SIMEC Mining – Tahmoor Coal

Tahmoor North Western Domain
Longwalls West 1 and West 2

Management Plan for Potential Impacts to Roads and Maritime Services Infrastructure

Prepared by Mine Subsidence Engineering Consultants
on behalf of
the Technical Committee

Transport
Roads & Maritime
Services

SIMEC MINING
Tahmoor Coking Coal

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DOCUMENT REGISTER

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Oct-19	MSEC1045-18	A	Draft for submission to RMS
Nov-19	MSEC1045-18	B	Final for submission to RMS following minor update of structural engineering report
Nov-19	MSEC1045-18	C	Final following feedback provided by RMS

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

- Simec Mining – Tahmoor Coal
- Roads and Maritime Services
- Cardno
- Mine Subsidence Engineering Consultants

It is further acknowledged that this Management Plan builds upon knowledge gained during the development Management Plans for the Douglas Park Bridges during the mining of Appin longwalls. The following organisations have contributed to these plans:

- South 32 Illawarra Coal
- Roads and Maritime Services
- Aecom
- Arup
- Cardno
- Parsons Brinckerhoff
- Pells Consulting
- Pells Sullivan Meynink
- Mine Subsidence Engineering Consultants
- Lynton Surveys

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MSEC1045-18-02	Far field monitoring	01

1.0 INTRODUCTION

1.1. Introduction

Tahmoor Coal is located approximately 80 km south-west of Sydney in the township of Tahmoor NSW. It is managed and operated by SIMEC Mining. Tahmoor Coal has previously mined 31 longwalls to the north and west of the mine's current location. Longwall 32 completed extraction in September 2019.

Tahmoor Coal plans to extract coal in a new series of panels in the Western Domain. Longwalls West 1 and West 2 (LW W1-W2) are the first two longwalls to be mined in the Western Domain. The longwall panels are located to the north of the current longwall series, and to the south of Cedar and Stonequarry Creeks, and to the west of the Main Southern Railway where it loops around the township of Picton. Infrastructure owned by Roads and Maritime Services (RMS) is located adjacent to this area and will not be directly mined beneath.

A summary of the dimensions of LW W1-W2 are provided in Table 1.1.

Table 1.1 Longwall dimensions

Longwall	Overall void length including the installation heading (m)	Overall void width including the first workings (m)	Overall tailgate chain pillar width (m)
LW W1	1875	283	-
LW W2	1685	283	39

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

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

1.2. RMS assets potentially affected by LW W1-W2

RMS requires that a risk assessment of subsidence impacts and far-field effects be conducted where longwalls are located within a distance of 5 times the seam depth to an RMS asset. The depth of cover above LW W1-W2 is approximately 500 metres.

A map showing the locations of RMS infrastructure in relation to LW W1-W2 is shown in Drawing No. MSEC1045-18-01.

Whilst there are no RMS assets in the immediate vicinity of LW W1-W2, there are two RMS assets within 5 times the seam depth (i.e. 2.5 km) of the longwalls:

- Victoria Bridge, Picton; and
- Menangle Street / Picton Road from the intersection at Argyle Street to approximately 1 km to the east of the intersection of Picton Road and Matthews Lane.

A summary table showing the closest distances of LW W1-W2 to RMS assets is shown in Table 1.2 and their locations are shown in Drawing No. MSEC1045-18-01, which is included in Appendix A of this Management Plan.

Table 1.2 Closest distances of LW W1-W2 to RMS Assets

RMS Asset	Distance to LW W1 (m)	Distance to LW W2 (m)
Victoria Bridge	1700 m	1400 m
Menangle Street – Picton Road	1800 m	1500 m

The potential for impacts on key civil infrastructure was identified early as a constraint in the mine planning phase. Key elements of the mine plan in the Western Domain included setting back longwalls an appropriate distance from critical civil structures such as the Picton Tunnel, Picton Viaduct and Argyle Street Underbridge on the Main Southern Railway, plus the Victoria Road Bridge over Stonequarry Creek such that it would be feasible to maintain their safety and serviceability. The longwall sequencing was also adjusted to extract from west to east towards these structures, providing an opportunity to monitor mine subsidence movements as longwalls are progressively extracted and allowing the mine plan to be adapted if unexpected adverse changes are observed.

1.3. Consultation

1.3.1. Consultation with Roads and Maritime Services

As part of the consultation phase of the Extraction Plan application process, RMS advised Tahmoor Coal on 13 May 2019 to conduct a risk assessment if the longwalls are located within a distance of 5 times the seam depth of RMS assets.

Details regarding consultation and engagement are outlined below:

- Meeting with Dony Castro (RMS), David Talbert (Tahmoor Coal) and Daryl Kay (MSEC) on 11 September 2019 to discuss the proposed extraction of LW W1-W2.
- Risk assessment with Dony Castro (RMS), Cyril Gunaratne (RMS), Robyn Lyster (RMS), David Talbert (Tahmoor Coal), Ingrid Dungey (Tahmoor Coal), Richard Woods (Cardno) and Daryl Kay (MSEC) on 17 October 2019 with respect to the proposed extraction of LW W1-W2 adjacent to RMS assets.
- Site visit with RMS to Victoria Bridge, with David Talbert (Tahmoor Coal), Richard Woods (Cardno) and Graeme Robinson (Robinson Rail).
- Meeting with Dony Castro (RMS), Robyn Lyster (RMS) and David Talbert (Tahmoor Coal) on 5 November 2019 to review draft Management Plan and provide feedback.
- Email correspondence between RMS, Tahmoor Coal, Cardno and MSEC as part of investigations.

Tahmoor Coal will consult regularly with RMS during the extraction of LW W1-W2 in relation to mine subsidence effects from mining.

1.3.2. Consultation with Government Agencies & Key Infrastructure Stakeholders

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

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 RMS infrastructure potentially or directly affected by mining operations as a result of the mining of Tahmoor LW W1-W2.

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

- Ensure the safe and serviceable operation of all surface infrastructure. Public and workplace safety is paramount. Ensure that the health and safety of people who may be present on RMS assets are not put at risk due to mine subsidence.
- Avoid disruption and inconvenience, or, if unavoidable, keep to minimal levels.
- Monitor ground movements and the condition of RMS infrastructure prior to mining, during mining, and for a period post-mining as advised by the Technical Committee.
- Initiate action to mitigate or remedy potential significant impacts that are expected to occur on the surface based upon investigations and assessments conducted to date. In this regard, mitigation works that effectively reduce mining risks to RMS infrastructure, functionality and road user safety must be established and commissioned before each longwall affects the Motorway.
- Provide a forum for the identification, discussion and resolution of technical safety matters related to subsidence effects on RMS infrastructure.
- Provide a contingency plan of action in the event that the impacts of mine subsidence are greater than those that are predicted.
- Establish a clearly defined decision-making process to ensure timely implementation of risk control measures for high consequence but low likelihood mine subsidence induced hazards that involve potential serious injury or illness to a person or persons that may require emergency evacuation, entry or access restriction or suspension of work activities.
- Establish lines of communication and emergency contacts.

This Management Plan provides detailed information about how the risks associated with mining LW W1-W2 adjacent to Victoria Bridge will be managed by Tahmoor Coal and RMS.

In future years, Tahmoor Coal plans to extract an additional two longwall panels (LW W3-W4) closer to Victoria Bridge. Additional site investigations and assessments were identified during the risk assessment for LW W1-W2 for the purposes of identifying subsidence hazards and assessing risks in preparation for the development of a subsidence management plan for LW W3-W4.

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

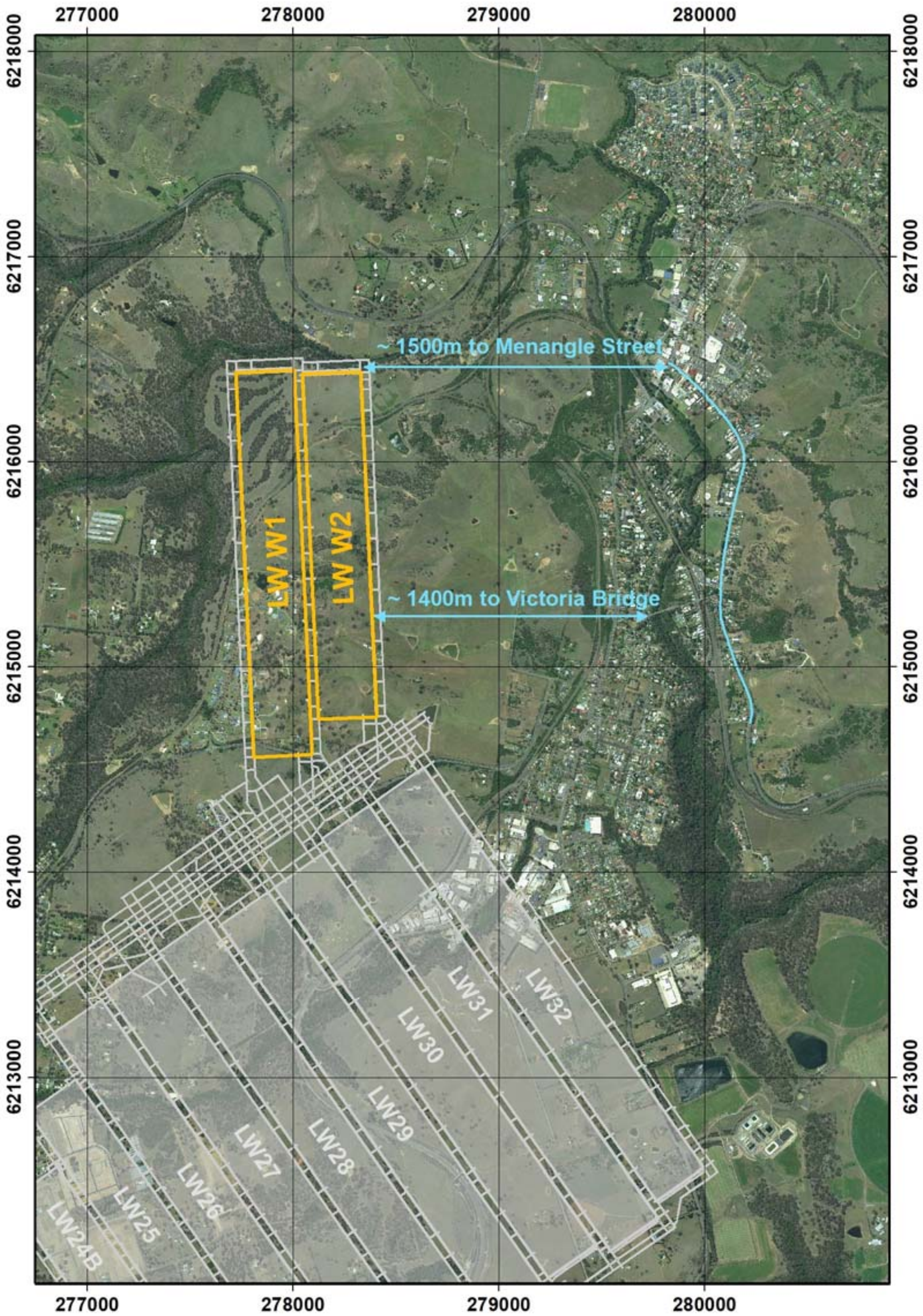

Fig. 1.1 Aerial Photograph overlaid with Mine Layout

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 be at risk due to mine subsidence and to take proactive action to defuse any unexpected developments. The major items at risk are:-

- Victoria Bridge
- Menangle Street – Picton Road

This Management Plan describes measures that will be undertaken as a result of the mining of LW W1-W2 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. MSEC1019 by Mine Subsidence Engineering Consultants (MSEC, 2019). Predictions are based on the planned configuration of LW W1-W2 at Tahmoor Coal (as shown in Drawing No. MSEC1045-18-01), 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 RMS.

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 MSEC1019 by Mine Subsidence Engineering Consultants.

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

1.7. Legal framework

The Extraction Plan for LW W1-W2 was submitted to the NSW Department of Planning and Environment in July 2019. LW W1 will not commence until the Extraction Plan is approved.

It is expected that the Extraction Plan will include a condition that Tahmoor Coal must ensure that roads and bridges be:

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

This Management Plan has also been developed in accordance with Tahmoor Coal's Built Features Management Plan for LW W1-W2.

Continuing consultation during the extraction of LW W1-W2 between Tahmoor Coal and RMS is via the Technical Committee.

This Management Plan was reviewed by the Technical Committee and endorsed by each member in their area of expertise before joint authorisation by RMS and Tahmoor Coal. This plan builds upon the investigations and knowledge gained from the successful implementation of Management Plans for the mining of longwalls at Appin Colliery near the Douglas Park Twin Bridges.

1.8. 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.

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

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

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

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

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

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

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

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

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

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

This Management Plan documents the risk control measures that are planned to manage risks to health and safety associated with the mining of LW W1-W2 in accordance with the WHS laws.

1.9. Documentation Control

This Management Plan is authorised for use when it is signed by representatives from Tahmoor Coal and RMS. Tahmoor Coal must not cause any subsidence impacts on RMS assets before this Management Plan is approved by the Department of Planning and Environment.

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

- Tahmoor Coal or its nominated representative will notify RMS and members of the Technical Committee and monitoring contractors of the authorisation of the Management Plan and issue an electronic copy.
- Tahmoor Coal or its nominated representative will issue the Management Plan to RMS and members of the Technical Committee.
- Tahmoor Coal or its nominated representative will instruct the members of the Technical Committee and monitoring contractors to remove the previous authorised version of the Management Plan 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. A decision to make minor changes to management or monitoring measures is undertaken on a case by case basis upon the recommendation of the Technical Committee. Approval for a minor change is given by the RMS Pavement Maintenance Planner if the minor change relates to pavements or the RMS Bridge Maintenance Planner if the minor change relates to bridges.

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

Minor changes include, but are not limited to:

- A change in management or monitoring measures after a longwall has completed mining. These may include:
  - Changes in monitoring frequencies or extents
- Adjustments to low level triggers
- Changes to frequencies, extents or timing of management or monitoring measures based on the findings of end of panel reviews by the Technical Committee,
- Changes to frequencies, extents or timing of management or monitoring measures based on changes in direction of longwall panels or minor changes to the mine plan, which do not materially change the management strategy.

Minor changes that relate to monitoring measures may require approval from RMS.

Major changes to management or monitoring measures will require an authorised revision of the Management Plan by Tahmoor Coal and RMS and will be undertaken on a case by case basis upon the recommendation of the Technical Committee. An example of a major change would be if the planned mitigation measures are changed. An authorised revision of the Management Plan may require approval from the Department of Planning and Environment.

1.10. Proposed mining schedule

It is planned that LW W1-W2 will extract coal working south from the northern end. This Management Plan covers longwall mining until completion of mining in LW W2 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 W1	November 2019	August 2020
LW W2	September 2020	May 2021

Please note the above Schedule is subject to change due to unforeseen impacts on mining progress. Tahmoor Coal will keep RMS informed of changes.

1.11. Compensation

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

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

2.1. Predicted subsidence movements due to the extraction of LW W1

The Victoria Bridge over Stonequarry Creek is located approximately 1700 m east of LW W1, and 1400 m east of LW W2. It is not predicted to experience conventional mine subsidence movements. Stonequarry Creek is not predicted to experience valley closure and upsidence movements.

Menangle Street – Picton Road is located approximately 1800 m east of LW W1, and 1500 m east of LW W2 at its closest point. The road is not predicted to experience subsidence, valley closure and upsidence movements.

The Victoria Bridge may experience absolute and differential far field horizontal movements and may be adversely affected. Further details are provided in the next section.

2.2. Far-field 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.

The observed incremental far-field horizontal movements resulting from the extraction of each longwall, in any location above goaf (i.e. above the currently mined or previously mined longwalls) or above solid coal (i.e. unmined areas of coal) are provided in Fig. 2.1. The observed incremental far-field horizontal movements above solid coal only, i.e. outside the extents of extracted longwalls, are provided Fig. 2.2. 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. 2.1 and Fig. 2.2 that the magnitude of the observed far-field horizontal movements over solid unmined areas of coal are lower and more consistent than the observed far-field horizontal movements over previously extracted longwalls.

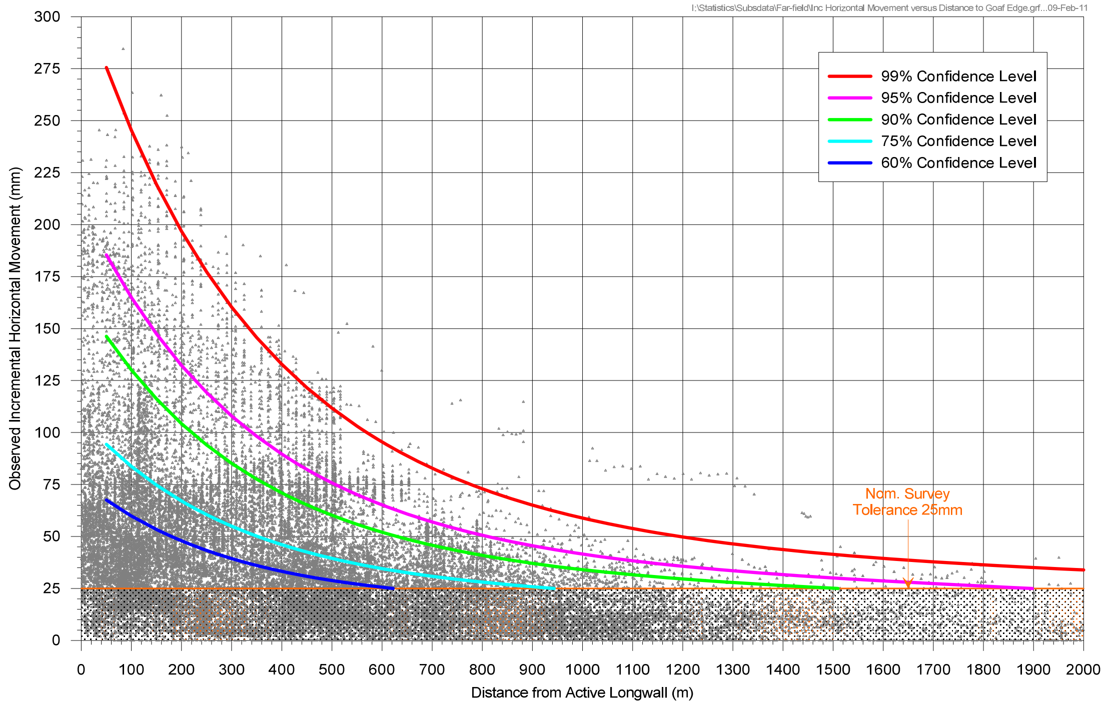

Fig. 2.1 Measured incremental far-field horizontal movements above goaf or solid coal

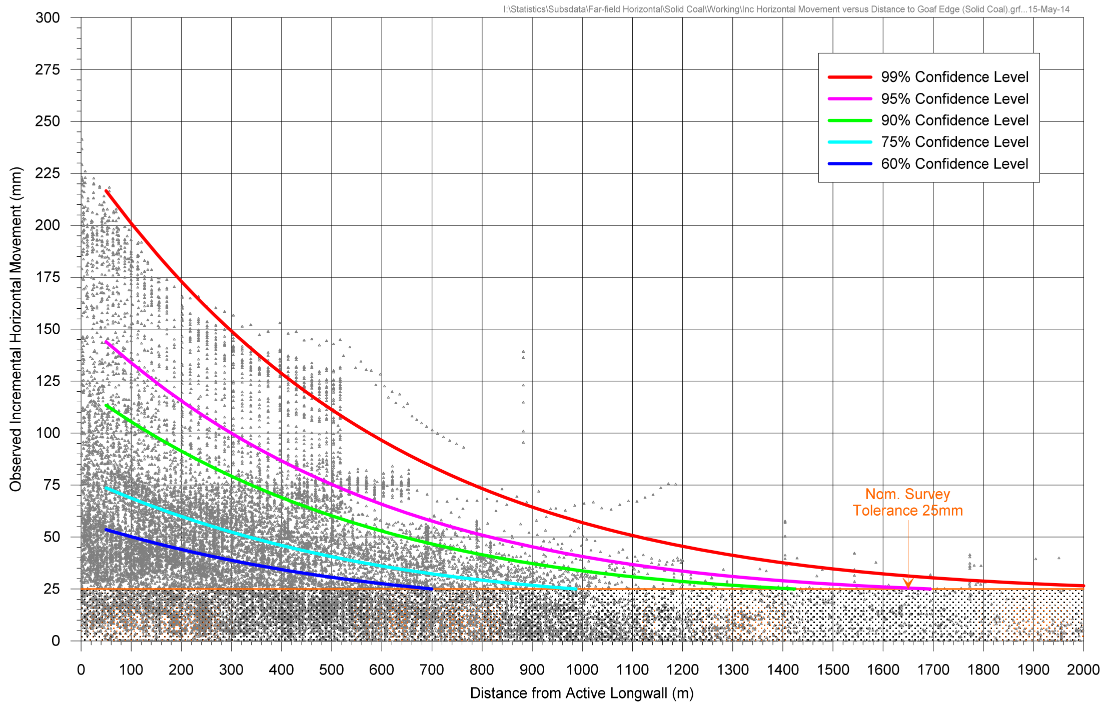

Fig. 2.2 Measured incremental far-field horizontal movements above solid coal only

As successive longwalls within a series of longwalls are mined, the magnitudes of the incremental far-field horizontal movements tend to decrease. The total far-field horizontal movement is not, therefore, the sum of the incremental far-field horizontal movements for the individual longwalls.

The predicted far-field horizontal movements resulting from the extraction of longwalls are very small and could 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 survey tolerance. The impacts of far-field horizontal movements on the natural features and items of surface infrastructure within the vicinity of longwalls are not expected to be significant, except where they occur at large structures which are sensitive to small differential movements.

The Victoria Bridge could experience far-field horizontal movements resulting from the proposed mining. LW W1 is located 1400 metres from the bridge. It can be seen from Fig. 2.2, that incremental far-field horizontal movements up to 40 mm have been recorded at this offset distance. LW W2 is located 1700 metres from the bridge. It can be seen from Fig. 2.2, that incremental far-field horizontal movements up to 25 mm have been recorded at this offset distance.

As shown later in this report, measured incremental movements due to the extraction of LW 32 are at the lower end of the measured range, with measured movements of 29 mm at 630 metres from LW 32 (Thirlmere Way Underbridge), 16 mm at 940 metres from LW 32 (Connellan Crescent Overbridge) and less than 15 mm at Victoria Bridge at 1600 metres from LW32.

The potential for impacts on the Victoria Bridge 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. 2.3 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.

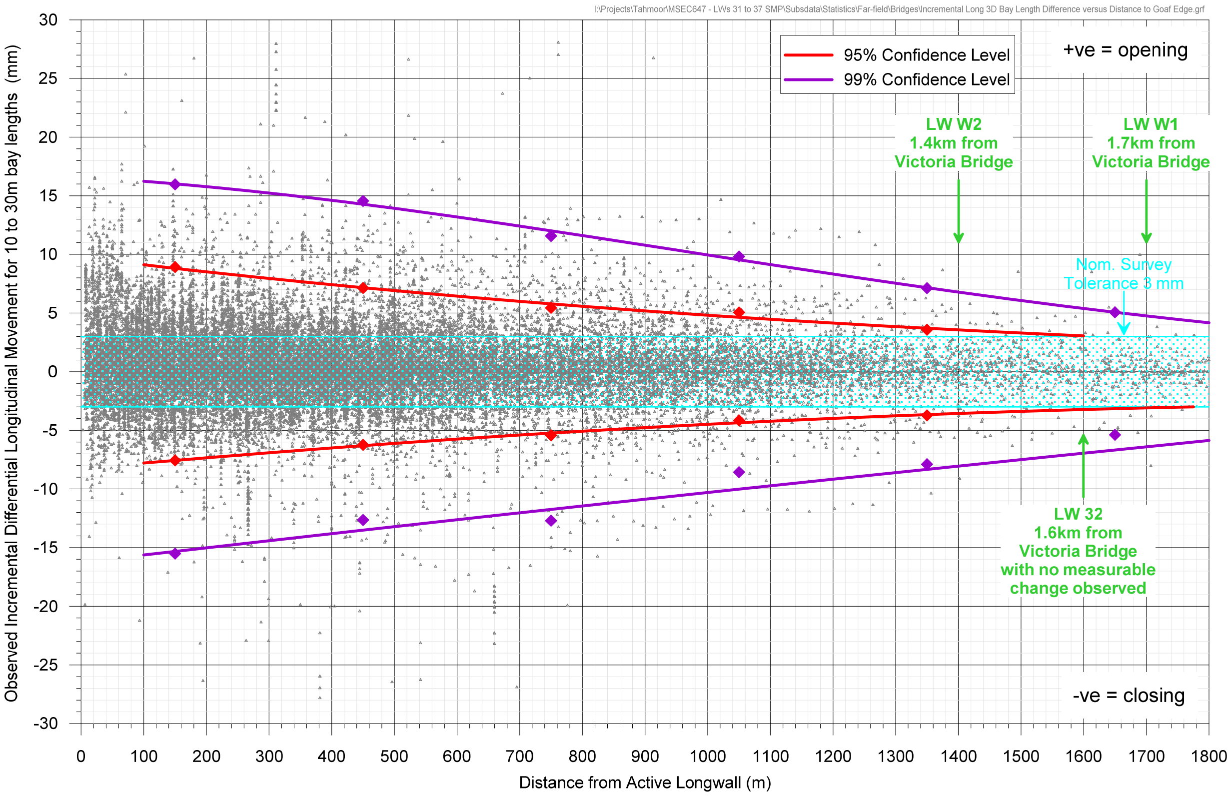

Fig. 2.3 Observed incremental differential longitudinal horizontal movements versus distance from active longwall for marks spaced between 10 and 30 metres

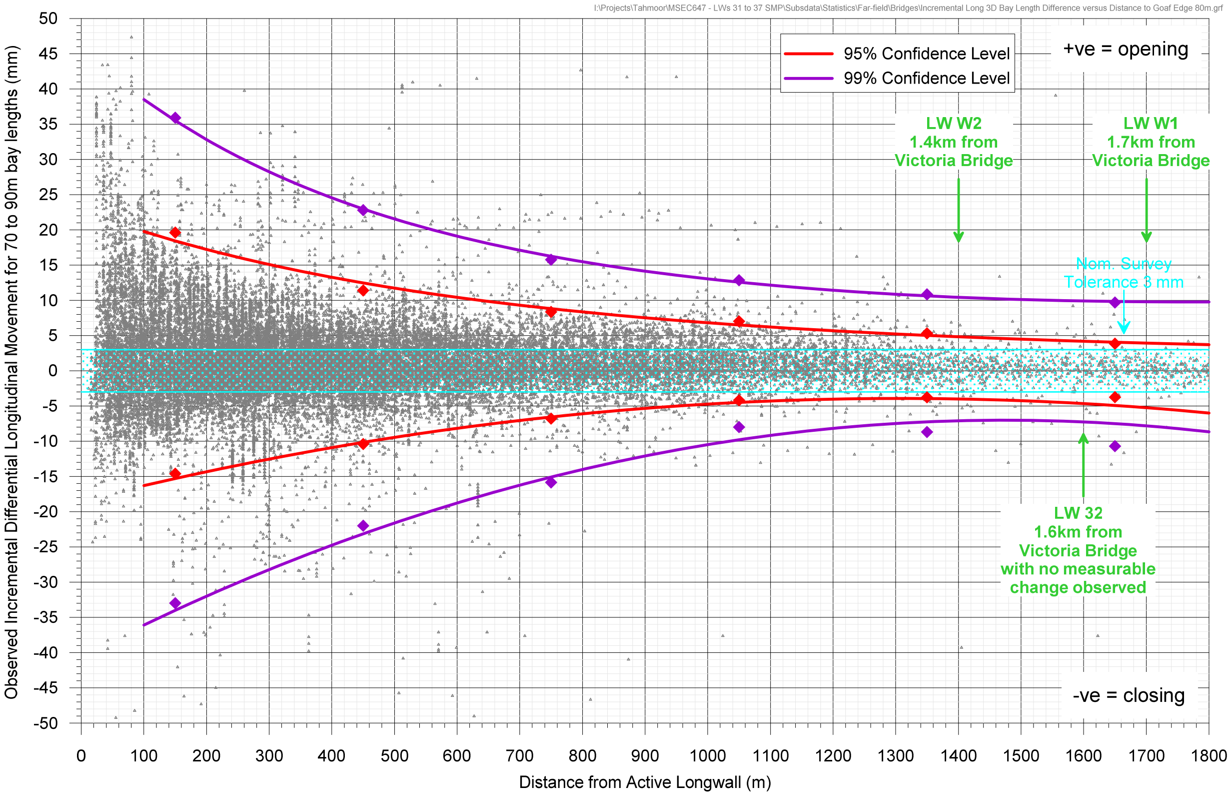

Fig. 2.4 Observed incremental differential longitudinal horizontal movements versus distance from active longwall for marks spaced between 70 and 90 metres

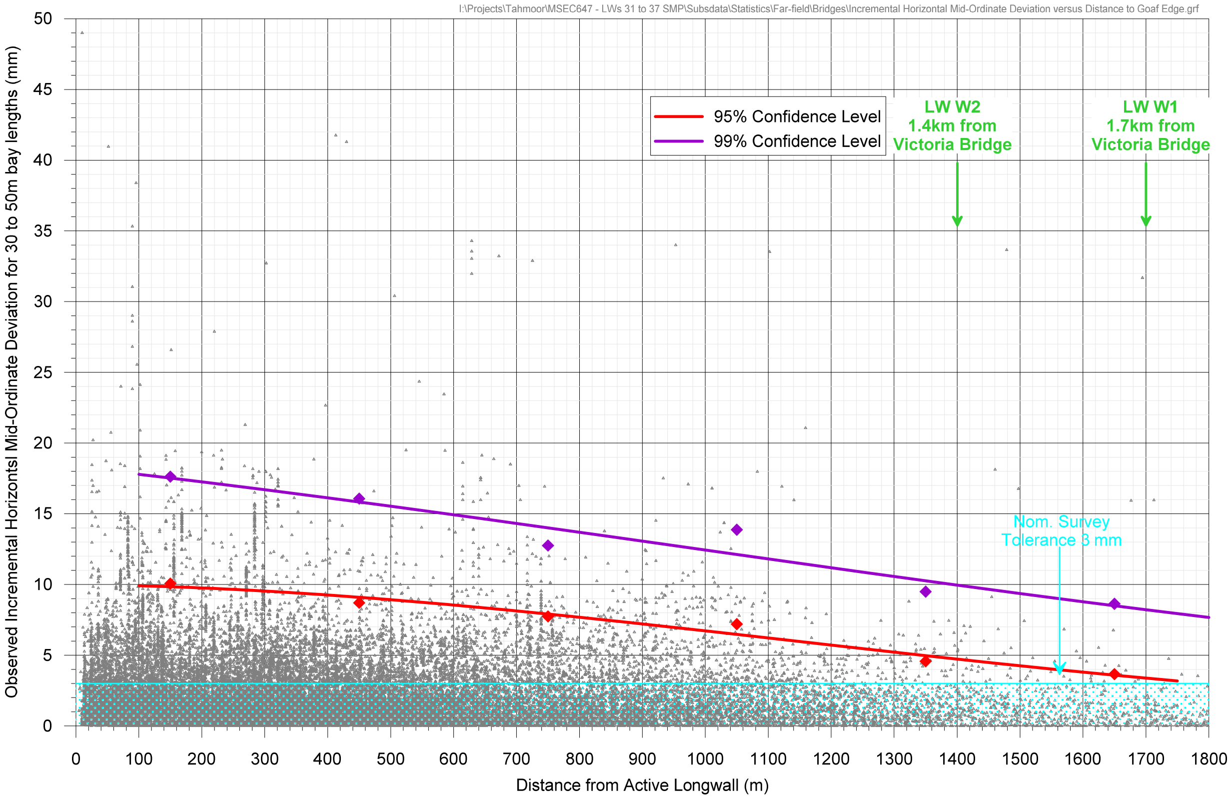

Fig. 2.5 Observed incremental differential horizontal mid-ordinate deviation versus distance from active longwall for marks spaced between 30 and 50 metres

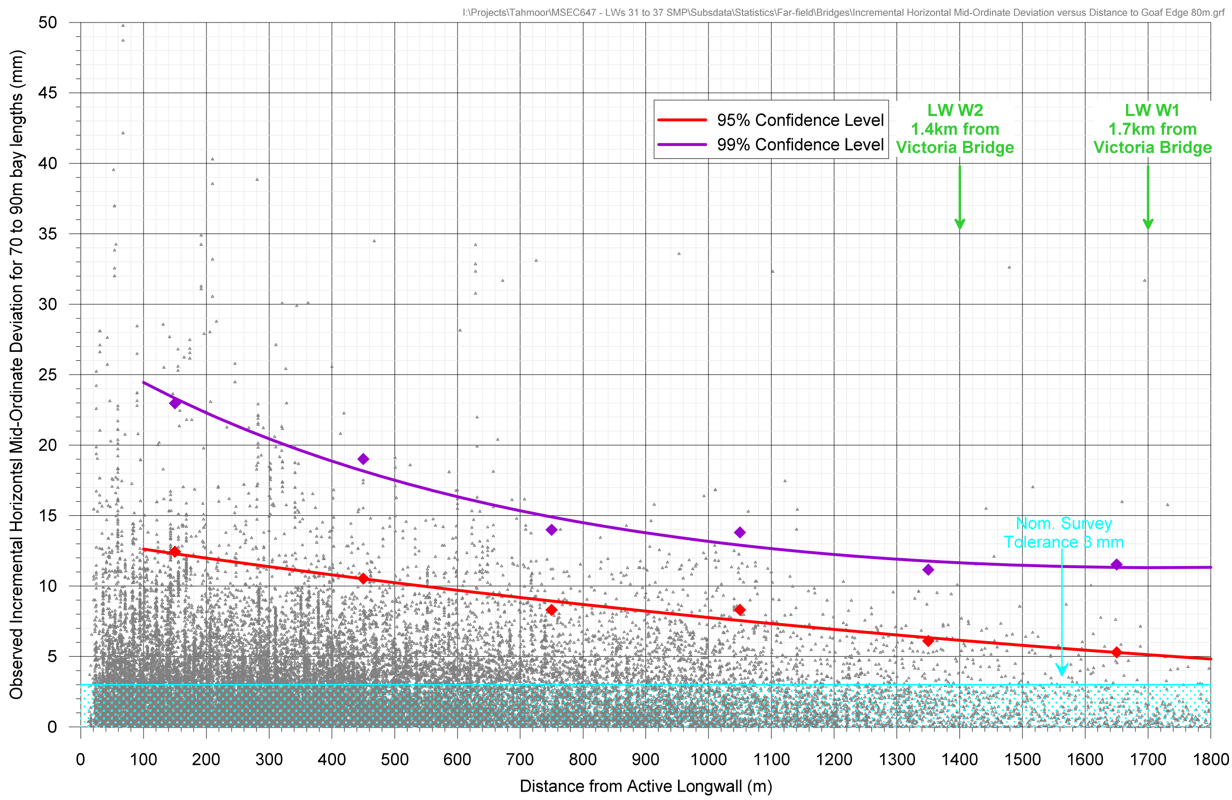

Fig. 2.6 Observed incremental differential horizontal mid-ordinate deviation versus distance from active longwall for marks spaced between 70 and 90 metres

A summary of the probabilities of exceedance for incremental differential horizontal movements for survey bays at 1400 metres and 1700 metres from the nearest goaf edge, based on the fitted General Pareto Distribution function, is provided in Table 2.1.

Table 2.1 Probabilities of exceedance for incremental differential horizontal movements for survey bays located at 1400 and 1700 metres 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 30m		Pegs spaced between 70 and 90m	
		Opening (mm)	Closure (mm)	Opening (mm)	Closure (mm)
1400 m (LW W1)	1 in 20 (0.05)	4	4	5	4
	1 in 100 (0.01)	7	8	10	7
1700 m (LW W2)	1 in 20 (0.05)	3	4	4	5
	1 in 100 (0.01)	5	6	10	8

A summary of the probabilities of exceedance for incremental horizontal mid-ordinate deviations for survey bays at 1400 metres and 1700 metres from the nearest goaf edge, based on the fitted General Pareto Distribution function, is provided in Table 2.2.

Table 2.2 Probabilities of exceedance for incremental horizontal mid-ordinate deviations for survey bays located at 1400 and 1700 metres 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
1400 m (LW W1)	1 in 20 (0.05)	5	6
	1 in 100 (0.01)	10	12
1700 m (LW W2)	1 in 20 (0.05)	3	5
	1 in 100 (0.01)	8	11

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.

As shown later in this Management Plan, measured differential movements due to the extraction of previous LW 32 are at the lower end of the measured range, with no measurable differential movements recorded across Victoria Bridge and the main railway structures.

As discussed in Section 2.3, however, the Victoria Bridge crosses mapped geological structures associated with the Nepean Fault zone to the side of LW W1-W2 and it is possible that differential movements could develop. The Nepean Fault zone is discussed in the next section of this Management Plan.

2.3. Nepean Fault

2.3.1. Identification of geological structures associated with the Nepean Fault

LW W1-W2 will be extracted alongside the Nepean Fault, which is a well-known regional scale geological feature that is an extension of the Lapstone Monocline.

Prior to the commencement of Longwall 32, Tahmoor Coal commissioned an engineering geologist from SCT (2018a) to undertake site inspections and mapping of the Nepean Fault. This work has provided detailed information on the nature and location of Nepean Fault, and second order geological structures associated with the fault.

The geological structures as mapped by SCT (2018a) have been overlaid with surface features within and adjacent to LW W1-W2. These are shown in Drawing No. MSE1045-18-01.

The Nepean Fault is mapped as "*an en-echelon distribution of first order faults with major offsets. Ramps are developed between these en-echelon fault surfaces. Numerous first order north-south faults, each of limited extent, step across the area investigated.*" (SCT, 2018a).

SCT (2018a) further advise that the fault zone is sub-vertical from surface to seam, based on site investigations and geological information gathered by Tahmoor Coal since 2014. The cross-section provided by SCT (2018a) has been reproduced in Fig. 2.7.

In addition to the mapped first order faults, SCT has mapped second order faults, which are described as "*mainly conjugate sets of strike slip faults and splay faults being observed between the en-echelon first order faults*."

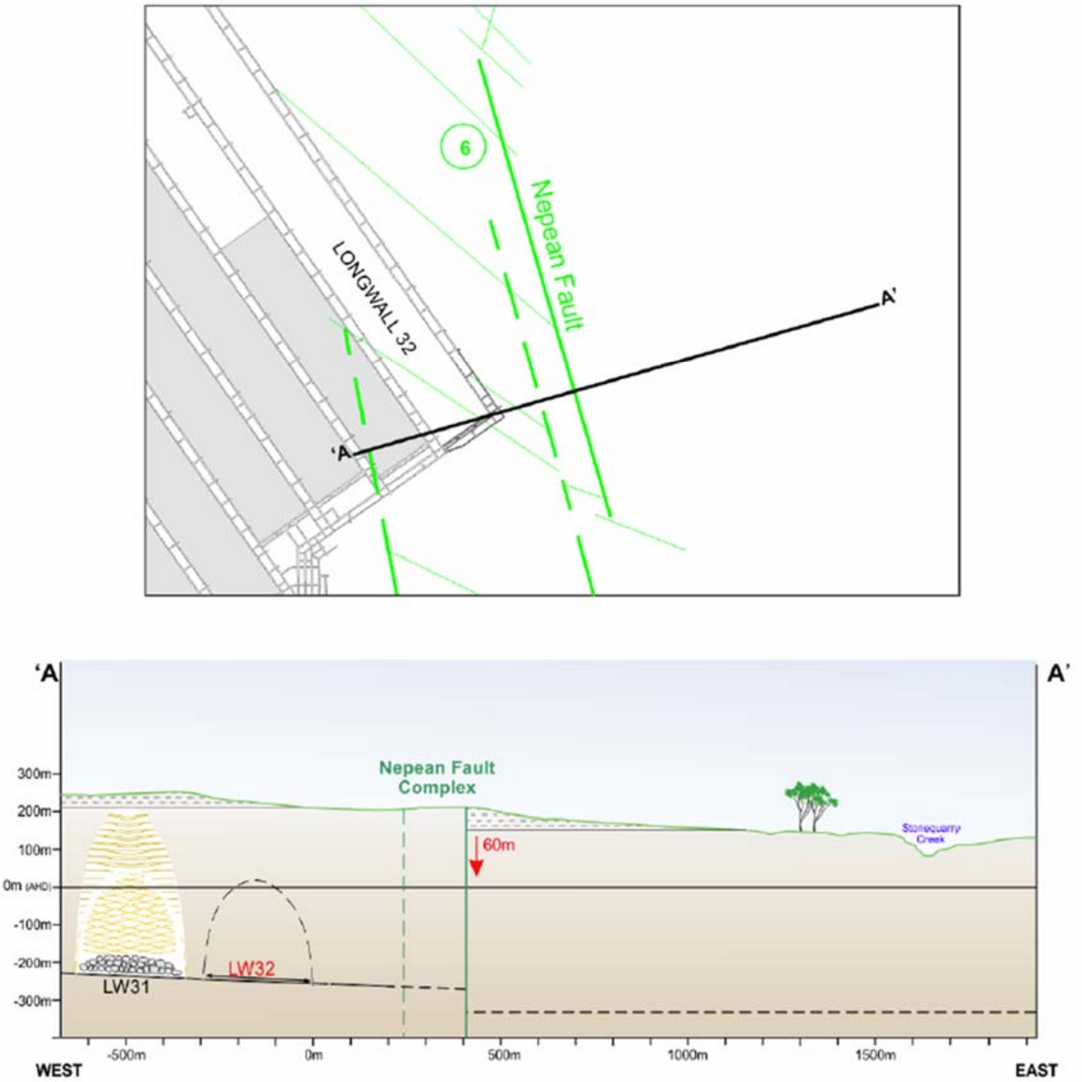

Fig. 2.7 Cross-section of Nepean Fault near Longwall 32 by SCT (2018a)

It can be seen from Drawing No. MSEC1045-18-01 that the built areas within Tahmoor and Picton are located near a mapped first order Nepean Fault zone, which follows the escarpment along the western bank of Stonequarry Creek. The Victoria Bridge crosses over Stonequarry Creek.

When assessing the potential for differential movements to occur across the Nepean Fault near the commencing end of Longwall 32, SCT (2018b) advised that the likelihood was low for a number of reasons, of which some are relevant to LW W1-W2.

- The mapped planes of the first order Nepean Fault are remote from the longwall.
- The Nepean Fault and associated fault structures are mapped as being sub-vertical. The geological structures that are recognised to be associated with unconventional subsidence are typically sub-horizontal i.e. bedding planes.
- Whilst mining induced stress changes are expected to occur on the fault because of longwall mining, they are not of a nature that would allow the fault plan to be destabilised and slip. This is because the stresses acting on the fault plane are not such that the fault is in limiting equilibrium, i.e. on the verge of instability.

Whilst the potential for mining-induced differential movements to develop at Victoria Bridge is considered to be remote, Tahmoor Coal has developed measures to manage potential impacts on the bridge during the mining of LW W1-W2.

2.3.2. Experience of subsidence movements between previously extracted longwalls and Nepean Fault at Tahmoor Coal Longwalls 24A to 31

Tahmoor Coal has surveyed subsidence along many streets during the mining of previous Longwalls 24A to 31. Some of these monitoring lines are located over solid, unmined coal, between the extracted longwalls and the Nepean Fault.

None of the survey lines cross first order faults, though two survey lines (Stilton Dam Line and Remembrance Drive East Line) cross mapped second order conjugate faults.

A study has been completed to ascertain whether irregular subsidence have occurred along the survey lines. The information provided an indication of the likelihood of irregular movements during the extraction of Longwall 32.

The locations of the survey lines relative to the Nepean Fault and associated geological structures is shown in Fig. 2.8.

The monitoring lines examined included.

- 900-Line, due to the extraction of LWs 12 and 13 (not shown in Fig. 2.8),
- LW24 Draw Line, due to the extraction of LWs 24A and 25
- LW25-XS1 Line, due to the extraction of LWs 25 and 26
- Greenacre Drive, due to the extraction of LWs 25 and 26
- Tahmoor Road Line, due to the extraction of LWs 25 to 27
- Myrtle Creek Avenue, due to the extraction of LWs 25 to 28
- Moorland Road, due to the extraction of LWs 25 to 28
- River Road South, due to the extraction of LWs 27 and 28
- Park Avenue, due to the extraction of LWs 25 to 28
- River Rd, due to the extraction of LWs 26 to 28
- Remembrance Drive, due to the extraction of LWs 24A to 30
- Remembrance Drive, due to the extraction of LWs 24A to 27
- Stilton Dam Northern Line, due to the extraction of LWs 29 to 31 (refer Fig. 2.11)
- Remembrance Drive East, due to the extraction of LW31 (refer Fig. 2.12)

The study found no increased subsidence, tilt or strains were measured along the survey lines that were located over unmined, solid coal areas between the extracted longwalls and the Nepean Fault.

A histogram of the maximum observed tensile and compressive strains measured along the selected survey lines for survey bays located over solid coal between previously extracted longwalls at Tahmoor and the Nepean Fault is provided in Fig. 2.9.

It can be seen from Fig. 2.9 that observed ground strains have been, on average, within survey tolerance. A pair of outlying data points are labelled in Fig. 2.9.

Pegs RE77 and RE78 are located within the base of Myrtle Creek, which is the main watercourse in the area. Whilst Myrtle Creek has experienced a small amount of valley closure at this location due to the mining of Longwalls 29 and 30, it can be seen from Fig. 2.10 that measured strains across the base of the Creek have varied greatly over time. The main reason for the variations is that the pegs are spaced only 3 metres apart, meaning that survey tolerance has a much greater influence on the measured result. Most survey bays in the Southern Coalfield are spaced apart by nominally 20 metres. The second reason is that variations have occurred after periods of heavy rainfall, where the pegs have been affected by swelling of the natural soils.

Pegs MD29 to MD30 appear to have been disturbed by construction works. The changes occurred after the completion of Longwall 26. The pegs, however, are located approximately 35 metres from the commencing end of Longwall 27, as shown in Fig. 2.10, but they experienced no changes during the mining of this longwall.

Notwithstanding these outliers, the statistics in Fig. 2.9 demonstrate that observed ground strains have been very small for survey pegs over solid coal, beyond the edges of the extracted longwalls at Tahmoor Coal .

Two survey lines (Stilton Dam Line and Remembrance Drive East Line) cross mapped second order conjugate faults. As shown in Fig. 2.11 and Fig. 2.12, observed subsidence, tilt and strain have been very low at these intersections. A very small bump was, however, observed along the Remembrance Drive East Line approximately 20 metres from the intersection point. Ground strains remained within survey tolerance at this location.

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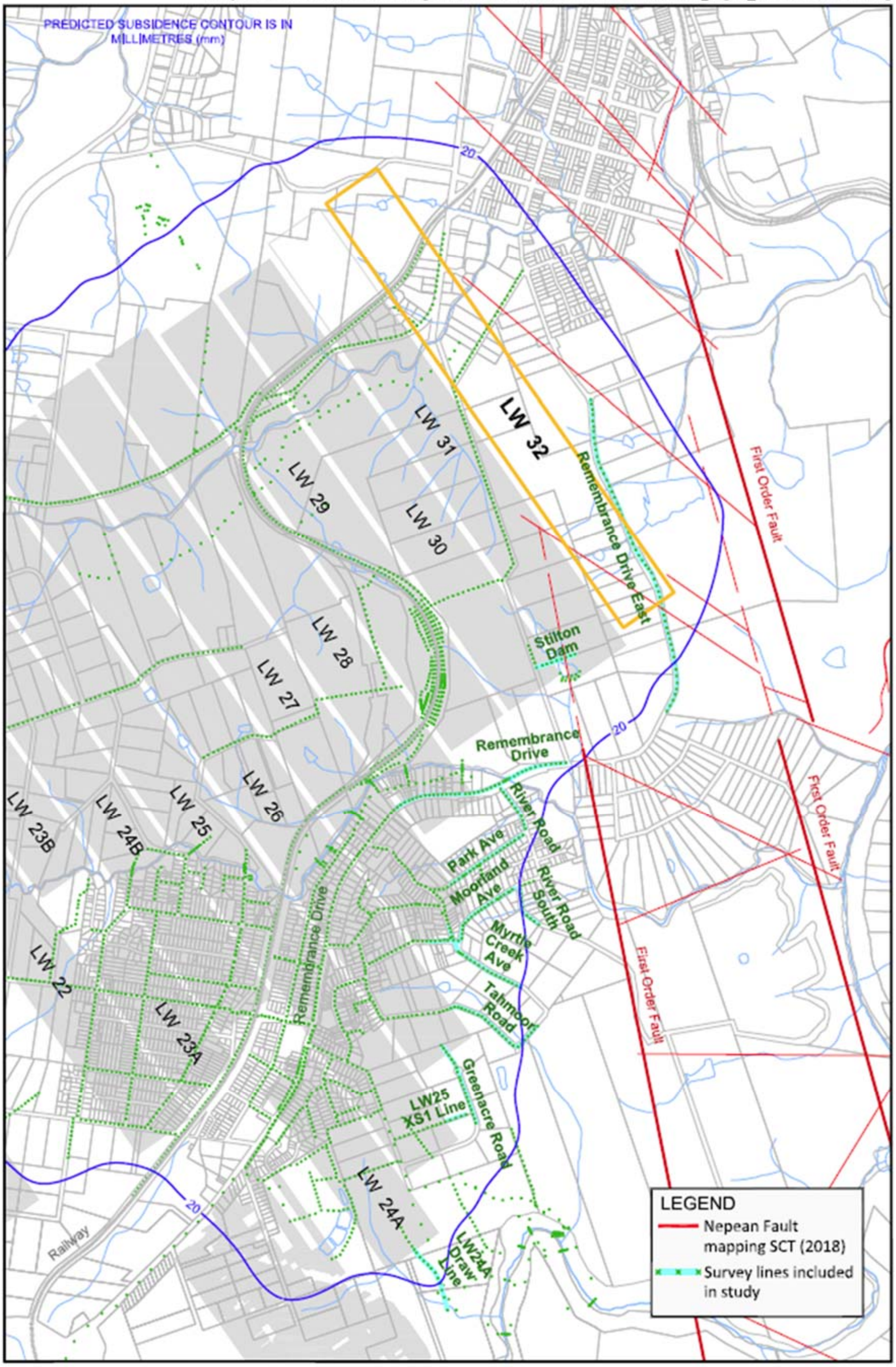


Fig. 2.8 Locations of ground survey lines in relation to the mapped geological structures by SCT (2018a

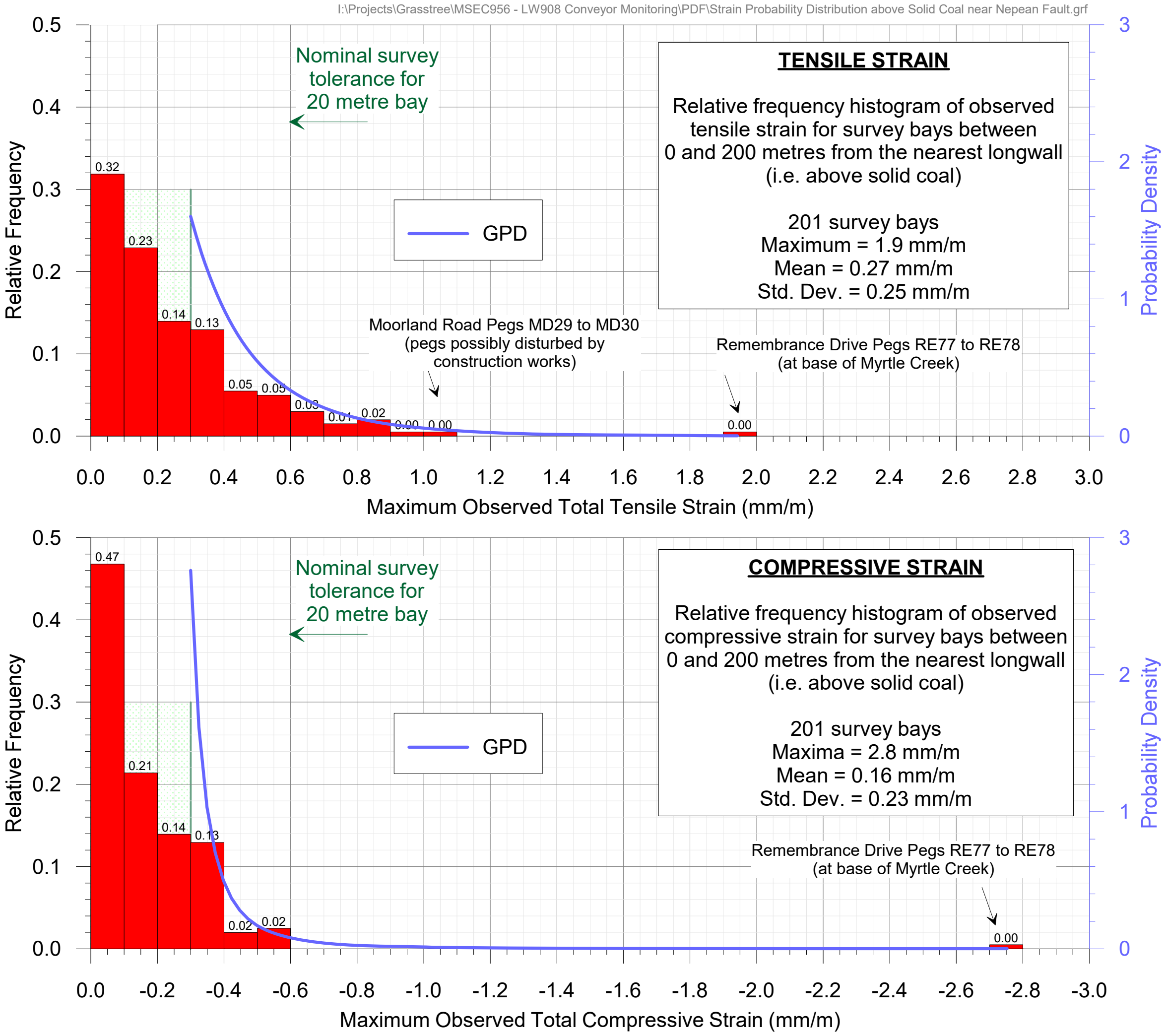


Fig. 2.9 distributions of the measured maximum tensile and compressive strains for bays located over solid coal between previously extracted longwalls at Tahmoor and the Nepean Fault

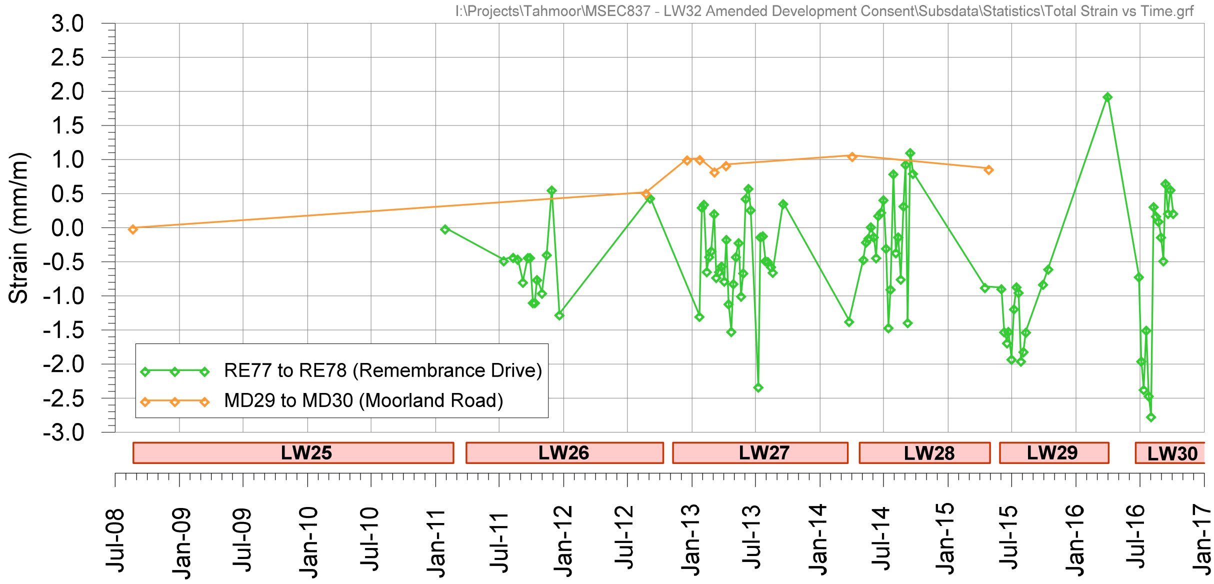


Fig. 2.10 Observed ground strains at selected sites during the mining of Longwalls 25 to 30

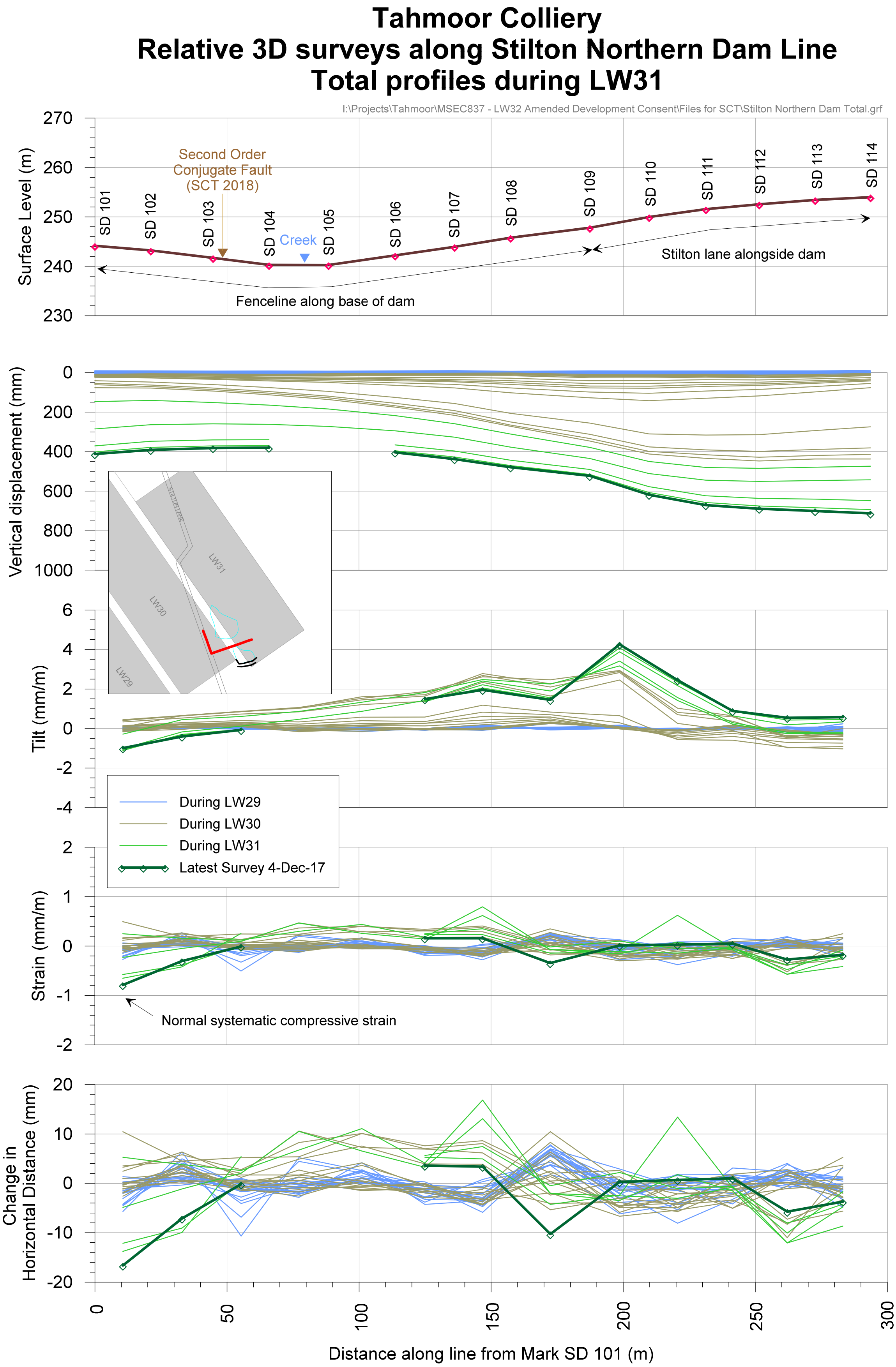


Fig. 2.11 Observed total subsidence profiles along the Stilton Northern Dam Line during the mining of Longwalls 29 to 31

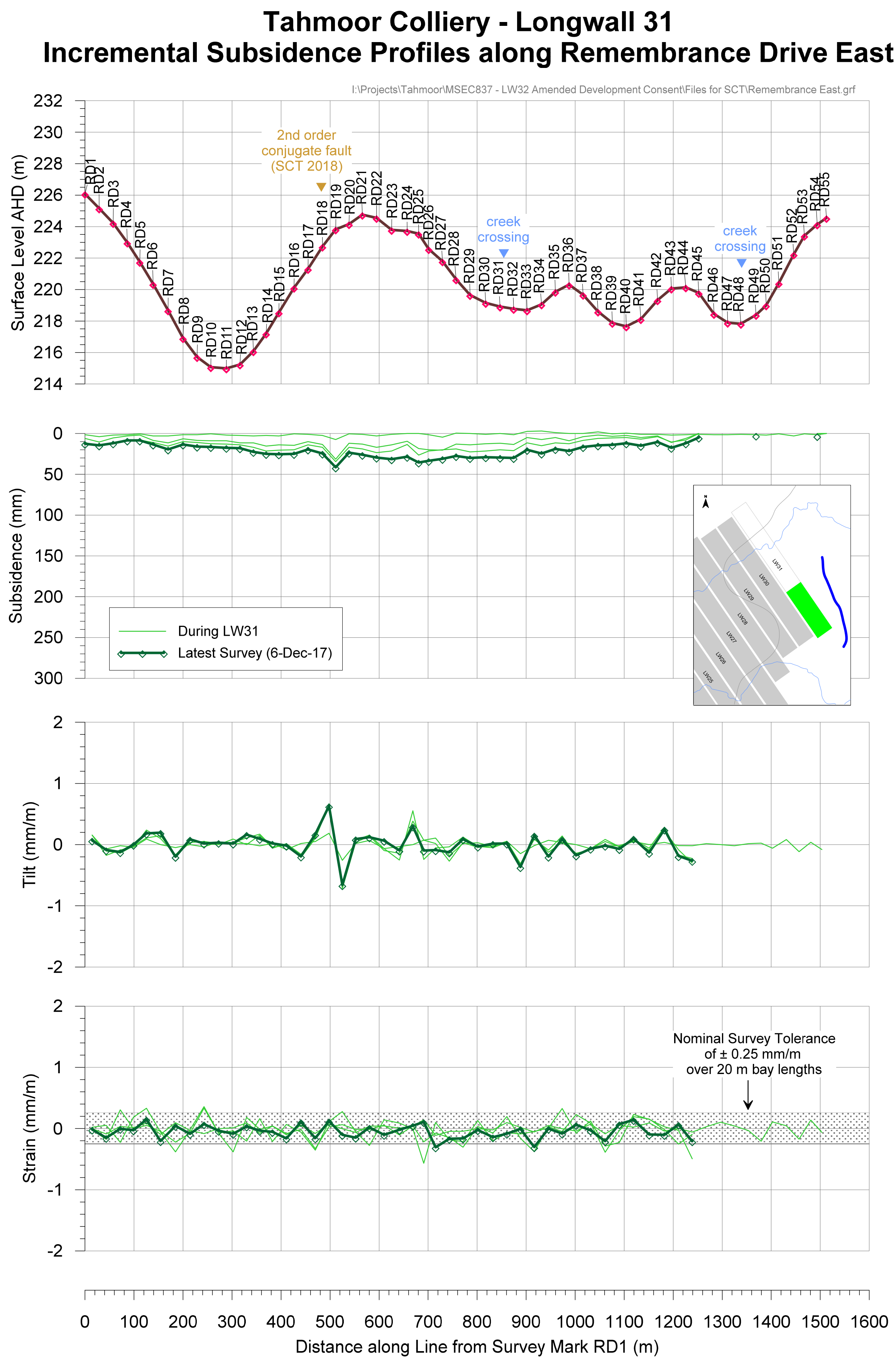


Fig. 2.12 Observed total subsidence profiles along the Remembrance Drive East Line during the mining of Longwall 31

2.3.3. Experience of subsidence movements across mapped geological structures associated with the Nepean Fault at PWRP during the extraction of Longwall 32

Tahmoor Coal has recently extracted Longwall 32 adjacent to another section of the Nepean Fault at Sydney Water's Picton Water Recycling Plant (PWRP). A mapped first order fault and a mapped splayed fault are located approximately 450 metres and 280 metres from Longwall 32, respectively.

Extensive monitoring was conducted at the PWRP to detect early potential adverse differential movements. Monitoring included traditional ground surveys, real time GNSS monitoring and laser distancemeters across the PWRP structures. No adverse impacts were observed at the PWRP during the mining of Longwall 32 and very minor differential horizontal movements, if any, were observed.

A map showing observed absolute horizontal movements at survey pegs located within the PWRP is shown in Fig. 2.13. The results show that the survey pegs have moved to the north, chasing the retreating longwall face. Of interest is that the pegs around the Western Dam have also moved to the east, away from LW 32 and towards Stonequarry Creek and the Nepean Fault.

Notwithstanding the vectors of horizontal movement around the Western Dam, the results show that horizontal movements across the mapped Nepean Fault structures were relatively consistent, with no obvious step change or zone of differential horizontal movement. This is further demonstrated by the results of monitoring along the NF-100 Line and NF-200 Lines, which are shown in Fig. 2.14 and Fig. 2.15, respectively.

The observations at the PWRP found very little evidence, if any, of differential horizontal movements across the mapped geological structures associated with the Nepean Fault during the mining of Longwall 32. It remains possible, however, that the bridge could experience differential far field horizontal movements as they are located at other sections of the Nepean Fault during the mining of LW W1-W2.

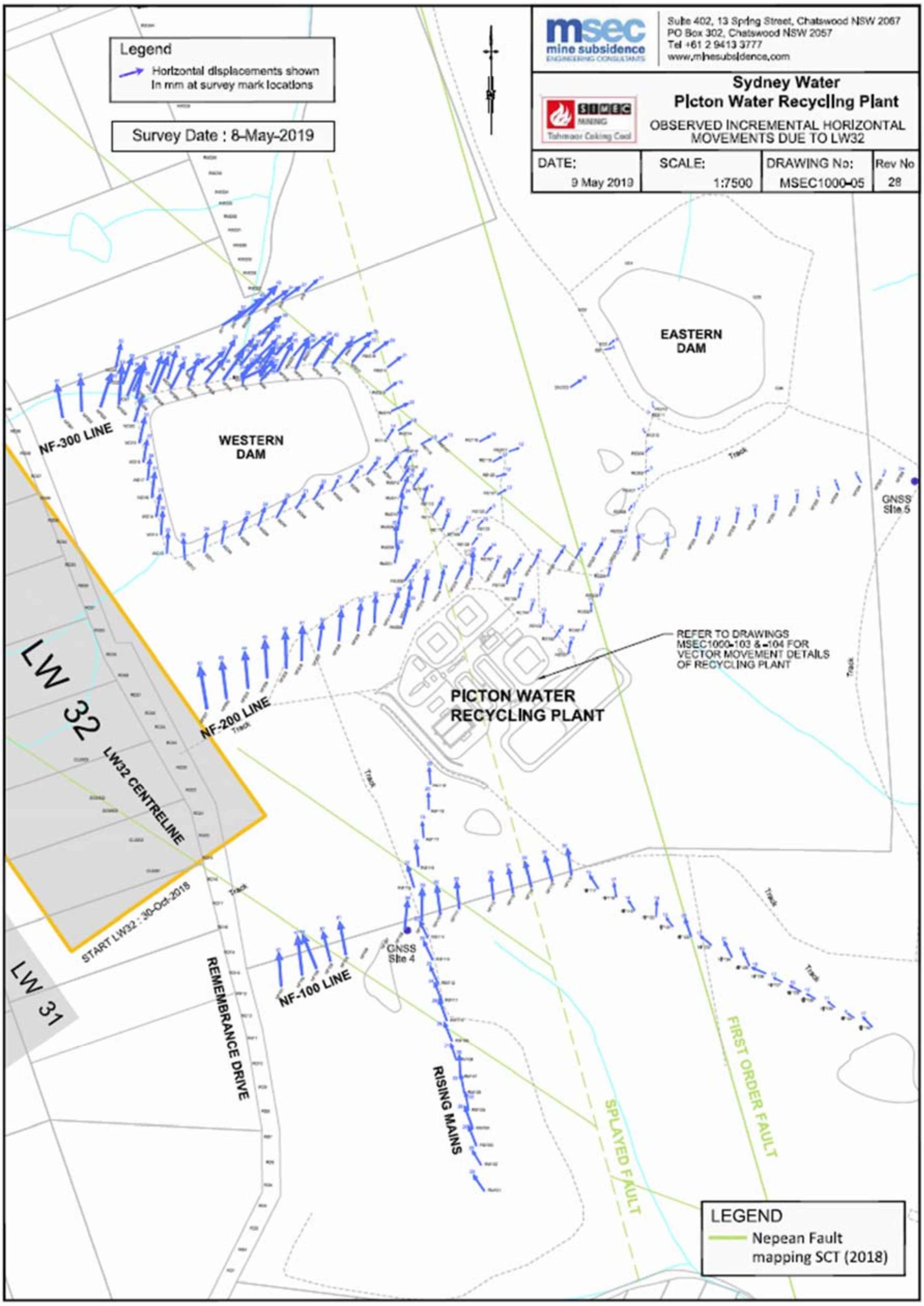


Fig. 2.13 Observed horizontal movements at the PWRP during the mining of LW 32

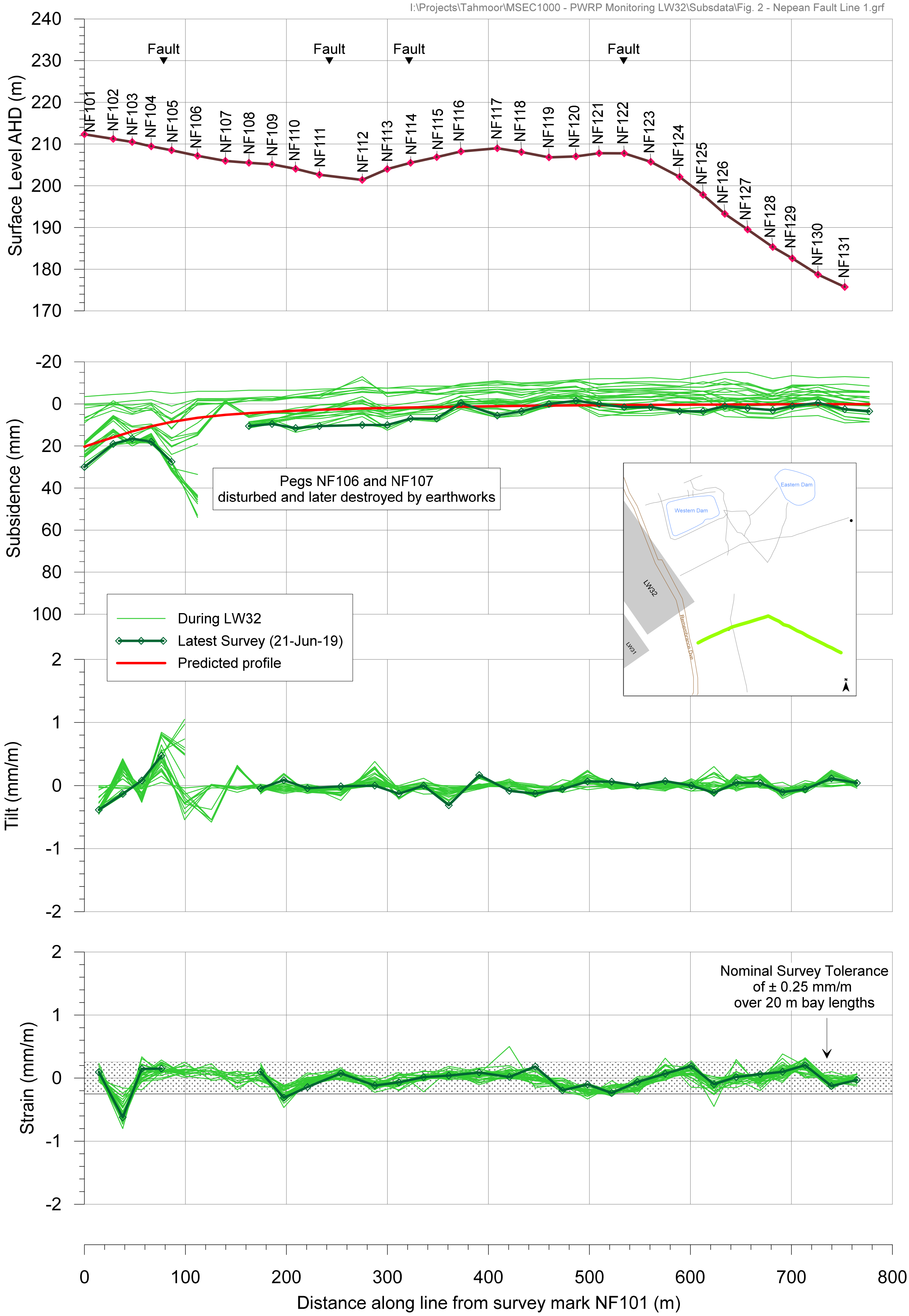


Fig. 2.14 Observed subsidence, tilt and strain along the NF-100 Line during the mining of LW 32

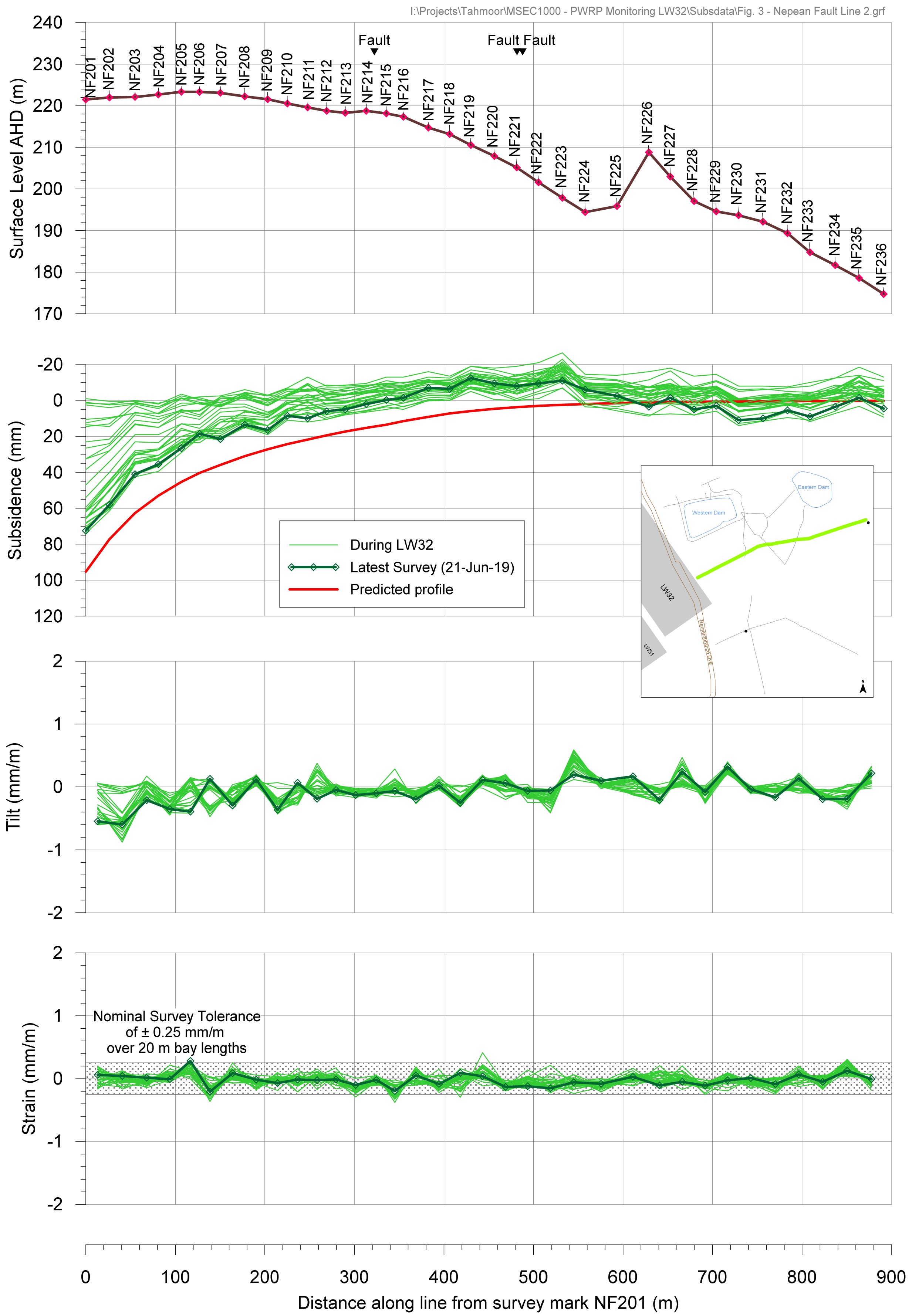


Fig. 2.15 Observed subsidence, tilt and strain along the NF-200 Line during the mining of LW 32

Three GNSS units continuously recorded their position during the mining of Longwall 32 within the PWRP property. Site 4 is located near the commencing end of Longwall 32. Site 5 is located on the other side of the surface expression of the Nepean Fault and Site 6 is located 1.6 km to the east of Longwall 32, away from the Nepean Fault. A map showing observed absolute horizontal movements are shown Fig. 2.16, where it can be seen that all three units have moved to the north and west at magnitudes and directions that are consistent with the ground surveys.

The GNSS units also demonstrated that horizontal movements developed gradually over time, as shown in Fig. 2.17.

Fig. 2.16 Observed horizontal movements at the PWRP GNSS units during the mining of LW 32

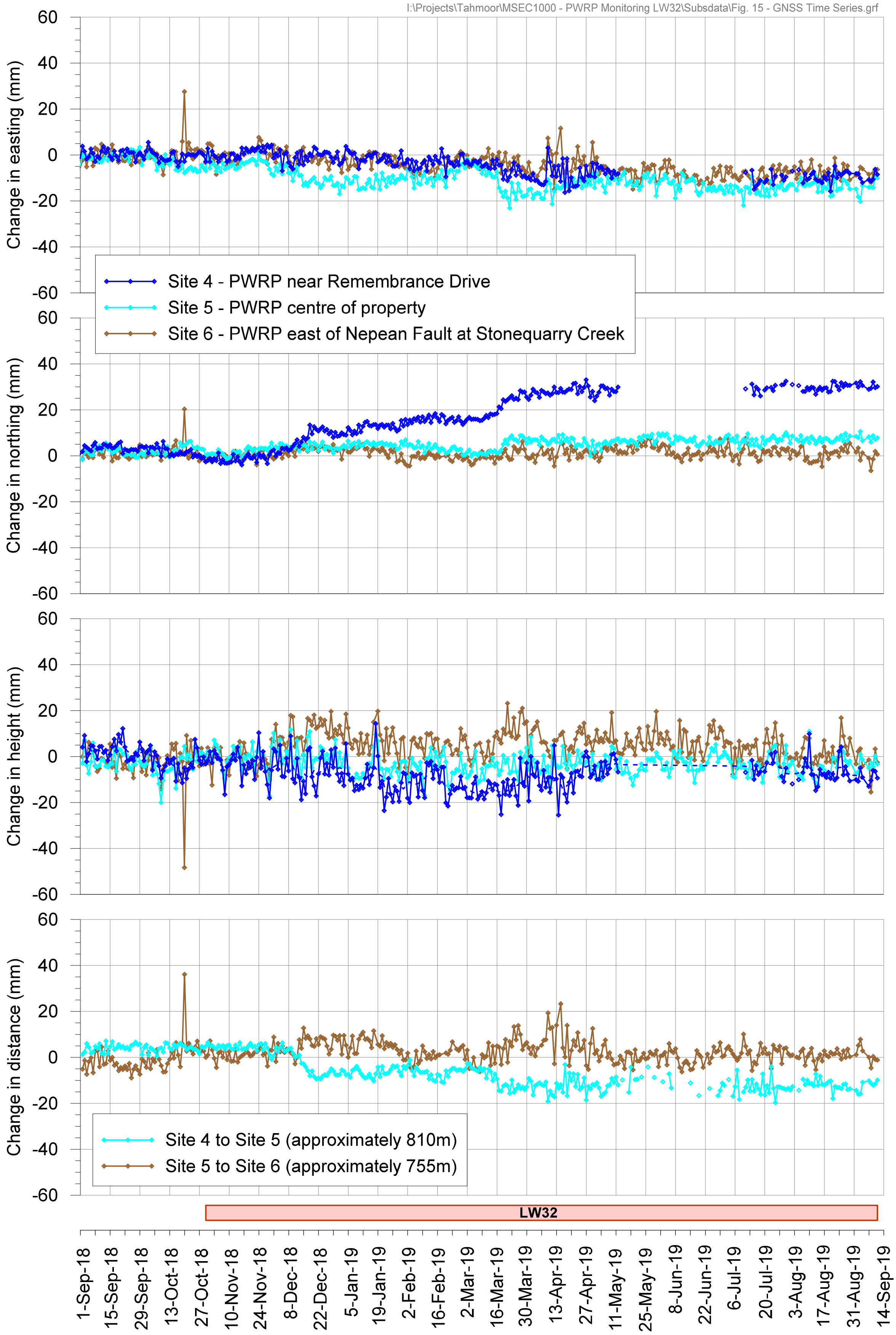


Fig. 2.17 Observed development of horizontal movements with time at the PWRP GNSS Units during the mining of LW 32

2.3.4. Far field monitoring program during the extraction of Longwall 32

Tahmoor Coal has installed a far-field monitoring survey network. These include a far-field horizontal movement monitoring program to investigate the potential for differential horizontal movements across the Nepean Fault.

- Thirlmere Way Rail Underbridge (89.326 km)
- Connellan Crescent Railway Overbridge (89.080 km)
- Argyle Street Rail Underbridge (86.13 km)
- Picton Viaduct (85.42 km)
- Prince Street Overbridge (85.17km)
- Picton Tunnel (87.85 km)
- Victoria Bridge over Stonequarry Creek

The locations of the structures and far field survey marks are shown in Fig. 2.18. Two pegs have been installed at each of the Picton Viaduct and Victoria Road Bridge as these structures span the surface expression of the Nepean Fault over Stonequarry Creek.

Observed total horizontal movements during the mining of LW 31 and LW 32, and observed incremental horizontal movements during the mining of LW 32 are shown in Fig. 2.18 and Fig. 2.19, respectively.

Measurable horizontal movements have occurred at Thirlmere Way Underbridge and Connellan Crescent Overbridge and it is possible that minor horizontal movements have occurred at the Picton Tunnel. These structures are located on the western side of the mapped geological structures associated with the Nepean Fault. No measurable horizontal movements have been observed for the structures near Stonequarry Creek on the eastern side of the mapped geological structures associated with the Nepean Fault.

It is further observed that the predominate direction of horizontal movements at Thirlmere Way Underbridge and Connellan Crescent Overbridge are to the east, towards the Nepean Fault and Stonequarry Creek. The results are consistent with absolute 3D surveys along the rail corridor, as shown in Fig. 2.20. No differential movements have been observed across any of the structures during the mining of Longwalls 31 and 32.

Further details are provided for each railway structure are provided below.

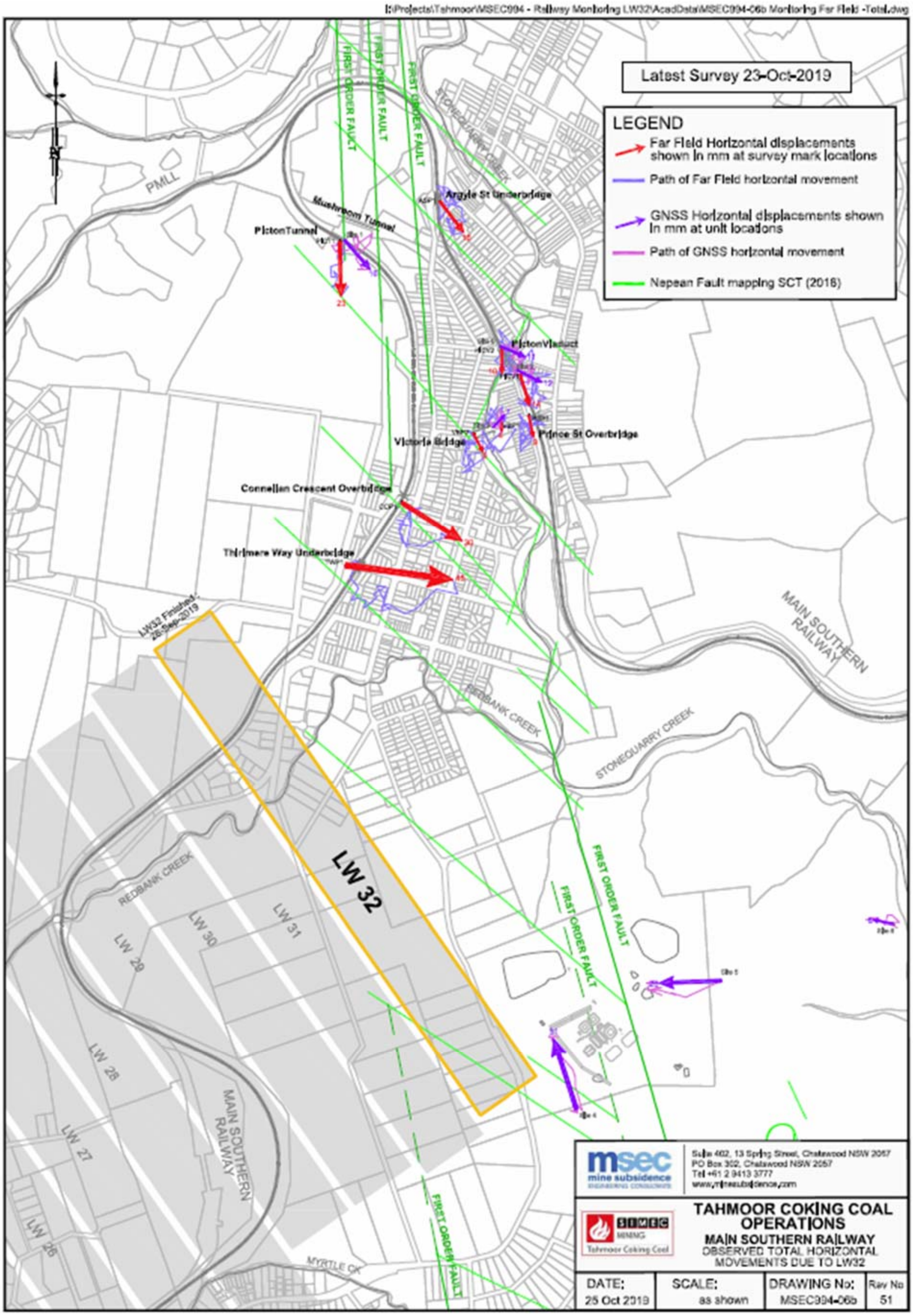


Fig. 2.18 Observed total horizontal movements during the mining of LW 31 and LW 32

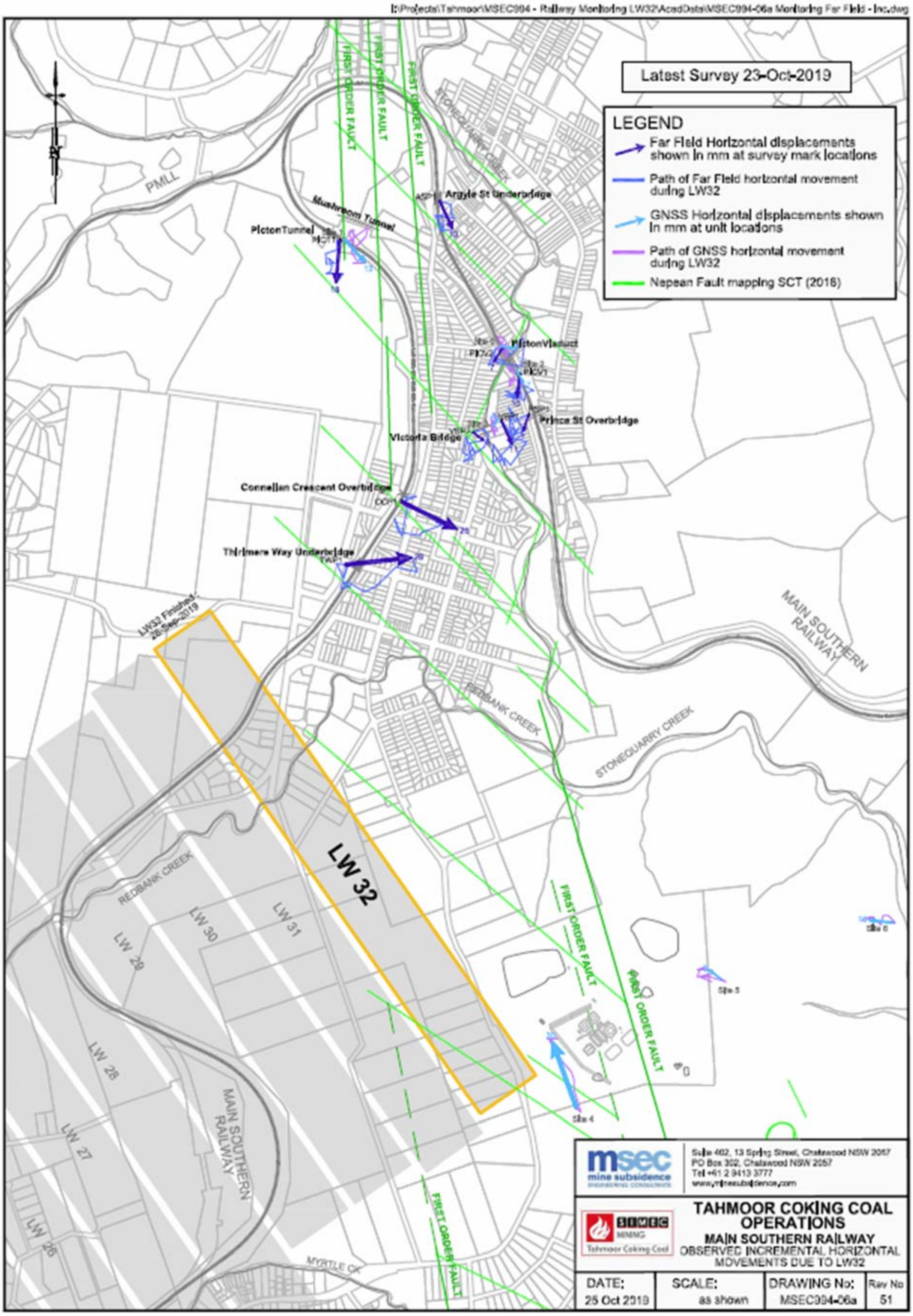


Fig. 2.19 Observed incremental horizontal movements during the mining of LW 32

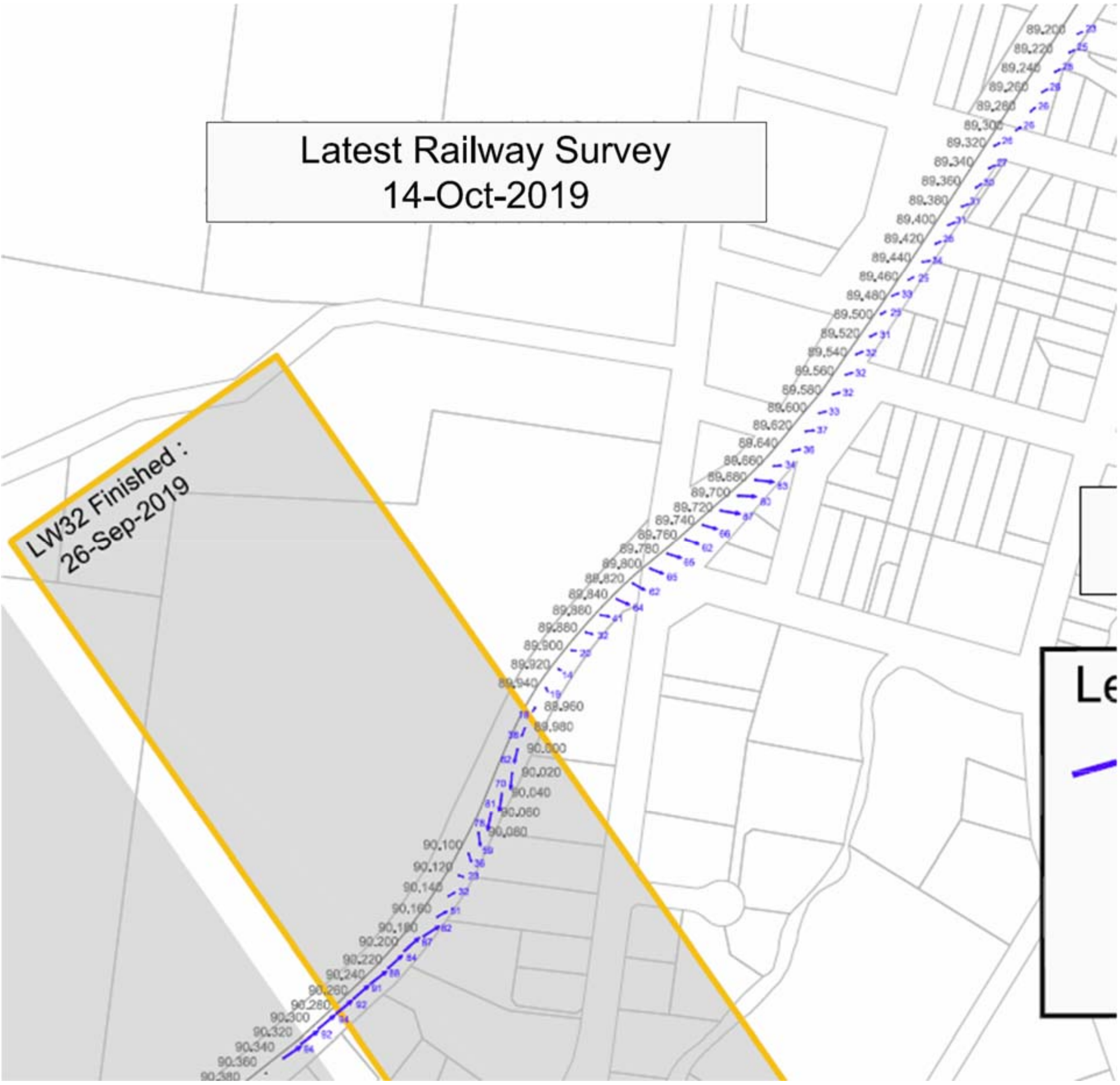


Fig. 2.20 Observed incremental horizontal movements along Railway during the mining of LW 32

2.3.5. Thirlmere Way Rail Underbridge at 89.326 km

The Thirlmere Way Rail Underbridge (89.326 km) is located 630 metres from Longwall 32. The bridge is a single span brick arch structure with brick spandrel walls, as shown in Fig. 2.21.

Fig. 2.21 Thirlmere Way Rail Underbridge at 89.326 km

Absolute 3D surveys have been conducted on a monthly basis at the Thirlmere Way Underbridge since December 2017 when the length of extraction of LW31 was approximately 900 metres. The observed changes in easting, northing and height are shown in Fig. 2.22, where it can be seen that the Underbridge has steadily moved to the east, with an increase during the last 3 months as LW32 approached the Underbridge. Minor changes were observed in the last month after mining had ceased.

Four prisms were installed at the base of the arch on 23 July 2018. The prisms were re-surveyed on 28 August 2019 and 23 October 2019, where it was found that measured changes in distance between the prisms were 2 mm or less, which is within survey tolerance. The results are consistent with weekly ground surveys that have been conducted along the rail corridor past the Underbridge, where measured tilts and ground strains in the vicinity of the Underbridge are also within survey tolerance.

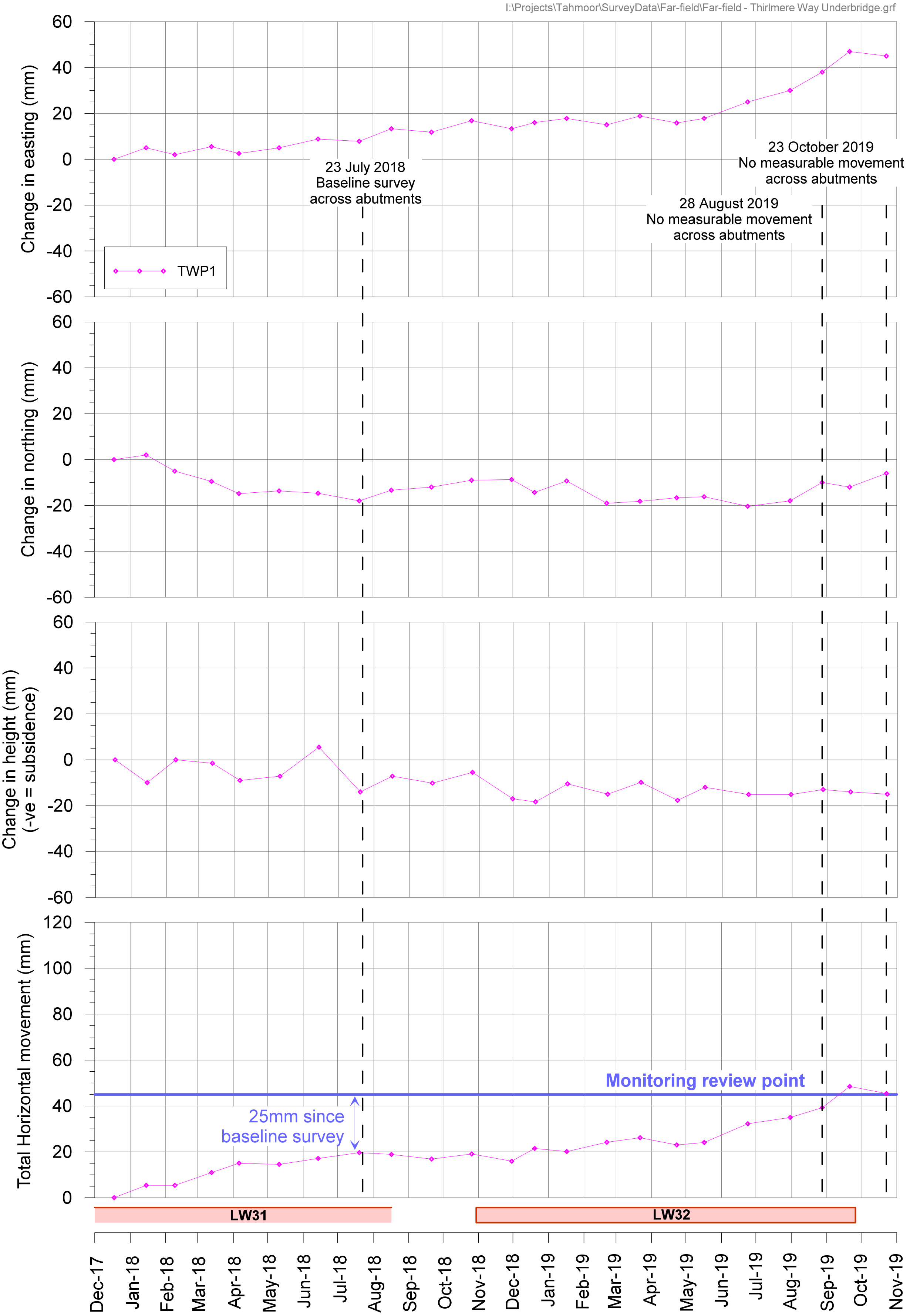


Fig. 2.22 Far-field movements at Thirlmere Way Rail Underbridge

2.3.6. Connellan Crescent Railway Overbridge at 89.080 km

The Connellan Crescent Railway Overbridge (89.080 km) is located 940 metres from Longwall 32. The bridge is constructed with masonry abutments and the deck is supported by a reinforced concrete arch, as shown in Fig. 2.23.

Fig. 2.23 Connellan Crescent Railway Overbridge at 89.080 km

Absolute 3D surveys have been conducted on a monthly basis at the Connellan Crescent Overbridge since December 2017 when the length of extraction of LW31 was approximately 900 metres. The observed changes in easting, northing and height are shown in Fig. 2.23, where it can be seen that the Overbridge has moved to the east during the last 3 months as LW32 approached the Overbridge. The Overbridge may also have moved slightly to the south. A minor continued easterly movement was measured in the last month after mining had ceased.

Four prisms were installed at the base of the concrete arch on 23 July 2018. The prisms were re-surveyed on 28 August 2019 and 23 October 2019, where it was found that measured changes in distance between the prisms were 1 mm or less, which is within survey tolerance.

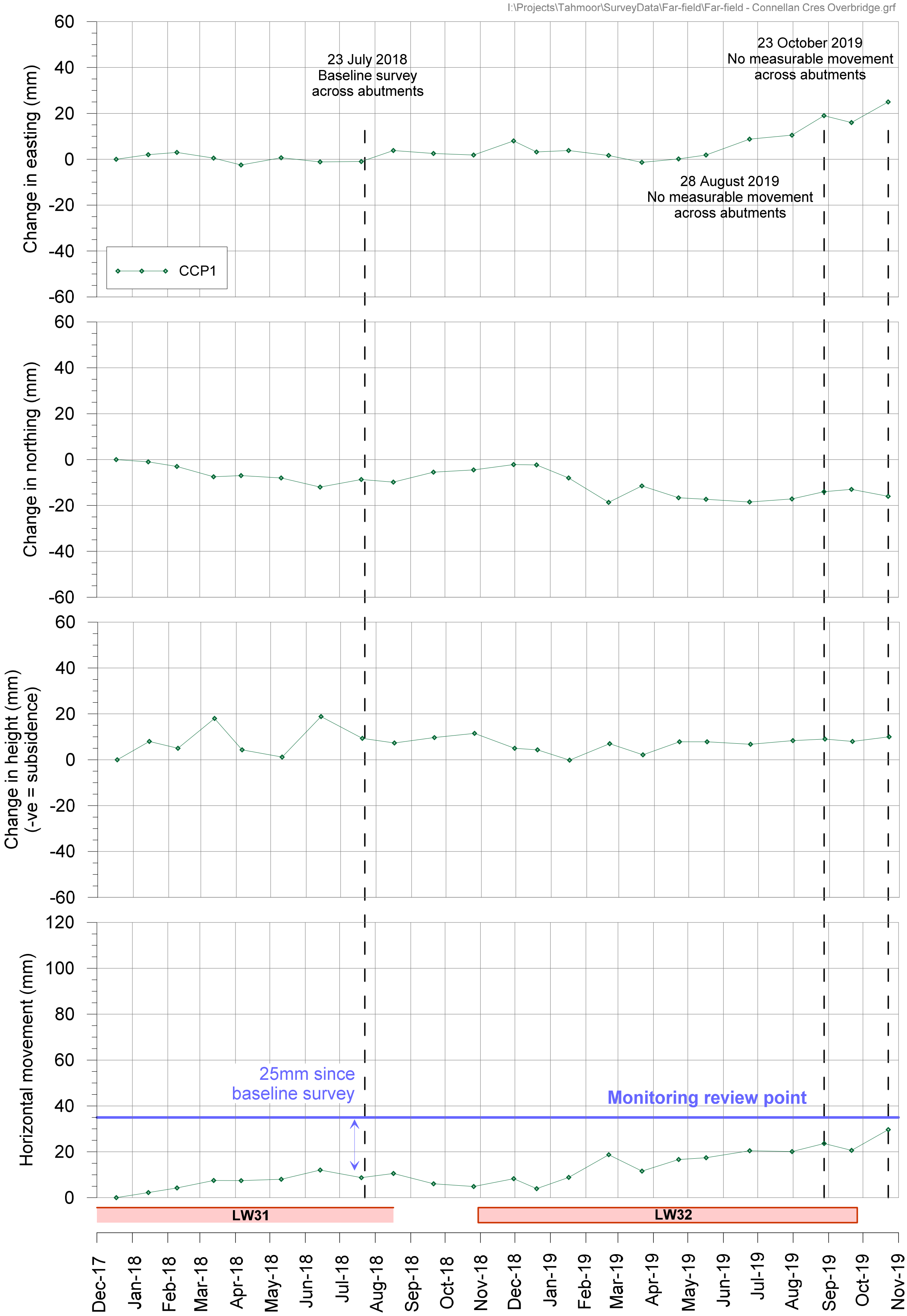


Fig. 2.24 Far-field movements at Connellan Crescent Rail Overbridge

2.3.7. Picton Tunnel

The Picton Tunnel (87.850 km) is located 1.6 km from Longwall 32. The Tunnel is constructed with masonry arches as shown in Fig. 2.25.

Fig. 2.25 Picton Railway Tunnel – Southern Portal

Absolute 3D surveys have been conducted on a monthly basis at a ground mark that is located above the Picton Tunnel since December 2017 when the length of extraction of LW31 was approximately 900 metres. A GNSS unit, which continuously measures its absolute horizontal and vertical position in real time, was also installed adjacent to the ground survey mark.

The observed changes in easting, northing and height of the ground mark and the GNSS unit are shown in Fig. 2.26. It can be seen that a very slight but ongoing trend of southward movement has been measured by both ground survey methods at the Tunnel during the extraction of Longwall 32.

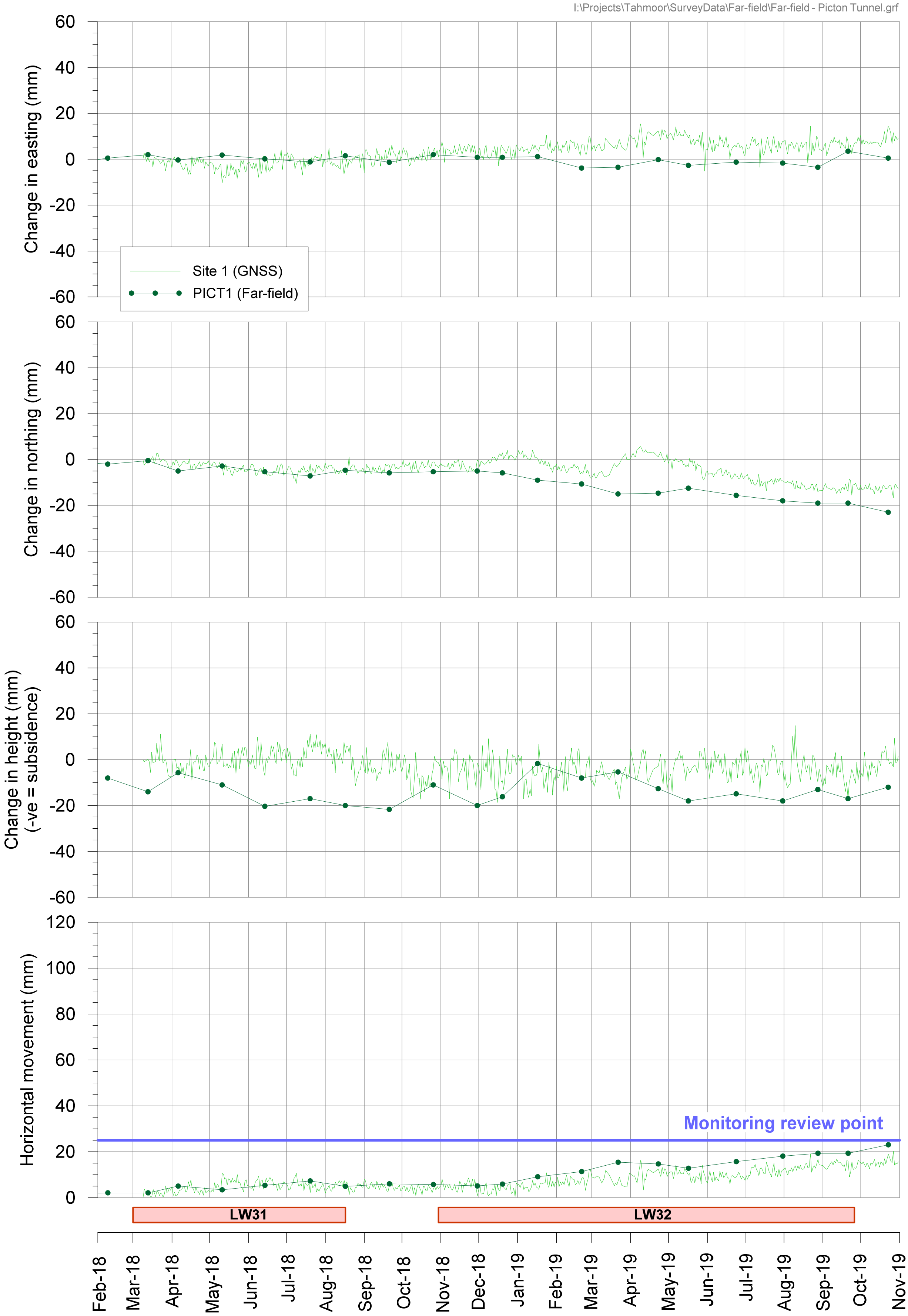


Fig. 2.26 Far-field movements at Picton Railway Tunnel

2.3.8. Argyle Street Underbridge

The Argyle Street Rail Underbridge (86.160 km) is located 2 kilometres north-east of Longwall 32. The bridge is a single span masonry brick arch structure with brick spandrel walls, as shown in Fig. 2.27.

Fig. 2.27 Argyle Street Rail Underbridge at 86.160 km

Absolute 3D surveys have been conducted on a monthly basis at the Argyle Street Underbridge since December 2017 when the length of extraction of LW31 was approximately 900 metres. The observed changes in easting, northing and height are shown in Fig. 2.28, where it can be seen that measured changes are within survey tolerance.

Four prisms were installed at the base of the arch on 23 July 2018, as shown in Fig. 2.28. The prisms were re-surveyed on 28 August 2019, where it was found that measured changes in distance between the prisms were 2 mm or less, which is within survey tolerance.

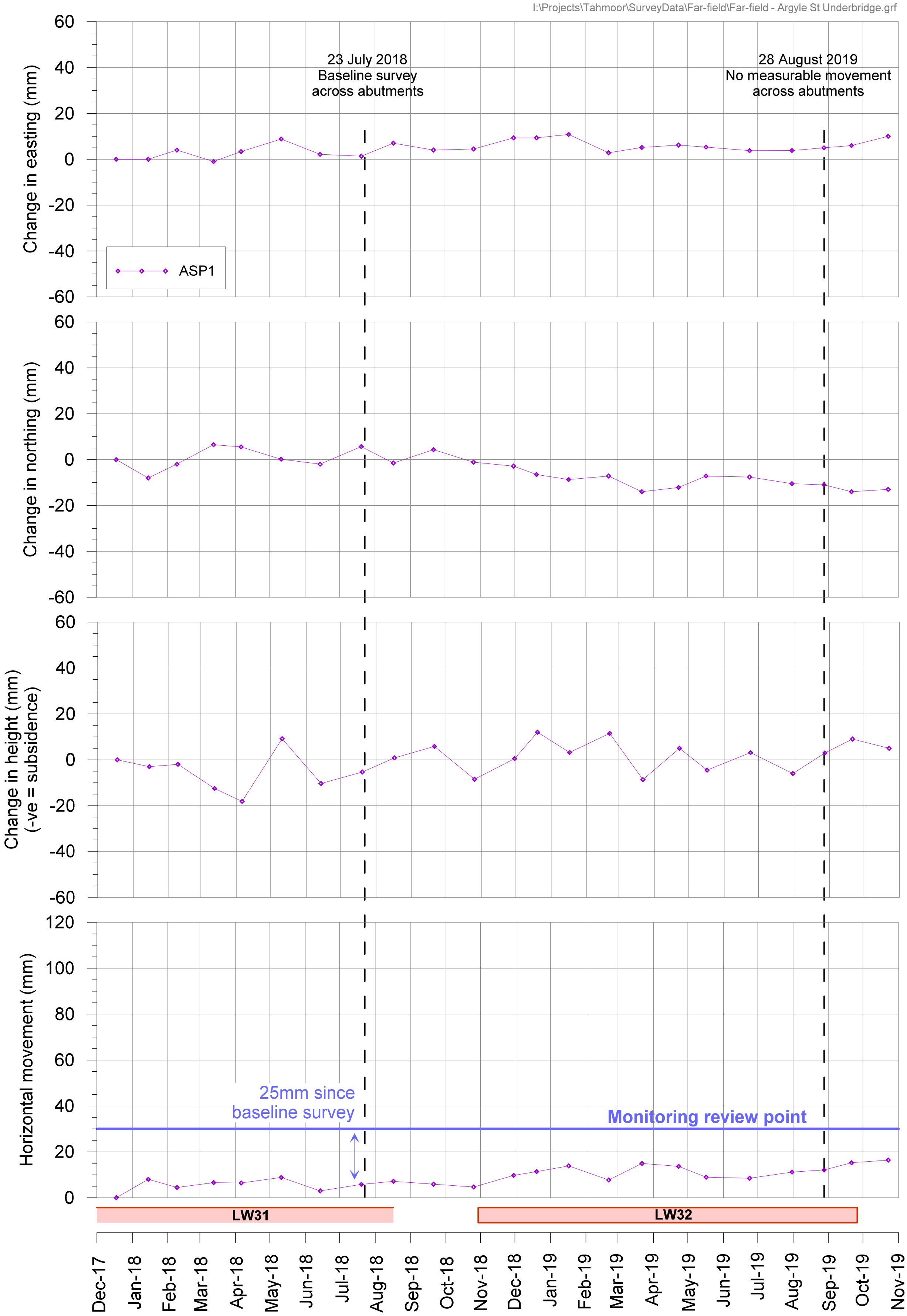


Fig. 2.28 Far-field movements at Argyle Street Rail Underbridge

2.3.9. Picton Viaduct at 85.420 km

The Picton Viaduct (85.42 km) is located 1.6 km north-east of Longwall 32. The viaduct is a five-span stone arch structure across Stonequarry Creek, as shown in Fig. 2.29.

Fig. 2.29 Picton Viaduct at 85.42 km over Stonequarry Creek

The Picton Viaduct was built in 1867 and is the oldest stone arch railway bridge in NSW. It is an item of heritage significance.

The Picton Viaduct crosses Stonequarry Creek, which follows the alignment of mapped geological structures associated with the Nepean Fault.

Absolute 3D surveys have been conducted at both ends of the Picton Viaduct on a monthly basis since December 2017 when the length of extraction of LW31 was approximately 900 metres. Two GNSS units, one at each of the Viaduct continuously measure their absolute horizontal and vertical position in real time. The units are located near the ground survey marks.

The observed changes in easting, northing and height of the ground marks and the GNSS units are shown in Fig. 2.31. It can be seen that measured changes in eastings and northings are within survey tolerance.

A gradual fall in height was measured by the GNSS unit at the northern end of the Viaduct during the warmer months, which was inconsistent with the survey results at the ground mark. As a precautionary measure, the structure surveys were re-measured and the results confirmed that the Viaduct had not experienced any measurable differential vertical movements.

A site inspection of the GNSS unit found that it had been fixed to the post via U-bolts and the U-bolts had gradually slipped down the post due to vibration from passing trains, as evidenced by rust marks on the post approximately 40 mm above the U-bolt, as shown in Fig. 2.30. Screws have since been installed and no further has been observed.

Fig. 2.30 Observed slippage of U-bolt down the post at northern GNSS unit

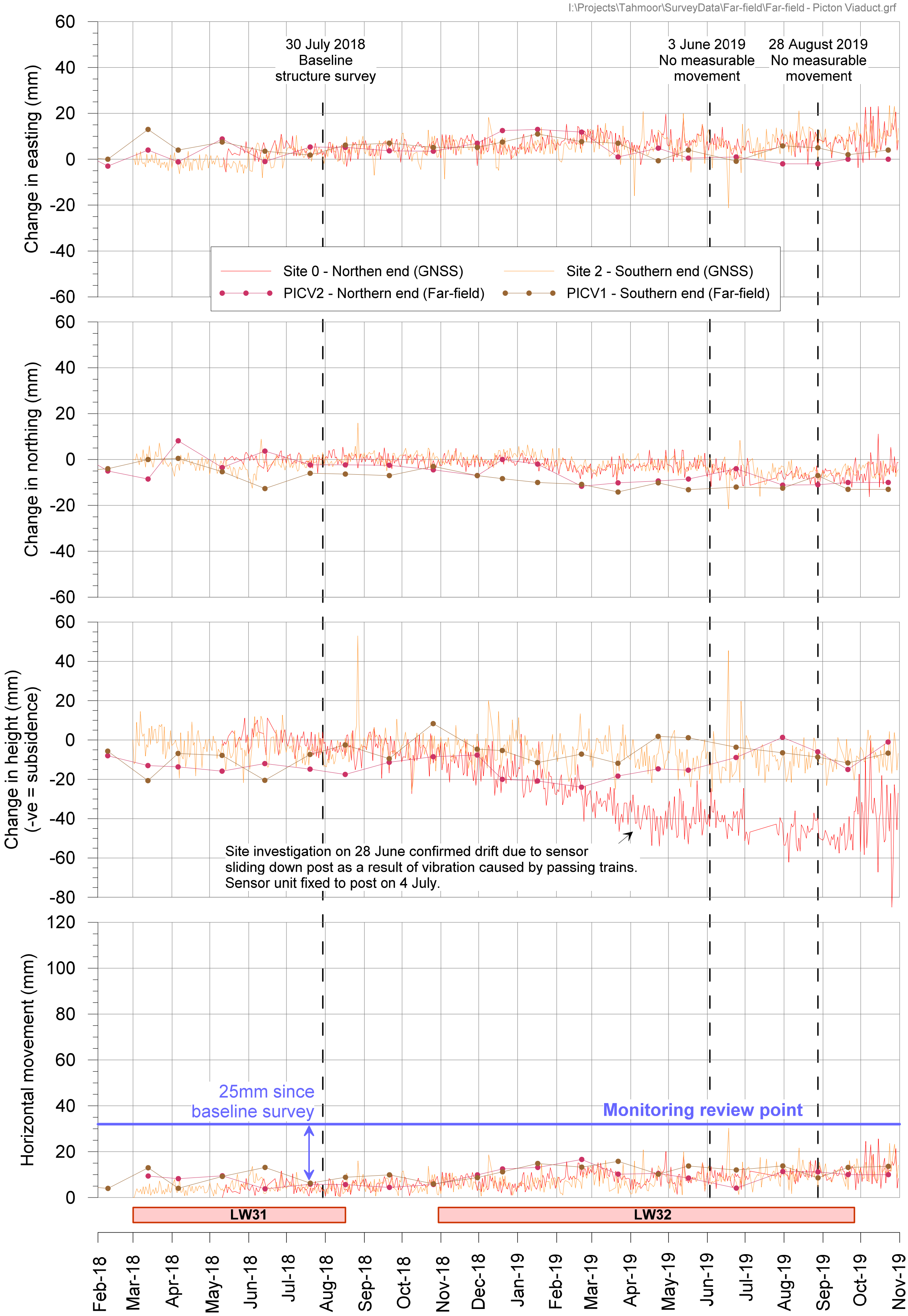


Fig. 2.31 Far-field movements at Picton Viaduct

Twelve prisms were installed and surveyed on 30 July 2018 at each end of the Viaduct to the base of the intermediate arches, on both sides. The marks were measured in local 3D coordinates. The prisms were surveyed on 3 June and 28 August 2019. Measured changes were within survey tolerance, as shown in Fig. 2.32.

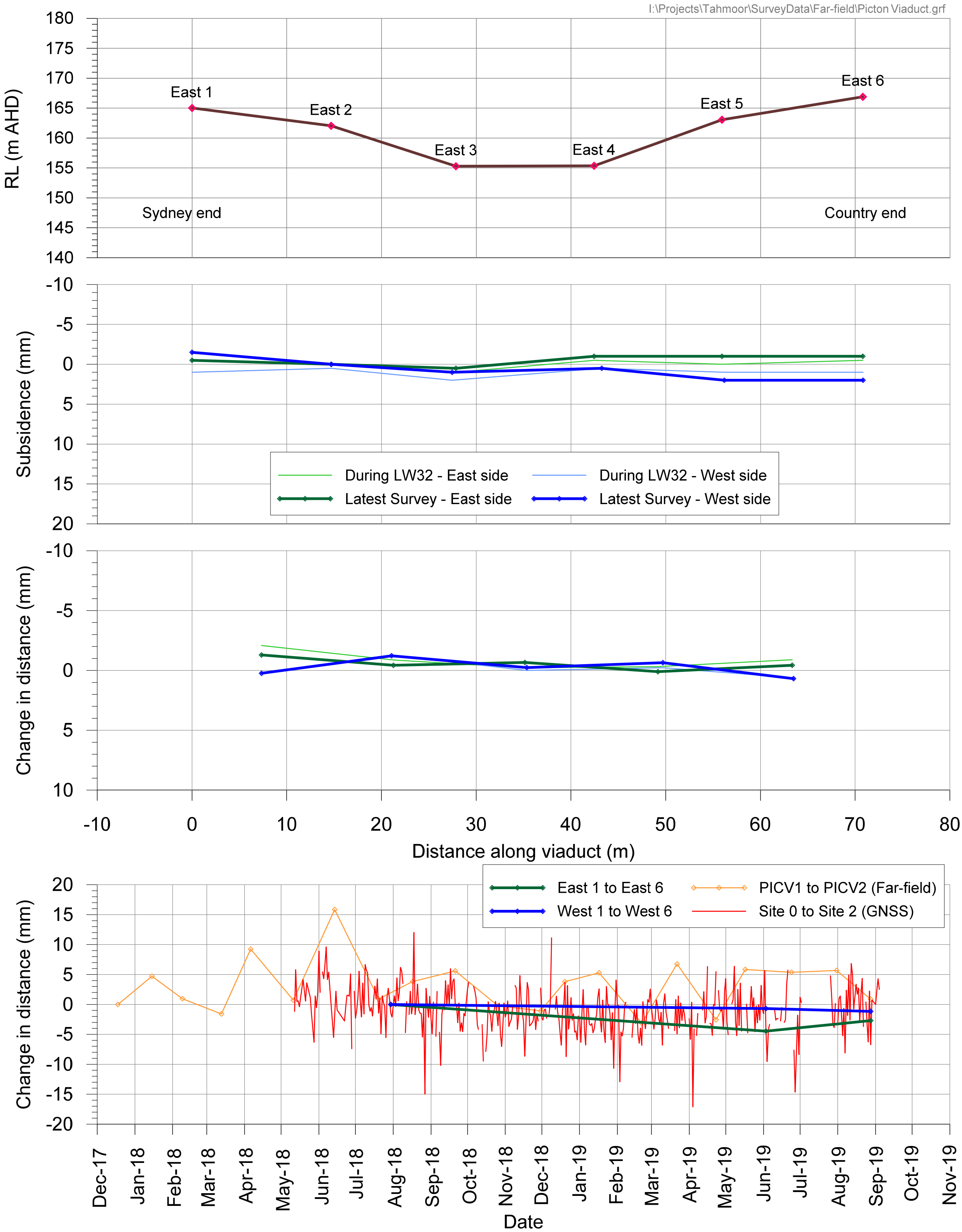


Fig. 2.32 Observed differential vertical and horizontal movements along the Picton Viaduct

2.3.10. Prince Street Overbridge at 85.17 km

The Prince Street Overbridge (85.17 km) is located 1.6 kilometres north-east of LW 32. The bridge is a steel framed overbridge with steel handrails with the deck supported by bearings on concrete headstocks and brickwork piers, as shown in Fig. 2.33.

Fig. 2.33 Prince Street Overbridge at 85.17 km

Absolute 3D surveys have been conducted on a monthly basis at the Prince Street Overbridge since December 2017 when the length of extraction of LW31 was approximately 900 metres. The observed changes in easting, northing and height are shown in Fig. 2.34, where it can be seen that measured changes are within survey tolerance.

Four prisms were installed at the base of the brick piers on 23 July 2018, as shown in Fig. 2.34. The prisms were re-surveyed on 28 August 2019, where it was found that measured changes in distance between the prisms were 1 mm or less, which is within survey tolerance.

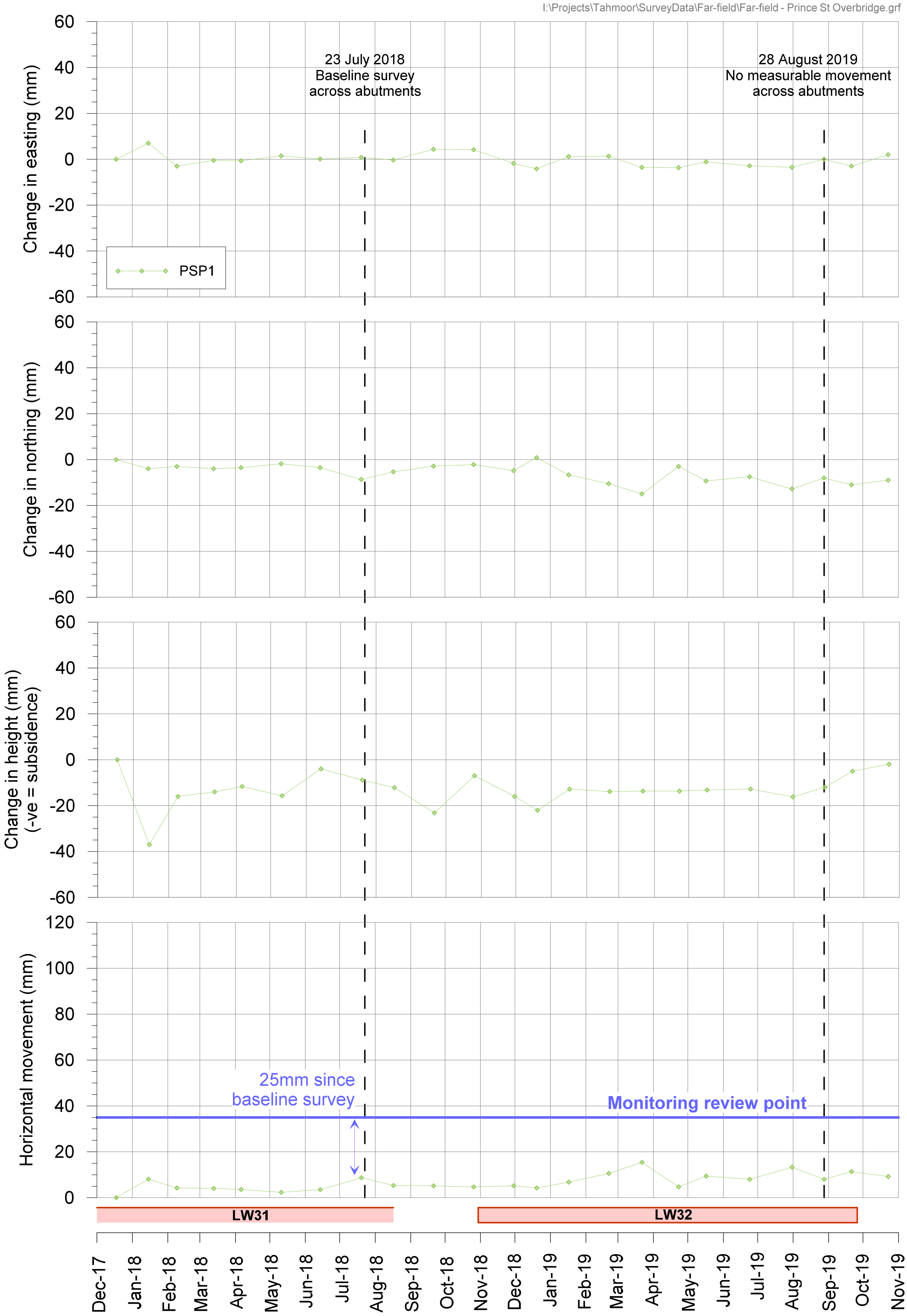


Fig. 2.34 Far-field movements at Prince Street Overbridge

2.4. Victoria Bridge over Stonequarry Creek

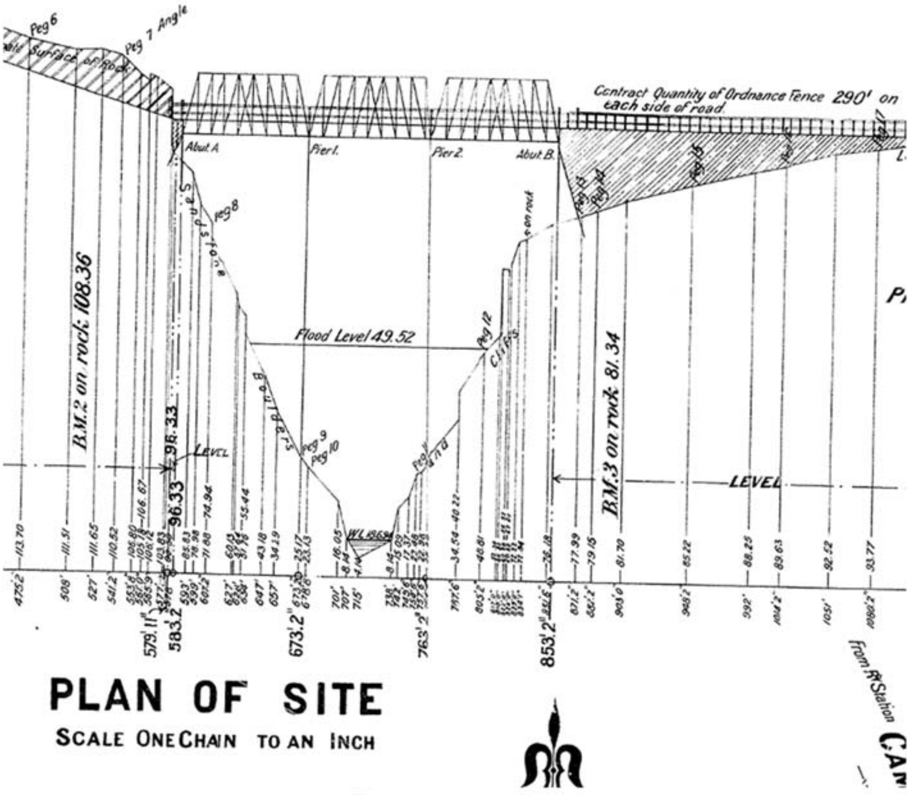
The Victoria Bridge over Stonequarry Creek at Picton consists of three Allan type timber truss spans over 19.5 metre high timber trestles or piers (Cardno, 2019). The Bridge has no approach spans and each of the main spans is 24.7 metres in length. The Bridge can accommodate a single lane of traffic, with a signposted load limit of 5 tonnes. Photographs of Victoria Bridge are provided in Fig. 2.35 to Fig. 2.37.

Fig. 2.35 Victoria Bridge

Fig. 2.36 Victoria Bridge from Western Abutment A

Fig. 2.37 Victoria Bridge timber trestles

Construction of the Victoria Bridge was completed in 1897 and the structure is listed on the State Heritage Register on the basis of its technical and historical significance. A copy of part of the design drawings is shown in Fig. 2.38.



Drawings courtesy RMS

Fig. 2.38 Longitudinal section from original design drawings of Victoria Bridge dated July 1896

The timber Allan Truss consists of timber compression members and wrought iron rod tension members, with a timber bottom chord. The timber trestles consist of timber members that the connected by bolts. The trestles are supported on dwarf walls via timber sills that are bolted to the walls via hold down bolts. The dwarf walls have been constructed with unreinforced concrete that are 1.4 m thick and 18.3 m long (Cardno, 2019).

A diagram showing the general arrangement of the Victoria Bridge is shown in Fig. 2.39.

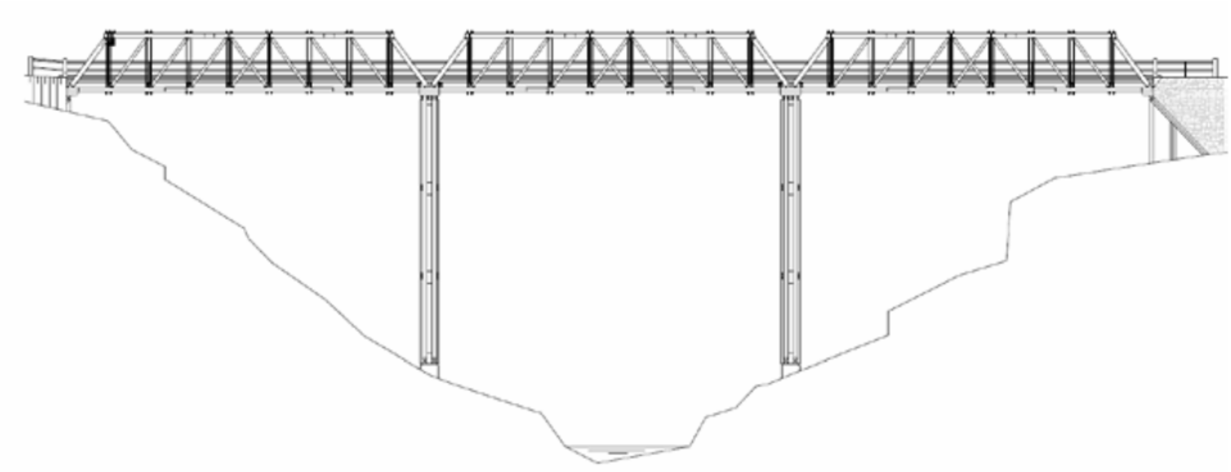


Diagram courtesy RMS with western Abutment A on left hand side

Fig. 2.39 General arrangement of Victoria Bridge

RMS is responsible for maintaining the Victoria Bridge. Rehabilitation works have been completed in recent years and further works are planned in the coming years. A summary of the rehabilitation works is provided in the structural engineering report by Cardno (2019). The completed works include:

- Replacement of various timber truss members over the life of the bridge, as required; and
- Reconstruction of Abutment B at the eastern end of the Bridge (circa 2007).

RMS is currently undertaking rehabilitation works at the Bridge. The works include:

- Replacement of various timber truss members in the top chord and in the piers; and
- Reconstruction of Abutment A at the western end of the Bridge.

Preliminary works for the reconstruction works at Abutment A have commenced, with daytime road closures in place as required.

2.4.1. Observed ground movements

Absolute 3D surveys have been conducted at both ends of the Victoria Bridge on a monthly basis since December 2017 when the length of extraction of LW31 was approximately 900 metres. A GNSS unit was mounted on the eastern Abutment B to continuously measure its absolute horizontal and vertical position in real time. The original GNSS unit was vandalised in May 2019 and was replaced in July 2019. Photographs of the damaged original unit and the new unit are shown in Fig. 2.40.

The observed horizontal movement vectors at the ground marks VBP1 and VBP2 and the GNSS unit are shown in Fig. 2.41. The measurement movements of the ground marks are within survey tolerance (± 10mm in easting and northing, or 14mm as a vector), which is demonstrated by the positions of the current vectors relative to the previously measured paths of movement. The measured vector of the GNSS unit is similarly very small and within survey tolerance of unit, noting that the its path of movement are tighter than those measured by static GPS methods at the ground marks.

The observed changes in easting, northing and height of the ground marks and the GNSS unit are shown in Fig. 2.42. It can be seen that measured changes in eastings and northings are within survey tolerance.

Fig. 2.40 Damaged old and new GNSS Unit 3 at Victoria Bridge on Eastern Abutment B

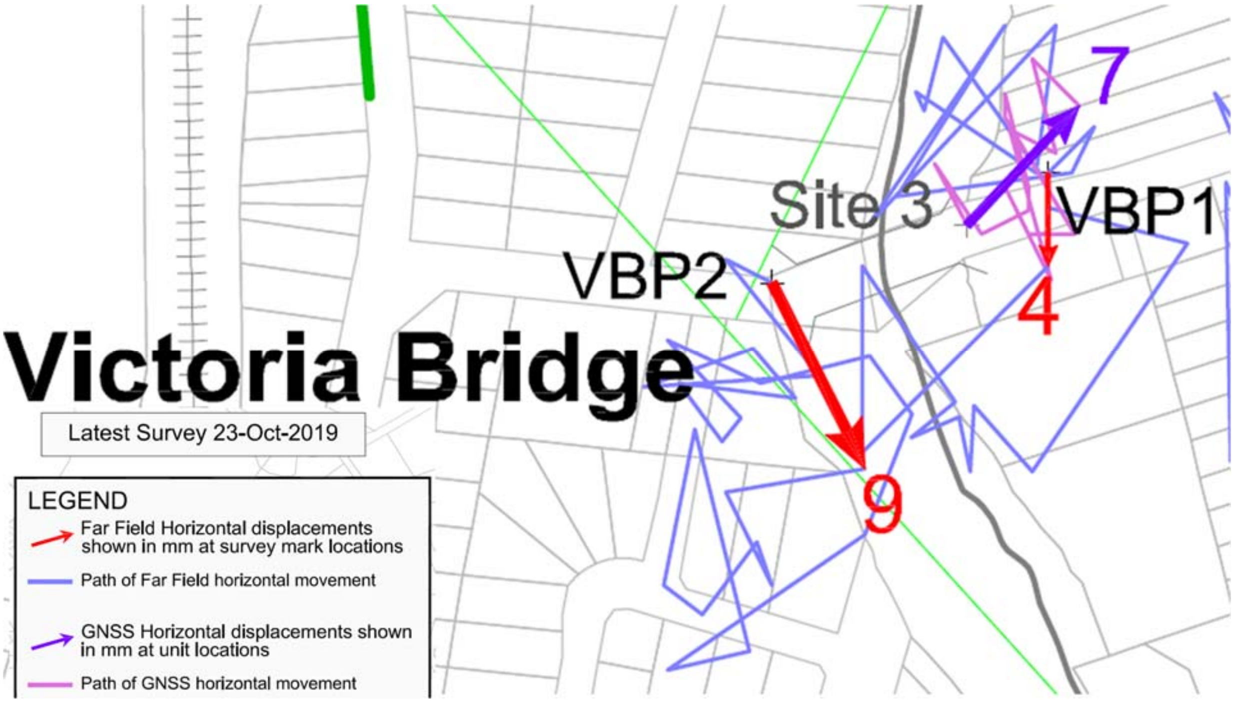


Fig. 2.41 Observed total horizontal movements at Victoria Bridge during mining of LWs 31 and 32

Eight prisms were installed and surveyed on 30 July 2018 at each end of the Bridge and at the base of the timber trestles, on both sides. A plan view layout of the marks is shown in Fig. 2.43. The marks were measured in local 3D coordinates.

The prisms were re-surveyed on 28 August 2019. Measured changes were within survey tolerance, as shown in Fig. 2.44. It is noted, however, that some prisms were obscured by the preliminary currently being undertaken at the Bridge. By way of comparison, differential movements between the two far-field ground marks VBP1 and VBP2 are shown in Fig. 2.44. As the accuracy of the static GPS survey of the ground marks is ± 10mm in easting and northing, it is understandable that the calculated differential movements are slightly noisier compared to the measured changes across the abutments from the local 3D structure survey.

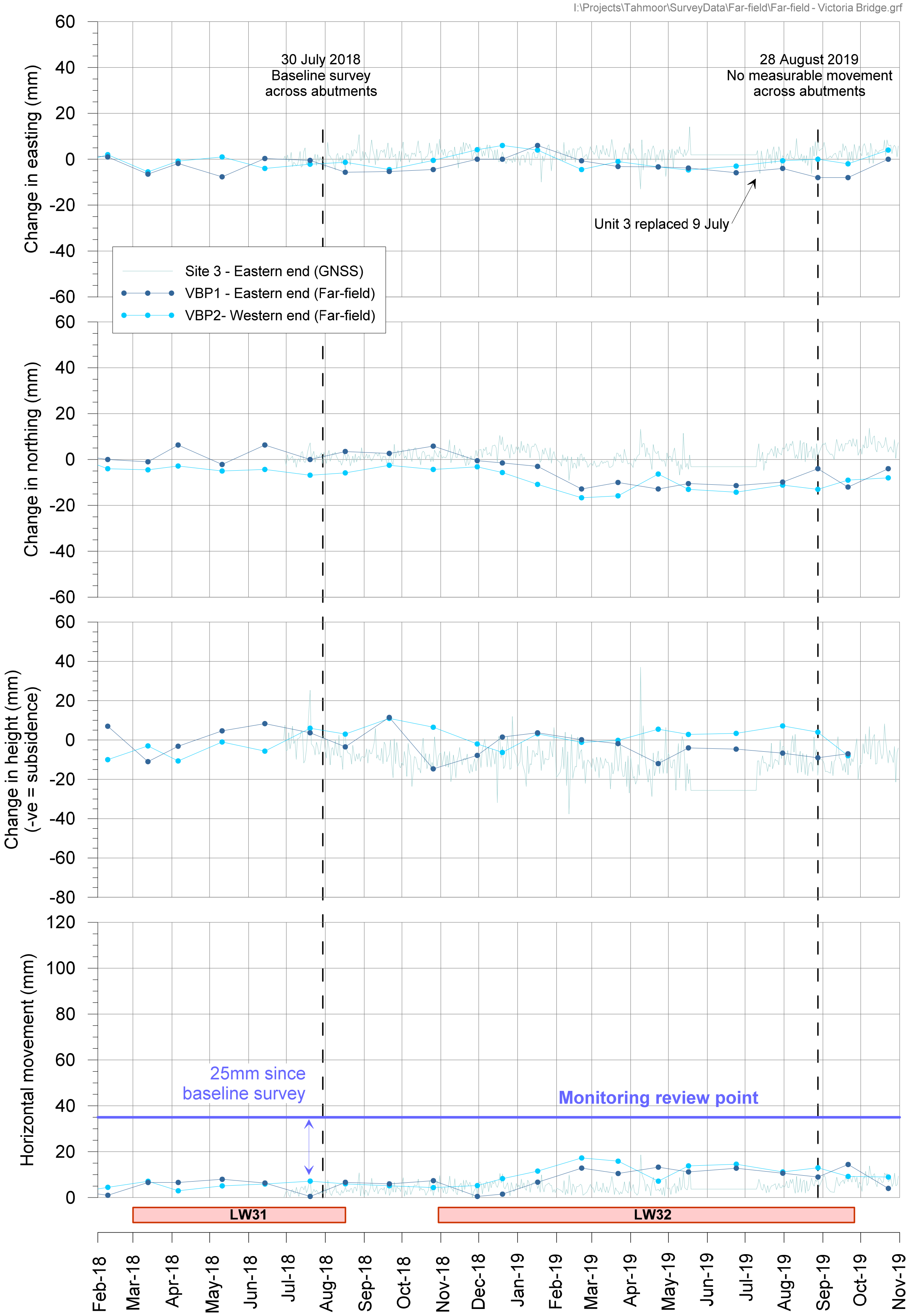


Fig. 2.42 Far-field movements at Victoria Bridge

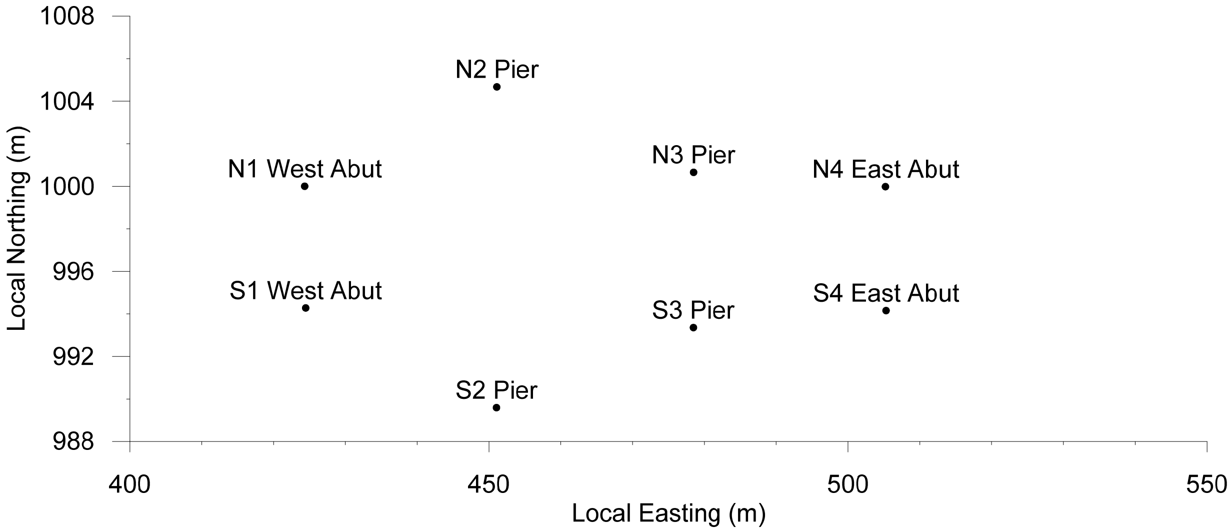


Fig. 2.43 Layout of survey marks in Plan View at Victoria Bridge

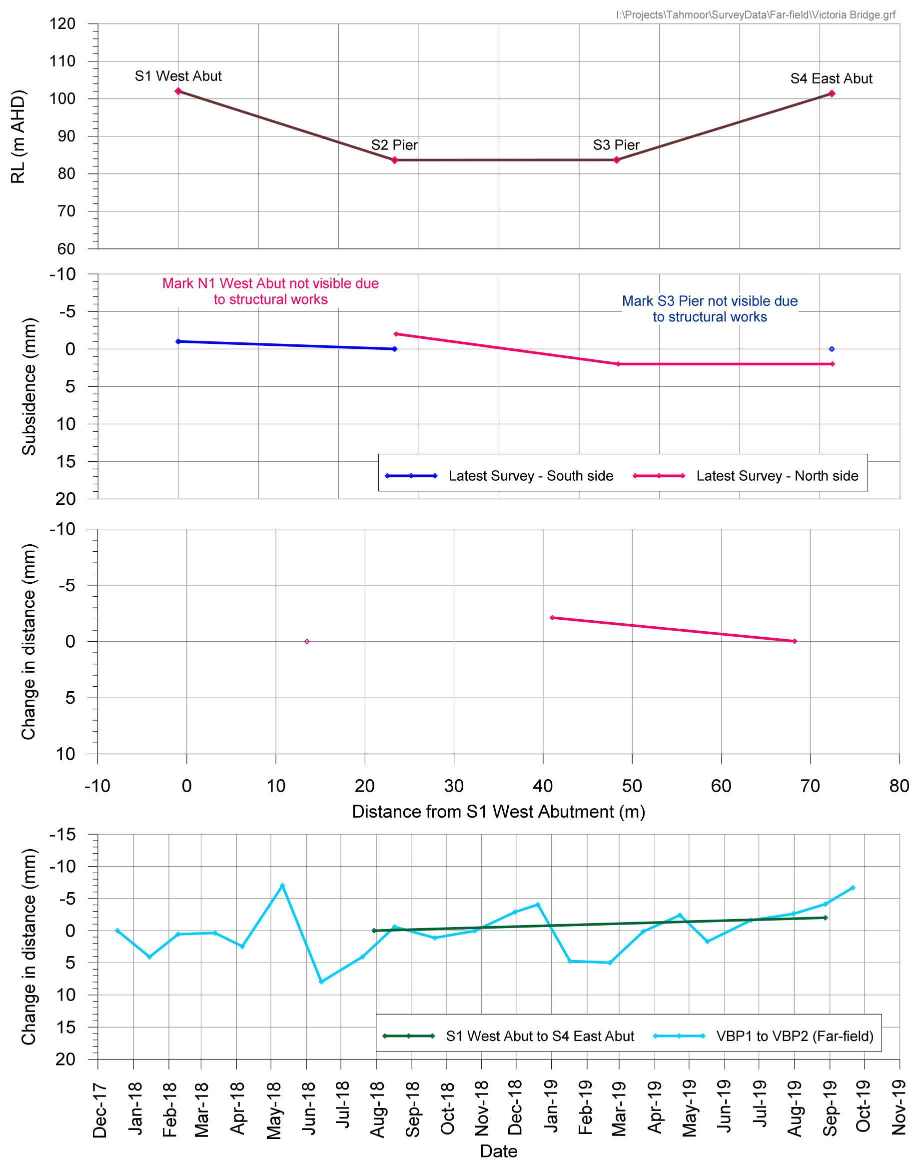


Fig. 2.44 Structure surveys at Victoria Bridge

2.4.2. Structural assessment

A structural inspection and assessment of the Victoria Bridge has been conducted by Cardno (2019). A copy of the report is included in the Appendix of this Management Plan.

Cardno (2019) advised that the timber bridge is very flexible compared to most concrete and steel bridges. Distortion of the structure from differential ground movements between supports in the vertical, longitudinal and transverse directions will generally not cause any significant stresses in the structural components.

Cardno assessed potential impacts due to differential vertical and differential longitudinal and transverse horizontal movements and considered the potential for impacts during the period of reconstruction of Abutment A.

- Differential vertical ground movements

  Cardno (2019, Section 4.3) advised differential vertical ground movements between the piers and abutments are unlikely to result in significant stresses on the bridge truss or the bridge piers. For example, the estimated additional stress from a 10 mm differential vertical movement of Pier 1 relative to Abutment A and Pier 2 is 0.65 MPa at the timber bottom chord. The timber bottom truss chords have no stresses from dead or live loads and so have a large reserve capacity to accommodate small bending stresses that might arise for differential vertical movements at the bridge supports. Cardno advises that the characteristic stress capacity of the timber is likely to be at least 34 MPa in compression and 42 MPa in tension if it was F17 timber and is most likely to be higher as the timber is likely to be either F22 or F27 grade. Based on the above, the bending stress in the bottom chord induced by subsidence represents a small percentage of the bending stress capacity.

  Potential changes can be monitored by surveying targets on the bridge.

- Differential transverse ground movements

  Cardno (2019, Section 4.4) advised that differential transverse ground movements could result in the base of one or both trestle piers to move upstream or downstream relative to the abutments. The differential transverse movements would cause the truss superstructure to bend in the transverse direction. Cardno advised that the three truss spans are very flexible in the transverse direction due to the nature of the deck construction, such that transverse bending stresses would be negligible. As the deck is flexible in the transverse direction, no significant stresses would be generated in the timber trestles.

  Cardno also advised that ground supporting the concrete bases could experience tensile or compressive strains. The concrete bases are likely to readily accommodate compressive strains. Tensile cracks could develop in the concrete in response to tensile strains but the cracks would not adversely affect the structural performance of the bases.

  Potential changes can be monitored by surveying targets on the bridge.

- Differential longitudinal ground movements

  Cardno (2019, Section 4.5) advise that the truss superstructure is stiff in the longitudinal direction because the bottom chords are effectively continuous over the three spans (i.e. there are no intermediate movement joints). The abutment and pier bases, which are fixed to the ground, will move longitudinally closer together or further apart if there is differential longitudinal ground movement but the abutment and pier tops, where they are fixed to the truss, will stay at the same spacings. The bridge can accommodate differential longitudinal movements between the abutments via a gap that exists at the reconstructed eastern Abutment B, as shown in Fig. 2.45. The width of the gap is nominally 20 mm, as shown in Fig. 2.45.

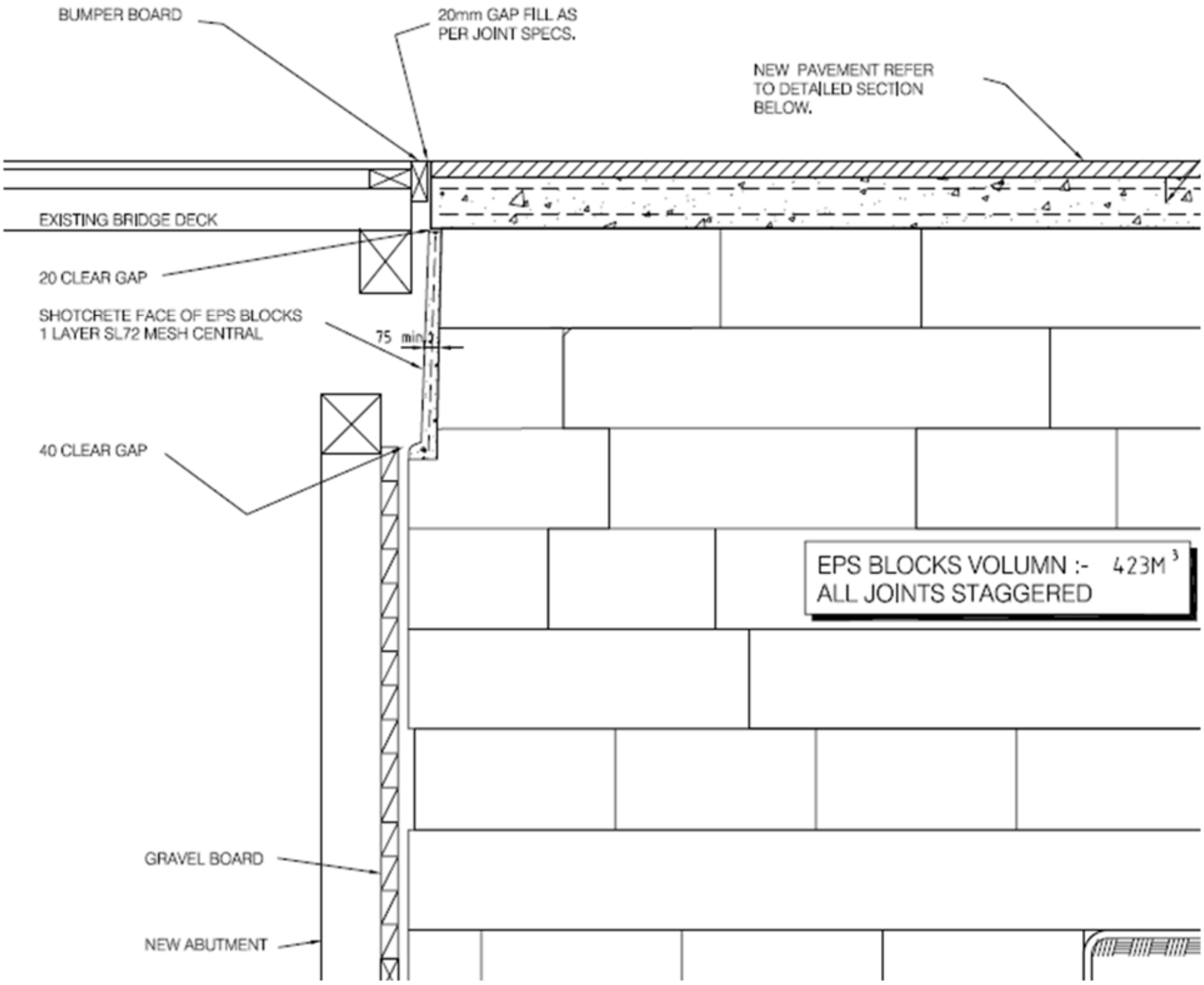
  If mining results in closure between the abutments, the gap will close until the timber bumper board makes contact with the road pavement above the abutment. Once the gap is closed, further ground closure between the abutments can be accommodated via small gaps that are present between the timber deck stringers.

  Cardno advised that even after the gaps between the deck stringers are closed, the timber deck can accommodate some additional compression. For example, a 20 mm compression the deck would result in a stress of approximately 4.5 MPa. The characteristic compression capacity of the timber members is 34 MPa, which is well in excess of 4.5 MPa. This scenario, however, can be avoided by cutting back the timber bumper board to recreate the gap.

In between the abutments, the two trestle piers and Abutment B are flexible in the longitudinal direction, such that differential longitudinal ground movements between the supports will not cause any significant stresses in the truss spans, the timber trestles or the timber abutment.

If the distance between abutments is observed to open, the gap between the bumper board and the concrete slab would simply open up and there would be no effect on the bridge structure.

Potential changes can be monitored by surveying targets on the bridge, and monitoring the gap at Abutment B. The gap may need to be cleaned of debris.



Drawing courtesy RMS, extracted from Drawing No. PNPN5381-D-206, Iss E by MBK South Coast, 27-07-07

Fig. 2.45 Section through reconstructed Abutment B showing gap between deck and abutment

- Potential impacts during Reconstruction of Abutment A

  Cardno (2019) has reviewed the design drawings for the reconstruction of the western Abutment A. Currently, the ends of the truss bottom chords / corbels are notched around the supporting timber at Abutment A, preventing relative movement between the truss and Abutment A. During reconstruction of Abutment A, the truss will be jacked up and disconnected from Abutment A, allowing the whole superstructure to move longitudinally with little restraint. It is possible that the bridge could move longitudinally during the reconstruction works, closing the gap at Abutment B, which should be avoided. It would be possible to move the bridge longitudinally to maintain the gap or even slightly open the gap further during the reconstruction works. Cardno recommends that the bridge and the gap be monitored before, during and after the reconstruction works.

Based on the information above, Tahmoor Coal, RMS and the Technical Committee considered and selected risk controls for the Victoria Bridge due to the extraction of LW W1-W2 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 controls were identified that can 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

The following Engineering Controls have identified that will put in place a structure or item that prevents or minimises risks.

- Mine layout design
  Tahmoor Coal has amended its mine layout to set back longwalls an appropriate distance from the Victoria Bridge such that it would be feasible to maintain its safety and serviceability. The longwall sequencing was also adjusted to extract from west to east towards the Victoria Bridge, providing an opportunity to monitor mine subsidence movements as longwalls are progressively extracted and allowing the mine plan to be adapted if unexpected adverse changes are observed.

- Clean and maintain gap at Abutment B
  The gap will be inspected and cleared of debris as required. The gap will be maintained during the reconstruction works to ensure that it can accommodate potential mining-induced changes during the mining of LW W1-W2.

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 Victoria Bridge.

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

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

  - Absolute 3D survey of the position at both ends of the Bridge (installed during LW31)
  - Continuous, automated GNSS monitoring at eastern Abutment B (installed during LW31)
  - Relative 3D surveys of the eight existing prisms at the base of the intermediate piers and on the abutments (installed near end of LW31), and at additional marks at the tops of the trestle piers and at the abutments (install prior to end of December 2019).
  - Measure the existing gap between the timber buffer board and the approach pavement at Abutment B.
  - Dilapidation inspection of Victoria Bridge (complete).
  - Implementation of planned responses, if triggered by monitoring results. These may include:
    - Detailed inspections by structural engineer
    - Maintain the gap by adjusting the timber buffer board or saw cutting the end of the approach pavement.
    - Adjusting the Bridge if required, in consultation with heritage consultant.
    - As a worst case scenario, temporary bridge closure can be implemented in accordance with a traffic management plan, which is currently in effect during dayworks at the Bridge and will be in place during the planned reconstruction works at Abutment A between February and April 2020. Traffic can be diverted around the Bridge along Menangle Street and Argyle Street.

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

2.5. Menangle Street – Picton Road

RMS is responsible for maintaining the full length of Menangle Street - Picton Road starting from the intersection at Argyle Street in Picton. Picton Road is called Menangle Street between the intersection with Argyle Street and intersection with Matthews Lane in Picton.

As Menangle Street – Picton Road is located more than 1.5 km from LW W1-W2, the potential for mining-induced impacts on the road pavement is extremely low.

RMS routinely monitors the condition of Menangle Street – Picton Road as part of its maintenance program. The last Gipsicam recording along the road was conducted on 9 March 2018 and photographs have been provided to Tahmoor Coal.

Tahmoor Coal has inspected the condition of Menangle Street – Picton Road in October 2019 as a baseline inspection and will conduct inspections every 3 months during the mining LW W1-W2.

In the unlikely event that changes in road condition are detected and the changes are confirmed to mining-induced, the road will be repaired in accordance with the *Coal Mine Subsidence Compensation Act 2017.*

3.1. Main Risk Assessment

A risk assessment for the mining of LW W1-W2 was conducted on 17 October 2019 at RMS offices in Wollongong, which was attended by representatives of RMS, Tahmoor Coal, Cardno and MSEC. The risk assessment was built upon the experience gained from the mining of Tahmoor Longwall 32.

A report of the methods and results of the risk assessment is provided in a report by Tahmoor Coal (2019). A brief summary is provided below.

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

- Roads and Maritime Services
- Cardno
- Mine Subsidence Engineering Consultants
- Tahmoor Coal

The risk analysis was conducted with the purpose of identifying risks associated with the mining of LW W1-W2 adjacent to Victoria Bridge. The risk assessment was conducted in accordance with the RMS risk matrix as presented by Arup. The risk matrix and definitions are shown in Fig. 3.1.

The risks were assessed taking into account existing and planned controls. A summary of these results are provided in Table 3.1. 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), Moderate (M), High (H) or Extreme (E).

ROADS & MARITIME SERVICES
RISK ASSESSMENT - SUBSIDENCE IMPACTS ON RMS ASSETS
RISK MATRIX

Transport Roads & Maritime Services

LIKELIHOOD		CONSEQUENCES 1 (Insignificant)	2 (Minor)	3 (Moderate)	4 (Major)	5 (Catastrophic)	6 (Unthinkable)
Multiple	O	H	E	E	E	E	E
Almost Certain	A	H	H	E	E	E	E
Likely	B	M	H	H	E	E	E
Possible	C	L	M	H	E	E	E
Unlikely	D	L	L	M	H	E	E
Rare	E	L	L	M	H	H	E
Hypothetical	F	L	L	L	M	H	H

Low	Low risk; managed by routine procedures.
Moderate	Moderate risk; requires above normal attention.
High	High risk; ALARP must be applied.
Extreme	Extreme risk; not acceptable and must be reduced.

ARUP

Source: RMS / Arup

Fig. 3.1 RMS Risk Matrix and Definitions

Table 3.1 Summary of Risk Assessment

Aspect, Consideration Risk Issue	Potential Consequence Description	Consequence	Likelihood	Level of Risk
Vertical subsidence	Differential vertical displacement	Insignificant	Rare	Low
Valley closure	Loss of expansion capacity	Insignificant	Rare	Low
Valley closure	Reset expansion joint at eastern abutment	Moderate	Rare	Medium
Horizontal shear	Lateral distortion of deck	Insignificant	Rare	Low
Valley opening	Opening of gap between deck and abutment causing potential trip hazard	Insignificant	Rare	Low
Differential far field subsidence	Distortion of road pavement along Menangle Street – Picton Road	Insignificant	Rare	Low

3.2. 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 RMS infrastructure.

Mine subsidence hazards have been identified, investigated and analysed in a systematic manner by examining each aspect of the infrastructure, as described in Sections 2.4 and 2.5 of this Management Plan.

The following mine subsidence hazards were identified that could give rise to risks to health and safety due to the extraction of LW W1-W2.

- Formation of step hazard at gap between deck and abutment.

The identification and risk assessment process took into account the location of RMS structures relative to LW W1-W2 and the associated timing and duration of the subsidence event, as described in Section 1.10 of this Management Plan.

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 RMS 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 RMS infrastructure. These are described in Chapter 4 of this Management Plan.

3.2.1. Subsidence impact management process

Tahmoor Coal has developed and acted in accordance with subsidence management plans to manage potential impacts during the mining of Longwalls 22 to 32. The management strategy has been reviewed and updated based on experiences gained during the mining of Longwalls 22 to 32 and the strategy for LW W1-W2 includes the following process:

1. Regular consultation with RMS before, during and after mining.
2. Site-specific investigations.
3. Development and implementation of mitigation measures following inspections by a bridge engineer.
4. Development and implementation of monitoring and inspections during mining within the active subsidence area.

A flowchart illustrating the subsidence impact management process prior to, during and after RMS infrastructure experiences mine subsidence movements is shown in Fig. 3.2.

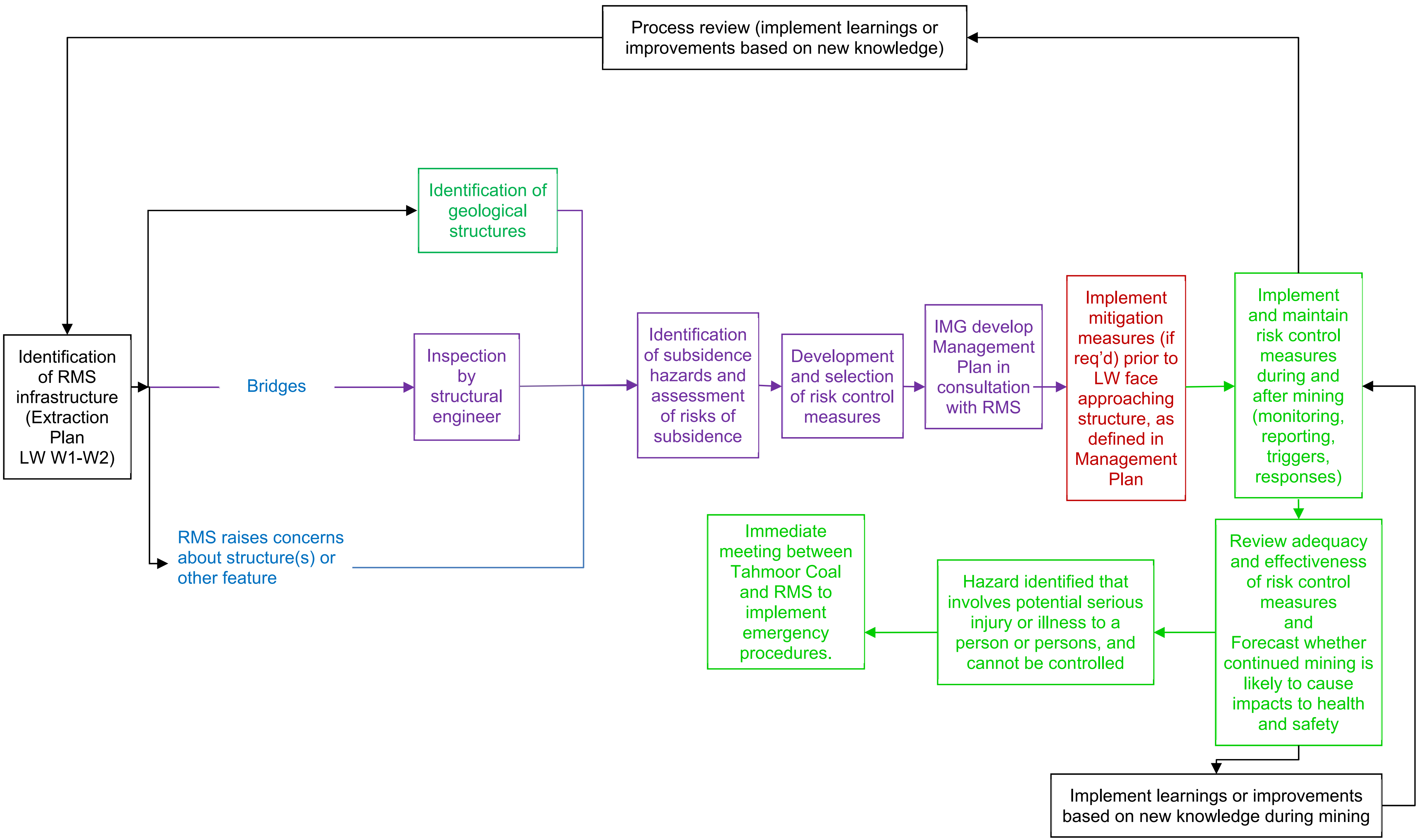


Fig. 3.2 Flowchart for subsidence impact management process

4.1. Roles and Responsibilities

4.1.1. RMS Infrastructure Services Manager

The RMS Infrastructure Services Manager is responsible for taking the necessary actions required to manage the potential for impacts to RMS surface infrastructure due to the development of mine subsidence movements.

In the case of this Management Plan, the RMS Infrastructure Services Manager is supported by the RMS Bridge Maintenance Planner in matters relating to the Victoria Bridge and the RMS Pavement Maintenance Planner in matters relating to Menangle Street – Picton Road.

4.1.2. RMS Bridge Works Manager

The RMS Bridge Works Manager is responsible for coordinating maintenance works on the Victoria Bridge, including the reconstruction works for the western Abutment A.

4.1.3. Technical Committee (TC)

The Technical Committee (TC) provides information and advice to the RMS Infrastructure Services Manager during the mining period and to receive directions. The TC will meet either in person or via teleconference at regular intervals as required. The TC will:

- Assess the monitoring results
- Consider whether any additional management actions are required
- Forecast whether there will be any subsidence impacts to the operation and safety of the Victoria Bridge, Menangle Street – Picton Road in the short to medium term due to the continued extraction of LW W1-W2.

Members of the TC include:

- RMS Pavement Maintenance Planner
- RMS Bridge Maintenance Planner
- RMS Bridge Works Manager (as required)
- Tahmoor Coal
- Cardno
- MSEC

The Resources Regulator and SA NSW may participate in Technical Committee meetings as an observer.

4.1.4. Alternative contacts

All members of the TC have provided alternative contacts during the mining period. The alternative contacts can be contacted should the primary contact be unavailable.

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

4.2. 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 4.3 to Section 4.6. 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 W1-W2.

4.3. 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 3.2.

- Clean and maintain gap at Abutment B of Victoria Bridge
  The gap will be inspected and cleared of debris as required. The gap will be maintained during the reconstruction works to ensure that it can accommodate potential mining-induced changes during the mining of LW W1-W2.

4.4. Monitoring plan

The locations and extents of monitoring measures for LW W1-W2 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, noting that the Victoria road bridge is located more than 1350 metres from LW W1-W2.

4.4.1. Far field monitoring of structures

Tahmoor Coal installed a far-field monitoring survey network during the mining of LW31. These include a far-field horizontal movement monitoring program to investigate the potential for differential horizontal movements across the Nepean Fault.

- Thirlmere Way Rail Underbridge (89.326 km)
- Connellan Crescent Railway Overbridge (89.080 km)
- Argyle Street Rail Underbridge (86.13 km)
- Picton Viaduct (85.42 km)
- Prince Street Overbridge (85.17km)
- Picton Tunnel (87.85 km)
- Victoria Road Bridge over Stonequarry Creek

Two pegs have been installed at each of the Picton Viaduct and Victoria Road Bridge as these structures span the surface expression of the Nepean Fault.

Prior to start of LW W1, Tahmoor Coal have extended the far field monitoring network to provide a greater spread of monitoring data on the western side of the mapped Nepean Fault zone, plus one additional location on the eastern side.

- Subway at 88.133 km;
- Ballast top underbridge at 84.687 km;
- Matthews Lane Overbridge at 84.551 km; and
- Abbotsford Bridge on Barkers Lodge Road over Stonequarry Creek.

The Bridge Street Overbridge will also be included as part of the far field network.

The locations of the structures and far field survey marks are shown in Drawing No. MSEC1045-18-02. Two pegs have been installed at each of the Picton Viaduct and Victoria Road Bridge as these structures span the surface expression of the Nepean Fault.

Absolute 3D surveys

Ground pegs have been installed or will be installed at the above locations prior to the start of LW W1. Photographs of the survey pegs installed above the Picton Tunnel and Picton Viaduct are shown in Fig. 4.1.

The pegs will be surveyed in absolute 3D on a monthly basis during the extraction of LW W1-W2.

Continuous GNSS monitoring

The GNSS points are fixed survey stations that continuously measure their absolute horizontal and vertical position in real time. In addition to the absolute 3D ground survey pegs, continuous GNSS monitoring points were installed at seven sites during the mining of Longwall 31.

- Picton Viaduct at 85.42 km – two units
- Picton Tunnel at 87.85 km
- Victoria Road Bridge over Stonequarry Creek on eastern Abutment B
- Sydney Water Picton Water Recycling Plant – three units

The two units at the Picton Viaduct have been installed in the ground at each end of the Viaduct, as this structure spans the surface expression of the Nepean Fault. The locations are shown in Drawing No. MSEC1045-18-02.

The three units within the Sydney Water Picton Water Recycling Plant may be relocated during the mining of LW W1-W2, subject to approval by Sydney Water.

The GNSS system will record an average reading for each day and the data will be reviewed monthly during the mining of LW W1-W2. A more regular review of the data will be considered if significant absolute or differential movements are observed.

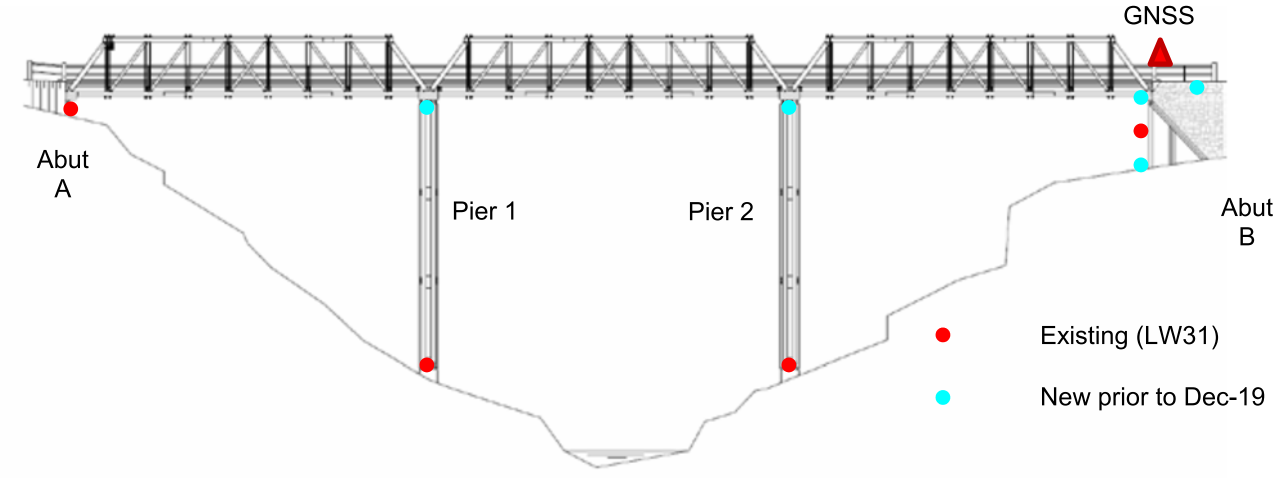
Photographs courtesy Southern Rail Surveys

Fig. 4.1 Ground survey peg installed above Picton Tunnel (left) and Picton Viaduct (right)

4.4.2. Structure surveys at Victoria Bridge

In addition to the far-field monitoring program, eight prisms were installed and surveyed on 30 July 2018 at each end of the Bridge and at the base of the timber trestles, on both sides.

In accordance with recommendations by Cardno (2019), additional marks will be installed at the tops of the trestle piers and at the abutments prior to the end of December 2019.



Note: Diagram is representative of survey marks on both sides of the Victoria Bridge

Fig. 4.2 Locations of existing and new prisms on both sides of Victoria Bridge

4.4.3. Gap between timber buffer board and road pavement on Abutment B

The gap between the timber buffer board and road pavement on Abutment B will be measured prior to the end of December 2019. Marks will be placed on the Bridge to measure any changes across the gap during mining, including during the reconstruction works at Abutment A.

4.4.4. Dilapidation survey of Victoria Bridge

RMS has conducted inspections of the Victoria Bridge as part of its maintenance program and reconstruction works. An additional dilapidation inspection was completed by Tahmoor Coal in October 2019.

4.4.5. Visual inspections of Menangle Street – Picton Road

RMS conducts routine vehicle-based visual inspections of the condition of Menangle Street – Picton Road. The last inspection was conducted in March 2018.

Tahmoor Coal has conducted a baseline visual inspection of Menangle Street – Picton Road from Argyle Street to the intersection with Matthews Road. Inspections will continue during mining.

4.4.6. Provision of raw monitoring data

Ground monitoring data will be provided by Tahmoor Coal to all members of the TC and MSO within 48 hours of survey. All other raw monitoring data is available to all members of the TC upon request.

4.4.7. Changes to monitoring frequencies

Monitoring frequencies are specified in the Risk Control Procedures (see Appendix A).

Tahmoor Coal will not reduce monitoring frequencies or stop monitoring until agreed by RMS (via recommendation by the Technical Committee).

It is also possible that small losses of monitoring data may occur if survey marks are damaged or vandalised during the mining period. The TC 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 movements and the decision shall be communicated in the monitoring reports.

4.5. Trigger levels

Trigger level in relation to Victoria Bridge

Monitoring Review Point Trigger levels are in accordance with the trigger recommended by the structural engineer Cardno. Exceedence of the trigger levels will require a technical review of observations and consideration of whether to increase the gap between the timber buffer board and the road pavement. The monitoring review point trigger levels are less than the overall capacity of the Bridge to accommodate differential movements, providing adequate time to respond before impacts occur.

Trigger level in relation to the road pavement

The trigger level in relation to Menangle Street – Picton Road is detection of potential mining-induced damage to the pavement, based on visual inspections. Exceedence of the trigger level will require a technical review of observations and consideration of whether the damage is mining-induced, and if it decided that impact is mining-related, repair of the pavement in accordance with the *Coal Mine Subsidence Compensation Act 2017.*

4.6. Response plan

The following responses are available to reduce the potential for impacts of mining induced ground movements on the Victoria Bridge and Menangle Street – Picton Road pavement. These will be implemented in response to the monitoring data.

The general management strategy is to detect changes in ground movements and structure condition early, monitor the behaviour of the structures in response to ground movements and, if necessary, undertake planned additional management measures to avoid impacts on road safety and operations. This is achieved by regular assessment of monitoring results during the mining period, including the forecast of possible exceedences of triggers due to the continued extraction of the longwalls.

Site inspection

If the Monitoring Review Trigger is exceeded, the Victoria Bridge will be inspected by a structural engineer.

Victoria Bridge

The following response measures may be implemented if impacts occur on the Victoria Bridge.

- Adjust gap between timber buffer board and road pavement on Abutment B. This can be achieved by either replacing the board with a thinner piece of timber, or saw cutting the end of the pavement approach slab and AC surface.
- Remove trip hazard on pedestrian walkway
- Adjust the structure as required, in accordance with requirements by heritage consultant

Menangle Street – Picton Road

The following response measures may be implemented if impacts occur on the road pavement.

- Mill and resheet pavement surface as required.

Traffic Management

While the above responses are expected to be undertaken without affecting vehicle traffic, a temporary bridge closure can be managed by RMS if required as a last resort measure, in accordance with a traffic management plan. A traffic management plan is currently in effect during dayworks at the Bridge and will be in place during the planned reconstruction works at Abutment A between February and April 2020. Traffic can be diverted around the Bridge along Menangle Street and Argyle Street.

Slow or stop longwall

As for closure of the bridge, these are last resort management measures. If required, the longwall mining process can be slowed or stopped if the impact to Victoria Bridge is unacceptable to RMS.

It is further noted that a review will be undertaken during the mining of each longwall. If higher than expected adverse impacts are observed, Tahmoor Coal will consider whether to shorten the length of extraction of the subsequent longwall or longwalls.

Response times

Given the large offset distances between LW W1-W2 and the RMS assets, rates of change are very low, providing considerable time to respond if required. Approximate response times are summarised in Table 4.1. 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 TC based on an assessment of latest monitoring data on a monthly 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 4.1 Approximate response times

Response Measure	Approximate Response Time	Comments
Provide additional support to bridge (e.g. adjust gap between deck and abutment)	Within one week	There is plenty of material readily available from nearby suppliers to adjust the gap or provide additional support if required.
Temporary bridge closure	Less than 24 hours	A temporary bridge closure can be arranged at short notice in consultation by RMS under existing traffic management plans

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

As part of the ongoing process of subsidence management for RMS infrastructure, additional measures to manage subsidence due to the extraction of future longwalls will be planned and installed. This may include, among other things:

- The installation and commissioning of additional monitoring measures
- The installation of measures to mitigate potential impacts to structures
- 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 RMS.

4.8. Risk control procedures

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

4.9. Triggers from other monitoring measures

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

4.10. Reporting of results

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

Monitoring measure	Monitoring by	Report by
Ground surveys and bridge surveys	SRS	MSEC
GNSS monitoring	MNC	MSEC
Visual inspections along Menangle Street – Picton Road	Building Inspection Services	MSEC
Structural inspections and analysis of results (if required)	Cardno	Cardno
Longwall position	TC	MSEC
Summary Status Report	-	MSEC
TC Meeting Minutes	-	MSEC

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 be monthly.

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 TC whether there will be any subsidence impacts to the operation and safety of RMS assets in the next monitoring period due to the continued extraction of LW W1-W2.

5.0 REHABILITATION PLAN

Any damage that occurs will be repaired by RMS in consultation with SA NSW. Funding of the repairs shall be in accordance with the *Coal Mine Subsidence Compensation Act 2017*.

6.0 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 RMS to conduct a review.

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.

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8.0 REFERENCES

	AS/NZS ISO 31000:2009 Risk Management – Principles and guidelines
MSO (2017)	Managing risks of subsidence – Guide | WHS (Mines and Petroleum Sites) Legislation, NSW Department of Planning & Environment, Resources Regulator, Mine Safety Operations, February 2017.
MSEC (2019)	Tahmoor Coal - Longwalls W1 and W2 - Subsidence Predictions and Impact Assessments for Natural and Built Features due to the Extraction of the Proposed Longwalls W1 and W2 in Support of the Extraction Plan Application. (Report No. MSEC1019, Revision B, July 2019), prepared by Mine Subsidence Engineering Consultants.
Cardno (2019)	Investigation of Potential Effects of Ground Movement due to Mining – Victoria Bridge, Picton NSW, Cardno, Rev 5, 7 November 2019
Tahmoor Coal (2019)	Risk Assessment Report – Far Field Subsidence Impacts – Victoria St Bridge, Picton, 17 October 2019.

Appendix A – Risk Control Procedures for LW W1-W2

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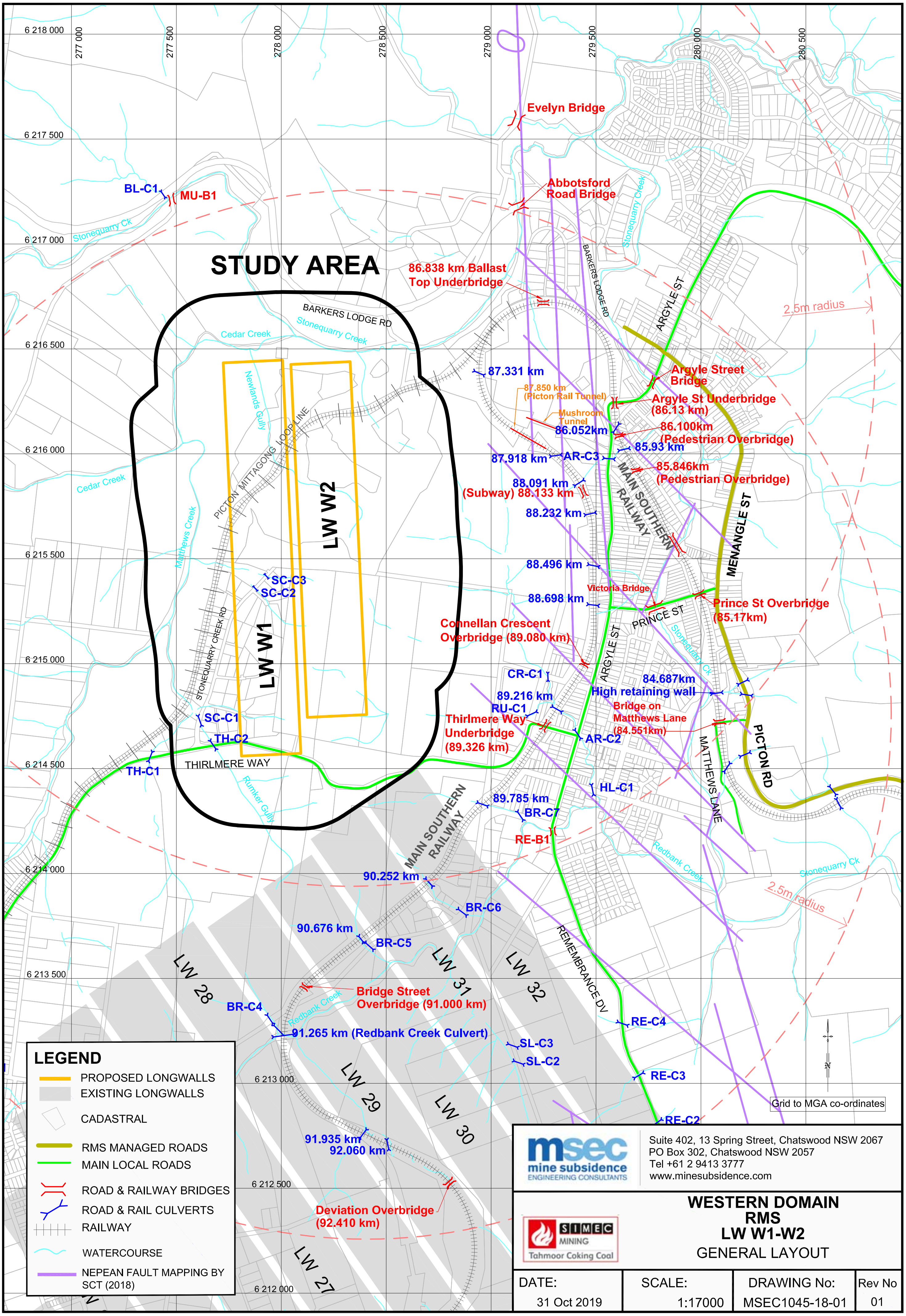

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SIMEC MINING Tahmoor Coking Coal

WESTERN DOMAIN RMS LW W1-W2
GENERAL LAYOUT

DATE:	SCALE:	DRAWING No:	Rev No
31 Oct 2019	1:17000	MSEC1045-18-01	01

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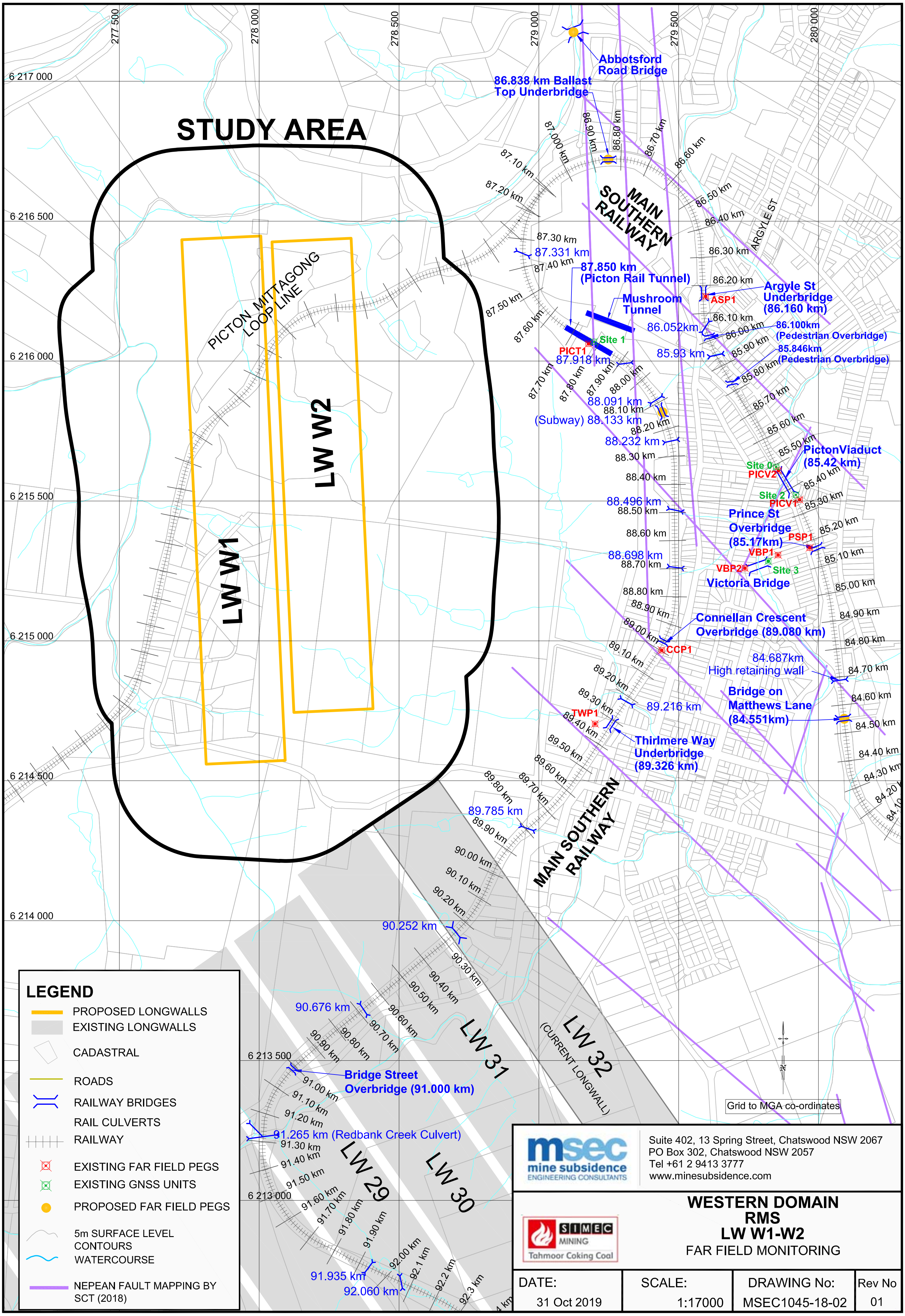

Table A. 1 Risk Control Procedures for LW W1-W2

RISK ISSUE	TRIGGER	CONTROL PROCEDURES	TIMING & FREQ	BY WHOM?
General Procedures				
<u>ABBREVIATIONS WIHIN THESE TABLES:</u> RMS = Roads and Maritime Services MSO = NSW Department of Planning & Environment, Resources Regulator, Mine Safety Operations SRS = Southern Rail Surveys (ground surveys and bridge surveys) SA NSW = Subsidence Advisory NSW MSEC = Mine Subsidence Engineering Consultants TC = Technical Committee	**None**	Continuous GNSS monitoring at Picton Viaduct (85.42 km), Picton Tunnel (87.85 km), Victoria Road Bridge over Stonequarry Creek	Continuous Recorded daily	Tahmoor Coal
		Far field absolute 3D surveys at Thirlmere Way Underbridge (89.326 km), Connellan Crescent Overbridge (89.080 km), Argyle Street Rail Underbridge (86.13 km), Picton Viaduct (85.42 km), Prince Street Overbridge (85.17km), Picton Tunnel (87.85 km), Victoria Road Bridge over Stonequarry Creek, Bridge Street Overbridge (91.030km)	Monthly after 200 m extraction of LW W1-W2	SRS
		Install new far field absolute 3D surveys at Subway (88.133 km), Ballast Top Underbridge (84.687 km), Matthews Lane Overbridge (84.551 km), Abbotsford Road Bridge over Stonequarry Creek	Install and baseline survey prior to start of LW W1 (complete) Monthly after 200 m extraction of LW W1-W2	SRS
		Victoria Bridge – Local 3D survey of existing marks at base of piers and abutments	Monthly after 200 m extraction of LW W1-W2	SRS
		Victoria Bridge – Local 3D survey of additional survey marks at the tops of piers, at the top and base of Abutment B and the top embankment at Abutment B	Install prior to end of December 2019 then monthly during LW W1 Monthly after 200 m extraction of LW W2	SRS
		Inspect gap between timber buffer board and road pavement above Abutment B and clear debris if required	Prior to end of December 2019	RMS
		Measure gap between timber buffer board and road pavement above Abutment B	Initial measure prior to end of December 2019 then monthly during LW W1 Monthly after 200 m extraction of LW W2	SRS
		Dilapidation inspection of Victoria Bridge	Inspection complete	Robinson Rail
		Visual inspections along Menangle Street – Picton Road between intersection at Argyle Street and Matthews Lane	Baseline Complete Every 3 months during LW W1-W2	Tahmoor Coal
		Analyse and report results to TC, MSO, SA NSW	Monthly after 200 m extraction of LW W1-W2	Section 4.10
		TC meetings as required	Monthly or more / less frequently as decided by TC	TC
Damage to Victoria Bridge	**None**	Follow general procedures	-	-
	Monitoring Review Point Trigger **Less than 5 mm gap between timber buffer board and road pavement above Abutment B (not including debris)**	Notify TC,RMS, MSO and SA	Within one week	Tahmoor Coal
		TC undertake following actions: - assess monitoring data - consider whether to increase survey and/or inspection frequencies - consider whether to commence structural analysis - consider whether to increase gap - consider whether any additional management measures are required - consider whether to temporarily close Bridge in accordance with traffic management plan	Within 48 hours of notification	Technical Committee
	Trip hazard forms in pedestrian walkway at gap between deck and Abutment B	Notify TC, MSO and SA	Within one week	Tahmoor Coal
		TC undertake following actions: - remove trip hazard - assess monitoring data - consider whether to increase survey and/or inspection frequencies - consider whether to commence structural analysis - consider whether any additional management measures are required	Within 48 hours of notification	Technical Committee
	A hazard has been identified that involves potential serious injury or illness to a person or persons on public property and cannot be controlled	Notify TC, MSO and SA	Within 24 hours	Tahmoor Coal
		TC undertake following actions: - assess monitoring data - consider whether to increase survey and/or inspection frequencies - consider whether to commence structural analysis - consider whether to increase gap - consider whether any additional management measures are required - consider whether to temporarily close Bridge in accordance with traffic management plan	Within 48 hours of notification	Technical Committee

Note: Unless specified above, each control procedure will continue until such time that the TC and RMS agree to cease. TC 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 W1-W2 (continued)

RISK ISSUE	TRIGGER	CONTROL PROCEDURES	TIMING & FREQ	BY WHOM?
Damage to Menangle Street – Picton Road	**None**	Follow general procedures	-	-
	Monitoring Review Point Trigger **Change identified that may be due to mining-related movements**	TC undertake following actions:: - consider whether impacts are due to mining-related movements - increase monitoring and reporting procedures - repair pavement	As required	TC
		Report trigger exceedence and TC decisions to MSO and SA NSW if it was agreed that impacts were due to mining-related movements	Within one week	Tahmoor Coal

Appendix B – Supporting Documents

Please find enclosed the following supporting documents:

- Cardno (2019) *Investigation of Potential Effects of Ground Movement due to Mining – Victoria Bridge*, Picton NSW, Cardno, Rev 5, 7 November 2019
- Tahmoor Coal (2019) *Risk Assessment Report – Far Field Subsidence Impacts – Victoria St Bridge*, Picton, 17 October 2019.

Investigation of Potential Effects of Ground Movement Due to Mining

Victoria Bridge, Picton NSW

80020038

Prepared for
Tahmoor Coal Pty Ltd

7 November 2019

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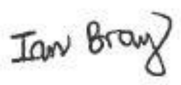
Approved By:



Name : Ian Bray
Job title : Senior Bridge Engineer

Date Approved 4/11/2019

Document History

Version	Effective Date	Description of Revision	Prepared by	Reviewed by
1	29/10/2019	First Draft	R. Woods	
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4	04/11/2019	Reviewed Final	R. Woods	I Bray
5	07/11/2019	Reviewed Final – Amdt 1	R. Woods	I Bray

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Tables

Figures

1 Introduction

Tahmoor Coal has carried out longwall mining in the vicinity of Victoria Bridge at Picton (Longwalls LW31 to LW32) and is planning to carry out further mining of another set of longwalls (LW W1 to LW W4). Tahmoor Coal is currently preparing a Management Plan for mining LW W1 and LW W2. Victoria Bridge is owned and maintained by Roads and Maritime Services (RMS). It is located to the north east of longwalls LW31 to LW37 and approximately 1.6 km from the closest point, which is the northern end of LW32. The future longwalls, LW W1 to LW W4, are to the west of Victoria Bridge and the closest point of the two longwalls that are the subject of the Management Plan, LW W1 and LW W2, will be 1.7 km and 1.4 km respectively from the bridge site.

Cardno was commissioned by Tahmoor Coal Pty Ltd in October 2019 to investigate the potential effects on Victoria Bridge of ground movement due to the mining of longwalls LW W1 and LW W2 and to advise on appropriate monitoring of the bridge structure and surrounding ground.

This report presents the findings of that investigation and provides recommendations for monitoring the bridge during mining.

2 Description of Victoria Bridge

The Bridge over Stonequarry Creek at Picton was completed in 1897 and consists of three Allan type timber truss main spans on very tall timber trestles (piers). The bridge has no approach spans and each of the main spans is 27.4m in length. The bridge is listed on the State Heritage Register on the basis of its technical and historical significance.

Victoria Bridge can accommodate a single lane of traffic. The bridge currently has a signposted load limit of 5 tonnes.

The truss is a timber Allan Truss, consisting of timber compression members and wrought iron rod tension members with a timber bottom chord. The top chord, bottom chord and diagonal members comprise double timber flitches with timber spacers. The cross girders rest on the bottom chord and consist of single timber beams which extend beyond the truss structure. The cross girders are spaced at 3.05m centres, with six timber longitudinal stringers supported on top of the cross girders. The stringers support a 4" thick timber plank deck. RMS has no information related to the wearing course and they have assumed that it comprises 4" timber sheeting and a 15mm thick bituminous surfacing on top of the timber deck.

The timber trestles are approximately 19.5m high and are supported on "Dwarf Walls" which appear from the drawings to have been constructed of unreinforced concrete. The dwarf walls are 1.4m thick and 18.3m long. The timbers of the trestles are connected using bolts and the sill members at the base are bolted to the dwarf walls with hold down bolts.

Due to deterioration and damage to the timber, rehabilitation works have been undertaken to ensure adequate safety to the bridge users. Completed rehabilitation works include the replacement of various timber truss members over the life of the bridge and the replacement of Abutment B at the eastern end to a new design (around 2007). The reconstruction of Abutment B replicated the appearance of the original design in timber, except that it included a reinforced concrete strip footing on rock and the main foundation. However, the timber walls do not function as a retaining wall to resist earth pressure from the approach embankment. The end of the approach embankment has been reconstructed using Expanded Polystyrene (EPS) blocks and is self-supporting. The EPS blocks are overlain by a concrete slab with an asphaltic concrete (AC) wearing surface. The timber walls of the new abutment have been constructed with a 40mm clear gap to the EPS blocks. At the road surface, a bumper board has been fixed to the end of the timber deck and there is a 20mm clear gap between the bumper board and the concrete slab and AC. Refer to Figure 2-1.

The timber structure of the reconstructed Abutment B is approximately 5m high and is quite flexible in the longitudinal direction. This flexibility is for movement in westerly as well as the easterly directions because the clear gaps to the EPS blocks and pavement allow unrestrained movement in that direction (at least up to the 20mm required to close the gap between the pavement and buffer board). The truss bottom chord timber corbels are notched over the timber sill of the abutment, preventing relative movement between these two elements. Thermal expansion and contraction of the truss spans is therefore accommodated by unrestrained swaying of the timber abutment in the longitudinal direction.

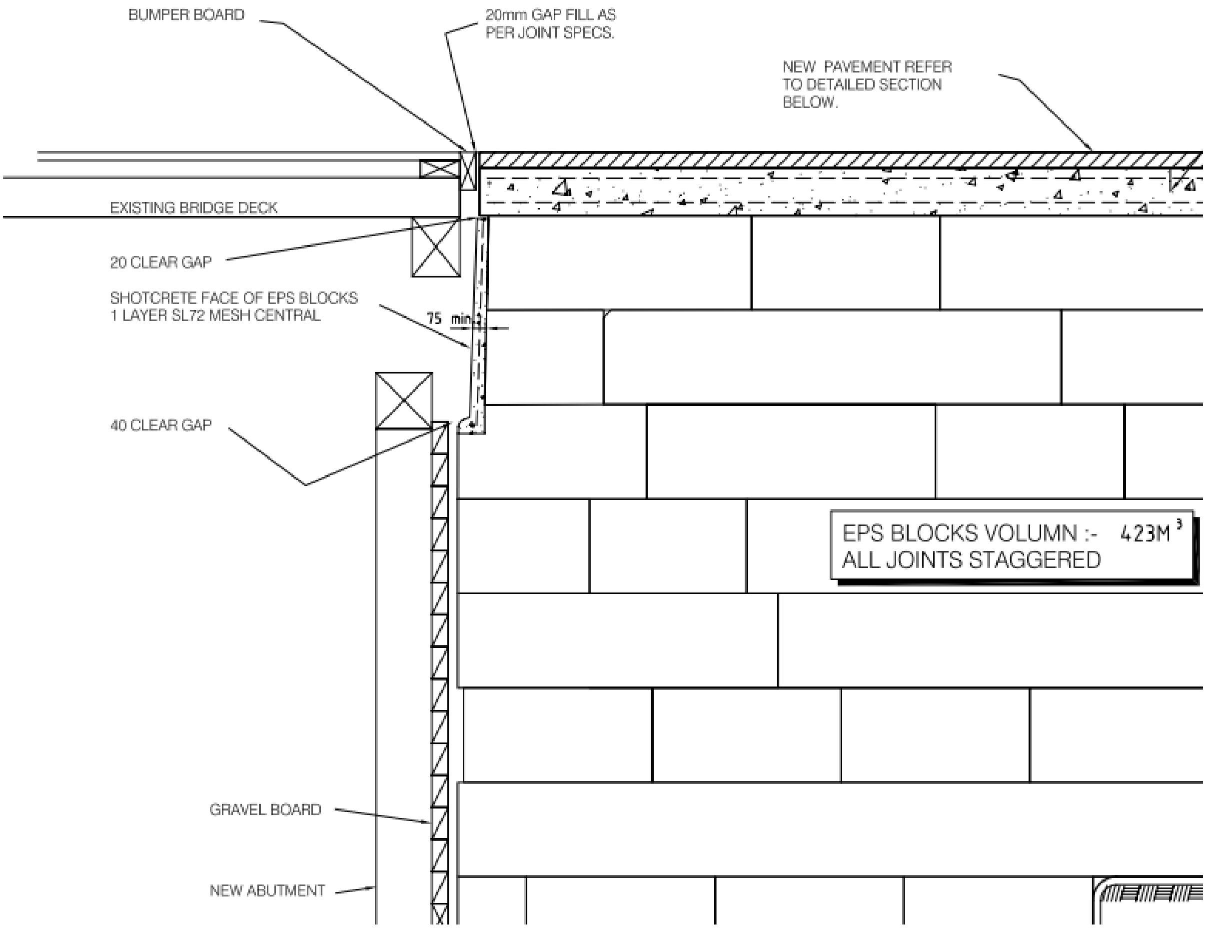

Figure 2-1 Reconstructed Abutment B - Section

The reconstruction of Abutment A at the western end is about to commence. It will comprise a reinforced concrete sill beam supported by reinforced concrete bored piers socketed into the rock. A major outcome of the replacement of this abutment is that it will have the capacity to resist all design braking forces (in the longitudinal direction).

Although the bridge was not originally designed for braking forces, any such longitudinal forces applied to the deck would have been resisted mainly the abutments because of the longitudinal flexibility of the tall timber trestles. Originally, Abutment A would have taken the larger portion of this force because it was much shorter than Abutment B. After the reconstruction of Abutment B, when it to became very flexible longitudinally, all braking forces would be required to be resisted by the Abutment A. Hence the need for the reconstruction to a new design.

RMS has provided copies of the drawings of the original 1897 bridge, a copy of the Options Study Report for Replacement of Abutment A and concept drawings of the reconstruction of Abutment B (western end) to Cardno. The above information about the bridge is largely based on information in those documents.

3 Predicted Ground Movements

Predictions of potential ground movements at the site of the bridge have been prepared by Mine Subsidence Engineering Consultants (MSEC) who have been engaged by Tahmoor Coal and these have been provided to Cardno and are reported in the Management Plan.

Although horizontal ground movements can occur in any direction, it is generally convenient to consider the components of these movements in two orthogonal directions, with one aligned with the direction of the bridge. Movements parallel with the centreline of the bridge are referred to a longitudinal movements and those perpendicular to the centreline (i.e. upstream/downstream) are referred to as transverse movements.

For prediction of differential longitudinal ground movements, MSEC use measured “opening” and “closing” movements between survey pegs that are typically spaced at 20m intervals and which have been obtained from surveys of a large number of monitoring lines near many mines in the southern coalfields. For predictions of differential transverse ground movements, MSEC use recorded “mid-ordinate” offsets which is the offset of the middle of three pegs (20m apart) from a straight line drawn between the other two pegs. From the same data, MSEC have determined the opening and closing movements over a distance of 70 to 90m, which can represent longitudinal movements between the abutments of the 82m long bridge.

The predicted ground movements provided by MSEC have been determined on a statistical basis. They have provided values at 95% and 99% confidence levels. A 95% confidence level means that there is a 95% probability that the actual ground movement will be less than or equal to value predicted.

The likely relative ground movements at Victoria Bridge, based statistically on measured ground survey data from past longwalls are presented in Table 3-1.

Table 3-1 Relative Ground Movements at Victoria Bridge

Offset Distance	Confidence Level	Opening (mm) Over		Closing (mm) Over		Mid-ordinate deviation Over 40m
		20m	70 – 90m	20m	70 - 90m	
1400m	95%	4	5	4	4	5
	99%	7	10	8	7	10
1700m	95%	3	3	4	5	3
	99%	5	10	6	8	8

4 Effects of Predicted Ground Movements

4.1 Overview

Structures are generally not affected by whole body movement of the body of ground on which they are supported. Such whole body movements of the structure, whether they be horizontal, vertical, tilting or a combination, generally do not cause any “change in shape” of the structure and therefore do not induce any stresses.

In structural engineering, “changes in shape” of a structure are referred to as distortions and distortions often (but not always) result in stresses in the structural members. Distortions of a structure, resulting in stresses, can only occur when one part of a structure moves relative to another part. Ground movements can cause structural distortions when part of the ground that is “attached to” (i.e. supporting) one part of the structure moves relative to the ground “attached to” another part of the structure. Therefore, it is the “relative” or “differential” ground movements that are significant to the bridge. The magnitude of the stresses developed depends on the magnitude of the distortions and the stiffness of the components of the structure.

The structural form of the Victoria Bridge is such that it is “attached” to the ground at four points, the two abutments and the two trestle piers.

4.2 Assessment Methodology

Where predicted differential ground movements are large and the stiffness of the structure is great, it is usual to carry out structural computer modelling of the bridge to determine the stresses induced in the various structural elements from the differential ground movements. In the case of Victoria Bridge, the predicted differential movements are small and the timber bridge is very flexible compared to most concrete or steel bridges. Therefore, a qualitative assessment of the effects of differential ground movement on the bridge has been carried out, based on the author’s experience with timber bridges, including timber truss spans supported on timber trestles.

4.3 Differential Vertical Ground Movement

Differential vertical ground movement between piers and abutments is predicted to be very small and probably nil. The bridge superstructure consists of three effectively simply supported truss spans. As such, differential vertical ground movement between the piers and abutments will not cause any significant stresses in either the truss or trestle pier members. However, the bottom timber chords of the truss are continuous at the two piers so differential vertical movement will cause a small localised bending stress in these chords at these locations.

The estimated timber stress from a 10mm differential vertical movement of Pier 1 relative to Abutment A and Pier 2 is 0.65 MPa. At this location, the timber bottom chords have no stresses from dead load or live load and so have a large reserve of bending capacity to accommodate any small bending stresses that might arise from differential vertical movement of the bridge supports.

While the stress grade of the timber is not known, RMS's expert in heritage timber trusses, Amy Nicholas, has advised me that it is most likely F22 or F27 and almost would certainly be F17. For F17 timber, the characteristic stress capacity in bending (f'_b) is 42 MPa and in compression (f'_c) is 34 MPa. (Refer Table A1 of AS5100.9:2017). The bending stress in the bottom chord induced by subsidence is only a small % of the bending stress capacity.

4.4 Differential Transverse Ground Movement

Differential transverse ground movement could cause the base of one or both trestle piers to move upstream or downstream relative to an imaginary line between the two abutments. Such differential transverse movement will cause the superstructure to bend in the transverse direction.

The most severe effect would occur if one pier moves transversely relative to the two abutments and the other pier. The 99% confidence level mid-ordinate deviation ground movement over 40m is 10mm so the corresponding transverse differential movement of one pier would be slightly greater than this (likely to be < 15mm)

The three truss spans are very flexible in transverse bending so the stresses caused by the differential transverse movement of the ground and trestles would be negligible. The flexibility of the superstructure in transverse bending is a result of the deck construction. As noted above, the deck is constructed of six timber longitudinal stringers supporting a 4" thick transverse timber plank deck. Such a deck has no significant transverse bending stiffness compared to say a 180mm x 5000mm wide reinforced concrete deck. There is no steel rod bracing system installed on this bridge, unlike some other timber truss spans, which would increase the transverse bending stiffness somewhat.

Because the deck is so flexible in transverse bending, the transverse force transmitted from to the deck from the pier when it's base moves transversely is very small. Therefore, no significant stresses are generated in the members of the timber trestle.

The concrete bases for the trestle piers are 18.3m long so the ground (rock) supporting the bases could stretch or compress over the length of the base by the predicted opening or closure ground movement (which is nominally over 20m). This "straining" of the ground could be tensile or compressive. The response of the unreinforced bases depends on the strength of the "bond" at the interface between the concrete and the rock.

If the straining is compressive and the bond is strong, compressive stresses could be induced in the base. However, even unreinforced concrete is strong in compression and the induced stresses are likely to be well within the compression capacity of the concrete.

If the straining is tensile and the bond is strong, tensile stresses could be induced in the concrete. As the concrete is weak in tension, cracking transverse to the base axis could occur. However, transverse cracks in the concrete will not affect the structural performance of the bases. The bases would be structurally adequate even if vertical joints had been deliberately formed during construction.

4.5 Differential Longitudinal Ground Movement

Differential longitudinal ground movement is almost always in the direction that causes the abutments to move together (closure).

The 99% confidence level differential longitudinal ground movement (max) over 20m is 8mm. The 99% confidence level differential longitudinal ground movement (max) over the 82m distance between abutments is estimated to be 10mm. (Refer to Table 3-1).

The truss superstructure is stiff in the longitudinal direction because the bottom chords are effectively continuous over the three spans (i.e. there are no intermediate movement joints). The abutment and pier bases, which are fixed to the ground, will move longitudinally closer together or further apart if there is differential longitudinal ground movement but the abutment and pier tops, where they are fixed to the truss, will stay at the same spacings. If the western embankment, the EPS blocks and supported pavement move with the natural ground below, the gap between the bumper board fixed to the end of the timber deck and the concrete slab and AC (20mm when Abutment B was reconstructed) will close.

Because the two trestle piers and Abutment B (the part supporting the trusses) are flexible in the longitudinal direction, this behaviour will not cause any significant stresses in the truss spans, the timber trestles or the timber abutments, provided the gap between the bumper board and the concrete slab remains open.

In the unlikely event that the longitudinal differential ground movement between abutments exceeds the abovementioned gap, the approach pavement concrete slab will contact the buffer board and a compression force will develop between these two elements. The buffer board will transmit this compression force to the timber deck stringers. It is possible that some of this compression will transfer to the bottom chords of the truss but it is unlikely to be of significant magnitude because of the flexibility of the load path between those components. The compressive stress that would develop in the deck stringers in this situation depends on whether the end to end connection between stringers are butt joints or have some gaps. It is likely that there are gaps between the ends of the stringers, reducing or eliminating the possibility of building up compressive stresses. Even if all the stringer joints are butt joints, the maximum compressive stress that could be induced is small.

For example, a 20mm compression (after gap closure) of the 82m long stringers without splice gaps would induce a maximum compressive stress of about 4.5 MPa without allowance for reduction due to creep. Because closure movement would occur over weeks, timber creep will reduce this compressive stress. The characteristic compression capacity of the timber members is 34 MPa, which is well in excess of 4.5 MPa.

In the remote possibility that opening movement occurs between abutments, the gap between the bumper board and the concrete slab would simply open up and there would be no effect on the bridge structure.

4.6 Summary of the Effects of Ground Movement

Because of the flexibility of the Victoria Bridge, distortion of the structure from differential ground movements between supports in the vertical, longitudinal and transverse directions will generally not cause any significant stresses in the structural components. The 99% confidence level closure movement (differential longitudinal movement) is not sufficient close the gap between the buffer board and the approach pavement at the western Abutment B, assuming that the gap remaining at the completion of reconstruction of Abutment A is at least 10mm. If the gap were to close fully, there is a possibility that compression stresses in the deck stringers may result but the magnitude depends on the combined size of all gaps between stringers at the end to end splices. Even if there are no gaps the compressive stress in the stringer will be small compared to their capacity.

5 Monitoring of Effects of Ground Movements

5.1 Aims and Types of Monitoring

Monitoring of the Victoria Bridge has the primary aims of measuring relative movement of the ground between the locations where substructure elements (abutments and piers) are founded and the distortion of the structure as a result of differential movements of the ground. Monitoring by conventional survey of key points on the bridge and the adjacent ground has typically been used for this purpose. The accuracy is typically 2 to 3mm. Measurement of the change in distance between key points on the structure, using rulers or tape measures, has also been used and is typically more accurate (to 0.5mm) and is less vulnerable to disturbance.

5.2 Recommended Monitoring

For this bridge, the recommended points at which survey targets should be attached and at which measurements are to be taken and the purpose they serve are described in Table 5-1.

Table 5-1 Recommended Survey Target Locations and Measurements

Id	Location	Movement Measured	Comment
1	Concrete Base at each Pier	Ground at pier and pier base	The pier base will generally move with the ground. One target on each base is sufficient. However, a target at each end of each base has already been installed so use all 4 targets.
2	Concrete Base at Abutment B	Ground movement at Abutment B	The timber structure at reconstructed Abutment B is supported on a concrete base beam which has been founded on rock. The base will move with the ground. One target is required. The base beam is buried an unknown distance below ground. If too deep, target should be attached to sound rock near Abutment B.
3	Rock or concrete base at Abutment A	Ground Movement at Abutment B	The positioning of the target should take into account the upcoming construction work at this abutment. Existing temporary support concrete bases, founded on rock, may be suitable. One target required.
4	Structure at Tops of Piers	Top of pier and truss at supports	Targets can be either attached to the top sill member of the pier trestle or the lower part of the truss in line with the pier. Truss is rigidly fixed to the pier so both will move together. One target required.
5	Timber Structure at tops of Abutments	Ends of truss at abutments	Targets can be either attached to the top sill member of the timber abutment or the lower part of the truss in line with the supporting timbers as both will move together. One target required.
6	Top of embankment at Abutment B	Top of embankment	This embankment, which was reconstructed using EPS blocks is structurally separated from the timber work supporting the truss and may move differently to both the end of the truss (Id 5) and the natural ground (Id 2). One target required.
7	Buffer Board at Abutment B	Change in gap between buffer board and approach pavement	the most direct assessment of the distortion that could have an adverse impact on the bridge structure.

It is essential that all targets are fixed rigidly to the ground or structure and fully protected from accidental or deliberate disturbance. For targets in accessible locations, consider using screwing targets into robust threaded sockets to allow removal after each survey.

There are some existing survey targets on the bridge which have been used for monitoring the structure for the effects of ground movements from LW31 to LW37. Existing targets are located at:

> Both ends of each pier base (Id 1),

> Both sides of Abutment A (Id 3). These have been partly obscured by the construction works.

> Both sides of Abutment B. These are located part way up the vertical timber members of the reconstructed abutments (between Id 2 and Id 5) to be out of easy reach. They are not at the most beneficial locations.

Monitoring measurement Id 7 is to determine the change in distance between the buffer board and the approach pavement at Abutment B. This measurement allows the most direct assessment of the only effect of ground movement that has a possibility (albeit very remote) of having an adverse impact on the bridge structure.

The gap between the buffer board and the approach pavement was shown on the concept drawings of the abutment reconstruction to be 20mm. It is not known what the “as-built” gap was and how it varied across the deck. The current gap is difficult to measure as there is some debris in the gap. If there is a significant amount of debris in the gap, it should be removed to allow the intended movement across the gap. There should be ongoing maintenance to ensure the gap remains free of debris.

5.3 Frequency of Monitoring

The recommended frequency of monitoring depends on the stage of mining and how much movement has occurred. Initially, monitoring can be monthly and this should increase to weekly if significant differential ground movement occurs (say 10mm between any 2 points or 5mm closure of the buffer board gap) or reduced to two monthly or quarterly if no differential ground movement, above survey tolerances, is detected.

5.4 Mitigation Actions and Trigger Levels

Because the bridge structure can readily tolerate differential ground movements and the predicted differential ground movements are so small, it is considered unnecessary to develop in detail mitigation measures that might be required.

The only circumstance envisaged which may require mitigation measures is if the buffer board gap closes almost completely. The probability of this happening is less than 1%. This circumstance will be detected by the change in the measured gap.

There are a number of possible mitigation measures that could be undertaken, all of which are relatively simple. These include:

> Removing the buffer board and replacing it with a thinner one to create a larger gap;

> Saw cutting the end of the approach pavement (slab and AC) to create a larger gap;

The recommended trigger for action is when the minimum gap over the full width of the interface reduces to 5mm (after removing any debris).

5.5 Impacts of Reconstruction of Abutment A

The reconstruction of Abutment A could have the effect of “resetting” any closure movements that have occurred to date. Currently, the ends of the truss bottom chords/corbels are notched around the supporting timber at Abutment A, preventing relative movement. During reconstruction of the abutment, the truss will be jacked up and the supporting timbers removed, eliminating that connection. The truss will be supported on adjacent temporary trestles which only restrain the superstructure horizontally by friction.

During the jacking of the truss and the transfer of load to the temporary trestle, there is a possibility that the whole superstructure may move slightly longitudinally. There will be little restraint of this movement from the piers and Abutment B timber structure as these are very flexible, as noted above. If such longitudinal movement occurs in the direction to cause closure of the gap, the bridge would have less capacity to accommodate ground closure movement between abutments from mining. This should be avoided. On the other hand, the opportunity could be taken to move the superstructure longitudinally to increase the buffer board gap at Abutment B (or to reinstate the intended initial gap) thereby providing greater capacity to accommodate ground closure movement.

To detect possible longitudinal movement of the superstructure during the jacking and subsequent construction activities, measurement of the buffer board gap should commence before jacking of the bridge occurs. It would also be beneficial, but not essential, for all the other survey targets to be set up and survey commenced before the bridge jacking. This should enable any effects of the jacking and construction to be identified and “differentiated” from ground movement effects.

Far Field Subsidence Impacts - Victoria St Bridge, Picton

Step 3: Identify the risks, causes and potential consequences			Step 4: Identify the existing controls to manage the identified risks	Steps 6, 7 & 8: Determine the Expected Consequence / Likelihood applicable to the Expected Consequence / Current level of risk				Step 10: PMC	Step 11: Treat the Risks			
Risk Description - Something happens......	**Consequence - resulting in:**	**Causes - Caused by**	**Existing Control Description**	**Expected Consequence Category**	**Expected Risk Consequence**	**Risk Likelihood**	**Current Risk Rating**	**Potential Maximum Consequence**	**Treatment plans/tasks (Description)**	**Task Owner**	**Due Date**	**Comments**
Mining of LWW1 and W2 at distances of >1.0km on Victora Road Bridge	Diferential vertical displacement	Conventional Subsidence	Flexible timber truss structure Mine plan (avoiding major structures) GNSS unit on Eastern abutment to monitor movement Two survey markings at Eastern and Western ends of bridge Survey marks on abutments and base of piers at both sides LWW1&2 survey data RMS inspection and maintenance regime Option to close bridge	Infrastructure	1 (Insignificant)	E (Rare)	Low	1 (Insignificant)	Prepare Management Plan Review drawings and perform site structural inspection Dilapidation report to be completed prior to LW commencement	DT DT DT	04/11/2019 25/10/2019 10/11/2019	Richard to complete inspection by 25/10/19
	Loss of expansion capacity	Valley Closure	Flexible timber truss structure Mine plan (avoiding major structures) GNSS unit on Eastern abutment to monitor movement Two survey markings at Eastern and Western ends of bridge Survey marks on abutments and base of piers at both sides LWW1&2 survey data RMS inspection and maintenance regime Option to close bridge	Infrastructure	1 (Insignificant)	E (Rare)	Low	3	Survey expansion gap between truss and Eastern abutment	DT	20/12/2019	Baseline prior to LW start up
	Valley closure resulting in need to reset expansion joint at Eastern abuttment	Valley Closure	Flexible timber truss structure Mine plan (avoiding major structures) GNSS unit on Eastern abutment to monitor movement Two survey markings at Eastern and Western ends of bridge Survey marks on abutments and base of piers at both sides LWW1&2 survey data RMS inspection and maintenance regime Option to close bridge	Infrastructure	3 (Moderate)	E (Rare)	Medium	3 (Moderate)	Survey expansion gap between truss and Eastern abutment Prepare Management Plan Review drawings and perform site structural inspection	DT DT DT	20/12/2019 04/11/2019 10/11/2019	

	Lateral distortion of deck	Far-field effects differential horizontal movments ground shear in horizontal direction	Flexible timber truss structure Mine plan (avoiding major structures) GNSS unit on Eastern abutment to monitor movement Two survey markings at Eastern and Western ends of bridge Survey marks on abutments and base of piers at both sides LWW1&2 survey data RMS inspection and maintenance regime Option to close bridge	Infrastructure	1 (Insignificant)	E (Rare)	Low	3 (Moderate)	Prepare Management Plan Review drawings and perform site structural inspection	DT DT	04/11/2019 25/10/2019	
	Gap/Trip hazard between deck and abutment	Valley opening	Flexible timber truss structure Mine plan (avoiding major structures) GNSS unit on Eastern abutment to monitor movement Two survey markings at Eastern and Western ends of bridge Survey marks on abutments and base of piers at both sides LWW1&2 survey data RMS inspection and maintenance regime	Safety	1 (Insignificant)	E (Rare)	Low	1 (Insignificant)				
Menangle St from Matthews Lane to Argyle St	Deformation of road	Differential subsidence	Annual road condition survey Flexible pavement road Mine plan	Infrastructure	1 (Insignificant)	E (Rare)	Low	1 (Insignificant)	Dilapidation Report to be completed Pre-mining road inspection to be completed	DT DT	10/11/2019 10/11/2019	