SIMEC Mining – Tahmoor Coal

Management Plan for extraction of Tahmoor South LW S1A-S6A beneath the Main Southern Railway

Revision C

Prepared by Mine Subsidence Engineering Consultants on behalf of the ARTC / Tahmoor Coal Rail Management Group

Commercial in Confidence

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AUTHORISATION OF MANAGEMENT PLAN

Authorised on behalf of ARTC	**Authorised on behalf of Tahmoor Coal Pty Ltd**
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Date: 16 December 2022	**Date:** 16 December 2022

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This Management Plan has been prepared by Mine Subsidence Engineering Consultants on behalf of the Railway Management Group. The Railway Management Group acknowledges contributions from a project team that is comprised of specialists in a variety of fields. The following organisations have contributed to this plan:

- Tahmoor Coal
- ARTC
- Bloor Rail
- Globetech
- JMA Solutions
- Michael Nicholson Consulting / Unit Zero
- Mine Subsidence Engineering Consultants
- Newcastle Geotech
- Pidgeon Civil Engineering
- Robinson Rail
- Southern Rail Surveys
- SweetingConsulting

ABBREVIATIONS AND DEFINITIONS

ARTC	Australian Rail Track Corporation
MSO	NSW Department of Planning & Environment, Resources Regulator, Mine Safety Operations
ONRSR	Office of the National Rail Safety Regulator
Globetech	Automated Monitoring Contractor for Track
SRS	Southern Rail Surveys (ground surveys within rail corridor)
SA NSW	Subsidence Advisory NSW
MSEC	Mine Subsidence Engineering Consultants
RMG	Rail Management Group
RMC	Rail Maintenance Contractor (Bloor Rail)
RRG	Rail Response Group
RSRG	Rail Structures Response Group
PCE	Pidgeon Civil Engineering
JMA	JMA Solutions (structural engineer)
SMEC	SMEC (ground surveys beyond rail corridor)
TC	Tahmoor Coal
ZTL	Zero toe load clips
Deed	Legally binding statement of commitments, in this case between ARTC and Tahmoor Coal
License	Formal permission to do something, in this case for Tahmoor Coal to access the Main Southern Railway corridor and undertake work
CWR	Continuously Welded Rail
Cess	Clear area at base of railway cuttings
First workings	Underground roadways (headings) to provide access for workers, conveyors and ventilation
Installation Heading	Underground roadway developed at the commencing end of the longwall panel to install the longwall equipment
Maingate	Underground roadway along the “solid coal” side of the longwall panel (leading edge of panel), where the main longwall panel conveyor is installed
Tailgate	Underground roadway along the opposite side of the longwall panel to the maingate
Chain pillar	A block of coal left unmined between the longwall extraction panels.

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1.0 INTRODUCTION

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 received approval in October 2022 for its Extraction Plan for Longwalls S1A to S6A (LW S1A-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. The Main Southern Railway is located within this area.

The location of LW S1A-S6A relative to the Railway is shown in Fig. 1.1. A more detailed plan is provided in Drawing No. MSEC1201-01, which is included in Appendix B at the back of this Management Plan. The Study Area in Fig. 1.1 is defined as the surface area within which items of railway infrastructure have been identified and assessed for their potential to experience mine subsidence impacts as a result of the proposed extraction of LWs S1A to S6A. The extent of the Study Area has been conservatively defined by combining the areas bounded by an angle of draw from the edges of the longwalls to the surface of 35 degrees, or the predicted subsidence contour of 20 mm contour, resulting from the extraction of LWs S1A to S6A, whichever is greater.

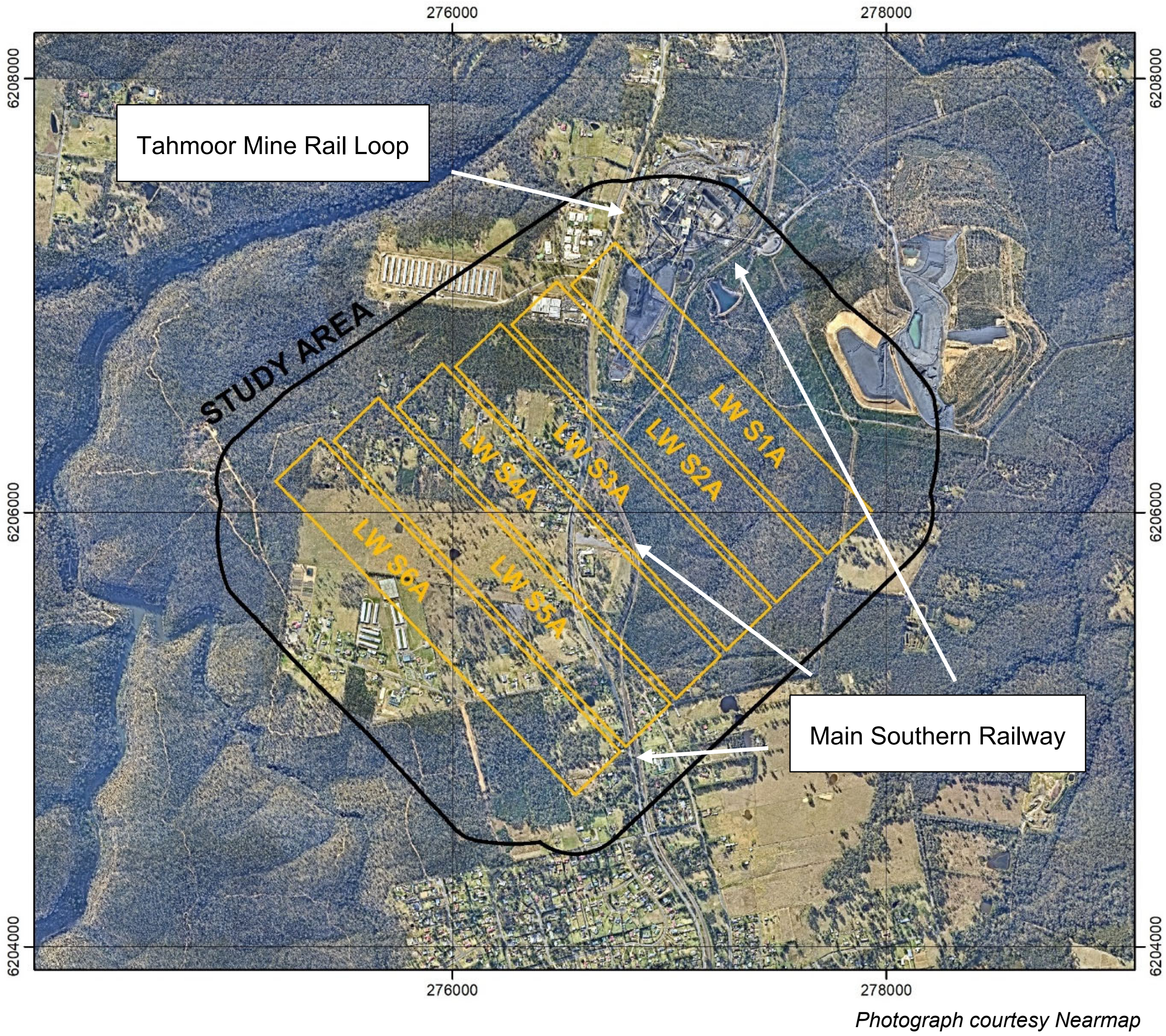

Fig. 1.1 LW S1A-S6A overlaid on aerial photograph

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A summary of the dimensions of LW S1A-S6A is 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 Main Southern Railway will be managed by Tahmoor Coal and the Australian Rail Track Corporation (ARTC).

The Management Plan is a live document that can be amended in agreement with ARTC at any stage of mining, to meet the changing needs of ARTC and Tahmoor Coal.

1.2. Australian Rail Track Corporation (ARTC)

The Australian Rail Track Corporation (ARTC) is a company created as a result of the Commonwealth and mainland State Governments Inter-Government Agreement in 1997 for the establishment of a 'one-stop shop' for rail operators seeking access to the interstate standard gauge rail network between Brisbane and Perth. The company organisation commenced operations on 1 July 1998.

Australian Rail Track Corporation Ltd (ARTC) is a company under the Corporations Act whose shares are owned by the Commonwealth and overseen by the Minister for Transport and Regional Services and Minister for Finance and Administration on behalf of the Commonwealth.

On September 4th, 2004, ARTC agreed to a 60 year lease of designated NSW State owned railway lines and infrastructure of which the Main Southern Line is part. As part of the lease, ARTC have assumed responsibility for the maintenance of leased tracks.

1.3. Rail operations along the Main Southern Railway potentially affected by LW S1A-S6A

The area to be potentially affected by the extraction of LW S1A-S6A includes part of the Main Southern Line rail corridor, which extends from Sydney to Albury. The original Main Southern line extended from Picton to Mittagong in 1867. The railway through Tahmoor and Bargo was constructed around 1919, when the new railway alignment from Picton to Mittagong was opened.

During the 1990's, construction commenced on upgrading the Up and Down tracks to strengthen the track infrastructure. This has included replacing timber sleepers with heavy duty concrete sleepers and resurfacing, regrading and realigning the existing 53 and 60 kg/m track. The dual track is configured as dedicated Up and Down lines, with all signals being remotely controlled by ARTC Train Control located at Junee. The track between Tahmoor and Bargo is an automatic signalled area.

The Up and Down tracks service a range of rail traffic including:

- Heavy haul coal and minerals traffic;
- Containerised traffic;
- Grain and agricultural products; and
- Local, Interstate and Intrastate passenger traffic.

A map showing the location of the Main Southern Railway infrastructure in relation to LW S1A-S6A is shown in Drawing No. MSEC1201-01.

Approximately 3 km of track is located within the Study Area between kilometrages 98 km and 101 km. Approximately 2.1 km of track is located directly above proposed Longwalls S1A to S5A, between 98.6 km and 100.7 km.

The railway line is a dual track consisting of 60 kg rail on concrete sleepers with a mix of straight and curved track sections within the Study Area. The maximum speed limits on both tracks are 95 km/h for normal services and 105 km/h for XPT services. A photograph of a section of the railway at 98.2 km is provided in Fig. 1.2.

Fig. 1.2 Main Southern Railway at 98.2 km

While there are no bridges along the Main Southern Railway within the Study Area, some bridges outside the Study Area may experience far-field movements during the mining of LW S1A-S6A. A summary of the closest distances of LW S1A to S6A to railway bridges is provided in Table 1.2.

Table 1.2 Bridges potentially affected by far-field movements

Bridge	Closest horizontal distance (m)	Closest LW	Closest LW end
Railway Viaduct over Bargo River	1,750 m	LW S1A	Finishing end (North-western 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)
Wellers Road Overbridge over the Main Southern Railway	370 m	LW S6A	Commencing end (South-eastern end)

The railway bridges are owned by Transport for NSW. The Bargo River Viaduct is maintained by ARTC. The other three bridges are maintained under contract by UGL.

In addition to the major railway structures listed in Table 1.2, there are a number of smaller railway structures within the Study Area. These include:-

- Culverts and embankments;
- Cuttings;
- Tahmoor Mine's conveyor crossing over the Main Southern Railway; and
- Signalling, electrical and telecommunications equipment.

1.4. Objectives

The primary objectives of this Management Plan are to establish procedures to identify, measure, control, mitigate and repair potential impacts that might occur on surface and sub-surface rail infrastructure potentially or directly affected by mining operations as a result of the mining of Tahmoor LW S1A-S6A.

The objectives of the Management Plan have been developed to:-

- Maintain the safe and serviceable operation of all affected rail infrastructure, with public and workplace safety paramount;
- Avoid, as far as practicable, any impediment to ARTC's business including impact on speed or frequency of passenger or freight trains;
- Prevent significant disruption and inconvenience to ARTC operations and minimise the maintenance effort required as a result of the impact of the mining during the course of the longwall mining operations directly beneath and adjacent to the track;
- Avoid or minimise disruption and inconvenience to the travelling public and ARTC freight clients;
- Monitor ground movements and the condition of surface infrastructure prior to mining, during mining and for a period post mining as advised by the Rail Management Group;
- Initiate action to mitigate or remedy potential impacts that may occur during longwall mining affecting the surface as well as sub-surface rail infrastructure;
- Provide a plan of action in the event that the impacts of mine subsidence are greater than those that are predicted (contingency plan);
- Provide a forum to report, discuss and record impacts to both the surface and sub-surface rail infrastructure; and
- Establish lines of communication, emergency contacts, procedures and protocols.

1.5. Scope

The Management Plan is to be used to protect and monitor the condition of surface features and items of infrastructure identified to potentially be at risk due to mine subsidence. The major items at risk are:-

- Railway tracks, formation and drainage;
- Cuttings;
- Embankments;
- Culverts;
- Bridges; and
- Signalling and communications systems.

This Management Plan describes measures that will be undertaken as a result of the mining of LW S1A-S6A only.

1.6. 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. MSEC1201-01), 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 ARTC.

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. The Plan includes measures to detect early potential increased subsidence, so that additional monitoring and response measures can be implemented before potentially severe impacts occur.

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1.7. Consultation

1.7.1. Consultation with ARTC

Tahmoor Coal regularly consults with ARTC in relation to mine subsidence effects. This included 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 for LW S1A-S6A are outlined below:

- Introduction to Tahmoor South project, with first presentation to ARTC in January 2014;
- Risk assessment for Tahmoor South, attended by representatives from ARTC, Tahmoor Coal and members of the Rail Management Group in August 2021. Representatives from the Office of the National Rail Safety Regulator (ONRSR) also attended as observers;
- Presentation by Tahmoor Coal and members of the Rail Management Group to ARTC Management in Wagga Wagga in August 2022;
- Presentation and Submission of draft Management Plan for review and comment in November 2022; and
- Ongoing consultation on a weekly / monthly basis with ARTC during the mining of previous longwalls beneath the Railway. Weekly ARTC meetings during the mining of previously extracted LW W4 included planning for the Tahmoor South project.

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

1.7.2. Consultation with Government Agencies & Key Infrastructure Stakeholders

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

1.8. 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	October 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 ARTC informed of changes.

1.9. Overall management of rail assets due to mining – governance arrangements

Governance arrangements, predominantly comprising a decision-making process and a governance structure, are implemented over and above the Rail Management Plan.

The Rail Management Plan incorporates the implementation of the mitigation, monitoring and management measures to avoid impact to rail safety and serviceability, and to achieve the required management outcomes. This is achieved by actively monitoring and managing any actual or potential subsidence impacts on the rail infrastructure and operations.

However, the governance arrangements also incorporate the ultimate management measures of restricting or suspending the extraction of LW S1A-S6A to achieve overall outcome compliance, where the measures detailed in the Rail Management Plan are not able to be achieved, or there is uncertainty in achieving the defined performance measures, namely:

- That the Main Southern Railway must be always safe and serviceable; and
- Damage that does not affect the safety or serviceability must be fully repairable, and must be fully repaired.

A structured decision-making process is incorporated into these governance arrangements to periodically review the means by which the required management outcomes are achieved either by effective operation of the Rail Management Plan, and consequent authorisation of unrestricted longwall operations, or if unachievable, to achieve the same required management outcomes by restricting or suspending longwall operations.

The governance arrangements are shown diagrammatically below.

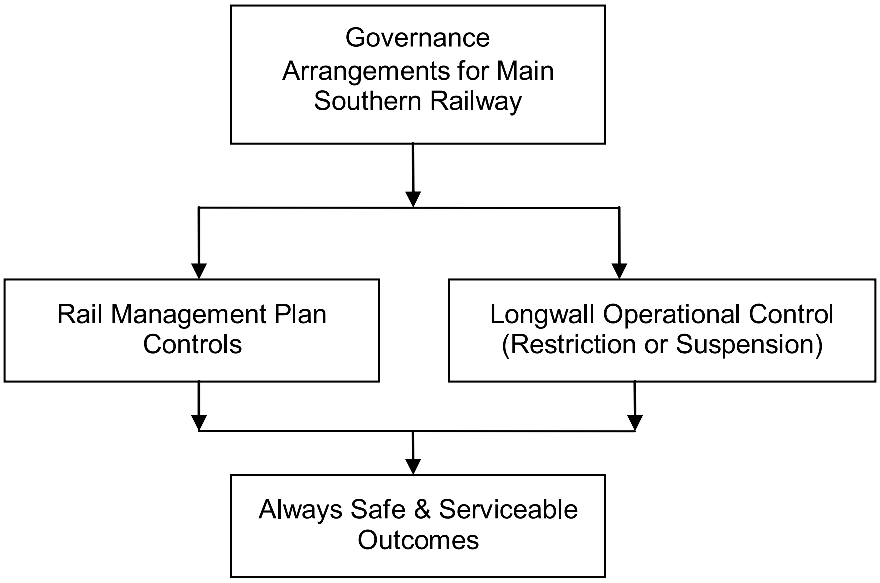

Fig. 1.3 Overall governance arrangements

The governance arrangements are intended to provide oversight and are supported by the risk mitigation, monitoring and management actions detailed in the Rail Management Plan. Included in the governance arrangements are a governance structure and a formalised decision-making process.

The governance arrangements provide an additional process review, where Tahmoor Coal senior management are informed and participate in the overall decision-making process.

In addition, the governance arrangements incorporate the consideration and continuing authorisation of the continuity and rate of extraction of longwall mining into the decision-making process. Additional communication and consultation with ARTC senior management is also included.

1.10. Legal framework

Tahmoor Coal received development consent for the Tahmoor South Project in April 2021 and approval of the Extraction Plan for LW S1A-S6A in October 2022.

The Development Consent includes Condition C5, which requires that Tahmoor Coal must ensure that the Main Southern Railway be:

- Always Safe and Serviceable; and
- Damage that does not affect safety or serviceability must be fully repairable, and must be fully repaired at the cost of the Applicant.

This Management Plan has also been developed in accordance with Tahmoor Coal's Built Features Management Plan, which was submitted as part of the Extraction Plan for LW S1A-S6A.

Continuing consultation during the extraction of LW S1A-S6A between Tahmoor Coal and ARTC is via the governance arrangements, as described in Section 1.9 and the Rail Management Group established to carry out the objectives of the Deed and Licence between Tahmoor Coal and ARTC.

This Management Plan was reviewed by the Rail Management Group and endorsed by each member in their area of expertise before joint authorisation by ARTC / Tahmoor Coal. This plan builds upon the investigations and knowledge gained from the successful implementation of Management Plans for the mining of Longwalls 22 to 32, and LW W1-W4, beneath and adjacent to the Main Southern Railway.

This Management Plan is referenced in the Deed and Licence between Tahmoor Coal Pty Ltd and ARTC. The Deed and Licence represent the legal agreement between the two parties.

1.11. 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) 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. Clause 5(i) of Part 1 of the Regulation defines a **Principal Mining Hazard**:

> "*as any activity, process, procedure, plant, structure, substance, situation or other circumstance relating to the carrying out of mining operations that has a reasonable potential to result in multiple deaths in a single incident or a series of recurring incidents, in relation to any of the following:*
>
> *(i) subsidence.*

There is a reasonable potential for the mining of LW S1A-S6A to result in multiple deaths in a single incident on the Main Southern Railway unless the risks are managed and controlled effectively.

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; and*
- *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 beneath the Main Southern Railway in accordance with the WHS laws.

1.12. Documentation control

This Management Plan is authorised for use when it is signed by representatives from Tahmoor Coal and ARTC. Tahmoor Coal must not cause subsidence impacts on the Railway before this Management Plan is authorised by ARTC.

The following actions will be undertaken once the Management Plan is approved:

- Tahmoor Coal or its nominated representative will notify ARTC and members of the Rail Management Group and monitoring contractors of the authorisation of the Management Plan and issue an electronic copy or hard copy under document control;
- Tahmoor Coal, or its nominated representative, will forward the Management Plan to ARTC and upload on to Tahmoor Coal intranet; and
- Tahmoor Coal, or its nominated representative, will instruct the members of the Rail Management Group and monitoring contractors to remove any previous authorised version of the Management Plan from their systems or identify them as superseded.

During or after the mining of each longwall, minor changes may be made to management or monitoring measures from time to time in accordance with this plan. A decision to make minor changes to management or monitoring measures is undertaken on a case by case basis upon the recommendation of the Rail Management Group. Authorisation for a minor change is given by the Manager Asset Maintenance Services North-South either via an ARTC-Tahmoor Coal Governance meeting and reconfirmed separately in writing or email.

Minor changes do not require an authorised revision of the Management Plan. Tahmoor Coal, or its nominated representative, will notify members of the Rail Management Group and monitoring contractors, MSO and ONRSR of the authorised minor change in the monitoring reports, and separately in writing or by email.

Minor changes include, but are not limited to:

- A change in management or monitoring measures after a longwall has moved away from each section of railway or has completed mining. These may include:
    - Removal of expansion switches, or removal of zero toe load clips and reinstatement of standard resilient fastenings;
    - Removal of track baulks;
    - Changes in monitoring and inspection frequencies or extents; and/or
    - Turning off alarms from all or some of the automated monitoring system to some or all members of the Rail Response Group

  The changes described above may be undertaken in accordance with this Management Plan if the three criteria, as described in Section 5.4 of the Management Plan, are met.
- Minor adjustments to Yellow or Red triggers to align with amendments to ARTC standards;
- Minor changes to frequencies, extents or timing of management or monitoring measures based on the findings of ongoing investigations and reviews by the Rail Management Group; and
- Minor changes to frequencies, extents or timing of management or monitoring measures based on minor changes to the mine plan, which do not materially change the management strategy.

Major changes to management or monitoring measures will require an authorised revision of the Management Plan by Tahmoor Coal and ARTC and will be undertaken on a case by case basis upon the recommendation of the Rail Management Group. MSO and ONRSR will be informed of the authorised revision of the Management Plan by Tahmoor Coal.

2.1. Predicted subsidence movements due to the extraction of LW S1A-S6A

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.

The predicted profiles of conventional subsidence and tilt along the alignment of Main Southern Railway, resulting from the extraction of the proposed longwalls, are shown in Fig. 2.1. The initial and the predicted post mining grade of the track are also shown in this figure.

A summary of the maximum predicted total conventional subsidence parameters along the alignment of the railway, after the extraction of each of the proposed longwalls, is provided in Table 2.1. The predicted subsidence effects are predominately due to Longwalls S1A to S5A, which directly mine beneath the railway.

Table 2.1 Maximum predicted total conventional subsidence parameters along the alignment of the Main Southern Railway after the extraction of the proposed LWs S1A to S6A

Longwall	Maximum predicted total subsidence (mm)	Maximum predicted change in Grade (%)	Maximum predicted total hogging curvature along alignment (km^{-1})	Maximum predicted total sagging curvature along alignment (km^{-1})
After LW S1A	775	0.55	0.06	0.12
After LW S2A	1000	0.75	0.08	0.20
After LW S3A	1150	0.65	0.09	0.20
After LW S4A	1250	0.70	0.10	0.20
After LW S5A	1300	0.70	0.10	0.20
After LW S6A	1350	0.85	0.10	0.20

The maximum predicted conventional strains for the railway, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1.5 mm/m tensile and 3.0 mm/m compressive. Non-conventional movements can also occur as a result of, among other things, anomalous movements. The analysis of strains provided in 2.4 includes those resulting from both conventional and non-conventional anomalous movements.

Predicted changes in cant and long twist for the railway are shown in Fig. 2.2.

The railway 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. An analysis of strains along whole monitoring lines during the mining of previous longwalls in the Southern Coalfield is discussed in Section 2.4.2 and the results are provided in Fig. 2.13. The strains in Fig. 2.13 are based on a nominal bay length of 20 metres.

As it is planned to manage mining-induced ground strains by the implementation of the track expansion system, a more relevant prediction is a change in horizontal distances over bay lengths of 200 metres, which is roughly equivalent to the planned distances between expansion switches and anchor points. Predicted changes in horizontal distances over bay lengths of 200 metres for LW S1A to S6A are shown in Fig. 2.3 to Fig. 2.8. The predictions do not include predictions of valley closure at each of the creek crossings, which are provided separately in this management plan.

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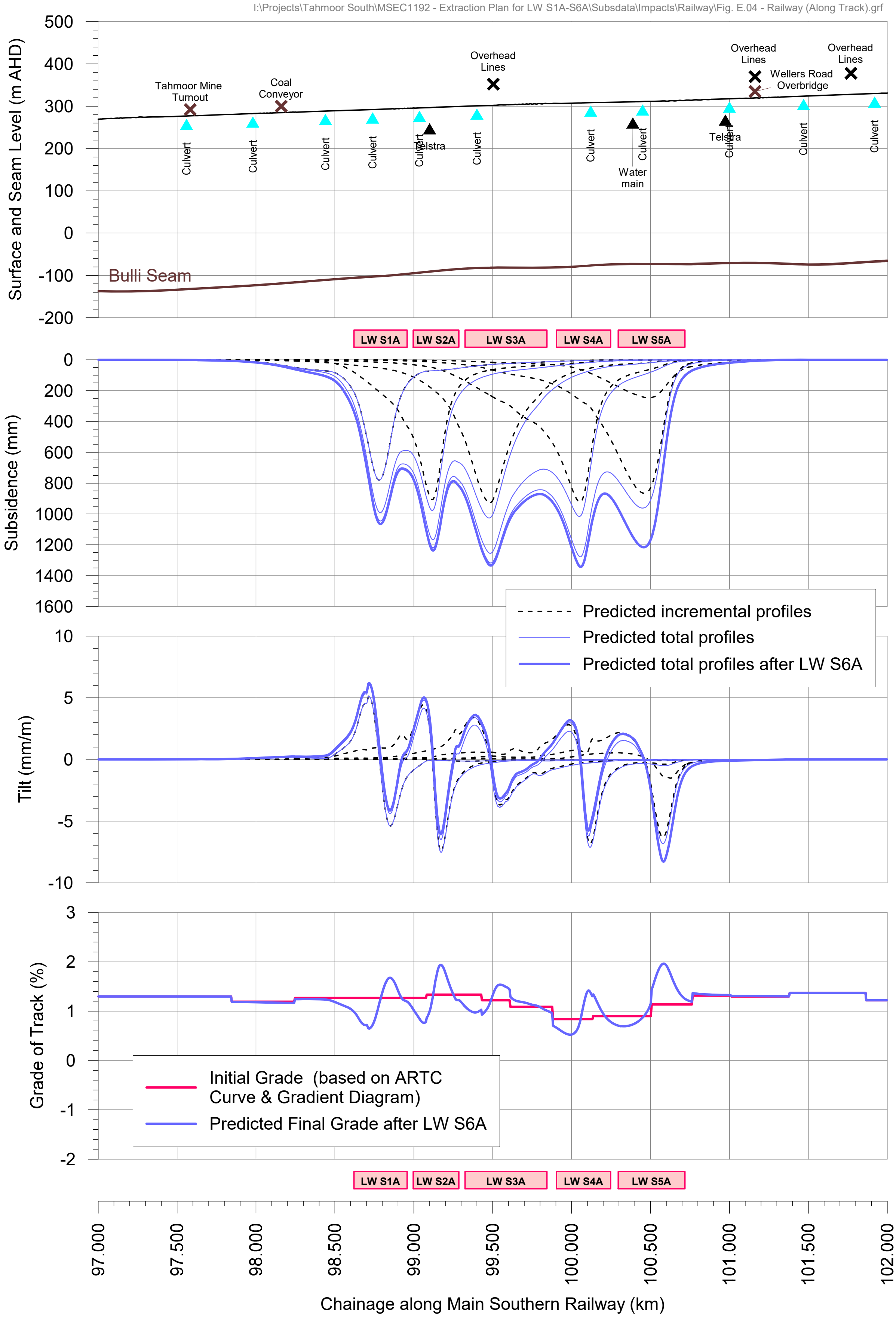

Fig. 2.1 Predicted profiles of conventional subsidence, tilt and change in grade along the Main Southern Railway due to the extraction of LW S1A-S6A

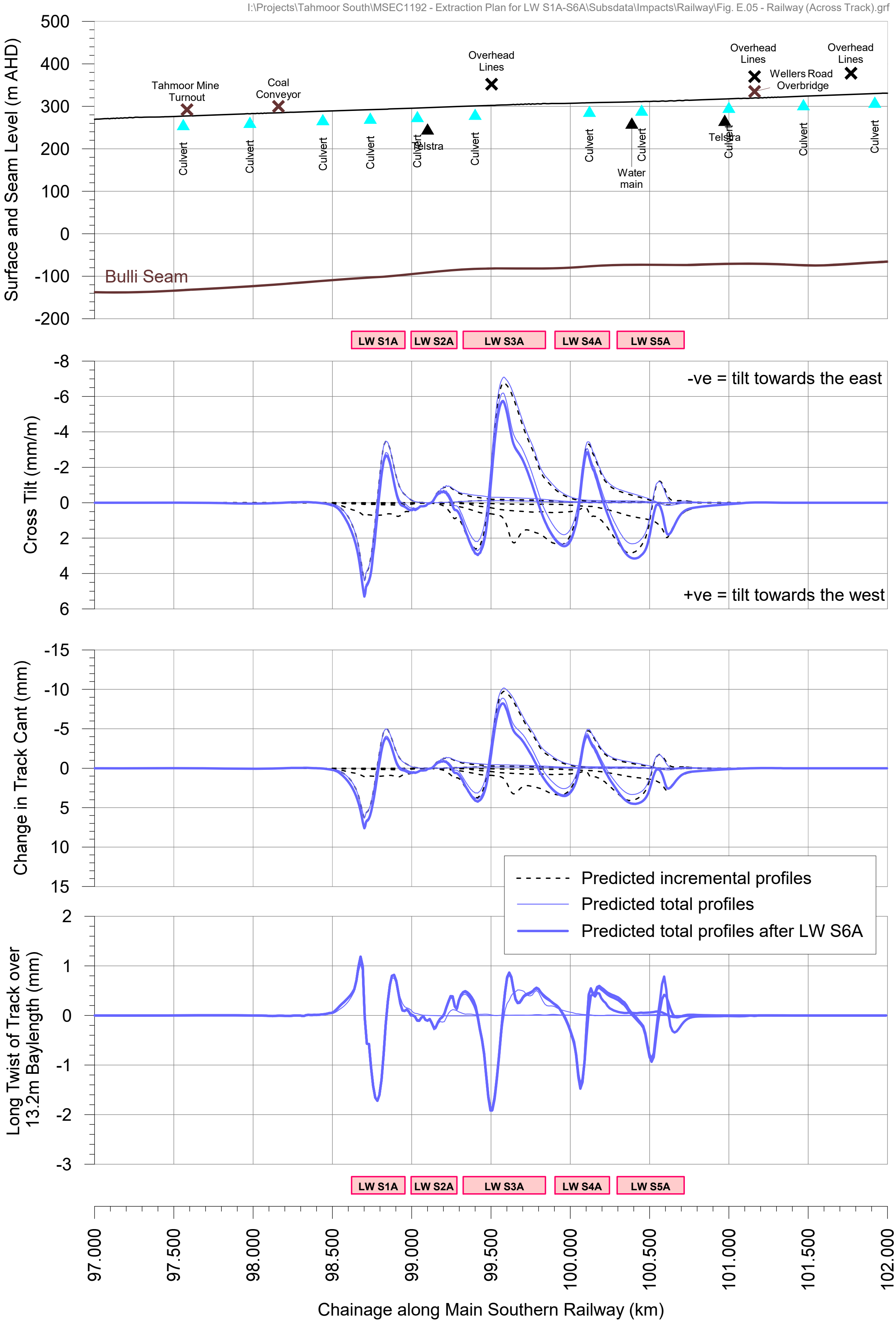

Fig. 2.2 Predicted profiles of conventional cross tilt, change in track cant and long twist along the Main Southern Railway due to the extraction of LW S1A-S6A

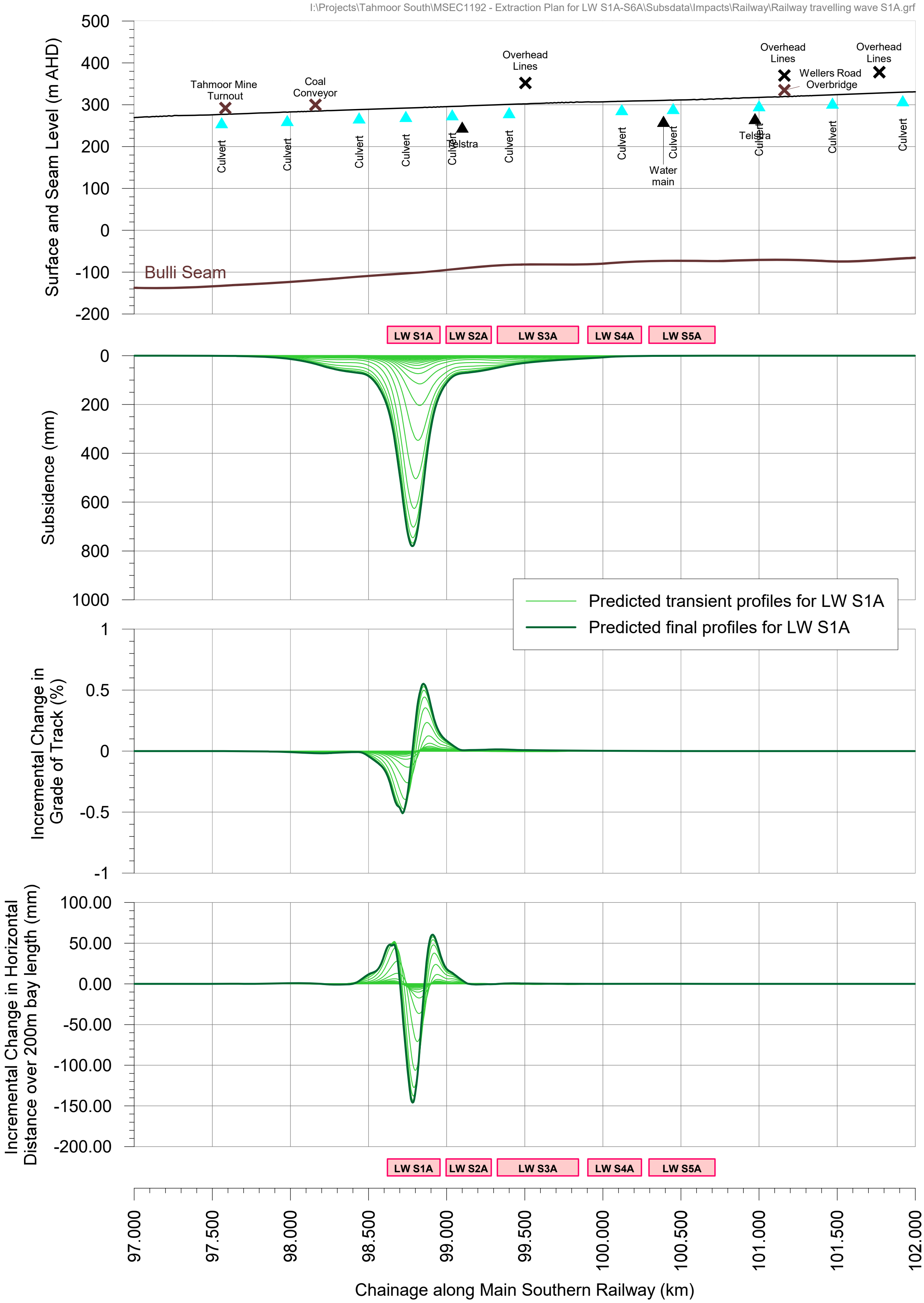

Fig. 2.3 Predicted profiles of conventional incremental subsidence, change in grade and change in horizontal distances over 200 metre long bay lengths along the Main Southern Railway due to the extraction of LW S1A only

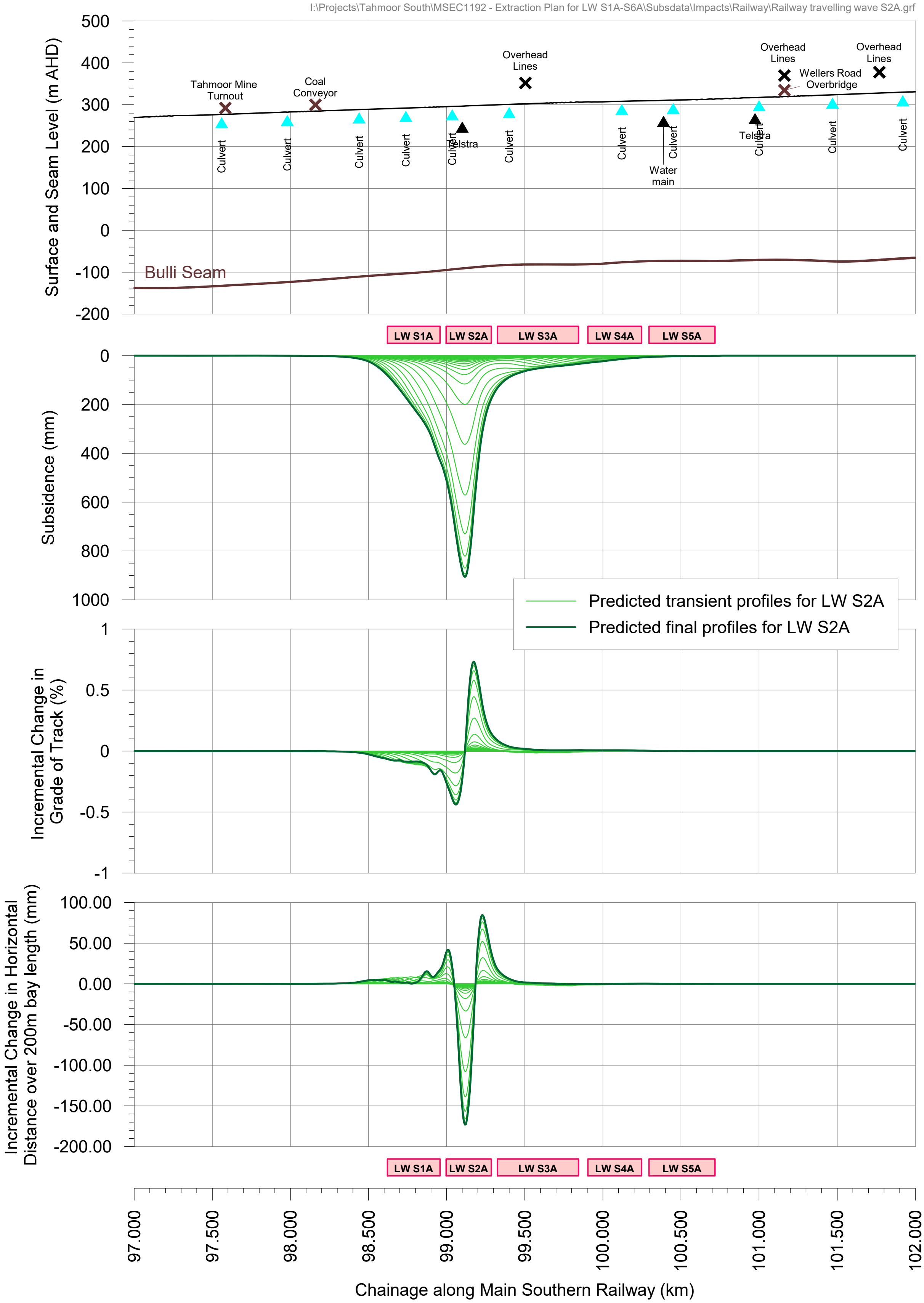

Fig. 2.4 Predicted profiles of conventional incremental subsidence, change in grade and change in horizontal distances over 200 metre long bay lengths along the Main Southern Railway due to the extraction of LW S2A only

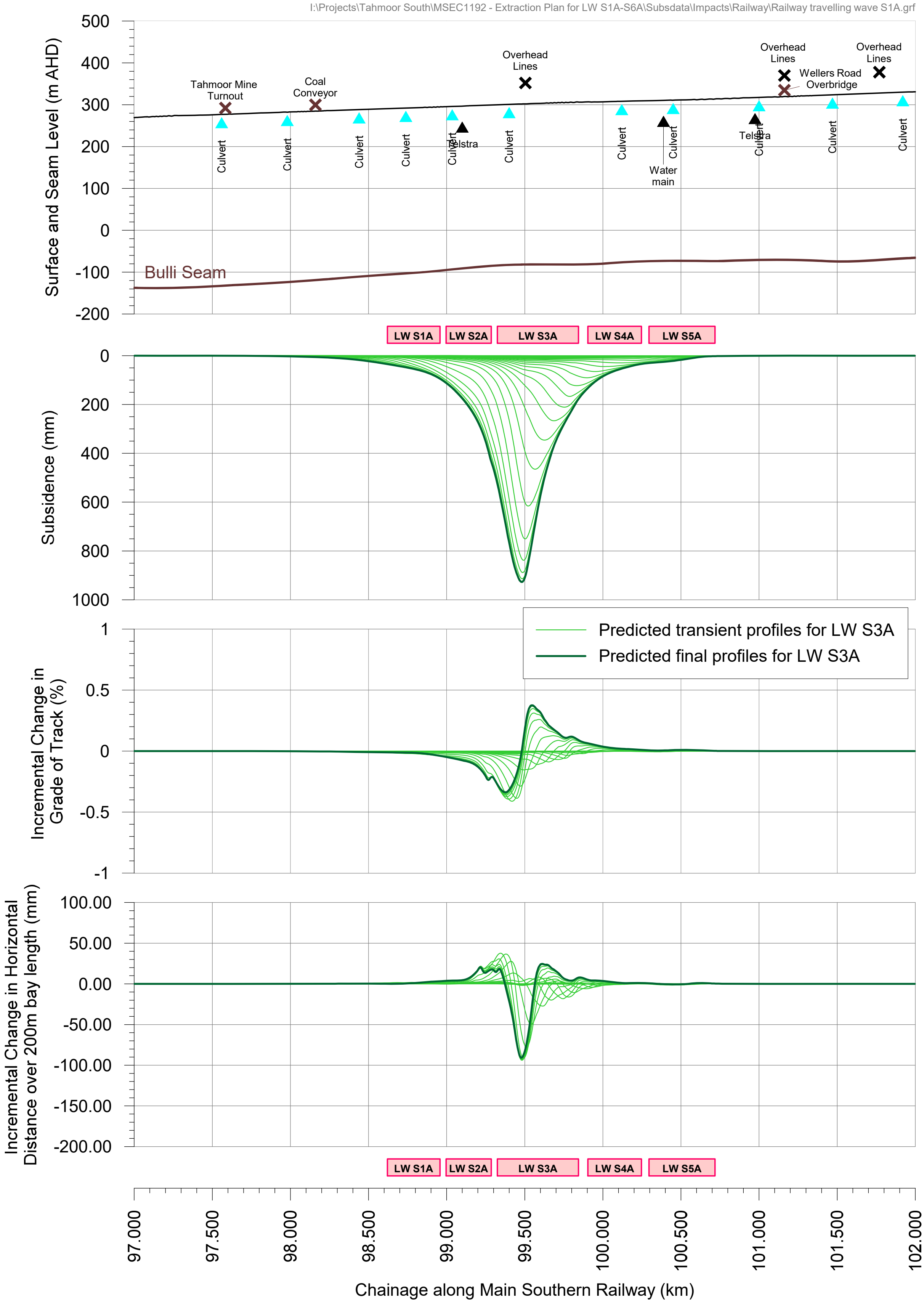

Fig. 2.5 **Predicted profiles of conventional incremental subsidence, change in grade and change in horizontal distances over 200 metre long bay lengths along the Main Southern Railway due to the extraction of LW S3A only**

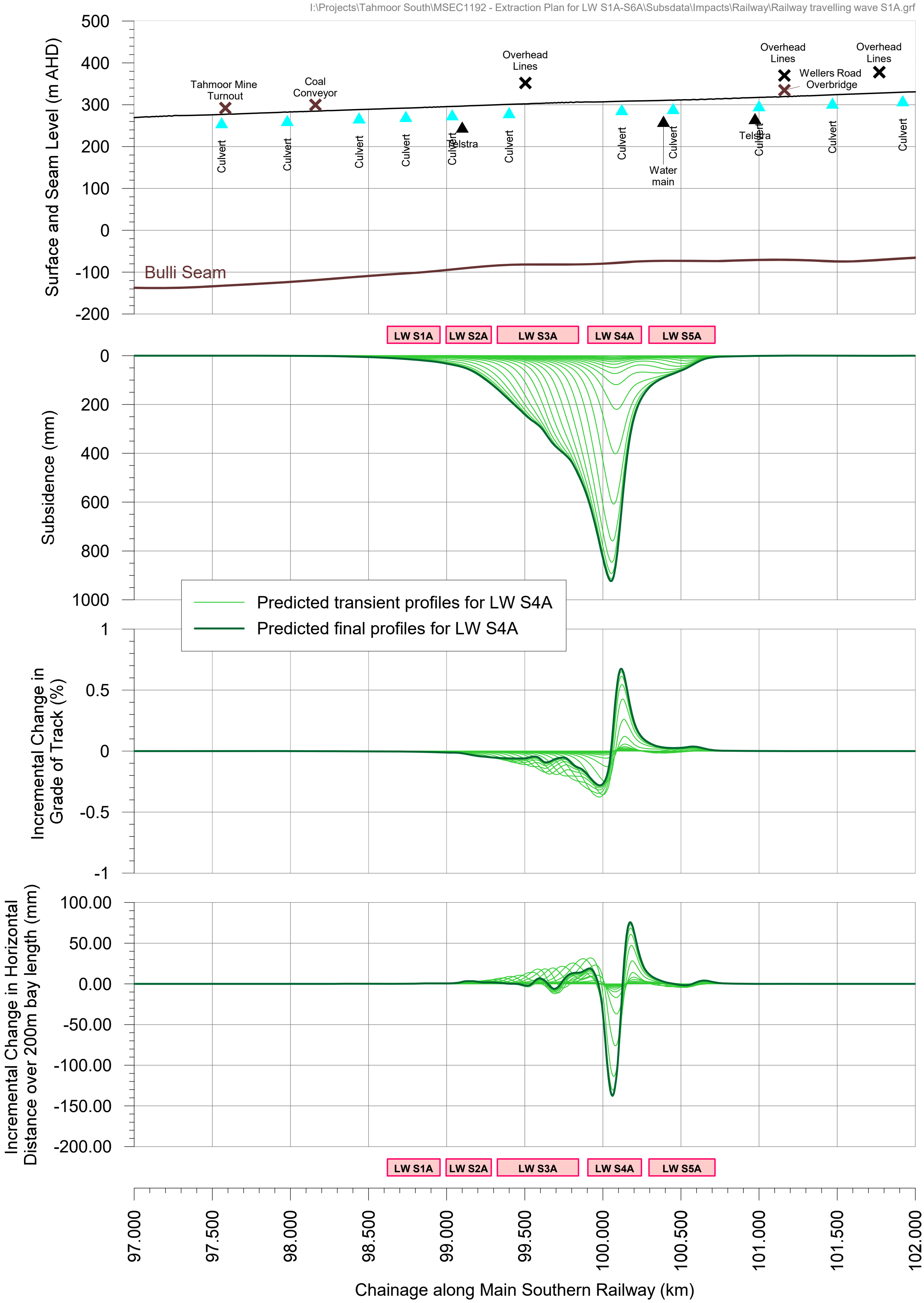

Fig. 2.6 **Predicted profiles of conventional incremental subsidence, change in grade and change in horizontal distances over 200 metre long bay lengths along the Main Southern Railway due to the extraction of LW S4A only**

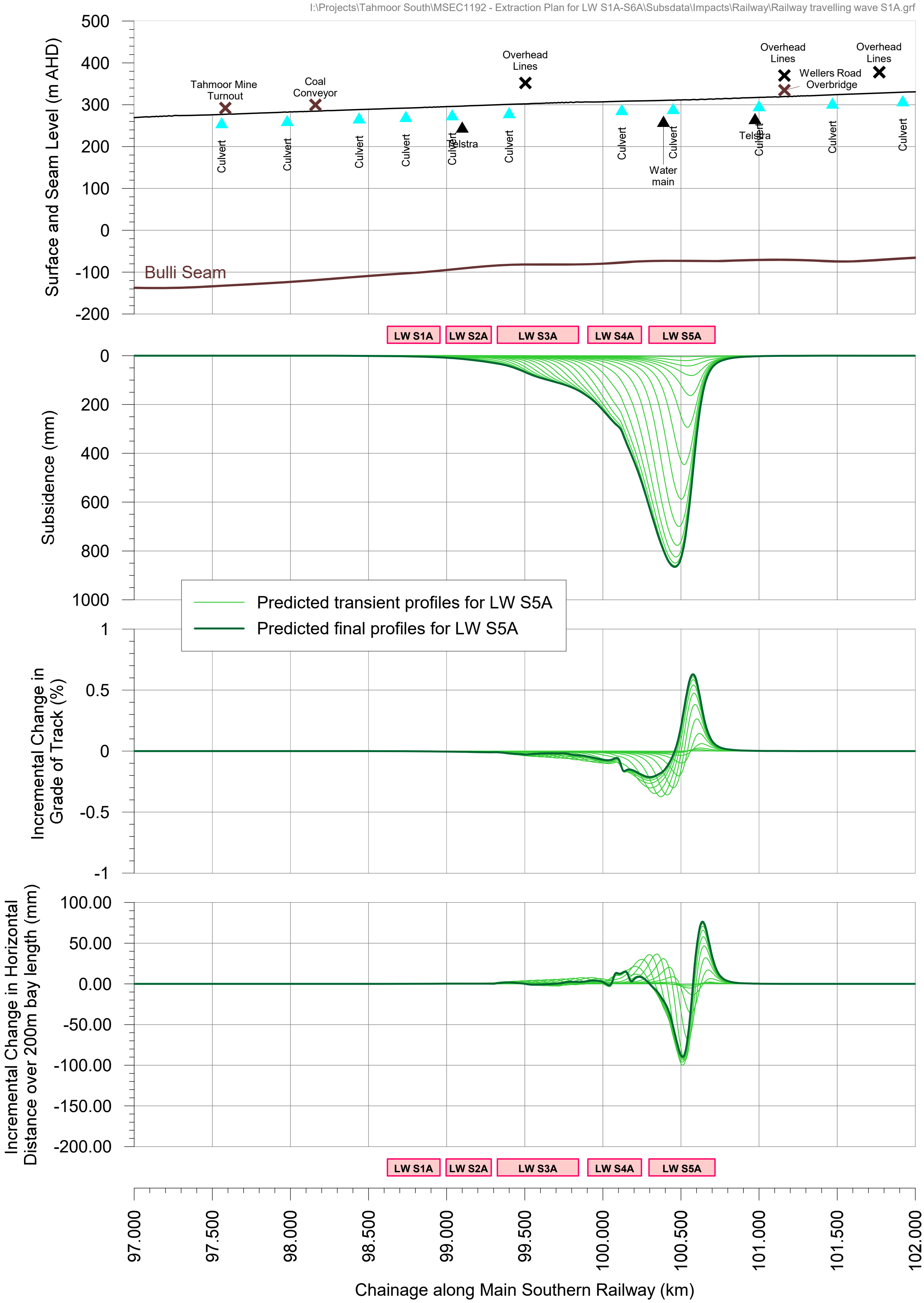

Fig. 2.7 Predicted profiles of conventional incremental subsidence, change in grade and change in horizontal distances over 200 metre long bay lengths along the Main Southern Railway due to the extraction of LW S5A only

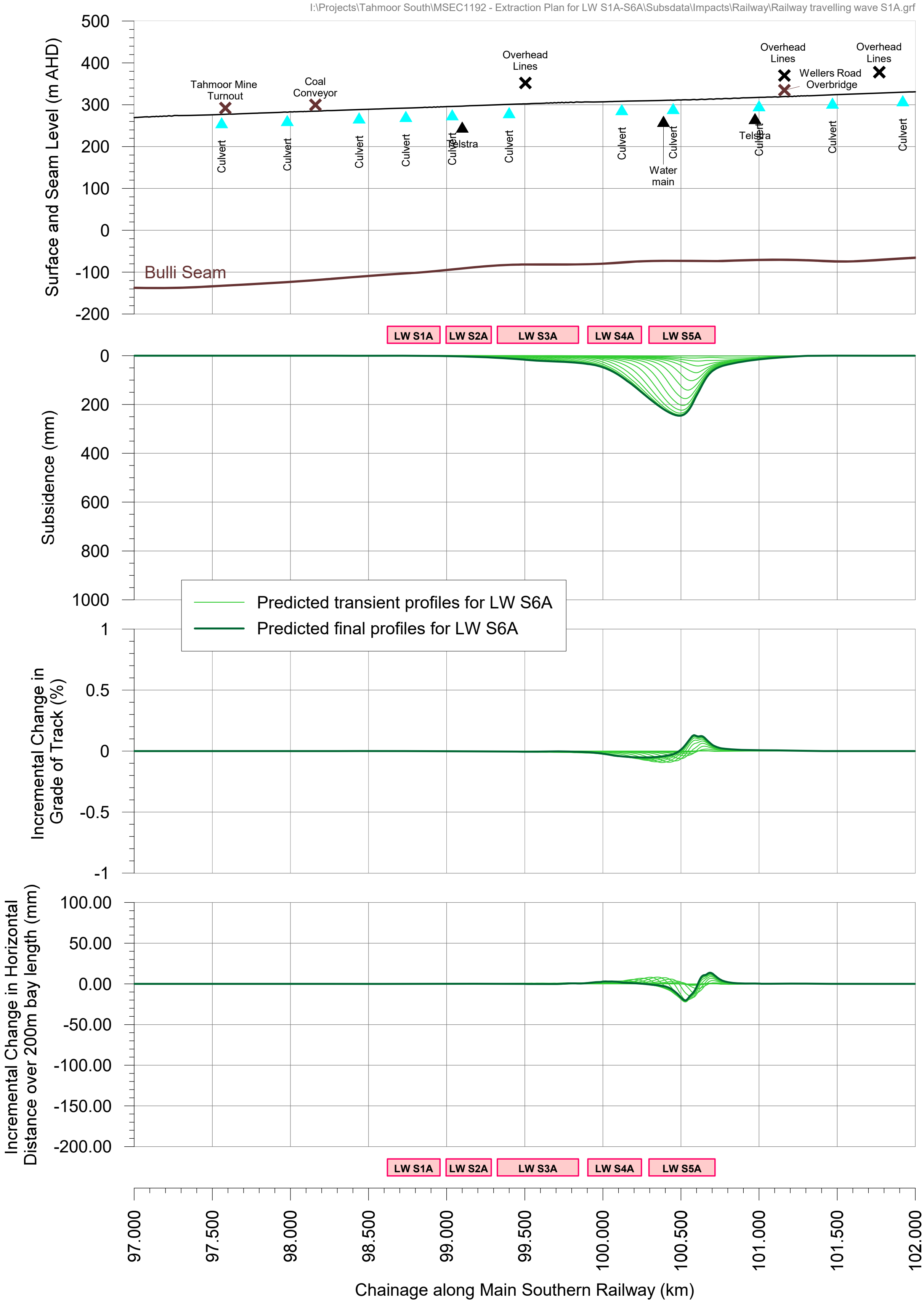

Fig. 2.8 Predicted profiles of conventional incremental subsidence, change in grade and change in horizontal distances over 200 metre long bay lengths along the Main Southern Railway due to the extraction of LW S6A only

2.2. 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. 2.9. 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. Similar increased subsidence movements were also observed above the southern ends of LWs 25 to 27 and the commencing end of LW 32. These were very unusual events for the Southern Coalfield and were 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 the Railway are adequate and effective.

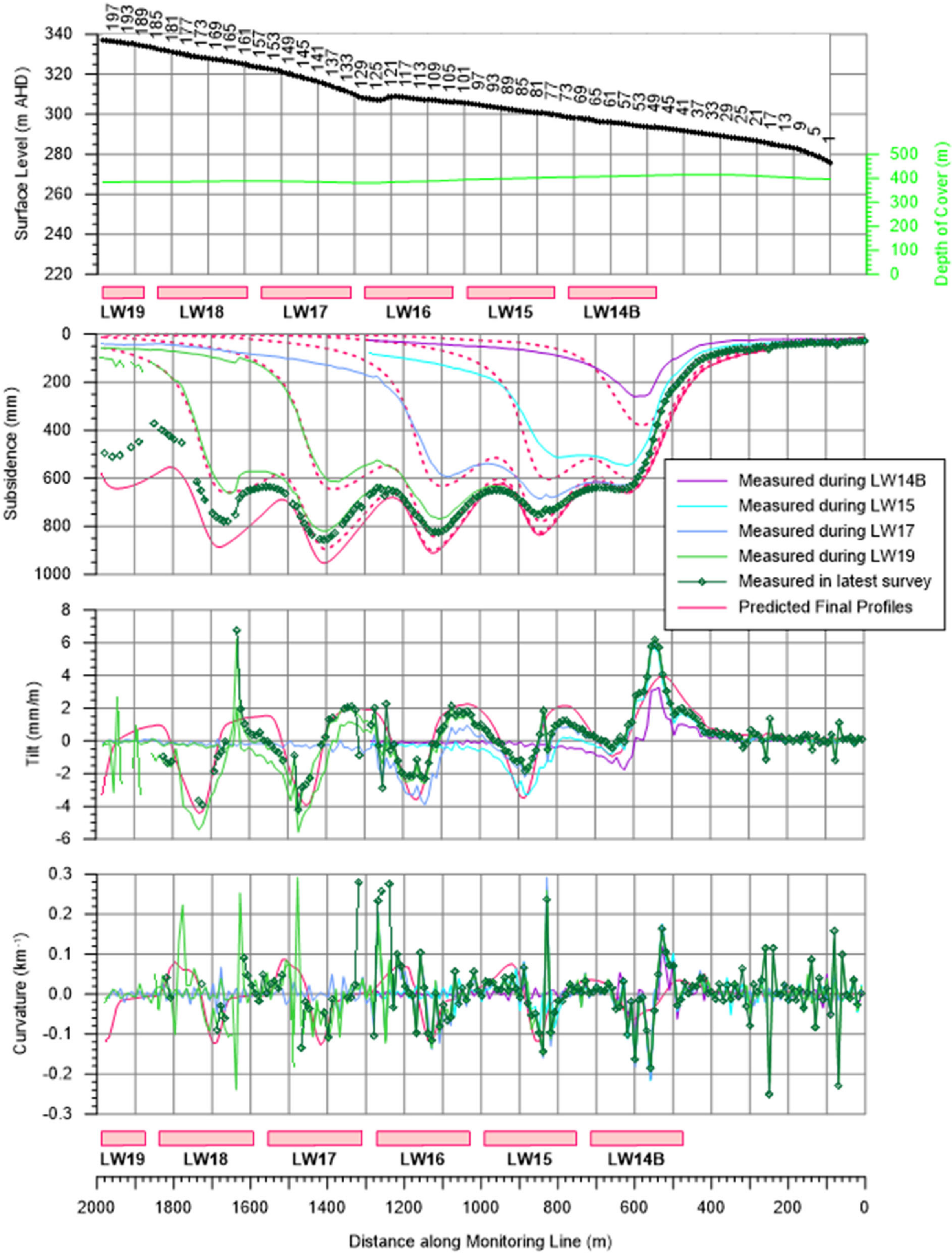

Fig. 2.9 **Comparison between observed and predicted subsidence along 1000 Line across LWs 14B to 19 at Tahmoor Mine**

2.3. 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. 2.10.

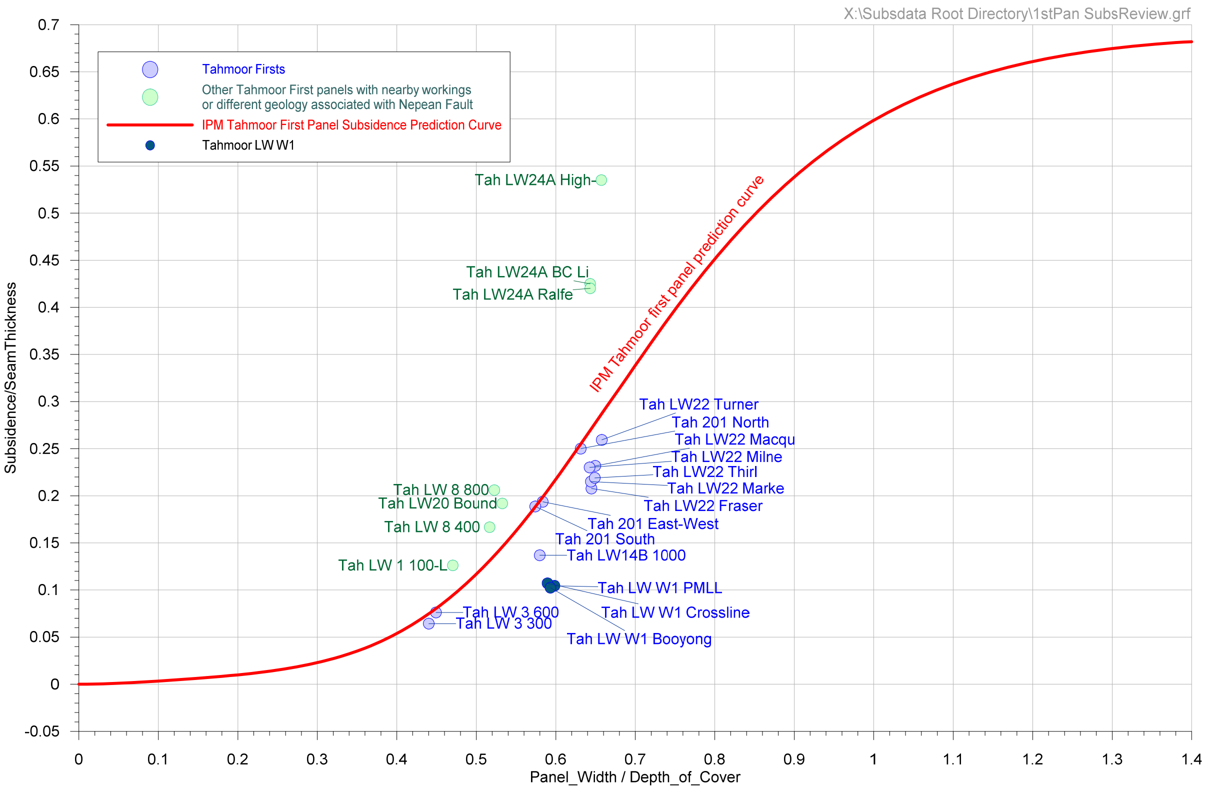

Fig. 2.10 Comparison between observed and predicted maximum subsidence for single panels at Tahmoor Mine

It can be seen from Fig. 2.10 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. 2.10 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 the Railway are adequate and effective.

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2.4. 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. The strains resulting from damaged or disturbed survey marks have also been excluded.

2.4.1. Analysis of strains measured in survey bays

Predictions of strain above goaf

MSEC's 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 have 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. 2.11. Probability distribution functions, based on fitted *Generalised Pareto Distributions* (GPDs), have also been shown in this figure.

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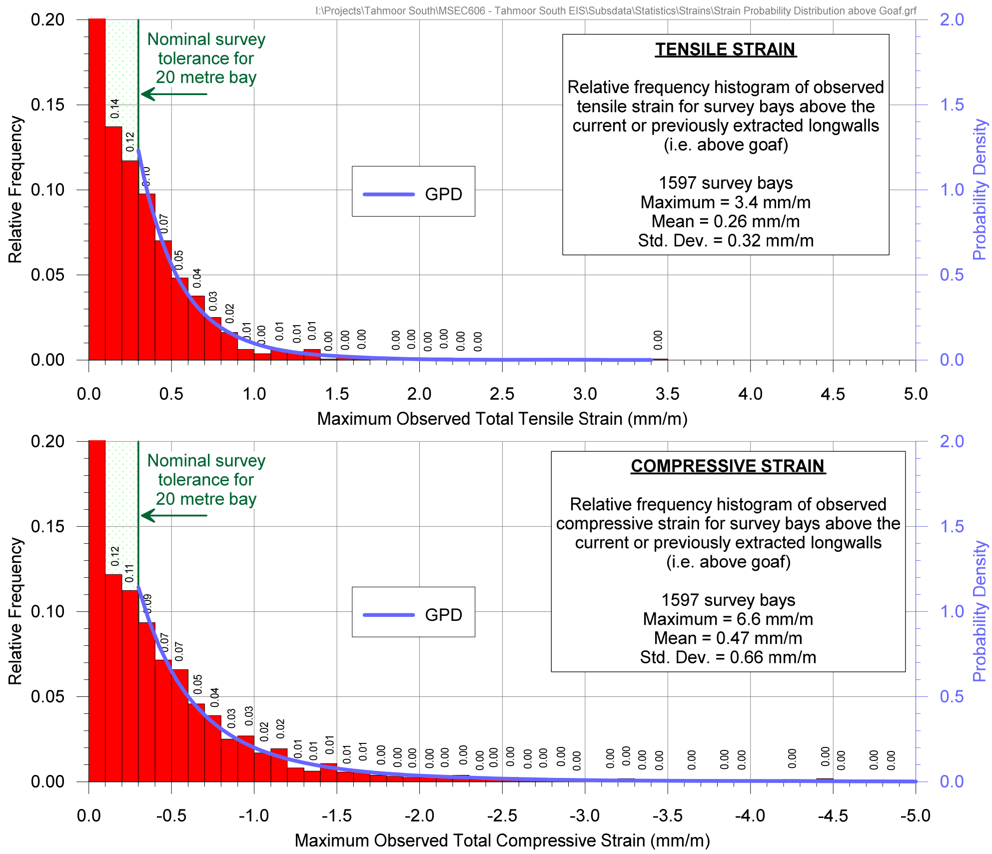

Fig. 2.11 Distributions of the maximum measured tensile and compressive strains for survey bays located above goaf at Tahmoor, Appin and West Cliff Collieries

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. 2.12. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

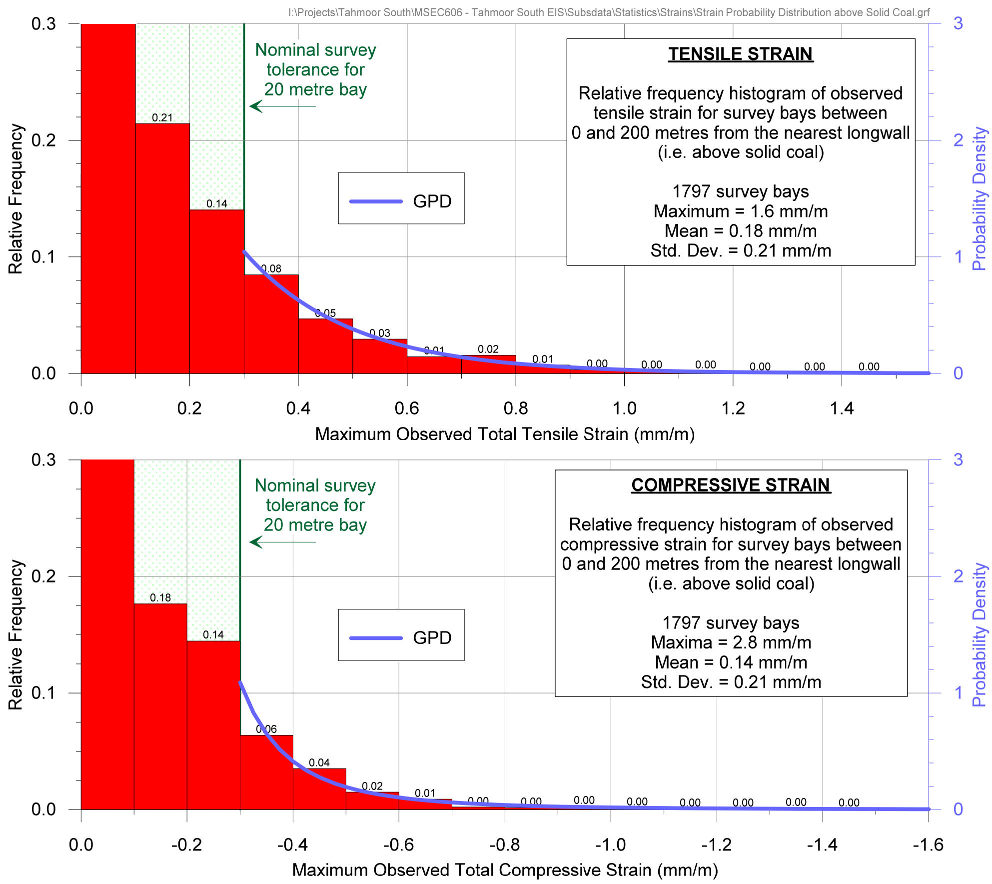

Fig. 2.12 Distributions of the maximum measured tensile and compressive strains for survey bays located above solid coal at Tahmoor, Appin and West Cliff Collieries

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.

2.4.2. Analysis of strains measured along whole monitoring lines

For linear features such as the railway track, 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. 2.13.

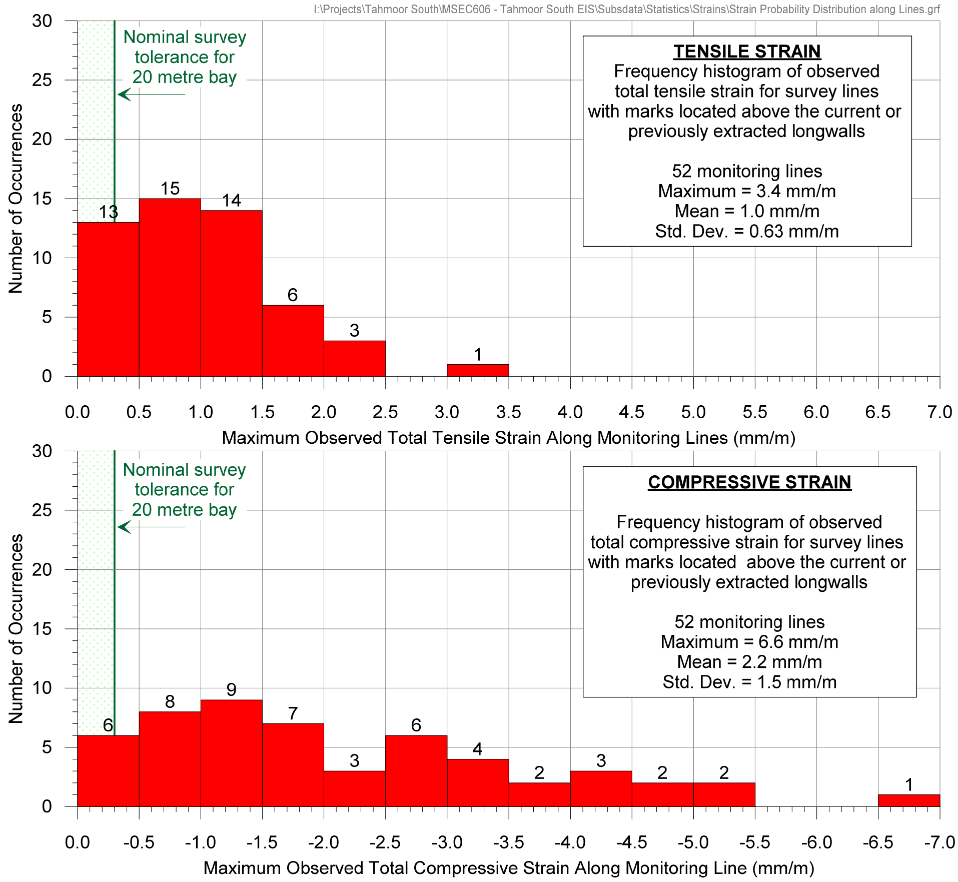

Fig. 2.13 Distributions of measured maximum tensile and compressive strains anywhere along the monitoring lines at Tahmoor, Appin and West Cliff Collieries

It can be seen from the above figure, that 48 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.

2.4.3. 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. 2.14. 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.

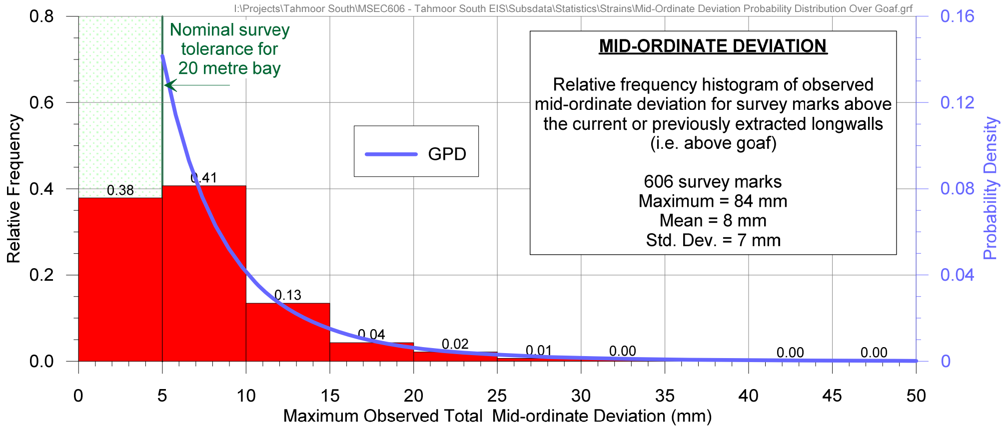

Fig. 2.14 Distribution of measured maximum mid-ordinate deviation during the extraction of previous longwalls in the Southern Coalfield for marks located above goaf

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.

2.4.4. Analysis of changes in horizontal distances over long bay lengths

The predicted incremental changes in horizontal distances over a 200 metre bay length along the railway are shown in Fig. 2.3 to Fig. 2.8. A summary of predicted maximum incremental changes is shown in Table 2.2.

Table 2.2 Predicted conventional changes in horizontal distances over a 200 metre bay along the Railway

Stage of Mining	Maximum predicted incremental ground extension (mm)	Maximum predicted incremental ground shortening (mm)
During LW S1A	60	150
During LW S2A	80	200
During LW S3A	40	100
During LW S4A	80	140
During LW S5A	80	100
During LW S6A	20	20

A comparison between predicted and observed maximum changes in horizontal distances over a 200 metre bay during the mining of Tahmoor North longwalls is provided in Table 2.3.

Table 2.3 Comparison between Predicted and Observed Changes in Horizontal Distance over a 200 metre bay along the ARTC monitoring line during mining of Tahmoor North longwalls

Stage of Mining	Maximum Predicted Incremental Ground Extension (mm)	Maximum Observed Incremental Ground Extension (mm)	Maximum Predicted Incremental Ground Shortening (mm)	Maximum Observed Incremental Ground Shortening (mm)
During LW25	60	30	110	60
During LW26	80	35	105	100
During LW27	80	60	115	105
During LW28	70	104	105	196
During LW29	70	50	100	208
During LW30	75	42	105	90
During LW31	70	117	105	136
During LW32	60	94	95	147

It can be seen that for Longwalls 25 to 27 and Longwall 30, there was a reasonable correlation between predicted and observed maximum changes in horizontal distances. In the case of Longwalls 28, 29, 31 and 32, however, observed maximum ground extension and shortening exceeded predictions.

When the predicted profiles of changes in horizontal distances along the railway are compared with observations, however, some substantial differences are found. The reasons for the differences are mainly associated with the influence of valley closure at Myrtle Creek, Skew Culvert, Redbank Creek and in the case of Longwall 31, the creek crossing at 90.676 km. In contrast, there has generally been a reasonable relationship between predicted and observed locations of maximum ground extension and opening along the Main Southern Railway above Appin Colliery because the Railway does not cross any significant valleys.

In the case of Longwall 32, there were no significant valleys at the northern end of the site directly above the longwall. Non-conventional movements developed at 90.080 km, resulting in higher ground shortening.

In the case of LW S1A-S6A, the predicted conventional changes in horizontal distances are greatest above LW S2A and LW S4A as these longwalls are oriented roughly square to the railway. The railway crosses a number of creeks within the Study Area. While the creeks are less incised compared to Myrtle Creek and Redbank Creek above the Tahmoor North longwalls, ground strains may concentrate across the valleys. Additional valley closure movements are predicted to occur in addition to the predictions of conventional movement shown in Fig. 2.3 to Fig. 2.8.

While good progress has been made, the prediction of changes in horizontal distances over long bays is not an exact science.

A statistical analysis of observed ground strains has been undertaken over long bay lengths. The distribution of maximum observed incremental ground shortening and opening along monitoring lines for bay lengths of 200 metres (± 10 metres) are shown in Fig. 2.15.

It can be seen in Table 2.3 that the observed changes in horizontal distance over 200 metres along the Railway at Tahmoor North lie within the middle of the range of previously observed values.

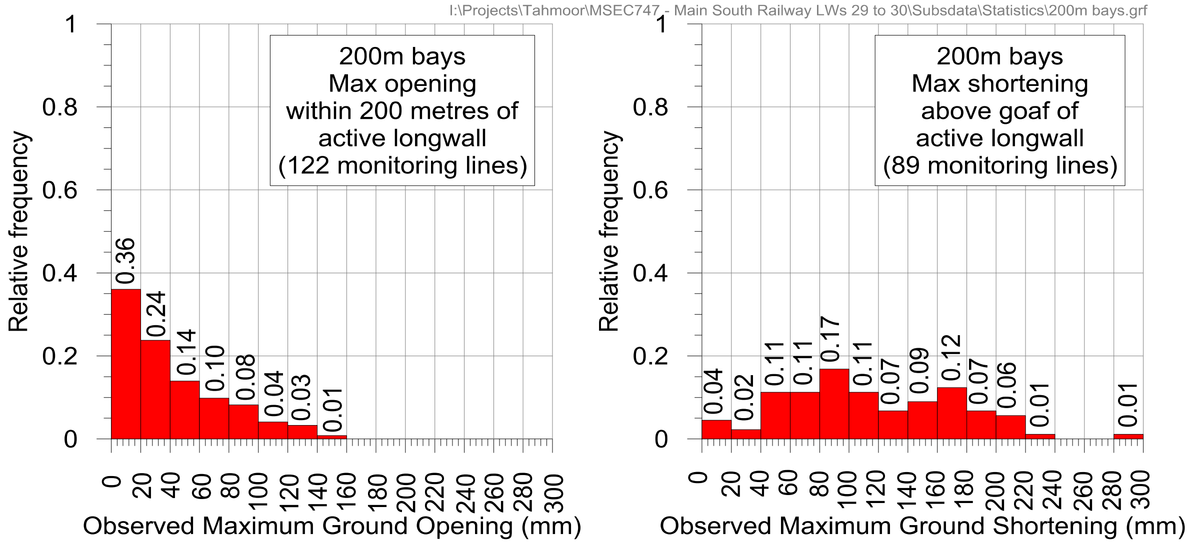

Fig. 2.15 Distribution of maximum observed incremental ground shortening and opening over 200 metre bay lengths due to the mining of a longwall

The observed changes in horizontal distances over long bay lengths were effectively managed during the mining of Longwalls 25 to 32 by the track expansion system. Expansion switches were adjusted as required during mining in response to changes in horizontal distances over long bay lengths between expansion switches and anchor points. The extent of track expansion system has been designed for each longwall to accommodate the majority of differential horizontal movements along the track. While some differential horizontal movements will develop beyond the track expansion system in CWR track, the rates of change in ground strain and rail stress have been found to be sufficiently low that rail stresses can be adequately managed in CWR track with infrequent rail adjustments.

2.5. Non-conventional subsidence

Non-conventional movements can be caused by a number of factors, including valley closure and upsidence, and from changes in local geology. They are typically localised and characterised by "spikes" in observed subsidence, tilt, curvature and strain profiles. They are most commonly observed as a combination of an irregularity or bump in the subsidence profile and compressive strain, although other combinations have been observed. An empirical prediction method has been developed for valley upsidence and closure movements. However, non-conventional subsidence is very difficult to predict accurately beyond valleys due to the limited available knowledge about local near-surface geology.

In relation to valleys, a conservative model has been developed to predict valley closure and upsidence (Waddington & Kay, 2002). The Railway crosses a number of culverts above LW S1A-S6A and predictions of upsidence and closure movements are provided in Section 3.4 of this Management Plan using that method.

In relation to other types of non-conventional movement, it is very difficult to know the exact nature of local geology across the whole surface area above the longwalls. It is therefore extremely difficult to predict exactly where non-conventional movements will occur and what the magnitude of movement might be. For this reason, observations of some non-conventional movements can often not be explained and these are therefore labelled as "anomalous".

Mining beneath urban and semi-rural areas at Tahmoor and Thirlmere by Tahmoor Mine Longwalls 22 to 32 provides valuable "whole of panel" information. A plot of locations of potential non-conventional movement is shown in Fig. 2.16. The locations were selected based on ground monitoring results or observed impacts that appear to have been caused by non-conventional movement. A total of approximately 59 locations (not including valleys) have been identified over the extracted Longwalls 22 to 32. The surface area directly above the longwalls is approximately 9.1 km^2. This equates to a frequency of 6 sites per square kilometre or one site for every 16 hectares. The non-conventional movements were mainly characterised by elevated compressive ground strains that varied up to a maximum of approximately 5 mm/m.

I:\Projects\Tahmoor\MSEC1065 - LW32 End of Panel Report\AcadData\Diagram Anomalies LW22 to LW32.dwg

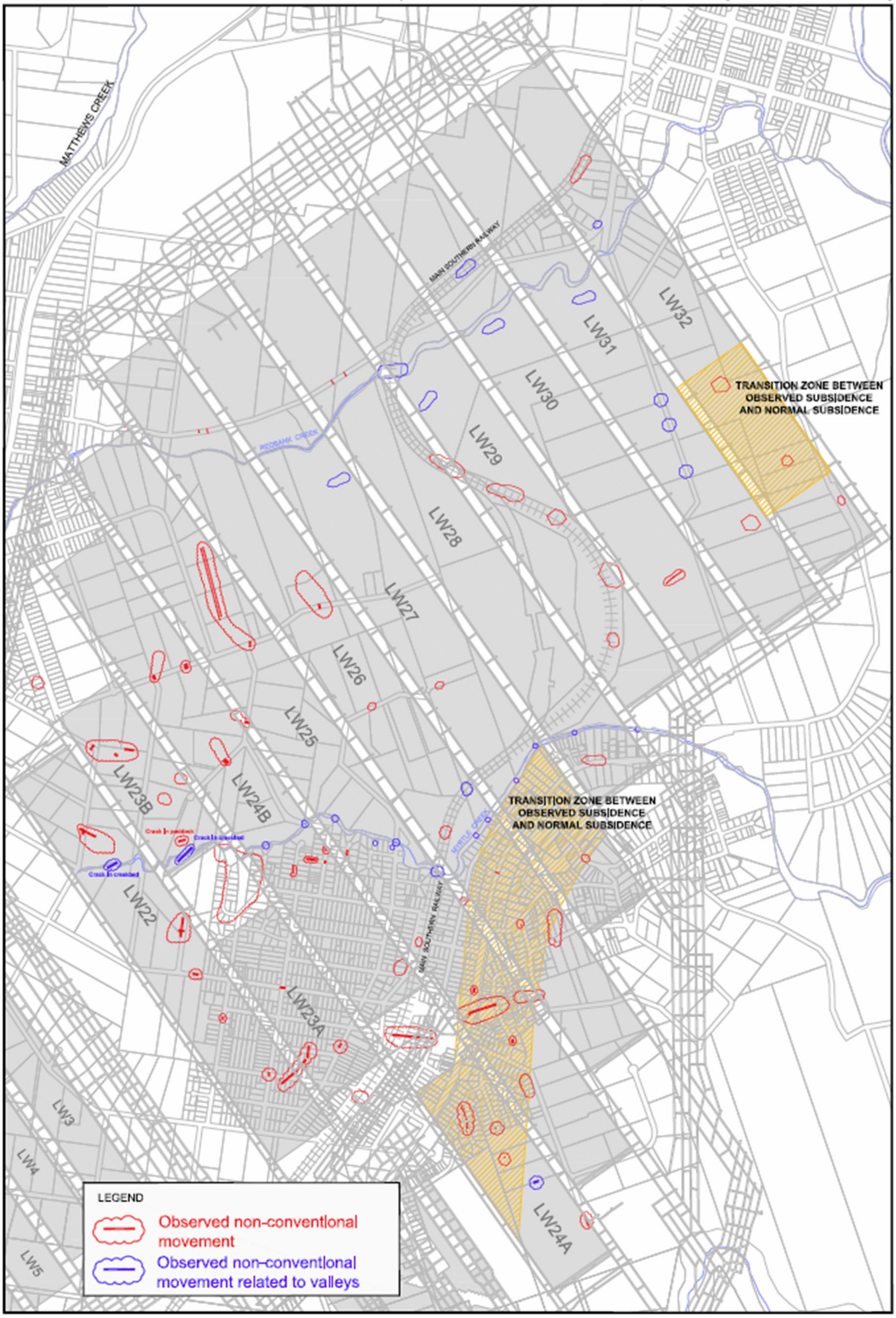

Fig. 2.16 Locations of potential non-conventional movement

The largest known case of non-conventional movement in the Southern Coalfield occurred above Appin Colliery Longwall 408 (Swarbrick, *et al.*, 2007). In this case, a low angle thrust fault was re-activated in response to mine subsidence movements, resulting in differential vertical and horizontal movements across the fault. Observations at the site showed that the non-conventional movements developed gradually over a period of time. Regular ground monitoring across the fault indicated that the rate of differential movement was less than 0.5 mm/day at the time non-conventional movements could first be detected. Subsequently as mining progressed, the rate of differential movement increased to a maximum of 28 mm/week.

Another example occurred at a low angle fault that intersected the Main Southern Railway in the Deviation Cutting at Tahmoor, which was located directly above Longwall 29. The site was monitored extensively during the mining of Longwalls 28 to 31. This included three monitoring lines along the railway cutting, and survey prisms along the railway track.

The results of observed changes in vertical alignment of the pegs along the railway cutting are shown in Fig. 2.17. It can be seen that the most significant changes occurred during the mining of Longwall 29. The changes, however, developed gradually over time, allowing the railway track to be adjusted such that trains could continue to travel through the site.

A gradual development of differential movements have been consistently observed during the mining of previous longwalls at Tahmoor Mine. While some sites have experienced severe impacts, the subsidence movements developed gradually, allowing time for repair before they became unsafe.

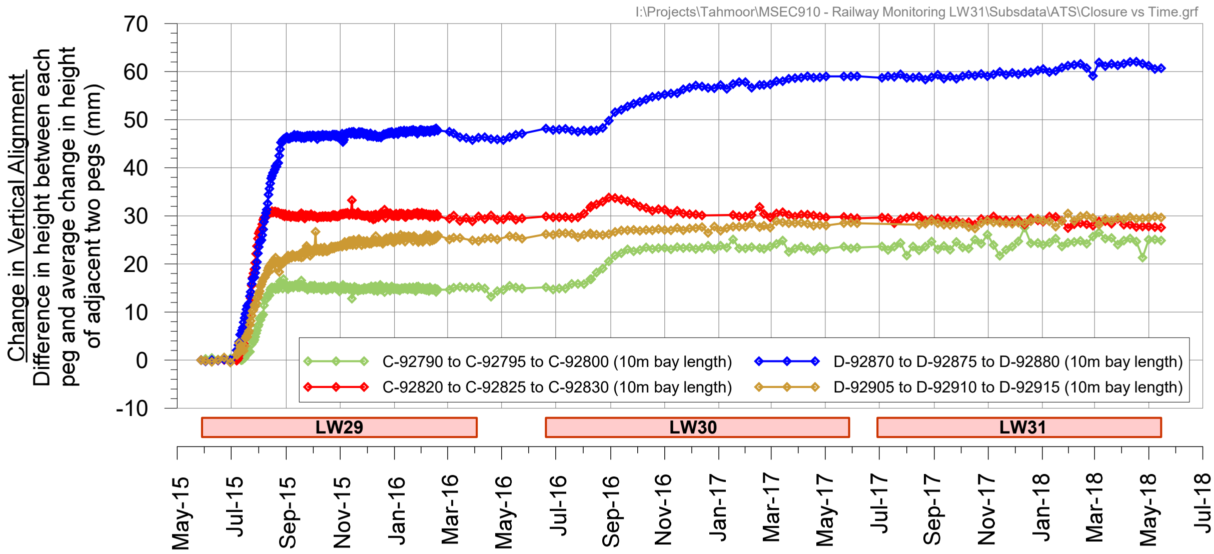

Fig. 2.17 Changes in vertical alignment across a geological fault within a railway cutting during the mining of Longwalls 29 to 31 at Tahmoor Mine

Tahmoor Mine has undertaken comprehensive geological exploration of the overburden and the Illawarra Coal Measures within the Tahmoor South project area using several geological and geotechnical consultants (MBGS, 2013; Gordon Geotechniques, 2013; SCT, 2013a) and a number of geological structures have been identified.

Several fault structures were identified and the two main structures that separate the mining domains are the Nepean Fault zone and the Central Fault zone. These and other identified faults and igneous intrusions are shown in Drawing No. MSEC1201-01. It can be seen that the Railway crosses a mapped dyke near a creek crossing at 98.445 km to the side of LW S1A.

Whilst the location where mapped geological structures intersect with the Main Southern Railway is located well away from LW S1A-S6A, there remains a possibility that non-conventional movements may develop away from the creek crossings at locations as yet unknown. It is noted that while comprehensive drilling and seismic exploration has been carried out, further in-seam drilling is planned to be undertaken and additional smaller geological structures may be discovered at that time.

Non-conventional movements are, however, expected to develop gradually as per previous experiences during mining in the Southern Coalfield at similar depths of cover, allowing adequate time to identify movements early and respond before they impact on the safety and serviceability of the railway.

Tahmoor Coal undertakes geological investigations and mapping of new locations of observed non-conventional movements when required on an ongoing basis. Measures to manage potential impacts on the railway will be reviewed when new information becomes available.

2.6. Development of subsidence movements over time

Monitoring of subsidence movements during the mining of previously extracted longwalls at similar depths of cover in the Southern Coalfield have shown that subsidence movements develop gradually over time, and with no observed indication of large or sudden step changes. This has been observed consistently along the Railway during the mining of Longwalls 25 to 32 and Appin Longwalls 703 to 708 and Appin Longwalls 901 and 902.

In each case, the observations have shown that subsidence movements develop gradually over time, with no obvious indication of large and sudden step changes, as inferred from the large database of weekly survey data, or high frequency automated continuous monitoring. The Automated Total Station in the Deviation Cutting, for example, has measured gradual changes in differential ground movements and railway track geometry at 2 hourly intervals specifically where the track crosses a geological fault.

Importantly, rail monitoring at Appin and Tahmoor Collieries have shown that the rails move differentially in a gradual manner, whether the track has been converted to the track expansion system or operating as standard continuously welded rail (CWR).

The subsidence effect at a point on the surface can be likened to a form of a wave. This wave moves across the ground at approximately the same speed as the longwall face retreats within the longwall panel but the impact of the surface subsidence wave is modified by the depth of cover and the overburden geology.

When the extraction of coal from a panel first commences, there is no immediate surface subsidence, but as the coal within the panel is extracted and the resulting void increases in size, subsidence develops gradually above the goaf area. As mining approaches and before a point is undermined, subsidence movements start to develop and then, after the longwall face passes beyond the point, the maximum value of subsidence is reached and despite further mining occurring within the panel, this level of subsidence is not exceeded except for some small time-based residual movements.

An example of the gradual development of subsidence is shown in Fig. 2.18, which shows the development of subsidence of survey pegs that are located along the centreline of Tahmoor Mine's Longwall 27. The development of subsidence is plotted against the distance of each survey peg to the longwall face at the time of each survey. It shows that subsidence at a point above Longwall 27 typically did not commence until the longwall face had approached to within 200 metres of the point and that the majority of the subsidence movements had developed after the longwall face had passed each point by a distance of approximately 400 to 600 metres. The average extraction rate of Longwall 27 was approximately 40 metres per week, so it can be seen that subsidence typically developed over a period of approximately 15 to 20 weeks.

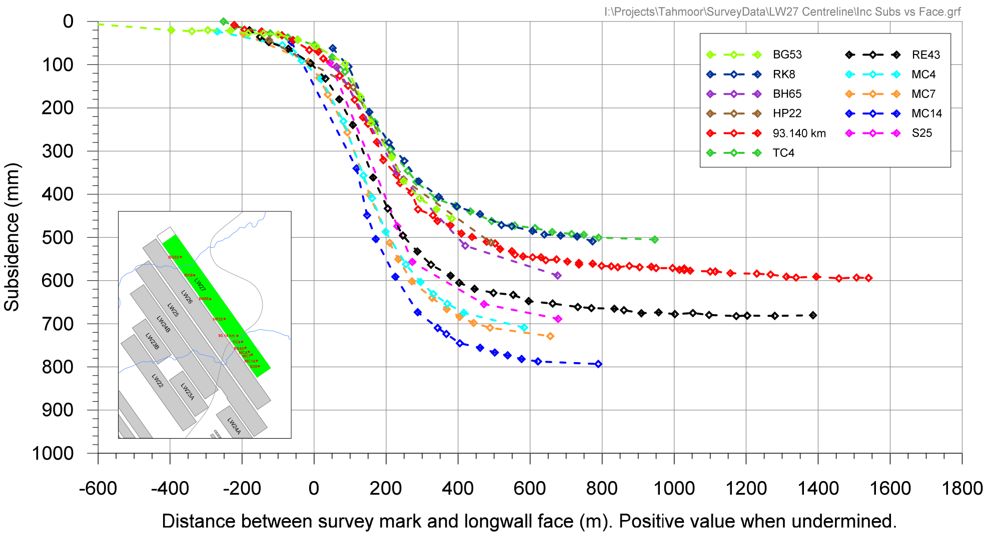

Fig. 2.18 Observed development of subsidence along Longwall 27 centreline versus distance to longwall face

As further adjacent panels are extracted, additional subsidence can be experienced above the previously mined panel or panels. However, a point is reached where a maximum value of subsidence occurs over the series of panels irrespective of whether more panels are later extracted.

Differential vertical and horizontal subsidence movements, such as tilt, curvature, strain and valley closure and upsidence are also observed to develop gradually as mining progresses.

The gradual development of subsidence movements allows potential impacts on surface features to be managed effectively. This is because with the implementation of an effective monitoring program, unexpected or anomalous subsidence ground movements can be detected early and actions taken in response well before potentially severe impacts occur.

2.7. Long-term residual subsidence

Residual subsidence is defined as the additional, time-dependent subsidence that develops after mining is completed or moved sufficiently far enough away from the affected area to be outside the zone of active subsidence. As a general guide, immediate active subsidence forms 90 to 95 % of the total subsidence at a point on the surface in most cases, and this occurs when mining is within the area of influence of the point (Holla and Barclay, 2000).

In the case of LW S1A-S6A, residual subsidence that would occur after the mining of LW S1A will be accelerated by the extraction of LW S2A and so on. This was taken into account when making subsidence predictions for LW S1A-S6A.

It is predicted that portions of the Railway above previously extracted LW S4A to 6A will continue to subside in small amounts over a long period of time after LW S6A is extracted. The residual vertical subsidence movements will be accompanied by small residual ground strains.

This Management Plan provides for monitoring the effects of residual subsidence on the railway. This will be undertaken by ground surveys, rail stress gauges and visual inspections but at reduced frequencies compared to monitoring undertaken above the active longwall as the rates of change in differential ground movements are substantially reduced.

2.8. 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 individual 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. 2.19.

The observed incremental far-field horizontal movements above solid coal only, i.e. outside the extents of extracted longwalls, are provided Fig. 2.20. 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. 2.19 and Fig. 2.20 that the magnitudes 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.

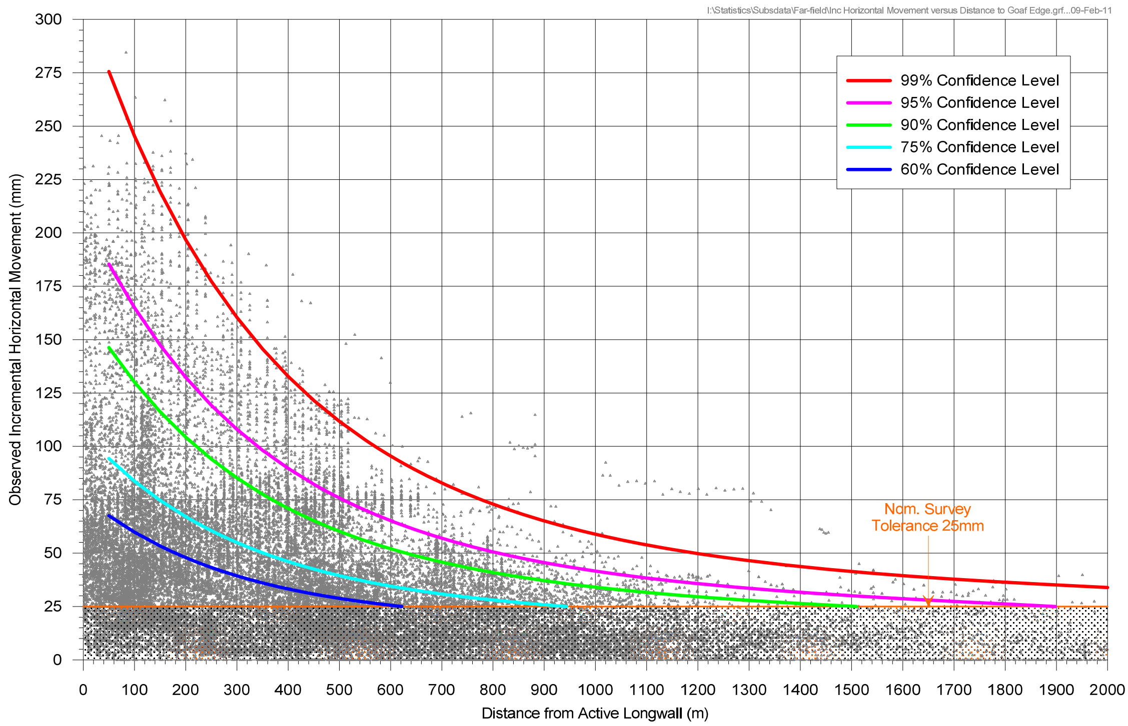

Fig. 2.19 Observed incremental far-field horizontal movements above goaf or solid coal

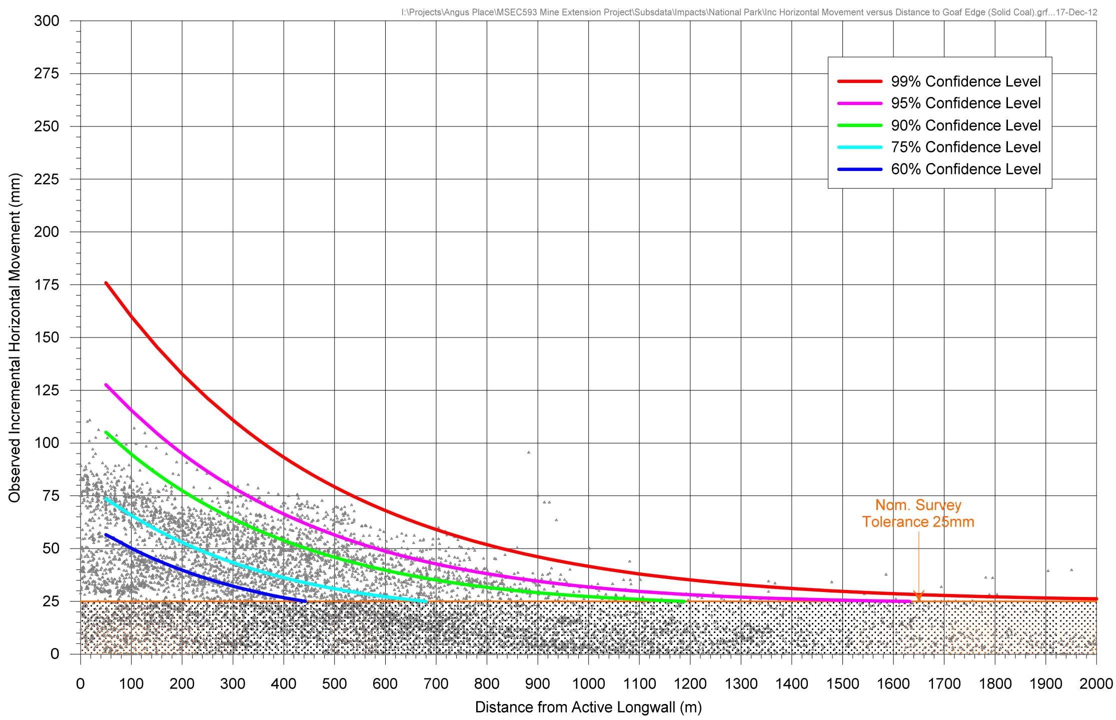

Fig. 2.20 Observed incremental far-field horizontal movements above solid coal only

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 2.4.

Table 2.4 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 Railway 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 370 metres and 2,000 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 does 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. 2.21 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.

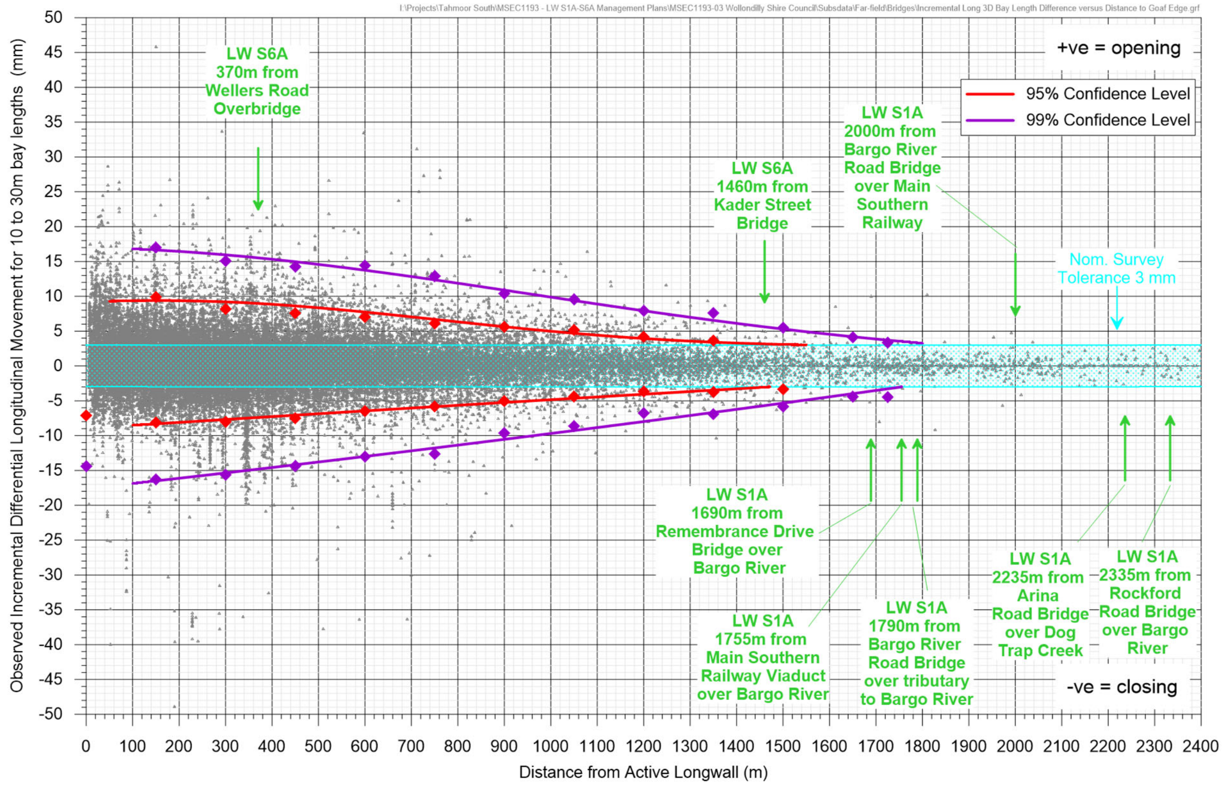

Fig. 2.21 Observed incremental differential longitudinal horizontal movements versus distance from active longwall for marks spaced between 10 and 30 metres

The results in Fig. 2.21 are relevant to the single span overbridges on Bargo River Road Overbridge (Potter's Cutting and Wellers Road Overbridge, which are less than 20 metres. They are also relevant to the intermediate spans on the Remembrance Drive Bridge and Railway Viaduct over the Bargo River.

The Railway Viaduct over the Bargo River has an overall length of approximately 75 metres. Observed changes in horizontal distances for survey marks spaced between 70 and 90 metres are shown in Fig. 2.22. 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.

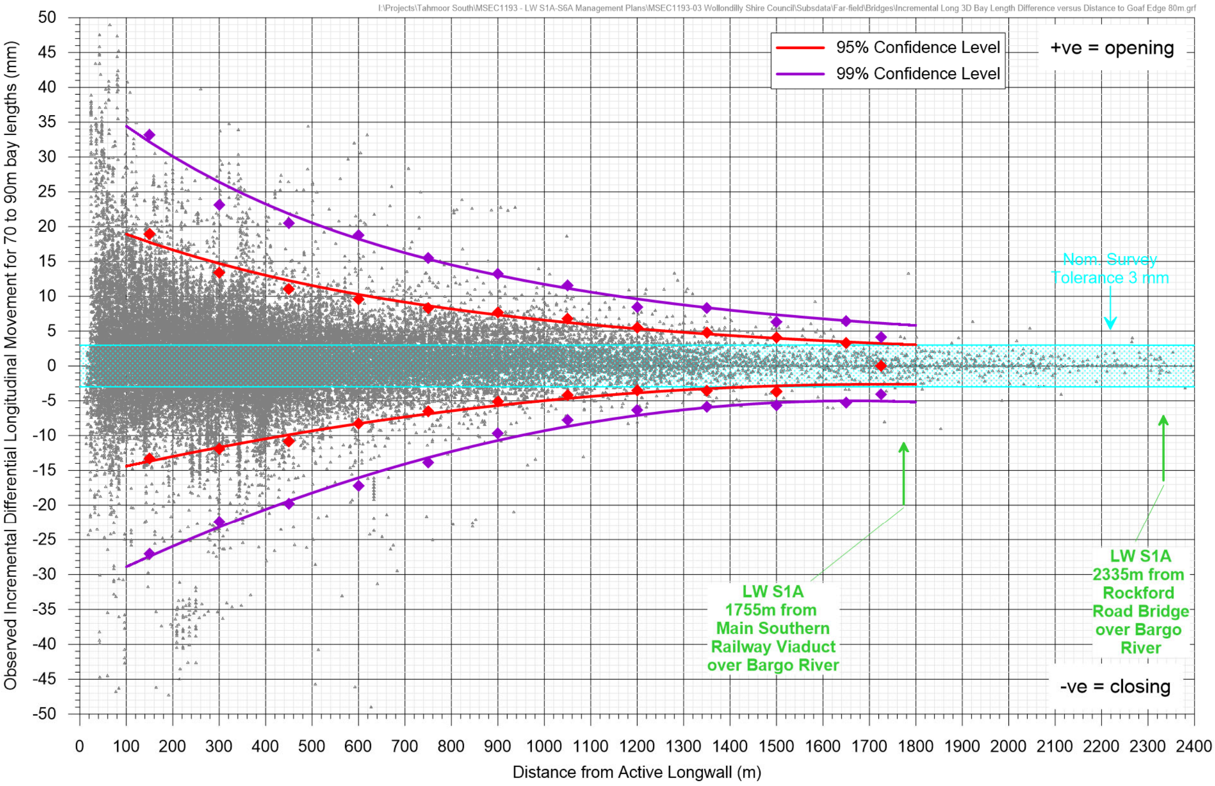

Fig. 2.22 Observed incremental differential longitudinal horizontal movements versus distance from active longwall for marks spaced between 70 and 90 metres

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 Fig. 2.23. 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.

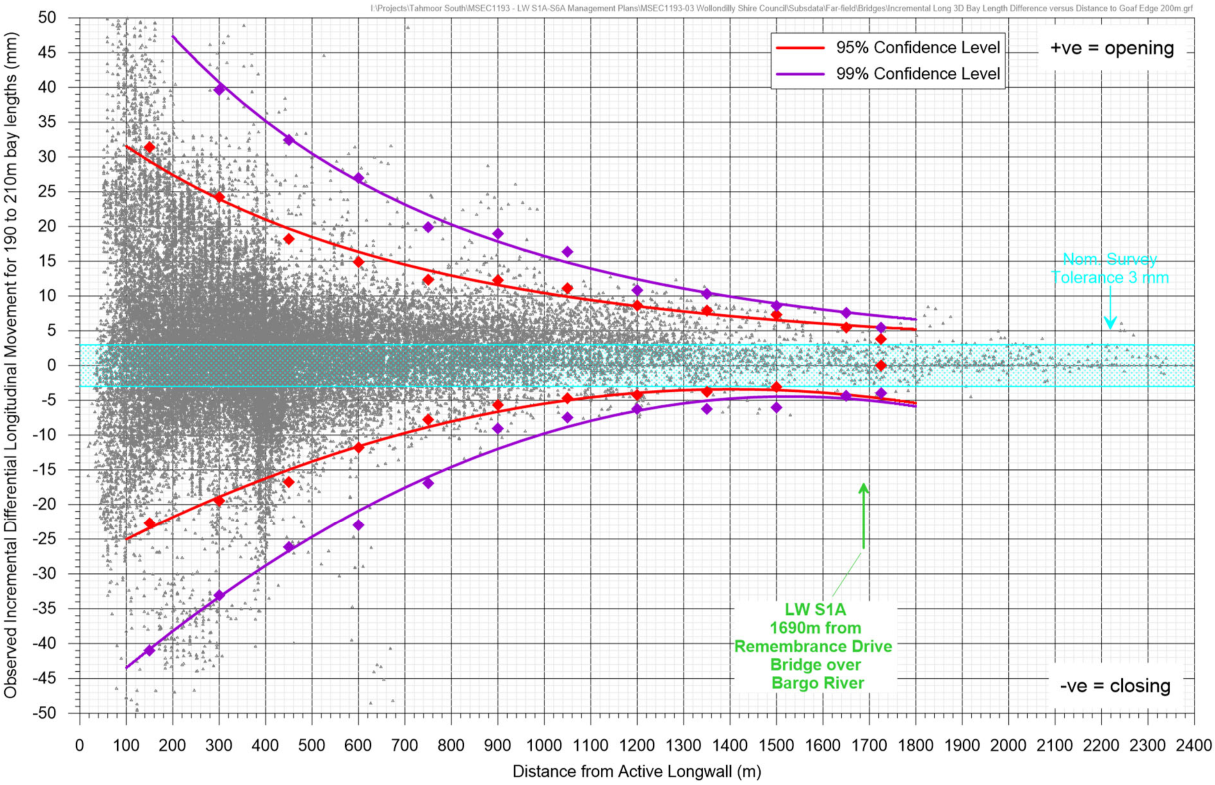

Fig. 2.23 Observed incremental differential longitudinal horizontal movements versus distance from active longwall for marks spaced between 190 and 210 metres

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 2.5. 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 2.5 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. 2.24.

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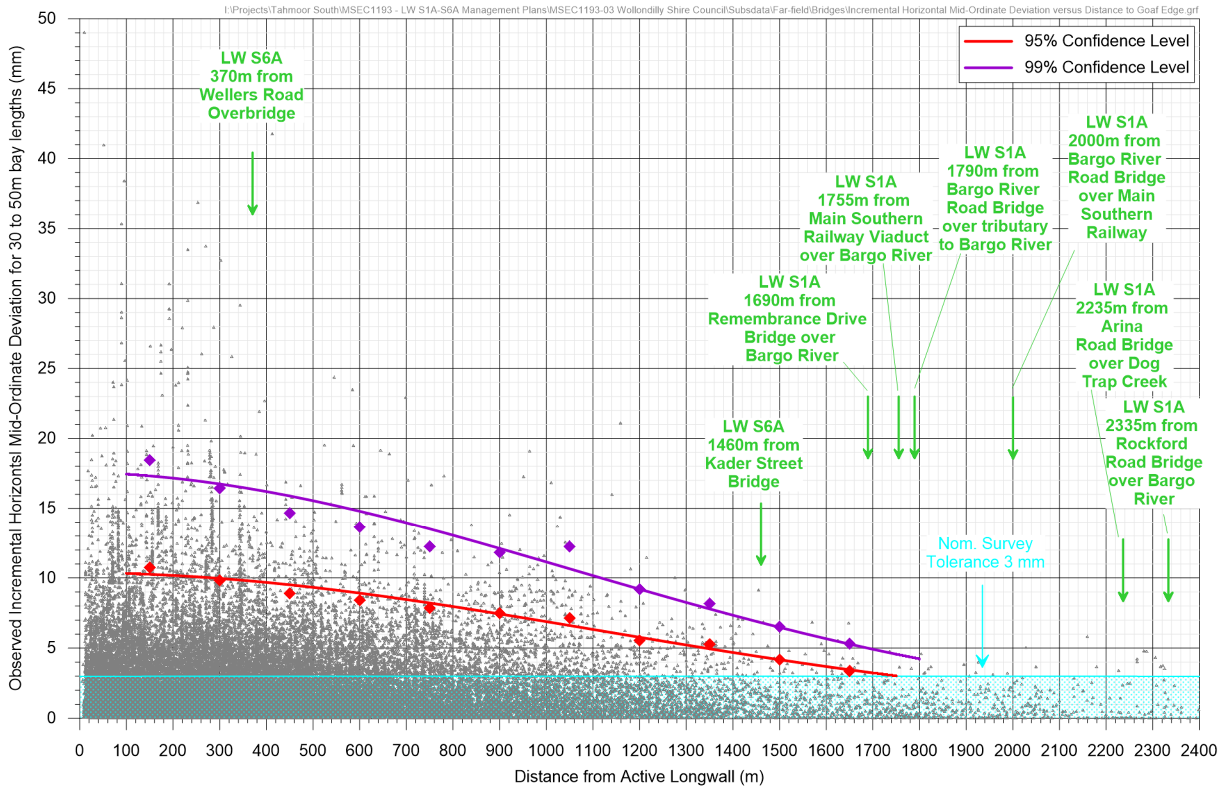

Fig. 2.24 Observed incremental differential horizontal mid-ordinate deviation versus distance from active longwall for marks spaced between 30 and 50 metres

The results in Fig. 2.24 are relevant to the single span bridges on Bargo River Road Overbridge (Potter's Cutting and Wellers Road Overbridge, which are less than 20 metres. They are also relevant to the intermediate spans on the Remembrance Drive Bridge and Railway Viaduct over the Bargo River.

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 2.6. 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 2.6 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	Pegs spaced between 190 and 210m
350 m (Wellers Road Overbridge)	1 in 20 (0.05)	9	N/A	N/A
	1 in 100 (0.01)	14		
1700 m to 2400 m (other Bridges)	1 in 20 (0.05)	3	5	5
	1 in 100 (0.01)	8	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.

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2.9. Potential for residual far-field movements after slowing or stopping longwalls

Residual subsidence is defined as the additional, time-dependent subsidence that develops after mining is completed or has moved sufficiently far enough away from the affected area to be outside the zone of active subsidence. As a general guide, immediate active subsidence forms 90 to 95 % of the total subsidence at a point on the surface in most cases, and this occurs when mining is within the area of influence of the point (Holla and Barclay, 2000).

While it is understood that residual subsidence movements continue to develop after a longwall slows or stops mining, the majority of the understanding is based on observations of survey pegs that were located directly above longwalls. The ground surface located directly above mined longwall panels experience residual subsidence movements where the predominant mechanism for movement is the ongoing consolidation of the goaf material and subsided strata directly above it until it reaches equilibrium.

There are thought to be at least three mechanisms that can influence the horizontal and vertical movement of points on the surface due to underground mining (Mills, 2011 and Kay and Waddington, 2014).

- Conventional or systematic subsidence movements due to the collapse or goafing of the overburden rocks directly above the extracted coal seam, and the subsidence of the strata directly above it;
- Non-conventional related movements due to the influence of topography or other local or regional weaknesses in the overburden, such as faulting, natural joints or bedding planes with low frictional characteristics; and
- Far-field movements due to stress relief and redistribution.

The movements that occur at points on the surface reflect the combination of these mechanisms. For points on the ground surface that are located directly above the extracted longwalls, the predominant mechanisms are the conventional movements and in some locations, the non-conventional movements.

For points on the surface that are remote from the longwalls, the stress relief and redistribution mechanisms that result in far-field movements become the dominant mechanism, though non-conventional movements can also occur beyond the normally accepted limits of conventional subsidence movements.

A study has been conducted for the purposes of this Management Plan to determine the potential for residual far-field movements after longwalls slow down and stop. The study has focussed on the observations of far-field survey sites that are located near the finishing ends of longwalls, with particular focus on measured valley closure movements.

Measured closure across cuttings were also examined but were not included in the study. This is because cuttings have not been located near the finishing ends of longwalls where it is possible to examine the effect of an immediate slowing or stopping of longwalls. The majority of cuttings have also been directly mined beneath, which means that a significant component of residual subsidence is due to conventional subsidence effects.

The study has investigated the following residual movements:

- Residual horizontal and vertical movements of GNSS units located near the finishing ends of Tahmoor LW W1-W2;
- Observed valley extension across Matthew Creek between GNSS units 18 and 19, which are located near the finishing ends of Tahmoor LW W1-W2;
- Observed valley closure across Victoria Bridge across Stonequarry Creek, which is located near the finishing end of Tahmoor LW W2;
- Observed valley closure across the Nepean River for survey lines located near the finishing ends of Appin LWs 702, 703, 707B and 708B;
- Observed valley closure across the Nepean River for survey lines located near the finishing ends of Appin LWs 901, 902 and 903;
- Observed valley closure across Harris Creek for survey lines located near the finishing ends of Appin LWs 901, 902 and 903;
- Observed valley closure across Sandy Creek Waterfall located near the finishing ends of Dendrobium LWs 6, 7 and 8; and
- Observed valley closure across the Eastern Tributary located near the finishing ends of Metropolitan LWs 303, 304 and 305.

Residual horizontal and vertical movements of GNSS units located near the finishing ends of LW W1-W2

Four continuously monitored GNSS sites are located near the finishing ends of LW W1-W2, as shown

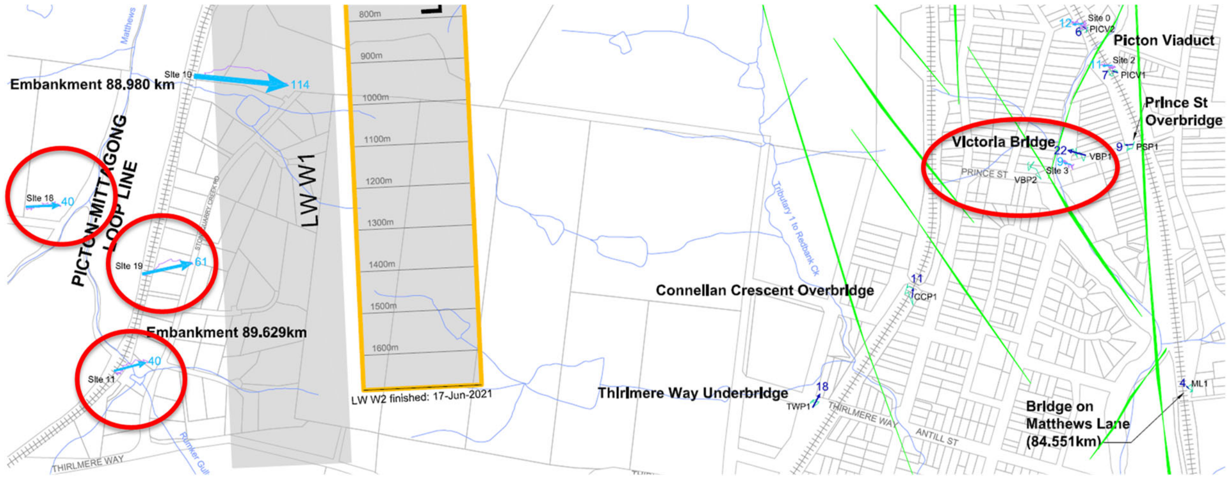

Fig. 2.25 Locations of GNSS sites near the finishing ends of Tahmoor LW W1-W2

GNSS Sites 11, 18 and 19 are located between 195 metres and 470 metres to the west of the longwall panels. GNSS Sites 18 and 19 are on opposite sides of Matthews Creek and observed changes in horizontal distances across the valley can be calculated from the GNSS results.

GNSS Site 3 on Victoria Bridge is located 1.4 km from the side of LW W2 on the eastern side of Stonequarry Creek and within the mapped Nepean Fault zone. The site is located downstream of Picton Viaduct and slightly closer to the longwalls than the Viaduct.

The GNSS Site 11 is located closest to the ends of the panels and observed changes in easting, northing and height are shown in Fig. 2.26. It can be seen that the site was experiencing active vertical subsidence and eastward movement as LW W1 and LW W2 reached their finishing ends. A clear reduction in the rates of change in subsidence and horizontal movement was observed immediately after the longwall slowed down during the bolt up stage and then stopped.

The analysis was repeated for GNSS Sites 18, 19 and Site 3 (Victoria Bridge). Changes in easting are shown in Fig. 2.27 and Fig. 2.28. Given that LW W1-W2 are oriented predominantly north-south, the observed changes in easting are oriented approximately transverse to the longwalls. There was very little change in northing or height observed at these sites. Daily rates of longwall extraction are also shown in Fig. 2.27 and Fig. 2.28.

The observations demonstrate the following:

- A clear reduction in rates of change once the longwall slowed and stopped at the finishing ends of LW W1-W2;
- A very slight but noticeable increase in the rate of change in easterly movements soon after LW W2 commenced extraction, which suggests that the early slight increases may be related to active extraction rather than residual movements post LW W1; and
- Very little change in easterly movements for the first two months after LW W2 slowed and stopped.

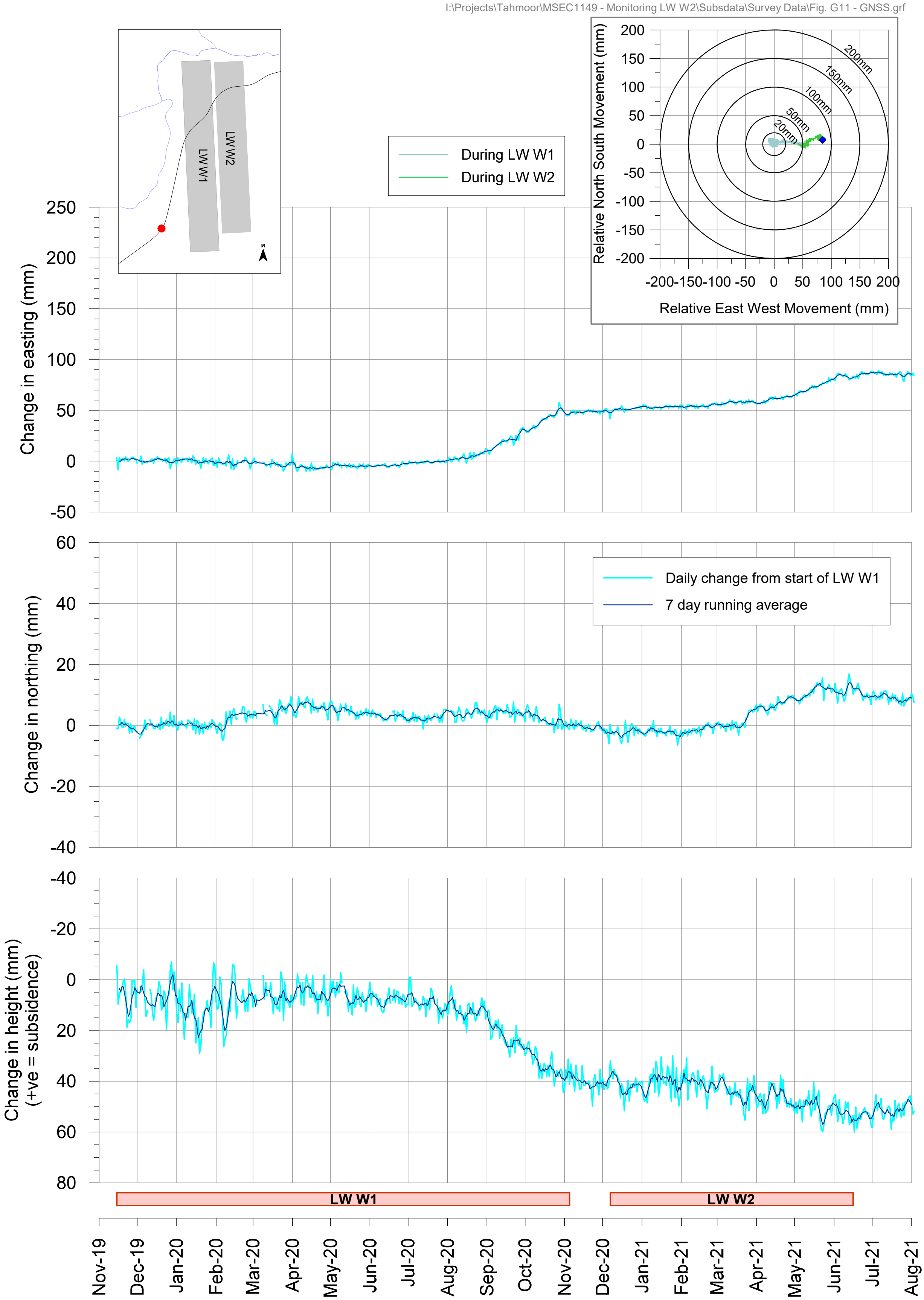

Fig. 2.26 Observed changes in Easting, Northing and Height at GNSS Site 11 during the mining of LW W1-W2

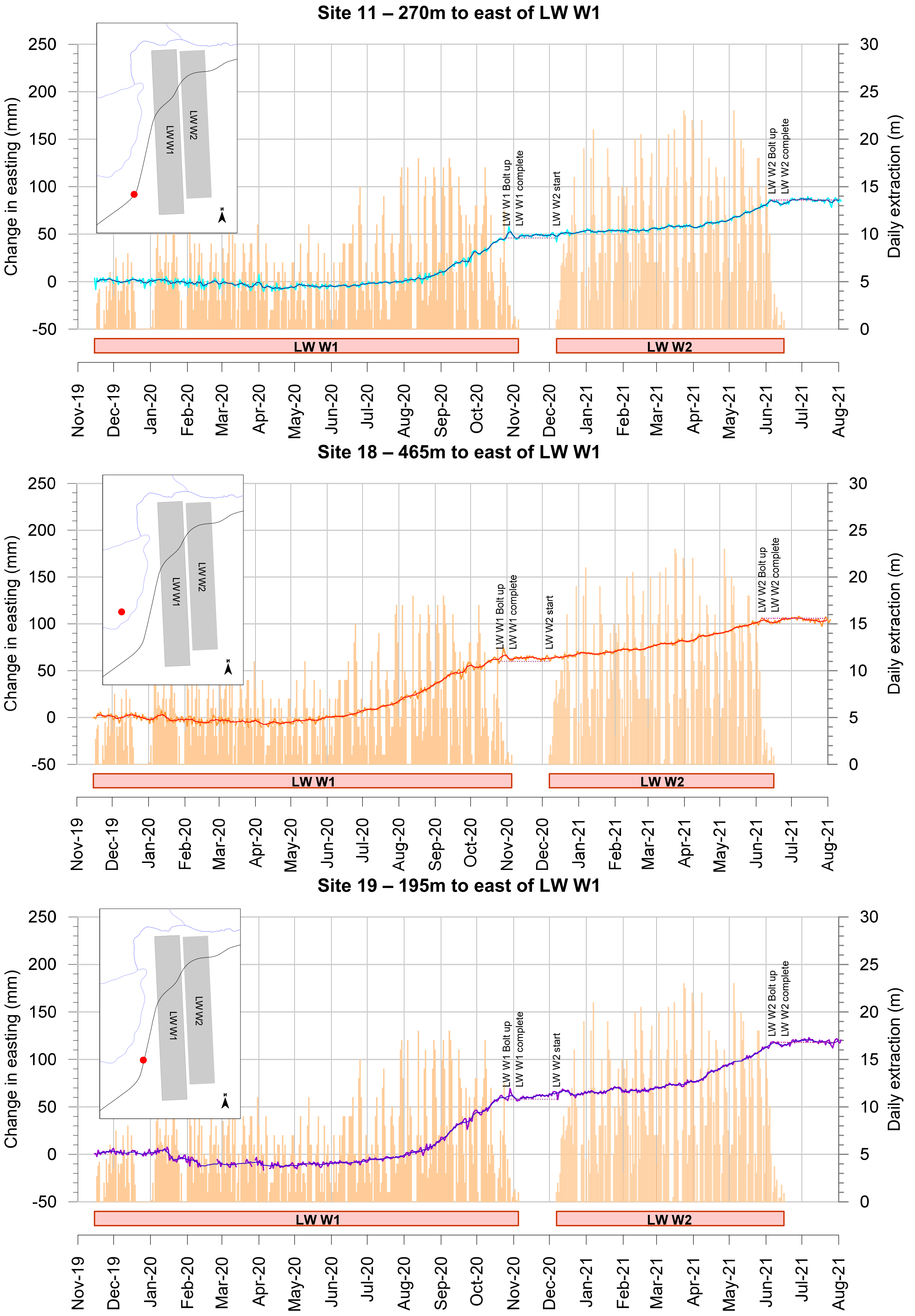

Fig. 2.27 Observed changes in Easting at GNSS Site 11, 18 and 19 during the mining of LW W1-W2

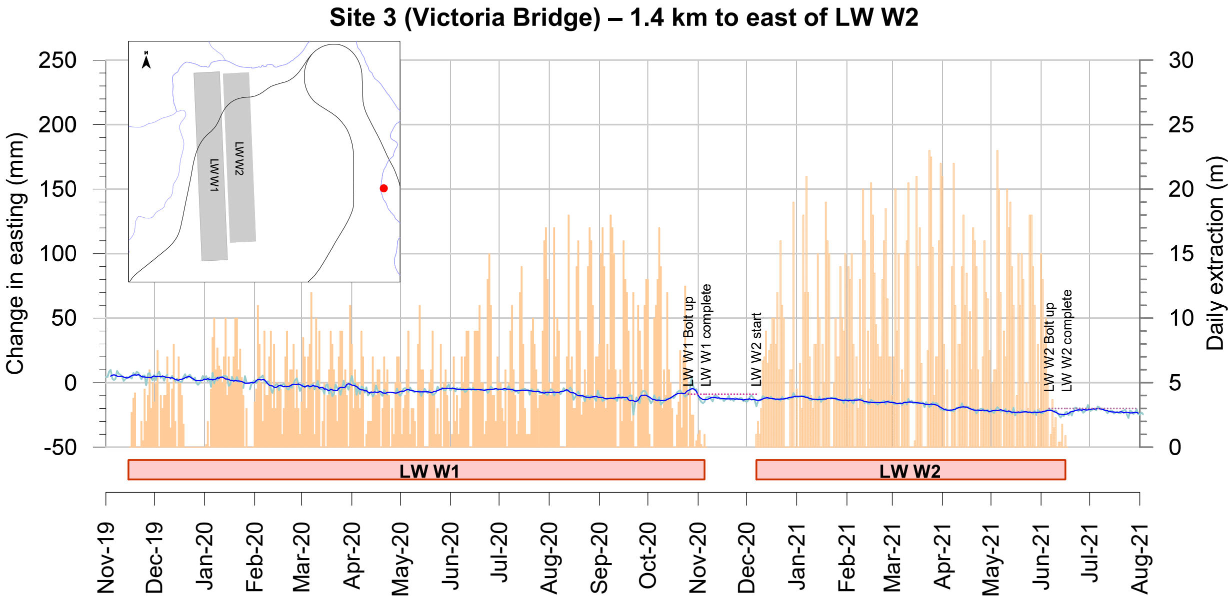

Fig. 2.28 Observed changes in Easting at GNSS Site 3 (Victoria Bridge) during the mining of LW W1-W2

Observed valley extension across Matthew Creek between GNSS units 18 and 19, which are located near the finishing ends of LW W1-W2

GNSS Sites 18 and 19 are located across Matthews Creek near the finishing ends of LW W1-W2. Due to their locations relative to the longwall, the GNSS units experienced mining-induced movements at different times, resulting in apparent closure and opening, as shown in Fig. 2.29. The net change between the sites was close to zero after the mining of LW W1, with little change until February 2021. Site 19 has moved closer to LW W2 compared to Site 18 during the mining of LW W2, resulting in net ground extension across the valley.

For both LW W1-W2, rates of change noticeably slowed after the longwall slowed and stopped, as shown in Fig. 2.29.

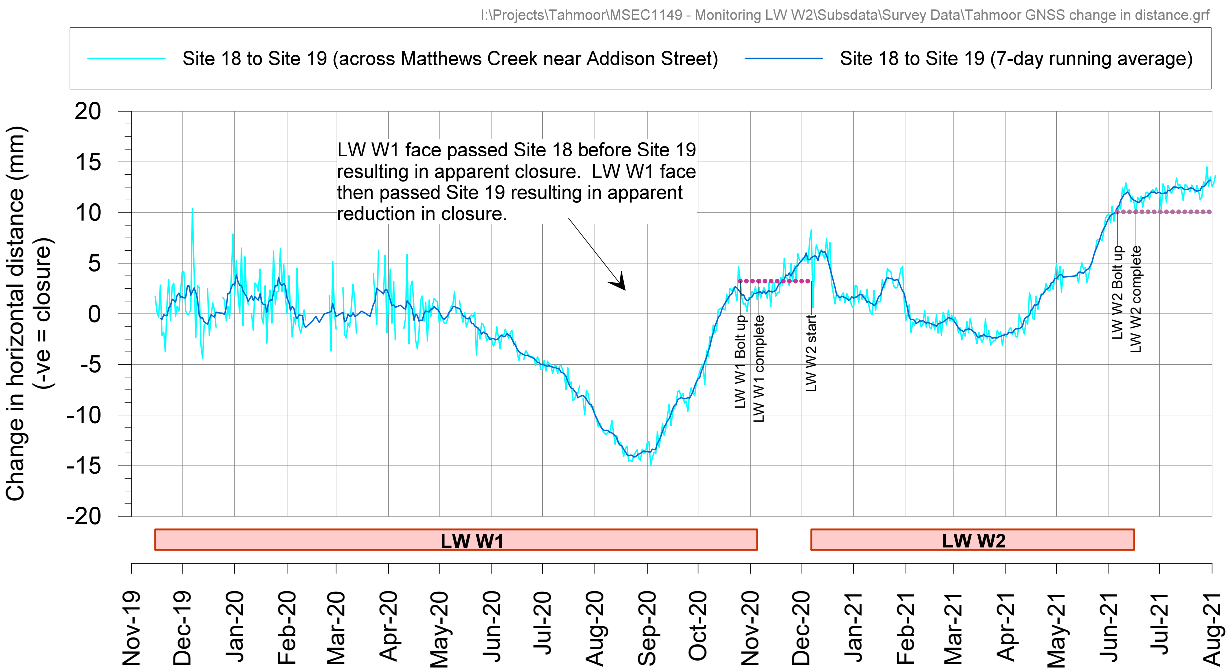

Fig. 2.29 Observed changes in horizontal distance between GNSS Sites 18 and 19 across Matthews Creek during the mining of LW W1-W2

__Observed valley closure across Victoria Bridge across Stonequarry Creek, which is located near the finishing end of LW W2__

Victoria Bridge is located approximately 1.4 km away from the side of LW W2. The Bridge spans across Stonequarry Creek, approximately 320 metres downstream from the Picton Viaduct. The site is located at the downstream end of the same stretch of Stonequarry Creek as the Picton Viaduct, which means that it crosses the same section of geological structure associated with the Nepean Fault as the Picton Viaduct.

As shown in Fig. 2.28, Victoria Bridge has moved to the west very slightly towards LW W1-W2 during mining. Surveys of survey marks fixed to the Bridge and ground have been conducted on a monthly basis.

Observed changes in horizontal distance between ground marks across Stonequarry Creek at Victoria Bridge during the mining of LW W1-W2 are shown in Fig. 2.30. Measured changes have been within survey tolerance.

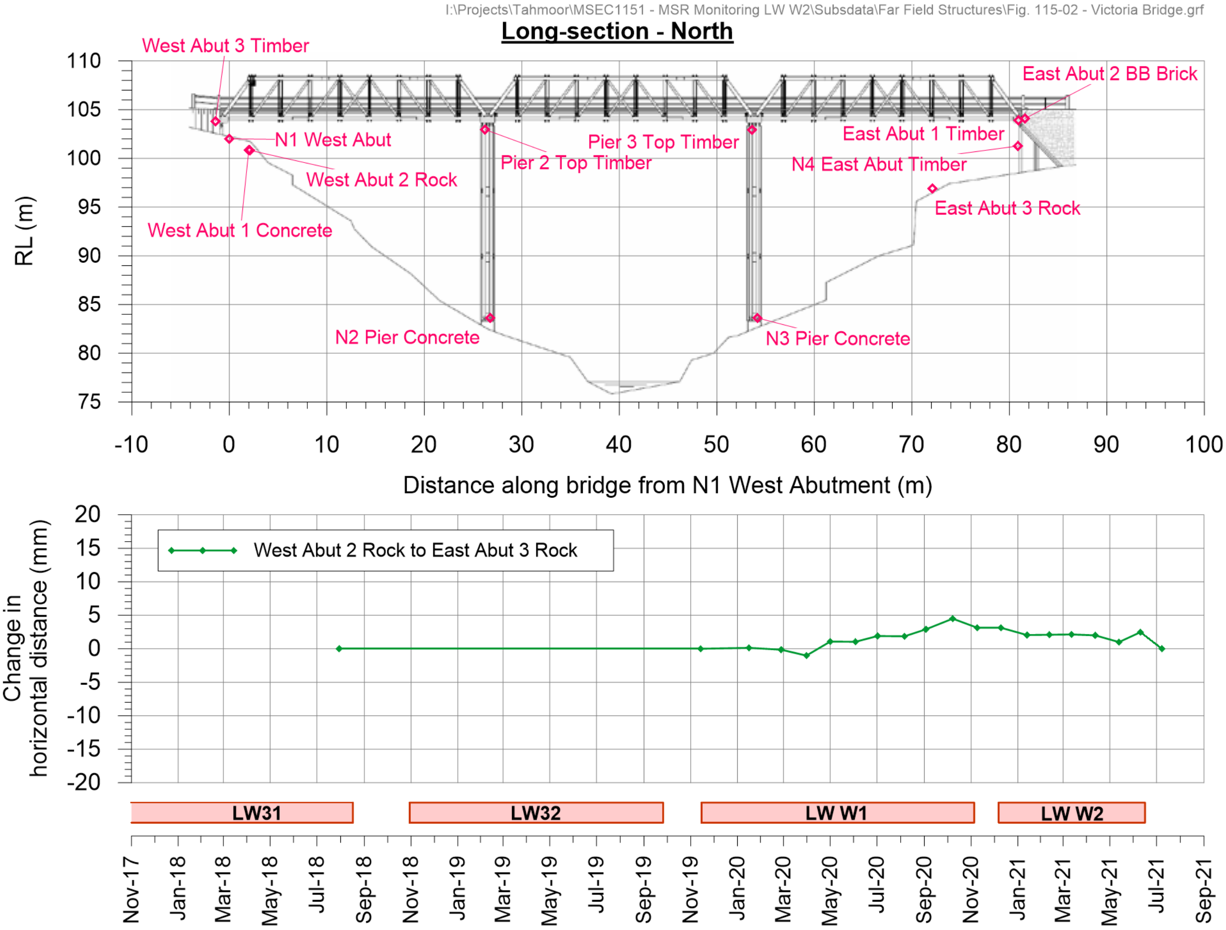

Fig. 2.30 Observed changes in horizontal distance between ground marks across Stonequarry Creek at Victoria Bridge during the mining of LW W1-W2

Observed valley closure across the Nepean River for survey lines located near the finishing ends of Appin LWs 702, 703, 707B and 708B

Appin Colliery has been monitoring valley closure across the Nepean River during the mining of LWs 702 to 707B. The locations of the cross lines relative to the longwalls are shown in Fig. 2.31.

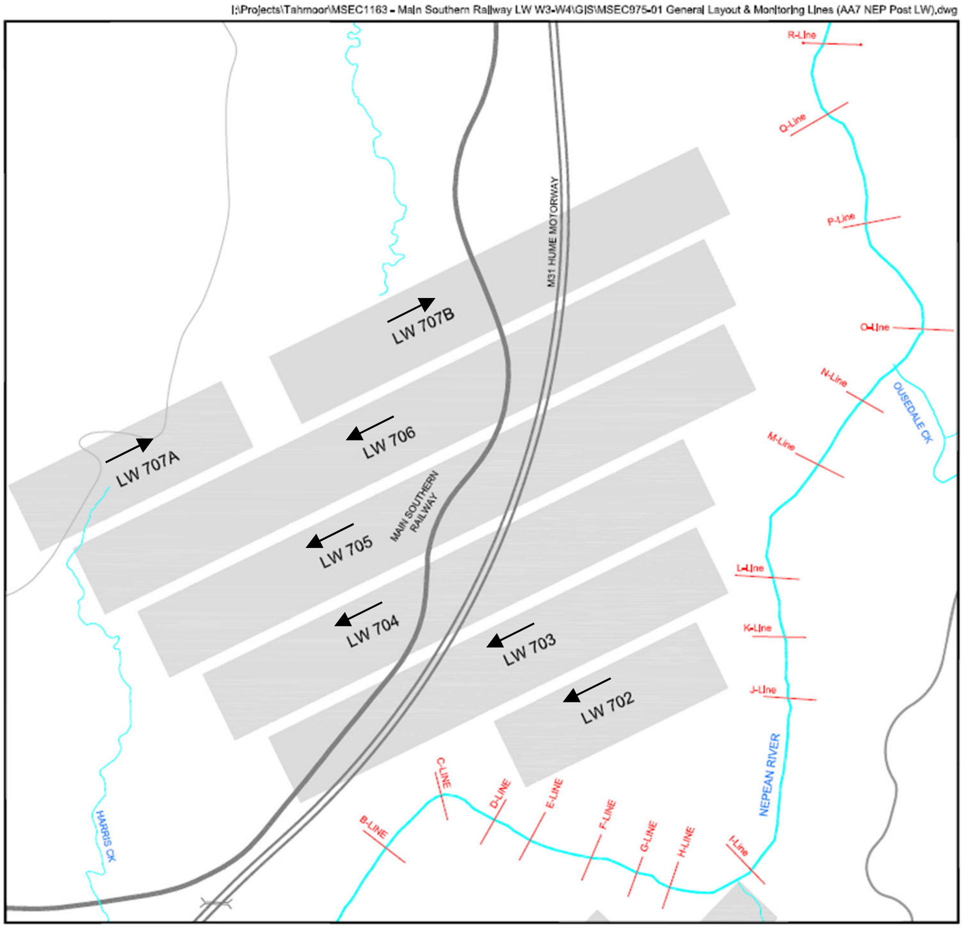

Fig. 2.31 Nepean River Crosslines at Appin Area 7

LWs 702 and 703 were extracted near the Nepean River towards the B to E Lines and the observed development of valley closure is shown in Fig. 2.32.

The direction of mining was reversed for LW 707B and the longwall approached the N to R Lines and the observed development of valley closure is shown in Fig. 2.33.

The observations demonstrate the following:

- A clear reduction in the rate of closure was observed at the completion of LW702;
- A clear reduction in the rate of closure was observed at the completion of LW703. A slight but noticeable increase in the rates of closure across the B Line and E Line in July 2011 during the mining of LW704, which suggests that the ongoing closure across these lines may be related to active extraction rather than residual movements post LW703; and
- A clear reduction in the rate of closure was observed at the completion of LW707B, though one more survey is required to confirm trends.

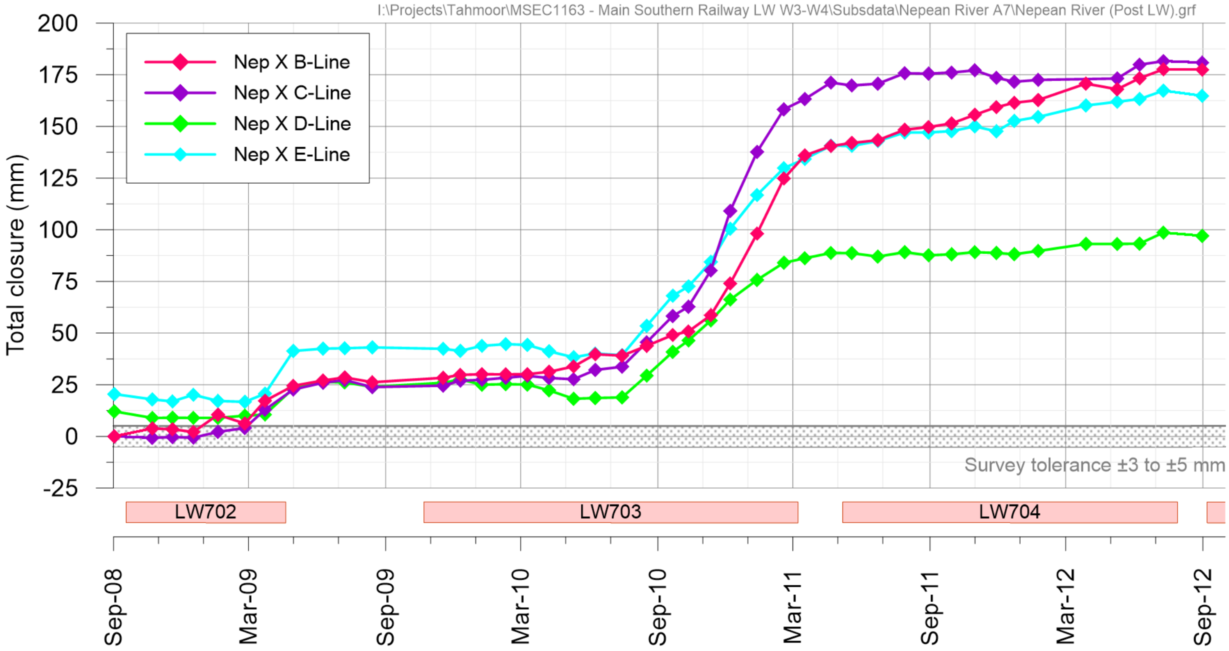

Fig. 2.32 Observed total closure for Nepean River Crosslines B to E during mining at Appin Area 7

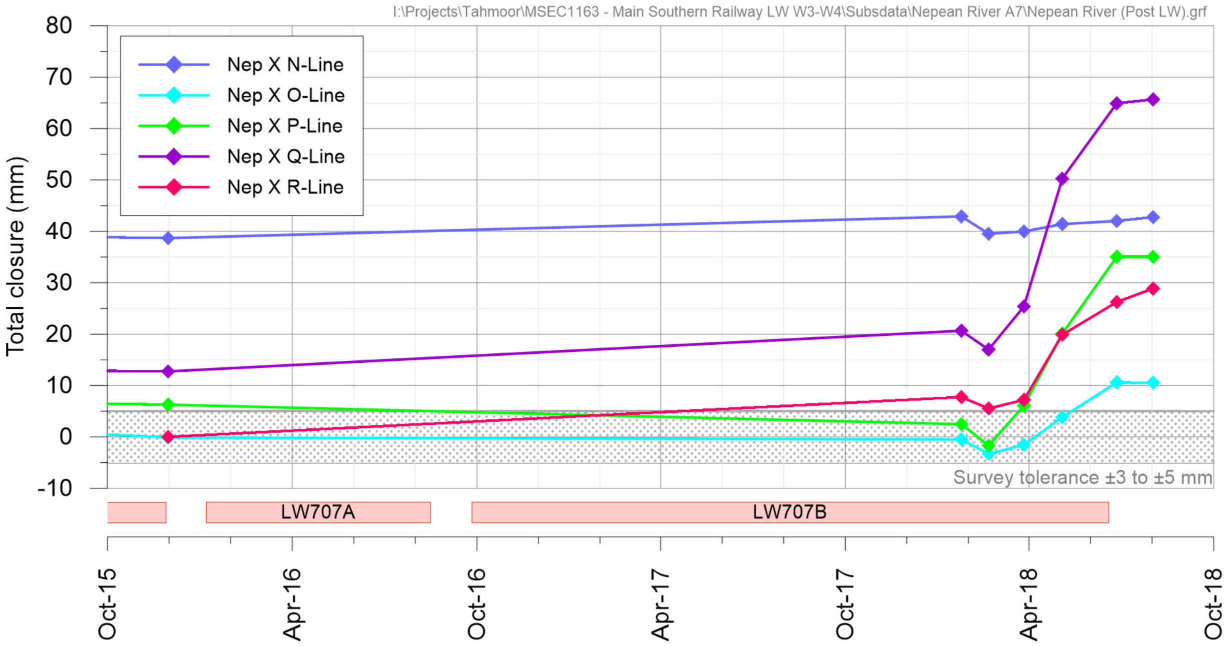

Fig. 2.33 Observed total closure for Nepean River Crosslines N to R during mining at Appin Area 7

Observed valley closure across the Nepean River for survey lines located near the finishing ends of Appin LWs 901, 902 and 903

Appin Colliery has been monitoring valley closure on a monthly basis across the Nepean River during the mining of LWs 901 to 903. The locations of the cross lines relative to the longwalls are shown in Fig. 2.34.

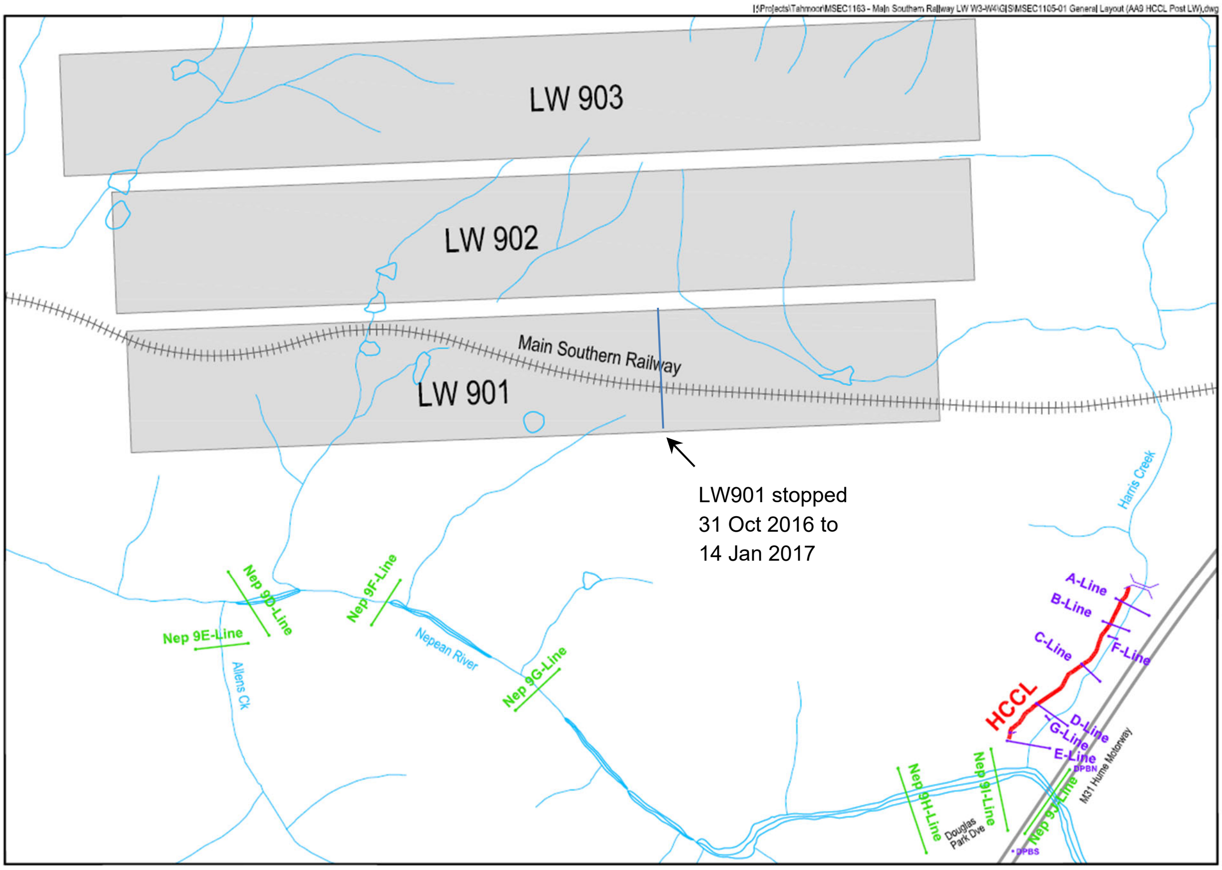

Fig. 2.34 Harris Creek and Nepean River Crosslines at Appin Area 9

The observed development of valley closure is shown in Fig. 2.35. The observations demonstrate the following:

- LW901 stopped between 31 October 2016 and 14 January 2017 (75 days), as shown in Fig. 2.35. A clear reduction in the rate of observed closure was observed across the D to G lines whilst the longwall stopped;
- A clear reduction in the rate of closure was observed at the completion of LW901 across the F, G, H and I Lines. Ongoing residual closure was observed across all lines between the last survey for LW901 and first survey for LW902. The maximum measured increase was 19 mm across the F Line, which had closed 193 mm at the completion of LW901;
- A clear reduction in the rate of closure was observed at the completion of LW902; and
- Very little change was observed during and after the mining of LW903.

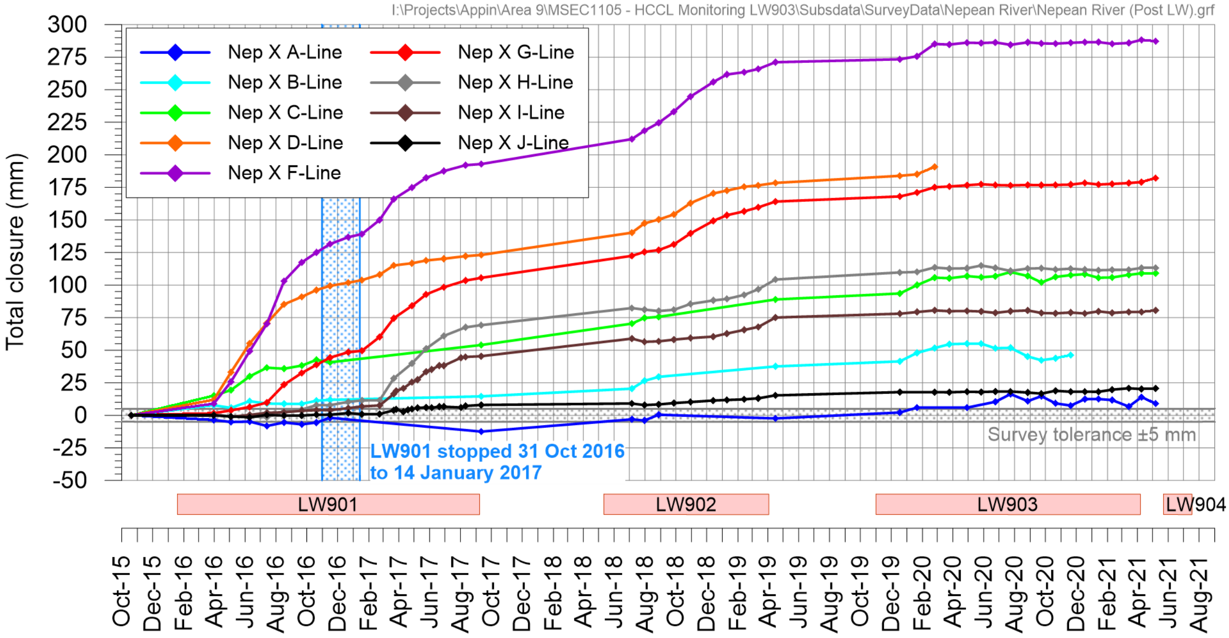

Fig. 2.35 Observed total closure for Nepean River Crosslines at Appin Area 9

Observed valley closure across Harris Creek for survey lines located near the finishing ends of Appin LWs 901, 902 and 903

Appin Colliery has been monitoring valley closure across Harris Creek during the mining of LWs 901 to 903. The locations of the cross lines relative to the longwalls are shown in Fig. 2.34. The observed development of valley closure is shown in Fig. 2.36. The observations demonstrate the following:

- A clear reduction in the rate of closure was observed at the completion of LW901 across the survey lines. Ongoing residual closure was observed across all lines between the last survey for LW901 and first survey for LW902;
- A clear reduction in the rate of closure was observed at the completion of LW902 and very little change was observed during and after the mining of LW903; and
- Considerable baseline survey data prior to the mining of LW901 measured a very small rise and fall in valley closure of 1 to 2 mm, which reflects a seasonal response of the surface strata to changes in temperature and rainfall. A similar seasonal response was observed after LWs 901, 902 and 903, which occurred in combination with ongoing residual valley closure effects.

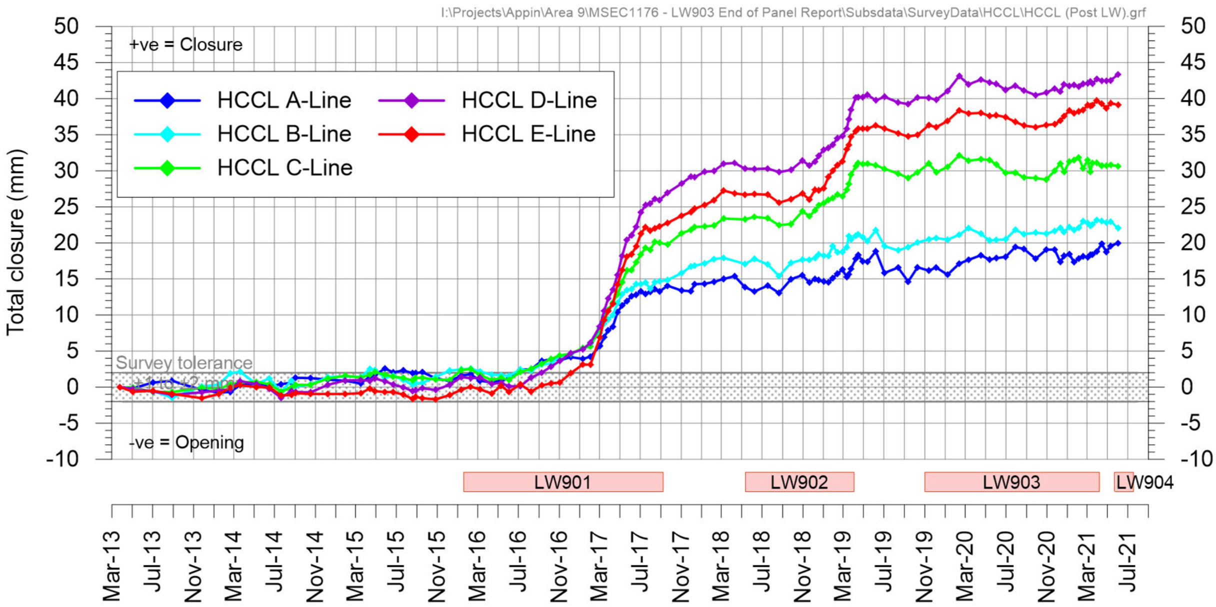

Fig. 2.36 Observed total closure for Harris Creek Closure lines

Observed valley closure across Sandy Creek Waterfall located near the finishing ends of Dendrobium LWs 6, 7 and 8

Dendrobium Mine monitored valley closure across Sandy Creek during the mining of LWs 6 to 8. The locations of the high resolution lines relative to the longwalls are shown in Fig. 2.37.

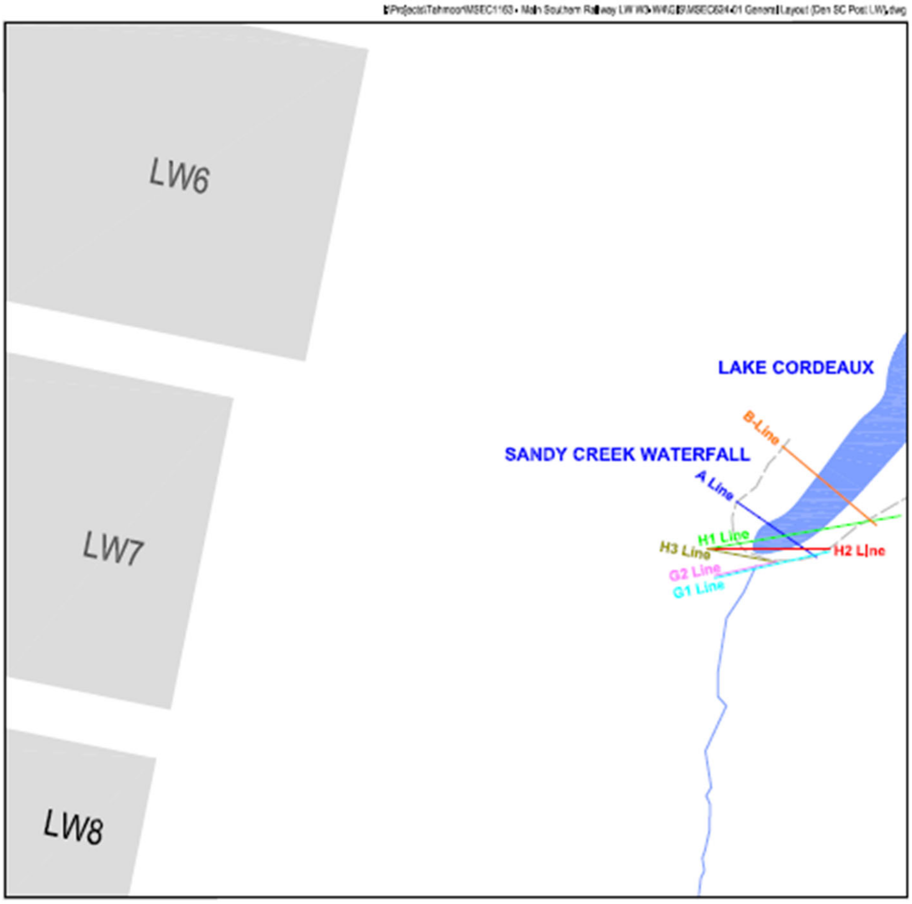

Fig. 2.37 Sandy Creek Waterfall high resolution lines at Dendrobium Area 3A

The observed development of valley closure is shown in Fig. 2.38.

The observations demonstrate the following:

- A clear reduction in the rate of closure was observed at the completion of LWs 6 to 8;
- Ongoing residual closure was observed across all lines after the completion end of each LW, though the magnitudes are very small;
- As reported for the Harris Creek survey lines, a small rise and fall in valley closure was observed after LWs 6 to 8, which reflects a seasonal response of the surface strata to changes in temperature and rainfall. Further information is provided in the paper by Walsh et al (2014).

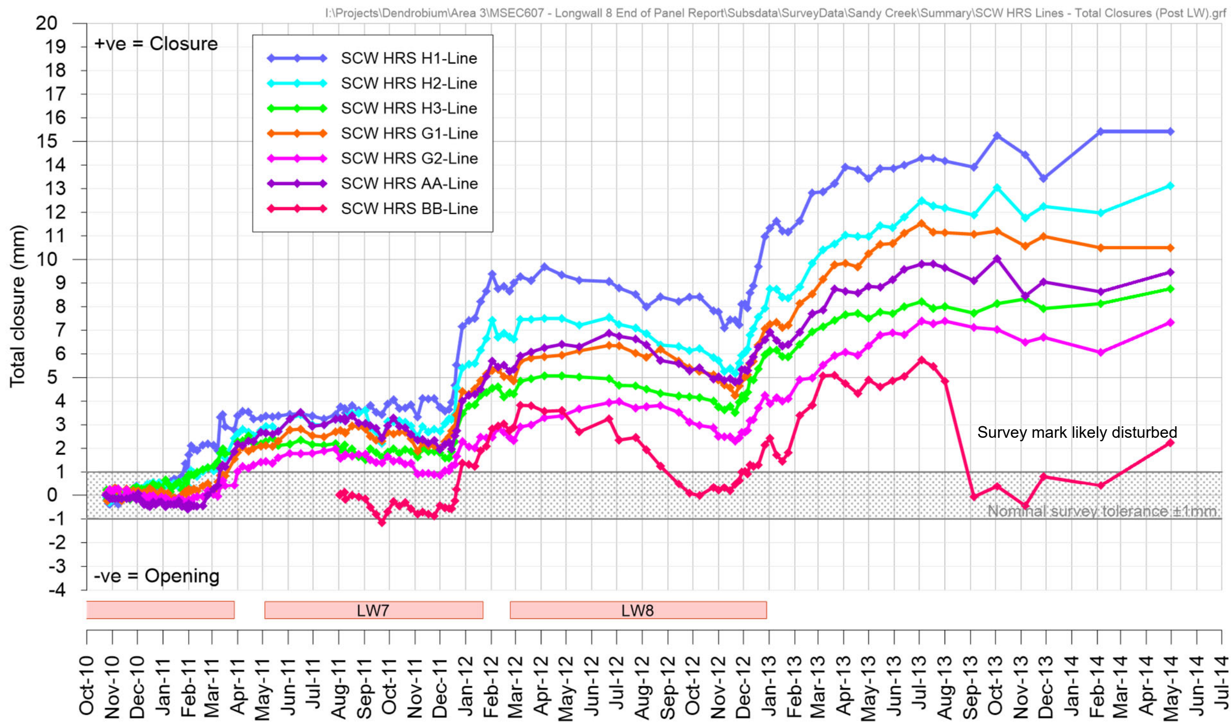

Fig. 2.38 Observed total closure for Sandy Creek Waterfall high resolution lines at Dendrobium Area 3A

Observed valley closure across the Eastern Tributary located near the finishing ends of Metropolitan LWs 303, 304 and 305

Metropolitan Colliery monitored valley closure across the Eastern Tributary during the mining of LWs 303 to 305. The locations of the high resolution survey lines relative to the longwalls are shown in Fig. 2.39.

The observed development of valley closure is shown in Fig. 2.40.

The observations demonstrate the following:

- A clear reduction in the rate of closure was observed at the completion of LWs 303 to 305;
- Ongoing residual closure was observed across both lines after the completion end of each LW, though the magnitudes are very small;
- For the majority of survey lines, maximum residual closure has occurred at the time of coldest temperature.

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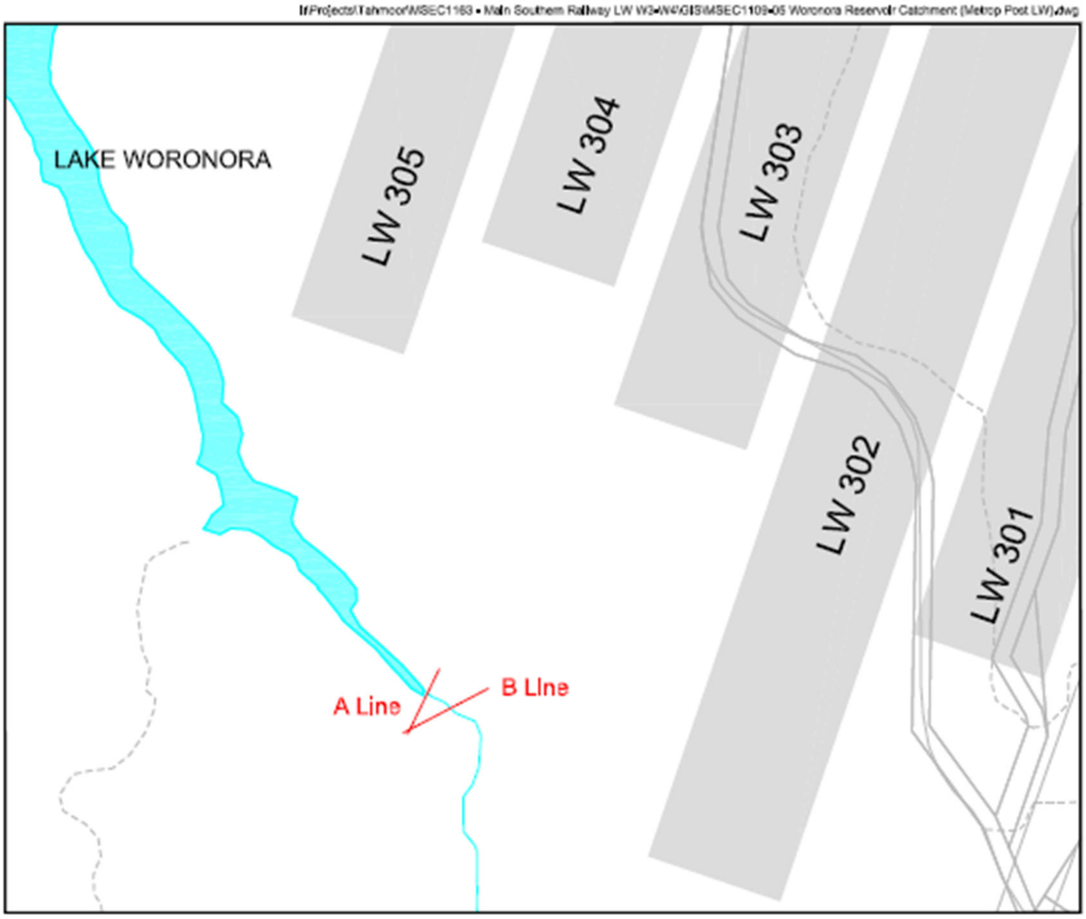


Fig. 2.39 Eastern Tributary high resolution lines at Metropolitan Colliery

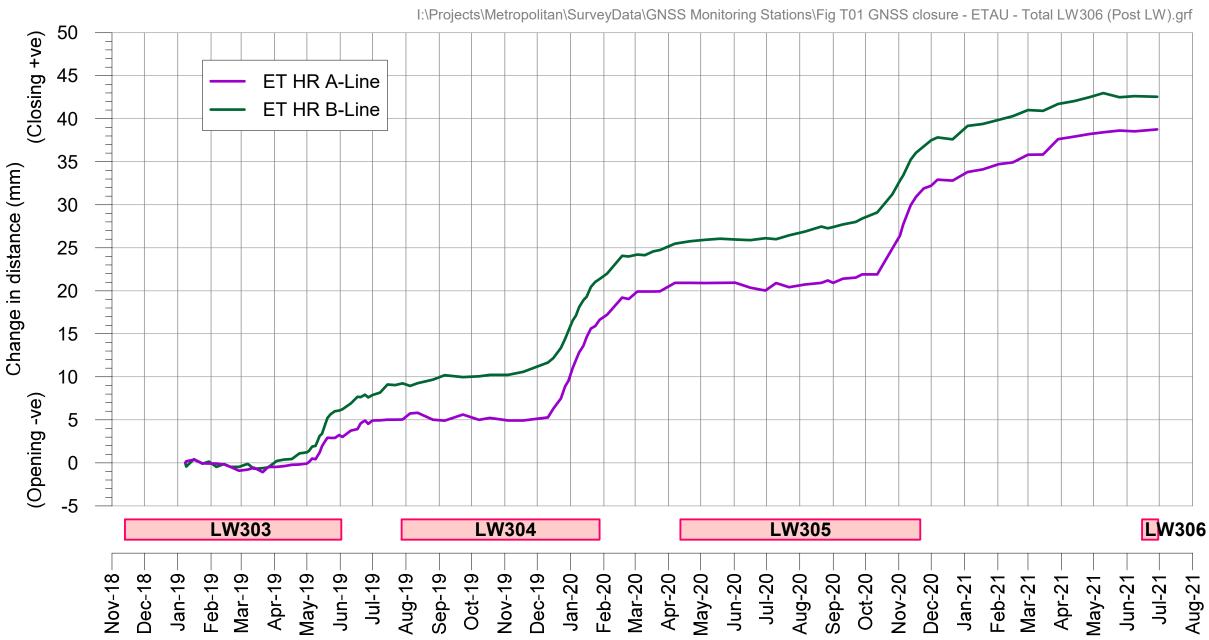


Fig. 2.40 Observed total closure for Eastern Tributary high resolution lines at Metropolitan Colliery

Summary and conclusions

The study has been conducted of residual horizontal movements and valley closure movements that have previously occurred remote from active longwalls.

Observations of GNSS units around LW W1-W2 have measured an immediate reduction in rates of change in horizontal movements when LW W1 and LW W2 have slowed down (bolt up stage) and ceased extraction.

Very little valley closure has developed beyond LW W1-W2, including across Matthews Creek to the west of the finishing end of LW W1 and across Stonequarry Creek downstream of the Picton Viaduct at Victoria Bridge. Observations from other sites in the Southern Coalfield have therefore been used to provide a conservative guidance for that amount of residual valley closure that might occur after a longwall stops.

Survey monitoring data has, therefore, been analysed at locations where valley closure has been measured near the finishing ends of previously extracted longwalls in the Southern Coalfield at Appin Colliery, Dendrobium Mine and Metropolitan Colliery.

The survey data showed that rates of valley closure noticeably reduced immediately following cessation of mining, which is not unexpected.

The greatest residual valley closures in the analysis were measured across the Nepean River during the mining of LW901, with a maximum residual closure of 19 mm across the F Line between the completion of LW901 and the start of LW902. The observed valley closure at the completion of LW901 was, however, 193 mm. This means that residual closure was approximately 10% of the measured value after mining had stopped.

Beyond the experiences of LW901 at Appin Area 9, maximum measured residual valley closures were 7 mm or less after mining had stopped.

There were 40 monitoring sites within the analysis where observed valley closure was 30 mm or less. The maximum measured residual closure was 5 mm, with an average residual closure of 2 mm. When expressed as a percentage, the residual closure can be up to 20% of the value that was measured when the longwall stopped but survey tolerance can represent a significant proportion of the measured residual movements.

This Railway Management Plan includes a commitment by Tahmoor Coal to stop mining if impacts are forecast to occur on the safety and serviceability of the Main Southern Railway that cannot be controlled. The study shows that stopping the longwall will be effective in quickly reducing the development of ongoing horizontal movements and valley closure along the Main Southern Railway.

The Rail Management Group will consider the potential for residual movements to occur when making recommendations to continue mining or stop longwall operations.

3.0 ASSESSMENT OF POTENTIAL MINE SUBSIDENCE IMPACTS ON RAILWAY

The Main Southern Railway is a dual track, consisting of continuously welded 60 kg/m rail on concrete sleepers with a mix of straight and curved track sections within the Study Area. The maximum speed limits on both tracks are 95 km/h for normal services and 105 km/h for XPT services.

Mine subsidence could result in impacts to the following rail infrastructure:

- Track geometry
- Rail stress
- Track formation and drainage
- Culverts
- Cuttings and embankments
- Bridges
- Signalling and Communications Systems

3.1. Track Geometry

The extraction of the proposed LWs S1A to S6A will result in changes to track geometry along the Main Southern Railway. Changes to track geometry are described using a number of parameters:-

- Vertical misalignment (top) – vertical deviation of the track from design;
- Horizontal misalignment (line) – horizontal deviation of the track from design;
- Changes in Track Cant – changes in superelevation across the rails of each track from design; and
- Track Twist – changes in superelevation over a length of track from design.

PCE (2022b) has assessed the current track condition based on recent track geometry surveys. PCE (2022b) advises that track geometry varies along the track, with some sections currently under a temporary speed restriction by ARTC. ARTC conducted production resurfacing in November 2022, which has improved track conditions. Some isolated locations have been identified that require some additional resurfacing. Prior to the influence of each longwall, Tahmoor Coal will adjust the potentially affected section of track to within operating tolerances where reasonably practicable.

The Australian Rail Track Corporation's National Code of Practice for Track Geometry (ARTC, 2021) provides allowable deviations in track geometry. Predictions of conventional subsidence, tilt and horizontal movement have been made at 5 metre intervals along the railway to calculate each track geometry parameters at any stage of mining. Predicted changes in cant and long twist for the railway are shown in Fig. 2.2.

A summary of the maximum allowable and maximum predicted changes in geometry are provided in Table 3.1.

Table 3.1 Allowable and predicted maximum changes in track geometry due to conventional subsidence movements

Track Geometry parameter	Description	Value at which speed limit is first applied*	Value at which trains are stopped*	Predicted maximum due to conventional subsidence
Top	Mid-ordinate vertical deviation Design Offset	29 mm over 6m chord 32 mm over 20m chord	32 mm over 6m chord 35 mm over 20m chord	< 5
Line	Mid-ordinate horizontal deviation over a 10 m chord	34 mm	44 mm	< 5
Change in Cant	Deviation from design superelevation across rails spaced 1.435 m apart	20 to 50 mm (depends on whether track is on a straight or curve)	40 to 75 mm (depends on whether track is on a straight or curve)	8
Long Twist	Changes in Cant over a 14 m chord	46 mm	52 mm	< 3

<u>Note</u>: Values have been taken from the trigger levels in the Railway Management Plan, which are based on the ARTC National Code of Practice (PCE, 2022a).

Table 3.1 shows that the predicted changes in track geometry are an order of magnitude less than the maximum allowable deviations specified in the National Code of Practice, if conventional subsidence occurs. For example, the maximum allowable change in cant is 75 mm over a length of 1.435 metres before the trains are stopped. In mining terminology, this represents a tilt of approximately 50 mm/m, which is substantially greater than the maximum predicted tilt anywhere above the proposed longwalls of 8.3 mm/m.

Visual inspections and daily track geometry recordings during the mining of Tahmoor Longwalls 25 to 32, Appin Longwalls 703 to 708 and Appin Longwalls 901 and 902 have confirmed that the impact of normal subsidence movements on track geometry has generally been very low and these very small changes in track geometry developed very gradually.

Significant changes in track geometry have been observed at isolated locations, the key observations are provided below:

- The most significant changes in track geometry have been experienced at isolated locations within railway cuttings, where the track formation is founded directly on rock (Kay et al, 2017).

  The most significant changes to date were observed in the Deviation Cutting at Tahmoor during the mining of Longwall 29, particularly across the geological fault at 92.850 km. The track was resurfaced multiple times during the mining of LW 29. The track profile along the Up Main Down Rail, as measured by the Automated Total Station, is shown in Fig. 3.1. A profile has also been projected to illustrate the track profile if resurfacing had not been undertaken, where it can be seen that a ground step in the order of 200 mm had progressively developed. The development of changes in vertical alignment of the track over time is shown in Fig. 3.2 and observed changes in vertical alignment of the ground is shown in Fig. 3.3.
- While substantial differential subsidence movements have developed in the natural ground beneath embankments, there has been little noticeable adverse impact on track geometry. It is considered that the embankment fill has buffered the ground movements. An exception to the above experiences was observed at 90.676 km above Tahmoor LW 31, where a change in lateral alignment of approximately 50 mm was observed.
- Differential subsidence movements have developed gradually during the mining of each longwall beneath the railway. Rates of change have, however been significant at isolated locations. The track has been resurfaced multiple times during these periods, with Temporary Speed Restrictions imposed as a precaution.
- Visual inspections could detect small changes at an early stage, at levels well below the trigger levels.
- The monitoring systems could detect very small changes in the ground and on the track. On some occasions, it has been found that changes in track geometry have occurred when longitudinal ground strains have been relatively minor. Surveys across the cuttings, however, measured substantial closure of the cutting faces. This was experienced during the mining of LW 32 at Tahmoor, when rough track was observed between 90.050 km and 90.150 km, resulting in the imposition of a 60 km/hour Temporary Speed Restriction (TSR). Observed closure was between 20 mm and 50 mm at the time the track misalignment was observed, as is shown in Fig. 3.4.

  For LW S1A-S6A, cuttings have been identified at 99.690 km, 100.700 km and 101.162 km, which is located directly above LW S3A, LW S5A and at Wellers Road Overbridge. Survey marks will be installed across these cuttings prior to the influence of LW S1A-S6A. A number of small, very shallow cuttings (less than 2 metres high) are also present directly above LW S1A-S6A.
- The RMG will consider additional management actions if measured closure exceeds 20 mm across the cutting. The frequency of track geometry trolley surveys has, for example, been increased by the Rail Management Group when cutting closure has been observed.
- Resurfacing work could be undertaken between trains.
- Localised changes in track geometry in areas of good track condition are more noticeable to drivers. This can result in rough ride reports from train drivers and imposition of Temporary Speed Restrictions well before trigger levels are reached. Earlier intervention may be required to avoid rough ride reports and this will be aim of the Rail Management Group (RMG) during the mining of LW S1A-S6A.

In light of the experiences during the mining of Tahmoor Longwalls 25 to 32, Appin Longwalls 703 to 708 and Appin Longwalls 901 and 902, the Rail Management Group has assessed that weekly ground surveys and weekly surveys by the track geometry recording trolley are more than adequate for detecting early adverse changes in track geometry. Additional ground surveys will be undertaken along and across the base of cutting at 99.690 km on a weekly basis during periods of active subsidence.

Twice weekly and daily surveys have previously been undertaken during the mining of previous longwalls and very little change was observed at this frequency. This frequency of survey is not planned initially during the extraction of LW S1A-S6A. If adverse changes in differential subsidence movements or track geometry are detected during mining, the frequency of ground surveys and/or track geometry trolley surveys can be increased if required.

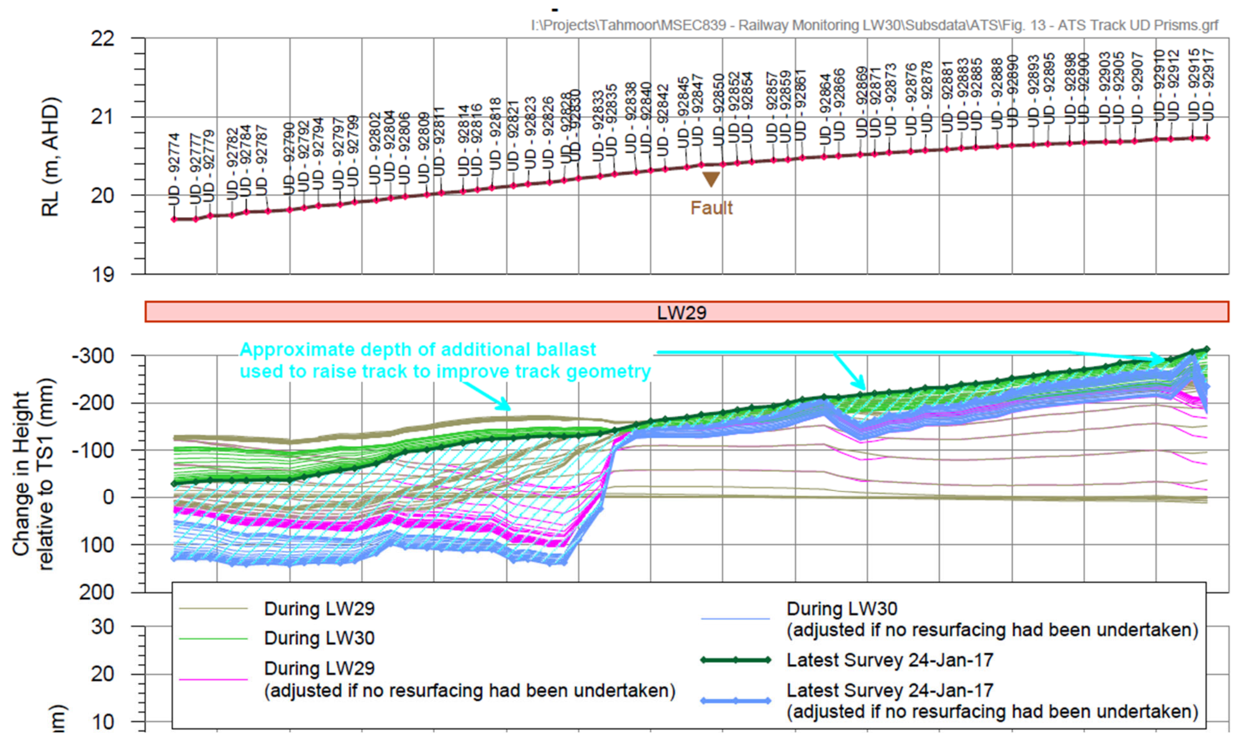


Fig. 3.1 Observed change in track geometry along the Up Main Down Rail across the geological fault at 92.850 km, with profile projected if no resurfacing had been undertaken

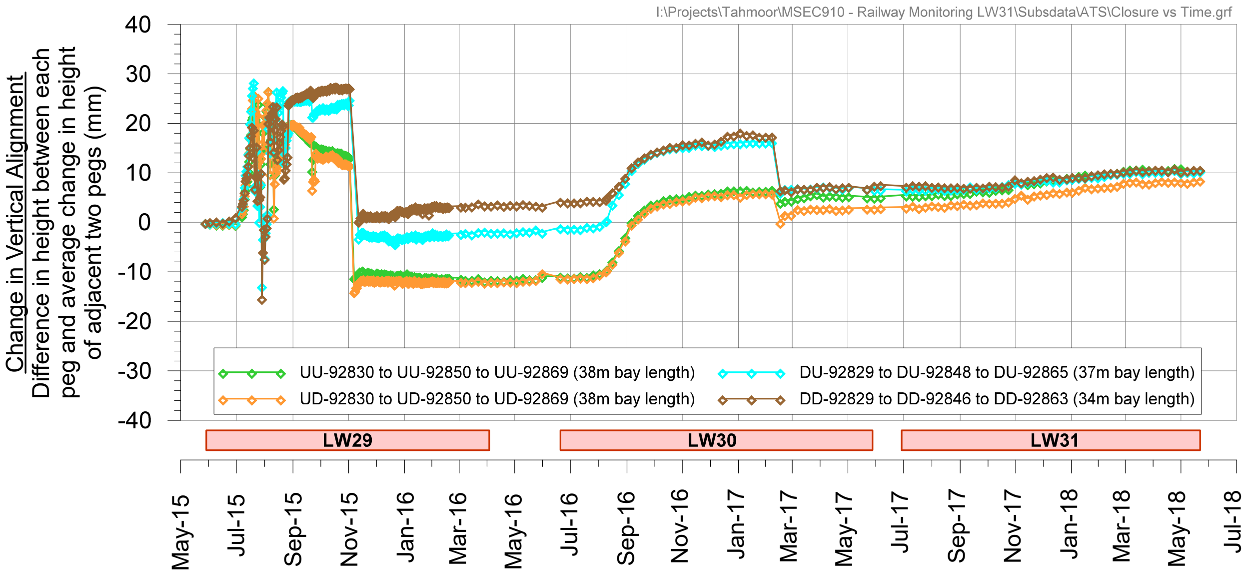


Fig. 3.2 Changes in vertical alignment of railway track across a geological fault within a railway cutting during the mining of Longwalls 29 to 31 at Tahmoor Mine

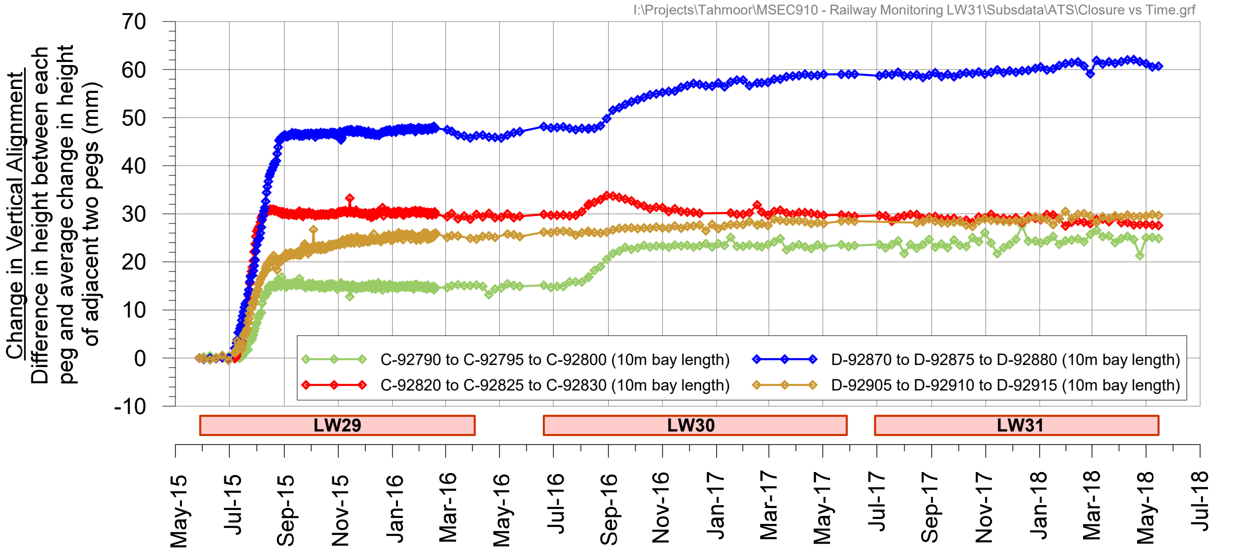
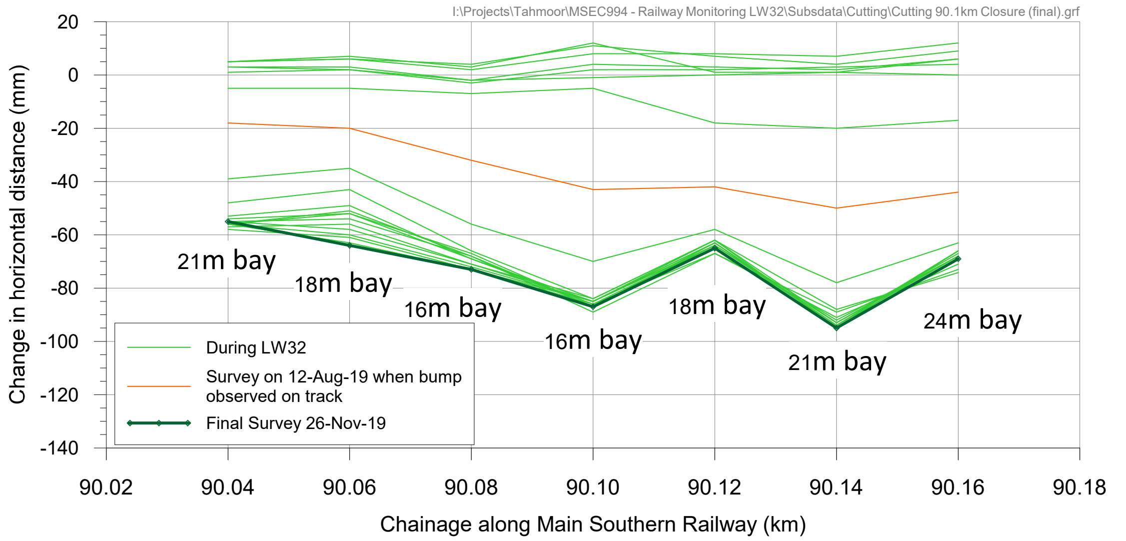


Fig. 3.3 **Changes in vertical alignment of ground pegs along railway track across a geological fault within a railway cutting during the mining of Longwalls 29 to 31 at Tahmoor Mine**



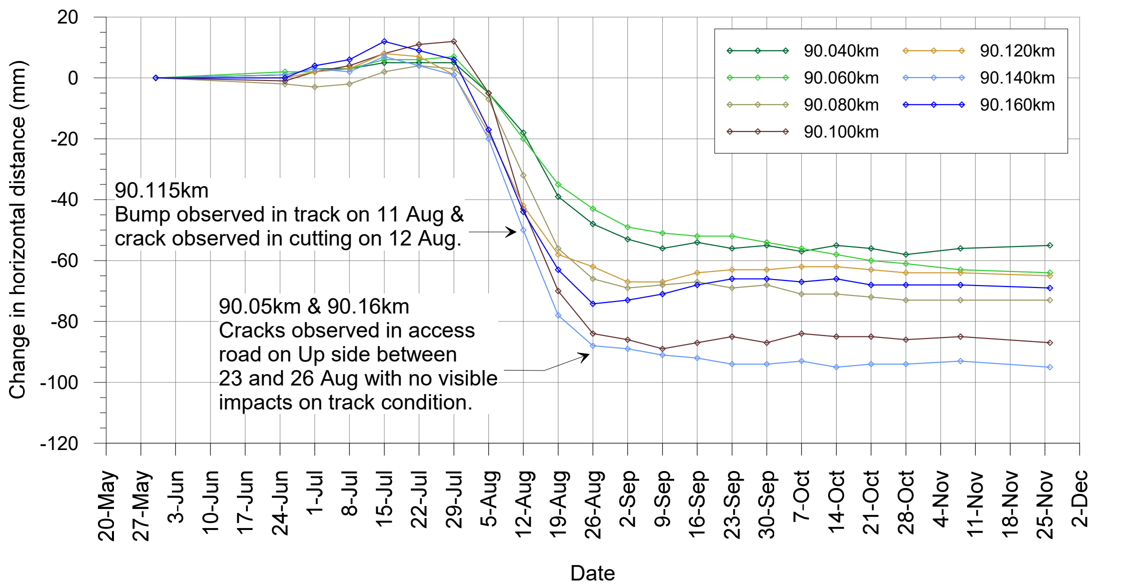


Fig. 3.4 **Observed closure across Cutting at 90.1 km during mining of LW32 at Tahmoor Mine**

3.1.1. Track centres

Track centres along the Main Southern Railway were originally set at a minimum distance of 3660 mm (PCE, 2022c). The ARTC Code of Practice now require a minimum track centres as 3792 mm along straight track, with adjustments for curved sections. Sections of track with tight track centres have been widened on an ad hoc basis during localised resurfacing and track widening projects.

Tahmoor Coal has measured track centres within the Tahmoor South project prior to mining. Areas with tight centres have been identified by PCE (2022c) at three locations (± 20 m): 98.620 km (above LW S1A); 99.600 km (above LW S3A); and at 101.200 km m (above LW S4A).

As discussed in Section 2.4, it expected that 99 % of the mining-induced strains measured *above goaf* for the proposed longwalls would be less than 2.0 mm/m tensile and 4.3 mm/m compressive. This equates to a change of 8 mm ground extension and 16 mm ground shortening over the track centre distance of approximately 3.8 metres.

As recommended by PCE (2022c), Tahmoor Coal will manage potential impacts on track centres by implementing the following monitoring and management measures:

- Prisms have been mounted at the three locations where tight centres have been observed;
- Changes in track centres will be surveyed on a monthly basis when each section of track experiences active subsidence;
- Changes in track cant will also be measured at these locations;
- The RMG will closely assess the site and consider whether additional management measures are required if the following trigger levels are exceeded:
  - Reduction in track centres of 5 mm; and
  - Changes in Cant of 5 mm.
- When resurfacing is required to be conducted during the extraction of LW S1A-S6A, the track centres will be widened in accordance with a local redesign of the track alignment.

3.1.2. Assessments and Planned Responses if Increased Subsidence Movements are observed

It is possible that localised substantial non-conventional movements may result in localised changes in track geometry that approach or exceed the trigger levels. This Management Plan has been developed to include trigger levels and planned responses in the event that increased subsidence movements approach or exceed the trigger levels.

The Rail Management Group (RMG) has also previously been asked to consider the potential for rapid ground stepping due to mine subsidence.

A thorough examination of empirical data has been conducted, including during the mining of Longwalls 25 to 32, Appin Longwalls 703 to 708 and Appin Longwalls 901 and 902 beneath the Main Southern Railway and Appin Longwalls 703 to 708 beneath the M31 Hume Motorway. The experienced have not found evidence of sudden or rapid development of ground stepping and found that subsidence movements developed gradually, including where substantial irregular or non-conventional movements had developed. The data includes observations of gradual development of a ground step at a geological fault above Appin Longwall 408, where it intersected with the Cataract Tunnel, the geological fault above Tahmoor Longwall 29, where it intersected with a fault at 92.850 km and where a geological fault intersected the railway at 71 km above Appin Longwalls 703 and 704.

In each case, due to the investigations carried out, a robust Management Plan and the proactive approach to project management during the mining of the longwalls, previously observed impacts to track geometry were detected, tracked and managed without resulting in significant impacts on the safe operation of the railway. In addition, the Rail Management Group is better prepared for LW S1A-S6A having additional knowledge of mining in the area from Longwalls 25 to 32, Appin Longwalls 703 to 708 and Appin Longwalls 901 and 902.

The RMG has developed a management strategy to incrementally resurface the track at regular intervals in the event of the development of substantial differential vertical and horizontal movement, including ground stepping. Important elements to the strategy are a robust monitoring regime and a fast and effective implementation of materials, equipment and labour to resurface the track and correct adverse rail stress levels.

A summary table of key measures is provided in Table 3.2 for clarification, with detailed supporting information and comments included afterward.

The prime inspection and monitoring systems to detect the rapid development of ground steps or bulges include the daily inspections by the Track Certifier and automated switch displacement and rail stress monitoring data. (PCE, 2011b).

Daily visual inspection by the Track Certifier involves a detailed visual examination of the track and corridor looking for any signs of changes in condition. It is required of the Track Certifier, and it has been normal practice during inspections of the track sections affected by mining subsidence, that when the track condition appears to be different from normal and appears to show signs of deteriorating track condition, detailed measurements are taken and recorded of the relevant track geometry parameters. These measurements can be undertaken manually or by the track recording trolley or by a survey of the rail profile of all four rails at close spacings (e.g. 5 metres), which was the preferred method adopted during the mining of Tahmoor Longwalls 28 and 29 and Appin Longwall 706.

Track conditions are such that it is relatively easy for the Track Certifier to identify locations that will require additional examination. PCE (2011b) has provided photographs at the end of the report to indicate how the Track Certifier views a range of track conditions, including a low priority track defect (not mining related).

During the mining of previous Longwalls 25 to 32, Appin Longwalls 703 to 708 and Appin Longwalls 901 and 902, the RMG previously adopted a BLUE trigger level based on an observation of more than 30 mm of switch opening or closing compared to a reading recorded 24 hours previously, after taking the effect of temperature into account (step displacement alarm). Experience has found that this trigger has not been exceeded and that information gathered from ground surveys, track geometry surveys and visual inspections have been more effective in identifying early the development of mining-induced ground stepping beneath the track. The strategy has been enhanced to include surveys along and across railway cuttings, where the most significant changes in track geometry have been experienced. Based on the above experiences, the RMG has decided to no longer implement a step displacement alarm during the mining of LW S1A-S6A.

While not relied upon explicitly as a primary management measure, it is further noted that a response plan has been developed to notify the Rail Response Group of incidents that are reported by train drivers or ARTC personnel, as described in Section 6.4 of the Management Plan.

In the event of non-conventional movements occurring at multiple sites during mining, adequate resources can be sourced to undertake increased track geometry monitoring and visual inspections at multiple sites and undertake localised resurfacing at multiple sites. Refer to Section 5.9 for further details on resourcing management measures for this project.

3.1.3. Selection of Risk Controls

Based on the above information, Tahmoor Coal, ARTC and the Rail Management Group considered and selected risk controls for track geometry in accordance with WHS laws.

It is noted the selected risk controls have been successfully implemented during the mining of Tahmoor Longwalls 25 to 32, Appin Longwalls 703 to 708 and Appin Longwalls 901 and 902. The controls have been reviewed and refined on an ongoing basis during the mining of these longwalls.

Elimination

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

Substitution

The following Substitution Control has been identified and selected that will change the environment so the hazards could be substituted for hazards with a lesser risk.

- Installation, monitoring and adjustment of a Track Expansion System.

  The main advantages of substituting the existing continuously welded rail (CWR) track to the Track Expansion System are listed below.

  - Continual management of mining-induced rail stress.
  - Substantial reduction in the number of track related interventions during active subsidence, when compared to conventional CWR management.
  - Substantial reduction in labour and resources required to make an adjustment. This reduces the time working on the track and improves track safety by minimising manual interventions. Adjustments can be made between the passages of trains without affecting the operation of the railway.

This is discussed in detail in Section 3.2.2.

Track baulks will also be installed above culverts that may be affected by the extraction of LW S1A-S6A and these could also be considered as Substitution Controls for track geometry. Further details are provided in Section 3.4.

Isolation

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

Engineering Controls

The following Engineering Controls were identified and selected to prevent or minimise risks.

- Baseline assessment of track condition and undertaking adjustments where required to within operating tolerances

  ARTC AK Car data and track geometry trolley data is analysed periodically, and resurfacing is undertaken as required during scheduled ARTC track possession weekends or in between train operations, as required.

- Storage of ballast on site to reduce the response time to undertake contingency response measures in the event that monitoring detects the early signs of adverse changes in track geometry.

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 Main Southern Railway.

- Implementation of a Monitoring Plan and Trigger Action Response Plan (TARP)

  As discussed above in Section 3.1.2, the RMG has developed and implemented a management strategy of detecting early the development of potential adverse subsidence movements and changes in track geometry, so that contingency response measures can be implemented before impacts on safety and serviceability develop.

Table 3.2 Summary of Management and Contingency Measures and Proposed Procedures/Processes for potential rapid development of change in track geometry

Monitoring Detection Method	Frequency	Trigger	Response / Contingency	Comments
Rail stress, switch displacement	Every 5 minutes	Grey, Blue, Yellow, Red	Notify RRG and Track Certifier within 15 minutes RRG teleconference within 15 minutes RRG review available data Immediate site inspection Resurface the track within 24 hours Adjust switch positions or CWR within 24 hours Immediate speed restriction or stop trains within 15 minutes	Positive experience of response system during mining of Tahmoor Longwalls 25 to 32, Appin Longwalls 703 to 708 and Appin Longwalls 901 and 902.
Detailed visual inspections by Track Certifier	Daily	Blue, Yellow, Red	Responses as above.	Experience during the mining of Tahmoor Longwalls 25 to 32, Appin Longwalls 703 to 708 and Appin Longwalls 901 and 902 showed that detailed visual inspections were very effective in detecting early deformations in the track. Frequency can be increased if required.
Track geometry trolley survey	Weekly	Blue	Responses as above.	Identifies trends and excursions from predictions early. Frequency can be increased if req'd.
Cutting survey	Weekly	Blue	RMG meeting to review available data and consider additional management actions, including increasing the frequency of surveys and inspections.	Experience has shown that impacts on track geometry have typically been experienced in cuttings. Cutting surveys are an effective method of detecting early potential deformations in the track. Frequency can be increased if required.

Note: In addition to the above alarms, there is regular review of automated rail stress and switch displacement monitoring data to identify trends and forecast switch positions (nominally daily during periods of active subsidence). This review identifies early departures from projected switch positions.

3.2. Rail Stress

3.2.1. Selection of Risk Controls

The extraction of LW S1A-S6A will result in changes in rail stress. Without the implementation of effective risk management controls, the potential changes could result in welded rail instability of the existing continuously welded rail (CWR) track.

Tahmoor Coal, ARTC and the Rail Management Group considered and selected risk controls in accordance with WHS laws to manage mining-induced changes in rail stress due to the extraction of LW S1A-S6A.

It is noted the selected risk controls have been successfully implemented during the mining of Tahmoor Longwalls 25 to 32, Appin Longwalls 703 to 708 and Appin Longwalls 901 and 902. The controls have been reviewed and continuously improved on an ongoing basis during the mining of these longwalls.

Elimination

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

Substitution

The following Substitution Control has been identified and selected that will change the environment so the hazards could be substituted for hazards with a lesser risk.

- Installation, monitoring and adjustment of a Track Expansion System.

  The main advantages of substituting the existing continuously welded rail (CWR) track to the Track Expansion System are listed below.

  - Continual management of mining-induced rail stress.
  - Substantial reduction in the number of track related interventions during active subsidence, when compared to conventional CWR management.
  - Substantial reduction in labour and resources required to make an adjustment. This reduces the time working on the track and improves track safety by minimising manual interventions. Adjustments can be made between the passages of trains without affecting the operation of the railway.

  This is discussed in detail in Section 3.2.2.

Isolation

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

Engineering Controls

The following Engineering Control has been identified and selected to prevent or minimise risks.

- Baseline assessment of Stress Free Temperature in sections of track that are located outside the limits of the Track Expansion system, which will be managed as continuously welded rail (CWR) track and undertaking adjustments where required so that SFT is within operating tolerances

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 Main Southern Railway.

- Implementation of a Monitoring Plan and Trigger Action Response Plan (TARP)

  As discussed later in Sections 3.2.2 and 3.2.3, the RMG has developed and implemented a management strategy of detecting early the development of potential adverse subsidence movements and changes in switch displacements and/or rail stress, so that contingency response measures can be implemented before impacts on the safety and serviceability develop.

3.2.2. Track Expansion System

A combination of expansion switches and ZTL clips has been designed to dissipate rail stress generated by mine subsidence movements and temperature. This has been successfully undertaken on straight and curved track during the mining of Tahmoor Longwalls 25 to 32, Appin Longwalls 703 to 708 and Appin Longwalls 901 and 902 beneath the Main Southern Railway (ARTC Type Approval 10/2942 and Type 4D – ARTC New Equipment and System Approval No. 11/9643, and Type 5 – ARTC New Equipment and System Approval No. 15/34296).

The main advantages of installing this system are listed below.

- Continual management of mining-induced rail stress.
- Substantial reduction in the number of track related interventions during active subsidence, when compared to conventional CWR management.
- Substantial reduction in labour and resources required to make an adjustment. This reduces the time working on the track and improves track safety by minimising manual interventions. Adjustments can be made between the passages of trains without affecting the operation of the railway.

The design of the track expansion system has been determined by the Rail Management Group, taking into account a number of factors, including:

- Predicted extent of subsidence during the extraction of the active longwall.

  As a general guide, the track expansion system aims to encompass the section of track that is predicted to experience approximately 100 mm or more of vertical incremental subsidence during the extraction of the active longwall. The design guide is based on experience from managing rail stresses in CWR track at Tahmoor, Douglas Park and elsewhere in NSW and from advice provided from projects in the United Kingdom.

  While changes in rail stress due to mining induced ground strains can develop in sections of track that are predicted to experience 100 mm or less vertical subsidence, the rates of change in ground strain and rail stress have been found to be sufficiently low that rail stresses can be adequately managed in CWR track with less frequent rail adjustments.

- Locations of likely future sites of non-conventional subsidence movements

  Depending on the circumstances of each longwall, the track expansion system may be extended beyond the predicted 100 mm limit of vertical subsidence to encompass sections of track that pass over sites of previously observed or likely future non-conventional subsidence movements. This includes creeks and known locations of near surface geological structures.

- Allowable lengths of free rail between switches and anchor points
  - The expansion switches are based on the improved design (Type 5 – ARTC New Equipment and System Approval No. 15/34296).

    Based on the experiences during mining at Tahmoor and Appin Collieries, the length of free rail on either side of a Type 5 switch generally been set to 180 metres.

- Avoidance of conflicts between expansion switches and particular track features, such as track baulks, level crossings and curve transition points.

An overall layout of expansion switches and anchor points is shown in Drawing No. MSEC1201-02 and the planned layout for each longwall is shown in Drawings Nos. MSEC1201-02-1A to 6A. In the case of LW S1A, it is noted ES4 has been installed even though it is not required until the extraction of LW S2A. ES4 was installed early for economic reasons.

A photograph showing installed expansion switches at 98.560 km (ES2) is shown in Fig. 3.5.

Each zone consists of anchor points at each end with an expansion switch in the centre. The locations of each anchor point and switch is detailed in Table 3.3.

Table 3.3 Locations of Anchor Points and Expansion Switches

Zone	Anchor Point Locations		Zone Length	Expansion Switch Location	LW S1A	LW S2A	LW S3A	LW S4A	LW S5A	LW S6A
	City	Country								
1	98.020	98.380	360 m	98.200	✓					
2	98.380	98.740	360 m	98.560	✓	✓				
3	98.740	99.100	360 m	98.920	✓	✓	✓			
4	99.100	99.460	360 m	99.280	✓	✓	✓	✓		
5	99.460	99.780	320 m	99.590		✓	✓	✓	✓	
6	99.780	100.140	360 m	99.960			✓	✓	✓	✓
7	100.140	100.500	360 m	100.320				✓	✓	✓
8	100.500	100.860	360 m	100.680					✓	✓

The Type 4D and Type 5 expansion switches have stop blocks attached to the base of the switch assembly to positively stop further movement from each of the switch rails at the design limits of their travel, in either direction. If a switch rail moves to the block, that is, beyond the switch position blue trigger, no further movement will occur. Under this circumstance, the subsequent changes that the track monitoring system will record would be changes in rail stress along the length of free rail. Changes in rail stress will commence from a "zero base" and are not likely to lead to a safety issue before the blue switch position trigger is responded to. For the reasons above, PCE (2012b) recommended Blue trigger levels, but no Yellow or Red trigger levels for the Type 4D expansion switches and the same recommendation applies to Type 5 switches. To date, no Type 4D or Type 5 expansion switches have reached their limit of travel.

Fig. 3.5 Expansion switches installed at 98.560 km (ES2) prior to influence of LW S1A

Assessments and Planned Responses if Increased Subsidence Movements are observed within Track Expansion System

This Management Plan includes trigger levels for movements at expansion switches at which responses will be undertaken if they are exceeded. The primary response will be to add or remove rail within the zero toe load clip area and reset the switch so that it can accommodate further differential horizontal movement. This can be undertaken efficiently during normal train operations. The adjustments can be made multiple times. It is possible that multiple adjustments will be required during the mining of LW S1A-S6A, even though the Type 5 switches can accommodate substantial differential horizontal movements.

3.2.3. CWR Track

Rail stresses in continuously welded rail (CWR) will be managed during mining for sections of CWR track located beyond the Track Expansion System, where only small levels of differential movements are expected to occur.

Management of rail stresses in CWR track is standard procedure for this type of railway track worldwide. This management is enhanced by the use of rail stress gauges and long bay surveys during periods of residual subsidence to provide higher levels of control than are normally used for CWR management. It has been successfully undertaken by the Rail Management Group on many occasions, including during the mining of Tahmoor Longwalls 25 to 32, Appin Longwalls 703 to 708 and Appin Longwalls 901 to 902 beneath the Main Southern Railway at the fringes of the subsidence zone where differential subsidence movements have been small. It has also been successfully undertaken during the mining of Glennies Creek longwalls beneath the Mt Owen Spur Line where no expansion switches were used and it was also successfully undertaken during the mining of Tahmoor Longwall 24B beneath the Main Southern Railway and LW W3-W4 adjacent to the Main Southern Railway.

Existing rail stresses in the track can be measured using established non-destructive techniques. Tahmoor Coal will conduct a baseline assessment of Stress Free Temperature (SFT) using VERSE testing for sections of track that will be managed as CWR track prior to the influence of each longwall. SFT will be adjusted, if required so that SFT is within operating tolerances when it experiences active subsidence.

The results from rail stress monitoring will be compared to results from ground surveys of pegs spaced every 20 metres along the track and long bay surveys. If greater than expected ground strain and changes in rail stress occur in localised areas, it will be possible to re-measure changes in SFT by VERSE tests and adjust SFT if required

Assessments and Planned Responses if Increased Subsidence Movements are observed

Adjustments can be made to continuously welded rails (CWR) to reset the stress free temperature to within the design tolerance for SFT so that they can accommodate additional subsidence movements during normal train operations. These adjustments can be planned in advance and made multiple times.

3.3. Rail Cuttings

The Main Southern Railway generally follows a ridgeline within the Study Area, with relatively small cuttings along the track that are less than 4 metres in depth.

The cuttings have been inspected and assessed by Newcastle Geotech (2022a). There are eight cuttings along the Main Southern Railway within the vicinity of LW S1A-S6A and a summary is provided in Table 3.4.

Table 3.4 Rail cuttings potentially affected by LW S1A-S6A

Kilometrage (km)	Length (m)	Description	Location relative to Proposed Longwalls
98.130 km	260	Up to 3m deep in heavily weathered shale battered at 45 degrees with a wide cess. Coal conveyor crosses over Railway above cutting.	Approx. 390 m to the side of LW S1A
98.610 km	140	Up to 1m deep in sandstone rock and soil battered at 40 degrees with wide cesses	Above LW S1A
98.895 km	190	Up to 1.5m deep battered at 35 to 40 degrees with wide cesses. Sandstone rock exposed in cess and batters	Above LW S1A
99.165 km	130	Up to 1m deep in sandstone rock and soil battered at 35 degrees with wide cesses	Above LW S2A
99.690 km	380	Up to 3.5m deep in soil and 70 degree competent sandstone rock with minor sub-horizontal shale layers up to 100mm thick. Battered at 35 to 40 degrees with wide cess up to 3m	Above LW S3A
100.310 km	120	Up to 2m deep in competent sandstone rock battered at 40 to 45 degrees. Wide cess with access road along the Up side toe	Above LW S5A
100.700 km	400	Up to 4m deep in gravelly sandy clay residual soil over weak weathered sandstone rock battered at 35 to 40 degrees. Wide cess with rail-to-toe width 4 to 5m	Above LW S5A
101.162 km	320	Up to 3m deep with up to 2m of fill above the cutting at the bridge abutments	Approx. 370 m beyond the end of LW S6A

Further details are provided in the report by Newcastle Geotech (2022a).

The largest three of the cuttings in Table 3.4 above are listed in ARTC's Geotechnical Risk Site database (99.690 km, 100.700 km and 101.162 km) and all three are listed as "very low risk classification of 6 (non-active site)" (Newcastle Geotech, 2022). Photographs of these cuttings are provided in Fig. 3.6 to Fig. 3.8.

Newcastle Geotech advises that there is no evidence of current or past instability of the batter slopes and no evidence of fault structures or sheared fractured ground observed in the cuttings.

Tahmoor Mine has successfully mined directly beneath railway cuttings during the extraction of Longwalls 25 to 32, with only minor impacts observed on cuttings.

In the unlikely event that the faces of these cuttings are impacted by mine subsidence, the failure is likely to be very minor, in the form of small fragments of rock, and likely to fall into the clear area at the base of the cutting (the *cess*).

Photograph courtesy Newcastle Geotech

Fig. 3.6 Railway cutting at 99.690 km looking to country

Photograph courtesy Newcastle Geotech

Fig. 3.7 Railway cutting at 100.700 km looking to country

Photograph courtesy Newcastle Geotech

Fig. 3.8 Railway cutting at 101.162 km looking to city

Selection of Risk Controls

Tahmoor Coal, ARTC and the Rail Management Group considered options and selected risk controls for the cuttings along the Main Southern Railway due to the mining of LW S1-S6A in accordance with WHS laws.

Elimination

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

Substitution

In this instance, no reasonably practicable substitution controls could be identified that would 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 put in place a structure or item that prevents or minimises risks.

The cutting cesses will be maintained so that drainage is maintained.

Administrative Controls

The following Administrative Controls were identified and selected. These will put in place procedures on site to minimise the potential of adverse impacts on the safety of the Main Southern Railway.

- Implementation of a Trigger Action and Response Plan (TARP)

  This control reduces the risk of embankment instability and culvert instability by early detection of the development of potential adverse subsidence movements and changes in the condition of the cuttings, so that contingency response measures can be implemented before impacts on the safety and serviceability of the embankments and railway track develop.

  - Absolute 3D and 2D surveys along a monitoring line along the railway.
  - Absolute 3D surveys every 20 metres along the crest and toe of the cuttings at 99.690 km, 100.700 km and 101.162 km.
  - Rail stress monitoring along the track.
  - Monitoring of track geometry using a track recording trolley.
  - Visual inspections of the track and cutting batters during mining by the Track Certifier and geotechnical engineer.
  - Implementation of planned responses, if triggered by monitoring results. These may include:
    - Inspections by geotechnical engineer
    - Clear material in the cess
    - Clean loose material on cutting batter slopes
    - Resurface track geometry

The Rail Management Group considers that the above assessments and planned responses are adequate even if observed differential subsidence movements are substantially greater than predicted.

3.4. Railway Culverts

There are seven culverts along the Main Southern Railway within the vicinity of LW S1A-S6A. A summary is provided in Table 3.8.

Table 3.5 Rail culverts potentially affected by LW S1A-S6A

Kilometrage (km)	Diameter (mm)	Description	Location relative to Proposed Longwalls
98.445 km	900 dia	Skewed brick arch culvert with 900 mm dia concrete extension on both sides	Approx. 170 m to the side of LW S1A
98.739 km	900 dia	Brick arch culvert with 900 mm dia concrete extension on both sides	Above LW S1A
99.035 km	1200 dia	Brick arch culvert with 1200 mm on UP side and 900 mm dia concrete extension on Down side. Piping failure observed above interface between brick arch culvert and concrete extension on Down side.	Above LW S2A
99.338 km	1500 dia	Skewed brick arch culvert with 1200 mm dia concrete extension on UP side and concrete extension on Down side washed downstream	Above LW S3A
100.121 km	1500 dia	Skewed brick arch culvert with 1500 mm dia concrete extension on both sides. Separation observed between brick arch culvert and concrete extension on Down side.	Above LW S4A
100.425 km	1500 dia	Skewed brick arch culvert with brick wingwalls on both sides (no concrete extensions)	Above LW S5A
101.000 km	1200 dia	Brick arch culvert with 900 mm dia concrete extension on both sides	Approx. 230 m beyond the end of LW S6A

Based on boreholes drilled by Newcastle Geotech, the culverts appear to be either founded on natural soils or on the rock surface with no evidence of the culverts being constructed against rock. Further details are provided in the report by Newcastle Geotech (2022a).

A dilapidation inspection has been completed by Robinson Rail (2022).

Photographs of culverts are shown in Fig. 3.9 to Fig. 3.15.

Photograph courtesy Newcastle Geotech

Fig. 3.9 Culvert with concrete extension on Up side at 98.445 km

Photograph courtesy Robinson Rail

Fig. 3.10 Culvert with concrete extension on Up side at 98.739 km

Photograph courtesy Newcastle Geotech

Fig. 3.11 Culvert with concrete extension on Up side at 99.035 km

Photographs courtesy Robinson Rail / Newcastle Geotech

Fig. 3.12 Culvert at 99.338 km on Up and Down sides

Photograph courtesy Robinson Rail

Fig. 3.13 Culvert with concrete extension on Up side at 100.121 km

Photograph courtesy Robinson Rail

Fig. 3.14 Culvert with concrete extension on Up side at 100.425 km

Photograph courtesy Newcastle Geotech

Fig. 3.15 Culvert with concrete extension on Up side at 101.000 km

The railway crosses a number of streams above LW S1A-S6A and valley-related movements could be experienced in these locations. A summary of the maximum predicted conventional subsidence and valley related movements for the railway culverts is provided in Table 3.6.

Table 3.6 Predicted Conventional Subsidence and Valley Related Movements for the Main Southern Railway Culverts within the Study Area

Location	Maximum predicted total subsidence (mm)	Maximum predicted total tilt (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)
98.445 km	125	< 0.5	< 0.01	< 0.01	20	20
98.739 km	1050	8.0	0.05	0.17	100	50
99.035 km	1000	5.0	0.05	0.04	100	75
99.338 km	1225	5.0	0.06	0.04	200	150
100.121 km	1225	7.0	0.08	0.09	200	100
100.425 km	1275	3.5	0.05	0.12	150	75
101.000 km	20	< 0.5	< 0.01	< 0.01	50	20

The values provided in Table 3.6 are the maximum predicted parameters within a 20 metre radius of each culvert.

Hazard identification, risk assessment and selection of risk controls

Given that the maximum predicted tilt is 8.0 mm/m, which equates to a 0.8% change in grade, it is expected that mining-induced conventional tilts will not substantially impact the drainage flows in the culverts. Vegetation, ballast and debris will, however, be cleared around the culverts to facilitate water flows, surveys and inspections during mining.

The main impact identified with the brick arch culverts is the potential for physical impacts to occur. It is possible that these culverts will experience some cracking and spalling of the masonry as a result of mining the longwalls. Cracking may occur in the masonry arch or in the wingwalls and headwalls. The predicted movements are not considered likely to result in collapse of the culvert.

However, given the potentially severe consequences of culvert collapse, the Rail Management Group has considered mitigation measures prior to each culvert experiencing subsidence movements. As the culverts are shallow buried, steel baulk structures will be placed above the culverts to prevent impacts on the track in the event of culvert collapse. The baulks can be further strengthened, if required if a culvert is experiencing severe impacts. Reinforced concrete pipe sleeves can also be inserted, if required, noting that the pipes are readily available at short notice from local suppliers.

Based on the information above, Tahmoor Coal, ARTC and the Rail Management Group considered and selected risk controls for the railway culverts due to the extraction of LW S1A-S6A in accordance with WHS laws.

Elimination

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

Substitution

The following Substitution Control has been identified and selected that will change the environment so the hazards could be substituted for hazards with a lesser risk.

- Installation of a track baulk above the culverts.

Isolation

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

Engineering Controls

The following Engineering Controls have been identified and selected to prevent or minimise risks.

- De-vegetation of the embankment batters and maintain culverts to keep them free flowing and facilitate monitoring of the embankments and culverts.
- Seal gap between the brick arch culvert headwall and concrete pipe extension on the Down side of Culvert at 99.035 km and repair sinkhole prior to influence of LW S1A.
- Reinstate concrete outlet pipe to Culvert at 99.338 km prior to influence of LW S3A.
- Seal gap between the brick arch culvert headwall and concrete pipe extension on the Down side of Culvert at 100.121 km prior to influence of LW S4A.

Administrative Controls

The following Administrative Controls were identified and selected. These will put in place procedures on site to minimise the potential of adverse impacts on the safety of the Main Southern Railway and maintain water flows.

- Implementation of a Trigger Action and Response Plan (TARP)

  This control reduces the risk of impacts on the structural integrity of the culverts by early detection of the development of potential adverse subsidence movements and changes in the condition of the culverts, so that contingency response measures can be implemented before impacts on the safety and serviceability of the culverts and the railway track occur.

  - Absolute 3D and 2D surveys along a monitoring line along the railway.
  - Track geometry surveys above culvert;
  - Rail stress monitoring along track;
  - Ground survey of culverts and embankments, as described in Drawings Nos. MSEC1201-05 to 12. Where brick arch culverts are visible, survey marks will be placed at the spring points on both sides of the culverts at the headwall. Where concrete extensions have been installed, one survey mark will be placed at the inlet / outlet;
  - Water level sensors in boreholes at embankments at 99.338 km, 100.121 km and 100.425 km;
  - Visual inspections by Track Certifier and geotechnical engineer (Track Certifier has confined space training);
  - Implementation of planned responses, if triggered by monitoring results. These may include:
    - Detailed inspections by structural engineer;
    - Increase monitoring and reporting procedures;
    - Repair damage to culvert;
    - Installation of props to headwalls and wingwalls; and
    - Strengthen track baulk above culvert;

With the implementation of the above management strategy, Tahmoor Coal will ensure that the culverts and track above them will remain safe and serviceable during the extraction of LWs S1A to S6A even if observed differential subsidence movements are substantially greater than predicted.

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3.5. Railway Embankments

The Main Southern Railway crosses relatively small valleys within the vicinity of LW S1A-S6A and the railway embankments are less than 7 metres in height. The embankments are typically constructed with local fill material and contain relatively steep batters.

The embankments have been inspected and assessed by Newcastle Geotech (2022a). There are seven fill embankments along the Main Southern Railway within the vicinity of LW S1A-S6A and a summary is provided in Table 3.8.

Table 3.7 Rail embankments potentially affected by LW S1A-S6A

Kilometrage (km)	Length (m)	Description	Location relative to Proposed Longwalls
98.445 km	160	Fill to 6m high with batter slopes to 33° with wide access road berm on US at toe of ballast and mid-height access road berm on DS. Water treatment dams on mine site upstream.	Approx. 170 m to the side of LW S1A
98.739 km	100	Fill to 5m high with batter slopes to 30° upside and 35° on downside with 4m wide access road berms on both sides. Water treatment dams on mine site upstream.	Above LW S1A
99.035 km	80	Fill up to 6m high with batter slopes up to 35° with 4m wide access road berms on both sides. Piping failure observed above interface between brick arch culvert and concrete extension on Down side.	Above LW S2A
99.338 km	270	Fill to 7m high with batters generally in order of 35°. Wide access road on US. Embankment on DS variable height (ballast slope) up to 3m above access road. Access road narrows to 3m above DS culvert at 99.340km with very steep batter below down to culvert. Concrete extension on Down side washed downstream, resulting in a very steep batter or scarp below the access road.	Above LW S3A
100.121 km	200	Fill to 6m high with batter slopes up to 35°. Wide access road berm on US. Downside 1.5m shoulder from ballast toe to crest 4m high embankment at 30° with access road below. Separation observed between brick arch culvert and concrete extension on Down side.	Above LW S4A
100.425 km	130	Wide access road berms up to 3.5m on both sides at toe of ballast. Embankment up to 6m high with batter slopes up to 35°.	Above LW S5A
101.000 km	50	Fill up to 5m high with batter slopes locally up to 35°. Wide access road berms on both sides.	Approx. 230 m beyond the end of LW S6A

Further details are provided in the report by Newcastle Geotech (2022a).

Three of the embankments in Table 3.8 above are listed in ARTC's Geotechnical Risk Site database (99.035 km, 99.338 km and 100.121 km) and all three are listed as "very low risk classification of 6 (non-active site)" (Newcastle Geotech, 2022), although Newcastle Geotech expects that the assessment at 99.338 km was conducted before the culvert washout occurred. Photographs of the embankments are provided in Fig. 3.16 to Fig. 3.22.

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Photograph courtesy Newcastle Geotech

Fig. 3.16 Embankment at 98.445 km on Up and Down side

Photograph courtesy Newcastle Geotech

Fig. 3.17 Embankment at 98.739 km on Up and Down side

Photographs courtesy Newcastle Geotech

Fig. 3.18 Embankment at 99.035 km on Up side with piping hole above culvert on Down side

Photographs courtesy Newcastle Geotech

Fig. 3.19 Culvert at 99.338 km on Up side and Down side where concrete extension has washed away, resulting in steep batter slope / scarp

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Photographs courtesy Newcastle Geotech

Fig. 3.20 Embankment at 100.121 km on Up side and Down side

Photographs courtesy Newcastle Geotech

Fig. 3.21 Embankment at 100.425 km on Up side and Down side

Photograph courtesy Newcastle Geotech

Fig. 3.22 Embankment at 101.000 km on Up and Down side

Newcastle Geotech advises that there is no evidence of current or past embankment instability observed at the embankments, with the exception of where there has been an issue with a culvert. Gaps have formed between the original brick arch culvert and downstream concrete pipe extensions at 99.035 km and 100.121 km, with piping erosion observed at 99.035 km. The downstream concrete pipe extension at 99.338 km has washed away, resulting in a steep batter slope / scarp adjacent to the access road.

While the three culvert defects do not impact on track stability, Tahmoor Coal and ARTC will rectify the culvert defects prior to mining directly beneath them.

Tahmoor Mine has successfully mined directly beneath railway embankment during the extraction of Longwalls 25 to 32, with no impacts observed to embankment stability. No impacts were also observed during the extraction of Tahmoor Longwalls W1-W3 beneath the Picton to Mittagong Loop Line nor during the extraction of Appin Longwalls 703 to 708 and Longwalls 901 to 902 beneath embankments in Douglas Park.

The experiences coincided with multiple significant rainfall events, including a 1 in 100 year event in June 2016 and four events in the order of 1 in 20 year events between February 2020 and June 2022 (Newcastle Geotech, 2022). Observations during the rainfall events have shown that while the embankment surface may become saturated, groundwater levels rise only slightly in response to the rainfall events.

Newcastle Geotechnics arranged for stability analyses to be carried out of the rail embankments by Morrow Geotechnics, based on:

- Cross-sectional data supplied by Southern Rail Surveys and detailed mapping by Newcastle Geotechnics;
- Geotechnical parameters based on an interpretation of embankment materials;
- Interpreted groundwater piezometric surface at 0.5 m to 1.0 m above the base of the fill; and
- Rail surcharge loading of 50 kPa.

The methodology did not include an assessment of stability with negative pore pressures (soil suction), which would be expected to have resulted in higher factors of safety.

The assessed factors of safety affecting track safety were greater than 1.5 for the Embankments at 98.445 km, 98.739 km, 99.035 km, 100.121 km and 100.425 km. The assessed factor of safety for the Embankment at 99.338 km at the location of the culvert extension washout on the Down side was 1.20 with a failure surface extending up through the access road from the toe of the downside batter slope, where the downstream washout has resulted in a localised over-steep batter. This factor only applies to a narrow 20 metre section of the Down side embankment, with factors of safety for other sections of the embankment in the order of 1.5.

Selection of Risk Controls

Based on the above assessments, Tahmoor Coal, ARTC and the Rail Management Group considered options and selected risk controls for the embankments along the Main Southern Railway due to the mining of LW S1A-S6A in accordance with WHS laws.

Elimination

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

Substitution

The following Substitution Control has been identified and selected that will change the environment so the hazards could be substituted for hazards with a lesser risk.

- Installation of a track baulk above the culverts.

Isolation

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

Engineering Controls

The following Engineering Controls have been identified and selected to prevent or minimise risks.

- De-vegetation of the embankment batters and maintain culverts to keep them free flowing and facilitate monitoring of the embankments and culverts.

- Seal gap between the brick arch culvert headwall and concrete pipe extension on the Down side of Culvert at 99.035 km and repair sinkhole prior to influence of LW S1A.

- Reinstate concrete outlet pipe and embankment profile to Culvert at 99.338 km prior to influence of LW S3A. The engineering design of the reinstatement will investigate the likely cause of the washaway and consider measures to mitigate further washaway of the culvert.

- Seal gap between the brick arch culvert headwall and concrete pipe extension on the Down side of Culvert at 100.121 km prior to influence of LW S4A.

Administrative Controls

The following Administrative Controls were identified and selected. These will put in place procedures on site to minimise the potential of adverse impacts on the safety of the Main Southern Railway.

- Implementation of a Trigger Action and Response Plan (TARP)

  This control reduces the risk of embankment instability and culvert instability by early detection of the development of potential adverse subsidence movements and changes in the condition of the embankments, so that contingency response measures can be implemented before impacts on the safety and serviceability of the embankments and railway track develop.

  - Absolute 3D and 2D surveys along a monitoring line along the railway.
  - Track geometry surveys above culvert;
  - Rail stress monitoring along track;

- Ground survey of culverts and embankments, as described in Drawings Nos. MSEC1201-05 to 12. Where brick arch culverts are visible, survey marks will be placed at the spring points on both sides of the culverts at the headwall. Where concrete extensions have been installed, one survey mark will be placed at the inlet / outlet;
- Automated, continuously operating horizontal extensometers (or equivalent) across the crests of the embankments at 99.338 km, 100.121 km and 100.425 km.
- Manual inclinometer surveys in boreholes at embankments at 99.338 km, 100.121 km and 100.425 km;
- Water level sensors in boreholes at embankments at 99.338 km, 100.121 km and 100.425 km;
- Visual inspections of the track, culvert and embankment during mining by the Track Certifier and geotechnical engineer.
- Implementation of planned responses, if triggered by monitoring results. These may include:
    - Inspections by geotechnical and/or structural engineer
    - Temporarily support the ballast shoulder by placing material on the crest of the embankment
    - Place permanent or temporary fill / rock spall to the base of the embankment
    - Tip fill material into scarp of slide until settlement effectively ceases
    - Add ballast to the railway track and lift track to restore track geometry
    - Provide additional forms of track support under or adjacent to the track as may be appropriate or feasible
    - Conduct additional strengthening of culvert and headwall
    - Strengthen track baulk

In the unlikely event that intervention works are required, short term temporary works can be undertaken at track level by hi-rail excavator include, but are not limited to; track support by placing and tamping ballast beneath the track; excavating and placing geotextile and rock fill to provide lateral support; and excavation of drainage slot (finger drains). Works and material placement can be undertaken under geotechnical direction by a high-rail excavator and hi-rail dump truck, such as the one owned and operated by Tahmoor Coal's appointed Rail Maintenance Contractor Bloor Rail.

The hi-rail excavator can access the track and operate in between train operations as the travel distance to enter and exit the track is very short. Trains can continue to operate on the opposite track whilst the hi-rail excavator is on the track.

If a slump develops in the batter slope, permanent or temporary fill / rock spall can be placed to the base of the embankment by dump trucks and excavators via the access roads, and rail operations can be maintained while works are underway.

In combination with intensive monitoring measures and inspections by the Track Certifier, including during extreme wet weather events, the response time to undertake physical response measures will be less than 24 hours.

The Rail Management Group considers that the above assessments and planned responses are adequate even if observed differential subsidence movements are substantially greater than predicted.

3.6. Bridges

There are no bridges along the Main Southern Railway 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 railway bridges are provided in Table 3.8.

Table 3.8 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)
Railway Viaduct over Bargo River	1,750 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)
Wellers Road Overbridge over the Main Southern Railway	370 m	LW S6A	Commencing end (South-eastern end)

3.6.1. Remembrance Drive Bridge over the Bargo River and Main Southern Railway

Description and setting

The Remembrance Drive Bridge spans across a bend in the Bargo River. The six-span dual lane Bridge is comprised of reinforced concrete abutments and wingwalls, with intermediate reinforced concrete piers on pad footings founded in sandstone (JMA, 2022a). A long-section of the Bridge is shown in Fig. 3.23.

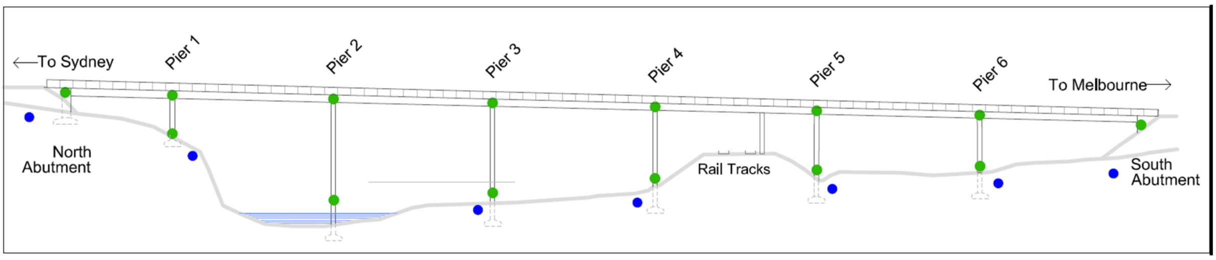

Fig. 3.23 Long-section of Remembrance Drive Bridge over Bargo River

The Bridge spans the Bargo River between Piers 1 and 3, and spans the Main Southern Railway on the southern bank of the Bargo River between Piers 4 and 5.

The bridge was constructed in 1967, replacing the last remaining single lane bridge on the Old Hume Highway. A photograph of the bridge during construction is shown in Fig. 3.24. The photograph shows the temporary props that were used to support the intermediate piers. The Main Southern Railway Viaduct is shown in the foreground, along with the now demolished old single lane bridge on the Old Hume Highway. Photographs of the Bridge are shown in Fig. 3.25 to Fig. 3.27.

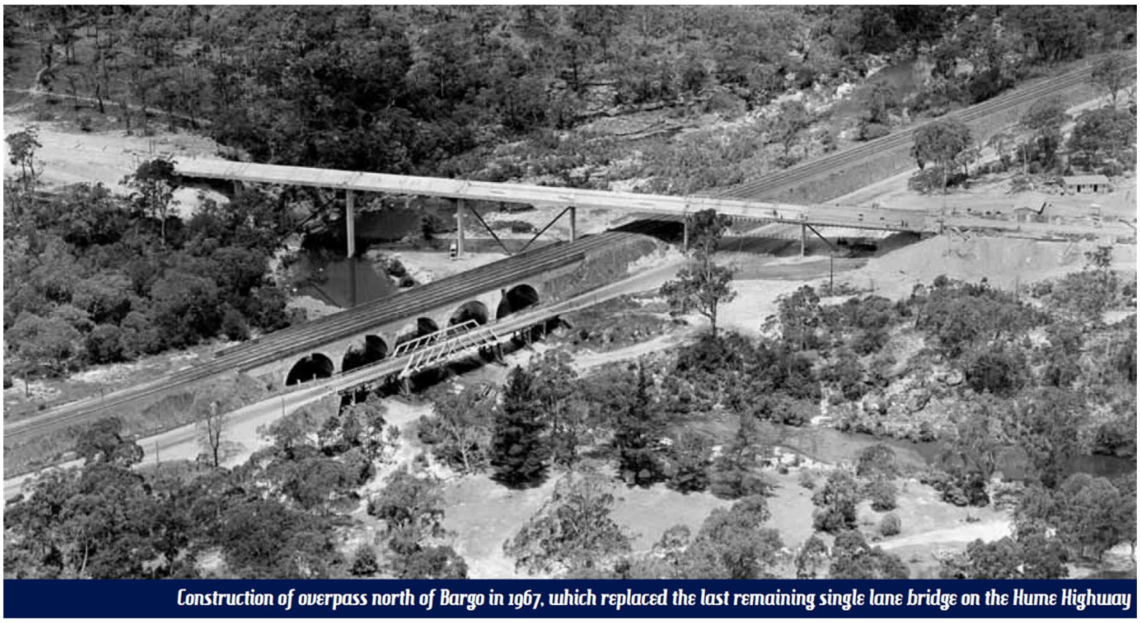

Fig. 3.24 Remembrance Drive Bridge over Bargo River during construction in 1967 (RMS, 2013)

Fig. 3.25 Remembrance Drive Bridge over Bargo River viewed from the west

Photograph courtesy JMA Solutions (2022a)

Fig. 3.26 Remembrance Drive Bridge over Bargo River at southern abutment

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Photograph courtesy Tahmoor Coal

Fig. 3.27 Fingerplate expansion joint at northern abutment of Remembrance Drive Bridge

Previous mining near the Bridge

Tahmoor Mine has extracted around all four sides of the Bridge, as shown in Fig. 3.28. The closest extracted panel was LW 5, which was 715 m from the Bridge. Tahmoor South LWs S1A to S6A are located in the southwest corner of the map below, with the closest distance of 1,690 metres to the Bridge.

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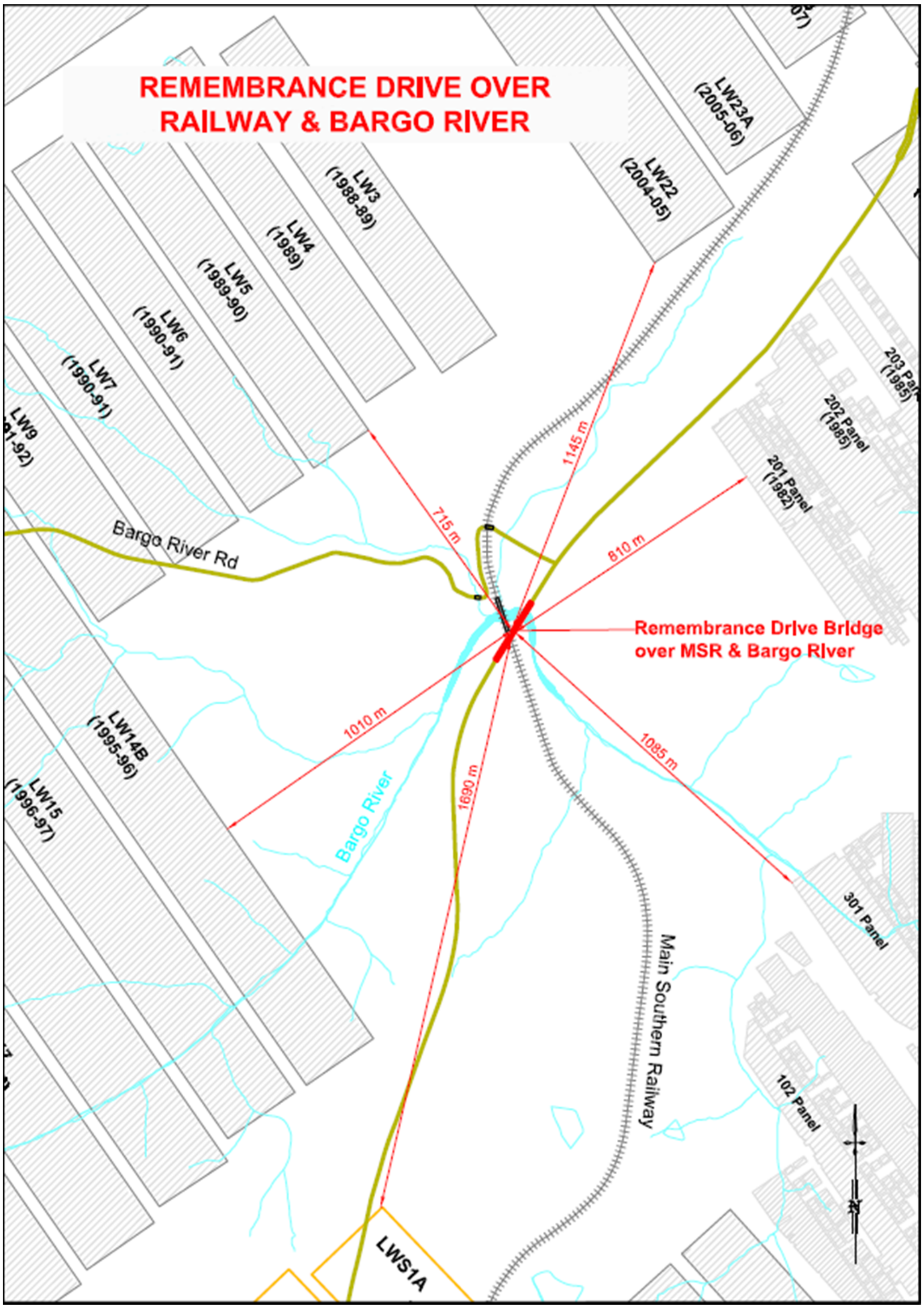

Fig. 3.28 Location of Remembrance Drive Bridge over Bargo River relative to mine layout

LWs 3 to 7 were setback conservatively to avoid damage to the Railway Viaduct and Remembrance Drive Bridge over the Bargo River. Based on the available knowledge of mine subsidence movements at the time of mining, the Bridge was not monitored by survey or visual inspection during the extraction of previous longwalls at Tahmoor Mine.

Potential historical and future mining-induced movements at the Bridge

Based on current knowledge, the Bridge may have experienced absolute and differential far-field horizontal movements during previous mining, and may experience additional movements during the extraction of LWs S1A to S6A.

A statistical analysis of potential absolute far-field horizontal movements is provided in Section 2.8 of this Management Plan, with results relevant to the Bridge highlighted in Table 3.9.

Table 3.9 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 Remembrance Drive 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)
600 (LW 5)	75	100
800 (LWs 3 to 6 and 200 Panels)	60	80
1000 (LWs 9 and 22 and 300 Panels)	50	65
1200 (LWs 22 to 24B)	40	50
1400 (LWs 22 to 24B)	30	45
1600 (LWs S1A to S6A)	26	35
1800	23	30
2000	22	27

A statistical analysis of potential differential far-field horizontal movements is provided in Section 2.8 of this Management Plan, with results relevant to the Bridge highlighted in Table 3.10. 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 3.10 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 Remembrance Drive Bridge over the Bargo River

Offset distance from LW	Probability of Exceedance	Incremental differential horizontal movements for pegs spaced between 190 and 210m (mm)		
		Opening (mm)	Closure (mm)	Horizontal mid-ordinate deviation (mm)
800 m (LWs 3 to 6 and 200 Panels)	1 in 20 (0.05)	13	8	9
	1 in 100 (0.01)	20	14	14
1000 m (LWs 9 and 22 and 300 Panels)	1 in 20 (0.05)	10	6	8
	1 in 100 (0.01)	16	10	13
1200 m (LWs 22 to 24B)	1 in 20 (0.05)	9	6	7
	1 in 100 (0.01)	12	10	11
1700 m to 2400 m (LWs S1A to S6A)	1 in 20 (0.05)	6	5	5
	1 in 100 (0.01)	7	6	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.

The above values are based on confidence levels of 95% and 99%. It is, therefore, likely that the Bridge previously experienced less than the above-mentioned absolute and differential movements during previous mining. The probability, for example, of the Bridge previously experiencing the sum total of the values above would be significantly less than 1%.

While surveys were not conducted during previous mining, it is possible to measure the current bridge geometry and assess the existing condition of the Bridge by inspection. This is discussed later in this section.

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 at 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 (2022b) 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. MSEC1201-01. 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.
- A site inspection at the Bridge found no obvious evidence of fault structures or zones of fractured rock were observed along the sandstone rock outcrop on the steep slopes and escarpment of the river valley. The sandstone rock along the northern and outside bend of the river gorge comprised sub-horizontally bedded competent sandstone rock extending from 40 metres west of the bridge to in excess of 100 metres to the east.
- A site inspection of the Bargo River was conducted up to 200 metres upstream and downstream of the Bridge. No evidence of faults, fractured rock or igneous dykes were observed in the sandstone rock along the creek bed and along the valley sides.
- 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.

Bridge condition surveys

The Remembrance Drive Bridge over the Bargo River is owned and maintained by Transport for NSW (ID OBS00096B). The Bridge is currently maintained under contract by UGL. The most recent structural inspection report was conducted in December 2020 by JJ Ryan Consulting, who was commissioned under a previous maintenance contract by John Holland (JJ Ryan, 2020). JJ Ryan (2020) report minor defects in the forms of cracks in concrete kerbs and sidewalks, which do not affect the load rating for the Bridge.

Tahmoor Coal has conducted surveys and inspections to assess the existing condition of the Bridge. A second purpose of the surveys and inspections is to determine whether the Bridge has experienced lateral or vertical misalignment during the mining of previous longwalls, and understand the capacity of the Bridge to accommodate potential additional subsidence movements.

The surveys and inspections included:

- Structural inspection by JMA Solutions, who advises that the bridge has been inspected from ground level and does not appear to be unserviceable. Some fine cracking is observed at the re-entrant corner of the edge girder on the downstream side of Span 7 at the southern abutment and a crack has been observed between the end block and box girder on the upstream side of Span 1 at the northern abutment.
- Laser scan of the Bridge were conducted to assess the current lateral and vertical alignment of the bridge deck and the piers (Precision Surveys, 2022). An image from the scan is shown in Fig. 3.29. The assessment found the following:
    - The vertical alignment of the Bridge deck at the pier connections is within measurement tolerances, with the exception of Pier 1, which was measured to be approximately 40 mm higher relative to a straight line drawn between the ends of the bridge deck. The deck was also observed to arch upwards between the pier connections, which is expected to occur in response to sustained prestressing forces on the girders.
    - The lateral alignment of the Bridge deck and piers are within measurement tolerances (less than 10 mm offset relative to straight line drawn between the ends of the bridge deck).
    - No measurable twist was observed to the bridge piers.
- Measurement of the structural gap between the deck and the northern abutment and the gap in the fingerplate expansion joint at the northern abutment.

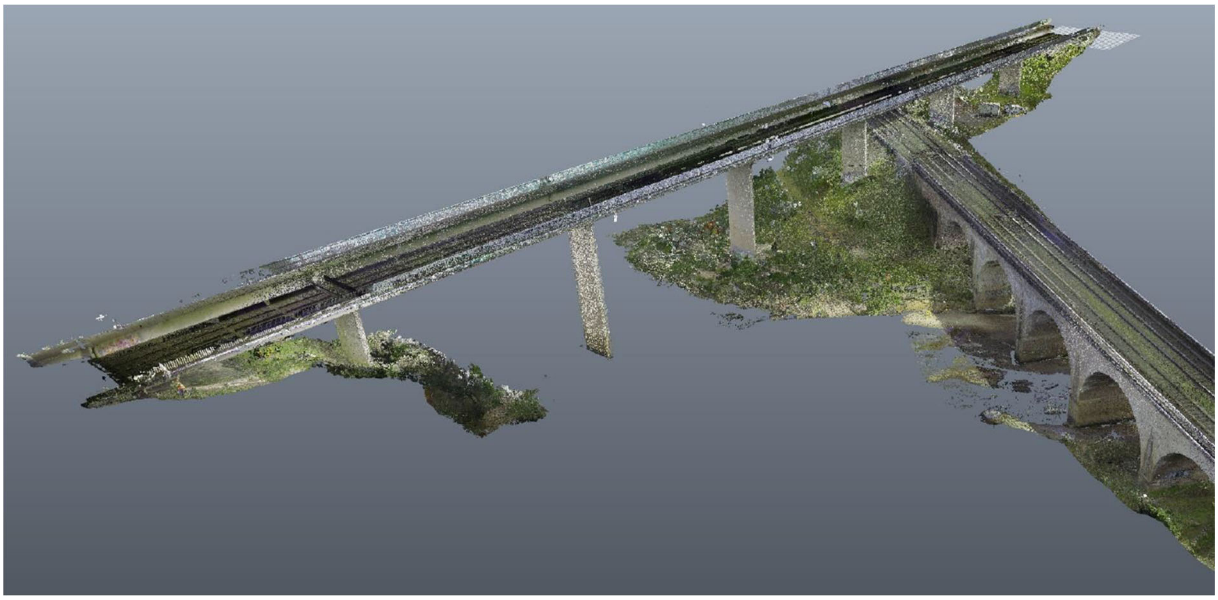

Fig. 3.29 Image produced from laser scan (Precision Surveys, 2022)

Structural investigation and assessment

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

- The bridge has been inspected from ground level and does not appear to be unserviceable. Some fine cracking is observed at the re-entrant corner of the edge girder on the downstream side of Span 7 at the southern abutment and a crack has been observed between the end block and box girder on the upstream side of Span 1 at the northern abutment.
- The bridge deck and pier structures are longitudinally tied to the southern abutment. The piers are, therefore, laterally restrained at the top and bottom and can, therefore, accommodate valley closure movements at the foundation level by bending.
- The bridge girders are pinned to the southern abutment by rocker bearings that prevent longitudinal movement. The girders at the northern abutment are supported on roller bearings that enable expansion, contraction and angular rotation.
- The bridge expands and contracts in response to changes in temperature via the rocker bearings underneath the deck and fingerplate expansion joint on the deck at the northern abutment. JMA advises that thermal expansion and contraction could be up to ± 38 mm of longitudinal movement, based on a ± 20 degree seasonal change in average temperature.

  Tahmoor Coal has taken baseline measurements of the gap between the deck and the northern abutment. Tahmoor Coal is currently collecting further measurements to track seasonal changes across the gap.
- The bridge deck is likely to have shortened over time due to creep and shrinkage. The amount of shortening depends on the timing of the installation of the deck girders to the piers relative to when the girders were cast, and the timing of the erection of the bridge girders during the seasonal temperature cycle. It is concluded that creep and shrinkage could account for the majority of the shortening that has been measured.
- Based on the above, it is expected that the Bridge could accommodate more than 80 mm of valley closure before the gap between the deck and the northern abutment is closed. The Bridge could accommodate 25 mm of valley opening before approaching the serviceability limit of the rocker bearings.
- If the bridge experiences transverse / lateral displacements due to mining, the deck is expected to rotate sideways via the rocker bearings that support the girders at the top of the piers. A structural analysis predicts an increase in stress in the tie-bars that restrain the top of the piers to the deck, reducing their capacity to absorb stresses that occur due to vehicle braking loads. Speed restrictions would, therefore, be recommended to manage potential impacts on the Bridge if it experiences transverse / lateral displacements until it is repaired.

- In the event that differential horizontal movements develop, it is possible to provide additional support to the Bridge by erecting steel props and cross-bracing around the slender piers to share the traffic live load and reduce pier slenderness.

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.

Summary of measures to manage potential impacts on Remembrance Drive Bridge over Bargo River

Tahmoor Coal has developed and selected risk control measures in consultation, co-ordination and co-operation with ARTC 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, where access is available. The locations are shown in Drawing No. MSEC1201-13;
- Absolute 3D of structure on the Bridge, as shown in Drawing No. MSEC1201-13. The marks have been installed;
- Absolute 3D of ground marks adjacent to the Bridge, as shown in Drawing No. MSEC1201-13. The majority of the marks have been installed. The surveyor has taken care to install the marks on stable ground, noting that some areas contain deep alluvial sand, preventing the installation of stable ground marks. Some marks have been installed on river bed on the Bargo River, which may be submerged during and after rainfall events;
- Measurement of the gap between the deck and the northern abutment;
- Visual inspections of the Bridge;
- Implementation of planned responses, if triggered by monitoring results. These may include:
  - Inspections by structural engineer;
  - Meeting by Bridge Technical Committee to assess the latest results and observations and consider management actions;
  - Increase monitoring and reporting procedures;
  - Construct temporary props and/or cross-bracing to provide additional support to the piers;
  - Resurface affected road pavement;
  - As a last resort emergency response measure, slow or stop the longwall and/or stop trains and vehicle traffic;
- 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 Bridge will not be put at risk due to differential mine subsidence movements due to the extraction of LWs S1A to S6A.

3.6.2. Railway Viaduct over the Bargo River

Description and setting

The Main Southern Railway spans across a bend in the Bargo River. The five-span dual brick arch Viaduct is comprised of brick arches supported by a sandstone springing course and brick abutments, with a parapet capping stone (JMA, 2022b), as shown in Fig. 3.30 and Fig. 3.31. The Viaduct is approximately 75 metres long and 9 metres wide. The pier centres are spaced every 15.02 metres with spans 2 to 4 across the Bargo River.

Photograph courtesy Tahmoor Coal

Fig. 3.30 Railway Viaduct over Bargo River

Photograph courtesy MNC Consulting

Fig. 3.31 Down side of Viaduct with Remembrance Drive Bridge over Bargo River in background

The Railway Viaduct over the Bargo River was constructed in 1919 as part of the major duplication of the Main Southern Railway. The Viaduct is listed as an Item of Heritage Significance on the State Heritage Register and as part of the Wollondilly Local Environmental Plan (2011).

Previous mining near the Viaduct

Tahmoor Mine has extracted around all four sides of the Viaduct, as shown in Fig. 3.32. The closest extracted panel was LW 5, which was 660 m from the Viaduct. Tahmoor South LWs S1A to S6A are located in the southwest corner of the map below, with the closest distance of 1,755 metres to the Viaduct.

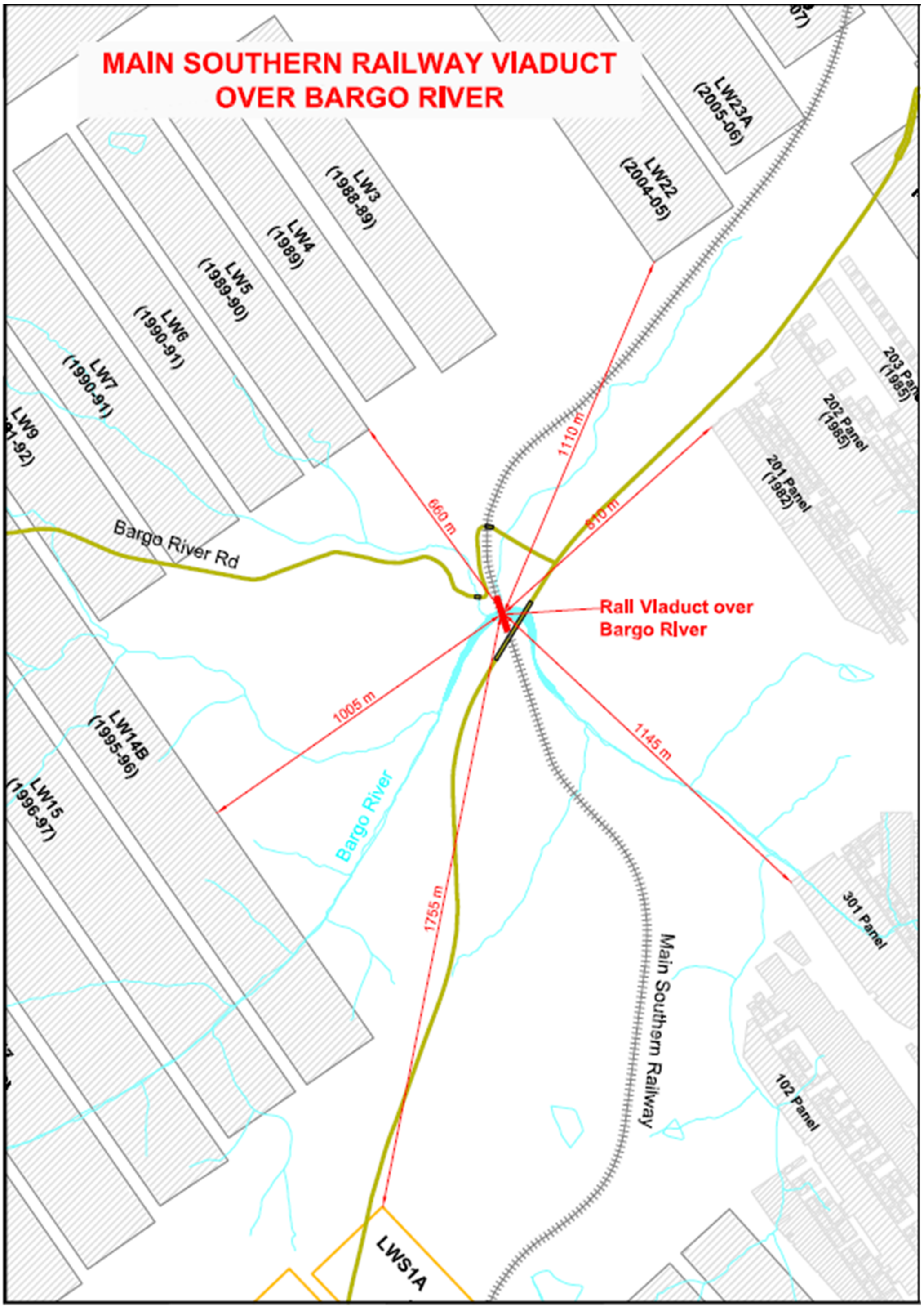

Fig. 3.32 Location of Railway Viaduct over Bargo River relative to mine layout

LWs 3 to 7 were setback conservatively to avoid damage to the Railway Viaduct and Remembrance Drive Bridge over the Bargo River. Based on the available knowledge of mine subsidence movements at the time of mining, the Bridge was not monitored by survey or visual inspection during the extraction of previous longwalls at Tahmoor Mine.

Potential historical and future mining-induced movements at the Viaduct

Based on current knowledge, the Viaduct may have experienced absolute and differential far-field horizontal movements during previous mining, and may experience additional movements during the extraction of LWs S1A to S6A.

A statistical analysis of potential absolute far-field horizontal movements is provided in Section 2.8 of this Management Plan, with results relevant to the Viaduct highlighted in Table 3.11.

Table 3.11 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 Railway Viaduct 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)
600 (LW 5)	75	100
800 (LWs 3 to 6 and 200 Panels)	60	80
1000 (LWs 9 and 22 and 300 Panels)	50	65
1200 (LWs 22 to 24B)	40	50
1400 (LWs 22 to 24B)	30	45
1600 (LWs S1A to S6A)	26	35
1800	23	30
2000	22	27

A statistical analysis of potential differential far-field horizontal movements is provided in Section 2.8 of this Management Plan, with results relevant to the Viaduct highlighted in Table 3.12. 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 3.12 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 Railway Viaduct over the Bargo River

Offset distance from LW	Probability of Exceedance	Incremental differential horizontal movements for pegs spaced between 190 and 210m (mm)		
		Opening (mm)	Closure (mm)	Horizontal mid-ordinate deviation (mm)
800 m (LWs 3 to 6 and 200 Panels)	1 in 20 (0.05)	13	8	9
	1 in 100 (0.01)	20	14	14
1000 m (LWs 9 and 22 and 300 Panels)	1 in 20 (0.05)	10	6	8
	1 in 100 (0.01)	16	10	13
1200 m (LWs 22 to 24B)	1 in 20 (0.05)	9	6	7
	1 in 100 (0.01)	12	10	11
1700 m to 2400 m (LWs S1A to S6A)	1 in 20 (0.05)	6	5	5
	1 in 100 (0.01)	7	6	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.

The above values are based on confidence levels of 95% and 99%. It is, therefore, likely that the Viaduct previously experienced less than the above-mentioned absolute and differential movements during previous mining. The probability, for example, of the Viaduct previously experiencing the sum total of the values above would be significantly less than 1%.

While surveys were not conducted during previous mining, it is possible to measure the current bridge geometry and assess the existing condition of the Bridge by inspection. This is discussed later in this section.

While the offset distances of LWs S1A to S6A to the Viaduct are substantial, there remains a chance that differential far-field movements could adversely affect the Viaduct. The Viaduct is situated at 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 (2022b) 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. MSEC1201-01. While the orientation of the structures are aligned with the downstream leg of the Bargo River, they are located away from the Viaduct. 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 Viaduct.
- A site inspection at the Viaduct found no obvious evidence of fault structures or zones of fractured rock. The Viaduct appears to be founded on competent sandstone of medium strength or better beneath Spans 2 to 4. The abutment on the Sydney end of the Viaduct appears to have founded on rock. It is expected that the abutment on the Country end is also founded on rock, though this end of the Viaduct is covered by alluvial soil.
- A site inspection of the Bargo River was conducted up to 200 metres upstream and downstream of the Viaduct. No evidence of fracturing or strata displacement associated with faulting or igneous dykes was observed across the extensive outcrop of sandstone rock that occurs beneath the Viaduct.
- The river alignment upstream of the Viaduct 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.

Viaduct condition surveys

The Railway Viaduct over the Bargo River is owned and maintained by Transport for NSW and managed by ARTC. ARTC has provided reports on structural inspections and geotechnical investigations of the Viaduct that were previously conducted by Opus and RCA Australia.

Tahmoor Coal has conducted surveys and inspections to assess the existing condition of the Bridge. A second purpose of the surveys and inspections is to determine whether the Bridge has experienced lateral or vertical misalignment during the mining of previous longwalls.

The surveys and inspections included:

- Structural inspection by JMA Solutions, who advises that the Viaduct has been inspected from ground level and does not appear to be unserviceable. The surface of the spandrel walls on both sides have been discoloured below the level of the concrete backing that was constructed. Horizontal cracking has been observed above and below the drainage outlets. While vertical cracking is observed along the parapet walls, presumably caused by rotation of the piers under rail traffic, no significant vertical cracking has been observed in the spandrel walls below the parapet, nor has any significant out-of-plane displacement been observed.
- Baseline photographs and videos were conducted along the Viaduct by UAV by MNC Consulting. JMA (2022b) advises that horizontal mortar joint cracking is present beneath the parapet walls, particularly at the two end spans, as shown in Fig. 3.33. The horizontal cracking is frequently observed in masonry arch bridges, including in the UK, and the most likely cause is vertical up and down movement the middle third of the arch and spandrel wall structure in response to train loads. No significant structural defects have been identified in the brick arches and spandrel walls.
- Laser scan of the Viaduct was conducted to assess the current lateral and vertical alignment of the parapet capping along the Viaduct and the piers (Precision Surveys, 2022). An image from the scan is shown in Fig. 3.29. The scan found that the vertical and lateral alignment of the parapet wall along the Viaduct was within measurement tolerances.

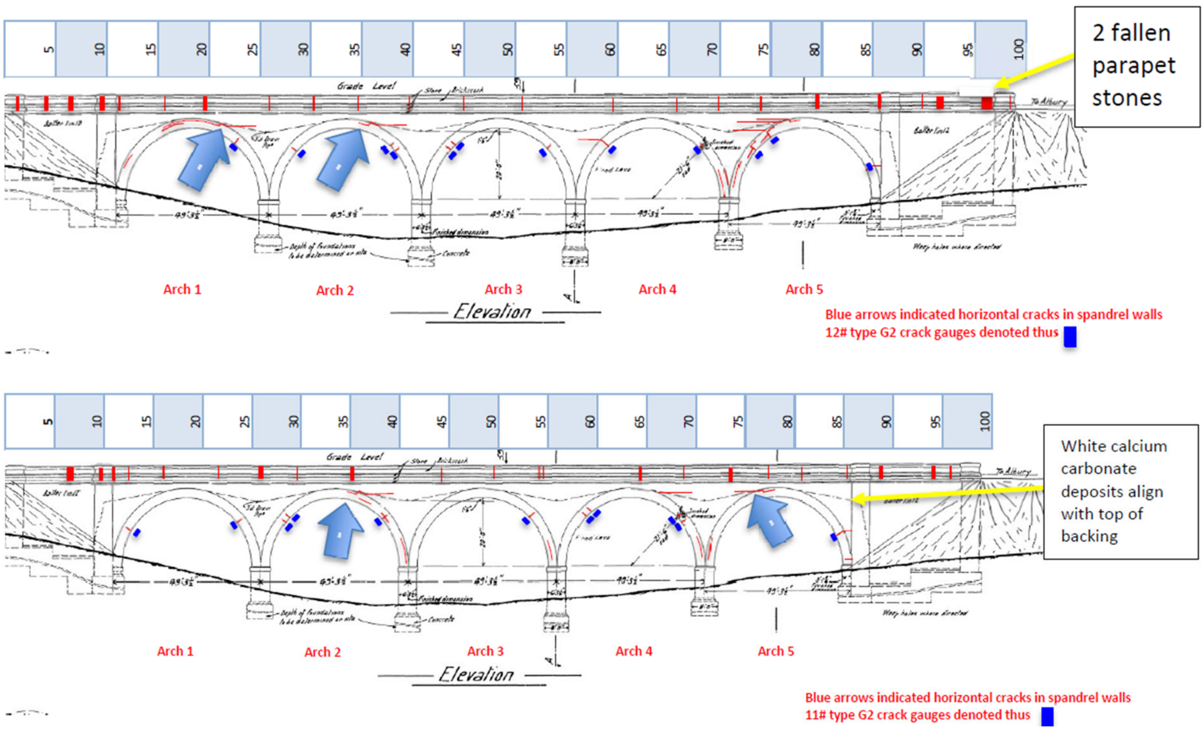

Fig. 3.33 Cracking identified from UAV inspection (JMA, 2022b)

Structural investigation and assessment

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

- The Viaduct has been inspected from ground level and does not appear to be unserviceable.
- Structural assessments for the Viaduct were developed based on the geometry of the structure and material properties gathered from previous investigations of nearby brick arch railway bridges. The analyses included scenarios of valley closure, sideways movement and vertical step displacements and in combination, over and above the 1 in 100 probabilities of exceedance that were provided in the statistical analyses. The structural modelling was built from lessons learnt during the structural assessment for the Picton Viaduct prior to the extraction of Tahmoor LW W3-W4, which was peer reviewed by masonry arch specialist from the United Kingdom, the late Bill Harvey (2021a).
- Whilst the structural modelling found that the structure could remain serviceable if it experienced up to nearly 50 mm of valley closure, it is recommended that longwall mining be controlled so that valley closure does not exceed 20 mm. It is noted that the recommendation could be re-assessed based on actual observations.
- The findings from the structural assessment and peer review for the Picton Viaduct are relevant for the Bargo Viaduct:
  - The structural modelling is limited by the necessary assumption that the structure has been constructed exactly to the design dimensions, with materials that are uniform in nature and condition;
  - In reality, the structure is likely to focus movements where “local properties may control behaviour”, such as weaknesses, defects and locations of weathering. These are difficult to predict ahead of time but can be detected during mining by detailed monitoring.
  - Bill Harvey (2021a) provided many case studies of deformations of masonry arch bridges in the United Kingdom. The case studies demonstrated that bridges of similar form of construction as the Picton Viaduct have previously experienced substantial deformations and remained in serviceable condition.
  - Valley closure was considered to be of most concern to the structure. There is potential for energy to be stored in the Viaduct as valley closure builds up. The stored energy could potentially release, resulting in impacts on rail stress. Following initial release, the Viaduct is expected to experience gradually increasing deformations.
  - The existing cracks in the Viaduct increase the flexibility of the structure and reduce the capacity of the Viaduct to store energy in response to potential future mining-induced

movements. The amount of energy that might be released by a fresh crack is, therefore, reduced.

  - 3-dimensional gauges will be installed to measure movement of the existing cracks.
  - In the unlikely event that valley closure develops, it will be possible to force the valley closure movements to respond in a preferred span. This can be achieved by making a small cut in the mortar across the width of the arch. In this case, Span 5 (country end) would be the preferred span to focus the closure movements due to access.

- Notwithstanding the above, an early warning trigger of 5 mm opening or closure is recommended to be adopted in the Management Plan, as it was for Picton Viaduct, to initiate further inspections and assessments. The recommended trigger level takes into account the uncertainty of whether the Viaduct experienced differential movements during the extraction of previous, closer longwall panels, even though the identified pattern of cracking does not appear to be consistent with previous mining-induced valley closure or transverse shear movements. The trigger level is sufficiently low that response measures can be implemented early before severe impacts develop, to ensure that the Viaduct remains safe and serviceable during and after mining.

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, which was completed in November 2022.

Summary of measures to manage potential impacts on Railway Viaduct over Bargo River

Tahmoor Coal has developed and selected risk control measures in consultation, co-ordination and co-operation with ARTC in accordance with WHS legislation to manage mining-induced changes on the Viaduct 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 Viaduct:

- Continuous GNSS monitoring at two locations at each end of the Viaduct. The two units S11 and S12 have been installed within the railway corridor, where access is available. The locations are shown in Drawing No. MSEC1201-13;
- Absolute 3D of structure on the Viaduct, as shown in Drawing No. MSEC1201-13. The marks have been installed;
- Absolute 3D of ground marks adjacent to the Viaduct, as shown in Drawing No. MSEC1201-13. The marks have been installed. The surveyor has taken care to install the marks on stable ground, noting that some areas contain deep alluvial sand, preventing the installation of stable ground marks. Some marks have been installed on the river bed on the Bargo River, which may be submerged during and after rainfall events;
- Baseline, detailed visual inspections of Viaduct by UAV (complete). A systematic and repeatable methodology has been designed and implemented;
- Baseline measurement of crack gauges by UAV (to be installed prior to 1000 metres of extraction of LW S1A, where access is available. Some gauges may need to be installed via rope access during a ARTC track possession;
- Visual inspections of the Viaduct; and

- Implementation of planned responses, if triggered by monitoring results. These may include:
  - Inspections by structural engineer;
  - Meeting by Bridge Technical Committee to assess the latest results and observations and consider management actions;
  - Additional inspections of crack gauges;
  - Increase monitoring and reporting procedures;
  - Install temporary track strengthening baulk;
  - Force closure to focus in desired Span 5 by diamond saw cut;
  - Repair cracked brickwork;
  - Provide additional support to the arch and parapet walls.
  - Fabricate and erect structural steel supports for the arch;
  - Adjust rail stress;
  - Adjust track geometry; and/or
  - As a last resort emergency response measure, slow or stop the longwall and/or stop trains;

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

The planned control measures can be conducted without approval under the *Heritage Act (1977)* as they involve emergency stabilisation activities / works necessary to secure safety where a structure poses a safety risk to its users or the public. Permanent restoration works would be completed to preserve the appearance of the heritage value of the Viaduct, as recommended by heritage consultant EMM (2021b) and approved by ARTC and government agencies.

3.6.3. Bargo River Road Overbridge (Potter's Cutting)

Description and setting

The Bargo River Road Overbridge spans across the Main Southern Railway at Potter's Cutting at 96.049 km. The 10.6 metre single-span dual lane masonry arch bridge is comprised of 5-course brick arch that is supported by brick abutments that are founded upon and against sandstone, with brick parapet walls. A concrete backing may have been installed behind the face brickwork, based on the observed differences in colour and cracking of the spandrel walls (JMA, 2022c). A photograph of the Overbridge is shown in Fig. 3.34.

Photograph courtesy JMA Solutions (2022c)

Fig. 3.34 Bargo River Road Overbridge (Potter's Cutting)

The overbridge was constructed in 1919 as part of the major duplication of the Main Southern Railway. The Bargo River Road connects the townships of Tahmoor and Couridjah. A photograph of the road pavement over the Overbridge is shown in Fig. 3.35. The brick parapet walls have experienced impacts from vehicle traffic. The cracks have been strengthened with galvanised steel channels, as shown in Fig. 3.36.

Photograph courtesy JMA Solutions (2022c)

Fig. 3.35 Bargo River Road pavement on Overbridge

Photograph courtesy JMA Solutions (2022c) with blue lines where crack gauges are recommended

Fig. 3.36 Steel plates across existing cracks in parapet walls

Previous mining near the Bridge

Tahmoor Mine has extracted around all four sides of the Overbridge, as shown in Fig. 3.37. The closest extracted panel was LW 5, which was 450 metres from the Overbridge. Tahmoor South LWs S1A to S6A are located in the southwest corner of the map below, with the closest distance of 1,995 metres to the Overbridge.

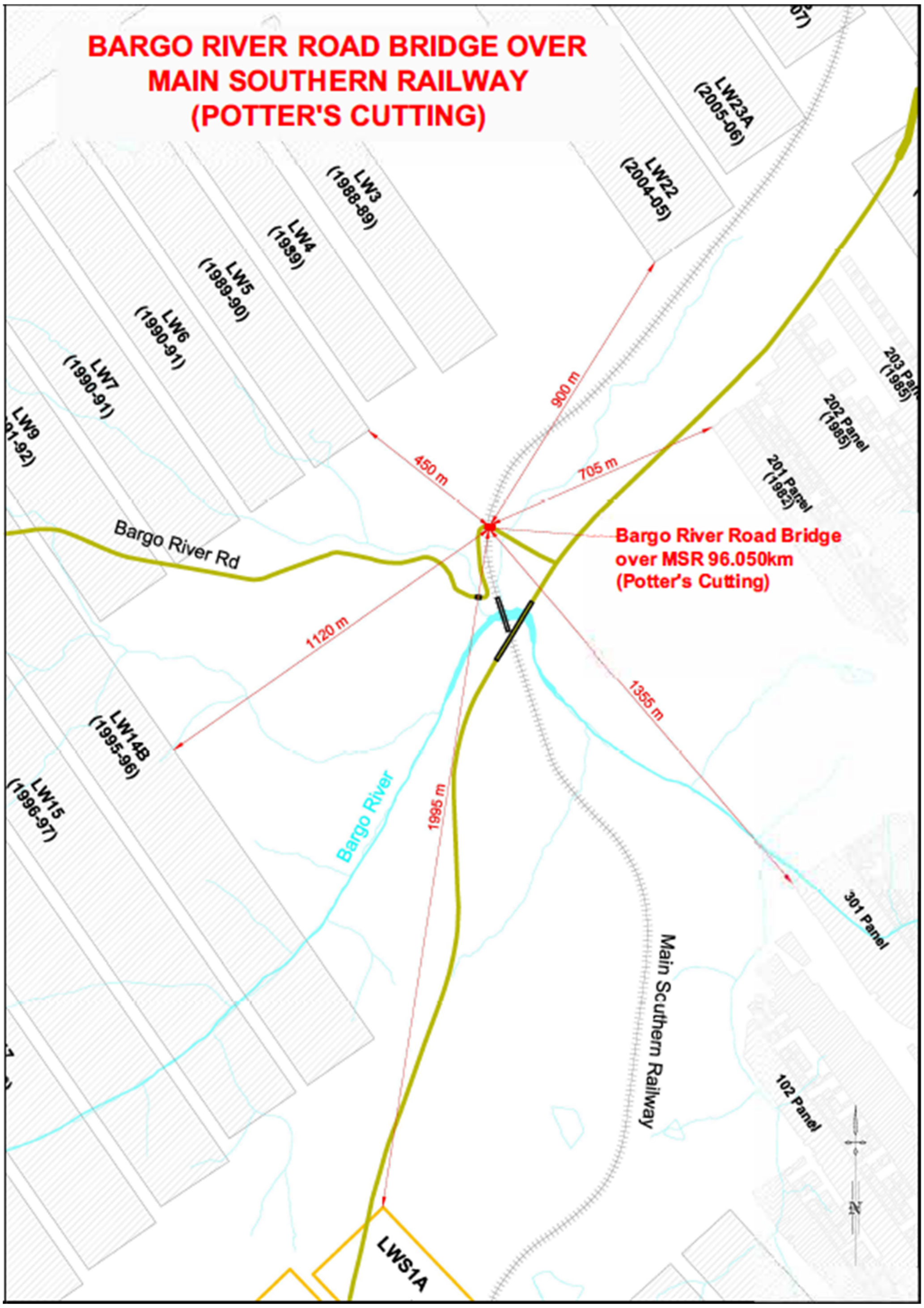

Fig. 3.37 Location of Bargo River Road Overbridge relative to mine layout

Potential historical and future mining-induced movements at the Overbridge

Based on current knowledge, the Overbridge may have experienced absolute and differential far-field horizontal movements during previous mining, and may experience additional movements during the extraction of LWs S1A to S6A.

A statistical analysis of potential absolute far-field horizontal movements is provided in Section 2.8 of this Management Plan, with results relevant to the Overbridge 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 Overbridge

Distance from active longwall (m)	Incremental horizontal movement within 95% confidence level (mm)	Incremental horizontal movement within 99% confidence level (mm)
400 (LWs 3 to 5)	90	120
600 (LWs 6 to 9)	75	100
800 (200 Panels)	60	80
1000 (LWs 14B and 22)	50	65
1200 (300 Panels)	40	50
2000	22	27

A statistical analysis of potential differential far-field horizontal movements is provided in Section 2.8 of this Management Plan, with results relevant to the Overbridge 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 Overbridge

Offset distance from LW (m)	Probability of Exceedance	Incremental differential horizontal movements for pegs spaced between 10 and 30m (mm)		
		Opening (mm)	Closure (mm)	Horizontal mid-ordinate deviation (mm)
400 (LWs 3 to 5)	1 in 20 (0.05)	9	8	9
	1 in 100 (0.01)	17	14	14
600 (LWs 6 to 9)	1 in 20 (0.05)	7	7	9
	1 in 100 (0.01)	14	13	14
800 (200 Panels)	1 in 20 (0.05)	6	6	8
	1 in 100 (0.01)	12	11	13
1000 (LWs 14B and 22)	1 in 20 (0.05)	5	5	7
	1 in 100 (0.01)	10	10	11
1200 (300 Panels)	1 in 20 (0.05)	4	4	6
	1 in 100 (0.01)	8	8	9
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.

The above values are based on confidence levels of 95% and 99%. It is, therefore, likely that the Overbridge previously experienced less than the above-mentioned absolute and differential movements during previous mining. The probability, for example, of the Overbridge previously experiencing the sum total of the values above would be significantly less than 1%.

While surveys were not conducted during previous mining, it is possible to measure the current bridge geometry and assess the existing condition of the Bridge by inspection. This is discussed later in this section.

While the offset distances of LWs S1A - S6A to the Bridge are substantial, there remains a chance that differential far-field movements could adversely affect the Bridge. Tahmoor Coal conducted a geological investigation and the results are provided below.

Geological mapping

Newcastle Geotech (2022b) 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. MSEC1201-01. While the orientation of the structures are aligned with the downstream leg of the Bargo River, they are located away from the Overbridge. The fault structures at seam level, 400 metres below ground, may not necessarily extend to the surface, but even if they did, 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 Overbridge.

- A site inspection at the Overbridge found no obvious evidence of fault structures or dykes directly beneath the Bridge or in the adjacent cutting. A minor low angle discontinuity was observed at 95.960 km (90 m from Bridge) with no evidence of displacement or fracturing along the plan and does not appear to represent a fault structure. A minor low angle discontinuity was observed at 95.750 km, with minor evidence of displacement and localised fracturing, which may comprise a very minor low angle thrust fault structure. These sites are located within the cutting on the Sydney side of the Overbridge.

Bridge condition surveys

The Bargo River Road Overbridge is owned and maintained by Transport for NSW. The Bridge is currently maintained under contract by UGL.

Tahmoor Coal has conducted structural inspections to assess the existing condition of the Bridge. A second purpose of the surveys and inspections is to determine whether the Bridge has experienced lateral or vertical misalignment during the mining of previous longwalls.

- JMA Solutions advises that the Bridge has been inspected from ground level and Elevated Work Platform and appears to be in serviceable condition, with no significant transverse or longitudinal cracking observed across the brick arch and abutments.

- Two areas along the edge of the brick arch gave a slightly drummy report on the sounding hammer but not along the side face of the arch. While no cracks were visible on the face brickwork, it is possible that some delamination is developing.

- Vertical cracking was observed along the internal surface of the parapet walls. The cracks have been reinforced using galvanised steel channels on the Country side and more significant strengthening measures have been applied on the Sydney side. An inclined strut has been installed, bearing against the top of the rock cutting. Opening or closure across the cutting may, therefore, directly impact the parapet support structure. JMA recommends that crack gauges be installed on the parapet walls during the mining of LW S1A-S6A.

Structural investigation and assessment

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

- The Bridge has been inspected and appears to be in a serviceable condition.

- Structural assessments for the Bridge were developed based on the geometry of the structure and material properties gathered from previous investigations of nearby brick arch railway bridges, particularly the Thirlmere Way Underbridge at Picton.

- A targeted structural analysis of the arch has been conducted, using material properties that were sampled and tested from the nearby Thirlmere Way Overbridge at Tahmoor that was built at the same time as the Bargo River Road Overbridge. The structural modelling was built from lessons learnt during the structural assessment for the Thirlmere Way Underbridge at Picton prior to the extraction of LW W3-W4.

- The analysis has identified mining-induced opening or closure across the span of the arch as the primary mechanism that could adversely impact on the structural integrity of the Overbridge, and that the capacity of the arch to accommodate the changes would be reduced if one abutment moved laterally or sideways relative to the other abutment. The structural analysis incrementally applied increasing opening and closure between the base of the abutment walls up to 15 mm of opening and 12 mm of closure, with up to 4 mm sideways shear displacement and found that the Bargo River Road Overbridge would experience cracking but remain serviceable.

- Notwithstanding the above, an early warning trigger of 5 mm opening or closure is recommended to be adopted in the Management Plan, as it was for the Thirlmere Way Underbridge, to initiate further inspections and assessments. The recommended trigger level takes into account the uncertainty of whether the Overbridge experienced differential movements during the extraction of previous, closer longwall panels, even though the identified pattern of cracking does not appear to be consistent with previous mining-induced valley closure or transverse shear movements. The trigger level is sufficiently low that response measures can be implemented early before severe impacts develop, to ensure that the Overbridge remains safe and serviceable during and after mining.

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, which was completed in November 2022.

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

Tahmoor Coal has developed and selected risk control measures in consultation, co-ordination and co-operation with ARTC 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 the Railway Viaduct. GNSS unit S11 is located approximately 250 metres from the Bridge;
- Local 3D surveys of structure and ground marks on the Bridge, as shown in Drawing No. MSEC1201-14, with one mark on the Bridge to be surveyed in Absolute 3D;
- Measurement of crack gauges, as recommended by structural engineer; and
- 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;
    - Install rolled steel reinforcement straps to the underside of the concrete arch;
    - Install mesh to underside of the arch;
    - Install shear reinforcement into brickwork in response to shear movements across the brick arch;
    - Install a temporary support structure within the road pavement to provide temporary support to the arch;
    - Provide additional support to parapet walls;
    - Repair cracked brickwork; and/or
    - 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 Wellers Road Overbridge will not be put at risk due to differential mine subsidence movements due to the extraction of LWs S1A to S6A.

3.6.4. Wellers Road Overbridge

Description and setting

The Wellers Road Overbridge spans across the Main Southern Railway at 101.162 km. The 8.27 metre single-span dual lane masonry arch bridge is comprised of a concrete arch on masonry abutments with masonry vehicle barrier walls. The concrete arch appears to have been reinforced with old steel rails but they have not been exposed to confirm they exist. The concrete arch has, therefore, been conservatively assessed as unreinforced (JMA, 2022d). A photograph of the Overbridge is shown in Fig. 3.38.

Fig. 3.38 Wellers Road Overbridge

The overbridge was constructed in 1919 as part of the major duplication of the Main Southern Railway. The Bridge is listed as an Item of Heritage Significance on the Wollondilly Local Environmental Plan (2011).

A photograph of the road pavement over the Overbridge is shown in Fig. 3.39. The brick parapet walls have experienced impacts from vehicle traffic.

Photograph courtesy JMA Solutions (2022d) with blue lines where crack gauges are recommended

Fig. 3.39 Wellers Road pavement on Overbridge

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Potential future mining-induced movements at the Overbridge

Wellers Road Overbridge is located 370 metres from the commencing end of LW S6A, as shown in Drawing No. MSEC1201-01. The bridge has not experienced mining-induced from previous longwall extraction at Tahmoor Mine.

The bridge is predicted to experience less than 20 mm of conventional subsidence, with negligible tilt, curvature and strain due to the extraction of LWs S1A to S6A.

A statistical analysis of potential absolute far-field horizontal movements is provided in Section 2.8 of this Management Plan, with results relevant to the Overbridge highlighted in Table 3.15.

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 Wellers Road Overbridge

Distance from active longwall (m)	Incremental horizontal movement within 95% confidence level (mm)	Incremental horizontal movement within 99% confidence level (mm)
350 (LW S6A)	100	130

A statistical analysis of potential differential far-field horizontal movements is provided in Section 2.8 of this Management Plan, with results relevant to the Overbridge highlighted in Table 3.16.

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 Wellers Road Overbridge

Offset distance from LW (m)	Probability of Exceedance	Incremental differential horizontal movements for pegs spaced between 10 and 30m (mm)		
		Opening (mm)	Closure (mm)	Horizontal mid-ordinate deviation (mm)
350 m	1 in 20 (0.05)	9	8	9
	1 in 100 (0.01)	17	14	14

While the Bridge is not expected to experience mining-induced movements, there remains a chance that differential far-field movements could adversely affect the Bridge.

Geological mapping

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

- The Bridge is founded on a cutting that is 3 metres high, with approximately 2 m high engineered fill over the crest of the cutting at the bridge abutments.
- The cutting is listed in the ARTC Geotechnical Risk Site database with a very low risk classification of 6 (non-active site).
- A site inspection at the Overbridge found no obvious evidence of current or past cutting instability or fault structures.

Bridge condition surveys

The Wellers Road Overbridge is owned and maintained by Transport for NSW. The Bridge is currently maintained under contract by UGL.

Tahmoor Coal has conducted structural inspections to assess the existing condition of the Bridge.

- Structural inspection by JMA Solutions (2022d), who advises that the Bridge has been inspected from ground level and Elevated Work Platform and appears to be in serviceable condition but cracking is observed on the brick parapet walls. Horizontal bed joint cracks were observed along the parapet walls on the Sydney and Country spandrel wall on the upside, which could be related to transient live load and earth pressure acting against the spandrel walls.
- The concrete arch was tested with 300-400 hammer sounding blows and found to return crisp return sound.
- JMA recommends that crack gauges be installed on the parapet walls during the mining of LW S1A-S6A.

Structural investigation and assessment

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

- The Bridge has been inspected and appears to be in a serviceable condition.
- Structural assessments for the Bridge were developed based on the geometry of the structure and material properties gathered from previous investigations of nearby concrete arch, masonry railway bridges, particularly the former Bridge Street Overbridge at Picton and the Thirlmere Way Overbridge at Tahmoor.
- A targeted structural analysis of the arch has been conducted, using material properties that were sampled and tested from the nearby Thirlmere Way Overbridge at Tahmoor that was built at the same time as the Wellers Road Overbridge. The structural modelling was built from lessons learnt during the structural assessment for the Bridge Street Overbridge at Picton prior to the extraction of LW 28.
- The analysis has identified mining-induced opening or closure across the span of the arch as the primary mechanism that could adversely impact on the structural integrity of the Overbridge, and that the capacity of the arch to accommodate the changes would be reduced if one abutment moved laterally or sideways relative to the other abutment. The structural analysis incrementally applied increasing opening and closure between the base of the abutment walls up to 25 mm of opening and closure, with up to 3 mm sideways shear displacement and found that the Wellers Road Overbridge would experience cracking but remain serviceable.
- Notwithstanding the above, an early warning trigger of 5 mm opening or closure is recommended to be adopted in the Management Plan to initiate further inspections and assessments. The trigger level is sufficiently low that response measures can be implemented early before severe impacts develop, to ensure that the Overbridge remains safe and serviceable during and after mining.

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, which was completed in November 2022.

Summary of measures to manage potential impacts on Wellers Road Overbridge

Tahmoor Coal has developed and selected risk control measures in consultation, co-ordination and co-operation with ARTC 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 the Wellers Road Overbridge (GNSS unit S15);
- Local 3D surveys of structure and ground marks on the Bridge, as shown in Drawing No. MSEC1201-15;
- Measurement of crack gauges, as recommended by structural engineer;
- Visual inspections of the Bridge; and
- 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;
  - Install rolled steel reinforcement straps to the underside of the concrete arch;
  - Install mesh to underside of the arch;
  - Install shear reinforcement into brickwork in response to shear movements across the brick arch;
  - Install a temporary support structure within the road pavement to provide temporary support to the arch;
  - Provide additional support to parapet walls;
  - Repair cracked brickwork; and/or
  - 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 Wellers Road Overbridge will not be put at risk due to differential mine subsidence movements due to the extraction of LWs S1A to S6A.

It is noted that planned measures to control risks to the Bridge will be continuously reviewed during the extraction of LW S1A-S6A. As each longwall progressively extracts closer to the Bridge it will be possible to introduce additional controls if required in the event that unexpected adverse changes are observed.

3.7. Tahmoor Mine overhead coal conveyor 3R

Tahmoor Mine's overhead coal conveyor 3R crosses over the Main Southern Railway near 98.160 km. It is located approximately 450 metres to the side of LW S1A.

The conveyor crosses the Railway at a small cutting and is supported by a series of steel trestle supports, as shown in Fig. 3.40 and Fig. 3.41.

Fig. 3.40 Tahmoor Mine overhead coal conveyor 3R over the Main Southern Railway near 98.160 km

Photograph courtesy Sweeting Consulting

Fig. 3.41 View along Tahmoor Mine overhead coal conveyor 3R over the Main Southern Railway near 98.160 km

The conveyor is predicted to experience approximately 50 mm of vertical subsidence at the railway crossing, with negligible tilts, curvature and strain.

The conveyor and trestle supports have been inspected and assessed by structural engineer JMA Solutions (2022e). The conveyor structure has been assessed using a structural model, where differential ground movements were applied to the structure at increasing amounts beyond the predicted movements, in addition to dead, live and wind loads. It was found that the structure could accommodate closure up to 15 mm before it may reach strength limit state in conjunction with a 500 year return period wind event.

JMA recommends that the structure be monitored during mining and consider implementing the following potential response measures if closure exceeds 10 mm:

- Elongate bolt holes in trestle column baseplates;
- Strengthen trestle columns;
- Install additional cable-stay bracing; and/or
- Erect temporary support structure on the access roadways on either side of railway.

In the worst case scenario, additional temporary supports can be installed adjacent to the existing trestles. A heavy duty propping system has been identified from Shore Hire in south-west Sydney, which is available to be delivered within 48 hours' notice.

Summary of measures to manage potential impacts on Conveyor Crossing

Tahmoor Coal has developed and selected risk control measures in consultation, co-ordination and co-operation with ARTC in accordance with WHS legislation to manage potential mining-induced changes on the Conveyor Crossing due to the extraction of LWs S1A to S6A.

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 Conveyor Crossing:

- Absolute 3D and 2D surveys along the rail corridor;
- Local 3D surveys of marks at the base and top of trestles along Conveyor 3R and mid span over the railway line;
- Automated, continuously operating laser distancemeter across trestles on either side of Main Southern Railway;
- Visual inspections of the Conveyor Crossing; and
- Implementation of planned responses, if triggered by monitoring results. These may include:
  - undertake structural inspection
  - increase monitoring and reporting procedures
  - elongate bolt holes in trestle column baseplates
  - strengthen trestle columns
  - install additional cable-stay bracing
  - erect temporary support structure on the access roadways on either side of railway

With the implementation of the above management strategy, Tahmoor Coal will ensure that the Conveyor Crossing will remain safe and serviceable during the extraction of LWs S1A to S6A even if observed differential subsidence movements are substantially greater than predicted.

3.8. ARTC Signalling and Communications Systems

The ARTC signalling system is controlled remotely by ARTC Train Control at Junee.

Signalling and communications systems that pass through or along the section of the rail corridor were identified and inspected by Signal Support Services. These include:

- Underground copper along the UP side and optical fibre cabling along the DOWN side of the rail corridor; and
- Signals.

Optical Fibre Cable

The optical fibre cable is buried in conduit and is used for CCTV security surveillance. The potential for impacts to the CCTV cable is considered low. Based on previous longwall mining experience, it has been found that optical fibre cables can typically tolerate conventional strains of the magnitudes experienced in the Southern Coalfield at these depths of cover without significant impact. This includes the experience at Tahmoor, where Longwalls 22 to 32 have mined directly beneath the optical fibre cable without any observed impact.

Copper Signal Cable

The insulated direct buried 50 core copper signal cable may be impacted by mining. The consequence of impacts to the signal cable can be extreme if it results in wrong side failure. Wrong side failure could occur if the insulation around the cables breaks, thereby exposing the copper cables and allowing them to cross over.

While there has been little experience of mining beneath the copper signal cable at Tahmoor North (it was a Microlok system), there has been extensive experience of mining directly the copper signal cable during the mining of Appin LWs 703 to 708B. No impacts have been observed on the cable, though insulation resistance tests detected a reduction in performance during the mining of LW 708B.

As part of the investigations and planning for the Appin longwalls, Signal Support Services (SSS, 2010) undertook load testing of the cables. The magnitude of strains required to break the cables was 100 mm/m or more. It was found, however, that when the cables failed, the copper cables remained in their extended state, while in the majority of cases, the insulation sheaths around the cables returned to their near-normal unstrained state, thereby exposing the copper cables. It is therefore possible that Wrong Side Failure could occur as a result of extreme tensile strain.

SSS inspected the buried signal cable on 17 January 2010 and confirmed that the installation method was consistent with the applicable standards at that time. A series of electrical tests (loop resistance and insulation resistance) were conducted on spare cores of the signal cable in accordance with ARTC standard SMP 23. These tests exceed the minimal acceptance standards for newly installed cables.

The information provided by SSS was reviewed by telecommunications expert Colin Dove (2010), who has extensive experience of longwall mining beneath telecommunications cables. Colin Dove advised that the signal cable is roughly equivalent to direct buried copper cables that have previously experienced subsidence movements without impacts in the Southern Coalfield during the mining of Appin LWs 301 and 302, Appin LWs 405 to 409, West Cliff LWs 31 to 33, Tahmoor LWs 20 and 21. These longwalls are of comparable width and depth of cover to the Appin longwalls. A similar direct buried copper cable also experienced subsidence movements without impacts in the Hunter Coalfield during the mining of Beltana LWs WhB1 to WhB5 at depths of cover of approximately 100 metres and observed maximum strains in excess of 10 mm/m over a 10 metre bay length. The subsidence movements at Beltana are substantially greater than those that are expected to generally occur above LW S1A-S6A.

Based on the above information, the probability of Wrong Side Failure as a result of the mining of LW S1A-S6A is considered to be extremely low for the reasons listed below.

- The strains required to break the cables are orders of magnitude greater than the normal range of subsidence strains that are expected to occur during the mining of LW S1A-S6A.
- The cable will be inspected and tested prior to the influence of LW S1A.
- Direct buried copper cables of similar construction have performed satisfactorily during similar and more extreme subsidence events than those expected to occur during the mining of LW S1A-S6A.

It is possible, however, that cable breakages could develop if severe ground deformations occur in the vicinity of the cables, such as ground stepping at a fault, even when the overall ground strains are compressive.

In such situations, however, it is possible to relieve the stress in the cables by exposing them to the surface. This will allow the cables to drape over the ground deformation.

Management measures have been developed in this Management Plan to manage the potential risk of cable breakage. This includes testing of the cables prior to the influence of LW S1A and at the end of each longwall unless triggered by high ground strains. A similar methodology was conducted during the mining of Appin LWs 703 to 708B.

Track Circuits

It is standard railway procedure to bond around rail joints and appropriate bonding will be installed during the installation of the expansion switches. This has been successfully undertaken during the installation of expansion switches at Tahmoor and Douglas Park.

3.9. Other Services

A number of pipelines and cables cross the Main Southern Railway above LW S1A-S6A.

- Sydney Water 450 mm diameter potable water main crossing at 100.40 km
- Telstra optical fibre cable crossings at 99.1 km and 100.98 km

Risks associated with each of these services are being managed separately by Tahmoor Coal in consultation with each of the utility service providers.

The Rail Maintenance Contractor will inspect any utility services that pass within the rail corridor, along with typical rail infrastructure, as part of the standard inspection regime.

4.1. Main Risk Assessment

A risk assessment for the mining of LWs S1A to S6A beneath and adjacent to the railway was conducted in August 2021 via MSTeams, which was facilitated by Hawcroft Miller Swan Consultants (HMS). The risk assessment was built upon the experience gained from the mining of Tahmoor Longwalls 25 to 32 in addition to the experience gained during the mining of Appin Longwalls 703 to 708 and Appin Longwalls 901 and 902.

Details of the methods and results of the risk assessment is provided in a report by HMS (2021). A brief summary is provided below.

The risk assessment was attended by representatives from the following organisations, companies and consultants:

- Australian Rail Track Corporation
- Robinson Rail
- Globetech
- John Matheson & Associates
- Mine Subsidence Engineering Consultants
- Newcastle Geotech
- Pidgeon Civil Engineering
- Bloor Rail
- Tahmoor Coal

The Structures Specialist and Track Specialist from the ONRSR attended the risk assessment as an observer.

The risk analysis was conducted with the purpose of identifying risks associated with the mining of LWs S1A to S6A beneath and adjacent to the Main Southern Railway infrastructure. The risk assessment was conducted in accordance with AS/NZS ISO 31000:2018, using the ARTC Risk Management Procedure, dated 26 May 2016. The risk matrix and definitions are shown in Fig. 4.1.

The risks were assessed taking into account existing and planned controls. A summary of these results are provided in Table 4.1. These results are used as a basis for the development of risk control procedures, which are provided in Chapter 4. The risks were ranked as Low (L), Medium (M), High (H) or Very High (VH).

	Risk Category	Consequence				
Safety category is focussed on Impact to People	S: Safety	No Medical Treatment Required	Lost Time Injury Results (LTI) OR Medical Treatment Required	Serious Injury Occurs	Single Fatality Occurs	Multiple but Localised Fatalities Occur
Asset category is focussed on Operations Impact, Track, Systems (Hardware & Software) and Human Assets	A: Assets	<6hrs Track Closure	>6hrs but <24hrs Track Closure	>24hrs but <48hrs Track Closure	>48hrs but <5 Days Track Closure	>5 Days Track Closure
Focussed on Financial Impact Cash flow, liquidity, Capital, Asset Value, Procurement & Contracts related exposure	F: Financial	<$250K	>$250K but <$2M	> $2M but <$10M	>$10M but <$50M	>$50M
Focussed on Environment Impact Heritage, Flora & Fauna, Archaeology & Indigenous, Pollution and Amenity (Public)	E: Environment	Contained Environmental Damage - fully recoverable (no cost or ARTC action required)	Isolated Environmental Damage - minimal ARTC remediation required	Localised/Clustered Environmental Damage - requiring remediation	Considerable Environmental damage - requiring remediation	Widespread long term or permanent damage to the environment - remediation required
Focussed on Regulatory/Legislation Exposure Non-compliance & Our Licence to Operate	R: Regulatory	Minimal or no Regulatory involvement	Notice to Produce Information	Improvement Notice or Threatened Action	Prohibition Notice or Fine/s	Prosecution of the company and/or its office holders
Focussed on Reputational Exposure Customer Dissatisfaction, Shareholder Support, Service Quality & Reliability, Public Image and Stakeholder Attitudes	R: Reputation	Isolated event able to be resolved [<7Days]	Management intervention required [>7days but <3mths]	Tactical (Business Unit / Divisional) intervention required [>3 months but <18mths]	Strategic intervention required [>18mths but <3years]	Corporate Loss of Shareholder and/or Customer support (tangible business impact) >3years
	Descriptor	*Not Significant*	*Minor*	*Moderate*	*Major*	*Extreme*

Likelihood Description	Frequency of Occurrence	Descriptor	Level	1	2	3	4	5
Is expected to occur in most circumstances	Once per month	*Almost Certain*	A	MED - 1A	MED - 2A	HIGH - 3A	V HIGH - 4A	V HIGH - 5A
Will probably occur in most circumstances	Between once a month and once a year	*Likely*	B	LOW - 1B	MED - 2B	HIGH - 3B	V HIGH - 4B	V HIGH - 5B
Might occur at some time	Between once a year and once in five years	*Possible*	C	LOW - 1C	LOW - 2C	MED - 3C	HIGH - 4C	HIGH - 5C
Could occur at some time	Between once in 5 years and once in 20 years	*Unlikely*	D	LOW - 1D	LOW - 2D	LOW - 3D	MED - 4D	MED - 5D
May occur in exceptional circumstances	Once in more than 20 years	*Rare*	E	LOW - 1E	LOW - 2E	LOW - 3E	LOW - 4E	MED - 5E

Source: HMS (2021)

Fig. 4.1 ARTC Risk Matrix and Definitions

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Table 4.1 Summary of Risk Assessment

Aspect, Consideration Risk Issue	Potential Consequence Description	Consequence	Likelihood	Level of Risk
Track Geometry and Rail Stress				
Changes to track geometry (vertical and horizontal misalignment, changes in track cant, track twist) due to subsidence, and/or deteriorating condition of track from non-mining causes, and/or step displacement across a fault structure in rock formation	Track Closure	Not significant	Rare	Low
Changes to rail stress leading to broken rail or buckle due to subsidence causing excessive compressive or tensile stress and/or poor track stability	Track Closure	Not significant	Rare	Low
Changes to track centres, clearances between track and clearances to structures (vertical and horizontal misalignment, changes in track cant, track twist) due to subsidence adversely affecting track geometry and/or deteriorating condition of track from non-mining causes, and/or step displacement across a fault structure in rock formation	Unplanned intervention on track	Not significant	Rare	Low
Changes to Tahmoor Colliery railway loop due to excessive compressive or tensile stress or poor track stability	Unplanned maintenance response	Not significant	Rare	Low
Tahmoor Coal Conveyor over rail due to loss of integrity of conveyor gantry structure due to mining-induced ground movements	Unplanned maintenance response	Minor	Rare	Low
Tahmoor Coal rail balloon loop road bridge over track due to loss of integrity of Amco tunnel structure due to mining-induced ground movements	Unplanned maintenance response	Minor	Rare	Low

Aspect, Consideration Risk Issue	Potential Consequence Description	Consequence	Likelihood	Level of Risk
Structures, cuttings, embankments and culverts				
Cracking of brick arch culverts at 98.445 km, 98.739 km, 99.035 km, 99.384 km, 100.130 km, 100.425 km, 101.000 km, 101.470 km and 101.920 km due to loss of integrity, leading to changes in track geometry and unplanned intervention	Speed restrictions Track closure Blockage of water way causing flooding Sinkhole undermining track Erosion Damage to culvert	Not significant	Rare	Low
Failure of embankments at 98.380 km to 98.500 km 98.700 km to 98.770 km 99.000 km to 99.050 km 99.250 km to 99.400 km 100.020 km to 100.220 km 100.400 km to 100.500 km leading to loss of track support and changes in track geometry	Speed restrictions Track closure Erosion	Not significant	Rare	Low
Blockage of cess drainage at cuttings at 98.000 km to 98.250 km 98.530 km to 98.650 km 98.800 km to 98.950 km 99.150 km 99.550 km to 99.850 km 100.250 km to 100.350 km 100.500 km to 100.850 km due to debris falling into cess	Unplanned maintenance response	Not significant	Rare	Low
Wellers Road Bridge at 101.162 km – due to impacts on bridge serviceability	Speed restrictions Road traffic control Unplanned maintenance response	Not significant	Rare	Low
Railway Viaduct over Bargo River 96.265 km (far-field effects)	Speed restrictions to allow bridge repairs	Not significant	Rare	Low
Remembrance Drive Bridge over rail 96.400 km (far-field effects)	Speed restrictions to allow bridge repairs	Not significant	Rare	Low
Signalling and Communications				
Damage to optic fibre cable due to extreme differential movement	Loss of security monitoring Lack of train information service Lack of other commercial use	Not significant	Rare	Low
Damage to direct buried cables due to extreme differential movement	Signal failure leading to train collision	Major	Rare	Low

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4.2. Consequence of Derailment

It can be seen from Table 4.1 that track closure was assessed to be the potential consequence for risks associated with impacts on track geometry and rail stress. The assessments were ranked with risk controls in place, which have been "proven over time".

The management measures described in this Management Plan have been developed to manage all potential impacts on the operation of the railway, including the potential for a high speed derailment. This includes the introduction of a temporary speed restriction at any time during mining, even before a trigger is reached. It is noted that, upon review of these management measures, the risk assessment workshop team determined that each identified risk leading to a potential consequence of derailment had been reduced to an SFAIRP level ("So Far As Is Reasonably Practicable").

4.3. 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 2, which could rise to risks to health and safety of people in the vicinity of the Main Southern Railway.

Mine subsidence hazards have been identified, investigated and analysed in a systematic manner by examining each aspect of the infrastructure, as described in Sections 3.1 to 3.9 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.

- Track geometry
- Rail stress
- Track expansion system
- Culverts and embankments
- Cuttings
- Bridges
- Signalling and Communications

The following mine subsidence hazards were identified that could give rise to risks to health and safety due to the extraction of LW S1A-S6A.

- Adverse changes in track geometry leading to derailment
- Adverse changes in rail stress leading to buckling of track or rail break, leading to derailment
- Failure of expansion switch, leading to derailment
- Failure of culverts, leading to loss of track support
- Failure of embankments, leading to loss of track support

The identification and risk assessment process took into account the location of infrastructure relative to LW S1A-S6A and the associated timing and duration of the subsidence event, as described in Section 2.6 of this Management Plan.

In the relation to the extraction of LW S1A-S6A, there is a reasonable potential to result in multiple deaths in a single incident on the Main Southern Railway unless the risks are managed and controlled effectively. The hazards are therefore identified as Principal Mining Hazards, as defined in Clause 5(i) of Part 1 of the *Work Health and Safety (Mines and Petroleum Sites) Regulation 2014.*

Whilst mine subsidence predictions and extensive past experiences from previous mining at Tahmoor Coal 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 railway infrastructure, as discussed in Section 1.6 and Chapter 2 of this Management Plan. In this case, creeks and geological structures have been mapped that intersect railway infrastructure.

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 in the vicinity of the Main Southern Railway. These are described in Chapter 5 of this Management Plan.

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5.1. Roles and Responsibilities

5.1.1. ARTC Manager – Ingleburn

The ARTC Manager – Ingleburn Is responsible for taking the necessary actions required to manage the potential for impacts to ARTC infrastructure due to the development of mine subsidence movements.

5.1.2. ARTC Train Control - Junee

The ARTC Train Control – Junee is responsible for controlling the passage of trains along the Main Southern Railway and recording track protection activities. There is a routine communication protocol between the ARTC Ingleburn, ARTC Train Control and qualified track certifiers. All rail traffic management activities required to address the potential impacts of mine subsidence will be undertaken in accordance with this communication protocol.

5.1.3. Rail Maintenance Contractor

Tahmoor Coal has appointed Bloor Rail as its self-performing operator to act as its Rail Maintenance Contractor (RMC). The RMC acts as the site safety manager for the section of rail corridor that will be affected by mine subsidence during the mining of each longwall.

The Rail Maintenance Contractor is responsible for:

- Assessing and certifying of track within the affected area;
- Coordinating responses to issues that occur on site, whether they are mining or non-mining related, including reporting and closing out of alarms;
- Ensuring that site work is undertaken safely in the accordance with relevant OH&S legislation and ARTC Network rules and procedures by its employees and other contractors working for Tahmoor Coal on site;
- Undertaking track-related work; and
- Direct point of contact to ARTC for rail maintenance.

Tahmoor Coal Safeworking Interface to ensure Rail Safety from Mining Operations

Status

Tahmoor Coal Mining provides mitigation and monitoring of the rail corridor rail assets to facilitate longwall mining under and near ARTC Main Southern Rail Corridor. Tahmoor Coal mining operation is an Integrated 3rd Party relationship, where Tahmoor Coal through the Rail Management Group maintain rail integrity during and after mine subsidence induced movements.

The Track Expansion Switch System installation, mitigation and monitoring is conducted under the current 2012 Deed of Agreement between Tahmoor Coal and ARTC. Under this Deed, Tahmoor Coal is responsible for maintaining rail safety within a defined area during active subsidence from longwall mining.

The mining process will directly affect ARTC assets with potential to change track geometry and track adjustment as the ground is subsided while the longwall moves under the Main Southern Rail Line

Given this unique arrangement, having unfettered track access is a primary requirement for Tahmoor Coal to operate and ensure rail safety, so that the commitments described under this management plan can be implemented effectively.

Tahmoor Coal have experienced, specialist companies contracted to provided quality service in accordance with the Deed. Tahmoor Coal has been mining under the Main Southern Railway without incident for 14 years and with very minimal disruption to ARTC rail operations.

ARTC has recently introduced significant changes to safeworking arrangements, which are called 3rd Party Processes. Tahmoor Coal recognises that these changes are important to ARTC's general safe-working management.

This section of the Management Plan describes how Tahmoor Coal, as an integrated process, will continue to maintain the asset and install mitigation measures, as prescribed under the Management Plan and the Deed.

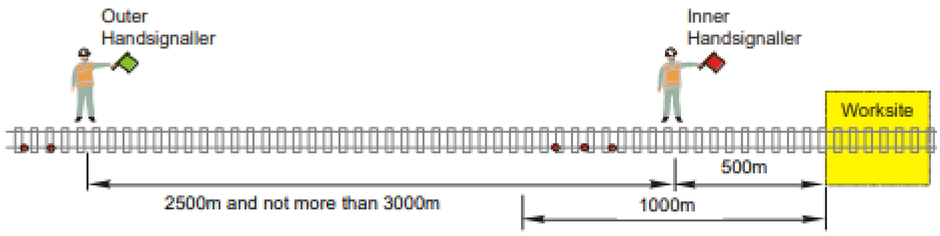
Safeworking Arrangements

Tahmoor Coal will work under the current ARTC rules and procedures as published and will utilise higher levels of Safeworking to complete tasks within the rail corridor.

Tahmoor Coal will complete all major component installations within the Config 14 Possessions, when there are extended periods of time where no trains are operating.

Tahmoor Coal, when working on track outside possession will operate, when possible, under Track Work Authority (TWA) on both the Up and Down mains to complete activity on the track. Tahmoor Coal will ensure ATP (As Traffic Permits) working and allow train flow to continue without delay. A diagram demonstrating the TWA arrangements is shown in Fig. 5.1.

Figure ANPR 702-1



Protecting a worksite using Handsignallers only

Fig. 5.1 Track Work Authority (TWA) arrangements

As Tahmoor Coal's longwall mining processes have the potential to change track geometry on a daily or weekly basis, emergency responses may also be required.

Other tasks within the rail corridor will use ARTC Safeworking rules to suit the task being performed.

- ASB – Inspections
- WIC – Survey works

Corridor Access Authority (CAA) process to arrange Access work orders

Tahmoor Coal will continue to use the current contracted resources, which are proven and highly experienced in operating in the high trafficked area between Picton and Mittagong to meet the obligations of the Management Plan and ensure rail safety.

Tahmoor Coal has appointed Southern Rail Services as a self-performing operator to conduct off track surveys within the rail corridor.

Given the unique situation of mine subsidence, Tahmoor Coal will continue to operate as described above to ensure that it can manage potential risks to rail safety, as described in this Management Plan.

5.1.4. Track Certifier

As part of the Rail Maintenance Contractor's obligations, it will provide a Track Certifier who is qualified to certify the track and railway structures. The RMC Track Certifier is responsible for:

- Visual inspections of track and structures within the rail corridor, including railway structures;
- Assessing and certifying the track;
- Undertaking manual track geometry measurements using standard ARTC methods, if required;
- Direct point of contact with ARTC Area Manager (Ingleburn) and Train Control at Junee, and Tahmoor Coal Control Centre.

ARTC may directly implement speed restrictions or stop trains. The RMC Track Certifier also has authority to take these actions. Communications with ARTC Train Control and ARTC Ingleburn will be conducted via the RMC Track Certifier.

The RMC Track Certifier will implement an action (such as a corrective action, or a speed restriction or stop trains) based on the following:

- Observations or measurement of a track exceedent; or
- Instructions from the RRG and/or RSRG; or
- Instruction from ARTC.

5.1.5. Rail Management Group (RMG)

The RMG is responsible for taking the necessary actions required to manage the risks that are identified from monitoring of the rail infrastructure. Members of the RMG include:

- ARTC Manager – Ingleburn
- ARTC Property Manager Wagga Wagga
- Tahmoor Coal Project Manager
- Bloor Rail (Rail Maintenance Contractor, RMC)
- Globetech (Automated Monitoring Contractor for track)
- Newcastle Geotech (geotechnical engineer)
- Graeme Robinson (Project Manager);
- JMA Solutions (structural engineer)
- Mine Subsidence Engineering Consultants (subsidence engineer);
- Pidgeon Civil Engineering (rail engineer);

MSO, ONRSR and Subsidence Advisory NSW may participate in Rail Management Group meetings as observers.

The RMG will meet in person or via teleconference at regular intervals during mining. The RMG will review the monitoring results and consider whether any additional actions are required.

The purpose of the reviews are to:

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

5.1.6. Rail Response Group (RRG)

Some members of the RMG are required to respond to alarms that are notified automatically from the electronic monitoring system for the railway track when monitoring results exceed pre-defined triggers. These members form a group called the Rail Response Group (RRG) and are "on call" at all times during the monitoring period. The members of the RRG are shown in Table 5.1.

Table 5.1 Members of the RRG

Member	Notification of Exceedence of Trigger Level			
	GREY	BLUE	YELLOW	RED
Bloor Rail (Rail Maintenance Contractor)	✓	✓	✓	✓
Track Certifier	✓	✓	✓	✓
Globetech (Automated Monitoring Contractor)	✓	✓	✓	✓
ARTC Area Manager – Ingleburn	✗	✗	✓	✓
Tahmoor Coal	✗	✗	✓	✓
Pidgeon Civil Engineering	✓	✓	✓	✓
Graeme Robinson (Project Manager)	✓	✓	✓	✓

Alarms will automatically be notified to all members of the RRG as per Section 6.2. Contact details for RRG members and their alternate contacts are provided in Chapter 9.0 .

The RRG will meet via teleconference using a dedicated, pre-arranged service. Should one of the nominated members of the RRG not respond to the nominated alarm, the member can be contacted directly from the teleconference. If, upon assessment of the monitoring information available, the RRG decides to initiate an immediate speed restriction, the Track Certifier or ARTC Area Manager – Ingleburn will notify ARTC Train Control – Junee.

PCE is responsible for keeping a register of all alarms received (whether by automated monitoring systems, ground monitoring systems or visual inspections) and closing out of all alarms.

5.1.7. Rail Structures Response Group (RSRG)

Some members of the RMG are required to respond to alarms that are notified automatically from the electronic automated monitoring system for railway structures when monitoring results exceed pre-defined triggers. These members form a group called the Rail Structures Response Group (RSRG) and are "on call" at all times during the monitoring period. The RSRG has been introduced to provide clarity among members of the RMG with respect to responsibilities upon notification of alarms relating to railway structures.

The members of the RSRG are shown in Table 5.2.

Table 5.2 Members of the RSRG

Member	Notification of Exceedence of Trigger Level	
	GREY alarm (Data Loss)	Crest extensometers
Bloor Rail (Rail Maintenance Contractor)	✓	✓
Track Certifier	✓	✓
Globetech	✓	✓
ARTC Area Manager – Ingleburn	✗	✓
Tahmoor Coal	✗	✓
Pidgeon Civil Engineering	✓	✓
Graeme Robinson (Project Manager)	✓	✓
Newcastle Geotech	✓	✓

Alarms will automatically be notified to all members of the RSRG as per Section 6.2. Contact details for RSRG members and their alternate contacts are provided in Chapter 9.0 .

The RSRG will meet via teleconference using a dedicated, pre-arranged service. Should one of the nominated members of the RSRG not respond to the nominated alarm, the member can be contacted directly from the teleconference. If, upon assessment of the monitoring information available, the RSRG decides to initiate an immediate speed restriction, the Track Certifier or ARTC Area Manager – Ingleburn will notify ARTC Train Control – Junee.

As for the RRG, PCE is responsible for keeping a register of all alarms received in relation to railway structures and closing out of all alarms.

5.1.8. Alternative contacts

All members of the RMG, RRG and RSRG have provided alternative contacts during the mining period. The alternative contacts can be contacted should the primary contact be unavailable.

Members of the RMG may arrange substitutes to attend RMG meetings on their behalf.

5.1.9. Tahmoor Coal Control Centre

The Tahmoor Coal Control Centre (TCC) will make sure the Track Certifier has received notification of alarm and are acting on it. The list of contacts will vary, depending on the nature, type and severity of the alarm. If the TCC cannot contact the Track Certifier, the operator will follow a pre-arranged contact list of back-up representatives.

5.2. 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.
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 3.1 to Section 3.9. 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-S6A.

5.3. Selection of Risk Controls for Railway Infrastructure

Based on the above assessments, Tahmoor Coal considered Method A and Method B risk control measures, in accordance with the process described in Section 5.2.

Elimination

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

Substitution

The following Substitution Controls have been identified and selected that will change the environment so the hazards could be substituted for hazards with a lesser risk.

Rail stress

- Installation, monitoring and adjustment of a Track Expansion System.

Culverts and embankments

- Installation of a track baulk above the culverts.

Isolation

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

Engineering Controls

The following Engineering Controls have been identified and selected to prevent or minimise risks.

Track geometry

- Baseline assessment of the condition of track geometry and undertaking adjustments where required to within operating tolerances
- Storage of ballast on site at the Tahmoor Mine junction to reduce the response time to undertake contingency response measures in the event that monitoring detects the early signs of adverse changes in track geometry.

Rail stress

- Baseline assessment of Stress Free Temperature in sections of track that are located outside the limits of the Track Expansion system for each longwall, which will be managed as continuously welded rail (CWR) track and undertaking adjustments where required so that SFT is within operating tolerances.

Railway cuttings

- Remove fallen material from the cess of cuttings.

Culverts and Embankments

- De-vegetation of the embankment batters and maintain culverts to keep them free flowing and facilitate monitoring of the embankments and culverts.
- Seal gap between the brick arch culvert headwall and concrete pipe extension on the Down side of Culvert at 99.035 km and repair sinkhole prior to influence of LW S1A.
- Reinstate concrete outlet pipe to Culvert at 99.338 km prior to influence of LW S3A.
- Seal gap between the brick arch culvert headwall and concrete pipe extension on the Down side of Culvert at 100.121 km prior to influence of LW S4A.

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 health and safety of people in relation to mining-induced damage to railway infrastructure.

- Implementation of a Monitoring Plan and Trigger Action Response Plan (TARP)
  As described in the Management Plan, Tahmoor Coal and ARTC 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 safety and serviceability develop.

  Monitoring measures are described in Section 5.5. Trigger levels are described in Section 5.6. Planned responses are described in 5.7. Risk control procedures (TARP) are described in Section 5.11 and Table A.1 in Appendix A.

5.4. Managing the Main Southern Railway in Stages during mining

The method of managing potential impacts on the Main Southern Railway can be broadly defined by three stages of subsidence development:

- Stage 1 – Early subsidence period, when the longwall face commences and approaches the railway.
- Stage 2 – Active subsidence period, when the longwall face is mining directly beneath the railway and is moving away.
- Stage 3 – Post-active subsidence period, when the longwall face moves away from the railway such that rates of change have reduced to low levels, the chance of new unexpected severe impacts developing at the railway is extremely low, and monitoring and management measures can be reduced accordingly.

A conceptual diagram of the three stages of managing rail stress is shown in Fig. 5.2.

Stage 1 (nominally from when the longwall face approaches to within 400 m of each section of railway track until longwall face approaches to within 200 m of each section of railway track)

As the longwall approaches the railway track, the installation and commissioning of the track expansion system and monitoring system will be undertaken and completed in accordance with ARTC standards and procedures for similar type components.

At this stage of mining, the magnitude and rates of change in subsidence movements are expected to be small. It is feasible to manage rail stresses in standard CWR track at this stage. Manual monitoring measures such as ground surveys and visual inspections will commence at an early stage of mining to establish baseline readings and detect the development of any irregular subsidence movement. The measures progressively increase in frequency as the longwall face approaches the track.

The timing and frequency of management and monitoring measures are described in Appendix A.

Alarms from the automated monitoring system are not required at this stage as the rates of change are small and urgent response is not required. If increased or irregular subsidence movements are detected, the frequency of monitoring measures can be increased or the automated monitoring system can be programmed to automatically send alarms to the RRG and/or RSRG.

Stage 2 (nominally from when longwall face approaches to within 200 m of each section of railway track until longwall face has passed each section of track by more than 400 m)

The majority of subsidence movements develop along the railway during this stage of mining and the full range of planned management and monitoring measures will be undertaken during this period. This includes the use of the track expansion system to dissipate mining-induced rail stress into the expansion switches. Alarms are automatically issued by the automated monitoring system during this stage.

The timing and frequency of management measures are described in Appendix A. In the case of LW S4A-S6A, the Railway is located near the commencing end of the longwall panels. A GNSS unit will be placed at approximately 100.6 km, which is located approximately 100 metres from the start position of the longwalls. Stage 2 will commence when 20 mm of vertical subsidence is measured by the GNSS unit, or the length of the extraction of LW S4A, S5A or S6A exceeds 200 m, whichever occurs first.

Stage 3 (nominally after the longwall face has passed each section of track by more than 400 m)

At this stage of mining, the longwall face has moved away from the railway such that rates of change have reduced to low levels, and the chance of new unexpected severe impacts developing at the railway is extremely low, and monitoring and management measures can be changed. At the depths of cover at Tahmoor Coal, this typically occurs when the longwall face moves away from a site by a distance of more than 400 metres.

At some point in time during this stage, it will become feasible to manage rail infrastructure in standard CWR track. The following changes to management and monitoring measures may be undertaken during Stage 3:

- The removal of zero toe load clips and reinstatement of standard resilient fastenings to reduce wear on the expansion switches and reduce the potential for exceedences of switch displacement triggers due to seasonal changes in temperature.
- The removal of expansion switches during a scheduled ARTC possession, though they may be left dormant, in place for use during the extraction of the next longwall.
- The removal of track baulks above culverts.
- Progressive reduction in monitoring and inspection frequencies and extents for the railway track, embankments, culverts, cuttings or bridges.
- Progressive disabling of automatically issued alarms from the automated monitoring system.

The changes described above may be undertaken in accordance with this Management Plan if the three criteria are met:

- The longwall face has moved away from the section of track targeted for change by a distance of more than 400 metres, or more than one month has passed after longwall extraction has finished.
- Based on an assessment of actual monitoring data available, the Rail Management Group (RMG) advises that the rates of change in subsidence have reduced to sufficiently low levels such that rail infrastructure can be managed with the changes in place without unacceptably impacting on ARTC's rail operations during the continued extraction of the longwall. The consideration will take into account the observed rates of change in subsidence and condition of the railway track or associated infrastructure, and position of the longwall relative to the railway.
- ARTC agrees to the proposed change either during an ARTC / Tahmoor Coal governance meeting as recorded by minutes of the meeting and reconfirmed separately in writing or email, as described in Section 1.12.

MSO and ONRSR will be informed of the change separately in writing or email. The notification will describe what changes have or will be undertaken to management measures and/or monitoring measures.

In relation to rail stress, it is noted that the Stage 3 change only relates to the method by which rail stresses will be managed. It represents a change from the use of a track expansion system to dissipate rail stress, to the standard method of managing CWR track. Adjustments can be made to CWR track to reset the stress free temperature so that they can accommodate additional subsidence movements during normal train operations. These adjustments can made be in advance and made multiple times, if required. The Management Plan already includes trigger levels and planned responses for managing rail stresses in CWR track, where the Yellow and Red trigger levels are the same as for track within the track expansion system. The changes will be governed by these triggers and planned responses.

If unexpected adverse movements develop at a section of track after Stage 3 criteria have been met, the Rail Management Group will consider whether additional management or monitoring measures are required. This may include reinstating Stage 2 management and/or monitoring measures.

Progressive migration of three stages during mining

As mining progresses, management and monitoring measures for each section of track or associated rail infrastructure will progressively migrate from Stage 1 to Stage 2 and, subject to authorisation by ARTC, Stage 3. Examples of the progressive migration of the three stages are provided in Fig. 5.3 and Fig. 5.4.

The timing of commencement and initial monitoring extent for each measure is defined in Appendix A.

It is noted that the longwalls are oriented relative to the track such that the longwall face will have passed some sections of the track before Stage 1 or 2 subsidence management commences, as illustrated in Fig. 5.3 and Fig. 5.4. These sections of track are located to the side of the active longwall, where the magnitude and rates of change in subsidence are expected to be very small. If increased or irregular subsidence movements are detected, Stage 2 subsidence management can be brought forward.

STAGE	STAGE 1 EARLY SUBSIDENCE	STAGE 2 ACTIVE SUBSIDENCE	STAGE 3 POST-ACTIVE SUBSIDENCE
ACTIVITIES	COMMISSION SYSTEM BASELINE READINGS EARLY SUBSIDENCE MONITORING	FULL RANGE OF SUBSIDENCE MANAGEMENT ACTIVITIES	DECOMMISSION SYSTEM TRACK TRENDS AND FORECAST ISSUES PREPARE FOR NEXT LW
DOCUMENTATION	DEFINED IN SUBSIDENCE MANAGEMENT PLAN	DEFINED IN SUBSIDENCE MANAGEMENT PLAN	DEFINED DURING STAGE 3, BASED ON ASSESSMENT BY RMG OF ACTUAL OBSERVATIONS

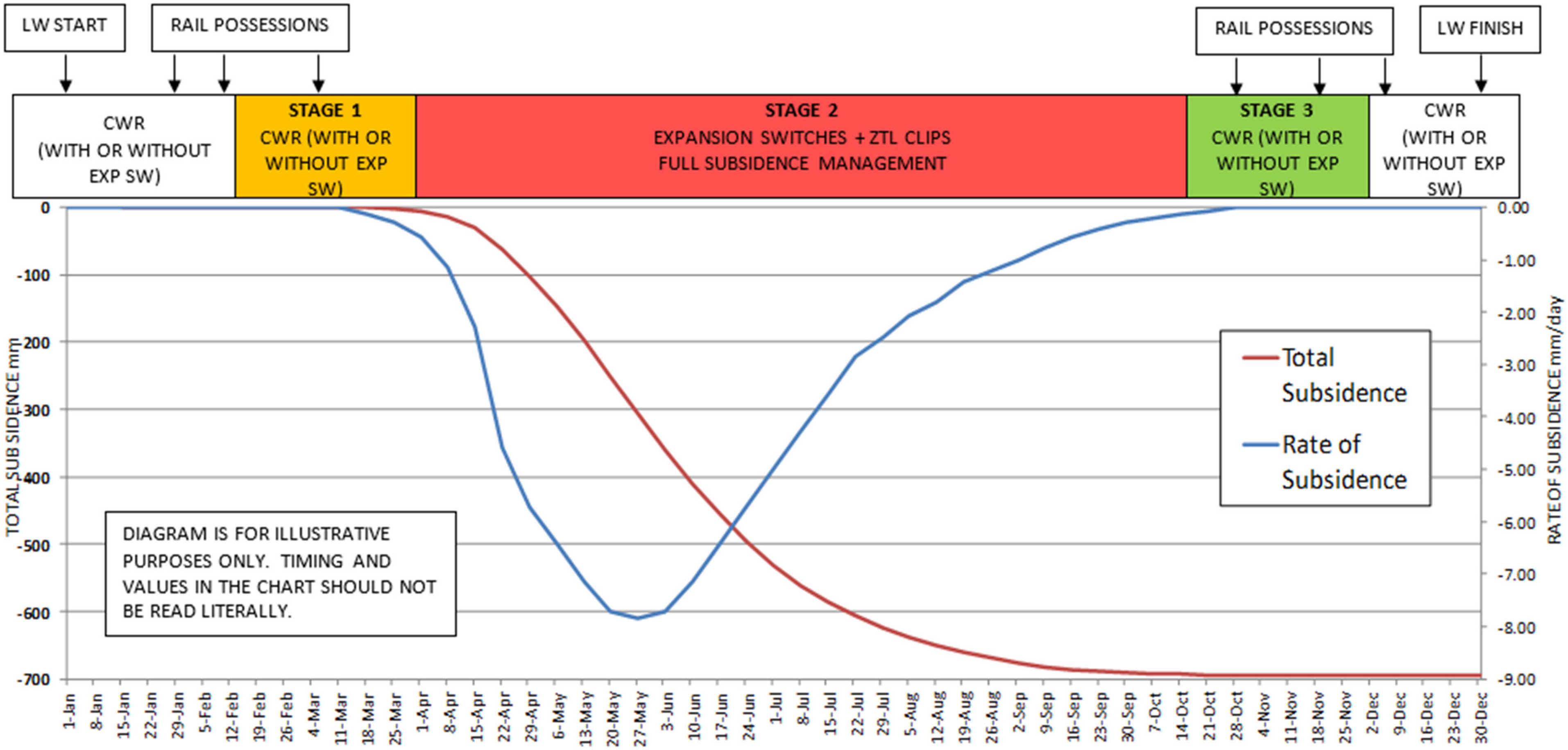


Fig. 5.2 Conceptual diagram showing stages of rail stress management during mining

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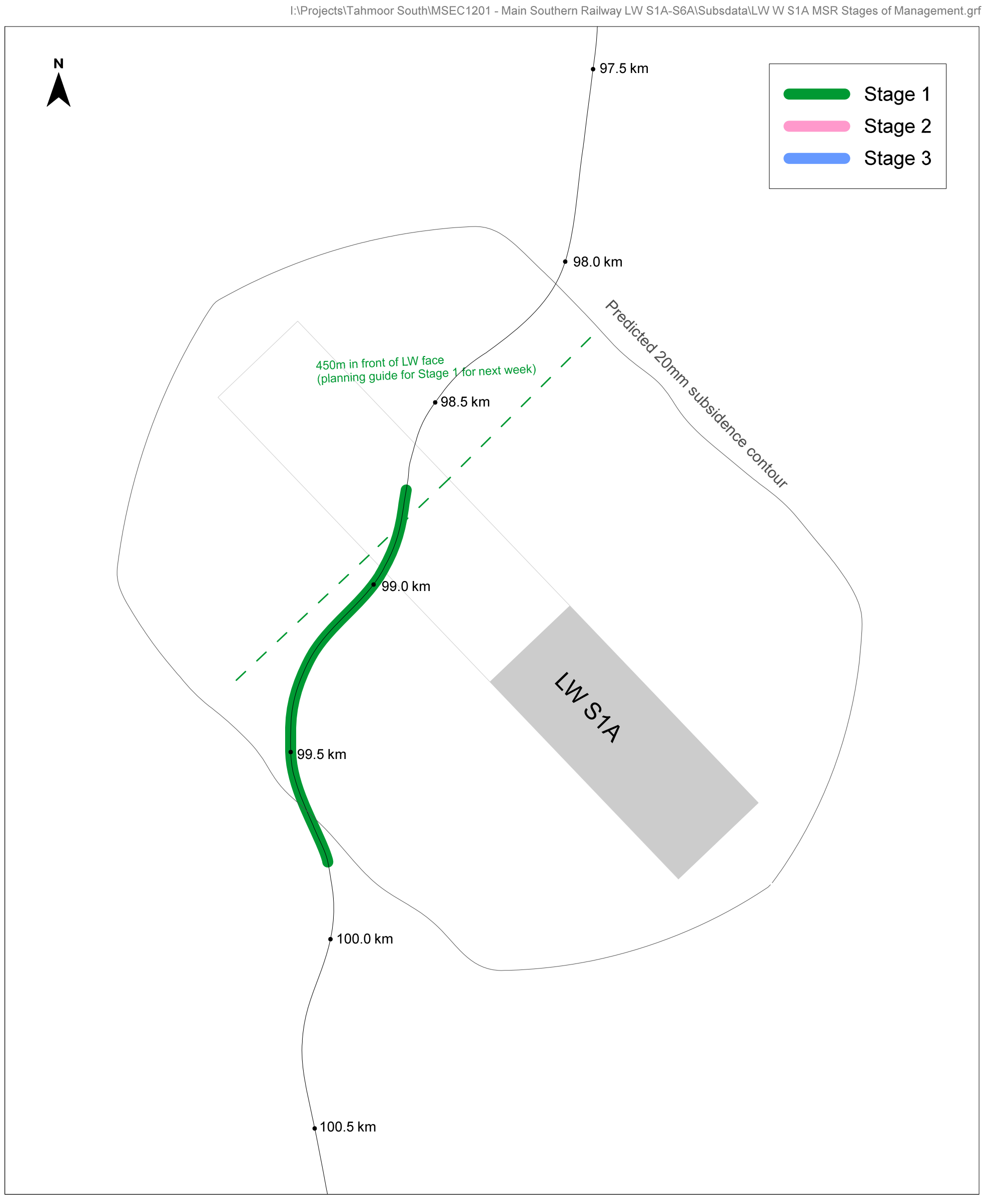
Commercial in Confidence



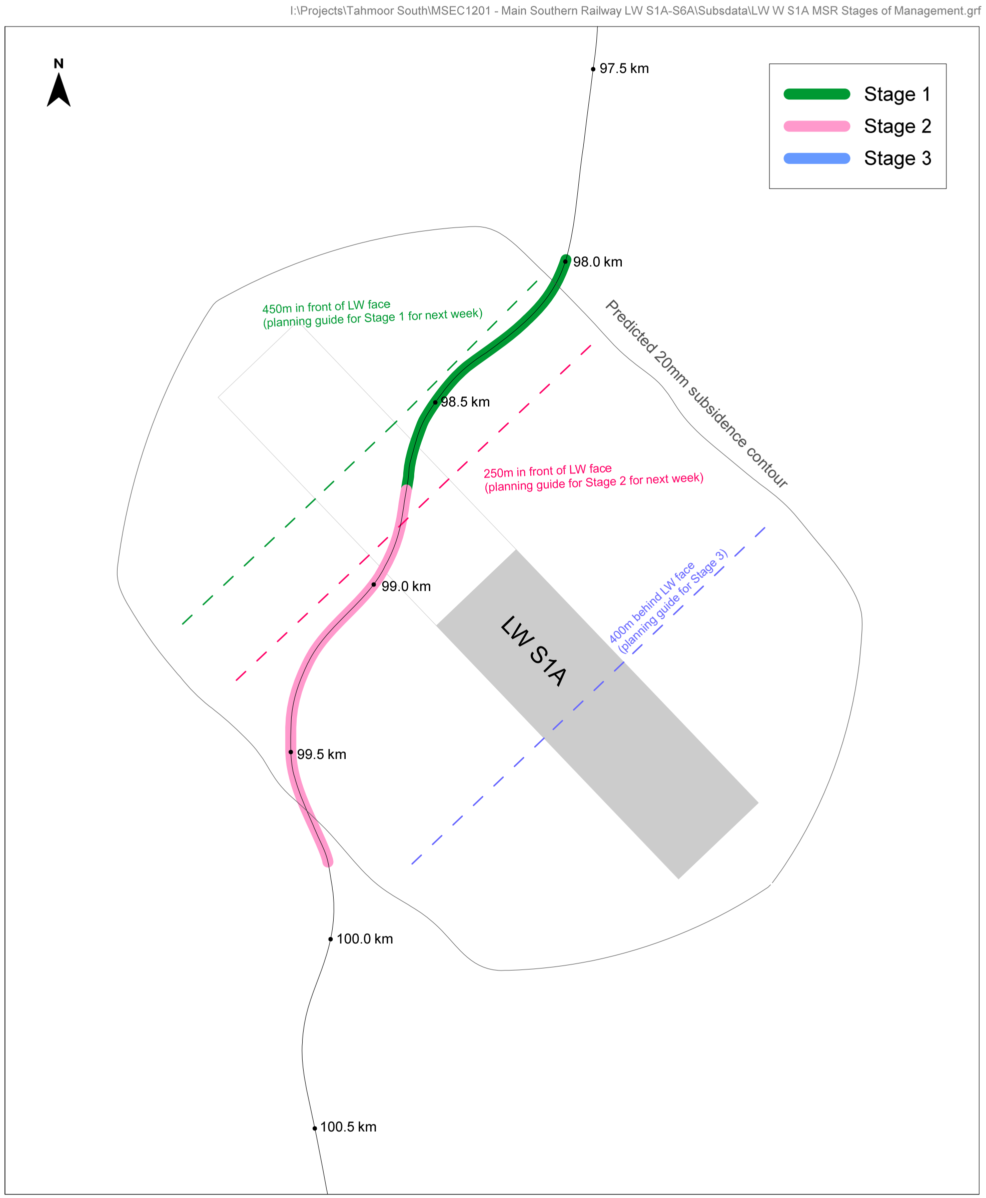


Fig. 5.3 Conceptual diagram showing early stages of management during mining of LW S1A

Commercial in Confidence

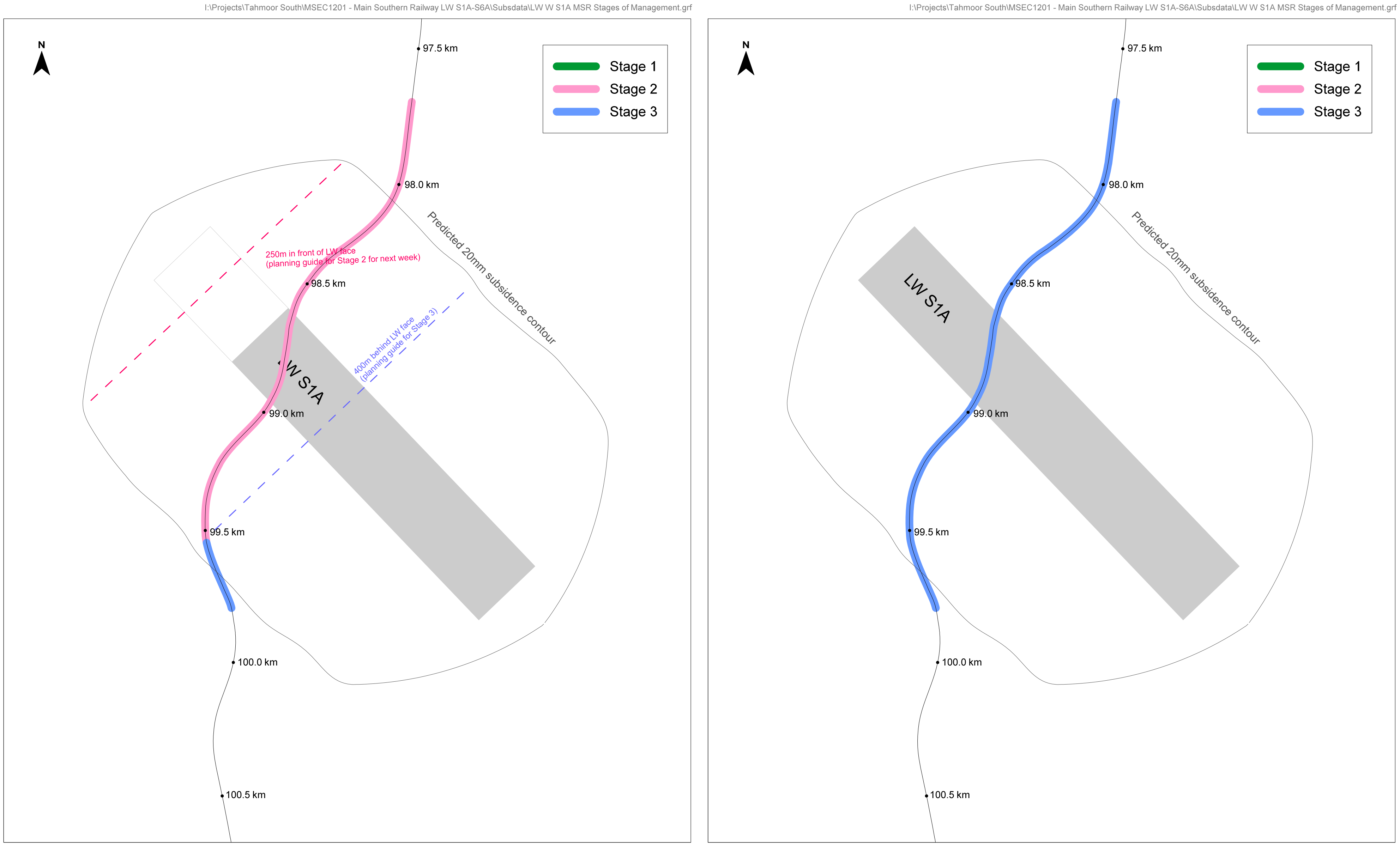


Fig. 5.4 Conceptual diagram showing final stages of management during mining of LW S1A

5.5. Monitoring Plan

The locations and extents of monitoring measures for LW S1A-S6A are provided in Appendix A.

While benign subsidence movements can be readily accommodated, measures are required for the purposes of managing potential impacts from irregular subsidence movements, such as ground stepping across geological faults. Should localised substantial non-conventional movements develop during mining, it is considered that, with the measures that are described in this Management Plan, they can be detected early before they exceed trigger levels.

While very rapid changes have not previously been recorded in the Southern Coalfield, it is considered that the prime inspection and monitoring systems of daily visual inspections, automated monitoring of switch displacements and rail stresses will initiate planned responses, including the immediate slowing or stopping of trains if Yellow or Red alarms are received during the period of active subsidence (Stage 2) when the Track Certifier is not on site.

5.5.1. 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 Drawing No. MSEC1201-03 and the GNSS units that are relevant to managing railway 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;
- GNSS at 100.700 km – A GNSS unit will be placed at 100.700 km prior to the commencement of LW S4A to monitor the initial development of subsidence following the commencement of LWs S4A to S6A.
- 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 Bridge 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.

5.5.2. Early warning survey line

A survey line has been installed along the southern boundary of Tahmoor Mine's property, as shown in Drawing No. MSEC1201-03. 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. 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.

5.5.3. Ground Monitoring

The following ground surveys will be undertaken by Tahmoor Coal during mining. Specific surveys for culverts, embankments and bridges are discussed later in this section.

- 2D and 3D monitoring along the rail corridor
- Rail creep monitoring at expansion switches, anchor points and within CWR track
- 2D long bay length surveys
  Long bay surveys will measure changes over long bay lengths between anchor points, expansion switches and two additional 100 metre long bays beyond the extents of the Track Expansion System for each longwall.

The main survey lines along the Railway consist of short posts on which small mini-prisms are placed for each survey.

5.5.4. Track Geometry Monitoring

The following measures will be undertaken to monitor track geometry during mining.

- Track geometry monitoring using a track recording trolley, such as the Amber Track Recording Trolley or equivalent.
- Visual track inspections by qualified track certifier.
- Track centre measurements at 98.620 km, 99.600 km and 101.200 km.
- Manual track geometry measurements, using track maintenance procedures (if triggered).
- Nominally quarterly track geometry monitoring by ARTC AK Car.

A photograph of the Amber trolley is shown in Fig. 5.5. The Amber trolley records gauge, track cant (superelevation) every 125 mm along the track. Twist is automatically calculated over any defined chord length. The data is uploaded to a handheld device, which will sound an alarm if a defined trigger is reached. The data will also be downloaded to a computer for email distribution, review and analysis.

The stated accuracy of the Amber trolley is ± 1 mm for gauge and track cant and ± 1.5 mm for twist. The Amber trolley or equivalent trolleys have successfully been used during the mining of Longwalls 25 to 32 and LW W1-W4 at Tahmoor Mine. The results have correlated well with ground survey results and quarterly AK Car monitoring data.

The stated accuracies of the Amber trolley have been adopted as benchmark performance criteria for alternative monitoring trolleys (the current trolley is a Krab).

Spare, back-up trolleys can be sourced from multiple sources, if required, in the event of damage or malfunction of the trolley during mining.

As for any work undertaken within the railway corridor, the operation of the track recording trolley is undertaken in accordance with standard rail safety protection procedures. The safety risks associated with operating a track recording trolley are considered acceptable to ARTC and Tahmoor Coal.

Photograph courtesy Pidgeon Civil Engineering

Fig. 5.5 Track Geometry Monitoring with Amber Trolley

5.5.5. Automated Monitoring of Rail Stress, Rail Temperature and Expansion Switch Displacement

The automated monitoring system will continuously monitor rail stress, rail temperature and expansion switch displacement during mining. The monitoring system will be progressively extended in accordance with the layout of expansion switches and anchor points for each longwall, which is provided in Drawings Nos. MSEC1201-02-1A to 6A.

The monitoring system consists of the following features:

- Rail stress gauges spaced along each rail within the zero toe load clip section of track so that there is a gauge at each anchor point and at least two working gauges between each expansion switch and anchor point. This means that the spacing of gauges is nominally 60 metres on each side of a Type 5 expansion switch or within CWR track.
- Rail stress gauges spaced along each rail within CWR track beyond the track expansion system by a distance equivalent to a 35 degree angle of draw from the edges of the longwall, or 200 metres from the anchor points, whichever is greater.
- As each longwall panel is extracted, monitoring of changes in rail stress due to long term residual subsidence will be conducted above previously extracted longwalls with at least one working gauge every 120 metres along each rail until rates of change reduce to negligible levels.
- Rail temperature gauges, with at least one temperature gauge at each rail stress monitoring location along the rail corridor, on the UP UP and DOWN DOWN tracks.
- Displacement sensors at each blade of each expansion switch.
- Associated loggers, cabling and other electrical and IT support systems.
- Monitoring system powered by solar charged batteries, with provision to replace the batteries with substantial capacity to maintain readings.
- Mobile internet connection for automated upload of data and remote access, with an automatic failover system in the event the primary system goes down.
- Mobile internet connection to the Tahmoor Coal Control Room, with dual SIM cards.
- Data storage back-up at off-site server (cloud based), which also provides web access. A second, live back-up web server (cloud server) is also provided in the event that the main server malfunctions or becomes off-line.
- Lightning protection measures, including segmentation of the monitoring system.

It is possible that the automatic monitoring system will record false readings for the following reasons.

- Intermittent spikes in monitoring results can occur due to short term, for example high impact loadings from poor wheel profiles. The loggers have been programmed to automatically detect these readings and not trigger an alarm unless they are sustained for three consecutive readings above the trigger level. In relation to the track, the monitoring system at GREEN level adopts a sampling rate of every five minutes. A gauge therefore needs to be above a trigger level for ten to fifteen minutes before an alarm is triggered.
- Extremely high readings are most likely a result of gauge, logger or cabling damage, particularly when they are accompanied by a sudden spike or spikes in the readings. The alarm system will interpret these results as a GREY alarm. This will initiate an immediate review by the RRG, who decide whether an immediate detailed inspection is required by the Track Certifier, or an inspection will be undertaken within 24 hours.
  - In relation to switch displacement readings, the GREY alarm is based on measurements being outside the operating range of the expansion switch.
  - In relation to rail stress readings, the gauges are able to record strains that, when converted to rail stress, can reach 6,500 MPa. Following a review, PCE (2011c) recommends that 0.2% Proof Stress levels (± 420 MPa) for rail steel would be an appropriate and conservative value for the RED to GREY boundary rail stress level. This provides a factor of safety of at least 3 over the RED trigger levels.
- Gauge drift can occur as a result of water ingress and possible long term wear and deterioration. Gauge drift will be identified through regular analysis and review of monitoring data.

Should the monitoring system be unavailable in part or full, track safety can be maintained by increasing visual inspections by on-site track certifiers until such time as the system is reinstated. Risk Control Procedures have been developed in this Management Plan to initiate this response.

From time to time, it will be necessary to maintain, make amendments to or repair parts of the automated monitoring systems. The Automated Monitoring Contractor will adhere to the following procedures when making changes to the monitoring system:

- Notification to the RMG of need to make changes;
- Description and reason of changes required;
- Description of what elements of the monitoring system will be taken “off-line”;
- Approval by RMG to make the changes;
- Implementation of additional monitoring procedures required during the shutdown (if any);
- Notification to Rail Maintenance Contractor and RMG of commencement and finish of shutdown period.

5.5.6. Monitoring of Culverts and Embankments

The following monitoring will be undertaken during the mining of LW S1A-S6A at culverts and embankments:

- Absolute 3D and 2D surveys along a monitoring line along the rail corridor;
- Absolute 3D surveys and relative 3D surveys of the culverts at inlet and outlet and embankments at 98.445 km, 98.739 km, 99.035 km, 99.338 km, 100.121 km, 100.425 km and 101.000 km along monitoring lines at crests and toes of embankment on both sides, as shown in Drawings Nos. MSEC1201-05 to 12;
- Horizontal extensometer (or equivalent) across the crests of the embankments at 99.338 km, 100.121 km and 100.425 km;
- Manual inclinometer surveys in boreholes at embankments at 99.338 km, 100.121 km and 100.425 km;
- Water level sensors in boreholes at embankments at 99.338 km, 100.121 km and 100.425 km;
- Dilapidation inspections of culverts; and
- Visual inspections by Track Certifier and geotechnical engineer.

The Track Certifier has confined space training and will inspect the culverts in detail via a confined space plan. A detailed baseline inspection will be conducted prior to the influence of subsidence.

5.5.7. Monitoring of Cuttings

The following monitoring will be undertaken during the mining of LW S1A-S6A at Cuttings at 99.69 km, 100.700 km and 101.162 km:

- Absolute 3D and 2D surveys along a monitoring line along the rail corridor;
- Absolute 3D surveys every 20 metres along the toe and crests of the cuttings;
- Visual inspections by Track Certifier and geotechnical engineer.

5.5.8. Ground and Structure Surveys at the Bridges and Viaduct

Tahmoor Mine will conduct the following surveys and inspections at the Railway Viaduct over the Bargo River:

- Continuous GNSS monitoring at two locations at each end of the Viaduct. The locations are shown in Drawing No. MSEC1201-13;
- Precision 2D survey of closure between ground marks located in stable ground at both ends of the Viaduct;
- Absolute 3D surveys of ground marks adjacent to the Viaduct, as shown in Drawing No. MSEC1201-13, with final locations of stable ground marks to be determined on site;
- Absolute 3D surveys prisms mounted on the Viaduct at the base and top of the intermediate piers and abutments, and above the centre of each arch, as shown in Drawing No. MSEC1201-13;
- Detailed visual inspections of Viaduct by UAV (baseline complete). A systematic and repeatable methodology has been designed and implemented;
- Measurement of crack gauges;
- Baseline laser scan of the Viaduct; and
- Visual inspections of the Bridge.

Tahmoor Mine will conduct the following surveys and inspections at the Remembrance Drive Bridge over the Bargo River:

- Continuous GNSS monitoring at two locations at each end of the adjacent Railway Viaduct. The locations are shown in Drawing No. MSEC1201-13;
- Precision 2D survey of closure between ground marks located in stable ground at both ends of the Bridge;
- Absolute 3D surveys of ground marks adjacent to the Bridge, as shown in Drawing No. MSEC1201-13, with final locations of stable ground marks to be determined on site;
- Absolute 3D surveys prisms mounted on the Bridge at the base and top of the intermediate piers and abutments, as shown in Drawing No. MSEC1201-13;
- Measurement of the gap between the bridge deck and northern abutment;
- Baseline laser scan of the Bridge; and
- Visual inspections of the Bridge.

Tahmoor Mine will conduct the following surveys and inspections at the Bargo River Road Overbridge (Potter's Cutting):

- Continuous GNSS monitoring at the Railway Viaduct. GNSS unit S11 is located approximately 250 metres from the Bridge;
- Local 3D surveys of structure and ground marks on the Bridge, as shown in Drawing No. MSEC1201-14, with one mark on the Bridge to be surveyed in Absolute 3D;
- Measurement of crack gauges, as recommended by structural engineer; and
- Visual inspections of the Bridge.

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

Tahmoor Mine will conduct the following surveys and inspections at the Wellers Road Overbridge:

- Continuous GNSS monitoring at the Wellers Road Overbridge (GNSS unit S15);
- Local 3D surveys of structure and ground marks on the Bridge, as shown in Drawing No. MSEC1201-15;
- Measurement of crack gauges, as recommended by structural engineer; and
- Visual inspections of the Bridge.

5.5.9. Provision of Raw Monitoring Data

Ground monitoring data will be provided by Tahmoor Coal to all members of the RMG and MSO within 48 hours of survey. Automated monitoring data is available to all members of the RMG and selected ARTC personnel via a password secured website. All other raw monitoring data is available to all members of the RMG upon request.

5.5.10. Changes to Monitoring Frequencies

Monitoring frequencies are specified in the Risk Control Procedures (see Appendix A), in line with the three Management Stages that are described in Section 5.4.

When Stage 3 is reached for each section of track or item of infrastructure, Tahmoor Coal will not reduce monitoring frequencies or stop monitoring until agreed by ARTC (via recommendation by the Rail Management Group). ARTC can agree to the proposed reduction either during an ARTC / Tahmoor Coal governance meeting as recorded by minutes of the meeting and reconfirmed separately in writing or email. MSO and ONRSR will be informed of the change separately in writing or email. The notification will describe what changes have or will be undertaken to management measures and/or monitoring measures.

It is also possible that small losses of monitoring data may occur if survey marks or automated monitoring equipment is damaged or vandalised during the mining period. It is also possible that the track geometry recording trolley may be temporarily damaged and require repair. The RMG will consider whether the monitoring measures should be reinstated or not, and/or whether alternative monitoring measures should be introduced. The consideration will be made on a case by case basis, based on the stage of mining and observed subsidence and rail movements and the decision shall be communicated in the monitoring reports.

5.6. Trigger Levels

Trigger levels for the Railway Track

Trigger levels have been divided into four categories, which relate to the safe operation of the trains as shown in Table 5.3.

Table 5.3 Trigger Levels

Trigger Level	Description
GREEN	Observations within operating tolerance. Operate as normal.
BLUE	Observations within operating tolerance but nearing limits. Investigate cause. Some action may be required to prevent operating restrictions. Immediately inspect site unless it is obvious that the cause of the trigger cannot be due to physical damage to rail infrastructure. Otherwise inspect within 24 hours. Return status to Green level.
YELLOW	Restrictions on operations. Immediate inspection required. Action required within 6 hours. Appropriate speed restriction may apply until altered to Green or Blue Level.
RED	Stop trains, inspect prior to next train, repair to lower category, pilot trains if safe.

The YELLOW and RED triggers are directly related to the safe operation of the trains and are linked to ARTC rail safety standards. The triggers are also consistent with the Douglas Park projects.

The BLUE trigger level is designed to provide an early warning to provide adequate time to assess and respond and is not linked to NSW rail safety standards. The RMG can review the adequacy of the BLUE trigger level during mining and adjust as agreed, without amending this management plan. Tahmoor Coal will inform ARTC, MSO and ONRSR of the details concerning changes to BLUE triggers made by the RMG. Tahmoor Coal will follow the recommendations of the RMG unless directed to the contrary by ARTC, MSO and ONRSR in relation to these matters.

Trigger levels are included as part of the Risk Control Procedures, which are shown in Appendix A and are unchanged from those adopted for Longwall 32, which are based on the latest ARTC standards (ETM-06-06) (PCE, 2022a).

PCE (2012b) has recommended trigger levels for measured switch displacements for the Type 5 expansion switches. Yellow and Red trigger levels are not recommended as stop blocks have been installed on the switches. If a switch rail moves to the block, no further movement will occur. Under this circumstance, the subsequent changes that the track monitoring system will record would be changes in rail stress along the length of free rail, and the measured rail stresses would be checked against Blue, Yellow and Red triggers.

The staged Blue, Yellow and Red trigger levels are reserved for track condition. Triggers that are not coloured in the Management Plan are not directly related to track condition. A response to an exceedence of each of these triggers should be determined on a case by case basis. Some of the triggers, such as those for the culverts, embankments and bridges are early warning, monitoring review point triggers. Other triggers, such as switches being destroyed by an unrelated derailment are not early warning triggers and require an immediate response.

Ground survey results provide some of the most important information to the RMG during mining. They provide an early indication of irregular subsidence movement from which trends can be determined, allowing the RMG to forecast locations where triggers might be exceeded and therefore assist the RMG to focus monitoring attention at these locations. This was demonstrated many times during the mining of Tahmoor Longwalls 25 to 32, Appin Longwalls 703 to 708 and Appin Longwalls 901 to 904. The RMG also regularly correlate ground survey data with track monitoring data, providing confidence in the overall monitoring system.

The inclusion of ground survey triggers in the Management Plan is, however, generally not recommended for the following reasons:

- Monitoring of track condition in the form of track geometry and rail stress can be directly linked to railway standards, while ground survey data cannot.
- Ground peg spacings are not suitable when compared to track geometry bay lengths specified in the railway standards.
- With respect to rail stress, the track expansion system effectively decouples the rails from the ground. As such, increased ground strain by itself may not result in an impact on the track.
- The railway is typically adjusted during mining in response to temperature or mining-induced movements. Ground survey triggers would not be able to reflect these adjustments as they are not directly related to the track. It would be very difficult to adjust ground survey triggers each time the track is adjusted.

Notwithstanding the above, ground survey triggers have been adopted for closure of the railway cuttings, to initiate considerations of additional management measures. Triggers have also been adopted for some GNSS units, to initiate more detailed surveys.

Trigger Levels in relation to Culverts and Embankments

Trigger levels are included as part of the Risk Control Procedures, which are shown in Appendix A, with further details provided in Section 3.5. The trigger levels are staged based on measurements and observations of the embankment.

If impacts are observed to any culvert, additional structural support can be provided or repairs undertaken to brickwork. The baulks installed in the track can be strengthened if the culvert is observed to deteriorate and there is a potential for piping failure or pot holing. This can be arranged at short notice.

Cracks observed to develop along the crest of embankments can be sealed to prevent water entering the embankment through the crack. If a slide is observed to form in the crest of the embankment, the ballast shoulder can be supported by placing permanent or temporary fill or rock spall. During extreme wet weather conditions, fill material can be tipped into the scarp of the slide until settlement effectively ceases. In a severe case, if a tension crack is observed across the access road and under the track, or a slump appears in the access road, or a depression is observed in the track, ballast can be added to the railway to restore track geometry, or a variety of forms of track support under the track could be employed in the short term to provide safety and serviceability of the track.

In the long term, the stability of the batter slope can be reviewed after rates of change reduce to low levels, and plans implemented to rehabilitate the embankment.

Planned responses are also in place to inspect the embankments during periods of extreme wet weather to slow or stop trains if required.

Trigger Levels in relation to the bridges

Early warning trigger levels are included as part of the Risk Control Procedures, which are shown in Appendix A. The trigger levels have been adopted to provide adequate time to respond before impacts occur.

Rail Traffic Management

While the above responses are expected to be undertaken without affecting the operation of the railway, rail traffic can be managed by ARTC if required.

Speed restrictions can be introduced rapidly through the ARTC communications system. Contact is made to ARTC Train Control via a phone call and ARTC Train Control can make contact with train drivers via a direct radio communications link. In addition to the direct communications link, Train Control can remotely operate the signals via the automated signalling system to stop trains at controlled signals within 5 minutes of being contacted by a Track Certifier.

Introduction of a temporary speed restriction can be undertaken if considered appropriate by the Rail Management Group, the Track Certifier or ARTC, based on actual monitoring results. Temporary speed restrictions can be introduced at any stage during mining, even while monitoring observations are within the GREEN level. A decision to introduce a temporary speed restriction will be based on regular assessment of monitoring results by the Rail Management Group during the mining period, including the forecast of possible exceedances of triggers due to the continued extraction of the longwall.

Slow or stop longwall

As for speed restrictions and stopping of trains, these are last resort management measures. If required, the longwall mining process can be slowed or stopped if the impact to rail operations is unacceptable to ARTC.

This Railway Management Plan includes a commitment by Tahmoor Coal to stop mining if impacts are forecast to occur on the safety and serviceability of the Main Southern Railway that cannot be controlled.

5.6.1. Grey Trigger for Automated Monitoring System Integrity

A GREY trigger will be raised automatically by the monitoring system if readings are missed by some or all gauges. There are a number of potential causes for missed readings, and these include:

- Loss of power to the monitoring system,
- Loss of communications from the automated monitoring system,
- Power surge,
- Vandalism,
- Damage from trackwork,
- Less than adequate data transfer,
- Damage from passing trains,
- Malfunction of monitoring equipment.

A GREY trigger will be raised automatically by the automated monitoring system if extremely high readings are recorded, as described in Section 5.5.5.

5.7. Response Plan

The following responses are available to reduce the potential for impacts of mining-induced ground movements on the railway. These will be implemented in response to the monitoring data.

The general management strategy is to detect changes in ground movements and track condition early, monitor the behaviour of the track in response to ground movements and, if necessary, undertake planned additional management measures within the GREEN level to avoid exceeding a BLUE trigger. This is achieved by regular assessment of monitoring results by the Rail Management Group during the mining period, including the forecast of possible exceedences of triggers due to the continued extraction of the longwall.

Rail Response Group and Rail Structures Response Group

Upon exceeding a trigger, the automated monitoring system will automatically notify members of the RRG and RSRG, as described in Section 5.1.6 and Section 5.1.7. The RRG and RSRG will meet via teleconference using a dedicated, pre-arranged service.

RRG and RSRG will undertake the following action(s) upon notification of a trigger:

- Contact ARTC Train Control and immediately stop trains upon notification of a RED alarm if the Track Certifier is not present on site at the time the alarm is triggered.
- Contact ARTC Train Control and immediately reduce track speed at the trigger site upon notification of a YELLOW alarm if the Track Certifier is not present on site at the time the alarm is triggered.
- assess monitoring data for cause of the alarm,
- assess trends and forecast if and/or when the YELLOW and RED trigger levels might be exceeded
- consider whether to increase survey and/or inspection frequencies
- consider whether to resurface the track
- consider whether any other additional management measures are required

If, upon assessment of the monitoring information available, the RRG or RSRG decides to initiate an immediate speed restriction, the Track Certifier or ARTC Area Manager – Ingleburn will notify ARTC Train Control – Junee.

In relation to the railway track, RED alarms have been received during mining at both Tahmoor and Appin Collieries. In each of these instances, the cause of the failure was due to a malfunction of, or damage to the monitoring system. The cause of the failure could be identified by the RRG in the form of erratic readings. In some instances, the Track Certifier was not on site and ARTC Train Control was contacted to immediately stop trains, in accordance with the management plans. It was fortunate that, in most cases, no trains were running through the site during the periods of time from when the alarm was received until the Track Certifier had travelled to site to inspect and certify the track. It was apparent to the RMG, however, that situations could arise when significant, unnecessary delays could result if a RED alarm was received during peak times of operation, even though the RRG was confident that the cause of the alarm was due to malfunction or damage to the monitoring system, and not due to physical damage to the railway.

In light of these experiences, if the Track Certifier is not present on site at the time a RED alarm is triggered, the RRG will contact ARTC Train Control and immediately stop trains. If, following an assessment of the monitoring information available after notification of a Red alarm, the RRG is confident that the cause of the trigger cannot be due to physical damage to the railway, the RRG may decide to allow trains to proceed through the section under caution at 20 km/hour prior to the Track Certifier arriving on site to inspect and certify the track.

Immediate Site Inspection

A site inspection will be undertaken by the Track Certifier if a trigger is exceeded. The Track Certifier will be on site to undertake an inspection within two hours of notification of an initial YELLOW or RED alarm if the monitoring status was at GREEN level prior to the exceedence of the trigger.

Prior to the development of the original management plan for Longwall 25 at Tahmoor Coal and Longwall 703 at Appin Colliery, the Rail Management Group had limited experience about the effectiveness and performance of the automated monitoring systems. While GREY or BLUE alarms did not indicate physical damage to the track, it was considered possible that they could be alerting the RRG to an issue that could not be fully understood from the monitoring system. An inspection by the Track Certifier provided the RRG with an independent assessment of track condition. It is for this reason that a mandatory site inspection was required following notification of any alarms.

During the extraction of eight longwalls at Tahmoor Mine and nine longwalls at Appin Colliery, the Rail Response Group has gained extensive experience and understanding of the effectiveness and performance of the automated monitoring systems. It is able to detect with confidence whether the cause of the trigger cannot be due to physical damage to the railway.

Some examples are outlined below from experience during the mining of Tahmoor Longwalls 25 to 32, Appin Longwalls 703 to 708 and Appin Longwalls 901 and 902 in Table 5.4.

Table 5.4 Examples where cause of alarm cannot be related to physical damage to the railway track or associated infrastructure

Grey or Blue Alarm	Reason
Loss of data from all sensors within a monitoring system (e.g. all rail stress gauges)	Sensors installed on the rails are connected to backbone signal cables that run in steel wired armoured cable on the side of the track and connect into a series of monitoring huts. It is not possible for physical damage to the track to cause a loss of data from all sensors. In this circumstance, the RRG will re-establish connection to gauges immediately. Upon receipt of data, it is established that the readings are within expectations. There is no need to immediately inspect the site.
Following receipt of a GREY trigger, the monitoring contractor remotely accesses the monitoring system and either confirms that readings are being received by local loggers in the monitoring hut, or reconnects or restarts the monitoring system	The cause of the GREY trigger is associated with monitoring acquisition and/or networking processes. Upon receipt of data, it is established that the readings are within expectations. There is no need to inspect the site.
Single gauge or gauges at the same kilometrage display erratic readings or no data is received from a single gauge or gauges connected at the same kilometrage.	Assessment of monitoring data by RRG indicates that gauges immediately adjacent to the gauge on the same rail, or adjacent to the gauge on adjacent rails are performing satisfactorily and within expectations. The gauge or connecting cables have clearly malfunctioned. In this circumstance, the RRG may direct the Track Certifier to inspect gauge within 24 hours and the Automated Monitoring Contractor will arrange to repair the gauge or connecting cables.
Readings exceed Blue trigger level as previously forecast by RMG but are not forecast to exceed the Yellow or Red trigger level	Gauge readings occasionally exceed BLUE trigger level as previously forecast by RMG in response to, for example, changes in temperature. While arrangements have been made to adjust the track, temperatures may exceed those forecast by the Bureau of Meteorology, leading to an earlier than expected exceedence of the BLUE trigger level. Upon receipt of the alarm, an assessment of monitoring data by the RRG indicates that and the track is operating as expected though the temperatures exceed predictions. Importantly, the RRG assesses that readings will not exceed the Yellow or Red trigger level. In this circumstance, the RRG can monitor conditions remotely until status returns to Green levels. The RMG may decide to expedite previously planned arrangements to adjust the track to avoid future exceedence of the BLUE trigger level.

Based on the above experiences, it is considered that mandatory immediate site inspections are not automatically required upon notification of GREY or BLUE alarms. If the Track Certifier is not present on site at the time when a GREY or BLUE alarm is triggered, the Track Certifier will initially attend the teleconference and contribute to the assessment by the RRG and/or RSRG, which is typically undertaken in less than 15 minutes. Following this assessment, the Track Certifier will immediately travel to site and inspect the site within two hours unless it is obvious that the cause of the trigger cannot be due to physical damage to the railway track or associated infrastructure. The Track Certifier will otherwise inspect the track within 24 hours.

Upon notification of a BLUE alarm, the Rail Maintenance Contractor will provide a Track Certifier on site continuously until the status of the monitoring system returns to GREEN levels if upon assessment of the monitoring data, the RRG and/or RSRG considers that it is possible that a YELLOW or RED trigger will be exceeded. This reduces the time to undertake a site inspection to within 15 minutes upon notification of a YELLOW or RED trigger. In the unusual event that the Track Certifier is not on site when a YELLOW or RED trigger is exceeded, the Track Certifier will contact ARTC Train Control to introduce a track speed of 20 km/h if a YELLOW trigger is exceeded, or stop trains if a RED trigger is exceeded.

A Track Certifier can be employed on site continuously at any stage during mining, even while monitoring observations are within the GREEN level. A decision to employ a Track Certifier on site continuously will be based on regular assessment of monitoring results by the Rail Management Group during the mining period, including the forecast of possible exceedences of triggers due to the continued extraction of the longwall.

Track Geometry

Track geometry can be adjusted using standard maintenance procedures if triggers are exceeded. Spare ballast will be stored on site for ready use. Equipment will be available for use at short notice.

Resurfacing of the track can be undertaken multiple times during mining without affecting the operation of the railway.

Expansion Switch Displacement

If the BLUE trigger is reached, adjustments can be made to the rails to reset the switches so that they can accommodate additional subsidence movements during normal train operations. These adjustments can be made multiple times without affecting train operations. Adjustments have been successfully undertaken during mining at Appin and Tahmoor Collieries.

Rail Stress

Rail stress will generally be managed as detailed in this management plan, primarily with the use of expansion switches and zero toe load clips.

Adjustments will also be made during normal train operations, if required, to continuously welded rails (CWR) to reset the stress free temperature so that they can accommodate additional subsidence movements. These adjustments can be made multiple times. This is a standard maintenance procedure that was effectively undertaken following the mining of Tahmoor Longwalls 23A, 24B, 24A, 25 to 32 and Appin Longwalls 703 to 708.

Culverts and Embankments

If impacts are observed to any culvert, additional structural support can be provided or repairs undertaken to brickwork. The track baulk can also be strengthened if the culvert is experiencing substantial impacts.

Planned responses in this management plan escalate depending on the trigger level that is exceeded, as described in Section 3.4. Cracks observed to develop along the crest of embankments can be sealed to prevent water entering the embankment through the crack. If a slide is observed to form in the crest of the embankment, the ballast shoulder can be supported by placing permanent or temporary fill or rock spall. During extreme wet weather conditions, fill material can be tipped into the scarp of the slide until settlement effectively ceases. In a severe case, if a tension crack is observed across the access road and under the track, or a slump appears in the access road, or a depression is observed in the track, ballast can be added to the railway to restore track geometry, or a variety of forms of track support under the track could be employed in the short term to provide safety and serviceability of the track.

In the long term, the stability of the batter slope can be reviewed after rates of change reduce to low levels, and plans implemented to rehabilitate the embankment.

Planned responses are also in place to inspect the embankments during periods of extreme wet weather to slow or stop trains if required.

Railway Bridges

The following responses are planned in the event of impacts on the Railway Viaduct:

- Install temporary track strengthening baulk;
- Force closure to focus in desired Span 5 by diamond saw cut;
- Repair cracked brickwork;
- Provide additional support to the arch and parapet walls.
- Fabricate and erect structural steel supports for the arch;
- Adjust rail stress;
- Adjust track geometry; and/or
- Implement temporary speed restriction.

The following responses are planned in the event of impacts on the Remembrance Drive Bridge over the Bargo River.

- Install temporary props to provide additional support to intermediate piers; and/or
- Replace bridge bearings.

The following responses are planned in the event of impacts on the Bargo River Overbridge and Wellers Road Overbridge:

- Install rolled steel reinforcement straps to the underside of the concrete arch;
- Install mesh to underside of the arch;
- Install shear reinforcement into brickwork in response to shear movements across the brick arch;
- Install a temporary support structure within the road pavement to provide temporary support to the arch;
- Provide additional support to parapet walls; and/or
- Repair cracked brickwork.

Conveyor crossing over Main Southern Railway

The following responses are planned in the event of impacts on the Conveyor Crossing:

- Elongate bolt holes in trestle column baseplates;
- Strengthen trestle columns;
- Install additional cable-stay bracing;
- Erect temporary support structure on the access roadways on either side of railway.

Rail Traffic Management

While the above responses are expected to be undertaken without affecting the operation of the railway, rail traffic can be managed by ARTC if required.

Speed restrictions can be introduced rapidly through the ARTC communications system. Contact is made to ARTC Train Control via a phone call and ARTC Train Control can make contact with train drivers via a direct communications link. In addition to the direct communications link, Train Control can remotely operate the signals via the automated signalling system to stop trains at controlled signals within 5 minutes of being contacted by a Track Certifier.

Introduction of a temporary speed restriction can be undertaken if considered appropriate by the Rail Management Group, the Track Certifier or ARTC, based on actual monitoring results. Temporary speed restrictions can be introduced at any stage during mining, even while monitoring observations are within the GREEN level. A decision to introduce a temporary speed restriction will be based on regular assessment of monitoring results by the Rail Management Group during the mining period, including the forecast of possible exceedences of triggers due to the continued extraction of the longwall.

Slow or stop longwall

As for speed restrictions and stopping of trains, these are last resort management measures. If required, the longwall mining process can be slowed or stopped if the impact to rail operations is unacceptable to ARTC.

Response times

Approximate response times are summarised in Table 5.5. In all cases, it is considered that the fast response times will not be required due to the proactive nature of the Management Plan. The potential for impacts will be forecast by the RMG based on an assessment of latest monitoring data on a weekly basis during mining. In this manner, it is expected that preparations can be made well before action is required and, as such, the response times listed below are unlikely to be needed.

Table 5.5 Approximate response times

Response Measure	Approximate Response Time	Comments
Adjustment of track geometry Adjustment of expansion switches Adjustment of CWR track	Less than 24 hours (within same day of request or following day, if required)	Bloor Rail have demonstrated many times that localised adjustment of track geometry, switches or CWR track can be undertaken on the day of request or on the following day, if required. While it is preferred to avoid it, night works could be undertaken in extreme circumstances.
Provision of additional support to culvert (e.g. props)	Less than 24 hours	There is plenty of material readily available on site, at the Tahmoor mine site, or from nearby suppliers to install props if required.
Improve embankment stability	Less than 24 hours	Material is available on site and more is readily available. The stability of the embankment can be improved within 24 hours' notice, initially focussing on critical areas. This may include sealing cracks, or placing embankment fill or rock spall to provide permanent or temporary support.
Strengthen baulk in track	Less than 24 hours	This can be arranged at short notice without affecting normal operations.
Provide additional support to conveyor crossing	Less than 48 hours	This can be arranged at short notice without affecting normal operations.
Temporary speed restriction or stop trains	Less than 15 minutes	Speed restrictions can be introduced rapidly through the ARTC communications system. Contact is made to ARTC Train Control via a phone call and ARTC Train Control can make contact with train drivers via a direct communications link. In addition to the direct communications link, Train Control can remotely operate the signals via the automated signalling system to stop trains at controlled signals within 5 minutes of being contacted by a Track Certifier.

5.8. Maintenance Plan

The Rail Maintenance Contractor will inspect and maintain the rail civil assets along the corridor during mining. The maintenance plan includes:

- Visual inspection (daily during active subsidence) of the track, formation, cuttings and embankments and structures;
- Maintain and adjust expansion switches and anchor points, including replace components affected by wear if required;
- Maintain and adjust track;
- Maintain access roads, gates, fences and drainage systems, including the cesses at the base of the rail cutting;
- Clean out sediment and/or debris following rain events in culverts;
- Quarterly manual non-destructive testing of switch rails;
- Manual grinding of expansion switch rails if required; and
- Inspect and treat steelwork for rust, if required

5.9. Resourcing

As part of the management control of this project, adequate resources, including labour, spare equipment and materials will be available to respond to single and multiple events as required during the mining period. These include:

Track Management

- Spare rail components on site, including but not limited to clips, ballast stockpiles, rail and sleepers
- Earthmoving and track resurfacing equipment readily available from multiple sources
- Track certifiers and maintenance crews on call

Monitoring

- Multiple redundancies in the design of the overall monitoring system, where monitoring parameters are being monitored by a number of different methods
- Spare components for the automated monitoring system, including but not limited to high lead time items such as loggers, rail stress gauges, displacement sensors, cabling, sensor installation accessories and IT support equipment.
- Back-up track geometry recording trolleys readily available from multiple sources
- Back-up ground survey pegs cut flush to ground adjacent to the elevated marks
- Proximity of other ground monitoring lines
- Pre-arranged, dedicated back-up representatives of members of the Rail Management Group

5.10. Measures to manage potential impacts from subsidence due to the extraction of future longwalls

As part of the ongoing process of subsidence management along the railway, the Rail Management Group will plan and install additional measures to manage subsidence due to the extraction of future longwalls. This may include, among other things:

- The installation of expansion switches to the south of the site;
- The installation and commissioning of monitoring measures to the south of the site;
- The installation of measures to mitigate potential impacts to culverts, embankments, cuttings, bridges and other railway structures; and
- The undertaking of trials to improve the understanding of the performance of management measures

The planning and installation of additional measures will be undertaken in consultation with and authorisation by ARTC. As a minimum, twice weekly track inspections will be undertaken by Tahmoor Coal while there are non-standard track components, such as expansion switches, installed in the track.

Where the additional measures include the undertaking of automated monitoring and notification of alarms, the frequency of reporting of monitoring data, response to alarms received and reporting of alarms will be determined as agreed between Tahmoor Coal and ARTC on a case by case basis.

5.11. Risk Control Procedures

The risk control procedures are discussed in detail throughout this Management Plan and are summarised in Appendix A.

6.1. Monitoring, Triggers and Response Flow Chart

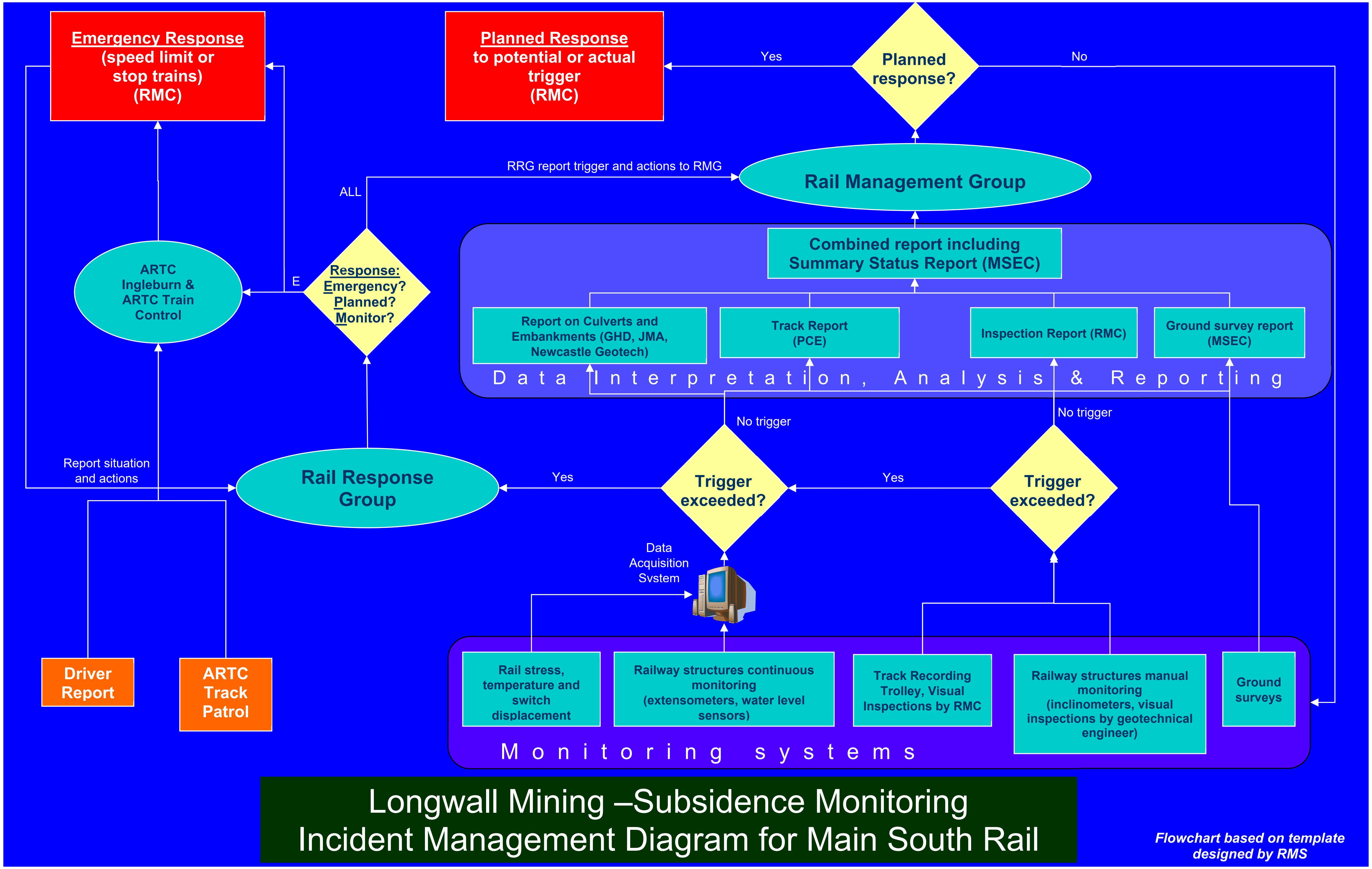


Fig. 6.1 Incident Management Diagram for Main Southern Railway

Commercial in Confidence

6.2. Triggers from the Automated Monitoring Systems

A diagrammatic flowchart for communication and response following the exceedence of automated triggers for the Railway track is shown in Fig. 6.2. Fig. 6.3 shows procedures to slow trains in relation to triggers received from the automated monitoring systems associated with the embankments.

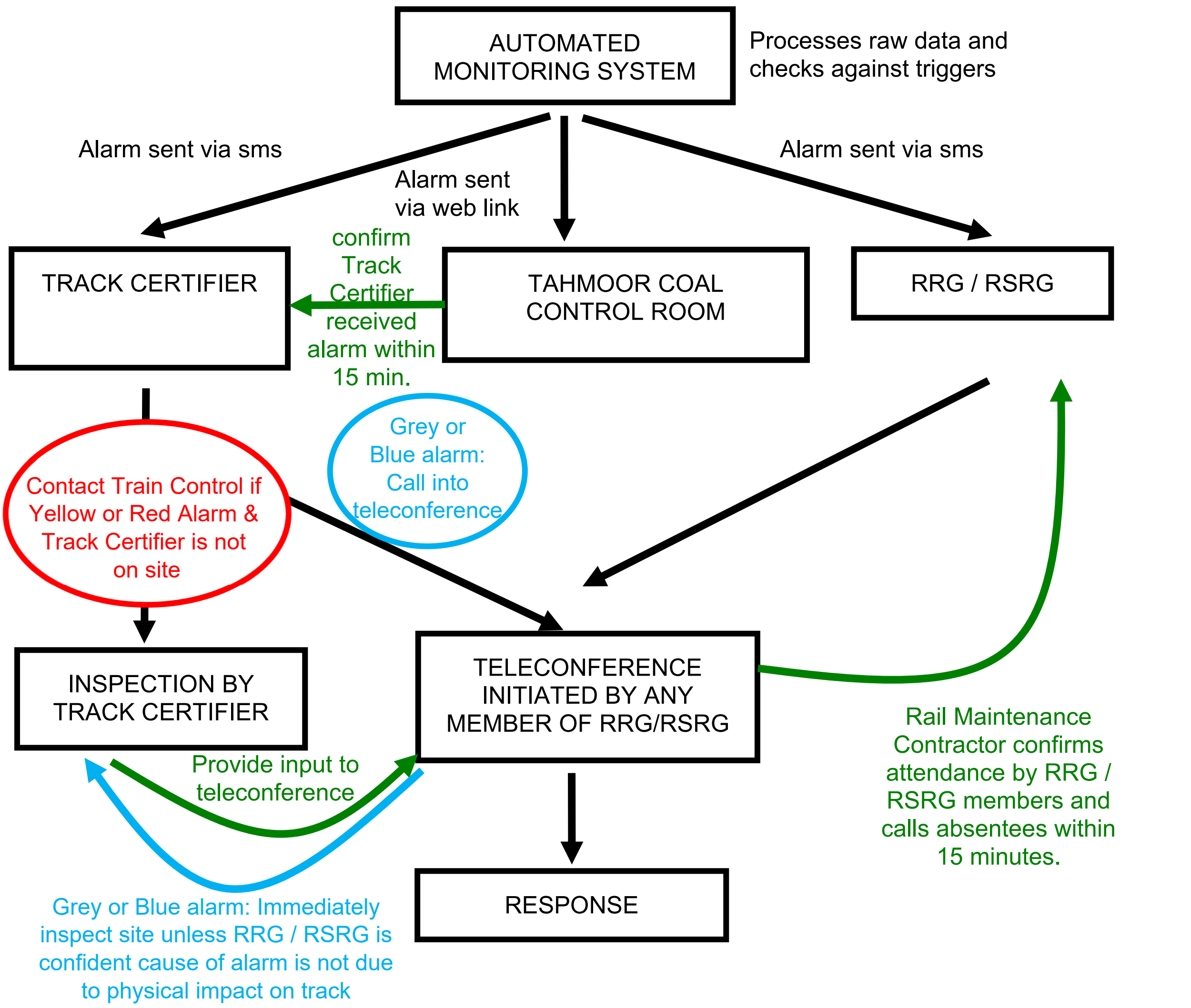


Fig. 6.2 Communication and Response Flowchart following exceedence of Automated Triggers for the Railway Track

Commercial in Confidence

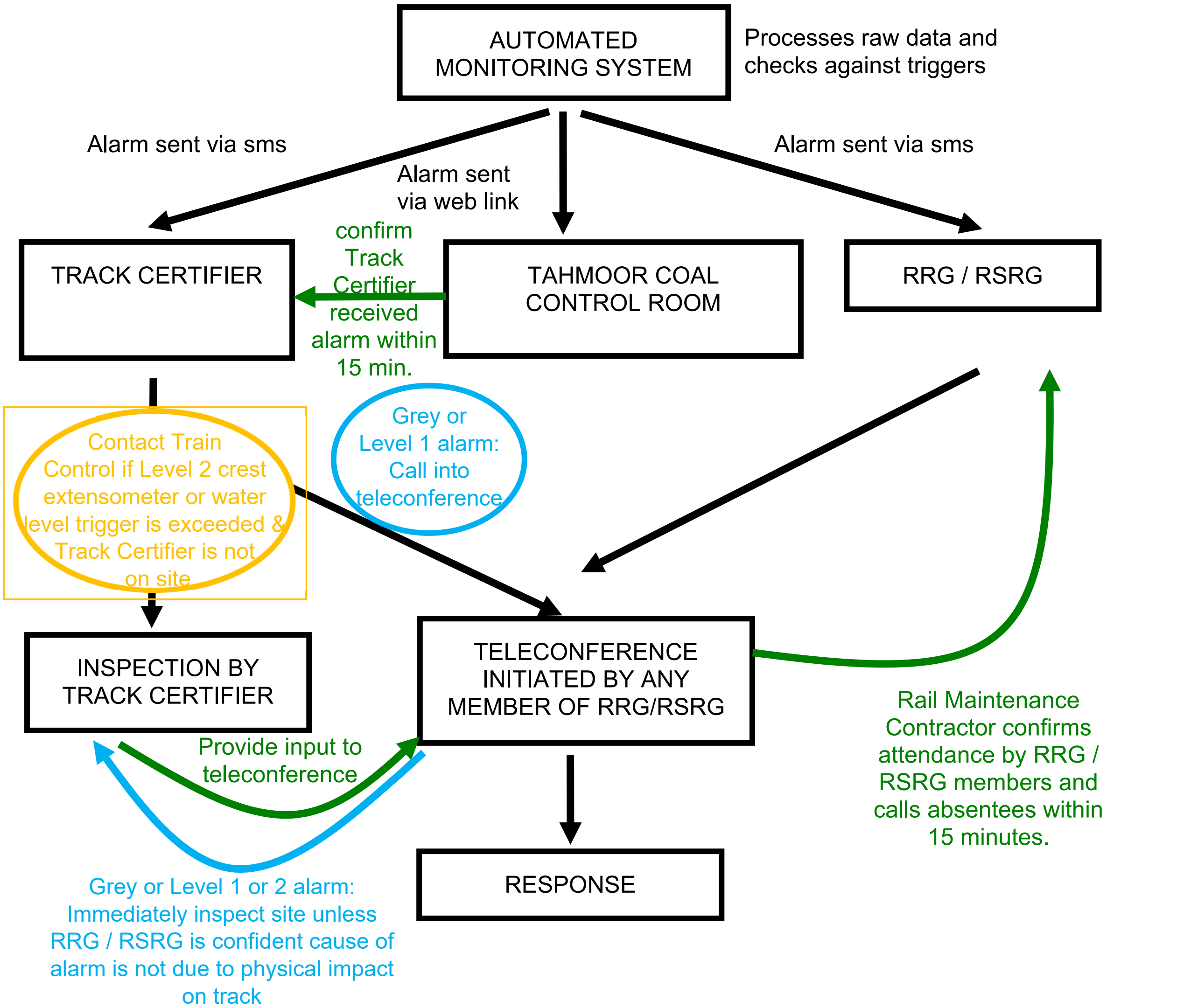


Fig. 6.3 Communication and Response Flowchart following exceedance of Automated Triggers for Embankments at 99.338 km, 100.121 km and 100.425 km

It is appreciated that the Track Certifier may not have reached site before the RRG and/or RSRG meets via a teleconference if the status of the monitoring system was at GREEN level before the trigger. While the Track Certifier is travelling to the site, it is likely that the RRG and/or RSRG will have assessed the monitoring data and undertaken action, which may include a resolution to reconvene the teleconference after the Track Certifier reaches site. Upon inspection, the Track Certifier may initiate action if impacts are observed, and report the findings of the inspection and any action undertaken to the RRG and/or RSRG.

Flowcharts showing responses to Red, Yellow, Blue and Grey triggers in relation to the Railway track are shown in Fig. 6.4 to Fig. 6.7.

Fig. 6.8 shows procedures to slow or stop trains in relation to triggers received from the water level sensor for the Embankments at 99.338 km, 100.121 km and 100.425 km.

Fig. 6.9 shows procedures to slow or stop trains in relation to triggers received from the crest extensometers at the Embankments at 99.338 km, 100.121 km and 100.425 km, and visual inspections of all embankments that will be monitored during the extraction of LW S1A-S6A.

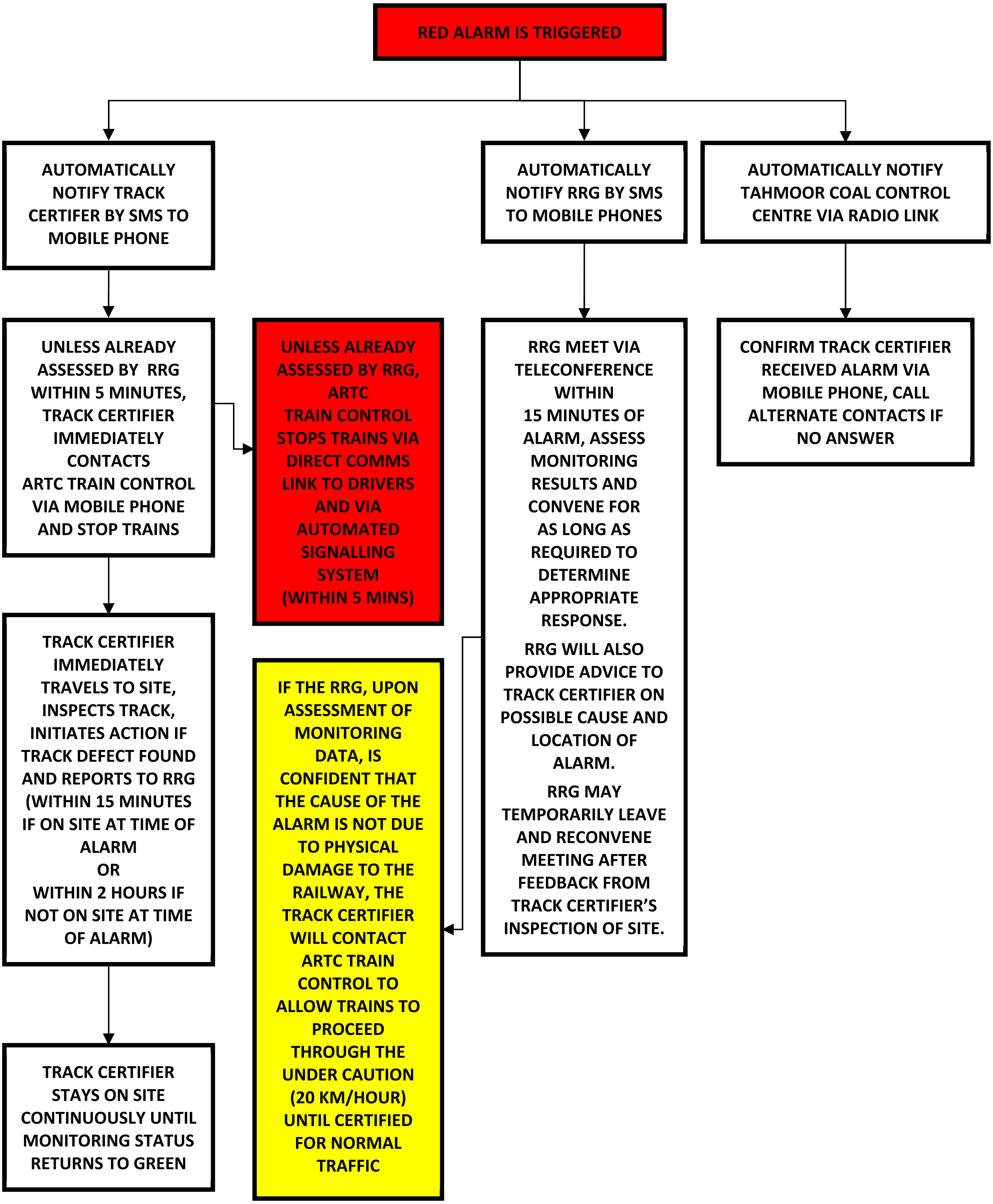


Fig. 6.4 Flowchart showing response to a Red Alarm

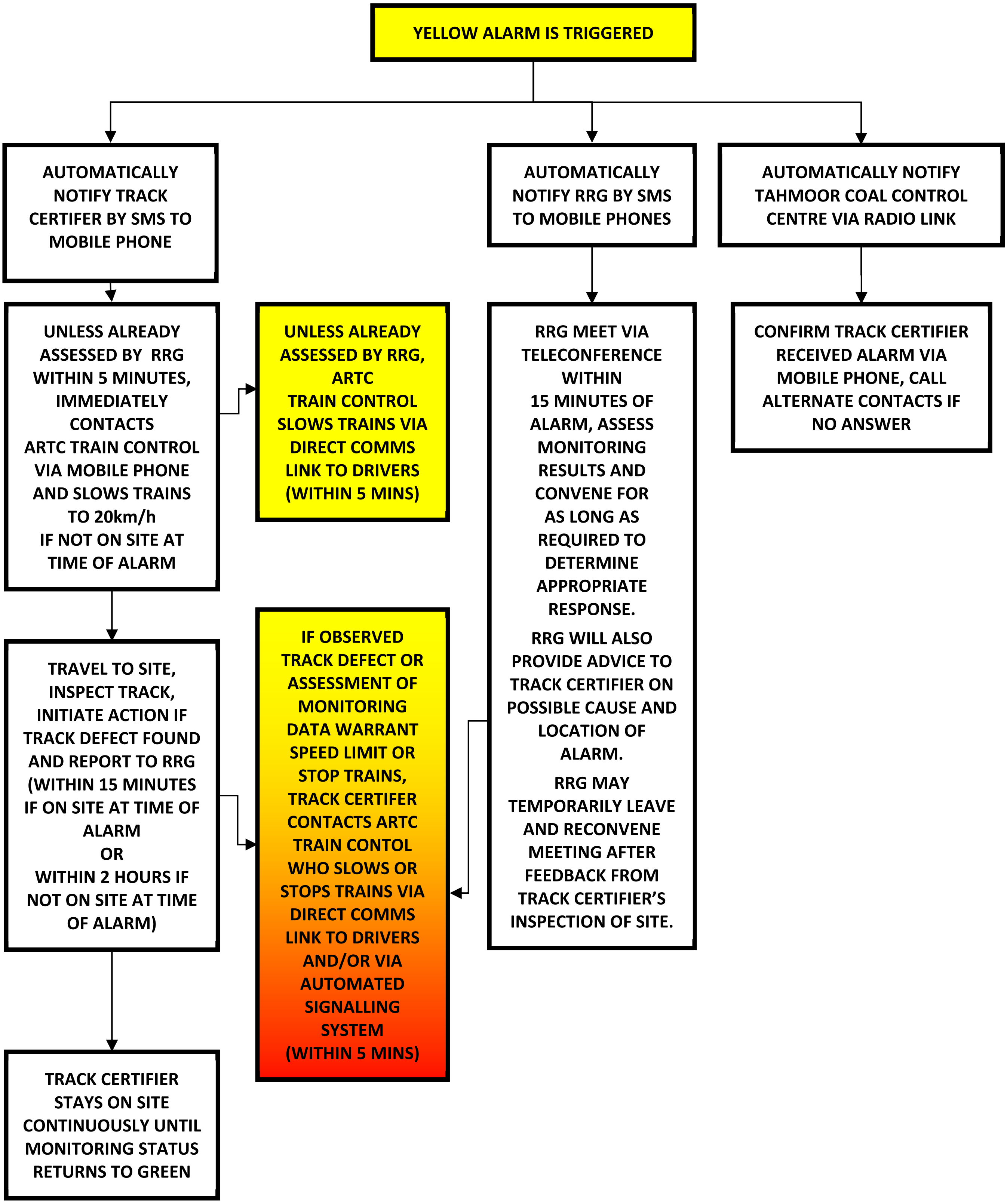


Fig. 6.5 **Flowchart showing response to a Yellow Alarm**

Commercial in Confidence

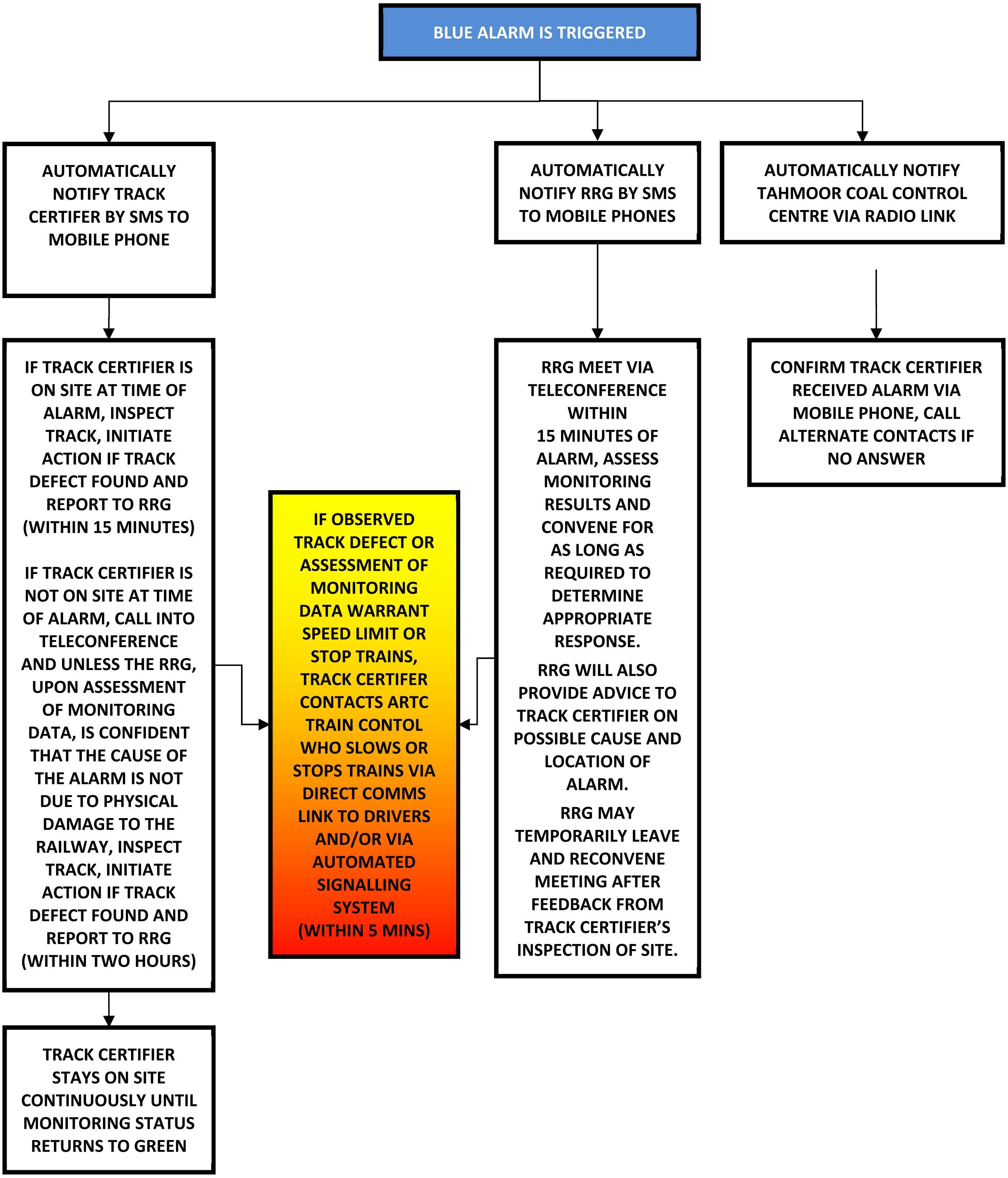


Fig. 6.6 Flowchart showing response to a Blue Alarm

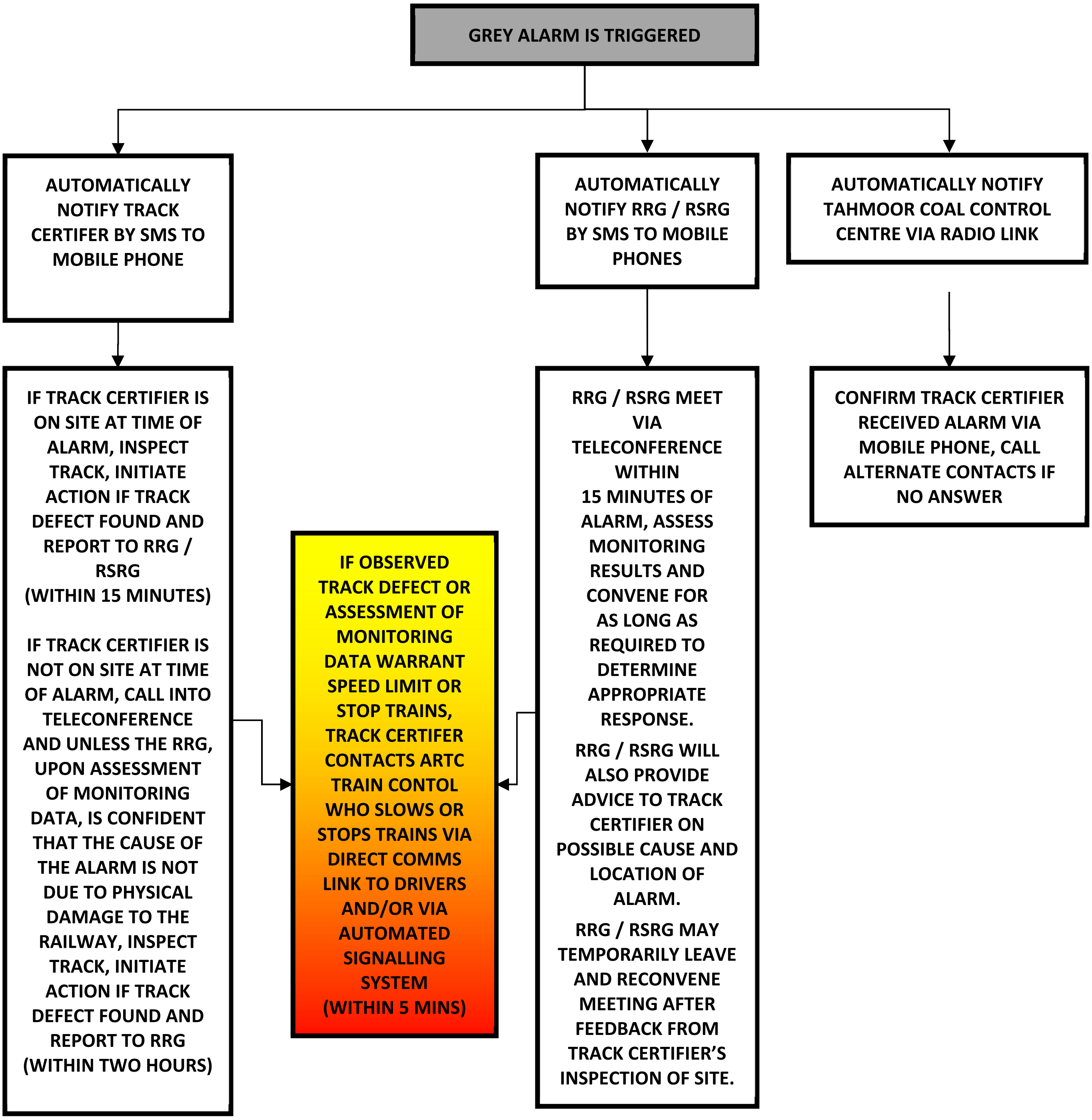


Fig. 6.7 Flowchart showing response to a Grey Alarm

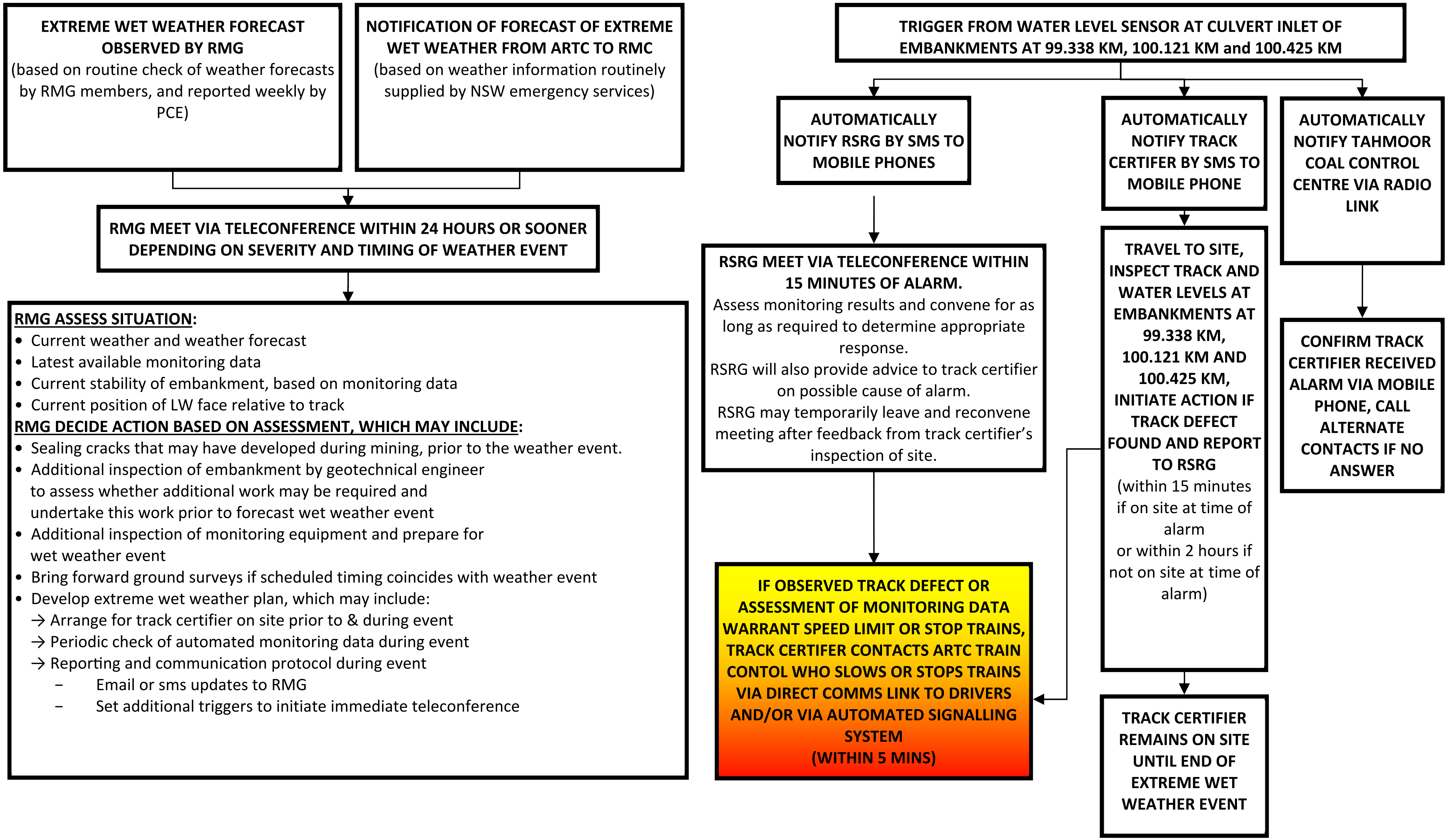


Fig. 6.8 Flowchart showing response to Extreme Wet Weather forecast or alarm for embankments

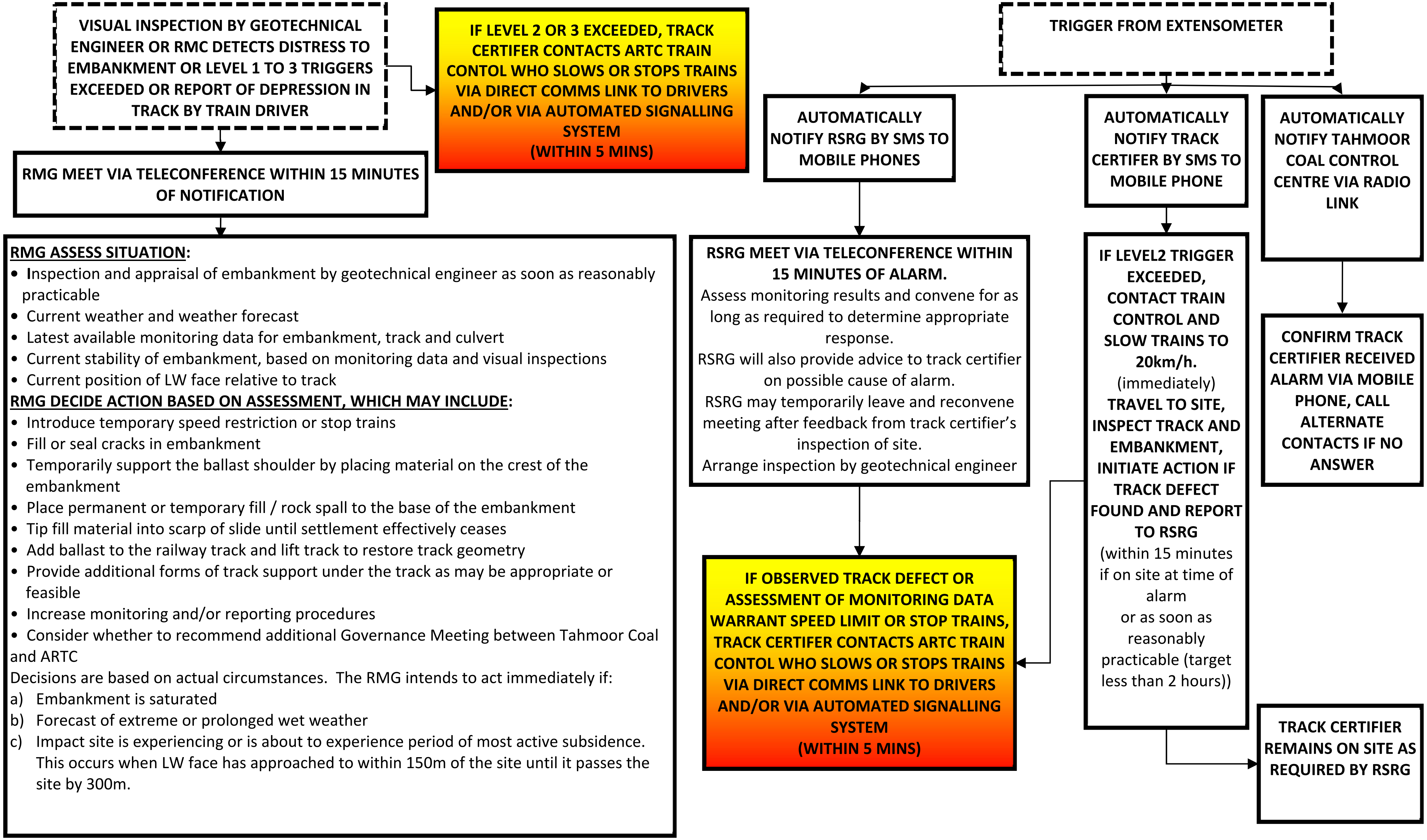


Fig. 6.9 Flowchart showing response to early warning triggers for embankment stability

6.3. Triggers from other Monitoring Measures

Triggers may also be activated from other monitoring measures such the track geometry recording trolley or visual inspections. Upon exceedence of trigger levels, the party responsible for monitoring will notify the RRG and/or RSRG by phone and/or email and the RRG and/or RSRG will meet via teleconference.

6.4. Reports from ARTC Personnel and Train Drivers

Routine response procedures have been developed by ARTC upon reports of potential hazardous conditions from ARTC personnel (e.g. track patrol) and train drivers. ARTC Area Manager – Ingleburn will contact the RRG and/or RSRG if the report incident is related to this project.

6.5. Reporting of Results

All monitoring results are analysed by designated members of the RMG. The following reports will be provided to the RMG:

Monitoring Measure	Monitoring By	Report By
Ground surveys	SRS	MSEC
GNSS monitoring	Unit Zero	MSEC
Structure monitoring	SRS	MSEC
Rail creep	SRS	PCE
Rail stress, rail temperature and switch displacement	Globetech	PCE
Track geometry	RMC	PCE
Crest extensometers and water level sensors	Globetech	Newcastle Geotech
Inclinometer monitoring and visual inspection of embankments	Newcastle Geotech	Newcastle Geotech
Laser distancemeter	Sweeting Consulting	MSEC
Visual track inspections	RMC	RMC
Other railway infrastructure inspections and safety related matters	RMC	RMC
Automated monitoring system status	Globetech	Globetech
Longwall position	TC	MSEC
Summary Status Report	-	MSEC
RMG Meeting Minutes	-	Robinson Rail

The reports will provide the following information:

- Analysis of results;
- Identify trends and irregularities;
- Compare with predictions (where relevant);
- Forecast possible exceedence of triggers; and
- Recommend whether any further actions are required.
- The timing of reports will vary during the mining period, with frequency aligned with stages of subsidence management.

A one to two page status report will periodically provide the following information:

- Position of longwall relative to railway;
- Summary of management actions since last report;
- Summary of consultation with stakeholders 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 by the RMG whether there will be any subsidence impacts to the operation and safety of the Railway in the next monitoring period due to the continued extraction of LW S1A-S6A.

6.6. Web-based reporting of results

Electronic monitoring data will be posted on the project website, for which access is available to all members of the RMG.

6.7. Communication with MSO and ONRSR

MSO and ONRSR will be kept informed during and after mining via monitoring reports and status reports.

MSO and ONRSR will be informed of changes to management measures separately in writing or by email following authorisation by ARTC. The notification will describe what changes have or will be undertaken to management measures and/or monitoring measures.

It is also possible that small losses of monitoring data may occur if survey marks or automated monitoring equipment is fails, damaged or vandalised during the mining period. It is also possible that the track geometry recording trolley may be temporarily damaged and require repair. The RMG will consider whether the monitoring measures should be reinstated or whether alternative monitoring measures should be introduced while monitoring measures are being repaired. The consideration will be made on a case by case basis, based on the stage of mining and observed subsidence and rail movements.

Tahmoor Coal will inform ARTC, MSO and ONRSR of the details concerning the loss of monitoring data and decisions taken by the RMG in the monitoring and/or status reports.

6.8. Training and Induction

Training, inductions and briefings have previously been undertaken for the Rail Management Group, ARTC Ingleburn staff, Junee Train Control and Tahmoor Coal Control Centre.

Briefings were undertaken for the groups listed below.

- ARTC Ingleburn staff: Non-standard track system, likely subsidence, monitoring activities, alarm procedures, notification of alarms, response procedures;
- ARTC Train Control: Non-standard track system, likely subsidence, monitoring activities, alarm procedures, notification of alarms, response procedures;
- Track Certifiers: Full briefing on management plans, non-standard track system, likely subsidence, monitoring activities, operation of track geometry monitoring device, alarm procedures, notification of alarms, response procedures, reporting procedures, contact lists, use of web-based system. The briefing will include instruction on the identification of warning signs that indicate potential instability of geotechnical features such as embankments and cuttings; and
- Tahmoor Coal Control Centre: Triggers, TCCC actions and reporting

Tahmoor Coal will conduct a briefing and induction with Train Control prior to the influence of LW S1A on the Railway.

7.0 REHABILITATION PLAN

Any damage that occurs will be repaired by Tahmoor Coal in consultation with ARTC and Subsidence Advisory NSW. Funding of the repairs shall be in accordance with the Deed of Agreement between the ARTC and Tahmoor Coal and with consideration of the role of Subsidence Advisory NSW.

Sections of track will be rehabilitated following the removal of switches and returned to normal CWR track once it is considered that future mine subsidence movements will not impact on each section of track. Rehabilitation includes regrading and realignment of the track in accordance with ARTC requirements. A 'handover' procedure is being developed by ARTC/RMG to enable a seamless transition between ARTC and Tahmoor Coal once work in each track section is satisfactorily completed.

8.0 AUDITING 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.
- 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.
- Observation of significant variation between observed and predicted subsidence.
- Identification of improved methods of managing the identified risks.
- A request by ARTC to conduct a review.

A compliance audit was completed for Longwalls 29 and 30 by HMS Consultants in June 2017 (HMS, 2017). No major non-conformances were found. The principal findings of the Audit are listed below.

- The Rail Management Plans have achieved the defined performance measures, which are listed below.
  - That the Main Southern Railway must be always safe and serviceable; and
  - Damage that does not affect safety or serviceability must be fully repairable, and must be fully repaired.
- ARTC has a high level of confidence in the Rail Management Plan.

Other key findings of the Audit are listed below.

- There is a high level of compliance with the Rail Management Plans.
- The Rail Management Plans are risk based, very comprehensive and have been enhanced over time taking on-board continuous improvement opportunities.
- The web based information management system is effective in managing and communicating information.
- The Rail Management Group is effective in implementing the Rail Management Plan requirements.
- Whilst the rail monitoring system has occasionally triggered false alarms, there has not been a situation where a rail integrity concern has occurred without an alarm being triggered.

Should an additional audit of the Management Plan be required, 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.

Changes to management or monitoring measures will be undertaken in accordance with the procedures described in Section 1.12.

9.0 CONTACT LIST

Name (* denotes RMG member)	Contact details	Alternate	Alternate contact details
ARTC			**Sydney 3 – Network Control Centre (Junee)** Ph: (02) 6924 9803 Sydney 3 Emergency Ph: (02) 6924 9863 **Train Transit Manager** **Network Control Centre South (Junee)** Ph: (02) 6924 9809 Fax: (02) 6930 5308 Train Transit Manager Emergency Ph: (02) 6924 9869 **ARTC Ingleburn** Ph: (02) 4868 0620 Fax: (02) 4868 0637
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Peter Haskard Manager Engineering Interstate Network	Ph: (03) 9313 9205 Mob: 0427 001 828 phaskard@artc.com.au	Contact Michael Irons, Sladjan Mitic or Brian Cooper if unavailable	
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Tahmoor Coal Control	(02) 46 400 111		
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Ray Ramage A/Principal Subsidence Engineer & A/Principal Inspector	Ph: (02) 4931 6645 Mob: 0402 477 620 ray.ramage@regional.nsw.gov.au	Phil Steuart Inspector	Ph: (02) 4931 6648 phil.steuart@regional.nsw.gov.au
		Alan Blakeney Senior Mine Safety Officer (Subsidence Engineering)	Ph: 0473 461 118 alan.blakeney@ regional.nsw.gov.au

Name (* denotes RMG member)	Contact details	Alternate	Alternate contact details
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Subsidence Advisory NSW			
Matthew Montgomery Infrastructure Manager	Ph: (02) 4677 1967 Mob: 0425 275 564 Fax: (02) 4677 2040 Matthew.Montgomery@customerservice.nsw.gov.au	Contact Picton Office if unavailable on (02) 4677 1967	
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Mark Delaney*	Mob: 0428 689 509 markdelaney@newcastlegeotech.com.au	Contact Graeme Robinson if unavailable	
JMA Solutions			
John Matheson*	Ph: (02) 9979 6618 Mob: 0418 238 777 john@jmasolutions.com.au	Contact Mark Delaney or Graeme Robinson if unavailable	
Robinson Rail			
Graeme Robinson*	Ph: (02) 4998 7152 Mob: 0410 455 911 robinsonrail@iinet.net.au	Contact Allan Pidgeon or Ross Barber if unavailable	
Mine Subsidence Engineering Consultants			
Daryl Kay*	Ph: (02) 9413 3777 Mob: 0416 191 304 daryl@minesubsidence.com	James Barbato	Ph: (02) 9413 3777 Mob: 0403 685 530 james@minesubsidence.com
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Bloor Rail (Rail Maintenance Contractor)			
Chris Bloor*	Ph: (02) 4257 9399 Mob: 0422 807 231 Fax: (02) 4256 0172 chris@BloorRail.com.au	On call Track Certifier	
On Duty Track Certifier	Mob: 0422 033 410	Contact Chris Bloor or Curtis McClelland if unavailable	
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APPENDIX A. Risk Control Procedures for LW S1A to S6A

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Table A. 1 Risk Control Procedures for LW S1A-S6A

RISK ISSUE	TRIGGER	CONTROL PROCEDURES	TIMING & FREQ	BY WHOM?
General Procedures				
	GREEN	**EARLY WARNING MONITORING**		
	GREEN	Continuous GNSS monitoring for S1 to S15 as shown in Drawing No. MSEC1201-03	GNSS units S1 to S15 installed Continuous readings, with data averaged over 24 hours and recorded once per day until end of LW S6A.	Tahmoor Coal (Unit Zero)
	GREEN	Continuous GNSS monitoring at 100.70 km	Install prior to start of LW S4A Continuous readings, with data averaged over 24 hours and recorded once per day until end of LW S6A.	Tahmoor Coal (Unit Zero)
	GREEN	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)
	GREEN	**RAILWAY TRACK**		
	GREEN	3D ground survey along rail corridor *Extents for 3D surveys:* *LW S1A: 99.80km to 98.74km (AP2) and then extend to the north to include pegs that are at least 400 metres in front of the LW face, up to 97.70 km. (End of LW from 97.70 km to 99.80km)* LW S2A: *100.20km to 99.46km (AP4) and then extend to the north to include pegs that are at least 400 metres in front of the LW face, up to 98.18 km. (End of LW from 100.20km to 97.70km)* LW S3A: *100.60km to 99.78km (AP5) and then extend to the north to include pegs that are at least 400 metres in front of the LW face, up to 98.38 km. (End of LW from 100.60km to 98.20km)* LW S4A: *101.16km to 100.14km (AP6) and then extend to the north to include pegs that are at least 400 metres in front of the LW face, up to 98.74 km. (End of LW from 100.90km to 98.38km)* LW S5A: *101.16km to 100.14km (AP6) and then extend to the north to include pegs that are at least 400 metres in front of the LW face, up to 99.10 km. (End of LW from 101.16km to 98.92km)* LW S6A: *101.16km to 100.14km (AP6) and then extend to the north to include pegs that are at least 400 metres in front of the LW face, up to 99.46 km. (End of LW from 101.16km to 99.28km)*	Pegs installed initially from 97.7 km to 99.8 km for LW S1A Extend line and baseline survey pegs prior to start of each LW or active LW face approaching within 600 metres of survey line. Monthly 3D surveys commencing as per below (Stage 1): LW S1A: start after 700m extraction LW S2A: start after 550m extraction LW S3A: start after 300m extraction LW S4A: at LW start LW S5A: at LW start LW S6A: at LW start End of LW S1A-S6A.	SRS
	GREEN	Focussed 2D ground survey along rail corridor *Extents for focussed 2D surveys:* *LW S1A: 99.80km to 98.74km (AP2) and then extend to the north to include pegs that are at least 200 metres in front of the LW face, up to 97.70 km. (End of LW from 97.70 km to 99.80km)* LW S2A: *100.20km to 99.46km (AP4) and then extend to the north to include pegs that are at least 200 metres in front of the LW face, up to 98.18 km. (End of LW from 100.20km to 97.70km)* LW S3A: *100.60km to 99.78km (AP5) and then extend to the north to include pegs that are at least 200 metres in front of the LW face, up to 98.38 km. (End of LW from 100.60km to 98.20km)* LW S4A: *101.16km to 100.14km (AP6) and then extend to the north to include pegs that are at least 200 metres in front of the LW face, up to 98.74 km. (End of LW from 100.90km to 98.38km)* LW S5A: *101.16km to 100.14km (AP6) and then extend to the north to include pegs that are at least 200 metres in front of the LW face, up to 99.10 km. (End of LW from 101.16km to 98.92km)* LW S6A: *101.16km to 100.14km (AP6) and then extend to the north to include pegs that are at least 200 metres in front of the LW face, up to 99.46 km. (End of LW from 101.16km to 99.28km)*	Pegs installed from initially from 97.7 km to 99.8 km for LW S1A Extend line and baseline survey pegs prior to start of each LW or active LW face approaching within 600 metres of survey line. Weekly 2D surveys commencing as per below (Stage 2): LW S1A: start after 900m extraction LW S2A: start after 750m extraction LW S3A: start after 500m extraction LW S4A: start after GNSS at 100.70km subsides more than 20mm after LW start or 200m extraction, whichever occurs first LW S5A: start after GNSS at 100.70km subsides more than 20mm after LW start or 200m extraction, whichever occurs first LW S6A: start after GNSS at 100.70km subsides more than 20mm after LW start or 200m extraction, whichever occurs first End of LW S1A-S6A.	SRS
	GREEN	Rail creep surveys of expansion switches, anchor points and CWR track (include all track expansion system zones where ZTL clips have been installed)	Weekly after ZTL clips have been installed	SRS
	GREEN	Long bay length ground surveys *Extents for long bay length ground surveys as per focussed 2D surveys*	Weekly as per focussed 2D surveys (Stage 2)	SRS
	GREEN	Continuously monitor rail stress, rail temperature and switch displacement *Extents for active subsidence monitoring:* *LW S1A: 99.78km to 98.74km (AP2) and then extend to the north to include gauges that are at least 200 metres in front of the LW face, up to 97.78 km.* LW S2A: *100.14km to 99.46km (AP4) and then extend to the north to include gauges that are at least 200 metres in front of the LW face, up to 98.14 km.* LW S3A: *100.44km to 99.78km (AP5) and then extend to the north to include gauges that are at least 200 metres in front of the LW face, up to 98.38 km.* LW S4A: *101.10km to 100.14km (AP6) and then extend to the north to include gauges that are at least 200 metres in front of the LW face, up to 98.74 km.* LW S5A: *101.10km to 100.14km (AP6) and then extend to the north to include gauges that are at least 200 metres in front of the LW face, up to 99.10 km.* LW S6A: *101.10km to 100.14km (AP6) and then extend to the north to include gauges that are at least 200 metres in front of the LW face, up to 99.46 km.*	Readings every 5 minutes Gauges installed from initially from 97.78 km to 99.78 km for LW S1A Extend and commission system as per timings in Drawings Nos. MSEC1201-04-1A to 6A. Alarmed as per below (Stage 2) LW S1A: start after 900m extraction LW S2A: start after 750m extraction LW S3A: start after 500m extraction LW S4A: at LW start LW S5A: at LW start LW S6A: at LW start	Globetech

GENERAL TRIGGER LEVELS

Trigger Level	Description
GREEN	Observations within operating tolerance. Operate as normal.
BLUE	Observations within operating tolerance but nearing limits. Investigate cause. Some action may be required to prevent operating restrictions. Immediately inspect site unless it is obvious that the cause of the trigger cannot be due to physical damage to rail infrastructure. Otherwise inspect within 24 hours. Return status to Green level.
YELLOW	Restrictions on operations. Immediate site inspection. Action required within 6 hours. Appropriate speed restriction may apply until altered to Green or Blue Level.
RED	Stop trains, inspect prior to next train, repair to lower category, pilot trains if safe.

ABBREVIATIONS WITHIN THESE TABLES:

ARTC = Australian Rail Track Corporation

MSO = NSW Department of Planning & Environment, Resources Regulator, Mine Safety Operations

ONRSR = Office of the National Rail Safety Regulator

Globetech = Automated Monitoring Contractor

SRS = Southern Rail Surveys (ground surveys within rail corridor)

SA NSW = Subsidence Advisory NSW

MSEC = Mine Subsidence Engineering Consultants

RMG = Rail Management Group

RMC = Rail Maintenance Contractor

RRG = Rail Response Group

RSRG = Rail Structures Response Group

PCE = Pidgeon Civil Engineering

JMA = JMA Solutions (structural engineer)

SMEC = SMEC (ground surveys beyond rail corridor)

TC = Tahmoor Coal

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RISK ISSUE	TRIGGER	CONTROL PROCEDURES	TIMING & FREQ	BY WHOM?
		Continuously monitor rail stress and rail temperature to monitor residual subsidence effects *Residual subsidence monitoring = at least one working gauge every 120 m along each rail (extent may be reduced from the north based on future assessment)*	Every 5 minutes	Globetech
		Track geometry surveys using Amber track mounted device or equivalent *Extents for track geometry surveys as per focussed 2D surveys*	Weekly as per focussed 2D surveys (Stage 2)	RMC
		Track centre measurements at 98.620 km, 99.600 km and 101.200 km	Monthly when track is in Stage 2	SRS
		Track inspection by qualified track certifier. The inspection will check ARTC infrastructure within the rail corridor, including the track, track expansion system, integrity of monitoring systems, culverts, embankments, cuttings, signals and Loc's and fences *The extent of visual inspections is the same as the extent of track geometry surveys plus dormant expansion switches*	Twice weekly whilst expansion switches are in track Daily as per below (Stage 2) LW S1A: start after 900m extraction LW S2A: start after 750m extraction LW S3A: start after 500m extraction LW S4A: start after GNSS at 100.70km subsides more than 20mm after LW start or 200m extraction, whichever occurs first LW S5A: start after GNSS at 100.70km subsides more than 20mm after LW start or 200m extraction, whichever occurs first LW S6A: start after GNSS at 100.70km subsides more than 20mm after LW start or 200m extraction, whichever occurs first	RMC
		RAILWAY CULVERTS AND EMBANKMENTS		
		Absolute 3D and 2D surveys along monitoring line along the railway	Absolute 3D monthly and 2D weekly as described for railway track	SRS
		Absolute 3D surveys and relative 3D surveys along monitoring lines on the crests and/or toes of the embankments on both sides and at culvert inlets and outlets. The layout of survey marks are shown in Drawings Nos. MSEC1201-05 to 12. *Install Culvert and Embankment at 98.445 km prior to 600 metres of extraction of LW S1A* *Install Culvert and Embankment at 98.739 km prior to 600 metres of extraction of LW S1A* *Install Culvert and Embankment at 99.035 km prior to 600 metres of extraction of LW S1A* *Install Culvert and Embankment at 99.338 km prior to 600 metres of extraction of LW S1A* *Install Culvert and Embankment at 100.121 km prior to start of LW S3A* *Install Culvert and Embankment at 100.425 km prior to start of LW S3A* *Install Culvert and Embankment at 101.000 km prior to start of LW S5A*	Monthly when track above each culvert is in Stage 1 Weekly when track above each culvert is in Stage 2 End of LW S1A-S6A	SRS
		Automated, continuously operating horizontal extensometers (or equivalent) across the crests of the Embankments at 99.338 km, 100.121 km and 100.425 km *Install 99.338 km prior to 900 metres of extraction of LW S1A* *Install 100.121 km prior to start of LW S3A* *Install 100.425 km prior to start of LW S3A*	Every 15 minutes Operating as per timings in Drawings Nos. MSEC1201-04-1A to 6A. Alarmed when track above each culvert is in Stage 2	Globetech
		Inclinometer surveys of the Embankments at 99.338 km, 100.121 km and 100.425 km *Install 99.338 km prior to 600 metres of extraction of LW S1A* *Install 100.121 km prior to start of LW S3A* *Install 100.425 km prior to start of LW S3A*	Monthly when track above culvert is in Stage 1 and Stage 2	TC
		Automated, continuously operating water level sensors at culvert inlets to Embankments at 99.338 km, 100.121 km and 100.425 km *Install 99.338 km prior to 600 metres of extraction of LW S1A* *Install 100.121 km prior to start of LW S3A* *Install 100.425 km prior to start of LW S3A*	Every 15 minutes Operating as per timings in Drawings Nos. MSEC1201-04-1A to 6A. Alarmed when track above culvert is in Stage 2	Globetech
		Visual inspection of culverts and embankments by geotechnical engineer	Monthly when track above culvert is in Stage 1 Weekly when track above culvert is in Stage 2	Newcastle Geotech
		CUTTINGS		
		Absolute 3D and 2D surveys along monitoring line along the railway	Absolute 3D monthly and 2D weekly as described for railway track	SRS
		Absolute 3D surveys every 20 metres along the crests and/or toes of the cuttings *Install Cutting at 99.690 km prior to 450 metres of extraction of LW S2A* *Install Cutting at 100.700 km prior to start of LW S4A* *Install Cutting at 101.162 km prior to start of LW S5A*	Monthly when section of track is in Stage 1 Weekly when section of track is in Stage 2 End of LW S1A-S6A	SRS
		Visual inspection of cuttings by geotechnical engineer	Monthly when section of track is in Stage 1 Weekly when section of track is in Stage 2	Newcastle Geotech

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RISK ISSUE	TRIGGER	CONTROL PROCEDURES	TIMING & FREQ	BY WHOM?
	GREEN	**BRIDGES**		
		Pre-mining inspection and structural assessment of Bridges	Complete	JMA
		Geological inspection and mapping at Railway Viaduct, Remembrance Drive Bridge over Bargo River and Bargo River Road Overbridge (Potter's Cutting)	Complete	Newcastle Geotech
		Review by Bridge Technical Committee and modify planned management and monitoring measures for Railway Viaduct, Remembrance Drive Bridge over Bargo River, Bargo River Road Overbridge (Potter's Cutting) and Wellers Road Overbridge and implement, if required	Prior to 800 m of extraction of LW S1A	Bridge Technical Committee / Tahmoor Coal
		Brief ARTC on planned management and monitoring measures for Railway Viaduct, Remembrance Drive Bridge over Bargo River, Bargo River Road Overbridge (Potter's Cutting) and Wellers Road Overbridge	Prior to 800 m of extraction of LW S1A	Tahmoor Coal
		Continuous GNSS monitoring for S11, S12 (Railway Viaduct) and S15 (Wellers Road Overbridge) as shown in Drawing No. MSEC1201-03	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)
		Conduct Absolute 3D survey of structure and ground marks on the Railway Viaduct and Remembrance Drive Bridge over Bargo River as per Drawing No. MSEC1201-13	Install and baseline survey prior to LW S1A. Monthly after 1000m extraction of LWs S1A to S3A End of LW S1A-S3A.	Tahmoor Coal (SRS)
		Precision 2D survey of closure between ground marks located in stable ground at both ends of the Railway Viaduct and Remembrance Drive Bridge over Bargo River	Install and baseline survey prior to LW S1A. Monthly after 1000m extraction of LWs S1A to S3A End of LW S1A-S3A.	SRS
		Baseline detailed visual inspections of Railway Viaduct by UAV	Complete	TC
		Baseline laser scan of Railway Viaduct and Remembrance Drive Bridge over Bargo River	Complete	TC
		Monitoring of existing cracks with crack gauges on Railway Viaduct *Installation is targeted to be completed by 1000 m of extraction of LW S1A. Installation of some gauges may be delayed until rope access is available during an ARTC track possession.*	Install and baseline measure prior to 1000 m of extraction of LW S1A.	TC
		Measure gap between deck and northern abutment of Remembrance Drive Bridge over Bargo River	Install and baseline survey prior to LW S1A. Monthly after 1000m extraction of LWs S1A to S3A End of LW S1A-S3A.	Tahmoor Coal (SRS)
		Conduct Local 3D survey of structure and ground marks on the Bargo River Road Overbridge (Potter's Cutting) as per Drawing No. MSEC1201-14, with one mark on the Bridge to be surveyed in Absolute 3D	Install and baseline survey prior to LW S1A.	Tahmoor Coal (SRS)
		Monitoring of existing cracks with crack gauges on Bargo River Road Overbridge (Potter's Cutting)	Install and baseline measure prior to 1000 m of extraction of LW S1A. Monthly after 1000m extraction of LWs S1A to S3A End of LW S1A-S3A.	TC
		Conduct Local 3D survey of structure and ground marks on the Wellers Road Overbridge as per Drawing No. MSEC1201-15	Install and baseline survey prior to LW S1A. Monthly after 200m extraction of LWs S4A to S6A End of LW S1A-S6A.	Tahmoor Coal (SRS)
		Monitoring of existing cracks with crack gauges on Wellers Road Overbridge	Install and baseline survey prior to LW S4A. Monthly after 200m extraction of LWs S4A to S6A End of LW S1A-S6A.	TC

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Table A. 1 Risk Control Procedures for LW S1A-S6A (continued)

RISK ISSUE	TRIGGER	CONTROL PROCEDURES	TIMING & FREQ	BY WHOM?
General Procedures (continued)				
	GREEN	**COAL CONVEYOR CROSSING**		
		Survey horizontal distance between conveyor trestles on either side of Railway	Baseline survey prior to 700 m of extraction of LW S1A Weekly surveys after 1100 m of extraction of LW S1A and LW S2A End of LW S1A and S2A	SRS
		Automated, continuously operating laser distancemeter between conveyor trestles on either side of Railway	Installed Hourly	SweetingConsulting
		Visual inspections of conveyor crossing	Daily when track is in Stage 2	RMC
		OTHER MEASURES		
		Undertake investigations as required to assist in identifying potential locations of non-conventional movement. Reconsider management measures in light of new information that becomes available.	Ongoing	RMG
		Dilapidation inspections	Complete	Various
		Standard ARTC maintenance and control procedures - Twice weekly track patrol - AK track recording car - Base Operating Standards Mandatory Responses - Driver reports and temporary speedboards - Signalling and Communications procedures - Ultrasonic rail test (high rail)	As per ARTC procedures	ARTC
		Follow Railway Maintenance Plan including - quarterly manual non-destructive testing of expansion switches - switch inspections and maintenance - clip inspections and maintenance Refer Section 5.8 for details	As per Railway Maintenance Plan	RMC
		Brief and train: - Tahmoor Coal Control Room operators - Relevant ARTC staff Refer Section 5.8 for details	Prior to 900 m of extraction of LW S1A Brief and train new personnel as req'd	Robinson Rail
		Check and Audit maintenance and monitoring system performance	Periodically as determined by RMG	RMG
		Analyse and report results to RMG	Monthly when section of track is in Stage 1 Weekly when section of track is in Stage 2	Section 6.5
		RMG discuss results and consider whether any additional management measures are required	Monthly when section of track is in Stage 1 Weekly when section of track is in Stage 2 or as required by RMG	RMG
		RMG discuss progress with MSO and ONRSR	As required	RMG

Note: Unless specified above, each control procedure will continue until such time that the criteria for Stage 3 (post-active subsidence period) are met, as described in Section 5.4: The RMG may extend the monitoring period beyond the timing and frequency described based on assessment of actual monitoring data.

Table A. 1 Risk Control Procedures for LW S1A-S6A (continued)

RISK ISSUE	TRIGGER	CONTROL PROCEDURES	TIMING & FREQ	BY WHOM?
Track Geometry exceeds ARTC National Code of Practice, leading to: • Unplanned maintenance response • Temporary speed restrictions • Track closure • Derailment (see TRACK GEOMETRY TRIGGERS below)	GREEN	Follow general procedures (including track geometry monitoring)	-	-
	BLUE	Contact RRG and arrange teleconference	Within 15 minutes of determining exceedence of trigger level	Section 6.2 and Section 6.3
		RRG undertake following action(s): - investigate cause - assess monitoring data for trends and forecast if and/or when the YELLOW and RED trigger levels might be exceeded - consider whether to increase survey and/or inspection frequencies - consider whether to resurface the track - consider whether any other additional management measures are req'd	RRG meet via teleconference within 15 minutes of notification of exceedence of trigger level	RRG
		Inspect track at trigger point for visual signs of impact unless RRG is confident that cause of trigger cannot be due to physical damage to the railway Remain on site until status returns to GREEN level	Immediately following assessment of RRG via teleconference and arrive within 2 hours, if req'd Otherwise within 24 hours	RMC
		Report details of exceedence of trigger level and actions undertaken	Within one week	PCE
	YELLOW	Contact RRG and arrange teleconference	Within 15 minutes of determining exceedence of trigger level	Section 6.2 and Section 6.3
		Contact Train Control & introduce track speed of 20km/h. Inspect track at trigger point.	Immediately	RMC
		RRG undertake following action(s): - investigate cause and assess monitoring data for trends and forecast if and/or when the RED trigger level might be exceeded - decide whether to increase survey and/or inspection frequencies - decide whether to resurface the track - decide whether any other additional management measures are req'd - decide whether to introduce speed restrictions - consider whether to slow or stop mining if impact to rail operations is unacceptable to ARTC	RRG meet via teleconference within 15 minutes of notification of exceedence of trigger level	RRG
		Report exceedence of trigger level & RRG decisions to RMG, ARTC, MSO, ONRSR and SA NSW	Within 24 hours if the alarm is real	TC
		Report details of exceedence of trigger level and actions undertaken	Within one week	PCE
	RED	Contact RRG and arrange teleconference	Within 15 minutes of determining exceedence of trigger level	Section 6.2 and Section 6.3
		Stop trains and implement mandatory responses as required. Inspect track at trigger point.	Immediately	RMC
		RRG undertake following action(s): - investigate cause - decide whether to resurface the track - decide whether any other additional management measures are req'd - decide whether to introduce speed restrictions - consider whether to recommend to TC senior management to slow or stop mining if impact to rail operations is unacceptable to ARTC	RRG meet via teleconference within 15 minutes of notification of exceedence of trigger level	RRG
		Report exceedence of trigger level & RRG decisions to RMG, ARTC, MSO, ONRSR and SA NSW.	Within 24 hours if the alarm is real	TC
		Report details of exceedence of trigger level and actions undertaken	Within one week	PCE

TRACK GEOMETRY TRIGGERS

Units in mm	Difference from Design Cant	Twist	Top Mid-ordinate Vertical Deviation from Design Offset	Alignment Mid-ordinate Horizontal Deviation from Design Offset in a 10m Chord
GREEN	Tangents & R>2000m 0 to < 40 R < 2000m 0 to < 14	2m Chord 0 to < 16 14m Chord 0 to < 40	6m Chord 0 to < 26 20m Chord Inertial 0 to < 28 Krab 0 to < 39	0 to < 24
BLUE	Tangents & R>2000m ≥ 40 to < 50 R < 2000m (insufficient cant) ≥ 14 to < 20 R < 2000m (excess cant) ≥ 14 to < 50	2m Chord ≥ 16 to < 18 14m Chord ≥ 40 to < 46	6m Chord ≥ 26 to < 29 20m Chord Inertial ≥ 28 to < 32 Krab ≥ 39 to < 44	≥ 24 to < 34
YELLOW	Tangents & R>2000m ≥ 50 to < 75 R < 2000m (insufficient cant) ≥ 20 to < 40 R < 2000m (excess cant) ≥ 50 to < 75	2m Chord ≥ 18 to < 20 14m Chord ≥ 46 to < 52	6m Chord ≥ 29 to < 32 20m Chord Inertial ≥ 32 to < 35 Krab ≥ 44 to < 49	≥ 34 to < 44
RED	Tangents & R>2000m ≥ 75 R < 2000m (insufficient cant) ≥ 40 R < 2000m (excess cant) ≥ 75	2m Chord ≥ 20 14m Chord ≥ 52	6m Chord ≥ 32 20m Chord Inertial ≥ 35 Krab ≥ 49	≥ 44

Table A. 1 Risk Control Procedures for LW S1A-S6A (continued)

RISK ISSUE

Mining induced ground movements causes excessive compressive stress resulting in either misalignment of track, broken rail or curve pull-in potentially leading to:

- Unplanned maintenance response
- Temporary speed restrictions
- Track closure
- Side swipe
- Derailment

This risk issue applies to standard CWR track or track with expansion switches and zero toe load clips

or

Zero-toe load clips jam resulting in increase in rail stress potentially leading to:

- Unplanned intervention on track

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RAIL STRESS TRIGGERS

	Tension		Compression	
	Rail Stress in CWR	Rail Stress in Free Rail	Rail Stress in CWR	Rail Stress in Free Rail
Units	MPa	MPa	MPa	MPa
GREEN	0 to <114.2	0 to < 46.4	0 to > -83.3	0 to > -46.4
BLUE	≥ 114.2 to < 123.8	≥ 46.4 to < 123.8	≤ -83.3 to > -92.8	≤ -46.4 to > -92.8
YELLOW	≥ 123.8 to < 128.5	≥ 123.8 to < 128.5	≤ -92.8 to > -97.6	≤ -92.8 to > -97.6
RED	≥ 128.5	≥ 128.5	≤ -97.6	≤ -97.6

Note: Blue trigger levels transition between CWR and Free Rail sections, as recommended by the RMG.

TRIGGER	CONTROL PROCEDURES	TIMING & FREQ	BY WHOM?
GREEN	Follow general procedures (including rail stress, rail creep and switch displacement monitoring)	-	-
GREEN	Install, operate and monitor track expansion system (Note that CWR track will be managed until the track expansion system is installed).	Switches ES1 to ES4 installed for LW S1A. Install ES5 to ES8 as required in Table 3.3. Install ZTL clips prior to longwall face approaching within 400 m of each switch after monitoring system is commissioned	RMC
BLUE	Automatically notify RRG as per Alarm Notification Protocol	Within 15 minutes	Section 6.2
BLUE	Immediately inspect track at trigger point for visual signs of impact if on site at time of alarm	Within 15 minutes	RMC
BLUE	RRG undertake following action(s): - investigate cause - assess monitoring data for trends and forecast if and/or when the YELLOW and RED trigger levels might be exceeded - consider whether to increase survey and/or inspection frequencies - consider whether to adjust the track or expansion switches - consider whether any other additional management measures are req'd	RRG meet via teleconference within 15 minutes of alarm notification	RRG
BLUE	Inspect track at trigger point for visual signs of impact unless RRG is confident that cause of trigger cannot be due to physical damage to the railway Remain on site until status returns to GREEN level	Immediately following assessment of RRG via teleconference and arrive within 2 hours, if req'd Otherwise within 24 hours	RMC
BLUE	Report details of alarm and actions undertaken	Within one week	PCE
YELLOW	Automatically notify RRG as per Alarm Notification Protocol	Within 15 minutes	Section 6.2
YELLOW	Contact Train Control & introduce track speed of 20km/h. Inspect track at trigger point.	Immediately	RMC
YELLOW	RRG undertake following action(s): - contact Train Control & introduce track speed of 20km/h if Track Certifier is not on site unless RRG is confident the cause of trigger cannot be due to physical damage to the railway within 5 minutes of alarm notification - investigate cause and assess monitoring data for trends and forecast if and/or when the RED trigger level might be exceeded - decide whether to increase survey and/or inspection frequencies - decide whether to adjust the track or expansion switches - decide whether any other additional management measures are req'd - decide whether to introduce speed restrictions - consider whether to slow or stop mining if impact to rail operations is unacceptable to ARTC	RRG meet via teleconference within 15 minutes of alarm notification	RRG
YELLOW	Report exceedence of trigger level & RRG decisions to RMG, ARTC, MSO, ONRSR and SA NSW	Within 24 hours if the alarm is real	TC
YELLOW	Report details of alarm and actions undertaken	Within one week	PCE
RED	Automatically notify RRG as per Alarm Notification Protocol	Within 15 minutes	Section 6.2
RED	Stop trains and implement mandatory responses as required unless RRG is confident the cause of trigger cannot be due to physical damage to the railway within 5 minutes of alarm notification. Inspect track at trigger point.	Immediately	RMC
RED	RRG undertake following action(s): - investigate cause - advise ARTC Area Manager Ingleburn that trains can proceed under caution at 20km/h prior to Track Certifier arriving on site if confident that cause of trigger cannot be due to physical damage to the railway - decide whether to adjust the track or expansion switches - decide whether any other additional management measures are req'd - decide whether to introduce speed restrictions - consider whether to recommend to TC senior management to slow or stop mining if impact to rail operations is unacceptable to ARTC	RRG meet via teleconference within 15 minutes of alarm notification	RRG
RED	Report exceedence of trigger level & RRG decisions to RMG, ARTC, MSO, ONRSR and SA NSW	Within 24 hours if the alarm is real	TC
RED	Report details of alarm and actions undertaken	Within one week	PCE

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Table A. 1 Risk Control Procedures for LW S1A-S6A (continued)

<table>
<tr><th>RISK ISSUE</th><th>TRIGGER</th><th>CONTROL PROCEDURES</th><th>TIMING & FREQ</th><th>BY WHOM?</th></tr>
<tr><td rowspan="6">Switch fails potentially leading to:
• Unplanned maintenance response
• Speed restrictions
• Track closure
• Derailment
or
Switch exceeds operational limits due to excessive differential subsidence movements potentially leading to:
• Intervention on track
• Speed restrictions
TYPE 5 EXPANSION SWITCH DISPLACEMENT TRIGGERS
(TYPE APPROVAL 15/34296)
<table>
<tr><th></th><th>Switch Opening</th><th>Switch Closure</th></tr>
<tr><td>Units</td><td>mm</td><td>mm</td></tr>
<tr><td>GREEN</td><td colspan="2">Centre ± 135</td></tr>
<tr><td>BLUE</td><td>Centre ≤ -135</td><td>Centre ≥ 135</td></tr>
<tr><td>YELLOW</td><td>N/A due to stop blocks</td><td>N/A due to stop blocks</td></tr>
<tr><td>RED</td><td>N/A due to stop blocks</td><td>N/A due to stop blocks</td></tr>
</table>
Note: Expansion switch triggers apply to each switch blade and are measured from edge of base plate.</td>
<td>GREEN</td><td>Follow general procedures (including rail stress, rail creep and switch displacement monitoring, maintenance plan)</td><td>-</td><td>-</td></tr>
<tr><td rowspan="5">BLUE</td><td>Automatically notify RRG as per Alarm Notification Protocol</td><td>Within 15 minutes</td><td>Section 6.2</td></tr>
<tr><td>Immediately inspect track at trigger point for visual signs of impact if on site at time of alarm</td><td>Within 15 minutes</td><td>RMC</td></tr>
<tr><td>RRG undertake following action(s):
- investigate cause
- assess monitoring data for trends and forecast if and/or when the YELLOW and RED trigger levels might be exceeded
- consider whether to increase survey and/or inspection frequencies
- consider whether to adjust the track or expansion switches
- consider whether any other additional management measures are req'd</td><td>RRG meet via teleconference within 15 minutes of alarm notification</td><td>RRG</td></tr>
<tr><td>Inspect track at trigger point for visual signs of impact unless RRG is confident that cause of trigger cannot be due to physical damage to the railway
Remain on site until status returns to GREEN level</td><td>Immediately following assessment of RRG via teleconference and arrive within 2 hours, if req'd
Otherwise within 24 hours</td><td>RMC</td></tr>
<tr><td>Report details of alarm and actions undertaken</td><td>Within one week</td><td>PCE</td></tr>
<tr><td rowspan="2">Braking / acceleration loads resulting in rail creep that potentially leads to intervention on track (limits function of expansion switch)</td><td rowspan="2">GREEN</td><td>Follow general procedures (including rail stress, rail creep and switch displacement monitoring)</td><td>-</td><td>-</td></tr>
<tr><td>Install anchor points as per design</td><td>-</td><td>RMC</td></tr>
<tr><td>Switch allows excessive opening of a broken rail underneath rail traffic potentially leading to derailment</td><td>GREEN</td><td>Follow general procedures (including quarterly non-destructive testing of welds, maintenance plan). Note that rails are in zero-toe load track, which has effectively unstressed the rail and should not break.
Blue, Yellow and Red triggers and responses under “Switch Failure” also apply to this risk.</td><td>-</td><td>-</td></tr>
<tr><td>Switch becomes unserviceable due to uneven wear, inherent design or quality of steel</td><td>GREEN</td><td>Follow general procedures (including maintenance plan).</td><td>-</td><td>-</td></tr>
<tr><td rowspan="4">Switch or switches destroyed due to unrelated derailment, such that switches are removed and replaced by straight rail, potentially leading to train delays due to undertaking frequent adjustments of CWR track in response to continued mine subsidence movements</td><td rowspan="2">GREEN</td><td>Follow general procedures, including standard ARTC wayside detection, redundant monitoring controls (ground survey, track inspections, amber track geometry and automated monitoring systems) and on call maintenance.</td><td>-</td><td>-</td></tr>
<tr><td>Store critical spare parts on site</td><td>Prior to subsidence</td><td>RMC</td></tr>
<tr><td rowspan="2">Switch or switches destroyed by unrelated derailment</td><td>Notify RMG in accordance with Alarm Notification Protocol</td><td>Immediately</td><td>RMC</td></tr>
<tr><td>RMG meet and consider in consultation with ARTC Incident Management Team, MSO and ONRSR the implementation of additional control measures. These may include:
- repair switches and replace with spare parts as required
- introduce speed restrictions once track is re-opened by ARTC
- consolidate all remaining operational switches to one track and conduct single line working
- spread out all remaining operational switches on both tracks and reassess with smaller trigger levels for switch displacement due to longer free rail lengths
- increase monitoring frequency
- regular cut and re-stress of CWR track based on ground monitoring data
- consider need to stop or slow longwall progress until switches are operational</td><td>Within 24 hours</td><td>RMG</td></tr>
<tr><td rowspan="3">Damage to track circuits, from installation of expansion switches potentially leading to:
• Signal failure leading to train delays</td><td>GREEN</td><td>Install appropriate bonding</td><td>During installation of expansion switches</td><td>RMC</td></tr>
<tr><td rowspan="2">Bonding damaged</td><td>Repair bonding</td><td>As required</td><td>RMC</td></tr>
<tr><td>Report impact and actions taken to RMG, ARTC, MSO & ONRSR</td><td>Within one week</td><td>RMC</td></tr>
<tr><td rowspan="3">Damage to signals, potentially leading to:
• Signal failure leading to train delays</td><td>GREEN</td><td>Follow general procedures (including visual inspections within rail corridor)</td><td></td><td></td></tr>
<tr><td rowspan="2">Signals damaged</td><td>Repair signals</td><td>As required</td><td>RMC</td></tr>
<tr><td>Report impact and actions taken to RMG, MSO, ONRSR & SA NSW</td><td>Within one week</td><td>TC</td></tr>
</table>

Table A. 1 Risk Control Procedures for LW S1A-S6A (continued)

RISK ISSUE	TRIGGER	CONTROL PROCEDURES	TIMING & FREQ	BY WHOM?
Reduction in track centres at 98.620 km, 99.600 km and 101.200 km, where centre are currently tight	**GREEN**	Follow general procedures (including ground surveys, track centre surveys at 98.620 km, 99.600 km and 101.200 km and visual inspections within rail corridor)	-	-
	Reduction in track centres > 5 mm or Change in Cant in either track > 5 mm	RMG meet and consider whether any additional management measures are required, including: - detailed measurement of track centres - locally redesign track alignment - resurface track in accordance with redesign	As required	RMG
		Report details of RMG decision and actions undertaken	Within one week	Globetech
Loss of track geometry due to **localised ponding, or Loss in drainage grade** of culverts due to mining-induced tilts, potentially leading to: • Unplanned maintenance response	**GREEN**	Follow general procedures (including visual inspections within rail corridor)	-	-
	Ponding observed	Regrade drainage line	As required	RMC
		Report impact and actions taken to RMG	Within one week	RMC
Damage to Formation due to mining-induced surface cracks forming a bog hole in formation causing a loss of track geometry, potentially leading to: • Unplanned maintenance response	**GREEN**	Follow general procedures (including visual inspections within rail corridor)	-	-
	Surface crack observed	Repair crack or regrade drainage line or repair sewer pipes	As required	RMC
		Report impact and actions taken to RMG	Within one week	RMC
False alarms from automated monitoring systems potentially leading to: • Unnecessary speed restrictions	**GREEN**	Follow general procedures (including multiple redundancies in monitoring system)	-	-
		Develop maintenance, testing and audit program for automated monitoring systems	Prior to subsidence	Globetech/ PCE / Robinson Rail
		Develop alarm programming methods to filter obvious false alarms (refer Section 5.5.5). Reduce number of gauges with alarms enabled, where possible in accordance with the Management Plan.	Prior to subsidence	Globetech / RMG
	Excessive false alarms occur	RMG meet and consider whether any additional management measures are required, including: - reduce incidence of false alarms - replace or adjust gauge or cable - increase monitoring and reporting procedures	As required	RMG
		Report details of RMG decision and actions undertaken	Within one week	Globetech
Loss of all or part of automated monitoring system due to power surge, lightning strike, vandalism, power/comms failure, trackwork	**GREEN**	Follow general procedures (including multiple redundancies in monitoring system)	-	-
		Install back-up systems for power (battery), dual SIM, internet link to Tahmoor Coal Control Centre	Prior to subsidence	Globetech
		Program alarm alerts at off-site computer	Prior to subsidence	Globetech
		Store spare parts on site (gauges, loggers, batteries, router)	Prior to subsidence	Globetech
	GREY	Notify RRG in accordance with Alarm Notification Protocol	Within 15 minutes	Section 6.2
		Inspect track at trigger point if on site at time of alarm	Within 15 minutes	RMC
		RRG meet and consider whether any additional management measures are required, including: - investigate cause - install replacement battery - install secondary wireless network card - replace damaged components - increase monitoring and reporting procedures	RRG meet via teleconference within 15 minutes of alarm notification	RRG
		Inspect track at trigger point for visual signs of impact unless RRG is confident that cause of trigger cannot be due to physical damage to the railway Remain on site until status returns to GREEN level or until approved by RRG	Immediately following assessment of RRG via teleconference and arrive within 2 hours, if req'd Otherwise within 24 hours	RMC
		Report details of alarm and actions undertaken	Within one week	Globetech
False readings due to installation problem, failed gauge, software failure, programming error	**GREEN**	Follow general procedures (including multiple redundancies in monitoring system, regular analysis cross checking and reporting)	-	-
	False readings are found	Repair cause of false reading	As required	Globetech
		Report details of RMG decision and actions undertaken	Within one week	Globetech

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Table A. 1 Risk Control Procedures for LW S1A-S6A (continued)

RISK ISSUE	TRIGGER	CONTROL PROCEDURES	TIMING & FREQ	BY WHOM?
Damage to cutting face potentially leading to: • Blockage of drainage line	**GREEN**	Follow general procedures (including dilapidation survey, visual inspections of cutting, and ground surveys)	-	-
		Clear debris from cesses at base of batter slopes	As required	RMC
	Instability observed to cuttings	Notify RMG in accordance with Alarm Notification Protocol	As required by Track Certifier depending on severity of impact	RMC
		RMG meet and consider whether any additional management measures are required, which may include: - undertake geotechnical inspection - increase monitoring and reporting procedures - clear debris from cess at base of cutting faces	RMG meet via teleconference as required by Track Certifier depending on severity of impact	RMG
		Report impact and actions taken to ARTC, MSO & ONRSR	Within one week	TC
	Cutting closure exceeds 20 mm	Notify RMG in accordance with Alarm Notification Protocol	Within one week	RMC
		RMG meet and consider whether any additional management measures are required, which may include: - undertake geotechnical inspection - increase monitoring and inspections for potential impacts on track geometry and - increase reporting procedures	RMG meet via teleconference within one week	RMG
		Report trigger exceedence and actions taken to ARTC, MSO & ONRSR	Within one week	TC
Damage to optical fibre cable, potentially leading to: • Loss of security monitoring • Lack of train information service • Lack of other commercial use	**GREEN**	Follow general procedures (including visual inspections within rail corridor)	-	-
	Ground strain exceeds 3 mm/m (tensile or compressive	Notify RMG	As required by RMC depending on severity of impact	RMC
		RMG meet and consider whether any additional management measures are required, which may include: - undertake inspection by signalling expert - increase monitoring and reporting procedures - consider undertaking additional tests on optical fibre cable - consider exposure of cable and provide freedom of cable movement in vicinity of ground deformation	As required	RMG
		Report impact and RMG decisions to ARTC, MSO, ONRSR & SA NSW	Within one week	TC
	Cable damage	Repair cable	As required	RMC
		Report impact and actions taken to RMG, ARTC, MSO, ONRSR & SA NSW	Within one week	TC
Breakage of buried copper cable, potentially leading to: • Signal failure leading to train delays • Wrong Side Failure	**GREEN**	Follow general procedures (including dilapidation survey, visual inspections, ground survey, standard ARTC 'failsafe' signalling system, automated monitoring of signal)	-	-
		Inspect condition of cable	Prior to 900m of extraction of LW S1A	TC
		Conduct electrical tests on spare cores	Prior to 900m of extraction of LW S1A End of LW S1A-S6A	TC
	Ground strain exceeds 3 mm/m (tensile or compressive)	Notify RMG	As required by RMC depending on severity of impact	RMC
		RMG meet and consider whether any additional management measures are required, which may include: - undertake inspection by signalling expert - increase monitoring and reporting procedures - consider undertaking additional electrical tests on signal cable - consider exposure of cable to provide freedom of cable movement in vicinity of ground deformation	As required	RMG
		Report impact and actions taken to RMG, ARTC, MSO, ONRSR & SA NSW	Within one week	MSEC
	Cable damage	Repair cable	As required	RMC
		Report impact and actions taken to RMG, ARTC, MSO, ONRSR & SA NSW	Within one week	MSEC

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Table A. 1 Risk Control Procedures for LW S1A-S6A (continued)

<table>
<tr><th>RISK ISSUE</th><th>TRIGGER</th><th>CONTROL PROCEDURES</th><th>TIMING & FREQ</th><th>BY WHOM?</th></tr>
<tr><td rowspan="10">Damage to culverts or culvert floor potentially leading to:
• Changes in track geometry resulting from loss of support, leading to intervention
• Development of sinkhole and undermining track
• Loss of culvert integrity, leading to intervention
• Cracking and deformation</td><td rowspan="6">GREEN</td><td>Follow general procedures (including dilapidation survey, ground survey, visual inspections of culverts, track geometry monitoring)</td><td>-</td><td>-</td></tr>
<tr><td>De-vegetation of the embankment batters and maintain culverts to keep them free flowing</td><td>Before track above each culvert is in Stage 1</td><td>TC</td></tr>
<tr><td>Install above track baulks above culverts</td><td>Before track above each culvert is in Stage 2</td><td>TC</td></tr>
<tr><td>Seal gap between the brick arch culvert headwall and concrete pipe extension on the Down side of Culvert at 99.035 km and repair sinkhole</td><td>Prior to 900m of extraction of LW S1A</td><td>TC</td></tr>
<tr><td>Reinstate concrete outlet pipe to Culvert at 99.338 km</td><td>Prior to 800m of extraction of LW S3A</td><td>TC</td></tr>
<tr><td>Seal gap between the brick arch culvert headwall and concrete pipe extension on the Down side of Culvert at 100.121 km</td><td>Prior to 200m of extraction of LW S4A</td><td>TC</td></tr>
<tr><td rowspan="4">Damage to culvert such as cracking or gaps found at culvert joints or evidence of piping</td><td>Notify RMG and ARTC Structures Specialist</td><td>As required by RMC depending on severity of impact</td><td>RMC</td></tr>
<tr><td>RMG meet and consider whether any additional management measures are required, which may include:
- undertake structural inspection
- increase monitoring and reporting procedures
- repair culvert or provide additional support to culvert
- strengthen track baulk</td><td>As required</td><td>RMG</td></tr>
<tr><td>Report impact and RMG decisions to ARTC, MSO, ONRSR and SA NSW</td><td>Within one week</td><td>TC</td></tr>
<tr><td>Report details of impact and actions undertaken</td><td>Within one week</td><td>MSEC</td></tr>
<tr><td rowspan="7">Embankments
• Embankment slope failure or collapse of embankment caused by water saturation of fill due to blockage of culvert leading to build up of water, surcharge from impounded water and saturation of fill due to prolonged rainfall.
• Displacement / failure of embankment leading to loss of track support.
• Surface cracking of crest and embankment batters due to mining-induced vertical or horizontal ground movements, leading to erosion of batters and long-term embankment instability.
• Cracking within embankment due to mining-induced vertical or horizontal ground movements and build up of water within embankment, flowing through cracks, leading to piping failure and formation of sink holes under the track
• Cracking of culvert causing loss of fill due to pot holing (vertical) due to mining-induced ground movements, particularly valley closure, leading to development of sinkhole and undermining track

Note:
Refer to other sections of the Risk Control Procedures for managing risks associated with changes in track geometry or changes to culverts</td><td rowspan="2">GREEN</td><td>Follow general procedures (including ground surveys, visual inspections, and for Embankments at 99.338 km, 100.121 km and 100.425 km: extensometers, manual inclinometers and culvert water level gauges).</td><td>-</td><td>-</td></tr>
<tr><td>Clear vegetation on the embankment batter and maintain culverts to keep them clear of debris to facilitate monitoring of the embankments and culverts.</td><td>Before track above each culvert is in Stage 1</td><td>-</td></tr>
<tr><td rowspan="5"><u>LEVEL 1</u>
Rate of change in crest extensometer distance exceeds 10 mm within 2 hours
or
Crest extensometer or ground surveys across crest measure extension of 25 mm
or
Visual signs of distress to embankment, such as tension crack along edge of embankment / access road</td><td>For alarms from extensometer: Inspect embankment at trigger point for visual signs of impact.</td><td>Immediate callout and arrive as soon as reasonably practicable (target less than 2 hours)</td><td>RMC</td></tr>
<tr><td>If tension crack observed along edge of embankment, Track Certifier to remain on site until such time that RMG agree that continuous 24 hour / 7 days a week presence by Track Certifier is not required.</td><td>Immediately following identification of tension crack</td><td>RMC</td></tr>
<tr><td>Undertake additional geotechnical inspection and appraisal</td><td>Within 24 hours</td><td>Newcastle Geotech</td></tr>
<tr><td>RSRG meet and review latest monitoring information from automated and manually acquired data for the embankment, culvert and the track, inspections by geotechnical engineer and Track Certifier, and latest weather forecasts.
RSRG consider whether any additional management measures are required, which may include:
- fill and seal cracks and/or regrade drainage line
- increase monitoring and reporting procedures
- arrange additional surveys to monitor potential displacement of embankment material</td><td>Within 15 minutes</td><td>RSRG</td></tr>
<tr><td>Report trigger exceedance and actions taken to RMG, ARTC, MSO & ONRSR in Railway Status Report</td><td>Within 24 hours if tension crack observed
Otherwise within one week</td><td>TC</td></tr>
</table>

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Table A. 1 Risk Control Procedures for LW S1A-S6A (continued)

RISK ISSUE	TRIGGER	CONTROL PROCEDURES	TIMING & FREQ	BY WHOM?
Embankments • Embankment slope failure or collapse of embankment caused by water saturation of fill due to blockage of culvert leading to build up of water, surcharge from impounded water and saturation of fill due to prolonged rainfall. • Displacement / failure of embankment leading to loss of track support. • Surface cracking of crest and embankment batters due to mining-induced vertical or horizontal ground movements, leading to erosion of batters and long-term embankment instability. • Cracking within embankment due to mining-induced vertical or horizontal ground movements and build up of water within embankment, flowing through cracks, leading to piping failure and formation of sink holes under the track • Cracking of culvert causing loss of fill due to pot holing (vertical) due to mining-induced ground movements, particularly valley closure, leading to development of sinkhole and undermining track **Note:** Refer to other sections of the Risk Control Procedures for managing risks associated with changes in track geometry or changes to culverts	<u>**LEVEL 2**</u> **Rate of change in crest extensometer distance exceeds 20 mm within 2 hours or Tension crack observed along the shoulder of the embankment within 4 m of the track, or across the access road, or slide in the crest of the embankment along the access road within 4 m of the track**	Contact Train Control & introduce track speed of 20km/h. If not already on site at time of alarm, inspect track and embankment at trigger point. Remain on site until such time that RMG agree that continuous 24 hour / 7 days a week presence by Track Certifier is not required.	Immediately If not on site at time of alarm, immediate callout and arrive as soon as reasonably practicable (target less than 2 hours)	RMC
		Undertake additional geotechnical inspection and appraisal	As soon as reasonably practicable	Newcastle Geotech
		RSRG meet and review latest monitoring information from automated and manually acquired data for the embankment, culvert and the track, inspections by geotechnical engineer and Track Certifier, and latest weather forecasts. RSRG consider whether any additional management measures are required, which may include: - stop trains - temporarily support the ballast shoulder by placing material on the crest of the embankment - place permanent or temporary fill / rock spall to the base of the embankment - tip fill material into scarp of slide until settlement effectively ceases - increase monitoring and reporting procedures - arrange additional surveys to monitor displacement, if required - consider whether to recommend additional Governance Meeting between Tahmoor Coal and ARTC (emergency response)	Within 15 minutes	RSRG
		Report trigger exceedance and actions taken to RMG, ARTC, MSO & ONRSR	Within 24 hours	TC
	<u>**LEVEL 3**</u> **Tension crack observed across the access road and under the track, or slump removes access road support for the embankment, or a report of depression in the track by train driver**	Contact Train Control & introduce track speed of 20km/h. If not already on site at time of alarm, inspect track and embankment at trigger point. Remain on site until such time that RMG agree that continuous 24 hour / 7 days a week presence by Track Certifier is not required.	Immediately If not on site at time of alarm, immediate callout and arrive as soon as reasonably practicable (target less than 2 hours)	RMC
		Undertake additional geotechnical inspection and appraisal	As soon as reasonably practicable	Newcastle Geotech
		RSRG meet and review latest monitoring information from automated and manually acquired data for the embankment, culvert and the track, inspections by geotechnical engineer and Track Certifier, and latest weather forecasts. RSRG consider whether any additional management measures are required, which may include: - stop trains - temporarily support the ballast shoulder by placing material on the crest of the embankment - place permanent or temporary fill / rock spall to the base of the embankment - tip fill material into scarp of slide until settlement effectively ceases - add ballast to the railway track and lift track to restore track geometry - provide additional forms of track support under the track as may be appropriate or feasible - increase monitoring and reporting procedures - arrange additional surveys to monitor displacement, if required - consider whether to recommend additional Governance Meeting between Tahmoor Coal and ARTC (emergency response)	Within 15 minutes	RSRG
		Report trigger exceedance and actions taken to RMG, ARTC, MSO & ONRSR	Within 24 hours	TC

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Table A. 1 Risk Control Procedures for LW S1A-S6A (continued)

RISK ISSUE	TRIGGER	CONTROL PROCEDURES	TIMING & FREQ	BY WHOM?
Embankments • Embankment slope failure or collapse of embankment caused by water saturation of fill due to blockage of culvert leading to build up of water, surcharge from impounded water and saturation of fill due to prolonged rainfall. • Displacement / failure of embankment leading to loss of track support. • Surface cracking of crest and embankment batters due to mining-induced vertical or horizontal ground movements, leading to erosion of batters and long-term embankment instability. • Cracking within embankment due to mining-induced vertical or horizontal ground movements and build up of water within embankment, flowing through cracks, leading to piping failure and formation of sink holes under the track • Cracking of culvert causing loss of fill due to pot holing (vertical) due to mining-induced ground movements, particularly valley closure, leading to development of sinkhole and undermining track **Note:** Refer to other sections of the Risk Control Procedures for managing risks associated with changes in track geometry or changes to culverts	**Forecast of extreme wet weather, as observed by RMG or notified by ARTC to RMC**	RMG meet and review latest monitoring information from automated and manually acquired data for the embankment, culverts and the track, inspections by geotechnical engineer and Track Certifier, and details of extreme wet weather forecast. RMG consider whether any additional management measures are required, which may include: - sealing cracks that may have developed during mining, prior to the weather event - additional inspection by geotechnical engineer to assess whether additional work may be required prior to weather event - additional inspection or monitoring equipment to prepare for weather event - bring forward ground surveys if their scheduled timing coincides with weather event - develop extreme wet weather plan, which may include arranging for Track Certifier on site during weather event, periodic checking of automated monitoring data during event, reporting and communication protocol during weather event.	As soon as reasonably practicable depending on severity and timing of weather event (target less than 24 hours)	RMG
		Report outcome of weather event to RMG, ARTC, MSO & ONRSR in Railway Status Report	Within one week	MSEC
	Water level at Culvert Inlets at 99.338 km, 100.121 km and 100.425 km reaches culvert obvert	Inspect embankment for flooding and condition of embankment and culvert	Immediate callout as soon as reasonably practicable (target less than 2 hours)	RMC
		RRG meet and review latest monitoring information from automated and manually acquired data for the embankment, culvert and the track, inspections by geotechnical engineer and Track Certifier, current weather observations and details of latest weather forecast. RRG consider whether any additional management measures are required, which may include: - continue visual monitoring by RMC until end of weather event - remove cause of blockage of culvert (if any and if possible) - decide whether to slow or stop trains based on other monitoring data	Within 15 minutes	RRG
		Report trigger exceedance and actions taken to RMG, ARTC, MSO & ONRSR in Railway Status Report	Within one week	MSEC
Conveyor Crossing • Loss of integrity of conveyor crossing structure.	**GREEN**	Follow general procedures (including trestle survey, laser distancemeters and visual inspections)	-	-
	Closure between trestles exceeds 10 mm	Notify RMG	Within one week	RMC
		RMG meet and consider whether any additional management measures are required, which may include: - undertake structural inspection - increase monitoring and reporting procedures - elongate bolt holes in trestle column baseplates - strengthen trestle columns - install additional cable-stay bracing - erect temporary support structure on the access roadways on either side of railway	RMG meet via teleconference within one week	RMG
		Report trigger exceedence and RMG decisions to ARTC, MSO, ONRSR and SA NSW	Within one week	TC
Damage to boundary fences potentially leading to: • Livestock entry into rail corridor	**GREEN**	Follow general procedures (including visual inspections within rail corridor)	-	-
	Damage to fence	Repair fence	As required	RMC
		Report impact and actions taken to RMG	Within one week	RMC

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Table A. 1 Risk Control Procedures for LW S1A-S6A (continued)

<table>
<tr><th>RISK ISSUE</th><th>TRIGGER</th><th>CONTROL PROCEDURES</th><th>TIMING & FREQ</th><th>BY WHOM?</th></tr>
<tr><td rowspan="10">Bridges
Impact on serviceability of bridge resulting in unplanned maintenance.
<table><tr><th>Trigger Level</th><th>Measured opening or closure between bridge abutments
(beyond seasonal fluctuation)</th></tr><tr><td>GREEN</td><td>-</td></tr><tr><td>MONITORING REVIEW POINT TRIGGER</td><td>Remembrance Drive Bridge over Bargo River > 7 mm
Railway Viaduct > 5 mm
Bargo River Road Overbridge (Potter's Cutting) > 5 mm
Wellers Road Overbridge > 5 mm
Increase in crack widths by more than 3 mm in widths to Viaduct or Bridges</td></tr></table></td><td>GREEN</td><td>Follow general procedures (including GNSS monitoring, ground and structure surveys, and visual inspections).</td><td>-</td><td>-</td></tr>
<tr><td rowspan="3">Monitoring Review Point Trigger for Railway Viaduct</td><td>Notify RMG, Bridge Technical Committee and ARTC (incl. ARTC Structures Specialist)</td><td>Within one week</td><td>MSEC</td></tr>
<tr><td>RMG meet and consider whether any additional management measures are required, which may include:
- undertake structural inspections
- measure changes to crack gauges
- increase frequency of surveys and inspections and reporting
- install temporary track strengthening baulk
- force closure to focus in desired Span 5 by diamond saw cut
- repair cracked masonry
- provide additional support to the arch and parapet walls
- fabricate and erect structural steel supports for the arch
- adjust rail stress
- adjust track geometry
- implement temporary speed restriction or stop trains
- continual review of rate of development of valley closure relative to longwall progress and consider whether to amend the Valley closure trigger of 20 mm
- consider whether to recommend to TC senior management to slow or stop mining if impact to rail operations is unacceptable to ARTC</td><td>As required</td><td>RMG & Bridge Technical Committee</td></tr>
<tr><td>Report trigger exceedence and RMG & Bridge Technical Committee decisions to ARTC, MSO, ONRSR and SA NSW</td><td>Within 24 hours</td><td>Tahmoor Coal</td></tr>
<tr><td rowspan="3">Valley closure at Railway Viaduct > 20 mm

(based on Precision 2D surveys of closure between ground marks located in stable ground at both ends of the Viaduct)</td><td>Stop longwall mining</td><td>Immediately
(subject to mine safety requirements)</td><td>TC</td></tr>
<tr><td>RMG meet and consider whether any additional management measures are required, which may include:
- fabricate and erect structural steel supports for the arch
- consider and implement measures to monitor the condition of the temporary support structures
- consider triggers for adjusting the support structures due to residual subsidence
- adjust the support structures to accommodate residual subsidence movements, if required
- consider works required to permanently restore the Railway Viaduct in consultation and approval by ARTC and government agencies.</td><td>As required</td><td>RMG</td></tr>
<tr><td>Report trigger exceedence and RMG decisions to ARTC, MSO, ONRSR and SA NSW</td><td>Within 24 hours</td><td>TC</td></tr>
<tr><td rowspan="3">Monitoring Review Point Trigger for Remembrance Drive Bridge over Bargo River</td><td>Notify RMG, Bridge Technical Committee and ARTC (incl. ARTC Structures Specialist)</td><td>Within one week</td><td>MSEC</td></tr>
<tr><td>RMG meet and consider whether any additional management measures are required, which may include:
- undertake structural inspections
- increase frequency of surveys and inspections and reporting
- construct temporary props and/or cross-bracing to provide additional support to the piers
- repair cracks in concrete elements
- replace bridge bearings
- resurface affected road pavement
- consider whether to recommend to TC senior management to slow or stop mining if impact to rail operations is unacceptable to ARTC</td><td>As required</td><td>RMG & Bridge Technical Committee</td></tr>
<tr><td>Report trigger exceedence and RMG & Bridge Technical Committee decisions to ARTC, MSO, ONRSR and SA NSW</td><td>Within 24 hours</td><td>Tahmoor Coal</td></tr>
</table>

Commercial in Confidence

Table A. 1 Risk Control Procedures for LW S1A-S6A (continued)

<table>
<tr><th>RISK ISSUE</th><th>TRIGGER</th><th>CONTROL PROCEDURES</th><th>TIMING & FREQ</th><th>BY WHOM?</th></tr>
<tr><td rowspan="3">Bridges
• Impact on serviceability of bridge resulting in unplanned maintenance.
<table><tr><th>Trigger Level</th><th>Measured opening or closure between bridge abutments (beyond seasonal fluctuation)</th></tr><tr><td>GREEN</td><td>-</td></tr><tr><td>MONITORING REVIEW POINT TRIGGER</td><td>Remembrance Drive Bridge over Bargo River > 7 mm
Railway Viaduct > 5 mm
Bargo River Road Overbridge (Potter’s Cutting) > 5 mm
Wellers Road Overbridge > 5 mm
Increase in crack widths by more than 3 mm in widths to Viaduct or Bridges</td></tr></table></td><td rowspan="3">Monitoring Review Point Trigger for Bargo River Road Overbridge or Wellers Road Overbridge</td><td>Notify RMG, Bridge Technical Committee and ARTC (incl. ARTC Structures Specialist)</td><td>Within one week</td><td>MSEC</td></tr>
<tr><td>RMG meet and consider whether any additional management measures are required, which may include:
- undertake structural inspections
- measure changes to crack gauges
- increase frequency of surveys and inspections and reporting
- install roller steel reinforcement straps to the underside of the concrete arch;
- install mesh to underside of the arch;
- install temporary support structure within the road pavement to provide temporary support to arch;
- provide additional support to parapet walls; and/or
- repair cracked brickwork
- consider whether to recommend to TC senior management to slow or stop mining if impact to rail operations is unacceptable to ARTC</td><td>As required</td><td>RMG & Bridge Technical Committee</td></tr>
<tr><td>Report trigger exceedence and RMG & Bridge Technical Committee decisions to ARTC, MSO, ONRSR and SA NSW</td><td>Within 24 hours</td><td>Tahmoor Coal</td></tr>
</table>

APPENDIX B. Drawings

Drawings

Drawing No.	*Description*	*Revision*
MSEC1201-01	Railways & Associated Infrastructure	B
MSEC1201-02	Switches & Anchor Points LW S1A to LW S6A	B
MSEC1201-02-1A	Switches & Anchor Points LW S1A	B
MSEC1201-02-2A	Switches & Anchor Points LW S2A	B
MSEC1201-02-3A	Switches & Anchor Points LW S3A	B
MSEC1201-02-4A	Switches & Anchor Points LW S4A	B
MSEC1201-02-5A	Switches & Anchor Points LW S5A	B
MSEC1201-02-6A	Switches & Anchor Points LW S6A	B
MSEC1201-03	Monitoring Plan	B
MSEC1201-04-1A	Timing of Monitoring Measures LW S1A	B
MSEC1201-04-2A	Timing of Monitoring Measures LW S2A	B
MSEC1201-04-3A	Timing of Monitoring Measures LW S3A	B
MSEC1201-04-4A	Timing of Monitoring Measures LW S4A	B
MSEC1201-04-5A	Timing of Monitoring Measures LW S5A	B
MSEC1201-04-6A	Timing of Monitoring Measures LW S6A	B
MSEC1201-05	Culvert & Embankment 98.445 km Monitoring	B
MSEC1201-06	Culvert & Embankment 98.739 km Monitoring	B
MSEC1201-07	Cutting 98.895 km, Culvert & Embankment 99.035 km Monitoring	B
MSEC1201-08	Culvert & Embankment 99.338 km Monitoring	B
MSEC1201-09	Cutting 99.690 km Monitoring	B
MSEC1201-10	Culvert & Embankment 100.121 km Monitoring	B
MSEC1201-11	Culvert & Embankment 100.425 km and Cutting 100.70 km Monitoring	B
MSEC1201-12	Embankment 101.00 km at Wellers Road Overbridge Monitoring	B
MSEC1201-13	MSR Railway Viaduct & Remembrance Drive Bridge over Bargo River	B
MSEC1201-14	Bargo River Road Bridges Monitoring	B
MSEC1201-15	Wellers Road Overbridge Monitoring	B

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TAHMOOR SOUTH PROJECT LWS1A TO LWS6A

RAILWAYS & ASSOCIATED INFRASTRUCTURE

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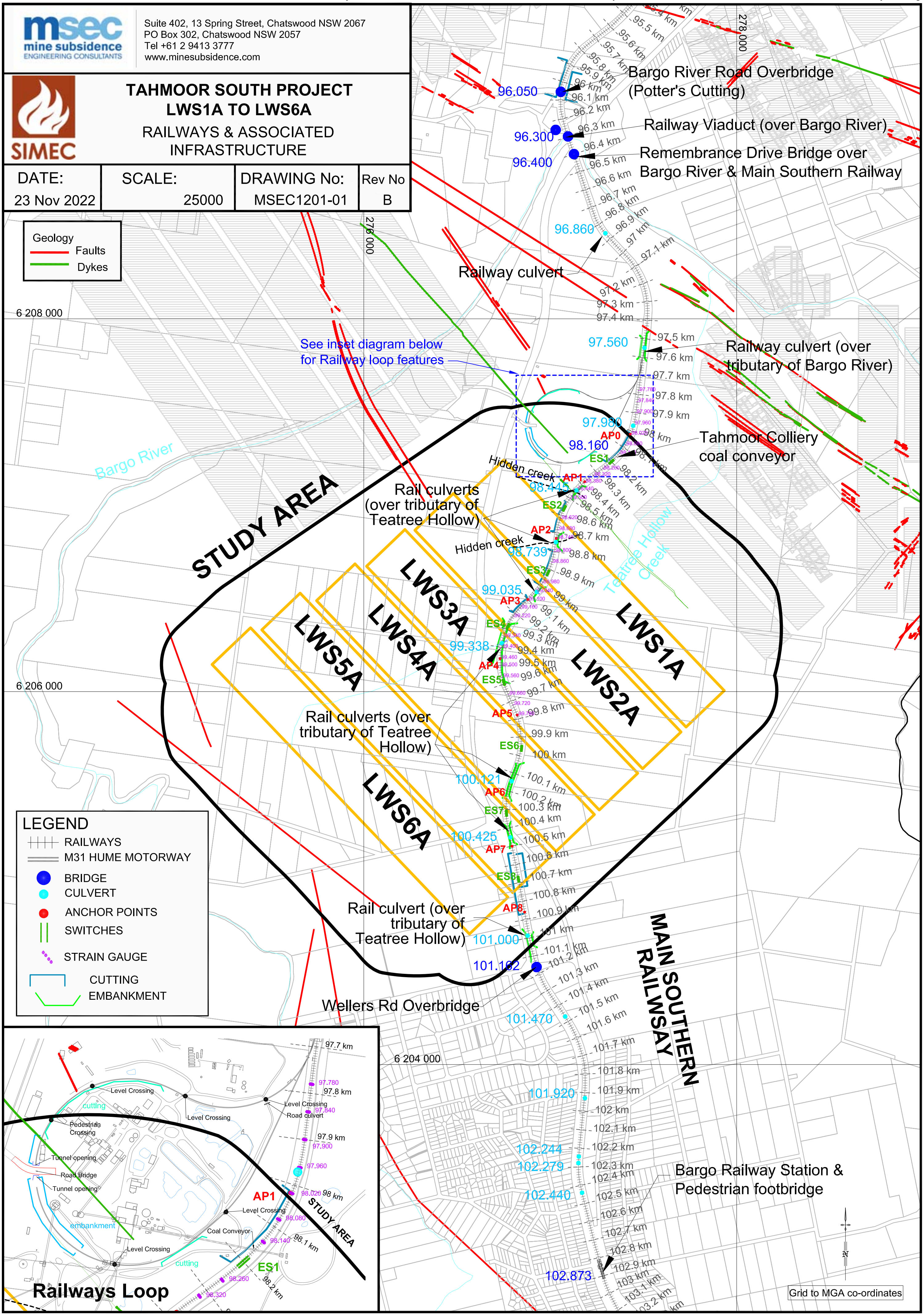

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TAHMOOR SOUTH PROJECT LWS1A TO LWS6A

MAIN SOUTHERN RAILWAY

SWITCHES & ANCHOR POINTS LWS1A TO LWS6A

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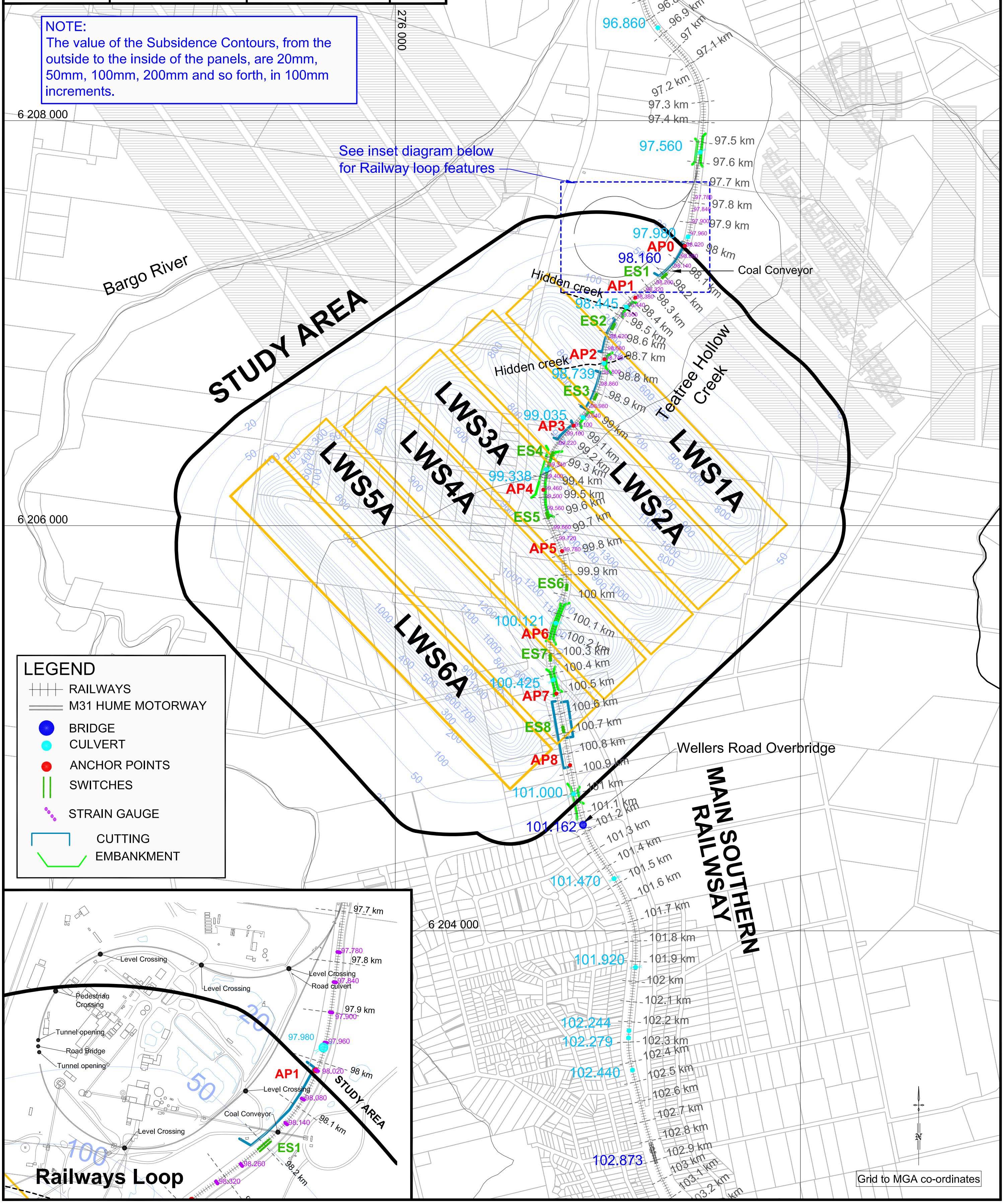
The value of the Subsidence Contours, from the outside to the inside of the panels, are 20mm, 50mm, 100mm, 200mm and so forth, in 100mm increments.



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LWS1A TO LWS6A

SWITCHES & ANCHOR POINTS
LWS1A

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NOTE:
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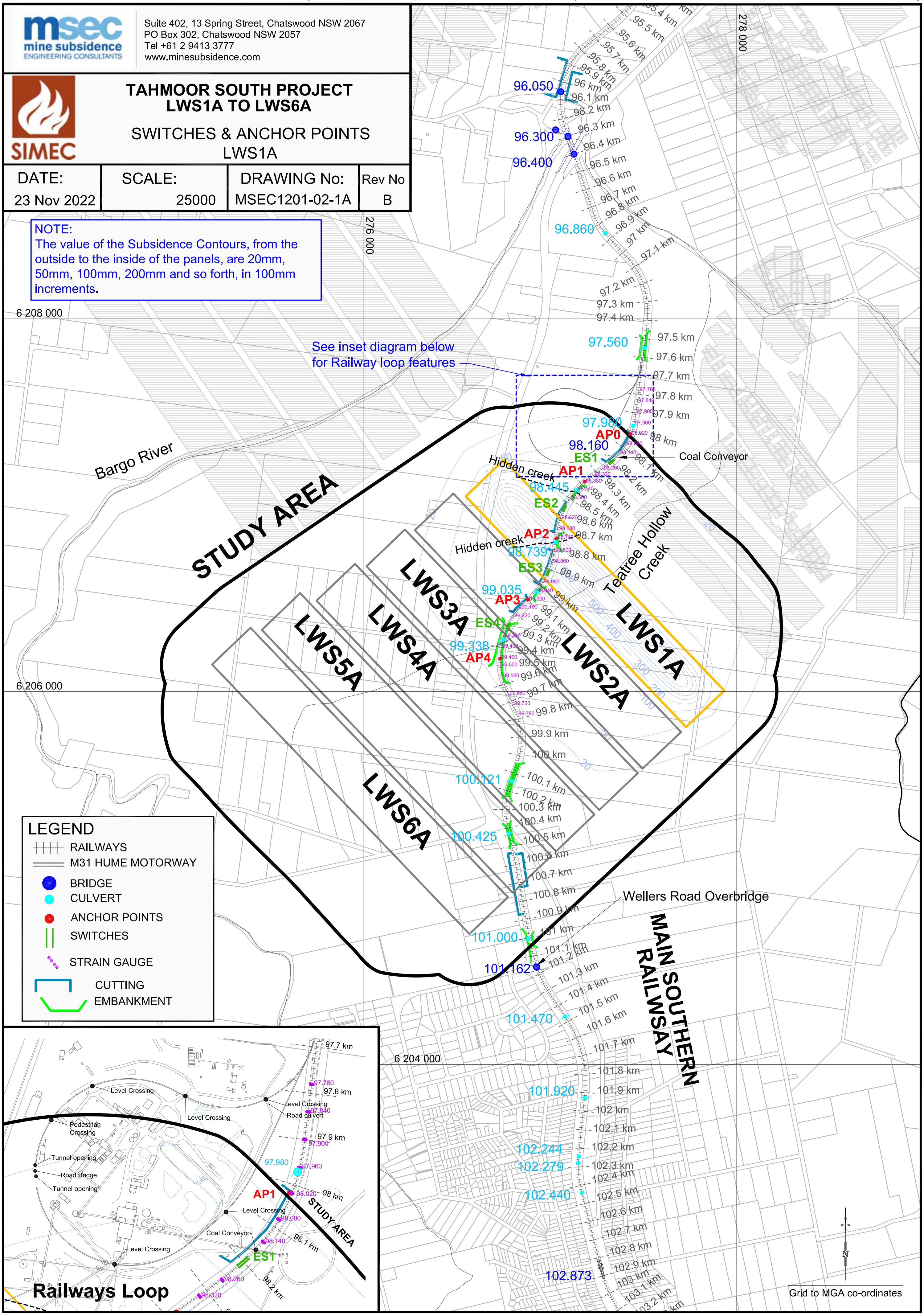

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SWITCHES & ANCHOR POINTS LWS2A

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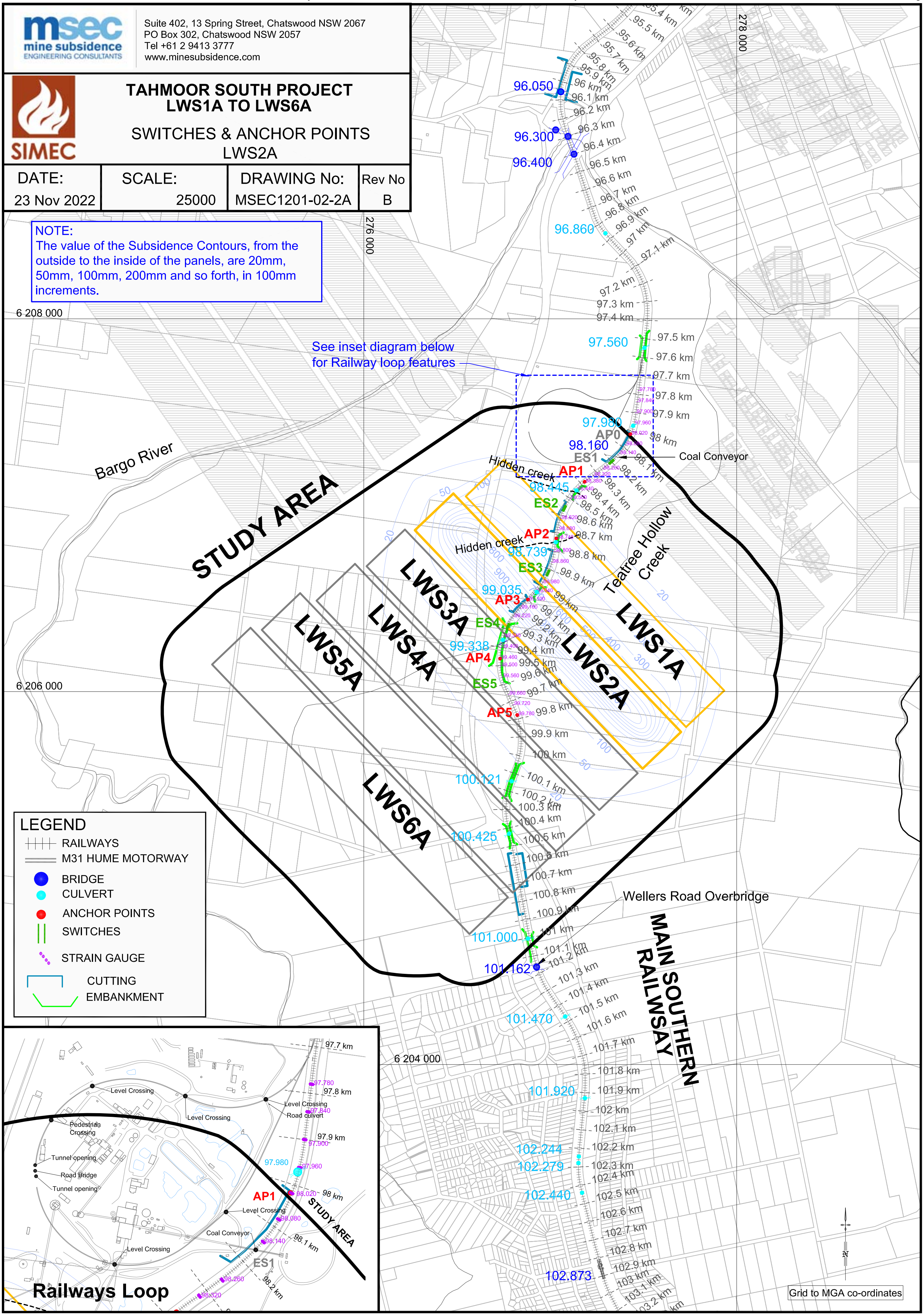

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LWS1A TO LWS6A

SWITCHES & ANCHOR POINTS
LWS3A

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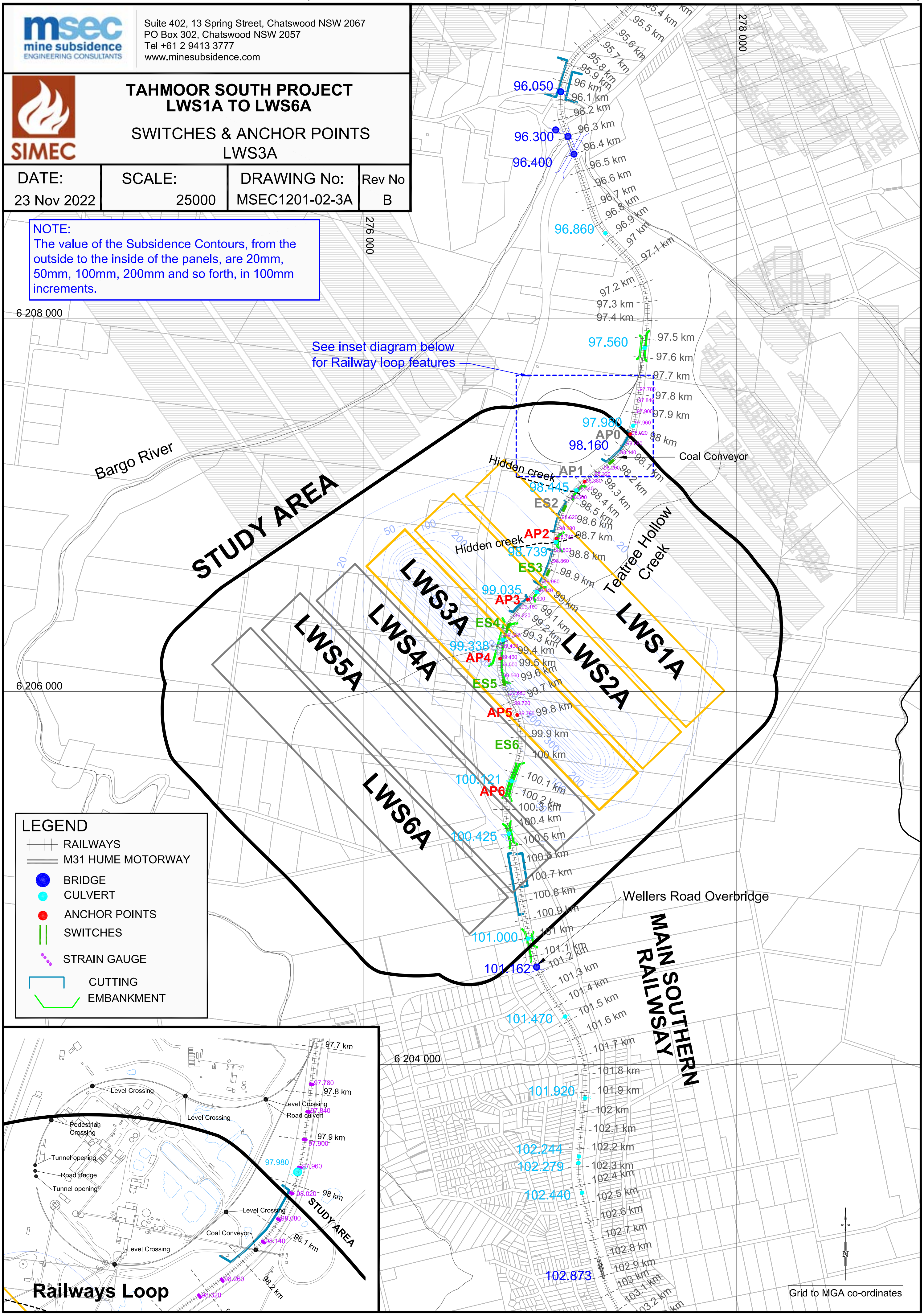

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SWITCHES & ANCHOR POINTS LWS4A

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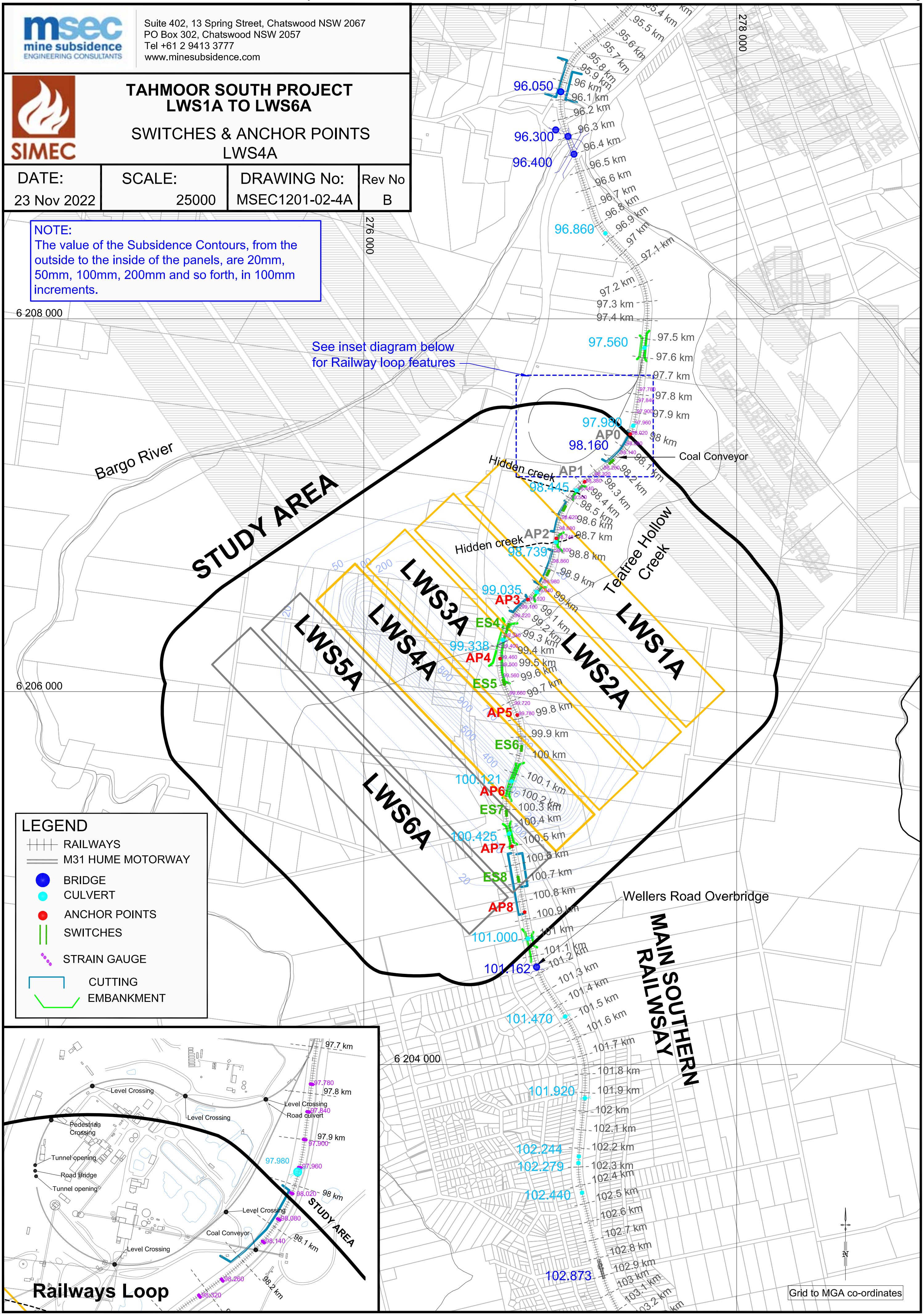

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SWITCHES & ANCHOR POINTS LWS5A

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NOTE:
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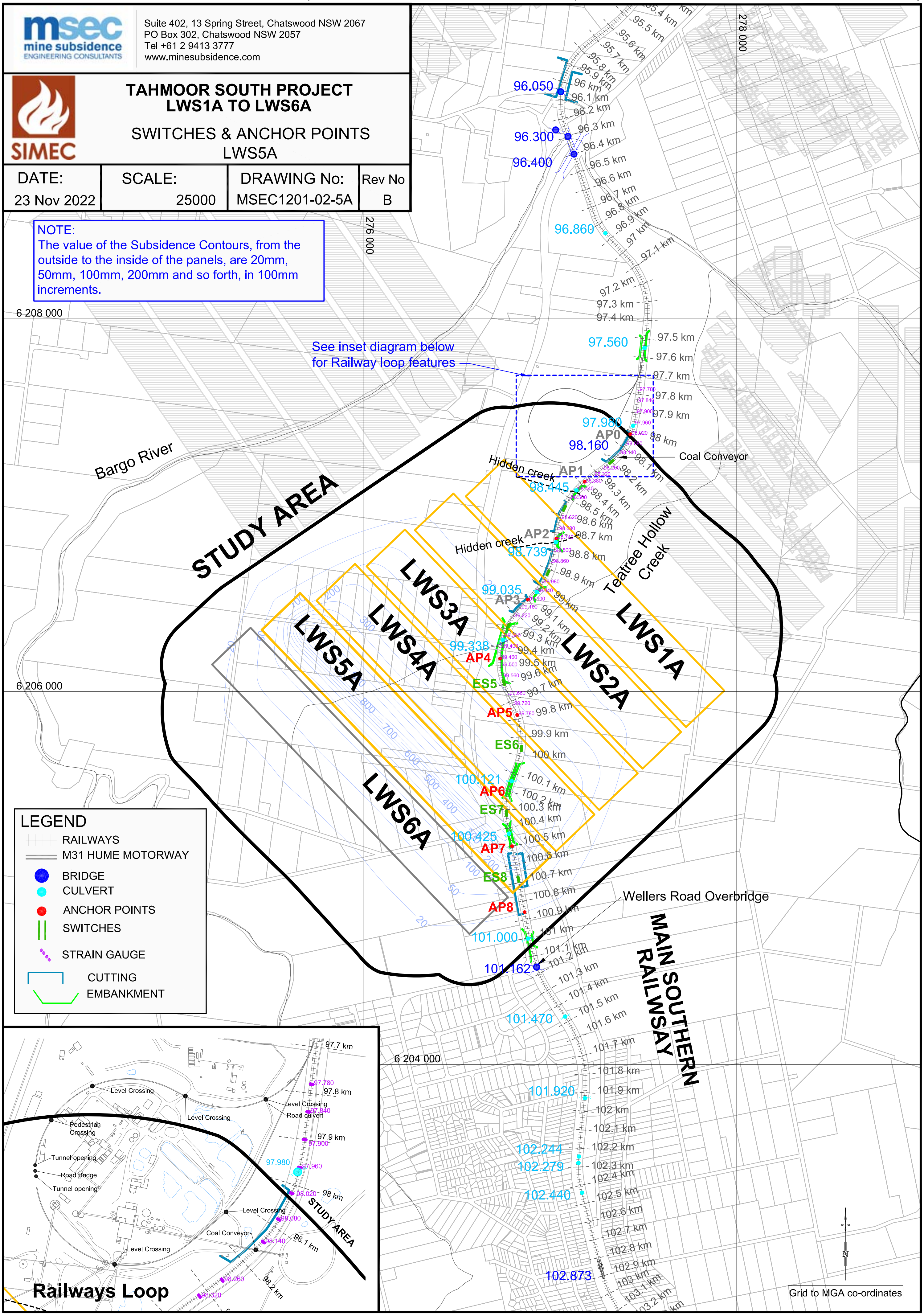

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SWITCHES & ANCHOR POINTS LWS6A

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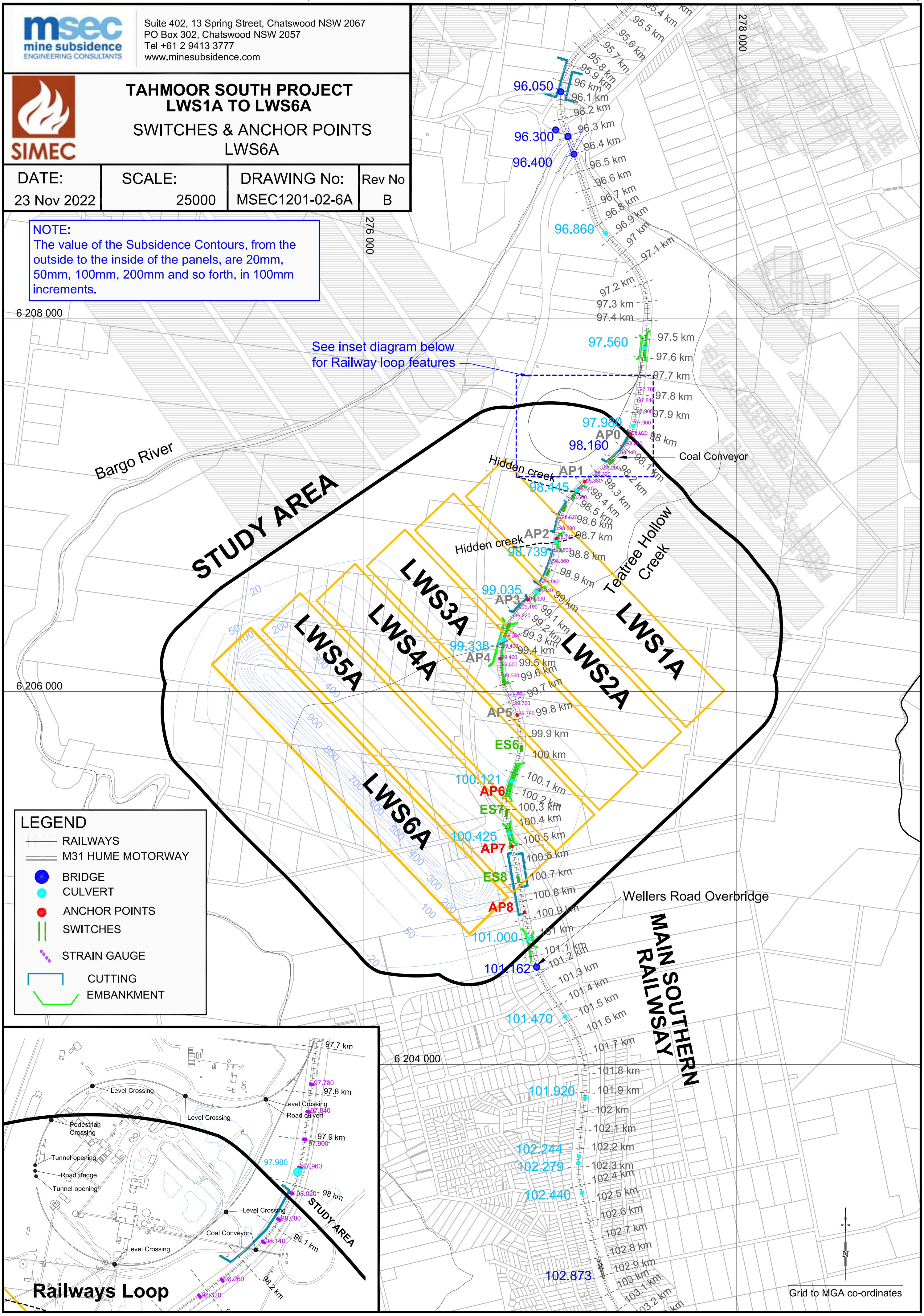

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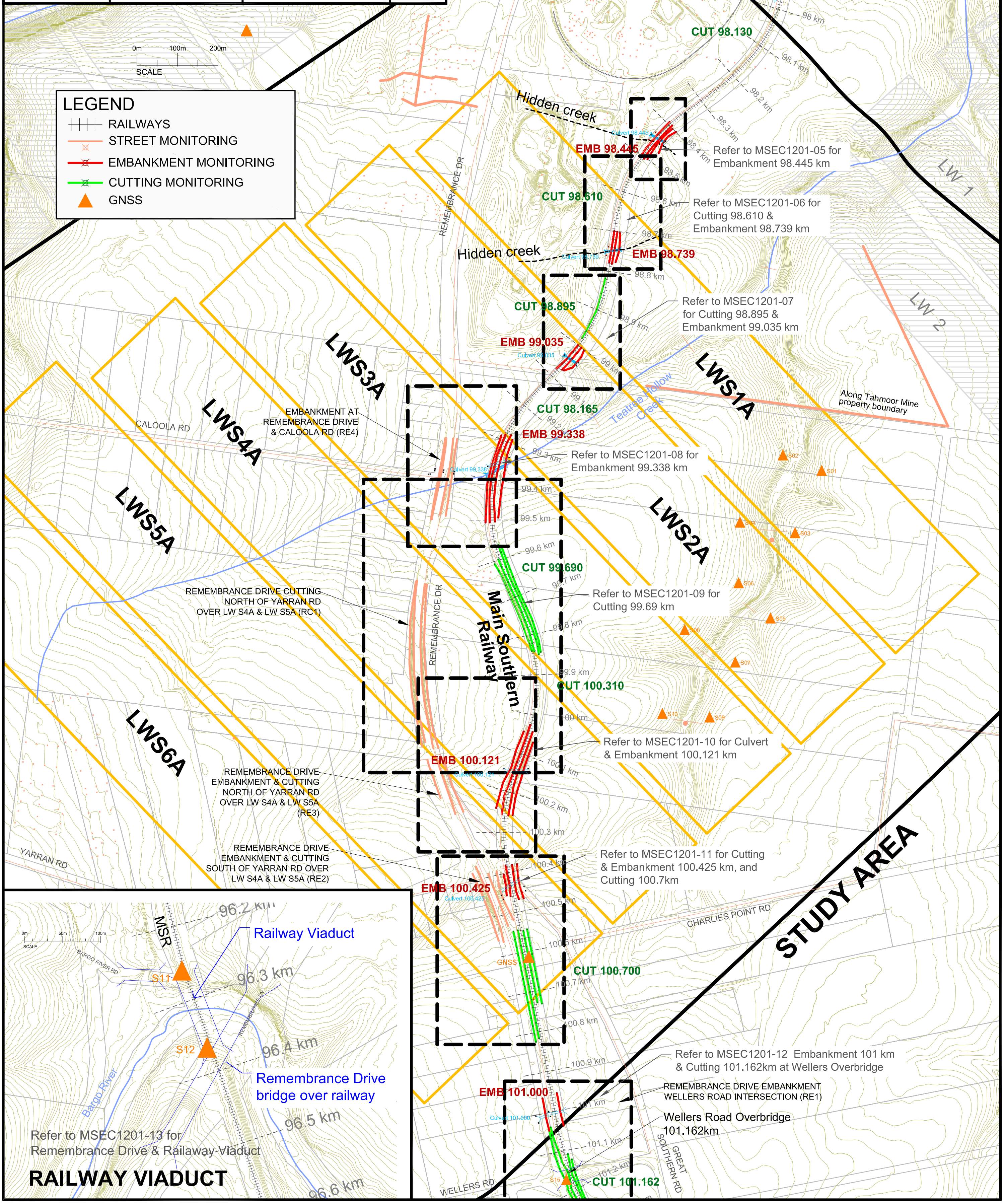

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TIMING OF MONITORING MEASURES - LWS1A

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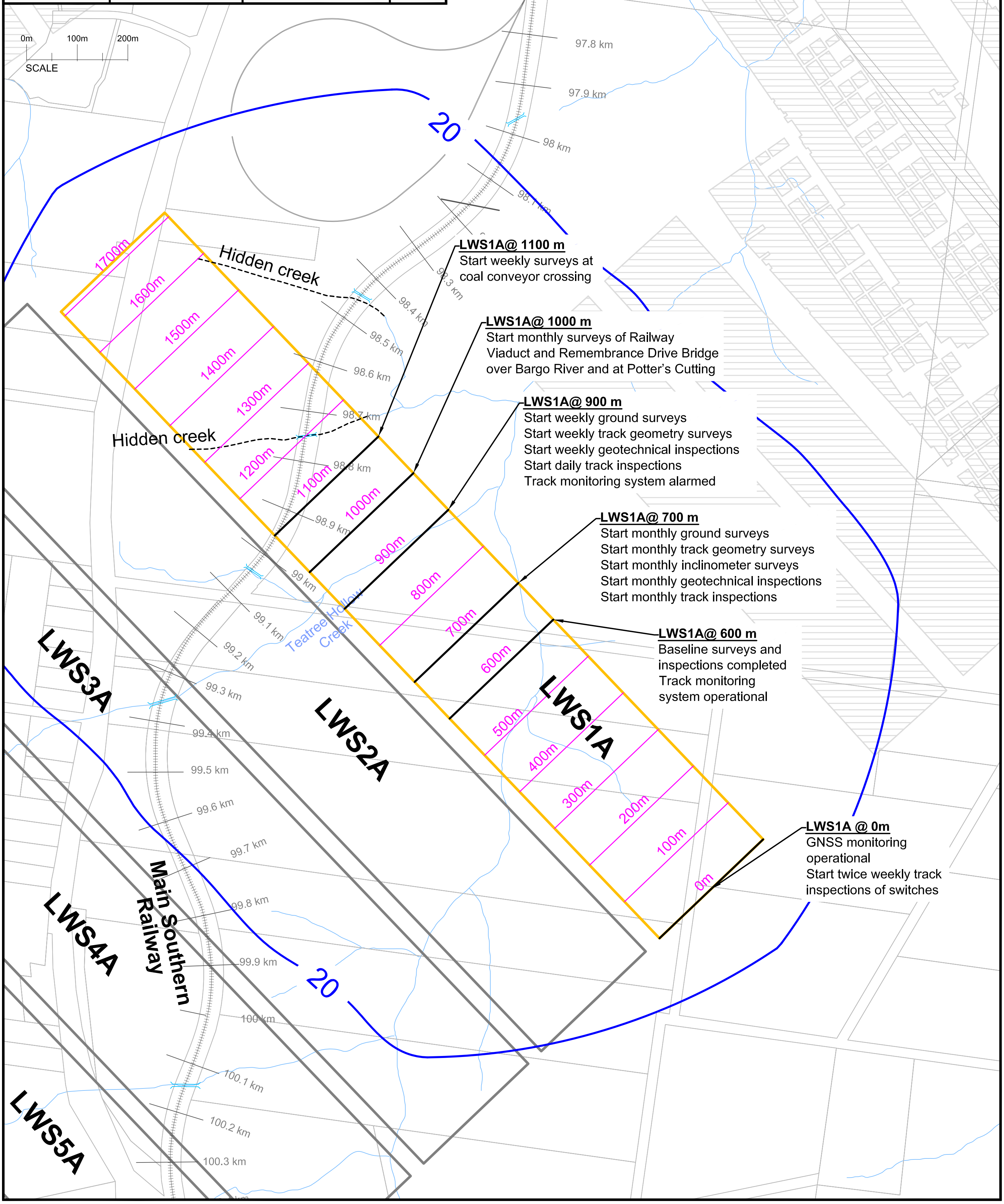

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TIMING OF MONITORING MEASURES - LWS2A

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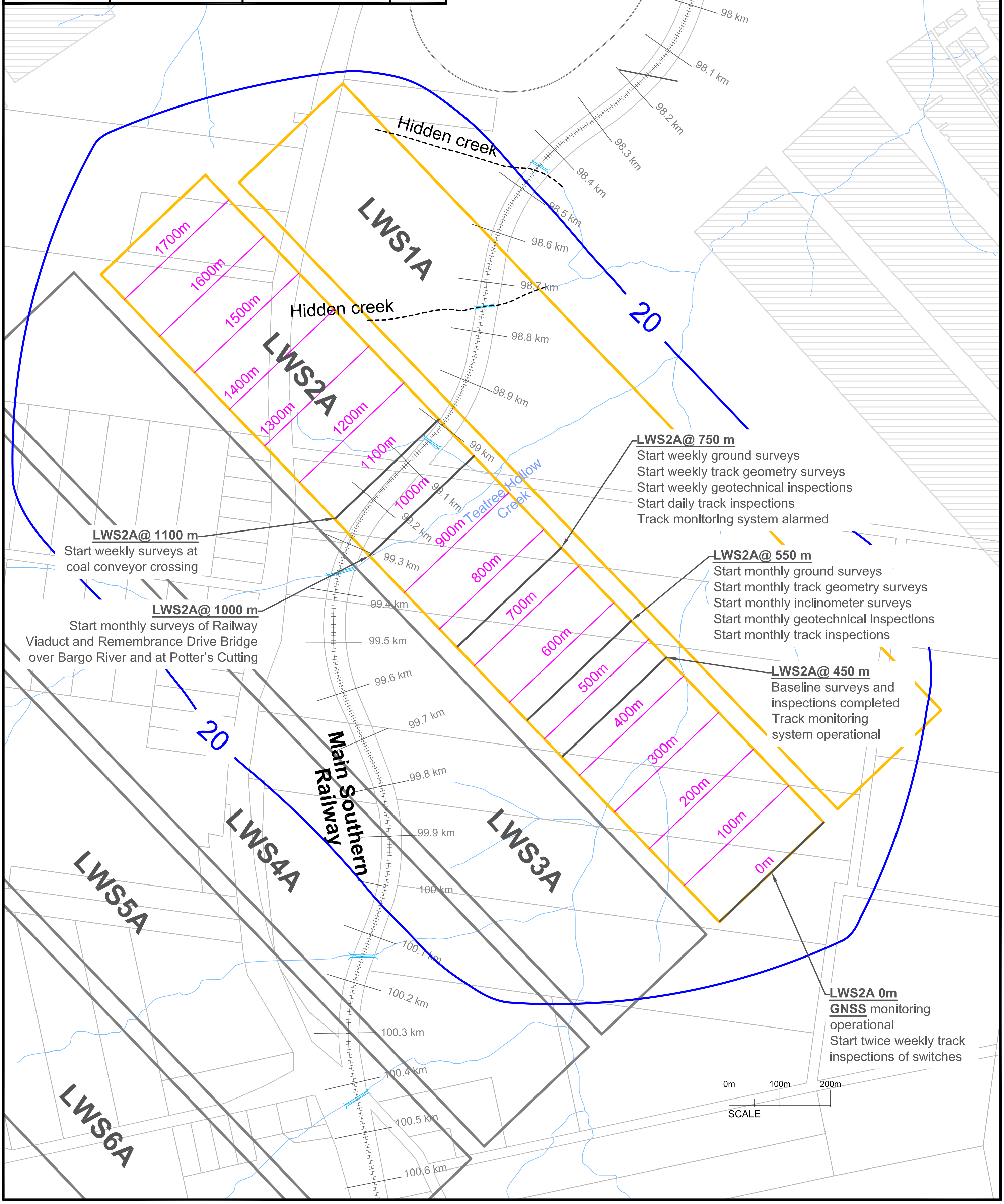

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TIMING OF MONITORING MEASURES - LWS3A

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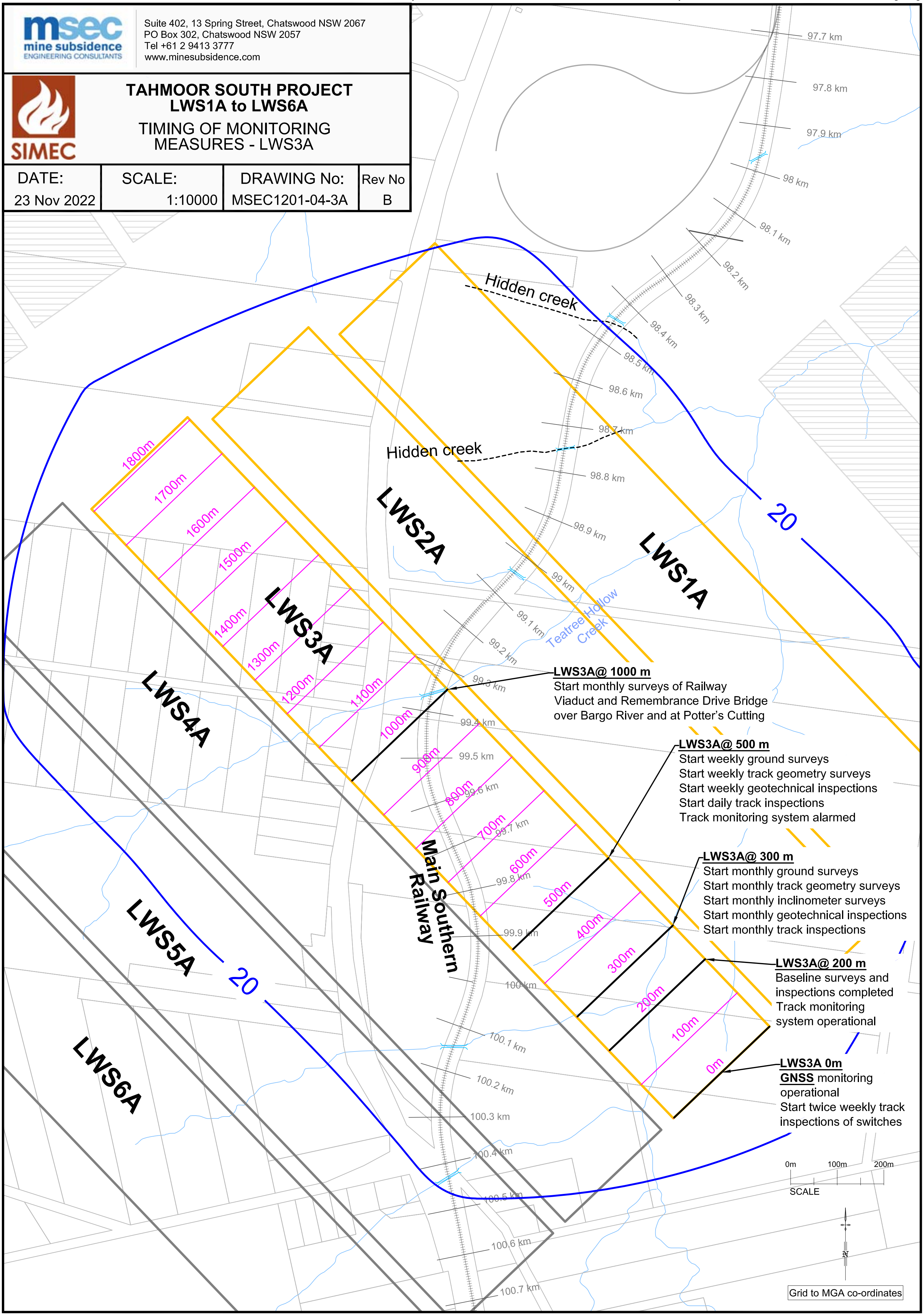

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TIMING OF MONITORING MEASURES - LWS4A

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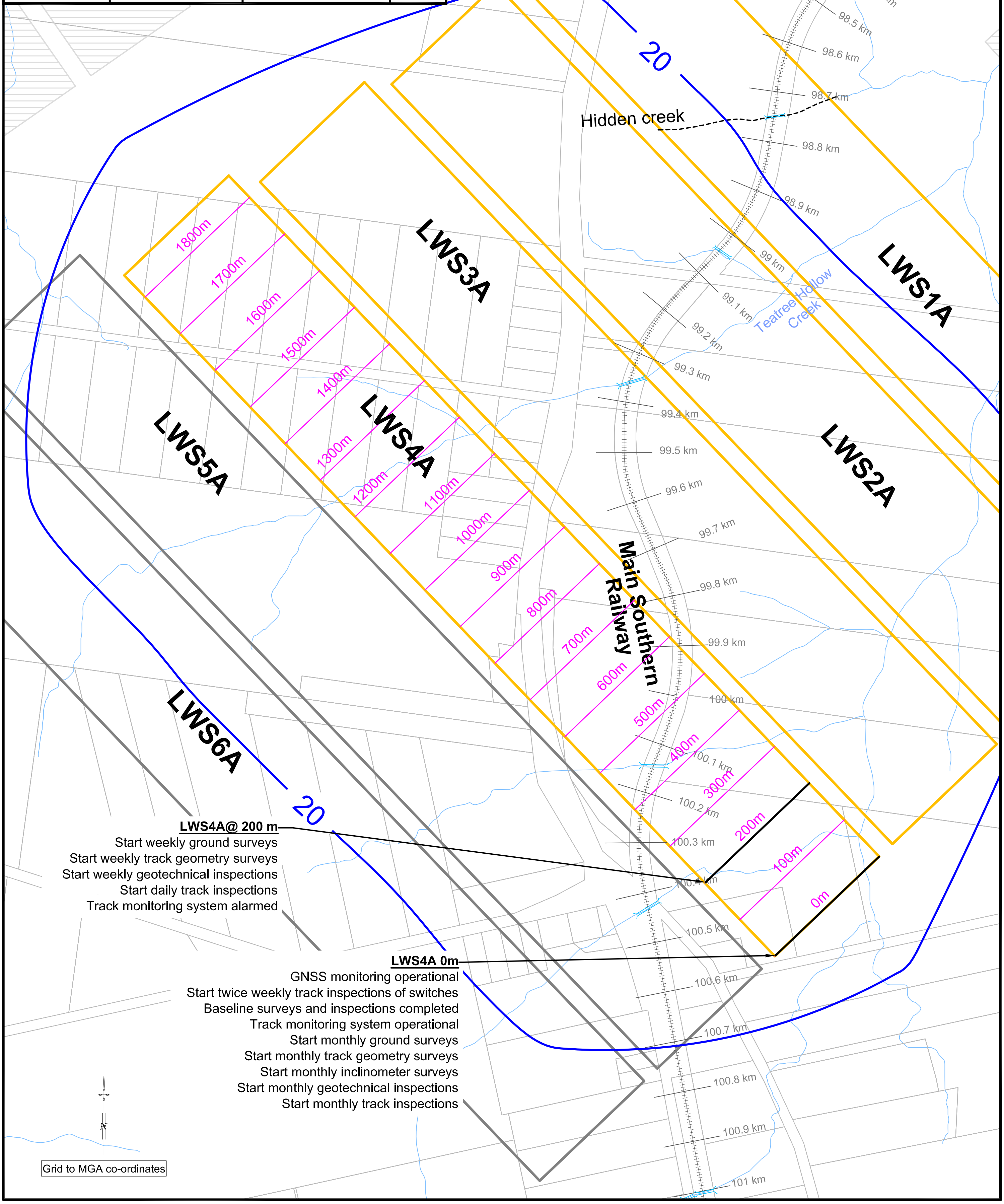

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TIMING OF MONITORING MEASURES - LWS5A

DATE:	SCALE:	DRAWING No:	Rev No
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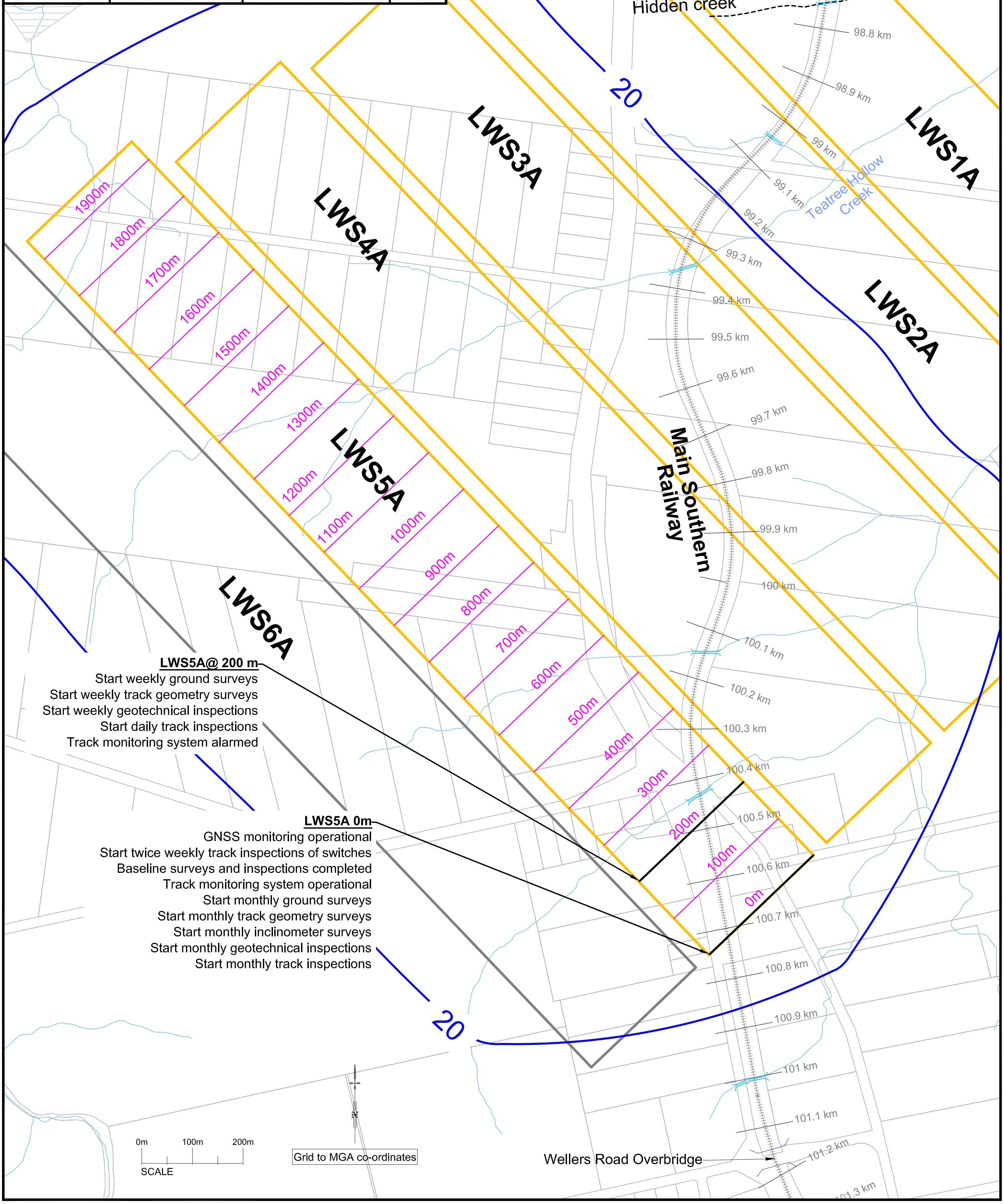

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TIMING OF MONITORING MEASURES - LWS6A

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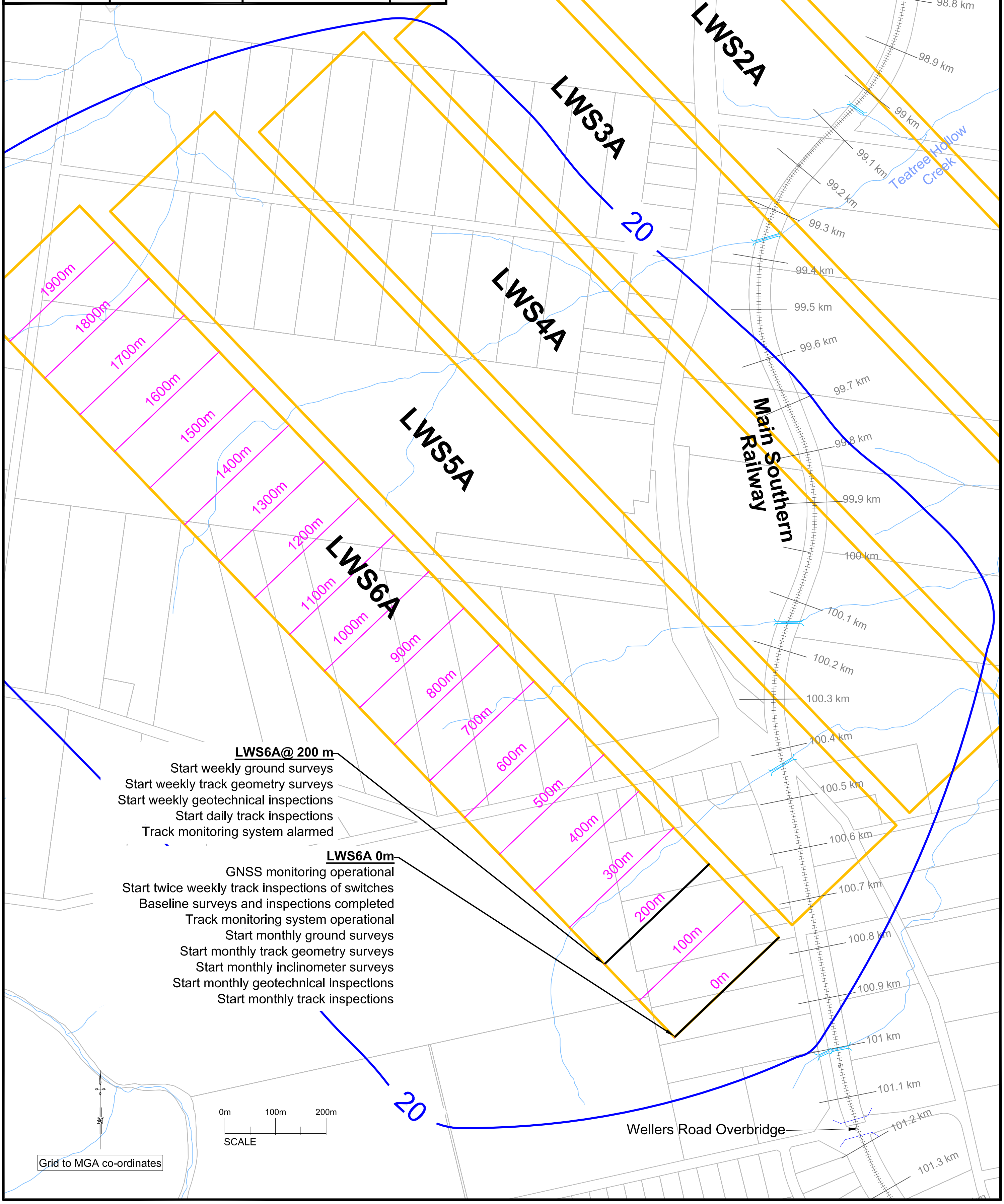

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LWS1A to LWS6A
MAIN SOUTHERN RAILWAY
CULVERT & EMBANKMENT 98.445 km
MONITORING

DATE:	SCALE:	DRAWING No:	Rev No
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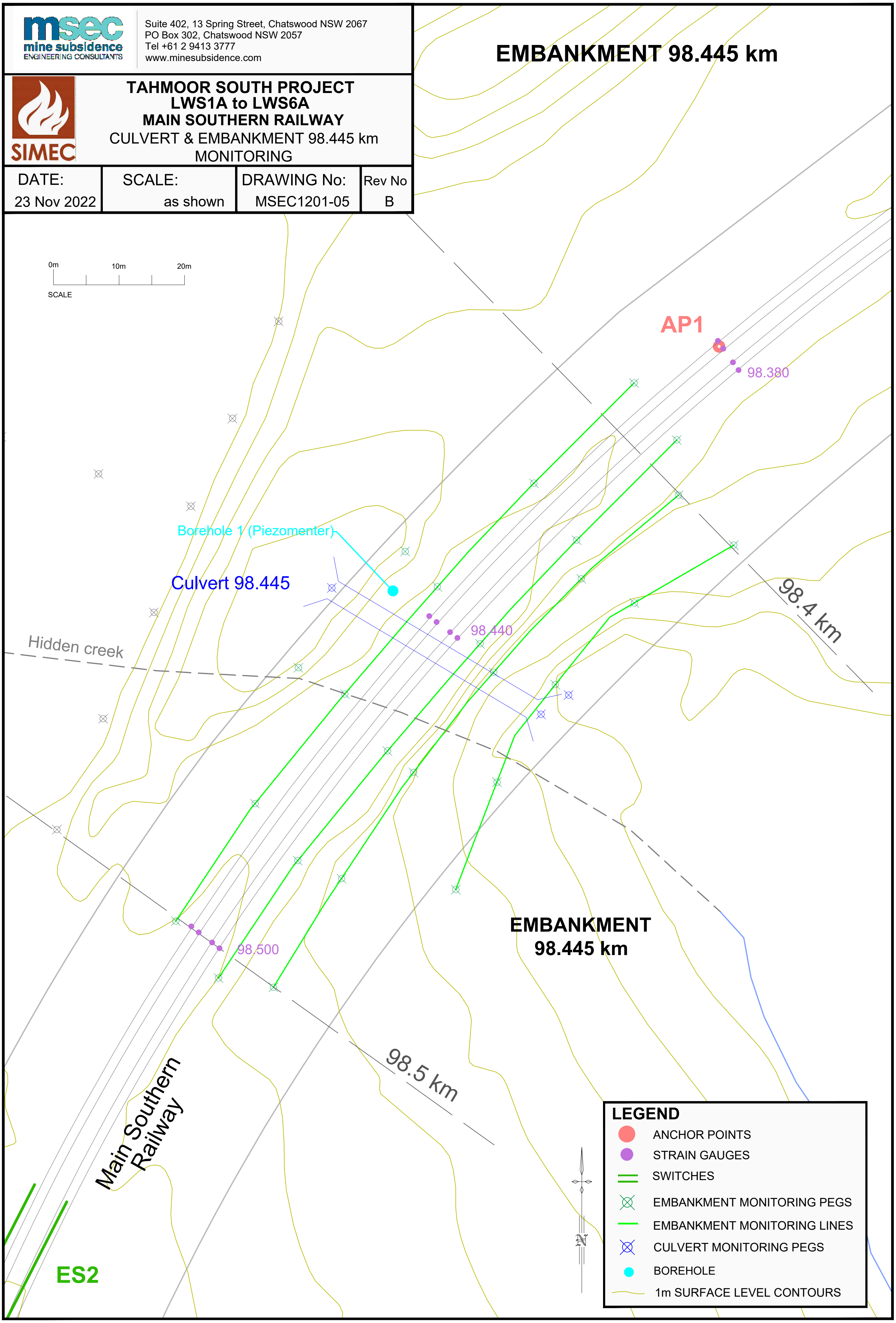

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LWS1A to LWS6A
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CULVERT & EMBANKMENT 98.739 km
MONITORING

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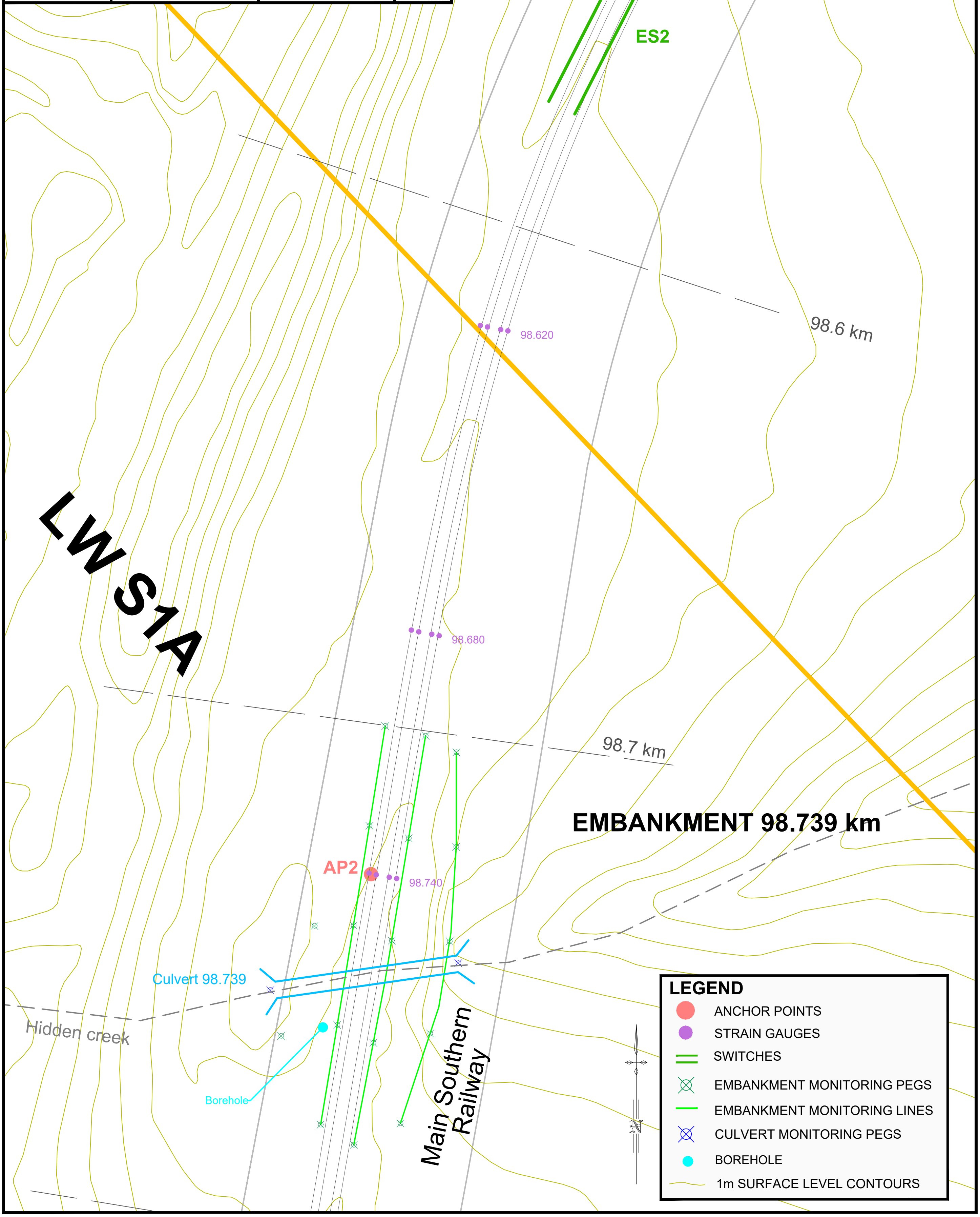

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LWS1A to LWS6A
MAIN SOUTHERN RAILWAY
CUTTING 98.895, CULVERT &
EMBANKMENT 99.035 km MONITORING

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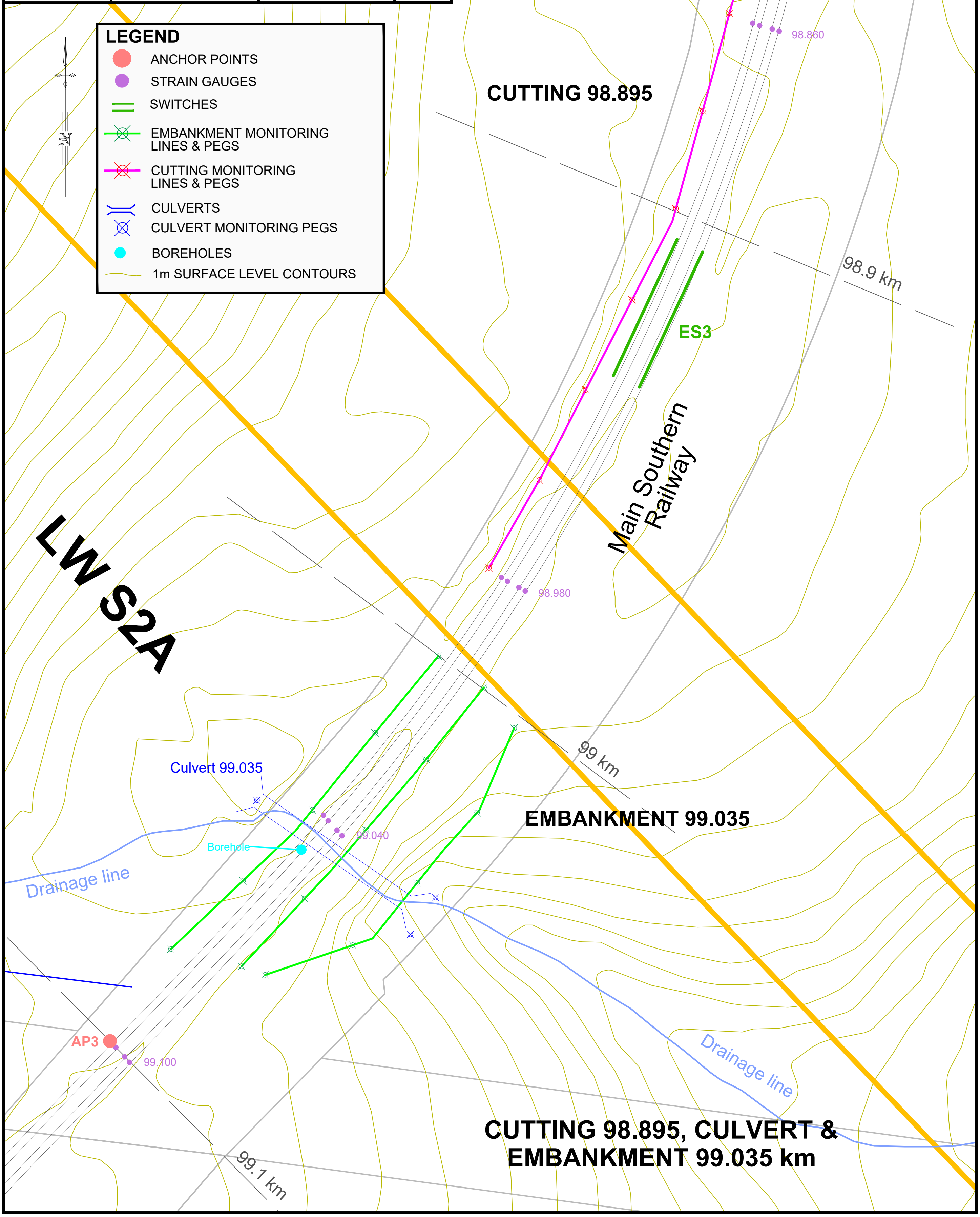

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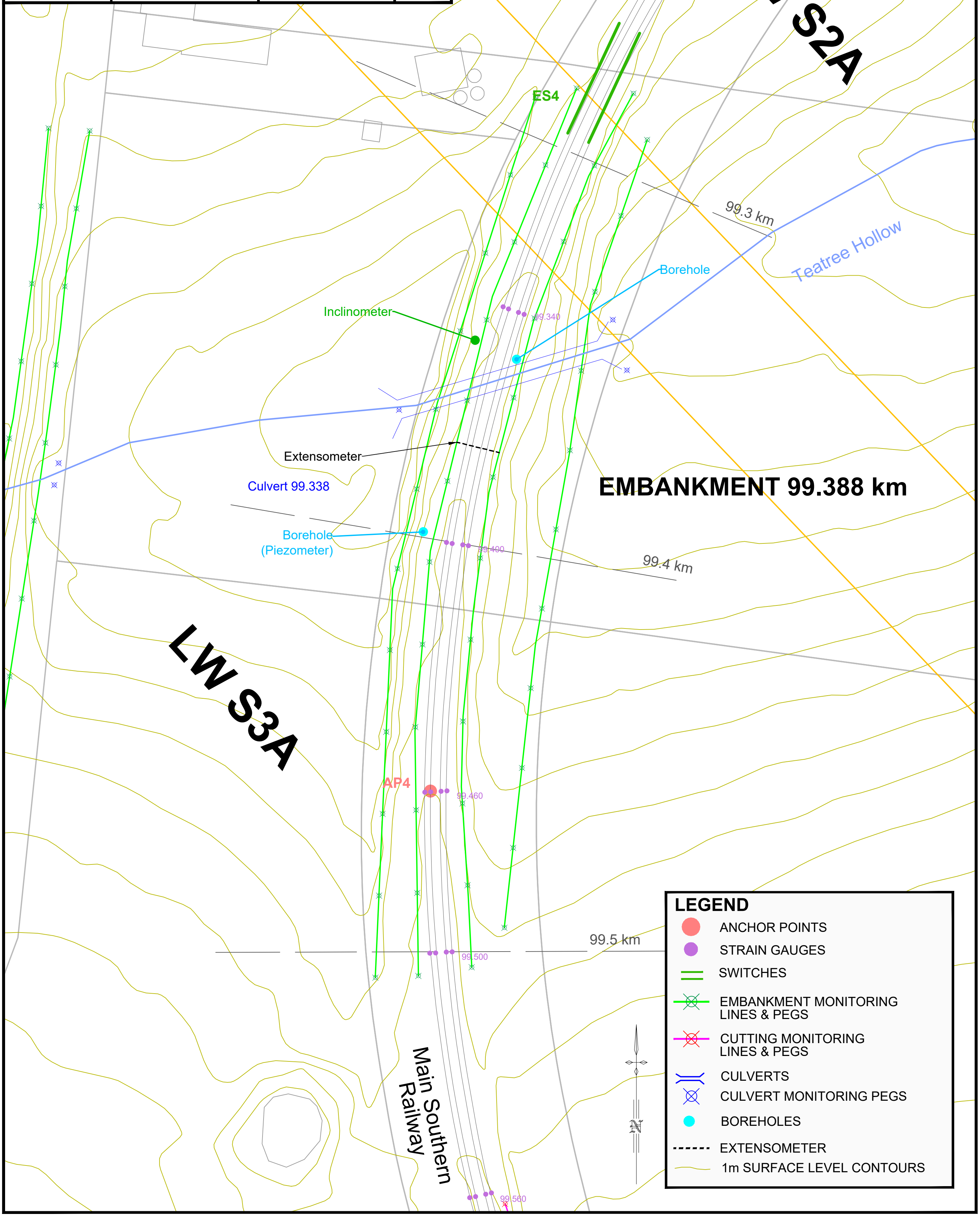
TAHMOOR SOUTH PROJECT
LWS1A to LWS6A
MAIN SOUTHERN RAILWAY

CULVERT & EMBANKMENT 99.338 km MONITORING

DATE:	SCALE:	DRAWING No:	Rev No
23 Nov 2022	as shown	MSEC1201-08	B



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LWS1A to LWS6A
MAIN SOUTHERN RAILWAY
CUTTING 99.690 km MONITORING PLAN

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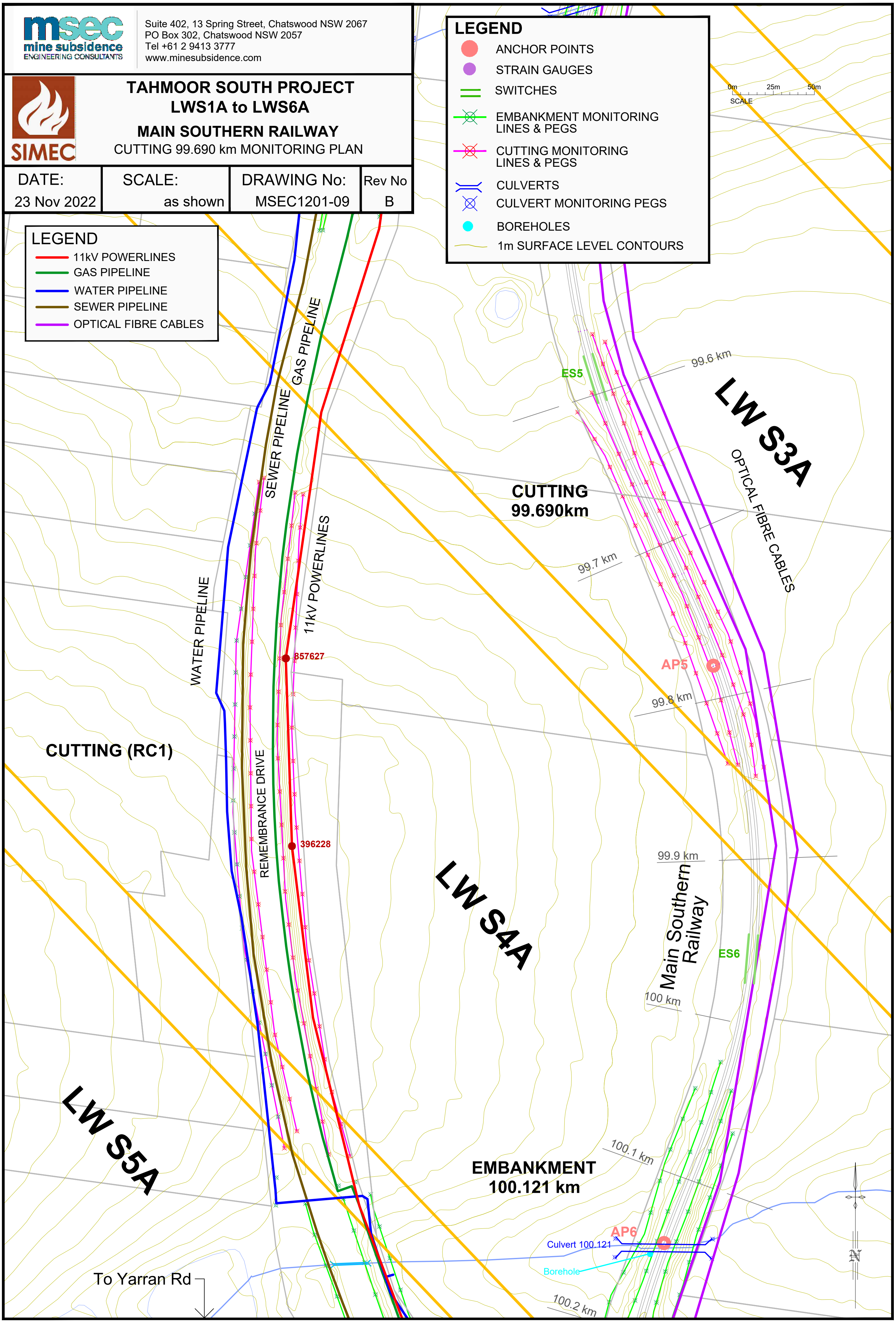

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LWS1A to LWS6A
MAIN SOUTHERN RAILWAY
CULVERT & EMBANKMENT 100.121 km
MONITORING PLAN

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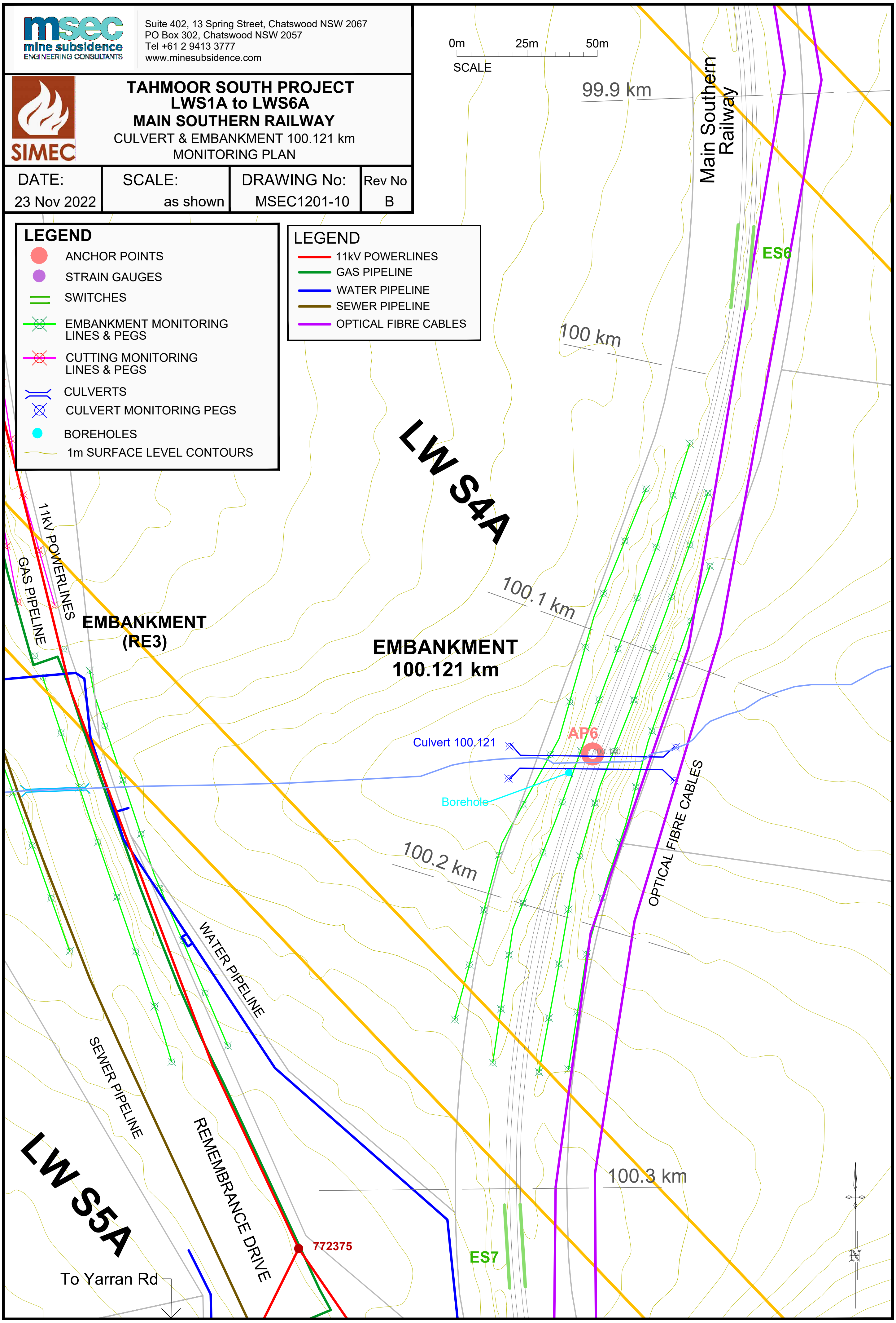

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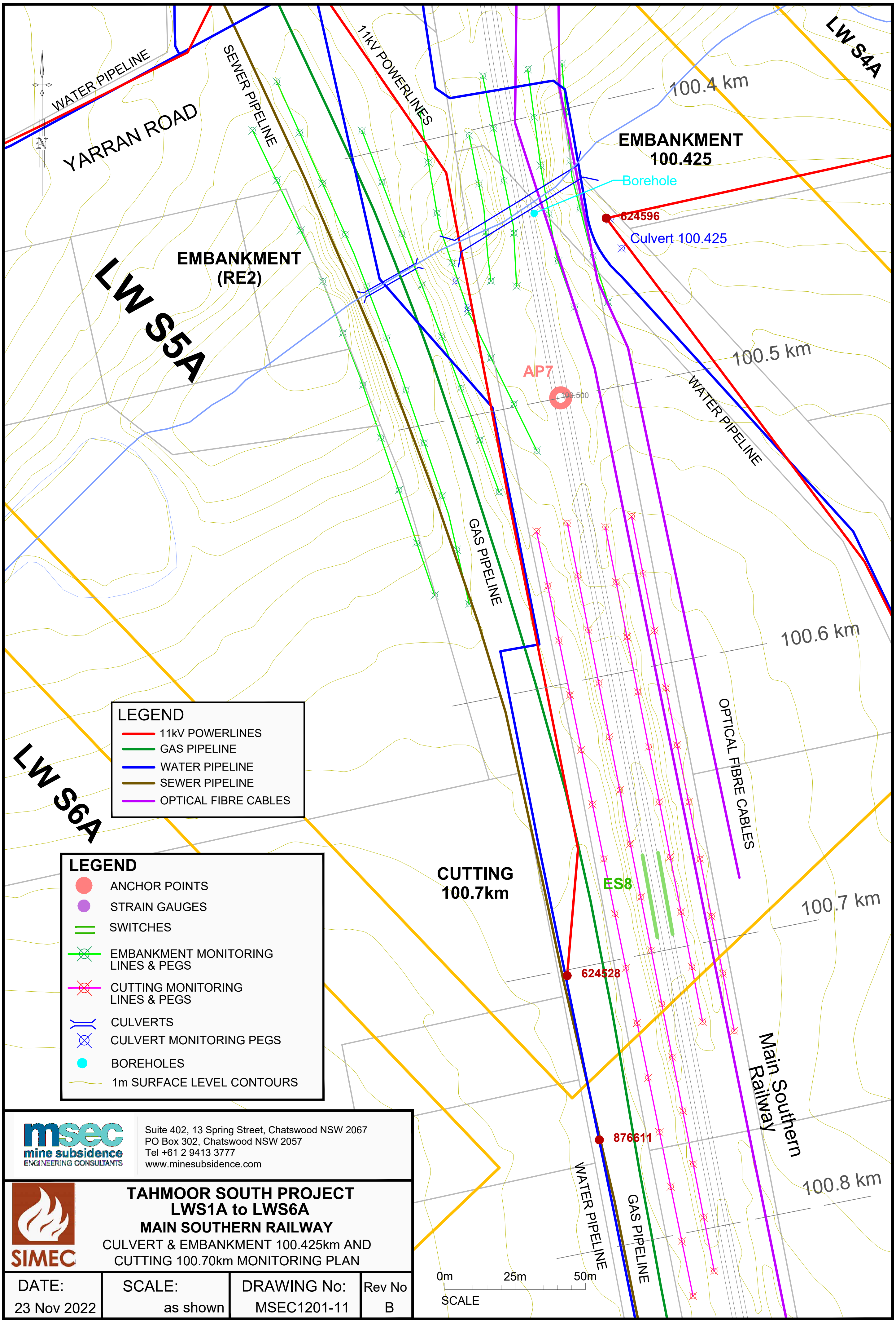

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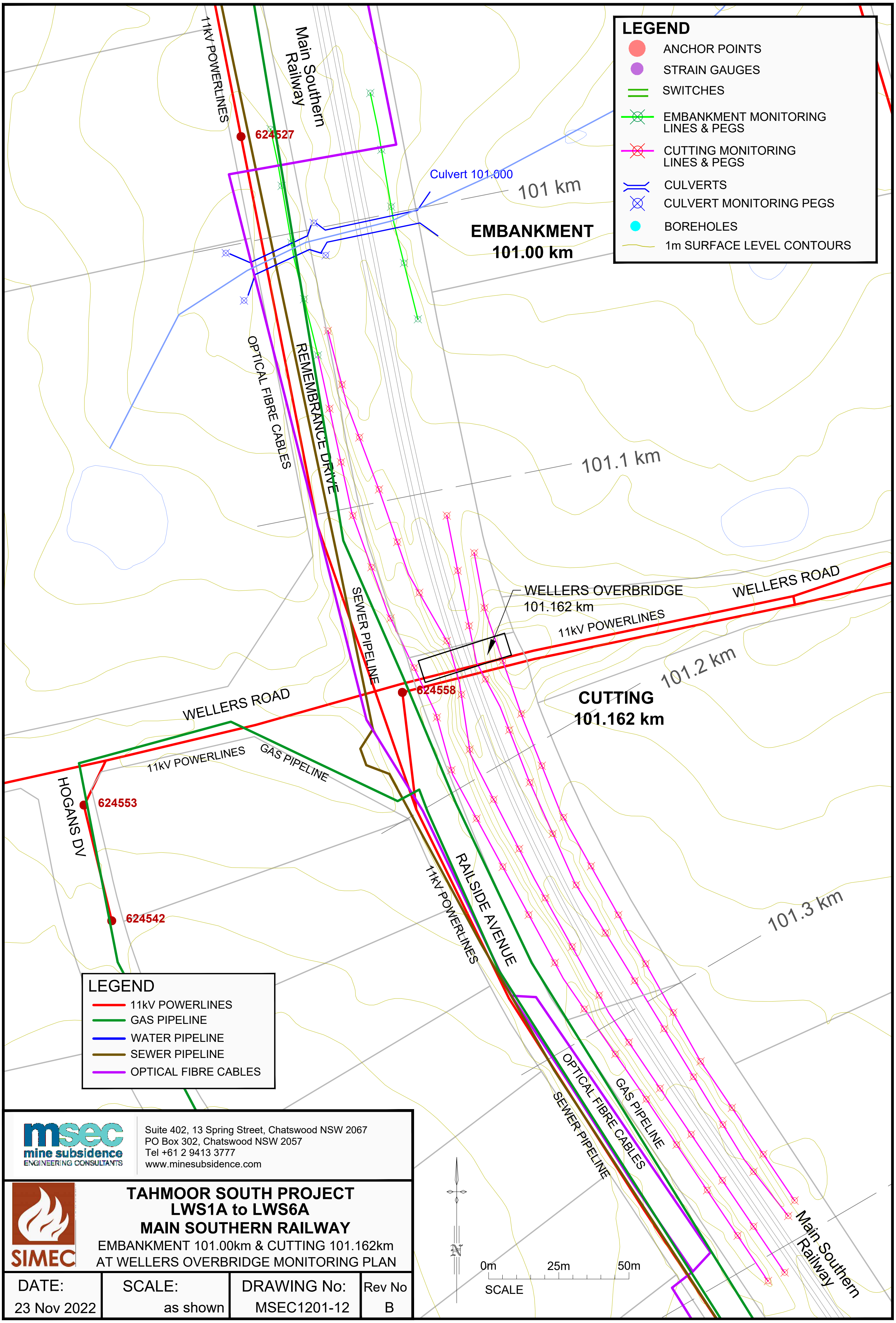

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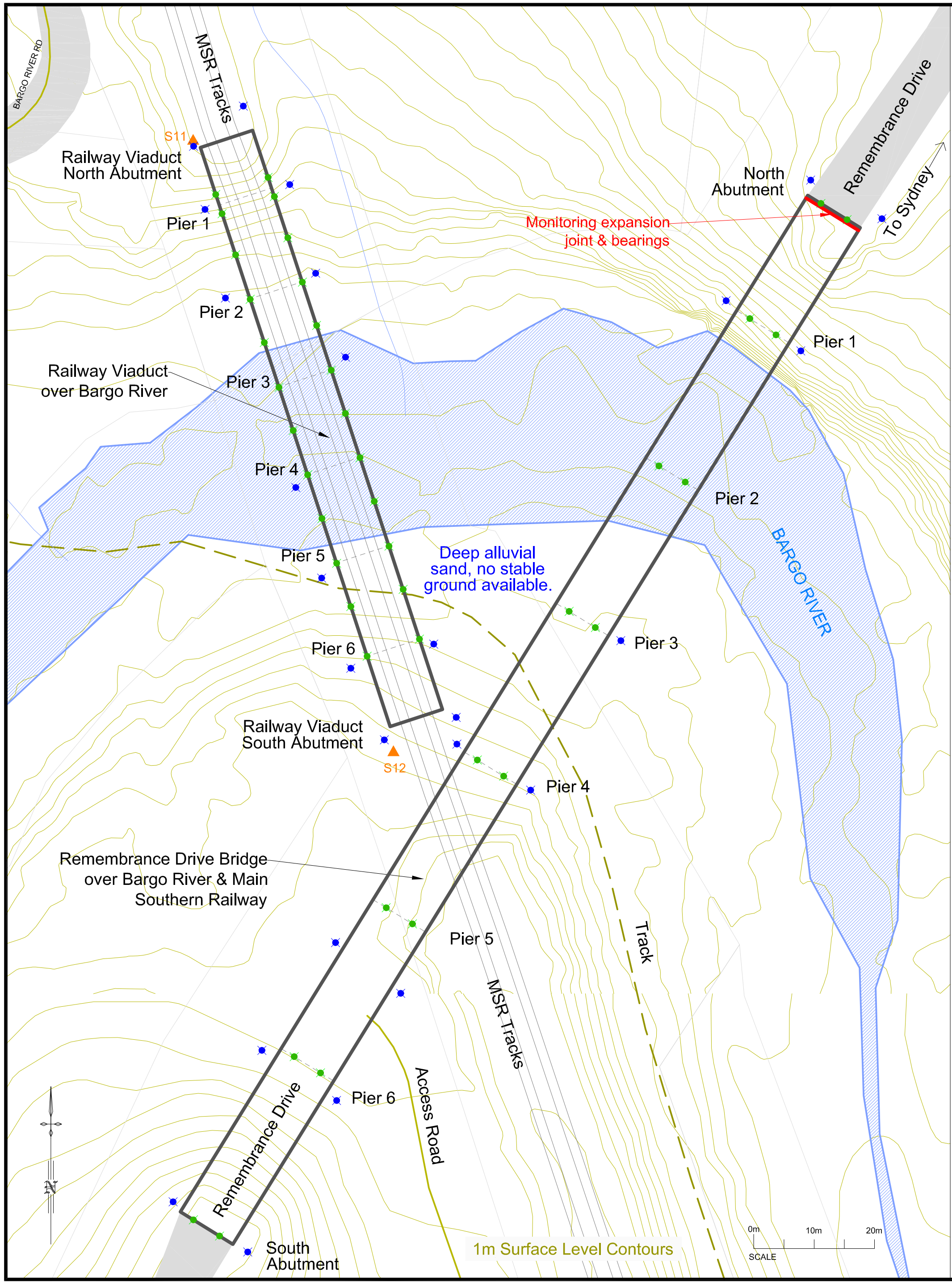
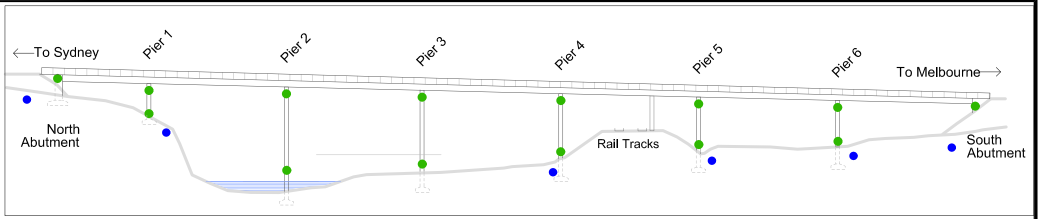
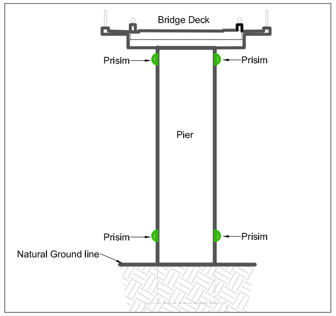
TAHMOOR SOUTH PROJECT
LWS1A to LWS6A
MAIN SOUTHERN RAILWAY
EMBANKMENT 101.00km & CUTTING 101.162km
AT WELLERS OVERBRIDGE MONITORING PLAN

DATE:	SCALE:	DRAWING No:	Rev No
23 Nov 2022	as shown	MSEC1201-12	B

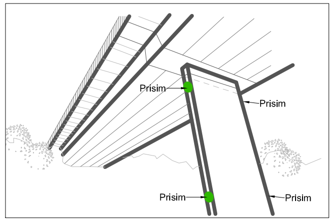




ELEVATION - REMEMBRANCE DRIVE BRIDGE OVER BARGO RIVER

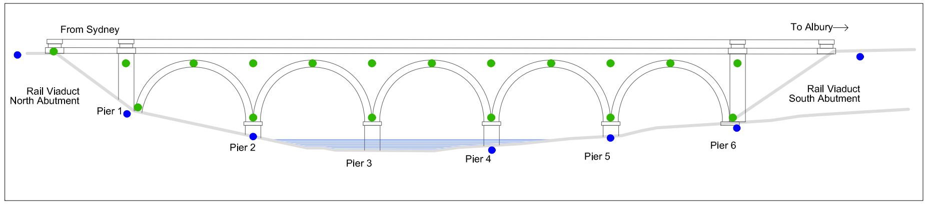


TYPICAL PIER (nts)



DIAGRAM

- PROPOSED STRUCTURE PRISMS
- PROPOSED GROUND PEGS



ELEVATION - RAILWAY VIADUCT OVER BARGO RIVER

LEGEND

- PROPOSED STRUCTURE PRISMS
- PROPOSED GROUND PEGS
- PROPOSED GNSS

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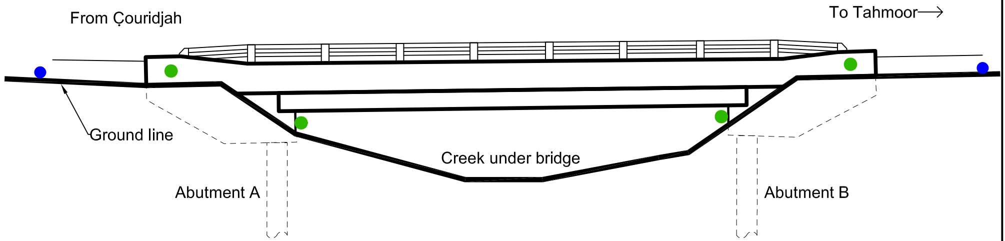
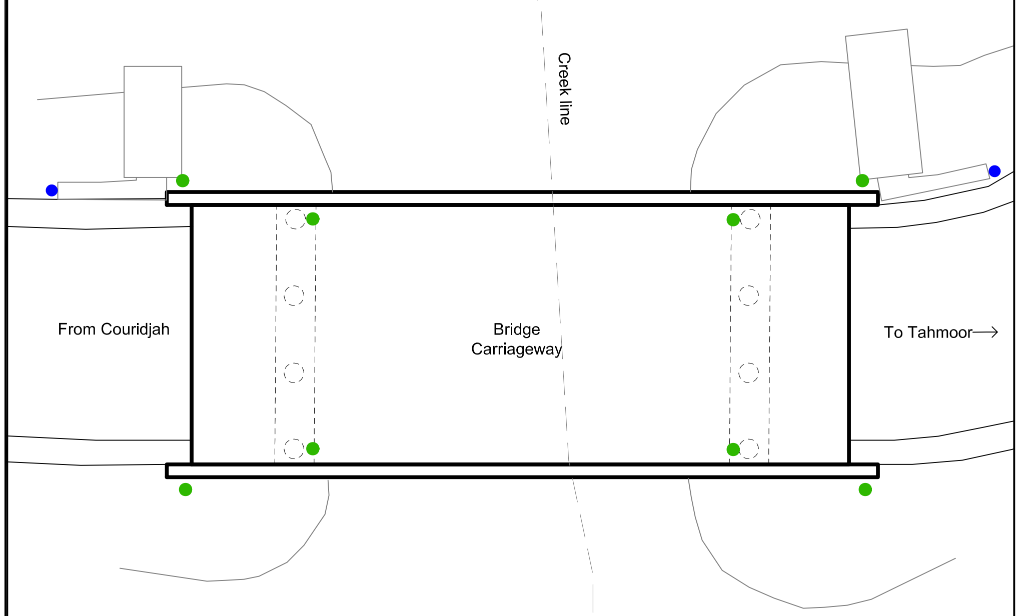
TAHMOOR SOUTH PROJECT
LWS1A TO LWS6A
MSR RAILWAY VIADUCT & REMEMBRANCE DRIVE BRIDGE OVER BARGO RIVER MONITORING PLAN

DATE:	SCALE:	DRAWING No:	Rev No
23 Nov 2022	as shown	MSEC1201-13	B

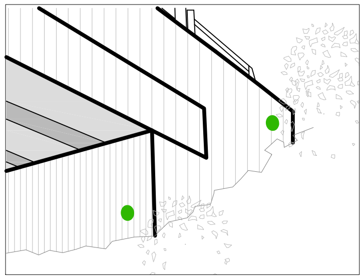


ELEVATION BRIDGE OVER CREEK



PLAN VIEW BRIDGE OVER CREEK

BARGO RIVER ROAD BRIDGE OVER TRIBUARY OF BARGO RIVER



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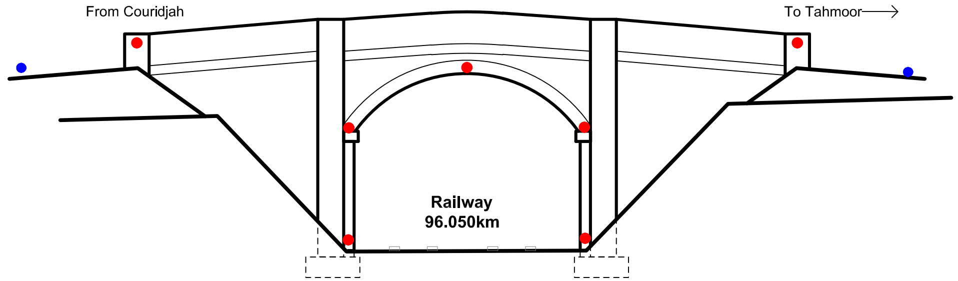
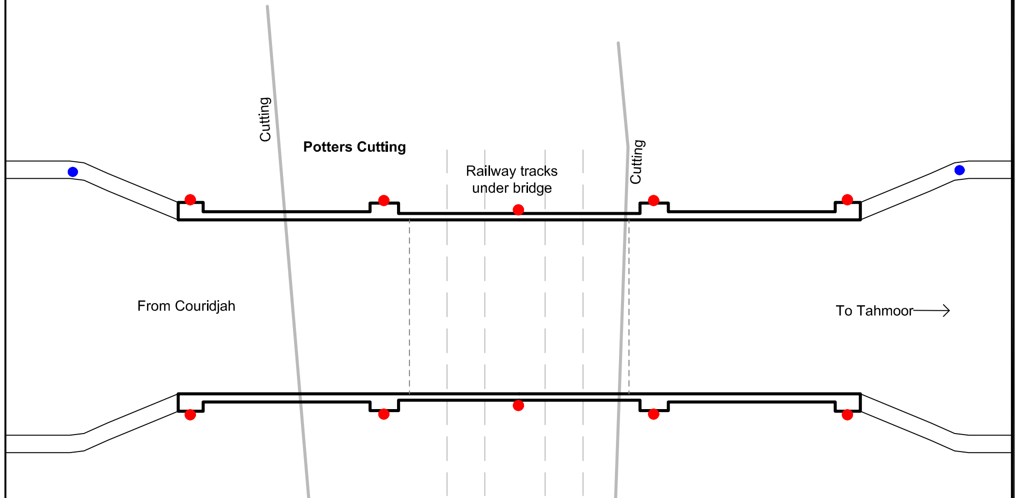


ELEVATION BRIDGE OVER RAILWAY



PLAN VIEW BRIDGE OVER RAILWAY 96.050km

BARGO RIVER ROAD BRIDGE OVER MAIN SOUTHERN RAILWAY

LEGEND

- PROPOSED STRUCTURE PRISMS
- PROPOSED GROUND PEGS
- EXISTING MONITORING PRISMS

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TAHMOOR SOUTH PROJECT LWS1A TO LWS6A

BARGO RIVER ROAD BRIDGES MONITORING PLAN

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23 Nov 2022	nts	MSEC1201-14	B

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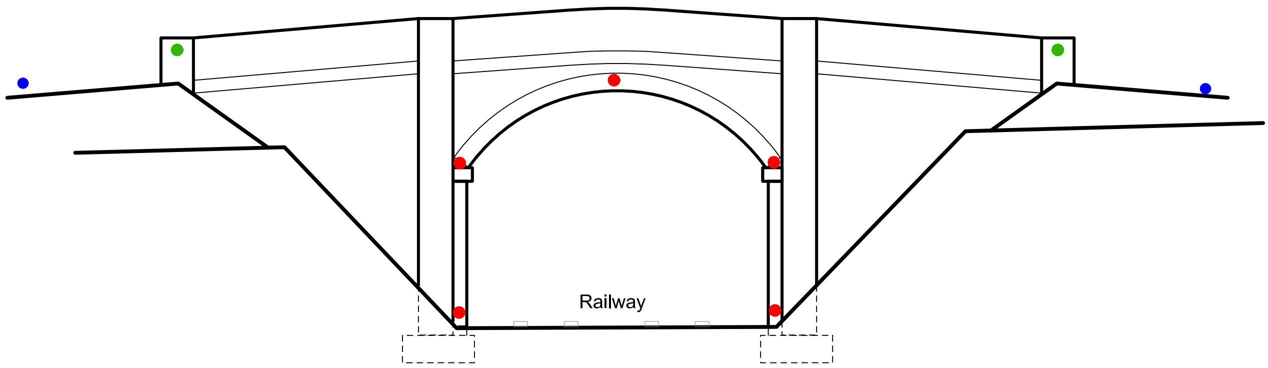
TAHMOOR SOUTH PROJECT
LWS1A TO LWS6A
WELLERS ROAD OVERBRIDGE
MONITORING PLAN

DATE:	SCALE:	DRAWING No:	Rev No
23 Nov 2022	as shown	MSEC1201-15	B

LEGEND
- INSTALLED STRUCTURE PRISMS
- PROPOSED STRUCTURE PRISMS
- PROPOSED GROUND PEGS
- INSTALLED GNSS

WELLERS ROAD BRIDGE



ELEVATION BRIDGE OVER RAILWAY

PLAN VIEW BRIDGE OVER RAILWAY

WELLERS ROAD OVERBRIDGE OVER RAILWAY

APPENDIX C. Supporting Documentation

Supporting Documentation

HMS, (2021).	*Tahmoor South Longwalls LW1A – LW6A Potential Impacts on the ARTC's Main Southern Railway Line Risk Assessment*. Report No. HMS1479, Final Report, HMS Consultants, September 2021.
JMA (2022a)	*Structure Investigation Report – Impact of Far Field Movement, Remembrance Driveway Bridge over Bargo River, Tahmoor*, JMA Solutions, Report No. R0799-R2, November 2022.
JMA (2022b)	*Structure Investigation Report – Impact of Far Field Movement, Bargo Railway Viaduct, Tahmoor*, JMA Solutions, Report No. R0803-R3, November 2022.
JMA (2022c)	*Structure Investigation Report – Overbridge at Potters Cutting*, JMA Solutions, Report No. R0795-R3, October 2022.
JMA (2022d)	*Structure Investigation Report – Wellers Road Overbridge, Bargo*, JMA Solutions, Report No. R0806-R2, November 2022
JMA (2022e)	*Structure Investigation Report – Conveyor 3R over Main Southern Railway*, JMA Solutions, Report No. R0798, June 2022
Newcastle Geotech (2022a)	*Simec Mining – Tahmoor South – Longwalls S1A to S6A – Main Southern Rail – Embankment and Cutting Geotechnical Assessment*, Newcastle Geotech, Report No. 493-8, October 2022.
Newcastle Geotech (2022b)	*Mapping of Geological Conditions – Bargo River Bridge Structures – Tahmoor South Project – Bargo*, Newcastle Geotech, Report No. 493-5, 9 August 2022.
PCE (2022a)	*Tahmoor South Track Geometry Standards*, Pidgeon Civil Engineering, Report Date – 31 October 2022.
PCE (2022b)	*Tahmoor South Track Condition*, Pidgeon Civil Engineering, Report Date – 02 November 2022.

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