APPENDIX 5

Flood Impact Assessment: LW31-37

Tahmoor Coal

Flood Impact Assessment: LW31-37

Tahmoor Coal Pty Ltd

1072-02-B, 3 December 2014

Report Title	Tahmoor Coal Flood Impact Assessment: LW31-37
Client	Tahmoor Coal Pty Ltd
Report Number	1072-02-B

Revision Number	Report Date	Report Author	Reviewer
0	3 December 2014	AT/DS	DN

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1 Introduction

1.1 PROJECT OVERVIEW

Tahmoor Coal operates an underground coal mine located near the townships of Tahmoor and Picton in the Southern Highlands of New South Wales (NSW). Continuation of mining operations requires the development of Longwall Panels 31 to 37 (shown in Figure 1.1) which will result in the subsidence beneath Stonequarry, Cedar, Matthews and Redbank Creeks. The potential impacts of developing the longwall panels will be managed through various management plans, including a subsidence management plan.

1.2 PROJECT SCOPE

To assist in the development of the subsidence management plan, WRM Water & Environment Pty Ltd (WRM) was commissioned by Tahmoor Coal Pty Ltd (TC) to assess the impacts on existing flood levels caused by the subsidence associated with the mining of longwall panels 31 to 37 (LW31 to LW37). Detailed hydrologic and hydraulic modelling has been undertaken to quantify these impacts.

The flood impact assessment methodology was based on the development of a runoff routing model (XP-RAFTS) to estimate design flood discharges and a two-dimensional hydraulic model (TUFLOW) to estimate design flood levels, extents, depths and velocities for existing and post-subsidence conditions.

1.3 REPORT STRUCTURE

This report details the methodology and results of the flood impact assessment. The report is structured as follows:

- Section 2 describes the background information and drainage characteristics of the catchments in the vicinity of LW31 to LW37.
- Section 3 describes the development and verification of the hydrologic model and the estimation of design flood discharges.
- Section 4 describes the development of the hydraulic model used in the study and the estimation of design flood extents, depths and velocities.
- Section 5 presents the hydraulic model results for existing and post-subsidence conditions.
- Section 6 presents a summary of findings.

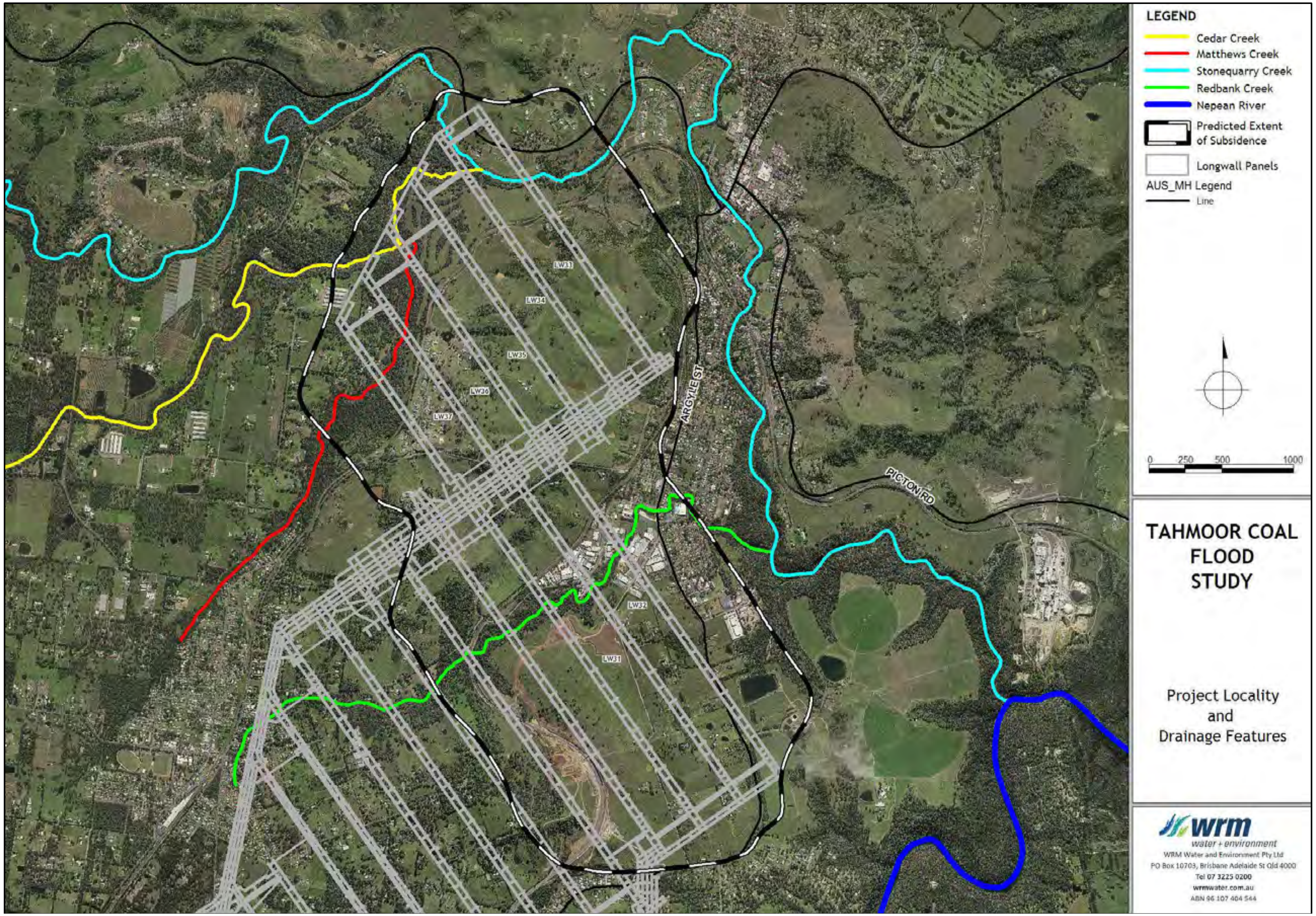

Figure 1.1 – Tahmoor Coal, Project Locality and Drainage Features

2 Background Information

2.1 DRAINAGE CHARACTERISTICS

The Project area is located between the towns of Tahmoor and Picton, approximately 66 km south-west of Sydney. Stonequarry Creek, Cedar Creek, Matthews Creek and Redbank Creek, which all traverse the Project area, are tributaries of the Nepean River. For the purposes of this investigation, the Project area has been divided into two catchment areas, referred to as the Matthews Creek catchment and Redbank Creek.

2.1.1 Matthews Creek catchment

The Matthews Creek catchment includes the Cedar Creek, Matthews Creek and Stonequarry Creek catchments. Stonequarry Creek flows roughly west to east before turning south and flowing through the town of Picton to join the Nepean River. Cedar and Matthews Creeks also flow west to east before joining Stonequarry Creek approximately 1.5 km north-west of Picton.

The Matthews Creek total catchment, which has an area of approximately 43 km^2, originates approximately 8.9 km south-west of the junction of the three creeks. The catchment is largely undeveloped or agricultural land, although it does include a small portion of the township of Thirlmere to the south (see Figure 2.1).

2.1.2 Redbank Creek catchment

Redbank Creek flows roughly west to east through the township of Thirlmere before joining Stonequarry Creek just south of Picton, approximately 2.5 km upstream of the junction with the Nepean River.

The Redbank Creek total catchment covers an area of approximately 8 km^2 and incorporates areas of both Thirlmere and Picton townships. The remainder of the catchment is undeveloped or agricultural land as shown in Figure 2.1.

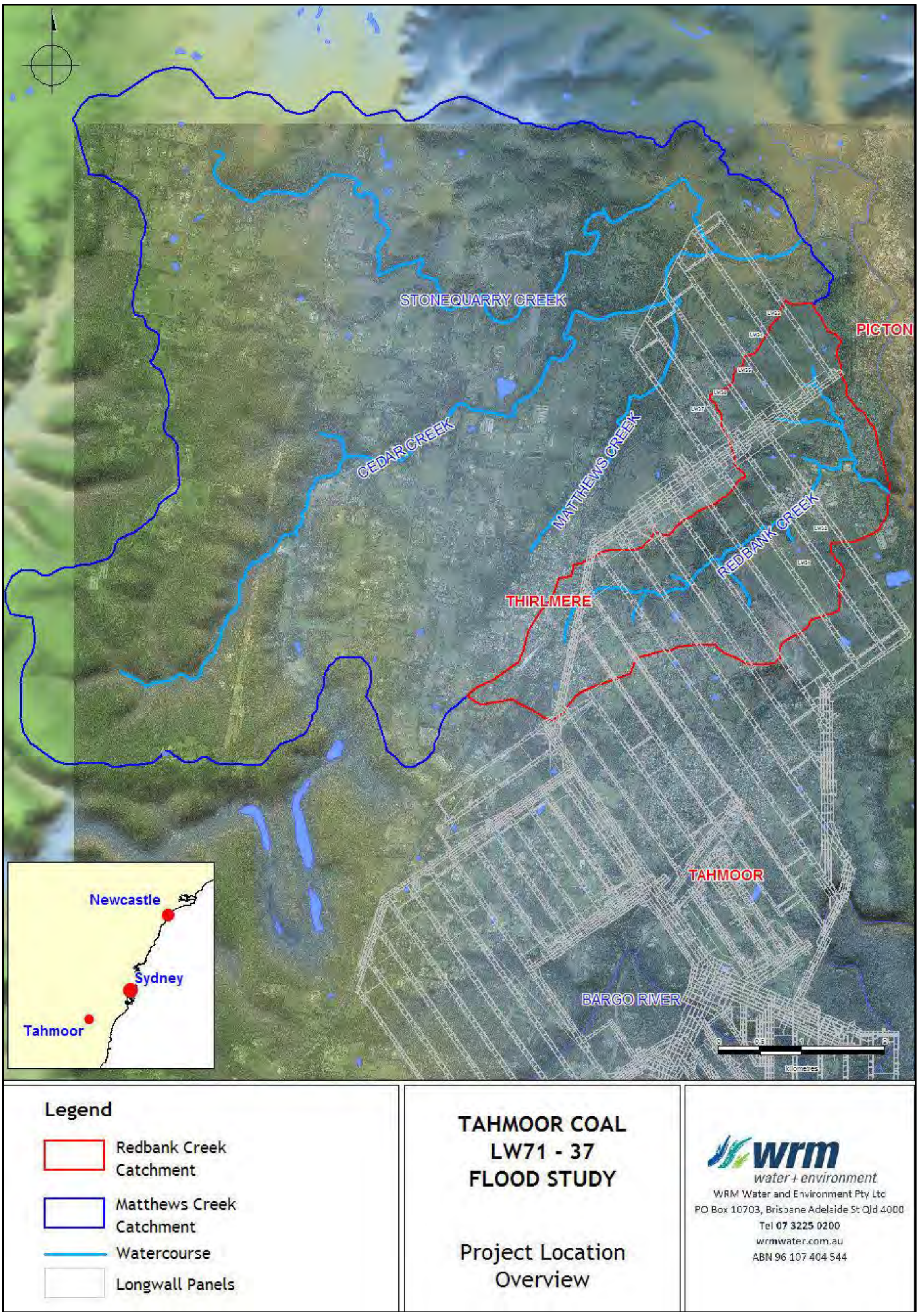

Figure 2.1 – Project area overview

2.2 TOPOGRAPHIC DATA

Topographic aerial survey data for the study area was provided by Mine Subsidence Engineering Consultants (MSEC). The aerial laser scanning (ALS) data, which was obtained from a fixed wing aircraft in June 2013, was supplied as a digital elevation model (DEM) with a grid size of 2.0 m. Predicted subsidence levels were also supplied for LW22 – LW30 and LW31 – LW37. The ground elevation data utilised for the existing (pre-LW31 – LW37 subsidence) incorporates existing subsidence from LW22 – LW30. It should be noted that LW32A has been excluded from this assessment.

2.3 PREVIOUS STUDIES

Two flood investigations have been recently undertaken in the vicinity of the project area:

- *Myrtle and Redbank Creeks Flood Study,* undertaken by Hughes Trueman Pty Ltd for Xtrata Coal Tahmoor, 2009; and
- *Stonequarry Creek: 2D Modelling and Climate Change Assessment,* undertaken by WorleyParsons for Wollondilly Shire Council, 2011.

The Hughes Trueman report includes an analysis of Redbank Creek using a steady-state one-dimensional HEC-RAS hydraulic model. The hydrology was based on a Rational Method calculation for the catchment.

The WorleyParsons report encompasses the Picton region with the hydraulic model boundary commencing downstream of the area of interest for this investigation.

Relevant information from the Hughes Trueman and the WorleyParsons studies was compared to the results of this investigation.

3 Hydrologic model development

3.1 OVERVIEW

Flood discharges within the Matthews Creek and Redbank Creek catchments were estimated using the XP-RAFTS runoff-routing software package (XP Software, 2013). The Matthews Creek and Redbank Creek catchment boundaries and the XP-RAFTS model subcatchments are shown in Figure 3.1 and Figure 3.2, respectively.

3.2 MODEL PARAMETERS

The Matthews Creek and Redbank Creek XP-RAFTS subcatchment boundaries were delineated using the available topographic data. Catchment development conditions and land use allocations were based on aerial photographs. The models were configured based on the following assumptions:

- Catchment slopes were determined from supplied topographic data;
- An impervious fraction of 40% and 10% was adopted for developed and undeveloped land use, respectively. Where subcatchments contained both land uses types, a value was determined based on the proportion of each land use within the subcatchment;
- PERN 'n' values of 0.04 and 0.08 were adopted for developed and undeveloped land use, respectively. Where subcatchments contained both land uses types, a value was determined based on the proportion of each land use within the subcatchment;
- Initial and continuing losses (IL & CL) were determined for each subcatchment based on the relationship with fraction impervious shown in Table 3.1;
- An areal reduction factor of 1.0 was adopted for all events; and
- A global 'Bx' factor of 1.0 and 1.2 was adopted for the Matthews Creek and Redbank Creek models, respectively.

Table 3.1 - Initial and continuing losses

Fraction Impervious (%)	Initial Loss (mm)	Continuing Loss (mm/h)
15	15.0	2.5
15 to 35	11.25	1.88
35	7.5	1.25

3.2.1 Subcatchments

The arrangement of subcatchments within the Matthews Creek and Redbank Creek catchments is shown in Figure 3.1 and Figure 3.2 respectively. Full details of adopted subcatchments parameters are provided in Appendix A.

3.2.2 Routing links

The arrangement of routing links within the Matthews Creek and Redbank Creek catchments is shown in Figure 3.1 and Figure 3.2 respectively. A channel routing 'X' factor of 0.25 was adopted for all routing links in both models. Channel routing 'K' values were calculated based on link length and assuming an average flow velocity of 1.5m/s. Full details of adopted routing link parameters are provided in Appendix A.

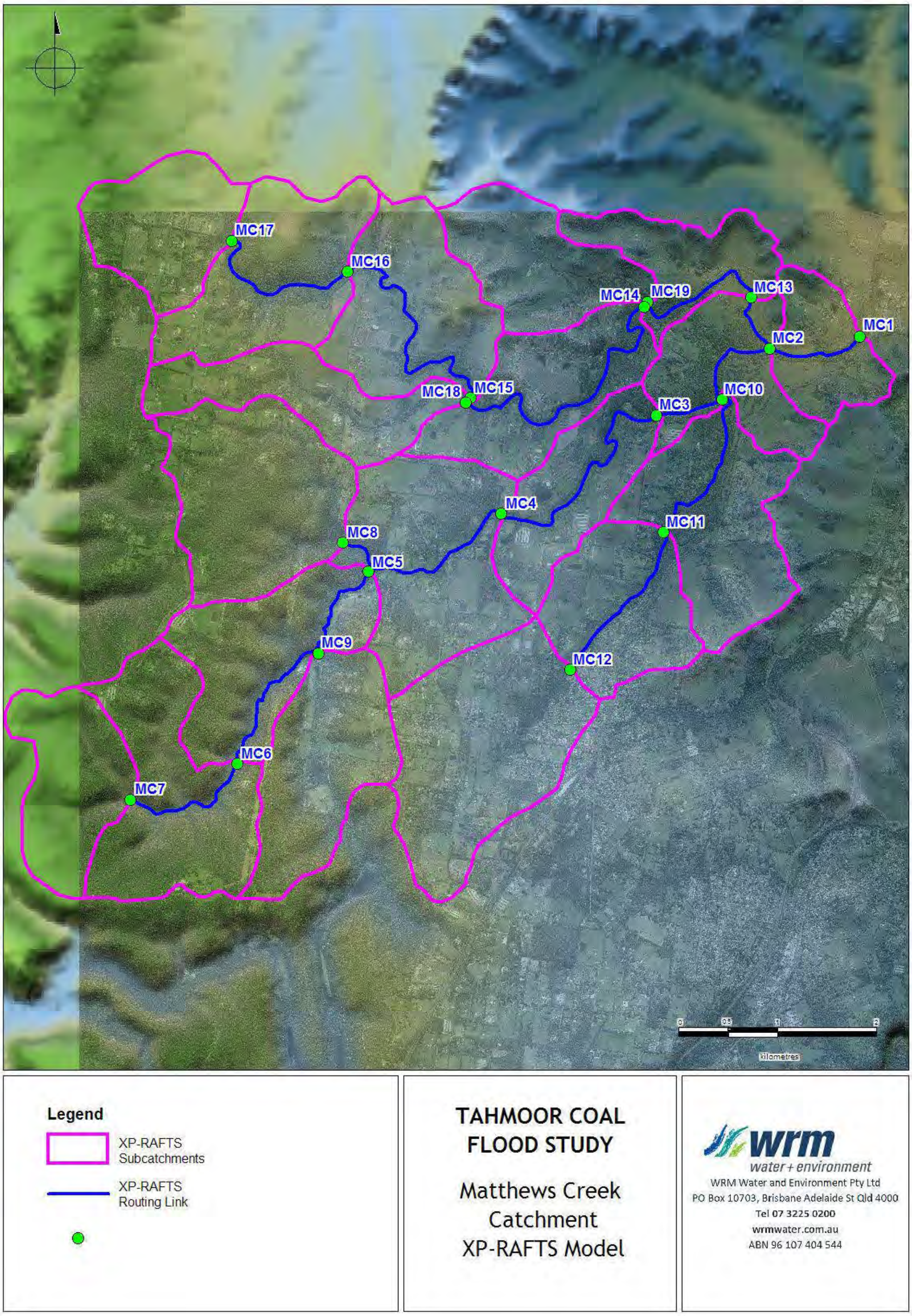

Figure 3.1 – Matthews Creek XP-RAFTS model configuration

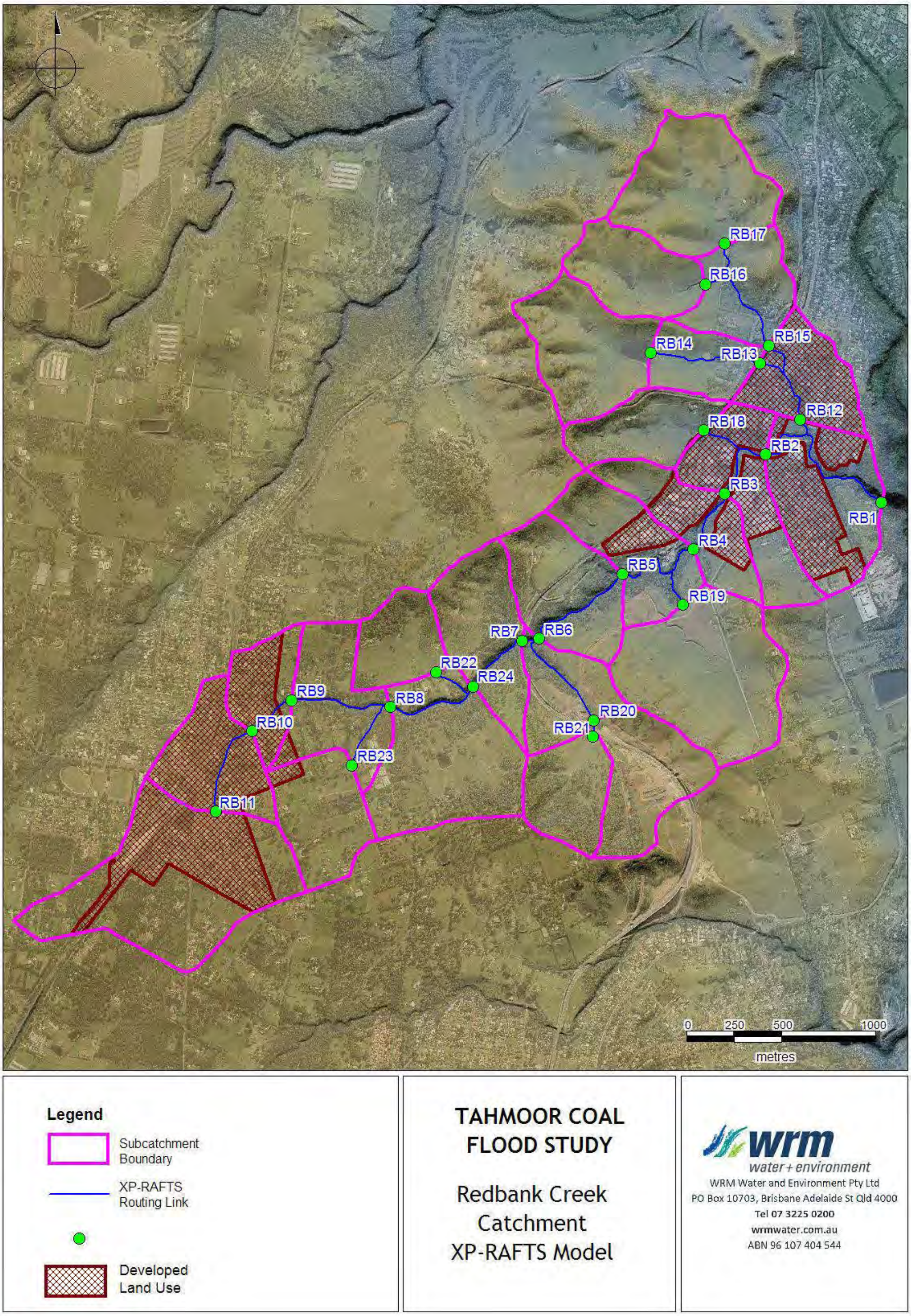

Figure 3.2 – Redbank Creek XP-RAFTS model configuration

3.3 ESTIMATION OF DESIGN DISCHARGES

3.3.1 Methodology

The Matthews Creek and Redbank Creek XP-RAFTS models were used to estimate design discharges for the 1% AEP event, using design rainfall intensities. Estimates of peak design discharges were then validated against Rational Method estimates of peak design discharge for a number of key locations.

3.3.2 Design rainfall data

Design rainfall data was obtained from the Bureau of Meteorology (BOM) AR&R 1987 IFD tool (BOM, 2014). Table 3.2 shows the design rainfall intensities adopted.

Table 3.2 - Adopted design rainfall intensities

Duration	1% AEP Design Intensity (mm/h)	
(min)	Redbank Creek Catchment	Matthews Creek Catchment
5	222	218
10	171	167
20	124	120
30	101	97.2
60	68.6	66.1
120	45.6	44.0
180	35.7	34.4
360	23.5	22.7

3.3.3 Design discharges and critical durations

To identify critical storm durations for flooding in the Redbank Creek and Matthews Creek catchments, the XP-RAFTS models were run for a range of storm durations from 15-minutes to 72-hours for the 1% AEP design event. The Matthews Creek catchment was found to have a critical duration of 6 hours, while the Redbank Creek catchment was found to have a critical duration of 2 hours.

3.3.4 Rational Method validation

Design discharges estimated by XP-RAFTS were validated against Rational Method discharges for the following locations (refer Figure 3.1 and Figure 3.2):

- MC1, MC3, MC11 and MC 13 for the Matthews Creek catchment; and
- RB1, RB2, RB12 and RB24 for the Redbank Creek catchment.

In addition to validation against the Rational Method estimates, XP-RAFTS design discharge estimates were also compared to design discharges from previous flood studies of the same catchments. Table 3.3 shows the comparison of XP-RAFTS estimates, Rational Method estimates and previous flood study estimates of peak design discharges.

Comparison of Rational Method and XP-RAFTS peak design discharge estimates showed that XP-RAFTS model estimates were generally within 20% of Rational Method estimates for both Matthews Creek and Redbank Creek, with the exception of location RB2 which was within 26%. It should be noted that the Rational Method for Eastern New South Wales (Pilgrim, 1998) makes no allowance for variations in catchment slope or degree of development. Results for both models compared favourably against previous flood studies. As such, the XP-RAFTS model peak design discharges have been adopted for this study.

Table 3.3 – Comparison of XP-RAFTS and Rational Method 1% AEP peak discharges

Reporting Location	Rational Method (m³/s)	XP-RAFTS (m³/s)	Difference (%)	Previous Study (m³/s)
MC1 (Catchment outlet)	276	319	-15%	300 [a,b]
MC3	138	143	-4%	-
MC11	57.3	47.0	18%	-
MC13	118	105	11%	-
RB1 (Catchment outlet)	77.9	95.0	-22%	-
RB2	58.9	74.0	-26%	73.1 [c]
RB12	24.7	21.3	14%	-
RB24	32.9	35.7	-9%	36.4 [c]

a. Stonequarry Creek 2D Modelling and Climate Change Assessment (Worley Parsons, 2011)

b. Approximate value estimated from hydrograph figure as an exact value was not reported.

c. Myrtle and Redbank Creeks Flood Study – Final Report (Hughes Trueman, 2009)

4 Hydraulic model development

4.1 OVERVIEW

The TUFLOW hydrodynamic model (WBM, 2010) was used to simulate the existing and post-subsidence conditions flow behaviour in the Matthews Creek and Redbank Creek catchments. TUFLOW represents hydraulic conditions on a fixed grid by solving the full two-dimensional depth averaged momentum and continuity equations for free surface flow. The model automatically calculates breakout points and flow directions within the study area.

4.2 MODEL EXTENT

Separate TUFLOW models were developed to estimate flood depths and extents in the Matthews Creek and Redbank Creek catchments. The configuration of each model is shown in Figure 4.1 and Figure 4.2. The Redbank Creek TUFLOW model, which used a 1 second time step, extends from approximately 0.4 km upstream of the Railway Culvert to approximately 0.35 km upstream of the confluence of Redbank and Stonequarry Creeks. The Matthews Creek TUFLOW model, which was simulated using the TUFLOW GPU Solver, used a variable time step determined by the modelling software package. The Matthews Creek TUFLOW model extends from approximately 1.6 km upstream of the confluence of Matthews and Cedar Creek to immediately upstream of the Barkers Lodge Road Bridge over Stonequarry Creek. Both models were developed using a 1 m grid.

4.3 ADOPTED BED ROUGHNESS

The TUFLOW model uses Manning's 'n' values to represent hydraulic resistance (notionally channel or floodplain roughness). No calibration data is available for the study areas. Therefore Manning's 'n' values were based on the guidelines given in Chow (1959). Discrete regions of continuous vegetation types and land uses were mapped, and an appropriate roughness value assigned to each region. Vegetation and land use mapping was undertaken using aerial photography and is shown in Figure 4.1 and Figure 4.2. The Manning's 'n' values applied to the Redbank Creek model were:

- Creek Channel: 'n' = 0.07
- Thick vegetation: 'n' = 0.09
- Roads: 'n' = 0.02
- Urban Drainage Channel: 'n' = 0.06
- Default: 'n'= 0.05

The Manning's 'n' values applied to the Matthews Creek catchment model were:

- Creek Channel: 'n' = 0.08
- Thick vegetation: 'n' = 0.09
- Waterbodies: 'n' = 0.045
- Default: 'n' = 0.06

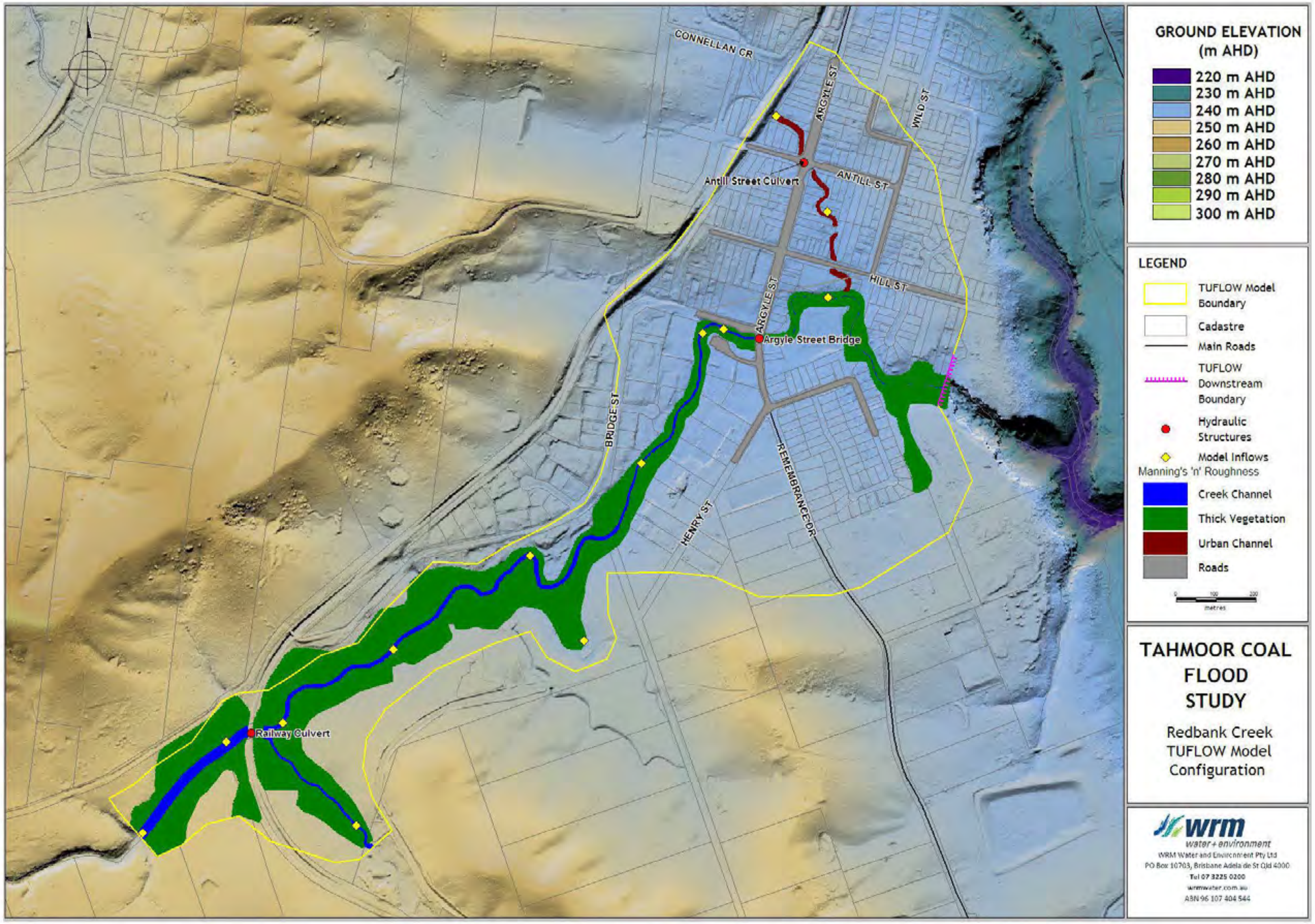

Figure 4.1 – Redbank Creek TUFLOW Model Configuration

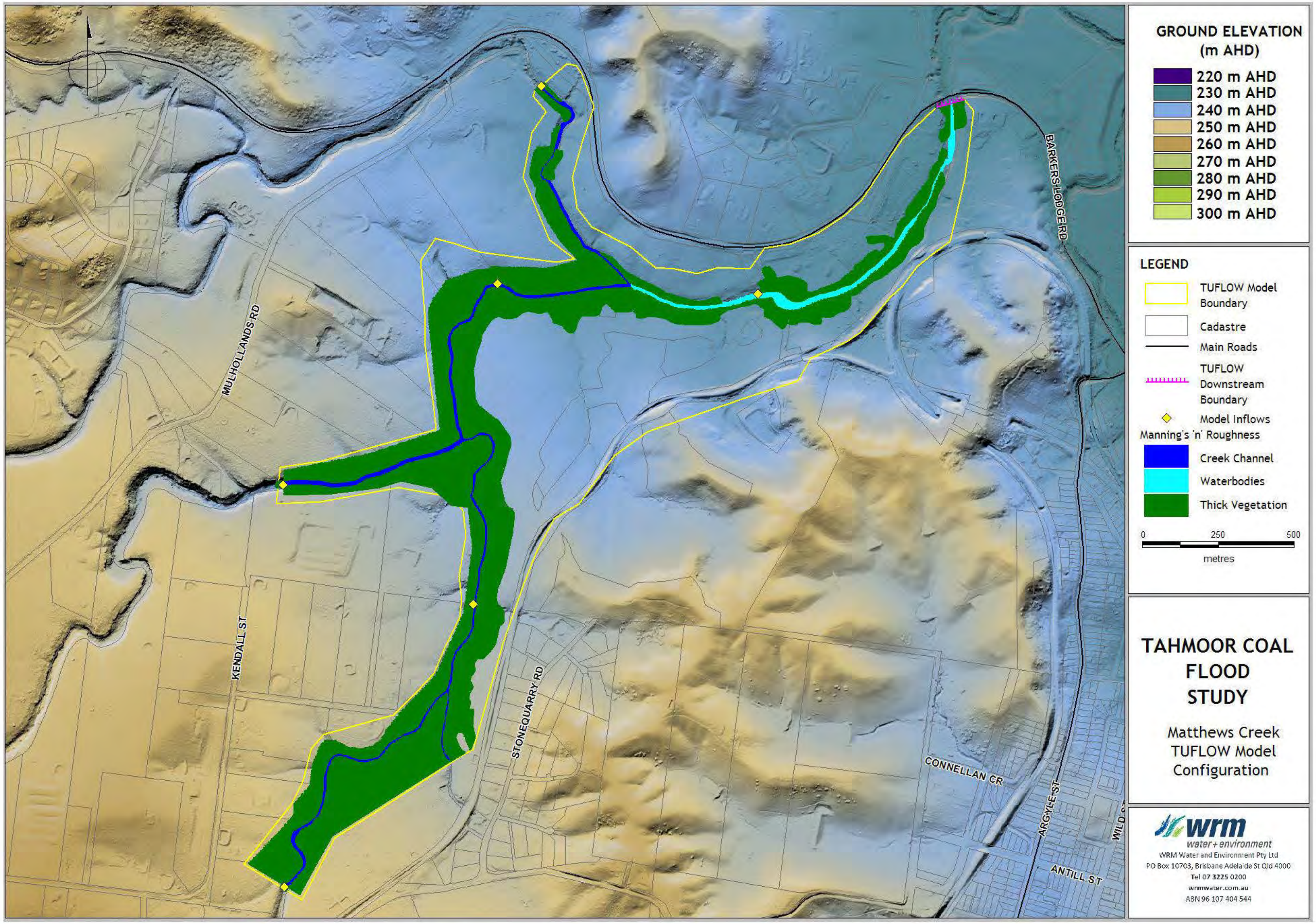

Figure 4.2 – Matthews Creek TUFLOW Model Configuration

4.4 BOUNDARY CONDITIONS

The downstream boundary in the Redbank Creek TUFLOW model is located approximately 0.7 km downstream of the Argyle Street crossing of Redbank Creek. A normal depth flood slope of 0.005 m/m was applied to the Redbank Creek model as the downstream tailwater boundary. This boundary condition was based on flood gradients that were representative of the bed slopes at the model boundaries.

A HT (water level) Boundary was used as the downstream boundary in the Matthews Creek TUFLOW model immediately upstream of the Barkers Lodge Road crossing of Stonequarry Creek. As outlined in the TUFLOW GPU model release notes, using this type of boundary and applying a level that is below the lowest ground elevation along the boundary results in the model being forced to adopt normal flow conditions and water is able to exit the model.

Design discharge hydrographs extracted from the XP-RAFTS hydrologic model were adopted as inflows at the TUFLOW model boundaries as shown in Figure 4.1 and Figure 4.2.

4.5 HYDRAULIC STRUCTURES

The Redbank Creek TUFLOW model includes three hydraulic structures which are shown in Figure 4.1. These structures were included in the TUFLOW model as 1D hydraulic structures (Railway and Antill Street culverts) and as a layered 2D-flow constriction (Argyle Street Bridge). The arrangement of the Antill Street culvert (2 No. 2.1 m x 1.2 m) and the Argyle Street Bridge structure, shown in Figure 4.3 and Figure 4.4, respectively, was determined following an inspection of the Project area.

The configuration of the Railway culvert (see Figure 4.5) was obtained from design drawing supplied by the client. This structure is a brick-lined culvert approximately 60 m long and is currently being reinforced against potential subsidence impacts.

There are no hydraulic structures within the Matthews Creek catchment modelling area.

4.6 POST-SUBSIDENCE TOPOGRAPHY

The ground levels within the existing case hydraulic models were amended to include the proposed post-subsidence ground elevations. The post-subsidence topographic data for LW31 to LW37 was supplied by MSEC and excludes LW32A. Figure 4.6 and Figure 4.7 show the location of the predicted subsidence in relation to the TUFLOW model boundaries.

The adopted hydrology, Manning's 'n' values and tailwater conditions for the post-subsidence models were identical to those included in the existing scenario models.

Figure 4.3 – Photograph showing the Antill Street culvert

Figure 4.4 – Photograph showing the Argyle Street Bridge

Figure 4.5 – Photograph showing the Railway Culvert

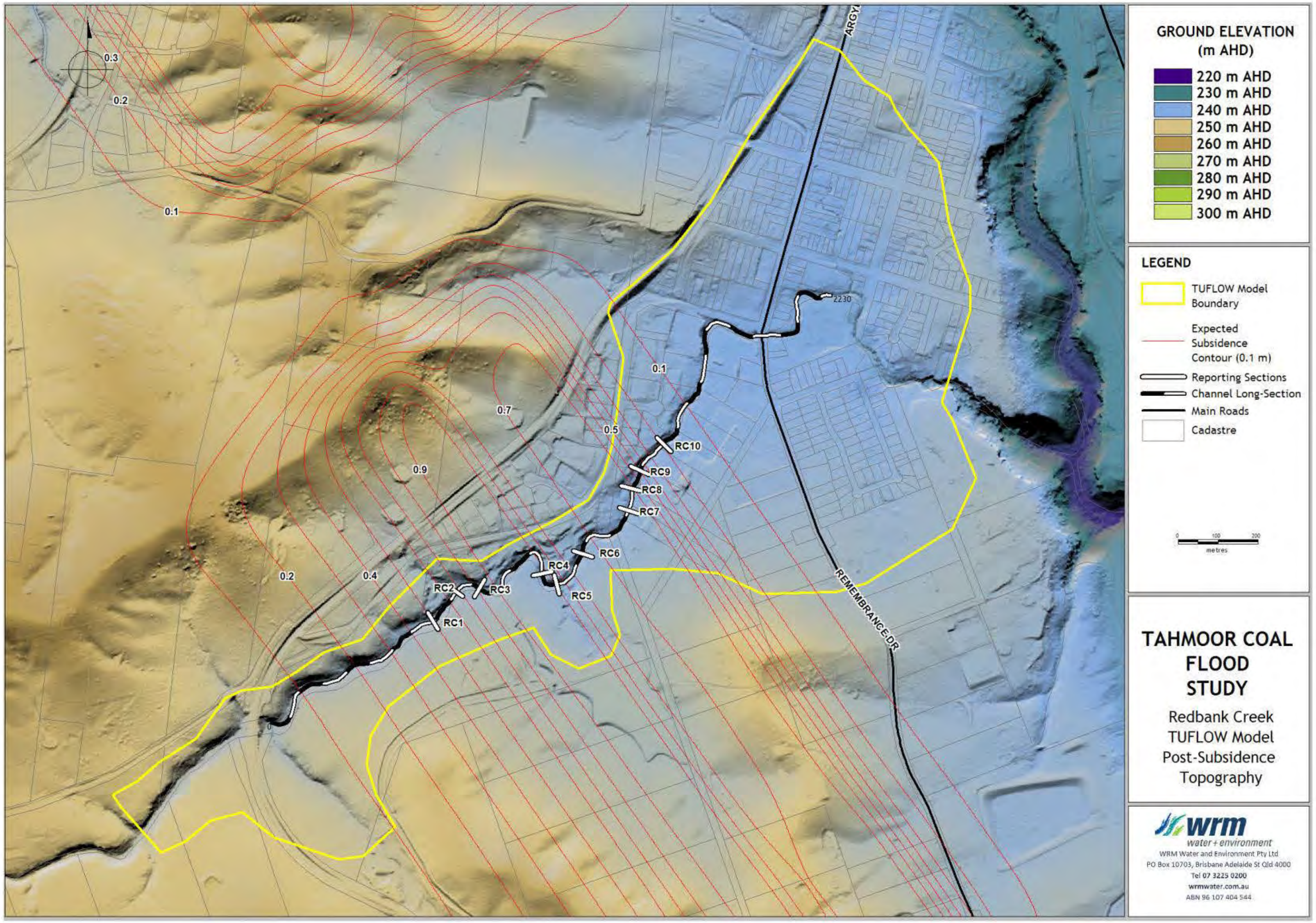

Figure 4.6 – Predicted Subsidence, Redbank Creek TUFLOW Model

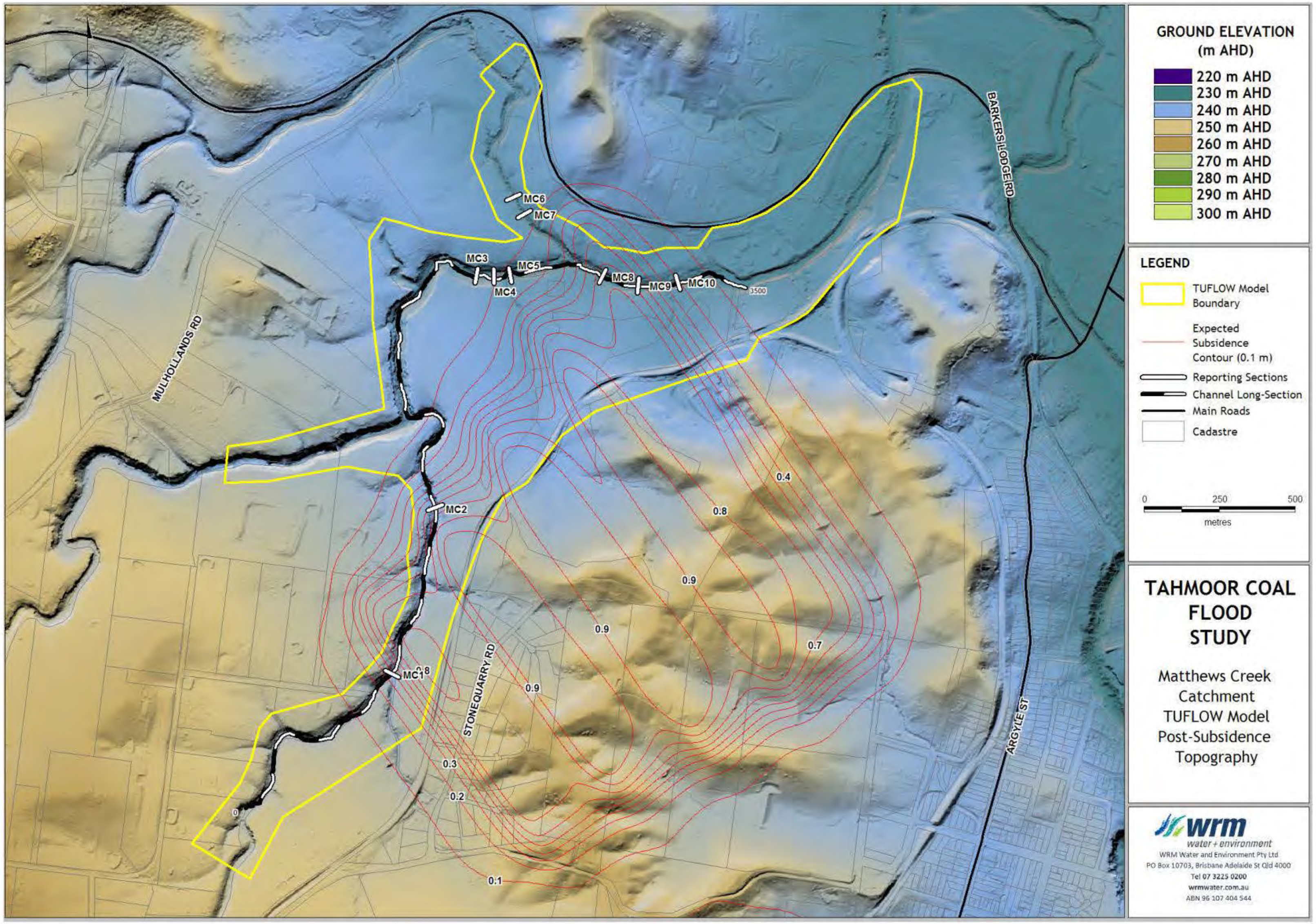

Figure 4.7 – Predicted Subsidence, Matthews Creek Catchment TUFLOW Model

5 Hydraulic Modelling Results

5.1 OVERVIEW

The TUFLOW model was used to determine design flood levels, depths, extents and velocities in Redbank Creek and in the Matthews Creek catchment for the 1% AEP design flood for the existing conditions. The 1% AEP design event was subsequently simulated for the post-subsidence conditions. Plans showing the depth, extent and velocity under existing conditions for the 1% AEP design event are presented in Appendix B. Plans showing the depth, extent and velocity under post-subsidence conditions for the 1% AEP design event are presented in Appendix C.

5.2 EXISTING CONDITIONS MODEL RESULTS

5.2.1 Redbank Creek

Flooding in Redbank Creek is typically contained in the creek channel with the exception of overbank flow located in the north-eastern extent of the hydraulic model downstream of the Antill Street culvert and in the vicinity of the Argyle Street Bridge. Depths in these areas range between 0.2 m and 1.0 m. Depths in the creek channel are significant in places with flood depths in excess of 4.0 m located downstream of the Argyle Street bridge.

Stream velocities in Redbank Creek are high (point velocities greater than 2.5 m/s) during the 1% AEP design event. The velocities in the overbank flow path downstream of Antill Street and in the vicinity of the Argyle Street Bridge are slightly lower (less than 2.0 m/s).

5.2.2 Matthews Creek

Flooding in the Matthews Creek catchment is contained within the Matthews Creek, Cedar Creek and Stonequarry Creek channels with depths typically in excess of 4.0 m in numerous locations. Stream velocities are very high with point velocities in excess of 3.5 m/s in the section of Stonequarry Creek near of the downstream boundary.

5.3 POST-SUBSIDENCE MODEL RESULTS

Plans showing the design depth, flood extent and velocity under post-subsidence conditions for the 1% AEP design event are presented in Appendix C. Plans showing the change in the 1% AEP flood levels and stream velocities due to the inclusion of the predicted LW31 to LW37 subsidence are presented in Appendix D.

An analysis of the impacts caused by the predicted subsidence indicates that a reduction in flood level occurs in both the Redbank Creek and Matthews Creek catchment modelling areas. Changes in water level typically reflect the change in ground elevations caused by the subsidence with a maximum reduction in water level of -0.97 m in the Redbank Creek model and -0.75 m in the Matthews Creek catchment model.

The impact of the subsidence caused by the mining of LW31 to LW37 does not result in an increase in flood levels in the Redbank Creek and Matthews Creek catchment modelling areas.

A comparison between water levels and ground elevations for the existing and post-subsidence condition models is shown in Figure 5.1 and Figure 5.2. The chainages shown in these figures correspond to the long-sections shown in Figure 4.6 and Figure 4.7.

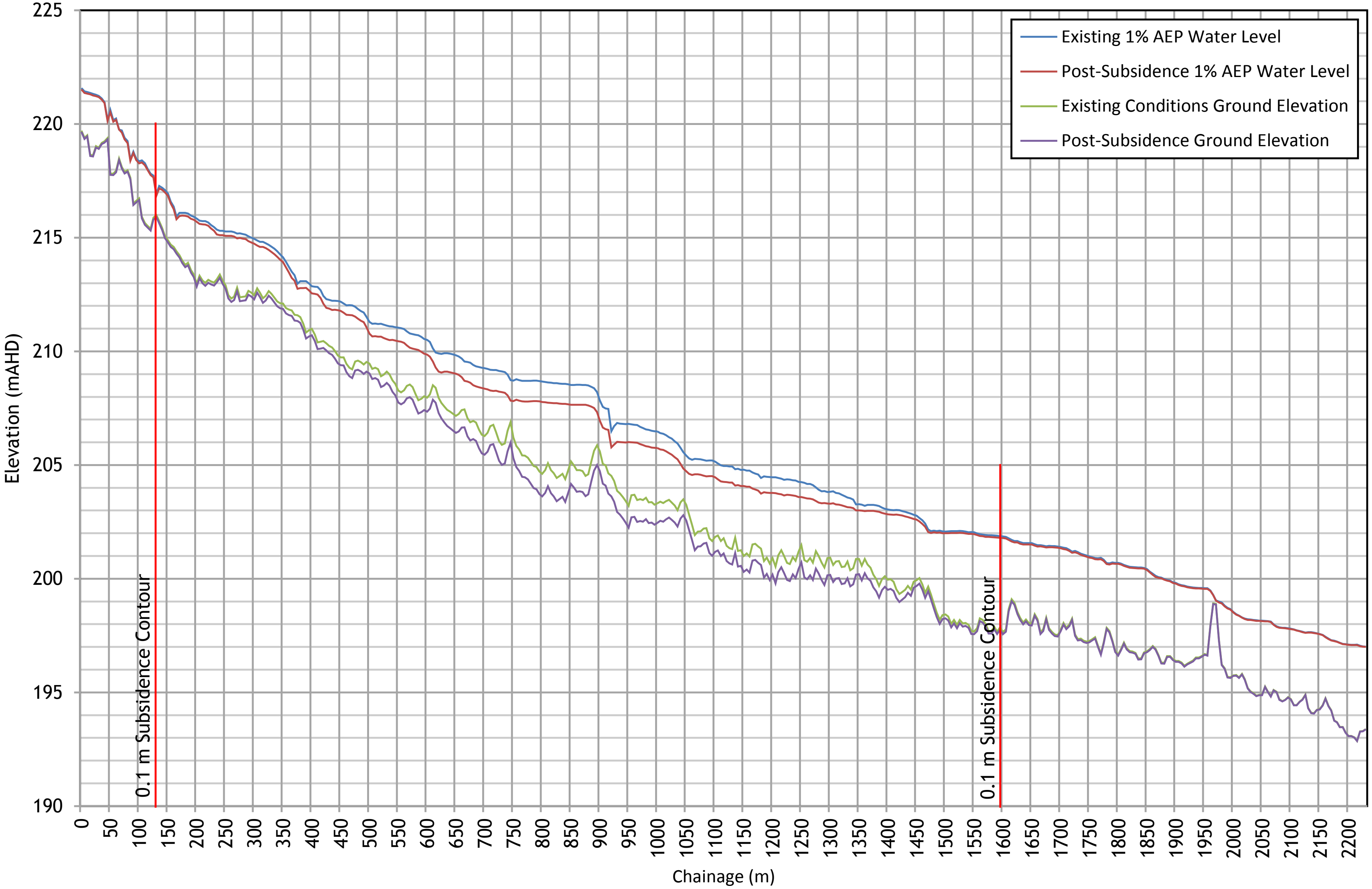

Figure 5.1 - Comparison of water levels and ground elevations, Redbank Creek model

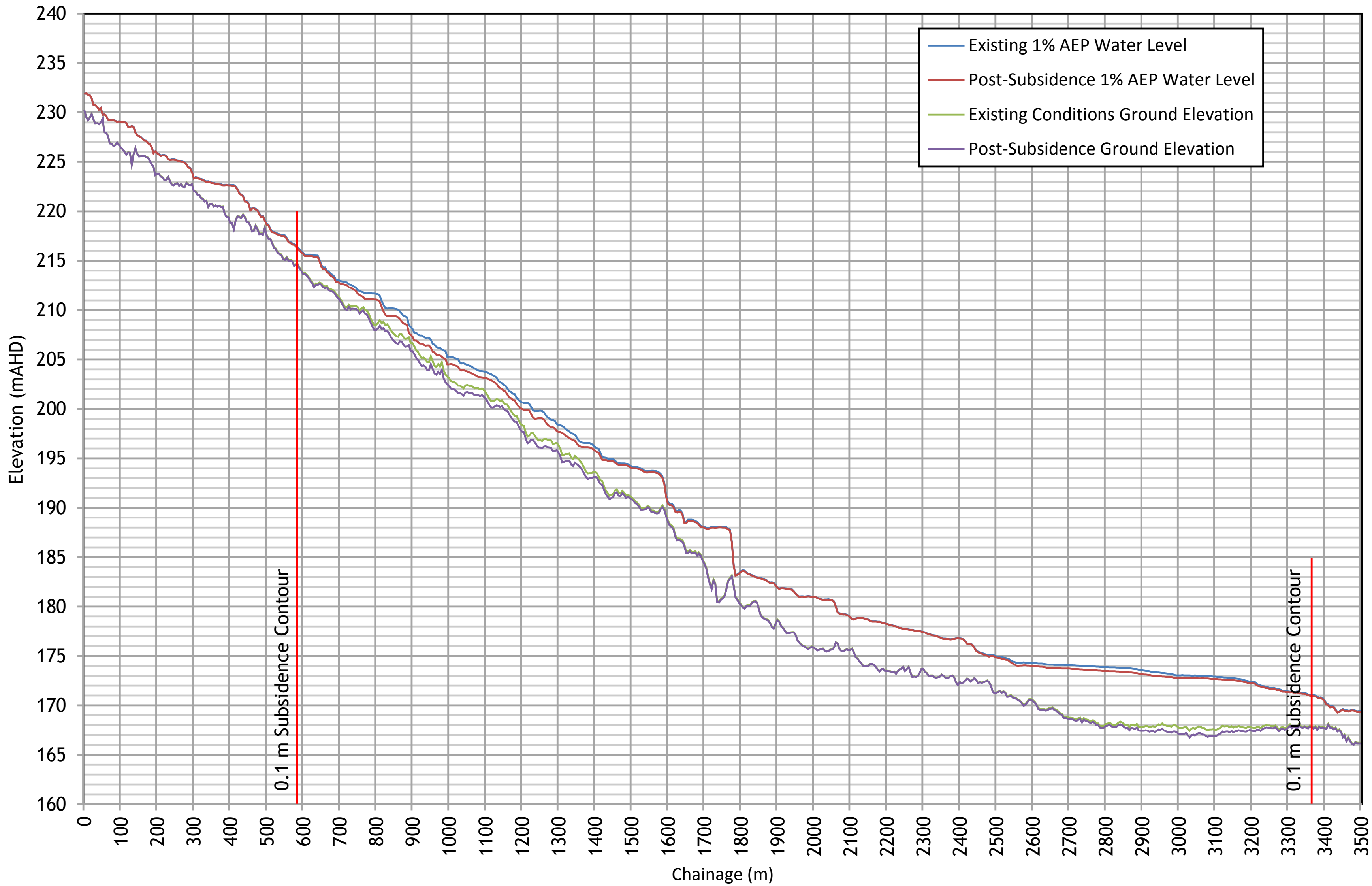

Figure 5.2 - Comparison of water levels and ground elevations, Matthews Creek catchment model

The impact of the predicted subsidence on stream velocities indicates a maximum reduction in point velocities of 0.92 m/s and a maximum increase of 0.77 m/s in the Redbank Creek model and a maximum reduction in point velocity of 0.58 m/s and a maximum increase in point velocity of 0.65 m/s occurring within the Matthews Creek catchment modelling area. A comparison of averaged stream velocities at various cross section locations (see Figure 4.6 and Figure 4.7) is shown in Table 5.1 and Table 5.2. This comparison indicates that the change in average stream velocities is relatively minor within both modelling areas.

Table 5.1 - Comparison of average stream velocities, Redbank Creek model

Reporting Location	Existing Conditions (m/s)	Post-Subsidence Conditions (m/s)	Difference (m/s)
RC1	1.86	1.98	0.12
RC2	1.21	1.51	0.30
RC3	1.35	1.52	0.17
RC4	1.47	1.41	-0.07
RC5	1.63	1.55	-0.08
RC6	1.67	1.70	0.04
RC7	1.74	1.48	-0.26
RC8	1.05	0.91	-0.14
RC9	1.46	1.30	-0.16
RC10	1.50	1.45	-0.05

Table 5.2 - Comparison of average stream velocities, Matthews Creek catchment model

Reporting Location	Existing Conditions (m/s)	Post-Subsidence Conditions (m/s)	Difference (m/s)
MC1	1.51	1.74	0.23
MC2	2.76	2.48	-0.28
MC3	2.73	2.97	0.24
MC4	1.69	1.82	0.13
MC5	1.16	1.25	0.09
MC6	1.64	1.86	0.22
MC7	1.58	1.92	0.34
MC8	2.11	1.89	-0.22
MC9	1.74	1.63	-0.11
MC10	2.52	2.42	-0.11

6 Summary

The subsidence caused by the mining of LW31 to LW37 will impact flood levels and velocities along Matthews Creek, Redbank Creek, Cedar Creek and Stonequarry Creek which traverse the Project area.

Hydrologic (XP-RAFTS) and hydraulic (TUFLOW) models were used to estimate design flood discharges, flood levels, depths, velocities and extents in the vicinity of the Project area for the 1% AEP design event for existing and post-subsidence conditions.

The results of the flood modelling are summarised as follows:

- Flows are generally contained within the channels of Matthews Creek, Redbank Creek, Cedar Creek and Stonequarry Creek with depths in excess of 4.0 m in the main channels;
- Overbank flow occurs in the Redbank Creek model in the vicinity of the Argyle Street Bridge and downstream of the Antill Street culvert. Depths in these areas range between 0.2 m and 1.0 m;
- Stream velocities in the main channels are relatively high (point velocities greater than 2.0 m/s and 3.5 m/s in Redbank Creek and in the Matthews Creek catchment, respectively). The velocity in the overbank flow areas is slightly lower (less than 2.0 m/s);
- An analysis of the impacts caused by the predicted subsidence on water levels and stream velocities in Redbank Creek and the Matthews Creek catchment indicates that a localised change in flood levels and stream velocities occurs during the 1% AEP design event. These localised changes are confined to the creek channels with a maximum reduction in water level of -0.97 m in the Redbank Creek model and -0.75 m in the Matthews Creek catchment model;
- The impact of the subsidence caused by the mining of LW31 to LW37 does not result in an increase in flood levels in the Redbank Creek and Matthews Creek catchment modelling areas;
- Changes to stream velocity are localised with a maximum reduction in point velocities of 0.92 m/s and a maximum increase of 0.77 m/s in the Redbank Creek model and a maximum reduction in point velocity of 0.58 m/s and a maximum increase in point velocity of 0.65 m/s in the Matthews Creek catchment modelling area; and
- A comparison of cross-section averaged stream velocities at various locations indicates that the change in average stream velocities is relatively minor in both modelling areas. There is a maximum increase of 0.3 m/s and a maximum decrease of -0.26 m/s occurring in the Redbank Creek modelling area representing a change in velocity of the order of 24% and 14%, respectively.
- A maximum increase of 0.34 m/s and a maximum decrease of -0.28 m/s occurs in the Matthews Creek catchment modelling area, representing a change in velocity of the order of 21% and 10%, respectively.

7 References

BMT WBM (2010)	*'TUFLOW User Manual - GIS Based 2D/1D Hydrodynamic Modelling'*, BMT WBM Pty Ltd, February 2011.
Chow (1959)	*'Open Channel Hydraulics'*, written by V.T. Chow, McGraw-Hill Book Company, NY, 1959.
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Pilgrim (1998)	*'Australian rainfall & Runoff – A Guide to Flood Estimation'*, Book IV, Section 1, Revised Edition, Institution of Engineers Australia, 1998.
WorleyParsons (2011)	*'Stonequarry Creek, 2D Modelling and Climate Change Assessment'*, Report prepared by WorleyParsons for Wollondilly Shire Council, July 2011.
XP Software (2013)	*'XP-RAFTS User Manual'*, XP Software, 2013.

Appendix A XP-RAFTS model parameters

A1 Matthews Creek catchment model

Table A.1 – Matthews Creek XP-RAFTS subcatchments parameters

Node	Area (ha)	Slope (%)	Fraction Impervious (%)	PERN 'n'
MC1	121.9	4.1	10	0.08
MC2	176.7	3.4	10	0.08
MC3	179.0	4.1	10	0.08
MC4	303.2	1.3	10	0.08
MC5	246.5	2.4	10	0.08
MC6	288.4	3.6	10	0.08
MC7	180.8	7.7	10	0.08
MC8	303.6	4.2	10	0.08
MC9	233.8	2.3	10	0.08
MC10	258.8	4.3	10	0.08
MC11	202.8	4.5	10	0.08
MC12	352.1	2.5	10	0.08
MC13	143.9	2.7	10	0.08
MC14	218.3	2.5	10	0.08
MC15	247.9	1.2	10	0.08
MC16	250.4	3.3	10	0.08
MC17	177.0	4.2	10	0.08
MC18	182.8	2.8	10	0.08
MC19	189.1	3.6	10	0.08

Table A.2 – Matthews Creek XP-RAFTS routing link parameters

Link	Length (m)	Channel Routing K (hr)	Channel Routing X
MC7 - MC6	1419	0.26	0.25
MC6 - MC5	2681	0.50	0.25
MC9 - MC5	1142	0.21	0.25
MC5 - MC4	1670	0.31	0.25
MC8 - MC4	2080	0.39	0.25
MC12 - MC11	1775	0.33	0.25
MC4 - MC3	2638	0.49	0.25
MC11 - MC10	1798	0.33	0.25
MC3 - MC2	1636	0.30	0.25
MC10 - MC2	997	0.18	0.25
MC13 - MC2	632	0.12	0.25
MC2 - MC1	1004	0.19	0.25
MC14 - MC13	1474	0.27	0.25
MC19 - MC13	1482	0.27	0.25
MC18 - MC14	3204	0.59	0.25
MC15 - MC14	3221	0.60	0.25
MC17 - MC16	1755	0.32	0.25
MC16 - MC15	2879	0.53	0.25

A2 Redbank Creek catchment model

Table A.3 – Redbank Creek XP-RAFTS subcatchments parameters

Node	Area (ha)	Slope (%)	Fraction Impervious (%)	PERN ‘n’
RB1	42.44	7.8	27.3	0.06
RB2	32.32	2.3	29.1	0.05
RB3	26.88	4.6	23.0	0.06
RB4	32.13	3.3	14.5	0.07
RB5	34.48	5.1	10.0	0.08
RB6	21.87	4.1	10.0	0.08
RB7	33.02	6.7	10.0	0.08
RB8	32.26	3.7	11.2	0.08
RB9	18.39	3.2	32.4	0.05
RB10	28.85	1.9	37.5	0.04
RB11	76.21	1.4	23.0	0.06
RB12	25.15	2.4	40.0	0.04
RB13	17.56	2.7	10.2	0.08
RB14	36.66	3.0	10.0	0.08
RB15	25.34	2.8	10.2	0.08
RB16	25.78	3.8	10.0	0.08
RB17	44.38	4.1	10.0	0.08
RB18	23.19	4.8	10.3	0.08
RB19	58.17	4.0	10.0	0.08
RB20	31.43	3.9	10.0	0.08
RB21	22.4	4.5	10.0	0.08
RB22	19.3	5.9	10.0	0.08
RB23	27.62	3.8	11.6	0.08
RB24	52.63	5.0	10.0	0.08
RB1	42.44	7.8	27.3	0.06

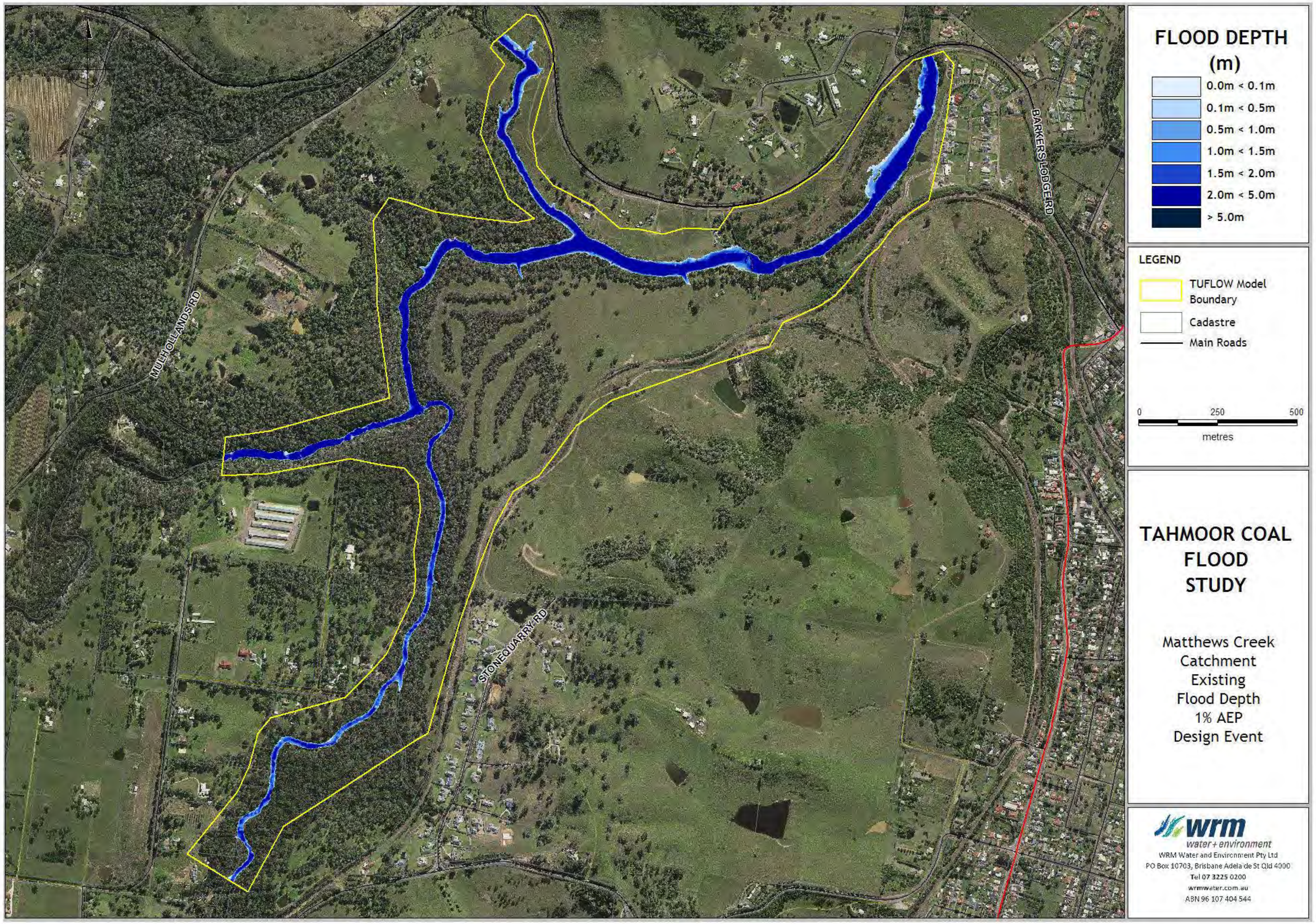
Table A.4 – Redbank Creek XP-RAFTS routing link parameters

Link	Length (m)	Channel Routing K (hr)	Channel Routing X
RB10 - RB9	272	0.05	0.25
RB11 - RB10	506	0.09	0.25
RB12 - RB1	721	0.13	0.25
RB13 - RB12	423	0.08	0.25
RB14 - RB13	603	0.11	0.25
RB15 - RB12	471	0.09	0.25
RB16 - RB15	566	0.1	0.25
RB17 - RB15	645	0.12	0.25
RB18 - RB2	360	0.07	0.25
RB19 - RB4	380	0.07	0.25
RB2 - RB1	947	0.18	0.25
RB20 - RB6	582	0.11	0.25
RB21 - RB20	85	0.02	0.25
RB22 - RB24	256	0.05	0.25
RB23 - RB8	399	0.07	0.25
RB24 - RB7	373	0.07	0.25
RB3 - RB2	399	0.07	0.25
RB4 - RB3	353	0.07	0.25
RB5 - RB4	558	0.1	0.25
RB6 - RB5	592	0.11	0.25
RB7 - RB6	92	0.02	0.25
RB8 - RB24	509	0.09	0.25
RB9 - RB8	536	0.1	0.25

Appendix B Existing Conditions Model Results

FLOOD DEPTH (m)
0.0m < 0.1m
0.1m < 0.5m
0.5m < 1.0m
1.0m < 1.5m
1.5m < 2.0m
2.0m < 5.0m
> 5.0m
LEGEND
TUFLOW Model Boundary
Cadastre
Main Roads
ANTILL ST
ARGYLE ST
REMEMBRANCE DR
TAHMOOR COAL FLOOD STUDY
Redbank Creek
Existing
Flood Depth
1% AEP
Design Event
wrm
water + environment
WRM Water and Environment Pty Ltd
PO Box 10703, Brisbane Adelaide St Qld 4000
Tel 07 3225 0200
wrmwater.com.au
ABN 96 107 404 544

VELOCITY (m/s)
0.0m/s < 0.5m/s
0.5m/s < 1.0m/s
1.0m/s < 1.5m/s
1.5m/s < 2.0m/s
2.0m/s < 2.5m/s
2.5m/s < 3.0 m/s
3.0m/s < 3.5m/s
3.0m/s < 4.0m/s
LEGEND
TUFLOW Model Boundary
Cadastre
Main Roads
metres
ANTILL ST
ARGYLE ST
REMEMBRANCE DR
TAHMOOR COAL FLOOD STUDY
Redbank Creek
Existing
Flood Velocity
1% AEP
Design Event
wrm
water + environment
WRM Water and Environment Pty Ltd
PO Box 10703, Brisbane Adelaide St Qld 4000
Tel 07 3225 0200
wrmwater.com.au
ABN 96 107 404 544

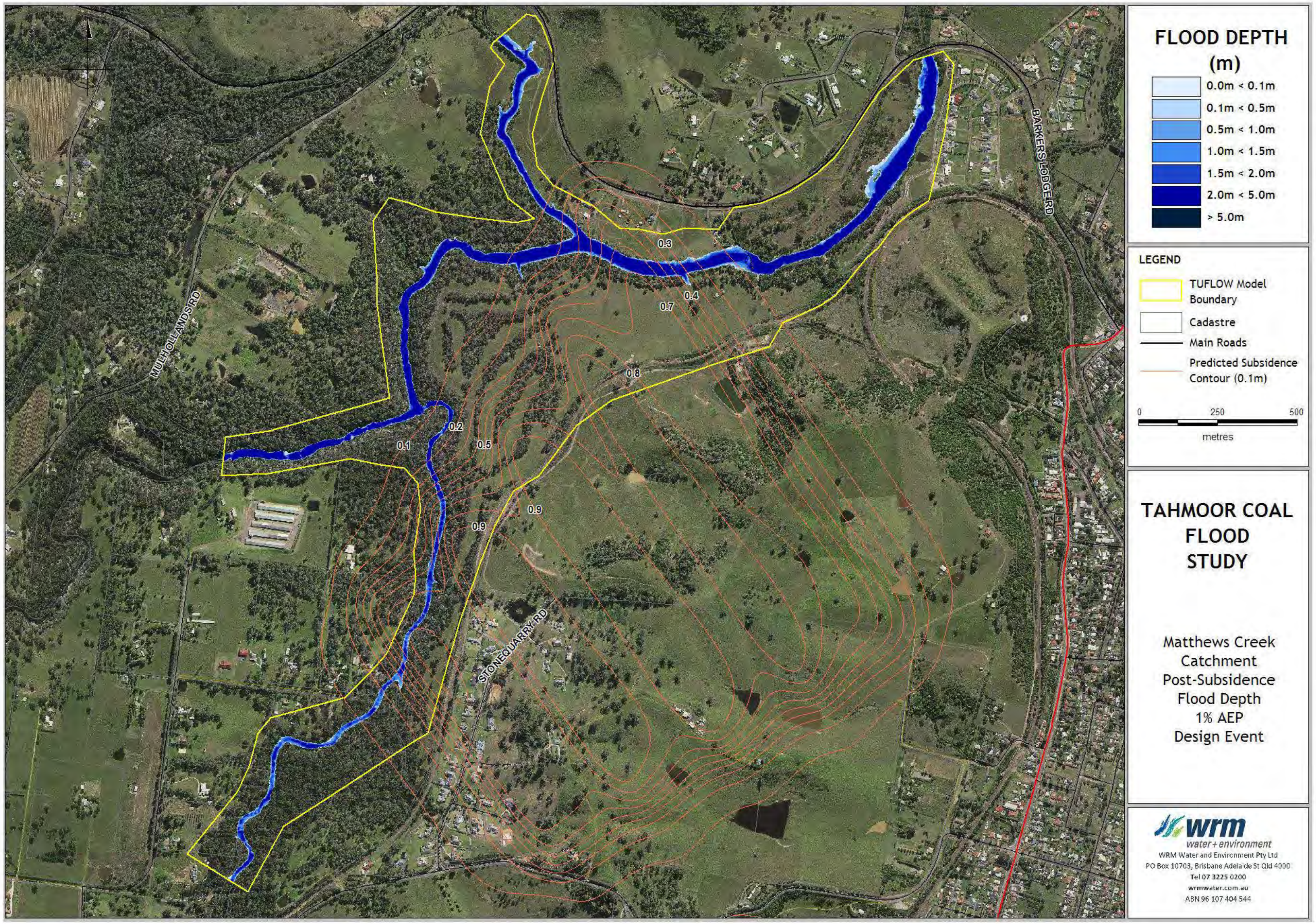

MULHOLLANDS RD
STONEQUARRY RD
BARKERS LODGE RD
FLOOD DEPTH (m)
0.0m < 0.1m
0.1m < 0.5m
0.5m < 1.0m
1.0m < 1.5m
1.5m < 2.0m
2.0m < 5.0m
> 5.0m
LEGEND
TUFLOW Model Boundary
Cadastre
Main Roads
0
250
500
metres
TAHMOOR COAL FLOOD STUDY
Matthews Creek Catchment
Existing
Flood Depth
1% AEP
Design Event
wrm
water + environment
WRM Water and Environment Pty Ltd
PO Box 10703, Brisbane Adelaide St Qld 4000
Tel 07 3225 0200
wrmwater.com.au
ABN 96 107 404 544


VELOCITY
(m/s)
0.0m/s < 0.5m/s
0.5m/s < 1.0m/s
1.0m/s < 1.5m/s
1.5m/s < 2.0m/s
2.0m/s < 2.5m/s
2.5m/s < 3.0 m/s
3.0m/s < 3.5m/s
3.0m/s < 4.0m/s
LEGEND
TUFLOW Model Boundary
Cadastre
Main Roads
0
250
500
metres
TAHMOOR COAL FLOOD STUDY
Matthews Creek Catchment Existing Flood Velocity 1% AEP Design Event
wrm
water + environment
WRM Water and Environment Pty Ltd
PO Box 10703, Brisbane Adelaide St Qld 4000
Tel 07 3225 0200
wrmwater.com.au
ABN 96 107 404 544
MULHOLLANDS RD
BARKERS LODGE RD
STONEQUARRY RD

Appendix C Post-Subsidence Model Results

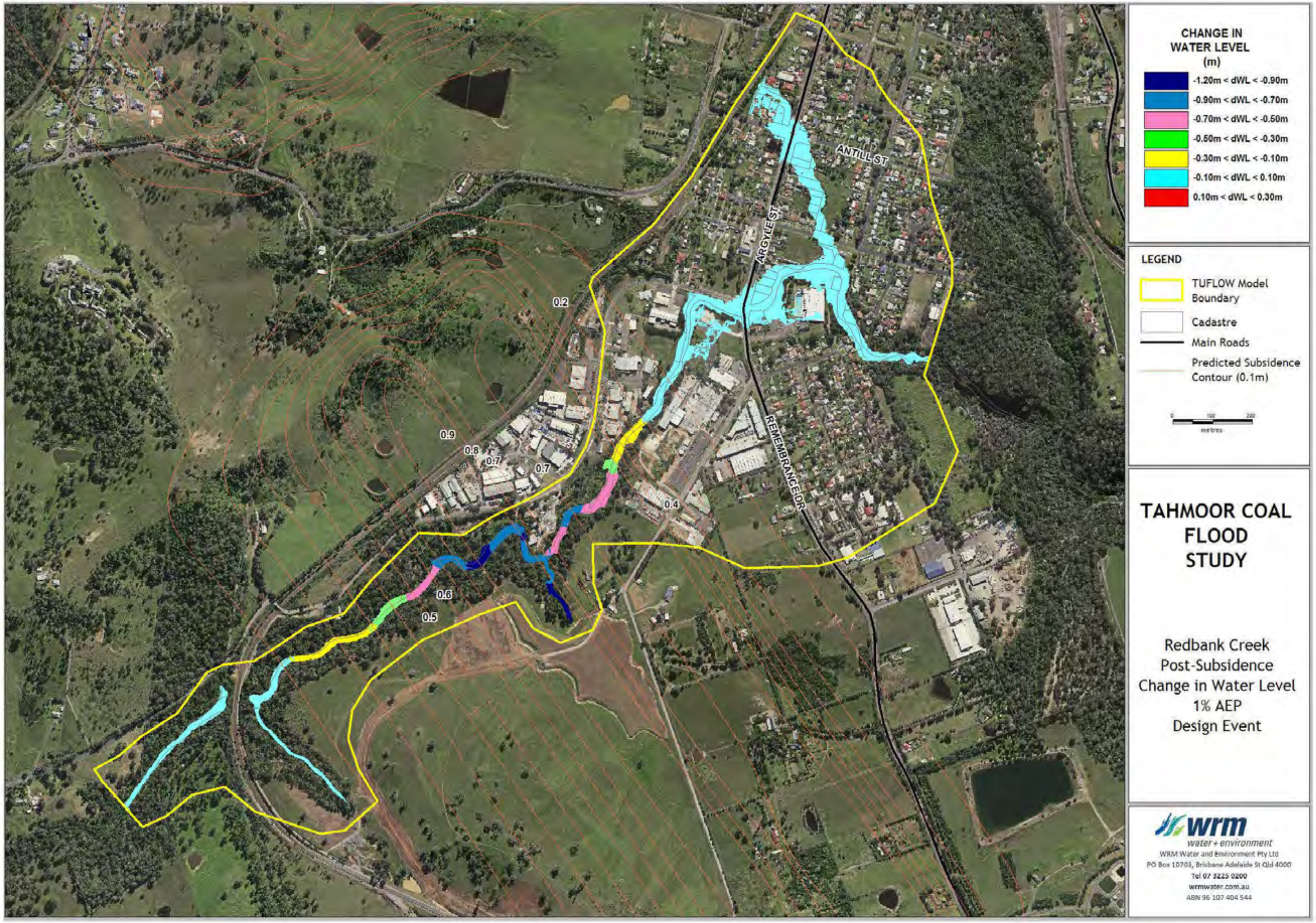

FLOOD DEPTH (m)
0.0m < 0.1m
0.1m < 0.5m
0.5m < 1.0m
1.0m < 1.5m
1.5m < 2.0m
2.0m < 5.0m
> 5.0m
LEGEND
TUFLOW Model Boundary
Cadastre
Main Roads
Predicted Subsidence Contour (0.1m)
metres
TAHMOOR COAL FLOOD STUDY
Redbank Creek
Post-Subsidence
Flood Depth
1% AEP
Design Event
wrm
water + environment
WRM Water and Environment Pty Ltd
PO Box 10703, Brisbane Adelaide St Qld 4000
Tel 07 3225 0200
wrmwater.com.au
ABN 96 107 404 544
ANTILL ST
ARGYLE ST
REMEMBRANCE DR
0.1
0.2
0.3
0.4
0.7
0.8
0.9

ANTILL ST
ARGYLE ST
REMEMBRANCE DR
0.1
0.2
0.3
0.4
0.6
0.7
0.7
0.8
0.9
VELOCITY (m/s)
0.0m/s < 0.5m/s
0.5m/s < 1.0m/s
1.0m/s < 1.5m/s
1.5m/s < 2.0m/s
2.0m/s < 2.5m/s
2.5m/s < 3.0 m/s
3.0m/s < 3.5m/s
3.0m/s < 4.0m/s
LEGEND
TUFLOW Model Boundary
Cadastre
Main Roads
Predicted Subsidence Contour (0.1m)
TAHMOOR COAL FLOOD STUDY
Redbank Creek
Post-Subsidence
Flood Velocity
1% AEP
Design Event
wrm
water + environment
WRM Water and Environment Pty Ltd
PO Box 10703, Brisbane Adelaide St Qld 4000
Tel 07 3225 0200
wrmwater.com.au
ABN 96 107 404 544


FLOOD DEPTH (m)
0.0m < 0.1m
0.1m < 0.5m
0.5m < 1.0m
1.0m < 1.5m
1.5m < 2.0m
2.0m < 5.0m
> 5.0m
LEGEND
TUFLOW Model Boundary
Cadastre
Main Roads
Predicted Subsidence Contour (0.1m)
0
250
500
metres
TAHMOOR COAL FLOOD STUDY
Matthews Creek Catchment Post-Subsidence Flood Depth 1% AEP Design Event
wrm water + environment
WRM Water and Environment Pty Ltd
PO Box 10703, Brisbane Adelaide St Qld 4000
Tel 07 3225 0200
wrmwater.com.au
ABN 96 107 404 544
MULHOLLANDS RD
BARKERS LODGE RD
STONEQUARRY RD
0.1
0.2
0.3
0.4
0.5
0.7
0.8
0.9


VELOCITY
(m/s)
0.0m/s < 0.5m/s
0.5m/s < 1.0m/s
1.0m/s < 1.5m/s
1.5m/s < 2.0m/s
2.0m/s < 2.5m/s
2.5m/s < 3.0 m/s
3.0m/s < 3.5m/s
3.0m/s < 4.0m/s
LEGEND
TUFLOW Model Boundary
Cadastre
Main Roads
Predicted Subsidence Contour (0.1m)
0
250
500
metres
TAHMOOR COAL FLOOD STUDY
Matthews Creek Catchment
Post-Subsidence
Flood Velocity
1% AEP
Design Event
wrm
water + environment
WRM Water and Environment Pty Ltd
PO Box 10703, Brisbane Adelaide St Qld 4000
Tel 07 3225 0200
wrmwater.com.au
ABN 96 107 404 544
MULHOLLANDS RD
BARKERS LODGE RD
STONEQUARRY RD
0.1
0.2
0.3
0.4
0.5
0.7
0.8
0.9

Appendix D Post-Subsidence Impacts



ANTILL ST
ARGYLE ST
REMEMBRANCE DR
0.2
0.9
0.8
0.7
0.7
0.4
0.6
0.5
CHANGE IN WATER LEVEL (m)
-1.20m < dWL < -0.90m
-0.90m < dWL < -0.70m
-0.70m < dWL < -0.50m
-0.50m < dWL < -0.30m
-0.30m < dWL < -0.10m
-0.10m < dWL < 0.10m
0.10m < dWL < 0.30m
LEGEND
TUFLOW Model Boundary
Cadastre
Main Roads
Predicted Subsidence Contour (0.1m)
0
100
200
metres
TAHMOOR COAL FLOOD STUDY
Redbank Creek
Post-Subsidence
Change in Water Level
1% AEP
Design Event
wrm
water + environment
WRM Water and Environment Pty Ltd
PO Box 10703, Brisbane Adelaide St Qld 4000
Tel 07 3225 0200
wrmwater.com.au
ABN 96 107 404 544


ANTILL ST
ARGYLE ST
REMEMBRANCE DR
0.2
0.9
0.8
0.7
0.7
0.4
0.6
0.5
CHANGE IN VELOCITY (m/s)
-0.50m/s < dV < -0.30m/s
-0.30m/s < dV < -0.20m/s
-0.20m/s < dV < -0.10m/s
-0.1m/s < dV < 0.1m/s
0.10m/s < dV < 0.20m/s
0.20m/s < dV < 0.30m/s
0.30m/s < dV < 0.50m/s
LEGEND
TUFLOW Model Boundary
Cadastre
Main Roads
Predicted Subsidence Contour (0.1m)
0
100
200
metres
TAHMOOR COAL FLOOD STUDY
Redbank Creek
Post-Subsidence
Change in Velocity
1% AEP
Design Event
wrm
water + environment
WRM Water and Environment Pty Ltd
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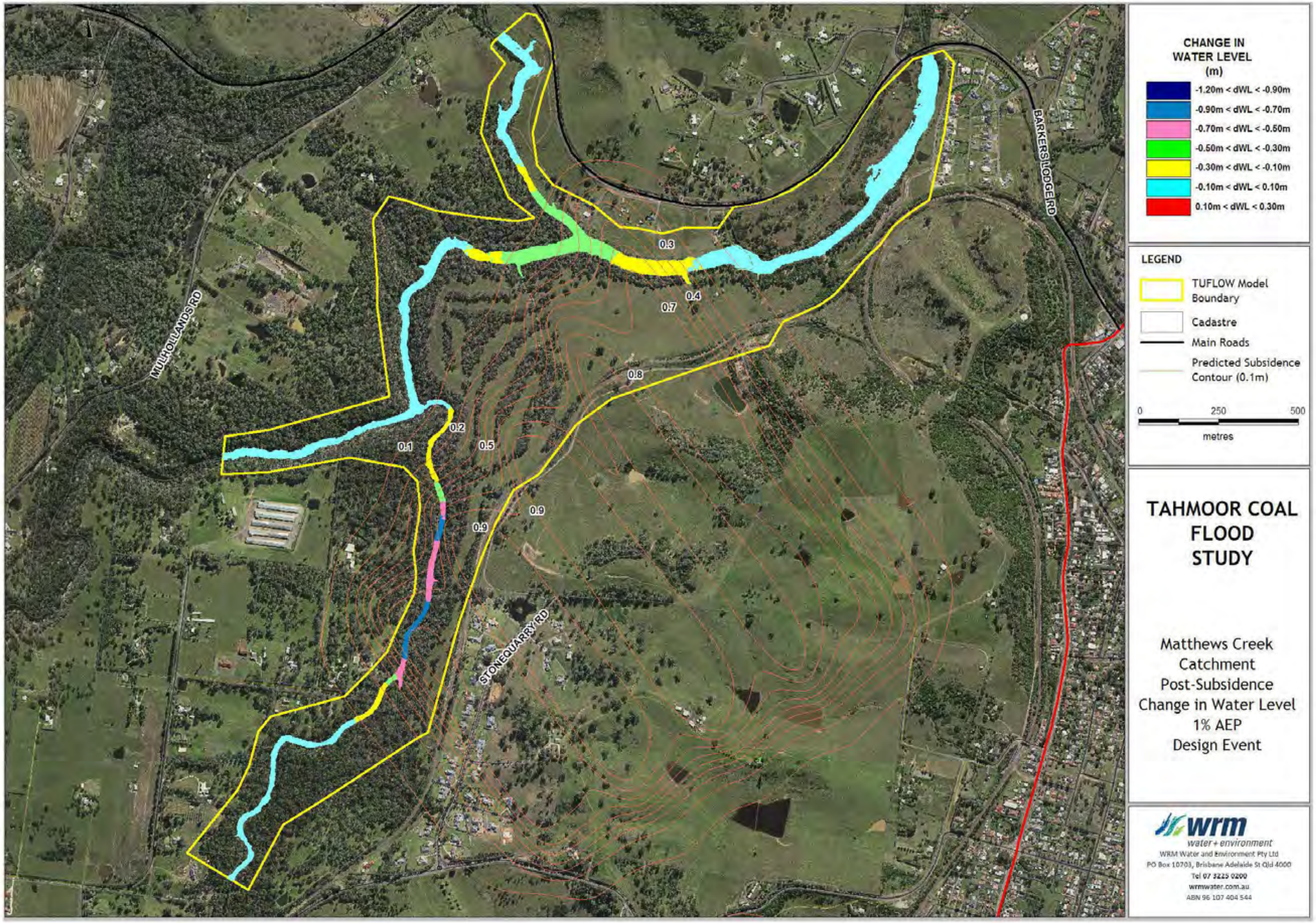
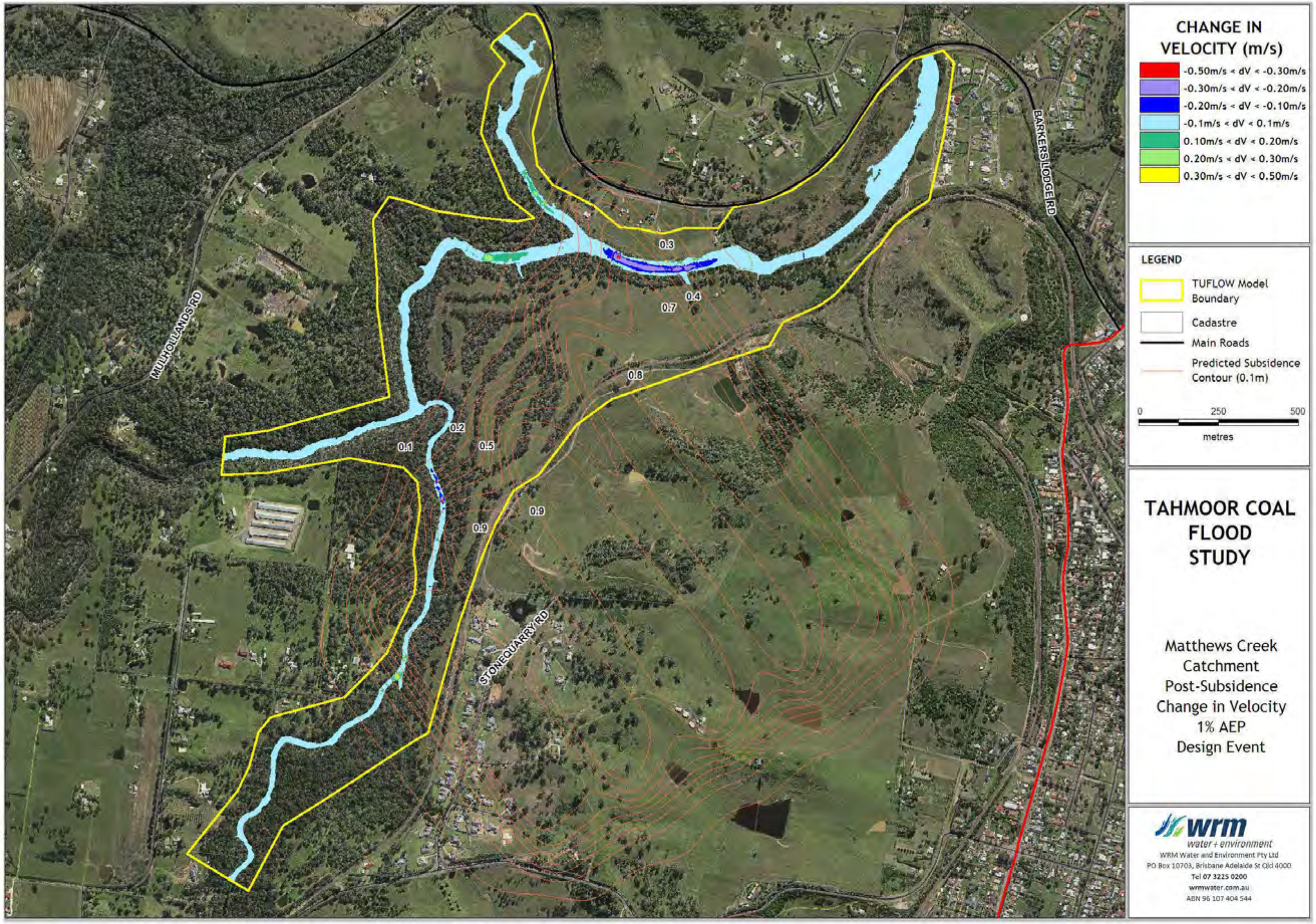
Tel 07 3225 0200
wrmwater.com.au
ABN 96 107 404 544



CHANGE IN WATER LEVEL (m)
-1.20m < dWL < -0.90m
-0.90m < dWL < -0.70m
-0.70m < dWL < -0.50m
-0.50m < dWL < -0.30m
-0.30m < dWL < -0.10m
-0.10m < dWL < 0.10m
0.10m < dWL < 0.30m
LEGEND
TUFLOW Model Boundary
Cadastre
Main Roads
Predicted Subsidence Contour (0.1m)
0
250
500
metres
TAHMOOR COAL FLOOD STUDY
Matthews Creek Catchment
Post-Subsidence
Change in Water Level
1% AEP
Design Event
wrm
water + environment
WRM Water and Environment Pty Ltd
PO Box 10703, Brisbane Adelaide St Qld 4000
Tel 07 3225 0200
wrmwater.com.au
ABN 96 107 404 544
MULHOLLANDS RD
BARKERS LODGE RD
STONEQUARRY RD
0.1
0.2
0.3
0.4
0.5
0.7
0.8
0.9
0.9


CHANGE IN VELOCITY (m/s)
-0.50m/s < dV < -0.30m/s
-0.30m/s < dV < -0.20m/s
-0.20m/s < dV < -0.10m/s
-0.1m/s < dV < 0.1m/s
0.10m/s < dV < 0.20m/s
0.20m/s < dV < 0.30m/s
0.30m/s < dV < 0.50m/s
LEGEND
TUFLOW Model Boundary
Cadastre
Main Roads
Predicted Subsidence Contour (0.1m)
0
250
500
metres
TAHMOOR COAL FLOOD STUDY
Matthews Creek Catchment Post-Subsidence Change in Velocity 1% AEP Design Event
wrm
water + environment
WRM Water and Environment Pty Ltd
PO Box 10703, Brisbane Adelaide St Qld 4000
Tel 07 3225 0200
wrmwater.com.au
ABN 96 107 404 544
MULHOLLANDS RD
BARKERS LODGE RD
STONEQUARRY RD
0.1
0.2
0.3
0.4
0.5
0.7
0.8
0.9
0.9

APPENDIX 6

Groundwater Assessment

23/10/2017

GeoTerra

Tahmoor Coal Pty Ltd
Tahmoor Underground
PO Box 100
TAHMOOR NSW 2573

Attn: Andrew Reid – Environment and Community Manager

Re: Tahmoor Underground Modification 4 – Groundwater Aspects

Andrew,

Please find enclosed a discussion on the groundwater aspects relating to the proposed Tahmoor Underground Modification 4 application.

GENERAL

We understand that Tahmoor Colliery already has an approval for extraction of Longwall 32, and that there is no change to the project description and that the Modification is required due to an improved understanding of the predicted minor subsidence levels, which now extend beyond those previously modelled, into an area delineated as nil subsidence in an earlier development consent.

The area of nil subsidence was initially defined in the current consent by local government land zoning boundaries that existed at the time of the original consent and the previous 20mm limit of subsidence.

LOCAL HYDROGEOLOGY

The predominant outcropping and sub-surface aquifers within the Tahmoor / Thirlmere / Picton area are within the Hawkesbury Sandstone, which are generally low yielding with low hydraulic conductivities.

Seven DPI-W registered private bores, two uncased coal exploration bores, four Tahmoor Colliery (DPI-W registered) open standpipe piezometers and six vibrating wire piezometers are located within the Tahmoor North mining area as shown in **Drawing 1**.

None of these piezometers or bores overlie the proposed Modification area, with the nearest comprising;

- P9 – a 23m deep open standpipe piezometer over Longwall 31 / 32 chain pillar, which is 520m west of the Mod Area
- GW105813 – 168m deep sealed private bore, which is not over any workings and is 480m south of the proposed Modification Area, and
- TNC40 – a 502m deep vibrating wire piezometer array, which is not over any workings and is approximately 630m north-west of the proposed Modification Area

GeoTerra PTY LTD ABN 82 117 674 941
Suite 204, 1 Erskineville Road, NSW
PO Box 530 Newtown NSW 2042
Phone: 02 9519 2190 Mobile 0417 003 502 Email: geoterra@iinet.net.au

Groundwater has been obtained from sandstone aquifers with yields ranging from 0.2L/sec to 5.0L/sec between 18m and 138m below surface.

DPI-W bore data indicates it is likely that significant aquifers are intersected below depths of approximately 18m to 60m, depending on whether the bore is spudded on top of a hill or in a valley. Shallower, low yielding groundwater may be present above that depth range as perched ephemeral aquifers.

Alluvial sediments within the plateau gullies and creek or river beds are too shallow to be used as aquifers for groundwater supply.

CURRENT AND PREDICTED GROUNDWATER IMPACTS

Potential depressurisation in response to the current and historic Tahmoor North underground workings in the Hawkesbury Sandstone is generally restricted to immediately over the extracted longwalls and radially out to approximately 300m from the workings. **Figure 1** illustrates the monitored open standpipe piezometer responses to date.

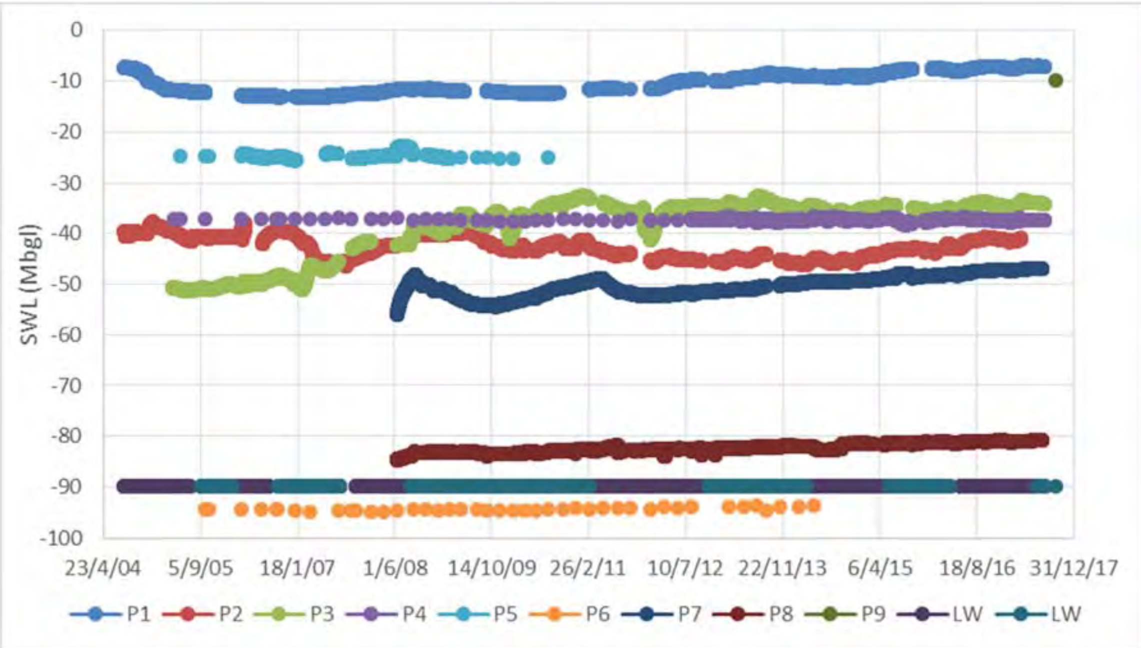


Figure 1 Standing Water Levels and Panel Extraction

At the Bulli Coal seam depth, significant depressurisation has been observed up to 930m from the active workings, although no significant response has been observed at a distance of approximately 1250m.

A schematic representation of the Tahmoor area stratigraphy is shown in **Figure 2**.

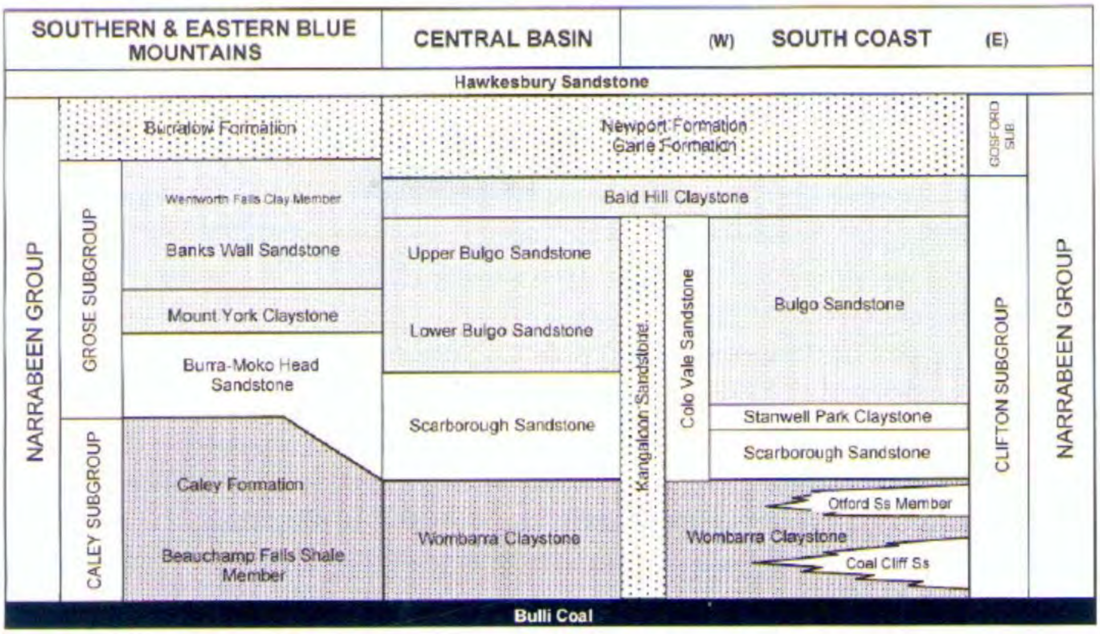


Figure 2 Tahmoor Area Stratigraphy

In open standpipe piezometers that were depressurised by longwall extraction, groundwater level recovery to the pre-mining depth was observed at;

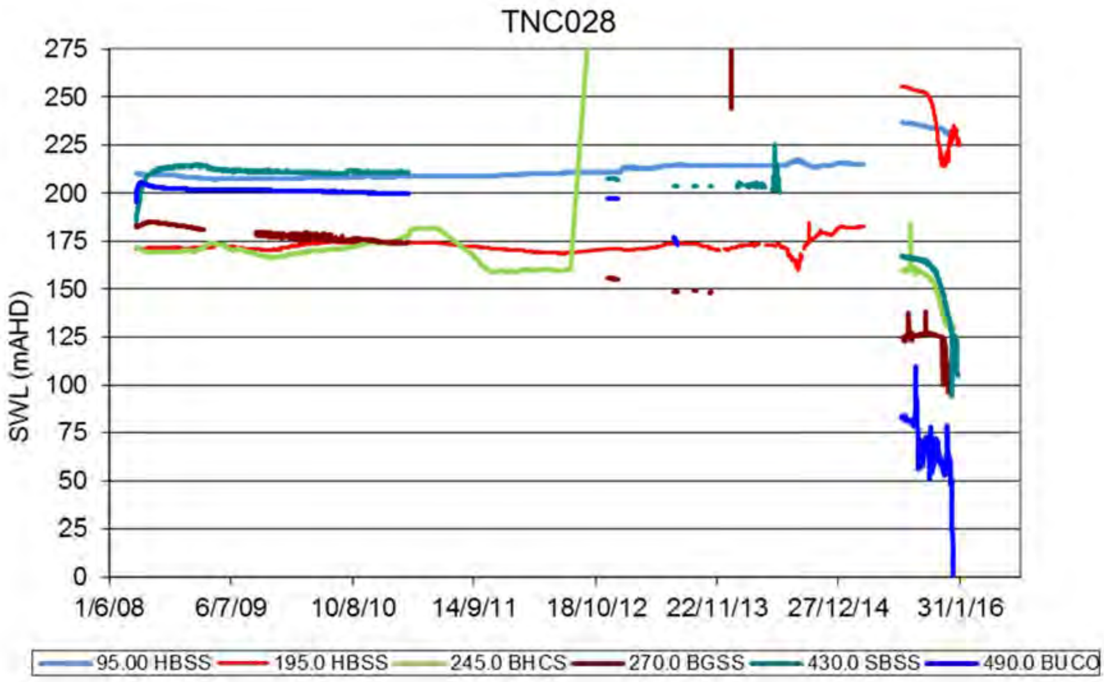
- P1 – had a 6.02m drawdown that peaked during June 2007 during extraction of Longwall 24B and took around 8 years and 8 months to recover to its pre mining level in February 2016;
- P2 - had a 5.47m drawdown that peaked during September 2007 after Longwall 24B extraction and took 11 months to recover to its pre mining level in September 2008, and;
- P7 - had two depressurisation events. The first was a 6.28m drawdown that peaked during November 2009 during extraction of Longwall 25 and took 1 ½ years to recover to its pre mining level during May 2011. The second 3.45m depressurisation peaked during November 2011 during extraction of Longwall 26 and recovered to its original level in approximately 3 ½ years around May 2015

Vibrating wire piezometer responses to longwall extraction within the overburden range between the Hawkesbury Sandstone and Bulli Seam as shown in **Figures 3** and **4.**

No notable recoveries were observed in the VWPs TNC28 and TNC29 over Longwalls 29 and 30 as the traces were discontinued due to rupturing of the VWP cables.

Groundwater level recoveries have also not been observed in TNC36, 40 and 43 below the Hawksbury Sandstone, except in the Bulgo Sandstone at TNC40.

None of the TNC36, 40 or TNC43 VWP arrays overly extracted workings, with TNC36 located approximately 1570m north-west of Longwall 30, whilst TNC40 is located approximately 970m north-east of Longwall 30 and TNC43 is located approximately 700m north-east of Longwall 30.



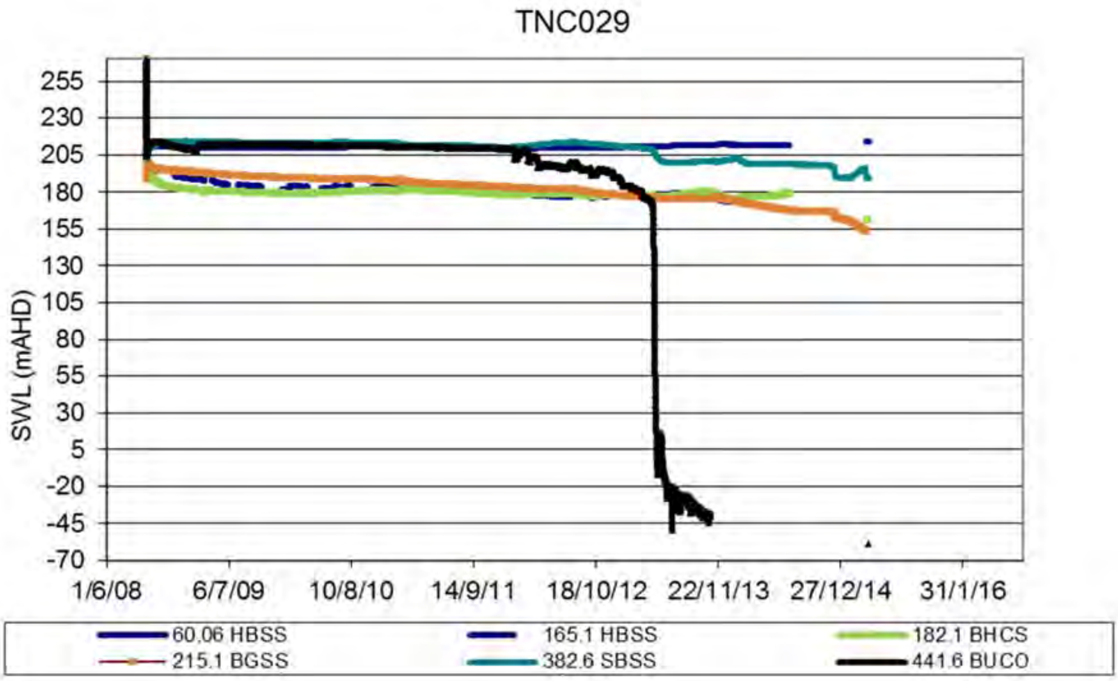


Figure 3 Vibrating Wire Piezometer TNC28 and 29 Groundwater Levels

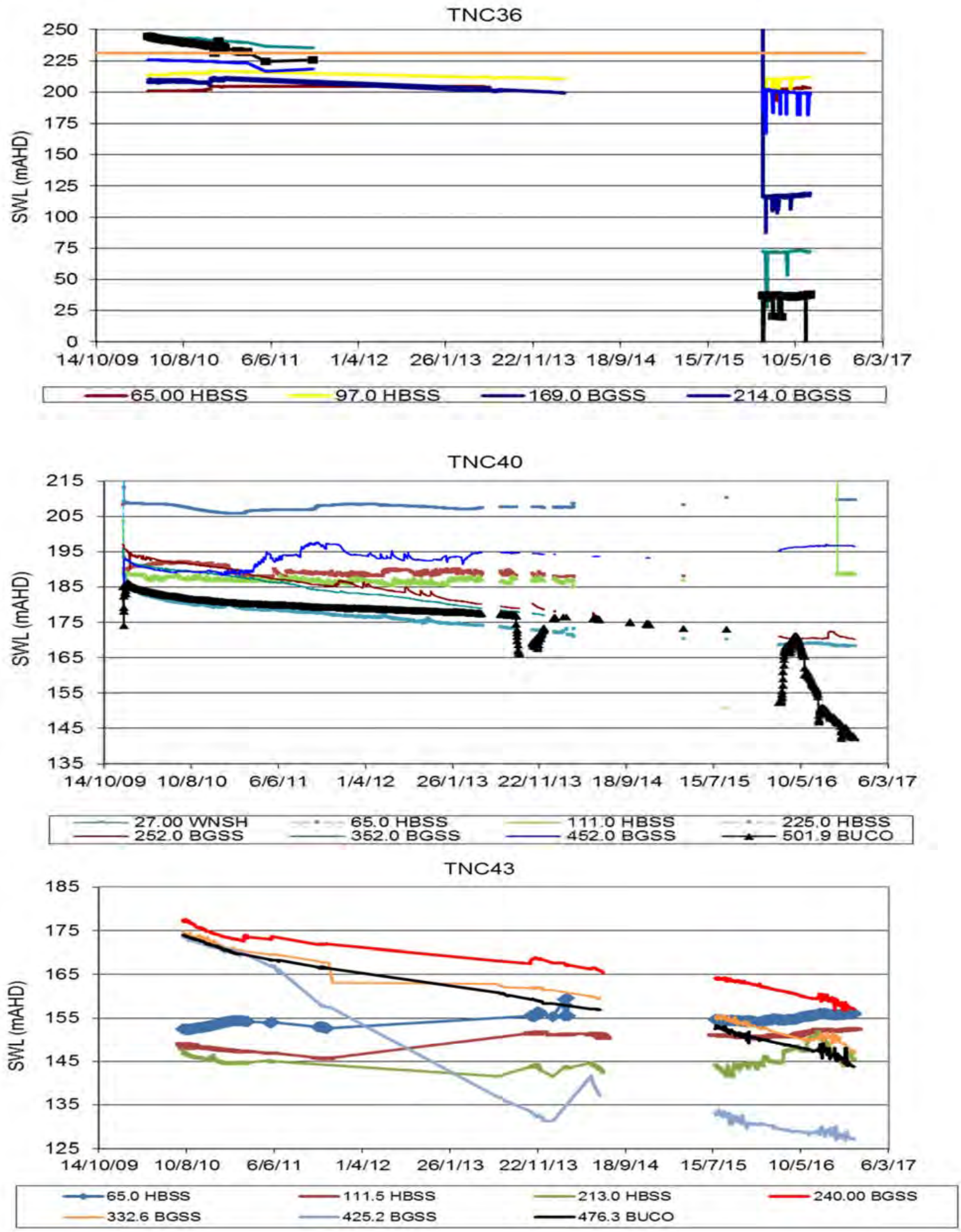


Figure 4 Vibrating Wire Piezometer TNC36, 40 and 43 Groundwater Levels

Longwall 32 is located approximately 200m south of the proposed Modification Area, and is therefore anticipated to have minor Hawkesbury Sandstone depressurisation and, in the underlying aquifers, sequentially up to significant depressurisation in the Bulli Seam.

It should be noted that the large depressurisation decreases seen in TNC28, 29 and TNC 40 within the Bulli Coal Seam (abbreviated to BUCO) are normal and within prediction as a result of the longwall extractions conducted to date.

The pressure drops occur as a result of extraction of the Bulli Coal Seam which generates a mined void within the seam, which, in turn, generates a low (atmospheric) pressure “sink” toward which the regional groundwater within the surrounding unmined coal seam flows laterally. The BUCO depressurisation response increases with proximity to the mined void. Where the VWP array in a sealed borehole overlies an extracted longwall, the water pressure reduction is greatest, whilst the data record abruptly stops, as observed in TNC28 and TNC29, when the VWP is undermined and the logger cables are broken.

The notable depressurisation observed within the overlying aquifers in the Scarborough Sandstone (SBSS), Bulgo Sandstone (BGSS) and Bald Hill Claystone (BHCS) within TNC28 are also normal and within prediction. They are due to vertical migration of depressurisation into the overburden, with generation of the atmospheric pressure “sink” associated with the mined void of a longwall.

The effect is also generated by increased secondary porosity within the overburden through fracturing and bedding separation due to subsidence of the strata. The vertical migration of depressurisation response decreases with height up into the overlying strata, and with horizontal distance out from the mined void. The Hawkesbury Sandstone (particularly the shallowest zones) are predominantly affected by strata fracturing and delamination depressurisation effects, as opposed to upward migration of depressurisation from the mined seam void.

There is no observed surface to seam hydraulic connectivity, i.e. the shallow aquifers and streams do not “drain” into the mine.

Figure 5 indicates the annual groundwater inflow to the mine since 2009 has been generally increasing due to the expansion of the mined void area, along with expansion of the associated low pressure inflow area from within the Bulli Seam and the adjacent overlying aquifers. However, it does not indicate extraction of groundwater from the shallow (Hawkesbury Sandstone) aquifers as they recover with time as shown in **Figures 1, 3** and **4.**

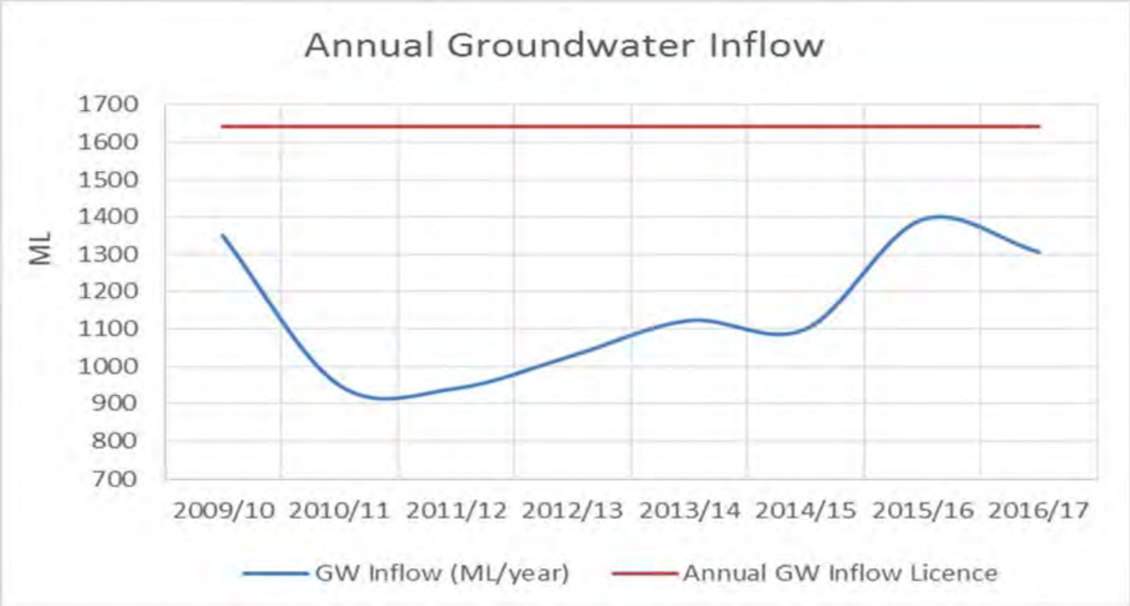


Figure 5 Tahmoor Colliery Total Annual Mine Groundwater Inflow

Figure 6 indicates that the Tahmoor Colliery cumulative rainfall deficit (or rainfall residual) in the same time period as **Figure 5** has an indefinite relationship with the mine's groundwater make, as its groundwater inflows are closely related to expansion of the mined area footprint and the related fractured overburden drawdown area above the workings.

Figure 6 Tahmoor Colliery Cumulative Rainfall Deficit

CONCLUSIONS
Altering the initially assessed subsidence of 20mm up to 70mm within the proposed Modification Area, will not , however, have any observable or significantly increased impacts on aquifers present within the Modification Area (including groundwater levels, quality, water users, Groundwater Dependent Ecosystems (GDEs) or groundwater recharge) compared to the originally assessed impacts

As no observable change is predicted on the aquifers, there are no anticipated increased impacts on the aquifers in terms of the NSW Aquifer Interference Policy.

As there are no private bores within the proposed Modification Area, Tahmoor Colliery's current practice of providing alternate supply of water during any interim periods of groundwater depressurisation until recovery occurs will not be required to be implemented.

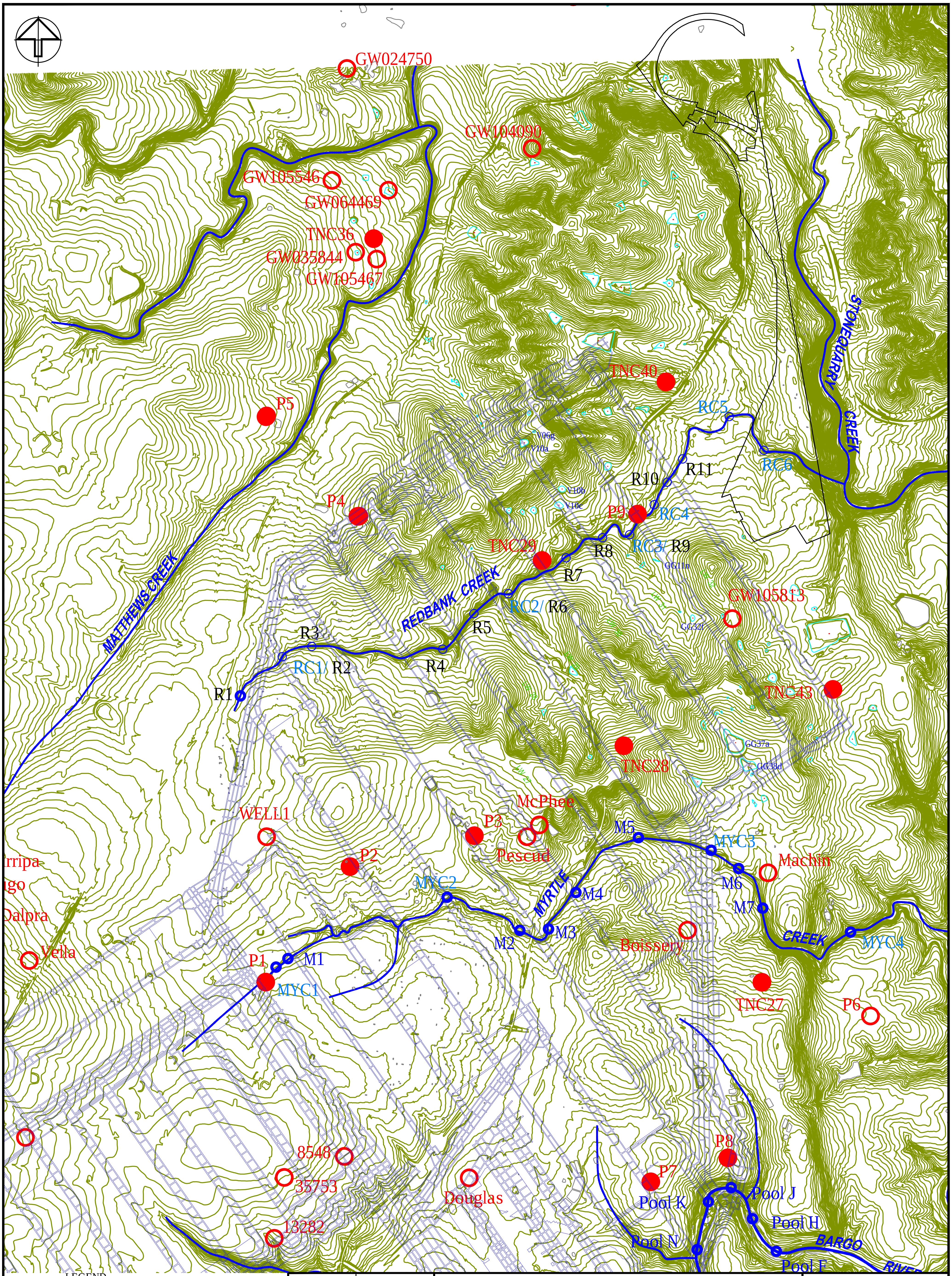
Based on the discussion outlined above, we assess there should be no material change to the approved mine subsidence impacts in regard to groundwater as there are no proposed changes to the approved mine plan at Tahmoor compared to the originally predicted impacts.

RECOMMENDATIONS
It is recommended that the current groundwater monitoring and management practices and processes in force at Tahmoor Colliery be continued.

Regards

GeoTerra Pty Ltd

Andrew Dawkins
Principal Hydrogeologist (AuSIMM CP-Env)



PROJECT:	TA30
DRAWN:	A. DAWKINS
DATE:	5 10 2017
SCALE:	1:30 000

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WATER MONITORING LOCATIONS

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DRAWING1

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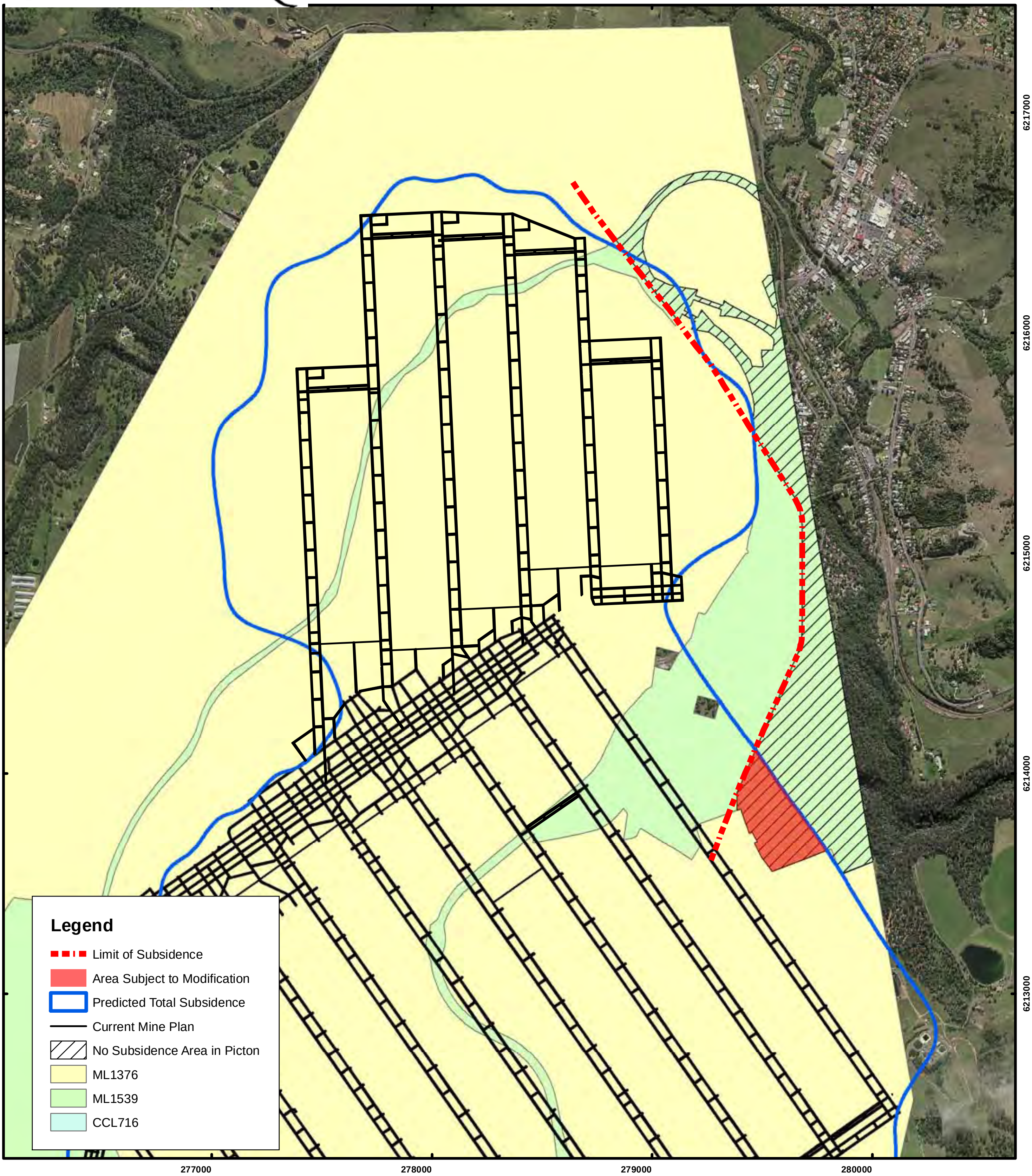
Tahmoor Colliery



Coordinate System: GDA 1994 MGA Zone 56
Projection: Transverse Mercator
Datum: GDA 1994

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Map Size: A4 Portrait

Ref: W:\Environment & Community\00 Arc GIS\Current\Mine Plans\Western Domain\Mine Plan Subsidence Boundaries.mxd

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