mine subsidence ENGINEERING CONSULTANTS

SIMEC

SIMEC Mining:

Tahmoor South Longwalls S1A to S6A

Management Plan for potential impacts to Wollondilly Shire Council Infrastructure

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Sep-22	MSEC1193-02	A	Draft for submission to Wollondilly Shire Council
Oct-22	MSEC1193-02	B	Final for submission following review by Bridge Technical Committee

References:-

AS/NZS ISO 31000:2009 Risk Management – Principles and guidelines

Douglas Partners (2022a) *Report on Geotechnical Assessment – Longwalls S1A to S6A, Bargo*, Douglas Partners, Report No. 210597.00, May 2022.

Douglas Partners (2022b) *Report on Geotechnical Investigation – Detailed Slope Stability Assessment, Longwalls S1A to S6A, Bargo*, Douglas Partners, Report No. 210597.02, August 2022.

JMA (2022a) *Structure Investigation Report – Impact of Far Field Movement, Remembrance Driveway Bridge over Bargo River, Tahmoor*, JMA Solutions, Report No. R0799-R1, August 2022.

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Tables

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Figures

Figures are prefaced by the number of the chapter or the letter of the appendix in which they are presented.

Drawings

Drawings referred to in this report are included in Appendix A at the end of this report.

Drawing No.	*Description*	*Revision*
MSEC1193-01-01	Monitoring plan	A
MSEC1193-03-01	Roads and associated infrastructure	A
MSEC1193-03-02	MSR Rail Viaduct & Remembrance Drive Bridge over Bargo River	A
MSEC1193-03-03	Bargo River Road Bridges	A
MSEC1193-03-04	Rockford Road Bridge over Bargo River	A
MSEC1193-03-05	Arina Road Bridge over Dogtrap Creek	A
MSEC1193-03-06	Wellers Road Bridge over Main Southern Railway	A
MSEC1193-03-07	Remembrance Drive Embankment over Teatree Hollow over LW S3A (RE4)	A
MSEC1193-03-08	Remembrance Drive Cutting and Embankment north of Yarran Road over LWs S4A and S5A (RE3)	A
MSEC1193-03-09	Remembrance Drive Embankment south of Yarran Road over LW S5A (RE2)	A
MSEC1193-03-10	Remembrance Drive Embankment at Wellers Road intersection beyond LW S6A (RE1)	A
MSEC1193-03-11	Remembrance Drive Cutting north of Yarran Road over LW S4A and S5A (RC1)	A

1.1. Background

Tahmoor Coal Pty Ltd (Tahmoor Coal), owns and operates Tahmoor Mine, an existing underground coal mine located approximately 80 km southwest of Sydney in the Southern Coalfields of New South Wales (NSW). Tahmoor Coal is a wholly owned entity within the SIMEC Mining division of the GFG Alliance group. Tahmoor Coal has extracted 36 longwalls to the north and west of the mine's surface facilities.

Tahmoor Coal received development consent in April 2021 for the Tahmoor South Project, which is an extension of the current Tahmoor Mine underground coal mining within the Bulli seam towards the south of the existing Tahmoor Mine.

Tahmoor Coal has submitted an Extraction Plan for Longwalls S1A to S6A (LWs S1A to S6A), which will be the first longwall panels to be extracted in the Tahmoor South domain. The proposed longwalls are located between Tahmoor's surface facilities to the north and the township of Bargo to the south. Infrastructure owned by Wollondilly Shire Council is located within this area.

A summary of the dimensions of LW S1A-S6A are provided in Table 1.1.

Table 1.1 Longwall dimensions

Longwall	Overall void length including the installation heading (m)	Overall void width including the first workings (m)	Overall tailgate chain pillar width (m)
LW S1A	1,711	283	-
LW S2A	1,768	285	38
LW S3A	1,808	285	36
LW S4A	1,860	285	36
LW S5A	1,949	285	36
LW S6A	1,999	285	36

This Management Plan provides detailed information about how the risks associated with mining beneath the infrastructure will be managed by Tahmoor Coal and Wollondilly Shire Council.

The Management Plan is a live document that can be amended at any stage of mining, to meet the changing needs of Tahmoor Coal and Wollondilly Shire Council.

1.2. Wollondilly Shire Council assets potentially affected by LW S1A-S6A

A map showing the locations of Wollondilly Shire Council infrastructure in relation to LW S1A-S6A is shown in Drawing No. MSEC1193-03-01.

The main road within the Study Area is Remembrance Drive which runs along the western side of the Main Southern Railway and crosses directly above the proposed Longwalls LW S1A-S6A. The road provides a connection between the M31 Hume Motorway and the township of Bargo with the township of Tahmoor to the north of the Study Area. The total length of Remembrance Driveway located within the Study Area is 3 km.

Caloola Road and Yarran Road are one-way sealed roads that connect to Remembrance Drive from the west. The two roads are located within the Study Area.

Great Southern Road runs alongside the eastern side of the Main Southern Railway and becomes Avon Dam Road, which connects to the M31 Hume Motorway. Only the northern end of Great Southern Road is located within the Study Area. Charlies Point Road is a sealed local road that connects Great Southern Road and Arina Road.

The local roads are maintained by Wollondilly Shire Council.

There are no bridges along local roads within the vicinity of LW S1A-S6A., though some bridges may experience far field movements during the mining of LW S1A-S6A. A summary of the closest distances of LW S1A to S6A to the bridges are provided in Table 1.2.

Table 1.2 Bridges potentially affected by far field movements

Bridge	Closest distance (m)	Closest LW	Closest LW end
Remembrance Drive Bridge over the Bargo River and Main Southern Railway	1,690 m	LW S1A	Finishing end (North-western end)
Bargo River Road Bridge over the Main Southern Railway (Potters Cutting Overbridge)	2,000 m	LW S1A	Finishing end (North-western end)
Bargo River Road Bridge over a tributary to Bargo River	1,790 m	LW S1A	Finishing end (North-western end)
Arina Road Bridge over Dog Trap Creek	2,235 m	LW S1A	Commencing end (South-eastern end)
Rockford Road Bridge over Bargo River	2,335 m	LW S1A	Commencing end (South-eastern end)
Wellers Road Overbridge over the Main Southern Railway	370 m	LW S6A	Commencing end (South-eastern end)

The Remembrance Drive Bridge over the Bargo River and Main Southern Railway and the two railway overbridges (Bargo River Road and Wellers Road) are managed by the railway infrastructure owners and operators. Risk control measures to manage potential impacts on these bridges are described in a separate management plan for the Main Southern Railway, which will be developed in consultation with the Australian Rail Track Corporation (ARTC) and Transport for NSW (TfNSW). A copy of that management plan can be provided to Wollondilly Shire Council.

There are several road drainage culverts located within the Study Area of LW S1A to S6A, as shown in Drawing No. MSEC1193-03-01. The culverts are reinforced concrete pipes (RCP), with the exception of one earthenware pipe on Charlies Point Road. The pipe diameters vary between 500 mm and 1.8 metres.

Some of the culverts along Remembrance Drive are buried in earth-filled embankments. Remembrance Drive also passes through an excavated road cutting.

1.3. Consultation

1.3.1. Consultation with Wollondilly Shire Council

Tahmoor Coal regularly consults with Wollondilly Shire Council in relation to mine subsidence effects. This includes consultation during the development of subsidence management plans for previous Longwalls 22 to 32 and LW W1-W4, and regular reporting of subsidence movements and impacts.

Details regarding consultation and engagement are outlined below:

- Feedback was provided by Wollondilly Shire Council in relation to the provision of structural drawings for bridges that are owned and managed by Council;
- Submission of draft Management Plan for review and comment on 15 September;
- Meeting with Mike Nelson, Akash Nafizul, Annette Bell and Richard Thackeray (Wollondilly Shire Council), Ross Barber, Amanda Fitzgerald, Amanda Bateman (Tahmoor Coal), and Daryl Kay (MSEC) on 30 September to discuss the draft Subsidence Management Plan for LWs S1A to S6A.

Tahmoor Coal will continue to consult regularly with Wollondilly Shire Council during the extraction of LW S1A-S6A in relation to mine subsidence effects from mining.

1.3.2. Consultation with Government Agencies & Key Infrastructure Stakeholders

Government agencies including the NSW Department of Planning & Environment, Resources Regulator, Mine Safety Operations, Subsidence Advisory NSW and key infrastructure stakeholders including Endeavour Energy, Sydney Water, Telstra and Jemena have also been consulted as part of the Extraction Plan approval process.

1.4. Limitations

This Management Plan is based on the predictions of the effects of mining on surface infrastructure as provided in Report No. MSEC1192 by Mine Subsidence Engineering Consultants (MSEC, 2022). Predictions are based on the planned configuration of LW S1A-S6A at Tahmoor South (as shown in Drawing No. MSEC1193-03-01), along with available geological information and data from numerous subsidence studies for longwalls previously mined in the area.

Infrastructure considered in this Plan has been identified from site visits and aerial photographs and from discussions between Tahmoor Coal representatives and Wollondilly Shire Council.

The impacts of mining on surface and sub-surface features have been assessed in detail. However, it is recognised that the prediction and assessment of subsidence can be relied upon only to a certain extent. The limitations of the prediction and assessment of mine subsidence are discussed in report MSEC1192 by Mine Subsidence Engineering Consultants.

As discussed in the report, there is a low probability that ground movements and their impacts could exceed the predictions and assessments. However, if these potentially higher impacts are considered prior to mining, they can be managed. This Management Plan will not necessarily prevent impacts from longwall mining, but will limit the impacts by establishing appropriate procedures that can be followed should evidence of increased impacts emerge.

1.5. Objectives

The objectives of this Management Plan are to establish procedures to measure, control, mitigate and repair potential impacts that might occur to roads, bridges and culverts.

The objectives of the Management Plan have been developed to:

- Ensure the safe and serviceable operation of all surface infrastructure. Public and workplace safety is paramount. Ensure that the health and safety of people who may be present on public property or Wollondilly Shire Council property are not put at risk due to mine subsidence;
- Avoid disruption and inconvenience, or, if unavoidable, keep to minimal levels;
- Monitor ground movements and the condition of infrastructure during mining;
- Initiate action to mitigate or remedy potential significant impacts that are expected to occur on the surface;
- Provide a plan of action in the event that the impacts of mine subsidence are greater than those that are predicted;
- Establish a clearly defined decision-making process to ensure timely implementation of risk control measures for high consequence but low likelihood mine subsidence induced hazards that involve potential serious injury or illness to a person or persons that may require emergency evacuation, entry or access restriction or suspension of work activities;
- Provide a forum to report, discuss and record impacts to the surface. This will involve Tahmoor Coal, Wollondilly Shire Council, relevant government agencies as required, and consultants as required; and
- Establish lines of communication and emergency contacts.

1.6. Scope

The Management Plan is to be used to protect and monitor the condition of the Wollondilly Shire Council infrastructure identified to be at risk due to mine subsidence and to ensure that the health and safety of people who may be present on public property or Wollondilly Shire Council property are not put at risk due to mine subsidence. The major items at risk are:

- Local roads;
- Culverts;
- Embankments;
- Cuttings; and
- Bridges.

The Management Plan only covers infrastructure that is located within the limit of subsidence, which defines the extent of land that may be affected by mine subsidence as a result of mining LWs S1A to S6A only. The management plan does not include other roads, bridges and culverts owned by Wollondilly Shire Council which lie outside the extent of this area.

1.7. Proposed mining schedule

It is planned that LW S1A-S6A will extract coal working northwest from the southeastern ends. This Management Plan covers longwall mining until completion of mining in LW S6A and for sufficient time thereafter to allow for completion of subsidence effects. The current schedule of mining is shown in Table 1.3.

Table 1.3 Schedule of Mining

Longwall	Start Date	Completion Date
LW S1A	September 2022	April 2023
LW S2A	May 2023	January 2024
LW S3A	February 2024	September 2024
LW S4A	October 2024	June 2025
LW S5A	July 2025	February 2026
LW S6A	March 2026	November 2026

Please note the above schedule is subject to change due to unforeseen impacts on mining progress. Tahmoor Coal will keep Wollondilly Shire Council informed of changes.

1.8. Definition of Active Subsidence Zone

As a longwall progresses, subsidence begins to develop at a point in front of the longwall face and continues to develop after the longwall passes. The majority of subsidence movement typically occurs within an area 150 metres in front of the longwall face to an area 450 metres behind the longwall face.

This is termed the "active subsidence zone" for the purposes of this Management Plan, where surface monitoring is generally conducted. The active subsidence zone for each longwall is defined by the area bounded by the predicted 20 mm subsidence contour for the active longwall and a distance of 150 metres in front and 450 metres behind the active longwall face, as shown by Fig. 1.1.

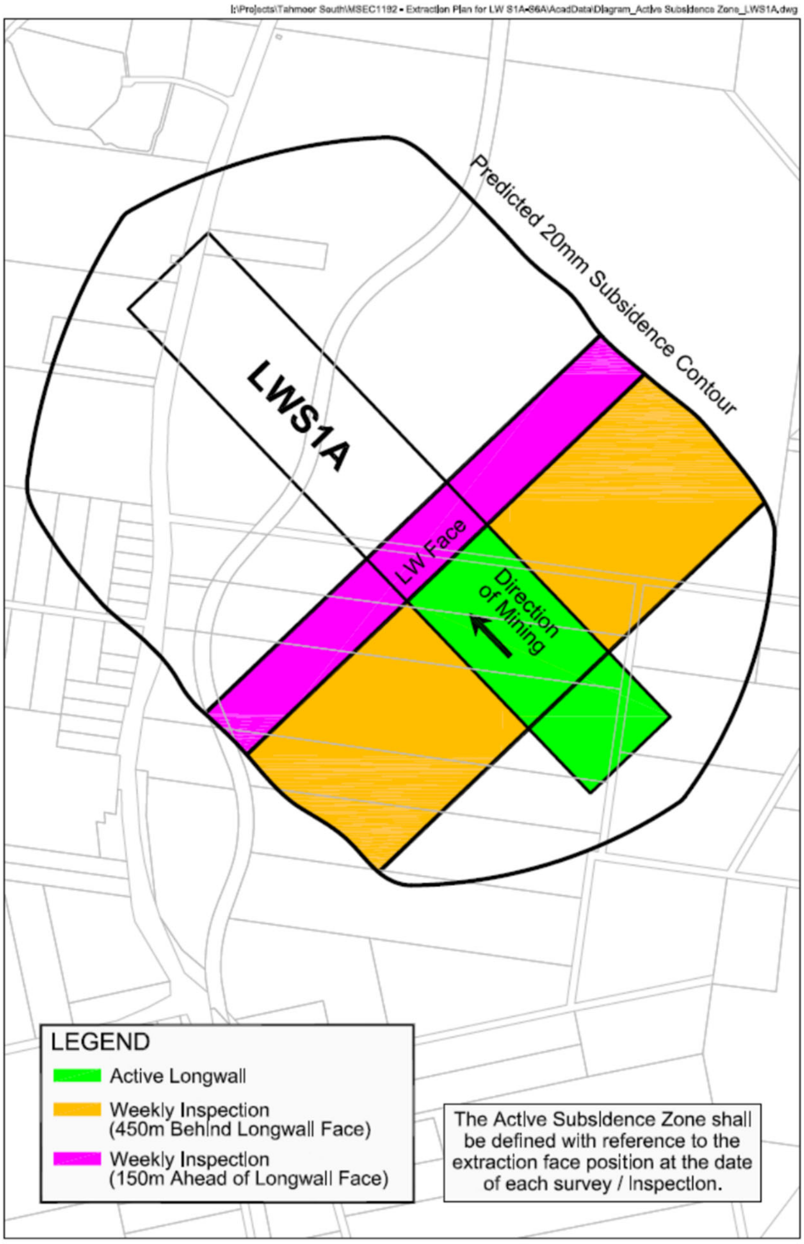

Fig. 1.1 Diagrammatic Representation of Active Subsidence Zone

1.9. Compensation

The *Coal Mine Subsidence Compensation Act 2017* (MSC Act) is administered by Subsidence Advisory NSW (Mine Subsidence Board).

Currently, under the *Coal Mine Subsidence Compensation Act 2017*, any claim for mine subsidence damage needs to be lodged with Subsidence Advisory NSW. Subsidence Advisory NSW staff will arrange for the damage to be assessed by an independent specialist assessor. If the damage is attributable to mine subsidence, a scope will be prepared and compensation will be determined. For further details please refer to *Guidelines – Process for Claiming Mine Subsidence Compensation* at www.subsideneadvisory.nsw.gov.au.

2.1. NSW Work Health & Safety Legislation

All persons conducting a business or undertaking (PCBUs), including mine operators and contractors, have a primary duty of care to ensure the health and safety of workers they engage, or whose work activities they influence or direct. The responsibilities are legislated in *Work Health and Safety Act 2011* and the *Work Health and Safety (Mines and Petroleum Sites) Act 2013* and associated Regulations (collectively referred to as the 'WHS laws').

The *Work Health and Safety (Mines and Petroleum Sites) Regulation 2014* commenced on 1 February 2015 and contains specific regulations in relation to mine subsidence.

As outlined in the Guide by the NSW Department of Trade & Investment Mine Safety:

"a PCBU must manage risks to health and safety associated with mining operations at the mine by:

- *complying with any specific requirements under the WHS laws*
- *identifying reasonably foreseeable hazards that could give rise to health and safety risks*
- *ensuring that a competent person assesses the risk*
- *eliminating risks to health and safety so far as is reasonably practicable*
- *minimising risks so far as is reasonably practicable by applying the hierarchy of control measures, any risks that it is are not reasonably practical to eliminate*
- *maintaining control measures*
- *reviewing control measures.*

The mine operator's responsibilities include developing and implementing a safety management system that is used as the primary means of ensuring, so far as is reasonably practicable:

- *the health and safety of workers at the mine, and*
- *that the health and safety of other people is not put at risk from the mine or work carried out as part of mining operations."*

Detailed guidelines have also been released by the NSW Department of Planning & Environment, Resources Regulator, Mine Safety Operations (MSO, 2017).

The risk management process has been carried out in accordance with guidelines published by the NSW Department of Planning & Environment, Resources Regulator, Mine Safety Operations (MSO, 2017). The following main steps of subsidence risk management have been and will be undertaken, in accordance with the guidelines.

1. identification and understanding of subsidence hazards
2. assessment of risks of subsidence
3. development and selection of risk control measures
4. implementation and maintenance of risk control measures, and
5. continual improvement and change management.

Each of the above steps have been or will be conducted together with the following processes.

1. consultation, co-operation and co-ordination, and
2. monitoring and review.

This Management Plan documents the risk control measures that are planned to manage risks to health and safety associated with the mining of LW S1A-S6A in accordance with the WHS laws.

2.2. General

The method of assessing potential mine subsidence impacts in the Management Plan is consistent with the Australian/New Zealand Standard for Risk Management (AS/NZS ISO 31000:2009). The Standard defines the terms used in the risk management process, which includes the identification, analysis, assessment, treatment and monitoring of potential mine subsidence impacts. In this context:-

2.2.1. Consequence

'The outcome of an event expressed qualitatively or quantitatively, being a loss, injury, disadvantage or gain. There may be a range of possible outcomes associated with an event.' The consequences of a hazard are rated from negligible to catastrophic.

2.2.2. Likelihood

'Used as a qualitative description of probability or frequency.' The likelihood can range from rare to almost certain.

2.2.3. Hazard

'A source of potential harm or a situation with a potential to cause loss.'

2.2.4. Method of assessment of potential mine subsidence impacts

The method of assessing potential mine subsidence impacts combines the likelihood of an impact occurring with the consequence of the impact occurring. In this Management Plan, the likelihood and consequence are combined via the SIMEC Risk Matrix to determine an estimated level of risk for particular events or situations. A copy of the Risk Matrix is included in the Appendix of this Management Plan.

3.1. Maximum predicted conventional subsidence parameters

Predicted mining-induced conventional subsidence movements were provided in Report No. MSEC1192, which was prepared in support of Tahmoor Coal's Extraction Plan for LW S1A-S6A.

A summary of the maximum predicted values of incremental conventional subsidence, tilt and curvature, due to the extraction of each of the proposed amended longwalls, is provided in Table 3.1. The predicted ground strains are discussed in Section 3.4. The predicted tilts provided in this table are the maxima after the completion of each of the proposed longwalls. The predicted curvatures are the maxima at any time during or after the extraction of each of the proposed longwalls.

Table 3.1 Maximum predicted incremental conventional subsidence, tilt and curvature resulting from the extraction of each of the proposed longwalls

Longwall	Maximum predicted incremental conventional subsidence (mm)	Maximum predicted incremental conventional tilt (mm/m)	Maximum predicted incremental conventional hogging curvature (km^{-1})	Maximum predicted incremental conventional sagging curvature (km^{-1})
LW S1A	800	7.0	0.08	0.22
LW S2A	950	7.5	0.08	0.22
LW S3A	950	8.0	0.09	0.22
LW S4A	950	8.0	0.09	0.22
LW S5A	950	8.0	0.10	0.22
LW S6A	975	8.3	0.09	0.23

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature, after the extraction of each of the proposed amended longwall series, is provided in Table 3.2.

Table 3.2 Maximum predicted total conventional subsidence, tilt and curvature after the extraction of each of the proposed longwalls

Longwalls	Maximum predicted total conventional subsidence (mm)	Maximum predicted total conventional tilt (mm/m)	Maximum predicted total conventional hogging curvature (km^{-1})	Maximum predicted total conventional sagging curvature (km^{-1})
LW S1A	800	7.0	0.08	0.22
LW S2A	1,000	8.0	0.10	0.22
LW S3A	1,200	8.0	0.10	0.22
LW S4A	1,250	8.5	0.13	0.22
LW S5A	1,350	9.0	0.14	0.22
LW S6A	1,350	9.5	0.14	0.24

The maximum predicted total subsidence, after the completion of the proposed longwalls, is 1,350 mm which represents around 61 % of the extraction height. The maximum predicted total conventional tilt is 9.5 mm/m (i.e. 0.95 %), which represents a change in grade of 1 in 95. The maximum predicted total conventional curvatures are 0.14 km^{-1} hogging and 0.24 km^{-1} sagging, which represent minimum radii of curvature of 7.1 kilometres and 4.2 kilometres, respectively.

The values provided in the above table are the maximum predicted conventional subsidence parameters which occur within the Study Area.

3.2. Comparison of Measured and Predicted Subsidence at Tahmoor Mine

Predictions using MSEC's Incremental Profile Method have been continually tested and refined during the mining of previous Longwalls 22 to 32 and Longwalls West 1 to West 3 (LW W1-W3), as described in Report No. MSEC1192.

The extraction of longwalls at Tahmoor Mine has generally resulted in mine subsidence movements that were typical of those observed above other collieries in the Southern Coalfield of NSW at comparable depths of cover.

Longwalls 14B to 19 were mined between 1995 and 2002 and are located adjacent to LW S1A-S6A. A comparison between observed and predicted subsidence, tilt and curvature is shown along the 1000 Line in Fig. 3.1. While there is reasonable correlation, it is highlighted that, in some locations the observed subsidence, tilts and curvatures have exceeded prediction.

It is also difficult make meaningful comparisons between the profiles of raw observed curvature and predicted conventional curvature. The reason for this is that survey tolerance can be a large proportion of the measured curvatures and hence this can result in very irregular curvature profiles. When observed curvatures have been derived from smoothed subsidence profiles, a reasonable correlation between predicted and observed profiles can generally be found. Further details are provided in Report No. MSEC1192.

While reasonable correlations have generally been observed at Tahmoor Mine, substantially increased subsidence was observed over the predicted subsidence levels during the mining of LW 24A and then similar increased subsidence movements were also observed above the southern ends of LWs 25 to 27 and the commencing end of LW 32. This was a very unusual event for the Southern Coalfield and are linked to the presence of the Nepean Fault. Further details are provided in Report No. MSEC1192.

While the proposed LW S1A-S6A are not located near the Nepean Fault, the experiences are a reminder that increased subsidence movements can occur. Tahmoor Coal has extensive experience in successfully managing potential subsidence impacts on surface features, even when actual subsidence is substantially greater than the magnitudes that have been predicted above LW S1A-S6A.

This Management Plan, therefore, includes monitoring to measure the development of subsidence during the early stages of extraction to confirm that subsidence is developing within predictions. The Management Plan has been developed to manage potential impacts that could occur even if greater than predicted subsidence occurs. The plan includes regular reviews of observed subsidence movements to ensure that planned measures to manage potential subsidence impacts on Council infrastructure are adequate and effective.

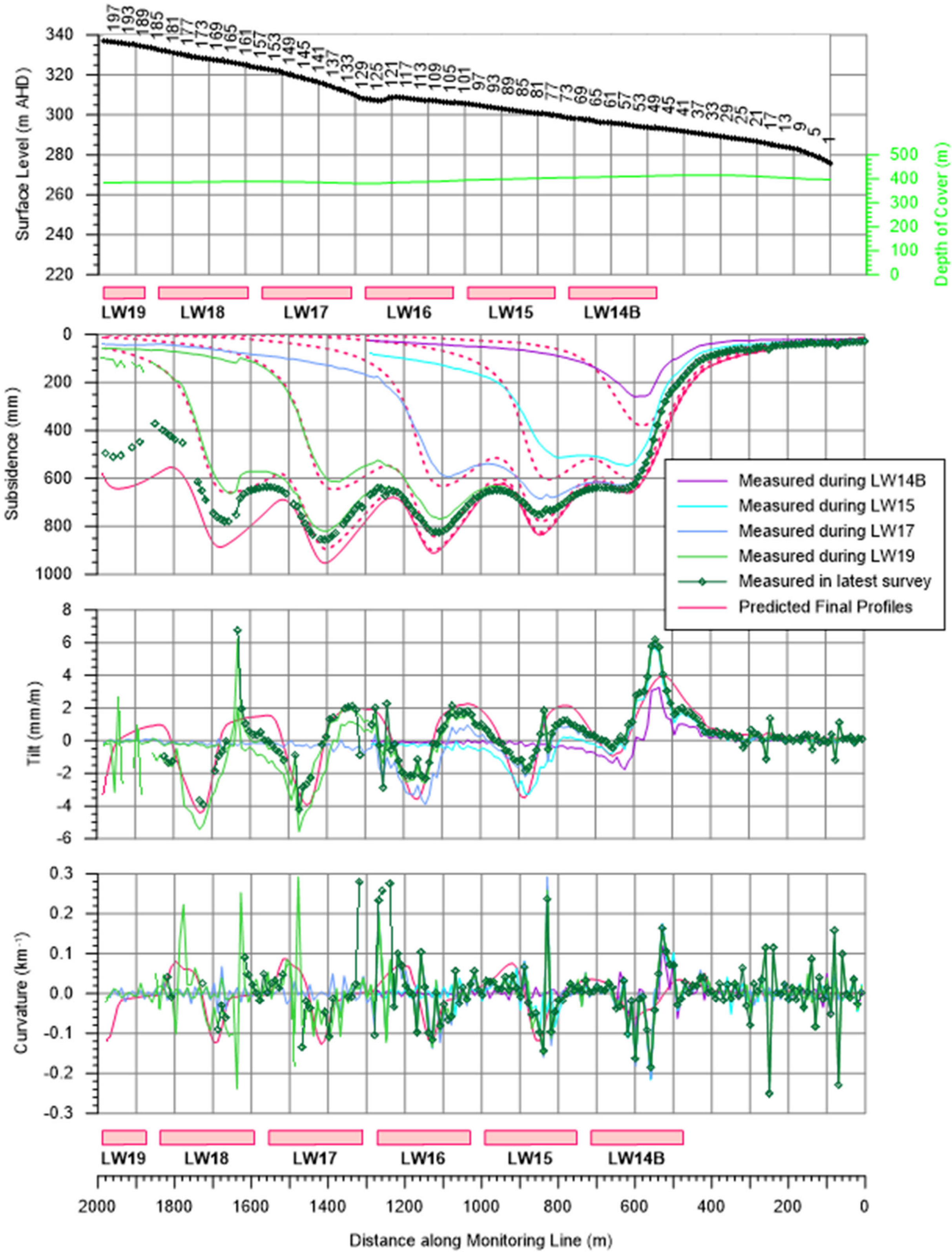

Fig. 3.1 Comparison between observed and predicted subsidence along 1000 Line across LWs 14B to 19 at Tahmoor Mine

3.3. Comparison of measured and predicted subsidence for single panels

Predictions using MSEC's Incremental Profile Method have been continually tested and refined during the mining of previous Longwalls 22 to 32 and LW W1-W3, as described in Report No. MSEC1192.

In this case, LW S1A will be first longwall in a new series.

Observed subsidence above single panels is typically more variable than above subsequent longwall panels in a series. The variations are due to different strengths of the overburden strata above the panel, which is supported on all four sides of the longwall.

A review of observed subsidence for single panels at Tahmoor Mine has been conducted. A summary of observed maximum subsidence against predictions from the calibrated Incremental Profile Method is provided in Fig. 3.2.

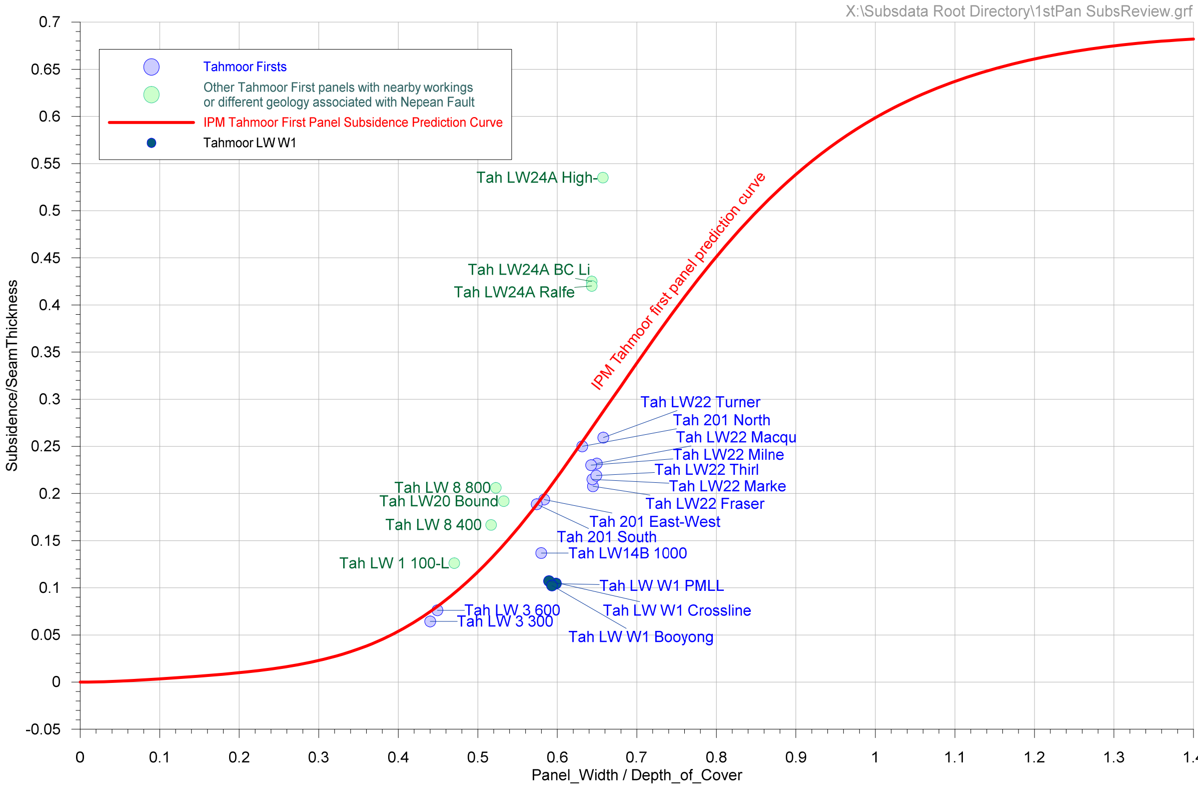

Fig. 3.2 Comparison between observed and predicted maximum subsidence for single panels at Tahmoor Mine

It can be seen from Fig. 3.2 that there has been a reasonable correlation between predicted and observed maximum subsidence for some single panels at Tahmoor Mine. This includes LW 14B, which is located adjacent to LW S1A. LW 1 was also adjacent to LW S1A but while it was the first longwall extracted at Tahmoor Mine, total extraction had occurred immediately adjacent to the longwall. LW 1 is, therefore, not an isolated, single panel and can be considered to be the second panel in a series.

Special circumstances also exist for other cases that are highlighted in green in Fig. 3.2 along with LW 1. LWs 8, 20 and 24A were also located adjacent to total extraction workings are not isolated, single panels. LWs 8 and 24A were also located near the Nepean Fault where increased subsidence movements have been observed.

This Management Plan, therefore, includes plans to measure the development of subsidence during the early stages of extraction of LW S1A to confirm that subsidence is developing within predictions. The Management Plan has been developed to manage potential impacts that could occur even if greater than predicted subsidence occurs. The plan includes regular reviews of observed subsidence movements to ensure that planned measures to manage potential subsidence impacts on Council infrastructure are adequate and effective.

3.4. Predicted strain

The prediction of strain is more difficult than the predictions of subsidence, tilt and curvature. The reason for this is that strain is affected by many factors, including ground curvature and horizontal movement, as well as local variations in the near surface geology, the locations of pre-existing natural joints at bedrock, and the depth of bedrock. Survey tolerance can also represent a substantial portion of the measured strain, in cases where the strains are of a low order of magnitude. The profiles of observed strain, therefore, can be irregular even when the profiles of observed subsidence, tilt and curvature are relatively smooth.

In previous MSEC subsidence reports, predictions of conventional strain were provided based on the best estimate of the average relationship between curvature and strain. Similar relationships have been proposed by other authors. The reliability of the strain predictions was highlighted in these reports, where it was stated that measured strains can vary considerably from the predicted conventional values.

Adopting a linear relationship between curvature and strain provides a reasonable prediction for the conventional tensile and compressive strains. The locations that are predicted to experience hogging or convex curvature are expected to be net tensile strain zones and locations that are predicted to experience sagging or concave curvature are expected to be net compressive strain zones. In the Southern Coalfield, it has been found that a factor of 15 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains.

At a point, however, there can be considerable variation from the linear relationship, resulting from non-conventional movements or from the normal scatters which are observed in strain profiles. When expressed as a percentage, observed strains can be many times greater than the predicted conventional strain for low magnitudes of curvature. In this report, therefore, we have provided a statistical approach to account for the variability, rather than providing a single predicted conventional strain.

The data used in the analysis of observed strains included those resulting from both conventional and non-conventional anomalous movements, but did not include those resulting from valley-related effects, which are discussed separately in the impact assessments for the natural and built features provided in Chapters 5 and 6. The strains resulting from damaged or disturbed survey marks have also been excluded.

3.4.1. Analysis of strains measured in survey bays

For features that are in discrete locations, such as building structures, farm dams and archaeological sites, it is appropriate to assess the frequency of the observed maximum strains for individual survey bays.

Predictions of strain above goaf

A database of survey data has been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of the previous longwalls at Tahmoor, Appin and West Cliff Collieries, for survey bays that were located directly above goaf or the chain pillars that are located between the extracted longwalls, which has been referred to as "*above goaf*".

A histogram of the maximum observed total tensile and compressive strains measured in survey bays above goaf, for monitoring lines at Tahmoor, Appin and West Cliff Collieries is provided in Fig. 3.3. Probability distribution functions, based on fitted *Generalised Pareto Distributions (*GPDs), have also been shown in this figure.

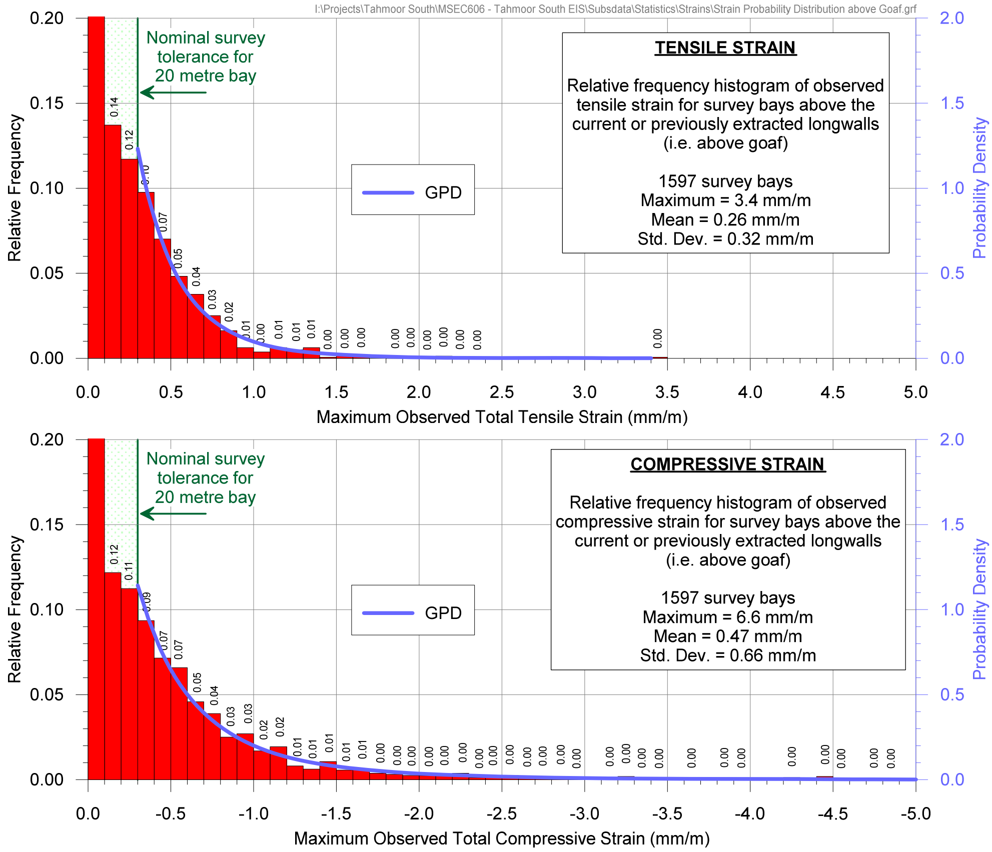

Fig. 3.3 Distributions of the maximum measured tensile and compressive strains for survey bays located above goaf at Tahmoor, Appin and West Cliff Collieries

The 95 % confidence levels for the maximum total strains that the individual survey bays *above goaf* experienced at any time during mining at Tahmoor, Appin and West Cliff Collieries were 0.9 mm/m tensile and 1.6 mm/m compressive. The strains for the proposed longwalls are predicted to be 20 % to 40 % greater than those previously observed at these collieries and, therefore, it is expected that 95 % of the strains measured *above goaf* would be less than 1.3 mm/m tensile and 2.2 mm/m compressive.

The 99 % confidence levels for the maximum total strains that the individual survey bays *above goaf* experienced at any time during mining at Tahmoor, Appin and West Cliff Collieries were 1.4 mm/m tensile and 3.1 mm/m compressive. Similarly, it is expected that 99 % of the strains measured *above goaf* for the proposed longwalls would be less than 2.0 mm/m tensile and 4.3 mm/m compressive.

Predictions of strain above solid coal

The survey database has also been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of the previous longwalls at Tahmoor, Appin and West Cliff Collieries, for survey bays that were located beyond the goaf edges of the mined panels and positioned on unmined areas of coal, i.e. outside panels but within 200 metres of the nearest longwall goaf edge, which has been referred to as "*above solid coal*".

A histogram of the maximum observed tensile and compressive strains measured in survey bays above solid coal, for monitoring lines at Tahmoor, Appin and West Cliff Collieries is provided in Fig. 3.4. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

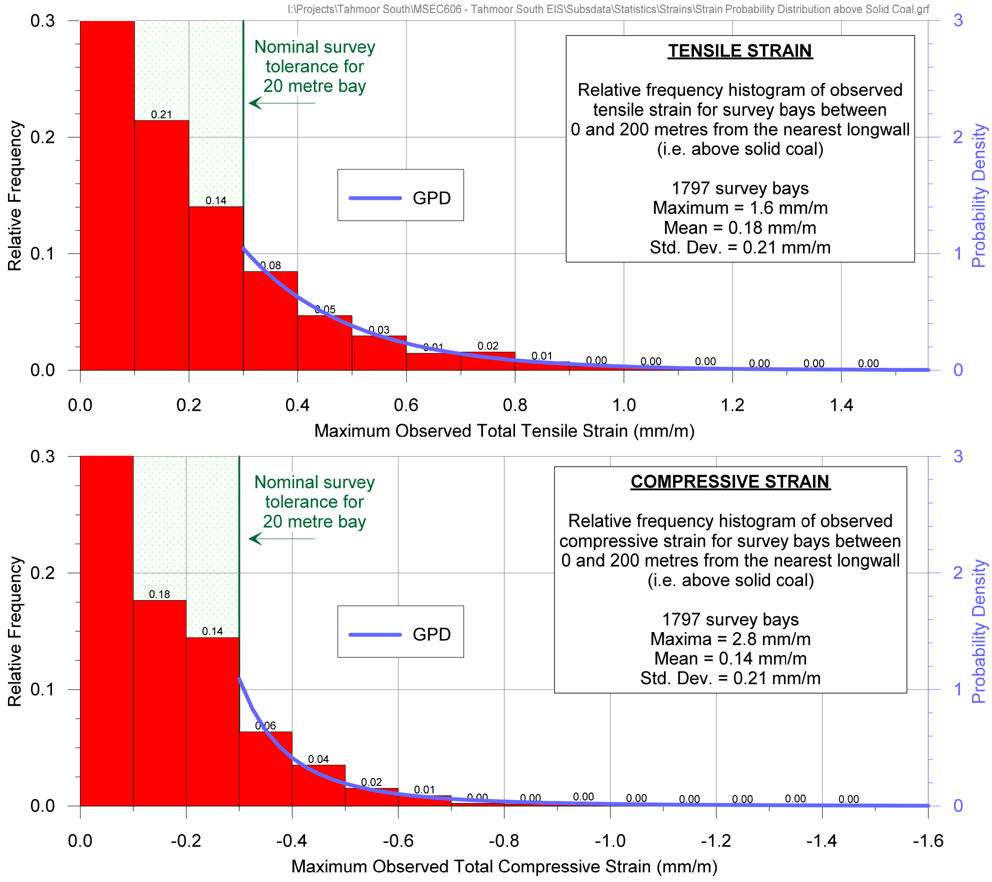

Fig. 3.4 Distributions of the maximum measured tensile and compressive strains for survey bays located above solid coal at Tahmoor, Appin and West Cliff Collieries

The 95 % confidence levels for the maximum total strains that the individual survey bays *above solid coal* experienced at any time during mining at Tahmoor, Appin and West Cliff Collieries were 0.6 mm/m tensile and 0.5 mm/m compressive. The strains for the proposed longwalls are predicted to be 20 % to 40 % greater than those previously observed at these collieries and, therefore, it is expected that 95 % of the strains measured *above solid coal* would be less than 1.0 mm/m tensile and compressive.

The 99 % confidence levels for the maximum total strains that the individual survey bays *above solid coal* experienced at any time during mining at Tahmoor, Appin and West Cliff Collieries were 0.9 mm/m tensile and compressive. Similarly, it is expected that 99 % of the strains measured *above solid coal* adjacent to the proposed longwalls would be less than 1.5 mm/m tensile and compressive.

3.4.2. Analysis of strains measured along whole monitoring lines

For linear features such as roads, cables and pipelines, it is more appropriate to assess the frequency of the maximum strains measured along whole monitoring lines, rather than for individual survey bays. That is, an analysis of the maximum strains measured anywhere along the monitoring lines, regardless of where the strain occurs.

A histogram of maximum observed total tensile and compressive strains measured anywhere along the monitoring lines, at any time during or after the extraction of the previous longwalls Tahmoor, Appin and West Cliff Collieries, is provided in Fig. 3.5.

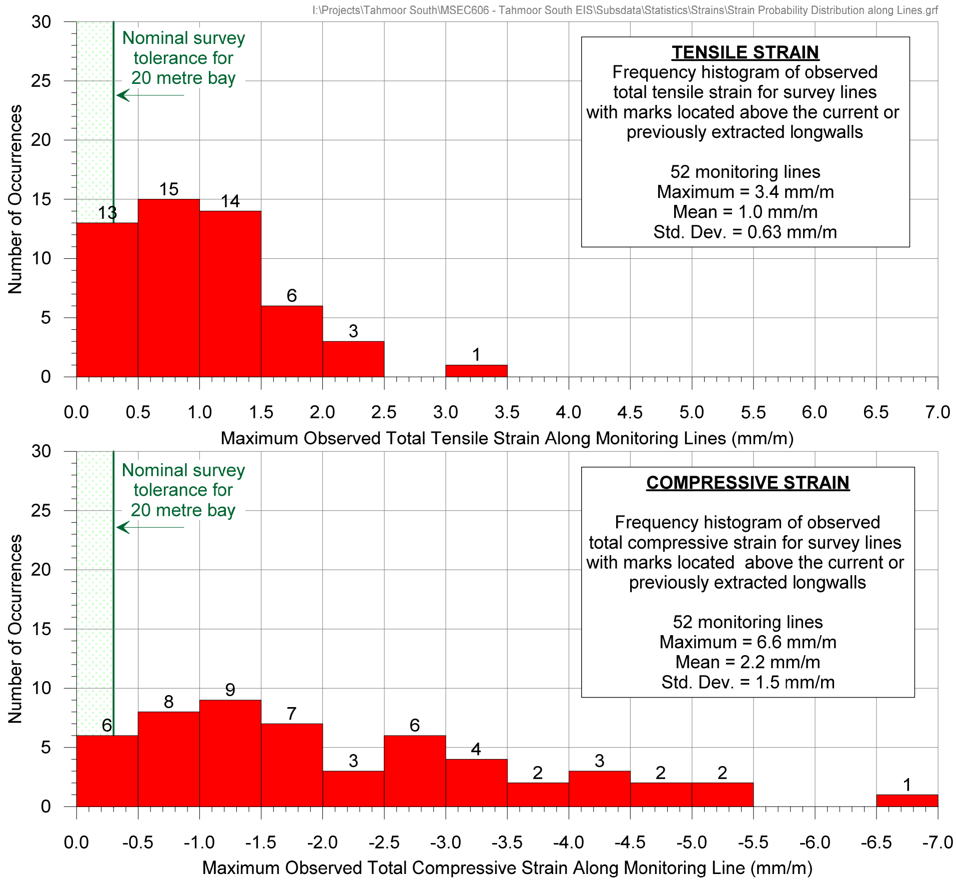

Fig. 3.5 Distributions of measured maximum tensile and compressive strains anywhere along the monitoring lines at Tahmoor, Appin and West Cliff Collieries

It can be seen from the above figure, that 42 of the 52 monitoring lines (i.e. 92 % of the total) at Tahmoor, Appin and West Cliff Collieries had recorded maximum total tensile strains of 2.0 mm/m, or less. The strains for the proposed longwalls are predicted to be 20 % to 40 % greater than those previously observed at these collieries and, therefore, it is expected that 92 % of the monitoring lines above the proposed longwalls would experience maximum tensile strains of 3.0 mm/m, or less.

It can also be seen, that 45 of the 52 monitoring lines (i.e. 87 % of the total) at Tahmoor, Appin and West Cliff Collieries had recorded maximum total compressive strains of 4.0 mm/m, or less. The strains for the proposed longwalls are predicted to be 20 % to 40 % greater than those previously observed at these collieries and, therefore, it is expected that 87 % of the monitoring lines above the proposed longwalls would experience maximum compressive strains of 5.5 mm/m, or less.

3.4.3. Analysis of shear strains

Ground strain comprises two components, being normal strain and shear strain, which can be interrelated using a Mohr's Circle analysis. The magnitudes of the normal strain and shear strain components are, therefore, dependent on the orientation in which they are measured. The maximum normal strains (i.e. principal strains) are those in the direction where the corresponding shear strain is zero.

Normal strains along monitoring lines can be measured using 2D and 3D techniques, by taking the change in horizontal distance between two points on the ground and dividing by the original horizontal distance between them. This provides the magnitude of normal strain along the orientation of the monitoring line but, this strain may not necessarily be the maximum (i.e. principal) strain.

Shear deformations are more difficult to measure, as they are the relative horizontal movements perpendicular to the direction of measurement. However, 3D monitoring techniques provide data on the direction and the absolute displacement of survey marks and, therefore, the shear deformations perpendicular to the monitoring line can be determined. It is possible to gain an understanding of the shear strain along a monitoring line with repeat measurements, but, in accordance with rigorous definitions and the principles of continuum mechanics, (e.g. Jaeger, 1969), it is not possible to accurately determine horizontal shear strains in any direction relative to the monitoring line using 3D monitoring data from a straight line of survey marks.

Shear deformations perpendicular to monitoring lines can be described using various parameters, including horizontal tilt, horizontal curvature, horizontal mid-ordinate deviation, angular distortion and shear index. In this report, horizontal mid-ordinate deviation has been used as the measure for shear deformation, which is defined as the differential horizontal movement of each survey mark, perpendicular to a line drawn between two adjacent survey marks.

The frequency distribution of the maximum total horizontal mid-ordinate deviations measured at survey marks above goaf, for previously extracted longwalls in the Southern Coalfield, is provided in Fig. 3.6. As the typical survey bay length was 20 metres, the calculated mid-ordinate deviations were over a chord length of 40 metres. The probability distribution function, based on the fitted GPD, has also been shown in this figure.

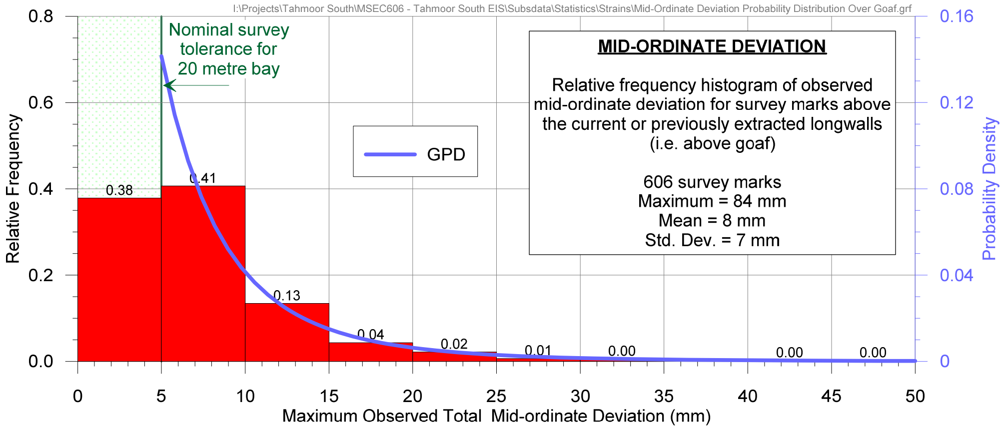

Fig. 3.6 Distribution of measured maximum mid-ordinate deviation during the extraction of previous longwalls in the Southern Coalfield for marks located above goaf

The 95 % and 99 % confidence levels for the maximum total horizontal mid-ordinate deviation that the individual survey marks located above goaf experienced at any time during mining were 20 mm and 35 mm, respectively. The shear deformations for the proposed longwalls are estimated to be 20 % to 40 % greater than those previously observed at Tahmoor, Appin and West Cliff Collieries and, therefore, it is expected that 95 % and 99 % of the horizontal mid-ordinate deviations measured above the proposed longwalls would be less than 30 mm and 50 mm, respectively.

3.5. Predicted far-field horizontal movements

The measured horizontal movements at survey marks which are located beyond the longwall goaf edges and over solid unmined coal areas are often much greater than the observed vertical movements at those marks. These movements are often referred to as *far-field movements*.

Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low-levels of strain. These movements generally do not result in impacts on natural features or built environments, except where they are experienced by large structures which are very sensitive to differential horizontal movements.

In some cases, higher levels of far-field horizontal movements have been observed where steep slopes or surface incisions exist nearby, as these features influence both the magnitude and the direction of ground movement patterns. Similarly, increased horizontal movements are often observed around sudden changes in geology or where blocks of coal are left between longwalls or near other previously extracted series of longwalls. In these cases, the levels of observed subsidence can be slightly higher than normally predicted, but these increased movements are generally accompanied by very low levels of tilt and strain.

In addition to the conventional subsidence movements that have been predicted above and adjacent to the proposed longwalls, far-field horizontal movements will also be experienced during the extraction of the proposed longwalls.

The observed incremental far-field horizontal movements resulting from the extraction of incremental longwall panels, in any location above goaf, i.e. above the currently mined or previously mined panels, or above solid coal, i.e. unmined areas of coal, are provided in Fig. 3.7.

The observed incremental far-field horizontal movements above solid coal only, i.e. outside the extents of extracted longwalls, are provided Fig. 3.8. Survey lines have been selected from Tahmoor, Appin, West Cliff and Tower Collieries.

The confidence levels, based on fitted *Generalised Pareto Distributions* (GPDs), have also been shown in these figures to illustrate the spread of the data. It can be seen from Fig. 3.7 and Fig. 3.8 that the magnitude of the observed far-field horizontal movements over solid unmined areas of coal are lower and more consistent than the observed far-field horizontal movements over previously extracted panels.

As successive longwalls within a series of longwalls are mined, the magnitudes of the incremental far-field horizontal movements decrease. The total far-field horizontal movement may be less, therefore, than the sum of the incremental far-field horizontal movements for the individual longwalls.

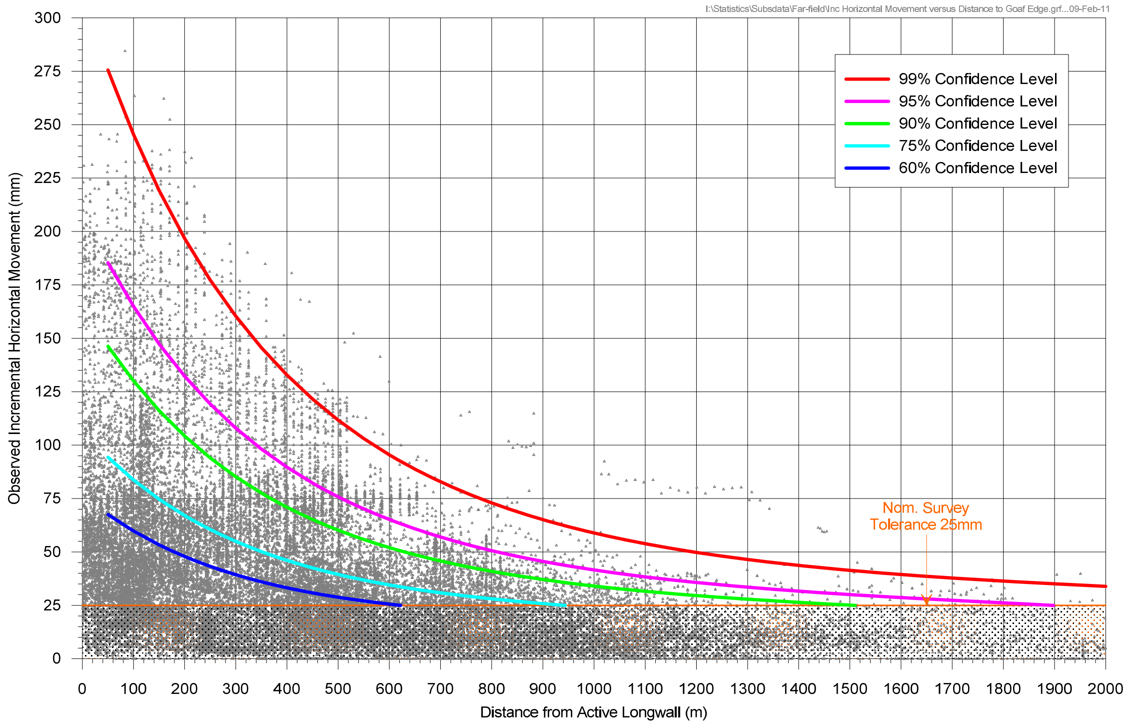

Fig. 3.7 Observed incremental far-field horizontal movements above goaf or solid coal

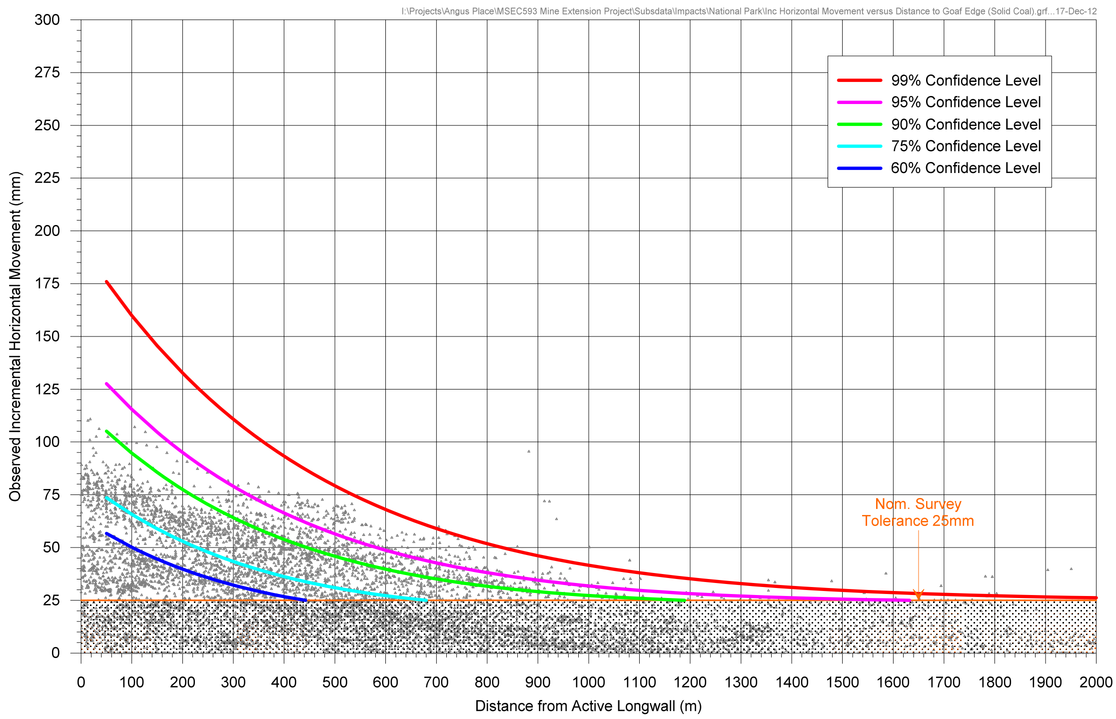

Fig. 3.8 Observed incremental far-field horizontal movements above solid coal only

Confidence levels have been determined from the selected empirical horizontal movement data from Tahmoor, Appin, West Cliff and Tower Collieries, using the fitted GPDs. In the cases where survey bays were measured multiple times during a longwall extraction, the maximum measured horizontal movement was used in the analysis. A summary of incremental horizontal movements within the 95% and 99% confidence levels are shown in Table 3.3.

Table 3.3 Confidence levels for incremental horizontal movement for survey marks above solid coal for monitoring lines at Tahmoor, Appin, West Cliff and Tower Collieries

Distance from active longwall (m)	Incremental horizontal movement within 95% confidence level (mm)	Incremental horizontal movement within 99% confidence level (mm)
200	110	145
400	90	120
600	75	100
800	60	80
1000	50	65
1200	40	50
1400	30	45
1600	26	35
1800	23	30
2000	22	27

The Council bridges may experience far field horizontal movements as a result of the extraction of LWs S1A to S6A. As the offset distances of the bridges to the planned longwall panels are between 1,690 metres and 2,335 metres, the horizontal movements are expected to be very small and can only be detected by precise surveys. Such movements tend to be bodily movements towards the extracted goaf area, and are accompanied by very low levels of strain, which are generally less than the order of survey tolerance (i.e. less than 0.3 mm/m).

The potential for impacts on the bridges do not result from absolute far-field horizontal movements, but rather from differential horizontal movements over the length of the structure. It can be seen from Fig. 3.9 that structures located well away from active longwalls are likely to experience relatively small differential horizontal movements, particularly given that a large proportion of the measured variations are within survey tolerance. Statistical analyses were not conducted for offset distances greater than 1800 metres as there are insufficient measurements beyond the nominal survey tolerance of 3 mm.

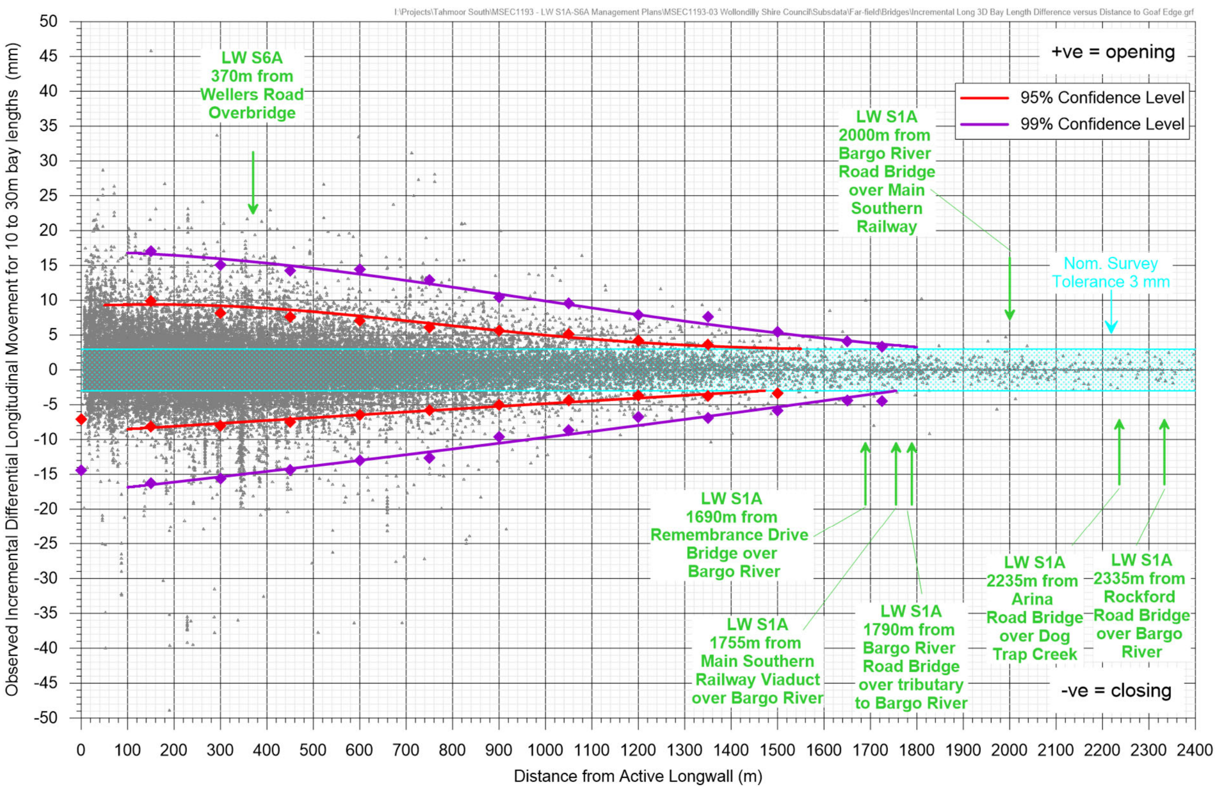

Fig. 3.9 Observed incremental differential longitudinal horizontal movements versus distance from active longwall for marks spaced between 10 and 30 metres

The results in Fig. 3.9 are relevant to the single span bridges on Bargo River Road, Arina Road and Wellers Road, which are less than 20 metres. They are also relevant to the intermediate spans on the Remembrance Drive Bridge over the Bargo River and Rockford Bridge.

The Rockford Road Bridge has an overall length of approximately 80 metres. Observed changes in horizontal distances for survey marks spaced between 70 and 90 metres are shown in Fig. 3.10. Statistical analyses were not conducted for offset distances greater than 1800 metres as there are insufficient measurements beyond the nominal survey tolerance of 3 mm.

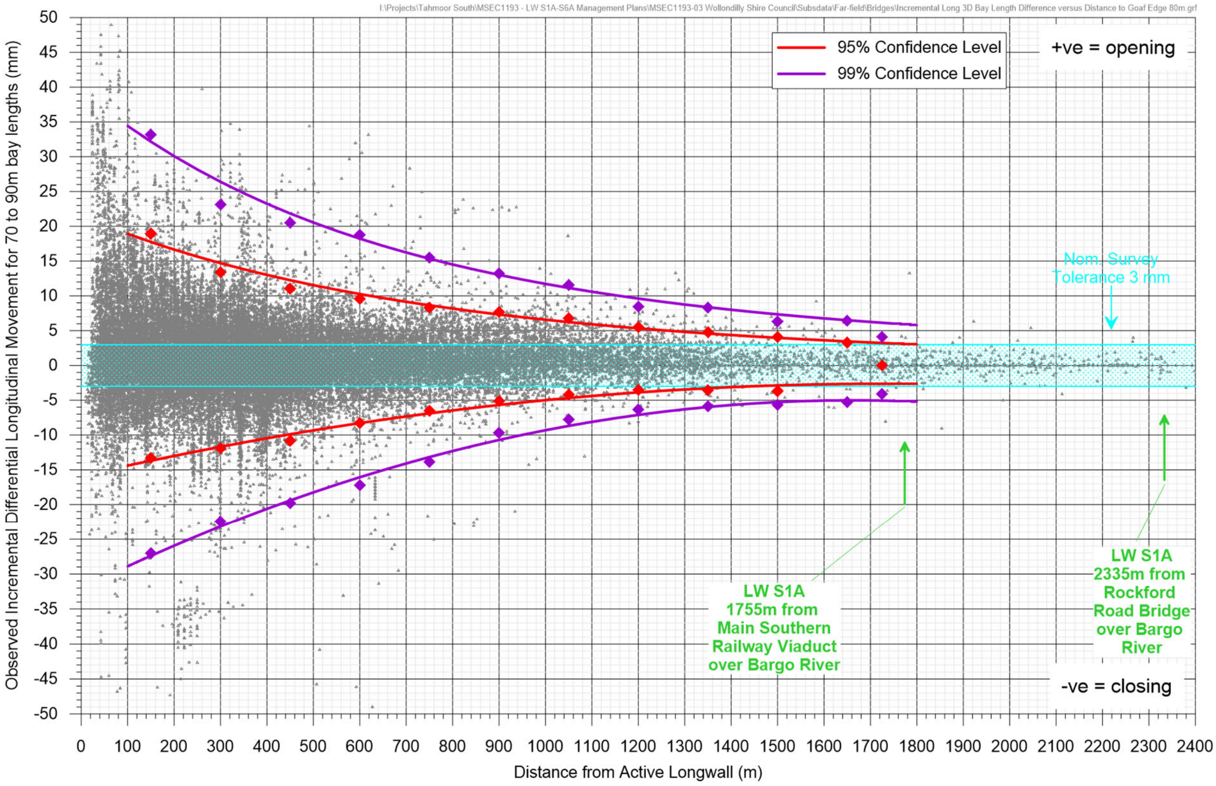

Fig. 3.10 Observed incremental differential longitudinal horizontal movements versus distance from active longwall for marks spaced between 70 and 90 metres

The Remembrance Drive Bridge over the Bargo River has an overall length of approximately 195 metres. Observed changes in horizontal distances for survey marks spaced between 190 and 210 metres are shown in Statistical analyses were not conducted for offset distances greater than 1800 metres as there are insufficient measurements beyond the nominal survey tolerance of 3 mm.

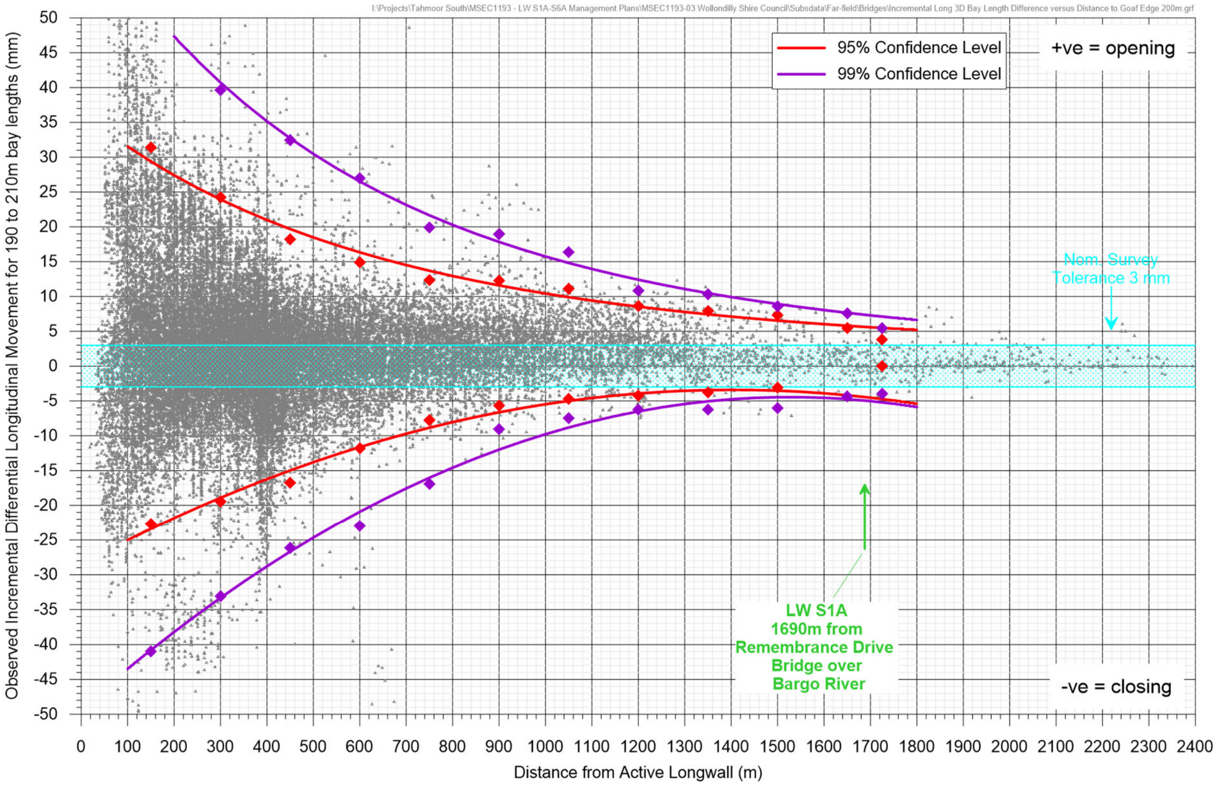

Fig. 3.11 Observed incremental differential longitudinal horizontal movements versus distance from active longwall for marks spaced between 190 and 210 metres

A summary of the probabilities of exceedance for incremental differential horizontal movements for survey bays at offset distances that are relevant to the Bridges, based on the fitted General Pareto Distribution function, is provided in Table 3.4. As discussed previously, there is insufficient data to estimate probabilities greater than 1800 metres as there are insufficient measurements beyond the nominal survey tolerance of 3 mm.

Table 3.4 Probabilities of exceedance for incremental differential horizontal movements for survey bays located from the nearest goaf edge in the Southern Coalfield

Offset distance from LW	Probability of Exceedance	Incremental differential horizontal movements (mm)					
		Pegs spaced between 10 and 30 m		Pegs spaced between 70 and 90 m		Pegs spaced between 190 and 210 m	
		Opening (mm)	Closure (mm)	Opening (mm)	Closure (mm)	Opening (mm)	Closure (mm)
350 m (Wellers Road Overbridge)	1 in 20 (0.05)	9	8	N/A	N/A	N/A	N/A
	1 in 100 (0.01)	17	14				
1700 m to 2400 m (other Bridges)	1 in 20 (0.05)	3	3	4	4	6	5
	1 in 100 (0.01)	4	4	6	5	7	6

It is possible that the bridges could experience shear deformations as a result of differential far field movements. In this report, horizontal mid-ordinate deviation has been used as the measure for shear deformation, which is defined as the differential horizontal movement of each survey mark, perpendicular to a line drawn between two adjacent survey marks. The frequency distribution of the maximum total horizontal mid-ordinate deviations measured at survey marks above solid coal, for previously extracted longwalls in the Southern Coalfield, is provided in Fig. 3.11.

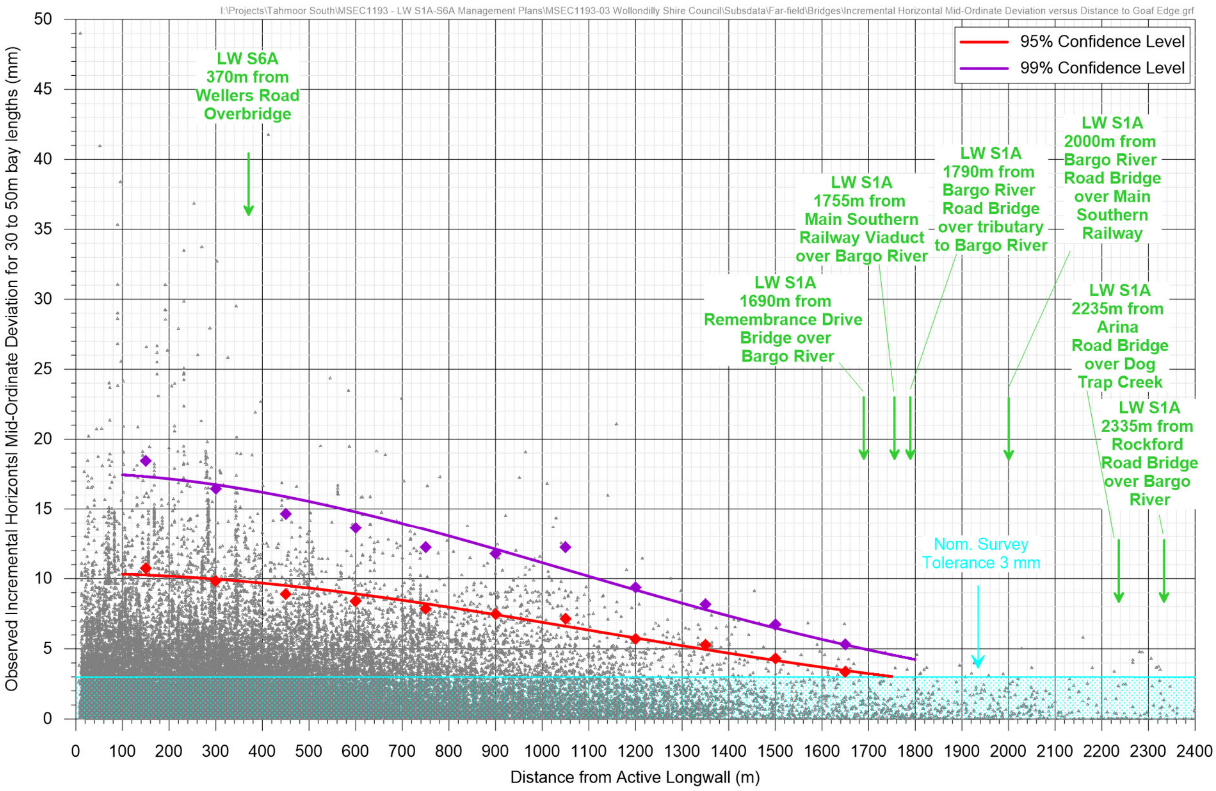

Fig. 3.12 Observed incremental differential horizontal mid-ordinate deviation versus distance from active longwall for marks spaced between 30 and 50 metres

The results in Fig. 3.11 are relevant to the single span bridges on Bargo River Road, Arina Road and Wellers Road, which are less than 20 metres. They are also relevant to the intermediate spans on the Remembrance Drive Bridge over the Bargo River and Rockford Bridge.

A summary of the probabilities of exceedance for incremental horizontal mid-ordinate deviations for survey bays at offset distances that are relevant to the Bridges, based on the fitted General Pareto Distribution function, is provided in Table 3.5. As discussed previously, there is insufficient data to estimate probabilities greater than 1800 metres as there are insufficient measurements beyond the nominal survey tolerance of 3 mm.

Table 3.5 Probabilities of exceedance for incremental horizontal mid-ordinate deviations for survey bays located from the nearest goaf edge in the Southern Coalfield

Offset distance from LW	Probability of Exceedance	Incremental horizontal mid-ordinate deviation (mm)	
		Pegs spaced between 10 and 30m	Pegs spaced between 70 and 90m
350 m (Wellers Road Overbridge)	1 in 20 (0.05)	9	N/A
	1 in 100 (0.01)	14	
1700 m to 2400 m (other Bridges)	1 in 20 (0.05)	3	5
	1 in 100 (0.01)	8	8

The results suggest that measured changes at these offset distances have typically been close to survey tolerance and that the results of the statistical analyses for the low probability events (i.e. 1 in 20 and 1 in 100) have likely been influenced by survey tolerance.

3.6. Managing public safety

The primary risk associated with mining beneath Council infrastructure is public safety. Tahmoor Coal has previously directly mined beneath or adjacent to more than 2000 houses and civil structures, commercial and retail properties, the Main Southern Railway and local roads and bridges. It has implemented extensive measures prior to, during and after mining to ensure that the health and safety of people have not been put at risk due to mine subsidence. People have not been exposed to immediate and sudden safety hazards as a result of impacts that have occurred due to mine subsidence movements.

Emphasis is placed on the words “immediate and sudden” as in rare cases, some structures have experienced severe impacts, but the impacts did not present an immediate risk to public safety as they developed gradually with ample time to repair the structure.

In the case of this Subsidence Management Plan, the potential for impacts on public safety has been assessed on a case by case basis. The assessments include those of a geotechnical engineer for steep slopes.

3.6.1. Subsidence Impact Management Process for Infrastructure

Tahmoor Coal has developed and acted in accordance with subsidence management plans to manage potential impacts during the mining of Longwalls 22 to 32 and LW W1-W4 at Tahmoor North. The management strategy has been reviewed and updated based on experiences gained during the mining of these longwalls and the strategy for LW S1A-S6A at Tahmoor South includes the following process:

1. Regular consultation with Wollondilly Shire Council before, during and after mining;
2. Site-specific investigations;
3. Implementation of mitigation measures following inspections by a structural engineer, a mine subsidence engineer, and, if required, a geotechnical engineer or other specialist engineer; and
4. Surveys and inspections during mining within the active subsidence area:
    - Detailed visual inspections and vehicle-based inspections along the streets;
    - Ground surveys along streets; and
    - Specific ground surveys and visual inspections, where recommended by an engineer based on the inspections and assessments.

A flowchart illustrating the subsidence impact management process prior to, during and after Wollondilly Shire Council infrastructure experiences mine subsidence movements is shown in Fig. 3.13.

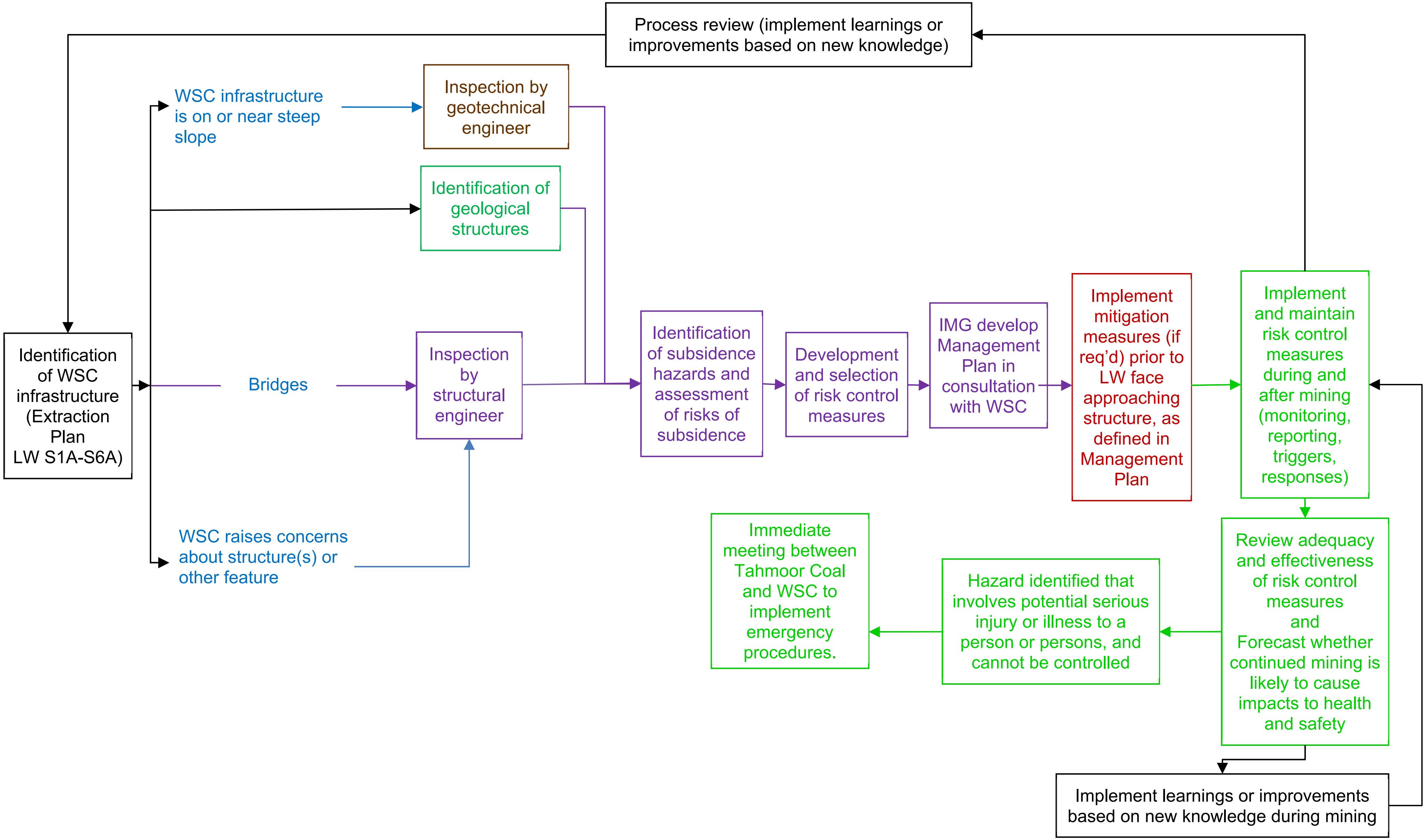

Fig. 3.13 Flowchart for Subsidence Impact Management Process

3.7. Summary of potential impacts

A summary of potential impacts on Wollondilly Shire Council infrastructure is provided in Table 3.6. The summary is consistent with the risk assessment undertaken by Tahmoor Coal (2021 and 2022). The results of the risk assessment are included in the Appendix.

Table 3.6 Summary of potential mine subsidence impacts

Risk	Likelihood	Consequence	Level of potential impact
Local Roads			
Minor cracking or heaving of pavement, kerbs and gutters	POSSIBLE	MINOR	MEDIUM
Major cracking or heaving of pavement, kerbs and gutters	RARE	MODERATE	LOW
Culverts and stormwater drain			
Cracking or spalling of pipework	UNLIKELY	MINOR	LOW
Embankments along Remembrance Drive			
Displacement leading to loss of road support resulting in potential road verge failure	UNLIKELY	MINOR	LOW
Displacement leading to loss of road support resulting in potential loss of carriageway	RARE	MODERATE	LOW
Cutting along Remembrance Drive			
Displacement leading to roadway being blocked or drainage fouled	UNLIKELY	NEGLIGIBLE	LOW
Displacement leading to deformation of pavement in the cutting	RARE	MODERATE	LOW
Bridges			
Loss of serviceability of Arina Road Bridge	RARE	NEGLIGIBLE	LOW
Loss of serviceability of Rockford Road Bridge	RARE	NEGLIGIBLE	LOW
Loss of serviceability of Bargo River Road Bridge	RARE	NEGLIGIBLE	LOW

Additional information on each potential impact is provided below.

3.8. Identification of subsidence hazards that could give rise to risks to health and safety

Clause 34 of the Work Health and Safety Regulation (2017) requires that the duty holder (in this case Tahmoor Coal), in managing risks to health and safety, must identify reasonably foreseeable hazards that could give rise to risks to health and safety.

This section of the Management Plan summarises hazards that have been identified in Chapter 3, which could give rise to risks to health and safety of people on Council infrastructure.

Using the processes described in Section 3.6 of this Management Plan, mine subsidence hazards have been identified, investigated and analysed in a systematic manner by examining each aspect of infrastructure, as described in Sections 3.9 to 3.13 of this Management Plan. Each of the aspects below could potentially experience mine subsidence movements that give rise to risks to the health and safety of people.

- Local roads;

- Culverts and embankments;
- Cuttings; and
- Bridges.

The following mine subsidence hazards were identified that could give rise to risks to health and safety on Council infrastructure due to the extraction of LW S1A-S2A:

- Potential major mine subsidence damage to local roads, particularly Remembrance Drive where vehicles travel at a higher speed (refer Section 3.9);
- Potential damage or loss of services to culverts (refer Section 3.10); and
- Potential embankment instability along Remembrance Driveway (refer Section 3.11).

The identification and risk assessment process took into account the location of infrastructure relative to LWs S1A to S6A and the associated timing and duration of the subsidence event, as described in Section 1.8 of this Management Plan.

Whilst mine subsidence predictions and extensive past experiences from previous mining at Tahmoor Mine were taken into account, the identification and risk assessment process recognised that there are uncertainties in relation to predicting subsidence movements, and uncertainties in how mine subsidence movements may adversely impact Council infrastructure, as discussed in Section 1.4 and Chapter 3 of this Management Plan. In this case, creeks have been mapped that intersect local roads.

Tahmoor Coal has considered the outcomes of the hazard identification and risk assessment process when developing measures to manage potential impacts on the health and safety of people, and potential impacts on Council property in general. These are described in Chapter 4 of this Management Plan.

3.9. Local roads

There are a number of local roads that are located above and adjacent to LWs S1A to S6A, as shown in Drawing No. MSEC1193-03-01.

- Remembrance Driveway
  The main road linking the M31 Hume Motorway with the townships of Bargo and Tahmoor. It runs along the western side of the Main Southern Railway and crosses directly above LWs S1A to S5A. The road provides a connection between the M31 Hume Motorway and the townships of Bargo and Tahmoor to the north of the Study Area. Remembrance Drive was previously the Old Hume Highway, which was constructed in the late 1820's and operated as the major transport route between Melbourne and Sydney until the M31 Hume Motorway was constructed in 1980.

  NSW Transport's online traffic volume viewer has a station on Remembrance Drive, Station ID T0492, located 580 metres to the west of Lupton Road and approximately 4 kilometres south of LWs S1A to S6A, which indicates an average annual daily two-way traffic volume of 4644 vehicles for 2022 (Douglas Partners (2022b). The traffic distribution is 90% cars and light vehicles and 10% heavy vehicles. The station has been recording since 2015. Over the last eight years, annual average daily traffic volumes have varied between 4532 – 5033, and the traffic distribution has varied between 90-92% light vehicles and 8-10% heavy vehicles.

  While Remembrance Drive generally traverses relatively flat terrain above the Study Area, it crosses Teatree Hollow at the intersection with Caloola Road via a road embankment. There are also small road at two other embankments and there is one embankment at the Wellers Road intersection. Remembrance Drive also passes through a road cutting above LW S4A. Potential impacts on the embankment and cutting are discussed separately in this Management Plan.

- Caloola Road
  A sealed no-through road that connects to Remembrance Drive from the west. Entry and exit ramps to Caloola Road are located along the base of the Remembrance Drive road embankment. Caloola Road will be directly mined beneath by LWs 3A to S4A.

- Yarran Road
  A sealed no-through road that connects to Remembrance Drive from the west. It will be directly mined beneath by LWs S5A and S6A.

- Great Southern Road
  A principal road linking to the M31 Hume Motorway to the east. It runs along the eastern side of the Main Southern Railway and only the northern end of the Road is located within the Study Area. The intersection of Great Southern Road and Charlies Point Road is located directly above the commencing end of LW S5A.

- Charles Point Road
  A sealed local road connecting Great Southern Road and Arina Road. The road runs beyond the commencing ends of LWs S1A to S5A.

A photograph of Remembrance Drive near the intersection with Caloola Road is provided in Fig. 3.14.

Photograph courtesy Building Inspection Services

Fig. 3.14 Remembrance Drive near Caloola Road

3.9.1. Predicted subsidence movements

The predicted profiles of conventional subsidence and tilt along the alignment of Remembrance Drive, resulting from the extraction of the proposed longwalls, are shown in Fig. 3.15. A summary of the maximum predicted total conventional subsidence parameters for Remembrance Drive, after the extraction of each of the proposed longwalls, is provided in Table 3.7.

The predicted tilts are the maxima along the alignment of the road after the completion of each of the proposed longwalls. The predicted curvatures are the maxima in any direction at any time during or after the extraction of each of the proposed longwalls.

Table 3.7 Maximum predicted total conventional subsidence parameters for Remembrance Drive due to the extraction of LWs S1A to S6A

Longwall	Maximum predicted subsidence (mm)	Maximum predicted tilt along alignment (mm/m)	Maximum predicted tilt across alignment (mm/m)	Maximum predicted hogging curvature in any direction (km^{-1})	Maximum predicted sagging curvature in any direction (km^{-1})
LW S1A	325	2.5	5.0	0.06	0.06
LW S2A	1000	5.0	5.5	0.08	0.20
LW S3A	1200	6.5	5.5	0.10	0.21
LW S4A	1250	6.0	6.0	0.12	0.21
LW S5A	1300	6.5	5.5	0.12	0.21
LW S6A	1350	7.5	5.5	0.12	0.21

The maximum predicted conventional strains for Remembrance Drive, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1.8 mm/m tensile and 3.2 mm/m compressive. Non-conventional movements can also occur as a result of, among other things, anomalous movements.

The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The road is a linear feature and, therefore, the most relevant distribution of strain is the maximum strains measured along whole monitoring lines above previous longwall mining. The analysis of strains along whole monitoring lines during the mining of previous longwalls in the Southern Coalfield is discussed in Section 3.4.2 and the results are provided in Fig. 3.5.

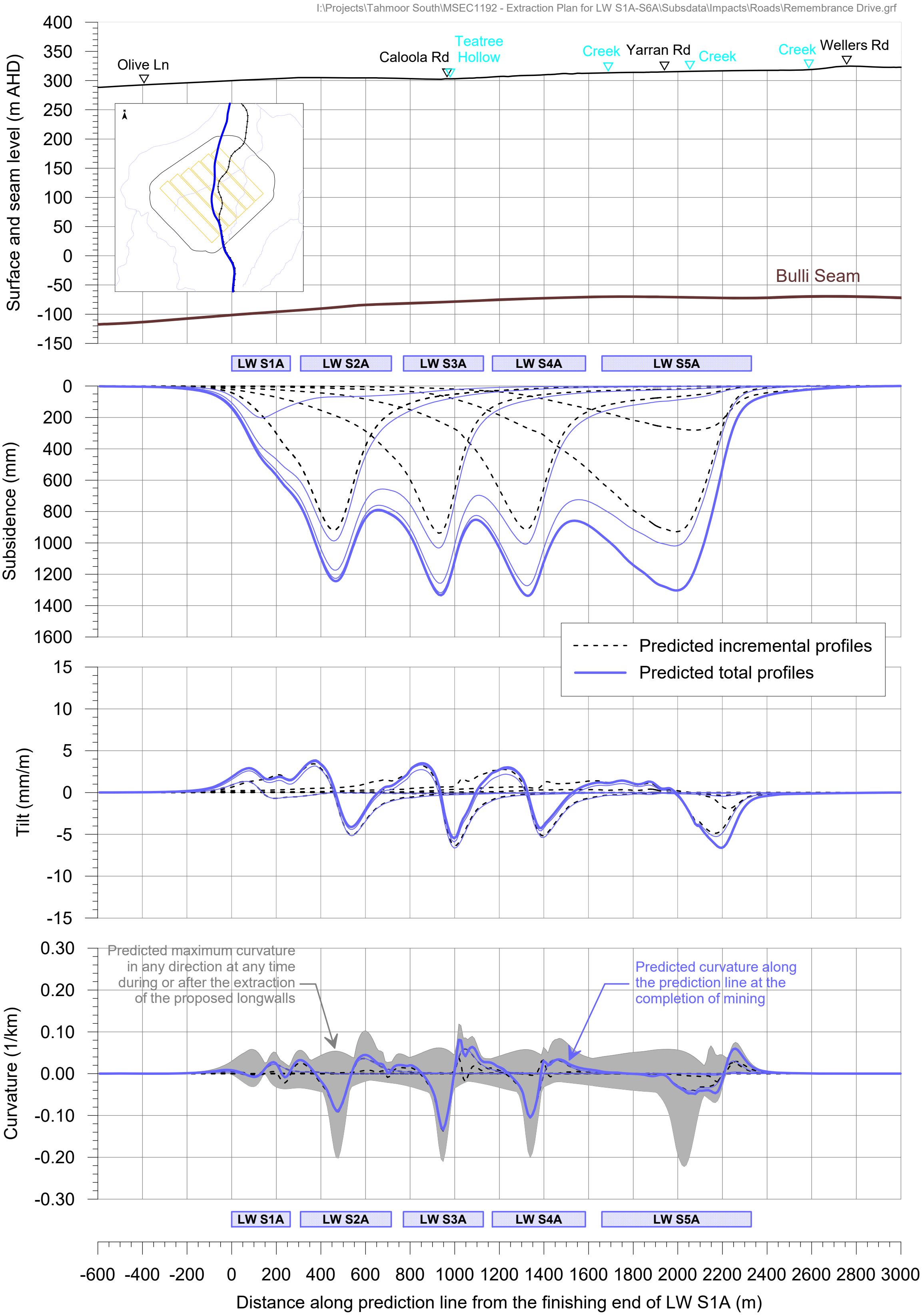

Fig. 3.15 Predicted profiles of total subsidence, tilt and curvature along Remembrance Driveway after the mining of LWs S1A to S6A

Each section of Remembrance Drive pavement will experience subsidence developing at different stages of mining, as each longwall face approaches and extract past it. The timing of subsidence development depends on the location of each section of pavement relative to the longwall panels and the position of the longwall face relative to each section of pavement at the time.

To illustrate the above, the predicted development of subsidence over time for sections of pavement that are located directly above the centrelines of LWs S1A to S6A are shown in Fig. 3.16. The timing of the periods of active subsidence at each point is based on the current mining schedule, assuming that the longwall face is extracted at a uniform rate from start to finish. As discussed in Section 1.7, the longwall schedule may vary depending on a variety of factors and the predicted timing of subsidence at each point may change.

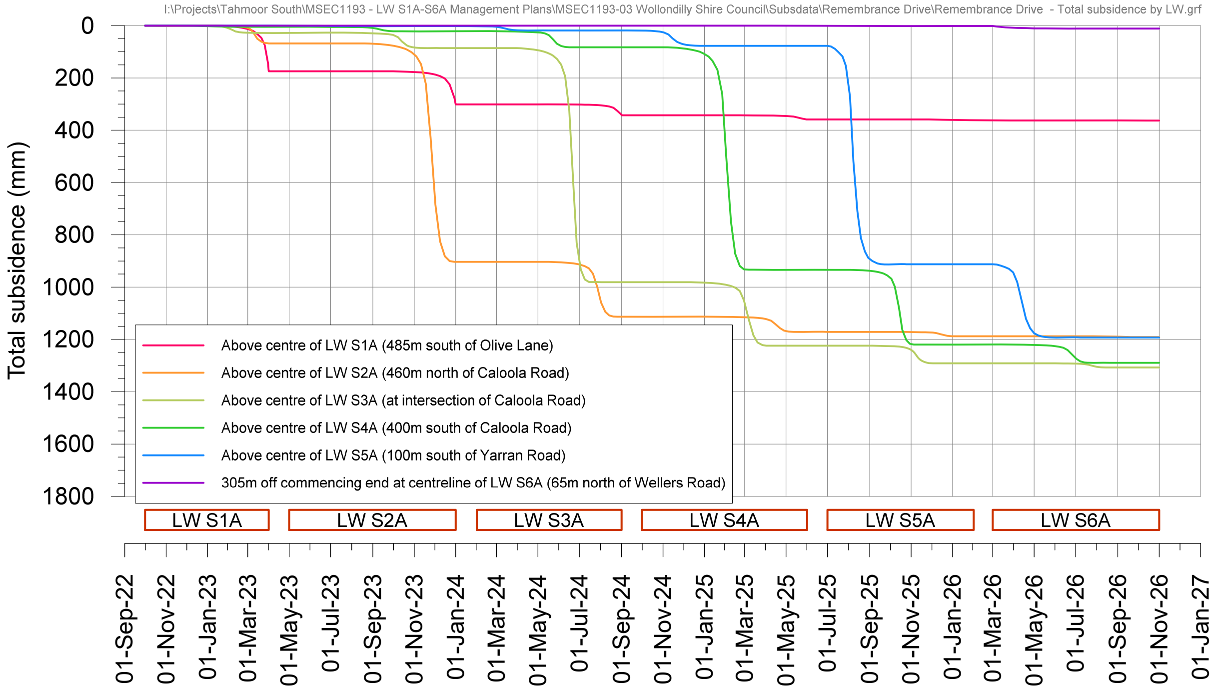

Fig. 3.16 Predicted development of vertical subsidence at selected points along Remembrance Driveway over time during the mining of LWs S1A to S6A

Caloola Road is located directly above LWs S3A to S5A and, therefore, could experience the full range of predicted subsidence movements. The predicted profiles of conventional subsidence and tilt along the alignment of Caloola Road, resulting from the extraction of the proposed longwalls, is shown in Fig. 3.17.

A summary of the maximum predicted total conventional subsidence parameters for Caloola Road, after the extraction of each of the proposed longwalls, is provided in Table 3.8.

The predicted tilts are the maxima along the alignment of the road after the completion of each of the proposed longwalls. The predicted curvatures are the maxima in any direction at any time during or after the extraction of each of the proposed longwalls.

Table 3.8 Maximum predicted total conventional subsidence parameters for Caloola Road due to the extraction of LWs S1A to S6A

Longwall	Maximum predicted subsidence (mm)	Maximum predicted tilt along alignment (mm/m)	Maximum predicted tilt across alignment (mm/m)	Maximum predicted hogging curvature in any direction (km^{-1})	Maximum predicted sagging curvature in any direction (km^{-1})
LW S1A	20	< 0.5	< 0.5	< 0.01	< 0.01
LW S2A	80	< 0.5	< 0.5	< 0.01	< 0.01
LW S3A	875	5.5	6.0	0.09	0.09
LW S4A	1100	5.0	6.0	0.11	0.20
LW S5A	1300	5.5	5.5	0.11	0.20
LW S6A	1350	6.5	6.0	0.11	0.20

Yarran Road is located directly above LWs S5A and S6A and, therefore, could experience the full range of predicted subsidence movements. The predicted profiles of conventional subsidence and tilt along the alignment of Yarran Road, resulting from the extraction of the proposed longwalls, is shown in Fig. 3.18.

A summary of the maximum predicted total conventional subsidence parameters for Yarran Road, after the extraction of each of the proposed longwalls, is provided in Table 3.9.

The predicted tilts are the maxima along the alignment of the road after the completion of each of the proposed longwalls. The predicted curvatures are the maxima in any direction at any time during or after the extraction of each of the proposed longwalls.

Table 3.9 Maximum predicted total conventional subsidence parameters for Yarran Road due to the extraction of LWs S1A to S6A

Longwall	Maximum predicted subsidence (mm)	Maximum predicted tilt along alignment (mm/m)	Maximum predicted tilt across alignment (mm/m)	Maximum predicted hogging curvature in any direction (km^{-1})	Maximum predicted sagging curvature in any direction (km^{-1})
LW S1A	< 20	< 0.5	< 0.5	< 0.01	< 0.01
LW S2A	< 20	< 0.5	< 0.5	< 0.01	< 0.01
LW S3A	20	< 0.5	< 0.5	< 0.01	< 0.01
LW S4A	100	< 0.5	< 0.5	< 0.01	< 0.01
LW S5A	1000	7.5	2.0	0.09	0.20
LW S6A	1000	7.5	4.5	0.09	0.25

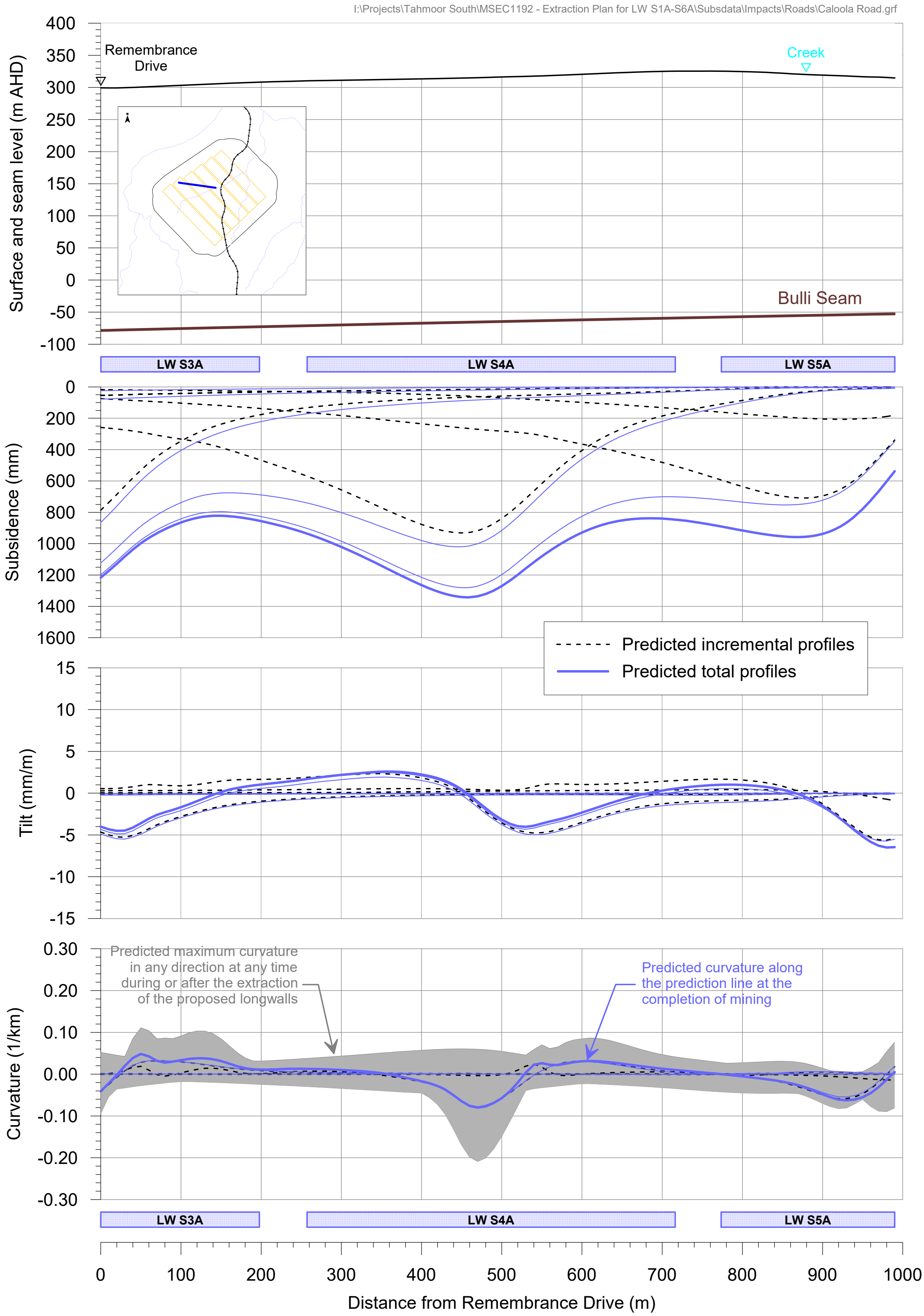

Fig. 3.17 Predicted profiles of total subsidence, tilt and curvature along Caloola Road after the mining of LWs S1A to S6A

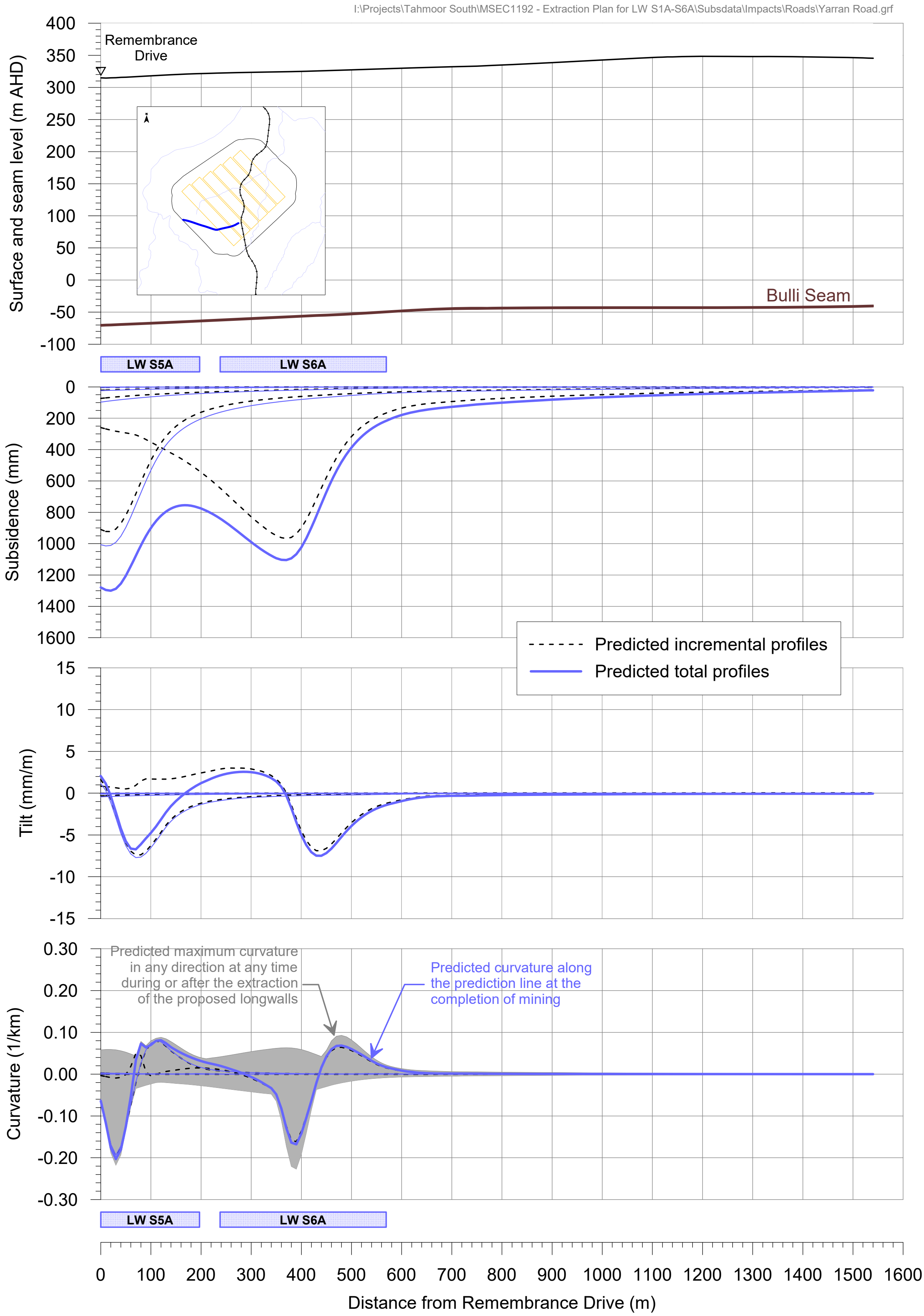

Fig. 3.18 Predicted profiles of total subsidence, tilt and curvature along Yarran Road after the mining of LWs S1A to S6A

Charlies Point Road is generally located beyond the commencing ends of LWs S1A to S5A and is expected minor subsidence movements. The predicted profiles of conventional subsidence and tilt along the alignment of Charlies Point Road, resulting from the extraction of the proposed longwalls, are shown in Fig. 3.19.

A summary of the maximum predicted total conventional subsidence parameters for Charlies Point Road, after the extraction of each of the proposed longwalls, is provided in Table 3.10.

The predicted tilts are the maxima along the alignment of the road after the completion of each of the proposed longwalls. The predicted curvatures are the maxima in any direction at any time during or after the extraction of each of the proposed longwalls.

Table 3.10 Maximum predicted total conventional subsidence parameters for Charlies Point Road due to the extraction of LWs S1A to S6A

Longwall	Maximum predicted subsidence (mm)	Maximum predicted tilt along alignment (mm/m)	Maximum predicted tilt across alignment (mm/m)	Maximum predicted hogging curvature in any direction (km^{-1})	Maximum predicted sagging curvature in any direction (km^{-1})
LW S1A	< 20	< 0.5	< 0.5	< 0.01	< 0.01
LW S2A	40	< 0.5	< 0.5	< 0.01	< 0.01
LW S3A	40	< 0.5	< 0.5	< 0.01	< 0.01
LW S4A	50	< 0.5	< 0.5	0.01	< 0.01
LW S5A	190	2.0	2.5	0.07	< 0.01
LW S6A	250	2.5	3.5	0.09	< 0.01

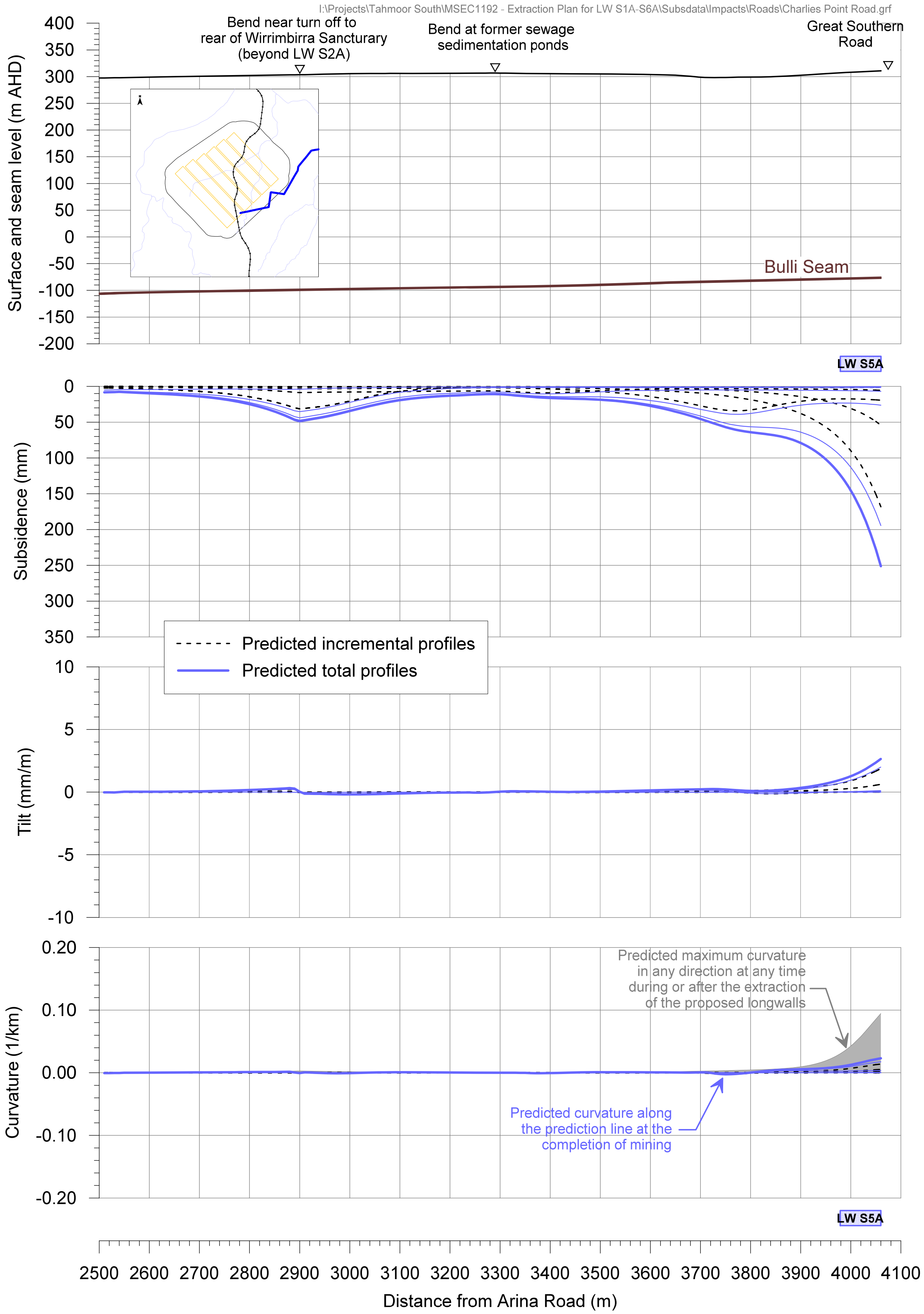

Fig. 3.19 Predicted profiles of total subsidence, tilt and curvature along Charlies Point Road after the mining of LWs S1A to S6A

3.9.2. Potential subsidence impacts on local roads

Extensive monitoring of road pavements has been undertaken during the extraction of Longwalls 22 to 32 and LW W1-W4 at Tahmoor Mine. This includes a network of ground monitoring lines and weekly visual inspections in areas that are experiencing active subsidence. Approximately 28 km of asphaltic pavement lies directly above the extracted longwalls and a total of 54 impact sites have been reported. The observed rate of impact equates to an average of one impact for every 520 m of pavement. In most cases, the impacts were relatively minor and were remediated by locally resurfacing the pavements, and did not present a public safety risk. Photographs of impacts observed on local roads at Tahmoor are provided in Fig. 3.20.

Impacts have also been observed to concrete kerbs, gutters and drainage pits. The impacts are most commonly focussed around driveway laybacks and involve cracking, spalling or buckling. Traffic signs and other road infrastructure have not previously experienced impacts due to mine subsidence.

As the predicted subsidence parameters for the proposed longwalls are greater than those at Tahmoor North, it is expected that the rates of impact on the local roads within the Study Area will be greater than experienced at Tahmoor. The impacts, however, can be managed with the implementation of suitable management strategies. Impacts on local roads have been successfully managed elsewhere in the NSW Coalfields, where the predicted subsidence parameters were similar to or greater than those predicted for the proposed longwalls.

The most severe impacts were located where substantial non-conventional movements had developed. These impact sites were identified using visual and ground monitoring, and remediation was undertaken during active subsidence to maintain the roads in safe and serviceable condition.

It is difficult to predict with certainty where non-conventional subsidence movements will occur along local roads. The most likely locations are where the roads cross drainage lines. In the case of LWs S1A to S6A, the local roads cross creek crossings at a number of locations, most notably Teatree Hollow and its associated tributaries.

Hidden creeks are defined as natural watercourses that appear to have been covered during development of a property or road. Hidden creeks have been identified from surface contours and historical aerial photographs. Two hidden creeks have been identified within the Study Area. The creeks were infilled as part of the development of Tahmoor Mine and their locations are shown in Drawing No. MSEC1193-03-01. It is possible that non-conventional movements could occur where the hidden creek alignments are projected to intersect with Remembrance Drive, resulting in impacts on the road pavement at these locations.

Tahmoor Coal has extensive experience of mining beneath railway cuttings (Kay et al, 2017). Non-conventional subsidence movements have been observed to develop within railway cuttings, resulting in impacts on track geometry. Remembrance Drive passes through a road cutting above LW S4A. It is possible the road pavement through the cutting will experience increased impacts during mining. Additional survey marks will be installed to assist with monitoring changes in the cutting, which is discussed later in this Management Plan.

Tahmoor Coal has developed and selected risk control measures in consultation, co-ordination and co-operation with Wollondilly Shire Council in accordance with WHS legislation. In this instance, there are no reasonably practicable controls which could eliminate, substitute or isolate the identified risks, nor engineering controls that could put in place a structure or item that prevents or minimises risks. Tahmoor Coal has identified controls that will manage potential issues associated with the identified risks:

- Local 2D survey of subsidence along local roads, as shown in Drawing No. MSEC1193-01-01;
- Absolute 3D survey of subsidence along Remembrance Drive;
- Visual inspections along local roads within the active subsidence zone;
- Additional surveys and/or inspections, if triggered by monitoring results;
- Repair of pavement if damage is observed;
- As a last resort, introduce a temporary speed restriction and/or temporary lane closure if a hazard has been identified that involves potential serious injury or illness to a person or persons and cannot be controlled; and
- Develop a traffic management plan to manage traffic along Remembrance Drive in the event that mining-induced damage requires repair.

With the implementation of the above management strategy, Tahmoor Coal will ensure that the health and safety of people along local roads will not be put at risk due to differential mine subsidence movements due to the extraction of LWs S1A to S6A.

A traffic management plan will be developed to the satisfaction of Council for the installation and continued monitoring of survey pegs. A traffic management plan will be developed to the satisfaction of Council to manage traffic along Remembrance Drive in the event that mining-induced damage develops along the road and requires repair.

Fig. 3.20 Impacts on local roads above Tahmoor Mine

3.10. Road drainage culverts

A number of culverts are located within the *Subsidence Study Area*, as shown in Drawing No. MSEC1193-0.-01. Almost every culvert is a reinforced concrete pipe (RCP), with the exception of one earthenware pipe on Charlies Point Road. The pipe diameters vary between 500 mm and 1.8 metres.

Teatree Hollow crosses between Remembrance Drive at the intersection with Caloola Road. The stream flows under Caloola Road via twin 1.2 metre diameter reinforced concrete culverts, which connect to twin, 1.35 metre diameter reinforced concrete culverts beneath bus stop at the end of Caloola Road. Photographs of both culverts are shown in Fig. 3.21. The culvert carries the pavement over Teatree Hollow and continues beneath Remembrance Drive.

Photograph courtesy Building Inspection Services

Fig. 3.21 Culvert beneath approach to Caloola Road and continuing under Remembrance Drive along Teatree Hollow

Two culverts are located in close proximity at the intersection between Remembrance Drive, Yarran Road and the Main Southern Railway. The 1800 mm RCP culvert beneath Remembrance Drive drains into a small parcel of privately owned land and a 2000 mm diameter brick arch culvert beneath the Main Southern Railway.

Photographs courtesy Building Inspection Services

Fig. 3.22 RCP culvert beneath Remembrance Drive and brick arch culvert beneath Main Southern Railway at 100.425 km with private land in between them

Remembrance Drive crosses Teatree Hollow and a number of its tributaries within the Study Area and valley-related movements could be experienced in these locations. A summary of the maximum predicted conventional subsidence and valley related movements for the crossing at Teatree Hollow is provided in Table 3.11.

Table 3.11 Predicted Conventional Subsidence and Valley Related Movements for the Culverts along Remembrance Drive within the Study Area

Location	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt along Culvert (mm/m)	Maximum Predicted Total Hogging Curvature (1/km)	Maximum Predicted Total Sagging Curvature (1/km)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
Teatree Hollow (Caloola Road)	1300	6.9	0.06	-0.18	250	150
Tributary to Teatree Hollow	1100	3.6	0.05	-0.04	125	100
Tributary to Teatree Hollow (Yarran Road)	1300	6.7	0.05	-0.22	150	75
Tributary to Teatree Hollow (Wellers Road)	25	< 0.5	< 0.01	< 0.01	40	25

3.10.1. Potential subsidence impacts on road drainage culverts

The maximum predicted tilt across Remembrance Drive is 6.9 mm/m (i.e. 0.69 %), which represents a change in grade of 1 in 145.

The predicted changes in grade are small, in the order of 1 % and, therefore, are unlikely to result in any adverse impacts on the serviceability of the drainage culverts. If the flow of water through any drainage culverts were to be adversely affected, as a result of the proposed mining, this could be remediated by re-levelling the affected culverts.

The predicted curvatures and strains could be of sufficient magnitudes to result in cracking in the culverts or the headwalls. It is unlikely, however, that these movements would adversely impact on the stabilities or structural integrities of the culverts.

The drainage culverts are located along drainage lines and could, therefore, experience valley related upsidence and closure movements. The drainage culverts are orientated along the alignments of the drainage lines and, therefore, the upsidence and closure movements are orientated perpendicular the main axes of the culverts and unlikely to result in adverse impacts to the culvert pipes.

Previous experience of mining beneath culverts in the NSW coalfields, at similar depths of cover, indicates that the incidence of impacts is low. Impacts have generally been limited to cracking in the concrete headwalls which can be readily remediated. In some cases, however, cracking in the culvert pipes occurred which required the culverts to be repaired or replaced.

There have been no reports of impacts to road drainage culverts during the mining of Longwalls 22 to 32, and LW W1-W4, with the exception of a culvert headwall on Bridge Street during the mining of Longwall 31. The low incidence of impacts is understandable as the culverts are typically constructed of jointed circular concrete pipes, which are able to tolerate substantial differential ground movements. While it is possible that the culverts could experience physical impacts such as cracking, the probability is considered low.

Potential impacts on the drainage culverts can be managed by visual inspection and, where required, any affected culverts can be repaired or replaced.

Tahmoor Coal and Wollondilly Shire Council have previously developed and acted in accordance with risk management plans to manage potential impacts to roads drainage culverts during the mining of Longwalls 22 to 32 and LW W1-W4. The management plans have included a commitment by Tahmoor Coal to conduct surveys and visual inspections along local roads across the creeks and culverts, and repair the culverts if required. The same management strategy is planned for culverts potentially affected by LWs S1A to S6A.

Survey lines will be installed along the local roads and monitoring data will be used to determine whether the culverts have experienced significant differential subsidence movements. Visual inspections will be conducted when they experience active subsidence. If any adverse impacts were to occur as the result of mining, the affected culverts could be repaired or replaced.

3.11. Road embankments

There are four embankments along Remembrance Drive above LWs S1A to S6A. The embankments were present as part of the Old Hume Highway. It is understood that no failures have been recorded to the embankments over their 190 years of operation (Douglas Partners, 2022b). Detailed information are provided for each embankment below.

3.11.1. Remembrance Drive Embankment over Teatree Hollow at Caloola Drive (RE4)

Remembrance Drive crosses Teatree Hollow via an engineered fill embankment over twin 1.35 metre diameter reinforced concrete culverts. The embankment is approximately 350 metres long and 4.2 metres high at its highest point. Approach ramps run alongside the embankment on the western, northbound or upstream side of the embankment. A photograph along the road embankment to Remembrance Drive at Teatree Hollow on the upstream side is shown in Fig. 3.23. A side-on view of the embankment from the intersection at Caloola Road is shown in Fig. 3.24. A photograph along the road embankment to Remembrance Drive at Teatree Hollow on the downstream side is shown in Fig. 3.25.

Photograph courtesy Building Inspection Services

Fig. 3.23 Remembrance Drive embankment at intersection with Caloola Road on upstream side

Fig. 3.24 Remembrance Drive embankment from intersection with Caloola Road on upstream side

Photograph courtesy Douglas Partners

Fig. 3.25 Remembrance Drive embankment from intersection with Caloola Road on downstream side

The embankment is located directly above LW S3A. Predictions along the road and at the culvert were provided in Sections 3.9 and 3.10 of this Management Plan.

The embankment has been inspected and assessed by geotechnical engineer Douglas Partners (2022a and 2022b), who have labelled the embankment as RE4 in its report. The embankment has batter slopes between 30 and 38 degrees with localised sections up to 45 degrees. The embankment fill typically comprised moderately to well compacted silty clay, sandy clay, sand silty clay. The toe along the western side of the embankment has been cut-back to construct a drain along the edge of the road.

The embankment has shoulder lanes on both sides that are at least 2.7 metres wide. The travel lanes are setback at least 3 to 4 metres from the crest of the embankment on both sides. Douglas Partners have conducted a NSW RMS slope risk analysis of the embankment and assessed the risk level as ARL5, which is the lowest risk level.

Douglas Partners (2022b) have also completed a detailed slope stability assessment and advised that there is sufficient robustness in the current stability of the embankment to ensure that planned contingency measures can be effectively implemented in a timely manner to ensure that the embankment remains safe and serviceable even if deviations from the results of the risk assessments and/or uncertainties are identified during the development of subsidence. Douglas Partners did not identify sections of the embankment with inadequate stability. There are no signs of deep-seated movement in the pavement or discernible signs of seepage.

There has been extensive experience of mining directly beneath railway and highway embankments during previous longwall mining in the Southern Coalfield. No impacts have been observed to embankment stability. The embankment will, however, be monitored by surveys and inspections during periods of active subsidence. The key management strategy is to maintain serviceability of the culverts beneath the embankment. In the unlikely event that the embankment slope experiences impacts during mining, the embankment can be repaired by sealing cracks, or placing permanent fill or rock spall at the base of the embankment. In the extremely unlikely event that an instability occurs that affects road safety, traffic could be diverted to the other travel lane whilst repairs are conducted. A traffic management plan will be developed to the satisfaction of Council to manage traffic along Remembrance Drive in the event that an emergency lane closure is required on the embankment.

Services infrastructure run along the crest and base of the embankment on both sides, including Jemena's 150 mm gas main, Sydney Water's 450 mm diameter potable water main and 180 mm diameter sewer main and optical fibre cables.

Tahmoor Coal have conducted a detailed survey of the Jemena gas main, which runs along the eastern, southbound or downstream side of the embankment. From the northern end of the embankment, the gas pipeline runs along the toe of the embankment and then changes direction, running up the embankment batter slope and along the crest over the creek and along the southern half of the embankment. A map of the surveyed location of the gas main along the embankment is shown in Drawing No. MSEC1193-07.

An as-built survey is currently being conducted along Sydney Water's potable water main, which runs along the western, southbound or upstream side of the embankment.

The purpose of the services surveys is to provide input to contingency planning in the unlikely event that observed differential mine subsidence movements at the embankment exceed levels that trigger a response to excavate and expose the pipeline(s) to relieve a potential build-up of stress in the pipework. The contingency plans are included in the subsidence management plans that are being developed in consultation with Jemena and Sydney Water. The contingency plans will include a traffic management plan, which will be provided to Council for review and approval.

3.11.2. Remembrance Drive Embankment over Tributary to Teatree Hollow north of Yarran Road (RE3)

Remembrance Drive crosses a shallow tributary to Teatree Hollow via an engineered fill embankment over a 900 mm diameter reinforced concrete culvert. The embankment is approximately 165 metres long and 3.9 metres high at its highest point. Photographs along the road embankment to Remembrance Drive north of Yarran Road are shown in Fig. 3.26 and Fig. 3.27.

Photograph courtesy Douglas Partners

Fig. 3.26 Remembrance Drive embankment north of Yarran Road on upstream side

Photograph courtesy Douglas Partners

Fig. 3.27 Remembrance Drive embankment north of Yarran Road on downstream side

The embankment is located directly above LW S5A. Predictions along the road and at the culvert were provided in Sections 3.9 and 3.10 of this Management Plan.

The embankment has been inspected and assessed by geotechnical engineer Douglas Partners (2022a and 2022b), who have labelled the embankment as RE3 in its report. The embankment has batter slopes between 30 and 36 degrees with localised sections up to 38 degrees. The embankment fill typically comprised moderately to well compacted silty clay, sandy clay, sand silty clay. The toe along the western side of the embankment has been cut-back to construct a drain along the edge of the road.

The embankment has shoulder lanes on both sides that are at least 2.7 metres wide. The travel lanes are setback at least 3 to 4 metres from the crest of the embankment on both sides. Douglas Partners have conducted a NSW RMS slope risk analysis of the embankment and assessed the risk level as ARL5, which is the lowest risk level.

Douglas Partners (2022b) have also completed a detailed slope stability assessment and advised that there is sufficient robustness in the current stability of the embankment to ensure that planned contingency measures can be effectively implemented in a timely manner to ensure that the embankment remains safe and serviceable even if deviations from the results of the risk assessments and/or uncertainties are identified during the development of subsidence. Douglas Partners did not identify sections of the embankment with inadequate stability. There are no signs of deep-seated movement in the pavement or discernible signs of seepage.

As described for the road embankment RE4, the key management strategy is to maintain serviceability of the culvert beneath the embankment. In the unlikely event that the embankment slope experiences impacts during mining, the embankment can be repaired by sealing cracks, or placing permanent fill or rock spall at the base of the embankment. In the extremely unlikely event that an instability occurs that affects road safety, traffic could be diverted to the other travel lane whilst repairs are conducted. A traffic management plan will be developed to the satisfaction of Council to manage traffic along Remembrance Drive in the event that an emergency lane closure is required on the embankment.

Services infrastructure run along the crest and base of the embankment on both sides, including Jemena's 150 mm gas main, Sydney Water's 450 mm diameter potable water main and 180 mm diameter sewer main and optical fibre cables.

Tahmoor Coal have conducted a detailed survey of the Jemena gas main, which runs along the eastern, southbound or downstream side of the embankment. An as-built survey is currently being conducted along Sydney Water's potable water main, which crosses over Remembrance Drive at the embankment. From the northern end, the water main runs along the western, southbound or upstream side of the embankment before crossing over the embankment and runs along the eastern, northbound or downstream side of the embankment.

As described for the road embankment RE4, contingency plans for excavating and exposing the pipelines crossing the embankment RE3 will be included in the subsidence management plans that are being developed in consultation with Jemena and Sydney Water. The contingency plans will include a traffic management plan, which will be provided to Council for review and approval.

A series of farm dams are located upstream of the road embankment north of Yarran Road. Whilst the likelihood of impacts on the dam walls is considered to be very low, the dams will be inspected for impacts during periods of active subsidence. Water levels will be lowered, if required, to minimise the chance of impacts of dam break on the road embankment.

3.11.3. Remembrance Drive Embankment over Tributary to Teatree Hollow south of Yarran Road (RE2)

Remembrance Drive crosses a tributary to Teatree Hollow via an engineered fill embankment over a 1.8 metre diameter reinforced concrete culvert. The embankment is approximately 220 metres long and 7.8 metres high at its highest point. Photographs along the road embankment to Remembrance Drive south of Yarran Road are shown in Fig. 3.28 and Fig. 3.29.

Photograph courtesy Douglas Partners

Fig. 3.28 Remembrance Drive embankment south of Yarran Road on upstream side

Photograph courtesy Douglas Partners

Fig. 3.29 Remembrance Drive embankment south of Yarran Road on downstream side

The embankment is located directly above LW S5A. Predictions along the road and at the culvert were provided in Sections 3.9 and 3.10 of this Management Plan.

The embankment has been inspected and assessed by geotechnical engineer Douglas Partners (2022a and 2022b), who have labelled the embankment as RE2 in its report. The embankment has batter slopes between 35 and 40 degrees with localised sections up to 45 degrees. The embankment fill typically comprised moderately to well compacted silty clay, sandy clay, sand silty clay.

The embankment has shoulder lanes on both sides that are at least 2.7 metres wide. The travel lanes are setback at least 3 to 4 metres from the crest of the embankment on both sides. Douglas Partners have conducted a NSW RMS slope risk analysis of the embankment and assessed the risk level as ARL5, which is the lowest risk level.

Douglas Partners (2022b) have also completed a detailed slope stability assessment and advised that there is sufficient robustness in the current stability of the embankment to ensure that planned contingency measures can be effectively implemented in a timely manner to ensure that the embankment remains safe and serviceable even if deviations from the results of the risk assessments and/or uncertainties are identified during the development of subsidence. Douglas Partners did not identify sections of the embankment with inadequate stability. There are no signs of deep-seated movement in the pavement or discernible signs of seepage.

As described for the road embankment RE4, the key management strategy is to maintain serviceability of the culvert beneath the embankment. In the unlikely event that the embankment slope experiences impacts during mining, the embankment can be repaired by sealing cracks, or placing permanent fill or rock spall at the base of the embankment. In the extremely unlikely event that an instability occurs that affects road safety, traffic could be diverted to the other travel lane whilst repairs are conducted. A traffic management plan will be developed to the satisfaction of Council to manage traffic along Remembrance Drive in the event that an emergency lane closure is required on the embankment.

Services infrastructure run along the crest and base of the embankment on both sides, including Jemena's 150 mm gas main and 180 mm diameter sewer main and optical fibre cables. Sydney Water's 450 mm diameter potable water main does not run along this embankment.

Tahmoor Coal have conducted a detailed survey of the Jemena gas main, which runs along the eastern, southbound or downstream side of the embankment.

The purpose of the services survey is to provide input to contingency planning in the unlikely event that observed differential mine subsidence movements at the embankment exceed levels that trigger a response to excavate and expose the pipeline(s) to relieve a potential build-up of stress in the pipework. The contingency plans are included in the subsidence management plan that is being developed in consultation with Jemena. The contingency plan will include a traffic management plan, which will be provided to Council for review and approval.

A farm dam is located upstream of the road embankment south of Yarran Road. Whilst the likelihood of impacts on the dam wall is considered to be very low, the dam will be inspected for impacts during periods of active subsidence. Water levels will be lowered, if required, to minimise the chance of impacts of dam break on the road embankment.

A house and shed are located upstream of the road embankment south of Yarran Road. Whilst the likelihood of instability of the embankment or blockage of the culvert is considered to be very low, the consequences of these impacts are higher compared to other embankments as they may result in impacts on the property due to potential flooding.

The Main Southern Railway is located immediately downstream of the Remembrance Drive embankment. The 1500 mm dia brick arch railway culvert is located at 100.425 km. The waterway will be inspected and maintained to ensure water drains through both the road and railway culverts. A detailed subsidence management plan is also being developed in consultation with the Australian Rail Track Corporation (ARTC). The management plan will include management of potential impacts on the railway embankments and culverts.

3.11.4. Remembrance Drive Embankment at intersection of Wellers Road (RE1)

Remembrance Drive intersects Wellers Road via a road embankment. A culvert is located at the northern end of the embankment, immediately adjacent to the Main Southern Railway. The embankment is approximately 250 metres long and 5.1 metres high at its highest point. Photographs along the road embankment to Remembrance Drive at the Wellers Road intersection are shown in Fig. 3.30 and Fig. 3.31.

Fig. 3.30 Remembrance Drive embankment at Wellers Road intersection

Photograph courtesy Douglas Partners

Fig. 3.31 Remembrance Drive embankment south of Yarran Road on downstream side

The embankment is located approximately 370 metres beyond the commencing end of LW S6A at the Wellers Road Overbridge. Predictions along the road and at the culvert were provided in Sections 3.9 and 3.10 of this Management Plan.

The embankment has been inspected and assessed by geotechnical engineer Douglas Partners (2022a and 2022b), who have labelled the embankment as RE1 in its report. The embankment has batter slopes between 30 and 38 degrees with localised sections up to 45 degrees. The embankment fill typically comprised moderately to well compacted silty clay, sandy clay, sand silty clay. Table drains are located on both sides of the embankment.

The embankment has shoulder lanes on both sides that are between 1.5 metres and 2.3 metres wide. The travel lanes are setback at least 2 to 3 metres from the crest of the embankment on both sides. Douglas Partners have conducted a NSW RMS slope risk analysis of the embankment and assessed the risk level as ARL5, which is the lowest risk level.

Douglas Partners (2022b) have also completed a detailed slope stability assessment and advised that there is sufficient robustness in the current stability of the embankment to ensure that planned contingency measures can be effectively implemented in a timely manner to ensure that the embankment remains safe and serviceable even if deviations from the results of the risk assessments and/or uncertainties are identified during the development of subsidence. Douglas Partners did not identify sections of the embankment with inadequate stability. There are no signs of deep-seated movement in the pavement or discernible signs of seepage.

In the unlikely event that the embankment slope experiences impacts during mining, the embankment can be repaired by sealing cracks, or placing permanent fill or rock spall at the base of the embankment. In the extremely unlikely event that an instability occurs that affects road safety, traffic could be diverted to the other travel lane whilst repairs are conducted. A traffic management plan will be developed to the satisfaction of Council to manage traffic along Remembrance Drive and Wellers Road in the event that an emergency lane closure is required on the embankment.

Services infrastructure run along the crest and base of the embankment on both sides, including Jemena's 150 mm gas main and 180 mm diameter sewer main and optical fibre cables. Sydney Water's 450 mm diameter potable water main does not run along this embankment.

Tahmoor Coal have conducted a detailed survey of the Jemena gas main, which runs along the eastern, southbound or downstream side of the embankment.

The purpose of the services survey is to provide input to contingency planning in the unlikely event that observed differential mine subsidence movements at the embankment exceed levels that trigger a response to excavate and expose the pipeline(s) to relieve a potential build-up of stress in the pipework. The contingency plans are included in the subsidence management plan that is being developed in consultation with Jemena. The contingency plan will include a traffic management plan, which will be provided to Council for review and approval.

The Main Southern Railway is located immediately downstream of the Remembrance Drive embankment. The 900 mm dia brick arch railway culvert is located at 101.000 km. The waterway will be inspected and maintained to ensure water drains through both the road and railway culverts. The waterway will be inspected and maintained to ensure water drains through both the road and railway culverts. A detailed subsidence management plan is also being developed in consultation with ARTC. The management plan will include management of potential impacts on the railway embankment and culverts. The management plan will also include management of potential impacts on Wellers Road Overbridge.

3.11.5. Summary of measures to manage potential impacts on Remembrance Drive embankments

Tahmoor Coal has developed and selected risk control measures in consultation, co-ordination and co-operation with Wollondilly Shire Council in accordance with WHS legislation. In this instance, there are no reasonably practicable controls which could eliminate, substitute or isolate the identified risks.

One engineering control has been identified that prevents or minimises risks, which is to ensure the culverts are clear and free of vegetation.

Tahmoor Coal has identified controls that will manage potential issues associated with the identified risks:

- Absolute 3D and 2D surveys along Remembrance Drive;
- Local 3D / Absolute 3D survey of embankments with pegs spaced along the crest and toe on both sides of each embankment. Pegs spacings are generally every 20 metres. The layout of survey marks is shown in Drawings Nos. MSEC1193-03-07 to MSEC1193-03-10;
- Local 3D / Absolute 3D survey of culverts with survey marks located at the spring point on both sides at the outlet and inlet of the culverts. Survey marks will also be installed at the midpoint of the 1.8 metre diameter reinforced concrete culvert south of Yarran Road;
- Visual inspections along Remembrance Drive pavement, embankments and culverts during periods of active subsidence by a building inspector and geotechnical engineer;
- Visual inspections of dams immediately upstream of road embankments during periods of active subsidence by building inspector and geotechnical engineer;
- Implementation of planned responses, if triggered by monitoring results. These may include:
  - Inspections by geotechnical engineer;
  - Increase monitoring and reporting procedures;
  - Fill and seal cracks and/or regrade drainage lines;
  - Place permanent or temporary fill / rock spall to the base of the embankment;
  - Resurface affected road pavement;
  - Additional visual inspections of culvert following periods of extreme wet weather;
  - As a last resort emergency response measure, introduce a temporary speed restriction and/or temporary lane closure until instability is repaired.
- Develop a traffic management plan to manage traffic along Remembrance Drive in the event that mining-induced damage requires repair.

With the implementation of the above management strategy, Tahmoor Coal will ensure that the health and safety of people in the vicinity of the road embankments will not be put at risk due to differential mine subsidence movements due to the extraction of LWs S1A to S6A.

A traffic management plan will be developed to the satisfaction of Council for the installation and continued monitoring of survey pegs. A traffic management plan will be developed to the satisfaction of Council to manage traffic along Remembrance Drive in the event that mining-induced damage develops along the road and requires repair.

3.12. Road cutting

Remembrance Drive passes through a rock cutting between Caloola Road and Yarran Road. The cutting is approximately 430 metres long and 5 metres high at its highest point. Photographs along the road cutting are shown in Fig. 3.32 and Fig. 3.33.

Photograph courtesy Douglas Partners

Fig. 3.32 Remembrance Drive cutting above LW S4A looking east

Source: Google Streetview

Fig. 3.33 Remembrance Drive cutting showing cross-section

The cutting is located directly above LW S4A. Predictions along the road were provided in Section 3.9 of this Management Plan.

The cutting has been inspected and assessed by geotechnical engineer Douglas Partners (2022a), who have labelled the embankment as RC1 in its report. The cutting has batter slopes between 41 and 45 degrees in sandstone has shoulder lanes on both sides that are between 1.5 metres and 2.3 metres wide. The sandstone in the cut is very low to low strength and highly weathered in the upper cut grading into medium to thickly bedded, medium to high strength, moderately to slightly weathered sandstone in the lower and middle sections of the cut. A drain is located above the road cutting on the eastern side.

Tension cracking was observed behind the crest above the road cutting opposite No. 3122 Remembrance Drive.

The toe of the cutting is approximately 4.4 to 5.4 metres from the edge of the travel lanes on both sides. Douglas Partners have conducted a NSW RMS slope risk analysis of the embankment and assessed the risk level between ARL5, which is the lowest risk level and ARL3, which is within the tolerable range.

Tahmoor Coal has extensive experience of mining beneath railway cuttings in the Southern Coalfield of NSW at similar depths of cover (Kay et al, 2017). While impacts have not previously been observed to batter slopes, non-conventional subsidence movements have been observed to develop within railway cuttings, resulting in impacts on track geometry. The sides of some cuttings (but not all) have been observed to close in response to mine subsidence.

Based on previous experiences in rail cuttings, it is possible that the Remembrance Drive cutting could experience mining-induced impacts on the road pavement. The sub-base supporting the pavement is likely to have minimal cover to the underlying rock such that mining-induced deformations in the bedrock could be reflected in the pavement. The potential impacts can, however, be managed by regular surveys and visual inspections during mining with repairs conducted as required.

Tahmoor Coal has developed and selected risk control measures in consultation, co-ordination and co-operation with Wollondilly Shire Council in accordance with WHS legislation. In this instance, there are no reasonably practicable controls which could eliminate, substitute or isolate the identified risks.

Two engineering controls have been identified that prevents or minimises risks, which are listed below.

- Scale the cutting batter slopes to remove loose debris and rocks, and
- Clear the cutting drainage lines and maintain the drainage lines to ensure that they remain free of debris and vegetation during mining.

Tahmoor Coal has identified controls that will manage potential issues associated with the identified risks:

- Absolute 3D and 2D surveys along Remembrance Drive;
- Local 3D / Absolute 3D survey of the cutting with pegs spaced along the crest and toe on both sides of the cutting. Pegs spacings are generally every 20 metres. The layout of survey marks is shown in Drawing No. MSEC1193-03-11;
- Visual inspections along Remembrance Drive pavement and cutting during periods of active subsidence by building inspector and geotechnical engineer;
- Implementation of planned responses, if triggered by monitoring results. These may include:
    - Inspections by geotechnical engineer;
    - Increase monitoring and reporting procedures;
    - Resurface affected road pavement;
    - Fill and seal cracks and/or regrade drainage lines;
    - As a last resort emergency response measure, introduce a temporary speed restriction and/or temporary lane closure until pavement or batter slope is repaired.
- Develop a traffic management plan to manage traffic along Remembrance Drive in the event that mining-induced damage requires repair.

With the implementation of the above management strategy, Tahmoor Coal will ensure that the health and safety of people in the vicinity of the road cutting will not be put at risk due to differential mine subsidence movements due to the extraction of LWs S1A to S6A.

A traffic management plan will be developed to the satisfaction of Council for the installation and continued monitoring of survey pegs. A traffic management plan will be developed to the satisfaction of Council to manage traffic along Remembrance Drive in the event that mining-induced damage develops along the road and requires repair.

3.13. Bridges

There are no bridges along local roads within the vicinity of LW S1A-S6A., though some bridges may experience far field movements during the mining of LW S1A-S6A. A summary of the closest distances of LW S1A to S6A to the bridges are provided in Table 3.12.

Table 3.12 Bridges potentially affected by far field movements

Bridge	Closest distance (m)	Closest LW	Closest LW end
Remembrance Drive Bridge over the Bargo River and Main Southern Railway	1,690 m	LW S1A	Finishing end (North-western end)
Bargo River Road Bridge over the Main Southern Railway (Potters Cutting Overbridge)	2,000 m	LW S1A	Finishing end (North-western end)
Bargo River Road Bridge over a tributary to Bargo River	1,790 m	LW S1A	Finishing end (North-western end)
Arina Road Bridge over Dog Trap Creek	2,235 m	LW S1A	Commencing end (South-eastern end)
Rockford Road Bridge over Bargo River	2,335 m	LW S1A	Commencing end (South-eastern end)
Wellers Road Overbridge over the Main Southern Railway	370 m	LW S6A	Commencing end (South-eastern end)

The Remembrance Drive Bridge over the Bargo River and Main Southern Railway and the two railway overbridges (Bargo River Road and Wellers Road) are managed by the railway infrastructure owners and operators. Risk control measures to manage potential impacts on these bridges are described in a separate management plan for the Main Southern Railway, which will be developed in consultation with the Australian Rail Track Corporation (ARTC) and Transport for NSW (TfNSW). A copy of that management plan can be provided to Wollondilly Shire Council.

3.13.1. Bargo River Road Bridge

Description and setting

The Bargo River Bridge spans across a tributary to the Bargo River near the Bargo River Reserve. The 14.4 metre single-span dual lane Bridge is comprised of a reinforced concrete deck on reinforced concrete abutments and wingwalls (JMA, 2022b). The approach to the Bridge is shown in Fig. 3.34.

Google Streetview

Fig. 3.34 Bargo River Road Bridge over tributary to Bargo River

The bridge was constructed in 2013, replacing an old bridge that used to carry traffic along the Old Hume Highway. A photograph of the bridge from stream level is shown in Fig. 3.35 and a photograph of the bridge abutment is shown in Fig. 3.36.

Photograph courtesy JMA Solutions (2022b)

Fig. 3.35 Bargo River Road Bridge (JMA, 2022b)

Photograph courtesy JMA Solutions (2022b)

Fig. 3.36 Bargo River Road Bridge abutment (JMA, 2022b)

Previous mining near the Bridge

Tahmoor Mine has extracted around all four sides of the Bridge site, as shown in Fig. 3.37. As shown by the dates of extraction, the new 2013 Bridge has been constructed after previous mining has occurred.

Tahmoor South LWs S1A to S6A are located in the southwest corner of the map below, with the closest distance of 1,785 metres to the Bridge.

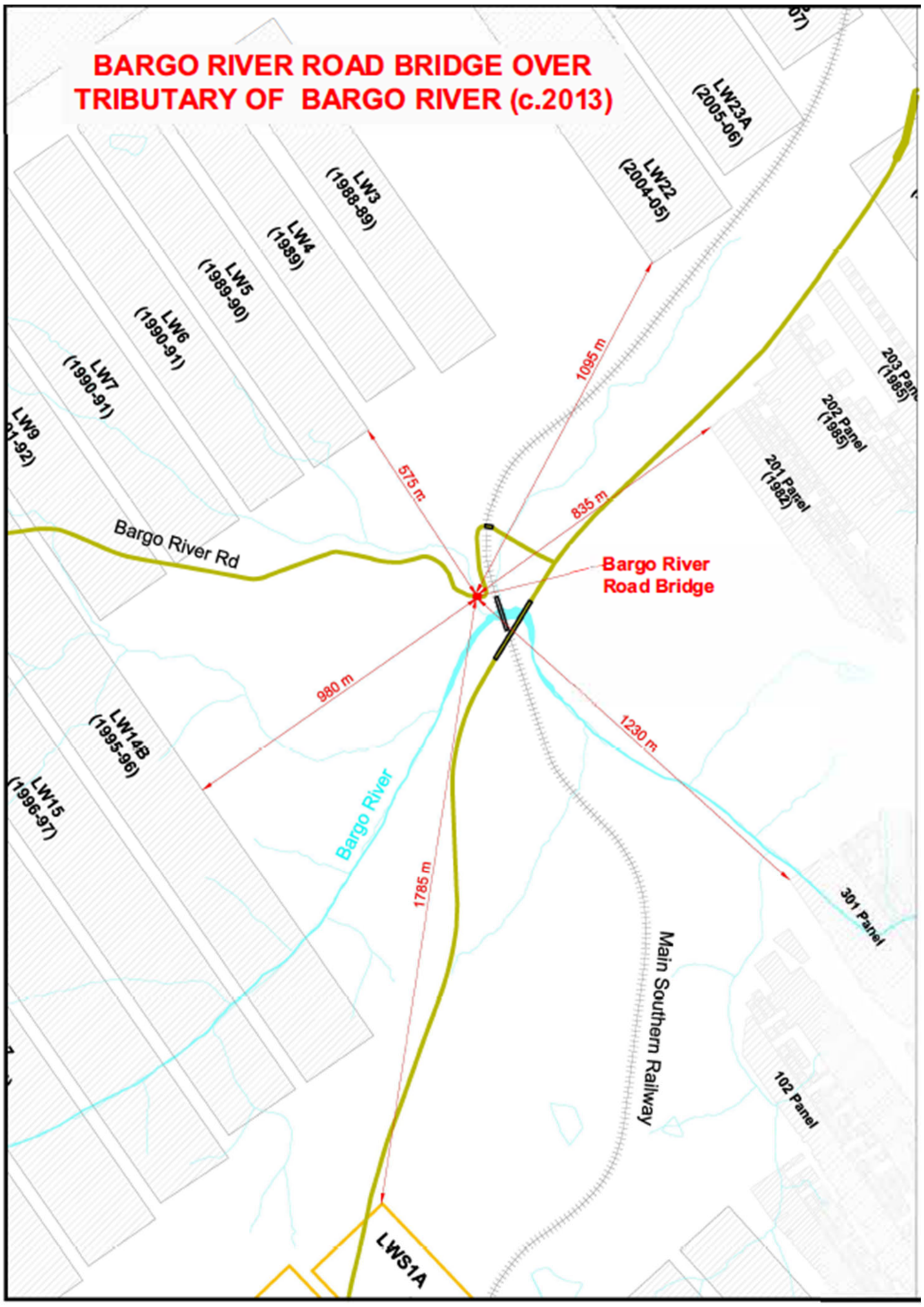

Fig. 3.37 Location of Bargo River Bridge relative to mine layout

Potential future mining-induced movements at the Bridge

The Bridge may experience mining-induced movements during the extraction of LWs S1A to S6A.

A statistical analysis of potential absolute far field horizontal movements is provided in Section 3.5 of this Management Plan, with results relevant to the Bridge highlighted in Table 3.13.

Table 3.13 Confidence levels for incremental horizontal movement for survey marks above solid coal for monitoring lines at Tahmoor, Appin, West Cliff and Tower Collieries at offset distances equivalent to Bargo River Road Bridge

Distance from active longwall (m)	Incremental horizontal movement within 95% confidence level (mm)	Incremental horizontal movement within 99% confidence level (mm)
1600 (LWs S1A to S6A)	26	35
1800 (LWs S1A to S6A)	23	30
2000	22	27

A statistical analysis of potential differential far field horizontal movements is provided in Section 3.5 of this Management Plan, with results relevant to the Bridge highlighted in Table 3.14. As discussed previously, there is insufficient data to estimate probabilities greater than 1800 metres as there are insufficient measurements beyond the nominal survey tolerance of 3 mm.

Table 3.14 Probabilities of exceedance for incremental differential horizontal movements for survey bays located from the nearest goaf edge in the Southern Coalfield at offset distances equivalent to Bargo River Road Bridge

Offset distance from LW	Probability of Exceedance	Incremental differential horizontal movements for pegs spaced between 10 and 30m (mm)		
		Opening (mm)	Closure (mm)	Horizontal mid-ordinate deviation (mm)
1700 m to 2400 m (LWs S1A to S6A)	1 in 20 (0.05)	3	3	3
	1 in 100 (0.01)	4	4	8

The results suggest that measured changes at these offset distances have typically been close to survey tolerance and that the results of the statistical analyses for the low probability events (i.e. 1 in 20 and 1 in 100) have likely been influenced by survey tolerance.

While the offset distances of LWs S1A to S6A to the Bridge are substantial, there remains a chance that differential far field movements could adversely affect the Bridge. The Bridge is situated near a bend in the Bargo River. The bend is likely to have been influenced by surface geology. Tahmoor Coal conducted a geological investigation and the results are provided below.

Geological mapping

Newcastle Geotech (2022) has conducted a geotechnical investigation and advised the following:

- Geological structure mapping by Tahmoor Coal has identified fault structures at seam level. The locations of the fault structures are shown in Drawing No. MSEC1193-03-01. While the orientation of the structures are aligned with the downstream leg of the Bargo River, they are located away from the Bridge. The fault structures at seam level, 400 metres below ground, may not necessarily extend to the surface but even if they did extend to the surface, Newcastle Geotech advised that it would likely only be offset by approximately 100 metres from the mapped position at seam level, assuming a 15 degree inclination. The mapped structures do not, therefore, intersect the Bridge.
- The river alignment upstream of the Bridge is formed along a prominent north-east striking lineament and the downstream leg is formed along a prominent north-west striking lineament. In the absence of observable fault structures along the river bed, it is inferred that the linear nature of the river alignment in the area is the results of river bed formation along dominant joint sets rather than along fault or fractured rock zones.
- A site inspection at the Bridge identified a horizontal sheet outcrop of moderately weathered medium strength sandstone rock occur at creek bed level, which extends below the abutments.
- A site inspection of the tributary was conducted from the confluence to the Bargo River up to 100 metres upstream of the Bridge. No obvious evidence of geological structures comprising faults (fractured and displaced rock strata) or dykes (igneous intrusion) were observed along the creek bed. Some minor features were observed near the Bridge, including preferential weathering

along a NSW joint feature 15 metres downstream of the Bridge, and a localised stepped surface across the sandstone outcrop due to closely spaced bedding planes.

Bridge condition inspection

The Bridge was inspected by structural engineer John Matheson, who advises that the structure was in serviceable condition at the time of the inspection with no significant cracking observed (JMA, 2022b).

Structural investigation and assessment

JMA Solutions (2022b) has conducted a structural investigation and assessment of the Bridge and advised the following:

- The bridge consists of precast reinforced concrete girders on reinforced concrete abutments and piers. The Bridge spans approximately 14.4 metres.
- The bridge abutments are protected from scouring with riprap armour.
- While 20 mm wide gaps are present between the ends of the bridge deck and the abutment walls, the deck girders are tied to the abutments via 32 mm diameter stainless steel dowels within 40 mm diameter sleeves.
- The deck is likely to experience creep and shrinkage over time. Taking into account expansion and contraction of the deck due to changes in temperature and creep and shrinkage, there is no excess movement capacity at the dowels to accommodate closure between the abutments.
- JMA (2022b) recalls observations during the previous mining of Tahmoor Longwalls 23A and 24B beneath the Castlereagh Street Bridge, which was of similar construction. The bridge resisted minor mining-induced closure between the abutments.
- In the unlikely event that valley closure develops between the abutments, the closure is likely to be resisted by the dowels, the bridge deck and the road formation and backfill behind the abutments.
- In the unlikely event that the bridge experiences transverse horizontal movements between the abutments, the bridge deck is likely to pivot around the centreline of the bridge at both abutments, resulting in loads on the dowels.
- While the likelihood of mining-induced differential movements on the Bridge is considered low, it is recommended that the Bridge be monitored during the extraction of LWs S1A to S6A.
- In the extremely unlikely event that the bridge experiences mining-induced closure or opening of the abutments, and/or transverse shear, it is recommended that the dowels on one side of the Bridge be disconnected to avoid uncontrolled failure of the dowels. The deck could be reconnected to the abutments after mining-induced movements have eased.

Bridge Technical Committee

Following consultation between Tahmoor Coal and the Resources Regulator, Tahmoor Coal has appointed a Technical Committee to review the findings from site investigations and structural assessments. The Technical Committee will assist with the development of the management plan for the Bridge, which will be completed prior to 800 metres of extraction of LW S1A. The Technical Committee inspected the Bridge on 8 September 2022.

The Technical Committee inspected the Bridge on 8 September 2022 and provided feedback on the structural reports and reviewed the monitoring plan on 6 October 2022.

Summary of measures to manage potential impacts on Bargo River Road Bridge

Tahmoor Coal has developed and selected risk control measures in consultation, co-ordination and co-operation with Wollondilly Shire Council in accordance with WHS legislation to manage mining-induced changes on the Bridge due to the extraction of LWs S1A to S6A. The measures will be reviewed by the Technical Committee prior to 800 metres of extraction of LW S1A.

Elimination

In this instance, no reasonably practicable controls could be identified that would eliminate the identified risks.

Substitution

In this instance, no reasonably practicable controls could be identified that will change the environment so the hazards could be substituted for hazards with a lesser risk.

Isolation

In this instance, no reasonably practicable controls could be identified to isolate a hazard from any person exposed to it.

Engineering Controls

In this instance, no reasonably practicable controls could be identified to prevent or minimise risks.

Administrative Controls

The following Administrative Control was identified and selected that will put in place procedures on site to minimise the potential of impacts on the safety of the Bridge:

- Continuous GNSS monitoring at two locations across the bend in the Bargo River. The two units S11 and S12 have been installed within the railway corridor near the Railway Viaduct, where access is available. The locations are shown in Drawing No. MSEC1193-03-02. GNSS unit S11 is located within 100 metres of the Bridge;
- Local 3D surveys of structure and ground marks on the Bridge, as shown in Drawing No. MSEC1193-03-03, with one mark on the Bridge to be surveyed in Absolute 3D;
- Visual inspections of the Bridge;
- Implementation of planned responses, if triggered by monitoring results. These may include:
  - Inspections by structural engineer;
  - Assess the latest results and observations and consider management actions;
  - Increase monitoring and reporting procedures;
  - Disconnect the bridge deck from one of the abutments;
  - Resurface affected road pavement;
  - As a last resort emergency response measure, slow or stop the longwall and/or vehicle traffic.

With the implementation of the above management strategy, Tahmoor Coal will ensure that the health and safety of people in the vicinity of the Bridge will not be put at risk due to differential mine subsidence movements due to the extraction of LWs S1A to S6A.

3.13.2. Rockford Road Bridge over the Bargo River

Description and setting

The Rockford Road crosses the Bargo River between Tahmoor and Pheasants Nest. The six-span dual lane Bridge was constructed in 1966 and comprises reinforced concrete abutments, with intermediate reinforced concrete piers on pad footings, founded in sandstone (JMA, 2022c). The Bridge was modified in 1994 prior to the mining of Tahmoor Longwalls 12 and 13. A photograph of the original and modified Bridge is shown in Fig. 3.38.

Original Bridge (1966)

Modified Bridge (post mining in1994)

Fig. 3.38 Rockford Road Bridge over Bargo River

Extensive mitigation measures were installed by the Mine Subsidence Board in 1994 prior to successfully mining directly beneath the Bridge (Waddington and Kay, 1995). The pad footings were tied together by encasing them in reinforced concrete. The concrete tie-beams were then used to support a jacking frame that ensured the bridge deck remained planar during the mining period.

Photographs of the bridge modification and jacking works prior to the mining of Longwalls 12 and 13 are shown in Fig. 3.39 to Fig. 3.42. Current photographs of the Bridge are shown in Fig. 3.43 and Fig. 3.44.

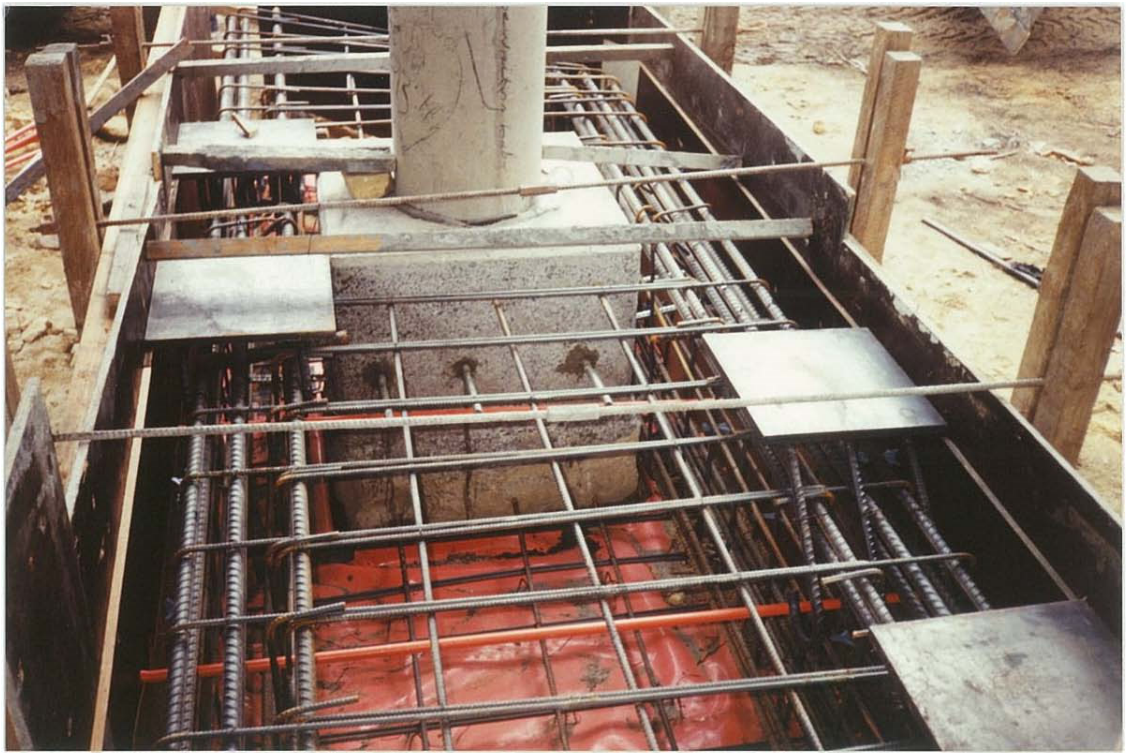

Fig. 3.39 Pad footings tied together at Rockford Road Bridge prior to mining of LW12

Fig. 3.40 Headstock bents / upstands removed at Rockford Road Bridge prior to mining of LW12

Fig. 3.41 Jacking frames installed at Rockford Road Bridge over Bargo River

Fig. 3.42 Modified approach ramps to Rockford Road Bridge over Bargo River

Photograph courtesy JMA Solutions (2022a)

Fig. 3.43 Current view of Southern abutment of Rockford Road Bridge over Bargo River

Photograph courtesy JMA Solutions (2022c)

Fig. 3.44 Current view along deck of Rockford Road Bridge over Bargo River

Previous mining near the Bridge

Tahmoor Mine has extracted Longwall 12 directly beneath the Rockford Road Bridge, as shown in Fig. 3.45. Tahmoor South LWs S1A to S6A are located in the southwest corner of the map below, with the closest distance of 2,295 metres to the Bridge.

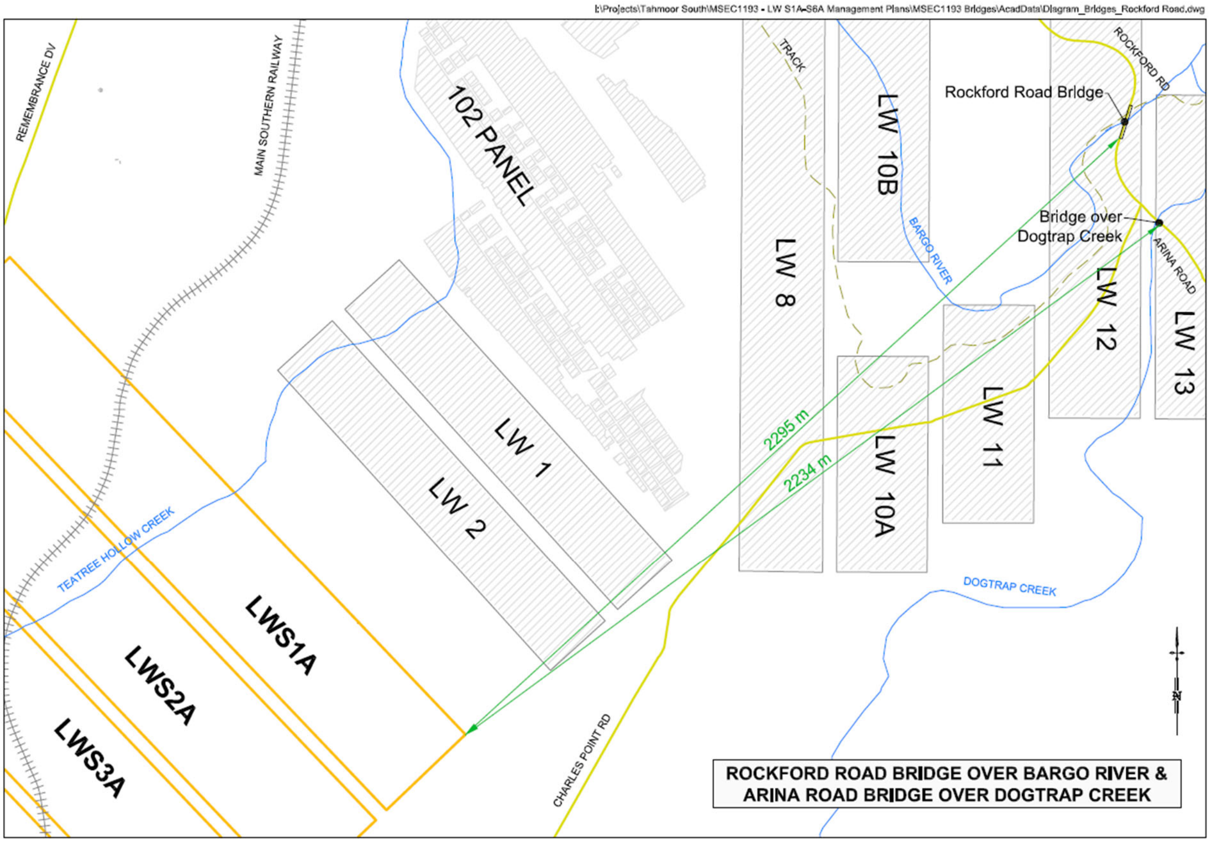

Fig. 3.45 Location of Rockford Road Bridge over Bargo River and Arina Road Bridge over Dog Trap Creek relative to mine layout

The Bridge was monitored continuously and frequently adjusted as necessary during periods of active subsidence due to the mining of Longwalls 12 and 13.

Subsidence surveys were conducted periodically by Tahmoor Coal. Survey marks were placed on the abutments, foundations and deck of the bridge structure. Survey marks were also placed in the ground including on the supporting rockbar along the alignment of the Bridge, and along a survey line that was transverse to the Bargo River. The locations of the previous survey marks are shown in Drawing No. MSEC1193-03-04.

Summary graphs showing observed subsidence, tilt and changes in horizontal distances along the bridge deck and bridge foundations are shown in Fig. 3.46 to Fig. 3.49. It can be seen from Fig. 3.46 and Fig. 3.47 that the jacking operations successfully adjusted the bridge deck so that it remained a planar configuration with articulating approach ramps at each abutment. Changes were focussed between the deck and the abutments at each end. Greater changes were observed at foundation level, as expected and shown in Fig. 3.48 and Fig. 3.49.

A summary graph showing the development of vertical subsidence during the mining of Tahmoor Longwalls 12 and 13 is shown in Fig. 3.50. The development of closure is also shown between the abutments and transverse to the Bargo River in Fig. 3.50. It can be seen that closure in a direction that was transverse to the River was greater than observed closure along the Bridge, which is skewed to the River.

The bridge experienced superficial cracking at the northern abutment at the junction between the supporting column and the headstock beam during the mining of Longwall 12 (Waddington and Kay, 1995). Hairline cracking was also noted in the tie beams, indicating that they had been subjected to bending and tension.

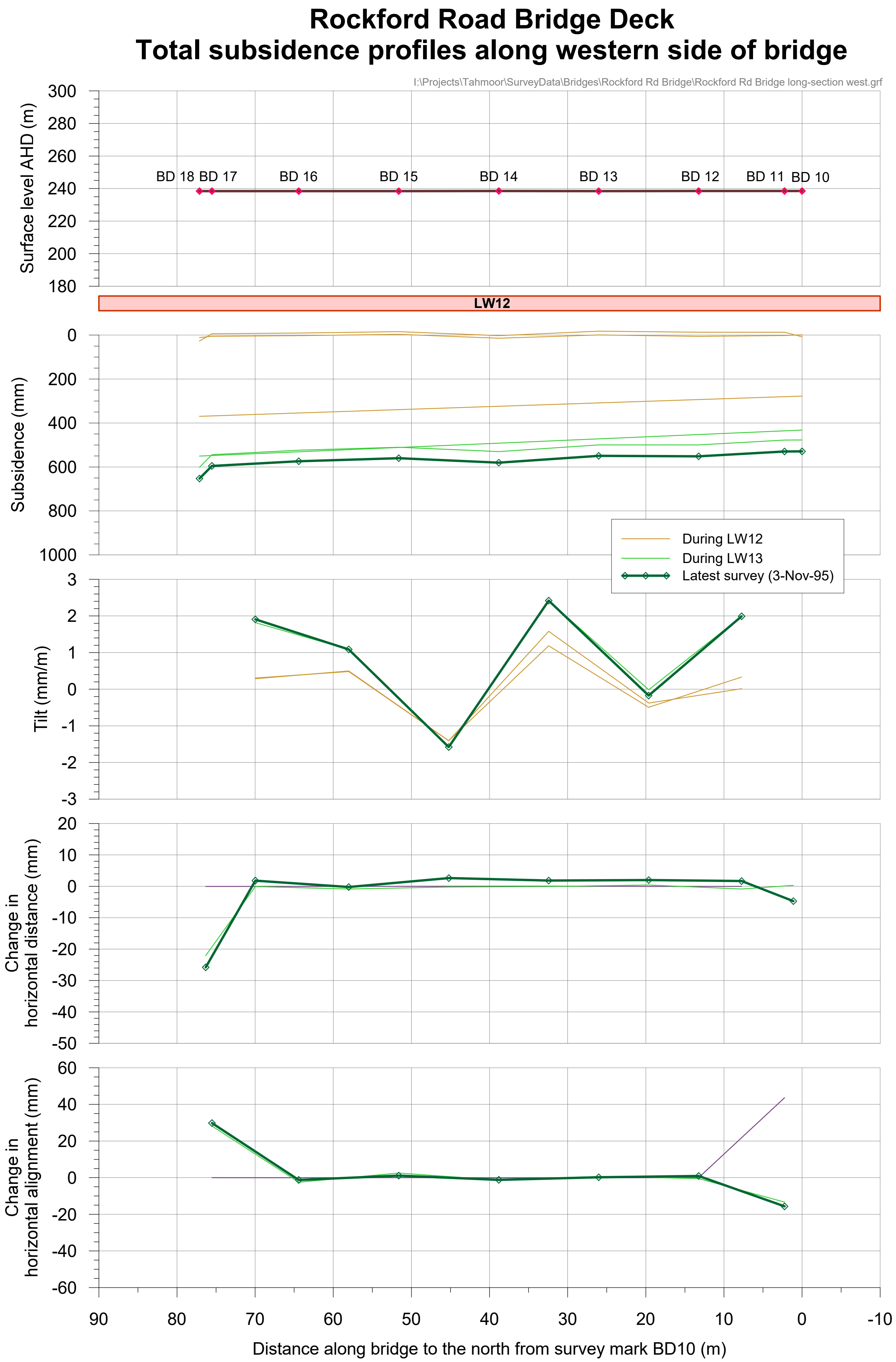

Fig. 3.46 Observed subsidence, tilt and changes in horizontal distances along the bridge deck on western side of Rockford Road Bridge

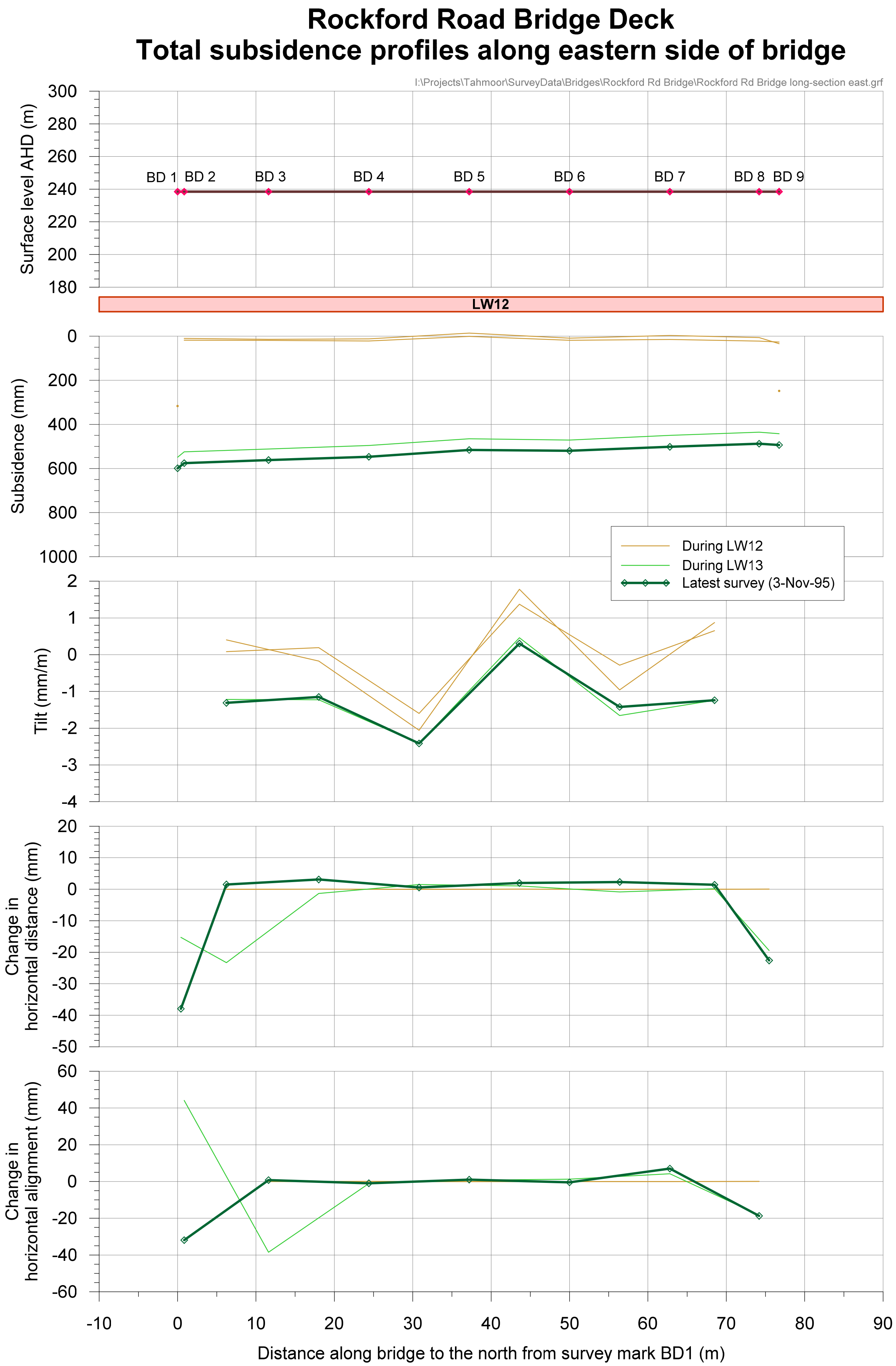

Fig. 3.47 Observed subsidence, tilt and changes in horizontal distances along the bridge deck on eastern side of Rockford Road Bridge

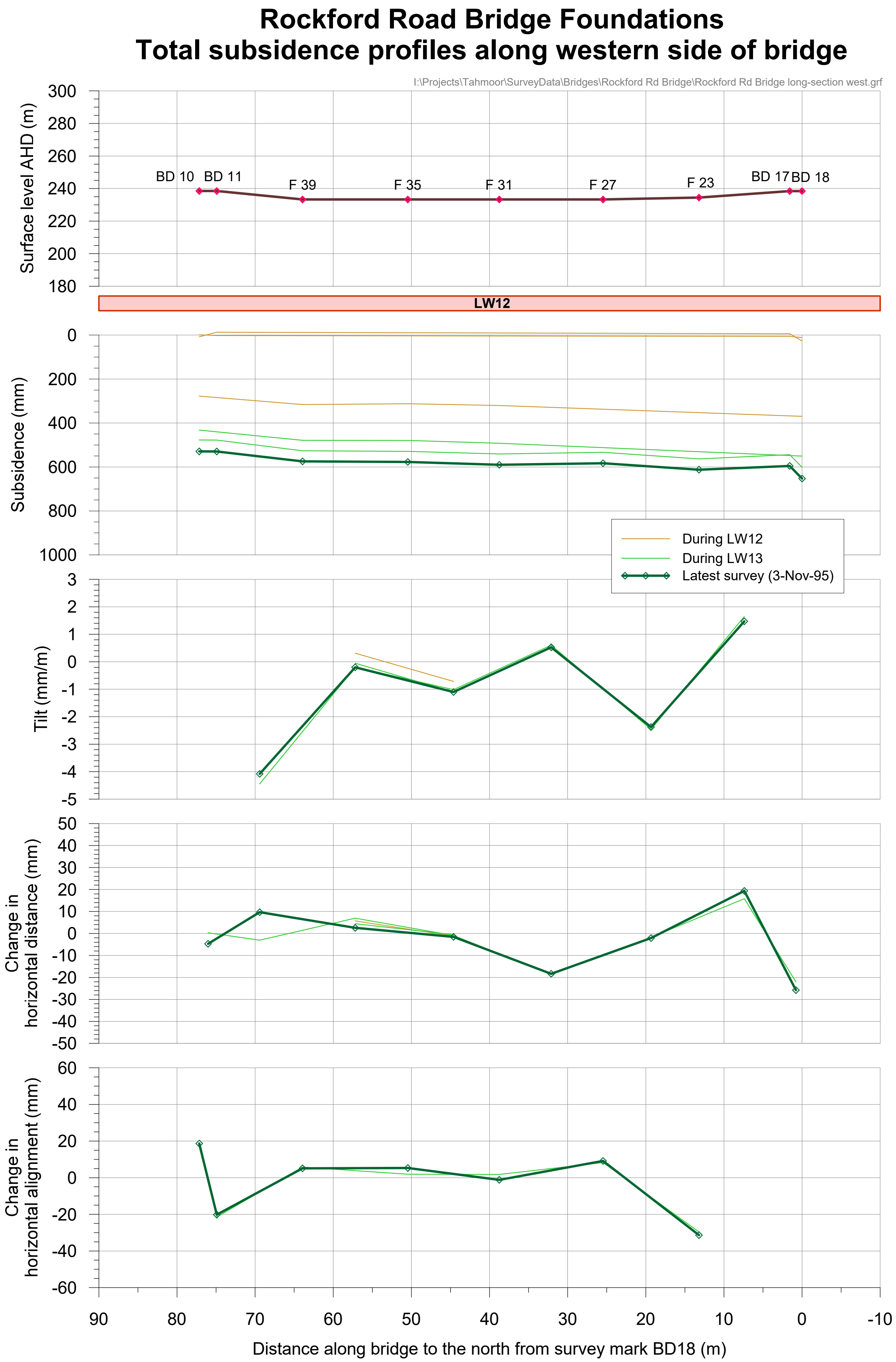

Fig. 3.48 **Observed subsidence, tilt and changes in horizontal distances along the bridge piers and abutments on western side of Rockford Road Bridge**

Rockford Road Bridge Foundations
Total subsidence profiles along eastern side of bridge

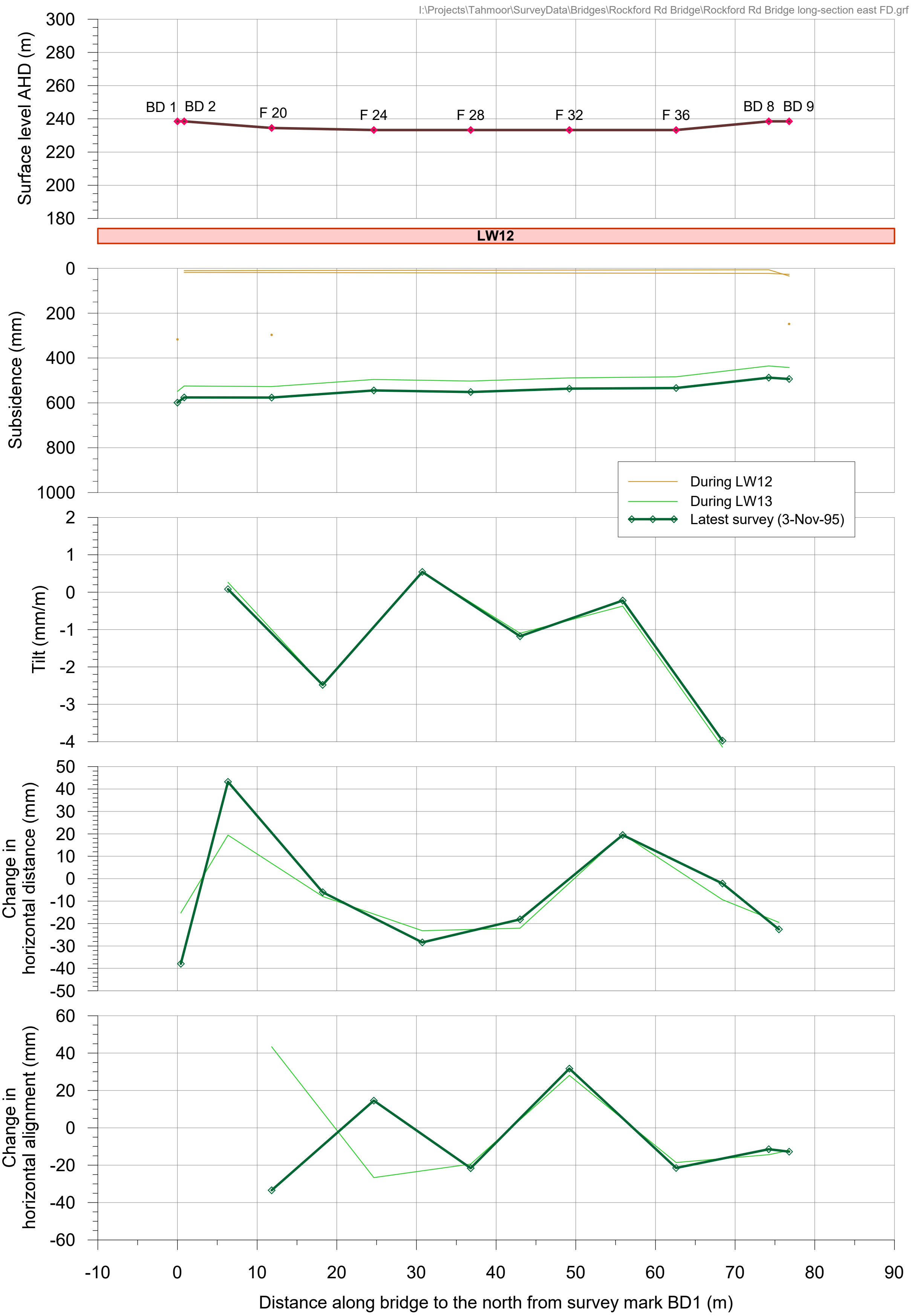

Fig. 3.49 **Observed subsidence, tilt and changes in horizontal distances along the bridge piers and abutments on eastern side of Rockford Road Bridge**

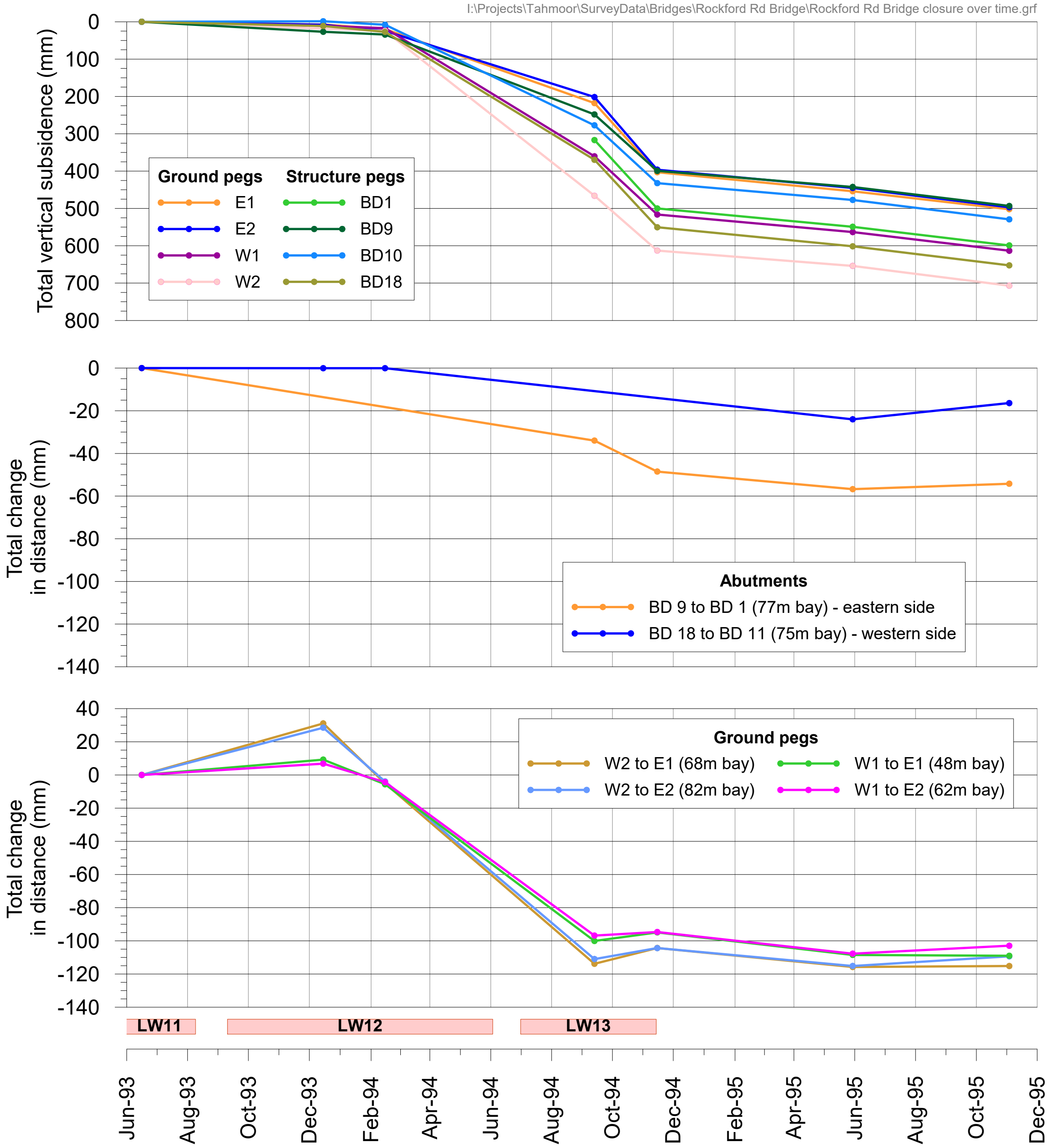

Fig. 3.50 Development of subsidence and closure across Rockford Road Bridge during the mining of LWs 12 and 13

Potential future mining-induced movements at the Rockford Road Bridge

Whilst the likelihood is very low, the Bridge may experience some minor additional absolute and differential movements during the extraction of LWs S1A to S6A.

A statistical analysis of potential absolute far field horizontal movements is provided in Section 3.5 of this Management Plan, with results relevant to the Bridge highlighted in Table 3.13.

Table 3.15 Confidence levels for incremental horizontal movement for survey marks above solid coal for monitoring lines at Tahmoor, Appin, West Cliff and Tower Collieries at offset distances equivalent to Rockford Road Bridge over the Bargo River

Distance from active longwall (m)	Incremental horizontal movement within 95% confidence level (mm)	Incremental horizontal movement within 99% confidence level (mm)
2000 (LWs S1A to S6A)	22	27

A statistical analysis of potential differential far field horizontal movements is provided in Section 3.5 of this Management Plan, with results relevant to the Bridge highlighted in Table 3.14. As discussed previously, there is insufficient data to estimate probabilities greater than 1800 metres as there are insufficient measurements beyond the nominal survey tolerance of 3 mm.

Table 3.16 Probabilities of exceedance for incremental differential horizontal movements for survey bays located from the nearest goaf edge in the Southern Coalfield at offset distances equivalent to Rockford Road Bridge over the Bargo River

Offset distance from LW	Probability of Exceedance	Incremental differential horizontal movements for pegs spaced between 70 and 90m (mm)		
		Opening (mm)	Closure (mm)	Horizontal mid-ordinate deviation (mm)
1700 m to 2400 m (LWs S1A to S6A)	1 in 20 (0.05)	4	4	5
	1 in 100 (0.01)	6	5	8

The results suggest that measured changes at these offset distances have typically been close to survey tolerance and that the results of the statistical analyses for the low probability events (i.e. 1 in 20 and 1 in 100) have likely been influenced by survey tolerance.

While there remains a chance that the extraction of LWs S1A to S6A could result in differential far field movements at the Bridge, the likelihood is considered to be extremely low given:

- The 2.2 kilometre offset distances of LWs S1A to S6A to the Bridge are substantial;
- LWs S1A to S6A are separated from the Bridge by five previously extracted longwalls and a large bend in the Bargo River upstream of the Bridge; and
- Surveys during the mining of LWs 12 and 13 measured relatively minor closure of 60 mm along the Bridge, due to its skewed alignment to the Bargo River. Potential movements due to the extraction of LWs S1A to S6A will be orders of magnitude less than previously observed due to the remote position of the Bridge relative to the proposed longwalls.

In the extremely unlikely event that adverse movements occur during the mining of LWs S1A to S6A, differential movements may focus where they previously occurred at the locations shown in Fig. 3.48 and Fig. 3.49.

Structural investigation and assessment

JMA Solutions (2022c) has conducted a structural investigation and assessment of the Bridge and advised the following:

- The bridge appeared to be in serviceable condition when inspected on 23 May 2022.
- Gaps were measured on 23 May 2022 between the parapet kerbs and abutments on the upstream (western) and downstream (eastern) sides of the Bridge. Gaps are currently present to accommodate additional valley closure movements except on the downstream (eastern) side of the northern abutment, as shown in Table 3.17.

Table 3.17 Measured gaps between kerbs and abutments at Rockford Road Bridge (JMA, 2022c)

Side of Bridge	Northern abutment (mm)	Southern abutment (mm)	Total closure capacity (mm)
Upstream (western)	39	11	50
Downstream (eastern)	2	35	37

- The bridge girders are supported by an elastomeric bearing strip at the pier headstocks and elastomeric bearing pads at the abutments. If valley closure or opening occurs, the abutments could move towards or away from the creek line, causing joint closure or opening and shear strain in the elastomeric bearings.
- If the bridge experiences transverse / lateral displacements due to mining, the deck is expected to pivot at the abutments, causing sidesway of the pier and headstock bents.
- Based on current modelling, the bridge structure is expected to remain serviceable if it experiences up to 20 mm of valley closure or opening and 20 mm of transverse step displacement due to the extraction of LWs S1A to S6A. The modelled deformations are well beyond the values that were provided at a probability of exceedance of 1 in 100, and well beyond the accuracy of the proposed survey methodology.
- In the extremely unlikely event that more than 20 mm of valley closure or opening or transverse step displacements develop at the Bridge, it is possible to cut greater gaps between the parapet kerbs and the abutments to accommodate additional valley closure, or to cut gaps at the headstock bents to accommodate additional transverse movements. The bearings may need to be reset or replaced if the actual movements exceed their capacities for shear.

Bridge Technical Committee

Following consultation between Tahmoor Coal and the Resources Regulator, Tahmoor Coal has appointed a Technical Committee to review the findings from site investigations and structural assessments. The Technical Committee will assist with the development of the management plan for the Bridge, which will be completed prior to 800 metres of extraction of LW S1A. The monitoring plan for the Bridge was reviewed prior to the commencement of LW S1A.

The Technical Committee inspected the Bridge on 8 September 2022 and provided feedback on the structural reports and reviewed the monitoring plan on 6 October 2022. Six additional survey marks were placed on the bridge deck, as recommended by the Technical Committee.

__Summary of measures to manage potential impacts on Rockford Road Bridge over Bargo River__

Tahmoor Coal has developed and selected risk control measures in consultation, co-ordination and co-operation with Wollondilly Shire Council in accordance with WHS legislation to manage mining-induced changes on the Bridge due to the extraction of LWs S1A to S6A. The measures will be reviewed by the Technical Committee prior to 800 metres of extraction of LW S1A.

Elimination

In this instance, no reasonably practicable controls could be identified that would eliminate the identified risks.

Substitution

In this instance, no reasonably practicable controls could be identified that will change the environment so the hazards could be substituted for hazards with a lesser risk.

Isolation

In this instance, no reasonably practicable controls could be identified to isolate a hazard from any person exposed to it.

Engineering Controls

In this instance, no reasonably practicable controls could be identified to prevent or minimise risks.

Administrative Controls

The following Administrative Control was identified and selected that will put in place procedures on site to minimise the potential of impacts on the safety of the Bridge:

- Local 3D surveys of structure and ground marks on the Bridge, as shown in Drawing No. MSEC1193-03-04, with one mark on the Bridge to be surveyed in Absolute 3D;
- Survey gaps between the parapet kerbs and the abutments;
- Visual inspections of the Bridge;
- Implementation of planned responses, if triggered by monitoring results. These may include:
    - Inspections by structural engineer;
    - Assess the latest results and observations and consider management actions;
    - Increase monitoring and reporting procedures;
    - Cut gaps between the parapet kerbs and the abutments;
    - Cut gaps to the headstock bents / upstands;
    - Resurface affected road pavement;
    - As a last resort emergency response measure, slow or stop the longwall and/or vehicle traffic;
- Develop a traffic management plan to manage traffic along Rockford Road Bridge in the event that mining-induced damage requires repair.

With the implementation of the above management strategy, Tahmoor Coal will ensure that the health and safety of people in the vicinity of the Bridge will not be put at risk due to differential mine subsidence movements due to the extraction of LWs S1A to S6A.

3.13.3. Arina Road Bridge over Dog Trap Creek

Description and setting

The Arina Road crosses Dog Trap Creek between Tahmoor and Pheasants Nest. The single-span dual lane Bridge spans 8.6 metres and comprises reinforced concrete deck on reinforced concrete abutments (JMA, 2022d). The Bridge was mined directly beneath by Tahmoor Longwalls 12 and 13. Photographs of the Bridge in 1994, prior to mining, are shown in Fig. 3.51. Recent photographs of the Bridge in 2022 are shown in Fig. 3.52.

Fig. 3.51 Arina Road Bridge over Dog Trap Creek prior to mining in 1994

Photographs courtesy JMA Solutions (2022d)

Fig. 3.52 Current view of Arina Road Bridge over Dog Trap Creek

Previous mining near the Bridge

Tahmoor Mine has extracted Longwalls 12 and 13 directly beneath the Arina Road Bridge, as shown previously in Fig. 3.45. Tahmoor South LWs S1A to S6A are located in the southwest corner of the map below, with the closest distance of 2,230 metres to the Bridge.

Engineering inspections and assessments were conducted by structural engineers Rickard & Partners in addition to their study on Rockford Road Bridge (Waddington and Kay, 1995). Whilst options were considered to jack the bridge deck, it was decided to manage potential impacts on the bridge by monitoring and responding to impacts, if required, with no modifications or mitigation measures implemented prior to the influence of mining.

The Bridge was monitored by a combination of visual inspections and surveys of marks that were mounted on each end of the abutments (four marks in total).

A summary plot showing the locations of the survey marks and the final measured horizontal movement vectors after the mining of Longwall 13 is shown in Fig. 3.53. Summary graphs showing the development of vertical subsidence, tilt and changes in horizontal distances along and across the bridge abutments are shown in Fig. 3.54. It can be seen from the results that the bridge experienced approximately 20 mm of closure between the abutments.

Very little impact was observed to the Bridge during the mining of Longwalls 12 and 13. It is understood that no adjustments were made to the Bridge after mining.

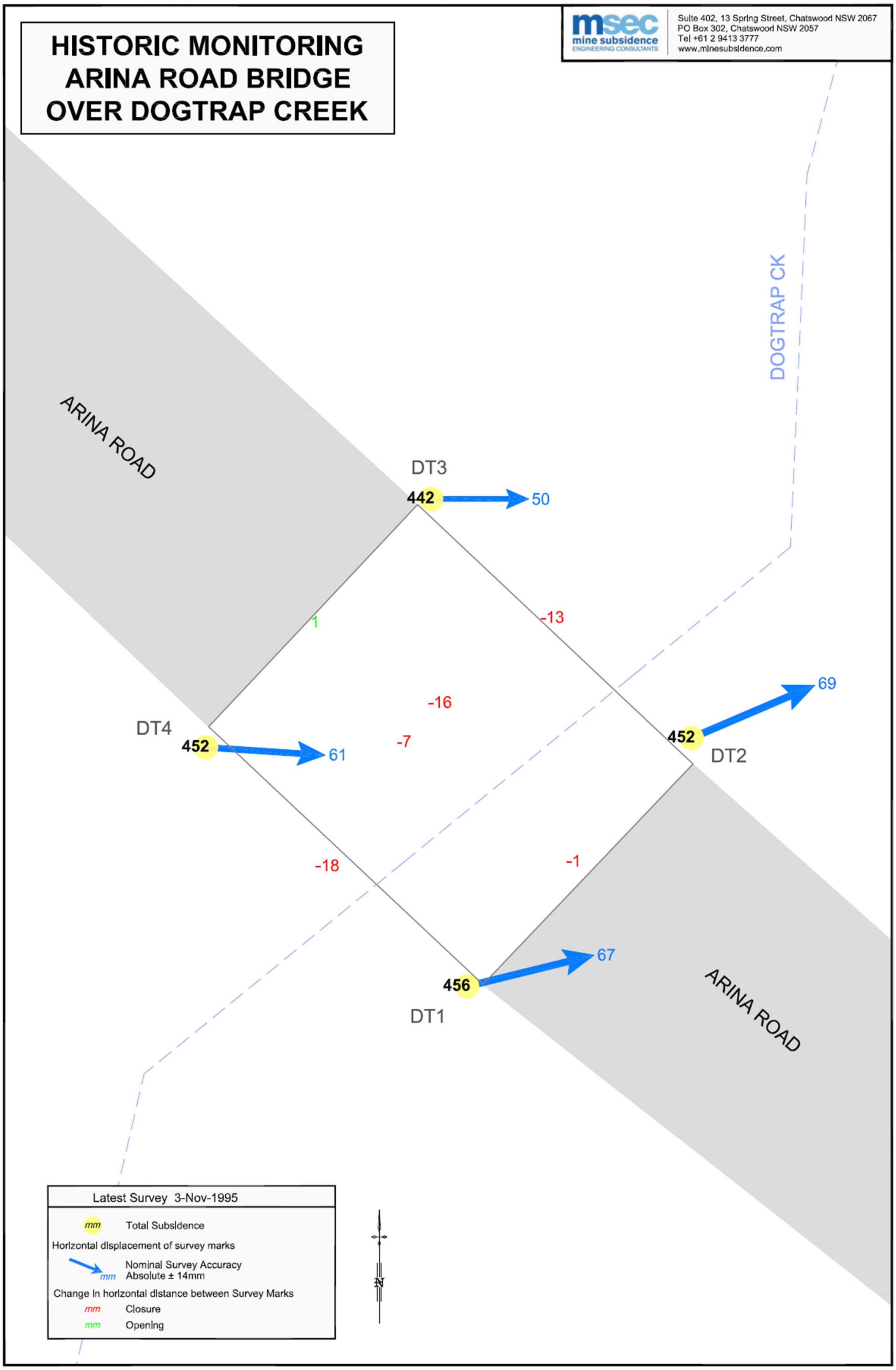

Fig. 3.53 **Observed subsidence and horizontal movements on the Arina Road Bridge during the mining of Tahmoor Longwalls 12 and 13**

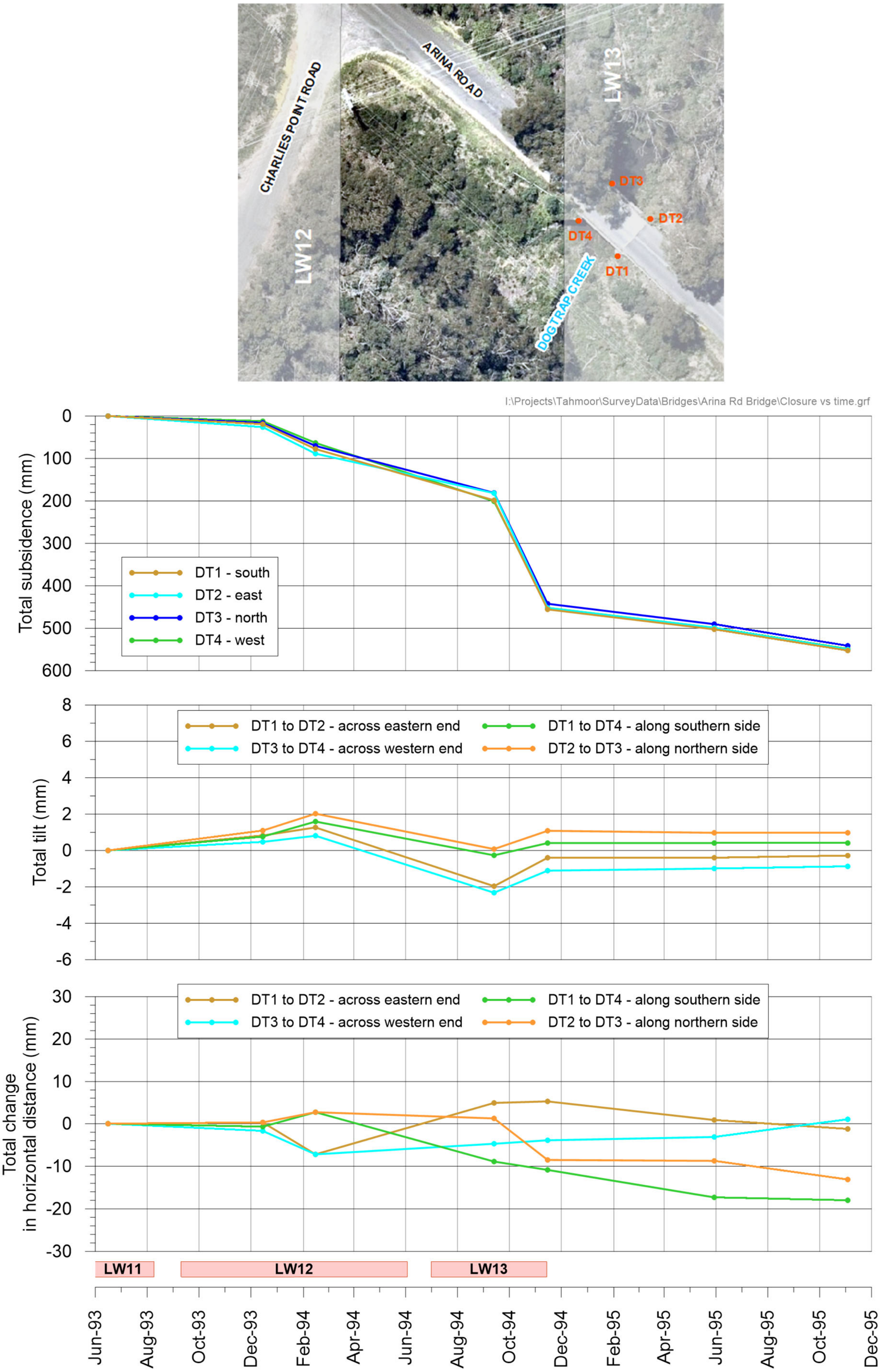

Fig. 3.54 Observed subsidence, tilt and changes in horizontal distances on the Arina Road Bridge during the mining of Tahmoor Longwalls 12 and 13

Potential future mining-induced movements at the Arina Road Bridge

Whilst the likelihood is very low, the Bridge may experience minor additional absolute and differential movements during the extraction of LWs S1A to S6A.

A statistical analysis of potential absolute far field horizontal movements is provided in Section 3.5 of this Management Plan, with results relevant to the Bridge highlighted in Table 3.13.

Table 3.18 Confidence levels for incremental horizontal movement for survey marks above solid coal for monitoring lines at Tahmoor, Appin, West Cliff and Tower Collieries at offset distances equivalent to Arina Road Bridge over Dog Trap Creek

Distance from active longwall (m)	Incremental horizontal movement within 95% confidence level (mm)	Incremental horizontal movement within 99% confidence level (mm)
2000 (LWs S1A to S6A)	22	27

A statistical analysis of potential differential far field horizontal movements is provided in Section 3.5 of this Management Plan, with results relevant to the Bridge highlighted in Table 3.14. As discussed previously, there is insufficient data to estimate probabilities greater than 1800 metres as there are insufficient measurements beyond the nominal survey tolerance of 3 mm.

Table 3.19 Probabilities of exceedance for incremental differential horizontal movements for survey bays located from the nearest goaf edge in the Southern Coalfield at offset distances equivalent to Arina Road Bridge over Dog Trap Creek

Offset distance from LW	Probability of Exceedance	Incremental differential horizontal movements for pegs spaced between 10 and 30m (mm)		
		Opening (mm)	Closure (mm)	Horizontal mid-ordinate deviation (mm)
1700 m to 2400 m (LWs S1A to S6A)	1 in 20 (0.05)	3	3	3
	1 in 100 (0.01)	4	4	8

The results suggest that measured changes at these offset distances have typically been close to survey tolerance and that the results of the statistical analyses for the low probability events (i.e. 1 in 20 and 1 in 100) have likely been influenced by survey tolerance.

While there remains a chance that the extraction of LWs S1A to S6A could result in differential far field movements at the Bridge, the likelihood is considered to be extremely low given:

- The 2.2 kilometre offset distances of LWs S1A to S6A to the Bridge are substantial;
- LWs S1A to S6A are separated from the Bridge by five previously extracted longwalls and a large bend in the Bargo River to the southwest of the Bridge; and
- Surveys during the mining of LWs 12 and 13 measured relatively minor closure of 20 mm between the Bridge abutments. Potential movements due to the extraction of LWs S1A to S6A will be orders of magnitude less than previously observed due to the remote position of the Bridge relative to the proposed longwalls.

Structural investigation and assessment

JMA Solutions (2022d) has conducted a structural investigation and assessment of the Bridge and advised the following:

- The bridge appeared to be in serviceable condition when inspected on 23 May 2022.
- Horizontal cracking is observed on the surface of concrete that filled a gap between the spandrel and abutment wall. The cracking is cosmetic in nature and does not appear to impact the serviceability of the Bridge. Some erosion is observed beneath the toe of the northern abutment wall. No significant cracking was visible on the wingwalls when viewed from the bridge deck at the time of inspection.
- Gaps were measured on 23 May 2022 between the ends of the vehicle kerbs and abutment pillars on the upstream and downstream ends of the Bridge. Gaps are currently present to accommodate additional valley closure movements, as shown in Table 3.20.

Table 3.20 Measured gaps between kerbs and abutments at Arina Road Bridge (JMA, 2022d)

Side of Bridge	Northern abutment (mm)	Southern abutment (mm)	Total closure capacity (mm)
Upstream (western)	38	50	88
Downstream (eastern)	38	43	81

- It is understood that no adjustments were made to the Bridge after the mining of LWs 12 and 13. As the shear strains in the elastomeric bearings were not released, it may be necessary to replace the bearings if further valley closure develops across the abutments during the extraction of LWs S1A to S6A. Potential future damage to the bearings would not, however, result in structural damage to the bridge deck or abutments as the bearings will continue to support the vertical dead and live loads.
- Based on current modelling, the bridge structure is expected to remain serviceable if it experiences up to 20 mm of valley closure or opening due to the extraction of LWs S1A to S6A. The modelled deformations are well beyond the values that were provided at a probability of exceedance of 1 in 100, and well beyond the accuracy of the proposed survey methodology.
- In the extremely unlikely event that more than 20 mm of valley closure or opening or transverse step displacements develop at the Bridge, it is possible to install brackets to the underside of the bridge deck to provide supplementary lateral support to the abutments. It is noted that if valley closure occurs, it will develop gradually, allowing sufficient time to conduct the works. The bridge deck could also be jacked to relieve shear strain in the bearings or to replace them.

Bridge Technical Committee

Following consultation between Tahmoor Coal and the Resources Regulator, Tahmoor Coal has appointed a Technical Committee to review the findings from site investigations and structural assessments. The Technical Committee will assist with the development of the management plan for the Bridge, which will be completed prior to 800 metres of extraction of LW S1A. The monitoring plan for the Bridge was reviewed prior to the commencement of LW S1A.

The Technical Committee inspected the Bridge on 8 September 2022 and provided feedback on the structural reports and reviewed the monitoring plan on 6 October 2022. The Technical Committee noted that the prisms at the base of the abutment walls may be lost during high water flow events following periods of heavy rainfall. One of the four marks at the base of the abutment walls has not yet been installed due to ponding at the site. Tahmoor Coal will endeavour to install the mark at the earliest opportunity, preferably prior to the commencement of LW S1A.

Summary of measures to manage potential impacts on Arina Road Bridge over Dog Trap Creek

Tahmoor Coal has developed and selected risk control measures in consultation, co-ordination and co-operation with Wollondilly Shire Council in accordance with WHS legislation to manage mining-induced changes on the Bridge due to the extraction of LWs S1A to S6A. The measures will be reviewed by the Technical Committee prior to 800 metres of extraction of LW S1A.

Elimination

In this instance, no reasonably practicable controls could be identified that would eliminate the identified risks.

Substitution

In this instance, no reasonably practicable controls could be identified that will change the environment so the hazards could be substituted for hazards with a lesser risk.

Isolation

In this instance, no reasonably practicable controls could be identified to isolate a hazard from any person exposed to it.

Engineering Controls

In this instance, no reasonably practicable controls could be identified to prevent or minimise risks.

Administrative Controls

The following Administrative Control was identified and selected that will put in place procedures on site to minimise the potential of impacts on the safety of the Bridge:

- Local 3D surveys of structure and ground marks on the Bridge, as shown in Drawing No. MSEC1193-03-05, with one mark on the Bridge to be surveyed in Absolute 3D;
- Survey gaps between the vehicle kerbs and the abutments;
- Visual inspections of the Bridge;
- Implementation of planned responses, if triggered by monitoring results. These may include:
  - Inspections by structural engineer;
  - Assess the latest results and observations and consider management actions;
  - Increase monitoring and reporting procedures;
  - Cut gaps between the vehicle kerbs and the abutments;
  - Install brackets to the underside of the bridge deck;
  - Jack the bridge and relieve shear strain in the bearings or replace the bearings;
  - Resurface affected road pavement;
  - As a last resort emergency response measure, slow or stop the longwall and/or vehicle traffic;
- Develop a traffic management plan to manage traffic along Arina Road Bridge in the event that mining-induced damage requires repair.

With the implementation of the above management strategy, Tahmoor Coal will ensure that the health and safety of people in the vicinity of the Bridge will not be put at risk due to differential mine subsidence movements due to the extraction of LWs S1A to S6A.

4.1. Infrastructure Management Group (IMG)

The Infrastructure Management Group (IMG) is responsible for taking the necessary actions required to manage the risks that are identified from monitoring the infrastructure and to ensure that the health and safety of people who may be present on public property or Wollondilly Shire Council property are not put at risk due to mine subsidence. The IMG develops and reviews this management plan, collects and analyses monitoring results, determines potential impacts and provides advice regarding appropriate actions. The members of the IMG are highlighted in Chapter 8.

4.2. Bridge Technical Committee

Following consultation between Tahmoor Coal and the Resources Regulator, Tahmoor Coal has appointed a Bridge Technical Committee to review the findings from site investigations and structural assessments. The Technical Committee will assist with the development of the management plan for the Bridges, which will be completed prior to 800 metres of extraction of LW S1A.

The monitoring plan for the Bridge was reviewed prior to the commencement of LW S1A. The Technical Committee inspected the Bridge on 8 September 2022 and provided feedback on the structural reports and reviewed the monitoring plan on 6 October 2022.

The Bridge Technical Committee will also be contacted if observed mining-induced movements exceed trigger levels, as specified in this Management Plan.

4.3. Development and selection of risk control measures

Tahmoor Coal has developed and selected risk control measures in consultation, co-ordination and co-operation with the infrastructure owner in accordance with WHS legislation. In accordance with Clauses 35 and 36 in Part 3.1 of the Work Health and Safety regulation (2017) and the guidelines (MSO, 2017), a hierarchy of control measures has been considered and selected where reasonably practicable, using the following process:

1. Eliminate risks to health and safety so far as is reasonably practicable, and
2. If it is not reasonably practicable to eliminate risks to health and safety – minimise those risks so far as is reasonably practicable, by doing one or more of the following:
   (a) substituting (wholly or partly) the hazard giving rise to the risk with something that gives rise to a lesser risk;
   (b) isolating the hazard from any person exposed to it;
   (c) implementing engineering controls;
3. If a risk then remains, minimise the remaining risk, so far as is reasonably practicable, by implementing administrative controls; and
4. If a risk then remains, the duty holder must minimise the remaining risk, so far as is reasonably practicable, by ensuring the provision and use of suitable personal protective equipment.

A combination of the controls set out in this clause may be used to minimise risks, so far as is reasonably practicable, if a single control is not sufficient for the purpose.

There are primarily two different methods to control the risks of subsidence, namely:

- Method A – Selection of risk control measures to be implemented prior to the development of subsidence, (Items 1 and 2 above); and
- Method B – Selection of risk control measures to be implemented during the development of subsidence (Items 3 and 4 above).

Method A and B risk control measures are described in Section Local roads4.4 to Section 4.7. Prior to selecting Method B risk control measures, Tahmoor Coal has investigated and confirmed that the measures are feasible and effective for the site-specific conditions during the extraction of LW S1A-S2A.

4.4. Selection of risk control measures for council infrastructure

Based on its own assessments, and the assessments by the structural engineer, and the geotechnical engineer, Tahmoor Coal considered Method A and Method B risk control measures, in accordance with the process described in Section 4.2.

Elimination

In this instance, no reasonably practicable controls could be identified that would eliminate the identified risks.

Substitution

In this instance, no reasonably practicable controls could be identified that will change the environment so the hazards could be substituted for hazards with a lesser risk.

Isolation

In this instance, no reasonably practicable controls could be identified to isolate a hazard from any person exposed to it.

Engineering Controls

In this instance, the following engineering controls could be identified to put in place a structure or item that prevents or minimises risks.

- Ensure road culverts are clear and free of vegetation prior to and during periods of active subsidence;
- Scale the cutting batter slopes to remove loose debris and rocks, and
- Clear the cutting drainage lines and maintain the drainage lines to ensure that they remain free of debris and vegetation during mining.

Administrative Controls

The following Administrative Controls were identified and selected that will put in place procedures on site to minimise the potential of impacts on the safety of people in relation to mining-induced damage to Wollondilly Shire Council infrastructure:

- Implementation of a Monitoring Plan and Trigger Action Response Plan (TARP)
  As described in the Management Plan, Tahmoor Coal and Wollondilly Shire Council has developed and implemented a management strategy of detecting early the development of potential adverse subsidence movements in the ground, so that contingency response measures can be implemented before impacts on the safety and serviceability develop. The TARP includes the following:
  - Continuous GNSS monitoring along the centrelines of LWs S1A to S3A, at each end of the Main Southern Railway Viaduct over the Bargo River and at Wellers Road Overbridge;
  - Local 2D surveys along local roads as shown in Drawing No. MSEC1193-01-01. These include Remembrance Driveway, Caloola Road, Yarran Road, Great Southern Road and Charlies Point Road;
  - Absolute 3D survey of subsidence along Remembrance Drive;
  - Local 3D / Absolute 3D survey of embankments along Remembrance Drive with pegs spaced along the crest and toe on both sides of each embankment. Pegs spacings are generally every 20 metres. The layout of survey marks is shown in Drawings Nos. MSEC1193-03-07 to MSEC1193-03-10;
  - Local 3D / Absolute 3D survey of culverts with survey marks located at the spring point on both sides at the outlet and inlet of the culverts beneath the embankments along Remembrance Drive. Survey marks will also be installed at the midpoint of the 1.8 metre diameter reinforced concrete culvert south of Yarran Road;
  - Local 3D / Absolute 3D survey of the cutting on Remembrance Drive with pegs spaced along the crest and toe on both sides of the cutting. Pegs spacings are generally every 20 metres. The layout of survey marks is shown in Drawing No. MSEC1193-03-11;
  - Local 3D / Absolute 3D of structure and ground marks on the Bargo River Road Bridge, as shown in Drawing No. MSEC1193-03-03;
  - Local 3D / Absolute 3D of structure and ground marks on the Rockford Road Bridge, as shown in Drawing No. MSEC1193-03-03;
  - Survey gaps between the parapet kerbs and the abutments on the Rockford Road Bridge;
  - Local 3D / Absolute 3D of structure and ground marks on the Arina Road Bridge, as shown in Drawing No. MSEC1193-03-05;

- Survey gaps between the vehicle kerbs and the abutments on the Arina Road Bridge;
- Visual inspections along local roads, embankments, culverts and cuttings within the active subsidence zone by a building inspector. Embankments and cuttings will also be inspected by a geotechnical engineer;
- Visual inspections along Remembrance Drive pavement, embankments and culverts during periods of active subsidence by building inspector and geotechnical engineer;
- Visual inspections of dams immediately upstream of road embankments during periods of active subsidence by building inspector and geotechnical engineer;
- Visual inspections of the Bargo River Bridge, Rockford Road Bridge and Arina Road Bridge;
- Implementation of planned responses, if triggered by monitoring results. These may include:
  - Increase monitoring and reporting procedures;
  - Additional inspections of embankments or cuttings by geotechnical engineer;
  - Fill and seal cracks and/or regrade drainage lines;
  - Place permanent or temporary fill / rock spall to the base of the embankment;
  - Support scarp with fill material until settlement effectively ceases;
  - Disconnect the Bargo River Road Bridge from one of the abutments;
  - Cut gaps between the parapet kerbs and the abutments, or cut gaps to the headstock bents / upstands of the Rockford Road Bridge;
  - Cut gaps between the vehicle kerbs and the abutments, or install brackets to the underside of the bridge deck of the Arina Road Bridge;
  - Repair the pavement, culverts, bridges, embankments or cuttings if damage is observed;
  - Additional visual inspections of culverts following periods of extreme wet weather;
  - As a last resort emergency response measure, introduce a temporary speed restriction and/or temporary lane closure if a hazard has been identified that involves potential serious injury or illness to a person or persons and cannot be controlled; and
  - Develop a traffic management plan to manage traffic along Remembrance Drive in the event that mining-induced damage requires repair.

4.5. Monitoring measures

A number of monitoring measures will be undertaken during mining.

4.5.1. Continuous GNSS monitoring

Global Navigation Satellite System (GNSS) units are fixed survey stations that continuously measure their absolute horizontal and vertical positions in real time.

The locations of GNSS units are shown in Drawings No. MSEC1193-01-01 and the GNSS units that are relevant to managing Council infrastructure are summarised below:

- Centrelines of LWs S1A to S3A - The GNSS units are located in bushland within the Australian Wildlife Sanctuary. The units are proposed to track the development of subsidence and horizontal movements above the commencing ends of the longwalls. The monitoring data will provide the first subsidence results for each panel to compare against subsidence predictions. Conventional survey lines are not possible in this area due to thick vegetation, preventing lines of sight;
- Railway Viaduct across Bargo River - Two GNSS units have been installed within the Main Southern Railway corridor to measure far field movements, if any, between the abutments of the Viaduct. The two GNSS units will also allow valley closure, if any, to be detected. The results will be cross-checked by manual surveys across the Remembrance Drive over the Bargo River; and
- Wellers Road Overbridge - A GNSS unit has been installed at the Wellers Road Overbridge. to measure far field movements. The results will trigger surveys of the Bridge if they exceed trigger levels.

4.5.2. Early warning survey lines

LW S1A Tahmoor Mine Boundary

A survey line has been installed along the southern boundary of Tahmoor Mine's property, as shown in Drawing No. MSEC1192-01-01. The survey line has been installed with pegs spaced nominally 20 metres apart. The survey line commences at the south-eastern end at the end of an unsealed road that is accessed from Charlies Point Road. The line terminates at the top of Teatree Hollow due to thick vegetation.

The purpose of the survey line is to measure the subsidence profile across the width of LW S1A prior to experiencing significant subsidence along the Main Southern Railway and Remembrance Drive. It is planned to survey the line once a month during the period of active subsidence of LW S1A. Additional surveys can be conducted, if required.

Main Southern Railway

LWs S1A to S4A will extract directly beneath the Main Southern Railway prior to mining directly beneath Remembrance Drive and Caloola Road.

A survey has been installed along the Main Southern Railway, as shown in Drawing No. MSEC1192-01-01. The survey line has been installed with pegs spaced nominally 20 metres apart.

Surveys along the Railway will provide an early warning of the magnitude of subsidence that is likely to develop. The surveys will also detect the development of non-conventional subsidence movements along the Railway and provide an opportunity to project locations where potential non-conventional subsidence movements may occur along Remembrance Drive. The IMG can assess the monitoring results and assess whether any additional monitoring and management measures may be required to manage potential impacts along Remembrance Drive and Caloola Road.

It is planned to survey the line weekly during periods of active subsidence. Additional surveys can be conducted, if required.

4.5.3. Ground Surveys along streets

Survey lines have been or will be installed along Remembrance Drive, Caloola Road, Yarran Road, Charlies Point Road and Great Southern Road, as shown in Drawing No. MSEC1193-01-01.

The survey lines consist of pegs spaced nominally every 20 m. 2D surveys will measure levels and horizontal distances between adjacent pegs. Survey pegs along Remembrance Drive will be surveyed in 2D and 3D (level, eastings and northings). The purpose of the 3D surveys is primarily to assist with monitoring potential impacts on pipelines that run along the road.

Any work within the road reserve, including survey, must be done under an approved Road Occupancy Permit (under Section 138 of the Roads Act) via an application to Council. Tahmoor Coal will ensure that its surveyors will apply to Council prior to conducting surveys within the road reserves.

4.5.4. Ground Surveys along Remembrance Drive road embankments and culverts

Tahmoor Mine will conduct the following surveys and inspections of culverts and embankments along Remembrance Drive:

- Absolute 3D and 2D surveys along a monitoring line along Remembrance Drive.
- Local 3D / Absolute 3D survey of embankments along Remembrance Drive with pegs spaced along the crest and toe on both sides of each embankment. Pegs spacings are generally every 20 metres. The layout of survey marks is shown in Drawings Nos. MSEC1193-03-07 to MSEC1193-03-10.
- Local 3D / Absolute 3D survey of culverts with survey marks located at the spring point on both sides at the outlet and inlet of the culverts beneath the embankments along Remembrance Drive. Survey marks will also be installed at the midpoint of the 1.8 metre diameter reinforced concrete culvert south of Yarran Road.
- Visual inspections of the pavement, culvert and embankment during mining by a building inspector and geotechnical engineer.

4.5.5. Ground Surveys along Remembrance Drive cutting

Tahmoor Mine will conduct the following surveys and inspections of the cutting on Remembrance Drive:

- Absolute 3D and 2D surveys along a monitoring line along Remembrance Drive.
- Absolute 3D surveys every 20 metres along the toe of the cutting between 88.700 km and 89.050 km and at two locations across the crests of the cutting.
- Visual inspections of the pavement, drains and cutting batters during mining by a building inspector and geotechnical engineer.

4.5.6. Ground and Structure Surveys at the Bridges

Tahmoor Mine will conduct the following surveys and inspections at the Bargo River Road Bridge over a tributary to the Bargo River:

- Continuous GNSS monitoring at two locations across the bend in the Bargo River. The two units S11 and S12 have been installed within the railway corridor near the Railway Viaduct, where access is available. The locations are shown in Drawing No. MSEC1193-03-02. GNSS unit S11 is located within 100 metres of the Bridge;
- Local 3D surveys of structure and ground marks on the Bridge, as shown in Drawing No. MSEC1193-03-03, with one mark on the Bridge to be surveyed in Absolute 3D; and
- Visual inspections of the Bridge.

The observations at GNSS unit S11 will be used to trigger additional surveys of the Bargo River Road Bridge.

Tahmoor Mine will conduct the following surveys and inspections at the Rockford Road Bridge over the Bargo River:

- Local 3D surveys of structure and ground marks on the Bridge, as shown in Drawing No. MSEC1193-03-04, with one mark on the Bridge to be surveyed in Absolute 3D;
- Survey gaps between the parapet kerbs and the abutments; and
- Visual inspections of the Bridge.

Tahmoor Mine will conduct the following surveys and inspections at the Arina Road Bridge over Dog Trap Creek:

- Local 3D surveys of structure and ground marks on the Bridge, as shown in Drawing No. MSEC1193-03-05, with one mark on the Bridge to be surveyed in Absolute 3D;
- Survey gaps between the vehicle kerbs and the abutments; and
- Visual inspections of the Bridge.

In the case of the Rockford Road Bridge and Arina Road Bridge, which are located beyond the commencing ends of the longwall panels, monitoring will be conducted during the first 1000 metres of extraction of LWs S1A to S3A. The planned period of monitoring is based on observations of extensive monitoring during the mining of previously extracted longwalls at Tahmoor Mine, which have found that incremental subsidence has developed close to its full magnitude above the active longwall by the time the lengths of extraction of each panel have exceeded 1000 metres. Monitoring can continue if mining-induced changes are observed at the Bridges.

Observations of extensive monitoring during the mining of previously extracted longwall series at Tahmoor Mine have found that the total subsidence approaches close to its full magnitude by the time the third longwall panel in a series is extracted. It is, therefore, proposed to monitor for potential movements at the Bridges until the extraction of LW S1A to S3A. Monitoring can continue if mining-induced changes are observed at the Bridges.

In addition to the above bridges, Tahmoor Mine will be conducting surveys and inspections of the Remembrance Drive Bridge over the Bargo River (refer Drawing No. MSEC1193-03-02), the Bargo River Road Bridge over the Main Southern Railway (Potters Cutting, refer Drawing No. MSEC1193-03-03) and the Wellers Road Bridge over the Main Southern Railway (refer Drawing No. MSEC1193-03-06). Further details are provided in the Main Southern Railway Management Plan, which can be provided to Wollondilly Shire Council.

4.5.7. Visual inspections

Visual inspections will be undertaken during the period of active subsidence by an experienced inspector appointed by Tahmoor Coal who is familiar with mine subsidence impacts. The inspector will undertake the following:

- Visual inspections along streets within the active subsidence zone, and
- Visual inspections of culverts, embankments, cuttings and bridges.

4.5.8. Geotechnical inspections

Detailed visual inspections of culverts, embankments and cuttings will be conducted by geotechnical engineer Douglas Partners when each site is located within the zone of active subsidence

4.5.9. Structural inspections

Structural inspections will be undertaken by John Matheson if required by the IMG.

4.5.10. Changes to monitoring frequencies

Monitoring frequencies will continue while Wollondilly Shire Council infrastructure is experiencing active subsidence due to the extraction of LW S1A-S6A. As a general guide, monitoring is likely to continue until the longwall has moved away from the property by a distance of approximately 450 metres. Monitoring, however, may continue if ongoing adverse impacts are observed.

4.6. Triggers and Responses

Trigger levels have been developed by Tahmoor Coal based on engineering assessments and consultation with Wollondilly Shire Council.

Trigger levels for each monitoring parameter are described in the risk control procedures in Table 4.1.

Immediate responses, if triggered by monitoring results, may include:

- Increase in survey and inspection frequencies if required by the IMG;
- Additional surveys and inspections;
- Repair of impacts that create a serious public safety hazard; and
- As a last resort emergency response measure, introduce a temporary speed restriction and/or temporary lane closure if a hazard has been identified that involves potential serious injury or illness to a person or persons and cannot be controlled. This will be conducted in accordance with the Traffic Management Plan in consultation with Wollondilly Shire Council.

The risk control measures described in this Management Plan have been developed to ensure that the health and safety of people in the vicinity of council infrastructure are not put at risk due to mine subsidence. It is also an objective to avoid disruption to services, or if unavoidable, keep disruption and inconvenience to minimal levels.

With respect to the extraction of LW S1A to S6A, no potential hazards have been identified that could reasonably give rise to the need for an emergency response. Of the potential hazards identified in Section 3.8, only a bump in the road could possibly experience severe impacts that could give rise to the need for an emergency response. The likelihood is considered extremely remote and would require substantial differential subsidence movements to develop before such an event occurs.

As discussed in Section 3.1, mine subsidence movements will develop gradually and there will be ample time to identify the development of potentially adverse differential subsidence movements early, consider whether any additional management measures are required, and repair or adjust affected surface features, in close consultation with Wollondilly Shire Council.

As documented in Section 4.7, Tahmoor Coal and the IMG will review and assess monitoring reports and consider whether any additional management measures are required on a weekly basis. If potentially adverse differential subsidence movements are detected, it is anticipated that a focussed inspection will be undertaken in the affected area, and a decision will likely be made to increase the frequency of surveys and/or inspections. Additional management measures may also be implemented. It is therefore expected that, as a potential adverse situation escalates, Tahmoor Coal will be present on site on a more frequent basis to survey or inspect the affected site, and that Wollondilly Shire Council will be consulted on a more frequent basis.

Notwithstanding the above, if a hazard has been identified that involves potential serious injury or illness to a person or persons on public property or council infrastructure, and cannot be controlled, the immediate response is to remove people from the hazard. If such a situation is observed or is forecast to occur by either Tahmoor Coal or by people on public property, Tahmoor Coal and Wollondilly Shire Council will immediately meet and implement emergency procedures as detailed in the Traffic Management Plan.

4.7. Subsidence Impact Management Procedures

The procedures for the management of potential impacts to Wollondilly Shire Council infrastructure are provided in Table 4.1.

Table 4.1 Risk Control Procedures during the extraction of Tahmoor LW S1A-S6A

INFRASTRUCTURE	HAZARD / IMPACT	RISK	TRIGGER	CONTROL PROCEDURE/S	FREQUENCY	BY WHOM?
Local roads	Cracking, heaving or stepping of the pavements or unsealed surfaces	Medium / Low	None	Conduct geotechnical assessment of Remembrance Driveway embankments and cutting	Complete	Douglas Partners
				Continuous GNSS monitoring as shown in Drawing No. MSEC1193-01-01	GNSS units installed Continuous readings, with data averaged over 24 hours and recorded once per day until end of LW S6A.	Tahmoor Coal (Unit Zero)
				2D survey line along Tahmoor Mine property boundary	Pegs installed. Baseline survey prior to commencement of LW S1A. Monthly survey during LW S1A between 200m and 1300m extraction, and continue if ongoing adverse movements are observed. End of LW S1A.	Tahmoor Coal (SMEC)
				Conduct 2D / Absolute 3D surveys along Main Southern Railway in accordance with Railway Management Plan	Monthly 3D / Weekly 2D surveys for pegs within active subsidence zone during LWs S1A to S6A	Tahmoor Coal (SRS)
				Conduct 2D survey along Charlies Point Road	Pegs installed from eastern end survey line to bend at No. 80 Charlies Point Road. Baseline survey prior to start of LW S1A. Extend line and baseline survey to intersection of Great Southern Road prior to start of LW S2A. Monthly survey during LWs S1A-S5A between 200m and 800m extraction, and continue if ongoing adverse movements are observed. End of LW S1A-S6A.	Tahmoor Coal (SMEC)
				Conduct 2D / Absolute 3D surveys along Remembrance Drive	Pegs installed from northern boundary of Tahmoor Mine site to Caloola Road. Baseline survey prior to 900m extraction of LW S1A. Extend line and baseline survey pegs within predicted limit of incremental subsidence of each active LW, prior to active LW face approaching within 600 metres of survey line. Monthly 3D / Weekly 2D surveys for pegs within active subsidence zone commencing as per below: LW S1A: start after 1300m extraction LW S2A: start after 900m extraction LW S3A: start after 800m extraction LW S4A: start after 300m extraction LW S5A: start after 200m extraction LW S6A: start after 200m extraction Continue surveys until outside active subsidence zone or one month after end of LW and continue further if ongoing adverse movements are observed. End of LW S1A-S6A.	Tahmoor Coal (SMEC)
				Conduct 2D surveys along Caloola Road	Pegs installed. Baseline survey prior to 900m extraction of LW S1A.. Survey at end of LW S1A. Weekly 2D surveys for pegs within active subsidence zone commencing as per below: LW S2A: start after 900m extraction LW S3A: start after 900m extraction LW S4A: start after 900m extraction LW S5A: start after 900m extraction LW S6A: start after 900m extraction Continue surveys until outside active subsidence zone or one month after end of LW and continue further if ongoing adverse movements are observed. End of LW S2A-S6A.	Tahmoor Coal (SMEC)

INFRASTRUCTURE	HAZARD / IMPACT	RISK	TRIGGER	CONTROL PROCEDURE/S	FREQUENCY	BY WHOM?
				Conduct 2D surveys along Yarran Road	Install and baseline prior to start of LW S3A. Survey at end of LW S3A. Weekly 2D surveys for pegs within active subsidence zone commencing as per below: LW S4A: start after 200m extraction LW S5A: start after 200m extraction LW S6A: start after 200m extraction Continue if ongoing adverse movements are observed. End of LW S4A-S6A.	Tahmoor Coal (SMEC)
				Conduct 2D surveys along Great Southern Road	Install and baseline prior to start of LW S3A. Survey at end of LW S3A. Weekly 2D surveys for pegs within active subsidence zone commencing as per below: LW S4A: start after 200m extraction LW S5A: start after 200m extraction LW S6A: start after 200m extraction Continue if ongoing adverse movements are observed. End of LW S4A-S6A.	Tahmoor Coal (SMEC)
				Conduct Local 3D / Absolute 3D survey of Remembrance Drive Embankment over Teatree Hollow at Caloola Drive (RE4) as per Drawing No. MSEC1193-03-07.	Install and baseline survey prior to LW S2A. Monthly 3D / Weekly 2D surveys within active subsidence zone commencing as per below: LW S2A: start after 900m extraction LW S3A: start after 900m extraction LW S4A: start after 900m extraction LW S5A: start after 900m extraction Continue if ongoing adverse movements are observed. End of LW S2A-S6A.	Tahmoor Coal (SMEC)
				Conduct Local 3D / Absolute 3D survey of Remembrance Drive Embankment over Tributary to Teatree Hollow north of Yarran Road (RE3) as per Drawing No. MSEC1193-03-08.	Install and baseline survey prior to LW S3A. 3D Survey at end of LW S3A. Monthly 3D / Weekly 2D surveys within active subsidence zone commencing as per below: LW S4A: start after 400m extraction LW S5A: start after 400m extraction LW S6A: start after 400m extraction Continue if ongoing adverse movements are observed. End of LW S4A-S6A.	Tahmoor Coal (SMEC)
				Conduct Local 3D / Absolute 3D survey of Remembrance Drive Embankment over Tributary to Teatree Hollow south of Yarran Road (RE2) as per Drawing No. MSEC1193-03-09.	Install and baseline survey prior to LW S3A. 3D Survey at end of LW S3A. Monthly 3D / Weekly 2D surveys within active subsidence zone commencing as per below: LW S4A: start after 200m extraction LW S5A: start after 200m extraction LW S6A: start after 200m extraction Continue if ongoing adverse movements are observed. End of LW S4A-S6A.	Tahmoor Coal (SMEC)
				Conduct Local 3D / Absolute 3D survey of Remembrance Drive Embankment at intersection of Wellers Road (RE1) as per Drawing No. MSEC1193-03-10.	Install and baseline survey prior to LW S5A. 3D Survey at end of LW S5A. Monthly 3D after 200m extraction of LW S6A until 800m of extraction and continue if ongoing adverse movements are observed. End of LW S6A.	Tahmoor Coal (SMEC)
				Conduct Local 3D / Absolute 3D survey of Remembrance Drive Cutting (RC1) as per Drawing No. MSEC1193-03-11.	Install and baseline survey prior to LW S2A. 3D Survey at end of LW S2A. Monthly 3D / Weekly 2D surveys within active subsidence zone commencing as per below: LW S3A: start after 500m extraction LW S4A: start after 500m extraction LW S5A: start after 500m extraction LW S6A: start after 500m extraction Continue if ongoing adverse movements are observed. End of LW S3A-S6A.	Tahmoor Coal (SMEC)

INFRASTRUCTURE	HAZARD / IMPACT	RISK	TRIGGER	CONTROL PROCEDURE/S	FREQUENCY	BY WHOM?
				Detailed visual inspections of local roads, culverts, embankments and cuttings	Weekly for areas within the active subsidence zone during LWs S1A to S6A and continue if ongoing adverse movements or impacts are observed until one month after the extraction of each LW.	Tahmoor Coal (BIS)
				Detailed visual inspections by geotechnical engineer along Remembrance Driveway embankments and cutting	Monthly during periods of active subsidence of LW S2A to S6A, and continue if ongoing adverse movements are observed.	Douglas Partners
				Prepare traffic management plan for installation and measurement of survey pegs to satisfaction of WSC	Prior to start of LW S1A	Tahmoor Coal
				Prepare traffic management plan to manage traffic along Remembrance Drive in the event that mining-induced damage requires repair	Prior to start of LW S1A	Tahmoor Coal
				Apply to Council and obtain an approved Road Occupancy Permit under Section 138 of the Roads Act prior to conducting works in the road reserve, including survey.	Complete	Tahmoor Coal
				Analyse and report results to IMG	Weekly during LW S1A-S6A after the length of the extraction exceeds 200 metres.	Tahmoor Coal
				IMG discuss results and consider whether any additional management measures are required	Weekly during LW S1A-S6A after the length of the extraction exceeds 200 metres.	Tahmoor Coal
Local roads	Cracking, heaving or stepping of the pavements or unsealed surfaces	Medium / Low	Impacts occur to pavement	Notify all stakeholders, including WSC, Tahmoor Coal, Subsidence Advisory NSW and Resources Regulator	Within one week	Tahmoor Coal / WSC
				IMG, Tahmoor Coal and WSC meet to decide whether any additional management measures are required, including: - increase in frequency of surveys and visual inspections - increase in monitoring reporting - repair pavement in accordance with Traffic Management Plans	As required (target within 48 hours)	Tahmoor Coal / WSC
				Repair road in consultation with WSC	As required	Tahmoor Coal
			A hazard has been identified that involves potential serious injury or illness to a person or persons on public property or, or WSC property and cannot be controlled	IMG, Tahmoor Coal and WSC meet to decide whether any additional management measures are required, including: - emergency evacuation of hazardous area - demarcation to prevent people entering hazardous area, including diversion of traffic via Traffic Management Plan	Immediately	Tahmoor Coal / WSC
				Notify SRG of trigger exceedence and any management decisions undertaken (incl Subsidence Advisory NSW, Resources Regulator)	Within 24 hours of decision	Tahmoor Coal
Drainage culverts	Cracking or spalling	Low	None	Conduct ground surveys along streets, which cross over the culverts	Refer local roads section	Tahmoor Coal (SMEC)
				Conduct visual inspection for impacts	Refer local roads section	Tahmoor Coal (SMEC)
			Impacts occur	Notify all stakeholders, including WSC, Tahmoor Coal, Subsidence Advisory NSW and Resources Regulator	Within one week	Tahmoor Coal / WSC
				Repair culvert in consultation with WSC	As required	Tahmoor Coal

INFRASTRUCTURE	HAZARD / IMPACT	RISK	TRIGGER	CONTROL PROCEDURE/S	FREQUENCY	BY WHOM?
Remembrance Drive embankments	Displacement / failure of embankment leading to loss of support of pavement	Low	None	Ensure culverts are clear and free of debris	Prior to influence of LWs S1A to S6A	Tahmoor Coal
				Conduct ground surveys along crest and toe of both sides of Remembrance Drive embankments	Refer local roads section	Tahmoor Coal (SMEC)
				Conduct visual inspection of embankments and culverts	Refer local roads section	Tahmoor Coal (SMEC)
			Level 1 Change in distance across crest exceeds 25 mm Rate of change in distance across crest is greater than 10 mm in a week Visual signs of distress to embankment, such as tension crack along edge of embankment / access road Visual signs of distress to dam walls upstream of Remembrance Drive	Notify IMG	Within 24 hours	Tahmoor Coal
				Undertake additional geotechnical inspection and appraisal	Within 24 hours	Douglas Partners
				IMG meet and review latest monitoring information for the embankment, culvert and the pavement, inspections by geotechnical engineer and building inspector, and latest weather forecasts. IMG consider whether any additional management measures are required, which may include: - fill and seal cracks and/or regrade drainage line - increase monitoring frequency and reporting procedures - arrange additional monitoring locations to monitor potential displacement of embankment material - lower water level of dam(s) upstream of embankment (if relevant) - install variable message signs in preparation of potential traffic management measures	Within 24 hours	IMG
				Report trigger exceedance and actions taken to IMG, WSC, SA NSW & MSO in Status Report	Within 24 hours if tension crack observed Otherwise within one week	Tahmoor Coal
			Level 2 Tension crack observed along the embankment shoulder, or slide in the crest of the embankment	Notify IMG and WSC.	Immediately	Tahmoor Coal
				WSC inspection to consider and implement emergency traffic management measures, if required	Immediately	Tahmoor Coal / WSC
				Undertake additional geotechnical inspection and appraisal	As soon as reasonably practicable	Douglas Partners
				IMG meet and review latest monitoring information for the embankment, culvert and the pavement, inspections by geotechnical engineer and building inspector, and latest weather forecasts. IMG consider whether any additional management measures are required, which may include: - introduce temporary speed restriction or temporarily close affected shoulder and/or travel lane - place permanent or temporary fill / rock spall to the base of the embankment - increase monitoring frequency and reporting procedures - arrange additional monitoring locations to monitor potential displacement of embankment material	As soon as reasonably practicable	IMG
				Report trigger exceedance and actions taken to IMG, WSC, SA NSW & MSO	Within 24 hours	Tahmoor Coal
			Level 3 Tension crack observed across the pavement shoulder and travel lane(s), or slump or depression appears in the pavement	Notify IMG and WSC.	Immediately	Tahmoor Coal
				WSC inspection to consider and implement emergency traffic management measures, if required	Immediately	Tahmoor Coal / WSC
				Undertake additional geotechnical inspection and appraisal	As soon as reasonably practicable	Douglas Partners
				IMG meet and review latest monitoring information for the embankment, culvert and the pavement, inspections by geotechnical engineer and building inspector, and latest weather forecasts. IMG consider whether any additional management measures are required, which may include: - introduce temporary speed restriction or temporarily close affected shoulder and/or travel lane - place permanent or temporary fill / rock spall to the base of the embankment - resurface pavement to restore ride quality along travel lanes - provide additional forms of support under the pavement as may be appropriate or feasible - increase monitoring frequency and reporting procedures - arrange additional monitoring locations to monitor potential displacement of embankment material	As soon as reasonably practicable	IMG
				Report trigger exceedance and actions taken to IMG, WSC, SA NSW & MSO	Within 24 hours	Tahmoor Coal

INFRASTRUCTURE	HAZARD / IMPACT	RISK	TRIGGER	CONTROL PROCEDURE/S	FREQUENCY	BY WHOM?
Remembrance Drive cutting	Blockage of drainage lines or deformation of pavement in the cutting	Low	None	Scale the cutting batter slopes to remove loose debris and rocks Clear the cutting drainage lines and maintain the drainage lines to ensure that they remain free of debris and vegetation during mining	Prior to LW S2A and as required	Tahmoor Coal
				Conduct ground surveys along crest and toe of both sides of Remembrance Drive cutting	Refer local roads section	Tahmoor Coal (SMEC)
				Conduct visual inspection of cutting	Refer local roads section	Tahmoor Coal (SMEC)
			Closure across cutting exceeds 20 mm	Notify IMG	Within one week	MSEC
				IMG meet and consider whether any additional management measures are required, which may include: - undertake geotechnical engineering inspection - increase monitoring frequency and reporting procedures	Within one week	IMG
				Report trigger exceedance and actions taken to IMG, WSC, SA NSW & MSO in Status Report	Within one week	Tahmoor Coal
			Instability observed to cuttings	Notify IMG and WSC.	Immediately	Tahmoor Coal
				IMG meet and consider whether any additional management measures are required, which may include: - undertake geotechnical engineering inspection - increase monitoring frequency and reporting procedures - clear debris from drainage lines at base of cutting faces	Within 24 hours	IMG
				Report trigger exceedance and actions taken to IMG, WSC, SA NSW & MSO in Status Report	Within one week	Tahmoor Coal
Bridges	Loss of serviceability of Bridges	Low	None	Pre-mining inspection and structural assessment of Bridges	Complete	JMA
				Geological inspection and mapping at Bargo River Road Bridge	Complete	Newcastle Geotech
				Review of monitoring measures for Rockford Road Bridge and Arina Road Bridge and implement, if required	Prior to start of LW S1A (complete)	Bridge Technical Committee / Tahmoor Coal
				Review by Bridge Technical Committee and modify planned management and monitoring measures for Bargo River Bridge and review planned management measures for Rockford Road Bridge and Arina Road Bridge and implement, if required	Prior to 800 m of extraction of LW S1A	Bridge Technical Committee / Tahmoor Coal
				Brief WSC on planned management and monitoring measures for Bargo River Bridge and review planned management measures for Rockford Road Bridge and Arina Road Bridge	Prior to 800 m of extraction of LW S1A	Tahmoor Coal
				Conduct Local 3D survey of structure and ground marks on the Bargo River Road Bridge as per Drawing No. MSEC1193-03-03, with one mark on the Bridge to be surveyed in Absolute 3D	Install and baseline survey prior to LW S1A. Monthly surveys between 1000m and one month after end of extraction of LWs S1A to S3A and continue if ongoing adverse movements are observed. End of LW S1A-S3A.	Tahmoor Coal (SRS)
				Visual inspection of Bargo River Road Bridge	Baseline inspection prior to LW S1A Monthly inspections between 1000m and one month after end of extraction of LWs S1A to S3A and continue if ongoing adverse movements are observed. End of LW S1A to S3A	Tahmoor Coal (BIS)
				Conduct Local 3D survey of structure and ground marks on the Rockford Road Bridge as per Drawing No. MSEC1193-03-04, with one mark on the Bridge to be surveyed in Absolute 3D	Install and baseline survey prior to LW S1A. Monthly surveys between 200m and 1000m of extraction of LWs S1A to S3A and continue if ongoing adverse movements are observed. End of LW S1A-S3A.	Tahmoor Coal (SRS)
				Measure gaps between parapet kerbs and abutments of the Rockford Road Bridge	Install and baseline survey prior to LW S1A. Monthly surveys between 200m and 1000m of extraction of LWs S1A to S3A and continue if ongoing adverse movements are observed. End of LW S1A-S3A.	Tahmoor Coal (SRS)
				Visual inspection of Rockford Road Bridge	Baseline inspection prior to LW S1A Monthly inspections between 200m and 1000m of extraction of LWs S1A to S3A and continue if ongoing adverse movements are observed. End of LW S1A to S3A	Tahmoor Coal (BIS)

INFRASTRUCTURE	HAZARD / IMPACT	RISK	TRIGGER	CONTROL PROCEDURE/S	FREQUENCY	BY WHOM?
				Conduct Local 3D survey of structure and ground marks on the Arina Road Bridge as per Drawing No. MSEC1193-03-05, with one mark on the Bridge to be surveyed in Absolute 3D	Install and baseline survey prior to LW S1A. Monthly surveys between 200m and 1000m of extraction of LWs S1A to S3A and continue if ongoing adverse movements are observed. End of LW S1A-S3A.	Tahmoor Coal (SMEC)
				Measure gaps between vehicle kerbs and abutments of the Arina Road Bridge	Install and baseline survey prior to LW S1A. Monthly surveys between 200m and 1000m of extraction of LWs S1A to S3A and continue if ongoing adverse movements are observed. End of LW S1A-S3A.	Tahmoor Coal (SMEC)
				Visual inspection of Arina Road Bridge	Baseline inspection prior to LW S1A Monthly inspections between 200m and 1000m of extraction of LWs S1A to S3A and continue if ongoing adverse movements are observed. End of LW S1A to S3A	Tahmoor Coal (BIS)
			GNSS unit S11 subsides or moves horizontally more than 20 mm	Conduct additional survey of Bargo River Road Bridge	Within one week	Tahmoor Coal (SRS)
				Visual inspection of Bargo River Road Bridge	Within one week	Tahmoor Coal (BIS)
			Closure between bridge abutments exceeds 5 mm	Notify Bridge Technical Committee and WSC	Within one week	MSEC
				Bridge Technical Committee and WSC meet and consider whether any additional management measures are required, which may include: - undertake structural engineering inspection - increase monitoring frequency and reporting procedures - cut gaps between abutments and kerbs on Rockford Road Bridge or Arina Road Bridge - disconnect the bridge deck from one of the abutments on Bargo River Road Bridge - reset or replace bridge bearings	Within one week	Bridge Technical Committee
				Report trigger exceedance and actions taken to IMG, WSC, SA NSW & MSO in Status Report	Within one week	Tahmoor Coal
			Impacts observed to bridge	Notify Bridge Technical Committee and WSC	Within 24 hours	Tahmoor Coal
				WSC and Tahmoor Coal inspection to consider and implement emergency traffic management measures, if required	Immediately	Tahmoor Coal (JMA) / WSC
				Bridge Technical Committee and WSC meet and consider whether any additional management measures are required, which may include: - undertake structural engineering inspection - increase monitoring frequency and reporting procedures - cut gaps between abutments and kerbs on Rockford Road Bridge or Arina Road Bridge - disconnect the bridge deck from one of the abutments on Bargo River Road Bridge - reset or replace bridge bearings - repair damage to bridge, pavement approaches, and/or footpath approaches in consultation with WSC - as a last resort, slow or stop the longwall and/or vehicle traffic in accordance with Traffic Management Plan	Within 24 hours	Bridge Technical Committee
				Report trigger exceedance and actions taken to IMG, WSC, SA NSW & MSO in Status Report	Within 24 hours	Tahmoor Coal

5.1. Consultation, co-operation and co-ordination

Substantial consultation, co-operation and co-ordination has taken place between Tahmoor Coal and Wollondilly Shire Council prior to the development of this Management Plan, as detailed in Section 1.3.1.

The following procedures will be implemented during and after active subsidence of the property to ensure the continued effective consultation, co-operation and co-ordination of action with respect to subsidence between Tahmoor Coal and Wollondilly Shire Council:

- Reporting of observed impacts to Tahmoor Coal either during the weekly visual inspection or at any time directly to Tahmoor Coal;
- Distribution of monitoring reports, which will provide the following information on a weekly basis during active subsidence:
  - Position of longwall;
  - Summary of management actions since last report;
  - Summary of consultation with Wollondilly Shire Council since last report;
  - Summary of observed or reported impacts, incidents, service difficulties, complaints;
  - Summary of subsidence development;
  - Summary of adequacy, quality and effectiveness of management process;
  - Any additional and/or outstanding management actions; and
  - Forecast whether there will be any subsidence impacts to the health and safety of people due to the continued extraction of LW S1A-S6A.
- Convening of meetings between Tahmoor Coal and Wollondilly Shire Council at any time as required, as discussed in Section 5.2;
- Arrangements to facilitate timely repairs, if required; and
- Immediate contact between Tahmoor Coal and Wollondilly Shire Council if a mine subsidence induced hazard has been identified that involves potential serious injury or illness to a person or persons on public property or Wollondilly Shire Council property and may require emergency evacuation, entry restriction or suspension of work activities.

5.2. IMG meetings

The IMG undertakes reviews and, as necessary, revises and improves the risk control measures to manage risks to health and safety, and potential impacts to infrastructure.

The reviews are undertaken weekly during the period of active subsidence based on the results of the weekly surveys and visual inspections and summarised in the monitoring reports, as described in Section 5.1.

The purpose of the reviews are to:

- Detect changes, including the early detection of potential impacts on health and safety and impacts to council infrastructure;
- Verify the risk assessments previously conducted;
- Ensure the effectiveness and reliability of risk control measures; and
- Support continual improvement and change management.

IMG meetings may be held between Tahmoor Coal and Wollondilly Shire Council for discussion and resolution of issues raised in the operation of the Management Plan. The frequency of IMG Meetings will be as agreed between Tahmoor Coal and Wollondilly Shire Council.

IMG Meetings will discuss any incidents reported in relation to the relevant infrastructure, the progress of mining, the degree of mine subsidence that has occurred, and comparisons between observed and predicted ground movements.

It will be the responsibility of the meeting representatives to determine whether the incidents reported are due to the impacts of mine subsidence, and what action will be taken in response.

In the event that a significant mine subsidence impact is observed, any party may call an emergency IMG Meeting, with one day's notice, to discuss proposed actions and to keep other parties informed of developments in the monitoring of the infrastructure.

6.0 AUDIT AND REVIEW

This Management Plan has been agreed between parties and can be reviewed and updated to continually improve the risk management systems based on audit, review and learnings from the development of subsidence during mining and manage changes in the nature, likelihood and consequence of subsidence hazards.

The review process will be conducted to achieve the following outcomes:

- Gain an improved understanding of subsidence hazards based on ongoing subsidence monitoring and reviews, additional investigations and assessments as necessary, ongoing verification of risk assessments previously conducted, ongoing verification of assumptions used during the subsidence hazard identification and risk assessment process, ongoing understanding of subsidence movements and identified geological structures at the mine;
- Revise risk control measures in response to an improved understanding of subsidence hazards;
- Gain feedback from stakeholders in relation to managing risks, including regular input from business or property owners;
- Ensure on-going detection of early warnings of changes from the results of risk assessments to facilitate corrective or proactive management actions or the commencement of emergency procedures in a timely manner; and
- Ensure timely implementation of a contingency plan in the event that the implemented risk control measures are not effective.

Some examples where review may be applied include:

- Observation of greater impacts on surface features due to mine subsidence than was previously expected;
- Observation of fewer impacts or no impacts on surface features due to mine subsidence than was previously expected; and
- Observation of significant variation between observed and predicted subsidence.

Should an audit of the Management Plan be required during that period, an auditor shall be appointed by Tahmoor Coal to review the operation of the Management Plan and report at the next scheduled Plan Review Meeting. The Management Plan shall be audited for compliance with ISO 31000, or alternative standard agreed with Wollondilly Shire Council.

7.0 RECORD KEEPING

Tahmoor Coal will keep and distribute minutes of any IMG Meeting.

8.0 CONTACT LIST

Organisation	Contact	Phone	Email / Mail
NSW Department of Planning and Environment – Resources Regulator	Ray Ramage	(02) 4063 6485 0442 551 293	ray.ramage@planning.nsw.gov.au
	Phil Steuart	(02) 4063 6484	phil.steuart@planning.nsw.gov.au
Subsidence Advisory NSW	Matthew Montgomery	(02) 4677 1967 0425 275 564	Matthew.Montgomery@customerservice.nsw.gov.au
Douglas Partners	Rod Haselden*	(02) 4271 1836 0413 310 410	Roderick.Haselden@douglaspartners.com.au
JMA Solutions	John Matheson*	Ph: (02) 9979 6618 Mob: 0418 238 777	john@jmasolutions.com.au
Mine Subsidence Engineering Consultants (MSEC)	Daryl Kay*	(02) 9413 3777 0416 191 304	daryl@minesubsidence.com
SIMEC Mining Tahmoor Coal Project Manager	Ross Barber*	(02) 4640 0028 0419 466 143	ross.barber@simecgfg.com
SIMEC Mining Tahmoor Coal Approvals Specialist	April Hudson*	(02) 4640 0022 0466 380 992	April.Hudson@simecgfg.com
Wollondilly Shire Council Acting Team Leader Assets & Transport	Nafizul Akash*	(02) 4677 1100	nafizul.akash@wollondilly.nsw.gov.au
Wollondilly Shire Council Manager Assets, Transport & Engineering	Mike Nelson	(02) 4677 1180	mike.nelson@wollondilly.nsw.gov.au

* denotes member of Infrastructure Management Group

APPENDIX A. Drawings and Supporting Documentation

The following supporting documentation is provided in Appendix A.

Drawings

Drawing No.	*Description*	*Revision*
MSEC1193-01-01	Monitoring plan	A
MSEC1193-03-01	Roads and associated infrastructure	A
MSEC1193-03-02	MSR Rail Viaduct & Remembrance Drive Bridge over Bargo River	A
MSEC1193-03-03	Bargo River Road Bridges	A
MSEC1193-03-04	Rockford Road Bridge over Bargo River	A
MSEC1193-03-05	Arina Road Bridge over Dog Trap Creek	A
MSEC1193-03-06	Wellers Road Bridge over Main Southern Railway	A
MSEC1193-03-07	Remembrance Drive Embankment over Teatree Hollow over LW S3A (RE4)	A
MSEC1193-03-08	Remembrance Drive Cutting and Embankment north of Yarran Road over LWs S4A and S5A (RE3)	A
MSEC1193-03-09	Remembrance Drive Embankment south of Yarran Road over LW S5A (RE2)	A
MSEC1193-03-10	Remembrance Drive Embankment at Wellers Road intersection beyond LW S6A (RE1)	A
MSEC1193-03-11	Remembrance Drive Cutting north of Yarran Road over LW S4A and S5A (RC1)	A

Supporting Documentation

Douglas Partners (2022a) *Report on Geotechnical Assessment – Longwalls S1A to S6A, Bargo*, Douglas Partners, Report No. 210597.00, May 2022.

Douglas Partners (2022b) *Report on Geotechnical Investigation – Detailed Slope Stability Assessment, Longwalls S1A to S6A, Bargo*, Douglas Partners, Report No. 210597.02, August 2022.

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