

APPENDIX 13

Flood and Drainage Assessment

Austar Coal Mine Pty Ltd

**Austar Coal Mine
Flood and Drainage Assessment:
Stage 3**

September 2008



Austar Coal Mine Flood and Drainage Assessment: Stage 3

Prepared by
Umwelt (Australia) Pty Limited
on behalf of
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1.0 Introduction

1.1 Background

Austar Coal Mine is an underground mine formed from the former Ellalong, Pelton, Cessnock No.1 (Kalingo) and Bellbird South Collieries near Cessnock, NSW (refer to **Figure 1.1**). Austar Coal Mine is to be developed in three stages. A modification to consent (DA 29/56) was granted for Stage 1 of the mine in September 2006 and for the commencement of Stage 2 of the mine in June 2008. The modifications allowed the use of the technology known as Longwall Top Coal Caving (LTCC) to extract coal.

A flooding assessment of the Stage 2 longwalls was carried out by Umwelt (Australia) Pty Limited (Umwelt) in February 2007 as part of the Subsidence Management Plan (SMP) process.

Umwelt has been commissioned by Austar Coal Mine Pty Ltd (Austar) to prepare an Environmental Assessment (EA) as part of the project application for the Stage 3 Mining Area. This flood and drainage assessment has been undertaken as part of the overall EA for the project.

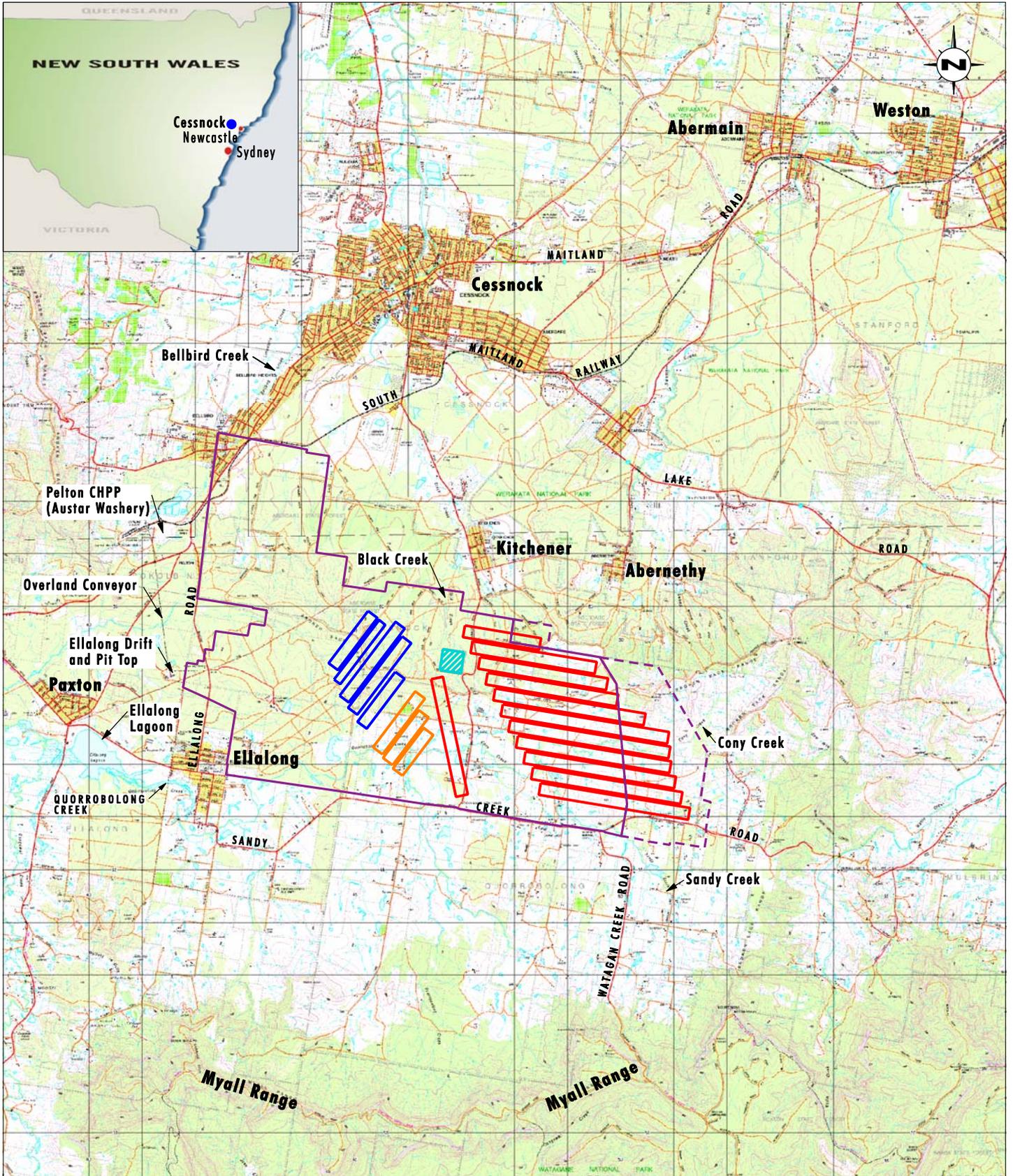
1.2 Scope of Assessment

The aim of this flood and drainage assessment is to define the potential impacts on flooding and drainage that may result from the underground mining of Stage 3 (refer to **Figure 1.1**).

This assessment builds on work undertaken for the Stage 2 flood assessment (Umwelt, 2007). The Stage 2 flood assessment is detailed in *Flooding Assessment: Longwalls A3, A4 and A5* (Umwelt, 2007).

This flood and drainage assessment has included the following stages of work:

- review of available meteorological and flooding data (refer to **Section 3**);
- extension of the Stage 2 Mining Area flood models to incorporate the proposed Stage 3 Mining Area (refer to **Section 5**);
- review of the model's suitability by comparing flood observations during the February 1990 and June 2007 storm events to the modelled 1990 storm event and 100 year Average Recurrence Interval (ARI) storm event for the existing (i.e. pre Stage 2 mining) landform (refer to **Section 6**);
- definition of base conditions for the assessment (i.e. pre Stage 2 mining and pre Stage 3 mining) (refer to **Section 7**); and
- investigation of potential impacts of the Stage 3 mining operations on flooding and drainage, including flood depths, velocities and durations in the Quorrobolong Valley (refer to **Section 8**).



Source: Topo Maps: LPI NSW, Longwall Layout: Austar Coal Mine

0 1.0 2.0 4km
1:100 000

Legend

- ▭ Layout for Stage 1 Longwall Panels
- ▭ Layout for Stage 2 Longwall Panels
- ▭ Conceptual Layout for Stage 3 Longwall Panels
- ▨ Surface Infrastructure Site
- ▭ Consolidated Mining Lease (CML) 2
- ▭ Proposed Stage 3 Extension Boundary

FIGURE 1.1
Locality Plan

2.0 Catchment Description

2.1 Physical Setting

The Stage 3 Mining Area is located within the Quorrobolong Creek/Cony Creek drainage system (also known as the Quorrobolong Valley) (refer to **Figure 2.1**). The Quorrobolong Valley upstream of Ellalong Lagoon (including Quorrobolong and Cony Creeks) has a catchment area of approximately 87 km² and mainly comprises state forest and cleared agricultural land that is predominantly used for grazing with some vineyards.

2.2 Topography and Drainage

The majority of the Stage 3 Mining Area is located immediately to the south of Broken Back Range and to the north of the Myall Range (refer to **Figure 2.1**). This area drains to Quorrobolong Creek system.

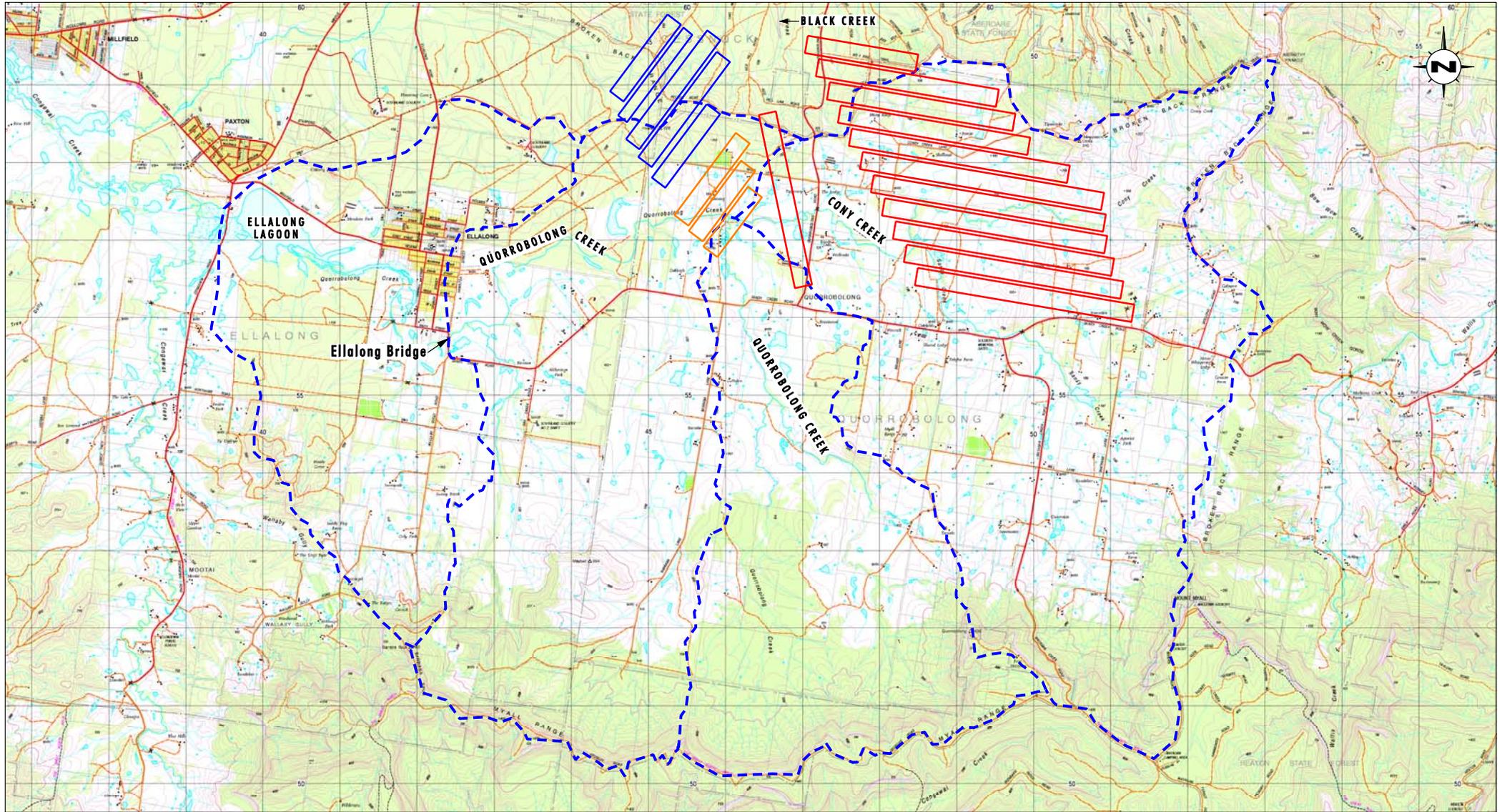
The highest elevation in the catchment area is 445 metres AHD (mAHD) and forms part of the Myall Range on the southern catchment boundary. Ellalong Bridge is constructed over Quorrobolong Creek approximately two kilometres upstream of Ellalong Lagoon.

The catchment area of the Quorrobolong valley upstream of Ellalong Bridge is approximately 78 km² (refer to **Figure 2.1**). The Quorrobolong Creek drainage system conveys runoff from the Broken Back and Myall Ranges to the west, past the township of Ellalong and into Ellalong Lagoon approximately 6 kilometres downstream of the mining area. Overflows from Ellalong Lagoon flow into Congewai Creek which flows in a westerly direction to Wollombi Brook. Wollombi Brook flows in a northerly direction into the Hunter River approximately 10 kilometres upstream of Singleton.

The northern portion of the mining area is characterised by gentle to moderate timbered slopes on ridge spurs that extend to the Broken Back Range. The area to the south of the timbered northern section has predominantly been cleared for grazing with small areas of vineyards and tree plantations also present. The majority of the creek lines in this area above the proposed Stage 3 Mining Area support riparian vegetation.

Sections of Cony Creek upstream of its confluence with Quorrobolong Creek and Sandy Creek upstream of its confluence with Cony Creek, exhibit alluvial floodplains that are up to 400 metres in width (refer to **Figure 2.2**). The alluvial flats in this area have predominantly been cleared for cattle grazing and contain a number of farm dams. Immediately downstream of the junction of Cony Creek and Quorrobolong Creek (which is approximately 800 metres downstream of Longwall A6 in the proposed Stage 3 Mining Area) the floodplain is constricted by a north-south orientated knoll which extends from the northern side of Quorrobolong Creek.

As shown on **Figure 2.3**, there are numerous drainage lines above the proposed Stage 3 Mining Area that make up the eastern portion of the Quorrobolong Creek drainage system. Drainage lines above proposed Longwalls A7 to A10 are typically first and second order streams. Above proposed Longwalls A11 to A17 first to fourth order streams are present. Downstream of the confluence of Sandy Creek and Cony Creek at the western end of proposed Longwall A16 and above proposed Longwall A6, the drainage system becomes a fifth order stream. As shown on **Figure 2.3** many sections of these creeks have been dammed.



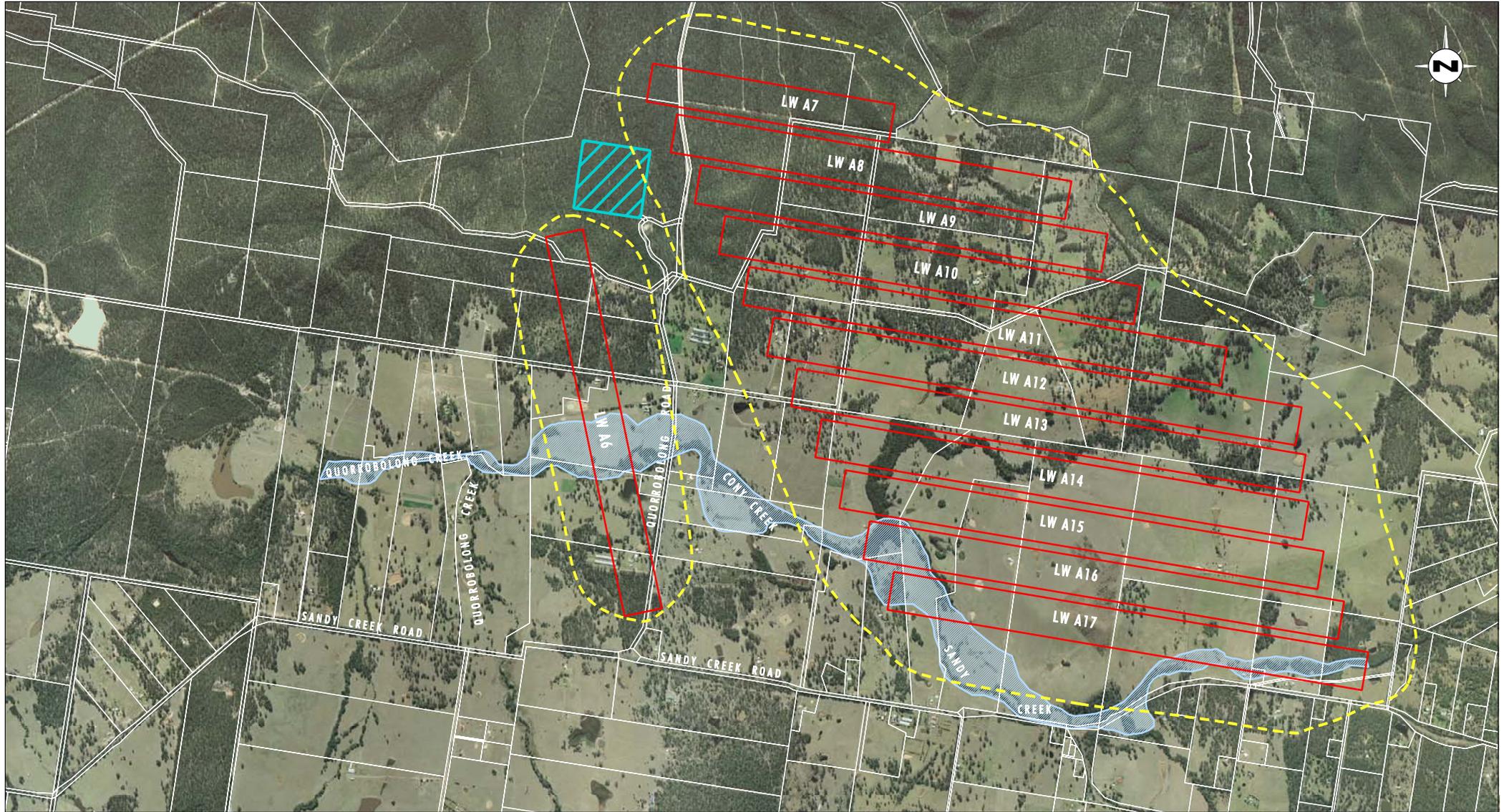
Source: Topo Maps: LPI NSW, Longwall Layout: Auster Coal Mine

0 1 2 3 km
1:70 000

Legend

- ▭ Layout for Stage 1 Longwall Panels
- ▭ Layout for Stage 2 Longwall Panels
- ▭ Conceptual Layout for Stage 3 Longwall Panels
- - - Catchment Boundary

FIGURE 2.1
Catchment Plan



Source: Longwall Layout: Austar Coal Mine, Cadastre: LPI NSW,
Aerial Photography: AAM Hatch 2006, Alluvial: Connell Wagner

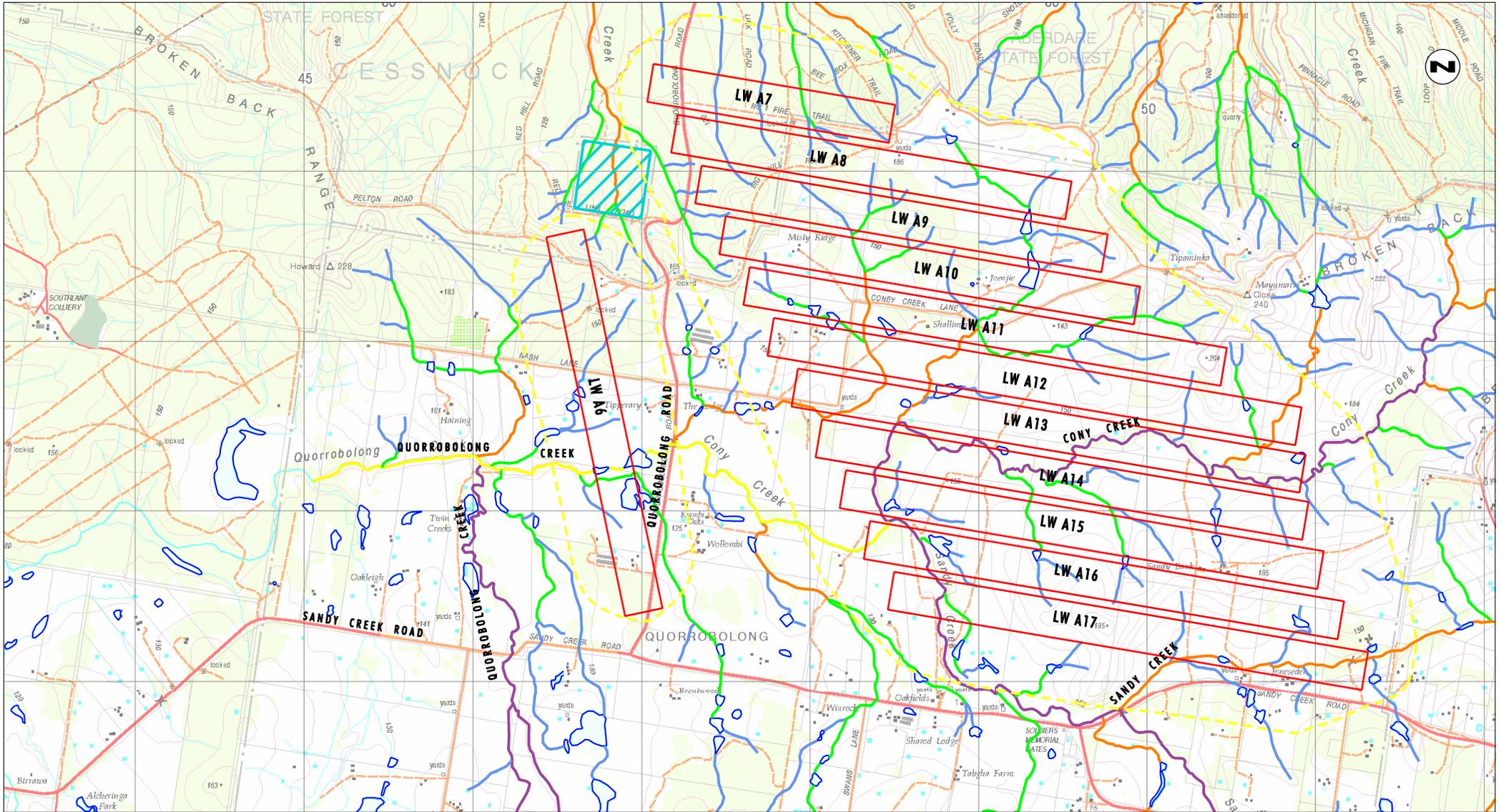
0 0.5 1 1.5km
1:32 000

Legend

- Conceptual Layout for Stage 3 Longwall Panels
- 20mm Subsidence Contour
- Surface Infrastructure Site
- Alluvial Area

FIGURE 2.2

Extent of Alluvium



Source: Topo Maps: LPI NSW, Longwall Layout: Astar Coal Mine

0 0.5 1 1.5 km
1:32 000

Legend

- ▭ Conceptual Layout for Stage 3 Longwall Panels
- ▭ 20mm Subsidence Contour
- ▭ Surface Infrastructure Site
- Stream Order 1
- Stream Order 2
- Stream Order 3
- Stream Order 4
- Stream Order 5

FIGURE 2.3

Drainage Lines

A small section of the northern part of the proposed Stage 3 Mining Area drains northward to the Black Creek system. These drainage lines are made up of first and second order streams.

2.3 Flooding Regime

Site inspection and review of the topographic data indicates that from a hydrodynamic modelling perspective there are three broad areas that experience different flooding regimes in the Quorrobolong Valley.

- Flooding within the narrow channels in the upper catchment. Flooding is confined by the relatively steep sides of the channels. These channels are most appropriately modelled using a one dimensional (1D) hydrodynamic flood model.
- Overland flow flooding, which affects the majority of the floodplain areas. This flow is predominantly two dimensional and is governed by the characteristics of the creek channels and overland flow areas. These areas are most appropriately modelled using a two (2D) dimensional hydrodynamic flood model.
- Backwater flooding due to natural and man-made constrictions (e.g. bridges). Flooding in these areas is defined by the hydraulic capacities of the constrictions and available flood storage zones upstream. These areas are most appropriately modelled using a 2D hydrodynamic model with calibration of the model being checked with reference to a 1D hydrodynamic model.

3.0 Available Data

3.1 Previous Flooding Investigations

Three previous flood studies have been carried out in the region of the Quorrobolong Valley.

The first, *Ellalong Flood Study* (Wayne Perry and Associates Pty Limited, 1993), was prepared for Cessnock City Council (Council). The *Ellalong Flood Study* investigated flooding on a minor tributary of Quorrobolong Creek in the north-west section of Ellalong Village. The domain of this flood study does not overlap the area of flood impact assessment for the Stage 3 Mining Area.

The second study is the *Wollombi Valley Flood Study* (Patterson Britton & Partners Pty Ltd, 2005) also prepared for Council. This study focused on flooding regimes in Wollombi Brook and Congewai Creek. The *Wollombi Valley Flood Study* has been accepted by Council to set development flood levels in the village of Wollombi. The Quorrobolong Valley forms part of the flood model for the *Wollombi Valley Flood Study*. However, the Quorrobolong Valley upstream of Ellalong Lagoon is modelled as a single catchment node in the XP-RAFTS model that was developed for the flood study. As a result this model does not provide sufficient information in regard to flooding in the Quorrobolong Valley to enable the potential impacts of the proposed underground mining within the Stage 3 Mining Area to be assessed. The *Wollombi Valley Flood Study* however does explore regional rainfall loss rates for the Wollombi Valley. These rainfall loss rates have been incorporated into the flood impact assessment for Austar Coal Mine (refer to **Section 5.1**).

The third study is the Stage 2 flood assessment, titled *Flooding Assessment: Longwalls A3, A4 and A5* (Umwelt, 2007). This study assessed the potential flooding impacts of the predicted subsidence due to Austar mining the Stage 2 Mining Area which is downstream of the proposed Stage 3 Mining Area. This study used an RMA-2 two dimensional hydrodynamic flood model to assess the potential changes to flooding as a result of the proposed mining of the Stage 2 Mining Area. As part of the calibration process, the output from the RMA-2 flood model that was developed was checked against flood observation data from a storm event that occurred in February 1990 and June 2007 (refer to **Section 6.3**). The model's sensitivity to rainfall losses and roughness factors were also explored (refer to **Section 6.2**) as part of the model calibration.

3.2 Survey Data

Accurate topographic survey data is required to describe the geometry of the land surface as used in the hydrodynamic model. In the simplest 1D model, a channel and its floodplain are represented by a series of cross sections orientated at right angles to the direction of flow. In more sophisticated 2D hydrodynamic models, such as the RMA-2 model used in this assessment, the geometry of the land surface is represented by a series of triangles or quadrilateral elements that make up a finite element mesh. The accuracy with which the land surface can be represented is governed by the accuracy of the topographic survey and the complexity of the developed finite element mesh.

3.2.1 Aerial Laser Survey

Aerial laser scanning (ALS) topographic survey data of the floodplain and surrounding catchment was collected by AAM Hatch during August 2006. This survey captured approximately 80 million survey points describing the land and channel system of the Quorrobolong Valley. The ALS survey captured a dense swath of points at a spacing of

approximately 0.9 metre intervals across the surface and an average absolute horizontal accuracy of less than 0.55 metres (AAM Hatch, 2006).

Verification of the vertical accuracy of the ALS was also undertaken by AAM Hatch as part of the quality assurance procedures. Levels derived from ALS on areas of open ground were compared with ground based survey. For 182 comparison points the standard deviation of the error was found to be approximately 40 mm (AAM Hatch, 2006). The supplied data was specified to have a vertical accuracy of 0.15 metres or better.

3.3 Meteorological Data

3.3.1 Data available

Rainfall data for the region is available from both the Bureau of Meteorology (BOM) and Austar Coal Mine.

Daily rainfall data is recorded at several BOM stations in the region. Only two of these stations lie within the catchment area of the Quorrobolong Valley (refer to **Figure 3.1**).

There are three BOM stations in the local area that have pluviographic rainfall data that record rainfall in 6 minute intervals. These stations are shown on **Figure 3.1**. None of these stations are located with the Quorrobolong Valley catchment area.

Rainfall data is also recorded at Austar Coal Mine in 10 minute intervals (refer to **Figure 3.1**). The Austar data is available for the period from April 2007 to date and includes data for the June 2007 storm.

3.3.2 Significant Rainfall Events

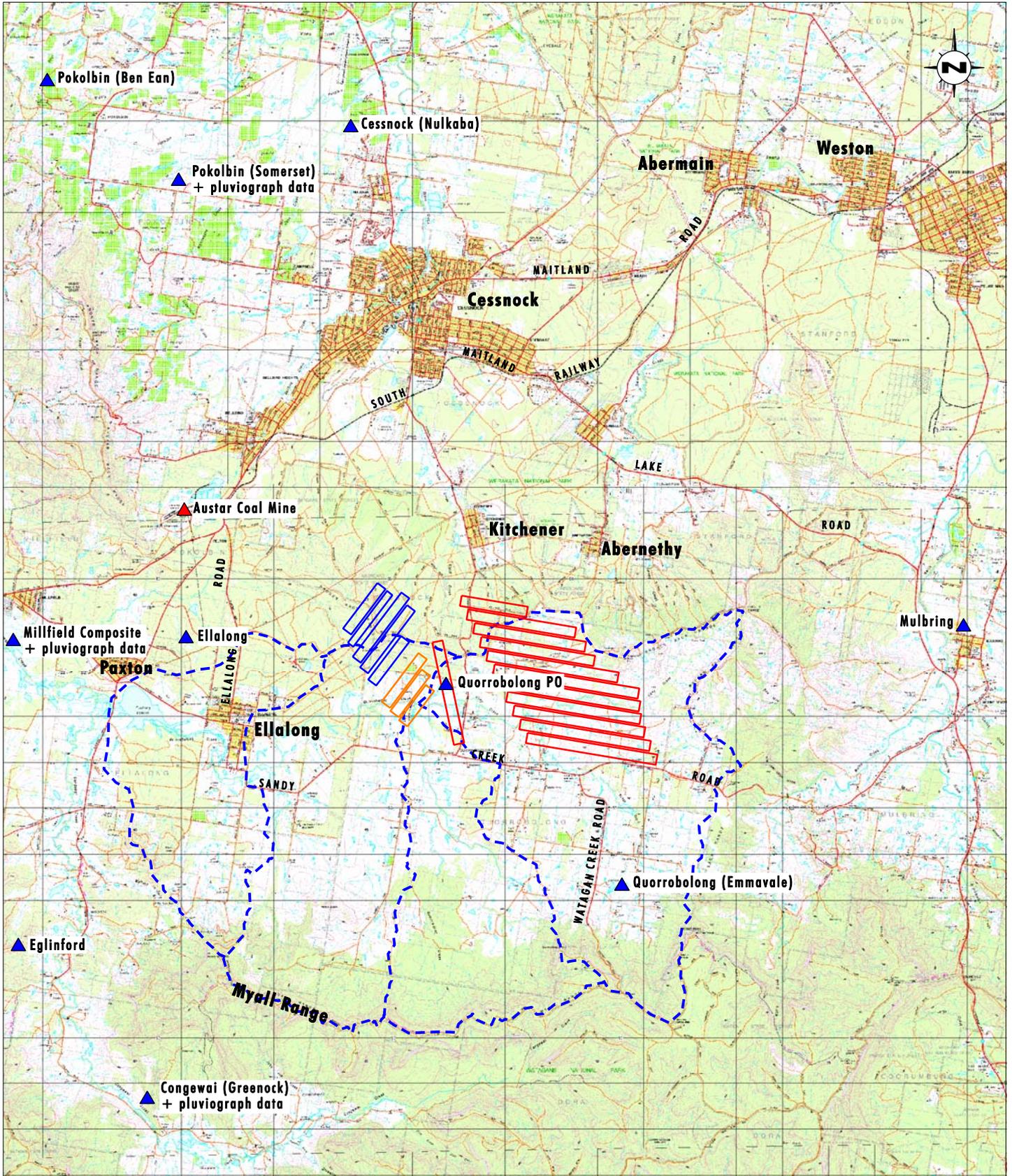
As part of the Stage 2 flood assessment (Umwelt, 2007) historical rainfall data was reviewed and the significant rainfall events analysed. This analysis has been extended as part of this study to include the June 2007 rainfall event.

The analysis of daily rainfall data for the BOM stations shows very little spatial variability in rainfall records between Ellalong, Mulbring, Millfield, Quorrobolong and Congewai. This indicates that the rainfall stations with longer periods of record, i.e. at Congewai and Mulbring have rainfall data that is suitably representative of the Quorrobolong Valley (Umwelt, 2007).

Analysis of historical rainfall data indicates that major storm events have occurred in the region at the following times:

- 16 April 1927 – equivalent to 100 year 24 hour ARI design storm event;
- 18 June 1930 – equivalent to 100 year 48 hour ARI design storm event;
- 18 June 1949 – equivalent to 100 year 24 hour ARI design storm event;
- 3 February 1990 – equivalent to 200 year 48 hour ARI design storm event; and
- 9 June 2007 – equivalent to 115 year 24 hour ARI design storm event, or 60 year 36 hour ARI storm event.

As such there have been five 100 year ARI storm events of varying durations that have occurred in the Quorrobolong Valley region during the last 80 years. A 100 year ARI storm



Source: Topo Maps: LPI NSW, Longwall Layout: Austar Coal Mine

0 1 2.5 5km
1:115 000

Legend

- ▭ Layout for Stage 1 Longwall Panels
- ▭ Layout for Stage 2 Longwall Panels
- ▭ Conceptual Layout for Stage 3 Longwall Panels
- - - Catchment Boundary
- ▲ BOM Rainfall Station
- ▲ Austar Coal Mine Rain Gauge

FIGURE 3.1

Location of Rainfall Stations

event means that for each and every year there is a 1% chance (a 1 in 100 chance) that the event will be equalled or exceeded. It does not mean that this event occurs only once in every 100 years. This analysis is based on intensity frequency duration (IFD) curves for the Quorrobolong Valley generated using data published in *Australian Rainfall & Runoff (AR&R)* (IEAust, 1987).

There have been other large storm events that have occurred within the valley of smaller equivalent average recurrence intervals over the period of record. However, in terms of major storm events (i.e. 100 year ARI or greater) there have been only five recorded major storm events since 1920.

3.4 Streamflow Data

No streamflow data is available for the Quorrobolong Creek/Cony Creek/Sandy Creek catchment areas.

3.5 Flood Level Data

Council has indicated that they hold no flood observation data for the Quorrobolong Valley upstream of Ellalong. Correspondence from Council (Mr John Booth, pers comm. 2007) stated:

"From discussions with Council's Civil Maintenance Manager, inundation of Quorrobolong Road between Baddeley Park and Kitchener has occurred from flooding in Black Creek (1990 and 1992). In addition, Sandy Creek Road would be inundated across the floodplain of Quorrobolong Creek in the vicinity of Forbes Bridge."

Quorrobolong Road between Baddeley Park and Kitchener is not located within the study area.

Council did not indicate when Sandy Creek Road has been inundated previously or provide information on the storm event or storm duration associated with the referenced inundation.

Council (Mr John Booth, pers comm. 2007) also indicated that design work undertaken by Tricad Pty Ltd in May 2001 indicated that the following calculated water levels at Forbes Bridge over Quorrobolong Creek at Sandy Creek Road during a 100 year ARI storm event:

- maximum headwater of 129.94 mAHD; and
- maximum tailwater level of 129.70 mAHD.

Council did not provide details of how these levels were calculated.

As part of the Stage 2 flood assessment (Umwelt, 2007), Umwelt met with two residents in the valley who observed the February 1990 flood event. These residents, Mr John Reid and Mr Bill Jones, provided historical flood level data for four locations for this storm event (refer to **Section 6.3**) in the vicinity of the Stage 2 Mining Area.

After the June 2007 storm event (refer to **Section 3.3.2**) Umwelt gathered flood level information along major roads in the valley and at Ellalong Lagoon. Umwelt also met with Mr Jim Muxlow and Mr John Brown, long-term residents of the valley, who provided flood level information for the storm event (refer to **Section 6.3**) in the vicinity of Quorrobolong Road.

4.0 Design Flood Estimation

As part of the Stage 2 flood assessment (Umwelt, 2007) design flood flows for Sandy Creek, Cony Creek and Quorrobolong Creek were estimated by two methods:

- probabilistic rational method (refer to **Section 4.1**); and
- regional flood frequency analysis (refer to **Section 4.2**).

The estimates derived by these methods were then compared to the design storm estimates from the Stage 2 flood assessment.

The findings of this analysis and a comparison against the *Wollombi Valley Flood Study* (Patterson Britton & Partners Pty Ltd, 2005) are presented in **Sections 4.1** to **4.4**. The 100 year ARI design flow estimates were subsequently compared the XP-Storm and RMA-2 model results (refer to **Section 6**).

4.1 Probabilistic Rational Method

The Probabilistic Rational Method (PRM) for peak flood estimation in eastern NSW is outlined in *AR&R* (IEAust, 1987). This peak flood estimation method was applied to the Quorrobolong Creek catchment downstream of the confluence with Cony Creek and at the bridge upstream of Ellalong. The results of the analysis are shown in **Table 4.1**.

Table 4.1 - Peak Flow Estimates – Probabilistic Rational Method – 100 year ARI Storm Event

Location	Area (km ²)	Time of Concentration T _c (hours)	Coefficient of Runoff C ₁₀	FF ₁₀₀	Design Discharge (m ³ /s)
Quorrobolong Creek downstream of confluence with Cony Creek	53	3.4	0.33	1.98	288
Quorrobolong Creek at Ellalong Bridge	78	4.0	0.33	1.98	362

4.2 Regional Flood Frequency Analysis

As part of the flood study for an adjacent valley, Hughes Trueman (*Flood Study: Mandalong Coal Mine*, 2004) carried out a regional flood frequency analysis for small catchments (i.e. up to 350 km²) located within the Central Coast and Lower Hunter regions. The regional flood frequency analysis was carried out using the Index Flood Method, as outlined in *AR&R* (IEAust, 1987).

The derived average, maximum and minimum design discharges for the Quorrobolong Creek catchment downstream of the confluence with Cony Creek and at the bridge upstream of Ellalong were derived using data from this analysis and are shown in **Table 4.2**.

Table 4.2 - Regional Flood Frequency Results – 100 year ARI Storm Event

Location	Design Discharge (m ³ /s) 100 year ARI Storm Event		
	Min	Avg	Max
Quorrobolong Creek downstream of confluence with Cony Creek	126	189	378
Quorrobolong Creek at Ellalong Bridge	156	468	819

4.3 Wollombi Valley Flood Study

In this study (Patterson Britton & Partners Pty Ltd, 2005) the Quorrobolong Valley upstream of Ellalong Lagoon is modelled as a single catchment node in XP-RAFTS (Node 10.01). The modelled peak discharges for the 100 year ARI storm event provided in the report are listed in **Table 4.3**.

Table 4.3 – Wollombi Valley Flood Study – 100 year ARI Storm Event Results

Storm Duration (mins)	Discharge (m ³ /s)
720	345
2160	332

Source: Patterson Britton & Partners Pty Ltd, 2005

4.4 Comparison of 100 year ARI Design Discharge Estimates

The regional methods and *Wollombi Valley Flood Study* (Patterson Britton & Partners Pty Ltd, 2005) give a wide range of estimates for the 100 year ARI storm event design discharge. The values are dependant on the different methods, and the parameters and inputs used. In order to better understand the implications of the range of estimated 100 year ARI storm event design discharges for the valley, sensitivity analysis was carried out for the 1D hydrodynamic model and the 2D hydrodynamic model (refer to **Section 6.2**).

5.0 Modelling Methodology

5.1 One Dimensional Hydrodynamic Model

As part of the Stage 2 flood assessment (Umwelt, 2007) a 1D hydrodynamic model of the catchment area was developed using XP-Storm. This model included the catchment above the proposed Stage 3 mining area. The XP-Storm model was developed in order to:

- gain an preliminary understanding of the flood behaviour of the valley;
- determine the inflows into a 2D hydrodynamic model;
- investigate and determine the outlet boundary conditions for the 2D hydrodynamic model; and
- estimate flood elevations to allow initial sizing of 2D RMA-2 network.

XP-Storm version 9.1, is a 1D hydrodynamic model which can be used to model stormwater flows in watercourses, culverts and street drainage systems. XP-Storm is suitable to calculate overland runoff generated from large natural or developed catchments and is capable of predicting flood levels as a result of backwater effects. Consequently XP-Storm is a suitable model to gain an initial understanding of the flood behaviour in the valley and in particular in the proposed mining areas, and to determine the boundary inflow and outflow conditions for the 2D hydrodynamic model.

5.1.1 Model Setup

The XP-Storm model developed for the Stage 2 flood assessment (Umwelt, 2007) was used to estimate inflow and outflow boundary condition for the Stage 3 flood model is detailed below. Additional detail was included in the model to accommodate for the inflow locations that would be used in the Stage 3 Mining Area RMA-2 model.

XP-Storm models a watercourse as a series of nodes along a channel, connected by drainage links. Nodes are the locations at which sub-catchment information may be entered into the model, including sub-catchment area, slope and percentage impervious area. Drainage links are characterised by a channel length, slope, cross section, maximum water depth, upstream and downstream channel inverts, and Mannings 'n'. The XP-Storm model layout used in the Stage 3 flood assessment is shown in **Figure 5.1**.

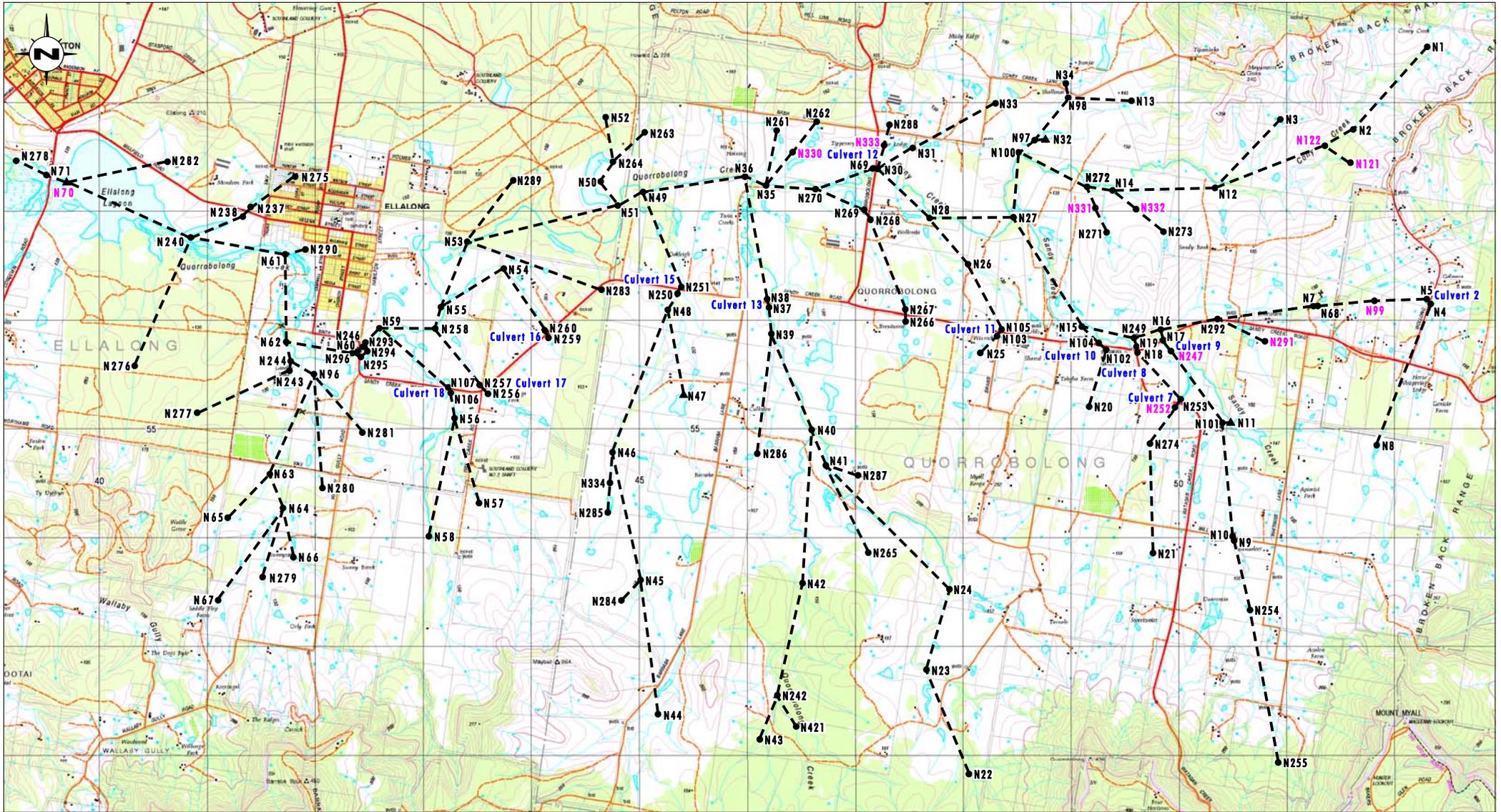
The critical parameters used in the XP-Storm analyses were:

- Laurenson Equation $S = BQ^{n+1}$

Where: S = volume of storage (m³)
 B = Storage Delay Parameter
 Q = instantaneous rate of runoff (m³/s)
 n = -0.285

- Initial and Continuing Rainfall Loss Rates

Where: Initial Loss Rate of 20 mm/hr
 Continuing Loss Rate of 2.5 mm/hr



Base Source: Topo Maps: LPI NSW

0 1 2 2.5 km
1:50 000

Legend

- XP-Storm Node
- XP-Storm Link
- XP-Storm Storage Node

FIGURE 5.1

XP-Storm Model Layout

The initial and continuing loss rates are sourced from the *Wollombi Valley Flood Study* (Patterson Britton & Partners Pty Ltd, 2005) and are consistent with values recommended by AR&R (IEAust, 1987).

The values of Mannings 'n' adopted are based on information gathered during site inspections for each of the catchment elements and from aerial photographs. The values used for Mannings 'n' to represent the different catchment elements are listed in **Table 5.1**.

Table 5.1 - Mannings 'n' values for Different Catchment Elements

Element	Mannings 'n'
Natural Channel Sections	0.060
Pervious Catchment Areas	0.35*
Impervious Catchment Areas	0.014*

Note: * denotes Mannings 'n' for overland flow

There are numerous culverts and two major bridges within the Quorrobolong Valley. Data was collected regarding the size, configuration and locations of these structures during a field inspection conducted by Umwelt in October 2006.

5.1.2 Design Flows

Design flow aspects of the 1D hydrodynamic model were determined as part of the Stage 2 flood assessment (Umwelt, 2007). These aspects are discussed below.

5.1.2.1 Design Rainfall Intensities and Temporal Patterns

Design rainfall data and temporal patterns were derived for the catchment area using the principles set out in Chapter 2 of AR&R (IEAust, 1987). These design rainfall intensities were translated into absolute rainfall depths for each ARI and storm duration for input into XP-Storm.

5.1.2.2 Areal Reduction Factors

Rainfall intensities derived using the processes outlined AR&R (IEAust, 1987) are only suitable to be used for areas up to 4 km². For larger areas an areal reduction factor may be used to take into account changes in rainfall intensity over larger areas.

Values for areal reduction factors (ARF) are presented in Figure 2.6 of AR&R (IEAust, 1987). The information presented is based on data from the United States of America and covers storm durations up to a maximum of 24 hours and catchment areas up to a maximum of 1000 km². The ARF are recommended by AR&R (IEAust, 1987) to be used for recurrence intervals up to 100 years.

Interpolation of Figure 2.6 (IEAust, 1987) presented in **Table 5.2** provides factors for up to a 24 hour storm event in a 78 km² catchment area.

Table 5.2 - Areal Reduction Factors (ARF) for 78 km² Catchment

Storm Duration (h)	ARF
3	0.957
6	0.966
12	0.978
24	0.980
36	*

* AR&R does not provide an estimate of ARF for storm events above 24 hours as the pluviographic data available at the time of publishing did not provide sufficient information (IEAust, 1987).

It can be seen from **Table 5.2** that due to the small catchment size relative to 1000 km² the ARF would provide a negligible reduction in the point rainfall values and hence have not been used for this assessment.

5.1.3 Model Results

As a result of the review of the Stage 2 flood assessment XP-Storm model and comparison of flow rates from other flow estimation methods (refer to **Section 4**) (Umwelt, 2007) it was considered that the peak flows predicted by the XP-Storm model developed are potentially underestimated. This is due to the nature of a 1D model and the complexity of the floodplain regions. The 1D model is suited to model flows in constrained creek systems, such as the upper reaches of the Quorrobolong Valley. However, when the creeks spill over the banks or overland flows occur such as across a floodplain, 2D flow results. A 1D model is not easily able to model these characteristics. This is considered to be the case in the middle and lower reaches of the Quorrobolong Valley. Comparison of the 1D model results with detailed digital terrain information indicates that the 1D model is assuming that significant portions of the floodplain and overbank areas are filled earlier within the modelled storm events compared to what occurs within the valley. As such the 1D model is overestimating the flood storage and detention of the valley, resulting in modelled peak discharges being lower than those expected.

In order to utilise the XP-Storm model to determine flood extents and flows a significant number of additional cross sections would need to be inserted into the model. It is considered that this is impractical. As such the 1D model has been used as a tool to:

- explore the critical storm duration for the valley;
- determine the inflows to the boundary of the RMA-2 model (refer to **Section 5.1.4**); and
- derive a relationship for the downstream boundary condition of the RMA-2 model (refer to **Section 5.1.4**).

5.1.4 Input to RMA-2 Model

5.1.4.1 Inflow Hydrographs

The XP-Storm model was used to determine the inflow hydrographs at 32 nodes positioned on the boundary of the RMA-2 model.

Sensitivity Analysis

During the Stage 2 flood assessment (Umwelt, 2007) the sensitivity of the inflow hydrographs generated by XP-Storm to changes in initial rainfall loss rate were examined. Initial rainfall loss rates of 10 mm and 35 mm were modelled and the total inflow hydrograph to the RMA-2 model compared to that with an initial rainfall loss of 20 mm sourced from the *Wollombi Valley Flood Study* (Patterson Britton & Partners Pty Ltd, 2005).

This analysis indicated that a change in the initial rainfall loss rate will have minimal effect on the inflow hydrographs used in RMA-2 model after the initial steady state flow period.

5.1.4.2 Downstream Boundary Condition

In flood modelling the nature of the downstream boundary of the flood model is very important to ensure that flood flows are not impacted upon by the location or definition of this boundary. In the Quorrobolong Valley in the vicinity of the proposed mining area there are two natural constrictions. One constriction is located immediately downstream of the Stage 2 Mining Area and the other over the chain pillar between Longwalls A4 and A5 of the Stage 2 Mining Area immediately downstream of the junction of Cony Creek and Quorrobolong Creek. These constrictions are considered to be the major controls to the flow regimes through the Stage 2 and Stage 3 Mining Areas. In addition, Ellalong Bridge, approximately 3 kilometres downstream of the mining areas also forms a flow constriction. At the bridge the flows are initially constricted by the bridge alone, however there is also a high level secondary flow path to the south of the bridge at a low point in Sandy Creek Road.

The Ellalong Bridge was chosen during the Stage 2 flood assessment (Umwelt, 2007) as the RMA-2 model boundary as it is a considerable distance from the assessment area and provides a well defined location to determine a stage discharge relationship for use as a boundary condition. To be conservative it was assumed that Ellalong Lagoon was full at the commencement of the modelling period.

Debris levels observed around Ellalong Lagoon after the June 2007 storm event indicate that the water levels in the lagoon reached approximately 3 metres above the normal water level during the storm event (refer to **Section 3.5**). Modelling indicates that this water level may be reached during a 100 year ARI 36 hour storm event if the culverts at Ellalong Lagoon are blocked or backwater levels in the creek downstream are sufficiently high as to restrict flows through the culvert (i.e. water is backed up from Wollombi Brook) or if a combination of these events occur.

Modelling of the 100 year ARI 36 hour (i.e. critical duration) storm event with a water depth in Ellalong Lagoon of 3 metres indicates that this level has the potential to increase flood levels by up to 300 mm at Ellalong Bridge from a flood depth of approximately 3.8 metres to 4.1 metres. The influence of this modelled increase in flood level becomes negligible approximately 1950 metres upstream of Ellalong Bridge (i.e. approximately 7500 metres upstream of Ellalong Lagoon). This location (which is the upstream limit of the extent of backwater effects from Ellalong Lagoon) is located approximately 2740 metres downstream of the Stage 2 Mining Area. The modelling results indicate that the flooding in the Stage 2 and Stage 3 Mining Areas is not influenced by the water level in Ellalong Lagoon.

The analysis described above indicates that although the stage discharge relationship (i.e. flow rate to water elevation) at Ellalong Bridge is influenced by water levels in Ellalong Lagoon, the upstream reaches of Quorrobolong Creek in the Stage 2 and Stage 3 Mining Areas are not. As such the stage discharge relationship for the combined bridge and road flows at Ellalong Bridge without backwater controlled flood levels in Ellalong Lagoon that was developed for the Stage 2 flood assessment (Umwelt, 2007) was used in this assessment to provide consistency between results for Stage 2 and Stage 3.

5.2 Two Dimensional Hydrodynamic Model

An RMA-2 two dimensional (2D) hydrodynamic model was developed for the Stage 2 flood assessment (Umwelt, 2007). As part of the Stage 3 flood assessment, finite element used for the Stage 2 RMA-2 model was extended to the east to include the floodplain regions proposed to be undermined by the Stage 3 Mining Area.

5.2.1 Topographic Data

5.2.1.1 Derivation of RMA-2 Network

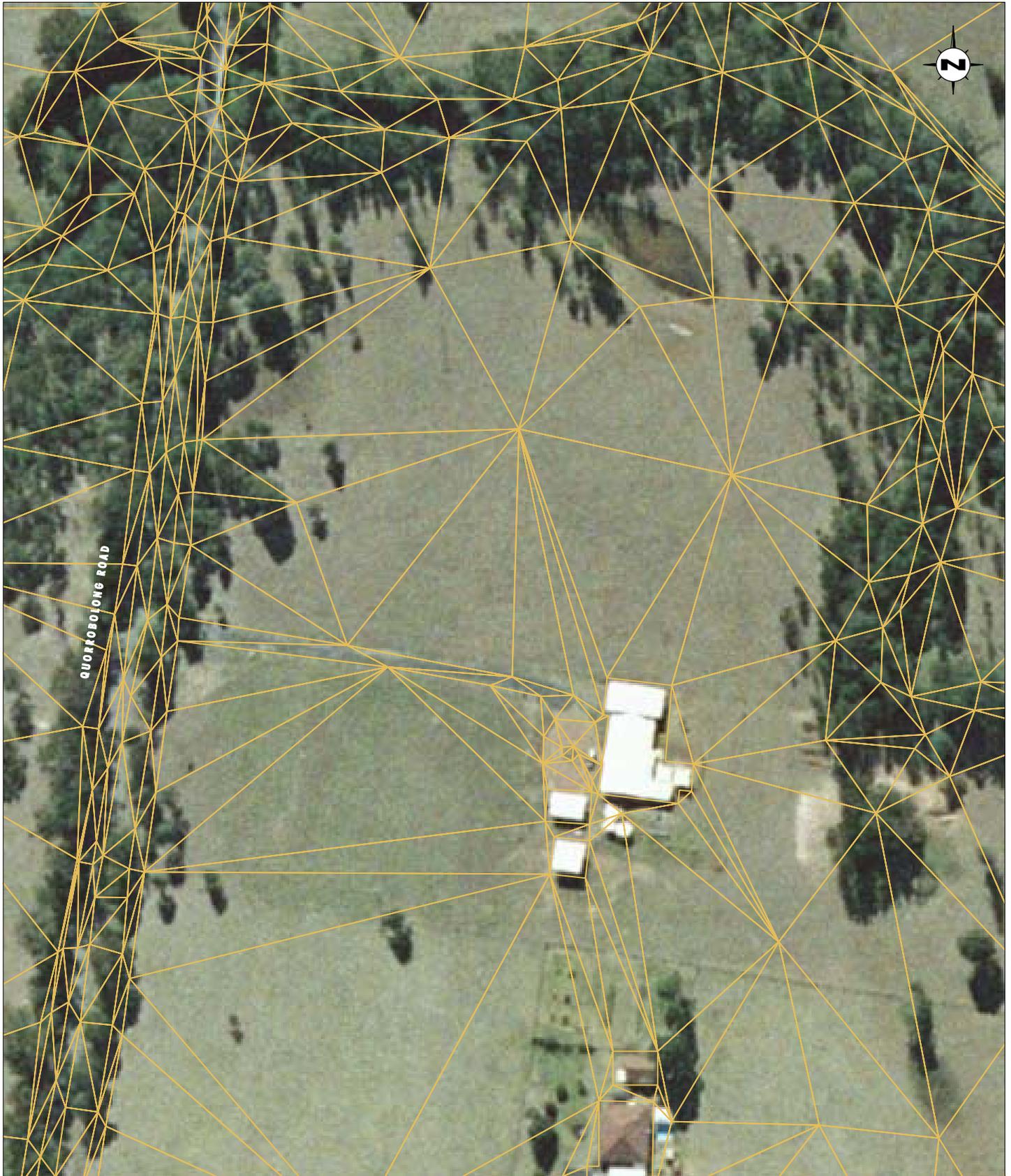
The RMA-2 two-dimensional hydrodynamic model uses a finite element mesh to represent the land surface as a series of triangular and quadrilateral shaped planes of variable size. Aerial laser scanning (ALS) survey was undertaken for the entire domain of the 2D model. This survey provided a 'cloud' of spot levels at an average 0.9 metre spacing. The availability of this high resolution data allows the RMA-2 network to incorporate additional detail into the definition of the landform including specific features such as houses, access tracks, creeks, etc.

The initial digital terrain model created using the ALS data was simplified to create a triangulated mesh of the data. As RMA-2 has a practical upper limit of approximately 50,000 elements, which equates to a numerical computation period of approximately 48 hours, the triangulated terrain model was simplified using a program called QSLIM (Garland & Heckbert, 1995). QSLIM uses an algorithm whereby survey points are removed one by one, based on the introduction of 'least error' or least change into the model, until the specified model size is achieved.

Analysis was undertaken to verify that the simplified landform was representative of the existing topography, with particular attention paid to hydraulically significant features and controls such as creek channels, drains and roads.

Detailed topographical features, including creek channels, houses, access tracks and roads were identified based on 100 mm contours derived from the ALS survey data. These features were represented as breaklines in the RMA-2 model topographic data. The creation of these breaklines has been used to force the finite element mesh model used to define a series of elements that have one side running along the breakline. This process ensures that the level along that feature or control (e.g. along the top of the creek bank) is defined in the model. Insertion of breaklines into the mesh is important when defining features such as roads that act as a barrier to flow. Additional detailed information was then defined for areas such as creeklines, swamps and culverts (refer to **Section 5.2.2**) and all this information was then incorporated into the RMA-2 network. An example of the network created around a house, access road and road is shown in **Figure 5.2**.

Element structures suitable to control inflows and outflows from the model also need to be defined during the development of the RMA-2 network. These structures were defined at



Source: Aerial Photography: AAM Hatch 2006

0 25 50 75 m
1:1500

Legend

 RMA-2 Network

FIGURE 5.2

Example of RMA-2 Network Detail

each of the 32 inflow points and at the outlet of the model. The structures are only created to assist in the mathematical computations of the model. As such any model results in these areas should be not relied on. For example, any indicated model results downstream of Ellalong Bridge do not represent the true flood behaviour at this location.

After setting up the landform features and controls in this way, the 2D RMA-2 hydrodynamic model was then run to determine an improved approximation of the flood extent during the 100 year ARI storm event. This initial flood extent was used to identify elements that would not be required in the RMA-2 network, thereby allowing a further reduction in the number of elements required to simulate flood events in the Quorrobolong Valley. Additionally, the elements where dwellings are located were removed, thus forming a 'no-flow' barrier within the network.

The RMA-2 network used for the Stage 3 flood and drainage assessment uses approximately 36,000 elements and 20,000 nodes to define the landform, hydraulic structures and inflow points of the Quorrobolong Valley floodplain (refer to **Figure 5.3**).

5.2.2 Model Setup

5.2.2.1 Channel Definition

The channels were defined using high resolution ALS survey data and the processes outlined in **Section 5.2.1**. ALS survey has the capacity to determine ground levels between trees and shrubs and hence provides greater channel in areas of dense vegetation that can be achieved using aerial photogrammetry.

5.2.2.2 Hydraulic Structures

Significant hydraulic structures that occur in the 2D model domain include roads, access tracks, culverts and bridges. These structures have been incorporated into the RMA-2 network as features defined by the surface levels extracted from the ALS survey data and sizing defined by field inspections (refer to **Section 5.2.1**).

5.2.2.3 Downstream Boundary Conditions

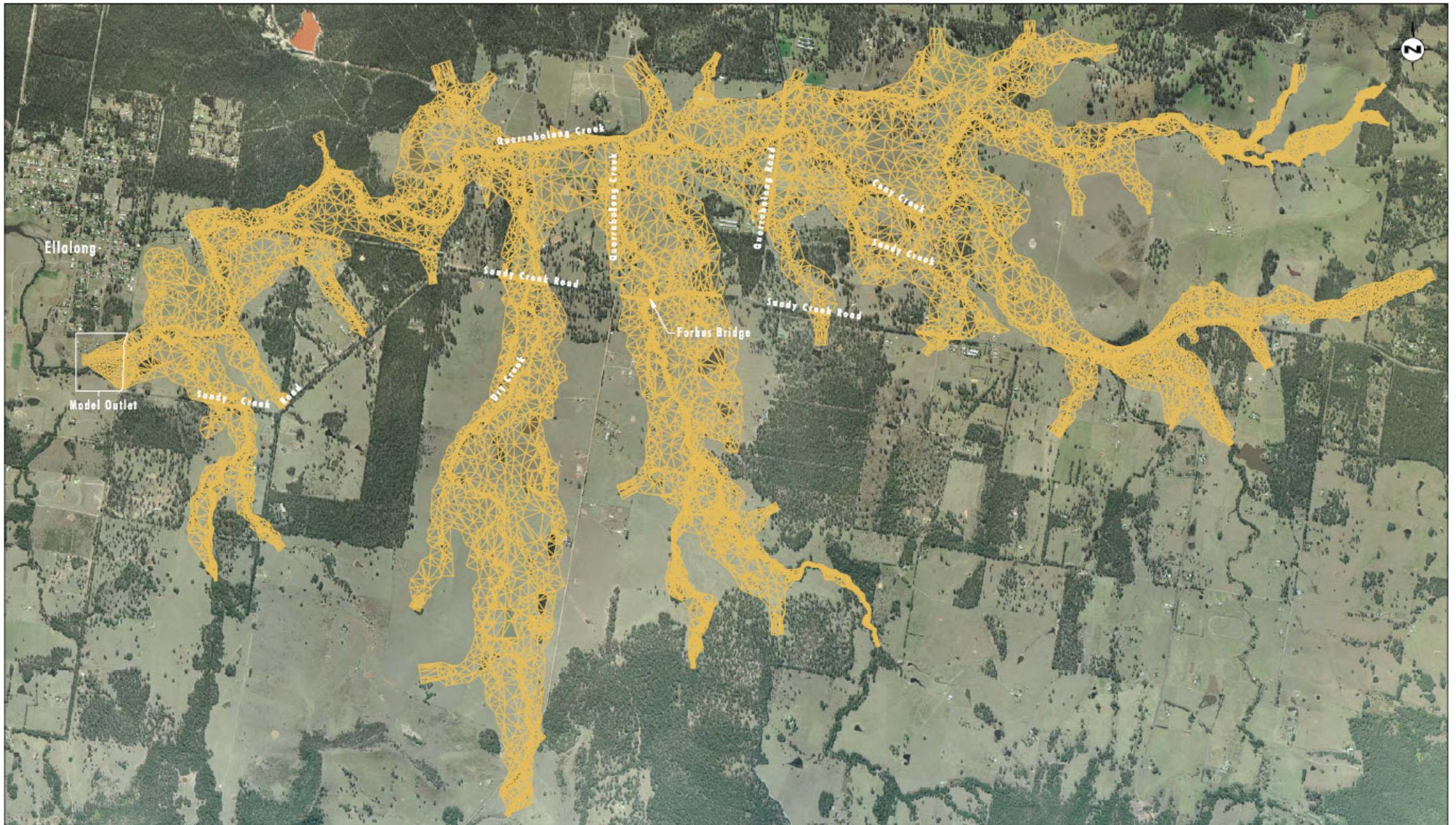
The downstream boundary of the RMA-2 model has been defined by a flow rating curve at downstream edge of the Ellalong Bridge. The rating curve at this location was established using the XP-Storm model (refer to **Section 5.1.4**). This rating curve was applied to the element outflow structure defined in the RMA-2 network (refer to **Section 5.2.1**).

5.2.2.4 Hydrograph Inputs

Hydrograph inputs at 32 sub-catchment inflow points were extracted from the XP-Storm model as discussed in **Section 5.1.4**. For purposes of sensitivity analysis, the XP-Storm model was run with a range of initial and continuing rainfall losses. Details of this analysis are set out in **Section 6.2**.

5.2.2.5 Hydraulic Roughness

The hydraulic roughness values used in the RMA-2 model have been determined from field inspection, aerial photography and representative values quoted in *AR&R* (IEAust, 1987).



Base Source: Aerial Photography: AAM Hatch 2006

0 400 800 1200m
1:27 000

Legend

 RMA-2 Network

FIGURE 5.3
RMA-2 Network

5.2.2.6 Influence of Marsh Elements

The RMA-2 model uses the concept of 'marsh elements' to assist in achieving a numerical solution in areas of the finite element mesh where wetting and drying occurs during the flood event. The 'marsh element' method treats the flow as an integration of both surface flow and shallow sub-surface flow. When the water surface elevation drops below the ground surface, rather than an element being turned off, which may cause numerical instability and poor convergence of the numerical solution, the flow is presumed to occur in a low-porosity shallow sub-surface flow zone. To implement the 'marsh element' solution, the porosity in the sub-surface zone is gradually varied over a transitional zone from the surface to sub-surface. The depth of the sub-surface zone is set to be just below the anticipated lowest water level of the flood model across the solution front. This required range, referred to as the bottom elevation shift or 'slot depth' is set to be the maximum difference between the highest ground surface elevation and lowest water surface elevation across the solution front of the model.

The following values have been used to describe the marsh elements for the 100 year ARI storm event:

- bottom elevation shift (slot depth) = 8.0 metres;
- depth range over which porosity reduces (transition range) = 0.25 metres; and
- effective porosity in the sub-surface zone (κ) = 0.005.

5.2.2.7 Initial Flow Conditions

Before it can accept inflow hydrographs, the RMA-2 model requires that steady state flow conditions be established throughout the model domain. It was found that inflows from the sub-catchments totalling approximately 50 m³/s were required to establish a stable numerical solution for flow and water levels that could be used as a starting point for analysing the effect of storm event inflows. As such the initial rainfall loss for all elements within the RMA-2 model is assumed to have occurred prior to the start of the modelling period.

5.2.2.8 Element Inflows

To account for rainfall on the surface of the floodplain, the RMA-2 model allows 'inflow' to each element in addition to the horizontal flow through the side boundaries. As noted above, the RMA-2 model developed for Quorrobolong Valley requires starting steady state flow conditions totalling approximately 50 m³/s in this instance. These conditions represent a situation in which the channels are almost full and the floodplain saturated. Accordingly, it is assumed that any rainfall onto the surface of the hydrodynamic model will contribute directly to the flow. In the RMA-2 model these conditions are represented by assuming zero initial and continuing rainfall loss within the boundary of the RMA-2 network. The rainfall inputs to the surface of the model use the same rainfall hyetograph as used for the XP-Storm model.