwater model, as prescribed under the conditions of Project Approval. Any offsite use will be subject to a detailed site specific investigation to assess the long term sustainability of reusing the water at that particular site.

2.1.3 Contaminated Water Management

No contaminated water is expected to be produced from the longwall workings. Details of the contaminated water system are given in the WMP (URS, 2011).

2.2 Available Water Allocations

Table 2-1 shows the water allocation licences held by NCOPL. An aquifer interference licence was obtained to dewater the underground workings and the remaining allocations are off-site licences from either the Great Artesian Basin or the Namoi River.

Table 2-1 Narrabri Coal Mine Water Allocation Licences

Licence	Water Access Licence &/or Groundwater Works	Access Licence Category	Water Body	Nominal Allocation (ML/yr)
90AL822538, 90WA822539		Mining	Gunnedah – Oxley Basin MDB Groundwater Source	818
90AL811346, 90CA811347	WAL15922, GW062433	Aquifer	Southern Recharge Groundwater Source	248
90AL812863, 90CA802130	WAL20152	Regulated River (General Security)	Lower Namoi Regulated River Water Souce	600
90AL802212, 90CA802130	WAL2728	Regulated River (General Security)		10
90AL801995, 90CA802130	WAL2671	Regulated River (General Security)		48
90AL802129, 90CA802130	WAL6762	Regulated River (High Security)		20
90AL812858, 90WA812891	WAL20131, GW969667	Aquifer	Upper Namoi Zone 5 Namoi Valley (Gin's Leap To Narrabri) Groundwater Source	150
90AL807276	WAL12833	Aquifer		67

The off-site allocations will be used to meet site demands in years where sufficient water cannot be collected on site. It is anticipated that this will only be required in the first four years of the mine life.

3 SUBSIDENCE ASSESSMENT AND IMPACTS

3.1 Application Area Analysis

The subsidence assessment by Ditton Geotechnical Services Pty Ltd (DGS, 2015) estimated the effects of the mining works. The mining lease is a 'Greenfields Site' (i.e. a mining area where no local prior knowledge of ground response to underground mining exists) and it was necessary to make predictions using proven empirical modelling techniques developed in other coalfields with similar geological conditions. Engineering science was also applied in the form of established analytical models of overburden and chain pillar behaviour, to compare to the empirical model results.

The depth of cover above the Hoskissons Coal Seam ranges from 160m to 270m with the depth of weathering typically varying from about 15m to 35m from the surface. Through a review of the available exploration data, DGS determined that the potential subsidence reducing 'massive' units in the overburden are the conglomerate of the Digby Formation, the intrusive basalt sill in the Napperby Formation and basalt lava flows of the Garrawilla Volcanics. It was thought that these massive units might reduce subsidence through bridging behaviour. Following assessment of actual post mining subsidence, DGS have concluded that no bridging has occurred and future assessments should assume the same.

Planned mining has been completed in LWs 101-103 and monitoring of the subsidence effects continues.

3.2 Potential Subsidence

The maximum subsidence for the panels is predicted to range between 2.57 m to 2.75 m (60% to 64% mining height). The maximum panel subsidence includes the subsidence above the chain pillars, which is estimated to range between 0.21 m and 0.54 m.

The recorded subsidence in LWs 101-103 has a maximum measurement of 2.671 m. This occurred in LW 103, however the other longwalls had similar figures. The measurements are less than 10% over the predicted maximum subsidence.

Maximum panel tilts are predicted to range between; 25 and 47 mm/m for a 'smooth' profile behaviour, and 38 and 71 mm/m for discontinuous movements. The concave and convex curvatures range from 0.4 to 3.3 km-1 (or radii of 2.5 km to 0.3 km). The maximum tensile strains are expected to range from 4 to 10 mm/m for a 'smooth' profile, and 11 to 26 mm/m for discontinuous movements. The compressive strains are estimated to range between 6 and 13 mm/m for a 'smooth' profile, and 14 to 33 mm/m for discontinuous movements.

The maximum measured tilt was 56.3 mm/m and this was generally focussed around Pine Creek Tributary 1. Other areas were within the predicted values. Strain values were variable with some results over the predicted values and others significantly lower.

The ground surface would tend to subside more towards the centre of the panel, ie. away from the chain pillars between the longwall panels.

3.3 Impacts of Subsidence

3.3.1 General

The DGS report suggested that the mining impacts are likely to include:

- surface cracks with widths of 40 mm to 130 mm;
- surface gradients are likely to increase or decrease by up to 3% (1.5°);
- potential ponding depths of 0.15 to 2.1 m may develop above several of the longwalls and creeks in the flatter areas of the site.
- Discontinuous fracturing would be expected to occur, increasing rock mass storage capacity and horizontal permeability without direct hydraulic connection to the workings. Rock mass permeability is unlikely to increase significantly outside the limits of extraction;
- Stock watering dams are likely to be damaged by mine induced cracking and/or shearing
- The various unsealed roads and tracks around the site are likely to be subject to cracking and/or heaving during mine subsidence development

The report acknowledged the uncertainties inherent in subsidence prediction and recognised that, in some cases, only worst case outcomes could be presented. Terms were used throughout the report to reflect the general probability of the impacts of subsidence. These terms and their meaning are detailed in Table 3-1 below.

Table 3-1 Qualitative Measures of Likelihood

Likelihood of Occurrence	Event implication	Indicative relative probability of a single event
Almost Certain	The event is expected to occur.	90-99%
Very Likely	The event is expected to occur, although not completely certain.	75-90%
Likely	The event will probably occur under normal conditions.	50-75%

Possible	The event may occur under normal conditions.	10-50%
Unlikely	The event is conceivable, but only if adverse conditions are present.	5-10%
Very Unlikely	The event probably will not occur, even if adverse conditions are present.	1-5%
Not Credible	The event is inconceivable or practically impossible, regardless of the conditions.	<1%

3.3.2 Surface Cracking

The DGS report further states that direct hydraulic connection to the surface, due to sub-surface fracturing above the panels, is considered unlikely to occur where cover depths are > 140 m. Subsurface aquifers within 112 m to 139 m above the proposed panels (i.e. 65 to 87 % of the cover depth) may be affected by direct hydraulic connection to the workings, with significant long-term increases to vertical permeability.

In-direct or discontinuous sub-surface fracturing could interact with surface cracks where cover depths are < 255 m. Dam storages could be lost and creek flows could be re-routed to below-surface pathways. These could either re-surface down-stream of the mining extraction limits, or remain permanently underground. This could have a potentially negative impact on the surface features that are reliant on this water source.

While single surface cracks are unlikely to reach the mine workings, there is a possibility (though unlikely) that interaction of surface cracking with sub-surface fractures may link the surface water to the underground workings. The watercourses are all ephemeral and, therefore, this would only become an issue during periods of rain. If flow were able to quickly enter the mine workings from the surface, it may pose a safety risk and would also cause a significant input into the mine water system. However this scenario is considered unlikely and associated safety and operational issues are dealt with in the appropriate mine management plans (i.e. Inrush Hazard Management Plan).

Surface cracks were observed with widths of typically 50 – 100 mm, but some were up to 200 mm. There are no reports on the depth of the cracks.

3.3.3 Surface Uplift

Valley closure and uplift movements are strongly dependent on the level of 'locked-in' horizontal stress immediately below the floor of the gullies. It is also dependant on the bedding thickness of the floor strata (i.e. thin to medium bedded sandstone is more likely to buckle than thicker beds). The influence of the aspect ratio (i.e. valley width/depth) is also recognised as an important factor, with deep, narrow valleys having greater ‘upsidence’ than broad, rounded ones, due to higher stress concentrations.

The valleys across Narrabri Mine’s mining lease are very broad between crests and this would suggest uplift to be a minor factor. There is also a lack of thick, massive beds of conglomerate and/or sandstone units along the valleys which further suggests that the development of ‘upsidence’ above the mine workings is likely to be negligible.

The monitoring of subsidence to date has not registered any uplift.

3.3.4 Land Slip and Erosion

The DGS report has suggested that there is a ‘very unlikely’ chance that a major slip might occur in the ground surface above the mine. Instead it is more likely that only minor changes in gradient will occur; however this may also have undesirable effects. It is possible that gradient changes along creek paths may increase erosion and, therefore, increase the sediment load being carried downstream. This may also cause instability in the banks of the creeks, at locations where erosion is increased.

Monitoring has shown a gradient change of 5.5% which was within the predicted range.

3.3.5 Surface Depression and Ponding

While the DGS report states that ponding may be an issue, further work has been carried out by WRM Water and Environment Pty Ltd (WRM, 2009). The WRM report assesses the possible ponding that may occur on and adjacent to a tributary of Pine Creek. It predicted that the ponding would generally be contained by the existing channel banks, but out of bank ponding would also occur. There would also be areas of increased erosion, as described in Section 3.3.4. Only one area of the mine site was inspected, but the results were deemed to be typical of the wider area. The report did conclude that major changes in channel geomorphology due to changes in channel location were unlikely.

It should be noted that ponded water is likely to have increased salinity from sitting on saline soils for an increased length of time. The ponding may also affect local farming, flora and fauna; however, there may be both positive and negative impacts. Ponding may take up land that has other uses; however, it may also act as an additional water source.

The monitoring to date shows that water ponds in the subsidence depressions and that this is focussed on the most upstream depression.

3.3.6 Water Storage Dams and Soil Conservation (Contour) Banks

There are a large number of farm dams of various size located across the potential subsistence area above LW 101 to 106. Non-engineered farm dams and water storages will be susceptible to surface cracking and tilting (i.e. storage level changes) due to mine subsidence. The tolerable tilt and strain values for the dams would depend upon the materials used, construction techniques, foundation type and likely repair costs to re-establish the dam's function and pre-mining storage capacity.

The expected phases of tensile and compressive strain development may result in breaching of the dam walls or water losses through the floor of the dam storage area. Loss or increase of storage areas may also occur due to the predicted tilting. Maximum tensile crack widths across dam wall or storage areas are estimated to range between 40 mm and 115 mm. Surface 'steps' or humps due to compressive shear failures are estimated to range between 50 mm and 140 mm. Damage to windmills and fences near the dams and soil conservation (contour) banks may also occur and require repairing.

As noted above, the water in the storage dams is likely to have increased salinity from sitting on saline soils for an increased length of time. Therefore, its sudden release in to the watercourse system may have detrimental effects on the environment. These effects will be diluted as the flow moves through the catchment.

The management of water storage dams stability and function is addressed in the Built Features Management Plan, which makes up part of the Extraction Plan.

Monitoring to date has shown that 5 small farm dams and a number of contour banks have been undermined with no impact to their function.

4 ENVIRONMENTAL CONSEQUENCES

This section outlines the environmental consequences that longwall mining can have on surface water and groundwater.

4.1 Surface Water

4.1.1 General Principles

Surface water, in terms of the EP-WMP, relates to any above ground water directly affected by the longwall mining process. In the case of the Narrabri Mine, the water bodies that may be impacted are; the ephemeral Pine and Kurrajong Creeks that traverse some of the proposed longwall panels; and adjacent farm dams.

Surface water quantity and quality of these water bodies may be impacted by subsidence caused by the longwall mining process. Subsidence development mechanisms are explained in detail in Section 4B.1.3 of the Environmental Impact Assessment for Narrabri Mine and recent subsidence assessment by DGS (2015) as summarised in Section 10.

This EP-WMP considers management strategies to minimise the effects of any subsidence that may be caused by the longwall mining process. This will be achieved by a combination of regular monitoring and reactive works. The Surface water quantity and quality of the ephemeral Pine and Kurrajong Creeks, that traverse some of the proposed longwall panels and adjacent farm dams, may be impacted upon by the following:

- Surface cracking
- Slope instability and erosion
- Surface uplift
- Ponded water
- Breach or alteration of farm dams and soil conservation (contour) banks
- Ground disturbance above longwall panels

4.1.2 Surface Cracking

Surface water quantity may be affected by surface cracking. Surface cracking may lead to water in Pine and Kurrajong Creeks (when they are flowing) leaving the creek via surface cracks and flowing into aquifers or into the mine. Water entering aquifers within the mine site boundary may resurface again further downstream thus resulting in no net loss in water for Pine and Kurrajong Creeks. However water flowing into the mine may lead to a decrease in water flowing down Pine and

Kurrajong Creeks and would be dealt with as stated in Section 6. Slope Instability and Erosion

Increased erosion and sediment transport may occur as a result of localised increases in the bed gradient of local watercourses due to differential ground movement or creek bank instability. Localised increases in bed gradient are most likely to occur immediately downstream of each chain pillar (where flow direction is perpendicular to the panel orientation) and would result in increased flow velocity and erosive potential of surface flows. Current and predicted profiles of Pine and Kurrajong Creeks have been provided in Section 4B1.6.3 of the Environmental Assessment (2009). Localised creek bank instability would provide a potential sediment load source for transportation downstream and associated degradation of water quality.

Areas of the overbank areas will also experience an increase in slope, which may in turn lead to an increase in erosion thus affecting surface water quality. Erosion and sediment transport would result in a degradation of water quality which may impact downstream water bodies and users. Changes in water quality as a result of erosion are generally observed as an increase in total suspended solids (TSS) and turbidity.

4.1.3 Surface Uplift

Surface uplift affects surface water in a similar manner to surface cracking and slope stability and erosion. Water may be diverted underground and an increase in erosion thus decrease in water quality may occur due to the change in slope.

4.1.4 Ponded Water

Surface water flowing to the creeks may pond in areas where it currently does not pond as a result of surface gradients changing due to the above mechanisms. Both the quantity and quality of surface water is affected should areas of ponded water develop. There may be a decrease in the quantity of water reaching the creeks as it ponds and evaporates rather than flowing to the creeks. There may be a change in water quality as salinity may increase if water ponds over saline soils.

4.1.5 Farm Dams and Soil Conservation (Contour) Banks

Water quality of farm dams may be affected by ponding water and/or redirection of flows with higher sediment loads due to erosion. This is due to the additional salts absorbed by the stationary water stored in the dam. The effects will have a short duration due to the limited capacity of the dams when compared to the catchment size for the downstream areas. The environmental impact is therefore secondary to the impact on the utility of the dam. This may result in a social and /or economic impact due to the effect on livestock

It should be noted that dams similar to those across ML1609 have been undermined by longwalls elsewhere in Australia and any damage and water supply impacts have been effectively managed. The dams were repaired and reinstated in a timely manner and an alternative supply of water was provided by the mine during the interim period.

4.1.6 Ground disturbance above longwall panels

Surface water may also be impacted upon by ground disturbance above the longwall panels associated with works to enable mining such as the installation of drainage (gas and water) boreholes. At this stage it is anticipated that boreholes will be required at approximately 50m intervals along the longwall development. Borehole installation will require:

- construction of access tracks to access the drill sites: this will involve the use of machinery to construct the track and may require the import of fill and implementation of temporary drainage crossings;
- clearing and ground disturbance (ie cut and fill) required to construct the drill pads: the drill rig will require a minimum area of 5m x 5m for each borehole;
- ongoing access to the installed boreholes for monitoring and maintenance purposes: which will involve vehicular traffic with consequent wear and maintenance.

The above activities have the potential to exacerbate erosion and have a direct impact on runoff quality from the disturbed areas.

These bores will also require licencing by DPI Water and the water extracted will make up part of the mines 818 unit shares in the Gunnedah-Oxley Basin MDB Groundwater Source. Narrabri Mine will submit licence applications with as much notice as possible guided by the findings from future revisions of this WMP.

4.2 Groundwater

4.2.1 Predicted Impacts on Groundwater

The two main potential impacts of proposed longwall mining on the hydrogeological environment were considered to be:

- Local and regional lowering of groundwater levels within the Permian-Jurassic strata, due to groundwater inflows to the mine workings, particularly as a result of enhanced permeability of the rock units within the subsidence affected zone above the longwall extraction panels. Some lowering of groundwater levels may also occur as a result of increased rock storage due to the stress relief fracturing associated with the underground mining.

- Possible impacts on near-surface groundwater, including the alluvial groundwater system of the Namoi Valley, and groundwater baseflow contributions to the Namoi River and other surface drainages

DGS (2015) predicts that discontinuous sub-surface fracturing is likely to interact with surface cracks where cover depths are < 255 m. Creek flows could be rerouted to below-surface pathways and re-surfacing down-stream of the mining extraction limits in these areas.

Discontinuous fracturing would be expected to occur above these limits and increase rock mass storage capacity and horizontal permeability without direct hydraulic connection to the workings.

Numerical groundwater modelling has been used to predict mine inflows and impacts on groundwater levels and baseflows, both locally and regionally. Principal findings of the modelling after all 26 longwall panels (LW101-126) have been mined include the following:

- The base case predictive modelling simulation predicted that groundwater inflows to underground workings would gradually increase over the mining of longwall panels LW101 to LW106 from an initial 78 ML/a (0.21 ML/d) in Year 1 to 508 ML/a (1.39 ML/d) at completion (Year 6) of these five panels,

- Large drawdowns are predicted to occur within the target Permian coal measures (Hoskissons Seam) close to the mine, as a result of groundwater flows into the mine workings. The drawdown cone is predicted to be relatively steep, and drawdowns exceeding 10 m would be limited to around 6 km to 7 km to the west, north and south, and around 2 km to the east of the underground workings. The Permian drawdown impact would extend much less to the east, where it would be limited by the truncation of the coal seam by an overlying unconformity. The region of predicted drawdown greater than 1 m in the Hoskissons Seam extends approximately 20 km to the west, 10km from the mined areas to the south and to the north, but not to the east where the seam is absent.

- Predicted groundwater level impacts in the overlying Triassic Napperby Formation are much less pronounced. Drawdowns of 1m or more are predicted to extend a maximum of approximately 10km to the west of the Mine Site.

- Impacts on Jurassic strata would be extremely small, and there will be effectively no measurable impact above the Purlawaugh Formation aquitard (i.e. in the Great Artesian Basin intake beds).

- Predicted impacts on river baseflows to the Namoi River to the east are very small. Baseflow in this reach is predicted to reduce by a maximum of around 0.22 ML/d, but this is only 2% of the total calculated baseflow contribution to this reach of around 10.3 ML/d.

Overall, these results indicate that the following impacts on water resources may occur due to the mining of longwall panels LW101 to LW106:

- There will be negligible impact on groundwater within the Pilliga Sandstone, and hence a negligible impact on recharge to the GAB.
- Negligible impacts on groundwater levels in the Namoi Valley alluvium are predicted, and existing groundwater users will not be affected.
- Continuous/connected fracturing induced by longwall mining has the potential to significantly impact groundwater stored in the fractured rock aquifers above the mine (up to the Garrawilla Volcanics). The potential for impact on other local groundwater users is mitigated by NCOPL's acquisition of several properties within the anticipated zone of impact.

The average water quality of mine inflows would be a composite blend of the water qualities from all groundwater sources contributing to inflows. The inflow water quality would initially be dominated by the groundwater from the Hoskissons Coal Seam and the underlying Arkarula Formation. Over time, as proportionally more groundwater flows from the higher units and from more distant parts of the area of predicted drawdown impact, the groundwater quality would change to reflect an increased contribution from those areas. This suggests that the groundwater quality of the Mining Area would be generally improved as lower salinity water is drawn from the units higher in the geological sequence into the void space of the underground mine.

DGS (2015) notes that the height of continuous fracturing predicted using the 2014 Geology Pi-Term Model are 26 to 83 m higher than the EA Report indicated. The overall impact should therefore be re-assessed by the groundwater modelling consultant.

5 SURFACE WATER MONITORING AND MANAGEMENT

5.1 Surface Water Monitoring

Narrabri Mine has a comprehensive surface water monitoring program in place across the mine site that incorporates:

- The collection of rainfall and meteorological data.
- The collection of water quality data for the ephemeral flowing Pine Creek and Kurrajong Creek.
- The collection of water quality and water level data for farm dams.

However, given that Pine and Kurrajong Creek are ephemeral in nature and classed as Schedule 1 streams in accordance with Department of Planning and Environment (DP&E) (2005), continuous water quantity and quality monitoring is not practical. The comparison of ephemeral water quality data between runoff events, to determine if mining is having an impact on these creeks, is difficult and of limited value. Comparison of water quality values across rainfall events is difficult due to the large natural variation in water quality indicators between rainfall events (Table 5-1 shows these large variations in values).

Therefore, this EP-WMP includes three additional monitoring points (shown by the blue text and diamonds in Figure 5-1) compared to the WMP (URS, 2011). These are all located at the upstream site boundary and allow the water quality to be monitored as it enters the site and before any potential effects of the longwall mining operation can be encountered. This will allow water quality indicators during single rainfall events to be compared for the upstream (i.e. no project impact) and downstream monitoring sites. These monitoring locations will be included in the monitoring network before the longwall mining process begins and is described in section 5.3.

The existing surface water quality data has a maximum of 12 records for any monitoring site and shows no discernible pattern for current conditions. This is largely due to the ephemeral nature of the watercourses, causing each flow event to be a “first flush” of the channel. This means that any debris that has collected in the channel since the last flow event will be washed down the channel, changing the water quality in an inconsistent manner.

The increase in monitoring locations will allow a comparison between the water quality of flow entering and leaving the mine site. This monitoring approach may allow correlations to be formed between the monitoring points as well as building a new baseline for flow entering the site. However, it is still possible that the ephemeral nature of the watercourses may mean that a natural correlation between upstream and downstream monitoring locations cannot be determined. In this case the data will be analysed for a consistent upwards trend in water quality indicators above those outlined in the Namoi River Catchment Action Plan (NCMA, 2007) which includes the ANZECC (2000) guidelines. If this is identified, Narrabri Mine will investigate the potential causes (refer to TARP).

The identified monitoring locations are located at the site boundaries and the relatively large distance between them may allow changes in quality that are not caused by the mining operation. However, constructing automatic water sampling equipment on either side of the first 5 longwall panels (101-105) and moving this equipment as mining progresses to other panels would involve disturbing the existing catchment environment several times, thereby causing a bigger impact on water quality than the potential predicted impacts from the mining itself. Therefore permanent stations are proposed at the sites identified in Figure 5-1 and Narrabri Mine will assess the data for correlations or trends as described above.

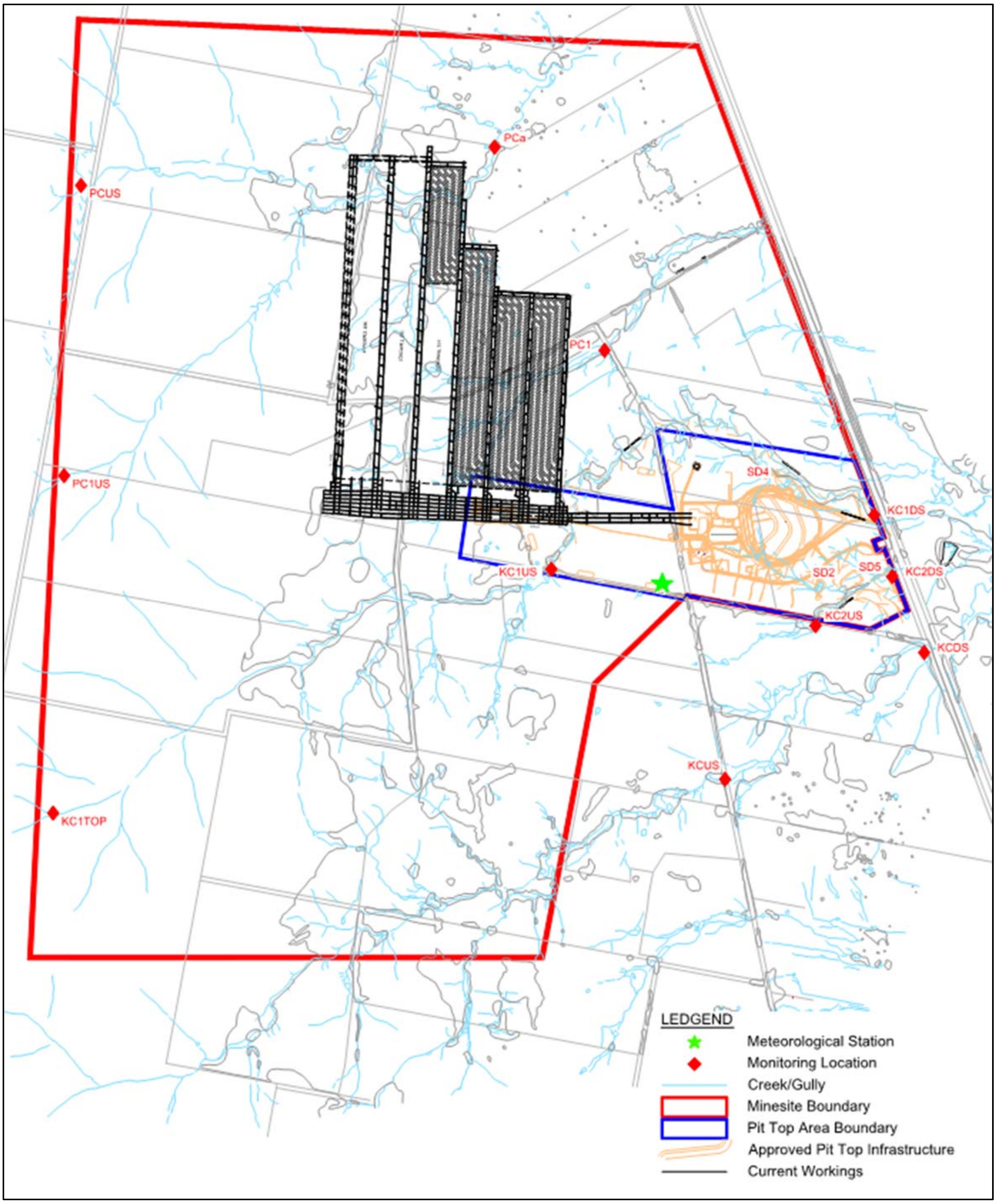

Figure 5-1 Surface Water and Meteorological Monitoring Locations

5.2 Baseline Water Quality

5.2.1 Local Catchment Water Quality

Since 2007 water quality monitoring has been undertaken at a number of locations on Pine Creek and Kurrajong Creek and their tributaries across the mine site. Table 5-1 shows a summary of water quality data collected during this period. The locations of the water quality monitoring sites are shown by the red text and diamonds in Figure 5-1. It should be noted that the data does not show any significant trends over time. In fact all the parameters generally show a random spread of data points over time.

Table 5-1 Water Quality Data for the Local Catchments in the Project Area

Parameter	No. Samples	Mean	Median	Min	Max	10th %ile	80th %ile
pH	231	7.3	7.3	5.8	8.7	6.8	7.6
Electrical Conductivity (µS/cm)	231	169	106	16	1300	50	205
Total Suspended Solids (mg/L)	231	150	68	2	2760	15	193
Oil & Grease (mg/L)	3	19	10	9	39	9.2	27.4
TOC	203	11	10	2	38	6	15

5.2.1 Regional Water Quality

The receiving water body of Pine and Kurrajong Creek is the Namoi River. Water quality data collected from two different locations for two different time periods has been analysed.

Over a 10 year period, the ANZECC (2000) default trigger values were exceeded 87% of the time for electrical conductivity (EC), 50% of the time for pH and 17% of the time for turbidity at one of these locations. There is insufficient water quality data at this location to derive a relationship between water quality and flow rates in the Namoi River. However, continuous water quality data, measuring EC, is available between 1995 and 2005 at the Gunnedah Station (GS419001), located 63 km upstream of the Narrabri Mine. The following is of note:

- EC varies between 200µS/cm and 1200µS/cm at Gunnedah with the majority of elevated EC values occurring when flows are lower than 1000 ML/d.
- There is a strong relationship between flow rate and EC with high flows, associated with floods, measuring lower EC values.
- Higher EC values tend to occur when there are limited releases from Keepit Dam to supply the downstream irrigation demand and the majority of the flow is being generated from the downstream catchments of the Peel and Mooki Rivers. This generally occurs during the winter months.
- Elevated EC values can occur for many months during low flow periods.

5.2.2 Water Quality Criteria and Triggers

Surface water compliance criteria are as prescribed by the Catchment Action Plan for the Namoi River (NCMA, 2007) which includes the ANZECC (2000) guidelines for

- Irrigation water – EC range of 650-1300µS/cm; and
- Aquatic Ecosystem Protection – mean values of Total Endosulphan <0.03µS/L and Atrazine <0.7µS/L.
- River Salinity of <550µS/cm 50% of the time and <1000 µS/cm 80% of the time

The ANZECC (2000) water quality trigger values for upland rivers are shown in Table 5-2. These triggers will be used, should it not be possible to establish baseline levels or a correlation between monitoring up and downstream of the underground workings.

Table 5-2 ANZECC (200) trigger values for upland rivers

Parameter	ANZECC (2000) Upland Trigger Value	Local Creek Background Concentration	
		Median	80^{th} %ile
pH	6.5 – 8.0	7.2	7.8
Electrical Conductivity (µS/cm)	30 – 350	126	235
Total Suspended Solids (mg/L)	–	84	179
Oil & Grease (mg/L)	–	10	27.4
Turbidity (NTU)	2 – 25		
Phosphorus (µg/L)	20		

ANZECC & ARMCANZ (2000) does not specify trigger values for oils and greases or total suspended solids (TSS). The range of default trigger values given for turbidity of between 2 and 25 NTU (ANZECC & ARMCANZ, 2000) can be used to indicate likely acceptable TSS values. At present, insufficient data is available to draw a correlation between TSS and turbidity. Both parameters would be measured in the future to allow a correlation to be made. Nutrients, such as phosphorus, are not currently monitored because the surrounding agricultural areas are likely to generate significantly higher nutrient levels in comparison to the mine.

The proponent proposes to work within the framework outlined in the NCMA (which incorporate the ANZECC 2000 trigger values) and the NSW Salinity Strategy for the longwall project to ensure that the ability to achieve these targets is not compromised.

5.3 Surface Water Monitoring Parameters and Schedule

5.3.1 Water Quality Monitoring Schedule

Current monitoring locations together with the additional monitoring locations will continue to be monitored in accordance with the sampling parameters and sampling frequencies set out in Table 5-3. Due to the ephemeral nature of the watercourses, sampling will be undertaken on an event-basis. The water quality monitoring program provides for the assessment of background (upstream) data for flow events in the various creeks and comparison to samples taken downstream of the mining impact area which should enable water quality changes as a result of mining to be identified.

Monitoring is the responsibility of the Environmental Officer and is conducted by a suitably qualified professional in accordance with the relevant Australian Standards. The frequency of monitoring and range of parameters analysed during flow and routine monitoring is reviewed after the first two years of operations.

Table 5-3 Water Quality Monitoring Schedule

Location	Parameters	Frequency
Site (Meteorological Monitoring)	Rainfall Wind speed and direction Temperature Relative Humidity Solar Radiation	Recording every 15 minutes
Farm dams	Water level EC Oil and Grease pH TSS TOC Turbidity	Monthly (adjusting frequency when trends are understood)
Ponding areas when Identified	EC	Monthly (adjusting frequency when trends are understood)
PCUS, PC1US, PC, PC1, KC1TOP, KC1US, KC1DS, KC2US, KC2DS, KCUS, KCDS	EC Oil and grease pH TSS TOC Turbidity	Daily during runoff events (samples can only be taken during runoff events as the creeks are ephemeral)

Areas of ponding that are identified will be sampled on a monthly basis to test how water salinity changes. This monitoring frequency can then be adjusted, as dictated by the results. This approach will also be taken for the farm storage dams across the site. Over time, regular water testing will build up a general trend for the condition of the water being collected. Further investigation can then be started, should these trends change during the mining operations.

5.3.2 Inspection Monitoring Schedule

The water quality data will need to be complimented with a programme of visual inspection. The existing monitoring program would be extended to include the monitoring of the impact of mining on the watercourses that traverse the proposed longwalls. The inspection monitoring would include the following components.

- Each Creek traversing a longwall will be surveyed at regular intervals to determine the ultimate level of the area.
- Photographs of the creek would be taken prior to mine subsidence and for 1 year after significant mine subsidence has ended (as defined in DGS 2011). These photographs would be taken following rainfall events of 38.4mm over a consecutive 5-day period, to assess whether erosion has occurred. This requirement is to be re-evaluated at the end of the monitoring period.
- A log of when inspections occur (and photographs taken) would be kept together with an assessment of the changes in erosion.

The above will be supplemented with aerial photography and survey data when they are made available on the existing monitoring schedule. These visual inspections coupled with survey will be able to easily identify changes in creek beds and erosion that may be attributed to mining activities rather than natural phenomena. For further detail of monitoring of surface cracking and erosion refer to the Land Management Plan.

NCOPL will review the frequency of monitoring and range of parameters analysed after the first two years of the Longwall Project.

5.4 Proposed Management Actions

The following management strategies will be employed to address the predicted impacts of longwall mining on surface water. Contingency measures are also presented should they be required. The presented actions focus on visual inspection as these can be easily conducted on a regular basis.

All works in the catchment will be carried out with due regard to erosion protection and sediment control. The mine currently has an Erosion and Sediment Control Plan (ESCP) that would be suitable for the intended works. The main reference material in NSW is ‘The Blue Book’ (Landcom, 2004), but other references include guidelines produced by the Australian arm of the International Erosion Control Association (IECA, 2009) and the ‘Managing Urban Stormwater: Soils and Construction, Volume 2E Mines and Quarries’ (OEH, 2008). These reference documents provide methods for assessing the potential for erosion and sedimentation as well as describing methods and systems for controlling negative impacts.

Given the variable nature of impact, mitigation strategies would be tailored to each individual location, considering the geomorphic characteristics, vegetation and soil types of each location.

5.4.1 Surface Cracking

Narrabri Mine will monitor areas above the underground workings that are likely to be affected by surface cracking on a monthly basis and/or significant rain events (defined as a 5 day 95th%ile rainfall event which is 38.4mm over 5 consecutive days). This would involve inspection of the areas on foot, or where access is available, by vehicle.

When cracks are identified, the location will be noted but no immediate action will be taken. It is expected that natural erosive forces will fill smaller cracks naturally. For larger cracks (>100mm) or those persisting without being naturally filled in, remedial works will be required. This will involve the scarification or light ripping of ground over, and on both sides of, the crack.

If these remedial works are insufficient to fill in a deeper or wider crack, a different approach will be required. Narrabri Mine will excavate the required volume of subsoil from stockpiles located at nearby gas drainage sites, ventilation sites or footprint of the Reject Emplacement Area, transfer it to the crack site and fill it in.

Creeks traversing a longwall panel will be inspected within 6 months of being crossed.

5.4.2 Slope Stability and Erosion

Given the ephemeral nature of the creeks, bed changes and erosion would be expected to occur as part of naturally occurring phenomena. Therefore the creeks are expected to naturally re-adjust to any changes in gradient and short term increase in erosion as a result of subsidence.

Part of the monitoring of the surface above the mine workings will include an assessment of the area’s most susceptible to post mining surface gradient changes (as identified in the DGS (2015) report Figures 16, 17, 18 and 19). This assessment will focus on the potential for accelerated erosion in creek beds and slopes with exposed soil. Creeks will be monitored for erosion following each runoff producing storm event. Any “non-natural” or erosion deemed to be in excess of natural rates of erosion will be repaired and remedial measures, such as check dams or drop structures, would be constructed, if necessary.

While considered unlikely, should large-scale slope instability be identified after mining, mitigation works will be required. Stabilisation works will be carried out, such as the installation of deep sub-surface drainage trenches (to reduce pore pressures) and the construction of strategic catch drains to improve surface run-off. In the event that erosion is identified, especially along the creek channels, the sections of damaged or steeply eroded banks would be stabilised.

5.4.3 Surface Uplift

The monitoring and remediation for uplift is very similar to that of surface cracking. The surface above the mining operations should be inspected for signs of uplift and associated cracking. If found, then the cracks should be filled in as previously described. Where uplift is identified, this should be reviewed to allow improved predictions after the completion of each longwall panel.

5.4.4 Ponded Water

Inspection of the watercourses over the subsidence zone of the mine site will occur on a monthly basis and following rainfall events. If ponding (as identified in the WRM report Figure 7.1) is identified, Narrabri Mine will implement the following mitigation strategy.

- If little vegetation of significance is impacted and water quality analysis confirms no increase in salinity, the ponding would be left to “self-correct” over time. The WRM report suggests that the continual action of erosion and sedimentation without mitigation measures is likely to ‘self-correct’ the geomorphic characteristics of the waterways over time.
- If important environmental features are impacted (i.e. riparian vegetation, Endangered Ecological Community or archaeological deposits) OR water quality analysis indicates an increase in salinity, the ponding will be assessed and remediation options will be developed to protect the affected environmental features and prevent saline water discharging downstream. The remediation will consider the requirements of the Biodiversity Management Plan and Heritage Management Plan.

5.4.5 Farm Dams and Soil Conservation (Contour) Banks

Appropriate impact management strategies are described in the Built Features Management Plan which makes up part of the Extraction Plan.

Should a water quality sample from farm dams, exceeded water quality guidelines for livestock, repeat sampling will be undertaken to confirm results exceed the trigger level. Should they exceed the trigger value a second time Narrabri Mine will provide an alternative water source, until the farm dam water satisfies the livestock water quality guidelines.

5.4.6 Ground disturbance above longwall panels

Appropriate management strategies during construction of access tracks and clearing will be implemented as per the approved ESCP. A ground disturbance protocol outlining the standard practices to control soil erosion and sedimentation will be prepared ahead of the planned disturbance. Strategies to control the impacts may include:

- Limit clearing to a designated path whilst seeking to disturb the minimum amount of vegetation (i.e. avoid mature trees, etc);
- Avoid drainage lines wherever possible;
- Implement erosion control measures for roadways: drainage socks along table drains, rock check dams to slow down runoff, etc;
- Implement erosion control measures for disturbed slopes: silt fences along contours;
- Schedule construction in the dry wherever possible.

For the drill pads, rehabilitate using fast growing pasture grasses once wells have been installed.

5.4.7 Contingency measures

In the event that; significant erosion; ponding which inundates significant areas of vegetation; or increased surface water salinity or pH outside the target range of ANZECC (2000) is identified (refer to Table 5-2), an impact mitigation strategy would be developed. The impact mitigation strategy may include the following approaches.

- Undertake a more detailed survey of watercourses based on the principles of the Index of Diversion Condition (IDC) developed for creek diversions as part of the ACARP program ‘Monitoring and Evaluation Program for Bowen Basin Diversions’ (ID&A 2000). IDC provides a rapid assessment of the condition of diversions and adjoining stream reaches. The purpose of the IDC is to flag potential management issues rather than provide a scientific assessment of a diversion or stream. It is an integrated suite of indicators that measures the geomorphic and riparian condition of a diversion and its upstream control and downstream reaches hence it could be adapted to monitor significant changes in surface morphology as a result of subsidence.
- Visible crack in the bed of the creek will be in-filled.
- Contour banks that cross chain pillars would be removed and reconstructed if appropriate for the ongoing land use (noting that the Proponent owns the majority of the land over LW 101 - 106 and as such is being managed to

achieve lower stocking rates and higher vegetation cover than has been historically the case).

- If significant areas of ponding are identified, the following assessment and mitigation would be made.
    - If little vegetation (or vegetation of conservation significance) occur within the ponded area, a channel would be excavated to allow the pond to free-drain. If this occurs, appropriate management measures would be followed to ensure that Aboriginal sites or significant vegetation is not impacted by the excavation (refer to Biodiversity Management Plan and Heritage Management Plan).
    - In the event that an increase in salinity is observed, the channel across the chain pillars would be excavated to reduce the gradient change which causes the pond to form (thereby reducing the time over which the salts can leach from the soil and enter the water). If salinity measurements fail to meet the criteria for surface water flows, the ponded water will be taken into the mine water system before any works are carried out.

6 GROUNDWATER MONITORING AND MANAGEMENT

6.1 Existing Groundwater Environment

The Environmental Assessment (EA) (R.W. Corkery & Co. Pty. Limited, 2009) presents a description of the hydrogeological environment in the vicinity of the mining operations, and predicted impacts on groundwater for stage 2 of the mining operations. These are summarised below.

6.1.1 Existing Groundwater Environment

The mine site is located within the Permo-Triassic Gunnedah Basin, which forms the central part of the north-south elongate Sydney-Gunnedah-Bowen Basin system. The Narrabri Mine is located near the northern and western boundaries of the Gunnedah Basin and the eastern margin of the Surat Basin, a sub-basin of the larger Great Artesian Basin. Hence, the rocks and sediments beneath and surrounding the Longwall Project can be grouped into:

- Undifferentiated Quaternary sediments;
- Jurassic Surat Basin sequence; and
- The Permo-Triassic Gunnedah Basin sequence.

6.1.1.1 Undifferentiated Quaternary Sediments

Undifferentiated Quaternary alluvial gravel, sand, silt and clay overlies the Jurassic and Triassic Sediments. The most significant alluvium occurs in association with the Namoi River, located 2-7 km east/north-east of the mine site, and approximately 4km from the underground workings. These alluvials increase in depth as they move away from the underground workings. The aquifer of the Namoi River alluvium supports irrigated agriculture in the region, and is considered to be stressed due to large over-allocations of groundwater extraction.

Water allocation from the Namoi River alluvium is managed under a Water Sharing Plan (Upper and Lower Namoi Groundwater Sources 2003). In response to the over-allocation of this resource, entitlements were previously reduced.

Minor localised and discontinuous alluvium occurs in association with the local ephemeral drainages crossing the mine site.

6.1.1.2 Surat Basin (Great Artesian Basin) Sequence (Jurassic)

The Surat Basin sequence consists of, from youngest to oldest, the Pilliga Sandstone, the Purlawaugh Formation, and the Garrawilla Volcanics.

The Pilliga Sandstone outcrops along the western margin of the mine site and consists of medium-bedded, cross-bedded, well sorted fine to coarse grained quartz sandstone. The Purlawaugh Formation subcrops beneath the central part of the mine site and consists of thinly-bedded, generally fine grained, silty lithic sandstone, siltstone and minor claystone with thin stony coal seams present in the lower part of the unit. The Garrawilla Volcanics consist mainly of alkali basalt flows with very minor intervening mudstone and clastic rocks, and unconformably overlie the Triassic Napperby Formation of the Gunnedah Basin sequence.

The Surat Basin sequence form part of the regional Great Artesian Basin (GAB) and correspond to the intake beds (GWMA 601) of the GAB. The Pilliga Sandstone is unsaturated within the mine site however it becomes partly saturated to the west of (down-dip from) the mine site, as the formation dips below the regional water table level. The Purlawaugh Formation has low porosity and permeability and is rarely considered as an aquifer with bore yields generally less than 0.5L/s. The groundwater of the intake beds of the GAB is not hydraulically connected with alluvial groundwater associated with the Namoi River.

6.1.1.3 Gunnedah Basin Sequence (Permian to Triassic)

The Gunnedah Basin sequence consists of, from youngest to oldest, the Napperby Formation, the Digby Formation, and the Balck Jack Group.

The Napperby Formation consists of a coarsening-up sequence of siltstone-sandstone-siltstone laminate, and fine to medium grained quartz-lithic sandstone. An intrusive dark green alkali basalt sill is present in the lower part of the Napperby Formation and is almost certainly related to the Garrawilla Volcanics.

The underlying Digby Formation consists mainly of thickly bedded, polymictic, lithic, pebble conglomerate with clasts of volcanics, meta-sediments and jasper in a lithic rich matrix. Minor finely to medium bedded, lithic sandstone beds are present towards the top of the unit.

The Black Jack Group consists of lithic sandstone, siltstone, claystone and coal with minor tuff. The Black Jack Group includes the Hoskissons Seam, dull lustrous coal consisting of a low ash working section (basal 4.2 m) and an upper high ash coal with claystone bands. The boundary between the Digby Formation and Black Jack Group consists of an angular unconformity such that in the eastern part of the mine site, the unconformity truncates the Hoskissons Seam at a depth of approximately 130m to 160m while in the west there is up to 20m of Black Jack Group above the Hoskissons Seam.

The Gunnedah Basin sequence contains local groundwater flow systems in fractured rock. Bore yields within the Gunnedah GWMA on and surrounding the mine site are generally low and similar to the Purlawaugh Formation.

6.2 Groundwater monitoring

6.2.1 General

Narrabri Mine has a groundwater monitoring program in place across the mine site that incorporates the collection of water quality and water level data from groundwater monitoring and local production bores. This groundwater monitoring network will be augmented by the installation of additional groundwater monitoring bores and vibrating wire piezometers to monitor and compare actual to predicted impacts.

The monitoring network will be used to assess the state of the ground water across the mine lease and beyond. If the groundwater is found to be changing in level or quality outside of predicted impacts or in a manner that is not consistent with predictions, further investigation will be carried out to identify the root cause. If this cause originates from the mining activity being carried out on site, corrective action will be taken.

Schedule 3 Condition 1 of the SoC states that any loss of flows to the GAB, caused by mining, should be managed, licenced or offset. The mine site is located in an area that currently has government embargos on new licences for surface and ground water extraction. Therefore any loss of flow above the currently licenced level (248 unit shares, licence 90AL811346) would have to be managed or offset. The monitoring system is described in the following sections and will allow Narrabri Mine to manage the use of groundwater. This is the first step in managing the potential loss of flow to the GAB, as well as allowing the monitoring of broader flow and quality conditions. The approach to be taken to alleviate any losses of flow will be developed, should the monitoring network reveal such a loss.

The monitoring of groundwater will also assess the volumes extracted from all bores, gas drainage and the mine workings against the applicable licences. It is not anticipated that Narrabri Mine will exceed its allocations; however an approach to manage this situation will be developed, should it arise.

6.2.2 Monitoring Locations

Additional monitoring bores have been installed within the Longwall Project Area since the completion of the Stage 1 groundwater assessment. The Narrabri Mine groundwater monitoring network now consists of 25 standing piezometers, and 7 vibrating wire piezometer bores which have been strategically located to target alluvium/colluvium, overburden and coal measures allowing the monitoring of both water level and water quality. In addition 11 government registered water supply bores have been identified for inclusion in the monitoring network subject to access and landowner approval. Table 6-1 lists all the groundwater monitoring bores with Figure 6-1 showing the location of these bores across the mine lease and surrounds. Two of the vibrating wire piezometer bores (P35 and P36, historically known as NC175 and NC179 respectively) are multilevel vibrating wire piezometer monitoring bores.

It is likely that a number of bores located above the longwall goaves will become obsolete as longwall extraction progresses. These will be progressively replaced after completion of active subsidence.

Narrabri Mine is currently in discussions with the Department of Primary Industries – Water (DPI Water) regarding expansion of the groundwater monitoring network to incorporate additional privately licensed water bores and/or the installation of new monitoring piezometers. DPI Water requires the bores/piezometers to be located to the east of the mine (to monitor possible impacts on the Namoi Alluvium) and to the west of the mine (to monitor possible impacts on the GAB). Use of existing bores and/or installation of piezometers will be subject to property access and licensing requirements associated with non-project related properties. Any additional monitoring locations will be incorporated in the Environmental Monitoring Program, to be submitted to DPI Water for Secretary approval, and any subsequent amendments to the WMP.

Groundwater volumes extracted from the bores and gas drainage will be measured using flow meters attached to the pumps used in the process. By recording the duration and rate of extraction, the volume can be calculated. It should be noted that the volumes extracted from these locations will form part of the 818ML of extraction permissible under groundwater entitlement 90AL822538 (Gunnedah-Oxley Basin MDB Groundwater Source).

Groundwater extracted from the mine workings are currently measured through pumping rates from the box cut sump.

Table 6-1 Groundwater Monitoring Network

Bore ID	Former Bore ID	DPI Water Licence Number	DPI Water GW Reference	MGA Easting	MGA Northing	Ground Level (mAHD)	Bore Depth (m)	Screen Interval (m bgl)	Formation
Standpipe Piezometers									
P01	NG1	90BL254481	GW968435	776116	6614694	316.059	50	44-50	Garrawilla Volcanics
P02	NG2	90BL254482	GW968436	777282	6616355	275.917	50	44-50	Napperby Formation
P03	NG3	90BL254483	GW968437	780433	6620115	236.312	45	34-40	Pamboola Formation
P04	NG4	90BL254484	GW968438	777490	6625553	248.957	30	24-30	Napperby Formation
P05	NG5	90BL254485	GW968439	778180	6628195	233.408	30	24-30	Pamboola Formation
P06	NG6	90BL254486	GW968440	772726	6626021	326.189	90	78-90	Pilliga Sandstone
P07	NG7	90BL254487	GW968441	768998	6624338	289.694	90	78-90	Pilliga Sandstone
P08	NC110S	90BL254663	GW968631	772697	6618421	322.110	65	57-63	Purlawaugh Formation
P09	GWB5S	90BL254958	GW968632	775127	6620209	287.600	30	24-30	Purlawaugh Formation
P10	NC30D	90BL254658	GW968633	774063	6616444	302.530	130	118-130	Napperby Formation (no sill)
P11	NC30S	90BL254959	GW968634	774066	6616447	302.400	50	44-50	Napperby Formation (no sill)
P12	NC98D	90BL254659	GW968635	776513	6619964	276.480	90	84-90	Napperby Formation(above sill)
P13	NC98S	90BL254690	GW968636	776526	6619972	276.480	30	24-30	Garrawilla Volcanics/Napperby
P14	NC100D	90BL254661	GW968637	775221	6622816	277.410	78	72-78	Napperby Formation(above sill)
P15	NC100S	90BL254961	GW968638	775221	6622818	277.410	30	24-30	Garrawilla Volcanics
P16	NC119D	90BL254660	?	772233	6623740	303.510	146	137-146	Garrawilla Volcanics
P17	NC119S	90BL254962	GW968639	772222	6623712	303.240	56	47-56	Purlawaugh Formation
P18	NC122	90BL254662	?	776826	6621802	270.900	146	143-146	Hoskissons Seam
P19	NC123R	90BL254963	GW968640	776827	6621543	275.090	187	184-187	Pamboola Formation
~~P20~~	~~NC127~~	~~90BL254964~~	~~GW968643~~	~~776482~~	~~6621837~~	~~272.940~~	~~162~~	~~159-162~~	~~Arkarula Formation~~

Bore ID	Former Bore ID	DPI Water Licence Number	DPI Water GW Reference	MGA Easting	MGA Northing	Ground Level (mAHD)	Bore Depth (m)	Screen Interval (m bgl)	Formation
P47		90BL256060		776166.06	6622585.864	288.780	30.5	8-30.5	Garrawilla Volcanics
P50A				775724.586	6620655.148	280.874	60	15-60	Garrawilla Volcanics
P50B				775732.589	6620661.533	280.874	8	5-8	Pilliga Sandstone
P50C				775738.357	6620666.523	280.874	2.5	1.5-2.5	Pilliga Sandstone
P51				777437.004	6620859.213	267.023	17.0	9-12	
Vibrating Wire Piezometers (March 2009)									
P21		90BL254965	GW969508	776851	6620363	275.000	200	160	Hoskissons Seam
P22		90BL254966	GW969509	776745	6620406	274.120	180	165	Hoskissons Seam
~~P23~~	~~NC175~~	~~90BL254967~~	~~GW969510~~	~~776226~~	~~6620693~~	~~286.035~~	~~199~~	~~Multi-Level~~	~~Multi-Level~~
P24	NC179	90BL254701	GW969642	776675	6621043	277.594	181	Multi-Level	Multi-Level
P25		90BL255167	GW969661	776703	6620326	270.000	200	165	Hoskissons Seam
P26		90BL255168	GW969973	776537	6620528	275.413	200	176	Hoskissons Seam
P27		90BL255169	GW969974	776531	6620485	275.355	180	176	Hoskissons Seam
P35		90BL255769	GW969937	776429	6620347	278.710	183	Multi-Level	
P36		90BL255770	GW969936	776338	6620441	281.500	190	Multi-Level	
P37		90BL255771	GW969934	776474	6620492	277.384	186	Multi-Level	
~~P38~~		~~90BL255772~~	~~GW969933~~	~~776385.09~~	~~6621640.07~~	~~274.160~~	~~169~~	~~Multi-Level~~	
P40		90BL256064		772814.744	6620823.133	321.220	360	Multi-Level	Multi-Level
P44		90BL256061		777434.3725	6623211.903	268.150	471	Multi-Level	Multi-Level
P45		90BL256062		779490.524	6620117.114	247.265	291	Multi-Level	Multi-Level
P46		90BL256063		777395.187	6617846.587	262.325	396	Multi-Level	Multi-Level
P48				775295.72	6623039.33	276.000	210	195	Hoskissons Seam
~~P49~~				~~775339.332~~	~~6622937.102~~	~~278.626~~	~~210~~		~~Hoskissons Seam~~

Bore ID	Former Bore ID	DPI Water Licence Number	DPI Water GW Reference	MGA Easting	MGA Northing	Ground Level (mAHD)	Bore Depth (m)	Screen Interval (m bgl)	Formation
Surface Water Containment Ponds									
P28		90BL255170	GW969662	778343	6620162	262.460	25	19-25	Napperby Formation(above sill)
P29		90BL255171	GW969635	778541	6619978	256.840	25	19-25	Napperby Formation(above sill)
P30		90BL255172	GW969963	778808	6620071	254.950	15	9-15	Napperby Formation(above sill)
P31		90BL255173	GW969961	778318	6620343	264.390	15	9-15	Napperby Formation(above sill)
P32		90BL255216	GW969959	778993	6620335	252.490	15	9-14	Napperby Formation(above sill)
P33		90BL255217	GW969964	778772	6620523.21	253.560	15	9-14	Napperby Formation(above sill)
P34		90BL255218	GW969684	778542	6620604.39	255.960	15	9-14	Napperby Formation(above sill)
DPI Water Registered Bores									
~~WB1~~		~~90BL028774~~	~~GW038662~~	~~777251~~	~~6622763~~	~~265.839~~	~~0~~	~~NK~~	~~?~~
WB2		90BL246067	GW966836	776382	6619701	281	0	22-26	Garrawilla Volcanics
WB3a		?	GW030299	779133	6631524	226	0	8.2-8.5	Alluvium
WB3b		?	GW030299	779133	6631524	226	0	35.1-36.3	Alluvium
WB4		?	GW030230	778957	6629746	224	0	11.3-15.9	Alluvium
WB5a		?	GW036004	785892	6618196	233	0	11-14.5	Alluvium
WB5b		?	GW036004	785892	6618196	233	0	26.5-28	Alluvium
WB6a		?	GW036005	786976	6615621	234	0	11.5-13	Alluvium
WB6b		?	GW036005	786976	6615621	234	0	76.7-78	Alluvium
WB7		90BL100346	GW038200	784440	6620521	230	0	NK	Alluvium
~~WB8~~		~~90BL100778~~	~~GW043315~~	~~777682~~	~~6623409~~	~~265.056~~	~~0~~	~~27.4-29.8~~	~~Alluvium~~
~~WB9~~				~~776563~~	~~6621158~~	~~282.197~~	~~186~~		
Namoi Bore				779131	6631920	223.2	62	32-46	Alluvium

Bore ID	Former Bore ID	DPI Water Licence Number	DPI Water GW Reference	MGA Easting	MGA Northing	Ground Level (mAHD)	Bore Depth (m)	Screen Interval (m bgl)	Formation
Namoi River				779332	6631962	222.3	-	-	Surface Water
Proposed Monitoring Locations									
P39				782320.2783	6619725.104		0		
P41				771626.5698	6624636.525		0		
P42				771100.7296	6617196.539		0		
P43				781146.6372	6619934.683		0		
P52				777118.417	6620808.42	268.801			
P53				776994.621	6620654.96	270.001			

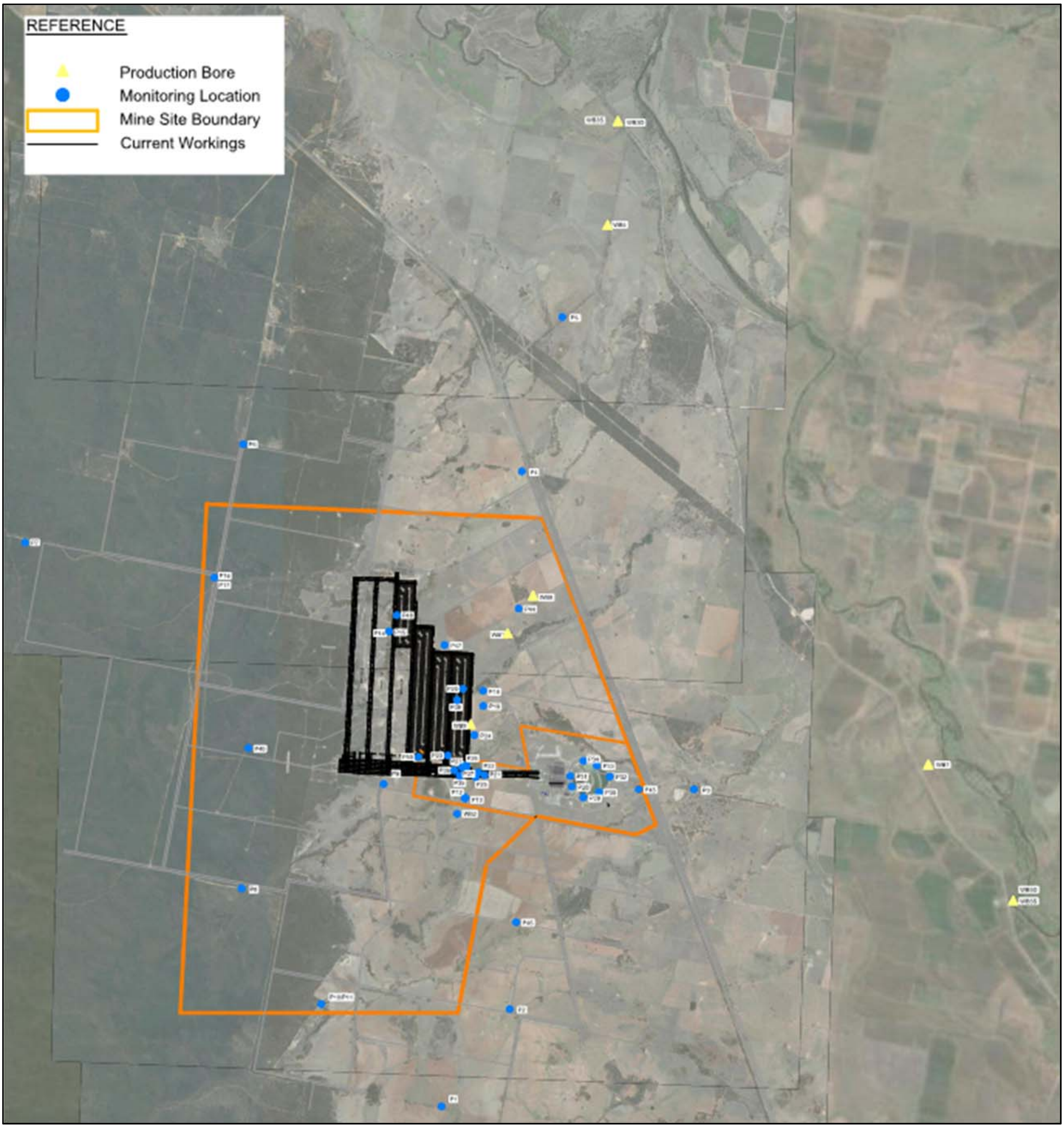

Figure 6-1 Groundwater Monitoring Network

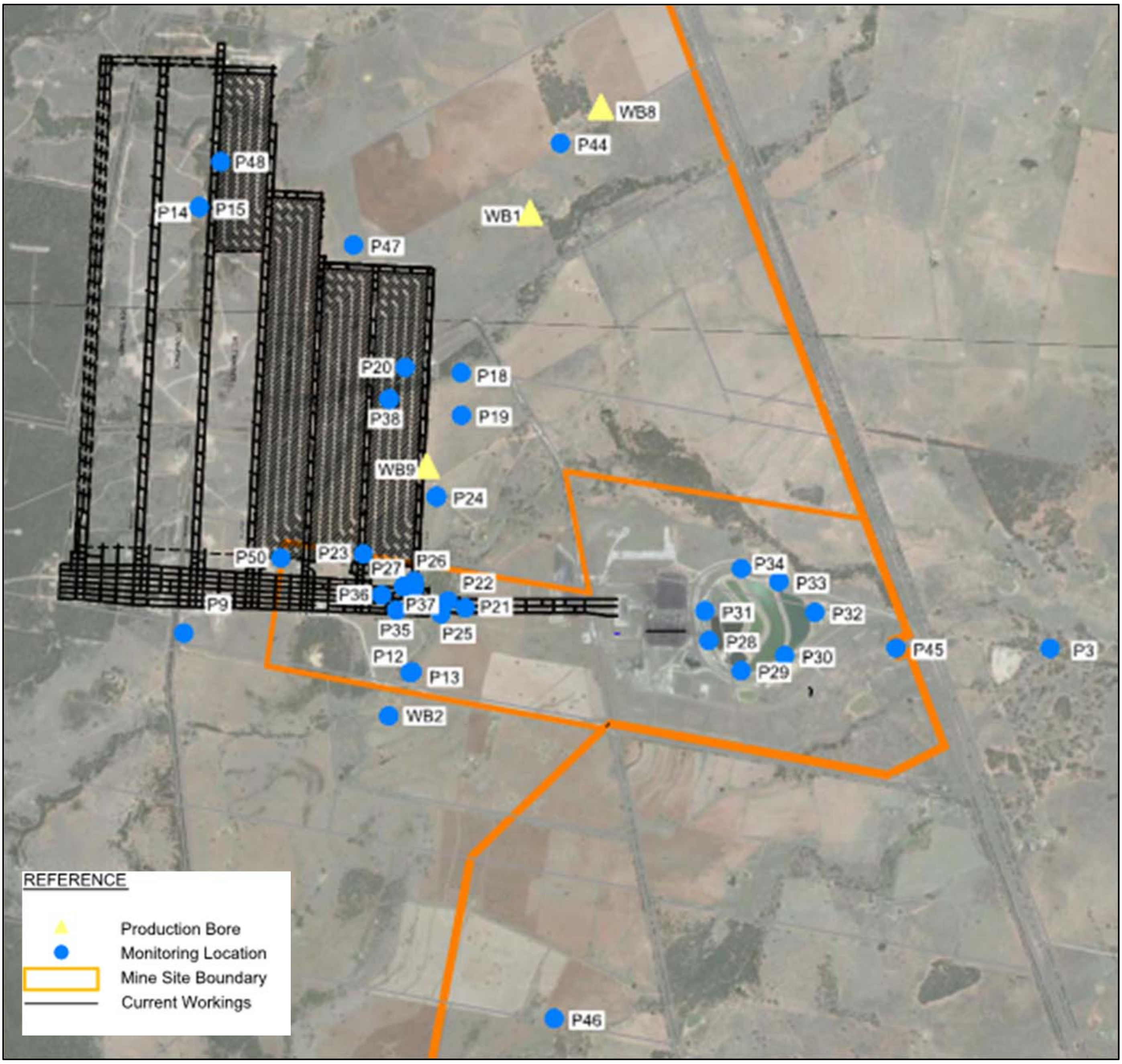

Figure 6-2 Groundwater Monitoring Network (Pit Top Area)

6.2.3 Baseline Data

Pre-mining baseline groundwater level and quality information has been collected periodically since 2007.

6.2.3.1 Groundwater Levels

Groundwater levels are monitored at all current and planned locations in the monitoring system. The VW piezometer bores are monitored for groundwater level/pressure only.

Three groundwater flow systems occur within the mine site area. The first is a shallow aquifer system that occurs within alluvium associated with the Namoi River, located approximately 4km east of LW101. This system forms the Upper Namoi Zone 5, Namoi Valley (Gin's Leap to Narrabri) Groundwater source. During construction of the box cut, seepage was seen from the underlying alluvium/colluvium and weathered rock (regolith) that sit above fresh rock. It is thought that this seepage came from isolated ponds that are not connected to any flow system. The remaining two systems are separate groundwater flow systems which occur predominantly in open fractures in the underlying fresh rock. The shallower of these occurs in Surat Basin Jurassic sediments that form part of the regional Great Artesian Basin and correspond to the intake beds (GWMA 601). The lower flow system is found in Gunnedah Basin sediments.

Within the mine site, groundwater levels in the shallow alluvium/colluvium/regolith aquifer are generally about 10-20m or more below ground level. Groundwater in these aquifers is localised and discontinuous and is influenced primarily by topography and local surface drainage.

The groundwater flow direction in the shallow groundwater system is, therefore, similar to the surface topography, i.e. east to northeast towards the Namoi River valley. Recharge to the shallow aquifer system is expected to occur by infiltration of rainfall through the surficial alluvium and regolith, with discharge occurring locally to the surface drainages.

Within the deeper hard rock aquifers, groundwater levels are generally in the range 25-55m below surface. The shallower of the two hard rock groundwater systems occurs within the Jurassic sediments, which sub-crop beneath the Project Area. The westerly dip on the strata exposes progressively younger units from east to west across the site. A deeper groundwater flow system occurs within the Permian-Triassic sediments which also dip in a westerly direction.

6.2.3.2 Groundwater Quality

Groundwater quality monitoring is routinely conducted by Narrabri Mine, with samples from all available monitoring bores in the network submitted for laboratory analysis of pH, EC, TDS, major anions, major cations and selected heavy metals (As, Cd, Cr, Cu, Ni, Pb, Zn, Hg, V, Mn). The main water quality characteristics (pH, TDS) in the mine area are summarised in Table 6-2.

The laboratory analysis results to date indicate pH to be in the neutral to slightly alkaline range of 6.7 to 8.2. Salinity ranges from fresh (<500 mg/L TDS) within the Purlawaugh Formation located to the west of the mine site (P7 and P8), to slightly brackish (1040 mg/L TDS) in the Garrawilla Volcanics, to strongly saline (up to 16800 mg/L TDS) within the Napperby Formation. Salinity within the Hoskissons Coal Seam ranges from as low as 1350 mg/L measured in P18 to 14200 mg/L TDS measured in recent in-seam drilling.

Table 6-2 Summary of Groundwater Quality Data

Formation	TDS mg/L		pH	
	Minimum	Maximum	Minimum	Maximum
Pilliga Sandstone	101	101	7.95	7.95
Purlawaugh Formation	295	14820	6.25	8
Garrawilla Volcanics	109	9400	6.27	8.1
Napperby Formation (above Sill)	226	1735	6.65	7.9
Napperby Formation (below Sill)	3160	16800	7.4	8.7
Digby Formation*	N/A	N/A	N/A	N/A
Hoskissons Coal Seam**	1350	14200	6.5	8.5
Arkarula Formation	7740	9630	6.7	7.1

* No sampling has occurred from the Digby Formation and salinity is assumed to be similar to the overlying Napperby Formation

** Initial sampling from the Hoskissons Coal Seam was limited to a single monitoring bore (P18) which indicated that salinity within the seam was less than 2000 mg/L TDS. Recent data from in-seam gas drainage program suggests salinity concentrations are as high as 14200mg/L TDS.

6.3 Groundwater Monitoring Schedule

6.3.1 Requirements for Subsidence Impact Monitoring

Narrabri Mine will implement a comprehensive monitoring program to investigate the subsidence impacts as they develop above longwall panels LW101 to LW106. Several multi-level vibrating wire piezometers are already in place to enable ongoing groundwater level monitoring. These are strategically placed within proposed chain pillars between LW101 and LW102 and just outside LW101. Additional multi-level vibrating wire piezometers and extensometers will be installed within other chain pillars and above the longwall panels before the relevant longwalls are extracted. These vibrating wire piezometers will be replaced if they become inoperable due to subsidence movements. The locations of future piezometers will be considered once the performance of the existing installations has been assessed. The lessons learnt will allow the future locations to be optimised, allowing improved quality in the monitoring process.

Groundwater monitoring bores and vibrating wire piezometers will also be installed between the mine site and the Namoi River alluvium in order to detect groundwater level (and hence base flow) impacts on the Namoi River.

Data on mine water inflows and outflows will be collected via:

- Metering of water pumped into the mine (for dust suppression, machinery operation etc);

- Metering of water pumped from sumps to the surface;
- Ventilation (rate and humidity); and
- Coal moisture content.

The groundwater level and quality information collected, together with the mine water inflows and outflows, would show changes in surface or groundwater flow entering the mine for comparison to and updating of the groundwater model.

6.3.2 General Monitoring Schedule

Table 6-3 and Table 6-4 defines the parameters and sampling frequency for each sampling location. The groundwater quality monitoring program allows for the collection of additional baseline data information and ongoing operational data.

Table 6-3 Groundwater Monitoring Schedule

Location	Parameters	Frequency
All monitoring bores P1,P2, P3, P4, P5, P6,P7,P8, P9, P10, P11,P12, P13, P14, P15, P16,P17,P18, P19, P28, P29, P30, P31, P32, P33, P34, P47, P50, P51, WB2, WB3a, WB3b, WB4, WB5a, WB5b, WB6a, WB6b and WB7 (and others as constructed)	Water level Water quality (see Table 6-4)	Water level monthly Water quality quarterly for pH and EC, annually for full water quality
Representative Bores	Water level EC pH TDS Metals Anions and Cations	Annually
Spring discharges (including Mayfield Spring)	Flow rate and water quality (pH, EC, TDS)	Monthly
Vibrating Wire Piezometers P21, P22, P24, P25, P26, P27, P35, P36, P37, P40, P44, P45, P46 and P48 (and additional VWPs as constructed)	Water level	4 hourly during first two years of mining and then daily by data logger with data logger downloaded monthly
Mine water pumped into and out of the mine (eg SIS extraction bores, sumps, machinery, dust suppression).	Water quality (see Table 6-4)	Daily (volume) Monthly (EC pH,) Quarterly (Full water quality)

* As groundwater response is understood, can become monthly

Data collected from the vibrating wire piezometers will be compared against initial groundwater and subsidence modelling predictions.

The increased frequency of water level monitoring as the longwall operations begin will allow a greater understanding of the groundwater response. This can then be used to refine the groundwater model and refine future predictions.

The frequency of monitoring and range of parameters analysed during flow and routine monitoring should be reviewed after the first two years of operations.

Table 6-4 Laboratory Analysis Suite for Groundwater

Class	Parameter
Physical parameters	EC, TDS, TSS and pH
Major cations	Calcium, magnesium, sodium and potassium
Major anions	Carbonate, bicarbonate, sulphate and chloride
Dissolved metals	Aluminium, arsenice, boron, cobalt, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, selenium, zinc
Nutrients	Ammonia, nitrate, phosphorus, reactive phosphorus

6.3.3 Groundwater Sampling Procedure

The sampling procedure is detailed in the WMP (URS, 2011).

6.4 Groundwater Impact Assessment Criteria

Impact assessment criteria have been adopted for:

- Mine inflow rate;
- Mine inflow water quality;
- Near surface groundwater levels, in particular groundwater levels within the Garrawilla Volcanics;
- Water levels in the Namoi River alluvium
- Impacts on surficial groundwater levels and/or creek base flows; and
- Impacts on existing licensed users.

The basis for and development of these adopted impact assessment criteria are discussed below.

6.4.1 Mine Inflow Rates

The predicted base case mine inflow rates have been shown in Table 6-5. The weighted average annual inflow rates for the first 6 years of mining (longwalls LW101 to LW106) rates gradually increase from 78 to 508ML per annum.

Table 6-5 Predicted Groundwater Inflows (Base Case) – Average Annual Inflows

Year	Groundwater Inflow			Year	Groundwater Inflow		
	m3/d	ML/d	ML/year		m3/d	ML/d	ML/year
1	**213**	**0.21**	**78**	16	3554	3.55	1297
2	**226**	**0.23**	**83**	17	3328	3.33	1215
3	**337**	**0.34**	**123**	18	3889	3.89	1419
4	**923**	**0.92**	**337**	19	3773	3.77	1377
5	**914**	**0.91**	**334**	20	3837	3.84	1401
6	**1393**	**1.39**	**508**	21	3807	3.81	1390
7	1386	1.39	506	22	2623	2.62	958
8	1746	1.75	637	23	3019	3.02	1102
9	1771	1.77	646	24	1956	1.96	714
10	2099	2.1	766	25	2281	2.28	832
11	1999	2	730	26	1559	1.56	569
12	2508	2.51	915	27	1709	1.71	624
13	2381	2.38	869	28	1174	1.17	429
14	3118	3.12	1138	29	1454	0.21	531
15	2901	2.9	1059				

Table Source: AquaTerrra (2009) Table 6.12

These estimates will be compared with the measured volumes being extracted from the underground workings and the predictions refined. The base case for the estimates includes a number of assumptions concerning the existing hydraulic conductivity of the strata above the mine workings and changes as a result of caving behaviour above the longwall goaf. As data is collected, these assumptions will be refined and future estimates improved through recalibration of the groundwater model. If flows significantly increase beyond the predictions, it may suggest that sub-surface fracturing above the underground workings and the resulting increase in hydraulic conductivity exceeds the assumptions used in the subsidence and groundwater models. It would potentially indicate that connective cracking extends to a greater height above the underground workings than predicted, potentially interacting with near-surface aquifers or with surface cracking.

This report only considers the first six years of mining activity, however it is noted that the predicted groundwater inflows exceed the current licence volumes in year 12. As the ground model improves, these estimates will be reassessed. This will allow Narrabri Mine to accurately plan its licencing strategy.

Daily recording of mine water inflows and outflows will be conducted to record potential sudden inflows as subsidence develops (as a result of groundwater inflow or connection to surface water flows). In consideration of the sensitivity analysis conducted on the groundwater model (Aquaterra, 2009) and the potential variability of mine inflows (on a daily basis compared to the weighted average annual inflow of the model), an observed inflow rate 100% in excess[1] of the predicted base case

[1] 'Day to day inflow rates may be highly variable as the longwall retreats and subsidence develops. A fracture zone may be intercepted which contributes increased inflow for a short period of time (days to weeks), but then inflow would be expected to return to the long term average. The groundwater model also assessed variability in parameters, including hydraulic conductivity, to examine potential variability in impact on groundwater (groundwater level drawdown and inflow rate) compared to the base case. The adoption of a 100% trigger level for variation in inflow rates is based on these two considerations.'

mean monthly inflow rate at any stage during the mine life sustained for 3 consecutive months would trigger an investigation and preparation of a response plan as detailed in Section 8 of this report.

The volumes extracted from the mine workings are passed through the box cut sump and flows pumped from here are measured. These volumes are included as part of the monitoring network and are reported in the Annual Environmental Management Report (AEMR). This forms the largest portion of flow that contributes to Narrabri Mine's licenced groundwater extraction volume.

6.4.2 Bore and Gas Drainage Water Extraction

As stated in Section 6.2.2, the groundwater volumes extracted from bores and gas drainage activities will be measured using flow meters on the pumping equipment. This water contributes to Narrabri Mine's total licenced extraction volume. The volumes extracted from each location will be recorded and included in the AEMR.

6.4.3 Impacts to Licensed Users

Due to the generally high groundwater salinities and low bore yields, there is very limited existing groundwater abstraction in the immediate mining area other than for coal mine dewatering. A list of licensed groundwater bores is included in Table 6-1.

Occasional small stock water supplies are drawn from near surface groundwater. Aquaterra (2009) considered that an impact on surrounding registered groundwater users should be treated as significant if it exceeds 15% of predicted drawdown (taking into account groundwater model sensitivity) as per the Statement of Commitments within the Project Approval.

The greatest impact during extraction of all longwall panels is predicted to occur within the Hoskissons Coal Seam, with drawdowns of 5m or more extending to 15km from the mine site at the end of mining. Drawdowns of 1m or more are predicted to extend to a maximum of approximately 20km from the mine site to the south west and 10km from the mined areas to the south. Drawdown to the east is limited by the truncation of the Hoskisson Coal Seam in sub-crop.

An observed drawdown in licensed bores which exceeds predicted drawdown would require a response action as detailed in Table 8-1.

6.4.4 Mine Inflow Water Quality

Groundwater within the coal measures is highly variable, with measured TDS ranging from 1350 mg/L to 14200 mg/L. The EC, salinity (TDS) and pH of mine water will be monitored throughout the mine life, but is considered a lagging indicator compared to changes in inflow rates or drawdown in groundwater level (due to the travel time through overlying strata). Significant changes in the trends of quality over a sustained period compared to baseline and /or predicted levels as shown in Figure 7.1 of Aquaterra (2009) would trigger a response action as detailed in Table 8-1.

Aquaterra considered that, based on the modelling, TDS of the mine inflows or dewatering discharge of more than 20% above that predicted by modelling is considered a potentially significant impact, and all relevant monitoring data will be provided to an approved experienced hydrogeologist for review and assessment of the impact on other users or the environment.

6.4.5 Groundwater Quality Criteria

Groundwater quality would be assessed predominantly against the NEPM livestock guidelines, given that this is the predominant (although limited) use of groundwater in the vicinity of the mine site.

Impacts on the water quality parameters of pH, EC, TDS, other major ions and heavy metals (not considered by the NEPM criteria) would be based on comparisons to baseline monitoring of groundwater quality taken from all groundwater bores within the mine site. The baseline dataset will include all groundwater quality monitoring conducted up to and including the first two years of mining. This will allow for the establishment of current hydrochemistry and seasonal trends. This baseline data will be used to determine background groundwater quality and determine groundwater trigger limits based on the site specific groundwater quality. A statistical analysis to determine the relevant trigger levels based on this site specific background groundwater quality will be conducted. These trigger levels will be based on arithmetic mean and two standard deviations. Variations or deviations from these trigger levels will facilitate the assessment of possible mine related impacts on the groundwater resources.

Table 6-6 Groundwater Quality Criteria

Analyte	Agricultural Irrigation (mg/L)	Livestock (mg/L)
Arsenic (total)	0.1	0.5
Cadmium	0.01	0.01
Chromium (total)	1.0	-
Chromium (VI)	0.1	1.0
Copper	0.2	0.5
Lead	0.2	1.0
Manganese	2.0	-
Mercury (total)	0.002	0.002
Nickel	0.02	1.0
Zinc	2.0	20.0
Calcium	-	1000

- No published values

Source: Modified after NEPC (1999)

A trigger to assess the cause and effects on groundwater quality will be implemented when there is a prolonged and extended non-conformance of the outlined criteria at a particular piezometer.

If a parameter is outside the designated NEPM criteria or exceeds its trigger value (two standard deviations or approximately the 97.5th percentile from the mean of the baseline data), then the cause will be investigated, and a remediation strategy proposed, if warranted.

6.4.6 Further Development of the Groundwater Model

The SoC within the approval conditions proposed recalibrating the groundwater model 6 months after the commencement of longwall extraction, and every 5 years thereafter, and at least 12 – 18 months prior to cessation of mining. Considering the time that it takes for subsidence to develop and impacts (particularly groundwater level drawdown in overlying aquifers) to develop, it is considered more prudent to recalibrate the groundwater model after 3 years of longwall extraction, and every 3 years thereafter. Following the first review, if necessary, the groundwater model will be recalibrated and revised forward impact predictions made.

It is proposed to calibrate this model with ongoing monitoring data from the site. Other circumstances which may trigger further development or refinement of the groundwater model include:

- A significant change to the mine plan or operations that would have the potential to alter subsidence behaviour/predictions, particularly in relation to (an increased) extent, or altered longwall caving and fracturing behaviour;

- Acquisition of new hydrogeological information, such as groundwater levels and aquifer properties (i.e. hydraulic conductivity) which are different to calibrated values used in the model; and
- Groundwater drawdown and inflows which significantly exceed model predictions for that stage of mining (refer to TARP in Section 8.3).

7 REPORTING AND REVIEW

Reporting and review of surface water and groundwater impacts, incidents and non-conformances will be carried out as per Schedule 6 – Environmental Management, Monitoring and Reporting. This will be made available in the Annual Environmental Management Report (AEMR) for the site, as well as on the Narrabri Mine website.

7.1 Surface Water

The Environmental Officer for the mine site retains an active database of monitoring results which will be updated on a regular basis. This will cover both catchment flows crossing the mine lease and water flowing or stored in the surface operating area. Any runoff event within affected surface watercourses will result in the triggering of a sampling event. All sampling results will be made available in the AEMR for the site, as well as on the Narrabri Mine website.

7.2 Groundwater

An active database of monitoring results, to be retained by the Environmental Officer, will be updated on a regular basis. Monitoring results will be made available in the AEMR, as well as on the Narrabri Mine website. The AEMR will present an overview of the performance of the groundwater monitoring network during the preceding 12 months and identify the proposed extraction, processing and rehabilitation activities and environmental management planned for the following 12 months.

As part of annual monitoring, it is the responsibility of Narrabri Mine to commission an experienced hydrogeologist to collate and review the monitoring data collected. This review will assess the impacts of the project on the groundwater environment, and to compare any observed impacts with those predicted from groundwater modelling. If significant variation is found between predicted impacts and observed operational monitoring data then notification of remediation will be required. Refer to Section 1.5 Responsibilities for details.

The ongoing monitoring program and collation of relevant data will provide the basis for continuing improvement in groundwater management across the site.

8 SURFACE AND GROUNDWATER RESPONSE PLAN

The surface and ground water response plan includes a protocol for managing and reporting any:

- incidents;
- complaints;
- non-compliances with statutory requirements; and
- exceedances of the impact assessment criteria and or performance criteria; and;

Records of any of these items along with the data collected as outlined in this section are to be maintained and available for review by the appropriate agency/authorities.

8.1 Surface Water

Monitoring will involve both the sediment and chemical content of the surface water and the physical movement of the flow. If these elements are altered significantly, then remediation will be required. The monitoring will be as described in Section 5.1.

8.1.1 Contingency Measures

The methods used to correct or compensate for the various changes in the surface water flow are described in Section 5.4. While there are no specific triggers, the general aim is to minimise the effect of subsidence to the surface water flow routes. There are performance indicators for the quality of the water and these may indicate the presence of subsidence; however visual inspection of the area is essential. The corrective action may not always be immediate, but this is intended to allow the majority of subsidence effects to occur before any action is taken.

8.1.2 Response Action

If an exceedance of the performance indicators within Pine Creek or Kurrajong Creek is observed (detailed in Section 5.1), then Narrabri Mine will follow the procedure listed below:

- Record the timing, location, environmental conditions and any potential contributing factors to the exceedance;
- Issue advice of the apparent exceedance to relevant agencies immediately;
- Sampling point and areas upstream inspected to ascertain cause of exceedance;

- Operational practices reviewed to determine if any current operational practice contributed to the exceedance;
- Implementation of ameliorative measures on site to minimise the potential for future exceedance. May include: alteration to operational practice, or maintenance for subsidence effects.
- Written advice to relevant agencies identifying actions undertaken to reduce future risk of exceedance within 14 days;;
- Where specific cause of exceedance cannot be identified, external advice may be sought; and
- Ongoing future monitoring to ensure ameliorative measures have been successful with concentration criteria being met.

All other surface water monitoring will be discussed in the AEMR with reference to relevant guidelines, such as the Australian and New Zealand Environment Control Council (ANZECC) guidelines.

In the event of any exceedance in concentration criteria, Narrabri Mine will advise DPI Water and other relevant agencies within 24 hours of detecting the exceedance in accordance with consent Condition 3 of Schedule 4. Narrabri Mine will also provide a written report within 14 days of the event to the relevant agencies which will:

- Describe the date, time and nature of the exceedance/incident;
- Identify the cause (or likely cause) of the exceedance/incident;
- Describe what action has been taken to date; and
- Describe the proposed measures to address the exceedance/incident.

The ongoing monitoring program and collation of relevant data will provide the basis for continuing improvement in surface water management across the site.

A Trigger Action Response Plan (TARP) is presented as Table 8-1. The TARP was initially developed for responses to groundwater triggers; however the surface water triggers have been included.

8.2 Groundwater

If adverse impacts or groundwater quality degradation are beyond predictions in the EA and this is caused by mine operations, contingency measures will be required. Narrabri Mine will: commission an assessment of the causes; develop a staged response program satisfactory to DPI Water to mitigate the adverse impacts; and establish and implement measures to manage further impact.

8.2.1 Contingency Measures

The identification process and response protocol to adverse outcomes are provided in the TARP (refer **Section 8.3**). The responses proposed incorporate a staged assessment and development of management measures deemed appropriate for each individual event should it occur.

Specific trigger levels have been designed to alert Narrabri Mine to observed parameter responses which are outside of normal variation and predicted responses, or where observed parameter values do not follow anticipated trends.

The triggers for instigation of response actions would occur when observed changes to monitored parameters exceed specified levels. Such changes in observed parameters or conditions include:

- Sudden in-rush of groundwater into the mine or measured flows in exceedance of predicted inflows;
- Significant change in observed water quality or groundwater levels between sampling rounds;
- Changes in trends over an extended period for groundwater levels and quality that are not consistent with the prediction models; and
- A significant increase or variation from predicted models.

8.2.2 Response Action

In the event of any exceedance detailed in Section 6.4, the following response action may be initiated:

- Narrabri Mine assessment to determine the reason for the exceedance which may include resampling or increasing monitoring frequency to confirm trend / exceedance or identify sampling anomaly.
- Refer the matter to an independent hydrogeologist for review if Narrabri Mine investigation is unable to identify reason for exceedance. Any such investigation (depending on nature of trigger) may include:
  - Review monitoring data
  - Review groundwater model
  - Review site water balance
  - Assessment of potential causes and consequences. Key considerations of the assessment may include:
    - Does the monitoring and investigation indicate that a performance measure, development consent condition or water licensing limit has been exceeded, (or is likely to be exceeded in the immediate future)

- What are the implications of the exceedence (other water users, mine water balance, Namoi River alluvium, GAB)

  - What are the potential factors that may have contributed to the exceedence
  - What actions, if any are required, to mitigate and/or minimise the potential for future impacts
  - Develop recommendations and report.

- If assessed as being caused by the mining operation, and it is further assessed to be likely to cause an adverse impact on an existing beneficial or environmental use of surface water or groundwater, then an appropriate preventative and/or remedial strategy would be recommended, which may comprise:
  - Additional monitoring;
  - Modification to mine plans;
  - Provision of alternative water supply or other agreed compensation; or
  - (If appropriate) no change to operations.

The above response program would be carried out in consultation with OEH and DPI Water.

Should any review or post-audit indicate a significant variance (refer Section 4.2) from the model predictions with respect to either water quality or groundwater levels, then the implications of such variance will be assessed, and appropriate response actions implemented in consultation with the DPI Water and other departments as appropriate.

If inflows deviate significantly (refer Section 4.2) from predictions, regular review of the groundwater model predictions against monitoring data will be carried out. Should the re-calibrated model show groundwater inflows beyond these cases described in the Environmental Assessment (EA), a separate detailed impact assessment will be conducted and mitigating measures determined.

8.3 Trigger Action Response Plan (TARP)

The Trigger Action Response Plan (TARP) has been developed to focus upon appropriate trigger and response actions for mitigation of impacts to the natural environment as a result of mining.

Monitoring serves to advise of changes to groundwater levels or quality that occur or to raise alert that an abnormal condition relating to mining has developed.

Each monitoring program has established trigger levels of particular impacts at which a response is needed, and to help define an appropriate response (Table

8-1). Management of impacts within predictions follows standard assessment review and response protocols.

The TARP has been designed to reference the risks that mining poses to the environmental receptors both within the mining area and beyond. Aspects assessed to be at risk are summarised in Section 4 and 6.4 of this report. These include both predicted and unpredicted impacts, and include:

- Groundwater level;
- Groundwater quality;
- Hydraulic connection to alluvium associated with the Namoi River;
- Discharges;
- Pumping bores/underground pumping stations; and
- Groundwater users (Private Bores).
- Surface water quality
- Ponding etc

Table 8-1 Trigger Action Response Plan (TARP)

	Monitoring		Response		
	Methodology	**Purpose**	**Trigger**	**Action**	**Responsibility**
Surface Water					
Water quality (Pine and Kurrajong Creeks)	**Sites:** PCUS, PC1US, PC, PC1, KC1TOP, KC1US, KC1DS, KC2US, KC2DS, KCUS, KCDS (see figure 5-1). **Parameters:** EC, oil and grease, pH, TSS, TOC, Turbidity. **Analysis:** Comparison of upstream and downstream results as well as to ANZECC water quality trigger levels. Review of water quality trends over time. Current monitoring suggests baseline data is within ANZECC guidelines however there are no discernible trends at this stage. **Frequency:** During runoff events (as practical).	To provide baseline water quality data. To identify potential surface water quality impacts as a result of mining activities (e.g. via subsidence cracking, ponding, erosion).	Exceedance of baseline values (Refer to Table 5-2). Long-term upwards trend towards ANZECC quality guideline limits.	Repeat sampling to confirm results exceed trigger level. Hydrologist (or similar specialist) to review sampling and climate data and confirm likely mining impact or otherwise. If mine-related, undertake physical inspection of affected surface and creeks to identify potential source of water quality degradation. Implement appropriate management or contingency response (i.e. repair of subsidence cracking, remediation of ponding, erosion control works and rehabilitation).	Environmental Officer.

	Monitoring		**Response**		
	Methodology	**Purpose**	**Trigger**	**Action**	**Responsibility**
Water quality – ponding	**Sites:** Longwall panels LW101-106. **Parameters:** Water quality sampling (EC) of surface water ponding in overbank areas. Identification of changes in topography that leads to ponding. **Analysis:** Comparison to ANZECC trigger levels and observing trend in quality over time. Identification of potential ponding areas via changes in topography. Identified via visual inspection and ALS survey. **Frequency:** Following formation of surface ponding and monthly during ponding occurrence. Monthly visual inspection and 6 monthly ALS survey.	To monitor potential salinity increases in water ponding over potential saline soils. To ensure that surface water ponding does not provide a potential source of salinity for downstream watercourses (Namoi River).	Exceedance of baseline values. Long-term upwards trend towards ANZECC quality guideline limits. Identified changes in topography either by visual inspection during an event or via survey information.	If little vegetation of significance is impacted and water quality analysis confirms no increase in salinity, the ponding would be left to “self-correct” over time. Should vegetation of significance be at risk or there is an exceedance of salinity, construct drainage (i.e. open channel / drain) works to ensure area is able to drain freely once substantial subsidence has ended. Rehabilitate and stabilise. Develop management actions through Risk Assessment for ponded water should this be shown to consistently exceed the ANZECC guidelines. Ecological benefits of ponded water should be considered before any of the above action is taken.	Environmental Officer.

	Monitoring		**Response**		
	Methodology	**Purpose**	**Trigger**	**Action**	**Responsibility**
Changes in watercourse morphology	**Sites:** Where Pine and Kurrajong Creeks traverse longwall panels LW101-106. **Parameters:** Water quality – use results from 'water quality' section above. Identification of changes in planform, creek grade, bank erosion and sedimentation. **Analysis:** Identified via visual inspection and subsidence monitoring survey. **Frequency:** Water quality - during runoff events (as practical). Morphology - monthly visual inspection and 6 monthly ALS survey.	To determine if subsidence due to mining is impacting on the morphology of Pine and Kurrajong Creeks. This can appear as changes in; planform, creek grade, bank erosion and sedimentation which effects water quality. This may occur in the channel and/or the wider floodplain.	Water quality triggers as described above may indicate changes in channel morphology. Identified changes in topography either by visual inspection during an event or via survey information	Identified changes in topography should be allowed to "self-correct" unless there is evidence of significant erosion. (or variation from predicted model results see figure 4B.7 of the Environmental Assessment (2009)). If erosion and deposition is identified as being significant, a qualified geomorphologist will be consulted to develop action plan which may involve further monitoring or remediation. - Monitoring may involve use of 'Index of Diversion Condition' principles as per ACARP. - Remediation works will be identified; these may include erosion protection works, removal of sedimentation and realignment of the watercourse.	Environmental Officer.

	Monitoring		Response		
	Methodology	**Purpose**	**Trigger**	**Action**	**Responsibility**
Ground disturbance above longwall panels	**Sites:** Areas that traverse the long wall panels. **Parameters:** Water quality – use results from 'water quality' section above. **Analysis:** Identified via visual inspection. **Frequency:** Water quality - during runoff events (as practical).	To determine if activities above longwall panels required to enable mining is impacting on surface erosion and in turn impact on water quality.	Visual inspection revealing excessive erosion or ineffective control measures. Water quality triggers as described above may indicate increased rates of erosion.	Continued monitoring of erosion; control measures as described in the mine site erosion and sediment control plan. If implemented erosion control measures are found to be failing, review causes and replace with like or better. Continue monitoring.	Environmental Officer.
Groundwater					
Groundwater Levels – Namoi River alluvial aquifer	**Sites:** Up-gradient background reference bores. Groundwater bores in alluvium. Vibrating wire piezometers and groundwater bores in Permian between mine site and alluvium. **Parameters:** Water level. **Analysis:** Comparison to predicted	To provide baseline water level data and to identify water level impacts. To verify that impacts in base flows to Namoi River Alluvium are consistent with model predictions. To re-calibrate and validate model with additional data.	Drawdown greater than maximum predicted impact in sensitivity analysis of groundwater model.	Engage hydrogeologist to undertake investigation and report on any identified changes /likely causes and recommendations in accordance with Section 8.2.2. Notify agencies when exceedance becomes known, and provide updates throughout investigation above, and at conclusion of assessment. Implement contingency responses as agreed with government agencies and in accordance with hydrogeologist	Environmental Officer.

	Monitoring		**Response**		
	Methodology	**Purpose**	**Trigger**	**Action**	**Responsibility**
	drawdown taking into account natural variations observed in background reference sites. Determine potential baseflow impacts during model review. **Frequency:** Manual monitoring of groundwater bores weekly and automatic groundwater level monitoring of VWPs every 4hours (downloaded monthly) during first two years of mining. Manual monitoring of groundwater bores quarterly and automatic groundwater level monitoring of VWPs every day (downloaded monthly) after first two years of mining.			recommendations.	
Groundwater Levels – Permian to Jurassic hard rock aquifers	**Sites:** Vibrating wire piezometers and groundwater bores in Permian. Private landholder bores (including identified springs to the south of the mine).	To provide baseline water level data and to identify water level impacts. To verify that impacts on GAB aquifers are consistent with model predictions.	Drawdown greater than 15% above predicted trend in VWPs, monitoring bores, and private landholder bores (not pumping affected).	Engage hydrogeologist to undertake investigation and report on any identified changes /likely causes and recommendations in accordance with Section 8.2.2. Notify agencies when	Environmental Officer**.**

	Monitoring		Response		
	Methodology	**Purpose**	**Trigger**	**Action**	**Responsibility**
	Parameters: Water level. **Analysis:** Comparison to predicted drawdown taking into account natural variations. **Frequency:** Manual monitoring of groundwater bores weekly and automatic groundwater level monitoring of VWPs every 4hours (downloaded monthly) during first two years of mining. Manual monitoring of groundwater bores quarterly and automatic groundwater level monitoring of VWPs every day (downloaded monthly) after first two years of mining.	To re-calibrate and validate model with additional data.		exceedance becomes known, and provide updates throughout investigation above, and at conclusion of assessment. Implement contingency responses as agreed with government agencies and in accordance with hydrogeologist recommendations.	
Hydraulic conductivity	**Sites:** Vibrating wire piezometers P26, P27, P35 P36 and P37 (and others as constructed at ends of panels, over panels and	To identify changes (pre and post mining) in permeability and provide data for on-going review and recalibration of groundwater predictive models.	Drawdown greater than 15% above predicted trend in VWPs and monitoring bores, or permeability greater than upper limits used in sensitivity analysis in groundwater model, or	Engage hydrogeologist and/or subsidence specialist to undertake investigation and report on any identified changes /likely causes and recommendations in	Environmental Officer.

	Monitoring		**Response**		
	Methodology	**Purpose**	**Trigger**	**Action**	**Responsibility**
	over chain pillars). Monitoring bores P15, P18, P19, P20, P47, P50 (and others as constructed at ends of panels, over panels and over chain pillars). Extenseometers to be constructed at ends of panels, over panels and over chain pillars. **Parameters:** Water level in all. In-situ hydraulic testing in monitoring bores and in all new bores or VWPs during drilling. **Analysis:** Comparison to predicted drawdown taking into account natural variations. Horizontal and vertical permeability compared to values used in groundwater model. **Frequency:** Manual monitoring of groundwater bores weekly from commencement of	To obtain site-specific data on fracturing behaviour and extent in overlying strata.	fracturing extends above Garrawilla Volcanics.	accordance with Section 8.2.2. Notify agencies when exceedance becomes known, and provide updates throughout investigation above, and at conclusion of assessment. Implement contingency responses as agreed with government agencies and in accordance with hydrogeologist recommendations.	

	Monitoring		**Response**		
	Methodology	**Purpose**	**Trigger**	**Action**	**Responsibility**
	adjacent longwall panel, increasing to daily from one month before longwall approach continuing until 3 months after longwall pass, otherwise as for 'Groundwater Levels – Permian to Jurassic hard rock aquifers'. Automatic groundwater level monitoring of VWPs every 4hours (downloaded monthly) from commencement of adjacent longwall continuing until 6 months of longwall pass, otherwise as for 'Groundwater Levels – Permian to Jurassic hard rock aquifers'. In-situ hydraulic testing of monitoring bores 3 months after passing of longwall. Insitu hydraulic testing during installation of new and replacement bores or VWPs.				
Mine water inflows – volume/rate	**Sites:** Surface to in seam extraction bores,	To verify that impacts of subsidence and groundwater drawdown are consistent with	An observed inflow rate 100% in excess of the predicted base case mean monthly inflow rate	Engage hydrogeologist and/or subsidence specialist to undertake investigation	Environmental Officer.

	Monitoring		**Response**		
	Methodology	**Purpose**	**Trigger**	**Action**	**Responsibility**
	sumps/pumps, water entry to mine. **Parameters:** Volume. **Analysis:** Comparison to predicted volumes in mine water management and groundwater models. **Frequency:** Daily recording of volumes.	model predictions. To re-calibrate and validate model with additional data.	at any stage during the mine life sustained for 3 consecutive months or inflow rate for a 3 month period 100% greater than the predicted base case total for that 3 month period.	and report on any identified changes /likely causes and recommendations in accordance with Section 8.2.2. Notify agencies when exceedance becomes known, and provide updates throughout investigation above, and at conclusion of assessment. Implement contingency responses as agreed with government agencies and in accordance with hydrogeologist recommendations.	
Mine water inflows – quality	**Sites:** Underground sumps/pumps, water entry to mine. **Parameters:** Water quality – full laboratory analysis suite (See Table 6-4). **Analysis:** Comparison to predicted water quality in mine water management and groundwater models.	To verify that impacts of subsidence and groundwater drawdown are consistent with model predictions. To re-calibrate and validate model with additional data.	Should the TDS of the mine inflows or dewatering discharge indicate an inflow salinity of more than 20% above that predicted by modelling at any stage during the mine life sustained for 3 consecutive months (and/or the 3-month rolling average exceeds the criteria)	Engage hydrogeologist and/or subsidence specialist to undertake investigation and report on any identified changes /likely causes and recommendations in accordance with Section 8.2.2. Notify agencies when exceedance becomes known, and provide updates throughout investigation above, and at conclusion of assessment. Implement contingency responses as agreed with	Environmental Officer.

	Monitoring		**Response**		
	Methodology	**Purpose**	**Trigger**	**Action**	**Responsibility**
	Frequency: Monthly for EC and pH. Quarterly (Full water quality).			government agencies and in accordance with hydrogeologist recommendations.	
Groundwater Quality	**Sites:** P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P11,P12, P13, P14, P15, P16, P17, P18, P19, P28, P29, P30, P31, P32, P33, P34, P47, P50, P51, WB2, WB3a, WB3b, WB4, WB5a, WB5b, WB6a, WB6b and WB7 (and others as constructed). **Parameters:** Water quality – full laboratory analysis suite (See Table 6-4). **Analysis:** Comparison to NEPM and baseline water quality (groundwater quality conducted up to and including the first two years of mining). **Frequency:** Quarterly for EC and pH.	To provide baseline water quality data and to identify water quality impacts.	Water quality exceeds NEPM guideline or exceeds baseline water quality (97.5th percentile of baseline data).	Engage hydrogeologist to undertake investigation and report on any identified changes /likely causes and recommendations in accordance with Section 8.2.2. Notify agencies when exceedence becomes known, and provide updates throughout investigation above, and at conclusion of assessment. Implement contingency responses as agreed with government agencies and in accordance with hydrogeologist recommendations.	Environmental Officer.

	Monitoring		**Response**		
	Methodology	**Purpose**	**Trigger**	**Action**	**Responsibility**
	Annually for other water quality.				

* Note 1 – If quarterly groundwater monitoring identifies that the groundwater level trigger has been exceeded, the water level in the affected piezometer will be measured within one month of the initial measurement. If the water level no longer exceeds the trigger level, the groundwater level measurements will continue as per the quarterly monitoring program. If the SWL still exceeds the trigger level, and Narrabri Mine is unable to ascertain the cause of the exceedance (eg. windmill in operation) the matter will be referred to relevant agencies and an independent hydrogeologist for review.

8.4 Unforeseen Impacts Protocol

Table 8-2 outlines the procedure to be followed (in general accordance with the criteria exceedance protocols detailed in **Section** 5 and **Section** 6) in the event that any unforseen surface or groundwater impacts are detected. This is in addition to the procedures already described and is intended to allow an initial response that can be tailored for similar future occurrences.

Table 8-2 Unforeseen Impact Procedure

Stage	Procedure
1	Review the unforeseen impact including consideration of: • Any relevant monitoring data; and • Current mine activities and land management practices in the relevant catchment
2	Commission an investigation by an appropriate specialist into the unforeseen impact, if considered appropriate by the Environmental Specialist.
3	Develop appropriate ameliorative measures based on the results of the above investigations, in consultation with the relevant authorities.
4	Implement additional monitoring where relevant to measure the effectiveness of the improvement measures.

9 REFERENCES

ACARP (2001)	*Monitoring & evaluation program for Bowen Basin river diversions*, report prepared by ID&A (2001)
ANZECC and ARMCANZ (2000)	'*Australian and New Zealand Guidelines for Fresh and Marine Water Quality'*, Australian and New Zealand Environment Control Council and Agricultural and Resource Management Council of Australia and New Zealand, Australia.
Aquaterra (2009)	*Narrabri Coal Project Hydrogeological Assessment of the*, prepared on behalf of Narrabri Coal Operations Pty Ltd (Part 2 of the *Specialist Consultant Studies Compendium*).
Coffey (2008)	'*Narrabri Coal Project Water Management Plan*, Report prepared by Coffey Geotechnics Pty Ltd for Narrabri Coal Pty Ltd
DGS (2015)	*Mine Subsidence Assessment for the Proposed Addition of Longwall (LW) 106 to the Approved LW101 to LW105 Extraction Plan at the Narrabri Mine, Narrabri*, prepared on behalf of Narrabri Coal Operations Pty Ltd
DGS (2011)	*Mine Subsidence Effect Predictions and Impact Assessment for the Proposed Longwalls 1 to 5 at the Narrabri Coal Mine, Narrabri,* Report prepared by Ditton Geotechnical Services Pty Ltd.
EPA (2007)	"*EPA Guidelines. Bunding and Spill Management*" EPA 080/07 Updated June 2007
GHD (2007)	*'Groundwater Assessment of the Narrabri Coal Project',* Report prepared by GHD Pty Ltd for Narrabri Coal Pty Ltd (Part 2 of the *Specialist Consultant Studies Compendium*).
Landcom (2006)	*The Blue Book - Managing Urban Stormwater (MUS): Soils and Construction*
IECA, (2009)	*Best Practice Erosion and Sediment Control*, produced by the Australasian arm of the International Erosion Control Association (IECA, 2009)
NCMA (2007)	*Catchment Action Plan 2010-2020,* produced by the Namoi Catchment Management Authority for the Namoi River
NEPC (1999)	*National Environment Protection (Assessment of Site Contamination)* Measure, NEPC, Adelaide.
OEH, 2008	*Managing Urban Stormwater: Soils and Construction, Volume 2E Mines and Quarries*
R.W. Corkery & Co. (2009)	*'Environmental Assessment for the Narrabri Coal Mine Stage 2 Longwall Project'* Report prepared by R.W. Corkery & Co. Pty. Limited

Resource Strategies (2015)	'*Narrabri Mine Modification 5 Environmental Assessment*' Report prepared by Resource Strategies Pty Ltd
URS (2007)	*'Report for Evaporation and Storage Dams, Narrabri Coal Pit Top Infrastructure'*, Report prepared by URS Pty Ltd for Narrabri Coal Pty Ltd.
URS (2011)	*'Narrabri Mine Water Management Plan'*, Report prepared by URS Pty Ltd for Narrabri Coal Pty Ltd.
WRM (2008)	*'Narrabri Coal Project Surface Water Management Plan'* prepared by WRM Water & Environment Pty Ltd for Narrabri Coal Pty Ltd
WRM (2009)	*'Narrabri Coal Mine Stage 2 Longwall Project Surface Water Assessment' Prepared by: WRM Water & Environment Pty Ltd November 2009 (Environmental Assessment (R.W. Corkery & Co. 2009) Specialist Consultant Studies Compendium Volume 1, Part 3)*

Note:

Reference has been made throughout this report to the Office of Environment and Heritage (OEH) which is the new name for the Department of Environment and Climate Change (DECC). All reference material and guidance is still applicable to the new department.

10 LIMITATIONS

URS Australia (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Narrabri Mine and only those third parties who have been authorised in writing by URS to rely on this Report.

It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this Report.

It is prepared in accordance with the scope of work and for the purpose outlined in the proposal approval email, dated 5 May 2015.

Where this Report indicates that information has been provided to URS by third parties, URS has made no independent verification of this information except as expressly stated in the Report. URS assumes no liability for any inaccuracies in or omissions to that information.

This Report was prepared between May and June 2015 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This Report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This Report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Except as required by law, no third party may use or rely on this Report unless otherwise agreed by URS in writing. Where such agreement is provided, URS will provide a letter of reliance to the agreed third party in the form required by URS.

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Except as specifically stated in this section, URS does not authorise the use of this Report by any third party.

It is the responsibility of third parties to independently make inquiries or seek advice in relation to their particular requirements and proposed use of the site.

Any estimates of potential costs which have been provided are presented as estimates only as at the date of the Report. Any cost estimates that have been provided may therefore vary from actual costs at the time of expenditure.

Appendix A – Addressing of State Department Comments

This section will be used to record the actions taken to address comments made on the different versions of the report.

Version F1 (addressing DPI Water comments)

The following table identifies the changes made to address the comments made in the DPI Water letter dated 1st September 2015 (ref.: ER20766 / OUT15 / 23412).

Location	Changes made to report
P17, Table 2.1	Access licence and approval number amended.
P17, Table 2.1	Water sources added to table. Minor table rearrangement to aid clarity.
P50, Table 6.3	Monitoring bore water level recording amended to weekly measurements. This will be in conjunction with daily monitoring (4 hourly during first two years) at VWP locations by data logger.

It is noted that the final two bullet points in the letter are general points that do not specifically relate to this report. The comments are noted, but do not result in changes to the report.