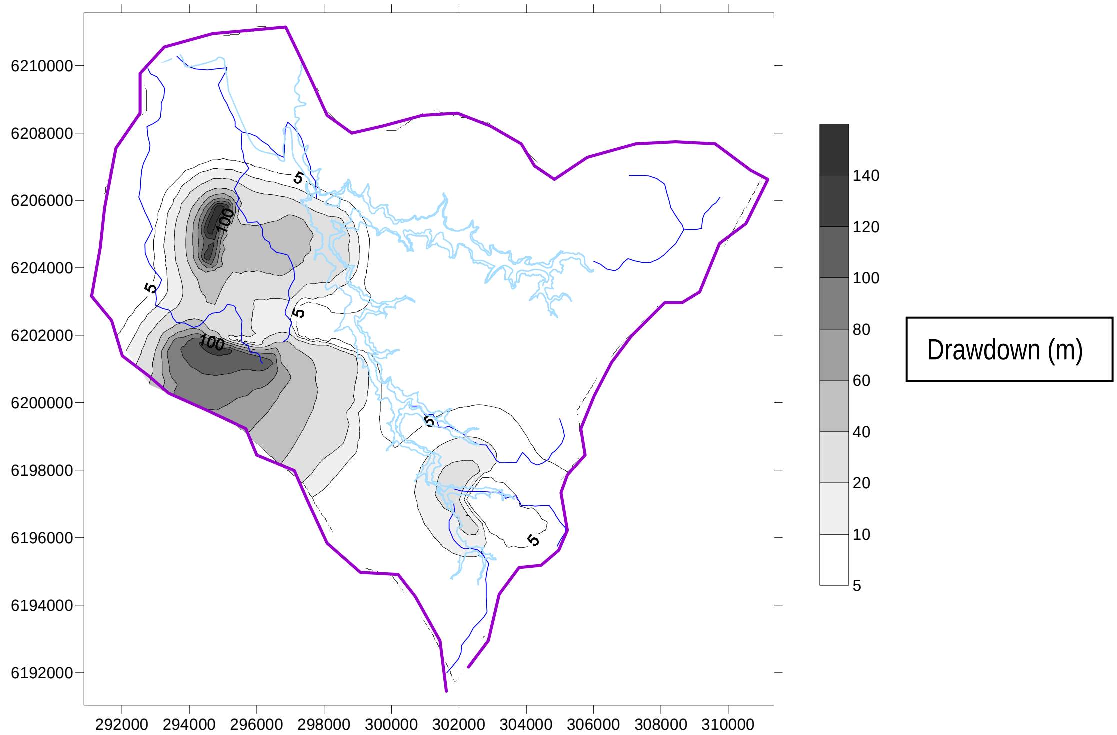

Figure 40 Scarborough Sandstone Drawdown After Mining Wonga West Area 4

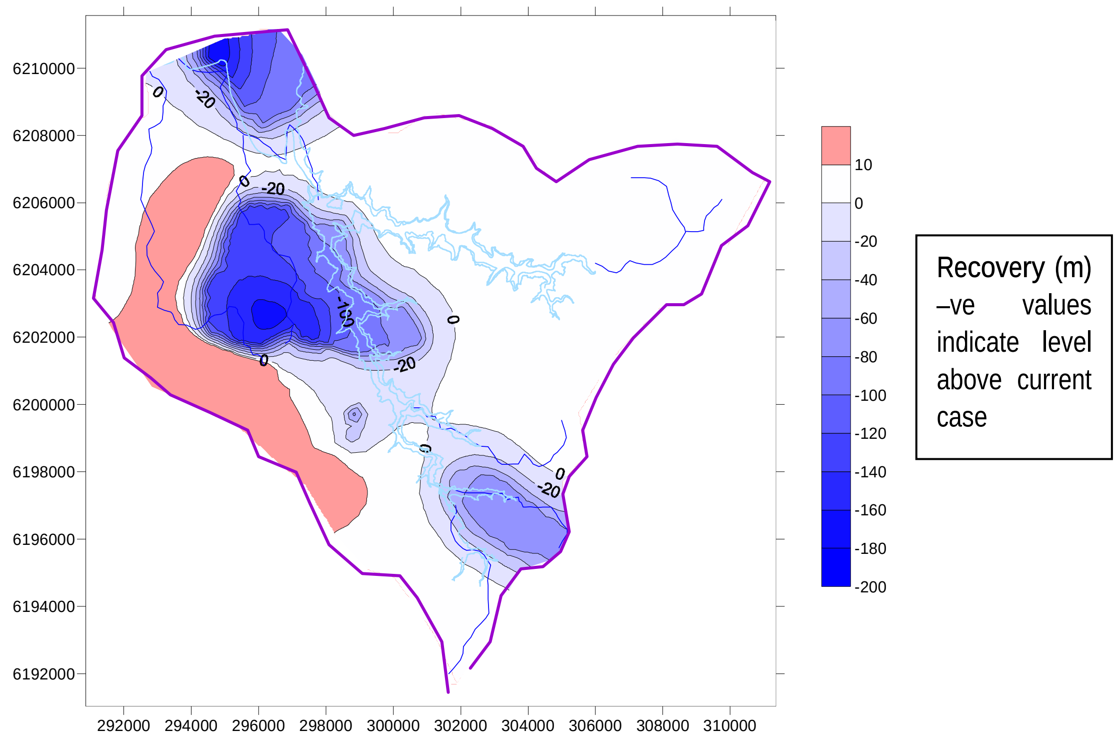

Figure 41 Scarborough Sandstone Recovery 10 Years After Mining Area 4

13.3.6 Bulli Seam

As shown in **Appendix E**, drawdown in the Bulli Seam at the end of mining Wonga East Area 2 and V Mains reaches up to 40m over Wonga East and up to 130m over V Mains.

At the completion of Area 4, Wonga East is predicted to be depressurised by approximately 10m, and Wonga West by up to 120m.

Ten years after mining is completed in Area 4, the Bulli Seam is modelled to recover by up to 110m above the present day levels at Wonga East and up to 190m over Wonga West.

13.3.7 Wongawilli Seam

Drawdown in the Wongawilli Seam at the end of mining Wonga East Area 2 and V Mains is modelled to reach up to 50m over Wonga East and up to 60m over Wonga West / V Mains as shown in **Appendix E**.

Figure 42 indicates that at the end of mining Wonga West Area 4, depressurisation is modelled to reach up to 40m over Wonga West and up to 90m over the Wonga East and main drive workings.

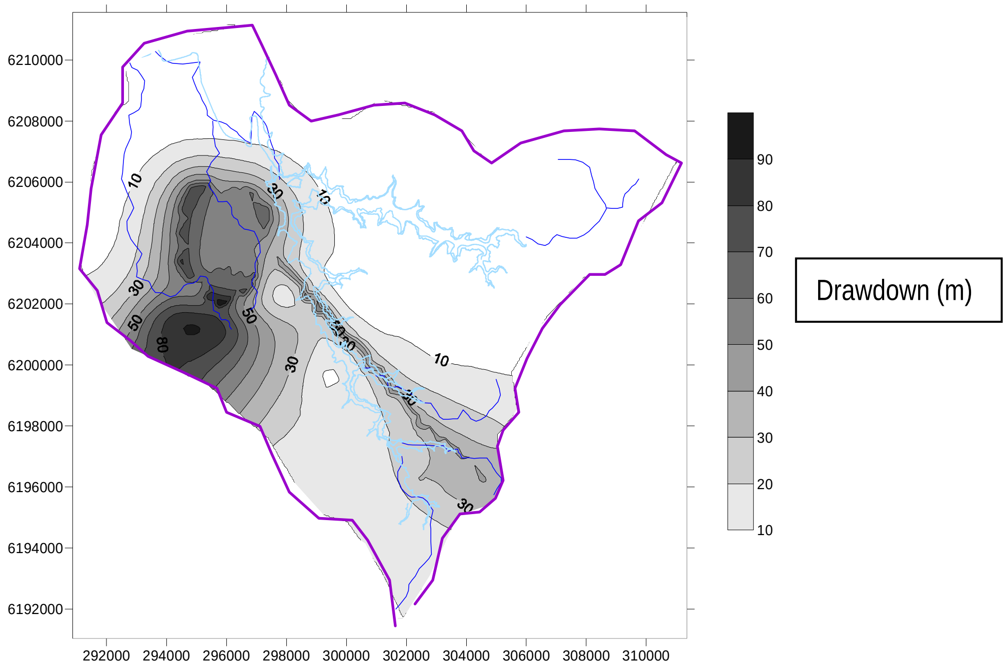

Figure 42 Wongawilli Seam Drawdown After Mining Area 4

Ten years after mining is completed, the Wongawilli Seam is modelled to recover by up to 160m above the present day levels at Wonga West and up to 100m over Wonga East as shown in **Figure 43** and **Appendix E**.

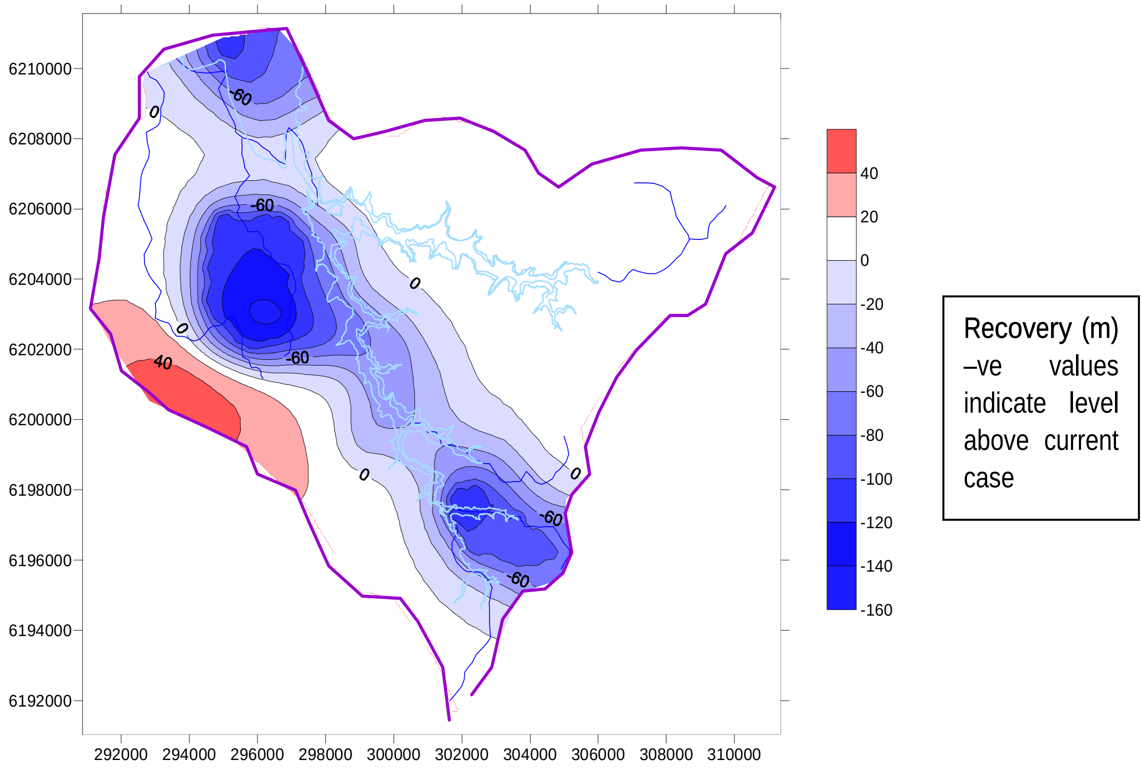

Figure 43 Wongawilli Seam Recovery 10 Years After Area 4

13.4 Stream Flow and Groundwater Connectivity

A number of mechanisms can potentially occur within shallow groundwater systems associated with streams as follows:

- direct flow of surface water into mining induced fracture systems and vertical drainage into the shallow basement groundwater system;
- flow of surface water from the "gaining – connected" or "gaining – disconnected" streams into the shallow groundwater system migrating along the local hydraulic gradient and re-emerging further down gradient in the catchment, with no hydraulic connection to the workings where the Bald Hill Claystone does not undergo subsidence related connective fracturing;
- reversal of water transfer from the shallow groundwater system to the "losing – disconnected" streams during periods of high recharge; or
- flow of stream water into the shallow groundwater system migrating along the hydraulic gradient to emerge further downstream within other groundwater catchment regimes.

Tracer tests using fluorescent dyes, or salts or other ecologically suitable markers can be used to assess the potential connection and through flow paths between stream and shallow groundwater systems. Although they have not been used in the Gujarat lease area to date, they could be used if required.

13.4.1 Cataract Creek

The geotechnical subsidence assessment conducted for this project proposal (Seedsman Geotechnics, 2012) concluded the multi-seam mined Bulli and Balgownie Seam workings at Wonga East have collapsed the majority, if not all, of the overburden sequence, and it was assessed there is no spanning capacity left in the Bulgo Sandstone directly above the proposed Wongawilli Seam longwalls.

Observations over longwall WE-A2-LW4, which was mined in the Wongawilli Seam, indicates that due to the previously fractured nature of the overburden above the Bulli and Balgownie Seam workings the subsidence “bowl” did not effectively extend outside of the longwall footprint (SCT Operations, 2012) and (Seedsman Geotechnics, 2012A).

In the multi-seam mined area, even though horizontal bedding subsidence displacement may have extended up into the upper Bulgo Sandstone, this does not mean a direct, free vertical drainage hydraulic connection is present from the surface to the workings.

Monitoring of mine water pump-out from workings to the east of Cataract Reservoir, along with prolonged observations from underground supervisors (S Wilson, Gujarat NRE, pers comm.) indicate there is no observed associated short term increase in mine water make from the current workings following significant rain in the Cataract Creek, Bellambi Creek or Cataract River (upstream of the reservoir) catchments over the Bulli, Balgownie and Wongawilli Seam workings.

Monitoring of water level trends in piezometer NRE-A over the multi-seam mined area indicates the upper Hawkesbury Sandstone down to the Upper Bulgo Sandstone lithologies have an enhanced response to rainfall recharge. However, no adverse effect on stream flow has been observed as the headwater tributaries and main channel of Cataract Creek have had continuous flow throughout the monitoring period.

The bord and pillar mined areas represented by the open standpipe and vibrating wire piezometers at NRE-B, C and D have a limited to minor response to rainfall recharge.

Where only Bulli seam first workings have been extracted, the proposed narrow longwalls and wide pillars are not predicted to destabilise the Bulli seam pillars sufficiently to cause fracturing or displacement that will extend into the upper Bulgo Sandstone (Seedsman Geotechnics, 2012).

This means there will be no predicted free drainage connection from surface to seam in these areas.

Beneath the plateau over the multi-seam mined Bulli and Balgownie workings between Cataract Creek and Bellambi Creek, extraction of the proposed longwalls is modelled to generate up to 4m of depressurisation in the upper Hawkesbury Sandstone at the end of mining Wonga East Area 2.

The modelled, localised reduction is anticipated to reduce the regional phreatic surface gradient from the plateau to the creek, as well as toward Cataract reservoir, thereby potentially reducing baseline seepage flow volumes to the creek and dam.

It is also possible that, if they exist, the location of seepage outflow points may be relocated up to 4m lower down in the catchment.

Based on the groundwater contours shown in **Drawing 8**, the modelled reduction in the upper Hawkesbury Sandstone phreatic surface over the proposed workings represents a change in gradient of flow toward Cataract reservoir from 0.021 to 0.019.

On the basis that there is no direct free drainage flow path to the workings, which is supported by water pumping monitoring in the current workings, the water level decline will be temporary, as the water table is anticipated to recover from 4 – 12m once the mining at Wonga East has been completed and dewatering in the area is restricted to keeping the main access drive dry.

Stream flow modelling indicates the average daily flow from Cataract Creek to Cataract reservoir is 11.73ML/day (WRM Water & Environment, 2012).

Modelled groundwater flow diagrams indicating the current, post Stage 1 (Area 2 and V Mains) as well as the post Stage 2 (Area 4) in the upper Hawkesbury Sandstone are shown in **Figure 44**.

The groundwater modelling predicts a 0.06ML/day loss of stream flow in the Cataract Creek catchment at the end of mining Area 2 and 0.07ML/day at the end of Area 4 as shown in **Table 10**.

The modelled changes are therefore relatively minor (0.5 – 0.6%) compared to the average flow in the creek to the Cataract Reservoir.

Table 10 Modelled Cataract Creek Stream Flow Changes

	Creek Catchment Area (km2)	Creek Flow Loss (ML/day)	Creek Flow Gain (ML/day)	Net Result (ML/day)	Change due to Proposed Mining Compared to Current Stage (ML/day)
Current	5.2	- 0.03	+ 0.36	0.33 (gaining)	-
End of Mining Area 2	5.2	- 0.04	+ 0.31	0.27(gaining)	0.06 (0.0115 ML/km^2/day) or 0.5% loss
End of Mining Area 4	5.2	- 0.04	+ 0.30	0.26 (gaining)	0.07 (0.0135 ML/km^2/day) or 0.6% loss

13.4.2 Cataract Creek, Cataract River (Upstream of Cataract Reservoir) and Bellambi Creek

Although groundwater level reductions are predicted over the Wonga East workings, the majority of the changes are contained within the Cataract Creek catchment, and as such, there is anticipated to be no observable change in stream flow or groundwater seepage in the Cataract River (upstream of Cataract Reservoir) and Bellambi Creek catchments due to the very low proportion of the two catchments that may be partially depressurised.

Modelled groundwater flow diagrams indicating the current, post Stage 1 (Area 2 and V Mains) as well as the post Stage 2 (Area 4) in the upper Hawkesbury Sandstone are shown in **Figure 44**.

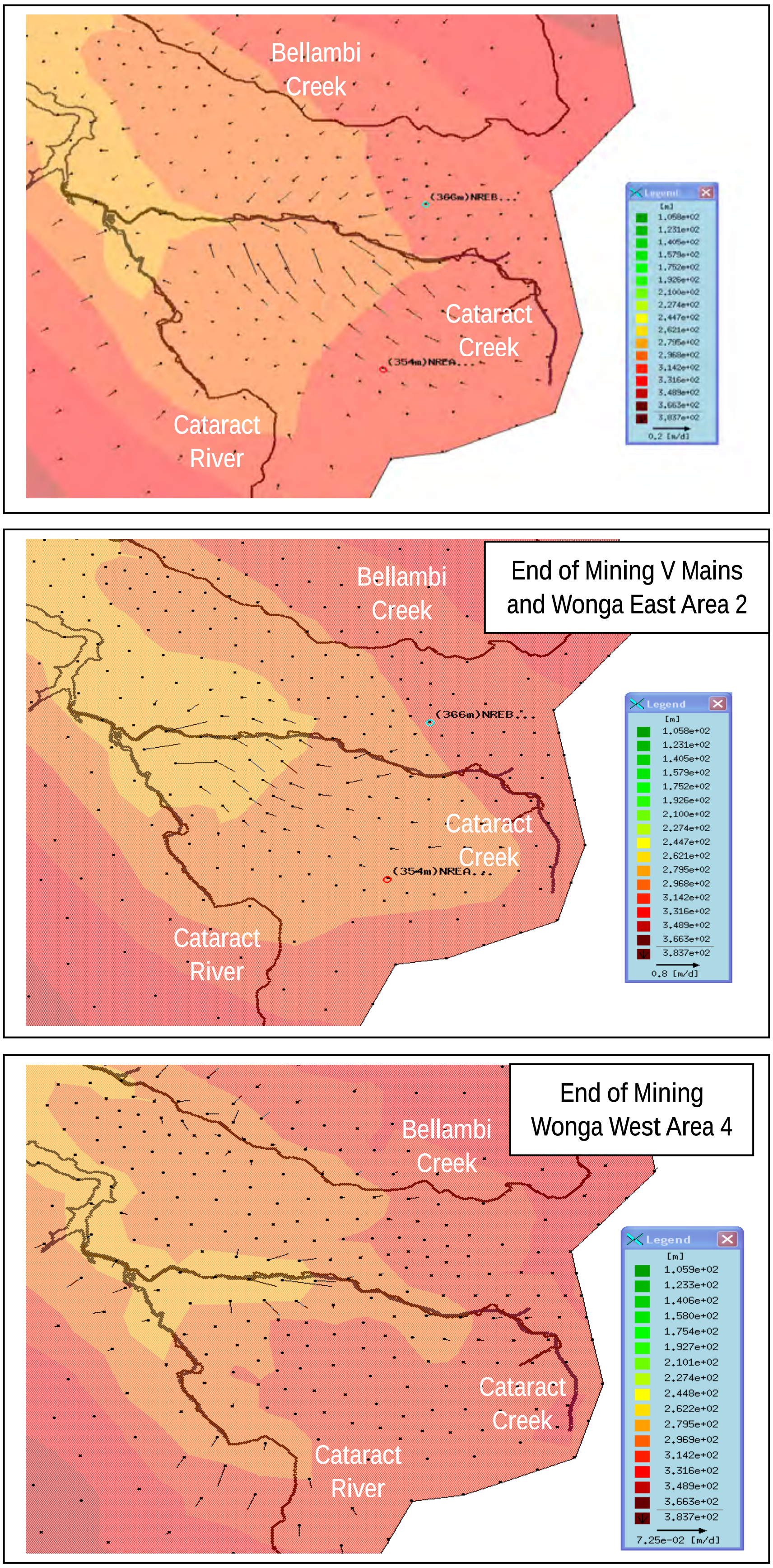

Figure 44 Wonga East Upper Hawkesbury Sandstone Groundwater Flow

13.4.3 Lizard and Wallandoola Creeks

The subsidence assessment (Seedsman Geotechnics, 2012) concluded that where the 200 and 300 series Bulli seam longwalls have been extracted, mining of the proposed Wongawilli Seam longwalls is predicted to generate constrained deflection, without deformation failure of the Bulgo Sandstone.

On this basis, vertical hydraulic fracture connection from the Bulgo Sandstone to the Hawkesbury Sandstone, through the Bald Hill Claystone is not predicted to be enhanced.

The mid to upper Bulgo Sandstone to lower Hawkesbury Sandstone is interpreted to remain as a vertical flow constrained zone following extraction of the Wongawilli Seam without enhanced vertical drainage.

This means that free draining hydraulic connection between the surface water system to the mine workings is not anticipated.

Extraction of the proposed longwalls is modelled to generate up to 12m of depressurisation in the upper Hawkesbury Sandstone (in Layer 2) in the upper headwaters of the Lizard and Wallandoola Creek catchments at the end of mining Area 4.

The modelled, localised reduction in the headwaters is not anticipated to reduce the overall phreatic surface gradient toward Cataract River (downstream of the reservoir), although there may be some lowering of seepage outflow elevation by up to 12m from the upper Hawkesbury Sandstone in the “gaining” reaches of the creeks downstream of the major waterfalls L1 and W1.

No effect on seepage point location or flows are anticipated in the “losing” reaches, upstream of the waterfalls, as the streams and regional groundwater are currently disconnected, and there is no currently observed regional groundwater seepage into the creeks in these reaches.

Stream flow modelling indicates the average daily flow from Lizard Creek and Wallandoola Creek to the Cataract River is 17.0ML/day and 33.0ML/day respectively (WRM Water & Environment, 2012).

Modelled groundwater flow diagrams indicating the current, Stage 1 and Stage 2 sequences in the upper Hawkesbury Sandstone (Layer 2) are shown in **Figure 45**.

The groundwater modelling predicts a 0.02ML/day gain of stream flow in the Lizard Creek catchment at the end of mining Area 2, followed by a 0.10ML/day loss at the end of Area 4 as shown in **Table 11**. The modelled changes are therefore relatively minor (0.12% gain to a 0.6% loss) compared to the average flow from Lizard Creek into Cataract River.

The groundwater modelling also predicts a 0.06ML/day loss of stream flow in the Wallandoola Creek catchment at the end of mining Area 2, followed by a 0.25ML/day loss at the end of Area 4. The modelled changes are therefore relatively minor (0.18% to 0.76% loss) compared to the average flow from Wallandoola Creek into Cataract River.

Table 11 Modelled Lizard And Wallandoola Creek Stream Flow Changes

	Creek Catchment Area (km^2)	Creek Flow Loss (ML/day)	Creek Flow Gain (ML/day)	Net Result (ML/day)	Change due to Proposed Mining Compared to Current Stage (ML/day)
Lizard Creek					
Current	17.1	- 0.50	+ 0.31	-0.19 (losing)	-
End of Mining Area 2	17.1	- 0.49	+ 0.32	-0.17(losing)	0.02 (0.0012 ML/km^2/day) or 0.1% gain
End of Mining Area 4	17.1	- 0.52	+ 0.23	-0.29 (losing)	0.10 (0.0058 ML/km^2/day) or 0.6% loss
Wallandoola Creek					
Current	33.2	- 0.70	+ 0.90	+ 0.20 (gaining)	-
End of Mining Area 2	33.2	- 0.76	+ 0.90	+ 0.14 (gaining)	0.06 (0.0018 ML/km^2/day) or 0.2% loss
End of Mining Area 4	33.2	- 0.70	+ 0.65	- 0.05 (losing)	0.25 (0.0075 ML/km^2/day) or 0.8% loss

Modelled groundwater flow diagrams indicating the current, post Stage 1 (Area 2 and V Mains) as well as the post Stage 2 (Area 4) in the upper Hawkesbury Sandstone at Wonga West are shown in **Figure 45**.

At Wonga West, no surface to seam free drainage is predicted, even though the overburden hydraulic connection may be enhanced by the predicted subsidence within the shallow (0 - 20m below surface) to mid (20 - 50m below surface) Hawkesbury Sandstone aquifers as well as within the enhanced vertical drainage zone between the goaf and the mid Bulgo Sandstone.

It is not anticipated there will be any observable effects on Lizard Creek or Wallandoola Creek stream flow due to the limited depressurisation predicted by the groundwater model in the upper Hawkesbury Sandstone, except possibly after extreme, extended dry periods.

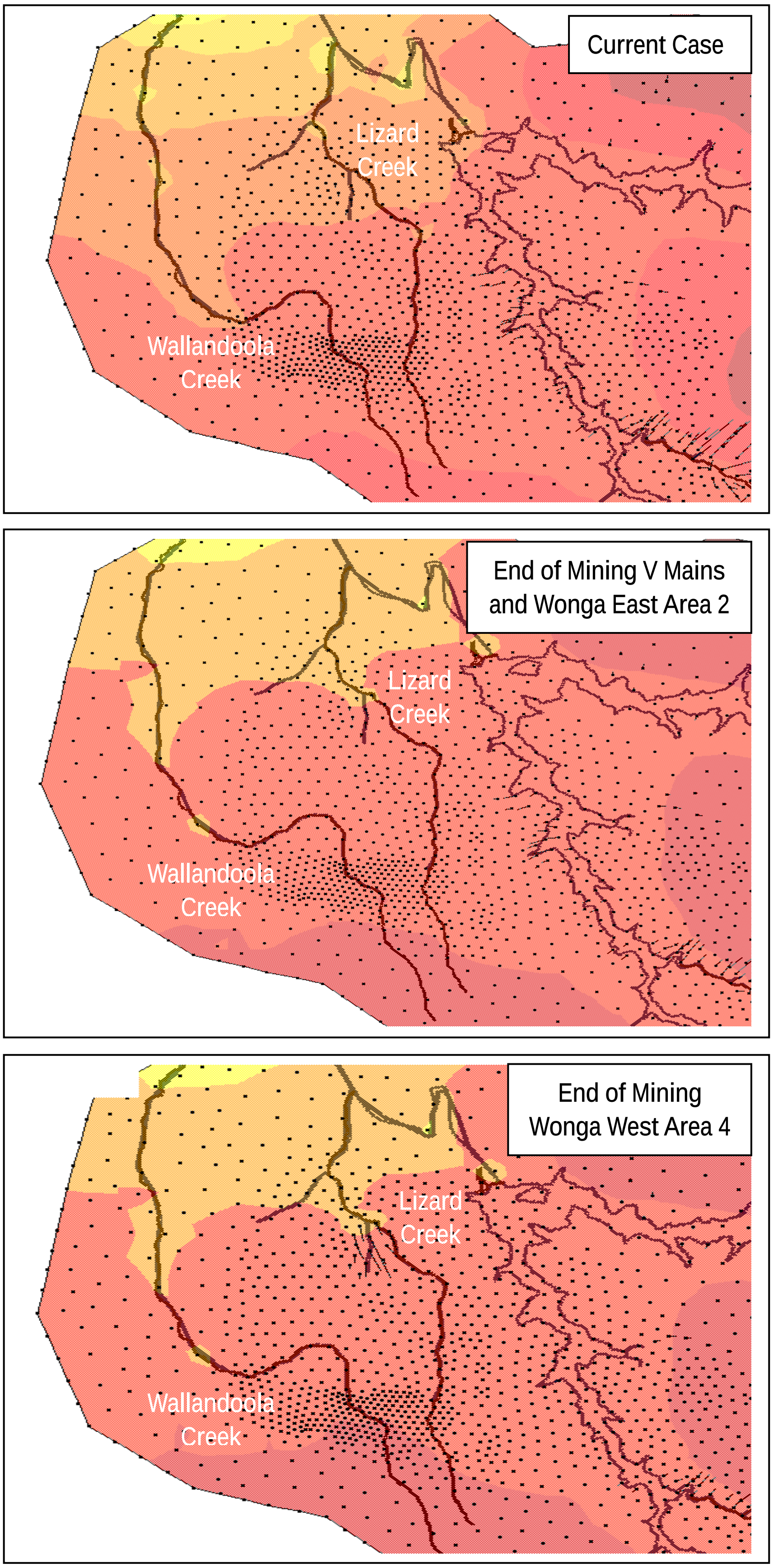

Figure 45 Wonga West Upper Hawkesbury Sandstone Groundwater Flow

13.5 Cataract Reservoir Inflow

Due to the proposed workings setback from the Cataract reservoir, no adverse stored water quantity or quality impacts are predicted to occur on or in Cataract reservoir based on the factors discussed in previous sections.

The groundwater model indicates a potential sub-surface transfer of stream flow to the underlying groundwater system of;

- 0.07ML/day for Cataract Creek;
- 0.03ML/day for Bellambi Creek;
- 0.25ML/day for Wallandoola Creek, and;
- 0.10ML/day for Lizard Creek

A potential annual transfer at the end of mining in Wonga East and Wonga West from stream flow to underflow, or throughflow, after 164.3ML/year, is predicted by the groundwater model. It is anticipated, however, that the water will flow via subsurface fractures and discharge down gradient into the lower section of the streams, and / or into Cataract Reservoir. As such, the change is anticipated to be a sub surface diversion, not an overall loss, to the surface water balance.

Cataract Reservoir has a full operating storage of 97,190ML. The lowest level of the storage that NRE is aware of is 27,620ML or 29.3% capacity on 20 July 2006.

If the low level figure is used, the sub-surface transfer of 164.3ML per year at the end of all proposed mining is less than 0.6% of the low level, or 0.17% of its full storage capacity..

13.6 Subsidence Interaction with Faults and Dykes

The Corrimal Fault is mapped to cross over the proposed Wonga East workings in longwalls WE-A2-LW6 to WE-A2-W9, however it is not anticipated to generate a hydraulic connection to the surface water system or Cataract Reservoir through extraction of WE-A2-LW6. The fault has been identified as a “hinge fault” with a varying throw of approximately 25m in the east, reducing to 1.8m at Maingate 5, and predicted to reduce to no displacement around longwalls WE-A2-LW7 and LW8.

In addition, a thin (<1m wide) highly weathered dyke is located over the Wonga East workings, however, due to its highly weathered clay state and associated low intrinsic permeability, undermining this structure is not anticipated to enhance its permeability or potential hydraulic connection to the surface water systems or to Cataract Reservoir.

If inflow monitoring in the mine, and observation of the piezometers installed over the Wonga East domain, indicate that there may be a potential for increased permeability along the Corrimal Fault due to mining induced changes, then the mining of subsequent panels can be adjusted through adaptive management of the mine workings. To date, mining in the Bulli seam on both sides of the Corrimal Fault (both first and second workings), has not resulted in observable increased flows to the mine workings.

The main structures adjacent to, but not overlying the Wonga West workings are the essentially east – west trending Bulli Fault, which is located to the north of the proposed workings, and the south-west north-east trending dyke that is located to south west of the proposed workings.

None of the known intrusive or fault structures overlying the proposed Wongawilli West workings are anticipated to be of sufficient scale or regional extent, after subsidence, to generate a direct hydraulic connection to the overlying surface water systems or Cataract Reservoir.

Based on past mining experience, the faults in the Bulli / Balgownie workings are essentially dry and are not anticipated to provide enhanced permeability fluid pathways in the proposed mining area.

No water inrush has been reportedly associated with faults or dykes in the Bulli or Balgownie workings (S Wilson, pers comm).

13.7 Groundwater Inflow to the Workings

The predicted average daily modelled inflow to the proposed NRE No.1 workings for each stage is shown in **Table 13**.

Table 12 Predicted Mine Inflows at the End of Mining

Stage	Current Inflow (ML/day)	Predicted Wongawilli Workings Inflow (ML/day)	Predicted Wongawilli Seam Inflow (ML/year)
Wonga East	0.2	1.4	511
Wonga West	0.9	1.7	621
TOTAL	**1.1**	**3.1**	**1131**

The modelled seepage rates into the workings may be enhanced if unidentified fracture related storages are intercepted, which may lead to short term increases of potentially up to 0.1 - 0.5ML/day which should dissipate over a period of weeks to months.

13.8 Groundwater Quality

Previous observations at NRE No.1 indicates that groundwater quality within the regional groundwater system has not been adversely affected, however there may be some localised increased iron hydroxide precipitation and limited lowering of pH if the groundwater is exposed to “fresh” surfaces in the strata through dissolution of unweathered iron sulfide or carbonate minerals.

The degree of iron hydroxide and pH change is difficult to predict, and can range from no observable effect to a distinct discolouration of the formation water. The discolouration does not pose a health hazard, however it can cause iron hydroxide precipitation at seepage points in local streams which can also be associated with algal matting and / or lowering of dissolved oxygen levels in the creek at the seepage point.

It should be noted that many Hawkesbury Sandstone aquifers in the Southern Coalfield already have significant iron hydroxide levels, and that ferruginous seeps can also be observed in previously un-subsided catchment areas.

As a result of the proposed workings, pH acidification of up to 1 order of magnitude may occur, however the change may be reduced if the aquifer has sufficient bicarbonate levels.

Outside of isolated iron hydroxide seepages, no adverse groundwater quality is anticipated to discharge from the proposed Wongawilli Seam workings subsidence areas.

13.9 Loss of Bore Yield

There will be no loss of bore yield as there are no private bores or wells registered by the NSW Department of Climate Change and Water – Office of Water (NOW) in the study area.

14. RISK ASSESSMENT

14.1 Pillar Run

A risk assessment was conducted for the potential pillar run issue in the Wonga East area (KNJ Consultants, 2012) and subsequently after WE-A2-LW4 was extracted as detailed below with regard to the selected natural features.

Stored waters of Cataract Dam - Hazard does not exist

Any potential pillar run would be terminated by a combination of the Corrimal Colliery barrier pillar and a barrier within the Bulli Seam workings extending from N6,196,700, E302,000 through to the Bulli Seam mains at N6,197,500.

The existence of the barrier is supported by the mine plan and subsidence data from the extraction of the Balgownie Seam longwalls. The observed subsidence above the previous Balgownie Seam longwalls was in accordance with expected behaviour of strata in this coalfield. In addition, the mine plan shows substantial pillars in the Bulli Seam in the vicinity of the stored waters of the Cataract Dam.

Cataract River - Hazard does not exist

The Cataract River is located to the south & east of the Corrimal Colliery barrier pillar, which would terminate any pillar run in the Bulli Seam that may be initiated from the Wonga East area.

Cataract Creek - Possible Low Risk

Without pillar run, it is anticipated that the bed of Cataract Creek could experience maximum vertical subsidence of up to 0.8m and strain levels of up to 9.5mm/m (Seedsman Geotechnics, 2012) with the current mine plan.

Possible worst case subsidence could occur over 7 days between the Bulli Seam Mains & the barrier pillar extending from N6,196,700, E302,000 through to the Bulli Seam Mains at N6,197500, for a creek length of approximately 400m.

The maximum reasonable consequence of the worst case scenario was possible ferruginous upwellings and fracturing of rock beneath the sandy creek bed with no substantial loss of water to the mine workings.

Upland Swamps – Possible Low Risk

Swamps associated with Cataract and Bellambi Creeks Cataract River could have a worse possible case of up to 1.2m subsidence over 7 days.

The maximum reasonable environmental consequence could be possible drying or water level reduction in the area of the swamp and fracturing of rock beneath the swamp with no substantial loss of water to the mine workings.

14.1.1 Non Conventional Subsidence, Far Field Impacts and Risk of Re-activation of Fracturing From Previous Mining

There are some examples of unusual subsidence related to geological structures, mainly dykes, but these are relatively rare. In general, faults and dykes do not significantly change surface subsidence behavior.

Previous mining on two levels has been conducted adjacent to or under the dykes and faults at Wonga East, with no evidence in the measured subsidence profiles of these features having any influence on surface subsidence behavior.

The main influence of these structures appears to have been at seam level where it has been difficult to mine through the dyke in the Balgownie Seam longwalls.

No strong evidence is available to indicate that structures may become reactivated as hydraulic pathways, or that they are either more or less hydraulically conductive than the surrounding strata or that they provide a connection between the surface and underground (SCT Operations, 2012).

Significant disturbance to the overburden strata through vertical subsidence is likely to be substantially avoided if surface features are not directly mined under because most of the vertical stretching that contributes to increased hydraulic conductivity is located directly over each longwall panel.

There is still potential for some disturbance and associated increase in the hydraulic conductivity as a result of secondary effects such as valley closure or where aquifers or stratigraphic with higher natural hydraulic conductivity, but these effects tend to be greater directly above each panel.

The valley closure impacts tend to be specific to topographic low points and are not necessary associated with increased vertical hydraulic conductivity to the mining horizon, although the impacts may be significant within the context of the river channel or valley infill swamp.

Subsurface mining disturbance to stratigraphic units that have naturally higher hydraulic conductivity may result in a pathway of increased hydraulic conductivity between groundwater stored in these units and the mining horizon. There is potential for the associated drawdown to extend well outside the footprint of individual longwall panels, particularly when horizontal movements that occur toward each longwall goaf result in a net volume increase of the aquifer.

However, the further away a longwall panel is from a given surface feature, the less likelihood there is for significant impact.

Far-field horizontal movements, valley closure movements, and lateral drawdown within the deep groundwater system are recognised to have potential to extend beyond, the limits of vertical subsidence, however these effects do not generally have a significant impact on mine inflows or surface water systems not overlying the subsidence zone (SCT Operations, 2012).

15. CUMULATIVE GROUNDWATER RELATED IMPACTS

15.1 Upland Swamps

The cumulative impact of previous subsidence effects on the adjoining, upstream swamp systems in the Cordeaux mine lease area cannot be definitively assessed as the pre-mining status of the associated Lizard Creek and Wallandoola Creek stream and swamp systems have not, to our knowledge, been monitored.

Current pool height and water quality monitoring data collected for this study indicates the Cordeaux swamps maintain seepage flow in to the Gujarat lease area, whilst ferruginous seepage is present in the streams, however, due to the lack of pre-mining data, no comment can be made as to whether the seepage is mining induced or not.

No other adjoining previous mining operations provide a cumulative impact on swamps in the Study area.

No swamps are present downstream of the Gujarat lease area.

15.2 Basement Groundwater

The cumulative impact of the existing and proposed NRE No. 1 workings along with the surrounding mines has been assessed in the existing and predictive model runs by including the effects of:

- subsidence and associated fracture propagation and hydraulic permeability distribution over non-mining areas, as well as over bord and pillar / pillar extraction or longwalls of variable widths on the regional groundwater pressure distribution;
- known or estimated degree of flooding in the adjoining workings;
- separation distance of adjoining workings (i.e. the Appin / Westcliff / Northcliff / Metropolitan / Tahmoor mining areas were interpreted to be sufficiently distant from the existing and proposed NRE1 workings to be discounted as discussed in **Appendix D**).

16. MONITORING, CONTINGENCY MEASURES & REPORTING

16.1 Swamp Monitoring

The existing suite of shallow piezometers installed within the NRE1 upland swamps should be monitored to gauge any changes in standing water levels and swamp groundwater quality over an active mining area and for all key water quality parameters on a regular basis for the duration and an appropriate time following mining.

It should be noted that no vehicular access is available within the upland swamps, and installation of any further piezometers will require entry on foot.

Prior to mining under or adjacent to a swamp, a Swamp Risk Management Plan (SRMP) should be developed which demonstrates that the predicted subsidence should ensure the size and functioning of the swamp, including potential changes in species composition or distribution within the swamp will not be adversely affected. It should ensure that water will not drain from the swamp due to subsidence or be re-distributed to an extent where such potential adverse changes could occur.

A monitoring program should be designed and implemented to:

- assess the swamp hydrology;
- provide advance warning of potential exceedances of subsidence predictions;
- detection of exceedances and adverse impacts on the swamp and underlying strata hydrology; and
- characterise the relationship between swamp/s and their role in recharging the regional groundwater systems.

16.1.1 Swamp Standing Water Levels

Standing water levels will be measured automatically, twice daily by pressure transducers and regularly by manual dip meter.

Should the standing water level or groundwater quality be unacceptably affected due to subsidence, the Colliery will investigate methods to ameliorate the situation until the water level or water quality recovers.

16.1.2 Swamp Groundwater Quality

At least one appropriately purged and collected, stored and transported groundwater sample should be collected from each swamp piezometer pre and post undermining to enable ongoing assessment of any subsidence related changes in groundwater quality. Samples should be analysed for the following:

- Field pH, electrical conductivity, temperature;
- total dissolved solids;
- Na / Ca / Na / K / SO4 / Mg / Cl / F;
- total alkalinity;
- total / filterable Fe, Mn, Al;
- filterable Ni, As, Li, Ba, Sr, Cu, Pb, Zn; and
- total nitrogen and total phosphorous

Observations should be made on the quantum of iron hydroxide precipitating from the pumped water before and after undermining.

16.2 Basement Groundwater Monitoring

16.2.1 Groundwater Levels

Piezometers to be included in the monitoring suite are shown in **Table 14**.

The suite is divided into standpipe and vibrating wire piezometers, with water level transducers and vibrating wire piezometers used to monitor standing water levels or pressure heads twice daily to assess variations in the colluvial and basement formations.

Table 13 Groundwater Level Monitoring Suite

	Piezometer Type
Basement	
NREA, C, D, E, G, NRE3, GW1A	Open Standpipe
NREA, B, D, NRE3, GW1	VWP
Colluvium	
SP1, SP2	Open Standpipe
Swamps	
PL1A, B PL18, PL25A, B, C, D	Lizard Creek catchment open standpipe
PW1, 4, 11	Wallandoola Creek catchment open standpipe
PCc2, 3, 4, 5A, 5B, 6	Cataract Creek catchment open standpipe
PCr1	Cataract River catchment open standpipe
PB4	Bellambi Creek catchment open standpipe

NOTE: VWP = vibrating wire piezometer

Inclusion of additional groundwater monitoring locations and depths will be incorporated, if required, following discussions with the SCA and NOW.

Monitoring will also involve bi-monthly manual standing water level measurement in all open standpipe piezometers, at which time the loggers will be downloaded and re-initiated as shown in **Table 15**.

Table 14 Standing Water Level Monitoring Method and Frequency

Monitoring Site	Sampling Method	Frequency / Download	Units
NREA, C, D, E, G, NRE3, GW1A	Water level logger / dip meter	twice daily / bi-monthly	mbgl
NREA, B, D, NRE3, GW1A	Vibrating wire piezometer	twice daily / quarterly	m head pressure
SP1, SP2	Water level logger / dip meter	twice daily / bi-monthly	mbgl
PL1A, B PL18, PL25A, B, C, D	Water level logger / dip meter	twice daily / bi-monthly	mbgl
PW1, 4, 11	Water level logger / dip meter	twice daily / bi-monthly	mbgl
PCc2, 3, 4, 5A, 5B, 6	Water level logger / dip meter	twice daily / bi-monthly	mbgl
PCr1	Water level logger / dip meter	twice daily / bi-monthly	mbgl
PB4	Water level logger / dip meter	twice daily / bi-monthly	mbgl

NOTE: mbgl = meters below ground level

16.2.2 Groundwater Quality

Tables 16 and **17** present the parameters to be measured, frequency of monitoring and sampling method for groundwater quality monitoring, with monitoring to continue for 12 months after mining has ceased.

Table 15 Groundwater Quality Monitoring Parameters

ANALYTES	Units	FREQUENCY
EC, pH	µS/cm, pH units	Bi - monthly
(EC, pH) + TDS, Na, K, Ca, Mg, F, Cl, SO4, HCO3, NO3, Total N, Total P, hardness, Cu, Pb, Zn, Ni, Fe, Mn, As, Se, Cd (metals filtered)	mg/L	Start / finish of panel for piezometers adjacent to a panel, or in an active mining area, otherwise 1 sample per year

The frequency of monitoring will be reassessed after mining is complete as it may be possible, depending on results, to lengthen the intervals. The frequency of monitoring and the parameters to be monitored may be varied by NOW once the variability of the groundwater quality is established.

Table 16 Groundwater Quality Monitoring Method and Frequency

Monitoring Site	Sampling Method	Frequency
Open Standpipe Piezometers	Pumped field meter readings	Bi-monthly
Open Standpipe Piezometers	Pumped sample for laboratory analysis	Start / finish of each panel for piezometers adjacent to a panel or in an active mining area, otherwise 1 sample per year

Groundwater samples should be collected at the start and finish of each panel from piezometers either adjacent to an active panel, or within an active mining area and analysed at a NATA registered laboratory for major ions and selected metals. Piezometers not within an active mining area should be sampled and analysed once per year.

It is anticipated that the groundwater program should be maintained in its current status, with possible modification of the program at the end of each panel after a review of all monitoring data has been conducted.

Additional piezometers may be added to the existing suite if required.

The groundwater monitoring program is anticipated to be extended beyond the active mining period in order to assess the potential long term change in groundwater level recovery and quality changes for 12 months after completion of mining.

16.3 Surface Water and Groundwater Connectivity

The potential for surface water and groundwater system hydraulic connectivity should be assessed through monitoring of stream flows in and near actively mined areas (as outlined in Geoterra 2012) as well as through monitoring and interpretation of the basement groundwater open standpipe and vibrating wire piezometers water levels / pressures and mine inflow changes.

16.4 Mine Water Pumping

The volume of water pumped into and out of the NRE No. 1 workings should be monitored daily to enable the differential groundwater seepage into the workings to be assessed.

16.5 Ground Survey

The ground surface over the proposed underground workings should be surveyed in accordance with DII subsidence monitoring requirements.

16.6 Rainfall

Daily rainfall data should be obtained from a local weather station for the duration of mining in the NRE No.1 catchment area.

16.7 Ongoing Monitoring

All results should be reviewed after each panel is completed and an updated monitoring and remediation program should be developed, if required, in association with NOW and DII.

16.8 Quality Assurance and Control

QA/QC should be attained by calibrating all measuring equipment, ensuring that sampling equipment is suitable for the intended purpose, using NATA registered laboratories for chemical analyses and ensuring that site inspections and reporting follow procedures outlined in the ANZECC 2000 Guidelines for Water Quality Monitoring and Reporting.

16.9 Impact Assessment Criteria

16.9.1 Groundwater Levels

Impact assessment criteria investigation trigger levels should be initially set where a groundwater level reduction exceeds more than 10% of the saturated aquifer thickness over a 12 month period, compared to the minimum height within the last 12 months of data, excluding any short term recharge peaks. Should the trigger be exceeded, the actual rate of change of water levels should be investigated to determine whether the change is solely subsidence induced or due to a range of other potential factors.

If a significant increase in the rate of water level decline is noted, based on interpretation by a qualified hydrogeologist, then an assessment should be conducted to determine the cause of the change (such as variation in climate or effects from adjacent mining operations) and to consider potential contingency measures that may be adopted.

16.9.2 Groundwater Quality

Groundwater quality impact assessment criteria are sourced from the Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC, 2000) for Aquatic Ecosystems as shown in **Table 18.**

Table 17 Groundwater Quality Impact Assessment Criteria

Indicator	Irrigation Criteria
pH	<6.5 or >7.5 or >10% variation over 4 months compared to previous 12 months data
Conductivity	>10% variation over 4 months compared to previous 12 months data
TDS	>350mg/L or >10% variation compared to previous 12 months data
Total Nitrogen	>250µg/L or >10% variation compared to previous 12 months data
Total Phosphorous	>20µg/L or >10% variation compared to previous 12 months data

A trigger to assess the cause and effects of adverse groundwater quality changes should be implemented when there is a prolonged and extended non-conformance of the outlined criteria at a particular piezometer. If a field parameter (pH, conductivity) is outside the designated criteria for at least six months in a sequence, or alternatively, exceeds its previous range of results by greater than a 10% variation for at least 4 months, then the cause should be investigated, and a remediation strategy should be proposed, if warranted.

The criteria and triggers should be reviewed after each 12 month block of data is interpreted and may be modified as appropriate, depending on the results.

If the impacts on the groundwater system resulting from future underground operations are demonstrated to be greater than anticipated, the proponent should:

- assess the significance of these impacts;
- investigate measures to minimise these impacts; and
- describe what measures would be implemented to reduce, minimise, mitigate or remediate these impacts in the future to the satisfaction of the Director-General, NOW and the Sydney Catchment Authority.

16.10 Contingency Procedures

Contingency procedures should be developed as required, with the measures to be developed being dependent on the issue that requires addressing.

The procedures should be used to manage any impacts identified by monitoring that demonstrate the groundwater management strategies may not have adequately predicted or managed the groundwater system's anticipated response to mining.

Activation of contingency procedures should be linked to the assessment of monitoring results, including water quality, aquifer hydrostatic pressure levels and the rate of water level changes.

Performance indicators should be identified prior to extraction of the proposed underground workings and a statistical assessment should be undertaken to detect when, or if, a significant change has occurred in the groundwater system which should benchmark the natural variation in groundwater quality and standing water levels.

A monitoring and management strategy along with an outline of a Trigger Action Response Plan (TARP) should be prepared to provide guidance on the procedures and actions required in regard to the surface water and groundwater systems in the proposed mining area.

16.11 Piezometer Maintenance and Installation

The current network should be maintained by protecting the wellhead from damage by animals and scrub fires by maintaining their steel sealed wellheads.

If required, the piezometers may be cleaned out by air sparging if they become clogged.

In the event that any new piezometers are required, they should be installed by suitably licensed drillers after obtaining the relevant bore licence from the SCA and NOW.

16.12 Reporting

Following completion of extraction of each panel, a report should be prepared for all prior panels that summarises all relevant monitoring to date. The report should outline any changes in the groundwater system over the relevant mining area.

The report should contain an interpretation of the data along with:

- a basic statistical analysis (mean, range, variable, standard deviation) of the results for the parameters measured;
- an interpretation of water quality and standing water level changes supported with graphs or contour plots; and
- an interpretation and review of the results in relation to the impact assessment criteria.

Relevant monitoring and management activities for each year should also be reported in the AEMR.

16.13 Adaptive Management

The proponent has provided an undertaking that it will terminate mining beneath Cataract Creek, through adaptive management measures relating to operation of the mine workings if subsidence and ground movements exceed 250mm and the creek is predicted to experience greater than negligible impact as defined by the project approval performance criteria.

An adaptive management plan should be developed to use the monitoring program to detect the need for adjustment to the mining operation so that the subsidence predictions are not exceeded and subsidence impacts creating a risk of negative environmental consequences do not occur.

The adaptive management procedures should be implemented to provide a systematic process for continually detecting impacts, validating predictions and improving mining operations to prevent further adverse impacts on the swamp and basement groundwater systems overlying the proposed mining domains.

Monitoring, evaluation, and reporting on management performance and ecological impact should be integrated into the site's core management systems to progress the technical understanding and predictive capability of subsidence effects, impacts and consequences on the sites surface water systems.

An evidence-based approach should be used to validate the extent to which outcomes are being achieved, with the monitoring results being related to, and demonstrating how management strategies have been achieved or where improvements can be made.

As longwalls WE-A2-LW4 to LW7 in Area 2 are planned to be mined first, and as they do not overlie the main channel or significant tributaries of Cataract Creek, they would provide a "baseline" monitoring opportunity to assess the effect of subsidence on fracture propogation and development through the overburden, height of fracturing, development of cracking at surface, changes to an upland swamp perched water system (Crus1) as well as flow and water quality in Cataract Creek and any changes in mine inflows.

Data gained from monitoring a suite of extensiometers, vibrating wire piezometer arrays and open standpipe piezometers as well as geochemical monitoring of groundwater and surface water and stream flow regimes over the panels would then be able to be used to update the curent geotechnical, hydrogeological and hydrological assessments for the proposed mining and to incorporate, if required, adaptive management measures for future panels.

Additional groundwater related monitoring that could be used to enhance the adaptive management process may include conducting:

- continuation of the existing mine water pump monitoring and updating the mine water balance;
- additional drilling, with a range of vibrating wire piezometers and core testing to establish the mechanical and hydraulic properties of the overburden in proximity to water dependent systems in the catchments (including swamps);
- installation of additional deep vibrating wire piezometers and extensiometers to assess/quantify the impacts of fracturing within the subsidence zone;
- installation of paired shallow piezometers (where appropriate) targeting swamps and the underlying shallow Hawkesbury Sandstone aquifer to assess their hydraulic connection and climatic implications;
- sediment profiling in swamps to characterise type, thickness and sensitivity to differential subsidence; and
- update the numerical modelling when sufficient additional data becomes available to enhance the prediction of subsidence zone fracture distributions, connectivity and groundwater transmissivity capacities.

17. POTENTIAL REHABILITATION MEASURES

While the nature and extent of possible subsidence impacts are considered to be manageable, the range of possible remediation or rehabilitation measures is discussed below.

17.1 Streams

For discussion of potential stream related rehabilitation measures, refer to (Geoterra, 2012).

17.2 Upland Swamps

Potential remediation measures for impacts on upland swamps could include:

- *installation of coir log dam erosion control structures at knick points in a swamp;*

Tilting of the swamp can re-direct runoff leading to scour and erosion or alter water distribution in a swamp. However, no swamps in the Study area have been assessed with a moderate or higher risk of drainage line alignment change in terms of their erosion and scour potential.

Coir logs can be installed at knick points for construction of small dams, and have been used successfully in swamp rehabilitation in the Blue and Snowy Mountains (BHP Billiton Illawarra Coal, 2009).

A trench is initially cut into the swamp so the first coir logs sits on the substrate or at ground level and is held by wooden stakes and bound with wire. The dam slows the flow and enables siltation behind the log with coir log dams constructed at intervals down the erosion channel. For increased flow filtering, the coir logs can be wrapped in jute fibre matting.

The main objective of siting erosion control structures is to maintain the saturated water level in the soil profile by reversing the hydraulic head to enable water to permeate back into the swamp (BHP Billiton Illawarra Coal, 2009).

The coir log dams can also capture sediment to restore an incised channel to the level of the surrounding intact soil layer and provide a barrier to headward erosion.

- *use of water spreading techniques, involving long lengths of coir logs and hessian `sausages' linked together across a swamp contour such that water flow builds up behind them and seeps through the water spreaders to maintain swamp moisture;*

Maintenance of swamp moisture can be enhanced by installing coir logs and hessian `sausages' linked across a swamp contour to build up water flow and enhance seepage through the spreaders which can be positioned in shallow trenches.

Erosion control and water spreading involves soft-engineering materials that would contribute to and function as part of the swamp system but would degrade and be integrated into the swamp (BHP Billiton Illawarra Coal, 2009).

- *sealing of surface cracks through the use of grouting products*

Where bedrock controlled features within or on the margins of a swamp are impacted from subsidence and there is limited ability for fractures to infill naturally, surface cracks can be sealed with grout, such as small quantities of cement with various additives mixed on-site and placed by hand with bunds used to contain local spillage.

- *injection grouting.*

Grouts and filler materials can be injected to fill voids in fractured strata via hand held drilling equipment to achieve a low permeability layer 1 - 2 m thick below the depth of a controlling rock bar.

Where colluvial soils overlie the sandstone, a grout may be injected through rods to seal voids in or under the soil or peat material.

Implementation of any management measures should be considered with regard to the specific circumstances of the subsidence impact, such as the location, nature and extent of the impact and the assessment of the potential environmental consequences of the remediation technique used.

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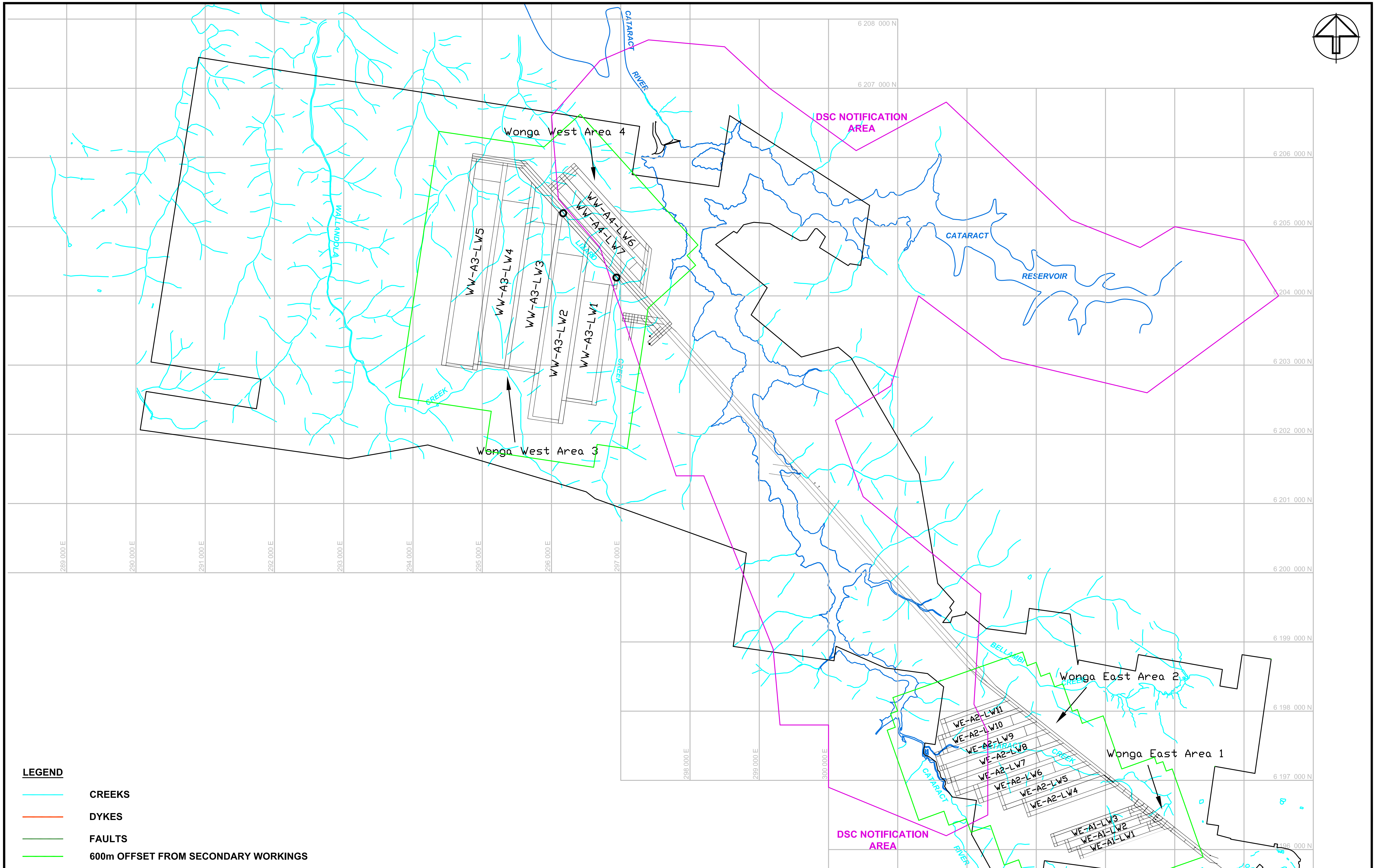

LEGEND

- CREEKS
- DYKES
- FAULTS
- 600m OFFSET FROM SECONDARY WORKINGS

PROJECT:	GUJ1-G-R1	GUJARAT NRE COKING COAL LTD NRE No.1 COLLIERY PROPOSED WONGAWILLI SEAM WORKINGS	GeoTerra DRAWING 1
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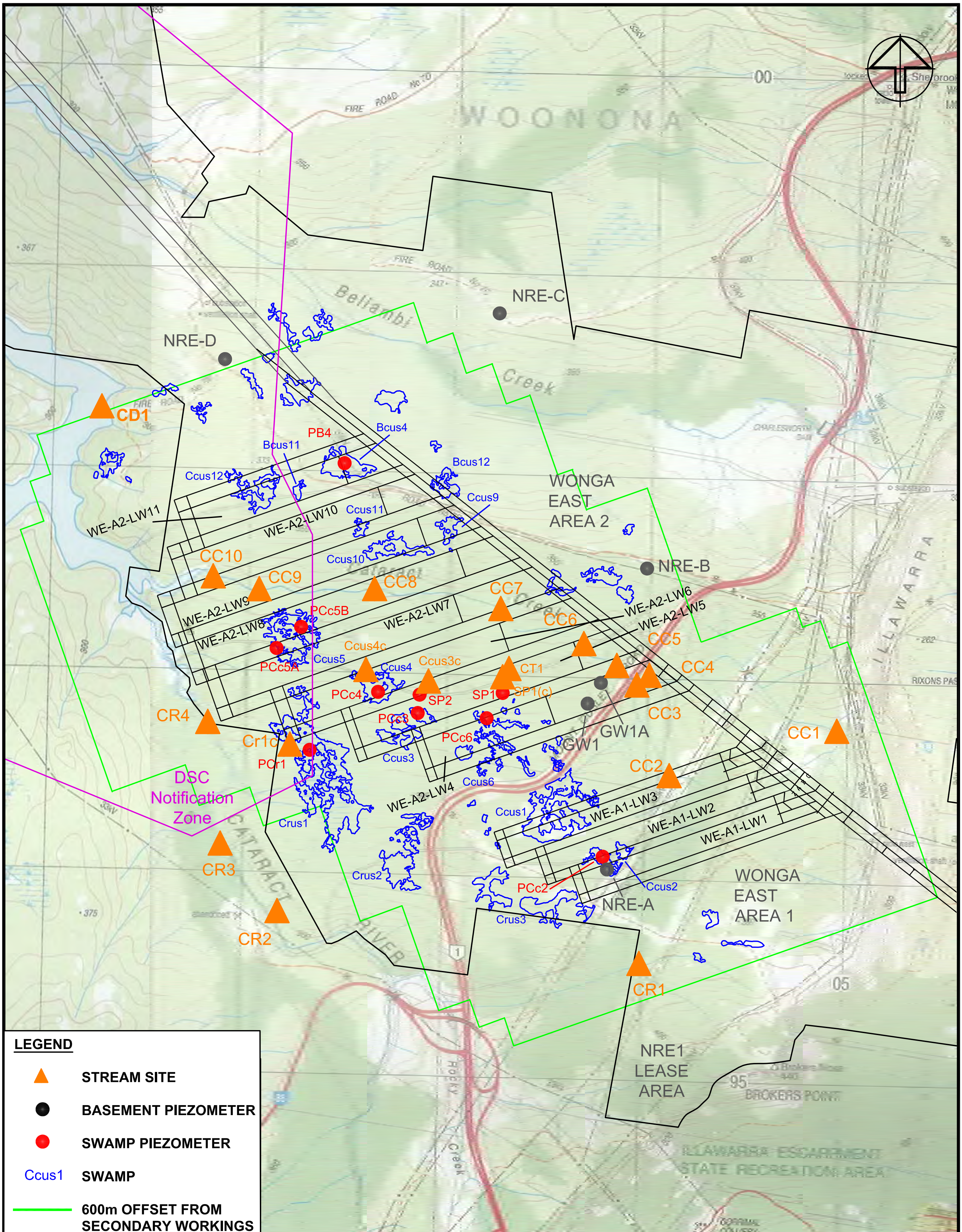

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DRAWN:	A. DAWKINS		
DATE:	19 Nov 2010	**Proposed Wonga East Workings and Monitoring Locations**	**DRAWING 2**
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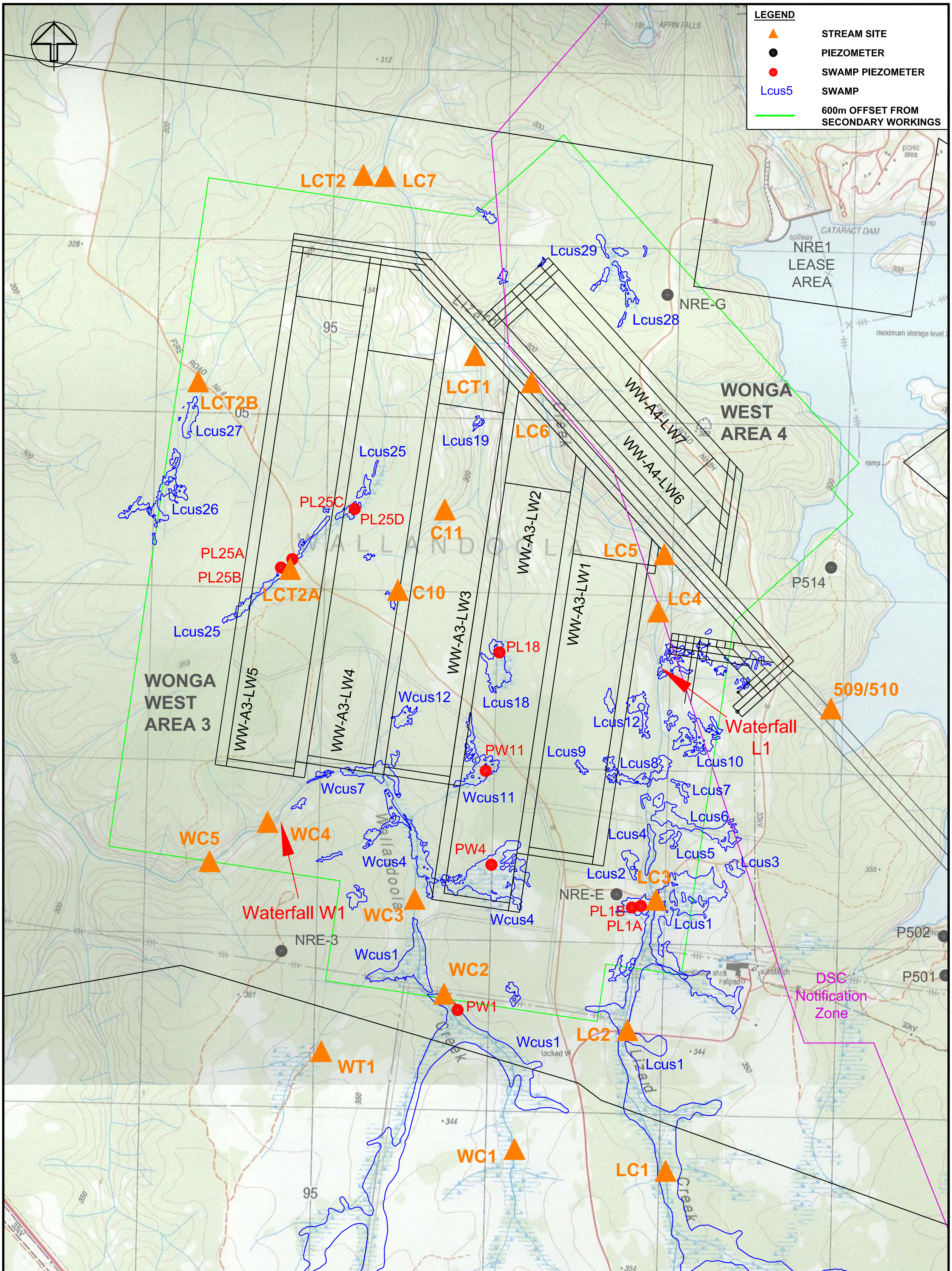

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DRAWN:	A. DAWKINS
DATE:	26 Oct 2012
SCALE:	1:200

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NRE No. 1 COLLIERY

Proposed Wonga West Workings and Monitoring Locations

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DRAWING 3