Fig. 6.36 Mushroom Tunnel

The Mushroom Tunnel is used as part of the vehicular access road along the Main Southern Railway. It is also occasionally used for heritage tours.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for these tunnels, after the completion of the proposed longwalls, is provided in Table 5.6. The predicted tilts and curvatures are the maxima in any direction during or after the extraction of each of the proposed longwalls.

Table 6.26 Maximum Predicted Total Conventional Subsidence Parameters for the Picton and Mushroom Tunnels Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
Picton Tunnel	30	< 0.5	< 0.01	< 0.01
Mushroom Tunnel	20	< 0.5	< 0.01	< 0.01

Whilst the tunnels could experience low level vertical subsidence, they are not expected to experience any measurable tilts, curvatures or strains, even if the predictions were exceeded by a factor of 2 times.

The Picton Rail and Mushroom Tunnels could experience far-field horizontal movements resulting from the proposed mining. It can be seen from Fig. 4.13, that incremental far-field horizontal movements around 150 mm have been measured at distances of 400 metres from previously extracted longwalls in the NSW Coalfields.

The potential for impacts on the tunnels do not result from absolute far-field horizontal movements, but rather from differential horizontal movements over the lengths of the structures. The potential for differential horizontal movements at the Picton Rail and Mushroom Tunnels has been assessed by statistically analysing the available 3D monitoring data from the Southern Coalfield.

The histograms of the maximum observed incremental opening and closing movements for survey marks spaced at 200 metres ±10 metres, at distances between 300 metres and 600 metres from active longwalls, are shown in Fig. 4.14. The *Generalised Pareto Distributions (GPDs)* which have been fitted to this data have also been shown in these figures.

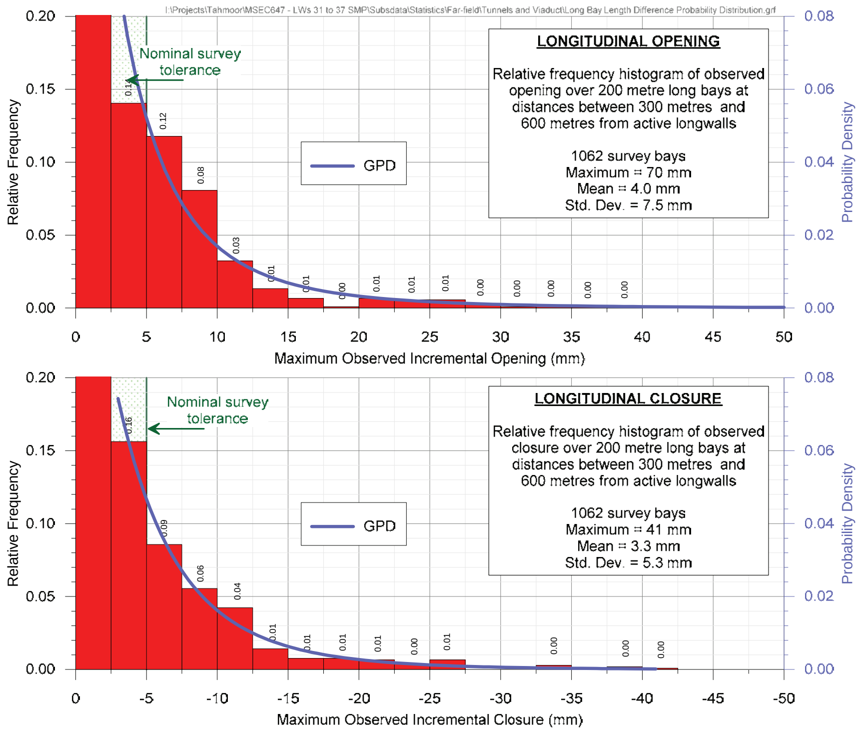


Fig. 6.37 Distributions of the Maximum Observed Incremental Opening and Closure for Survey Marks Spaced at 200 metres ±10 metres at Distances between 300 metres and 600 metres from Active Longwalls

The maximum incremental longitudinal movements over the lengths of the tunnels, based on the fitted GPDs to the available ground monitoring data, are 16 mm opening and 14 mm closure, based on the 95 % confidence levels.

Mid-ordinate deviation is a measure of differential lateral movement, which is the change in perpendicular horizontal distance from a point to a chord formed by joining points on either side. A schematic sketch showing the mid-ordinate deviation of a peg compared to its adjacent survey pegs between two survey epochs is provided in Section 6.6.2.

The histograms of the maximum observed incremental horizontal mid-ordinate deviation for three survey marks spaced a total of 200 metres ±10 metres, at distances between 300 metres and 600 metres from active longwalls, is shown in Fig. 4.16.

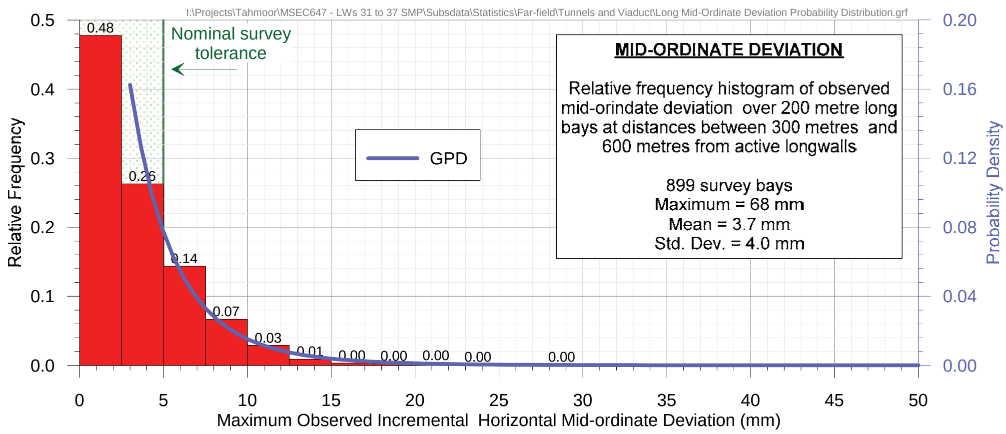


Fig. 6.38 Observed Incremental Horizontal Mid-Ordinate Deviation for Survey Marks Spaced a total of 200 metres ±10 metres at Distances between 300 metres and 600 metres from Active Longwalls

The maximum incremental horizontal mid-ordinate deviation over the lengths of the tunnels, based on the fitted GPD to the available ground monitoring data, is 11 mm, based on the 95 % confidence level.

Tahmoor Colliery has previously successfully extracted Longwall 26 adjacent to the former Redbank Railway Tunnel. The closest distance between the Tunnel and Longwall 26 was approximately 500 metres. The tunnel was successfully managed during mining, and similar management strategies could be adopted for the operating Picton Tunnel, given that subsidence predictions are similar.

Changes in horizontal distances across the width of the Tunnel were measured by automated total stations, tape extensometers and laser distancemeters, at numerous array locations along the length of the tunnel. Changes in horizontal distances correlated well with changes in temperature for all but one of the arrays.

Changes in horizontal distances along the 300 metre long length of the Tunnel were measured by traditional ground survey and by the automated total stations. It was found that the Tunnel shortened in length by a very small amount of approximately 5 mm.

Ground survey lines monitored subsidence movements on the ground surface above the Tunnel along the Tunnel centreline and across the Tunnel. The survey results did not indicate irregular subsidence movement in the vicinity of the Tunnel, though it is noted that the accuracy of the surveys was hindered by sharp changes in vertical elevation.

Inclinometer monitoring during the mining of Longwalls 25 and 26 measured very small rotation of the rock mass around the Tunnel towards the longwall. The presence of the Tunnel was recognised in the behaviour of the rock mass. Very small horizontal shears were detected, though none appeared to be within the horizon of the tunnel.

Detailed visual inspections of the masonry lining were undertaken at monthly intervals during mining. Some existing cracks were observed to lengthen during mining, particularly around one array, Array 3.

It is recommended that Tahmoor Colliery and ARTC undertake measures to manage potential impacts on the Picton Rail Tunnel and the Mushroom Tunnel during the mining of the proposed longwalls. It is recommended that the management measures be similar to those undertaken on the former Redbank Railway Tunnel during the mining of Longwall 26. The management measures include :-

- Assess pre-mining condition of the tunnels;
- Install a monitoring system, which includes, among other things, the monitoring of tunnel movements and movements of the ground above and around each tunnel;
- Regularly review and assess the monitoring data; and
- Conduct regular visual inspections of the tunnels.

With an appropriate management plan in place, it is considered that potential impacts on the Tunnels can be managed during the mining of the proposed longwalls, even if actual subsidence movements are greater than the predictions or substantial non-conventional movements occur.

6.8. Potable Water Infrastructure

The locations of the potable water infrastructure within the SMP Area are shown in Drawing Nos. MSEC647-16 and MSEC647-17. The predictions and impact assessments for the potable water infrastructure are provided in the following sections.

6.8.1. Description of the Potable Water Infrastructure

There are approximately 8 kilometres of water mains within the SMP Area, which are owned by Sydney Water. The potable water pipelines within the SMP Area are shown according to their pipe sizes in Drawing No. MSEC647-16.

A summary of the total lengths of each diameter of water main is provided in Table 6.27. It can be seen from the drawing and table that the water mains range in diameter between 100 mm and 200 mm, where 150 mm diameter pipes represent the majority of the network. The larger diameter water mains are located outside the SMP Area.

Table 6.27 Distribution of Water Mains by Pipe Diameter

Pipe Diameter (mm)	Total Length within SMP Area (m)	Percentage
100	1,858	23.1 %
150	3,526	43.8 %
180	113	1.4 %
200	2,554	31.7 %
Total	**8,051**	**100 %**

The pipes are also shown according to their type in Drawing No. MSEC647-17. The majority of the pipes are Cast Iron Cement Lined (CICL) pipes, with smaller lengths of Ductile Iron Cement Lined (DICL), and plastic PE, oPVC and uPVC pipes. The water pipelines are owned and operated by Sydney Water. A summary of the total lengths of each type of pipe is provided in Table 6.28.

Table 6.28 Distribution of Water Mains by Pipe Type

Pipe Type	Total Length within SMP Area (m)	Percentage
CICL	3149	39.1 %
DICL	1313	16.3 %
oPVC	911	11.3 %
uPVC	2551	31.7 %
PE	113	1.4 %
Unknown	15	0.2 %
Total	**8051**	**100 %**

The Sydney Water Depot is located on George Street outside the SMP Area. No valves within the distribution network are located within the SMP Area, as shown in Drawing No. MSEC647-17.

6.8.2. Predictions for the Potable Water Infrastructure

The potable water pipelines generally follow the alignments of the local roads within the SMP Area. The predicted profiles of incremental and total conventional subsidence, tilt and curvature for the pipelines which follow the alignments of Remembrance Drive, Bridge Street, Stonequarry Creek Road and Thirlmere Way are similar to those predicted along these roads, which are shown in Figs. E.15 to E.18.

The pipelines are located across the SMP Area and, therefore, are expected to experience the full range of the predicted mine subsidence movements. The maximum predicted subsidence parameters resulting from the extraction of the proposed longwalls are provided in Chapter 4.

The predicted strains for the potable water pipelines have been based on the statistical analysis of strains provided in Section 4.5. The pipelines are linear features and, therefore, the most relevant distributions of strain are the maximum strains measured anywhere along whole monitoring lines above the previously extracted longwalls, which are discussed in Section 4.5.2.

The potable water pipelines cross a number of tributaries and could experience valley related movements in these locations. The maximum predicted upsidence, closure and compressive strains at these tributary crossings are discussed in Section 5.4.

6.8.3. Impact Assessments for the Potable Water Infrastructure

The maximum predicted curvatures and the range of potential strains at the water infrastructure, resulting from the extraction of the proposed longwalls, are similar to those typically experienced elsewhere in the Southern Coalfield. Longwalls in the Southern Coalfield have successfully mined directly beneath water pipelines in the past, and some of these cases are provided in Table 6.29.

Table 6.29 Examples of Previous Experience of Mining Beneath Water Pipelines in the Southern Coalfield

Colliery and LWs	Pipelines	Observed Movements	Observed Impacts
Appin LW301 and LW302	0.6 km of 150 dia DICL 0.6 km of 300 dia CICL 0.6 km of 1200 dia SCL	650 mm Subsidence 4.5 mm/m Tilt 1 mm/m Tensile Strain 3 mm/m Comp. Strain (Measured M & N-Lines)	Leakage of the 150 mm and 300 mm CICL pipelines at a creek crossing, elsewhere no other reported impacts
Tahmoor LW22 to LW27	4.8 km DICL pipes 19.0 km CICL pipes	1370 mm Subsidence 8 mm/m Tilt 1.5 mm (typ) and up to 4.1mm/m Tensile Strain 2 mm (typ.) and up to 6.3 mm/m Comp. Strain (Extensive street monitoring)	A few reported impacts to the distribution network and a very small number of minor leaks in the consumer connection pipes, which are summarised below this table.
West Cliff LW5A3, LW5A4 & LW29 to LW34	2.8 km of 100 dia CICL pipe directly mined beneath	1100 mm Subsidence 10 mm/m Tilt 1 mm/m Tensile Strain 5.5 mm/m Comp. Strain (Measured B-Line)	No reported impacts

It can be seen from the above table, that the incidence of impacts on water pipelines is small.

Longwalls 22 to 27 at Tahmoor have directly mined beneath approximately 4.8 kilometres of DICL pipe and 19.0 kilometres of CICL pipe, with minimal impact to the distribution network reported. The reported impacts are listed below:

- There was a leak in a CICL water main on Glenanne Place during the mining of Longwall 24B. While there was no ground survey data to quantify the ground movements, the leak coincided with damage to the road pavement and damage to a fence. It is considered that non-conventional movements developed at this location;
- A water leak was observed in a CICL water main on York Street opposite the Tahmoor Town Centre during the mining of Longwall 25. While no impacts were reported to the road pavement and no elevated ground strain was observed at the leak, a bump was observed in the subsidence profile near the location of the leak;
- A CICL water main leaked on Moorland Road during Longwall 26, where increased ground strains and a small bump in the subsidence profile were observed. The pipe was repaired the same day;
- A CICL water leak was observed on York Street on two occasions during Longwall 26, at a site where increased strain and a bump were observed. The leak was repaired each time;
- A very small number of minor leaks have also been observed to consumer connection pipes on private properties. Remedial works were undertaken and the leaks repaired; and
- There was a leak in a 100mm diameter CICL water main in the last week of January 2013 during the mining of Longwall 27. The leak was repaired the same day.

Based on experience during the mining Longwalls 22 to 27, it is considered that the mining of the proposed longwalls is unlikely to result in any significant impact to the potable water infrastructure within the SMP Area. The range of subsidence movements is predicted to be similar to that experienced during the mining of Longwalls 22 to 27, and the nature of infrastructure within the SMP Area is similar to that located above Longwalls 22 to 27. The length of potable water pipe directly above Longwalls 31 to 37 is less than for Longwalls 22 to 27, and further to this, the majority of pipe above Longwalls 31 to 37 is uPVC, which is inherently flexible. Although these factors are likely to lead to low incidence of impact, it is still likely, however, that a small number of leaks will occur as a result of subsidence. These are most likely to occur where elevated strains and curvature are observed.

Impacts are more likely to occur in the locations of non-conventional movements or at the creek crossings. Any impacts are expected to be of a minor nature which could be readily remediated. The most noticeable example of this is the crossing of a 200 mm diameter DICL pipe along Remembrance Drive at Redbank Creek, which is understood to be direct buried in a trench beneath the creek.

Tahmoor Colliery and Sydney Water have developed and acted in accordance with an agreed risk management plan to manage potential impacts to potable water infrastructure during the mining of Longwalls 22 to 30. The management plan provides for ground and visual monitoring.

The management plan also provides for planned responses if triggered by the observations of impacts. If impacts occur to the network, Sydney Water is able to quickly repair leaks, if required.

The management plan is reviewed periodically by Tahmoor Colliery and Sydney Water.

It is recommended that Tahmoor Colliery and Sydney Water continue to develop management plans to manage potential impacts during the mining of the proposed longwalls. This will include focus on the management of potential impacts at creek crossings and drainage lines.

6.8.4. Impact Assessments for the Sydney Water Infrastructure Based on Increased Predictions

If the conventional subsidence movements exceeded those predicted by a factor of 2 times, the maximum tilt at the water infrastructure would be 11.1 mm/m (i.e. 1.1 %), or a change in grade of 1 in 90. The water pipelines are pressure mains and, therefore, are unlikely to be affected to any great extent by changes in gradient due to subsidence or tilt.

If the conventional subsidence movements exceeded those predicted by a factor of 2 times, the maximum curvature at the water infrastructure would be 0.22 km^{-1}, which represents a minimum radius of curvature of 4.5 kilometres and a compressive strain of 3.3mm/m. The curvatures and strains at the water infrastructure would still be less than those experienced where water infrastructure was directly mined beneath by the previously extracted longwalls at Tahmoor Colliery. Based on this experience, it would be expected that some minor leakages could occur, but the incidence of impact would still be expected to be low.

6.8.5. Recommendations for the Sydney Water Infrastructure

Tahmoor Colliery and Sydney Water have developed and acted in accordance with an agreed risk management plan to manage potential impacts to potable water infrastructure during the mining of Longwalls 22 to 30. It is recommended that this management plan is reviewed and updated to incorporate the proposed longwalls.

6.9. Sewerage Infrastructure

6.9.1. Description of Sewerage Infrastructure

There are approximately 8.3 kilometres of sewer pipes within the SMP Area, which are owned by Sydney Water. The Picton Regional Sewerage Scheme collects sewage from the urban area of Tahmoor and transports it by gravity and with pumps to the Picton Water Recycling Plant, which also lies within the SMP Area. The sewer pipes were installed in 2000.

The Picton Regional Sewerage Scheme also transfers sewage from the Bargo Priority Sewerage Program reticulation network, which was completed in 2014. The Bargo Priority Sewerage Program reticulation network, including the transfer main, is located outside the SMP Area.

With the exception of the rising mains, all of the sewer pipes are designed at self-cleansing grades. The average grade of the sewer pipes within the SMP Area is approximately 38 mm/m.

The design for the gravity sewer system was approved by the Mine Subsidence Board, on the condition that the sewers were installed at least 3 mm/m greater than the minimum grade required for the pipes to be self-cleansing.

The designs for the rising mains are certified in accordance with the requirement of the Mine Subsidence Board, which specified maximum vertical subsidence of 750 mm, maximum tensile strain of 1.5 mm/m, maximum compressive strain of 2.5 mm/m and maximum curvature of 8 kilometres.

The sewer pipes are constructed from PVC and have extra length sockets and rubber ring joints, which will allow them to accommodate tensile and compressive ground strains and curvature. The pipe sections are typically 3 metres long. The majority of the sewer mains are laid on sand and buried in trenches.

While the pipes are constructed of PVC, a number of pipes are concrete encased. There are two sections of pipe within the SMP Area that are concrete encased in horizontal bores: one beneath the Main Southern Railway and one beneath Remembrance Drive. One section of pipe is supported via a bridge aqueduct structure.

Information regarding the sewerage network has been provided in GIS format by Sydney Water, and has been used to provide detailed impact assessments on the sewers within the SMP Area.

The sewer pipelines within the SMP Area are shown according to their pipe sizes in Drawing No. MSEC647-18. It can be seen that a large proportion of the pipes within the SMP Area will not be mined directly beneath by the proposed longwalls. Of the 8.3 kilometres within the SMP Area, approximately 1.6 kilometres of pipes are located directly above the proposed Longwalls 31 to 37.

It can also be seen from this drawing that the sewer mains range in diameter between 100 mm and 450 mm. The larger sewer mains are located along Remembrance Drive and along mains that transfer sewage to the Picton Water Recycling Plant. A summary of the total lengths of each diameter of sewer pipe is provided in Table 6.30.

Table 6.30 Distribution of Sewer Pipes by Pipe Diameter

Pipe Diameter (mm)	Total Length within SMP Area (m)	Percentage
100	1,335	16.0 %
150	2,091	25.1 %
225	977	11.7 %
375	2,653	31.9 %
450	1,269	15.2 %
Total	**8,325**	**100 %**

The pipes are also shown according to their type in Drawing No. MSEC647-19. The majority of pipes are reticulation pipes that transport sewage to the rising mains and carrier pipes. A summary of the total lengths of each type of pipe is provided in Table 6.31.

Table 6.31 Distribution of Sewer Pipes by Pipe Type

Pipe Diameter (mm)	Total Length within SMP Area (m)	Percentage
Branch	2,138	25.7 %
Pressure Main	1,782	21.4 %
Property Connection Sewer	416	5.0 %
Reticulation	3,986	47.9 %
Scour	2	0.0 %
Total	**8,325**	**100 %**

The majority of the sideline and reticulation pipes are 100 mm and 150 mm in diameter, with a section of pipes along Henry Street and Bollard Place with a diameter of 225 mm. The rising mains are 375 mm and 450 mm in diameter, and the carriers are 375 mm and 450 mm in diameter.

There are two rising mains within the SMP Area, both of which finish at the Picton Water Recycling Plant. The sewage pumping station (Ref. SP0914) located near the end of Wild Street at Picton pumps sewage from the townships of Thirlmere and Picton to the Picton Water Recycling Plant. Sewage from the townships of Tahmoor, Bargo and Buxton are pumped via a rising main from a sewage pumping station (Ref. SP0920) that is located near the end of Suffolk Place at Tahmoor, located to the south of the SMP Area, beyond the extent of Drawing No. MSEC647-20. The proposed longwalls are not located directly beneath the rising mains.

6.9.2. Self-Cleansing Gravity Sewers

Longwalls 22 to 27 have directly mined beneath approximately 27.3 kilometres of sewer pipes. While changes in sewer grades have occurred as a result of mine subsidence, no blockages or reversals of grade have been observed. This includes observations at locations above Longwalls 24A to 27 where specific ground surveys were undertaken to confirm that mining-induced tilts did not exceed pre-mining grades.

There are approximately 6.5 kilometres of self-cleansing gravity sewers within the SMP Area. The pipes' ability to self-cleanse is dependent on their gradients, which vary according to the diameter of the pipe. The minimum grades for self cleansing are provided in the Picton Regional Sewerage Scheme Design and Construction Plan (Issue A, Rev. 1), and are shown in Table 6.32. The design for the sewer system was approved by the Mine Subsidence Board, on the condition that the sewers were installed at least 3 mm/m (0.3%) greater than the minimum grade required for the pipes to be self-cleansing, which are also shown in Table 6.32.

Table 6.32 Self-Cleansing Grade of Gravity Sewers and MSB Requirements

Pipe Diameter	Minimum Grade for Self-Cleansing (%)	Minimum Grade to comply with MSB Requirements (%)
100	1.25	1.55
150	0.50	0.80
225	0.33	0.63
300	0.25	0.55
375	0.20	0.50
450	0.16	0.46

The pre-mining grades of each section of pipe were provided in GIS format by Sydney Water. It is noted that 0.4 kilometres (5%) of sewer pipes did not have any recorded grades in the GIS. All of these pipes are, however, small in diameter (100 mm or 150 mm) and short in length, with an average length of approximately 5 metres.

Upon examination of this information, it was found that the pipe sections located directly above the proposed longwalls have been installed to grades greater than those required by the Mine Subsidence Board. The average grade of all pipe sections within the SMP Area was approximately 3.8%, or 38 mm/m.

The minimum grade of the reticulation pipes located directly above the proposed longwalls is 13.8 mm/m, which is well above the predicted maximum mining-induced tilt of 6 mm/m. It is therefore concluded that while the reticulation pipes will experience increases or reductions in grade due to the extraction of the proposed longwalls, the grades during and after mining are likely to remain greater than the grades required for self-cleansing.

The proposed longwalls will mine directly beneath the Thirlmere Carrier pipe on Bridge Street, as shown in Drawing No. MSEC647-19. The predicted profiles of incremental and total conventional subsidence and change in grade along the alignments of the Thirlmere Carrier Sewer, resulting from the extraction of the proposed longwalls, are shown in Fig. E.19 in Appendix E.

The minimum grade of the Carrier pipes located directly above the proposed longwalls is 5 mm/m. It can be seen, however, from the graph that the grades of the Carrier pipes within the SMP Area are not predicted to reduce below self-cleansing grade during or after the extraction of the proposed longwalls. This is because the locations of the predicted maximum mining-induced tilts that could reduce the grades of the pipes do not coincide with locations where the existing grades are small.

There are, however, a number of sections with low grades and some are predicted to experience a reduction in grade. These include two sections above proposed Longwalls 31 and 32. As shown in Fig. E.19, a short section of pipe above Longwall 30 is predicted to experience a reduction in grade below the minimum required for self-cleansing. The grade is predicted, however, to improve after the mining of Longwall 31.

It is concluded, therefore, that while the reticulation pipes will experience increases or reductions in grade due to the extraction of the proposed longwalls, the grades during and after mining are unlikely to reduce below the grades required for self-cleansing.

The risk associated with sewers that have grades less than self-cleansing is that a blockage may develop in the pipes over time. This risk can be reduced by periodic cleaning of the sewer, which incurs an increase in the cost of maintenance of the system, or by re-laying the pipes to higher grades, which may not be practically possible due to the topography of the land. It is noted in this case that the sections of pipe predicted to reduce in grades less than self-cleansing are quite short (less than 50 metres).

The potential impacts on grades along the Thirlmere Carrier have been previously managed successfully by Tahmoor and these are discussed in Section 6.9.9.

6.9.3. Sewer Pipes and Pipe Joints

Longwalls 22 to 27 have directly mined beneath approximately 27.3 kilometres of sewer pipes. The following observations have been made:

- There were no observations of damage during the mining of Longwalls 22 to 24 and Longwall 27;
- Physical damage was observed at three locations during the mining of Longwall 25. In each case the pipes remained serviceable, though repairs were required at each location:
    - Crushing and vertical bending of 150 mm diameter pipe at Abelia Street. The impacts coincide with a large measured ground strain of 4.6 mm/m (over a 22 metre bay length) between Pegs A12 and A13, a measured vertical bump in the subsidence profile and an observed hump in the road pavement. The pipe was repaired prior to the influence of Longwall 26 and no impacts were observed to the repaired pipe during the mining of this longwall;
    - Crushing and vertical bending of 150 mm diameter pipe at Remembrance Drive. The impacts coincide with a large measured ground strain of 2.8 mm/m (over a 37 metre bay length) between Pegs R1 and RE1, a measured vertical bump in the subsidence profile and an observed hump in the road pavement and roundabout. The pipe was repaired prior to the influence of Longwall 26 and no impacts were observed to the repaired pipe during the mining of this longwall;
    - Crushing and vertical bending of the 225 mm diameter horizontal bore between Amblecote Place and Myrtle Creek;
- Physical damage was observed at two new locations during the mining of Longwall 26. In each case the pipes remained serviceable, though repairs were required at each location:
    - Deformation and cracking of 100 mm diameter pipe at Tahmoor Road. The pipe was repaired;
    - Deformation of 150 mm diameter pipe between Abelia Street and Oxley Grove where non-conventional subsidence movements were observed (this may have occurred during the mining of Longwall 25). The pipe was repaired; and
    - Continued deformation of the 225 mm diameter concrete encased horizontal bore between Amblecote Place and Myrtle Creek from Castlereagh Street to Brundah Road. This required extensive repairs as the horizontal bore was located deep below the surface behind a number of houses. A new horizontal bore was installed as part of the repair solution.

Based on experience during the mining of Longwalls 22 to 27, it is considered that the mining of the proposed longwalls is unlikely to result in any significant impact to the sewer pipes and joints within the SMP Area. The range of subsidence movements is predicted to be similar to those experienced during the mining of Longwalls 22 to 27. The nature of infrastructure within the SMP Area is similar to that located above Longwalls 22 to 27. It is likely, however, that a small number of impacts will occur as a result of subsidence. These are most likely to occur where elevated strains and curvature are observed.

Elevated strains and curvatures are consistently observed across streams. The Thirlmere Carrier and reticulation sewer pipes cross a number of small streams at other locations in the SMP Area, including a hidden creek at Redbank Place. It is noted that the Thirlmere Carrier pipe crosses Redbank Creek via a pipe aqueduct. Potential impacts on the aqueduct are discussed in Section 6.9.6.

The Thirlmere Carrier also runs alongside Redbank Creek, including one section that is located directly above Longwall 32. The pipes may experience valley closure related impacts in these sections, even though they are not located across the creek. Sewer pipes are also located alongside Myrtle Creek and very different experiences were observed at two separate sites during the mining of Longwalls 25 to 27.

- The Tahmoor Carrier pipes ran alongside Myrtle Creek directly above previously extracted Longwalls 26 and 27. No impacts were observed to the pipes. The scenario is similar to the Thirlmere Carrier in that the pipes were buried at relatively shallow depths beneath the surface and are not concrete encased; and
- Deformation and substantial repairs were undertaken to the concrete encased horizontal bore that was located between Amblecote Place and Myrtle Creek from Castlereagh Street to Brundah Road. The scenario is not similar to the Thirlmere Carrier because the pipes behind Amblecote Place were concrete encased in a horizontal bore through rock. Shearing along bedding planes in the rock were transferred directly into the PVC pipes. In this case, the pipes were buried at relatively shallow depth beneath the surface in trenches and backfilled and were not concrete encased.

The potential impacts on sewer pipes have been previously managed successfully by Tahmoor and these are discussed in Section 6.9.9.

6.9.4. Rising Mains and Sewage Pumping Stations

There are two rising mains within the SMP Area, both of which finish at the Picton Water Recycling Plant. The rising mains represent the downstream end of the sewerage network.

The 450 mm diameter PVC rising main pumps sewage from the townships of Thirlmere and Picton to the Picton Water Recycling Plant from sewage pumping station (Ref. SP0914), which is located outside the SMP Area near the end of Wild Street at Picton. The proposed longwalls do not mine directly beneath the rising main, which is located just inside the boundary of the SMP area. The closest distance between the rising main and the side of proposed Longwall 32 is approximately 260 metres.

The rising main is predicted to experience less than 50 mm of conventional subsidence, with negligible mining-induced curvature and the likelihood of impacts from conventional subsidence is extremely low. This is assessment is supported by the experience of mining previously extracted Longwall 25 directly beneath the rising main that runs from the pumping station SP1045 at Castlereagh Street without any impacts.

There is a small likelihood that the rising main may experience impacts from non-conventional subsidence movements during the mining of Longwall 32. The rising main crosses two small creeks just north of where the pipes are diverted around a wastewater treatment dam. One of the creek lines is approximately parallel to the mapped alignment of the Nepean Fault. Given the offset distance of the proposed longwalls to the rising main, the likelihood of impacts is considered to be very low. It is recommended, however, that the potential impacts are managed during mining and this is discussed further in Section 6.9.9.

Sewage from the townships of Tahmoor, Bargo and Buxton is pumped via a rising main from a sewage pumping station (Ref. SP0920) that is located near the end of Suffolk Place at Tahmoor, located to the south of the SMP Area, beyond the extent of Drawing No. MSEC647-19. The proposed longwalls do not mine directly beneath the rising main, which is located just inside the boundary of the SMP area. The closest distance between the rising main and the end of proposed Longwall 32 is approximately 140 metres.

The rising main is predicted to experience less than 30 mm of conventional subsidence, with negligible mining-induced curvature and the likelihood of impacts from conventional subsidence is extremely low.

There is a small likelihood that the rising main may experience impacts from non-conventional subsidence movements during the mining of Longwall 32. The rising main runs along the side of a ridge that is approximately parallel to the mapped alignment of the Nepean Fault. Given the offset distance of the proposed longwalls to the rising main, the likelihood of impacts is considered to be rare. It is recommended, however, that the potential impacts are managed during mining and this is discussed further in Section 6.9.9.

6.9.5. Sewage Pumping Stations

There are no sewage pumping stations within the SMP Area. Pumping Station SP0914, which is located near the end of Wild Street, Picton is the closest pumping station to the proposed longwalls. The closest distance of proposed Longwall 32 to the pumping station is approximately 600 metres.

6.9.6. Pipe Aqueduct for Thirlmere Carrier over Redbank Creek

A 450 mm diameter pipe aqueduct for the Thirlmere Carrier is located over Redbank Creek within the SMP Area. The aqueduct is supported by reinforced concrete abutments with a central pier. A photograph of the aqueduct is shown in Fig. 6.39.

Photograph courtesy GeoTerra

Fig. 6.39 Pipe Aqueduct for Thirlmere Carrier over Redbank Creek

The proposed longwalls do not mine directly beneath the aqueduct. The closest distance between the aqueduct and the side of proposed Longwall 32 is approximately 200 metres.

A summary of the maximum predicted conventional subsidence and valley related movements for the aqueduct is provided in Table 6.33.

Table 6.33 Predicted Conventional Subsidence and Valley Related Movements for the Sewer Pipe Aqueduct

Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (1/km)	Maximum Predicted Total Sagging Curvature (1/km)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
70	< 0.5	< 0.01	< 0.01	30	40

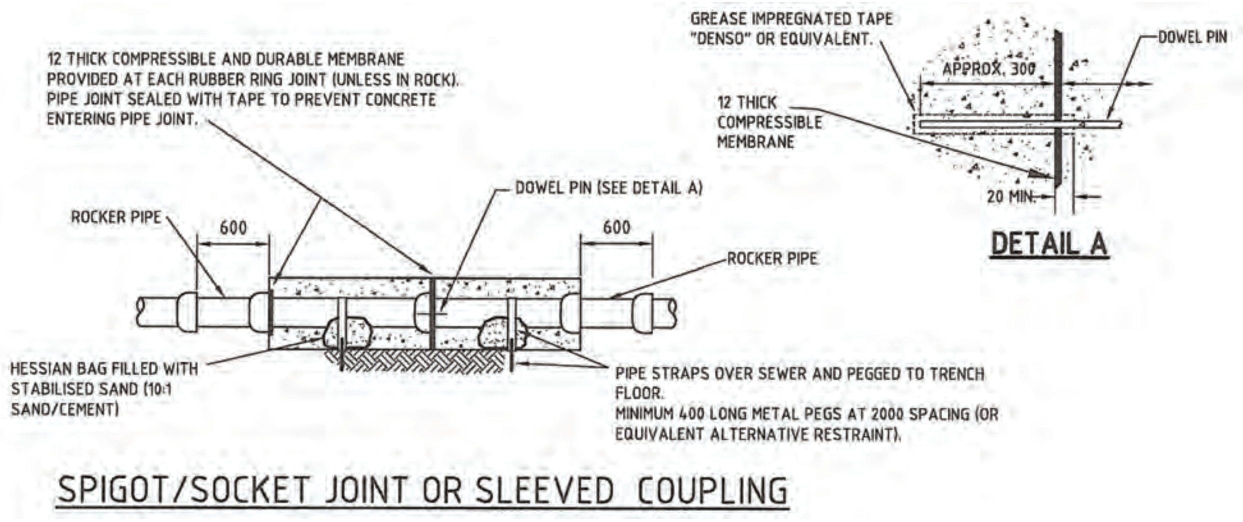
Whilst the predicted movements are small, the aqueduct may experience impacts due to the extraction of the proposed longwalls. If the pipe is fixed to the abutments and central pier, the fixings may prevent the pipe from sliding over them as they close towards each other. Upsidence may cause the central pier to move upwards, relative to the abutments, resulting in curvature. Differential lateral movements may cause the pipe to bend horizontally.

The potential impacts on the aqueduct can be managed by allowing the abutments and central pier to move independently to the pipe. Overall compressive stress on the pipe can be relieved, if required, by excavating and exposing the pipe so that strains are distributed along the pipe over a sufficiently long distance. Alternatively, an expansion joint could be installed into the pipe.

It is recommended that Tahmoor Colliery and Sydney Water develop an agreed risk management plan to manage potential impacts on the pipe aqueduct during the mining of Longwall 32. This is discussed further in Section 6.9.9.

6.9.7. Concrete Encasements and Horizontal Bores

There are 16 sections of pipe (total length of 240 metres) that are concrete encased within the SMP Area. These encasements are typically found beneath driveways and structures. The encasement is designed to accommodate ground strains via 12 mm thick compressible and durable membranes installed at each pipe joint. A standard Sydney Water design detail is shown in Fig. 6.40.



Extract of Sydney Water Standard Drawing No. SEW-1205-V

Fig. 6.40 Typical Sydney Water design of concrete encased pipe

Concrete encased sewers are more vulnerable to mine subsidence impacts when compared to normal sewers. The encasement has the potential to act as an anchor in the ground while the neighbouring pipes slide within the sand fill adjacent to it, thereby potentially concentrating differential movements at the interface. The pipes, however, have limited capacity to tolerate substantial changes in ground curvature as the movement is restricted by the dowel pins. The average length of the encasements is 15 metres. The shortest encasement is 2 metres in length and the longest encasement is 556 metres in length within the SMP Area.

There are 2 sections of pipe (total length of 63 metres) that are concrete encased horizontal bores within the SMP Area. There is a horizontal bore located beneath the Main Southern Railway above Longwall 29. The other horizontal bore is located where the Thirlmere Carrier crosses beneath Remembrance Drive. The proposed longwalls will not mine directly beneath this bore, which is located approximately 360 metres to the side of proposed Longwall 32. Horizontal bores are more vulnerable to mine subsidence impacts when compared to normal sewers as there are fewer pipe joints to accommodate the mining-induced ground strains.

6.9.8. Impact Assessments for the Sewerage Infrastructure Based on Increased Predictions

If the conventional subsidence movements exceeded those predicted by a factor of 2 times, the maximum tilts are unlikely to result in a reversal of grade of the pipes within the SMP Area as the existing grades of the pipes are substantially greater than the predicted tilts. A higher frequency of impacts on pipes may be experienced if the conventional subsidence movements exceeded those predicted by a factor of 2 times.

The rising mains are pressure mains and, therefore, are unlikely to be affected to any great extent by changes in gradient due to subsidence or tilt. As the pipes are located long distances away from the proposed longwalls, they are also unlikely to experience impacts if the conventional movements are exceeded by a factor of 2 times.

If the predicted closure and upsidence at the pipe aqueduct were exceeded by a factor of 2 times, the pipe and supporting structures would experience additional differential movements. It is expected that, with the implementation of mitigation measures, the aqueduct will be able to accommodate higher than predicted differential movements.

While the predicted ground movements are important parameters when assessing the potential impacts on the sewer infrastructure, it is noted that the impact assessments were primarily based on historical observations from previous longwall mining at Tahmoor Colliery. The overall levels of impact on the sewer infrastructure, resulting from the extraction of the proposed longwalls, are expected to be similar to those observed where longwalls have previously mined directly beneath infrastructure at Tahmoor Colliery.

6.9.9. Management of Potential Impacts to Sewerage Infrastructure

Tahmoor Colliery and Sydney Water have developed and acted in accordance with an agreed risk management plan to manage potential impacts to sewer infrastructure during the mining of Longwalls 22 to 30. The management plan is reviewed periodically by Tahmoor Colliery and Sydney Water. It provides for the following monitoring and inspection measures:

- General subsidence monitoring of streets;
- Detailed and frequent monitoring of changes in grade for sections of sewers that have been predicted to experience grades close to self-cleansing or reversal of grade;
- Visual inspections along streets, with increased frequency where sewers are located near creeks or cross beneath the Main Southern Railway;
- CCTV inspections before, during and after mining for some selected sewers; and
- Water quality monitoring of streams that are located near sewers.

The management plan also provides for planned responses if triggered by observations of impacts. These include:

- Additional surveys and inspections, particularly CCTV inspections and pit inspections;
- Temporary tanker flushing of pipes if the grades are reduced below trigger levels until the grade is increased by further mining or permanent regrading is undertaken;
- High pressure water jetting of sewer pipes;
- Bypass pumping of sewage in a temporary line around a potentially affected section of pipe; and
- Install a temporary lining within the sewer pipe to reduce chance of leakage until the damaged pipe is repaired or replaced.

It is recommended that Tahmoor Colliery and Sydney Water continue to develop management plans to manage potential impacts during the mining of the proposed longwalls. This will include focus on the management of potential impacts on grades for the Thirlmere carrier, which is the main pipe that is located above the proposed longwalls. It is recommended that additional measures be developed to manage potential impacts on the pipe aqueduct over Redbank Creek. These include:

- Engineering assessment of potential impacts on the pipe and aqueduct;
- Consideration of, and if agreed, implementation of mitigation measures such as:
    - Measures to allow the abutments and piers to move independently from the pipe; or
    - Installation of an expansion joint in the pipe;
- Surveys and visual inspections of the aqueduct during mining; and
- Adjustment of the support structures and pipe, if required in response to mining-induced movements.

6.10. Sewage Treatment Plants

6.10.1. Sydney Water Picton Water Recycling Plant

The Sydney Water Picton Water Recycling Plant (Picton WRP) is located on Remembrance Drive. The Picton WRP treats sewage from the townships of Tahmoor, Thirlmere, Bargo, Buxton and Picton.

An aerial photograph of the Picton WRP is shown in Fig. 6.41. The plant includes a number of structures, skimmers and tanks and a number of treated water storage dams, which are connected by a network of pipes. The design of the Picton WRP was approved by the Mine Subsidence Board.

Fig. 6.41 Aerial photograph showing Picton Water Recycling Plant overlaid with proposed longwalls

The proposed longwalls do not mine directly beneath structures and dams at the Picton WRP but proposed Longwall 32 will extract directly beneath a portion of the property. The closest distance between the Picton WRP structures and proposed Longwall 32 is approximately 275 metres. The closest distance between the nearest storage dam and the proposed Longwall 32 is approximately 100 metres.

The maximum predicted values of conventional subsidence, tilt and curvature for the structures and dams at the Picton WRP after the completion of each of the proposed longwalls, are included in Tables D.02 to D.08, in Appendix D. A summary of the maximum predicted subsidence parameters is provided in Table 6.34.

Table 6.34 Subsidence Predictions for the Picton Water Recycling Plant

MSEC Structure Reference ID	Description	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
PRE_020_h01	House	90	< 0.5	< 0.01	< 0.01
PRE_020_pu01	Sedimentation Pond	40	< 0.5	< 0.01	< 0.01
PRE_020_pu02	Sedimentation Pond	30	< 0.5	< 0.01	< 0.01
PRE_020_pu03	Skimmer Tanks	20	< 0.5	< 0.01	< 0.01
PRE_020_pu04	Skimmer Tanks	< 20	< 0.5	< 0.01	< 0.01
PRE_020_pu12	Structure	20	< 0.5	< 0.01	< 0.01
PRE_020_pu13	Structure	20	< 0.5	< 0.01	< 0.01
PRE_020_pu14	Structure	20	< 0.5	< 0.01	< 0.01
PRE_020_pu15	Structure	30	< 0.5	< 0.01	< 0.01
PRE_020_pu16	Structure	30	< 0.5	< 0.01	< 0.01
PRE_020_pu17	Structure	30	< 0.5	< 0.01	< 0.01
PRE_020_pu18	Structure	30	< 0.5	< 0.01	< 0.01
PRE_020_pu19	Structure	30	< 0.5	< 0.01	< 0.01
PRE_020_pu20	Structure	30	< 0.5	< 0.01	< 0.01
PRE_020_pu21	Structure	30	< 0.5	< 0.01	< 0.01
PRE_020_pu22	Structure	30	< 0.5	< 0.01	< 0.01
PRE_020_pu23	Structure	30	< 0.5	< 0.01	< 0.01
PRE_020_pu24	Structure	30	< 0.5	< 0.01	< 0.01
PRE_020_d01	Dam	125	0.5	< 0.01	< 0.01
PRE_020_d06	Dam	< 20	< 0.5	< 0.01	< 0.01

The predicted strains for the structures and dams have been based on the statistical analysis of strains provided in Section 4.5. The structures and dams are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays above unmined, solid coal, which are summarised in Section 4.5.1.

The predicted conventional subsidence movements for structures and dams at the Picton WRP are relatively small and it is extremely unlikely that they will experience adverse impacts from the extraction of the proposed longwalls. Comfort is drawn from the fact that the structures have been designed in accordance with the requirements of the Mine Subsidence Board.

The Picton WRP has, however, been constructed at the top of a ridge that is approximately parallel to the alignment of the Nepean Fault. It is possible but unlikely that differential movements could develop and that these may result in adverse impacts on the structures and dams.

Tahmoor Colliery and Sydney Water have developed and acted in accordance with an agreed risk management plan to manage potential impacts to sewer infrastructure during the mining of Longwalls 22 to 30. The management plan is reviewed periodically by Tahmoor Colliery and Sydney Water.

It is recommended that additional measures be developed to manage potential impacts on the Picton WRP to ensure that the plant remains safe and serviceable during mining. These include:

- Engineering assessment of potential impacts on the Picton WRP infrastructure;
- Surveys and visual inspections of the Picton WRP during mining; and
- Response plan in the unlikely event that impacts develop at the Picton WRP.

6.10.2. Wastewater Treatment Plant at Stonequarry Estate

A wastewater treatment plant (WTP) is located on the Stonequarry Estate site directly above proposed Longwall 33. The design of the WTP was approved by the Mine Subsidence Board.

An aerial photograph of the Stonequarry Estate WTP is shown in Fig. 6.41. The plant includes an assortment of tanks and structures and a dam, which are connected by a network of pipes.

Fig. 6.42 Aerial photograph showing Wastewater Treatment Plant on Stonequarry Estate

The maximum predicted values of conventional subsidence, tilt and curvature for the structures and dams at the WTP after the completion of each of the proposed longwalls, are included in Tables D.02 to D.08, in Appendix D. A summary of the maximum predicted subsidence parameters is provided in Table 6.35.

Table 6.35 Subsidence Predictions for the Stonequarry Estate Wastewater Treatment Plant

MSEC Structure Reference ID	Description	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
PSC_090_pu01	Structure	475	4.0	0.03	0.03
PSC_090_pu02	Tank	500	4.0	0.03	0.03
PSC_090_pu03	Tank	525	4.0	0.03	0.03
PSC_090_pu04	Tank	525	4.0	0.03	0.03
PSC_090_pu05	Tank	450	4.0	0.03	0.03
PSC_090_pu06	Tank	475	4.0	0.03	0.03
PSC_090_pu07	Tank	475	4.0	0.03	0.03
PSC_090_pu08	Tank	475	4.0	0.03	0.03
PSC_090_pu09	Tank	475	4.0	0.03	0.03
PSC_090_pu10	Tank	500	4.0	0.03	0.03
PSC_090_pu11	Tank	425	3.5	0.03	0.03
PSC_090_pu12	Tank	475	4.0	0.03	0.03
PSC_090_pu13	Structure	300	3.0	0.03	0.03
PSC_090_d01	Dam	775	4.0	0.02	0.05

The predicted strains for the structures and dams have been based on the statistical analysis of strains provided in Section 4.5. The structures and dams are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays above longwalls, which are summarised in Section 4.5.1. The structures and dams are expected to experience both tensile and compressive strains as the extraction faces of the proposed longwalls pass beneath them. At the completion of the proposed longwalls, the structures are predicted to experience hogging curvature and are more likely to be in final tensile zones and the dam is predicted to experience final sagging curvature and is more likely to be in final compressive zones.

As the design of the WTP has been approved by the Mine Subsidence Board, it is expected that the structures, dam and connecting services pipes will be able to accommodate mine subsidence movements. It is possible, however, that the WTP may experience non-conventional movements during the extraction of the proposed longwalls.

It is recommended that Tahmoor Colliery and Stonequarry Estate develop a subsidence management plan to manage potential impacts on the WTP during the mining of the proposed longwalls. It is recommended that measures be developed to manage potential impacts on the WTP to ensure that the plant remains safe and serviceable during mining. These include:

- Engineering assessment of potential impacts on the Picton WRP infrastructure;
- Surveys and visual inspections of the WTP during mining; and
- Response plan to repair the WTP if required.

6.11. Gas Infrastructure

The locations of gas infrastructure within and adjacent to the SMP Area are shown in Drawing No. MSEC647-20. The descriptions, predictions and impact assessments for this infrastructure are provided in the following sections.

6.11.1. Descriptions of the Gas Infrastructure

The gas reticulation network consists of 32 mm to 75 mm diameter nylon mains and a 160 mm diameter polyethylene main. The gas pipelines are owned and operated by Jemena.

The gas infrastructure within the SMP Area comprises direct buried continuous welded pipelines. A summary of the pipeline sizes, types and locations within the SMP Area is provided in Table 6.36.

Table 6.36 Gas Pipelines within the SMP Area

Diameter	Type	Total Length of Pipeline within SMP Area (m)	Percentage
32 mm	NY	2,344	35.6 %
50 mm	NY	992	15.1 %
63 mm	PE	179	2.7 %
75 mm	NY	244	3.7 %
160 mm	PE	2,824	42.9 %
	Total	**6,583**	**100 %**

6.11.2. Predictions for the Gas Infrastructure

The gas pipelines generally follow the alignments of the local roads within the SMP Area. The predicted profiles of incremental and total conventional subsidence, tilt and curvature for the pipelines which follow the alignments of Remembrance Drive, Bridge Street, Stonequarry Creek Road and Thirlmere Way are similar to those predicted along these roads, which are shown in Figs. E.15 to E.18.

The 32 mm NY pipelines are located across the SMP Area and, therefore, are expected to experience the full range of predicted mine subsidence movements. The maximum predicted subsidence parameters resulting from the extraction of the proposed longwalls are provided in Chapter 4.

A summary of the maximum predicted values of incremental conventional subsidence, tilt and curvature for gas pipelines along Bridge Street, Remembrance Drive and Stonequarry Creek Road, due to the extraction of each of the proposed longwalls, is provided in Table 6.37. A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for these pipelines, after the extraction of each of the proposed longwalls, is provided in Table 6.38.

Table 6.37 Maximum Predicted Incremental Conventional Subsidence, Tilt and Curvature for the Gas Pipelines along Bridge Street, Remembrance Drive and Stonequarry Creek Road

Location	Longwall	Maximum Predicted Incremental Subsidence (mm)	Maximum Predicted Incremental Tilt (mm/m)	Maximum Predicted Incremental Hogging Curvature (1/km)	Maximum Predicted Incremental Sagging Curvature (1/km)
32 mm NY Pipeline adjacent to Bridge Street	Due to LW31	700	5.0	0.05	0.10
	Due to LW32	700	3.5	0.03	0.07
	Due to LW33 to LW37	< 20	< 0.5	< 0.01	< 0.01
160 mm PE Pipeline adjacent to Remembrance Drive	Due to LW31	40	< 0.5	< 0.01	< 0.01
	Due to LW32	250	1.0	0.05	0.01
	Due to LW33 to LW37	< 20	< 0.5	< 0.01	< 0.01
50 mm NY Pipeline adjacent to Stonequarry Creek Road	Due to LW31 to LW33	< 20	< 0.5	< 0.01	< 0.01
	Due to LW34	30	< 0.5	< 0.01	< 0.01
	Due to LW35	150	1.0	0.02	< 0.01
	Due to LW36	650	5.0	0.05	0.11
	Due to LW37	675	4.0	0.06	0.11

Table 6.38 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Gas Pipelines along Bridge Street, Remembrance Drive and Stonequarry Creek Road

Location	Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (1/km)	Maximum Predicted Total Sagging Curvature (1/km)
32 mm NY Pipeline adjacent to Bridge Street	After LW30	1,200	5.5	0.09	0.13
	After LW31	1,225	5.5	0.09	0.13
	After LW32	1,225	4.5	0.09	0.13
	After LW37	1,225	4.5	0.09	0.13
160 mm PE Pipeline adjacent to Remembrance Drive	After LW30	< 20	< 0.5	< 0.01	< 0.01
	After LW31	50	< 0.5	0.05	< 0.01
	After LW32	300	1.0	0.06	0.01
	After LW37	300	1.0	0.06	0.01
50 mm NY Pipeline adjacent to Stonequarry Creek Road	After LW35	175	1.5	0.02	< 0.01
	After LW36	750	5.0	0.06	0.10
	After LW37	1,075	4.5	0.08	0.11

The values provided in the above table are the maximum predicted total conventional subsidence parameters which occur along the pipelines within the SMP Area, including the predicted movements resulting from the extraction of the approved Longwalls 22 to 30.

The predicted strains for the gas pipelines have been based on the statistical analysis of strains provided in Section 4.5. The pipelines are linear features and, therefore, the most relevant distributions of strain are the maximum strains measured anywhere along whole monitoring lines above the previously extracted longwalls, which are discussed in Section 4.5.2.

The gas pipelines cross a number of tributaries and could experience valley related movements in these locations. The maximum predicted upsidence, closure and compressive strains at these tributary crossings are discussed in Section 5.4.

6.11.3. Impact Assessments for the Gas Infrastructure

Longwalls 22 to 27 have directly mined beneath approximately 16.2 kilometres of gas pipes and no impacts have been recorded so far. The local nylon and 160 mm polyethylene main along Remembrance Drive are very flexible and have demonstrated that they are able to withstand the full range of subsidence experienced at Tahmoor to date. While no impacts have been experienced to date, the most vulnerable elements of the system are rigid copper pipe connections between the gas mains and houses.

For example, the 160 mm diameter polyethylene main along Remembrance Drive experienced no impacts during the mining of Longwall 25. This includes a ground strain of approximately 2.5 mm/m over a 37 metre bay along Remembrance Drive. If all of the compressive strain is concentrated at one location, this would equate to a strain of approximately 4 mm/m over a 20 metre bay. This experience provides some comfort that the gas pipes will be able to withstand upsidence, closure and elevated compressive strains as a result of valley related movements, as discussed in Section 5.4, during the mining of the proposed longwalls.

Based on experience during the mining of Longwalls 22 to 27, it is considered that the mining of the proposed longwalls is unlikely to result in any significant impact to the gas infrastructure within the SMP Area. The range of subsidence movements is predicted to be similar to those experienced during the mining of Longwalls 22 to 27.

Tahmoor Colliery and Jemena have developed and acted in accordance with an agreed risk management plan to manage potential impacts to gas infrastructure during the mining of Longwalls 22 to 28. The management plan includes ground and visual monitoring including the use of hand-held gas detection devices, and planned responses if triggered by observations of increased ground strains, ground curvature or localised surface deformations. Jemena inspectors have also conducted targeted regular inspections if triggered by monitoring results during the mining of Longwalls 24A and 25.

If the conditions are considered sufficient to potentially damage a section of pipe, Jemena is able to quickly uncover the pipe section, inspect the pipe for signs of stress and, if required, isolate the pipe section at short notice and repair, as documented in the management plan.

The management plan is reviewed periodically by Tahmoor Colliery and Jemena.

It is recommended that Tahmoor Colliery and Jemena continue to develop management plans to manage potential impacts during the mining of the proposed longwalls.

6.11.4. Impact Assessments for the Gas Infrastructure Based on Increased Predictions

If the actual subsidence movements exceeded those predicted by a factor of 2 times, the maximum curvature at the gas infrastructure would be 0.26 km^{-1}, which represents a minimum radius of curvature of 3.8 kilometres. In this case, the predicted conventional strains for the gas infrastructure would be 4 mm/m, which is no greater than concentrated compressive strain that has been applied previously without impact to similar gas infrastructure at Tahmoor.

6.11.5. Recommendations for the Gas Infrastructure

Tahmoor Colliery and Jemena have developed and acted in accordance with an agreed risk management plan to manage potential impacts to gas infrastructure during the mining of Longwalls 22 to 28. It is recommended that this management plan is reviewed and updated to incorporate the proposed longwalls.

6.12. Electrical Infrastructure

The locations of electrical infrastructure within the SMP Area are shown in Drawing No. MSEC647-21. The descriptions, predictions and impact assessments for the electrical infrastructure are provided in the following sections.

6.12.1. Descriptions of the Electrical Infrastructure

Endeavour Energy has an extensive electrical infrastructure network within the SMP Area. Information on the network has been provided by Endeavour Energy. The electrical infrastructure network within the SMP Area is shown according to the line voltage in Drawing No. MSEC647-21.

It can be seen from this drawing that the conductors include low voltage (LV), 11 kV and 66 kV cables. The majority of the conductors are 11 kV or LV cables, which provide power to individual properties. A summary of the total lengths of conductors is provided in Table 6.30.

Table 6.39 Distribution of Conductors by Voltage

Voltage	Total Length within SMP Area (km)	Percentage
Low voltage (LV)	24.9	56.7 %
11 kV	17.9	40.9 %
66 kV	1.0	2.4 %
Total	**43.8**	**100 %**

The conductors within the distribution network consist of overhead cables, supported by power poles, which are shown in Drawing No. MSEC647-21. There are 423 power poles within the SMP Area, all of which are single poles, including those that support the 66 kV conductors.

Low voltage service connections from the distribution network to houses and other structures are predominantly via overhead cables. There are, however, a small number of buried low voltage service connections, the majority of which have recently been installed at new subdivisions.

All of the service connections are relatively short in length. It is noted, however, that overhead service connections are typically pulled tight between each house and power pole.

The Endeavour Energy Picton Field Service Centre (Ref. HH06/1) is located on Bridge Street, Picton. The Service Centre is located within the SMP Area directly above Longwall 31, as shown in Drawing No. MSEC647-21. The Service Centre is shown in Fig. 6.43 and includes:

- A double storey steel portal frame building with steel sheeting to walls and roof on a concrete slab;
- A single storey office building, constructed on a concrete slab with masonry walls with a steel roof;
- Concrete hardstand area retained by a low height retaining wall; and
- Security fencing including an electric remotely operated sliding entry gate.

Fig. 6.43 Endeavour Energy Field Service Centre on Bridge Street, Picton

6.12.2. Predictions for the Electrical Infrastructure

The powerlines generally follow the alignments of the local roads within the SMP Area. The predicted profiles of incremental and total conventional subsidence, tilt and curvature for the powerlines which follow the alignments of Remembrance Drive, Bridge Street, Stonequarry Creek Road and Thirlmere Way are similar to those predicted along these roads, which are shown in Figs. E.15 to E.18.

The powerlines are located across the SMP Area and, therefore, are expected to experience the full range of the predicted mine subsidence movements. The maximum predicted subsidence parameters resulting from the extraction of the proposed longwalls are provided in Chapter 4.

6.12.3. Impact Assessments for the Electrical Infrastructure

The aerial powerlines will not be directly affected by the ground strains, as the cables are supported by poles above ground level. The cables may, however, be affected by changes in the bay lengths, i.e. the distances between the poles at the levels of the cables, resulting from differential subsidence, horizontal movements, and tilt at the pole locations. The stabilities of the poles may also be affected by conventional tilt, and by changes in the catenary profiles of the cables.

The maximum predicted subsidence and tilts at the powerlines, resulting from the extraction of the proposed longwalls, are similar to those typically experienced elsewhere in the Southern Coalfield, where mining has occurred at similar depths of cover. Longwalls in the Southern Coalfield have successfully mined directly beneath powerlines in the past, and some of these cases are provided Table 6.40.

Table 6.40 Examples of Previous Experience of Mining beneath Powerlines in the Southern Coalfield

Colliery and LWs	Length of Powerlines Directly Mined Beneath (km)	Observed Maximum Movements at Powerlines	Observed Impacts
Tahmoor LWs 22 to 27	36.2 km of 11 kV and 66kV cables 889 power poles	1370 mm Subsidence (Measured at Progress Street) 8 mm/m Tilt (Measured at Tahmoor Road)	Minor impacts only including adjustment of cable catenaries, pole tilts and to consumer cables which connect between the powerlines and houses.
Appin LW1 to LW12	5.2 km of 11 kV 104 power poles	850 mm Subsidence 6 mm/m Tilt (Measured WX-Line)	
Appin LW14 to LW29	1.0 km of 66 kV 4.6 km of 11 kV 76 power poles	1200 mm Subsidence 7 mm/m Tilt (Measured A-Line)	
Appin LW301 and LW302	0.6 km of 66 kV 0.2 km of 11 kV 14 power poles	650 mm Subsidence 4.5 mm/m Tilt (Measured M & N-Lines)	
Appin LW401 to LW409	3.6 km of 66 kV 0.6 km of 33 kV 3.2 km of 11 kV 109 power poles	700 mm Subsidence 5 mm/m Tilt (Measured A6000-Line)	
Appin LW702 to LW704	2.1 km of 11 kV 54 power poles	1100 mm Subsidence 7.5 mm/m Tilt (Measured MPR-Line)	
Dendrobium LW3 and LW5	1.2 km of 33 kV powerline	1100 mm Subsidence 40 mm/m Tilt (Measured D2000-Line)	
Tower LW1 to LW10	6.0 km of 66 kV 4.3 km of 11 kV 112 power poles	400 mm Subsidence 3 mm/m Tilt (Measured T & TE-Lines)	
West Cliff LW5A3 to LW5A4 & LW29 to LW34	1.0 km of a 66 kV 4.8 km of 11 kV 128 power poles	1100 mm Subsidence 10 mm/m Tilt (Measured B-Line)	

Longwalls 22 to 27 have directly mined beneath approximately 36.2 kilometres of electrical cables and 889 power poles and no significant impacts have been recorded so far. However, tension adjustments have been made by Endeavour Energy to some aerial services connections to houses. This is understandable as the overhead cables are typically pulled tight between each house and power pole.

While the experience at Tahmoor has been relatively benign, Endeavour Energy has been required to adjust power pole tilts and catenaries as a result of mine subsidence at other locations within the Southern Coalfield. This repair work is more substantial but the frequency of such impacts is very low.

The past experiences demonstrate that there have only been minor impacts on powerlines which have been directly mined beneath by previously extracted longwalls in the Southern Coalfield. Some remedial measures were required, which included adjustments to cable catenaries, pole tilts and to consumer cables which connect between the powerlines and houses. The incidence of these impacts was very low.

Based on this experience, and in particular the experiences during the mining of Longwalls 22 to 27, it is considered that the mining of the proposed longwalls is unlikely to result in any significant impact to the electrical infrastructure within the SMP Area. The range of subsidence movements is predicted to be similar to those experienced during the mining of Longwalls 22 to 27. The nature of infrastructure within the SMP Area is similar to that located above Longwalls 22 to 27.

It is likely, however, that a small number of adjustments to overhead services connections will be required. There is also a low probability that adjustment for power pole tilt or catenaries will be required as a result of mining based on experience of mining elsewhere in the Southern Coalfield.

The Endeavour Energy Picton Field Service is located directly above the proposed Longwall 31. A summary of the maximum predicted conventional subsidence, tilt and curvature for the main building of the Endeavour Energy Picton Field Service Centre (Ref. HH06/1a) is provided in Table 6.41.

Table 6.41 Subsidence Predictions for Endeavour Energy Picton Field Service Centre (main building)

Stage of Mining	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
After LW30	50	< 0.5	< 0.01	< 0.01
After LW31	375	4.5	0.06	0.06
After LW32	775	3.5	0.08	0.08
After LW37	775	3.5	0.08	0.08

The steel portal frame structures are inherently flexible and are expected to tolerate considerable differential subsidence movements during the mining of the proposed longwalls. Some impacts may be experienced, however, including cracking to concrete floors, wet areas and other finishes within the buildings.

The concrete hardstand areas may experience cracking and steps may develop at some locations, particularly at joints between the slabs. The security fencing and sliding gate may also experience impacts during mining.

The potential impacts can, however, be effectively managed with the implementation of a subsidence management plan, which would include visual inspections and repair of damage as required.

6.12.4. Impact Assessments for the Electrical Infrastructure Based on Increased Predictions

If the actual subsidence movements exceeded those predicted by a factor of 2 times, the maximum tilt at the powerlines would be 11 mm/m (i.e. 1.1 %), or a change in verticality of 1 in 90. In this case, the incidence of impacts would increase in the locations of greatest tilt, such as adjacent to the active longwall maingate and adjacent to the ends of the proposed longwalls. It would still be expected that any impacts could be remediated, including some adjustments of the cable catenaries, pole tilts and the consumer cables, as has been undertaken in the past.

While the predicted ground movements are important parameters when assessing the potential impacts on the powerlines, it is noted that the impact assessments were primarily based on historical observations from previous longwall mining in the Southern Coalfield. The overall levels of impact on the powerlines, resulting from the extraction of the proposed longwalls, are expected to be similar to those observed where longwalls have previously mined directly beneath powerlines in the Southern Coalfield.

6.12.5. Management of Potential Impacts to Endeavour Energy Infrastructure

Tahmoor Colliery and Endeavour Energy have developed and acted in accordance with an agreed risk management plan to manage potential impacts to electrical infrastructure during the mining of Longwalls 22 to 30. The management plan provides for ground and visual monitoring including specific surveys of critical power poles that have been identified within the network by Endeavour Energy and consultant Power Line Design.

The management plan also provides for planned responses if triggered by observations of impacts. If impacts occur to the network, Endeavour Energy is able to quickly make adjustments and restore power, if required.

The management plan is reviewed periodically by Tahmoor Colliery and Endeavour Energy. It is recommended that Tahmoor Colliery and Endeavour Energy continue to develop management plans to manage potential impacts during the mining of the proposed longwalls.

It is recommended that the management plan consider potential risks to the Picton Field Service Centre prior to the extraction of Longwall 30. As part of this consideration, it is recommended that an inspection be undertaken to determine whether there is any equipment on the premises that may be sensitive to mine subsidence movements.

6.13. Telecommunication Services

The locations of the telecommunications infrastructure within the SMP Area are shown in Drawing No. MSEC647-22. The descriptions, predictions and impact assessments for these features are provided in the following sections.

6.13.1. Descriptions of the Telecommunications Infrastructure

Telstra optical fibre cables are located above the proposed longwalls. The majority of Telstra optical fibre cables within the SMP Area are direct buried, with the newer cables housed inside conduit. The cables generally follow the alignments of Remembrance Drive, Bridge Street, Stilton Lane, Bollard Place, Henry Street, Wonga Road, Thirlmere Way, Barkers Lodge Road and Stonequarry Creek Road. There are approximately 13.2 kilometres of optical fibre cables that are located within the SMP Area, of which, 4.5 kilometres will be directly mined beneath by the proposed longwalls.

There are also direct buried copper telecommunications cables which are located across the SMP Area. There are approximately 24.7 kilometres of copper cables that are located within the SMP Area, of which, 6.3 kilometres will be directly mined beneath by the proposed longwalls.

A Telstra telecommunications tower is also located above the former Redbank Railway Tunnel, above the extracted Longwall 28.

6.13.2. Predictions for the Telecommunications Infrastructure

The predicted profiles of incremental and total conventional subsidence, tilt and curvature along the optical fibre cable which follows Stilton Lane and Henry Street, resulting from the extraction of the proposed longwalls, are shown in Fig. E.20, in Appendix E. The predicted profiles for the optical fibre cables which generally follow the alignments of Remembrance Drive, Bridge Street, Stonequarry Road and Thirlmere Way are similar to those predicted along these roads, which are shown in Figs. E.15 to E.18.

A summary of the maximum predicted values of incremental conventional subsidence, tilt and curvature for optical fibre cables, due to the extraction of each of the proposed longwalls, is provided in Table 6.42. A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for these cables, after the extraction of each of the proposed longwalls, is provided in Table 6.43.

Table 6.42 Maximum Predicted Incremental Conventional Subsidence, Tilt and Curvature for the Optical Fibre Cables

Location	Longwall	Maximum Predicted Incremental Subsidence (mm)	Maximum Predicted Incremental Tilt (mm/m)	Maximum Predicted Incremental Hogging Curvature (1/km)	Maximum Predicted Incremental Sagging Curvature (1/km)
Optical Fibre Cable adjacent to Bridge Street	Due to LW31	700	5.0	0.05	0.10
	Due to LW32	700	3.5	0.03	0.07
	Due to LW33 to LW37	< 20	< 0.5	< 0.01	< 0.01
Optical Fibre Cable adjacent to Remembrance Drive	Due to LW31	40	< 0.5	< 0.01	< 0.01
	Due to LW32	250	1.0	0.05	0.01
	Due to LW33 to LW37	< 20	< 0.5	< 0.01	< 0.01
Optical Fibre Cable adjacent to Stilton Lane and Henry Street	Due to LW31	675	2.0	0.06	0.11
	Due to LW32	700	5.0	0.06	0.11
	Due to LW33 to LW37	< 20	< 0.5	< 0.01	< 0.01
Optical Fibre Cable adjacent to Stonequarry Creek Road	Due to LW31 to LW33	< 20	< 0.5	< 0.01	< 0.01
	Due to LW34	30	< 0.5	< 0.01	< 0.01
	Due to LW35	150	1.0	0.02	< 0.01
	Due to LW36	650	5.0	0.05	0.11
	Due to LW37	675	4.0	0.06	0.11
Optical Fibre Cable adjacent to Thirlmere Way	Due to LW31 to LW35	< 20	< 0.5	< 0.01	< 0.01
	Due to LW36	30	< 0.5	< 0.01	< 0.01
	Due to LW37	250	1.5	0.04	0.03

Table 6.43 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Optical Fibre Cables

Location	Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (1/km)	Maximum Predicted Total Sagging Curvature (1/km)
Optical Fibre Cable adjacent to Bridge Street	After LW30	1,200	5.5	0.09	0.13
	After LW31	1,225	5.5	0.09	0.13
	After LW32	1,225	4.5	0.09	0.13
	After LW37	1,225	4.5	0.09	0.13
Optical Fibre Cable adjacent to Remembrance Drive	After LW30	< 20	< 0.5	< 0.01	< 0.01
	After LW31	50	< 0.5	0.05	< 0.01
	After LW32	300	1.0	0.06	0.01
	After LW37	300	1.0	0.06	0.01
Optical Fibre Cable adjacent to Stilton Lane and Henry Street	After LW30	1,075	5.0	0.07	0.11
	After LW31	1,150	4.0	0.07	0.11
	After LW32	1,175	5.0	0.07	0.11
	After LW37	1,175	5.0	0.07	0.11
Optical Fibre Cable adjacent to Stonequarry Creek Road	After LW35	175	1.5	0.02	< 0.01
	After LW36	750	5.0	0.06	0.10
	After LW37	1,075	4.5	0.08	0.11
Optical Fibre Cable adjacent to Thirlmere Way	After LW35	80	0.5	0.01	0.01
	After LW36	90	0.5	0.01	0.01
	After LW37	300	1.5	0.04	0.03

The values provided in the above table are the maximum predicted total conventional subsidence parameters which occur along the cables within the SMP Area, including the predicted movements resulting from the extraction of the approved Longwalls 22 to 30.

The predicted strains for the optical fibre cables have been based on the statistical analysis of strains provided in Section 4.5. The cables are linear features and, therefore, the most relevant distributions of strain are the maximum strains measured anywhere along whole monitoring lines above the previously extracted longwalls, which are discussed in Section 4.5.2.

The copper telecommunications cables are located across the SMP Area and, therefore, are expected to experience the full range of the predicted mine subsidence movements. The maximum predicted subsidence parameters resulting from the extraction of the proposed longwalls are provided in Chapter 4.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the Telstra telecommunications tower, after the extraction of each of the proposed longwalls, is provided in Table 6.44. The predicted tilts and curvatures are the maxima in any direction during or after the extraction of each of the proposed longwalls.

Table 6.44 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Telstra Tower

Location	Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (1/km)	Maximum Predicted Total Sagging Curvature (1/km)
Telstra Tower Located above Longwall 28	After LW30	1,100	3.5	0.05	0.08
	After LW31	1,125	3.5	0.05	0.08
	After LW32	1,125	3.5	0.05	0.08
	After LW37	1,125	3.5	0.05	0.08

The majority of the mine subsidence movements are predicted to develop as a result of the extraction of the approved Longwalls 28 to 30. The tower is predicted to experience an additional 30 mm of vertical subsidence resulting from the extraction of the proposed Longwalls 31 to 37. The additional tilts, curvatures and strains at the tower, due to the proposed longwalls, are predicted to be in the order of survey tolerance, i.e. not measurable.

6.13.3. Impact Assessments for the Telecommunications Infrastructure

The network will be subjected to a wide range of subsidence movements and the maximum predicted conventional subsidence parameters are provided in Section 4.2. The network is also likely to experience non-conventional movements, similar to those already experienced at Tahmoor.

Longwalls in the Southern Coalfield have successfully mined directly beneath copper telecommunications cables in the past, where the magnitudes of the predicted mine subsidence movements were similar to those predicted within the SMP Area. Some of these cases have been summarised in Table 6.45.

Table 6.45 Examples of Mining Beneath Copper Telecommunications Cables

Colliery and LWs	Length of Copper Cables Directly Mined Beneath (km)	Observed Maximum Movements at the Copper Cables	Observed Impacts
Tahmoor LW22 to LW27	42 km of underground cables and 4.0 km of aerial cables	1370 mm Subsidence 8 mm/m Tilt 1.5 mm (typ.) and up to 4.1mm/m Tensile Strain 2 mm (typ.) and up to 6.3 mm/m Comp. Strain (Extensive street monitoring)	No adverse impacts to underground cables. Some pole tilts and cable catenaries adjusted. Some consumer cables were re-tensioned as a precautionary measure
Appin LW401 to LW409	4 km of underground cables and 0.8 km of aerial cables	700 mm Subsidence 5 mm/m Tilt 1 mm/m Tensile Strain 2 mm/m Comp. Strain (Measured A6000-Line)	No adverse impacts
Appin LW702 to LW704	5.8 km of underground cables	1100 mm Subsidence 1.5 mm/m Tensile Strain 4 mm/m Comp. Strain (Measured HW2, ARTC and MPR Lines)	No adverse impacts
West Cliff LW29 to LW34	Longwalls have mined beneath 13 km of underground cables	1100 mm Subsidence 1 mm/m Tensile Strain 5.5 mm/m Comp. Strain (Measured B-Line)	No adverse impacts

It can be seen from the above table, that there were no reported impacts on the direct buried copper telecommunications cables in these cases. It is also understood, that there have been no adverse impacts on direct buried copper telecommunications cables elsewhere in the NSW Coalfields, where the depths of cover were greater than 400 metres, such as the case above the proposed longwalls.

It can also be seen from the above table, that there have been only minor impacts on aerial copper telecommunications cables in the above examples. Some remedial measures were required, which included adjustments to cable catenaries, pole tilts and consumer cables which connect between the poles and houses. The incidence of these impacts, however, was very low.

During the mining of Longwalls 22 to 24B at Tahmoor some aerial consumer lines were retensioned as a precautionary measure and air leakage occurred on an old lead main copper cable in conduit at two locations on Thirlmere Way during the mining of Longwall 22. The impacts to the old lead cable are the second known impact to such a cable during mining in the Southern Coalfield.

During the mining of Longwall 24A there was tilting of Telstra poles supporting the aerial cable network in the residential area of Tahmoor, around Courtland Avenue, Pandora Place, Tanya Place, Lintina Street and Mitchell Close. The movement of the poles created excess sag and tension within the aerial distribution network. Telstra, in consultation with the MSB, adjusted the cable tensions where necessary, to prevent loss of service, and where aerial cables crossed streets, to reduce hazard to traffic.

Adjustments to tension of aerial telecommunications cables were required during the mining of Longwall 26 on Tahmoor Road and Krista Place. Damage was also observed to a conduit on the north-western abutment of the Castlereagh St Bridge. No issues were detected during the mining of Longwall 27.

The buried optical fibre cable along Thirlmere Way and Remembrance Drive did not experience any impacts during the mining of Longwalls 22 to 27. This cable is located in conduit along Remembrance Drive and has not been impacted to date during the mining of Longwall 28. The experience includes a ground strain of approximately 2.5 mm/m over a 37 metre bay along Remembrance Drive. If all of the compressive strain is concentrated at one location, this would equate to a strain of approximately 4 mm/m over a 20 metre bay. An upsidence bump also formed in the ground at this location. This experience provides some comfort that the cable will be able to withstand upsidence, closure and elevated compressive strains as a result of valley related movements, as discussed in Section 5.4, during the mining of the proposed longwalls, though it is possible that the cable may be direct buried beneath creek crossings rather than in conduits.

The Telstra optical fibre, main copper cable and some local copper cables cross creeks directly above the proposed longwalls in six locations, and there are twelve other crossings within the SMP Area. Valley related movement predictions for these crossings are discussed in Section 5.4, and the Telstra optical fibre, main copper cable and local copper cables are expected to experience the range of predictions summarised in this section. These valley related movements include upsidence, closure and elevated levels of compressive strain It is possible that impacts may occur to the Telstra optical fibre, main copper cable and local copper cables in these locations, however few impacts have occurred to similar cables due to mining in the Southern Coalfield.

Based on experience during the mining of Longwalls 22 to 27, it is considered that the mining of the proposed longwalls is unlikely to result in any significant impact to the telecommunications cabling infrastructure within the SMP Area. The range of subsidence movements is predicted to be similar to those experienced during the mining of Longwalls 22 to 27. The nature of cabling infrastructure within the SMP Area is similar to that located above Longwalls 22 to 27. It is likely, however, that a small number of adjustments to overhead services connections to houses will be required and it is possible that impacts may occur to the main lead cables along Remembrance Drive and Thirlmere Way. Any minor impacts on the telecommunication cables would be expected to be relatively infrequent and easily repaired.

Tahmoor Colliery has successfully mined directly beneath the Telstra Mobile Phone Tower above Longwall 28 without adverse impacts. While the Tower has experienced mining-induced tilts, continuously operating tiltmeters and periodic ground surveys have confirmed that they were not of sufficient magnitude to adversely affect the serviceability of the Tower. The Tower is located just inside the SMP Area and it is predicted to experience small additional vertical subsidence movements (i.e. less than 50 mm) due to the extraction of the proposed longwalls with negligible additional tilt. It is extremely unlikely that the mobile phone services on the Tower will be adversely affected by the mining of the proposed Longwalls 31 to 37.

Tahmoor Colliery and Telstra have developed and acted in accordance with an agreed risk management plan to manage potential impacts to telecommunications infrastructure during the mining of Longwalls 22 to 28. The management plan provides for ground and visual monitoring, which includes detailed inspections of pits and cables prior to, during and after mining, and recording of cable pressures for main copper cables.

The management plan also provides for planned responses if triggered by observations of impacts. If impacts occur to the network, Telstra is able to quickly make adjustments and restore communications, if required.

The management plan is reviewed periodically by Tahmoor Colliery and Telstra. It is recommended that Tahmoor Colliery and Telstra continue to develop management plans to manage potential impacts during the mining of the proposed longwalls. In relation to the buried copper cables and optical fibre cables at creek crossings, it is recommended that a detailed subsidence management plan be developed prior to the extraction of Longwall 31.

6.13.4. Impact Assessments for Telecommunications Infrastructure Based on Increased Predictions

If the actual mine subsidence movements exceeded those predicted by a factor of 2 times, the maximum curvature at the telecommunications cables would be 0.24 km^{-1}, which represents a minimum radius of curvature of 4 kilometres. In this case, the predicted conventional strains for the telecommunications cables would be 4 mm/m. It can be seen from Table 6.45, that longwalls have successfully mined beneath optical fibre cables and copper telecommunications cables where, in some cases, the measured strains were greater than 4 mm/m.

It would still be expected, that the potential for elevated ground strains along the optical fibre cables could be managed using OTDR monitoring. Mitigation measures can be undertaken, such as excavating and exposing the cable, if strain concentrations are detected during the mining period.

If the actual far-field horizontal movements exceeded those predicted by a factor of 2 times, the strain associated with these movements would still be expected to be small, in the order of survey tolerance.

6.13.5. Recommendations for the Telecommunications Infrastructure

Tahmoor Colliery and Telstra have developed and acted in accordance with an agreed risk management plan to manage potential impacts to telecommunications infrastructure during the mining of Longwalls 22 to 28. It is recommended that this management plan is reviewed and updated to incorporate the proposed longwalls.

6.14. Public Amenities

There are 110 building structures which have been identified as Public Amenities within the SMP Area. The locations of these structures are shown in Drawing No. MSEC647-23 and details are included in Table D.01, in Appendix D. The descriptions, predictions and impact assessments for each of the Public Amenities located within the SMP Area are provided in the following sections.

6.14.1. Queen Victoria Memorial Gardens

The Queen Victoria Memorial Gardens (Property Ref. V04) is located on Thirlmere Way and comprises a total of 46 buildings, one pool and 12 dams, of which, 31 buildings, one pool and three dams are located within the SMP Area. The proposed longwalls do not mine directly beneath any of the structures or dams. Longwall 37 extracts directly beneath the south-eastern corner of the property and is located at a distance of 250 metres from the nearest building structure. The approved Longwalls 29 and 30 are located at distances of 140 metres from the nearest building structures.

The main three-storey buildings, one heritage listed building constructed in 1886 and one modern building, are both located outside the SMP Area. The proposed longwalls are approximately 400 metres from the original old main building and 500 metres from the new main building at their closest points. Photographs of the buildings are provided in Fig. 6.44 and Fig. 6.45 (Source: Niche, 2014c).

Fig. 6.44 Queen Victoria Memorial Gardens (Source: Niche, 2014c)

Fig. 6.45 Queen Victoria Memorial Gardens (Source: Niche, 2014c)

The maximum predicted values of conventional subsidence, tilt and curvature for the building structures associated with the Queen Victoria Memorial Gardens, after the completion of each of the proposed longwalls, are included in Tables D.02 to D.08, in Appendix D. A summary of the maximum predicted subsidence parameters is provided in Table 6.46.

Table 6.46 Subsidence Predictions for the Queen Victoria Memorial Gardens

Location	References	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
Queen Victoria Memorial Gardens	V04b, V04e, V04f, V04g, V04h, V04u, V04aa, V04ab, V04ac, V04ad, V04ae, V04af, V04ag, V04ar, V04at and V04au (16 total)	20 ~ 30	< 0.5	< 0.01	< 0.01
	V04a, V04i, V04aj, V04ak, V04al, V04aq and V04aw (7 total)	30 ~ 40	< 0.5	< 0.01	< 0.01
	V04j and V04ap (2 total)	40 ~ 50	< 0.5	< 0.01	< 0.01
	V04k, V04an, V04ao and V04am (4 total)	50 ~ 60	< 0.5	< 0.01	< 0.01
	V04l and V04o (2 total)	70 ~ 80	0.5	< 0.01	< 0.01

The predictions of vertical subsidence at the Queen Victoria Gardens are relatively small and may be exceeded. The property is located between two series of the longwall panels, Longwall series 22 to 32 and Longwall series 33 to 37. As discussed in Section 4.4 of the report, additional vertical settlement has previously been observed during the mining around other barriers of unmined coal, elsewhere in the Southern Coalfield. It is expected that additional vertical subsidence could develop above the barrier pillar, up to 150 mm greater than that predicted using the IPM. Whilst the observed vertical subsidence could exceed the predictions in this location, previous experience has found that this is not accompanied by any significant tilts, curvatures or strains, i.e. less than 0.5 mm/m which is in the order of survey tolerance.

The building structures are located at distances between 250 metres and 400 metres from the proposed longwalls. The histogram of the maximum observed tensile and compressive strains measured at these distances from the longwalls at Tahmoor Colliery is provided in Fig. 6.46. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

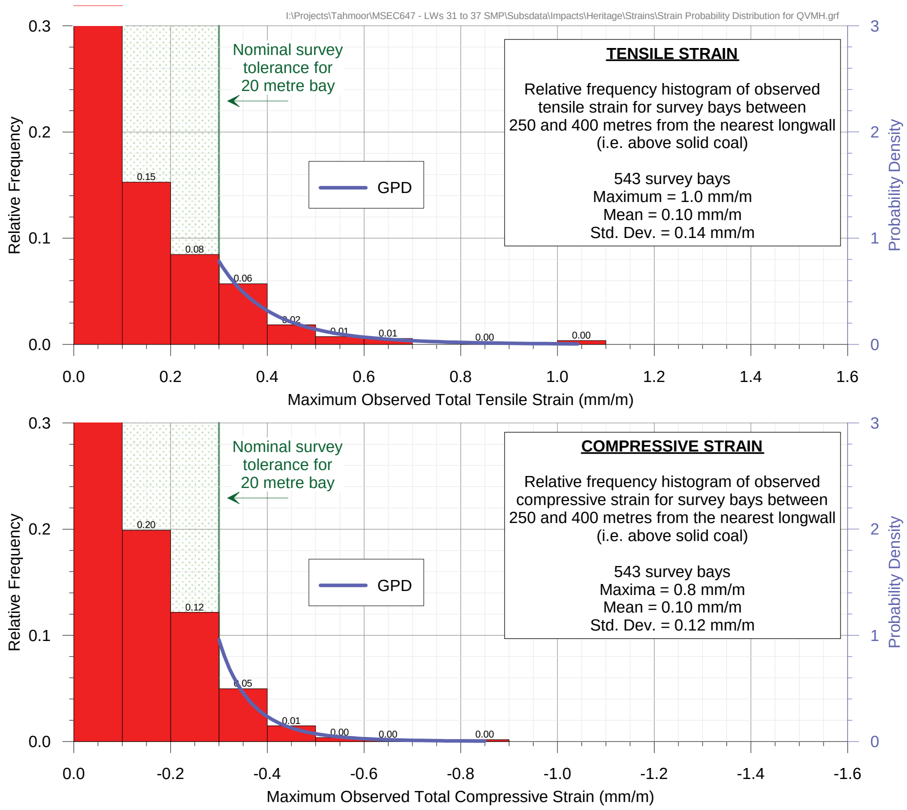


Fig. 6.46 Distributions of the Measured Maximum Tensile and Compressive Strains for Bays Located between 250 metres and 400 metres from Previous Longwalls at Tahmoor Colliery

Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during a longwall extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay).

The predicted strains based on the 95 % confidence levels are 0.4 mm/m tensile and 0.3 mm/m compressive, which are similar to the order of survey tolerance, i.e. not measureable.

The building structures are predicted to experience vertical subsidence ranging between 20 mm and 80 mm after the completion of the proposed longwalls. Whilst these structures could experience very low levels of vertical subsidence, they are not expected to experience any measurable tilts, curvatures or strains, even if the predictions were exceeded by a factor of 2 times.

There are a total of 430 structures located adjacent to but within the 26.5 degree angle of draw line for Longwalls 22 to 27. To date, impacts have been reported to 10 structures, which represents an impact rate of approximately 2 %. Nine of the 10 structures experienced very slight to slight impacts, with only one structure experiencing substantial impacts, which is discussed below.

The furthest reported impact beyond the end of a longwall at Tahmoor Colliery occurred at a house located approximately 175 metres beyond the end Longwall 23B. The impacts are unusual as they are substantial (cracking to walls) but no impacts are observed to any other structures within a 400 metre radius of it and no impacts are observed to pavements near it. The impacts have been treated as mining related as they were observed during the mining of Longwall 24B and a geological disturbed zone has been identified in the coal seam directly beneath it. The furthest impact of the side of a longwall at Tahmoor occurred at a house located approximately 200 metres from the tailgate of Longwall 24A, which comprised cracked tiles in the bathroom.

Based on the experience at Tahmoor Colliery, it is considered that there is a very low probability of adverse impacts to the building structures associated with the Queen Victoria Memorial Gardens as a result of the mining of the proposed longwalls. All structures are expected to remain in safe and serviceable conditions at all times.

Given the heritage and social significance of the site, however, it is recommended that Tahmoor Colliery develop a subsidence management plan in consultation with Home management and a heritage consultant. The management plan may provide for visual and ground monitoring during mining and responses in the very low chance of impacts occurring.

6.14.2. Places of Worship

There are two Places of Worship which have been identified within the SMP Area, being the *Hishouse Church* on Bridge Street and the *Plymouth Brethren Christian Church* on Wonga Road.

The Hishouse Church (Ref. HH14a) is located directly above the proposed Longwall 32. The church shares the building with the Bridge Street Sports Centre (refer to Section 6.14.6), which is a single storey structure with cavity brick walls and a metal sheet roof. The structure is predicted to experience 700 mm vertical subsidence, 5.5 mm/m tilt and 0.06 km^{-1} hogging and sagging curvatures (i.e. minimum radius of curvature of 17 kilometres).

The mining induced tilt could result in some minor serviceability impacts on the church, including door swings and issues with roof gutter and wet area drainage, all of which can be remediated using normal building maintenance techniques.

The assessed probabilities of impact due to the mining induced curvatures and strains have been determined using the method described in Appendix C and are: 73 % Nil or Category R0; 16 % Category R1 or R2; and 11 % Category R3 or greater. The repair categories R0 to R5 are described in Table C.4, in Appendix C. The mining induced curvatures and strains could result in cracking in the external brick walls and the internal finishes, which would be remediated by the Mine Subsidence Board.

It is unlikely that the structure would become unserviceable or unsafe as a result of these mining induced movements. Tahmoor Colliery will manage potential impacts to the structure during the mining of the proposed longwalls, in accordance with a risk management plan.

The Plymouth Brethren Christian Church (Ref. PWG_001_pa01) is located 360 metres north-east of the proposed Longwall 32. The church is a single storey structure with concrete tilt-up wall panels, metal sheet roof and a structural steel cantilever awning. The structure is predicted to experience 40 mm vertical subsidence resulting from the proposed mining. Whilst the church could experience low level vertical subsidence, it is not expected to experience any measurable tilts, curvatures or strains, even if the predictions were exceeded by a factor of 2 times. It is unlikely, therefore, that this church would experience adverse impacts as a result of the proposed mining.

6.14.3. Picton High School

The *Picton High School* (Property Ref. PAR_210) is located at 480 Argyle Street, Picton. The school is situated outside the extents of the proposed mining, at a minimum distance of 190 metres north-east of Longwall 32.

There are 64 building structures (Refs. PAR_210_pa01 to pa55 and PAR_210_pa57 to pa65) which are located within the SMP Area. These structures are shown in Drawing No. MSEC647 – Map 36, and details are provided in Table D.01, in Appendix D.

The main building structures are: the classrooms (refer to Fig. 6.47) which are single and double storey structures; the main hall (refer to Fig. 6.48) which is a single storey structure with portal framed roof with metal sheeting; demountable classrooms (refer to Fig. 6.49); covered walkways and outdoor learning areas (refer to Fig. 6.50); and amenities including mixed use courts (refer to Fig. 6.51).

According to structural engineer, John Matheson and Associates (JMA, 2014), the structures at the school are of the following structural types:

a. Single storey brick veneer classrooms;
b. Ductile steel framed structural steel walkways with structural steel roofing;
c. Demountable type structures;
d. Ductile steel framed structural steel COLA's with structural steel roofing
e. Structural steel framed multi-purpose hall with perimeter articulated cavity brickwork of relatively recent construction constructed on a concrete raft slab;
f. Two-storey classroom buidling, consisting of reinforced concrete framed beam and column structure;
g. Single storey articulated masonry structure with an internal structural steel frame on a reinforced concrete raft slab; and
h. Structural steel framed administration building, which has perimeter concrete block walls and clad metal walls, constructed on a concrete raft slab.

Fig. 6.47 Typical Classroom Buildings

Fig. 6.48 School Hall

Fig. 6.49 Typical Demountable Classroom Buildings

Fig. 6.50 Covered Walkways and Covered Outdoor Learning Area

Fig. 6.51 Mixed Use Courts

The maximum predicted values of conventional subsidence, tilt and curvature for the building structures associated with the Picton High School, after the completion of each of the proposed longwalls, are included in Tables D.02 to D.08, in Appendix D. A summary of the maximum predicted subsidence parameters is provided in Table 6.47.

Table 6.47 Subsidence Predictions for the Picton High School

Location	Number of Building Structures	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
Picton High School	8 total	20 ~ 30	< 0.5	< 0.01	< 0.01
	12 total	30 ~ 40	< 0.5	< 0.01	< 0.01
	16 total	40 ~ 50	< 0.5	< 0.01	< 0.01
	16 total	50 ~ 60	< 0.5	< 0.01	< 0.01
	12 total	60 ~ 70	< 0.5	< 0.01	< 0.01

The building structures are located at distances between 210 metres and 400 metres from the proposed longwalls. The histogram of the maximum observed tensile and compressive strains measured at similar distance from the longwalls at Tahmoor Colliery is provided in Fig. 6.46. The predicted strains based on the 95 % confidence levels are less than 0.5 mm/m tensile and compressive, which is similar to the order of survey tolerance, i.e. not measureable.

The building structures are predicted to experience vertical subsidence ranging between 20 mm and 70 mm after the completion of the proposed longwalls. Whilst these structures could experience very low levels of vertical subsidence, they are not expected to experience any measurable tilts, curvatures or strains, even if the predictions were exceeded by a factor of 2 times.

It is unlikely, therefore, that the Picton High School would experience adverse impacts as a result of the proposed mining, even if the predictions were exceeded by a factor of 2 times.

6.14.4. Pre-School and Day Care Centres

The *Busy Bees Pre-School and Long Day Care Centre* is located at 16 Bridge Street, Picton. The building structures (PBR_016_pa01 to pa03) are located around 300 metres north-east of the Longwall 32, at their closest point to the proposed longwalls.

The building structures are predicted to experience up to 50 mm vertical subsidence resulting from the proposed mining. Whilst the structures could experience low levels of vertical subsidence, they are not expected to experience any measurable tilts, curvatures or strains, even if the predictions were exceeded by a factor of 2 times.

It is unlikely that the pre-school and long day care centre would be adversely impacted by the proposed mining, even if the predictions were exceeded by a factor of 2 times.

6.14.5. Wollondilly Community Leisure Centre

The Wollondilly Community Leisure Centre (Property Ref. PAR_254) is located at 434 Argyle Street, Picton. The property is situated on the SMP Area boundary, north-east of the proposed Longwall 32, as shown in Drawing No. MSEC647 – Map 29.

There is only one structure (Ref. PAR_254_pa03), the outside swimming pool, which is partially located within the SMP Area, which is at a minimum distance of 460 metres from the proposed longwalls. The main building structure, which contains the gym, basketball court and indoor swimming pool, is located outside the SMP Area, and comprises a structural steel portal frame with concrete infill tilt-up panels and a metal sheet roof. Photographs of the leisure centre structures are provided in Fig. 6.52 and Fig. 6.53.

Fig. 6.52 Leisure Centre Outdoor Swimming Pool

Fig. 6.53 Leisure Centre Main Building (Located Outside the SMP Area)

The maximum predicted values of conventional subsidence, tilt and curvature for the structures associated with the Wollondilly Community Leisure Centre, after the completion of each of the proposed longwalls, are included in Tables D.02 to D.08, in Appendix D. A summary of the maximum predicted subsidence parameters is provided in Table 6.48.

Table 6.48 Subsidence Predictions for the Wollondilly Community Leisure Centre

Location	Ref.	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
Wollondilly Community Leisure Centre	PAR_254_pa03	< 20	< 0.5	< 0.01	< 0.01
	Other structures outside SMP Area	< 20	< 0.5	< 0.01	< 0.01

The predicted strains for these structures are less than 0.5 mm/m tensile and compressive, which is similar to the order of survey tolerance, i.e. not measureable.

The structures on the property are between 50 metres and 80 metres long and, therefore, could be sensitive to far-field horizontal movements. The potential for impacts do not result from absolute far-field horizontal movements, but rather from differential horizontal movements over the lengths of the structures. The potential for differential horizontal movements at these structures has been assessed by statistically analysing the available 3D monitoring data from the Southern Coalfield.

The histograms of the maximum observed incremental opening and closing movements for survey marks spaced at 100 metres ±10 metres, at distances between 400 metres and 600 metres from active longwalls, are shown in Fig. 6.34. The maximum incremental longitudinal movements over the lengths of the structures, based on the fitted GPDs to the available ground monitoring data, are 10 mm opening and 8 mm closure, based on the 95 % confidence levels.

The predicted differential horizontal movements at these structures are small and comprise a large proportion of survey tolerance, which is in the order of ±3 mm. The mining induced differential movements represent average strains less than 0.3 mm/m and, therefore, are not expected to be measurable. It is unlikely, therefore, that the structures associated with the Wollondilly Community Leisure Centre would experience adverse impacts, even if the predictions were exceeded by a factor of 2 times.

6.14.6. Bridge Street Sports Centre

The Bridge Streets Sport Centre (Ref. HH14a) is located above the proposed Longwall 32. The centre shares the building with Hishouse Church (refer to Section 6.14.2), which is a single storey structure with cavity brick walls and a metal sheet roof. The structure is predicted to experience 700 mm vertical subsidence, 5.5 mm/m tilt and 0.06 km^{-1} hogging and sagging curvatures (i.e. minimum radius of curvature of 17 kilometres).

As described in Section 6.14.2, the building could experience: some minor serviceability impacts, such as door swings and issues with roof gutter and wet area drainage, due to the mining induced tilt; and cracking in the external brick walls and the internal finishes, due to the mining induced curvature. It is unlikely that the structure would become unserviceable or unsafe as a result of these mining induced movements. Tahmoor Colliery will manage potential impacts to the structure during the mining of the proposed longwalls, in accordance with a risk management plan.

6.14.7. Office Buildings

There are office buildings within the Industrial Area located along Bridge and Henry Streets and above the proposed Longwalls 31 and 32. The descriptions, predictions and impact assessments for these structures are provided in Section 6.18.

6.14.8. Public Swimming Pools

There is an outdoor and an indoor swimming pool at the Wollondilly Community Leisure Centre, which is discussed in Section 6.14.5.

6.14.9. The Wollondilly Emergency Control Centre

The Wollondilly Emergency Control Centre (WECC) for the Rural Fire Services and SES is located at 65 Bridge Street, Picton, and is directly above the proposed Longwall 32. The building structures include the: Emergency Control Centre Building (Ref. HH25a to HH25d) which is a single storey brick structure with metal sheet roof; and the garage (Ref. HH29a/b) which is a steel framed shed with metal roof and wall cladding. Photographs of these building structures are provided in Fig. 6.54.

Fig. 6.54 Wollondilly Emergency Control Centre Building Structures

The maximum predicted values of conventional subsidence, tilt and curvature for the building structures associated with the WECC, after the completion of each of the proposed longwalls, are included in Tables D.02 to D.08, in Appendix D. A summary of the maximum predicted subsidence parameters is provided in Table 6.49.

Table 6.49 Subsidence Predictions for the Wollondilly Emergency Control Centre

Location	Ref.	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
WECC	HH25a to HH25d	675	6.0	0.06	0.06
	HH29a/b	775	5.5	0.03	0.03

The maximum predicted tilt is 6.0 mm/m (i.e. 0.6 %, or 1 in 165). The mining induced tilt could result in some minor serviceability impacts, including door swings and issues with roof gutter and wet area drainage, all of which can be remediated using normal building maintenance techniques.

The maximum predicted curvatures for the Emergency Control Centre Building (HH25a to HH25d) are 0.06 km^{-1} hogging and sagging, which represent minimum radii of curvature of 17 kilometres. The assessed probabilities of impact have been determined using the method described in Appendix C and are: 73 % Nil or Category R0; 16 % Category R1 or R2; and 11 % Category R3 or greater. The repair categories R0 to R5 are described in Table C.4, in Appendix C. The mining induced curvatures and strains could result in cracking in the external brick walls and the internal finishes, which would be remediated by the Mine Subsidence Board.

It is unlikely that the structure would become unserviceable or unsafe as a result of these mining induced movements. Tahmoor Colliery will manage potential impacts to the structure during the mining of the proposed longwalls, in accordance with a risk management plan

The maximum predicted curvatures for the garage (H29a/b) are 0.03 km^{-1} hogging and sagging, which represent minimum radii of curvature of 33 kilometres. The steel framed structure is flexible and would be expected to tolerate these curvatures without any major impacts.

6.14.10. Picton Fire Station

The Picton Fire Station is located on Argyle Street, at a distance of 250 metres north-east of the proposed Longwall 32. The station building comprises structural steel portal frames, with metal sheet roof and wall cladding and low level perimeter brick walls. A photograph of the station is provided in Fig. 6.55.

Fig. 6.55 Picton Fire Station

The building is predicted to experience 60 mm vertical subsidence resulting from the proposed mining. Whilst the structure could experience low levels of vertical subsidence, it is not expected to experience any measurable tilts, curvatures or strains, even if the predictions were exceeded by a factor of 2 times.

It is unlikely that the Picton Fire Station would experience adverse impacts from the proposed mining, even if the predictions were exceeded by a factor of 2 times.

6.14.11. Recommendations for the Public Amenities

It is recommended that property subsidence management plans are developed for each of the public amenities located directly above the proposed longwalls, including: inspection by an structural engineer prior to active subsidence and, if required, implementation of any preventive measures; visual and ground monitoring; and strategies to manage impacts during active subsidence.

6.15. Farm Land and Facilities

6.15.1. Agriculture Utilisation and Agriculture Improvements

The rural areas within the SMP Area have been cleared and are used mainly for light agricultural and residential purposes and, to a lesser extent, for commercial purposes. The land uses include the following:-

- Grassland – not grazed;
- Grassland – light grazing for cattle, horses and poultry; and
- Greenhouses.

6.15.2. Farm Buildings and Sheds

A total of 651 farm buildings and sheds (i.e. rural structures) have been identified within the SMP Area. These are shown in Drawing Nos. MSEC647-27 and MSEC647 – Maps 01 to 48, and details are provided in Table D.01, in Appendix D.

Predictions of subsidence, tilt and curvature have been made at the centroid and each vertex of each structure, as well as eight equally spaced points radially placed around each centroid and vertex at a distance of 20 metres. In the case of a rectangular shaped structure, predictions have been made at a minimum of 45 points within and around the structure. The maximum predicted subsidence parameters have been extracted from these predictions during and after each longwall, and have been used to assess the likely impacts.

The maximum predicted values of conventional subsidence, tilt and curvature for the rural structures, after the completion of each of the proposed longwalls, are included in Tables D.02 to D.08, in Appendix D. The distributions of the maximum predicted conventional subsidence, tilt and curvature for the structures within the SMP Area, resulting from the extraction of the proposed longwalls, are illustrated in Fig. 6.56 and Fig. 6.57.

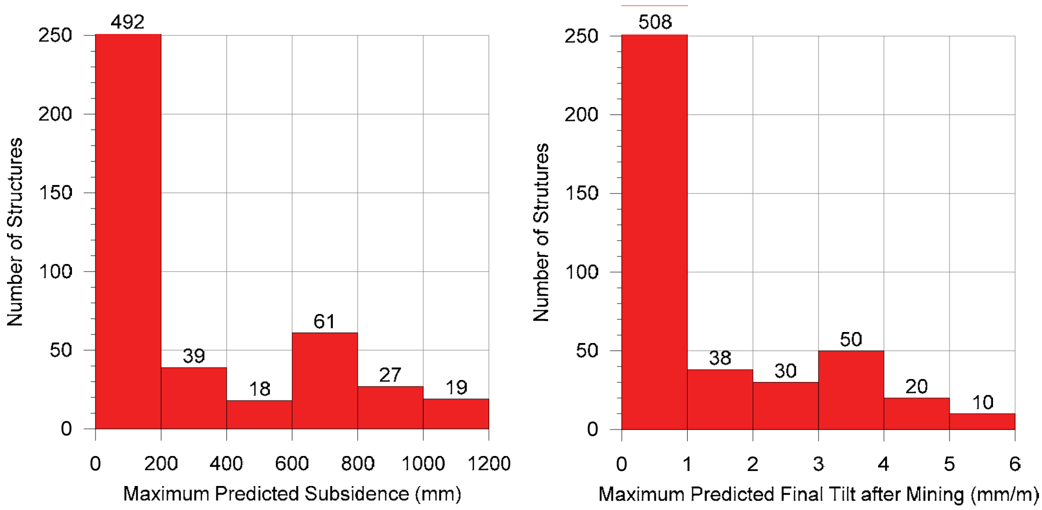


Fig. 6.56 Maximum Predicted Conventional Subsidence and Final Tilt for the Rural Structures

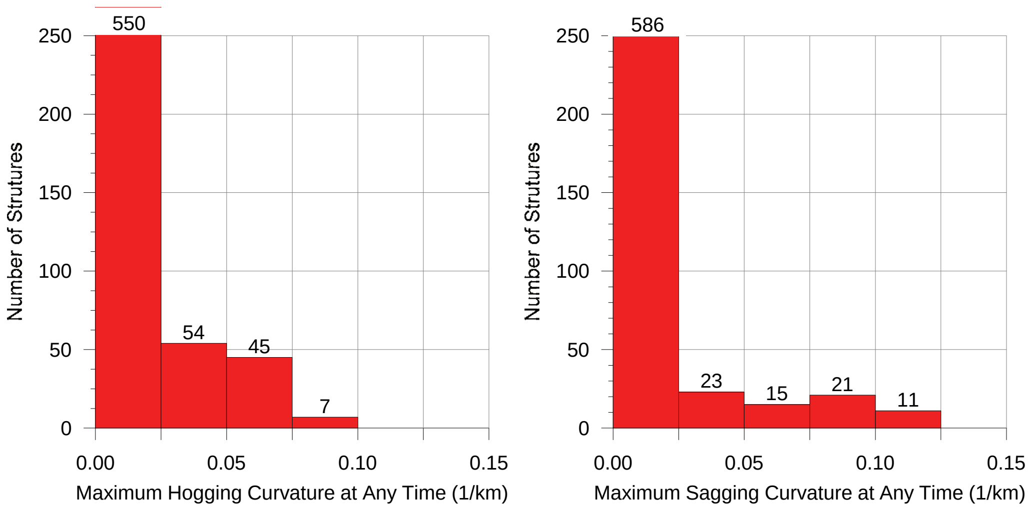


Fig. 6.57 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Rural Structures

The predicted strains for the rural structures have been based on the statistical analysis of strains provided in Section 4.5. The structures are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays above previous longwall mining, which are summarised in Section 4.5.1. The structures are expected to experience both tensile and compressive strains as the extraction faces of the proposed longwalls pass beneath them. At the completion of the proposed longwalls, the structures in locations of hogging curvature are more likely to be in final tensile zones and the structures in locations of sagging curvature are more likely to be in final compressive zones.

The risks to rural structures are that they could be damaged and/or rendered unserviceable from mine subsidence impacts. These include: garages; sheds; carports; tanks; greenhouses; hothouses; playhouses; and shade structures.

These structures are able to tolerate greater subsidence movements than houses as they are generally lighter, more flexible in construction, and smaller in size. The risk of damage to sheds and other domestic structures, therefore, is considerably less when compared to houses.

A total of 1,501 rural structures have experienced mine subsidence movements during the mining of Longwalls 22 to 27 and impacts have been reported to three structures. The rural structures with reported impacts were considered to be relatively minor and readily repairable. Any damage to sheds and other domestic structures will be repaired by the Mine Subsidence Board.

It is expected, therefore, that all rural buildings within the SMP Area would remain safe, serviceable and repairable during and after mining has been completed, provided that they are in sound existing condition. The risk of impact is clearly greater if structures are in poor condition though the chances of there being a public safety risk remain very low. There have been observations of the performance of some rural buildings in poor pre-mining condition and these buildings have not experienced impacts during mining. No impacts to farm buildings were reported during the mining of LW27.

Tahmoor Colliery has developed and acted in accordance with a risk management plan to manage potential impacts to farm buildings during the mining of Longwalls 22 to 27. The management plan provides for identification of buildings in poor pre-mining condition that are hazardous or may become hazardous due to mining, and visual kerbside monitoring of structures during active subsidence. If impacts occur, the structure will be repaired by the Mine Subsidence Board.

The management plan is reviewed periodically by Tahmoor Colliery. It is recommended that Tahmoor Colliery continue to develop management plans to manage potential impacts during the mining of the proposed longwalls.

There are two farm properties with substantial developments, being the Red Lea Chicken farm and the Market Garden farm, which are discussed in further detail below.

6.15.3. Water, Gas and Fuel Storage Tanks

There are water, gas and fuel storage tanks on some of the rural properties within the SMP Area.

The tanks themselves are typically constructed above ground level and, therefore, are unlikely to experience the full ground movements resulting from the proposed mining. It is possible, that any buried water pipelines associated with the tanks within the SMP Area could be impacted by the ground strains, if they are anchored by the tanks, or by other structures in the ground. Any impacts are expected to be of a minor nature and easily repaired.

There are two large aboveground fire water tanks on Property GG12, which are discussed in Section 6.18. There are also inground fuel storage tanks associated with the petrol station on Property PAR_062, on the corner of Argyle and Hill Streets, which is located just outside the SMP Area, and is discussed in Section 6.18.

6.15.4. Hydroponic and Irrigation Systems

There are hydroponic and irrigation systems on the rural properties, including the Chicken Farm (refer to Section 6.15.5) and the Market Garden Farm (refer to Section 6.15.6).

6.15.5. Chicken Farm

The Red Lea Chicken farm has five chicken sheds (Refs. TKE_006_c01 to TKE_006_c05) located within the SMP Area. These sheds are each approximately 125 metres long and 15 metres wide and comprise steel portal frames with metal sheet cladding.

The chicken sheds are located 160 metres north-west of LW37, at their closest points to the proposed longwalls. At this distance, the sheds are predicted to experience vertical subsidence up to 30 mm. Whilst the sheds could experience very low levels of vertical subsidence, they are not expected to experience any measurable tilts, curvatures or strains, even if the predictions were exceeded by a factor of 2 times.

The sheds could experience far-field horizontal movements resulting from the proposed mining. It can be seen from Fig. 4.13, that incremental far-field horizontal movements around 200 mm have been measured at distances of 100 metres from previously extracted longwalls in the NSW Coalfields.

The potential for impacts on the sheds do not result from absolute far-field horizontal movements, but rather from differential horizontal movements over the lengths of the structures. The potential for differential horizontal movements at these sheds has been assessed by statistically analysing the available 3D monitoring data from the Southern Coalfield, based on survey marks spaced at 140 metres ±10 metres, at distances between 100 metres and 300 metres from active longwalls.

The maximum incremental differential horizontal movements for the chicken sheds, based on the 95 % confidence levels for the fitted GPDs to the available ground monitoring data, are 16 mm opening, 15 mm closure and 14 mm mid-ordinate deviation.

It is unlikely that the chicken sheds would be adversely impacted by the proposed mining due to the flexible types of construction and due to the low level differential movements, even if the predictions were exceeded by a factor of 2 times.

6.15.6. Market Garden Farm on Stilton Lane

The property Ref. GG38 on Stilton Lane has nine market garden shade structures (Refs. GG38e to GG38n) which house succulent plants. These structures are located partially above the approved Longwall 30 and adjacent to the proposed Longwall 31. Photographs of the shade structures are provided in Fig. 6.58.

Fig. 6.58 Market Garden Shade Structures on Property GG38

The shade structures are predicted to experience up to: 450 mm vertical subsidence; 4.5 mm/m tilt (i.e. 0.5 %, or 1 in 220); and 0.04 km^{-1} hogging and sagging curvatures (i.e. minimum radius of curvature of 25 kilometres).

Tahmoor has successfully mined beneath these types of shade structures without adverse impacts. There have been impacts reported on shade structures elsewhere in the Southern Coalfield, however, these impacted structures were not monitored or actively managed during mine subsidence. It is recommended that management strategies are developed for the shade structures within the SMP Area including: visual and ground monitoring; and the implementation of preventive and remedial measures during active subsidence.

There is one farm dam (Ref. GG38d) on the property and a larger dam upstream on the adjoining property (Ref. GG37a) which has a dam wall approximately 8 metres high. These dams could potentially pose a risk to the structures and infrastructure on Property GG38 if the dam walls were adversely impacted as the result of mining. Further discussions and recommendations for these dams are provided in Section 6.16.

6.15.7. Fences

There are a number of farm fences within the rural areas of the SMP Area. The fences are constructed in a variety of ways, generally using either timber or metal materials. Fences are generally flexible in construction and can usually tolerate mine subsidence movements in the Southern Coalfield.

Tahmoor Colliery has mined directly beneath many farm fences during the mining of Longwalls 22 to 27. A total of 5 rural properties and 46 urban properties have reported impacts to fences and gates. The higher incidence of impacts to urban fences is considered to be due to their typical type of construction, namely Colorbond fences and security gates that are fitted tightly between fences and houses. Rural fences are typically more flexible in construction by comparison. No impacts to fences securing livestock were reported. Damaged fences are relatively easy to rectify by re-tensioning of fencing wire, straightening of fence posts, and if necessary, replacing some sections of fencing.

The most vulnerable sections of farm fences are gates, particularly long gates or those with latches, as they are less tolerant to differential horizontal movements and tilts between the gate posts and the ground. One gate, for example, experienced adverse impacts during the extraction of Longwall 22, although it is noted that this gate was located in close proximity to an area of irregular movement. If any gates are adversely impacted during the extraction of the proposed longwalls, they can be easily and quickly repaired.

Tahmoor Colliery has developed and acted in accordance with a risk management plan to manage potential impacts to farm fences during the mining of Longwalls 22 to 27. The management plan provides for visual kerbside monitoring of fences during active subsidence. If impacts occur, the fences will be repaired by the Mine Subsidence Board.

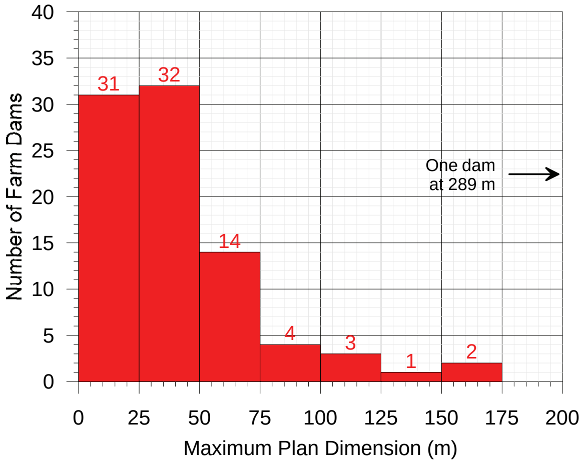
The management plan is reviewed periodically by Tahmoor Colliery. It is recommended that Tahmoor Colliery continue to develop management plans to manage potential impacts during the mining of the proposed longwalls.

6.16. Farm Dams

The locations of the farm dams within the SMP Area are shown in Drawing Nos. MSEC647-27 and MSEC647 – Maps 01 to 48. The predictions and impact assessments for the dams are provided in the following sections.

6.16.1. Descriptions of the Farm Dams

There are 88 farm dams which have been identified within the SMP Area. The locations of the dams are shown in Drawing Nos. MSEC647-27 and MSEC647 – Maps 01 to 48, and details are provided in Table D.09, in Appendix D. The locations and sizes of the farm dams were determined from an aerial photograph of the area. The distributions of the longest lengths and surface areas of the farm dams within the SMP Area are shown in Fig. 6.59.



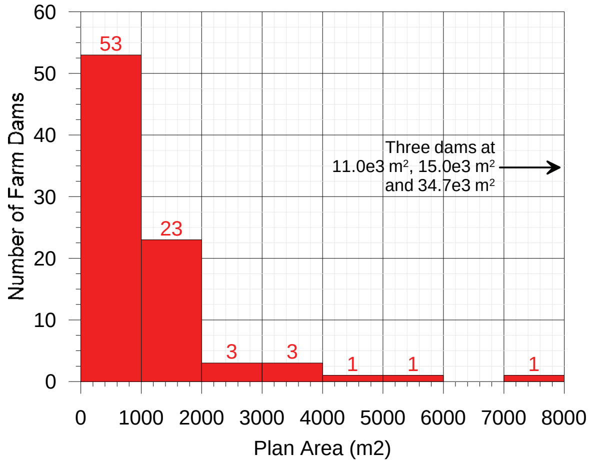


Fig. 6.59 Distributions of Longest Lengths and Surface Areas of the Farm Dams

The larger farm dams located directly above the proposed longwalls are:

- Dam Ref. GG37a is partially located above the proposed Longwall 31 and has a surface area of 11,000 m^2 and has a dam wall height of approximately 8 metres (refer to Fig. 6.60). There is a second dam located immediately downstream (Ref. GG38d), which is also partially located above the proposed Longwall 31, and has a surface area of 4,570 m^2. Both these dams are located upstream of the structures and infrastructure associated with the Market Garden farm on Stilton Lane (refer to Section 6.15.6);
- Dam Ref. PTH_105_d01 which is located directly above the proposed Longwall 34 and has a surface area of 7,280 m^2. There are no structures or infrastructure located immediately downstream of this dam; and
- Dam Ref. PSC_090_d01 which is located directly above the proposed Longwall 33 and has a surface area of 5,670 m^2. This dam is associated with the *Wastewater Treatment Plant at Stonequarry Estate*, which is discussed in Section 6.10.2.

Fig. 6.60 Dam Ref. GG37a

The dams are typically of earthen construction and have been established by localised cut and fill operations within the natural drainage lines.

6.16.2. Predictions for the Farm Dams

Predictions of conventional subsidence, tilt and curvature have been made at the centroid and around the perimeters of each farm dam. A summary of the maximum predicted values of conventional subsidence, tilt and curvature for each farm dam within the SMP Area is provided in Table D.09, in Appendix D.

The distributions of the maximum predicted conventional subsidence, tilt and curvature for the farm dams within the SMP Area, resulting from the extraction of the proposed longwalls, are illustrated in Fig. 6.61 and Fig. 6.62.

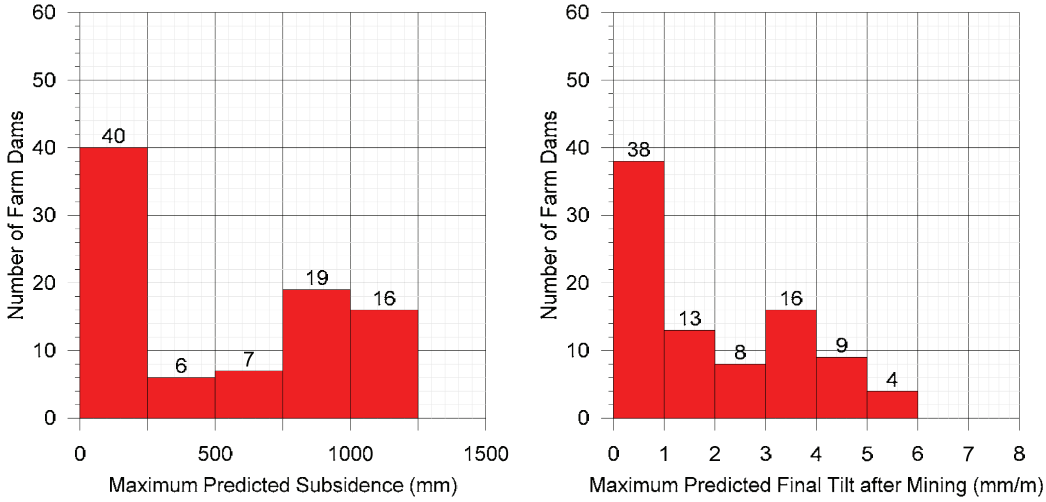


Fig. 6.61 Maximum Predicted Conventional Subsidence and Final Tilt for the Farm Dams

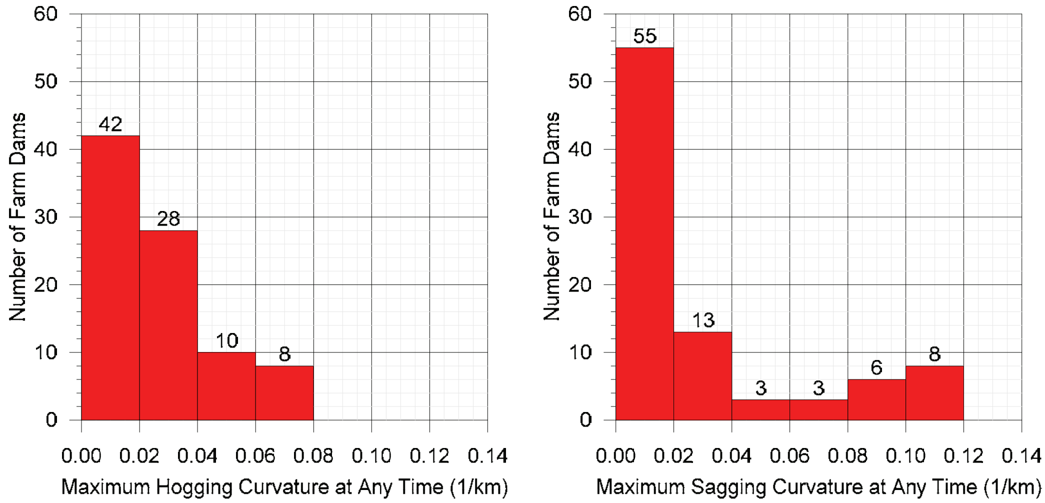


Fig. 6.62 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Farm Dams

The predicted strains for the farm dams have been based on the statistical analysis of strains provided in Section 4.5. The dams are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays above previous longwall mining, which are summarised in Section 4.5.1. The farm dams are expected to experience both tensile and compressive strains as the extraction faces of the proposed longwalls pass beneath them. At the completion of the proposed longwalls, the farm dams in locations of hogging curvature are more likely to be in final tensile zones and the farm dams in locations of sagging curvature are more likely to be in final compressive zones.

The farm dams have typically been constructed within the drainage lines and, therefore, may be subjected to valley related movements resulting from the extraction of the proposed longwalls. The equivalent valley heights at the dams are very small and it is expected, therefore, that the predicted valley related upsidence and closure movements at the dam walls would be much less than the predicted conventional subsidence movements and are generally not significant.

6.16.3. Impact Assessments for the Farm Dams

The maximum predicted conventional tilt at the farm dams within the SMP Area, at any time during or after the extraction of the proposed longwalls, is 5.5 mm/m (i.e. 0.6 %), or a change in grade in 1 in 180. Mining induced tilts can affect the water levels around the perimeters of farm dams, with the freeboard increasing on one side and decreasing on the other. Large tilts can potentially reduce the storage capacity of farm dams, resulting in overflowing, or can affect the stability of the dam walls.

The maximum predicted changes in freeboard at the farm dams within the SMP Area were determined by taking half the difference between the maximum predicted subsidence and the minimum predicted subsidence around the perimeters of the dams. The maximum predicted changes in freeboard at the farm dams within the SMP Area are provided in Table D.09, in Appendix D, and are illustrated in Fig. 6.63.

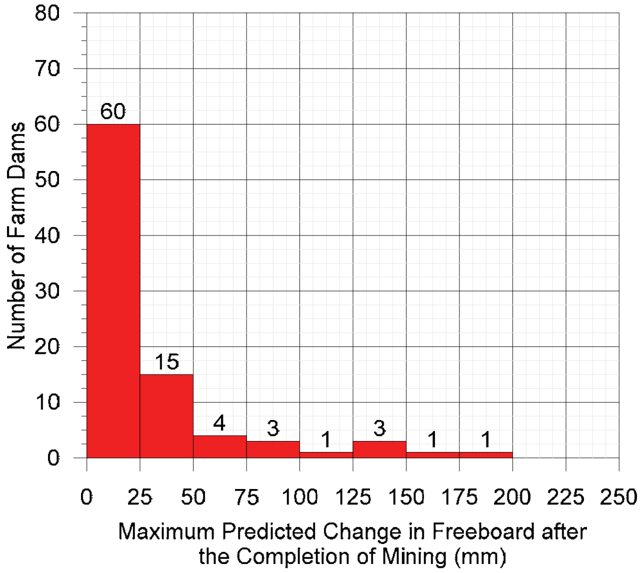


Fig. 6.63 Predicted Total Changes in Freeboards for the Farm Dams due to LW22 to LW37

The maximum predicted total change in freeboard at the farm dams is 200 mm, which occurs at Dam Ref. PTH_105_d01 after the extraction of the proposed Longwall 34. Changes in freeboard of 150 mm also occur at Dam Refs. GG04a, GG37a, GG38d and PTH_031_d01. The predicted changes in freeboard are relatively small and are unlikely, therefore, to result in any significant reductions in the capacities of the farm dams.

The maximum predicted curvatures for the farm dams are 0.07 km^{-1} hogging and 0.12 km^{-1} sagging, which represent minimum radii of curvatures of 14 kilometres and 8 kilometres, respectively. The maximum predicted strains for the dams located directly above the proposed longwalls are: 0.9 mm/m tensile and 1.8 mm/m compressive based on the 95 % confidence level; and 1.5 mm/m tensile and 3.5 mm/m compressive based on the 99 % confidence level.

It is possible that some minor cracking or leakage of water may occur in the farm dam walls which are subjected to the higher curvatures and strains, though any minor cracking or leakages could be readily identified and remediated as required. It is not expected that any significant loss of water would occur from the farm dams within the SMP Area, but any loss would flow into the tributary in which the dam was formed and would not result in any significant impacts on the environment.

There is a small possibility that high concentrations of strain could occur at faults, fissures and other geological features, or points of weakness in the strata, and such occurrences could be coupled with localised stepping at the surface. If this type of phenomenon coincided with a farm dam wall, there is a possibility that an impact on the dam wall could occur, but the likelihood of this occurring is very small. In the unlikely event that these impacts occur, they could be readily identified and remediated using well established dam construction and maintenance techniques. With the implementation of the appropriate remediation measures, there is unlikely to be any significant impacts on the ongoing operations of the farm dams within the SMP Area or on the downstream environment.

The nature of the dams within the SMP Area is similar to those located elsewhere in the Southern Coalfield. The dams are typically constructed from cohesive soils with reasonably high clay contents. The walls of the farm dams should be capable of withstanding tensile strains of up to 3 mm/m without significant impacts, because of their inherent plasticity. It is unlikely, therefore, that the maximum predicted conventional strains, resulting from the extraction of the proposed longwalls, would result in any significant impacts on the farm dams within the SMP Area.

A total 55 dams have been directly mined beneath by Longwalls 22 to 27 with one impact having been reported to a dam located directly above the extracted Longwall 27. This represents an impact rate of less than 0.5 %. The dataset includes some large water treatment dams above Longwall 24A. A similar experience is found at dams located above other extracted longwalls at Appin and West Cliff Collieries, where the depth of cover is similar. While no impacts have been reported to dam walls, seepage was observed at the base of one dam wall that is located above Longwall 702 at Appin Colliery.

Based on experience of mining beneath dams in the Southern Coalfield, it is considered that the mining of the proposed longwalls is unlikely to result in adverse impact to farm dams located within the SMP Area. The range of subsidence movements is predicted to be similar to those experienced during the mining of Longwalls 22 to 27.

There are building structures and infrastructure located immediately downstream of several farm dams within the SMP Area, including Dams Refs. GG37a, GG38d, GG32e and GG51e.

Dam Ref. GG37a has a large dam wall with a height of approximately 8 metres, which is located immediately upstream of Dam Ref. GG38d, which in turn is located immediately upstream of the building structures and infrastructure associated with the Market Garden farm on Stilton Lane (refer to Section 6.15.6). These dams could potentially pose risk to the structures and infrastructure on this property if the dam walls were adversely impacted as the result of mining.

It is recommended that management strategies are developed for these dams including: geotechnical assessment of the dam walls; visual and ground monitoring during active subsidence; and management strategies if significant non-conventional ground movements were detected, such as lowering the stored water levels in the dams and providing a temporary water source until remediation has been completed.

Tahmoor Colliery has developed and acted in accordance with a risk management plan to manage potential impacts to dams during the mining of Longwalls 22 to 27. The management plan provides for visual monitoring of dams immediately prior to and after active subsidence at each dam. If impacts occur to the dams, Tahmoor Colliery will supply water to the landowner on a temporary basis until the dam is repaired by the Mine Subsidence Board.

The management plan is reviewed periodically by Tahmoor Colliery. It is recommended that Tahmoor Colliery continue to develop management plans to manage potential impacts during the mining of the proposed longwalls.

6.16.4. Impact Assessments for the Farm Dams based on Increased Predictions

If the actual tilts exceeded those predicted by a factor of 2 times, the maximum tilt at the farm dams, at the completion of mining, would be 11 mm/m (i.e. 1.1 %, or 1 in 90). In this case, the maximum changes in freeboard would be around: 350 mm at Dam Ref. PTH_105_d01; 300 mm at Dams Refs. GG04a, GG37a and GG38d; and 250 mm at Dam Ref. PTH_031_d01. The remaining dams would still have changes in freeboard of 200 mm, or less. If the changes in freeboard were to adversely impact on storage capacities of any of the farm dams within the SMP Area, these could be remediated by raising the dam walls.

If the actual curvatures exceeded those predicted by a factor of 2 times, the likelihood and extent of cracking would increase for the farm dams located directly above the proposed longwalls. Any surface cracking would still be expected to be of a minor nature and could be readily repaired. With any necessary remedial measures implemented, it is unlikely that any adverse impacts on the farm dams would occur resulting from the extraction of the proposed longwalls. The experience of mining beneath farm dams at Tahmoor Colliery and elsewhere in the Southern Coalfield indicate that the likelihood of impact is very low.

6.16.5. Recommendations for the Farm Dams

Tahmoor Colliery has developed management plans to manage the potential impacts on the farm dams located above the existing and approved longwalls. It is recommended that detailed management strategies are developed for the Dams Refs. GG37a and GG38d including: geotechnical assessment of the dam walls; visual and ground monitoring during active subsidence; and management strategies if significant non-conventional ground movements were detected, such as lowering the stored water levels in the dams and providing a temporary water source until remediation has been completed.

6.17. Wells and Bores

The locations of the registered groundwater bores are shown in Drawing No. MSEC647-26. The locations and details of these were obtained from the Department of Natural Resources using the *Natural Resource Atlas* website (NRAtlas, 2014).

There were eight registered groundwater bores identified within the SMP Area, of which two are located directly above the proposed longwalls. A summary of the registered groundwater bores located within the SMP Area is provided in Table 6.50 below.

Table 6.50 Details of the Registered Groundwater Bores within the SMP Area

Ground Licence Number	Location	Depth (m)	Authorised / Intended Use
GW035844	110 metres south-west of LW37	45.7	Stock / Irrigation
GW064469	60 metres from LW36 and LW37	91.0	Domestic
GW072402	250 metres north-west of LW33	72.0	Domestic / Stock
GW104090	Directly above LW34	150.5	Irrigation / Stock
GW105228	260 metres north-east of LW33	63.0	Domestic / Stock
GW105467	35 metres south-west of LW37	120.0	Domestic / Stock
GW105546	320 metres north-west of LW37	163.0	Industrial Irrigation
GW105813	Directly above LW32	168.0	Domestic / Stock

It is likely that the groundwater bores will experience impacts as the result of the proposed mining, particularly those located directly above the proposed longwalls. Impacts would include lowering of the piezometric surface, blockage of the bore due to differential horizontal displacements at different horizons within the strata and changes to groundwater quality.

Tahmoor Colliery has developed and acted in accordance with a risk management plan to manage potential impacts to bores during the mining of Longwalls 22 to 27. The management plan provides for monitoring of standing water levels in piezometers and monitoring of groundwater quality. If impacts occur to the bores, Tahmoor Colliery would supply water to the landowner on a temporary basis, until the bore returns to operation, or is reinstated or replaced by the Mine Subsidence Board.

The management plan is reviewed periodically by Tahmoor Colliery. It is recommended that Tahmoor Colliery continue to develop management plans to manage potential impacts during the mining of the proposed longwalls.

Further discussions on the groundwater bores and groundwater resources are provided by *GeoTerra* (2014).

6.18. Industrial, Commercial and Business Establishments

6.18.1. Descriptions of the Industrial, Commercial and Business Establishments

There are a total of 161 structures identified within the SMP Area that are used for industrial, commercial or business purposes, of which, 77 structures will be directly mined beneath by the proposed longwalls. These include factories and workshops, and business or commercial establishments.

Most of the industrial, commercial and business structures are located around the industrial area along Bridge Street, Redbank Place, Bollard Place and Henry Street. There is another industrial area at Wonga Road.

The industrial, commercial and business establishments comprise a range of building uses and business types, including the following:

- Automotive repairers;
- Steel fabrication workshops;
- Food manufacturing plant;
- Self-storage;
- Endeavour Energy works depot;
- Picton Buslines and Wollondilly Cabs depot;
- Landscape supplies;
- Waste disposal company;
- Carwash (at Service Station, however service station structures located outside of SMP Area);
- Concrete batching plants; and
- Office type businesses, including an accountant and a drafting service.

Photographs showing a range of structure types within the SMP Area are provided in Fig. 6.64 to Fig. 6.67.

Photograph courtesy John Matheson & Associates

Fig. 6.64 Front elevation of concrete tilt panel structure

Photograph courtesy John Matheson & Associates

Fig. 6.65 Hoppers for concrete batching plant

Photograph courtesy John Matheson & Associates

Fig. 6.66 Large structural steel portal frame with metal cladding

Photograph courtesy John Matheson & Associates

Fig. 6.67 Structure with articulated perimeter cavity brickwork and clad metal framed walls around a ductile steel portal frame

Structural engineer, John Matheson and Associates (JMA), has inspected each of the commercial, industrial and business structures mainly from the street front, with site inspections of some buildings. Further structural inspections will be required prior to each structure being impacted by mining, to allow development of individual PSMP's. The purpose of the inspections was to identify structure types, structure and cladding ductility levels, whether dilapidation could be identified that could impair structural performance in the event that the structures are affected by mine subsidence and make recommendations for further actions prior to the extraction of the proposed longwalls.

JMA (2014) advises that the structures can be grouped within the following structure types:

a. Type A: Structural steel portal frames buildings with cross braced panels with perimeter brick walls to around 3 metres with clad metal framed walls above, to eave level. These buildings have one or two-storey front offices with cavity brickwork facades on jointed reinforced concrete ground slabs on engineered fill with columns supported by bored piers or pad footings founded on rock;
b. Type B: Structural steel portal frames buildings with cross braced panels with perimeter clad metal framed walls on jointed reinforced concrete ground slabs on engineered fill with columns supported by bored piers or pad footings founded on rock;
c. Type C: Tilt-panel wall structures that employ diaphragm roof bracing, constructed on jointed reinforced concrete ground slabs on engineered fill with bored pies supporting the tilt panel walls; and
d. Type D: Elevated hoppers on cross-braced frames, such as visible at the concrete batching plants.

A number of the structures also have structural features, such as cantilever structural steel awnings. Many of the larger industrial properties have multiple structures on them, with smaller structures also including structural steel, cavity brick and tilt panel construction.

Most of the industrial, commercial and business structures are inherently ductile because of their construction materials and detailing. Some establishments contain equipment that is sensitive to small differential subsidence movements, particularly tilt. These include gantry cranes, metal punching equipment and manufacturing equipment.

JMA (2014) concludes that the front of building inspections, whilst limited, did not indicate that any of the structures inspected were in a condition that could be construed as being more susceptible to the impacts of mine subsidence due to their dilapidated condition. It is possible, however, that some dilapidation could be discovered on further examination, which could be managed on a case-by-case basis.

6.18.2. Predictions and Impact Assessments for the Industrial, Commercial and Business Establishments

The predicted subsidence parameters for the structures, after the completion of each longwall, are provided in Tables D.02 to D.08, in Appendix D. The structures are predicted to experience between 20 mm and 1,100 mm of subsidence following the extraction of Longwalls 22 to 37, with tilts up to 6.0 mm/m, conventional hogging curvature up to 0.08 km^{-1} and conventional sagging curvature up to 0.12 km^{-1}.

The establishments could experience adverse impacts as a result of the extraction of the proposed longwalls. The majority of the impacts are likely to be minor serviceability impacts, such as door swings and issues with roof gutter and wet area drainage, all of which can be remediated using normal building maintenance techniques. More substantial serviceability impacts could develop at some establishments, as a result of non-conventional ground movements, which could require the relevelling of wet areas or, in some cases, the relevelling of parts of the building structures, or repair of cracks to hardstand areas, masonry wall elements or movement at joints of concrete tilt panels.

A small number of establishments may, however, experience substantial adverse differential subsidence movements, which have the potential to affect the safety and serviceability of the structures. It is difficult to predict which structures may experience these movements as they are influenced by the response of local geology beneath the structures to mining. The potential impacts can, however, be managed with the implementation of an effective and robust management plan, which is discussed later in this section.

There are six industrial, commercial and business structures which have been identified above a creek that has been infilled, which are termed a ‘hidden’ creek in this report. The structures are located on the eastern side of Redbank Place and are located directly above proposed Longwall 32. These structures could experience higher compressive strains and differential vertical movements due to valley closure and upsidence.

A total of 52 houses above hidden creeks have experienced subsidence during the mining of Longwalls 22 to 27 and 22 of these houses have experienced impacts, including five houses directly above Longwall 27. The impacted houses include some on Oxley Grove, where a creek had been infilled, and houses on York Street and Remembrance Drive where a small tributary to Myrtle Creek had been infilled. The claim rate of 42 % is higher than the overall claim rate and may represent a trend, though the impacts to these houses have been generally very minor (less than Category 1) and the sample size is small.

The observations of very minor impacts may be explained by the fact that the valleys in which the houses are located are very small and may not be sufficiently incised to generate significant upsidence and closure movements. If any movements do occur, it is also possible that they may not be completely transferred from the bedrock to the house through the constructed fill, depending on the design of the building foundations.

A similar experience may occur during the mining of the proposed longwalls beneath the establishments located above hidden creeks, though it is recommended that the potential for increased differential subsidence movements be considered.

Tahmoor Colliery has successfully developed and acted in accordance with risk management plans to manage potential impacts to complex factories and businesses during the mining of Longwalls 22 to 27, including a turkey processing plant, a large shopping centre and a number of shopfront structures along Remembrance Drive.

Each business is unique in terms of the structures on the property and the activities that are conducted on each property. This includes the use of specialised equipment (e.g. concrete hoppers, processing equipment in a workshops and steel fabrication plant).

Due to the unique nature of each business, it is recommended that individual subsidence management plans be developed in consultation with the owners of each business within the SMP Area. The management strategy for each business would include:

- Consultation with the owner of each business;
- Pre-mining inspections by a suitably qualified structural engineer and subsidence engineer;
- Identification and assessment of potential impacts to the operation of each business and safety of workers and the general public;
- Consideration of mitigation measures to reduce risk prior to the commencement of subsidence movements;
- Consideration of appropriate monitoring measures;
- Consideration of appropriate triggered responses during mining;
- Development of an agreed detailed subsidence management plan between Tahmoor Colliery and the owners of each business;
- Submission of the agreed management plan for approval by the Department of Trade and Investment, Regional Infrastructure and Services; and
- Action in accordance with the management plan during mining.

Each management plan is reviewed periodically by Tahmoor Colliery and the owners of each business.

It is recommended that Tahmoor Colliery develop management plans for each business to ensure that they remain safe and serviceable during and after the mining of the proposed longwalls. The subsidence management plans should be developed prior to each establishment experiencing subsidence movements as a result of extraction of the proposed longwalls.

With an appropriate management plan in place, it is considered that potential impacts on Industrial, Commercial and Business Establishments can be managed such that they remain safe and serviceable during the mining of the proposed longwalls, even if actual subsidence movements are greater than the predictions or substantial non-conventional movements occur.

6.18.3. Future New Businesses

It is likely that there will be a turnover of businesses and new businesses developed over time. Given that the structures are located directly above Longwall 31, it is likely that some existing businesses will not be present at the time of active subsidence, or will be replaced by new businesses. Existing businesses may purchase new equipment that is sensitive to differential movement. Some of the buildings are currently vacant and new tenants may be present at the time of mining.

It is therefore recommended that any industrial, business establishments be consulted when they are about to be impacted by mine subsidence to identify their needs and concerns.

6.19. Exploration Drill Holes

There are exploration drill holes located across the SMP Area. It is recommended that the open exploration drill holes are grouted and capped prior to the proposed longwalls mining directly beneath them.

6.20. Aboriginal Archaeological Sites

The locations of the Aboriginal archaeological sites within the SMP Area are shown in Drawing No. MSEC647-25. The predictions and impact assessments for the Aboriginal archaeological sites are provided in the following sections.

6.20.1. Descriptions of the Aboriginal Archaeological Sites

The detailed descriptions of the Aboriginal archaeological sites are provided by the specialist archaeological consultant in the report by *Niche* (2014c). There were 31 Aboriginal archaeological sites which have been identified within the SMP Area, of which 12 were located directly above the proposed longwalls. The identified Aboriginal archaeological sites are listed in Table D.10, in Appendix D, and a summary is provided in Table 6.51.

Table 6.51 Aboriginal Archaeological Sites Identified within the SMP Area

Type	Total Number within the SMP Area	Total Number Located Directly above the Proposed Longwalls
Open Camp Sites (Artefact scatters and Isolated Finds)	9	3
Rock Shelter with Grinding Grooves	1	0
Rock Shelters	13	7
Grinding Groove Sites	1	1
Modified Trees	1	1
PAD	5	1
Burial	1	0
Total	**31**	**12**

Further details on the Aboriginal archaeological sites are provided in the report by *Niche* (2014c).

6.20.2. Predictions for the Aboriginal Archaeological Sites

The maximum predicted subsidence parameters for the Aboriginal archaeological sites due to the mining of Longwalls 22 to 37 are provided in Table D.10, in Appendix D. A summary of the maximum predicted subsidence, tilt and curvatures for these sites is provided in Table 6.52. The predicted tilts are the maxima after the completion of any or all longwalls at any of the sites. The predicted curvatures are the maxima at any time during or after the extraction of the longwalls.

Table 6.52 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Aboriginal Archaeological Sites within the SMP Area due to Mining of Longwalls 22 to 37

Location	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
Open Sites (Artefact scatters and Isolated Finds)	1,100	4.0	0.05	0.11
Rock Shelter with Grinding Grooves	30	< 0.5	< 0.01	< 0.01
Rock Shelters	1,225	5.5	0.06	0.13
Grinding Groove Sites	775	5.5	0.03	0.12
Modified Trees	1,000	2.0	0.02	0.11
PAD	975	1.5	0.06	0.01
Burial	< 20	< 0.5	< 0.01	< 0.01

The predicted strains for the Aboriginal archaeological sites have been based on the statistical analysis of strains provided in Section 4.5. The sites are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays above previous longwall mining, which are summarised in Section 4.5.1. The sites are expected to experience both tensile and compressive strains as the extraction faces of the proposed longwalls pass beneath them. At the completion of the proposed longwalls, the sites in locations of hogging curvature are more likely to be in final tensile zones and the sites in locations of sagging curvature are more likely to be in final compressive zones.

The grinding groove sites located along the alignments of streams could also experience valley related movements. A summary of the predicted valley related movements for the grinding groove sites is provided in Table 6.53. The predicted upsidence and closure movements are the maximum values which occur within 20 metres of the site along the alignment of the stream, due to the extraction of Longwalls 22 to 37. The grinding groove site MCR 2014-12 is located on a rock platform, away from the valley base and, therefore, will not experience upsidence or compressive strain due to valley closure movements.

Table 6.53 Maximum Predicted Total Upsidence and Closure for the Grinding Groove Sites within the SMP Area

Site Ref.	Stream	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
52-2-2068	Stonequarry Creek	70	125
52-2-2082	Redbank Creek	200	200

The range of non-valley related movement strains above the proposed longwalls is expected to be similar to the range of strains measured during the previously extracted longwalls in the Southern Coalfield, which is described in Section 4.5. It is also likely that the Aboriginal archaeological sites located along the alignments of streams would experience elevated compressive strains as a result of valley closure movements.

The compressive strains resulting from valley related movements are more difficult to predict than conventional strains. It has been observed in the past, however, that compressive strains due to valley related movements between 10 mm/m and 20 mm/m (over a standard 20 metre bay length) have occurred above previously extracted longwalls at similar depths of cover, where the magnitudes of closure were similar to those predicted for the streams in the SMP Area.

6.20.3. Impact Assessments for the Aboriginal Archaeological Sites

There are nine Open Camp Sites (OCS) comprising of stone artefact scatters and four Potential Archaeological Deposits (PAD's) within the SMP Area; three of these OCS's are located directly above the proposed longwalls. These types of sites can potentially be affected by cracking in the surface soils or the fracturing of exposed bedrock as the result of the mine subsidence movements. It is unlikely, however, that the artefacts themselves would be impacted by surface cracking or fracturing.

Surface cracking in soils as the result of conventional subsidence movements at depths of cover greater than 400 metres, such as at Tahmoor Colliery, tends to be isolated and of a minor nature. Cracking is generally limited to the top few metres of the surface soils and generally does not require remediation. Fracturing of exposed bedrock has also been observed in the Southern Coalfield, with the larger fracturing tending to occur near the bases of rivers, creeks and valleys, as the result of valley related movements.

If any significant cracking in the surface soils were to occur and were to be left untreated, erosion channels could potentially develop. If remediation of the surface soils were to be required in the locations of these OCS's and PAD's, it is recommended that Tahmoor seek the required approvals from the appropriate authorities prior to any remediation works.

There are fourteen rock shelters with art within the SMP Area, 7 of which are located directly above the proposed Longwalls 31 to 37. The sites are located within rock overhangs along Matthews Creek, with the exception of one rock shelter site that is located on Redbank Creek above Longwall 29. These types of sites can potentially be impacted by mine subsidence movements including the fracturing of sandstone, rock falls, or water seepage through joints which may affect artwork. The main mechanisms which could potentially result in impact on sandstone shelters are the mining induced curvatures and strains.

The predicted curvatures and strains at the shelters within the SMP Area are in the range of those predicted to have occurred at rock shelters which have been previously mined beneath within the Southern Coalfield. It has been reported that, where longwall mining has previously been carried out in the Southern Coalfield, beneath 52 shelters, that approximately 10 % of the shelters have been affected by fracturing of the strata or shear movements along bedding planes and that none of the shelters have collapsed (Sefton, 2000). This suggests that the likelihood of significant impacts on the shelters within the SMP Area, resulting from the extraction of the proposed longwalls, is low.

There are two grinding groove sites located within the SMP Area, of which, one is located directly above the proposed longwalls, above Longwall 32.

Site 52-2-2082 is located on Redbank Creek directly above Longwall 32, and is predicted to experience conventional curvatures up to 0.03 km^{-1} hogging and 0.12 km^{-1} sagging. The maximum predicted conventional strains 0.5 mm/m tensile and 2 mm/m compressive. The site could experience non-conventional valley closure and upsidence, as predicted in Section 5.4.

It is possible that fracturing and buckling of the bedrock could occur in the vicinity of the grinding groove site as a result of the proposed longwalls, and that the fracturing intersects with a grinding groove. It is difficult to assess the likelihood of impact at this site, as there are many factors which cannot be quantified, such as the in situ stress, inclusions and existing weaknesses with the bedrock.

The potential for impacts on the grinding groove sites could be minimised by constructing slots in the bedrock around these sites and thereby isolating them from the mining induced curvatures and strains. It is possible, however, that the installation of the slots could result in greater impacts than those which would have otherwise developed as a result of mine subsidence. The preventive measures for these grinding groove sites, if considered necessary, would need to be developed based on the site specific conditions of these sites.

The remaining one grinding groove site is not located above longwalls, and is predicted to experience curvatures up to 0.01 km^{-1} hogging and 0.01 km^{-1} sagging. Site 52-2-2068 is located 175 metres north east of Longwall 33. The maximum predicted conventional strains are less than 0.5 mm/m tensile and less than 0.5 mm/m compressive. It is possible that some very minor and isolated fracturing could develop in the bedrock at this distance from the proposed longwalls. The likelihood of these fractures being coincident with the grinding groove is considered extremely low. Minor and isolated fracturing has been observed along streams up to around 400 metres outside previously extracted longwalls in the Southern Coalfield. It has been assessed that it is *very unlikely* that the grinding groove sites located outside the extents of the proposed longwalls would be adversely impacted, even if the predictions were exceeded by a factor of 2 times.

Further assessments and recommendations for the grinding groove sites are provided in a report by *Niche* (2014c).

There is one Modified Tree located within the SMP Area, positioned directly above Longwall 34. The maximum predicted total vertical subsidence is 1,000 mm.

It has been found from past longwall mining experience, that the incidence of impacts on trees is extremely rare. Impacts on trees due to mining induced surface deformations have only been previously observed in the NSW Coalfields where the depths of cover were extremely shallow, in the order of 50 metres, or on very steeply sloping terrain, in the order of 1 in 1 or greater.

The one burial site is located approximately 310 metres from the end of the proposed Longwall 33. This site is predicted to experience less than 20 mm of vertical subsidence and, therefore, it is unlikely to be adversely impacted by the proposed mining of Longwalls 31 to 37.

Further assessments of the potential impacts on the archaeological sites are provided in a report by *Niche* (2014c).

6.20.4. Impact Assessments for the Aboriginal Archaeological Sites Based on Increased Predictions

The impact assessments for the OCS's, PAD's and grinding groove sites were mainly based on the experience of surface cracking of soils and bedrock previously observed in the Southern Coalfield, rather than the magnitudes of the predicted mine subsidence movements. If the predicted conventional movements resulting from the extraction of the proposed longwalls were increased, the incidence and size of cracking in the surface soils would also increase, however, the method of remediation of the surface soils, if required, would be unlikely to change.

The impact assessments for the rock shelters were mainly based on experience of impacts on these types of sites previously observed in the Southern Coalfield, rather than the magnitude of predicted mine subsidence movements. It should then be noted, that the percentage of rock shelters previously impacted by mining in the Southern Coalfield, provided in the paper by Sefton (2000), included shelters mined beneath by longwalls where the predicted conventional movements were greater than those for the proposed longwalls, such as at Elouera Colliery and Dendrobium Mine, which were at shallower depths of cover.

The depth of cover at the Modified Tree is greater than 150 metres and the natural surface slopes are typically less than 1 in 2. It is unlikely, therefore, that the Modified Tree would be impacted as a result of the proposed mining, even if the predictions were exceeded by a factor of 2 times. This is on the basis that impacts to trees usually only occur on very steep slopes and/or at shallow depths of cover.

6.20.5. Recommendations for the Aboriginal Archaeological Sites

It is recommended that Tahmoor Colliery develop a management plan to manage the potential impacts to Aboriginal archaeological sites. Tahmoor Colliery has developed a management plan for rock shelter site 52-2-3254 on Redbank Creek. The management plan includes consultation with the community, monitoring and reporting.

6.21. Heritage Sites

The heritage sites within the SMP Area were identified by the specialist heritage consultant and the detailed descriptions are provided in the report by *Niche* (2014c). The structures identified as having heritage significance within the SMP Area are shown in Drawing No. MSEC647-25. There are also some additional heritage relics and artefacts that are located within the SMP Area which are also shown in this drawing.

A summary of the items of heritage significance within the SMP Area is provided in Table 6.54. The two railway bridges are located just outside the SMP Area, but have been included in this list, as these structures could be sensitive to far-field movements. The Queen Victoria Memorial Hospital, now referred to as the Queen Victoria Memorial Gardens, is also listed on the Register of the National Estate, and is discussed in the following section.

Table 6.54 Items of Heritage Significance

Item	Property or Structure Reference	Location	Description
Koorana Homestead Complex, 2240 Remembrance Drive, Tahmoor	GG32a, GG32c and GG33b	Directly above LW32	Main federation style house, stables, cottage and three brick wells
Pump House and Weir, at Matthews Creek	-	West of LW37	Collapsed corrugated iron pump house and sandstone block and concrete weir
Sandstone culvert, at Matthews Creek	PMR 88.98 km	Directly above LW36	Sandstone culvert along the Picton-Mittagong Railway Line, at Matthews Creek
Fairly Residence, 426 Argyle Street, Picton	PAR_264_h01	North-east of LW32	Federation style sandstone and brick bungalow
Mill Hill, Millers House and Archaeological Relics, 675 Thirlmere Way, Picton	V06a	Above main headings between LW31 and LW37	Federation style weatherboard house, small cottage, brick well and possible archaeological remains of windmill

Item	Property or Structure Reference	Location	Description
Queen Victoria Memorial Hospital, Thirlmere	Property V04	North-west of approved LW29 and LW30 and south-west of LW37	Large complex of buildings of various sizes and construction types. A total of 31 structures are located within SMP Area, refer to Section 6.14.1 for further details
Rural Landscape, Thirlmere Way	-	East-west across the SMP Area, above LW32 and partly above LW37	Example of pasture improvement on a working dairy farm.
Cottage at 796 Thirlmere Way, Picton	PTH_112_h01	South-east of LW34 and north-east of LW32	Weatherboard house
Thirlmere Way Rail Underbridge	MSR 89.326 km	North-east of LW32, south-east of LW33 and LW34, just outside of SMP Area	Brick arch railway bridge over Thirlmere Way
Picton conservation area	-	East of LW33, only partially inside the SMP Area	A number of different structures.
South Picton Railway Bridge	MSR 86.75 km	Outside of SMP Area, north-east of LW33	Brick arch railway bridge over Argyle Street

It is noted that the “Redbank Range Railway Tunnel”, also referred to as the “Mushroom Tunnel”, is listed as an item of heritage significance in the Wollondilly Local Environmental Plan (LEP). This tunnel is located adjacent to the Main Southern Railway, north-east of the proposed LW33, and is no longer in use.

Detailed descriptions are provided by the specialist heritage consultant in the report by *Niche* (2014c). Further details, predictions and impact assessments for these items of heritage significance are provided below.

Koorana Homestead Complex (2240 Remembrance Way, Tahmoor)

Koorana Homestead Complex is located directly above the proposed Longwall 32. The items of heritage significance include the Homestead (Ref. GG32a), the Cottage (Ref. GG32c) and the Stables (Ref. GG33b). Photographs of these structures are provided in Fig. 6.68 to Fig. 6.70.

Fig. 6.68 Homestead (Ref. GG32a)

Fig. 6.69 Cottage (Ref. GG32c)

Fig. 6.70 Stables (Ref. GG33b)

The maximum predicted values of conventional subsidence, tilt and curvature for these building structures, after the completion of each of the proposed longwalls, are included in Tables D.02 to D.08, in Appendix D. A summary of the maximum predicted subsidence parameters is provided in Table 6.55.

Table 6.55 Subsidence Predictions for the Koorana Homestead

Structure	Longwall	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
Homestead (Ref. GG32a)	After LW31	90	< 0.5	< 0.01	< 0.01
	After LW32	725	3.5	0.02	0.02
	After LW37	725	3.5	0.02	0.02
Cottage (Ref. GG32c)	After LW31	100	0.5	< 0.01	< 0.01
	After LW32	725	0.5	0.02	0.02
	After LW37	725	0.5	0.02	0.02
Stables (Ref. GG33b)	After LW31	90	< 0.5	< 0.01	< 0.01
	After LW32	725	1.5	0.02	0.02
	After LW37	725	1.5	0.02	0.02

The homestead, cottage and stables are all single storey cavity brick structures founded on brick piers or strip footings. The assessed probabilities of impact have been determined using the method described in Appendix C, and have been summarised in Table 6.56.

Table 6.56 Assessed Probabilities of Impact for the Koorana Homestead Complex

Location	Repair Category		
	No Claim or R0	R1 or R2	R3, R4 or R5
Homestead (Ref. GG32a)	73.2 %	16.3 %	10.5 %
Cottage (Ref. GG32c)	78.9 %	13.1 %	8.1 %
Stables (Ref. GG33b)	74.1 %	15.6 %	10.3 %

The repair categories R0 to R5 are described in Table C.4, in Appendix C.

It has been assessed that each of the structures have an approximate 90 % probability of experiencing either Nil or Category R0 to R2 impacts, which comprises generally minor impacts which "*affects a small proportion of external or internal claddings or linings, but does not affect the integrity of external brickwork or structural elements*".

Some building elements, such as the corrugated roof and plasterboard linings can be easily restored to pre-mining condition if impacts occur. Panels and linings can be restored and repainted.

Other building elements, such as the exposed brick chimneys are more difficult to restore to pre-mining condition if impacts occur. Given the age of the brickwork, it is likely that the mortar will be weaker than the bricks and differential movements are likely to crack the mortar rather than the bricks. Differential movements could potentially result in cracking of the mortar, the bricks or both. Given that the bricks appear to be variable in colour in some elements, it may be possible to replace cracked bricks in some elements without detracting from their aesthetic appearance.

Tahmoor Colliery has developed a subsidence management plan in consultation with a heritage consultant to manage the potential impacts to heritage structures during the mining of Longwalls 22 to 27. The management measures include a pre-mining inspection of the structures, visual inspections during mining and, if impacts occur, conduct a heritage impact assessment of any conservation works that are required to repair the structures.

It has been assessed that each of the structures have an approximate 10 % probability of experiencing more substantial impacts (i.e. Category R3 or greater). If severe ground deformations (i.e. non-conventional movements) were to develop at any of the structures at the Koorana Homestead Complex, temporary and permanent repairs could be undertaken to maintain the heritage value of the buildings.

It is noted, that the Repair Category R5 is reserved for instances where the Mine Subsidence Board has agreed with the owner to rebuild the structure as the cost of repair exceeds the cost of replacement. In the case of items of heritage significance, such a commercial decision would not apply and all attempts would be undertaken to minimise subsidence induced impacts to the structures progressively during active subsidence.

It is recommended that Tahmoor Colliery continue to develop plans to manage the potential for impacts on heritage structures. In the case of Koorana Homestead Complex, the management plan should be developed prior to the extraction of Longwall 31.

Pump House and Weir at Matthews Creek

The pump house and weir at Matthews Creek are located 330 metres south-west of the proposed LW37. The pump house is a collapsed corrugated iron structure built on a timber frame on top of large sandstone blocks, located 10 to 15 metres from the weir. The pump is still standing and there are other relics in the ruins. The pump appears to still be operational. The weir appears to be dry wall, built from sandstone blocks, with a concrete render (Niche, 2014c). A photograph of the pump house is provided in Fig. 6.71 (Source: Niche, 2014c).

Fig. 6.71 Pump House at Matthews Creek (Source: Niche, 2014c)

The maximum predicted subsidence at this site resulting from the extraction of the proposed longwalls is 40 mm. Whilst the site could experience low level vertical movements, it is not expected to experience any measurable tilts, curvatures or strains. It is unlikely, therefore, that the pump house and weir would be adversely impacted by the conventional ground movements, even if the predictions were exceeded by a factor of 2 times.

It is predicted that the creek in the vicinity of the site could experience 50 mm upsidence and 50 mm closure resulting from the proposed mining. The pump house is located on the side of the creek and, therefore, is not expected to experience the valley related upsidence or the compressive strain due to the valley closure movement. The weir could experience these low level valley related movements, however, due to its distance from the proposed longwalls, these movements are expected to be relatively uniformly distributed across the structure and not result in adverse impact.

No management measures are recommended for the pump house or weir.

Sandstone Culvert at Matthews Creek Tributary

The sandstone culvert at a tributary of Matthews Creek, on the Picton to Mittagong Loop Line (chainage 88.98 km), is formed from sandstone blocks. The culvert is recorded as being in good condition (Niche, 2014c). A photograph of the culvert is provided in Fig. 6.72 (Source: Niche, 2014c).

Fig. 6.72 Sandstone Culvert at Matthews Creek, Picton to Mittagong Loop Line (Source: Niche, 2014c)

A summary of the maximum predicted values of conventional subsidence, tilt and curvature for the sandstone culvert at Matthews Creek is provided in Table 6.57. The values provided in this table are the maxima within a 20 metre radius of the culvert.

Table 6.57 Subsidence Predictions for the Sandstone Culvert at Matthews Creek

Location	Longwall	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
Sandstone Culvert at Matthews Creek (PMR 88.98 km)	After LW34	< 20	< 0.5	< 0.01	< 0.01
	After LW35	60	< 0.5	< 0.01	< 0.01
	After LW36	625	5.5	0.05	0.06
	After LW37	1,000	4.5	0.05	0.06

The culvert is located along the alignment of Matthews Creek and, therefore, could also experience valley related upsidence and closure movements. The culvert is predicted to experience 250 mm upsidence and 150 mm closure resulting from the extraction of the proposed longwalls.

The maximum predicted tilt of 5.5 mm/m represents a change in grade less than 1 %. It is unlikely, therefore, that the serviceability of the culverts would be adversely impacted by the mining induced tilt.

The maximum predicted curvatures are 0.05 km^{-1} hogging and 0.06 km^{-1} sagging, which represent minimum radii of curvatures of 20 kilometres and 17 kilometres, respectively. The predicted conventional and valley related movements are likely to be sufficient to result in cracking, spalling and, possibly, dislodgement of the blocks.

It is recommended that Tahmoor Colliery develop management strategies for the culvert, to maintain its integrity during active subsidence, and to remediate it after the completion of active subsidence, if required. These management strategies should be developed in consultation with the heritage consultant and the Wollondilly Shire Council. Further discussions on the culverts along the Main Southern Railway and the Picton to Mittagong Loop Line are provided in Sections 6.2 and 6.3.

Fairly Residence (426 Argyle Street, Picton)

Fairly Residence at 426 Argyle Street Picton (Ref. PAR_264_h01), consists of a federation style sandstone and brick bungalow, with steel roof. The house features timber sash windows and also features iron lacework balustrade details. A photograph of the house is provided in Fig. 6.73 (Source: Niche, 2014c).

Fig. 6.73 Fairly Residence (Ref. PAR_264_h01) (Source: Niche, 2014c)

The residence is located 400 metres north-east of the proposed Longwall 32. The structure is predicted to experience 30 mm vertical subsidence resulting from the extraction of the proposed longwalls. Whilst the house could experience low level vertical movements, it is not expected to experience any measurable tilts, curvatures or strains. It is unlikely, therefore, that this structure would experience adverse impacts, even if the predictions were exceeded by a factor of 2 times.

675 Thirlmere Way, Picton (Mill Hill, Miller's House)

Miller's House (Structure Ref. V06a) is located around 100 metres from the end of Longwall 31. The items of heritage significance consist of a single-storey weatherboard house, and archaeological relics. The weatherboard house sits on brick and steel piers, and is therefore inherently structurally flexible, making it less prone to subsidence impact. A photograph of the house is provided in Fig. 6.74.

Fig. 6.74 Mill Hill, Miller's House (Ref. V06a)

The structure is predicted to experience 90 mm vertical subsidence, but is not expected to experience any substantial tilts, curvatures or strains. The assessed probabilities of impact have been determined using the method described in Appendix C and are: 93 % Nil or Category R0; 6 % Category R1 or R2; and 1 % Category R3 or greater. The repair categories R0 to R5 are described in Table C.4, in Appendix C. It is expected, therefore, that the house would experience nil or only minor impacts resulting from the extraction of the proposed longwalls. Impacts on the structure are likely to be limited to the external cladding or internal finishes, which can be more readily repaired.

Queen Victoria Memorial Hospital

The Queen Victoria Memorial Hospital, now referred to as the Queen Victoria Memorial Gardens, is located on Thirlmere Way and comprises a total of 46 buildings, one pool and 12 dams, of which, 31 buildings, one pool and three dams located within the SMP Area. The proposed longwalls do not mine directly beneath any of the structures or dams. Longwall 37 extracts directly beneath the south-eastern corner of the property and is located at distances of 250 metres from the nearest building structure. The approved Longwalls 29 and 30 are located at distances of 140 metres from the nearest building structures.

Further descriptions, the predictions and impact assessments for the building structures associated with the Queen Victoria Memorial Hospital are provided in Section 6.14.1. It has been assessed that the potential for adverse impacts on these structures is very low.

Rural Landscape, Thirlmere Way

The rural landscape on Thirlmere Way provides a good example of pasture improvement on a working dairy farm, and provides a picturesque setting important to the Queen Victoria Memorial Hospital. A photograph of the landscape is provided in Fig. 6.75 (Source: Niche, 2014c).

Fig. 6.75 Rural Landscape, Thirlmere Way (Source: Niche, 2014c)

The Rural Landscape adjacent to Thirlmere Way is partly located above the proposed Longwalls 31, 32, 36 and 37. The landscape could experience the range of predicted subsidence movements for these longwalls, which is summarised in Chapter 4.

The vertical subsidence transitions from the maximum values directly above the proposed longwalls to slightly reduced values above the chain pillars. These variations in the vertical subsidence of around 200 mm to 300 mm occur over distances of 320 metres and, therefore, are not visually perceptible. It is unlikely, therefore, that the vertical subsidence would reduce the visual aesthetics or the heritage value of the land.

The curvatures and strains could result in cracking or heaving in the surface soils. The surface deformations are expected to be isolated and of a minor nature, due to the high depths of cover at Tahmoor Colliery, with crack widths typically less than 25 mm. Any significant surface deformations could be remediated by locally regrading and recompacting the surface soils. No large scale slope failures are anticipated, as none have been observed in the Southern Coalfield as a result of longwall mining. It is unlikely, therefore, that the mining induced curvatures or strains would reduce the visual aesthetics or the heritage value of the land.

Cottage at 796 Thirlmere Way

796 Thirlmere Way is located north-east of Longwall 32. The items of heritage significance comprise a weatherboard house with corrugated steel roof, painted brick chimneys, double sash windows and front and rear verandahs. A photograph of the cottage is provided in Fig. 6.76 (Source: Niche, 2014c).

Fig. 6.76 Cottage at 796 Thirlmere Way (Source: Niche, 2014c)

The cottage is located at a distance of 450 metres south-east of Longwall 34, at its closest point to the proposed longwalls. At this distance, the structure is predicted to experience 20 mm vertical subsidence resulting from the proposed mining. Whilst the cottage could experience very low levels of vertical subsidence, it is not expected to experience any measurable tilts, curvatures or strains, even if the predictions were exceeded by a factor of 2 times. The likelihood of impacts to the cottage is considered very low.

Management strategies are recommended for the cottage, similar to those for the houses, which are provided in Section 6.23.

Thirlmere Way Rail Underbridge

The Thirlmere Way Rail Underbridge is located outside the SMP Area, however, it has been included in the assessments in this report as it could experience far-field movements. The predictions and impact assessments for the bridge are provided in Section 6.2.7. It has been assessed that the likelihood of impact on this bridge is very low.

Picton Conservation Area

The Picton Conservation Area includes a number of different elements which are "*harmoniously combined and framed by the surrounding steep hills*" (SHI listing) (Niche, 2014c). There are various structures associated with the Main Southern Railway located within the SMP Area, including the railway tunnel at Picton and railway deviation loop and the edge of the commercial precinct (Niche, 2014c). The extent of the Picton Conservation Area has been expanded in recent times to include the railway infrastructure, and this is the only reason that part of the Picton Conservation Area now falls within the SMP Area. This was previously not the case.

The original extent of the Picton Conservation Area is located outside the predicted 20 mm subsidence contour. It is unlikely that this area would experience adverse impacts, even if the predictions were exceeded by a factor of 2 times.

The extended area, including the railway tunnels and associated infrastructure, is partially located within the predicted 20 mm subsidence contour. The predictions and impact assessments for this infrastructure are provided in Section 6.2. It has been assessed that the likelihood of impact on this infrastructure is very low.

South Picton Railway Bridge

The South Picton Railway Bridge is located outside the SMP Area, however, it has been included in the assessments in this report as it could experience far-field movements. The predictions and impact assessments for the bridge are provided in Section 6.2.7. It has been assessed that the likelihood of impact on this bridge is very low.

6.22. Survey Control Marks

The locations of the state survey control marks within the vicinity of the proposed longwalls are shown in Drawing No. MSEC647-26. The locations and details of the survey control marks were obtained using the *Six Viewer* (2014).

The state survey control marks are located across the SMP Area and, therefore, would be expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the SMP Area is provided in Chapter 4.

The state survey control marks located outside and in the vicinity of the SMP Area are also expected to experience small amounts of subsidence and small far-field horizontal movements. It is possible that other survey control marks outside the immediate area could also be affected by far-field horizontal movements, up to 3 kilometres outside the SMP Area. Far-field horizontal movements and the methods used to predict such movements are described further in Section 4.6.

It will be necessary on the completion of the longwalls, when the ground has stabilised, to re-establish any state survey control marks that are required for future use. Consultation between Tahmoor Colliery and Land and Property Information will be required throughout the mining period to ensure that these survey marks are reinstated at an appropriate time, as required.

6.23. Houses

6.23.1. Descriptions of the Houses

There are 222 houses that have been identified within the SMP Area. The locations of the houses are shown in Drawing Nos. MSEC647-27 and MSEC647 – Maps 01 to 48, and details are provided in Table D.01, in Appendix D.

The locations, sizes, and construction details of the houses were determined from an aerial photograph of the area in 2013, kerbside inspections in December 2014 and *Google Street View*® in December 2014. In some cases, the houses could not be viewed from the street and in these cases the construction details could not be determined.

Given the long term nature of the proposed mining activity, it is likely that there will be a growth and renewal of houses over time. It is likely the total number of houses affected by the extraction of the proposed longwalls will be greater than currently identified.

The following provides further discussions on the details of the houses within the SMP Area.

Locations

The main township of Picton is located to the east of the proposed longwalls. There are 53 houses which are located directly above the proposed longwalls, i.e. 24 % of the total houses within the SMP Area. A summary of the number of houses located directly above each of the proposed longwalls is provided in Table 6.58.

Table 6.58 Number of Houses Located Directly above each of the Proposed Longwalls

Longwall	Number of Houses Directly Above Each Proposed Longwall	Percentage of the Total Number of Houses within the SMP Area
LW31	5	2
LW32	13	6
LW33	2	1
LW34	0	0
LW35	1	0.5
LW36	10	5
LW37	22	10
Total	**53**	**24 %**

Maximum Plan Dimension, Plan Area and Height

The distributions of the maximum plan dimensions and plan areas of the houses within the SMP Area are provided in Fig. 6.77. The majority of the houses are between 10 metres and 30 metres long, with an average length of around 21 metres. The majority of the houses have plan areas between 80 m^2 and 810 m^2, with an average area of around 250 m^2.

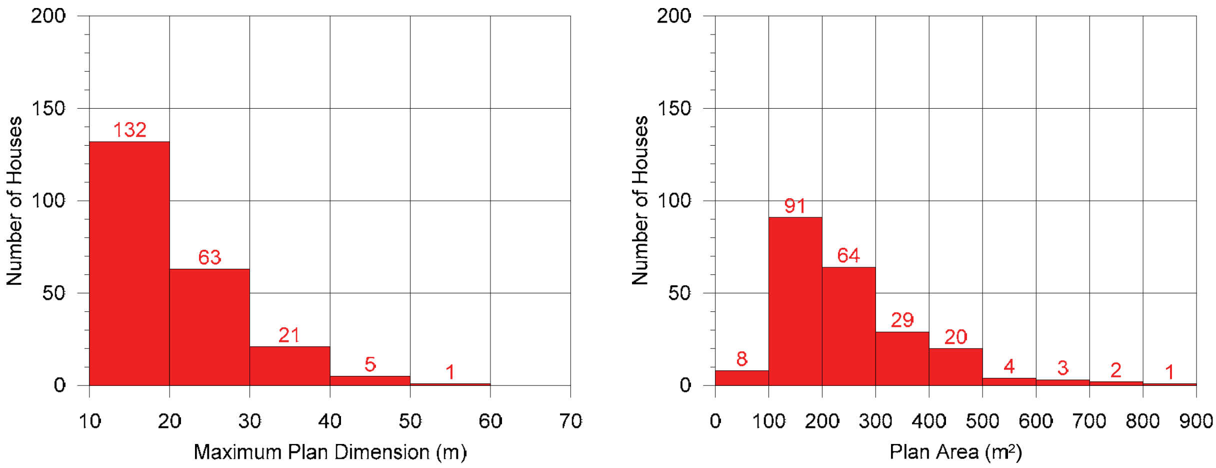


Fig. 6.77 Distribution of Houses by Maximum Plan Dimension and Plan Area

The houses have been categorised into four groups, on the basis of their maximum plan dimension and the number of stories. A summary of these house type categories is provided in Table 6.59 below. It is noted that two-storey houses include split-level houses.

Table 6.59 House Type Categories

House Type	Description	Number	Percentage
H1	Single-storey with maximum plan dimension less than 30 metres	157	71 %
H2	Single-storey with maximum plan dimension of 30 metres or greater	23	10 %
H3	Two-storey with maximum plan dimension less than 30 metres	26	12 %
H4	Two-storey with maximum plan dimension of 30 metres or greater	4	2 %
N/A	Cannot be identified from kerbside inspections	12	5 %

It can be seen from the above table that the majority of houses within the SMP Area are single-storey with a maximum plan dimension less than 30 metres (i.e. Type H1), and there are only four two-storey houses with a maximum plan dimension greater than 30 metres (i.e. Type H4) identified within the SMP Area.

A map showing the spatial distribution of houses by category is provided in Drawing No. MSEC647-29.

Type of Construction

The distributions of the wall and footing constructions of the houses within the SMP Area are provided in Fig. 6.78. The majority of the houses within the SMP Area are either brick or brick-veneer construction and are founded on strip footings.

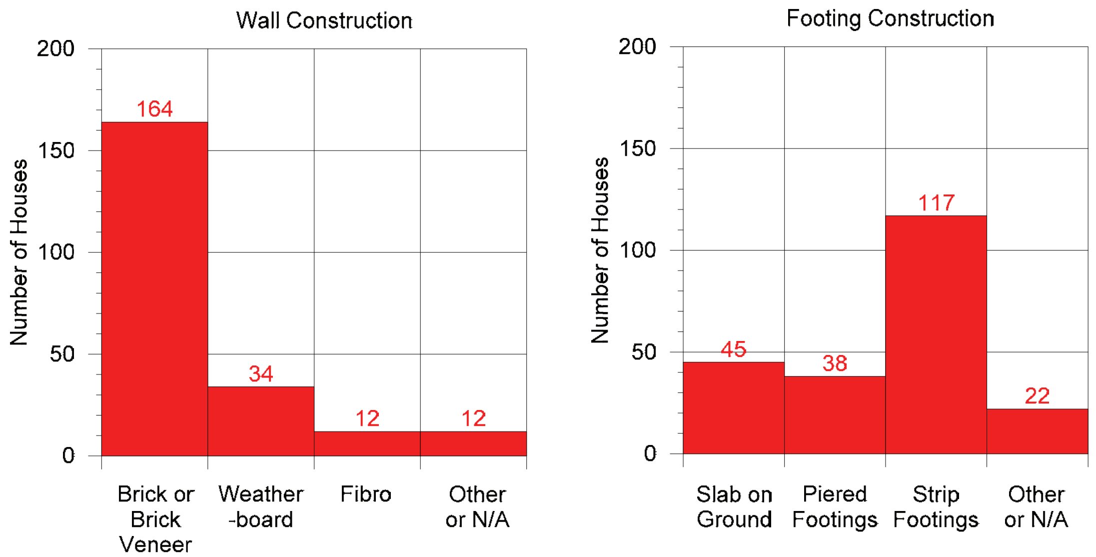


Fig. 6.78 Distributions of Wall and Footing Construction for Houses within the SMP Area

Following a review of impacts to houses during the mining of Tahmoor Longwalls 22 to 25, it was found that there was a noticeable difference in structural performance in response to mine subsidence movements between the following construction types:-

- Brick or brick-veneer houses constructed on a ground slab;
- Brick or brick-veneer houses constructed on strip footings; and
- Weatherboard or fibro houses constructed on either ground slabs or strip footings.

The distribution of houses by construction type is provided in Table 6.60.

Table 6.60 **Distribution of Houses by Construction Type**

Description	Number of Houses	Percentage of Houses
Brick or brick-veneer houses constructed on a ground slab	41	19 %
Brick or brick-veneer houses constructed on strip footings	123	55 %
Weatherboard or fibro houses constructed on either ground slabs or strip footings or other	46	21 %
Cannot be identified from kerbside inspections	12	5 %

A map showing the spatial distribution of houses by construction type is provided in Drawing No. MSEC647-30.

Age of Houses

The ages of the houses have been determined by examination of a series of historical aerial photographs provided by Land and Property Information and Tahmoor Colliery. The photographs that were available over the SMP Area were taken in 1961, 1966, 1975, 1983, 1994, 2002, 2005, 2008 and Tahmoor Colliery commissioned an aerial photograph over the area in 2013.

A histogram showing the distribution of houses by age is shown in Fig. 6.79. A map showing the spatial distribution of structures by age of house is provided in Drawing No. MSEC647-28. It can be seen from this figure, that the newest houses are predominately located above the proposed LW36 and LW37, with older houses predominately located above the proposed Longwalls 31 and 32.

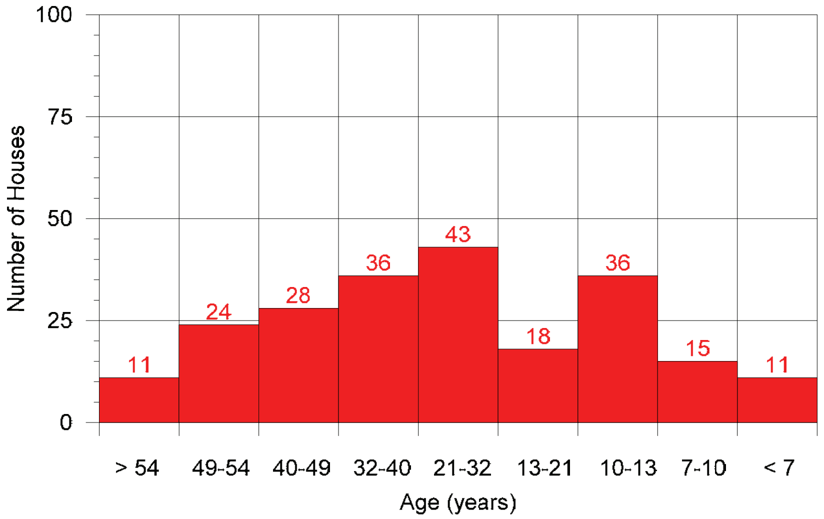


Fig. 6.79 Distribution of Houses by Age

Houses on Steep Slopes

A total of 11 houses within the SMP Area are located on or near steep slopes, being Refs. GG36a, PSC_092_h01, PSR_010_h01, PTH_001_h01, V05a, V06a, V07a, V08a, V09b, V11a and V15a. The locations of the building structures on or near steep slopes are shown in Drawing No. MSEC647-11 and MSEC647-12.

The numbers of each house type are: six of Type H1; two of Type H2; one of Type H3; none of Type H4; and two which could not be identified. The construction types of these houses are: two brick on slab on ground; two brick on strip footings; five timber framed houses; and two which could not be identified.

Houses above 'Hidden' Creeks

There is only one house which has been identified directly above a 'hidden' creek (Ref. PSC_027_h01). This house is located outside the extents of the proposed longwalls, at a distance of 70 metres south-west of the maingate of LW37. As shown in Drawing No. MSEC647-10, a number of houses are located close to but directly above some hidden creeks.

Houses outside Mine Subsidence Districts

The locations of the declared mine subsidence districts are shown in Drawing No. MSEC647-03. The Bargo Mine Subsidence District was proclaimed in 1975 and was extended over the Bridge Street Industrial Area in 1994. The Picton Mine Subsidence District was proclaimed in 1997.

There are 109 houses within the SMP Area which are located within the Bargo Mine Subsidence District, of which 31 were constructed prior to its declaration. There are also 38 houses located within the Picton Mine Subsidence District, of which, two were constructed prior to its declaration.

There are 75 houses within the SMP Area (i.e. 34 % of the total) which are located outside the declared mine subsidence districts. The numbers of each house type are: 55 of Type H1; three of Type H2; 10 of Type H3; two of Type H4; and five which could not be identified. A summary of the ages of the houses located outside the declared mine subsidence districts is provided in Table 6.61.

Table 6.61 Ages of Houses Located Outside the Declared Mine Subsidence Districts

Period of Construction	No. of Houses	Percentage of Houses Located Outside of the Declared MSDs
1961 or earlier	0	0 %
1962 to 1966	17	23 %
1967 to 1975	13	17 %
1976 to 1983	7	9 %
1984 to 1994	15	20 %
1995 to 2002	7	9 %
2003 to 2005	10	4 %
2006 to 2008	3	14 %
2009 to 2013	3	4 %

The majority of the houses located outside the declared mine subsidence districts are single-storey buildings less than 30 metres long (i.e. Types H1) and are between 20 and 50 years old.

Future House Construction

The statistics on building age provide a reasonable indication of the rate of growth of houses within the SMP Area. The total number of houses within the SMP Area with time is illustrated in Fig. 6.80.

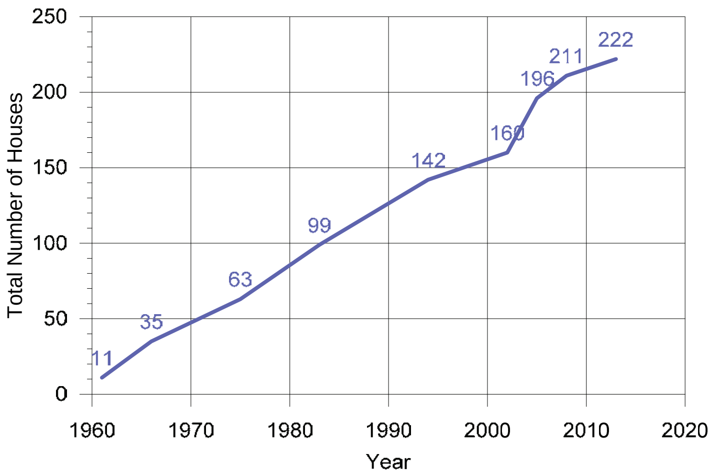


Fig. 6.80 Total Number of Houses within the SMP Area with Time

The highest rate of construction occurred between 2002 and 2005, with 36 houses constructed during this period, which equates to a maximum rate of 12 houses per year. However, since this time the rate of construction has decreased. There were 80 houses constructed over the past 20 years, which equates to an average rate of construction of approximately four houses per year.

6.23.2. Predictions for the Houses

Predictions of conventional subsidence, tilt and curvature have been made at the centroid and at the vertices of each house, as well as eight equally spaced points placed radially around the centroid and vertices at a distance of 20 metres. In the case of a rectangular shaped structure, predictions have been made at a minimum of 45 points within and around the structure.

Summaries of the maximum predicted values of conventional subsidence, tilt and curvature for each of the houses within the SMP Area, after the completion of each of the proposed longwalls, are provided in Tables D.02 to D.08, in Appendix D. The predicted tilts provided in these tables are the maxima in any direction after the completion of each of the proposed longwalls. The predicted curvatures are the maxima in any direction at any time during or after the extraction of each of the proposed longwalls.

The distribution of the predicted conventional subsidence parameters for the houses within the SMP Area are illustrated in Fig. 6.81, Fig. 6.82 and Fig. 6.83 below.

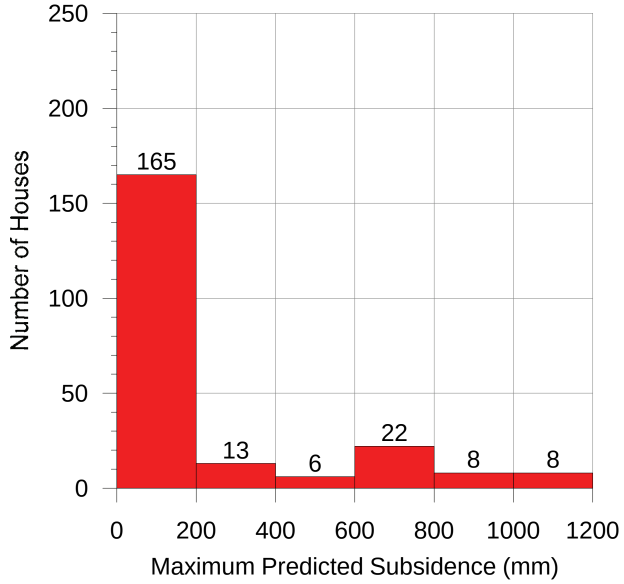


Fig. 6.81 Maximum Predicted Conventional Subsidence for the Houses within the SMP Area

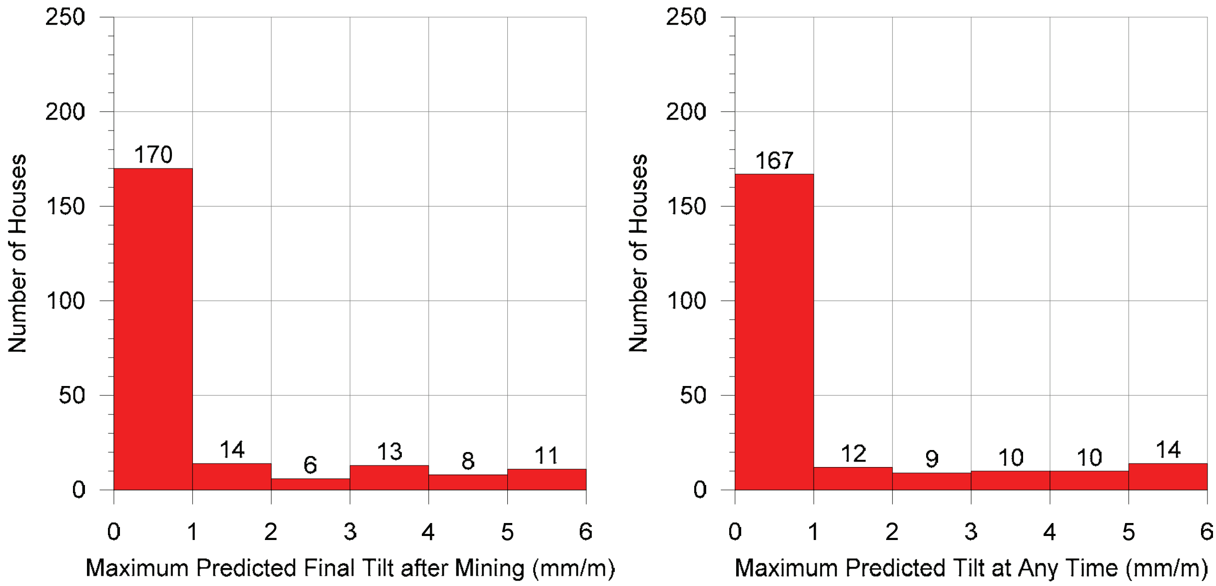


Fig. 6.82 Maximum Predicted Conventional Tilts After the Extraction of All Longwalls (Left) and Maximum Predicted Conventional Tilts After the Extraction of Any Longwall (Right)

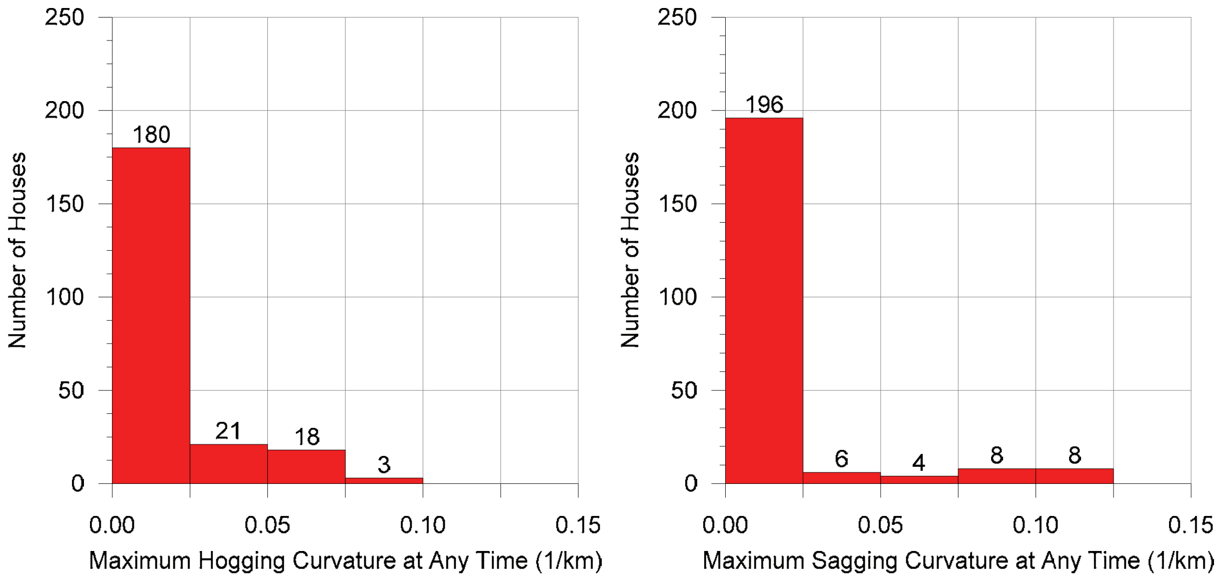


Fig. 6.83 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Houses within the SMP Area

The predicted strains for the houses have been based on the statistical analysis of strains provided in Section 4.5. The structures are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays above previous longwall mining, which are summarised in Section 4.5.1. The houses are expected to experience both tensile and compressive strains as the extraction faces of the proposed longwalls pass beneath them. At the completion of the proposed longwalls, the structures in locations of hogging curvature are more likely to be in final tensile zones and the structures in locations of sagging curvature are more likely to be in final compressive zones.

6.23.3. Impact Assessments for the Houses

The following sections provide the impact assessments for the houses within the SMP Area.

Potential Impacts Resulting from Vertical Subsidence

Vertical subsidence does not directly affect the stability or serviceability of houses. The potential for impacts on houses are affected by differential subsidence, which includes tilt, curvature and strain, and the impact assessments based on these parameters are described in the following sections.

Vertical subsidence can, in some cases, affect the heights of houses above the flood level. A detailed study has been undertaken by WRM (2014) to determine the extent of the flood prone areas after the completion of mining. The study found that stream flows are generally contained within the channels of Matthews Creek, Redbank Creek, Cedar Creek and Stonequarry Creek with depths in excess of 4 metres in the main channels within the SMP Area. The subsidence resulting from the mining of the proposed Longwalls 31 to 37 does not result in an increase in flood levels in the Redbank Creek and Matthews Creek catchment areas (WRM, 2014)

Potential Impacts Resulting from Tilt

The maximum predicted tilt for the houses within the SMP Area is 6 mm/m. The predicted final tilts for the majority of the houses (i.e. 170 structures, or 77 % of the total) are less than 1 mm/m, as most are located outside the extents of the proposed longwalls. The distribution of predicted final tilts for the houses within the SMP Area is provided in Fig. 6.84.

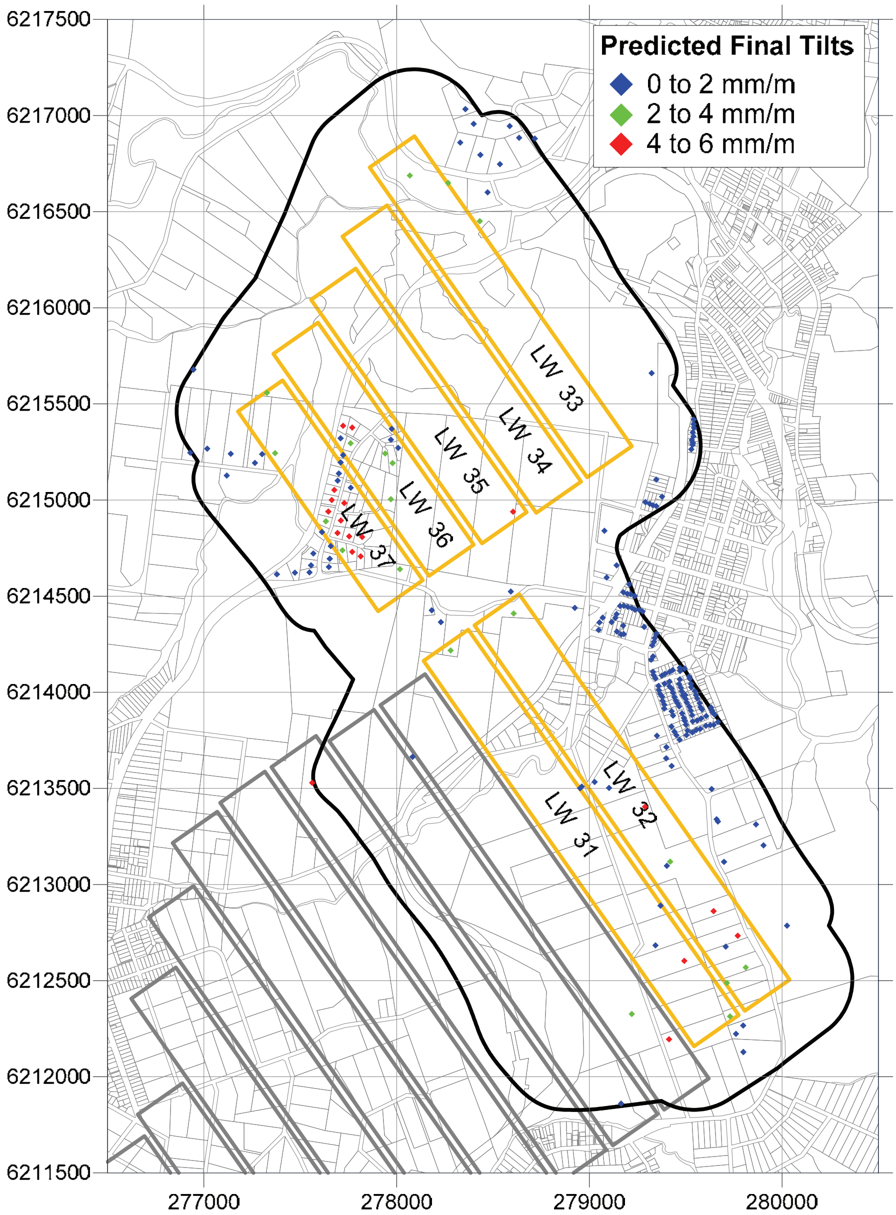


Fig. 6.84 Distribution of Predicted Finals Tilts for the Houses within the SMP Area

It has been found from past longwall mining experience that tilts of less than 7 mm/m generally do not result in any substantial impacts on houses. Some minor serviceability impacts can occur at these levels of tilt, including door swings and issues with roof gutter and wet area drainage, all of which can be remediated using normal building maintenance techniques.

It is expected, therefore, that only minor serviceability impacts would occur for the houses within the SMP Area as a result of the mining induced tilt. It is possible, however, that more substantial serviceability impacts could develop at some houses, as a result of non-conventional ground movements, which could require the relevelling of wet areas or, in some cases, the relevelling of parts of the building structures.

It is expected that, in all cases, the houses within the SMP Area will remain in safe and serviceable conditions as a result of the mining induced tilts, as tilts by themselves rarely impact on the stability of building structures at the levels that are predicted to occur.

Potential Impacts Resulting from Curvature and Strain

It has been found from past longwall mining experience that the majority of impacts on houses are a result of the mining induced curvature and strains. The methods for predicting and assessing impacts on building structures have developed over time as knowledge and experience has grown. MSEC has provided predictions and assessments for structures potentially affected by mining at Tahmoor Colliery using the latest methods available at the time.

Historically, the assessment of the potential impacts for houses was based on the calculated maximum crack widths in the external walls. Report No. MSEC157 which supported the SMP Application for Longwalls 24 and 26 adopted this '*previous method*'. It was recognised that this method did not consider the potential impacts from non-conventional ground movements, nor the potential for other types of impact, such as movement along the damp proof course.

The information collected during the mining of Longwalls 22 to 24A was reviewed in two parallel studies: one as part of a funded ACARP Research Project C12015 and one at the request of the Department of Primary Industries (DPI). The outcomes of the studies include:

- Review of the performance of the '*previous method*';
- Recommendations for improving the '*previous method*' of Impact Classification; and
- Recommendations for improving the '*previous method*' of Impact Assessment.

At the time of these studies, over 1,000 residential and significant civil structures had experienced subsidence movements, resulting from mining at Tahmoor Colliery, and impacts had been observed at over 150 houses. The experience gained and the data gathered during the mining of these longwalls were used to develop a '*revised method*' for the assessment of the potential impacts on houses. The background on the development of this method is provided in Appendix C.

The maximum predicted curvatures for the houses within the SMP Area are 0.08 km^{-1} hogging and 0.11 km^{-1} sagging, which represent minimum radii of curvatures of 13 kilometres and 9 kilometres, respectively. The predicted curvatures for the majority of the houses (i.e. 178 structures, or 80 % of the total) are less than 0.03 km^{-1}, as most are located outside the extents of the proposed longwalls. The distributions of the maximum predicted curvatures for the houses within the SMP Area are provided in Fig. 6.85.

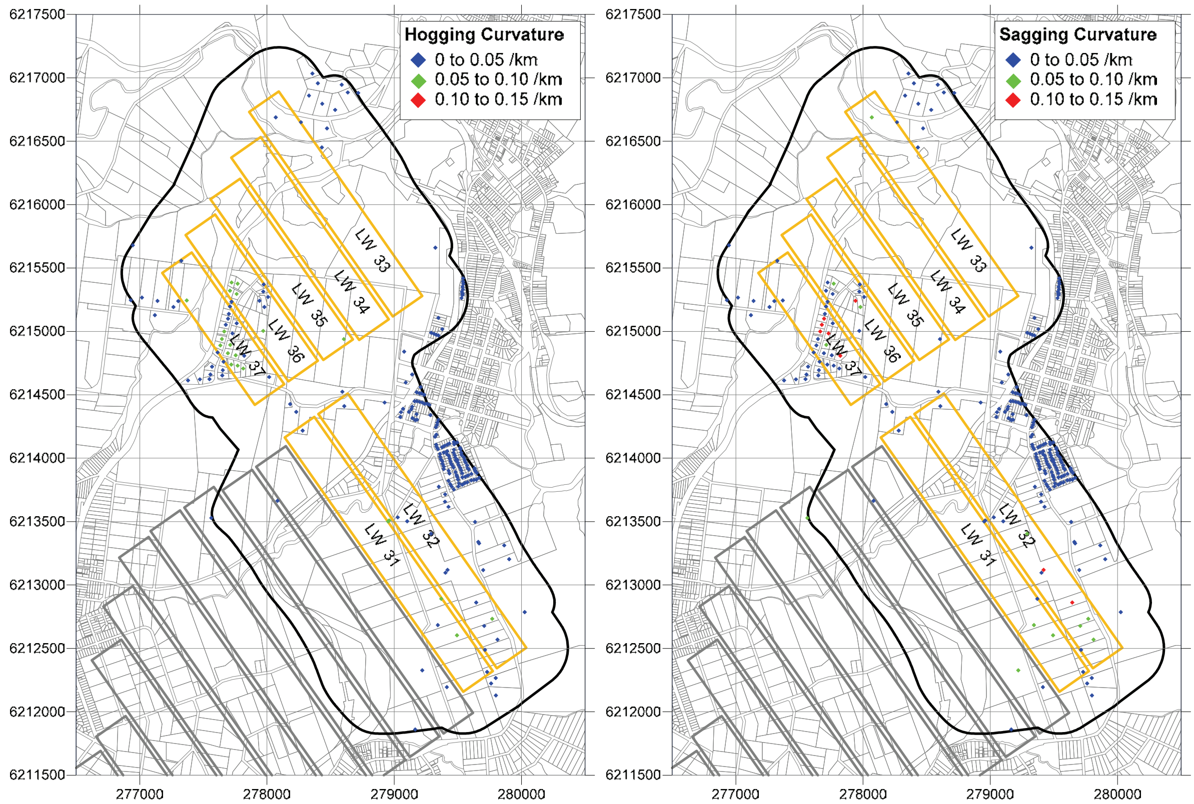


Fig. 6.85 Distributions of Maximum Predicted Curvatures for the Houses within the SMP Area

A summary of the maximum predicted movements and the assessed impacts for each of the houses within the SMP Area is provided in Tables D.02 to D.08, in Appendix D. The overall distribution of the assessed impacts for the houses within the SMP Area is provided in Table 6.62.

Table 6.62 Assessed Impacts for the Houses within the SMP Area

Location	Repair Category		
	No Claim or R0	R1 or R2	R3, R4 or R5
Houses Directly above the Proposed Longwalls (53 total)	80 % (≈ 42 houses)	14 % (≈ 7 houses)	6 % (≈ 4 houses)
Houses Outside the Proposed Longwalls (169 total)	94 % (≈ 159 houses)	5 % (≈ 8 houses)	1 % (≈ 2 houses)
All Houses within the SMP Area (222 total)	**90 % (≈ 200 houses)**	**7 % (≈ 16 houses)**	**3 % (≈ 6 houses)**

The repair categories R0 to R5 are described in Table C.4, in Appendix C.

It has been assessed that: 90 % or approximately 200 houses would experience Nil or Category R0 impacts; 7 % or approximately 16 houses would experience Category R1 or R2 impacts; and that 3 % or approximately 6 houses would experience Category R3 or greater impacts. Trend analyses following the mining of Longwalls 22 to 24A indicate that the chance of impact is higher for the following houses:

- Houses predicted to experience higher strains and curvature;
- Houses with masonry walls;
- Masonry walled houses that are constructed on strip footings;
- Larger houses; and
- Houses with variable foundations, such as those with extensions.

Severe impacts have previously occurred as a result of substantial non-conventional movements and in plateau areas away from incised valleys, the locations of which cannot be predicted prior to mining. The impacts, however, develop gradually such that they can be detected early and repairs can be undertaken incrementally to ensure that the houses remain safe and serviceable during mining.

As noted in Appendix C, at the time of writing ACARP Research Project C12015, the observed proportion of houses where the Mine Subsidence Board and affected landowners had decided to rebuild rather than repair (Category R5) impacts was less than 0.5 %. Since the publication of the research report, the proportion of houses where a decision has been made to rebuild has increased to approximately: 0.7 % overall; and 1.7 % above Longwalls 24A to 27 within the observed zone of increased subsidence.

The decision to rebuild rather than repair a house is based on a variety of factors. From an impact perspective, all houses previously impacted at Tahmoor Colliery could have been repaired rather than replaced, including those where a decision has been made to rebuild them. However, it is often simpler and more cost effective to rebuild, rather than to repair, a house with substantial impacts. It is for this reason that repair categories R3 to R5 have been combined in Tables D.02 to D.08.

It is expected, therefore, that the majority of the impacts on the houses would be repaired by the Mine Subsidence Board. It is possible that, for two or three houses of the six assessed to experience Category R3, or greater impacts, the costs of repairs could exceed the construction cost of the houses and, in these cases, the houses may be rebuilt.

The primary risk associated with mining beneath houses is public safety. Historically, residents have not been exposed to immediate and sudden safety hazards as a result of impacts that occur due to mine subsidence movements in the NSW Coalfields. Emphasis is placed on the words “immediate and sudden” as in rare cases, some structures have experienced severe impacts, but the impacts did not present an immediate risk to public safety as they developed gradually with ample time to relocate residents.

All houses within the SMP Area are expected to remain safe throughout the mining period, however, some houses could experience substantial impacts which may require that the residences be temporarily relocated to effect repairs.

Potential Impacts from ‘Hidden’ Creeks

Hidden creeks are defined as natural watercourses that appear to have been covered during development of a property or road. Hidden creeks have been identified from surface contours and historical aerial photographs.

There is only one house which has been identified above a 'hidden' creek, being Ref. PSC_027_h01. This house is located outside the extents of the proposed longwalls, at a distance of 70 metres south-west of the maingate of LW37. This house could experience slightly higher compressive strains due to valley closure movements. The experience from Tahmoor Colliery indicates that the potential impacts are no greater than those assessed for the houses located directly above the proposed longwalls.

This house is considered to have a greater chance of experiencing non-conventional upsidence and closure movements during mining. When tested against observations during the mining of Longwalls 22 to 28, however, no clear increase in frequency of impact is observed.

A total of 52 houses above hidden creeks have experienced subsidence during the mining of Longwalls 22 to 27 and 22 houses have experienced impacts, including five houses directly above Longwall 27. The impacted houses include some on Oxley Grove, Tahmoor, where a creek had been infilled, and houses on York Street and Remembrance Drive, Tahmoor, where a small tributary to Myrtle Creek had been infilled. The rate of impact is higher than the overall rate of impact of 42 % and may represent a trend, though the impacts to these houses have been generally very minor (less than Category 1) and the sample size is small.

The observations of very minor impacts may be explained by the fact that the valleys in which the houses are located are very shallow and may not be sufficiently incised to generate significant upsidence and closure movements. If any movements do occur, it is also possible that they may not be completely transferred from the bedrock to the house through the constructed fill, depending on the design of the building foundations.

6.23.4. Impact Assessments based on Increased Predictions

If the predicted tilts were exceeded by a factor of 2 times, the actual tilts would be: between 7 mm/m and 10 mm/m at 13 houses; and between 10 mm/m and 12 mm/m at 11 houses. It is likely that many of these houses would require more substantial remediation measures, including the relevelling of wet areas and adjustment of the roof gutters and, in some cases, it would be necessary to relevel part or all of the structures. It may not be possible to relevel all these structures and, in these cases, the houses would need to be rebuilt. However, in recent years, the Mine Subsidence Board has developed new technologies to relevel houses, particularly those on concrete ground slabs. The number of houses that may need to be rebuilt would be very small.

If the predicted curvatures and strains were exceeded by a factor of 2 times, the assessed impacts would be: 89 % or approximately 198 houses would experience Nil or Category R0 impacts; 8 % or approximately 18 houses would experience Category R1 or R2 impacts; and that 3 % or approximately 6 houses would experience Category R3 or greater impacts.

It is possible that the impacts to two or three of the six assessed to experience Category R3, or greater, could be sufficient such that the costs to rebuild would be greater than the costs of repair. It would still be unlikely that the residents would be exposed to immediate and sudden safety hazards, as any impacts would still be expected to develop gradually with ample time to relocate residents

Tahmoor Colliery has developed a subsidence management plan in consultation with the DTIRIS and the Mine Subsidence Board to manage the potential consequences if increased subsidence develops at the houses. Additional risk control procedures can be undertaken to manage the potential for increased impacts on houses. The Mine Subsidence Board has demonstrated its capacity to quickly respond to any claims for damage where they affect the safety or serviceability of structures. Building inspectors and structural engineers are available to inspect any affected structures within 24 hours on behalf of Tahmoor Colliery. If an impact occurs to a structure that represents a risk to public safety, the Mine Subsidence Board and Tahmoor Colliery are able to temporarily relocate residents at short notice.

It is important to recognise that while any potential risks to public safety must be responsibly managed, the likelihood of a severe public safety hazard occurring quickly at a structure is extremely low, even if the structure experiences increased subsidence, tilts and curvatures. This was observed during the mining of Longwalls 24A to 27 and is consistent with experiences gained during a long history of mining beneath structures in the Southern Coalfield. This experience shows that residents have not been exposed to immediate and sudden safety hazards as a result of impacts that occur due to mine subsidence movements. In rare cases, some structures have experienced severe impacts, but the impacts did not present an immediate risk to public safety as they developed gradually with ample time to relocate residents.

6.23.5. Management of Potential Impacts on the Houses

Tahmoor Colliery has extensive experience of mining beneath urban areas. It has developed and acted in accordance with a risk management plan to manage potential impacts to residential structures during the mining of Longwalls 22 to 28.

The Subsidence Management Process has been developed in consideration of the following facts and observations:

1. Australian standards have been available for use in the design of structures since 1948. Around half of the houses within the SMP Area have been constructed within and after the declaration of the Bargo (78 total, or 35 %) and the Picton (36 total, or 16 %) Mine Subsidence Districts;
2. There is sufficient redundancy in structural design such that ductile deformation will develop and be noticeable to residents before structural failure occurs;
3. Subsidence movements develop gradually over time at Tahmoor Colliery as they have above other previously extracted longwalls at similar depths of cover;
4. Experiences during the mining of Longwalls 22 to 27 have found that the most effective method of managing potential impacts on the safety and serviceability of structures are by way of community consultation. Residents living within the active subsidence zone have often provided early feedback to Tahmoor Colliery and/or the Mine Subsidence Board (MSB) about impacts developing at their houses or along their local roads. Contact is made well before impacts develop to a level of severity sufficient to become a safety hazard;
5. On the basis of the above, there is sufficient time for residents to notify Tahmoor Colliery or the MSB of significant displacement or deflection well before structural failure will occur;
6. The conclusions are supported by the observation that residents have not been exposed to immediate and sudden safety hazards as a result of impacts that occur due to mine subsidence movements at Tahmoor Colliery and above other previously extracted longwalls at similar depths of cover. This includes the recent experience at Tahmoor Colliery during the mining of Longwalls 22 to 27, which have affected more than 1,500 houses and civil structures; and
7. While severe impacts have developed during the mining of Longwalls 22 to 27, there is sufficient redundancy in structural design such that when structures have experienced severe impacts, they have developed gradually with ample time for residents to notify Tahmoor Colliery or the MSB to repair the structure and/or relocate residents before structural failure occurs (JMA, 2012).

While the three most important factors in managing risks to public safety are redundancy in structural design, gradual development of subsidence movements and an effective community consultation program, a number of additional management measures have been undertaken, including site specific investigations, regular surveys and inspections during mining and triggered response measures. The method of management would not change as additional houses are constructed in the future.

It is recommended that Tahmoor Colliery continue to develop management plans to manage potential impacts during the mining of the proposed longwalls. With appropriate management plans in place, it is considered that the houses will remain safe and serviceable at all times during mining for any orientation of longwalls within the extent of the longwall mining areas, even if actual subsidence movements were greater than the predictions or substantial non-conventional movements occurred.

6.23.6. Flats or Units

There were no flats or units identified within the SMP Area.

6.23.7. Associated Residential Structures

6.23.8. Swimming Pools

There are 44 privately owned swimming pools located within the SMP Area, of which 39 are inground and five are above ground. The locations of the swimming pools are shown in Drawing Nos. MSEC647-27 and MSEC647 – Maps 01 to 48, and the details are provided in Table D.11, in Appendix D.

Predictions of conventional subsidence, tilt and curvature have been made at the centroid and around the perimeters of each pool. A summary of the maximum predicted values of conventional subsidence, tilt and curvature for each pool within the SMP Area is provided in Table D.11, in Appendix D.

The predicted strains for the pools have been based on the statistical analysis of strains provided in Section 4.5. The pools are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays above previous longwall mining, which are summarised Section 4.5.1. The pools are expected to experience both tensile and compressive strains as the extraction faces of the proposed longwalls pass beneath them. At the completion of the proposed longwalls, the pools in locations of hogging curvature are more likely to be in final tensile zones and the pools in locations of sagging curvature are more likely to be in final compressive zones.

Mining-induced tilts are more noticeable in pools than other structures due to the presence of the water line and the small gap to the edge coping, particularly when the pool lining has been tiled. Skimmer boxes are also susceptible to being lifted above the water line due to mining tilt.

The Australian Standard AS2783-1992 (Use of reinforced concrete for small swimming pools) requires that pools be constructed level ± 15 mm from one end to the other. This represents a tilt of approximately 3.3 mm/m for pools that are 10 metres in length. Australian Standard AS/NZS 1839:1994 (Swimming pools – Pre-moulded fibre-reinforced plastics – Installation) also requires that pools be constructed with a tilt of 3 mm/m or less.

It can be seen from Table D.11, that nine pools within the SMP Area (i.e. 20 % of the total) are predicted to experience final tilts greater than 3 mm/m, at the completion of the proposed longwalls, which is greater than the Australian Standard. It is likely, therefore that these pools would require remediation of the pool copings after the completion of active subsidence. It is possible, if the tilts were fully realised at the pools with the higher predicted tilts, that the final tilts could be difficult to remediate and, in these cases, the pools would need to be rebuilt.

The maximum predicted conventional curvatures for the pools are 0.07 km^{-1} hogging and 0.11 km^{-1} sagging, which represent minimum radii of curvature of 14 kilometres and 9 kilometres, respectively. The ranges of predicted maximum curvatures for the pools are similar to those previously experienced at Tahmoor Colliery, which has directly mined beneath 155 pools. The incidence and levels of impacts on the pools within the SMP Area, therefore, are expected to be similar to those previously experienced at the colliery.

Observations during the mining of Tahmoor Colliery Longwalls 22 to 27 have shown that pools, particularly in-ground pools, are more susceptible to severe impacts than houses and other structures. Pools cannot be easily repaired and most of the impacted pools need to be replaced in order to restore them to pre-mining condition or better.

As of March 2014, a total of 155 pools have experienced mine subsidence movements during the mining of Tahmoor Colliery Longwalls 22 to 27, of which 142 were located directly above the extracted longwalls. A total of 32 pools have reported impacts, of which all except two pools were located directly above the extracted longwalls. This represents an impact rate of approximately 21 %. A higher proportion of impacts have been observed for in-ground pools, particularly fibreglass pools. The majority of the impacts related to tilt or cracking, though in a small number of cases the impacts were limited to damage to skimmer boxes or the edge coping.

There are 11 pools located directly above the proposed longwalls. It is expected, therefore, that two or three pools (i.e. 21 % of the total) would experience adverse impacts which could require them to be rebuilt.

While not strictly related to the pool structure, a number of pool gates have been impacted by mine subsidence during the mining of Longwall 22 to 27. While the gates can be easily repaired, the consequence of breaching pool fence integrity is considered to be severe. As a result, Tahmoor Colliery inspects the integrity of pool fences once a week during the active subsidence period.

6.23.9. Other Associated Residential Structures

A total of 651 associated residential structures (i.e. rural structures) have been identified within the SMP Area. The locations of these structures are shown in Drawing Nos. MSEC647-27 and MSEC647 – Maps 01 to 48, and details are provided in Table D.01, in Appendix D. The maximum predicted subsidence parameters for these structures are included in Tables D.02 to D.08, in Appendix D.

The risks to these rural structures are that they could be damaged and/or rendered unserviceable from mine subsidence impacts. These structures include: garages; sheds; carports; tanks; greenhouses; hothouses; playhouses; and shade structures.

These structures are able to tolerate greater subsidence movements than houses, as they are generally lighter, more flexible in construction, and smaller in size. The risk of damage to sheds and other domestic structures, therefore, is considerably less when compared to houses.

A small number of sheds and other domestic structures have reported impacts during the mining of Longwalls 22 to 27, all of which are considered to be relatively minor and easy to repair. Any damage to sheds and other domestic structures will be repaired by the Mine Subsidence Board.

It is therefore concluded that all associated residential structures are expected to remain safe, serviceable and repairable after mining has completed, provided that they are in sound existing condition. The risk of impact is clearly greater if structures are in poor condition though the chances of there being a public safety risk remain very low. There have been observations of the performance of some structures in poor pre-mining condition and these buildings have not experienced impacts during mining.

6.23.10. Rigid External Pavements

Adverse impacts on rigid external pavements, such as driveways and footpaths, are often reported to the Mine Subsidence Board in the Southern Coalfield. This is because pavements are typically thin relative to their length and width. The design of external pavements is also not regulated by Council or the Mine Subsidence Board.

A study by Mine Subsidence Engineering Consultants of 120 properties at Tahmoor and Thirlmere indicated that 98 % of the properties with external concrete pavements demonstrated some form of cracking prior to mining. These cracks are sometimes difficult to distinguish from cracks caused by mine subsidence. It is therefore uncertain how many claims for damage can be genuinely attributed to mine subsidence impacts.

It is anticipated that some impacts are likely to occur to these pavements in the form of cracking and buckling, although the majority are expected to be minor and would be easily repaired. A total of 108 properties have reported impacts to external pavements during the mining of Longwalls 22 to 27.

6.23.11. Fences in Urban Areas

There are a number of fences within the SMP Area. The fences are constructed in a variety of ways, generally using either timber or metal materials. Fences are generally flexible in construction and can usually tolerate mine subsidence movements in the Southern Coalfield.

The maximum predicted tilt resulting from the extraction of the proposed longwalls is 6.0 mm/m (i.e. 0.6 %, or 1 in 165). Fence post tilts of less than 10 mm/m are barely noticeable.

The most vulnerable sections of fences are gates, particularly long gates or those with latches, as they are less tolerant to differential horizontal movements and tilts between the gate posts and the ground. It has also been found that Colorbond fences are particularly susceptible to mine subsidence impacts as there is very little flexibility in their construction.

A total of 73 impacts have been reported to gates and fences within the urban areas during the extraction of Longwalls 22 to 27. These gates and fences are typically Colorbond gates, which have been constructed with small clearances. Gates are often fixed to one side of the house. This form of construction is vulnerable to differential movements that can occur between the fence post and the house.

It is therefore assessed that some fences could experience impacts as a result of the extraction of the proposed longwalls. Some impacts may occur to gates, which may need ongoing repairs as mining occurs. Damaged fences and gates are relatively easy to rectify by re-tensioning of fencing wire, straightening of fence posts, and if necessary, replacing some sections of fencing.

As discussed in Section 6.23.8, it is recommended that pool fences are monitored during mining in the interests of public safety.

6.23.12. Management of Potential Impacts to Residential Structures

Tahmoor Colliery has developed and acted in accordance with a risk management plan to manage potential impacts to residential structures during the mining of Longwalls 22 to 27. The management plan provides for identification of buildings in poor pre-mining condition that are hazardous or may become hazardous due to mining, and visual kerbside monitoring of structures during active subsidence. Where impacts occur, the structure will repaired by the Mine Subsidence Board.

The management plan is reviewed periodically by Tahmoor Colliery. It is recommended that Tahmoor Colliery continue to develop management plans to manage potential impacts during the mining of the proposed longwalls.

Further details on the management plan are provided in the following sections.

6.23.13. Public Safety

The primary risk associated with mining beneath structures is public safety. Comfort is drawn from the observation that residents have not been exposed to immediate and sudden safety hazards as a result of impacts that have occurred due to mine subsidence movements. This includes the recent experience at Tahmoor, which has affected more than 1,500 houses and civil structures.

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

The existing condition of structures varies above Longwalls 31 and 37. This is a function of age, structural design, construction workmanship and maintenance. Pre-mining inspections undertaken by Tahmoor Colliery have identified elements of structures that did appear to comply fully with Australian Standards, in regard to design and construction. In a small number of cases, the existing structural condition has been considered potentially unsafe and Tahmoor Colliery has undertaken measures to repair the defect.

There is a remote possibility that the comparatively small additional contribution of mine subsidence movements could be sufficient to result in the structures that do not meet Australian Standards to become potentially unstable.

Tahmoor Colliery has undertaken the following strategy to identify potentially 'unstable structures':

- Initial building identification – kerbside survey;
- Pre-mining geotechnical inspections of structures located on steep slopes;
- Pre-mining structural inspections of the following structures:
  - All public amenities and commercial and business establishments that are located directly above longwalls;
  - Structures that have been recommended for structural inspection by the geotechnical engineer;
- Pre-mining building inspections of the following structures:
  - Public amenities and commercial and business establishments with a maximum plan dimension of 15 metres or greater;
  - Houses and structures located above hidden creeks;
  - Houses and structures located on steep slopes, if recommended by the geotechnical engineer. In some cases structural inspections are conducted;
- Pre-mining building checks of the following structures:
  - Houses and structures located outside any Mine Subsidence District that are predicted to experience more than 150 mm of subsidence;
  - Houses estimated to have been constructed prior to the declaration of the Mine Subsidence Districts, and which are predicted to experience more than 150 mm of subsidence, and which have not already been directly mined beneath by longwalls;
- Pre-mining inspections conducted by the Mine Subsidence Board;
- Letters to all residents of structures that will soon be affected by subsidence. The letters invite the residents to contact Tahmoor Colliery should they have any concerns, or alternatively contact the Mine Subsidence Board for a pre-mining inspection;
- Inspections during mining, where any potentially unstable or unsafe structures may be identified:
  - Kerbside visual inspections twice a week, which is increased to daily if increased subsidence is observed;
  - Building inspections of public amenities and industrial, commercial and business establishments;
  - Building inspections of structures that have already reported impacts;
  - Inspections of pool fences; and
  - Structures and driveways located on steep slopes.

A total of 889 pre-mining inspections and 226 pre-mining checks have been undertaken by the Mine Subsidence Board and Tahmoor Colliery to date. Tahmoor Colliery has undertaken thousands of visual inspections of structures during the mining of Longwall 22 to 27. A reduced amount of inspections is expected to be undertaken during the mining of the proposed longwalls, as there are fewer structures located above the proposed mining area.

Tahmoor Colliery undertakes structural inspections of any structures that have been identified as being potentially unstable. Further management measures may be implemented following the findings of the inspection.

The management plan also provides for additional visual inspections and ground surveys in the event that increased subsidence is observed. This includes pre-mining checks of all structures within the affected area, daily visual inspections during active subsidence and weekly ground surveys of all streets. Tahmoor Colliery also consults with the Mine Subsidence Board to determine whether additional resources are required to assist with undertaking repairs to impacted structures.

6.23.14. Impacts to Serviceability or Cosmetic Impacts

The current management strategy in relation to serviceability or cosmetic impacts is reactive. The MSB will repair impacts when they occur. Tahmoor Colliery will conduct regular inspections of structures that have been impacted during mining to ensure that they remain safe.

A reactive method appears justified based on the relatively low probability of impact (approximately 15 %) and extremely low probability of moderate or severe impact (less than 5 %).

Mitigation is best conducted at building construction and some modification to current strip footing design is recommended. This is a longer term issue that needs to be considered in consultation with the MSB.

6.24. Known Future Developments

A proposed residential subdivision development is proposed within the SMP Area called the Clearview Development on Thirlmere Way, Picton (Proposal No. PP_2011_WOLLY_007_00). The proposal is to rezone land currently Zone RU2 Rural Landscape to part Zone R2 Low Residential and part Zone R5 Large Lot Residential under Wollondilly Local Environmental Plan 2011.

The location of the proposed Clearview Development in relation to the proposed longwalls is shown in Drawing No. MSEC647-27. If the proposal is approved an additional 426 blocks would be located within the SMP Area, partially above the proposed Longwalls 33 to 37. The property is currently not within a declared Mine Subsidence District.

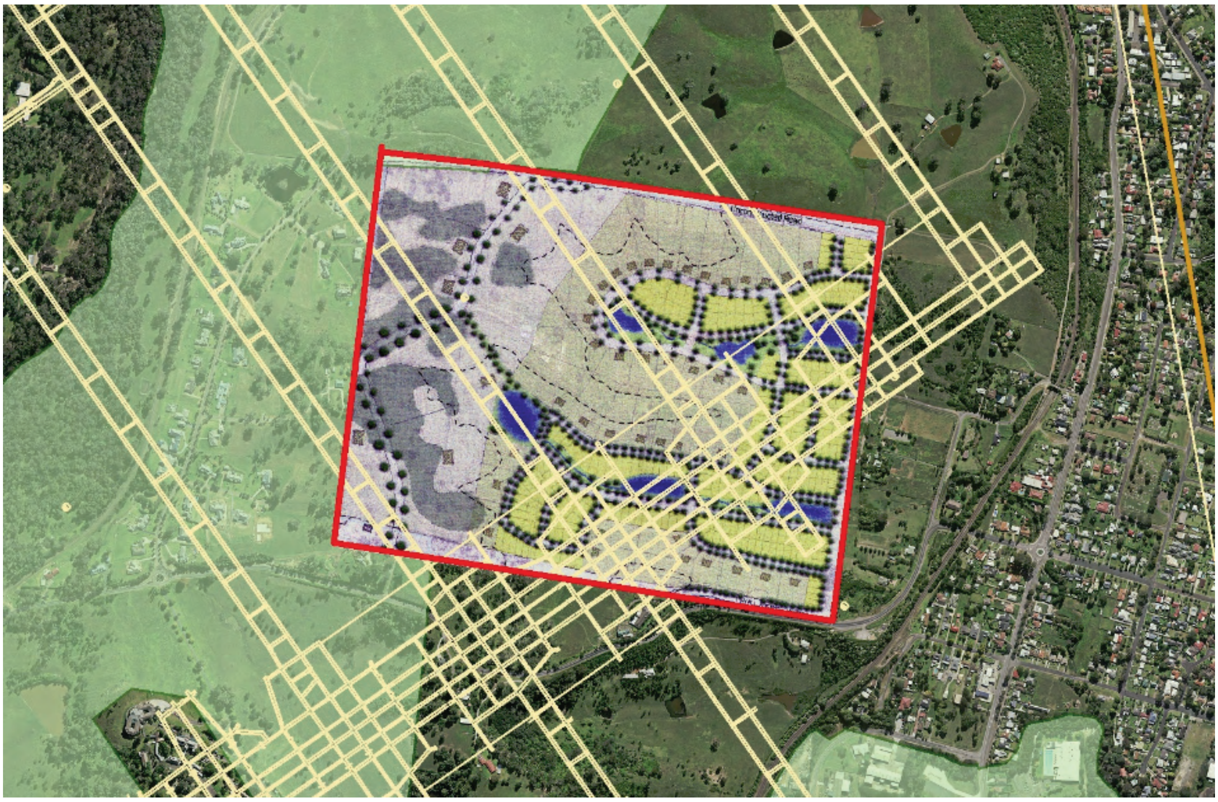


Fig. 6.86 Indicative Subdivision Layout for Proposed Clearview Development above proposed Longwalls 33 to 37

If the proposal is approved and new houses are constructed, it is considered that potential impacts on building structures and associated road and services infrastructure can be managed, using subsidence management measures described in this report. It is noted, however, that as part of the proposed development is located directly above proposed Longwalls 33 to 37, the total number of houses impacted by the proposed longwalls would increase.

APPENDIX A. GLOSSARY OF TERMS AND DEFINITIONS

Glossary of Terms and Definitions

Some of the more common mining terms used in the report are defined below:-

Angle of draw	The angle of inclination from the vertical of the line connecting the goaf edge of the workings and the limit of subsidence (which is usually taken as 20 mm of subsidence).
Chain pillar	A block of coal left unmined between the longwall extraction panels.
Cover depth (H)	The depth from the surface to the top of the seam. Cover depth is normally provided as an average over the area of the panel.
Closure	The reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of *millimetres (mm)*, is the greatest reduction in distance between any two points on the opposing valley sides. It should be noted that the observed closure movement across a valley is the total movement resulting from various mechanisms, including conventional mining induced movements, valley closure movements, far-field effects, downhill movements and other possible strata mechanisms.
Critical area	The area of extraction at which the maximum possible subsidence of one point on the surface occurs.
Curvature	The change in tilt between two adjacent sections of the tilt profile divided by the average horizontal length of those sections, i.e. curvature is the second derivative of subsidence. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of *1/kilometres (km-1)*, but the value of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*. Curvature can be either **hogging** (i.e. convex) or **sagging** (i.e. concave).
Extracted seam	The thickness of coal that is extracted. The extracted seam thickness is thickness normally given as an average over the area of the panel.
Effective extracted seam thickness (T)	The extracted seam thickness modified to account for the percentage of coal left as pillars within the panel.
Face length	The width of the coalface measured across the longwall panel.
Far-field movements	The measured horizontal movements at pegs that are located beyond the longwall panel edges and over solid unmined coal areas. Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain.
Goaf	The void created by the extraction of the coal into which the immediate roof layers collapse.
Goaf end factor	A factor applied to reduce the predicted incremental subsidence at points lying close to the commencing or finishing ribs of a panel.
Horizontal displacement	The horizontal movement of a point on the surface of the ground as it settles above an extracted panel.
Inflection point	The point on the subsidence profile where the profile changes from a convex curvature to a concave curvature. At this point the strain changes sign and subsidence is approximately one half of S max.
Incremental subsidence	The difference between the subsidence at a point before and after a panel is mined. It is therefore the additional subsidence at a point resulting from the excavation of a panel.
Panel	The plan area of coal extraction.
Panel length (L)	The longitudinal distance along a panel measured in the direction of (mining from the commencing rib to the finishing rib.
Panel width (Wv)	The transverse distance across a panel, usually equal to the face length plus the widths of the roadways on each side.
Panel centre line	An imaginary line drawn down the middle of the panel.
Pillar	A block of coal left unmined.
Pillar width (Wpi)	The shortest dimension of a pillar measured from the vertical edges of the coal pillar, i.e. from rib to rib.

Shear deformations	The horizontal displacements that are measured across monitoring lines and these can be described by various parameters including; horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index.
Strain	The change in the horizontal distance between two points divided by the original horizontal distance between the points, i.e. strain is the relative differential displacement of the ground along or across a subsidence monitoring line. Strain is dimensionless and can be expressed as a decimal, a percentage or in parts per notation. **Tensile Strains** are measured where the distance between two points or survey pegs increases and **Compressive Strains** where the distance between two points decreases. Whilst mining induced **strains** are measured **along** monitoring lines, ground **shearing** can occur both vertically, and horizontally **across** the directions of the monitoring lines.
Sub-critical area	An area of panel smaller than the critical area.
Subsidence	The vertical movement of a point on the surface of the ground as it settles above an extracted panel, but, 'subsidence of the ground' in some references can include both a vertical and horizontal movement component. The vertical component of subsidence is measured by determining the change in surface level of a peg that is fixed in the ground before mining commenced and this vertical subsidence is usually expressed in units of *millimetres (mm)*. Sometimes the horizontal component of a peg's movement is not measured, but in these cases, the horizontal distances between a particular peg and the adjacent pegs are measured.
Subsidence Effects	The deformations of the ground mass surrounding a mine, sometimes referred to as 'components' or 'parameters' of mine subsidence induced ground movements, including vertical and horizontal displacements, tilts, curvatures, strains, upsidence and closure.
Subsidence Impacts	The physical changes or damage to the fabric or structure of the ground, its surface and natural features, or built structures that are caused by the subsidence effects. These impacts considerations can include tensile and shear cracking of the rock mass, localised buckling of strata, bed separation, rock falls, collapse of overhangs, failure of pillars, failure of pillar floors, dilation, slumping and also include subsidence depressions or troughs.
Subsidence Consequences	The knock-on results of subsidence impacts, i.e. any change in the amenity or function of a natural feature or built structure that arises from subsidence impacts. Consequence considerations include public safety, loss of flows, reduction in water quality, damage to artwork, flooding, draining of aquifers, the environment, community, land use, loss of profits, surface improvements and infrastructure. Consequences related to natural features are referred to as environmental consequences.
Super-critical area	An area of panel greater than the critical area.
Tilt	The change in the slope of the ground as a result of differential subsidence, and is calculated as the change in subsidence between two points divided by the horizontal distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. Tilt is usually expressed in units of *millimetres per metre (mm/m)*. A tilt of 1 mm/m is equivalent to a change in grade of 0.1 %, or 1 in 1000.
Uplift	An increase in the level of a point relative to its original position.
Upsidence	Upsidence results from the dilation or buckling of near surface strata at or near the base of the valley. The term uplift is used for the cases where the ground level is raised above the pre-mining level, i.e. when the upsidence is greater than the subsidence. The magnitude of upsidence, which is typically expressed in the units of *millimetres (mm)*, is the difference between the observed subsidence profile within the valley and the conventional subsidence profile which would have otherwise been expected in flat terrain.
Void Length	The extracted length of the longwall or panel.

APPENDIX B.   REFERENCES

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APPENDIX C. IMPACTS ON BUILDING STRUCTURES

APPENDIX C METHOD OF IMPACT ASSESSMENT FOR HOUSES

C.1. Introduction

The methods for predicting and assessing impacts on building structures have developed over time as knowledge and experience has grown. MSEC has provided predictions and impact assessments for the building structures within the SMP Area using the latest methods available at this time.

Longwall mining has occurred directly beneath building structures at a number of Collieries in the Southern Coalfield, including Appin, West Cliff, Tower and Tahmoor Collieries. The most extensive data has come from extraction of Tahmoor Colliery, where more than 1,000 residential and significant civil structures have experienced subsidence movements. The experiences gained during the mining of these longwalls, as well as longwalls at other collieries in the Southern and Newcastle Coalfields, have provided substantial additional information that has been used to further develop the methods.

The information collected during the mining of Tahmoor Colliery Longwalls 22 to 24A has been reviewed in two parallel studies, one as part of a funded ACARP Research Project C12015, and the other at the request of the Department of Primary Industries (DPI).

The outcomes of these studies include:-

- Review of the performance of the previous method;
- Recommendations for improving the method of Impact Classification; and
- Recommendations for improving the method of Impact Assessment.

A summary is provided in the following sections.

C.2. Review of the Performance of the Previous Method

The most extensive data on house impacts has come from extraction of Tahmoor Colliery Longwalls 22 to 25 and a comparison between predicted and observed impacts is provided in Table C.1. The comparison is based on pre-mining predictions that were provided in SMP Applications for these longwalls and the observations of impacts using the previous method of impact classification. The comparison is based on information up to 30 November 2008. At this point in time, the length of extraction of Longwall 25 was 611 metres.

A total of 1,037 houses and civil structures were affected by subsidence due to the mining of Tahmoor Colliery Longwalls 22 to 25 at this time. A total of 175 claims have been received by the Mine Subsidence Board (not including claims that have been refused) of which 14 claims do not relate to the main residence or civil structure.

Table C.1 Summary of Comparison between Observed and Predicted Impacts for each Structure

Strain Impact Category	Total No. of Observed Impacts for Structures predicted to be Strain Impact Category 0	Total No. of Observed Impacts for Structures predicted to be Strain Impact Category 1	Total No. of Observed Impacts for Structures predicted to be Strain Impact Category 2	Total
No impact	483	373	20	876
Cat 0	31	70	6	107
Cat 1	8	9	1	18
Cat 2	7	11	2	20
Cat 3	2	2	0	4
Cat 4	3	5	0	8
Cat 5	3	1	0	4
Total	537	471	29	1037
% claim	**10 %**	**21 %**	**31 %**	16 %
% Obs > Pred	**4 %**	**4 %**	**0 %**	-
% Obs <= Pred	**96 %**	**96 %**	**100 %**	-

Note: Predicted impacts due to conventional subsidence only, as described in the SMP Application.

Given that observed impacts are less than or equal to predicted impacts in 96 % of cases, it is considered that the previous methods are generally conservative even though non-conventional movements were not taken into account in the predictions and assessments. However, when compared on a house by house basis, the predictions have been substantially exceeded in a small proportion of cases.

The majority, if not all, of the houses that have experienced Category 3, 4 or 5 impacts are considered to have experienced substantial non-conventional subsidence movements. The consideration is based on nearby ground survey results, where upsidence bumps are observed in subsidence profiles and high localised strain is observed. The potential for impact from non-conventional movements were discussed generally and not included in the specific impact assessments for each structure.

The inability to specify the number or probability of impacts due to the potential for non-conventional movements is a shortcoming of the previous method. It is considered that there is significant room for improvement in this area and recommendations are provided later in this report.

The comparison shows a favourable observation that the overall proportion of claims increased for increasing predicted impact categories. This suggests that the main parameters currently used to make impact assessments (namely predicted conventional curvature and maximum plan dimension of each structure) are credible. Please note that we have stated predicted conventional curvature rather than strain, as predictions of strain were directly based on predictions of conventional curvature.

A significant over-prediction is observed at the low end of the spectrum of impacts (Category 0 and 1). A number of causes and/or possible causes for the deviations have been identified:

- Construction methods and standards may mitigate against small differential ground movements.
- The impacts may have occurred but the residents have not made a claim for the following reasons:-
    - All structures contain some existing, pre-mining defects. A pre-mining field investigation of 119 structures showed that it is very rare for all elements of a building to be free of cracks. Cracks up to 3 mm in width are commonly found in buildings. Cracks up to 1 mm in width are very common. There is a higher incidence of cracking in brittle forms of construction such as masonry walls and tiled surfaces.
    - In light of the above, additional very slight Category 0 and 1 impacts may not have been noticed by residents. A forensic investigation of all structures before or after mining may reveal that the number of actual impacts is greater than currently known.
    - Similarly, impacts have been noticed but some residents may consider them to be too trivial to make a claim. While difficult to prove statistically, it is considered that the frequency of claims from tenanted properties is less than the frequency of claims from owner-occupied properties.
- The impacts have been noticed but some residents are yet to make a claim at this stage. It has been observed that there is a noticeable time lag between the moment of impact and the moment of making a claim. More claims are therefore expected to be received in the future within areas that have already been directly mined beneath.
- The predictive method is deliberately conservative in a number of ways.
    - Predicted subsidence movements for each structure are based on the maximum predicted subsidence movements within 20 metres of the structure.
    - An additional 0.2 mm/m of strain was added
    - Maximum strains were applied to the maximum plan dimension, regardless of the maximum predicted strain orientation.
    - The method of impact assessment does not provide for “nil impacts”. The minimum assessed level of impact is Category 0.
    - The impact data was based on double-storey full masonry structures in the UK.

Finally, it is considered that the previous method impact classification has masked the true nature and extent of impacts. It is recommended that an improved method of classification be adopted before embarking on any further analysis. This is discussed in the next section of this report.

C.3. Method of Impact Classification

C.3.1. Previous Method

The impacts to structures were previously classified in accordance with Table C1 of Australian Standard 2870-1996, but the Table has been extended by the addition of Category 5 and is reproduced below.

Table C.2 Classification of Damage with Reference to Strain

Impact Category	Description of typical damage to walls and required repair	Approximate crack width limit
0	Hairline cracks.	< 0.1 mm
1	Fine cracks which do not need repair.	0.1 mm to 1.0 mm
2	Cracks noticeable but easily filled. Doors and windows stick slightly	1 mm to 5 mm
3	Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weather-tightness often impaired	5 mm to 15 mm, or a number of cracks 3 mm to 5 mm in one group
4	Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window or door frames distort. Walls lean or bulge noticeably. Some loss of bearing in beams. Service pipes disrupted.	15 mm to 25 mm but also depends on number of cracks
5	As above but worse, and requiring partial or complete rebuilding. Roof and floor beams lose bearing and need shoring up. Windows broken with distortion. If compressive damage, severe buckling and bulging of the roof and walls.	> 25 mm

Note 1 of Table C1 states that *"Crack width is the main factor by which damage to walls is categorized. The width may be supplemented by other factors, including serviceability, in assessing category of damage.*

Impacts relating to tilt were classified according to matching impacts with the description in Table C.3, not the observed actual tilt. This is because many houses that have experience tilts greater than 5 mm have not made a claim to the MSB.

Table C.3 Classification of Damage with Reference to Tilt

Impact Category	Tilt (mm/m)	Description
A	< 5	Unlikely that remedial work will be required.
B	5 to 7	Adjustment to roof drainage and wet area floors might be required.
C	7 to 10	Minor structural work might be required to rectify tilt. Adjustments to roof drainage and wet area floors will probably be required and remedial work to surface water drainage and sewerage systems might be necessary.
D	> 10	Considerable structural work might be required to rectify tilt. Jacking to level or rebuilding could be necessary in the worst cases. Remedial work to surface water drainage and sewerage systems might be necessary.

C.3.2. Need for Improvement to the Previous Method of Impact Classification

It is very difficult to design a method of impact classification that covers all possible scenarios and permutations. The application of any method is likely to find some instances that do not quite fit within the classification criteria.

Exposure to a large number of affected structures has allowed the mining industry to appreciate where improvements can be made to all aspects including the identification of areas for improvement in the previous method of impact classification.

A number of difficulties have been experienced with the previous method during the mining period. The difficulty centres on the use of crack width as the main classifying factor, as specified in Table C1 of Australian Standard 2870-1996.

A benefit of using crack width as the main factor is that it provides a clear objective measure by which to classify impact. However, experience has shown that crack width is a poor measure of the overall impact and extent of repair to a structure. The previous method of impact classification may be useful for assessing impact to newly built structures in a non-subsidence environment but further improvement and clarification is recommended before it can be effectively applied to houses impacted by mine subsidence.

The following aspects highlight areas where the previous classification system could be improved.-

- *Slippage on Damp Proof Course*

  Approximately 30 houses have experienced slippage along the damp proof course in Tahmoor. Slippage on some houses is relatively small (less than 10 mm) though substantial slippage has been observed in a number of cases, such as shown in Fig. C.1 below.

Fig. C.1 Example of slippage on damp proof course

Under the previous classification method, the "crack" width of the slippage may be very small (Category 1) but the distortion in the brickwork is substantial. Moreover, the extent of work required to repair the impact is substantial as it usually involves re-lining the whole external skin of the structure. Such impacts would be considered Category 4 based on extent of repair but only Category 1 or 2 based on maximum crack width.

There is no reference to slippage of damp proof course in the previous method of impact classification. However, if the extent of repair was used instead of using crack width as the main factor, the impact category would be properly classified as either Category 4 or Category 5.

It was recommended that slippage of damp proof courses be added to the previous impact classification table.

- *Cracks to brickwork*

  In some cases, cracks are observed in mortar only. For example, movement joints in some structures have been improperly filled with mortar instead of a flexible sealant, as shown in Fig. C.2. In these situations, the measured crack width may be significant but the impact is relatively simple to repair regardless of the crack width.

Fig. C.2 Example of crack in mortar only

In other cases, a small number of isolated bricks have been observed to crack or become loose. This is usually straightforward to repair. Under the previous impact classification method, a completely loose brick could be strictly classified as Category 5 as the crack width is infinitely large. This is clearly not the intention of the previous method but clarification is recommended to avoid confusion.

If a panel of brickwork is cracked, the method of repair is the same regardless of the width. While it is considered reasonable to classify large and severe cracks by its width, it is recommended that cracks less than 5 mm in width be treated the same rather than spread across Categories 0, 1 and 2.

If a brick lined structure contains many cracks of width less than 3 mm, the impact would be classified as no more than Category 2 under the previous method of impact classification. The extent of repair may be substantially more than a house that has experienced only one single 5 mm crack. However, it is recognised that it is very difficult to develop a simple method of classifying impacts based on multiple cracks in wall panels. How many cracks are needed to justify an increase in impact category?

- *Structures without masonry walls*

  Timber framed structures with lightweight external linings such weatherboard panels and fibro sheeting are not referenced in the previous classification table. If crack widths were strictly adopted to classify impacts, it may be possible to classify movement in external wall linings beyond Category 3 when in reality the repairs are usually minor.

  It was recommended that the impact classification table be extended to include structures with other types of external linings.

- *Minor impacts such as door swings*

  Experience has shown that one of the earliest signs of impact is the report of a sticking door. In some instances, the only observed impact is one or two sticking doors. It takes less than half an hour to repair a sticking door and impact is considered negligible.

  Such an impact would be rightly classified as Category 0 based on the previous method of impact classification as there is no observed crack. However, the previous classification table suggests that sticking doors and windows occur when Category 2 crack widths develop. It was recommended that the impact classification table be amended in this respect.

C.3.3. Broad Recommendations for Improvement of Previous Method of Impact Classification

It was recommended that crack width no longer be used as the main factor for classifying impacts. This does not mean that the use of crack width should be abandoned altogether. Crack width remains a good indicator of the severity of impacts and should be used to assist classification, particularly for impacts that are moderate or greater.

By focussing on crack width, the previous impact classification table appears to be classifying impacts from a structural stability perspective. It was recommended that a revised impact classification table be more closely aligned with all aspects of a building, including its finishes and services. Residents who are affected by impacts are concerned as much about impacts to internal linings, finishes and services as they are about cracks to their external walls and a revised impact classification method should reflect this.

With crack width no longer used as the main factor, it was recommended that the wording of the descriptions of impact in the classification table be extended to cover impacts to more elements of buildings. In keeping with the previous method of assessment, the level of impact should distinguish between cosmetic, serviceability and stability related impacts:-

- Low impact levels should relate to cosmetic impacts that do affect the structural integrity of the building and are relatively straight-forward to repair,
- Mid-level impact categories should relate to impacts to serviceability and minor structural issues, and
- High level impacts should be reserved for structural stability issues and impacts requiring extensive repairs.

C.3.4. Revised Method of Impact Classification

The following revised method of impact classification has been developed.

Table C.4 Revised Classification based on the Extent of Repairs

Repair Category	Extent of Repairs
Nil	No repairs required
R0 **Adjustment**	One or more of the following, where the damage does not require the removal or replacement of any external or internal claddings or linings:- - **Door** or **window** jams or swings, or - Movement of **cornices**, or - Movement at external or internal **expansion joints**.
R1 **Very Minor Repair**	One or more of the following, where the damage can be repaired by filling, patching or painting without the removal or replacement of any external or internal brickwork, claddings or linings:- - Cracks in **brick mortar** only, or isolated cracked, broken, or loose **bricks** in the external façade, or - Cracks or movement < 5 mm in width in any external or internal wall **claddings**, **linings**, or **finish**, or - Isolated cracked, loose, or drummy floor or wall **tiles**, or - Minor repairs to any **services** or **gutters**.
R2 **Minor Repair**	One or more of the following, where the damage affects a small proportion of external or internal claddings or linings, but does not affect the integrity of external brickwork or structural elements:- - Continuous cracking in **bricks** < 5 mm in width in one or more locations in the total external façade, or - Slippage along the **damp proof course** of 2 to 5 mm anywhere in the total external façade, or - Cracks or movement ≥ 5 mm in width in any external or internal wall **claddings**, **linings**, **finish**, or - Several cracked, loose or drummy floor or wall **tiles**, or - Replacement of any **services**.
R3 **Substantial Repair**	One or more of the following, where the damage requires the removal or replacement of a large proportion of external brickwork, or affects the stability of isolated structural elements:- - Continuous cracking in **bricks** of 5 to 15 mm in width in one or more locations in the total external façade, or - Slippage along the **damp proof course** of 5 to 15 mm anywhere in the total external façade, or - Loss of bearing to isolated walls, piers, columns, or other load-bearing elements, or - Loss of stability of isolated structural elements.
R4 **Extensive Repair**	One or more of the following, where the damage requires the removal or replacement of a large proportion of external brickwork, or the replacement or repair of several structural elements:- - Continuous cracking in **bricks** > 15 mm in width in one or more locations in the total external façade, or - Slippage along the damp proof course of 15 mm or greater anywhere in the total external façade, or - Relevelling of building, or - Loss of stability of several structural elements.
R5 **Re-build**	Extensive damage to house where the MSB and the owner have agreed to rebuild as the cost of repair is greater than the cost of replacement.

As discussed at the start of this chapter, it is very difficult to design a method of impact classification that covers all possible scenarios and permutations. While the method has been floated among some members of the mining industry, it is recommended that this table be reviewed broadly.

The recommended method has attempted to follow the current Australian Standard in terms of the number of impact categories and crack widths for Categories 3 and 4. The method is based on the extent of repairs required to repair the physical damage that has occurred, and does not include additional work that is occasionally required because replacement finishes cannot match existing damaged ones. It is therefore likely that the actual cost of repairs will vary greatly between houses depending on the nature of the existing level and type of finishes used.

The impacts experienced at Tahmoor Colliery have been classified in accordance with the revised method of classification with good results. The method allowed clearer trends to be found when undertaking statistical analyses.

A comparison between the previous and revised methods is shown in Fig. C.3.

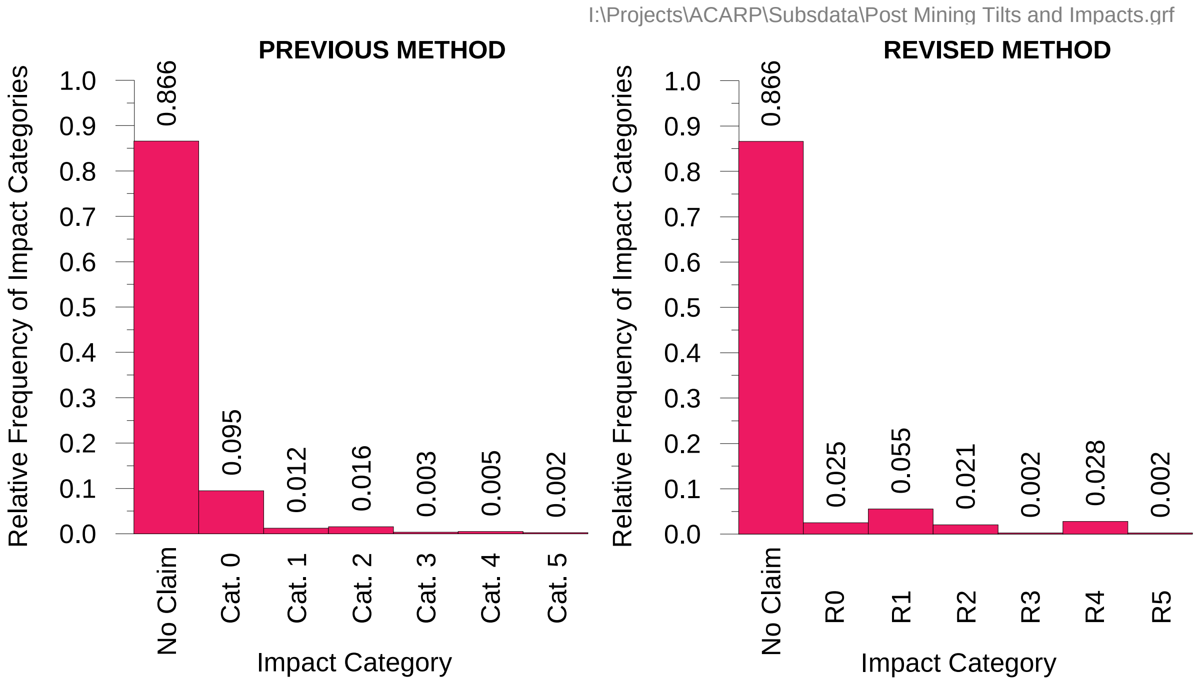


Fig. C.3 Comparison between Previous and Revised Methods of Impact Classification

It can be seen that there was an increased proportion in the higher impact categories using the revised method. This is brought about mainly by the recorded slippage on damp proof courses, which are classified as either Category 3 or Category 4 when they were previously classified as Category 1 or 2.

There was also a noticeable reduction in proportion of Category 0 impacts and noticeable increase in proportion of Category 1 impacts using the revised method. This is because the revised method reserves Category 0 impacts for impacts that did not result in cracking any linings, while the previous method allows hairline cracking to occur.

The consistent low proportion of Category 3 impacts under both the previous and current methods raises questions as to whether this category should be merged with Category 4.

C.4. Method of Impact Assessment

C.4.1. Need for Improvement of the Previous Method

The previous method of impact assessment provided specific quantitative predictions based on predicted conventional subsidence movements and general qualitative statements concerning the potential for impacts due to non-conventional movements. These non-conventional movements are additional to the predicted conventional movements.

This message was quite complex and created the potential for confusion and misunderstanding among members of the community who may easily focus on numbers and letters in a table that deal specifically with their house and misunderstand the message contained in the accompanying words of caution about the low level of reliability concerning predictions of conventional strain and potential for non-conventional movements.

This was unfortunately a necessary shortcoming of the previous method at the time as there was very little statistical information available to quantify the potential for impacts due to non-conventional movement. However, a great deal of statistical information is now available following the mining of Tahmoor Colliery Longwalls 22 to 24A and the method and message to the community can be improved.

While additional statistical information is now available, there remains limited knowledge at this point in time to accurately predict the locations of non-conventional movement. Substantial gains are still to be made in this area.

In the meantime, therefore, a probabilistic method of impact assessment has been developed. The method combines the potential for impacts from both conventional and non-conventional subsidence movement.

C.4.2. Factors that Could be Used to Develop a Probabilistic Method of Prediction

Trend analyses have highlighted a number of factors that could be used to develop a probabilistic method. The trends examined were:-

- *Ground tilt*

  This was found to be an ineffective parameter at Tahmoor Colliery as ground tilts have been relatively benign and a low number of claims have been made in relation to tilt.

- *Ground strain*

  There appears to be a clear link between ground strain and impacts, particularly compressive strain. The difficulty with adopting ground strain as a predictive factor lies in the ability to accurately predict ground strain at a point.

  Another challenge with using strain to develop a probabilistic method is that there is limited information that links maximum observed strains with observed impacts at a structure. Horizontal strain is a two-dimensional parameter and it has been measured along survey lines that are oriented in one direction only.

  The above issues are less problematic for curvature and the statistical analysis on the relationship between strain and curvature shows that the observed frequency of high strains increased with increasing observed curvature.

- *Ground curvature*

  Curvature appears to be the most effective subsidence parameter to develop a probabilistic method. The trend analysis showed that the frequency of impacts increased with increasing observed curvature.

  It should be noted that we are referring to conventional curvature and not curvatures that have developed as a result of non-conventional subsidence behaviour. This is because conventional curvature can be readily predicted with reasonable correlation with observations. It is also a relatively straight-forward exercise to estimate the observed smoothed or "conventional" curvature provided some ground monitoring is undertaken across and along extracted longwalls.

  Non-conventional curvature cannot be predicted prior to mining and is accounted for by using a probabilistic method of impact assessment.

  It has also been shown that the observed frequency of high strains increased with increasing observed curvature.

- *Position of structure relative to longwall*

  A clear trend was understandably found that structures located directly above goaf were substantially more likely to experience impact. The calculated probabilities may be applicable for mining conditions that are similar to those experienced at Tahmoor Colliery but will be less applicable for other mining conditions. An effective probabilistic method should create a link between the magnitude of differential subsidence movements and impact.

- *Construction type*

  Two trends have been observed. Not surprisingly, structures constructed with lightweight flexible external linings are able to accommodate a far greater range of subsidence movements than brittle inflexible linings such as masonry. The analyses merely quantified what was already well known. The second observation was that houses constructed with strip footings were noticeably more likely to experience impacts than houses constructed with a ground slab, particularly in relation to higher levels of impact. This is because houses with strip footings are more susceptible to slippage along the damp proof course.

- *Structure size*

  Trend analysis showed that larger structures attract a higher likelihood of impact. This is understandable as the chance of impacts increases with increasing footprint area. However, it is noted that the probability of severe impacts was not substantially greater for larger structures even though this would be expected if considering probabilities theoretically rather than empirically. It may be worthwhile including structure size as a factor in the development of a probabilistic method, though it is considered that it is a third order effect behind subsidence movements and construction type.

- *Structure age*

  The trend analysis for structure age did not reveal any noticeable trends.

- *Extensions, variable foundations and building joints*

  There is a clear trend of a higher frequency of impacts for structures that include extensions, variable foundations and building joints. The increased frequency appears to be related mainly to lower impact categories.

- *Urban or rural setting*

  While trends were observed, it is considered that they can be explained by other factors. However, consideration can be made to provide a more conservative estimate of probabilities in rural areas if structure size has not been taken into account.

C.4.3. Revised Method of Impact Assessment

A revised method of impact assessment has been developed. The method is probabilistic and currently includes conventional ground curvature and construction type as input factors.

Because of the relatively low number of buildings that suffered damage, the trends in the data were difficult to determine within small ranges of curvature. A decision was therefore taken to analyse the data in a limited number of curvature ranges, so that where possible a reasonable sample size would be available in each range. The ranges of curvature chosen were 5 to 15 kilometres, 15 to 50 kilometres and greater than 50 kilometres.

Because the incidence of damage for different construction types showed strong trends and because the sample size was reasonable for each type of structure, the data were analysed to determine the effect of radius of curvature on the incidence of damage for each of the three structure types and for each of the three curvature ranges.

The following probabilities are proposed in Table C.5.

Table C.5 Probabilities of Impact based on Curvature and Construction Type based on the Revised Method of Impact Classification

R (km)	Repair Category			
	No Repair or R0	R1 or R2	R3 or R4	R5
Brick or brick-veneer houses with Slab on Ground				
> 50	90 ~ 95 %	3 ~ 10 %	1 %	< 0.1 %
15 to 50	80 ~ 85 %	12 ~ 17 %	2 ~ 5 %	< 0.5 %
5 to 15	70 ~ 75 %	17 ~ 22 %	5 ~ 8 %	< 0.5 %
Brick or brick-veneer houses with Strip Footing				
> 50	90 ~ 95 %	3 ~ 10 %	1 %	< 0.1 %
15 to 50	80 ~ 85 %	7 ~ 12 %	2 ~ 7 %	< 0.5 %
5 to 15	70 ~ 75 %	15 ~ 20 %	7 ~ 12 %	< 0.5 %
Timber-framed houses with flexible external linings of any foundation type				
> 50	90 ~ 95 %	3 ~ 10 %	1 %	< 0.1 %
15 to 50	85 ~ 90 %	7 ~ 13 %	1 ~ 3 %	< 0.5 %
5 to 15	80 ~ 85 %	10 ~ 15 %	3 ~ 5 %	< 0.5 %

The results have been expressed as a range of values rather than a single number, recognising that the data had considerable scatter within each curvature range. While structure size and building extensions have not been included in the predictive tables, it is recommended to adopt percentages at the higher end of the range for larger structures or those with building extensions.

The percentages stated in each table are the percentages of building structures of that type that would be likely to be damaged to the level indicated within each curvature range. The levels of damage in the tables are indicated with reference to the repair categories described in the damage classification given in Table C.4.

To place these values in context, Table C.6 shows the actual percentages recorded at Tahmoor Colliery for all buildings within the sample.

Table C.6 Observed Frequency of Impacts observed for all buildings at Tahmoor Colliery

R (km)	Repair Category			
	No Claim or R0	R1 or R2	R3 or R4	R5
> 50	94%	4%	1%	0%
15 to 50	86%	9%	4%	0.7%
5 to 15	76%	17%	7%	0%

It can be seen that the proposed probabilities for the higher impact categories have been increased compared to those observed to date. These have been deliberately increased, because it has been noticed that some of the claims for damage have been submitted well after the event and it is possible that the numbers damaged in this category could be increased as further claims are received and investigated. These numbers are particularly sensitive to change because the sample size is very small. In light of the above, it is recommended that the probabilities be revisited in the future as mining progresses.

The ranges provided in Table C.5 have been converted into a set of probability curves to remove artificial discontinuities that are formed by dividing curvatures into three categories. These are shown in Fig. C.4. The probability curves are applicable for all houses and civil structures.

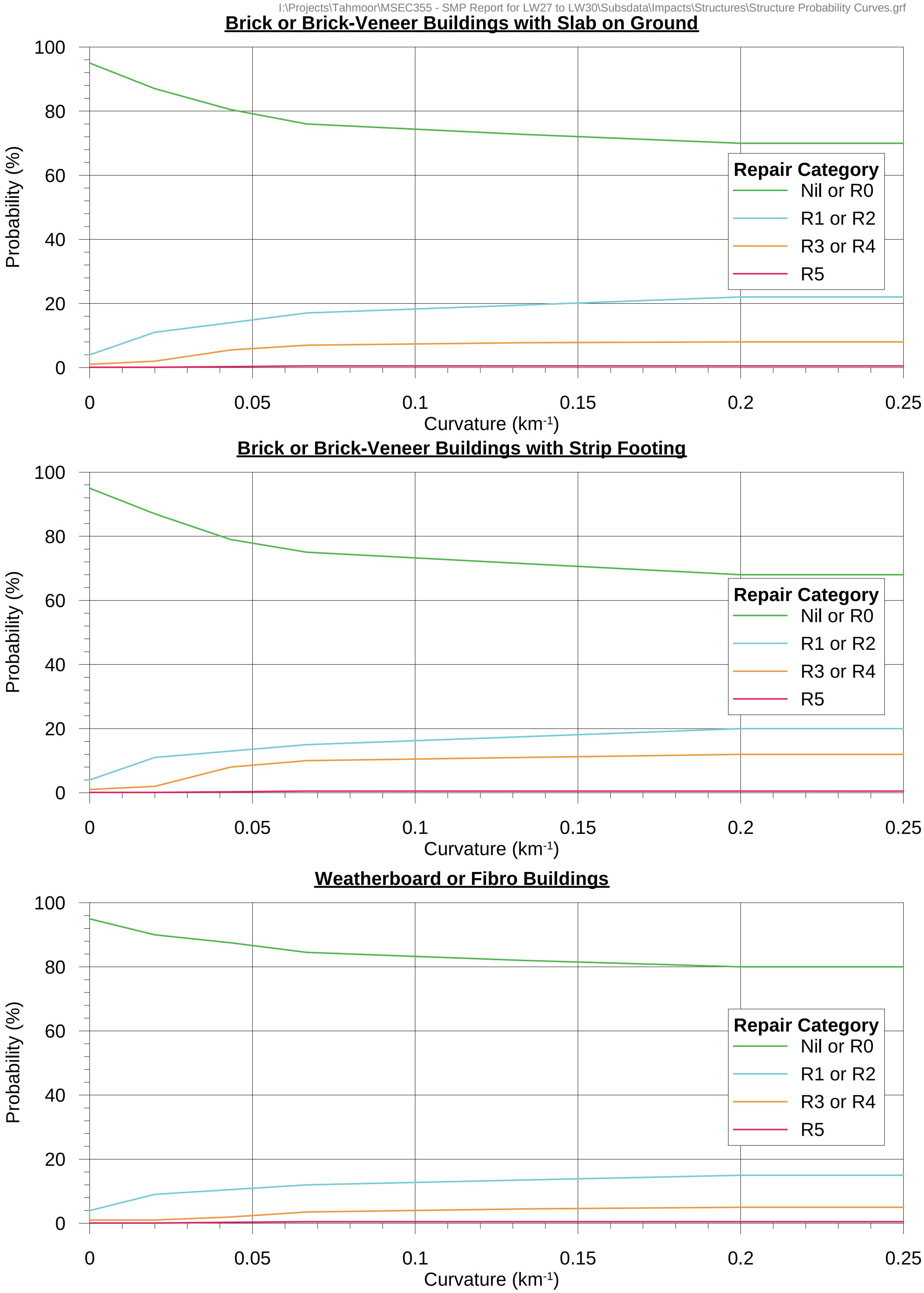


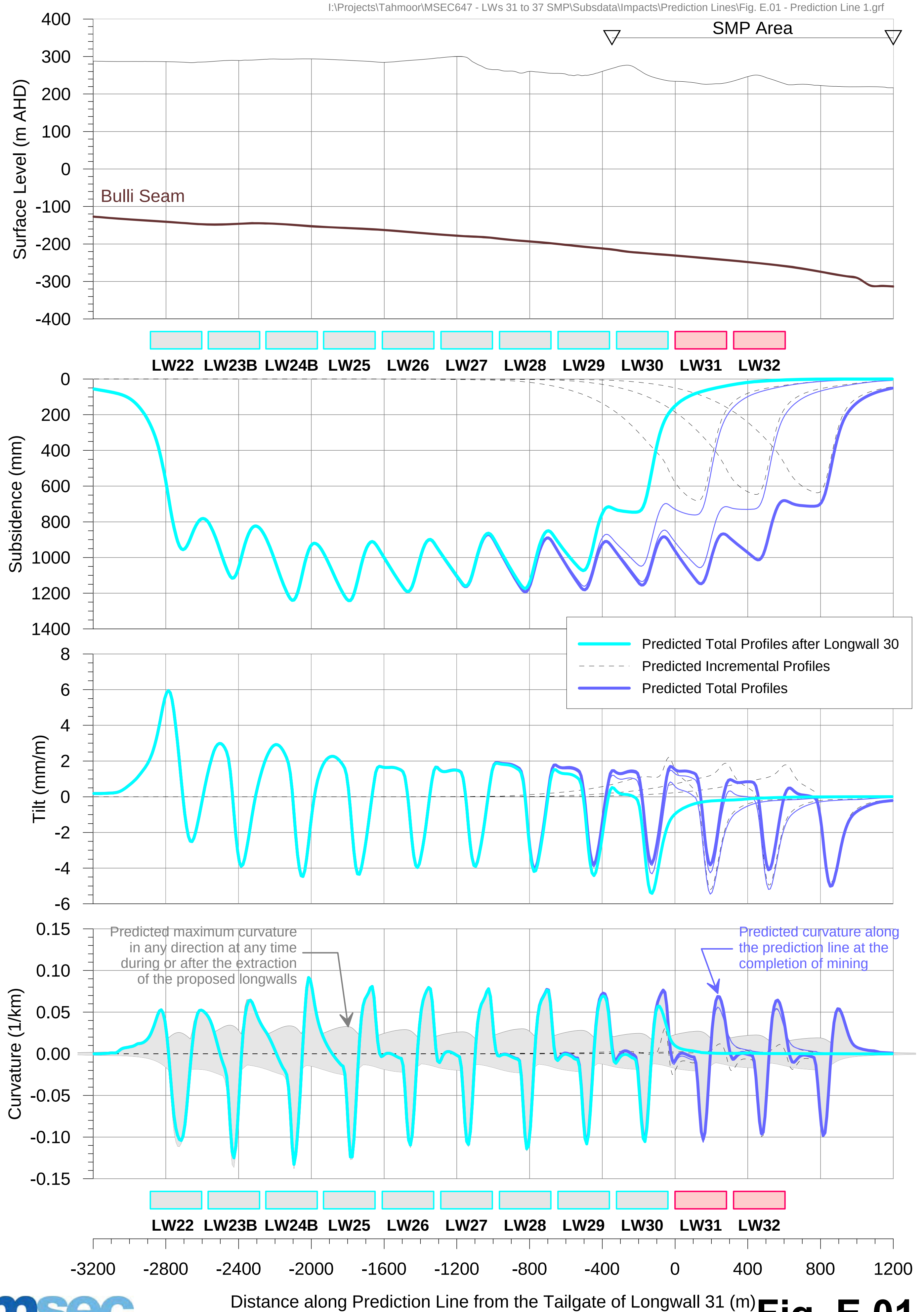
Fig. C.4 **Probability Curves for Impacts to Buildings**

APPENDIX D. TABLES

REFER TO VOLUME 2 FOR TABLES D.01 TO D.11

APPENDIX E. FIGURES

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 1 Resulting from the Extraction of Longwalls 22 to 32



msec

Fig. E.01

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 2 Resulting from the Extraction of Longwalls 33 to 37

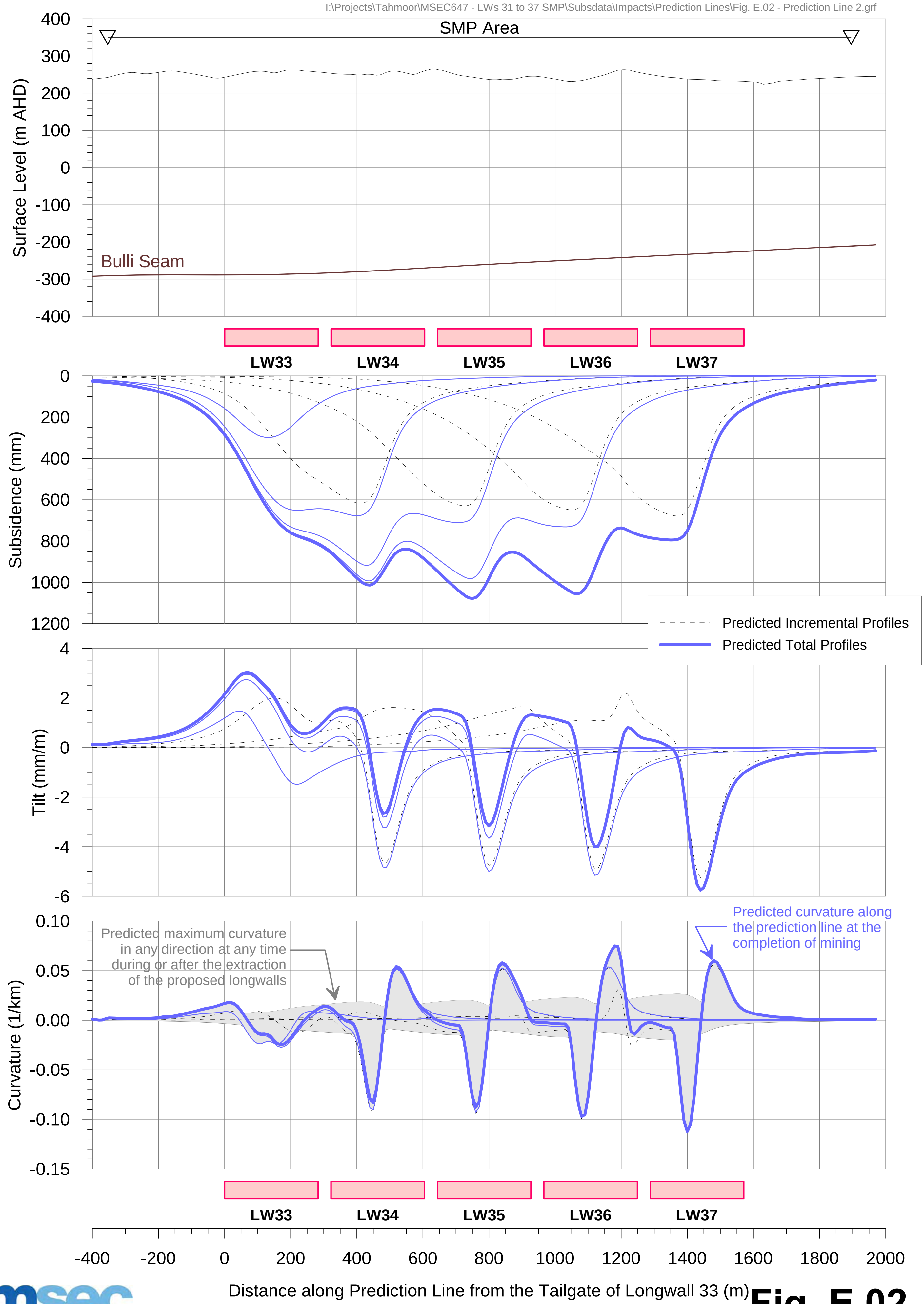


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Fig. E.02

Predicted Profiles of Subsidence, Upsidence and Closure along Redbank Creek Resulting from the Extraction of Longwalls 22 to 37

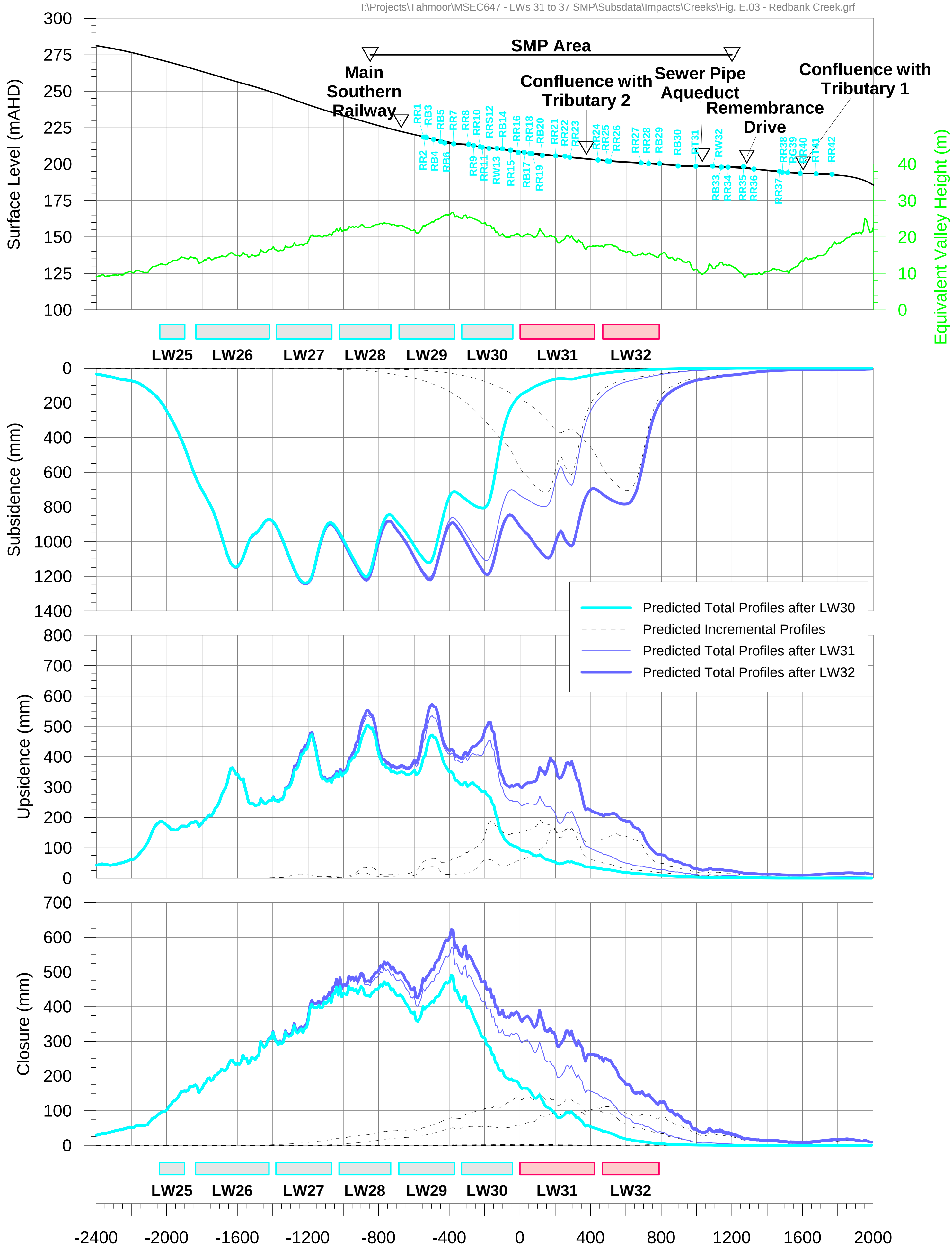

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Fig. E.03

Predicted Profiles of Subsidence, Upsidence and Closure along Tributary 2 to Redbank Creek Resulting from the Extraction of Longwalls 22 to 37

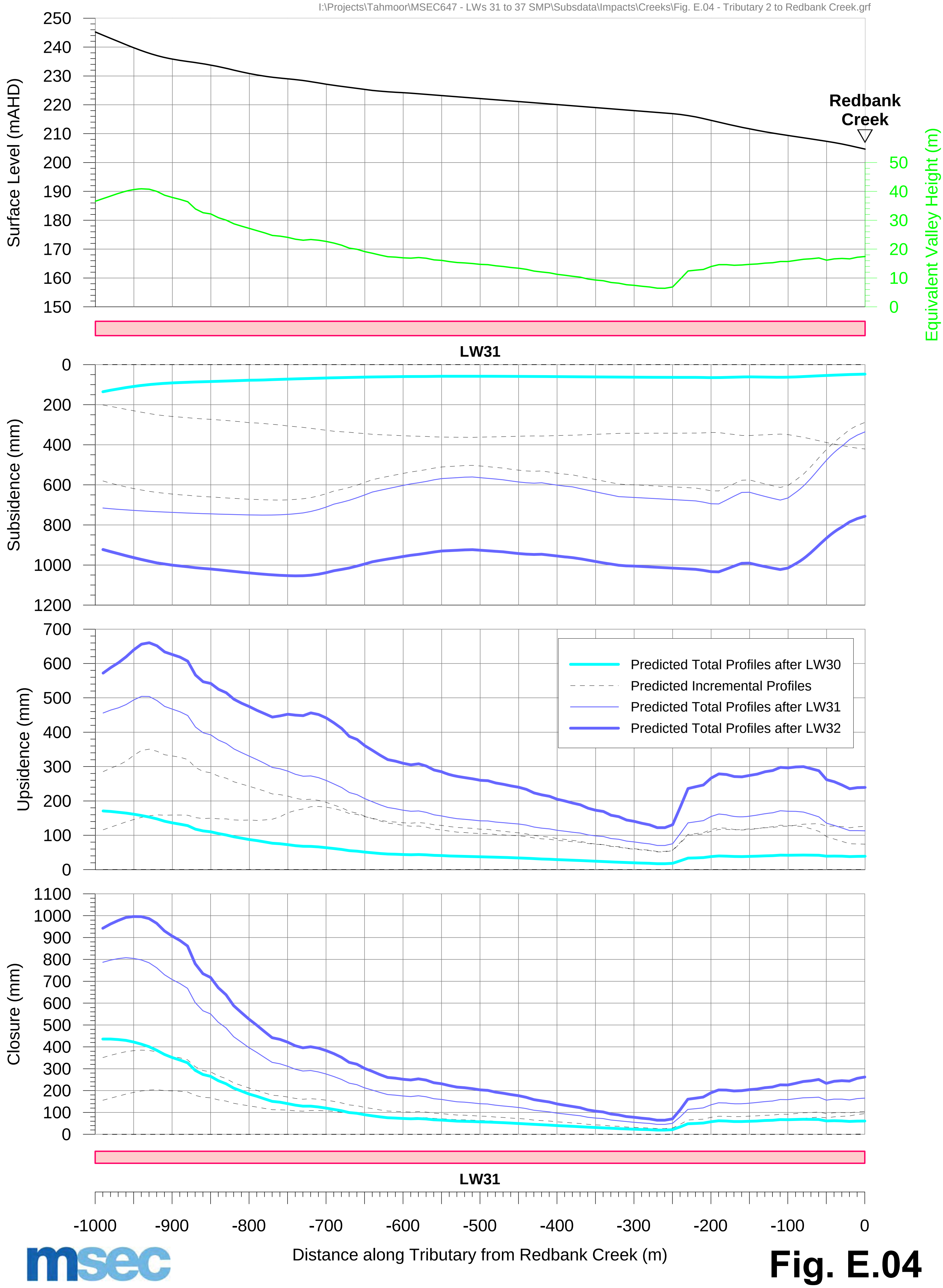
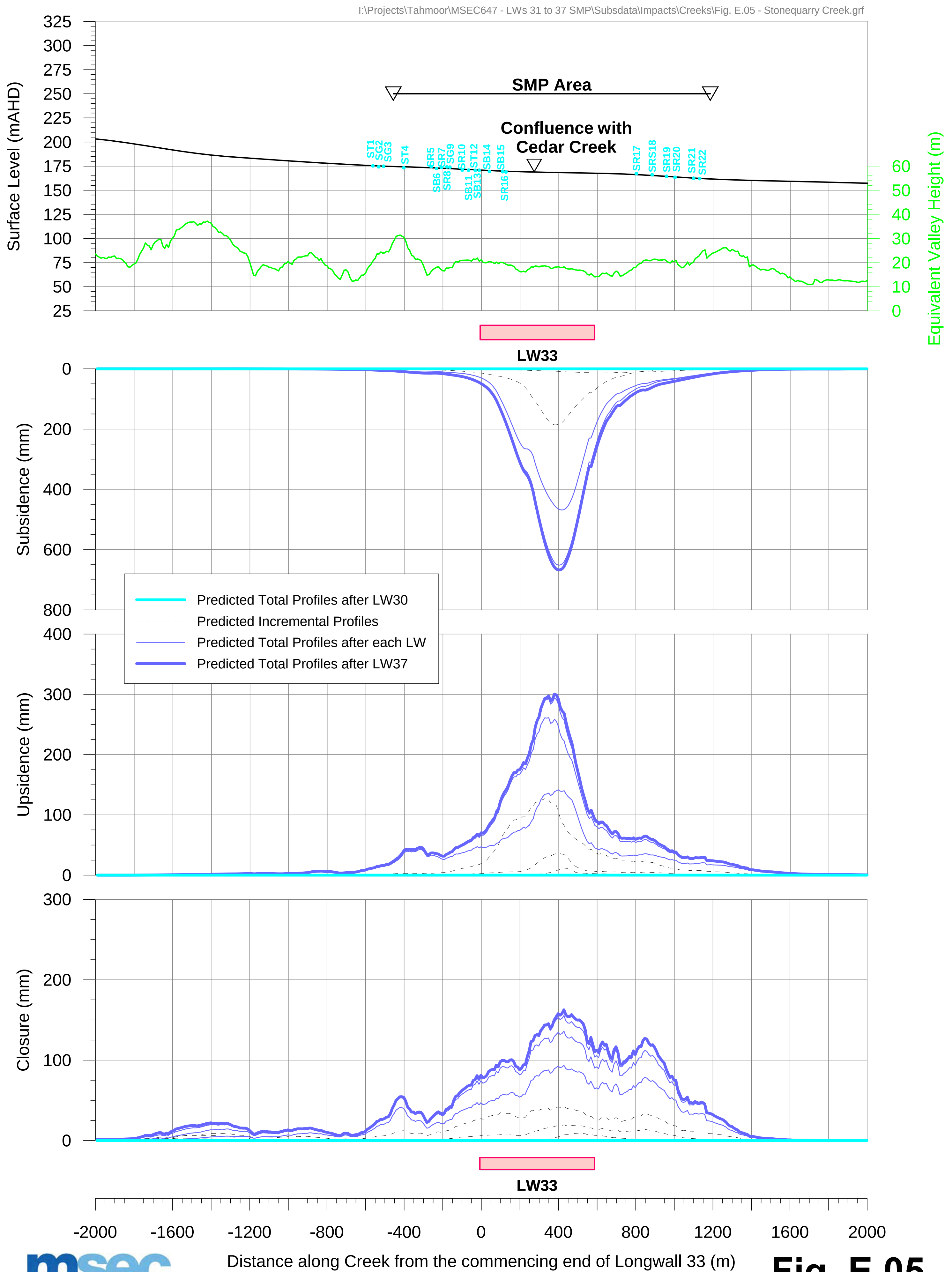


Fig. E.04

Predicted Profiles of Subsidence, Upsidence and Closure along Stonequarry Creek Resulting from the Extraction of Longwalls 22 to 37



msec

Fig. E.05

Predicted Profiles of Subsidence, Upsidence and Closure along Cedar Creek Resulting from the Extraction of Longwalls 22 to 37

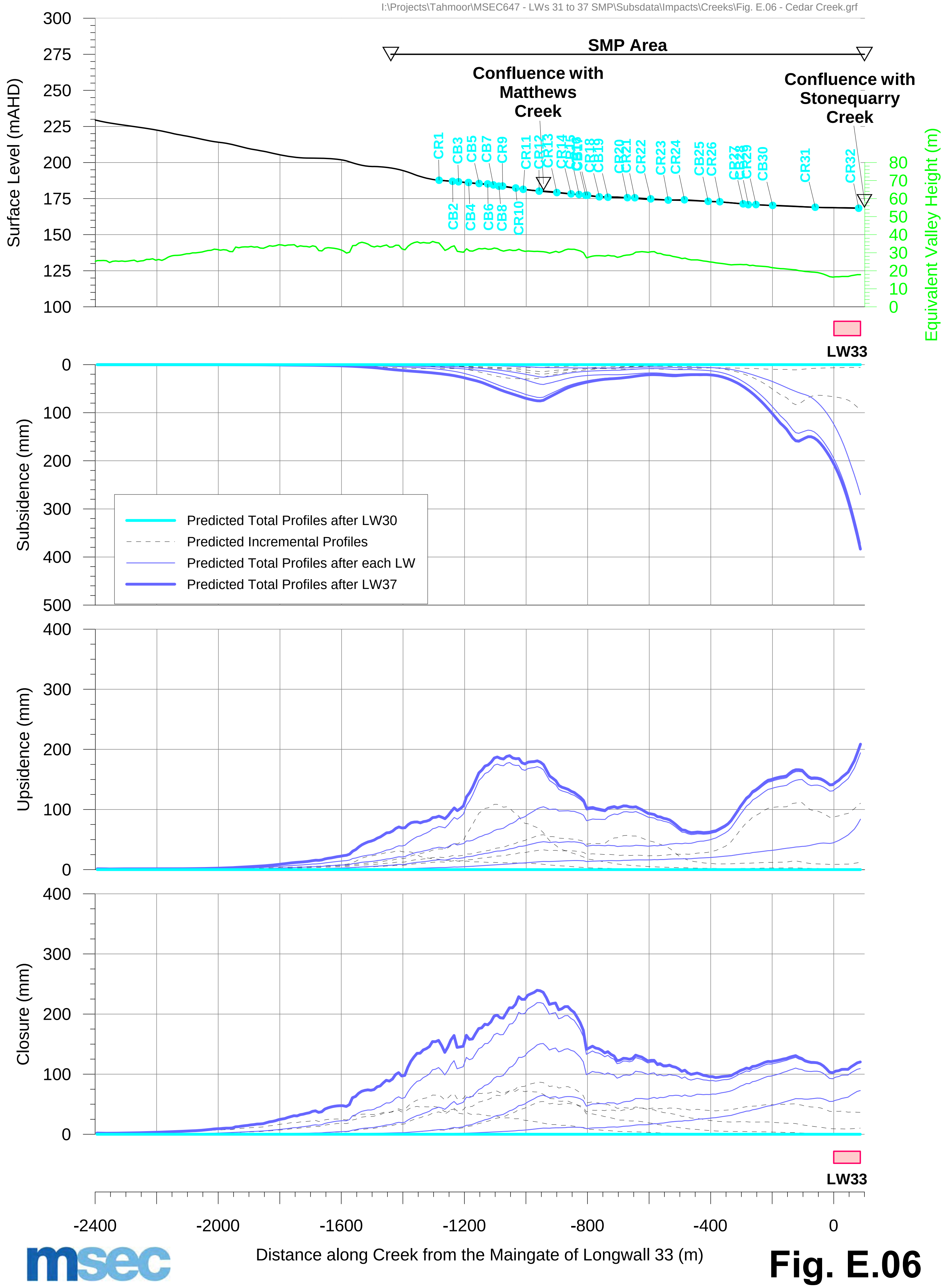


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Fig. E.06

Predicted Profiles of Subsidence, Upsidence and Closure along Stonequarry (Upper), Cedar and Matthews Creeks Resulting from the Extraction of Longwalls 22 to 37

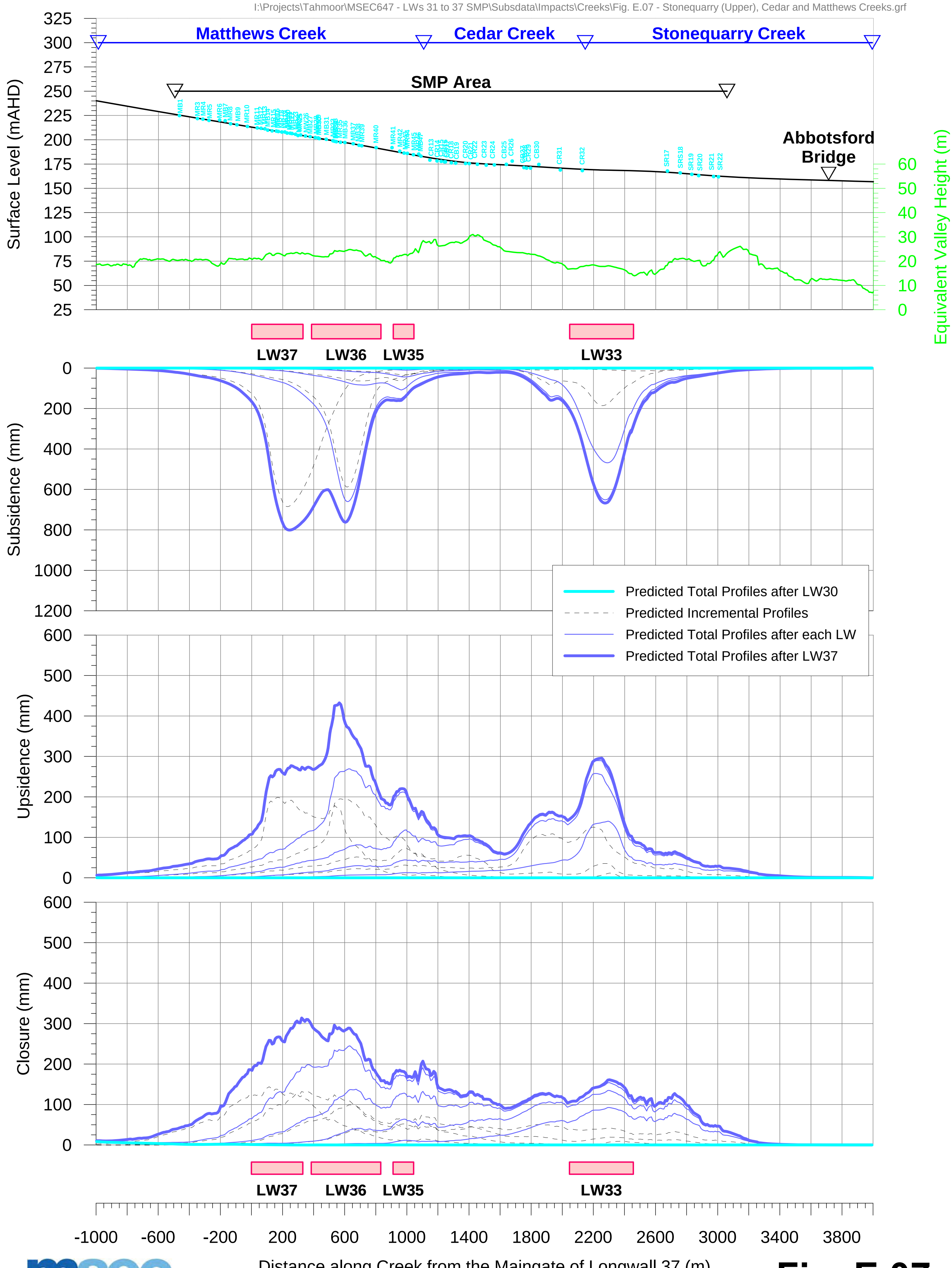

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Fig. E.07

Predicted Profiles of Subsidence, Upsidence and Closure along Tributary 1 to Matthews Creek Resulting from the Extraction of Longwalls 22 to 37

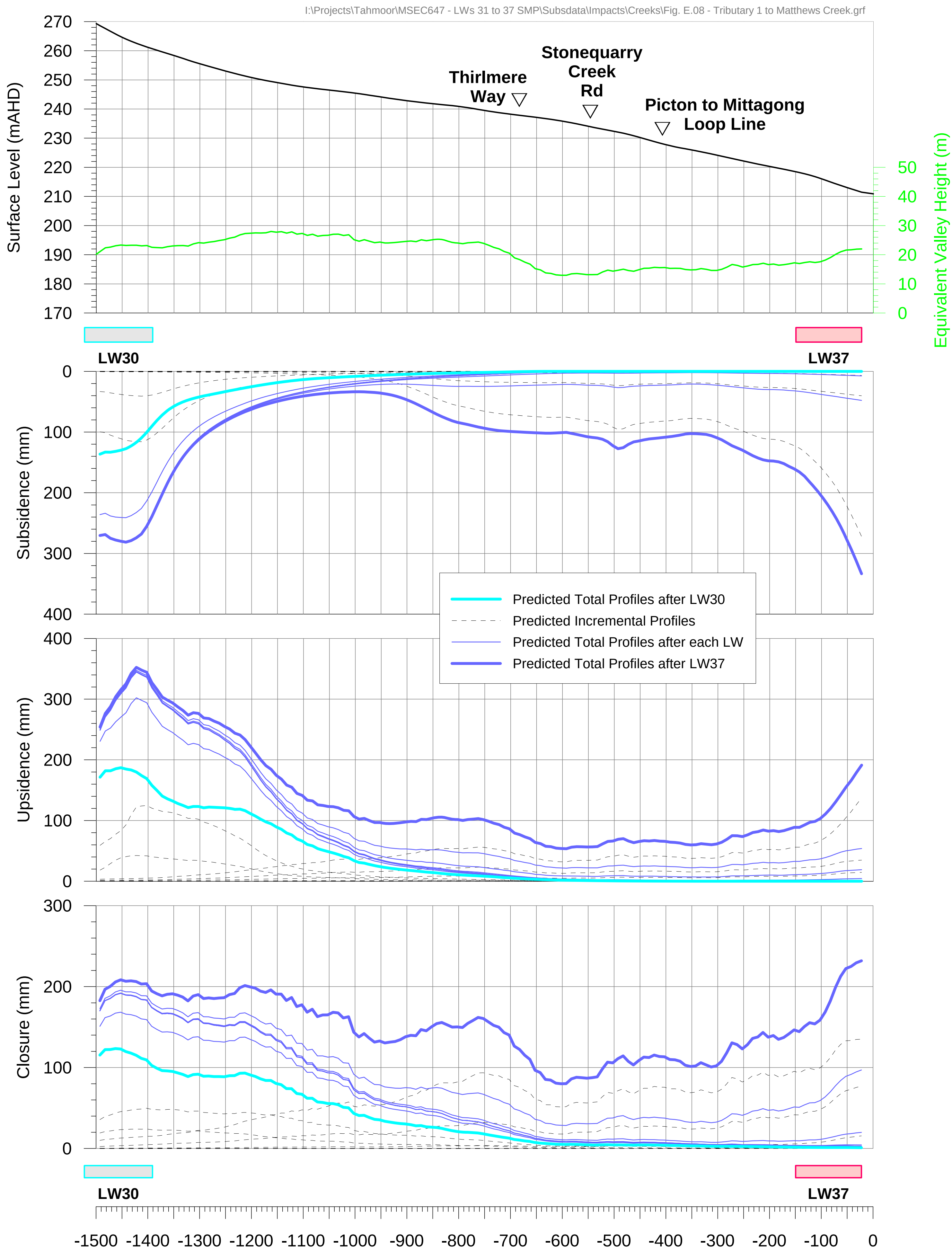

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Fig. E.08

Predicted Movements Along the Alignment of the Main Southern Railway Resulting from the Extraction of Longwalls 22 to 37

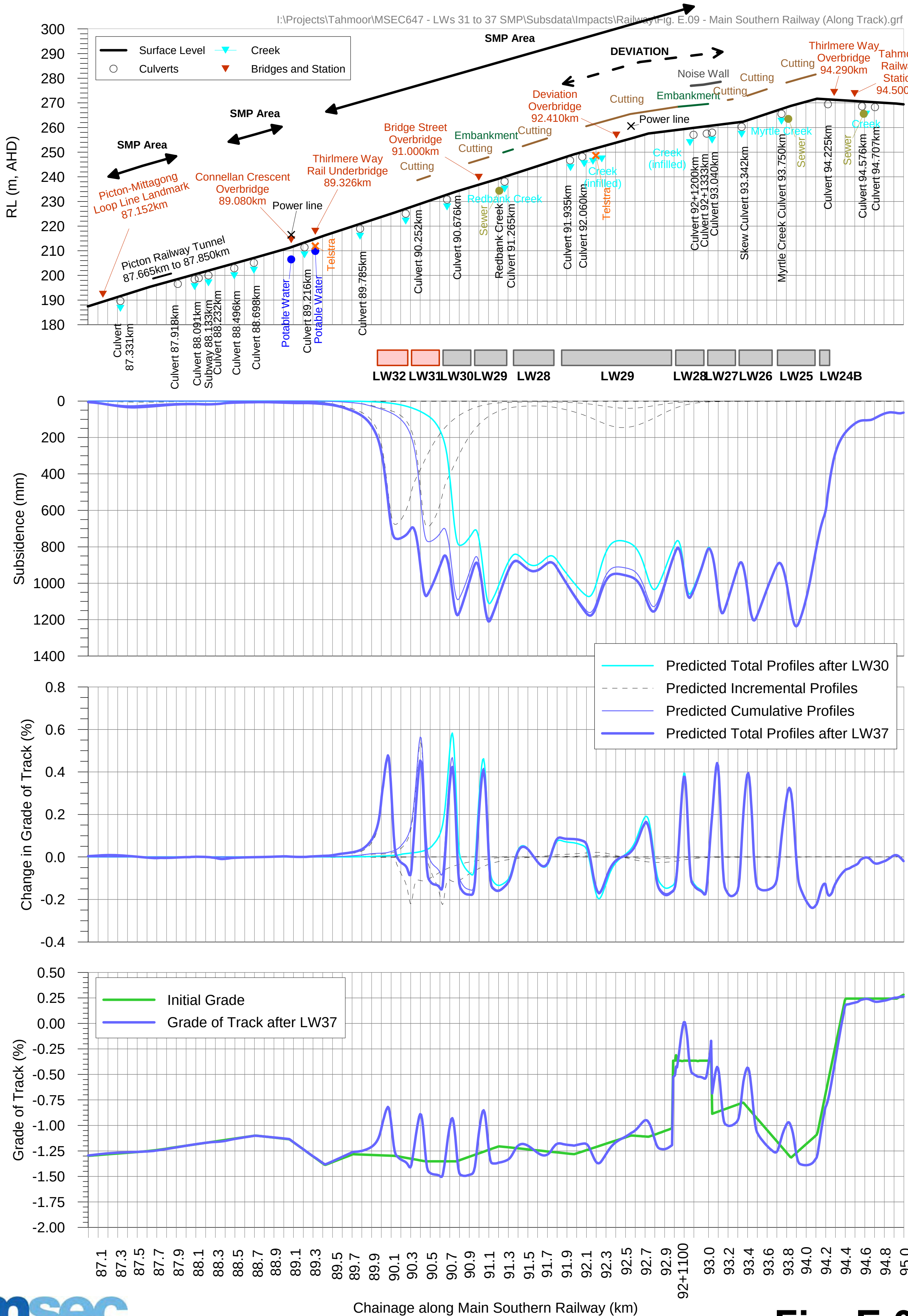

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Fig. E.09

Predicted Movements Across the Alignment of the Main Southern Railway Resulting from the Extraction of Longwalls 22 to 37

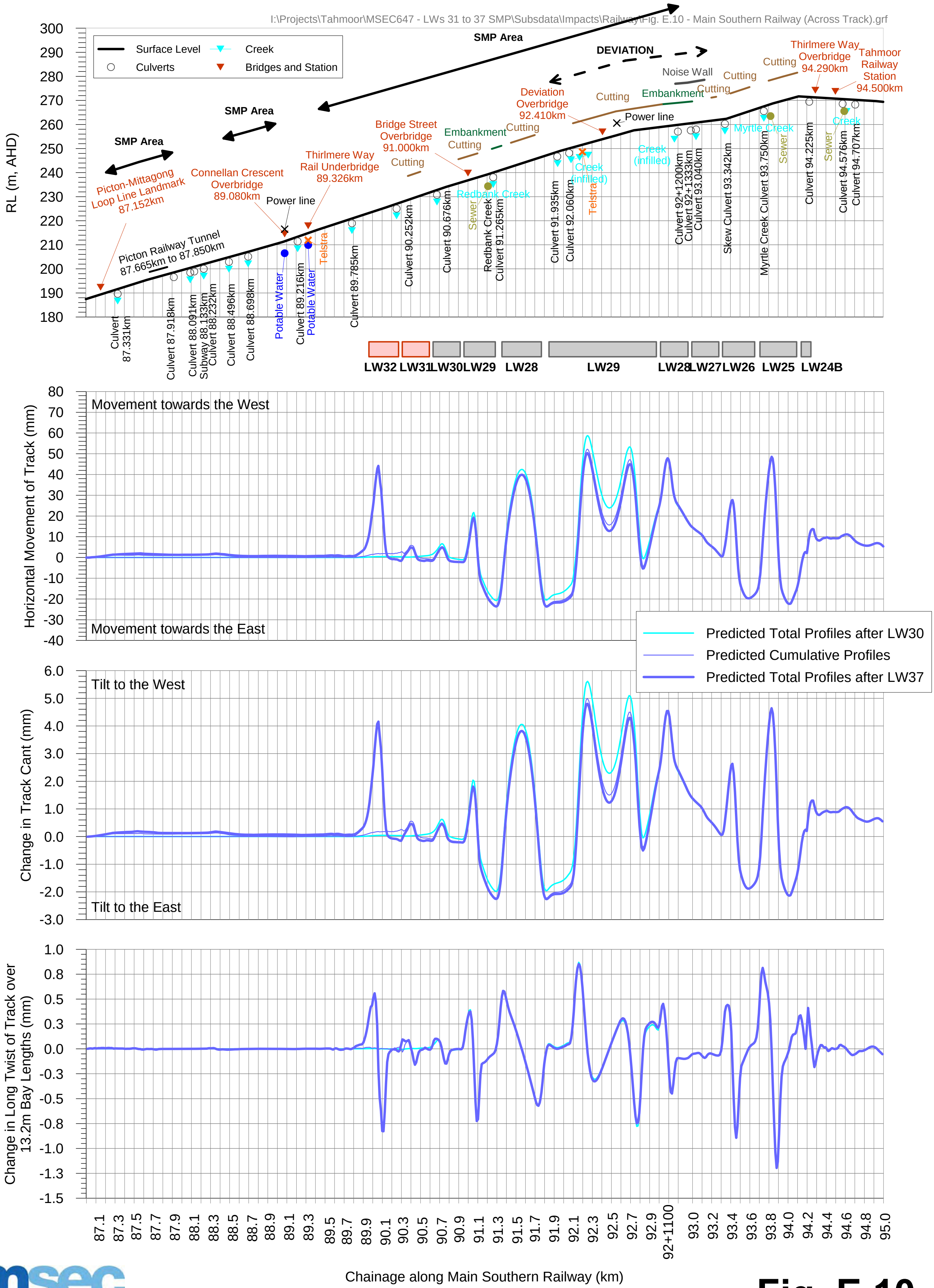

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Fig. E.10

Predicted Travelling Subsidence, Changes in Grade and Long Bay Lengths along the Main Southern Railway Resulting from the Extraction of Longwalls 31 and 32

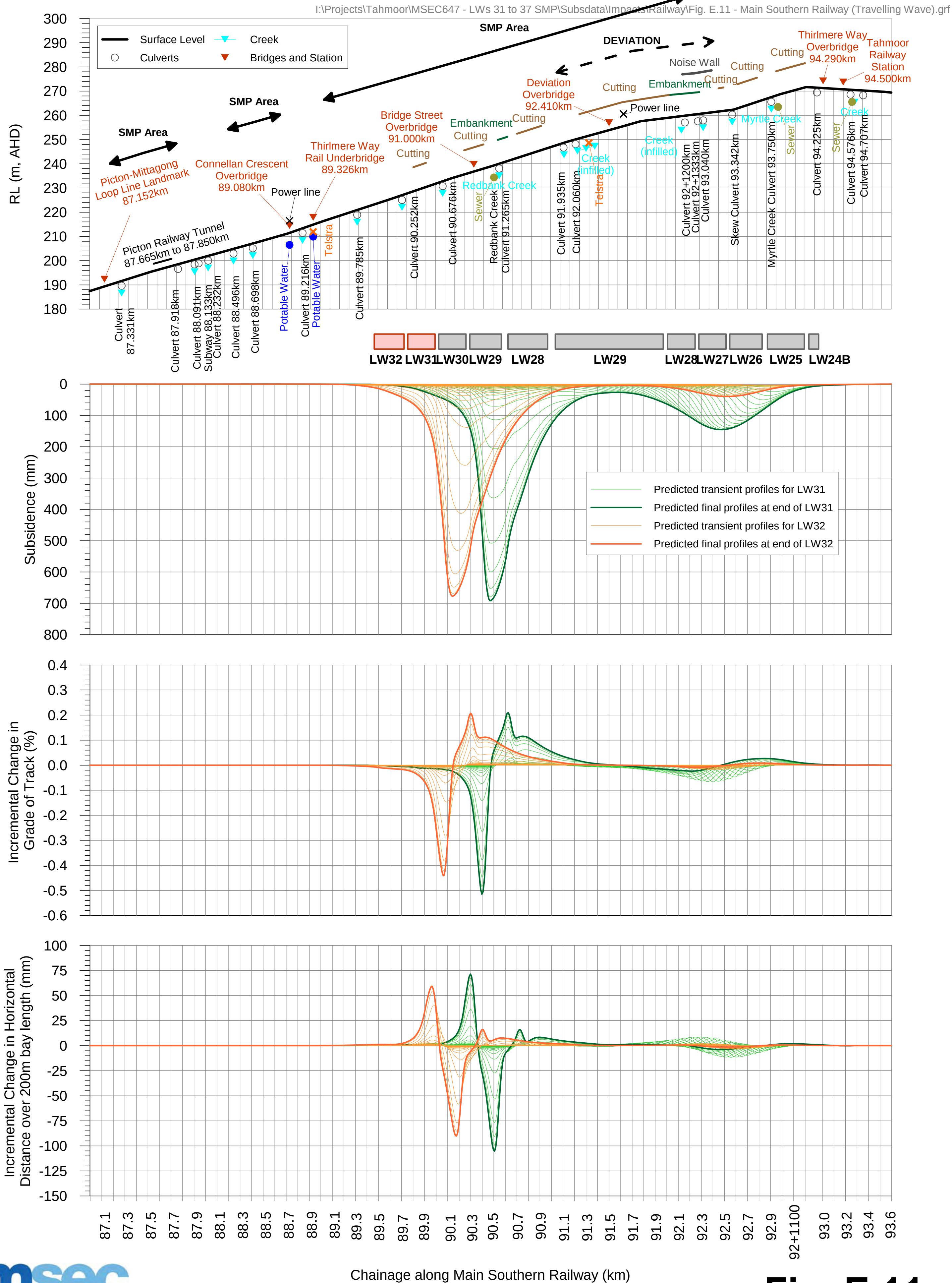

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Fig. E.11

Predicted Movements Along the Alignment of the Picton to Mittagong Loop Line Resulting from the Extraction of Longwalls 22 to 37

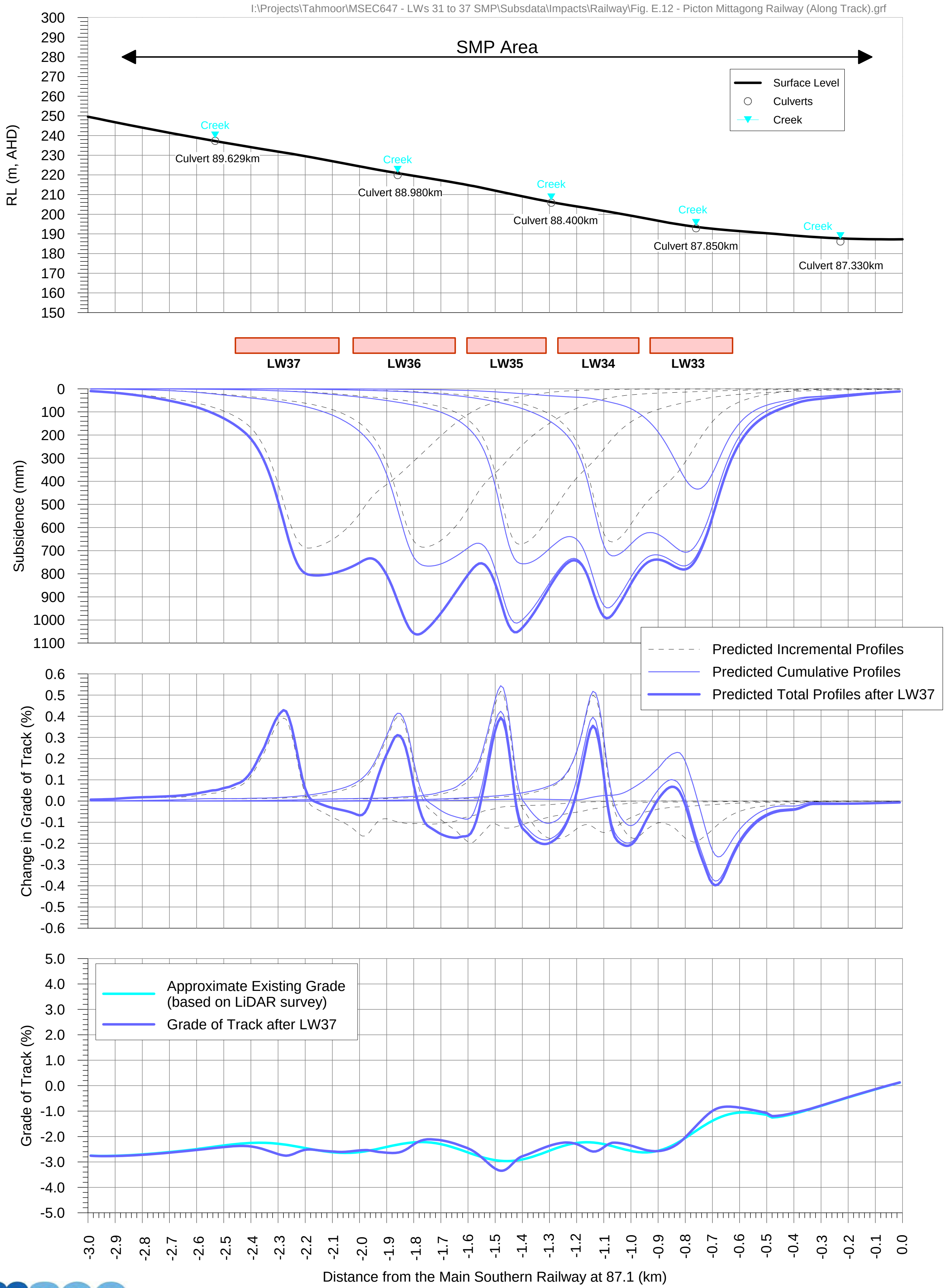

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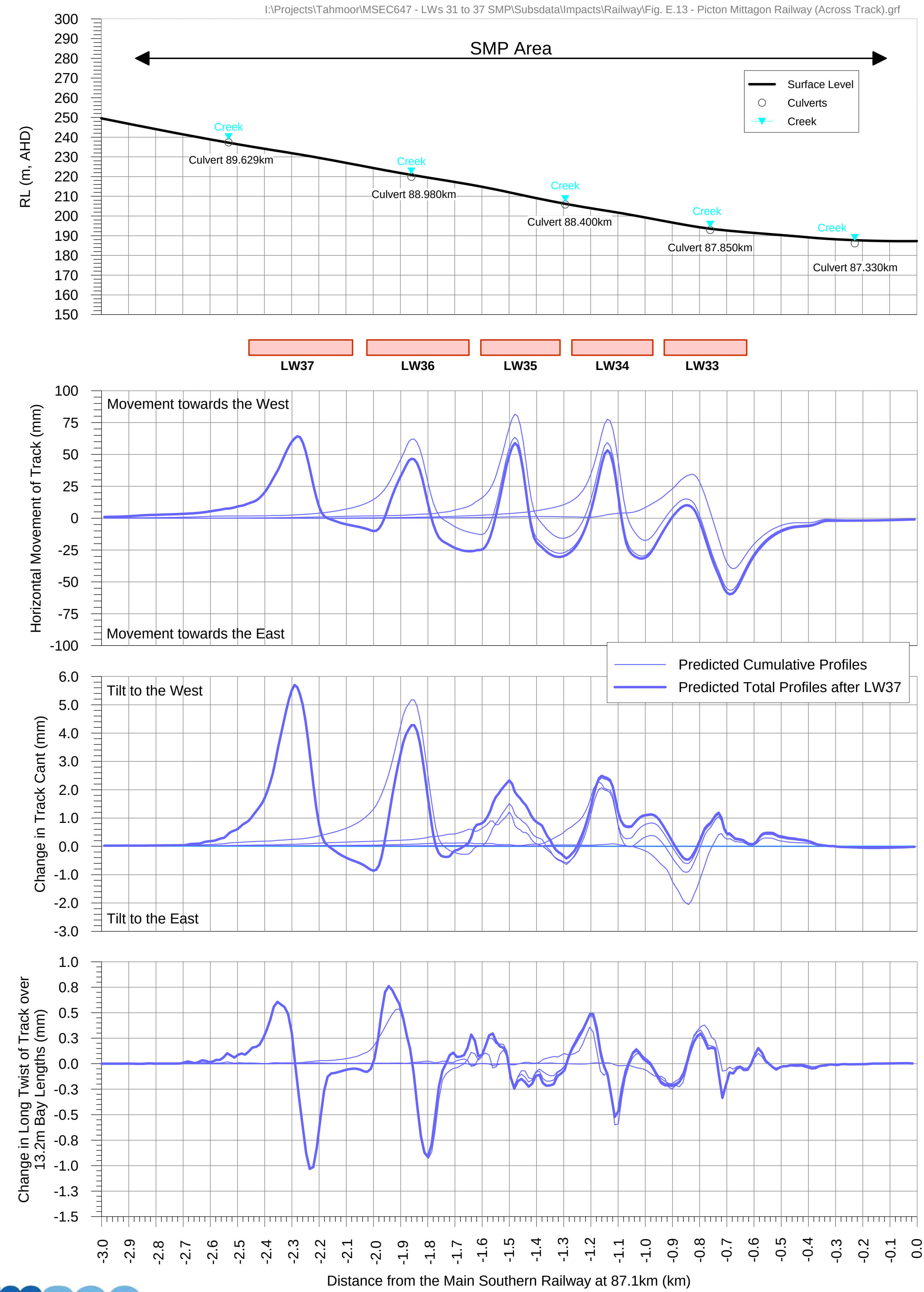
Fig. E.12

Predicted Movements Across the Alignment of the Picton to Mittagong Loop Line Resulting from the Extraction of Longwalls 22 to 37



msec

Fig. E.13

Predicted Travelling Subsidence, Changes in Grade and Long Bay Lengths along the Picton to Mittagong Loop Line Resulting from the Extraction of Longwalls 33 to 37

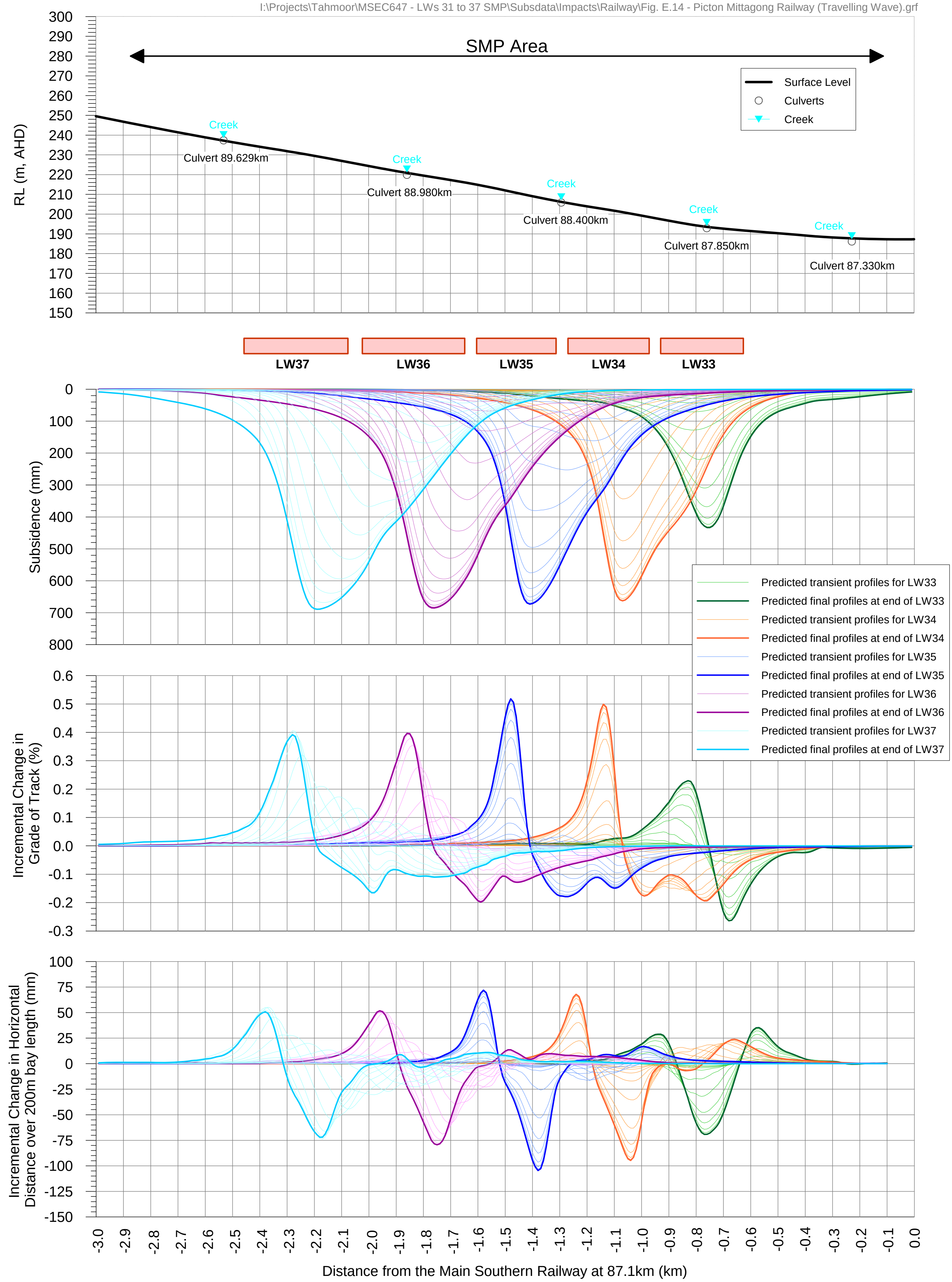


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Fig. E.14

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Remembrance Drive Resulting from the Extraction of Longwalls 22 to 37

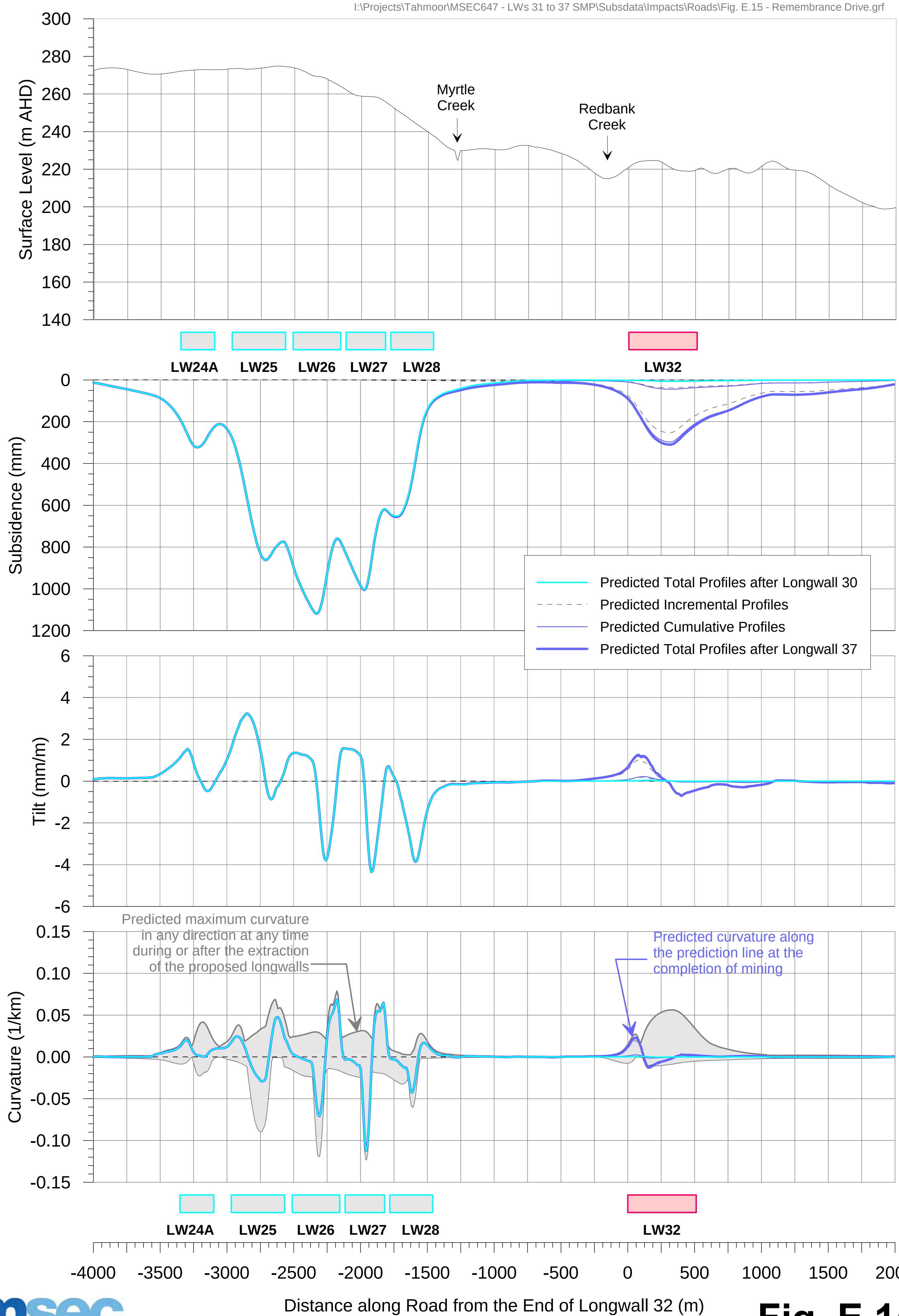

Fig. E.15

Predicted Profiles of Systematic Subsidence, Tilt and Curvature along Bridge Street Resulting from the Extraction of Longwalls 22 to 37

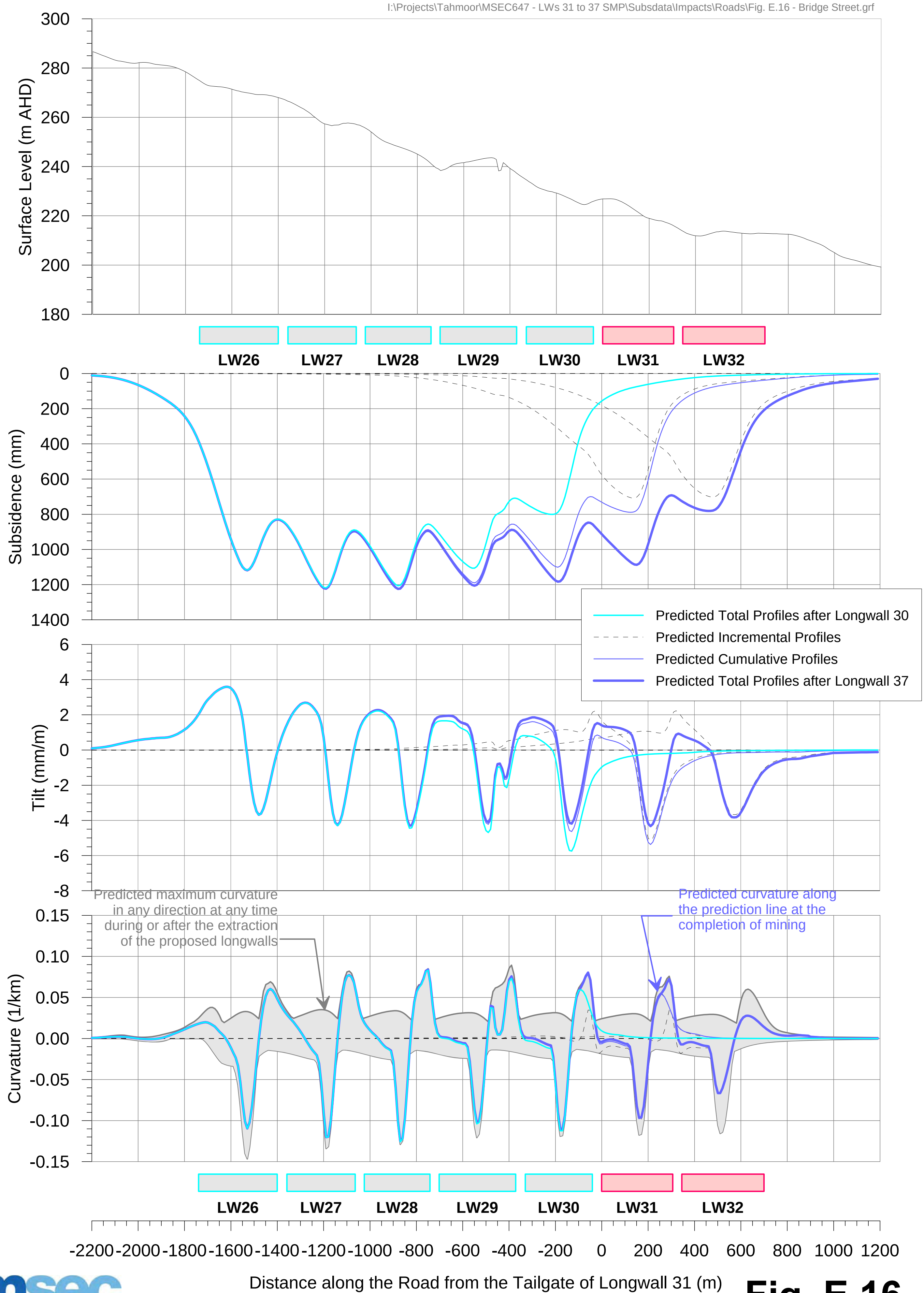

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Fig. E.16

Predicted Profiles of Systematic Subsidence, Tilt and Curvature along Stonequarry Creek Road due to the Extraction of Longwalls 22 to 37

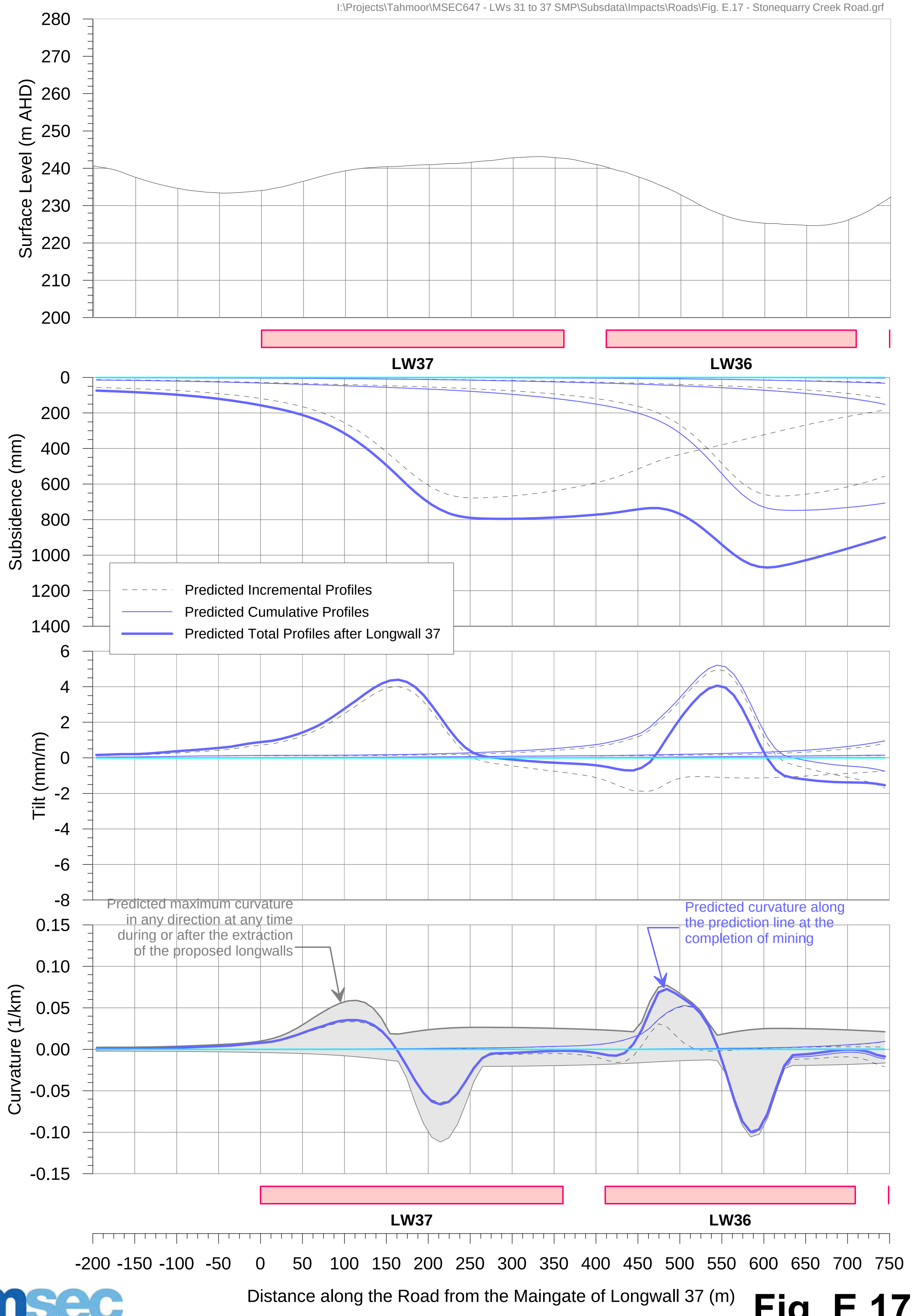

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Fig. E.17

Predicted Profiles of Systematic Subsidence, Tilt and Curvature along Thirlmere Way Resulting from the Extraction of Longwalls 22 to 37

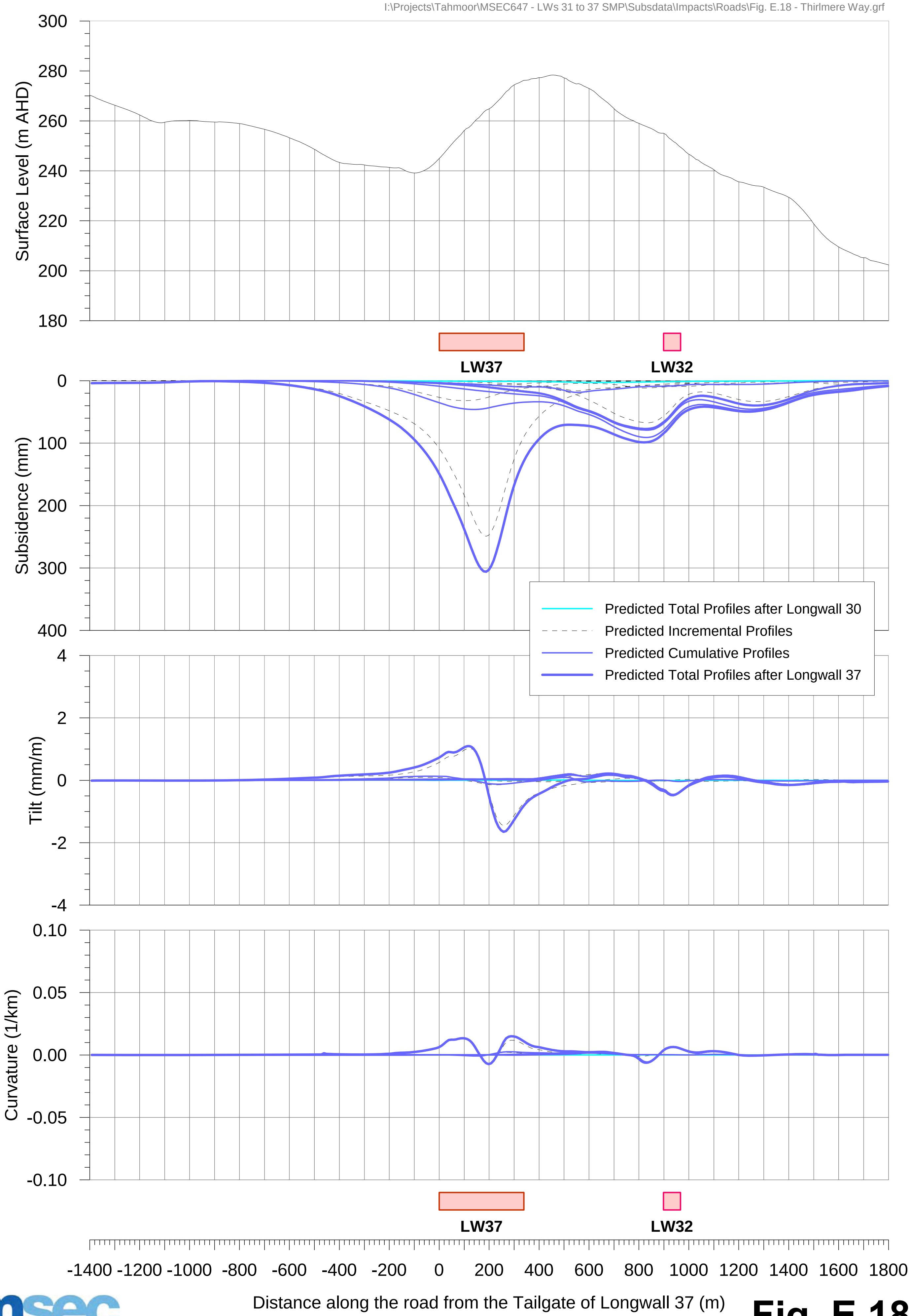
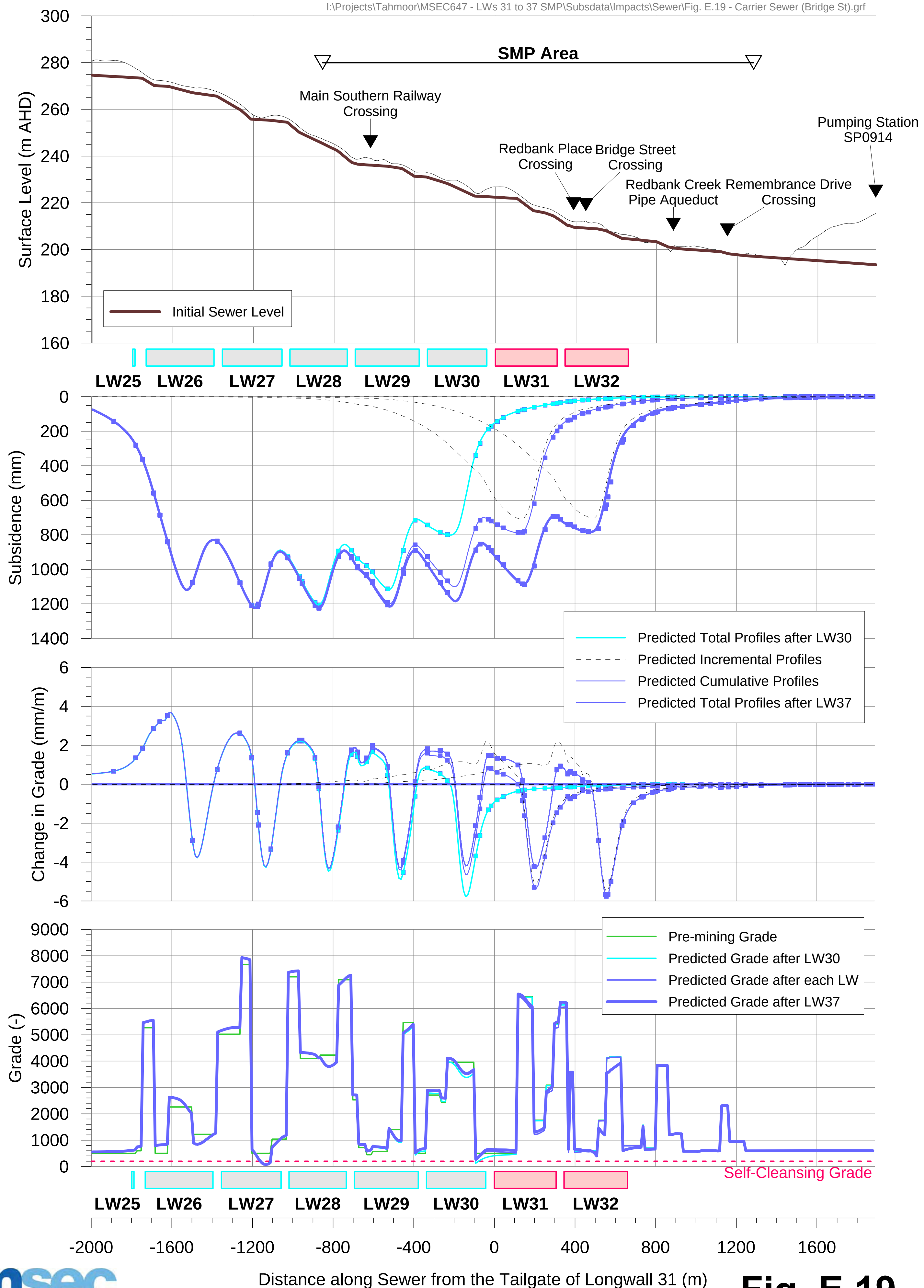


Fig. E.18

Predicted Profiles of Systematic Subsidence and Changes in Grade along Thirlmere Carrier Sewer Resulting from the Extraction of Longwalls 31 to 37



msec

Fig. E.19

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along the Optical Fibre Cable due to the Extraction of Longwalls 22 to 37

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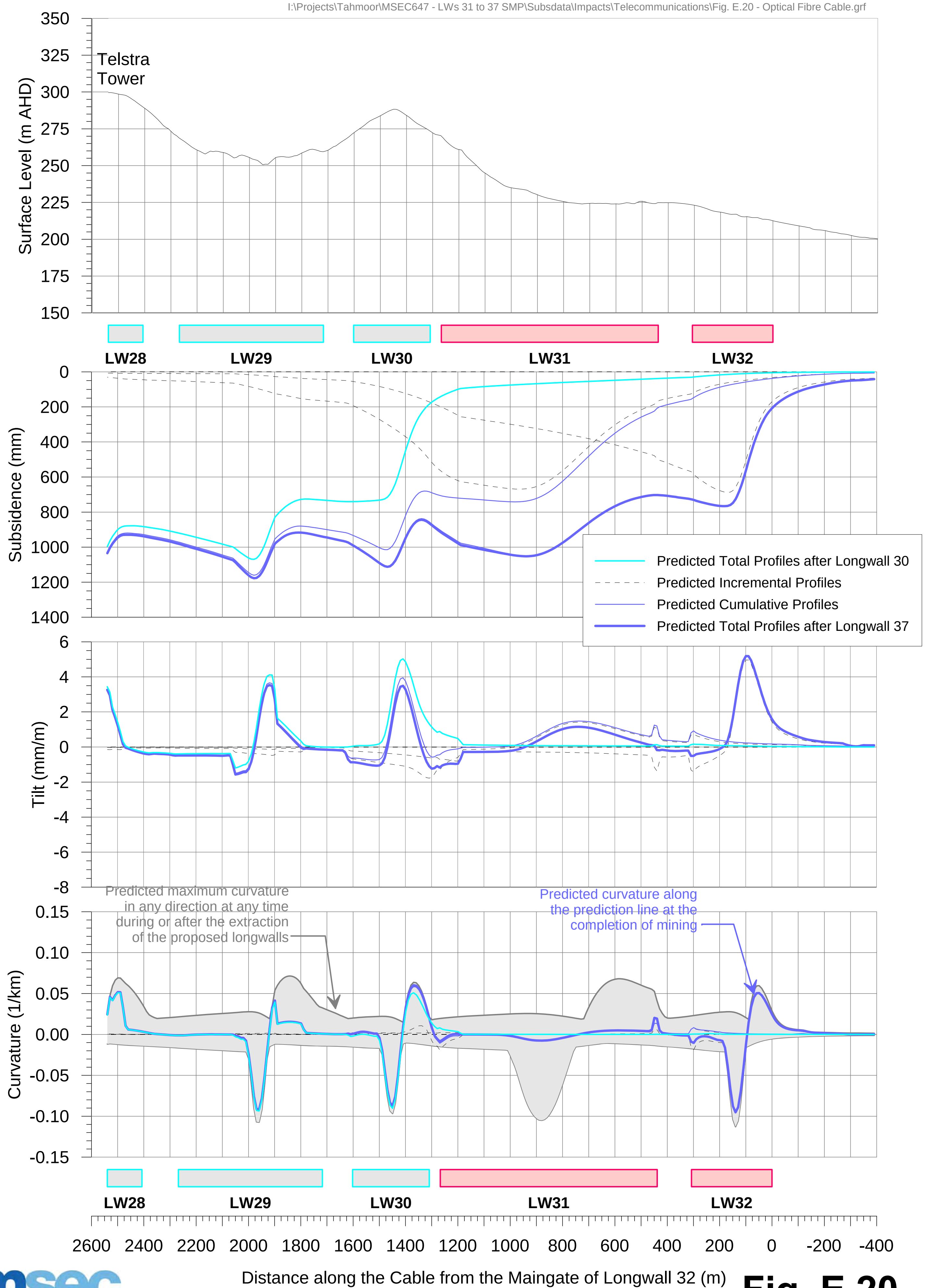

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Fig. E.20

APPENDIX F. DRAWINGS

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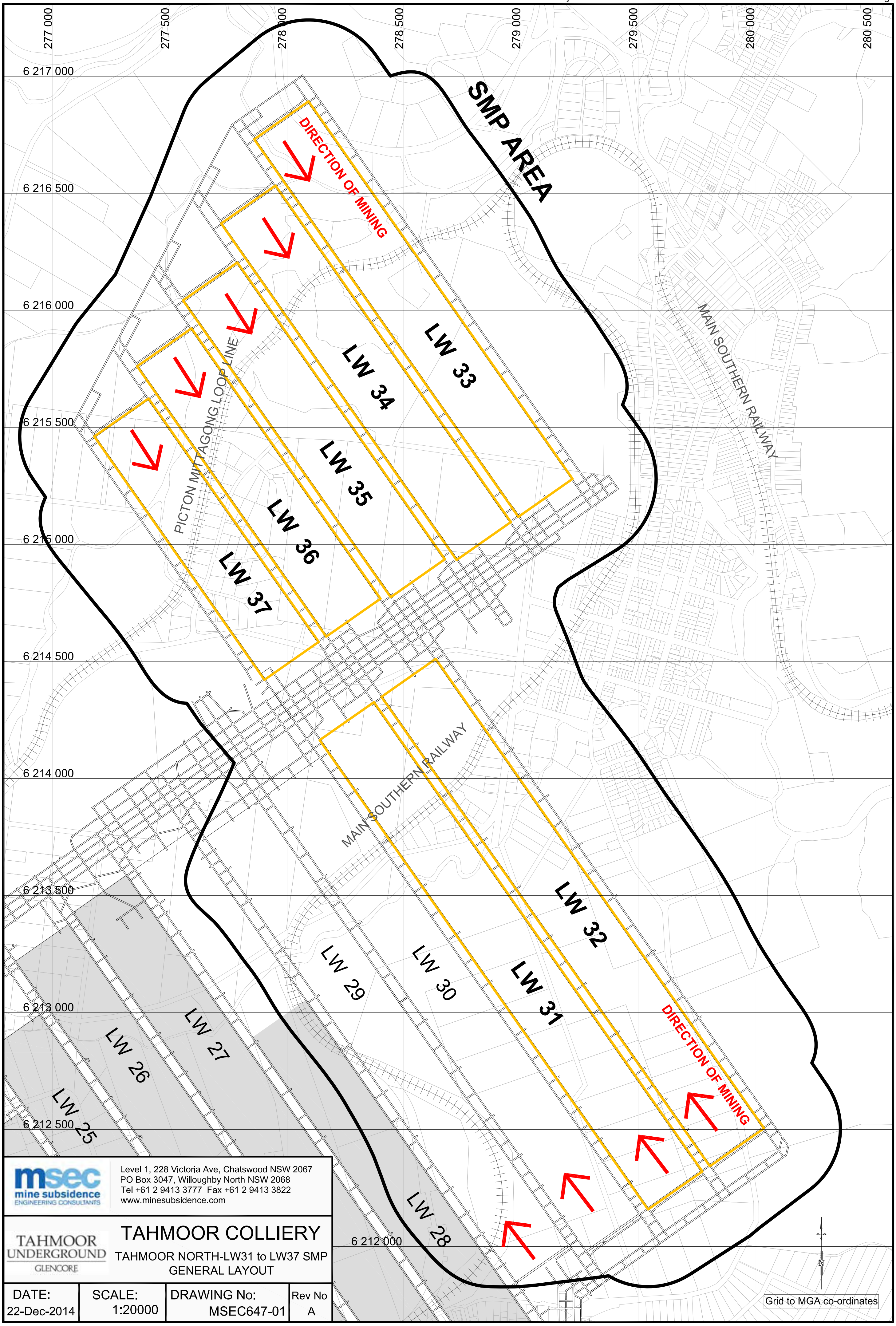

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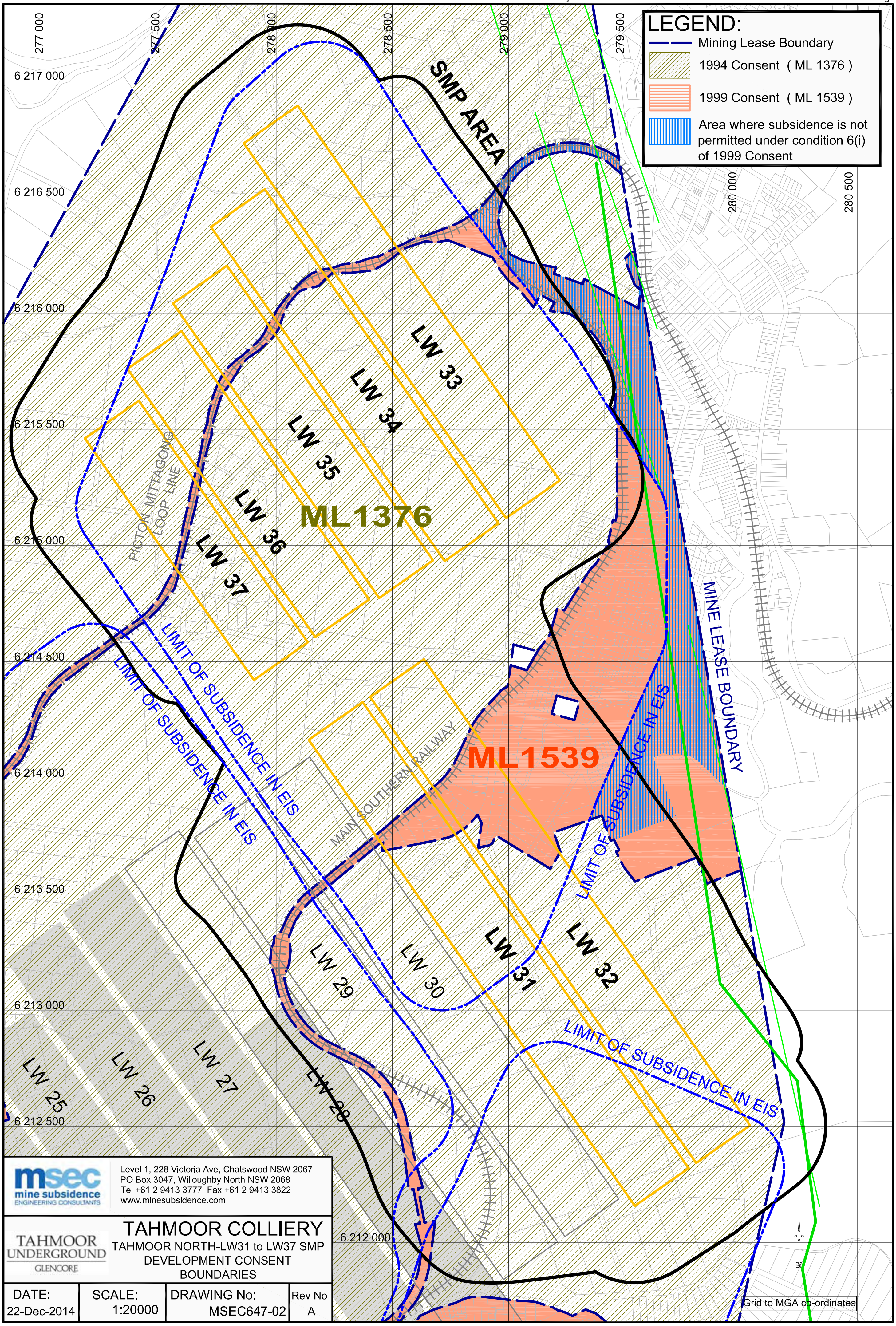

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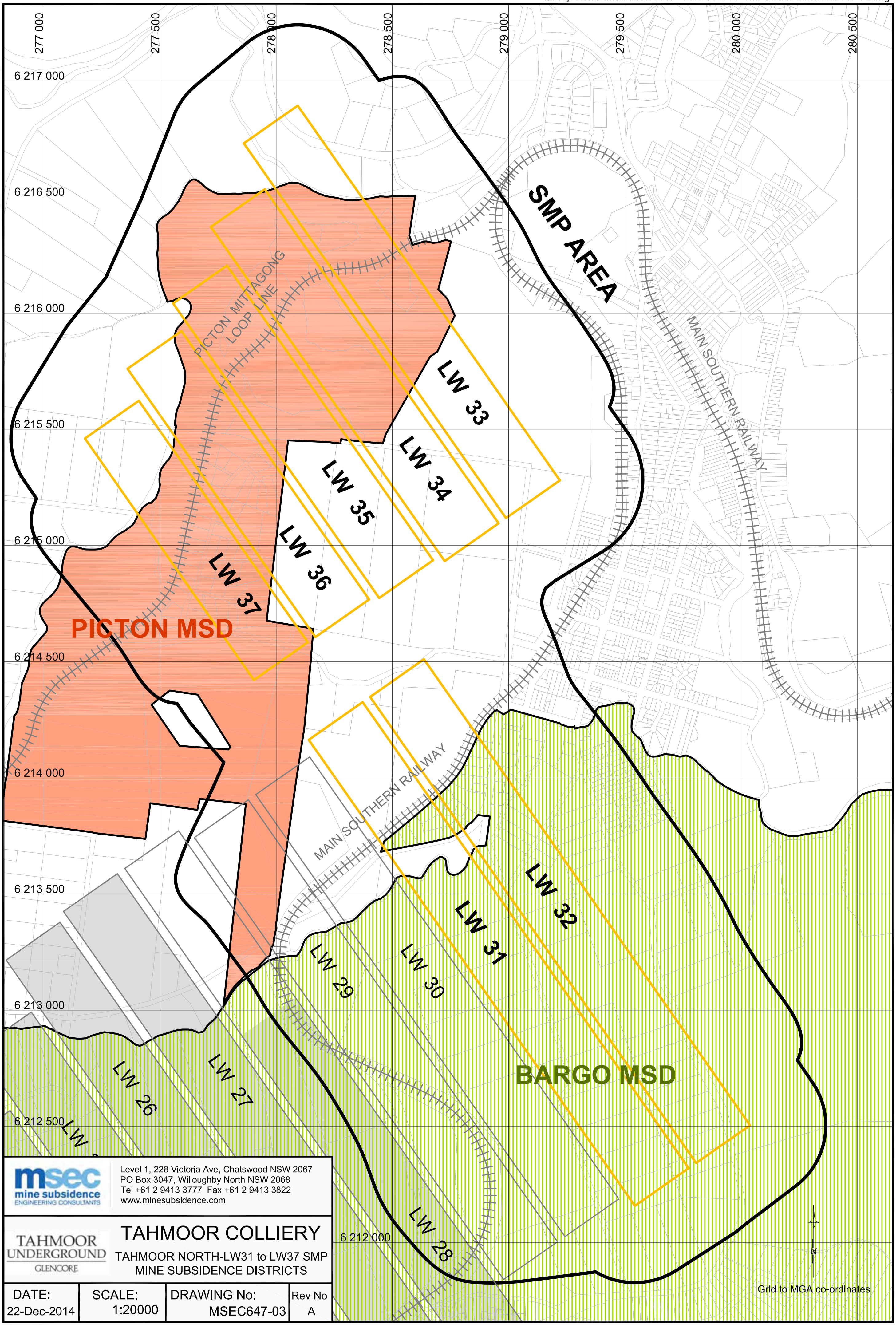

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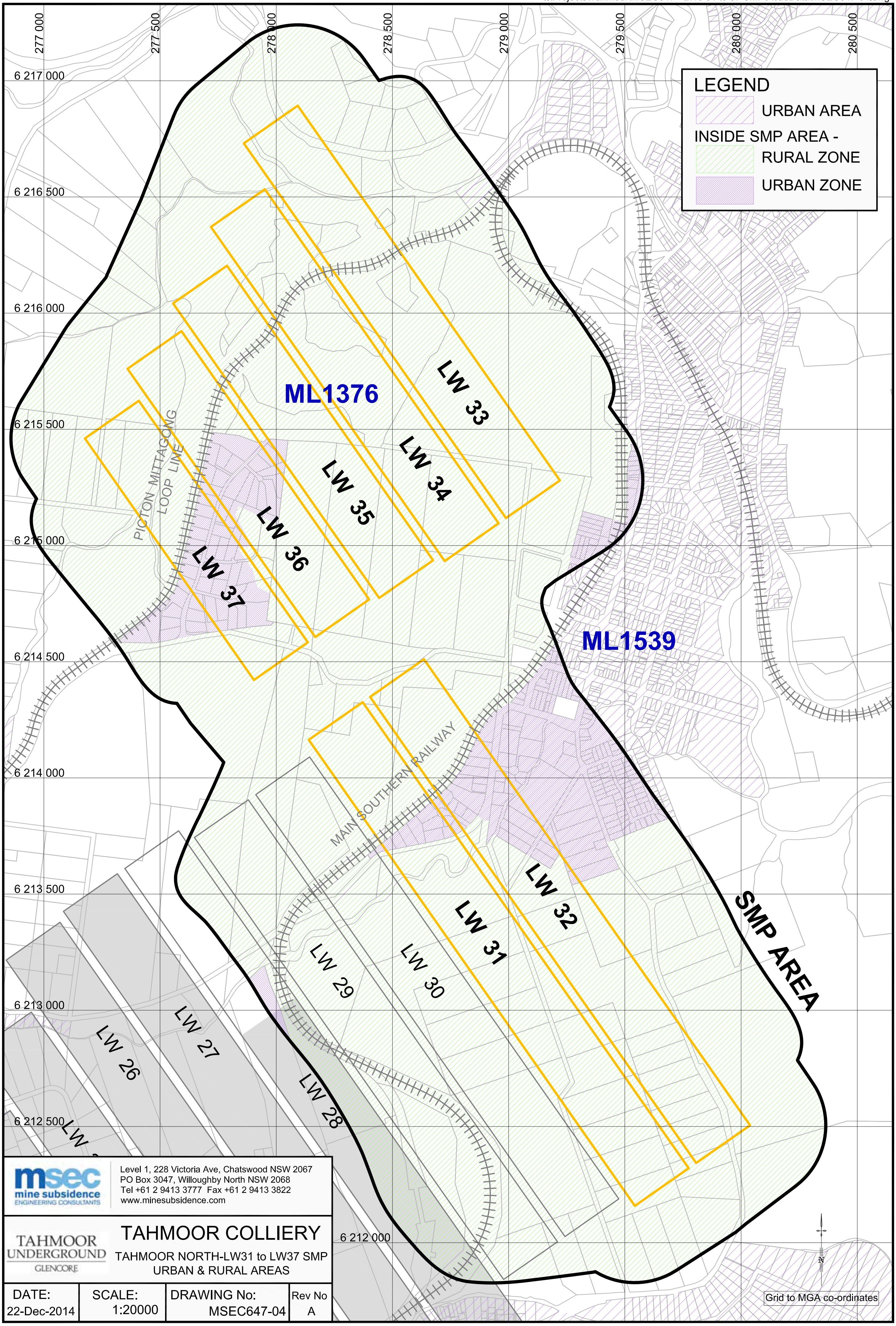

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH-LW31 to LW37 SMP
URBAN & RURAL AREAS

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22-Dec-2014	1:20000	MSEC647-04	A

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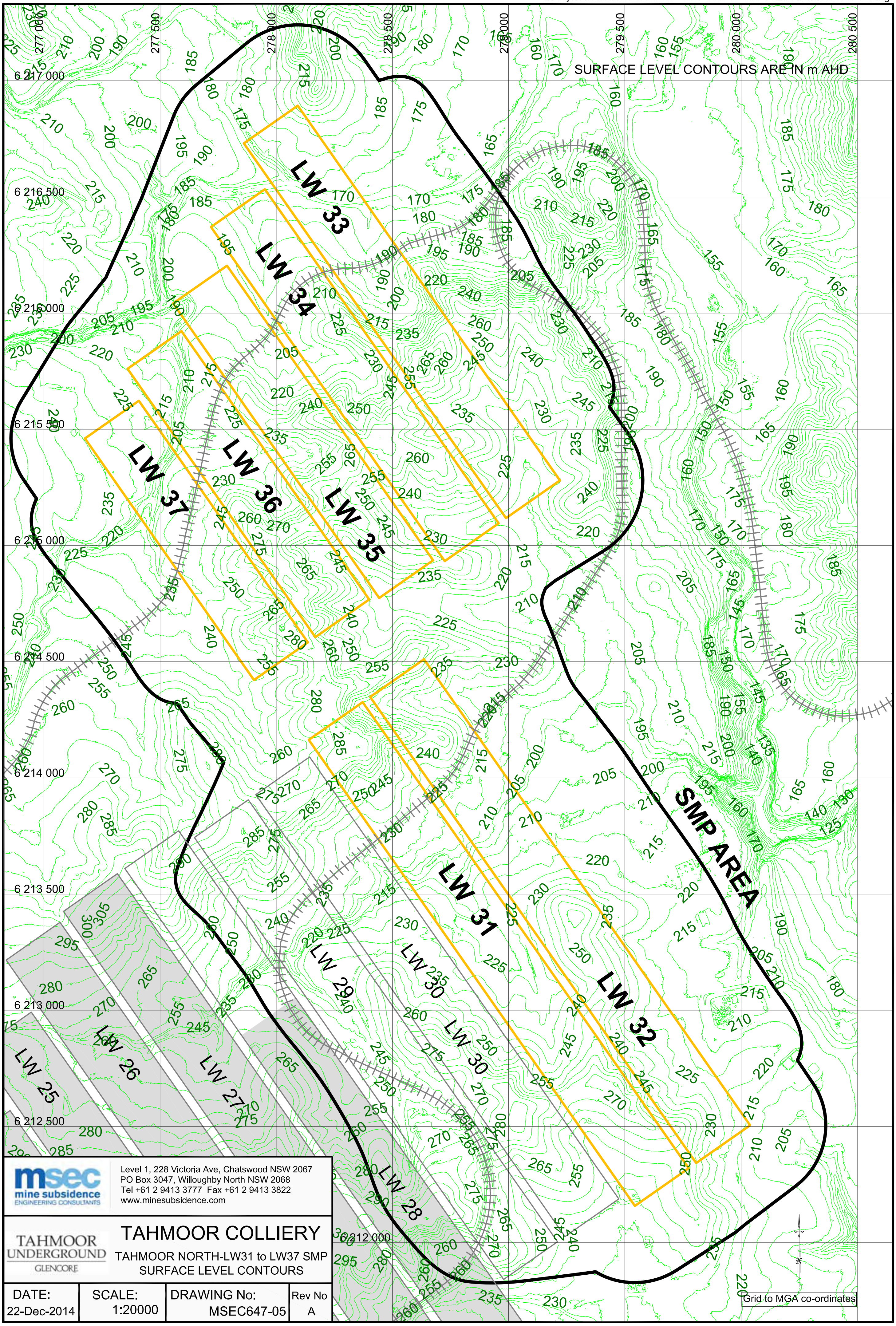

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TAHMOOR COLLIERY

TAHMOOR NORTH-LW31 to LW37 SMP
SURFACE LEVEL CONTOURS

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22-Dec-2014	1:20000	MSEC647-05	A

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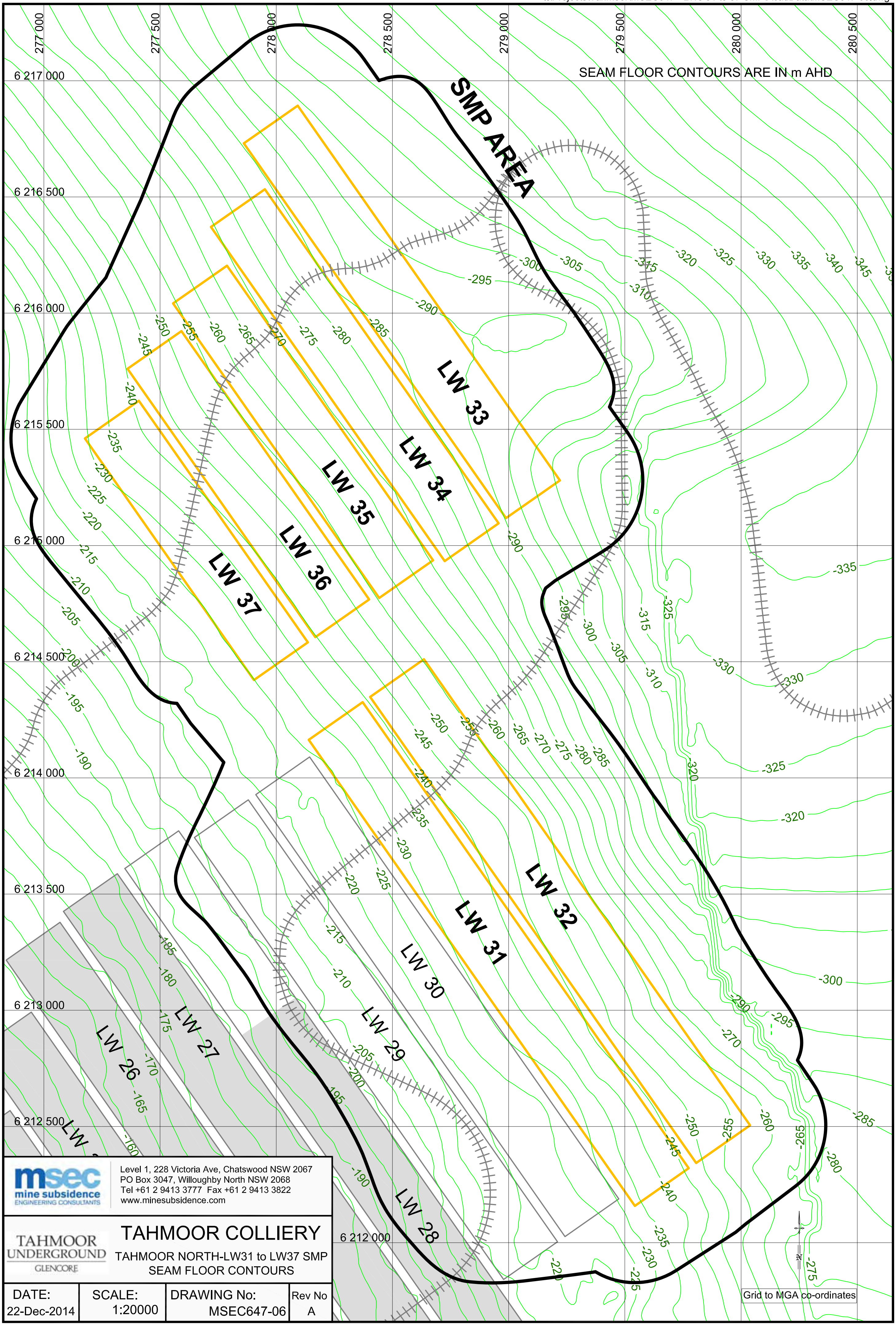

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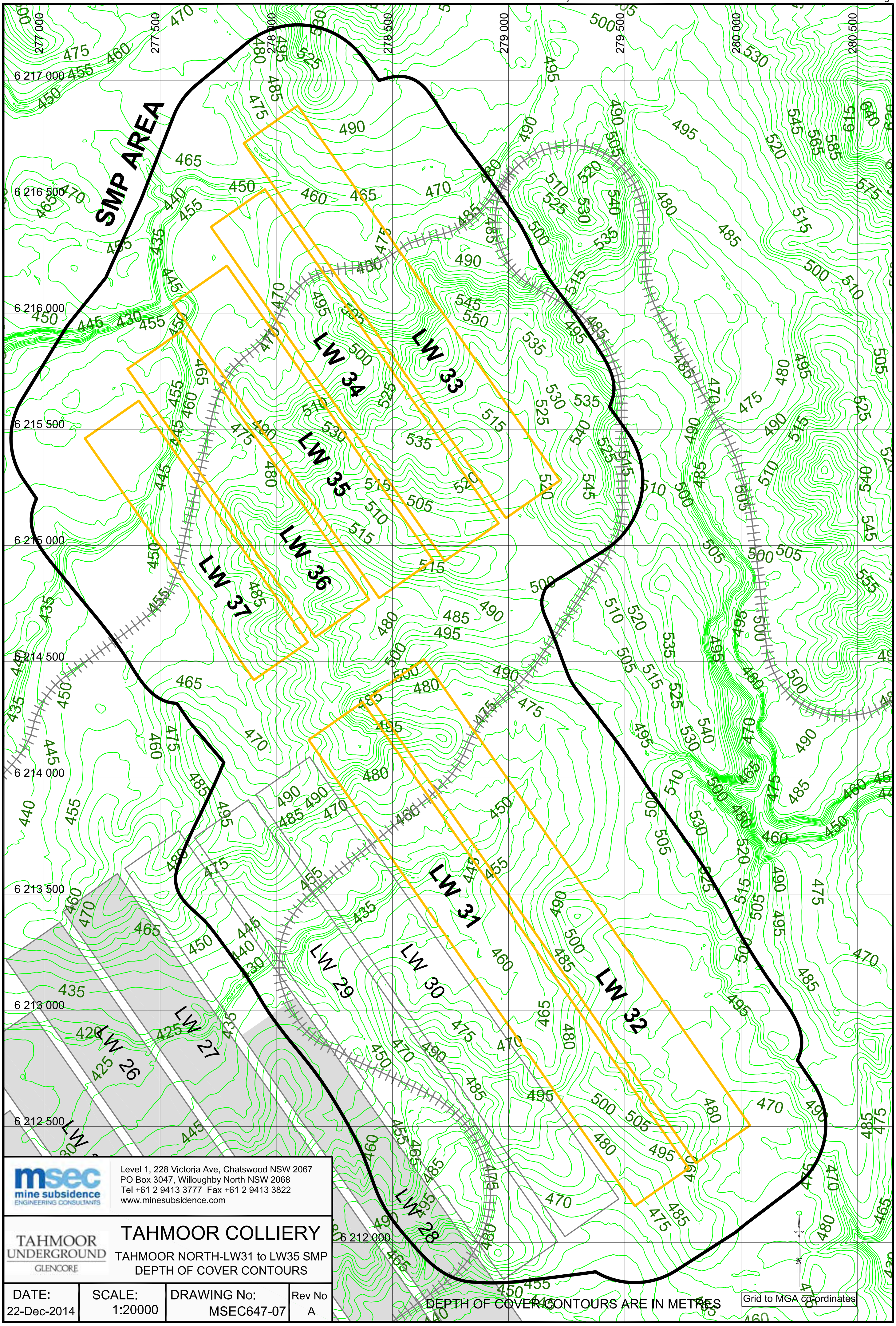

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH-LW31 to LW35 SMP
DEPTH OF COVER CONTOURS

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22-Dec-2014	1:20000	MSEC647-07	A

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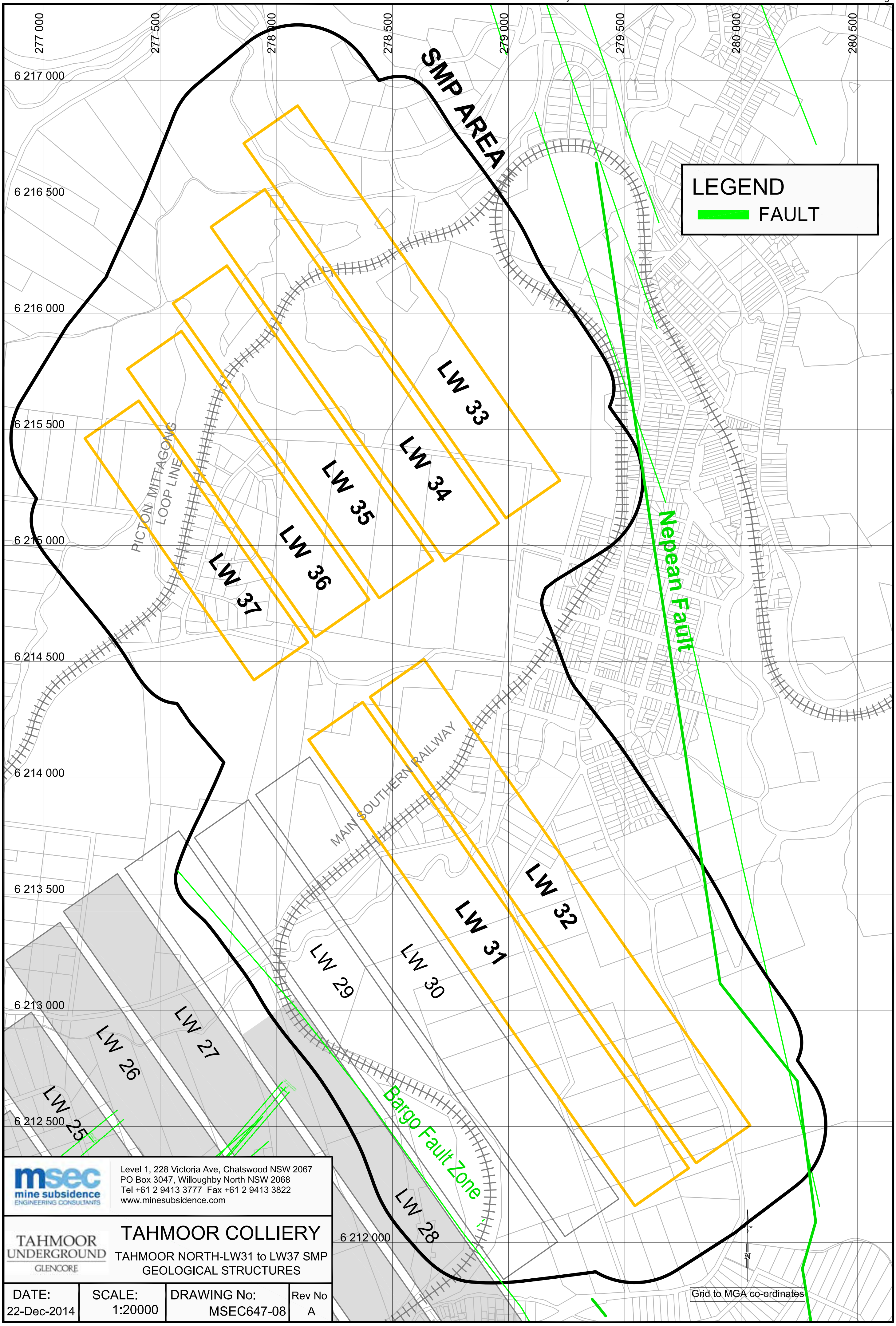

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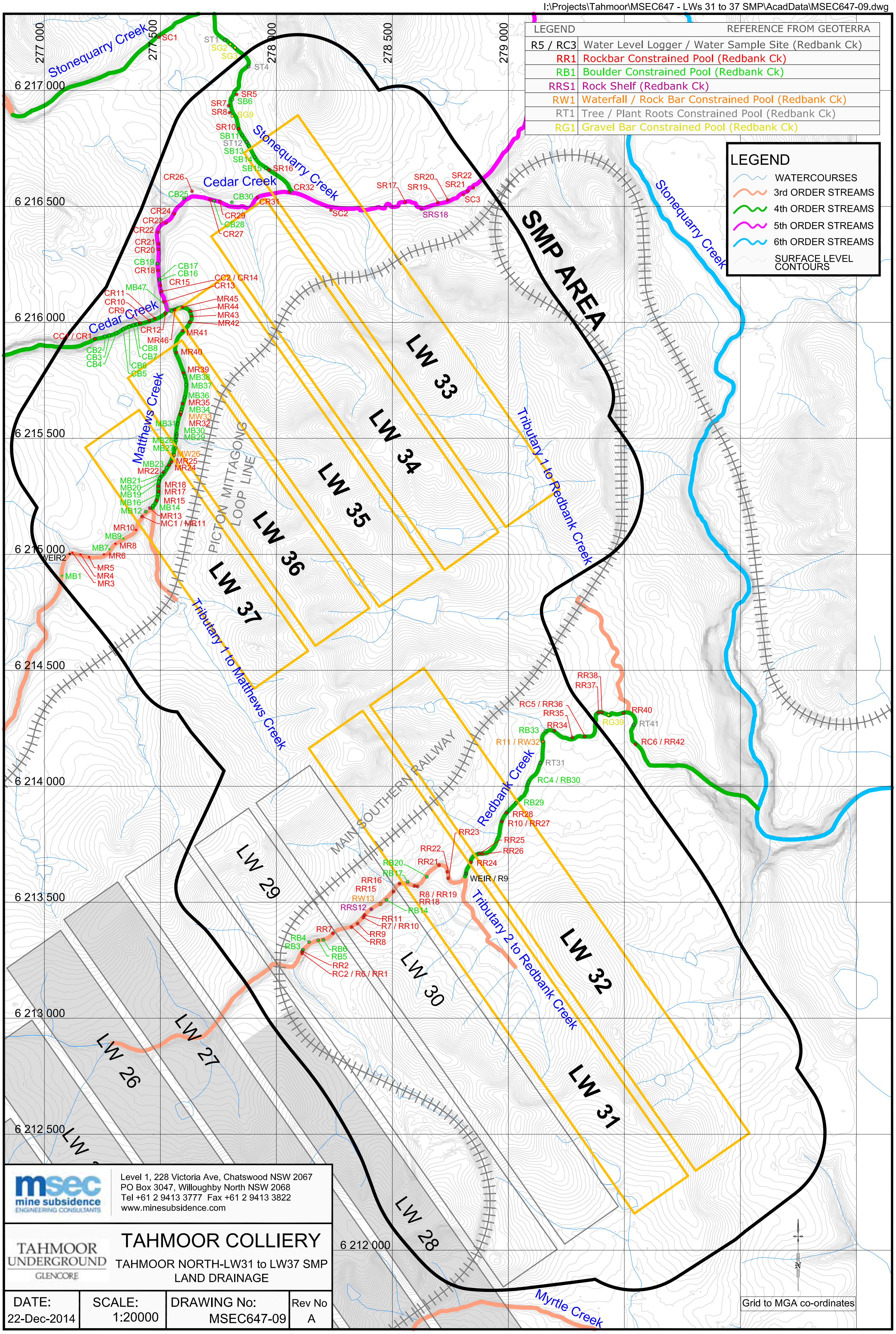
TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY
TAHMOOR NORTH-LW31 to LW37 SMP
GEOLOGICAL STRUCTURES

DATE:	SCALE:	DRAWING No:	Rev No
22-Dec-2014	1:20000	MSEC647-08	A



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LEGEND
REFERENCE FROM GEOTERRA
R5 / RC3 Water Level Logger / Water Sample Site (Redbank Ck)
RR1 Rockbar Constrained Pool (Redbank Ck)
RB1 Boulder Constrained Pool (Redbank Ck)
RRS1 Rock Shelf (Redbank Ck)
RW1 Waterfall / Rock Bar Constrained Pool (Redbank Ck)
RT1 Tree / Plant Roots Constrained Pool (Redbank Ck)
RG1 Gravel Bar Constrained Pool (Redbank Ck)
LEGEND
WATERCOURSES
3rd ORDER STREAMS
4th ORDER STREAMS
5th ORDER STREAMS
6th ORDER STREAMS
SURFACE LEVEL CONTOURS
SMP AREA
LW 33
LW 34
LW 35
LW 36
LW 37
LW 32
LW 31
LW 30
LW 29
LW 28
LW 27
LW 26
Stonequarry Creek
Cedar Creek
Matthews Creek
Redbank Creek
Myrtle Creek
Tributary 1 to Redbank Creek
Tributary 1 to Matthews Creek
Tributary 2 to Redbank Creek
PICTON MITTAGONG LOOP LINE
MAIN SOUTHERN RAILWAY
277 000
277 500
278 000
278 500
279 000
6 217 000
6 216 500
6 216 000
6 215 500
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6 212 000
Grid to MGA co-ordinates
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TAHMOOR NORTH-LW31 to LW37 SMP
LAND DRAINAGE
DATE: 22-Dec-2014
SCALE: 1:20000
DRAWING No: MSEC647-09
Rev No A

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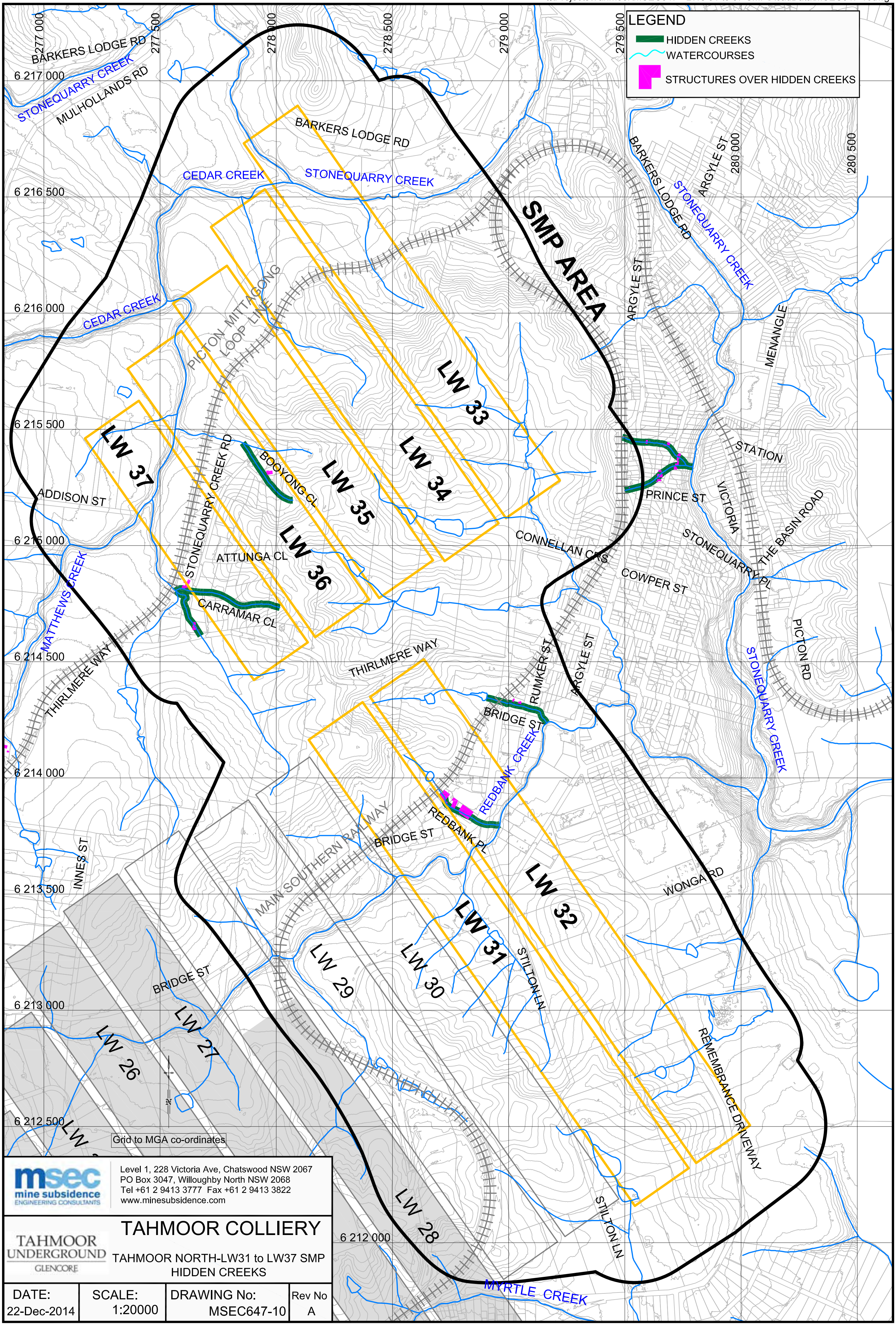

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH-LW31 to LW37 SMP
HIDDEN CREEKS

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22-Dec-2014	1:20000	MSEC647-10	A

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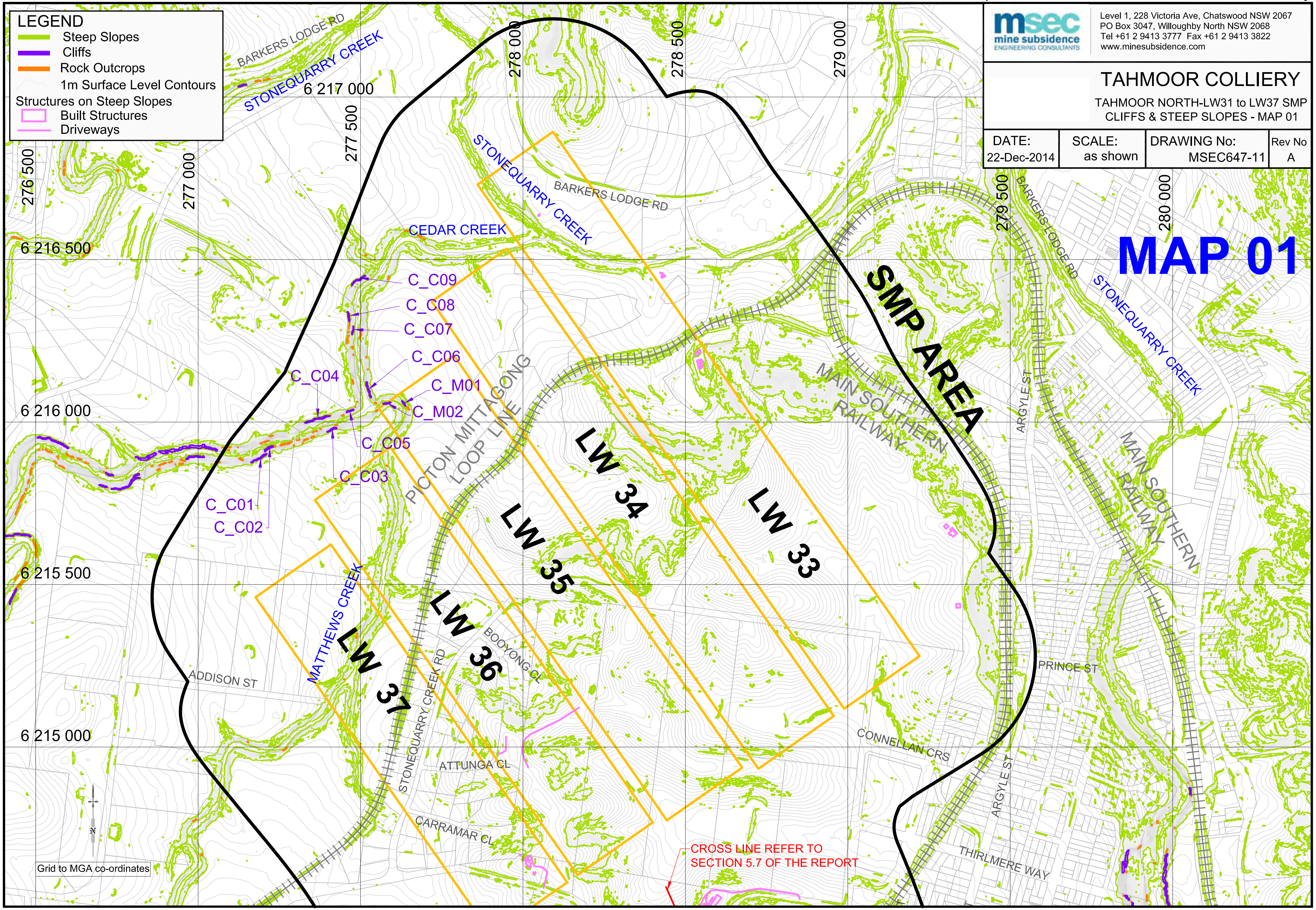

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TAHMOOR COLLIERY

TAHMOOR NORTH-LW31 to LW37 SMP
CLIFFS & STEEP SLOPES - MAP 01

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22-Dec-2014	as shown	MSEC647-11	A

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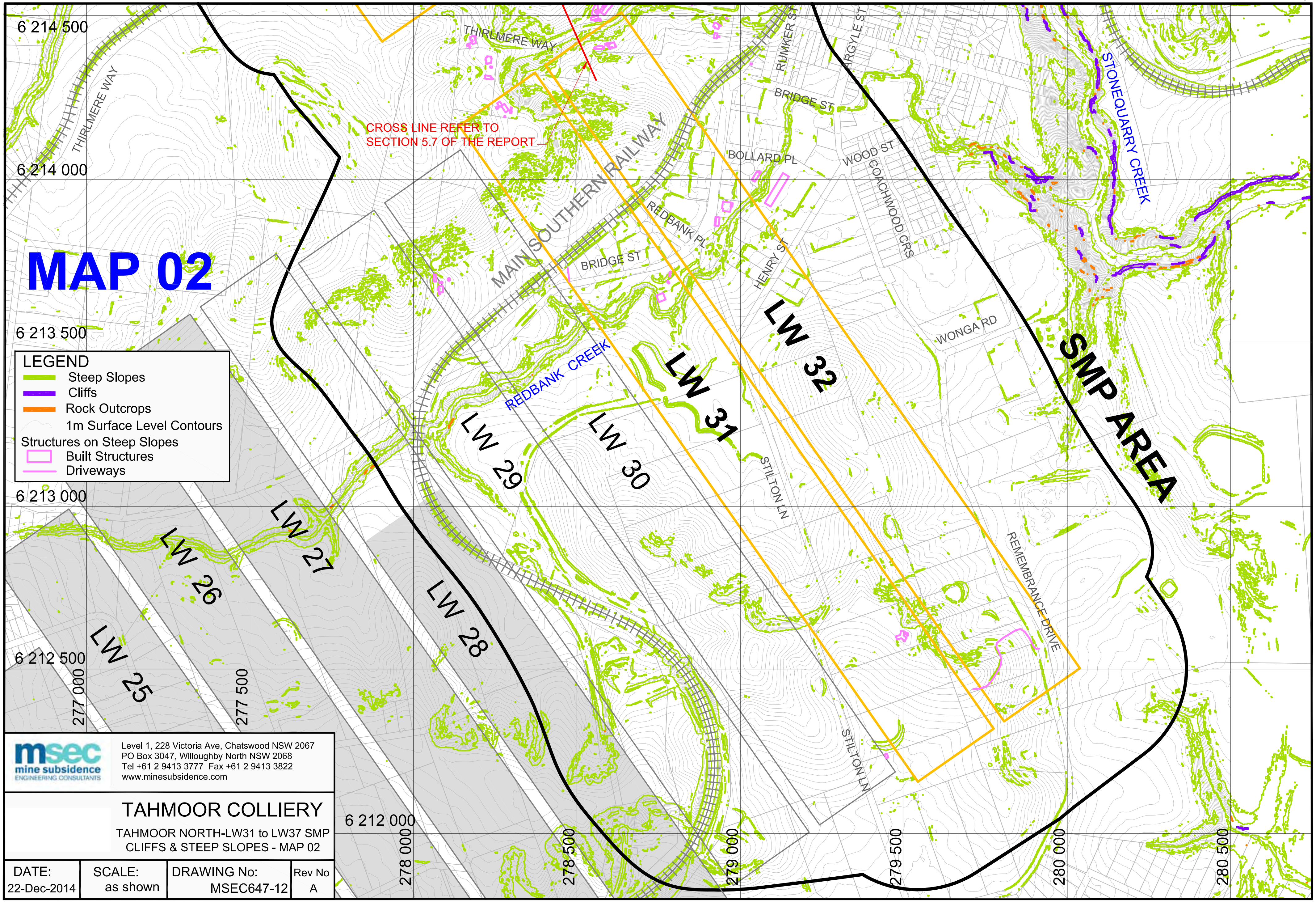

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TAHMOOR COLLIERY

TAHMOOR NORTH-LW31 to LW37 SMP
CLIFFS & STEEP SLOPES - MAP 02

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22-Dec-2014	as shown	MSEC647-12	A

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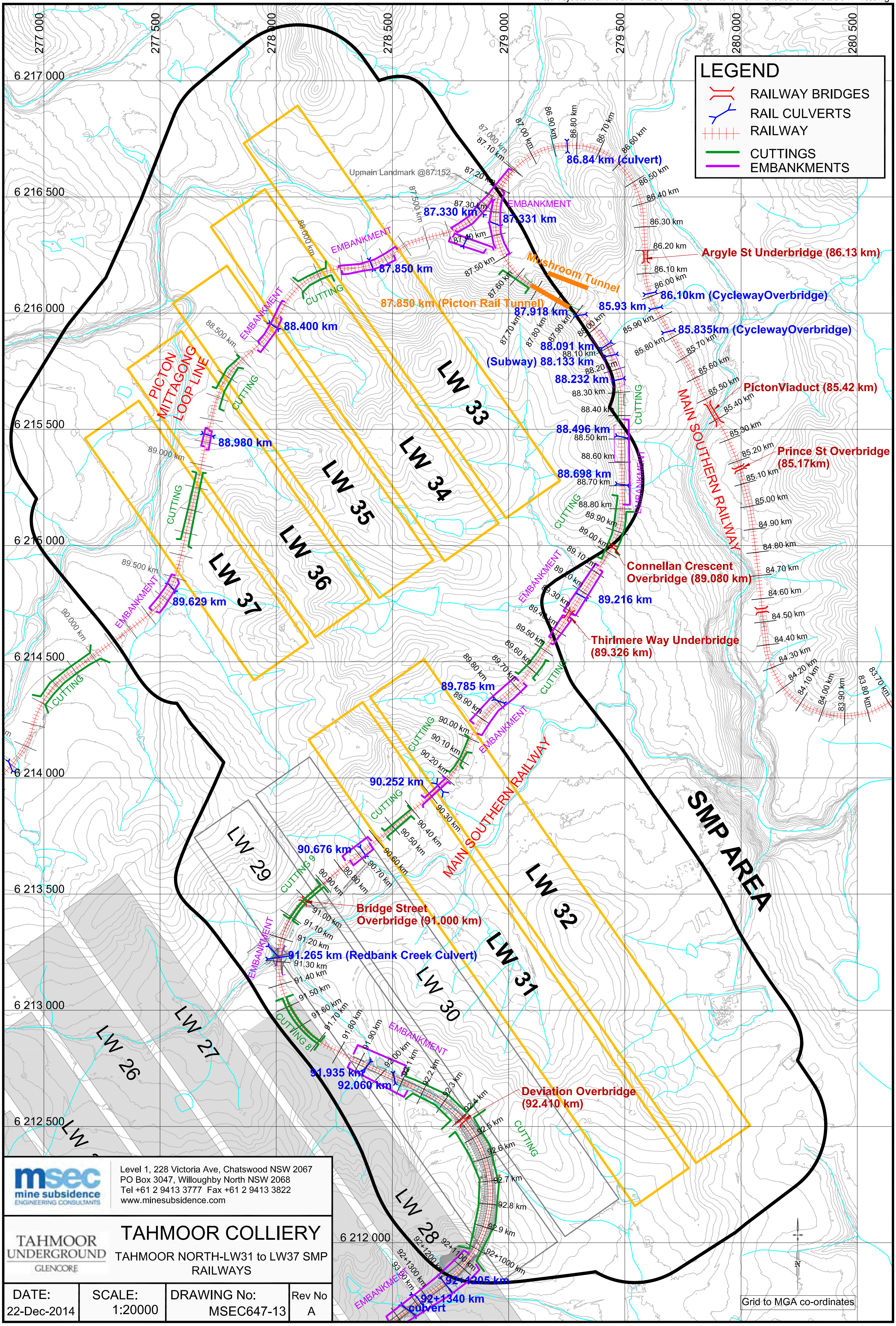

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH-LW31 to LW37 SMP RAILWAYS

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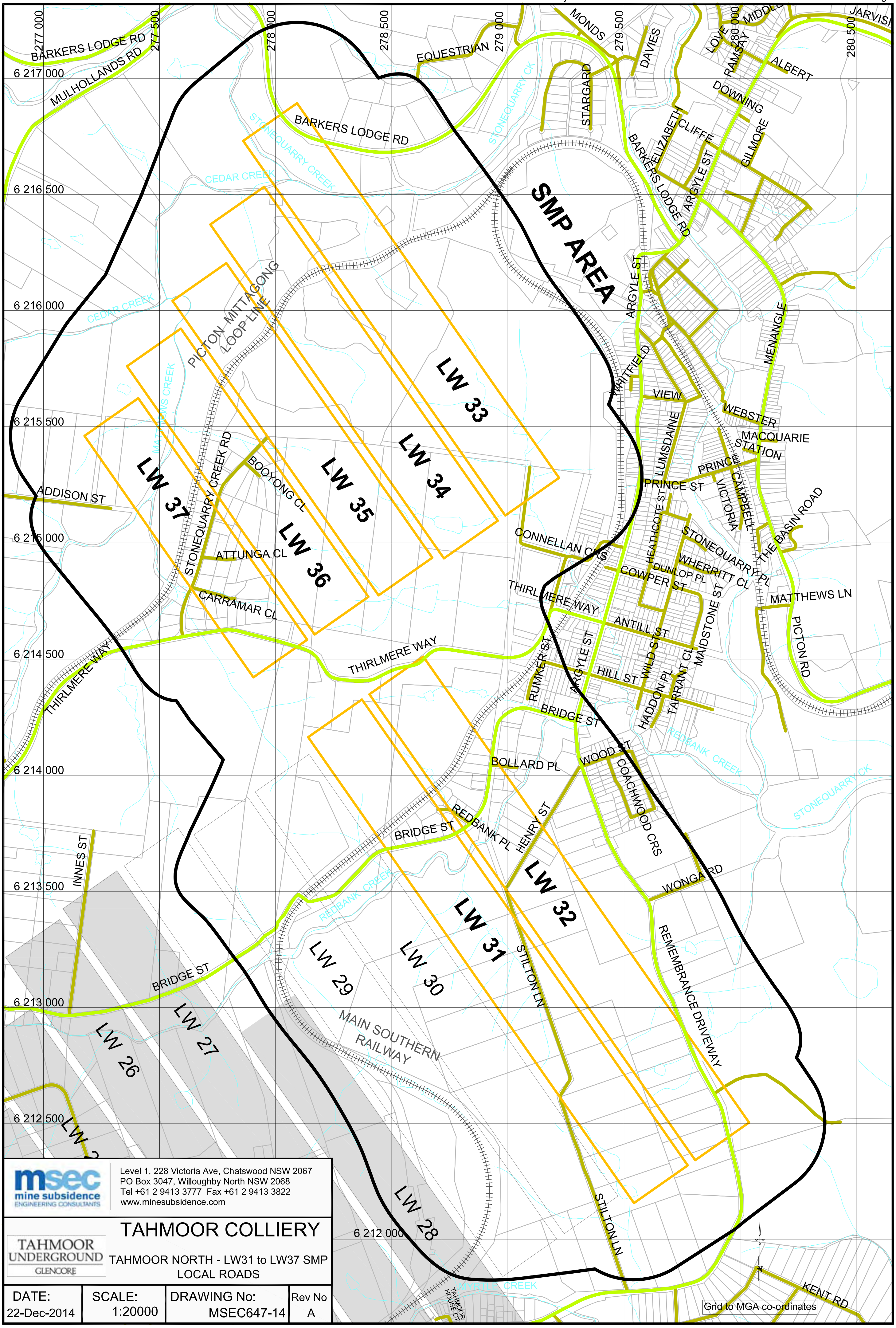

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TAHMOOR UNDERGROUND
GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH - LW31 to LW37 SMP
LOCAL ROADS

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22-Dec-2014	1:20000	MSEC647-14	A

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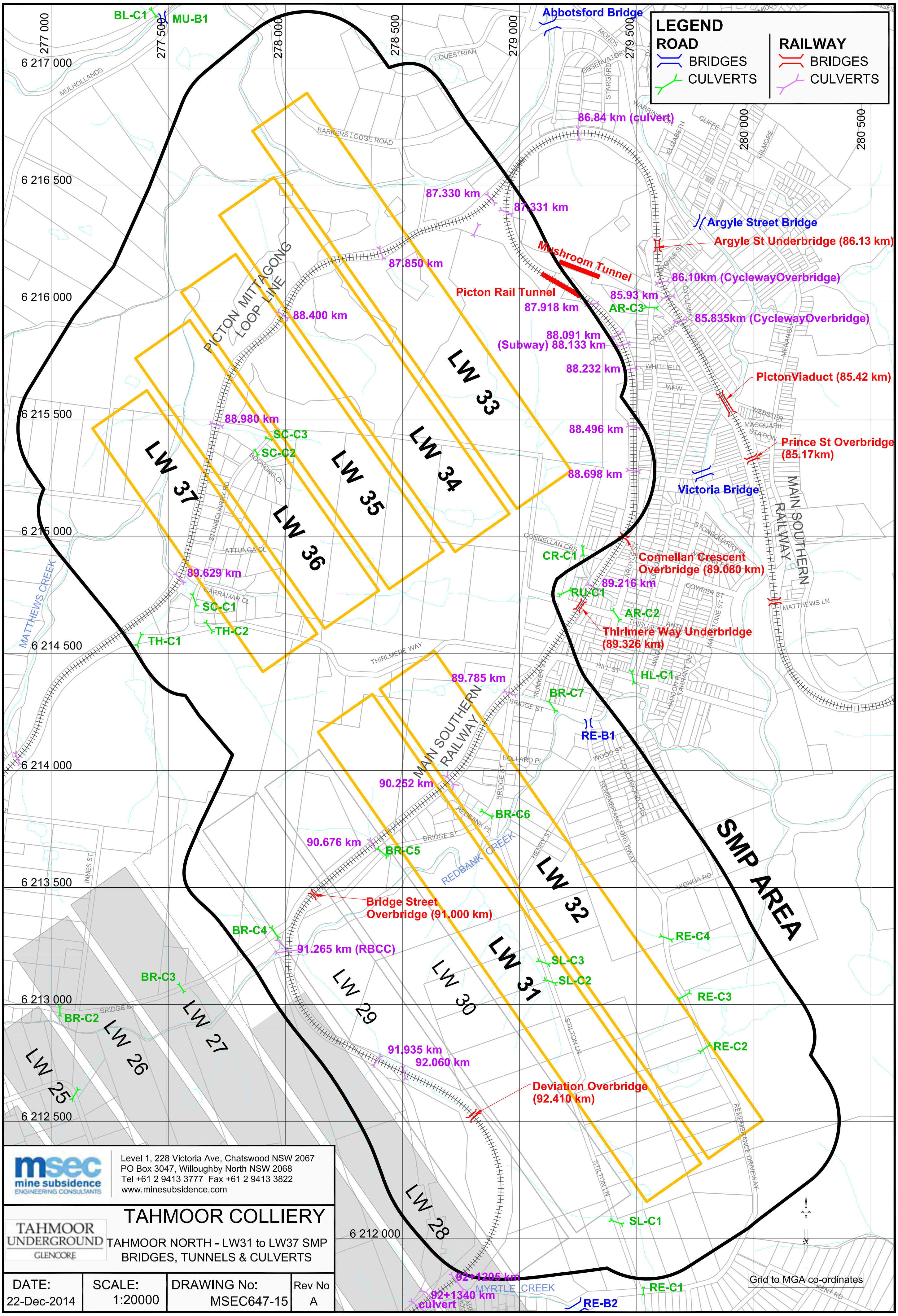

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH - LW31 to LW37 SMP
BRIDGES, TUNNELS & CULVERTS

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22-Dec-2014	1:20000	MSEC647-15	A

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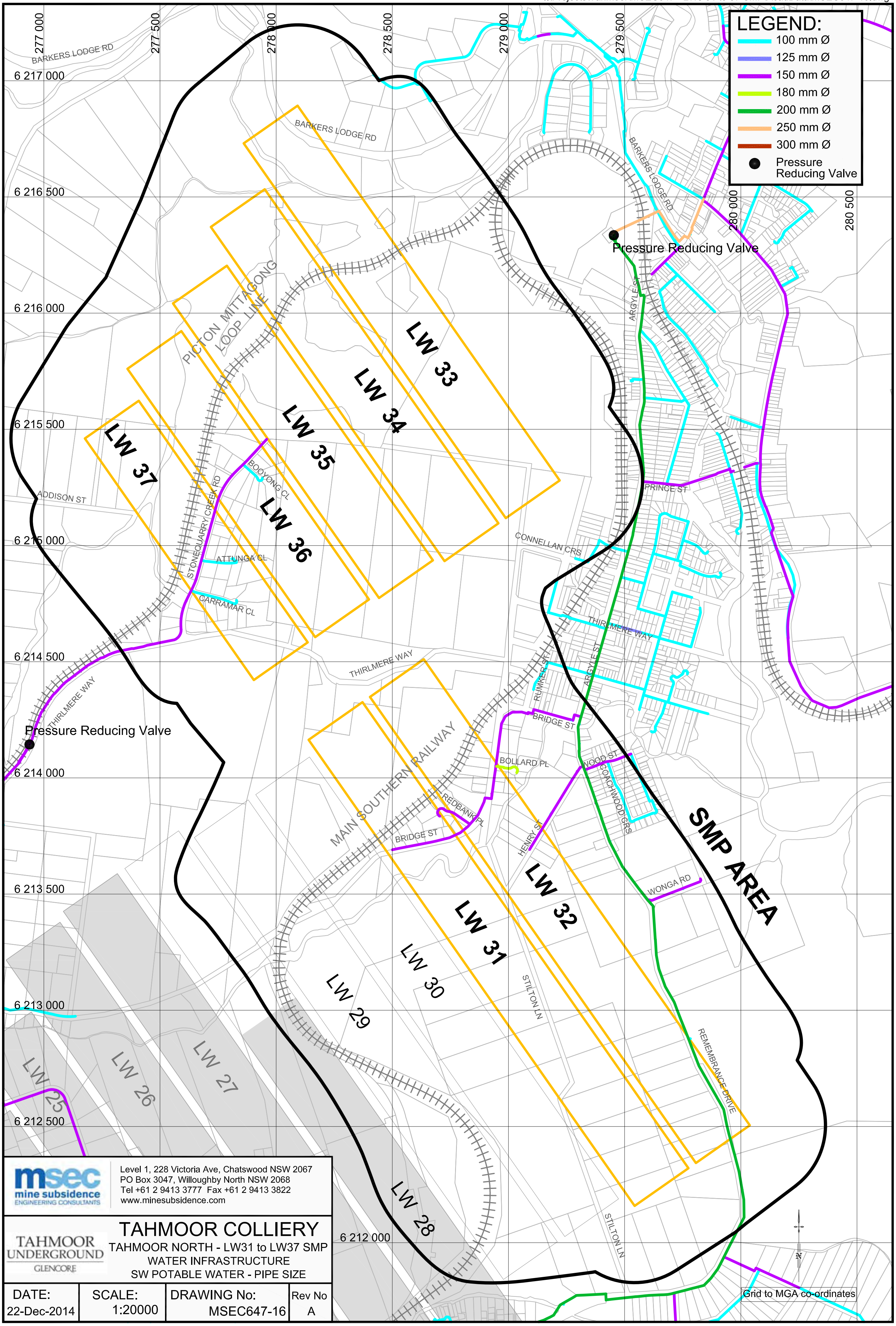

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH - LW31 to LW37 SMP
WATER INFRASTRUCTURE
SW POTABLE WATER - PIPE SIZE

DATE:	SCALE:	DRAWING No:	Rev No
22-Dec-2014	1:20000	MSEC647-16	A

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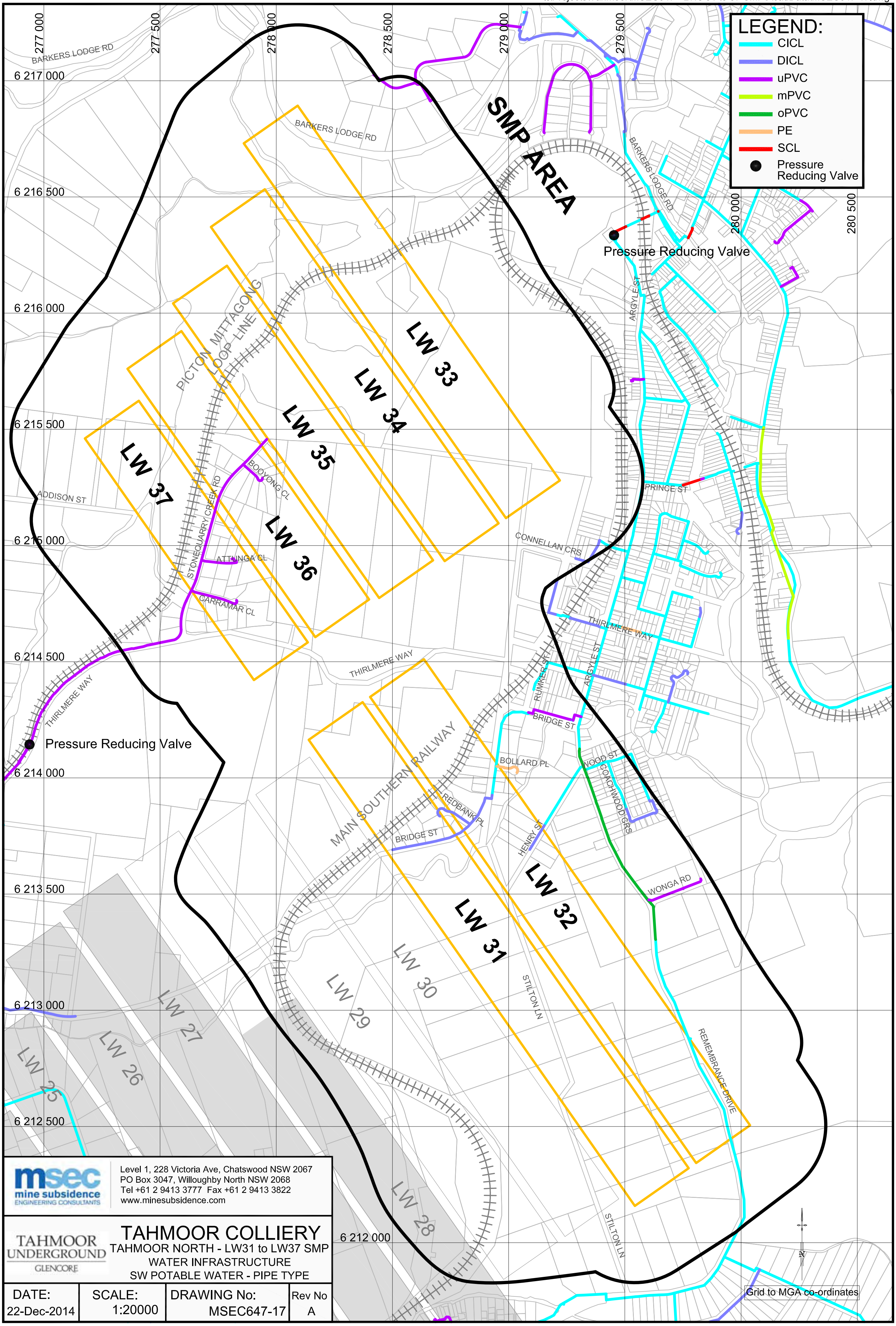

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH - LW31 to LW37 SMP
WATER INFRASTRUCTURE
SW POTABLE WATER - PIPE TYPE

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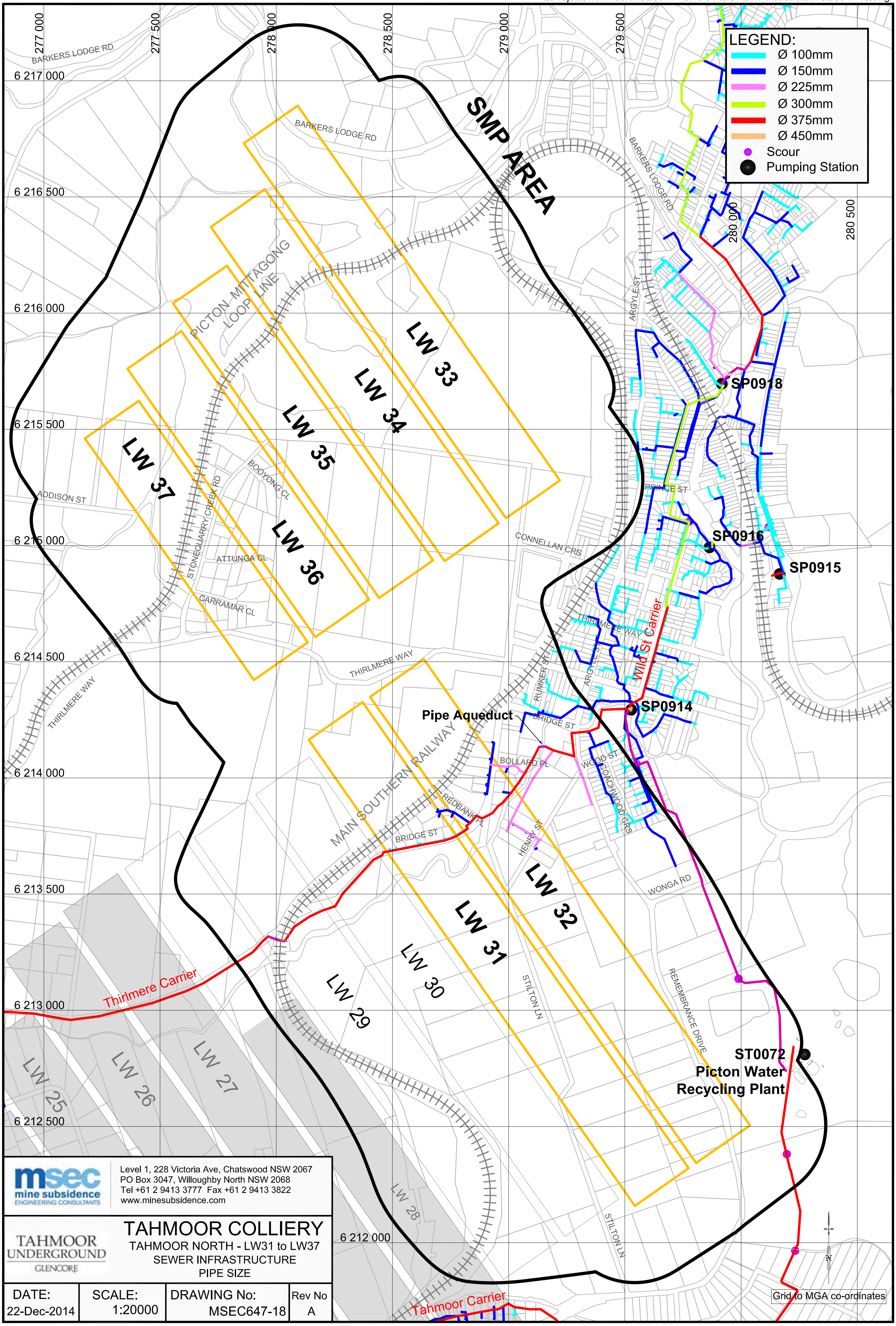

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH - LW31 to LW37
SEWER INFRASTRUCTURE
PIPE SIZE

DATE:	SCALE:	DRAWING No:	Rev No
22-Dec-2014	1:20000	MSEC647-18	A

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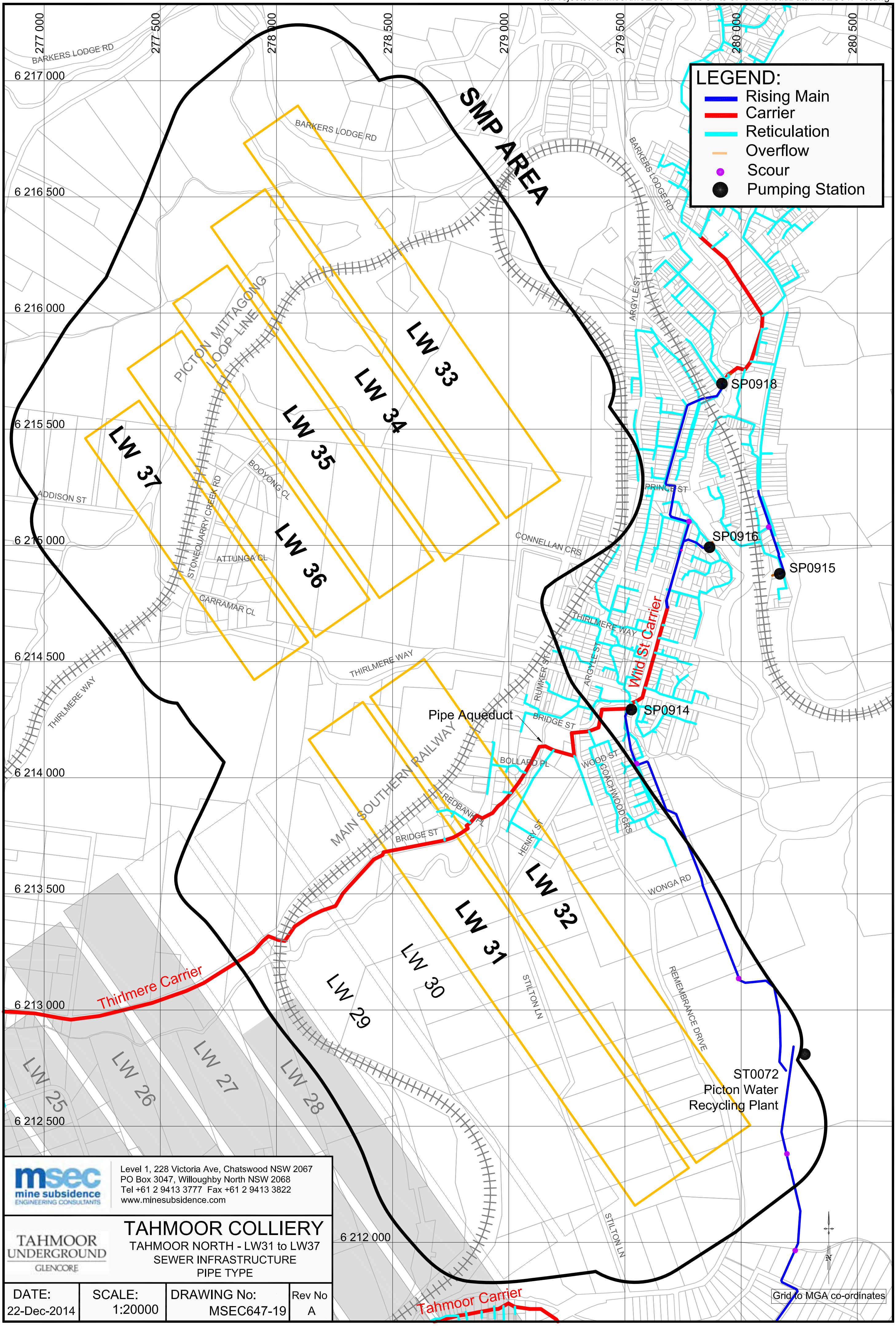

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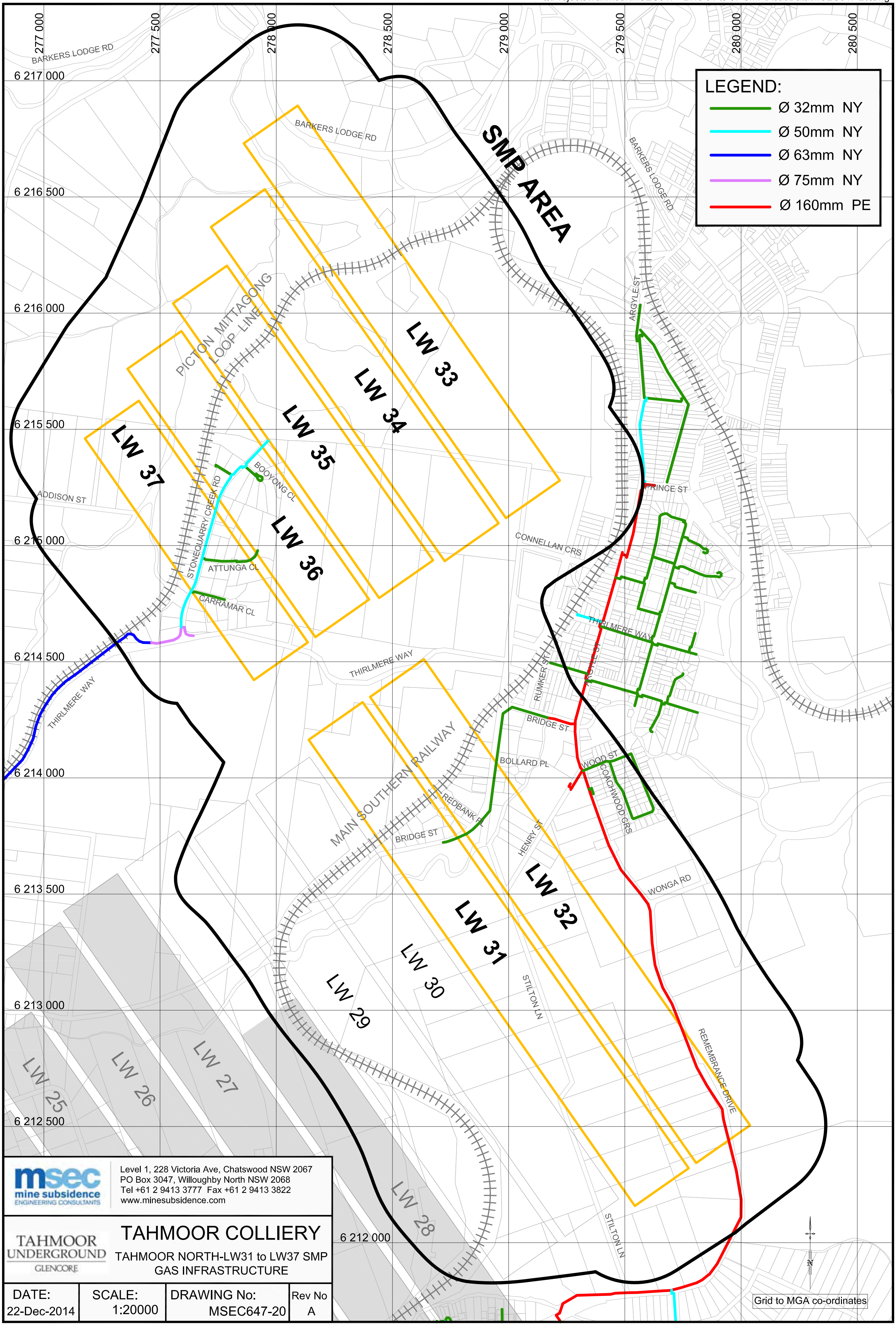

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TAHMOOR UNDERGROUND GLENCORE	TAHMOOR COLLIERY TAHMOOR NORTH-LW31 to LW37 SMP GAS INFRASTRUCTURE		
DATE: 22-Dec-2014	SCALE: 1:20000	DRAWING No: MSEC647-20	Rev No A

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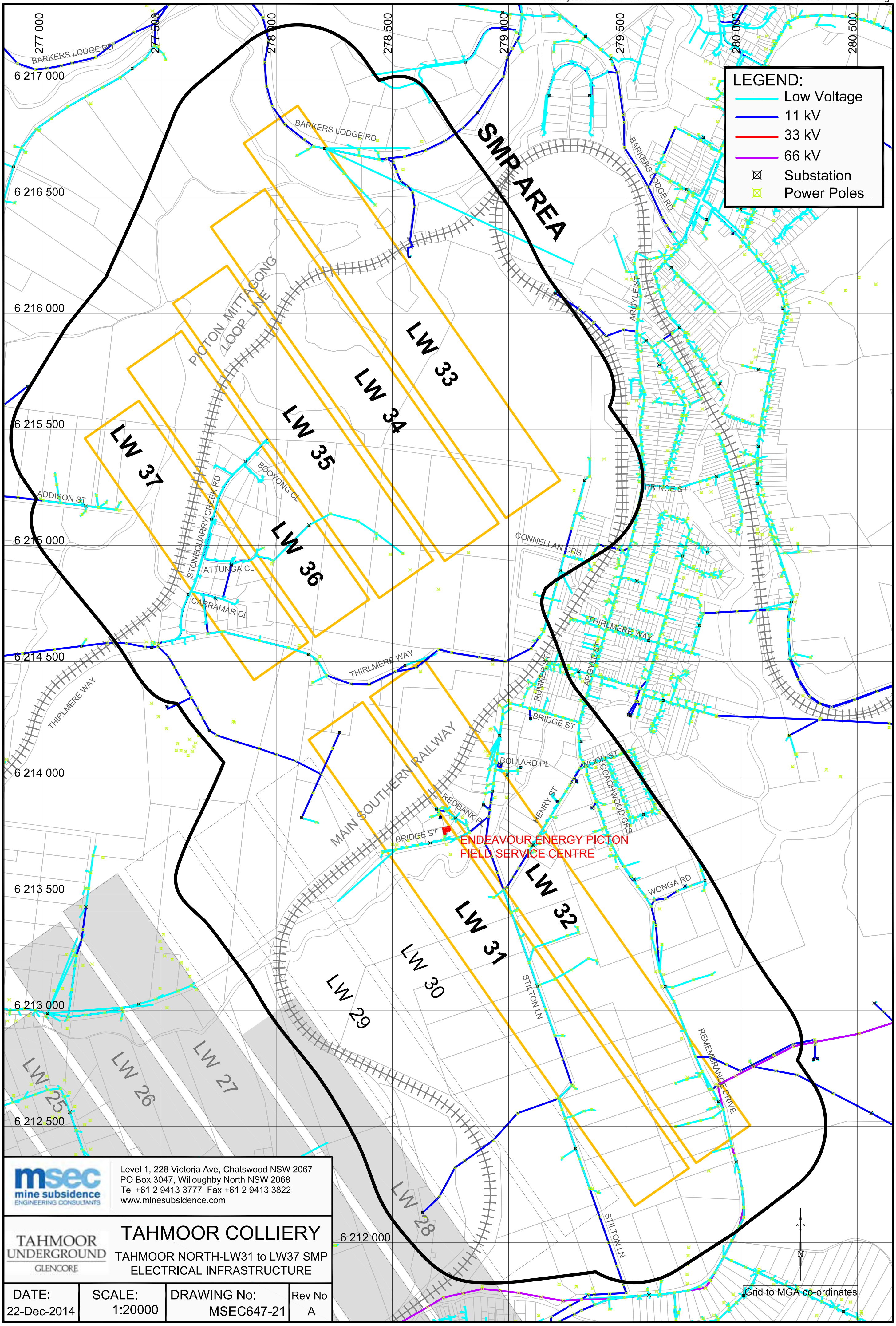

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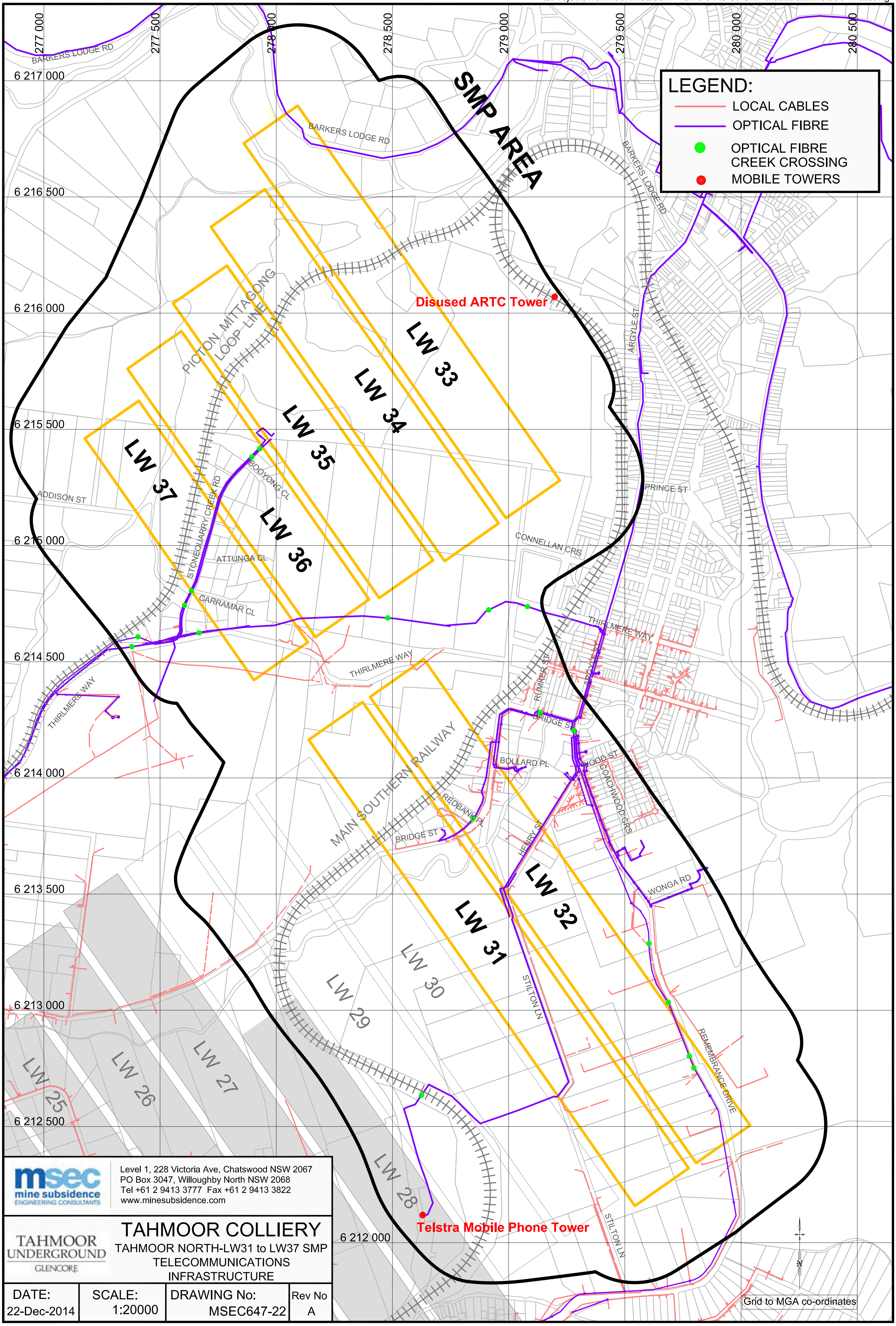

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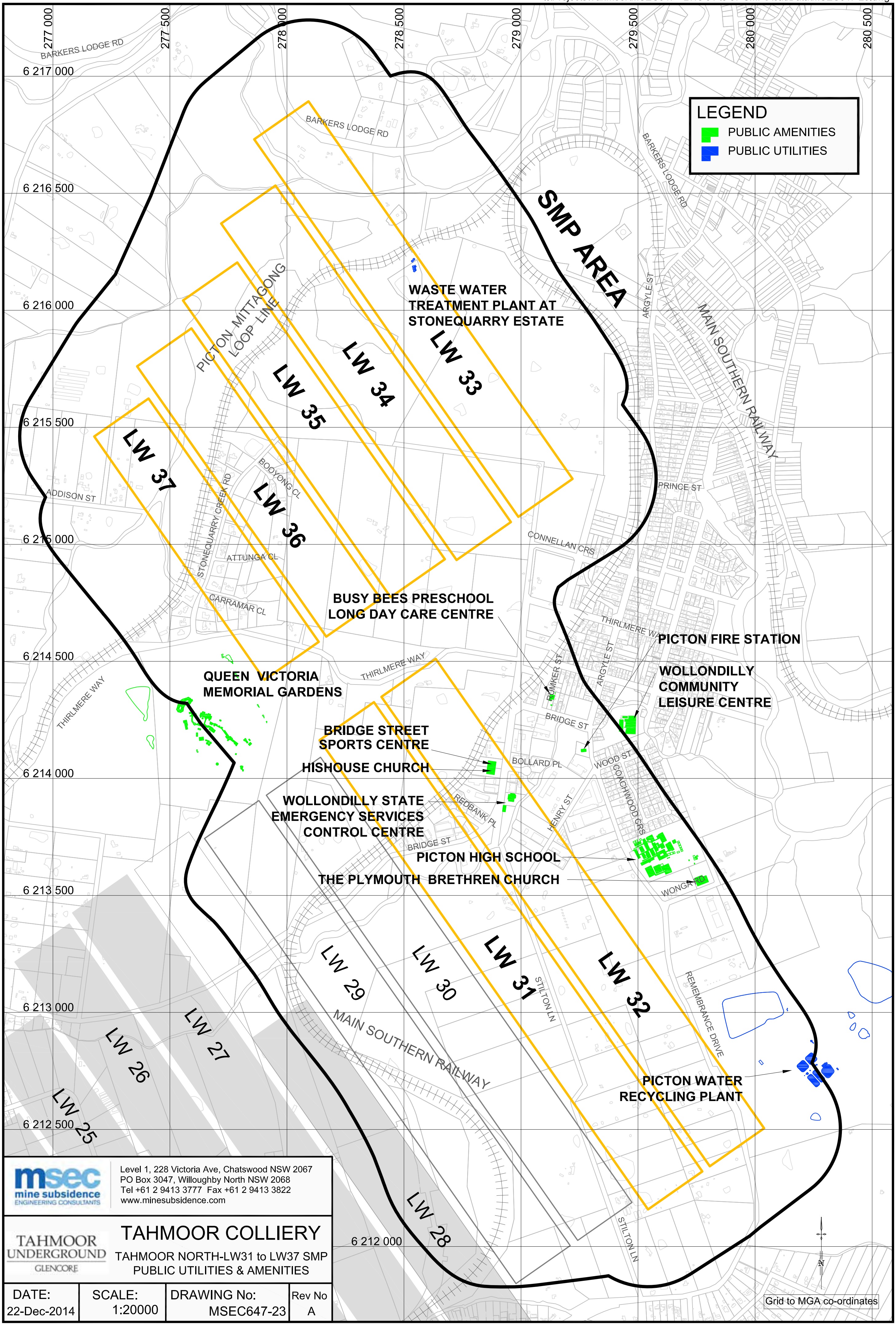

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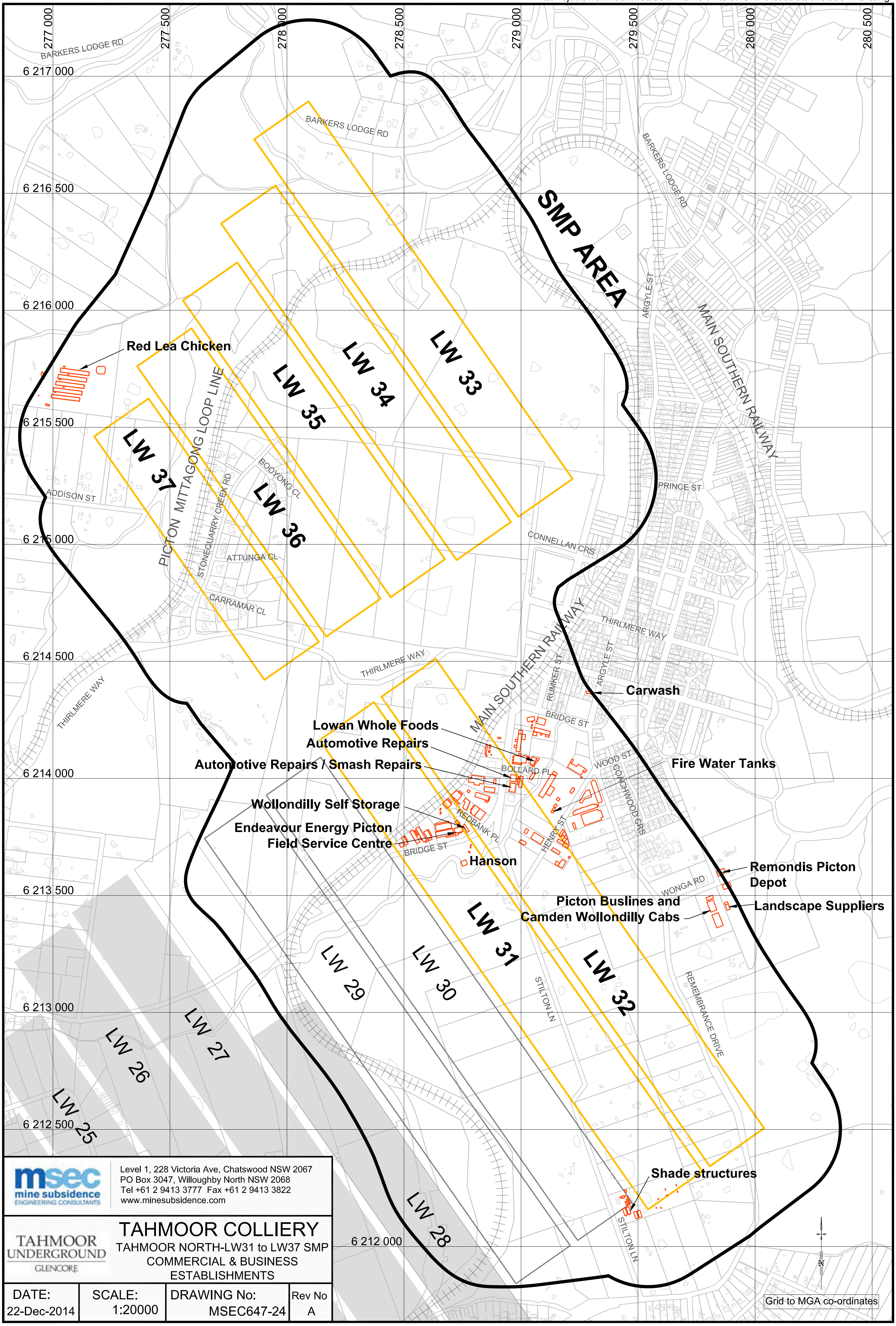

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH-LW31 to LW37 SMP
COMMERCIAL & BUSINESS ESTABLISHMENTS

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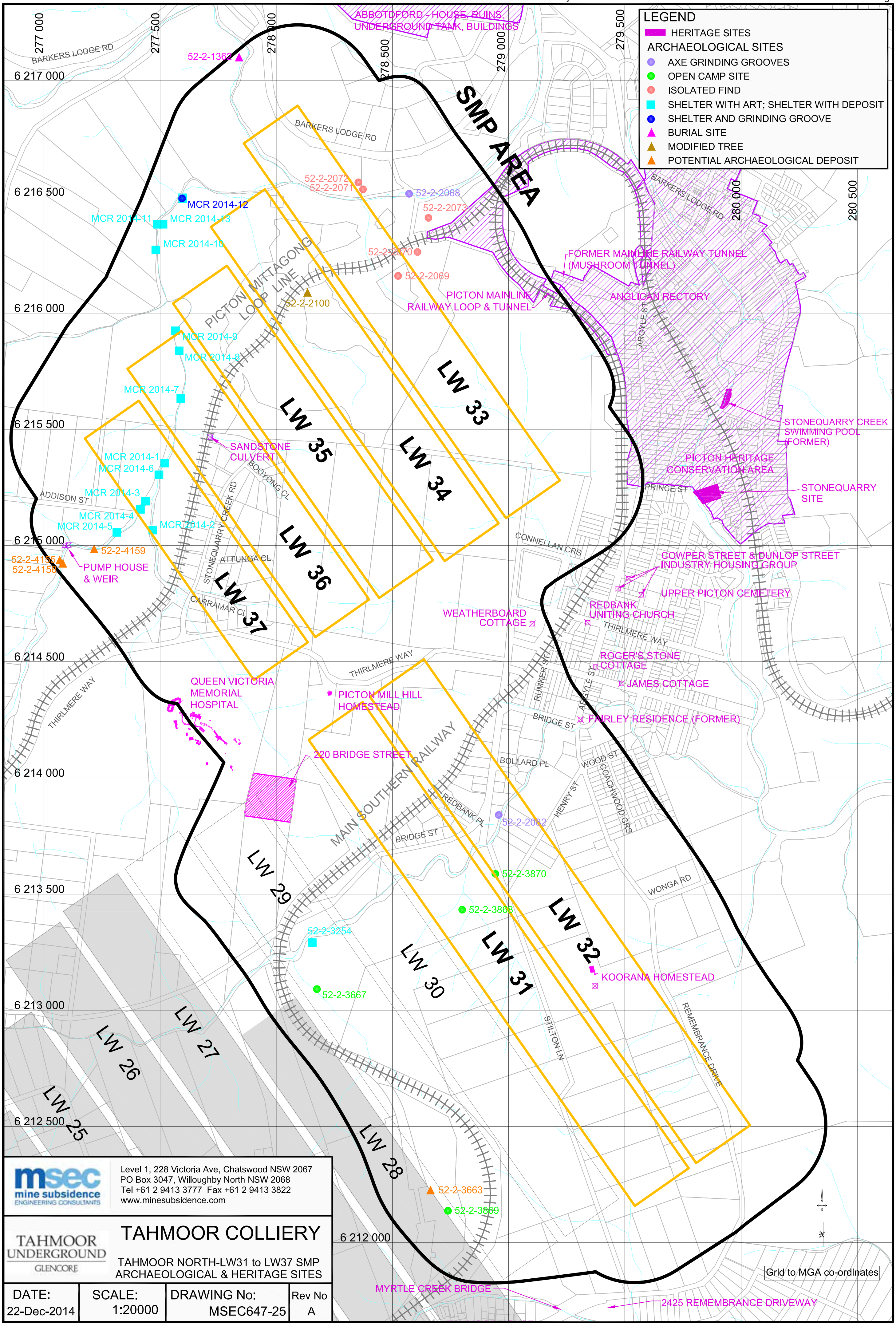

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH-LW31 to LW37 SMP
ARCHAEOLOGICAL & HERITAGE SITES

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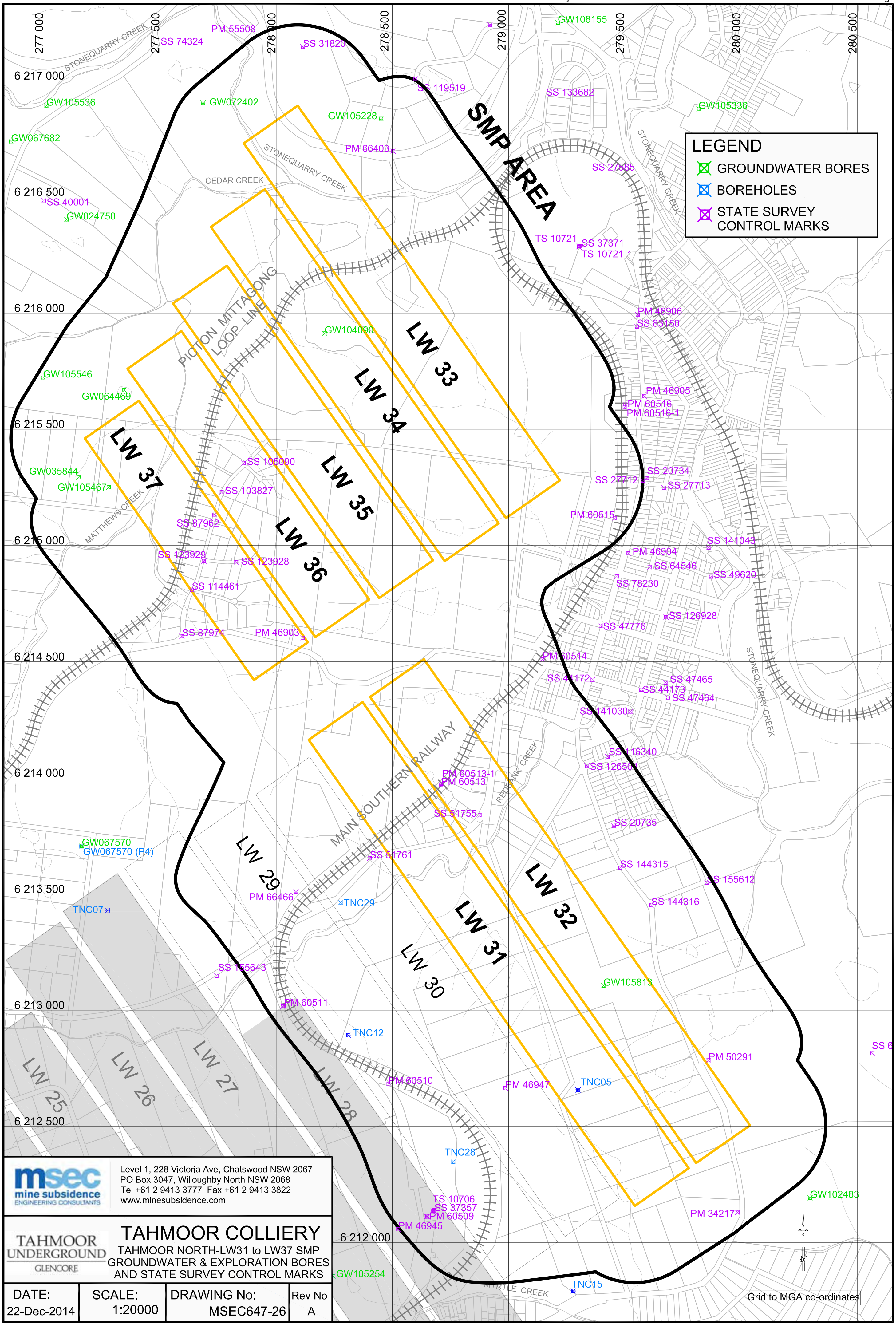

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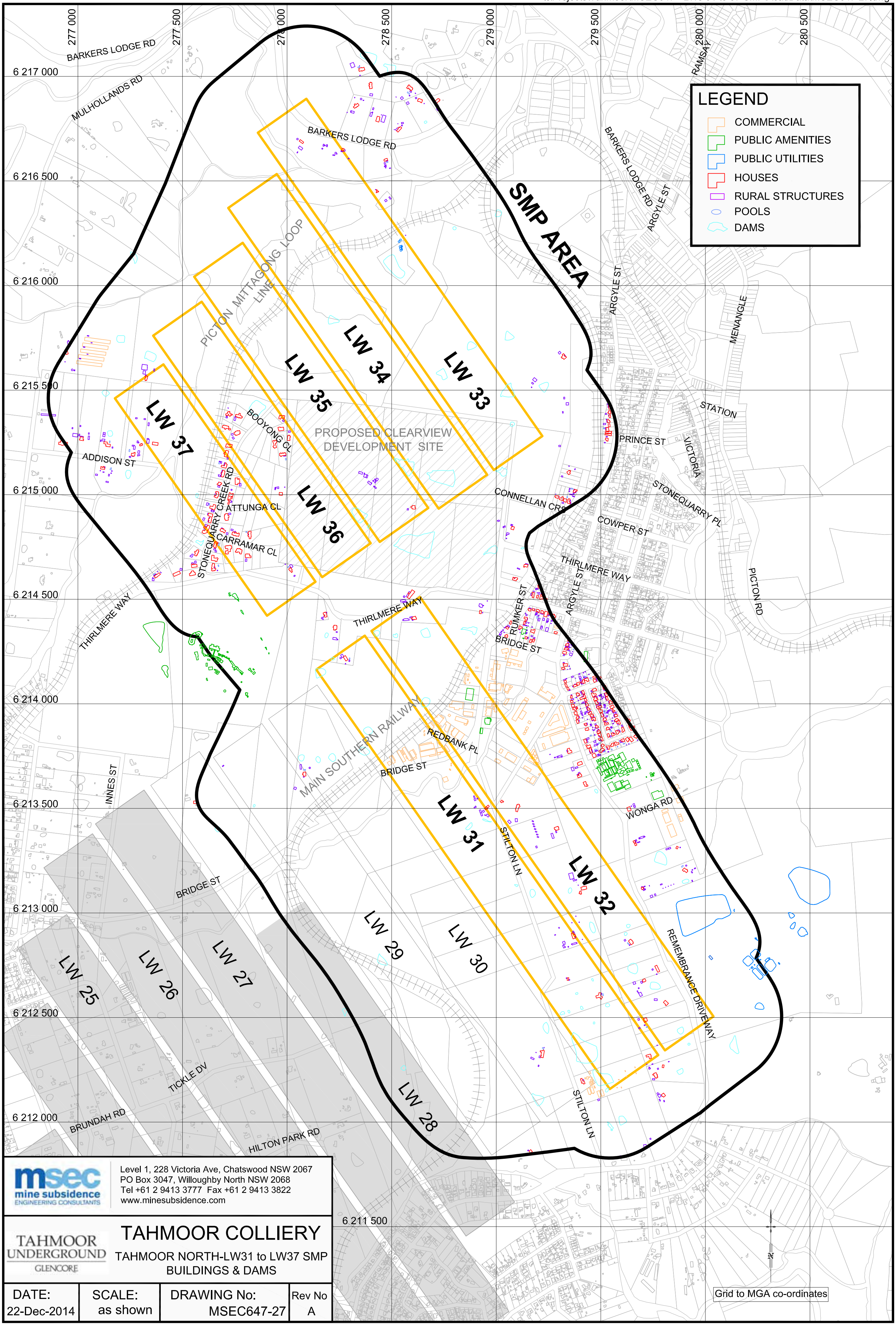

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH-LW31 to LW37 SMP
BUILDINGS & DAMS

DATE:	SCALE:	DRAWING No:	Rev No
22-Dec-2014	as shown	MSEC647-27	A

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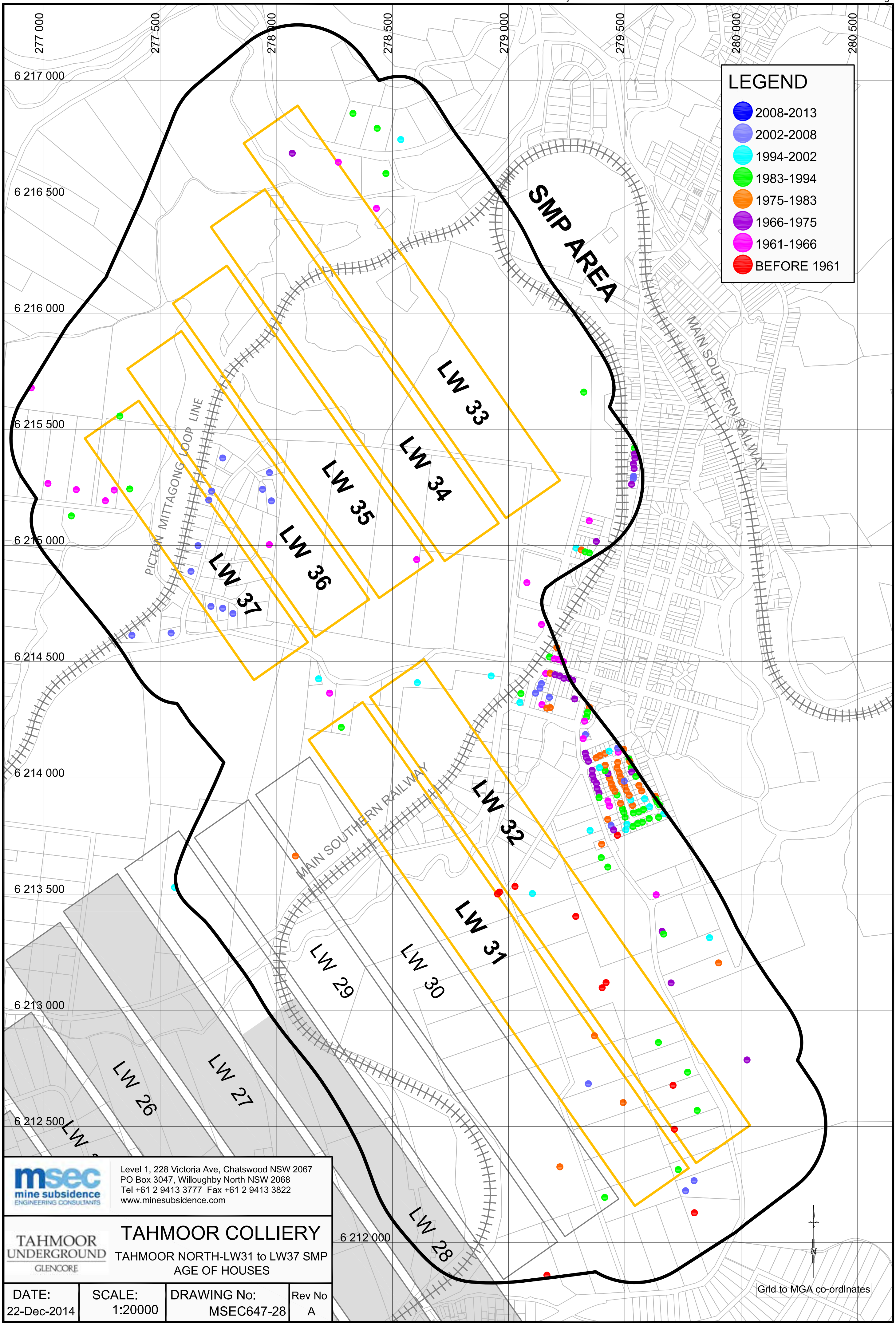

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY
TAHMOOR NORTH-LW31 to LW37 SMP
AGE OF HOUSES

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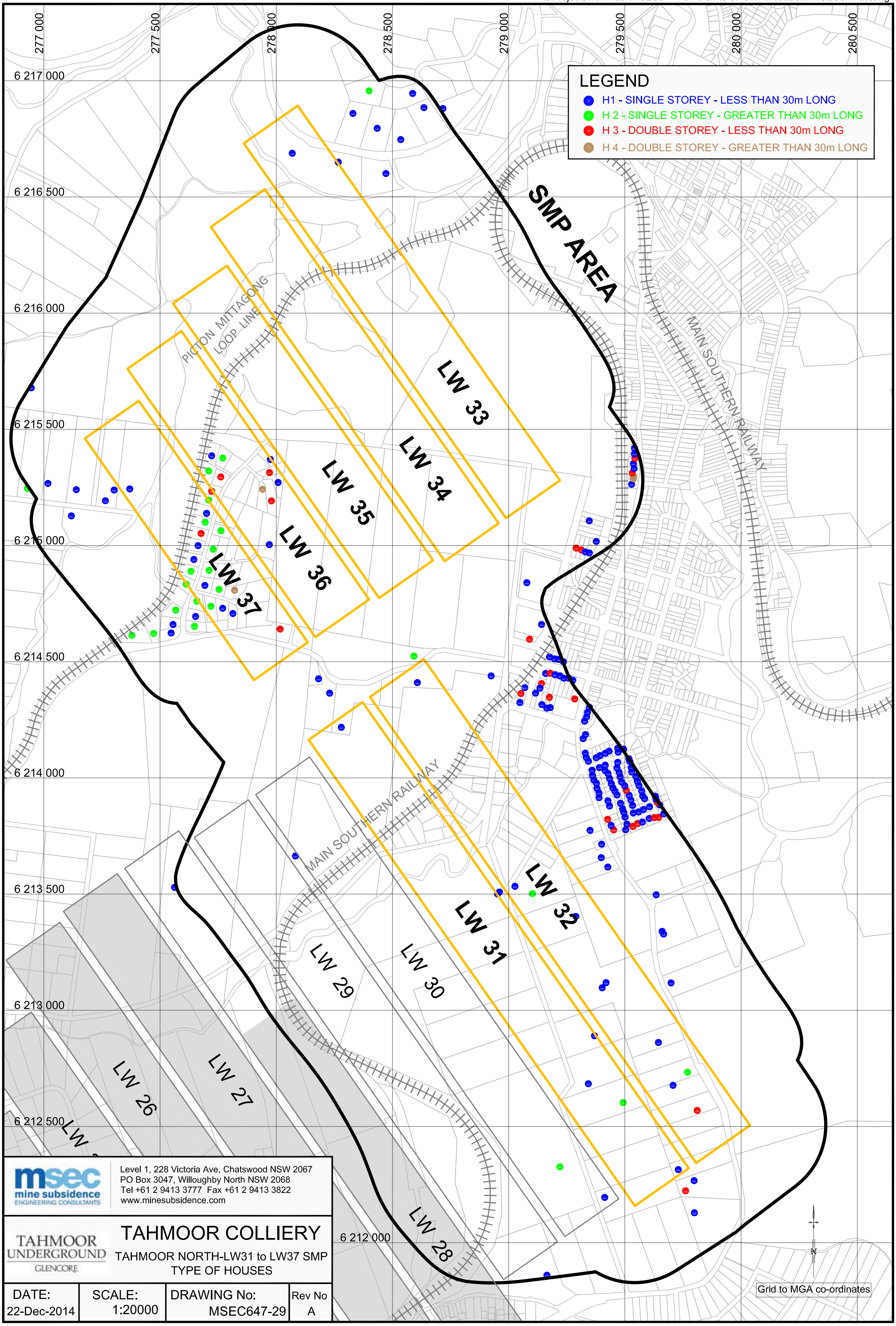

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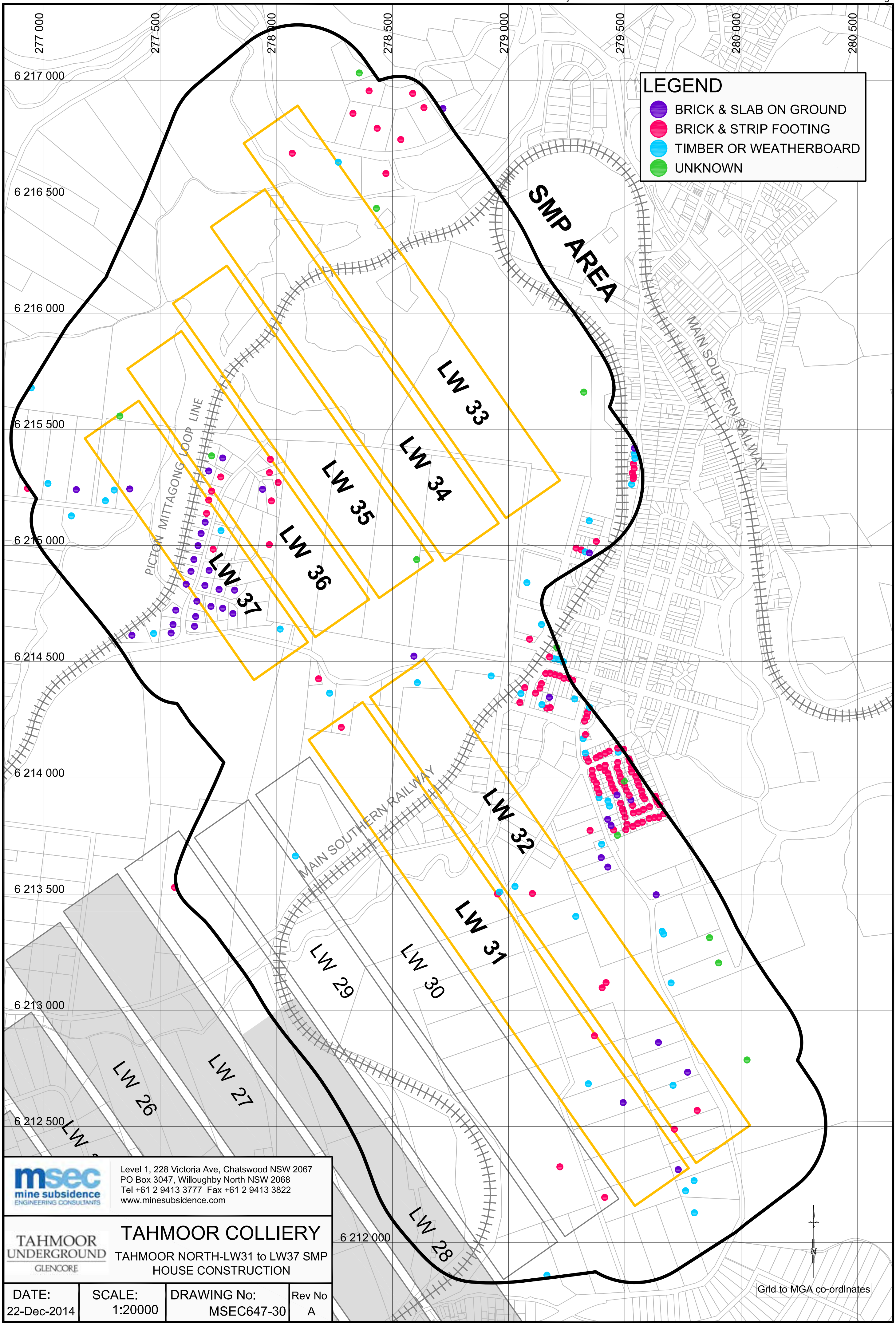

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH-LW31 to LW37 SMP
HOUSE CONSTRUCTION

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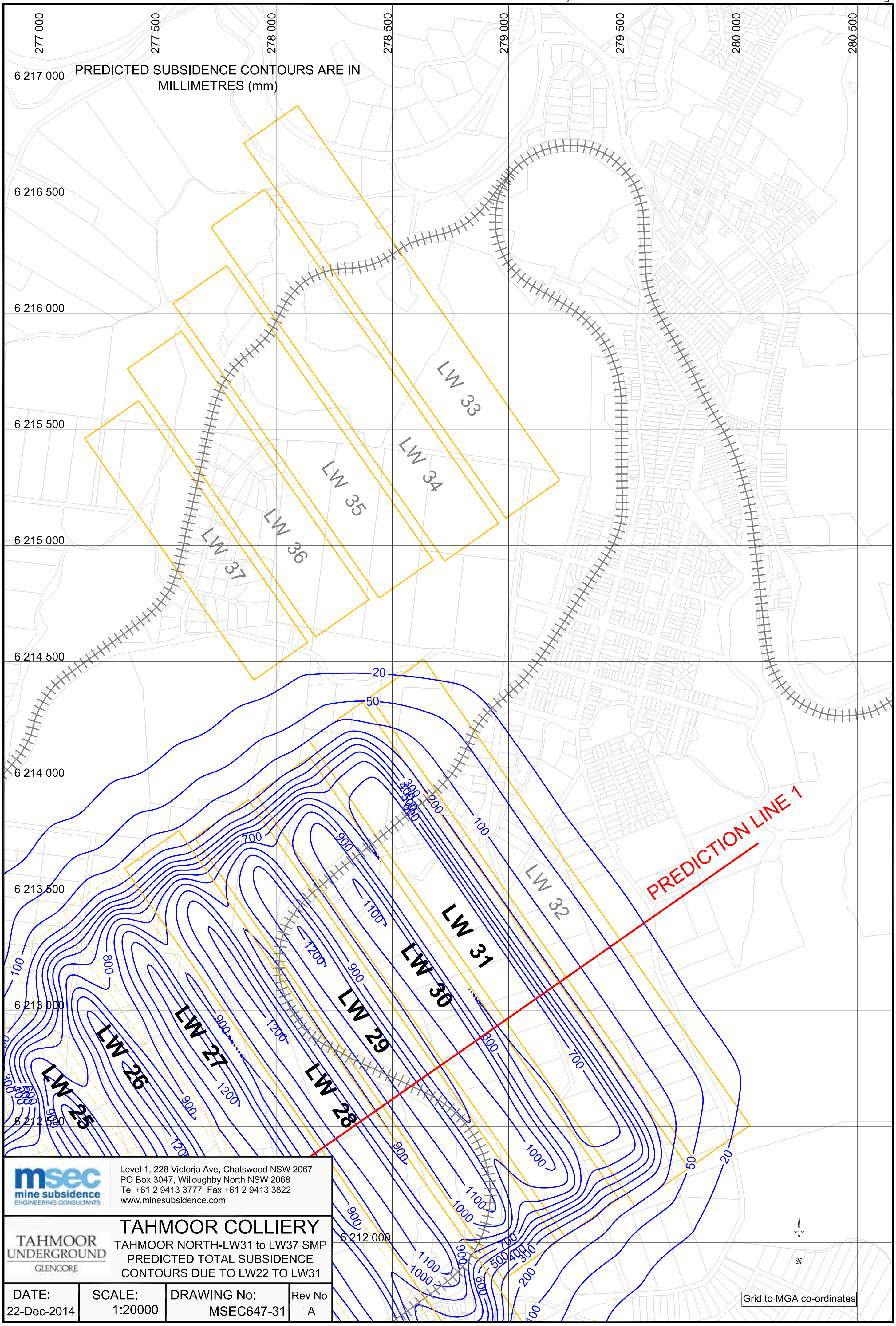

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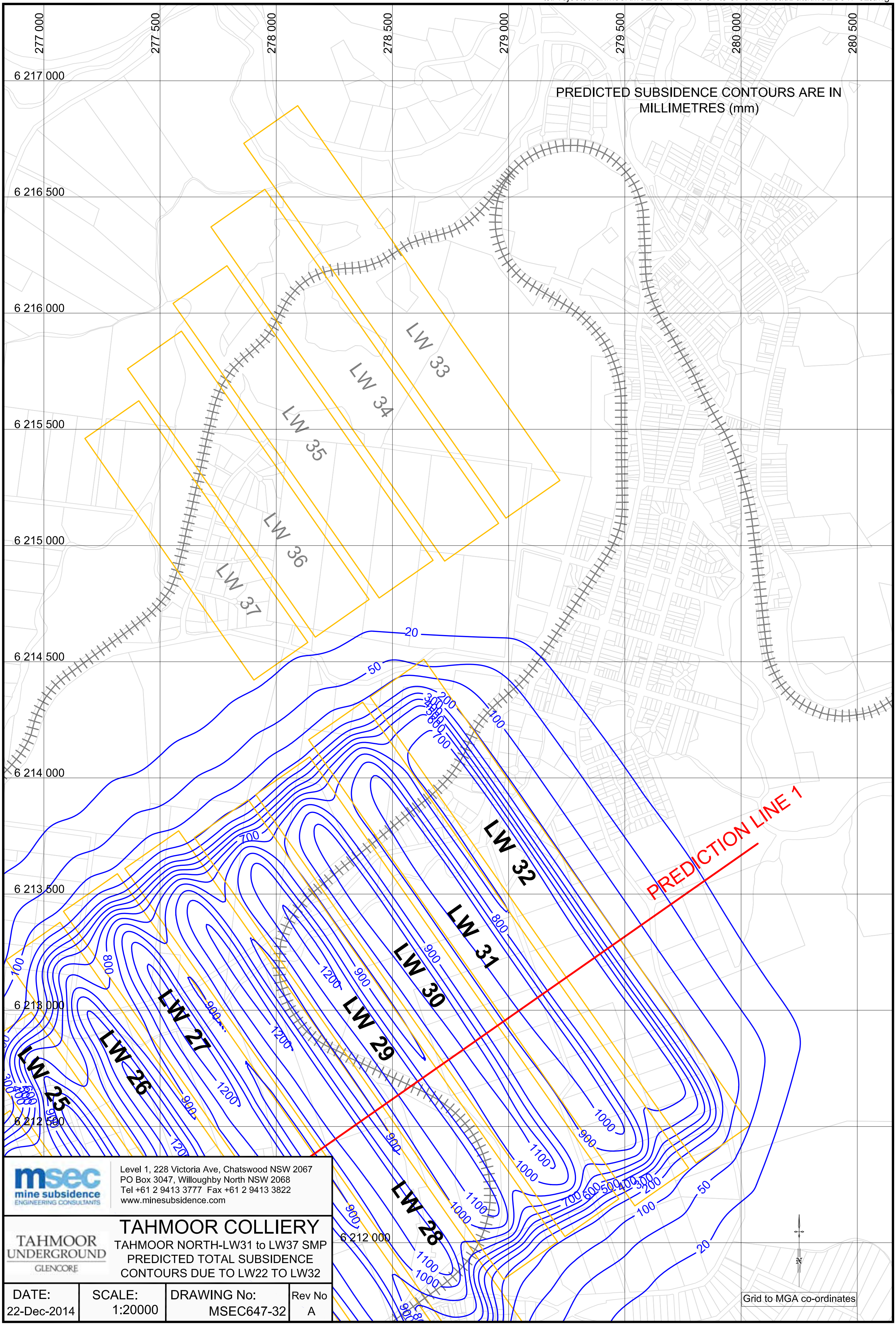

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH-LW31 to LW37 SMP
PREDICTED TOTAL SUBSIDENCE CONTOURS DUE TO LW22 TO LW32

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22-Dec-2014	1:20000	MSEC647-32	A

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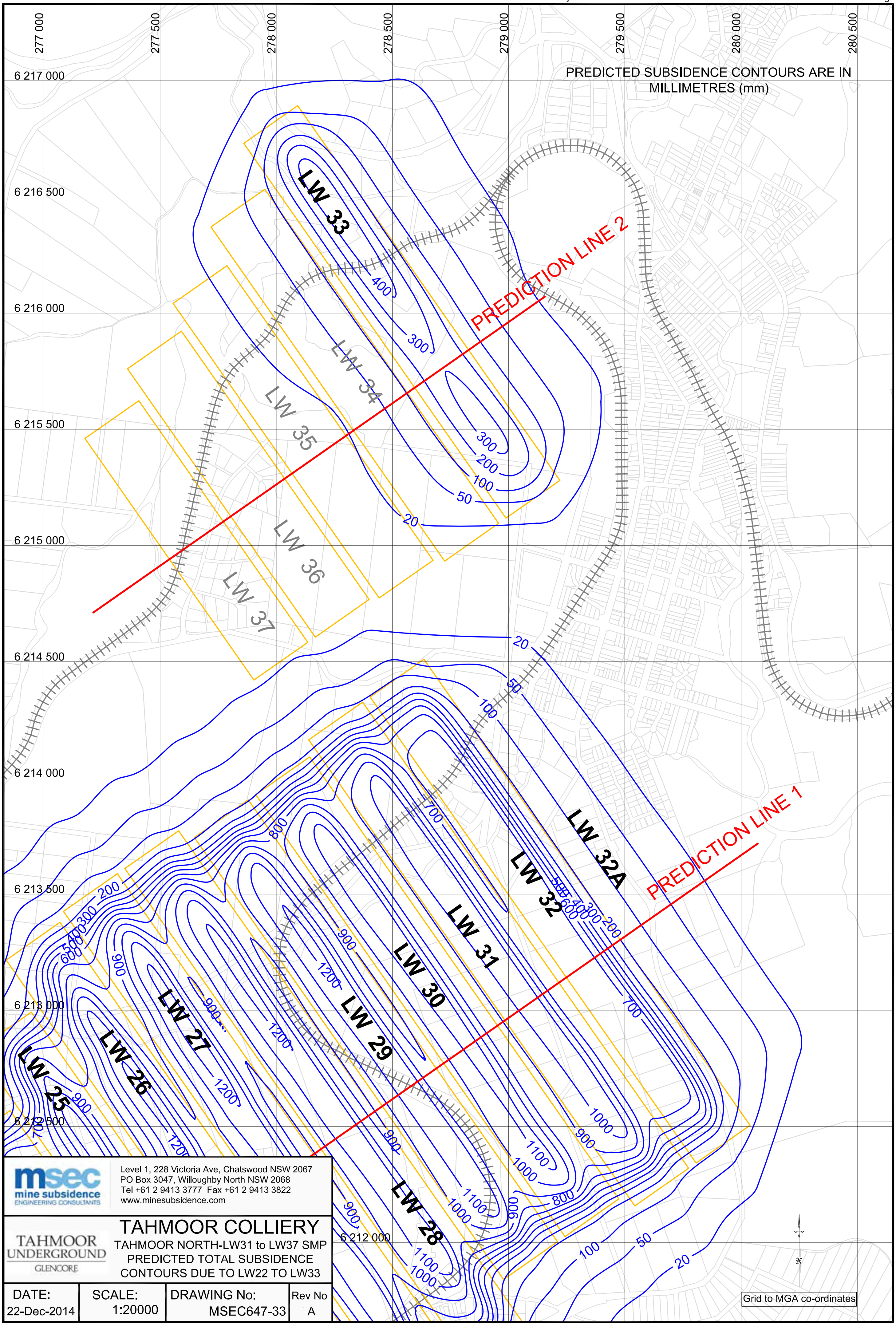

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH-LW31 to LW37 SMP
PREDICTED TOTAL SUBSIDENCE CONTOURS DUE TO LW22 TO LW33

DATE:	SCALE:	DRAWING No:	Rev No
22-Dec-2014	1:20000	MSEC647-33	A

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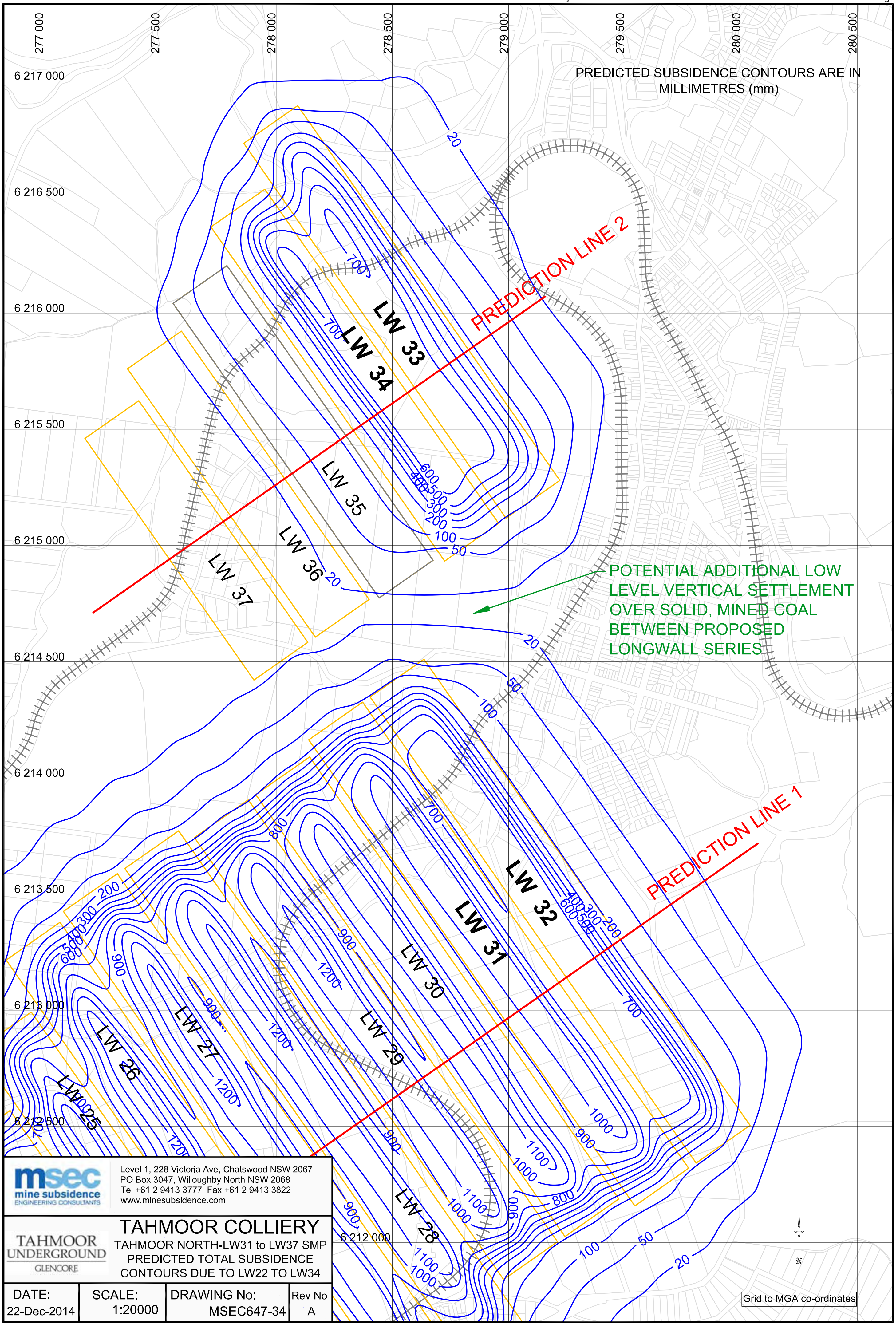

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH-LW31 to LW37 SMP
PREDICTED TOTAL SUBSIDENCE CONTOURS DUE TO LW22 TO LW34

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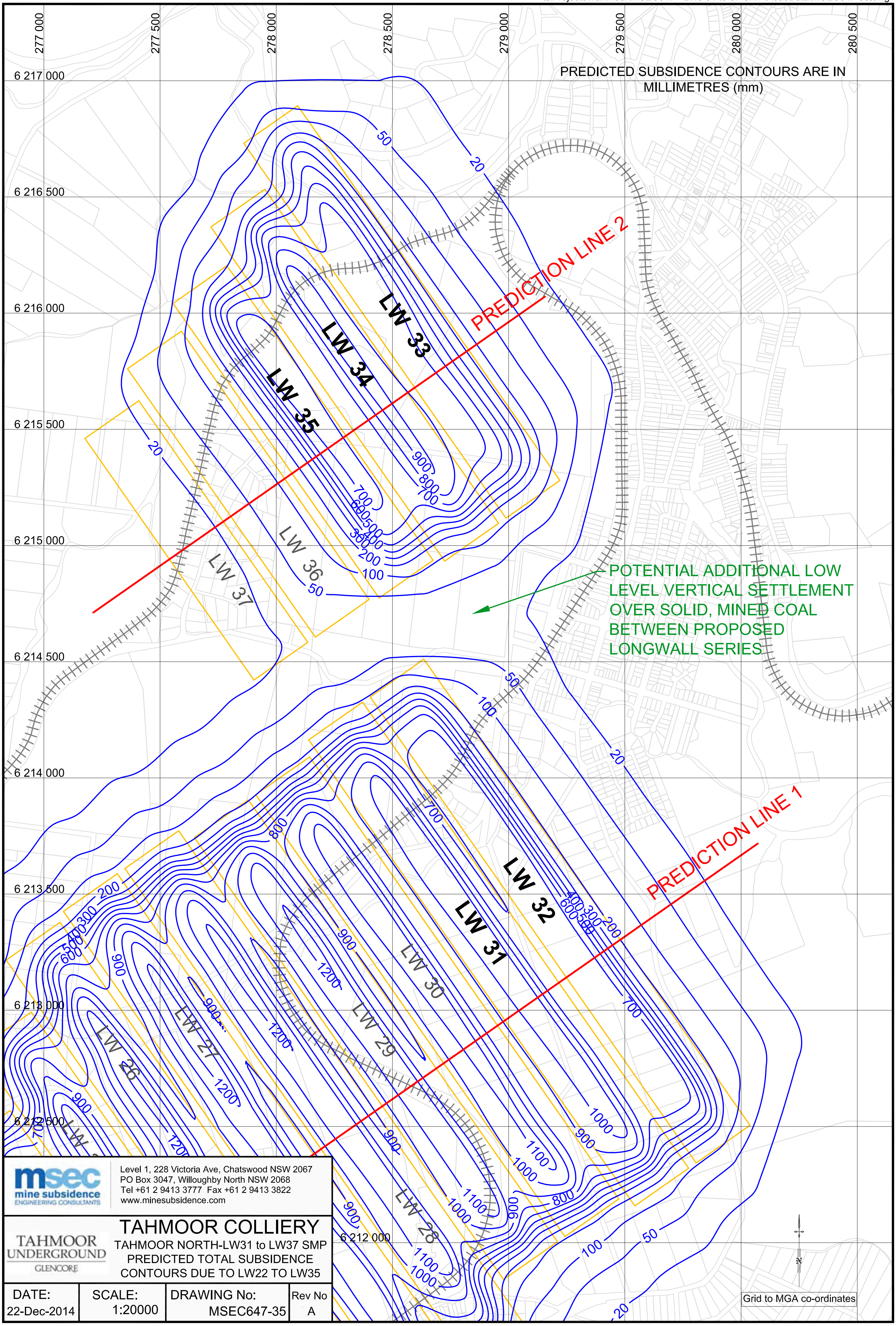

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH-LW31 to LW37 SMP
PREDICTED TOTAL SUBSIDENCE CONTOURS DUE TO LW22 TO LW35

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22-Dec-2014	1:20000	MSEC647-35	A

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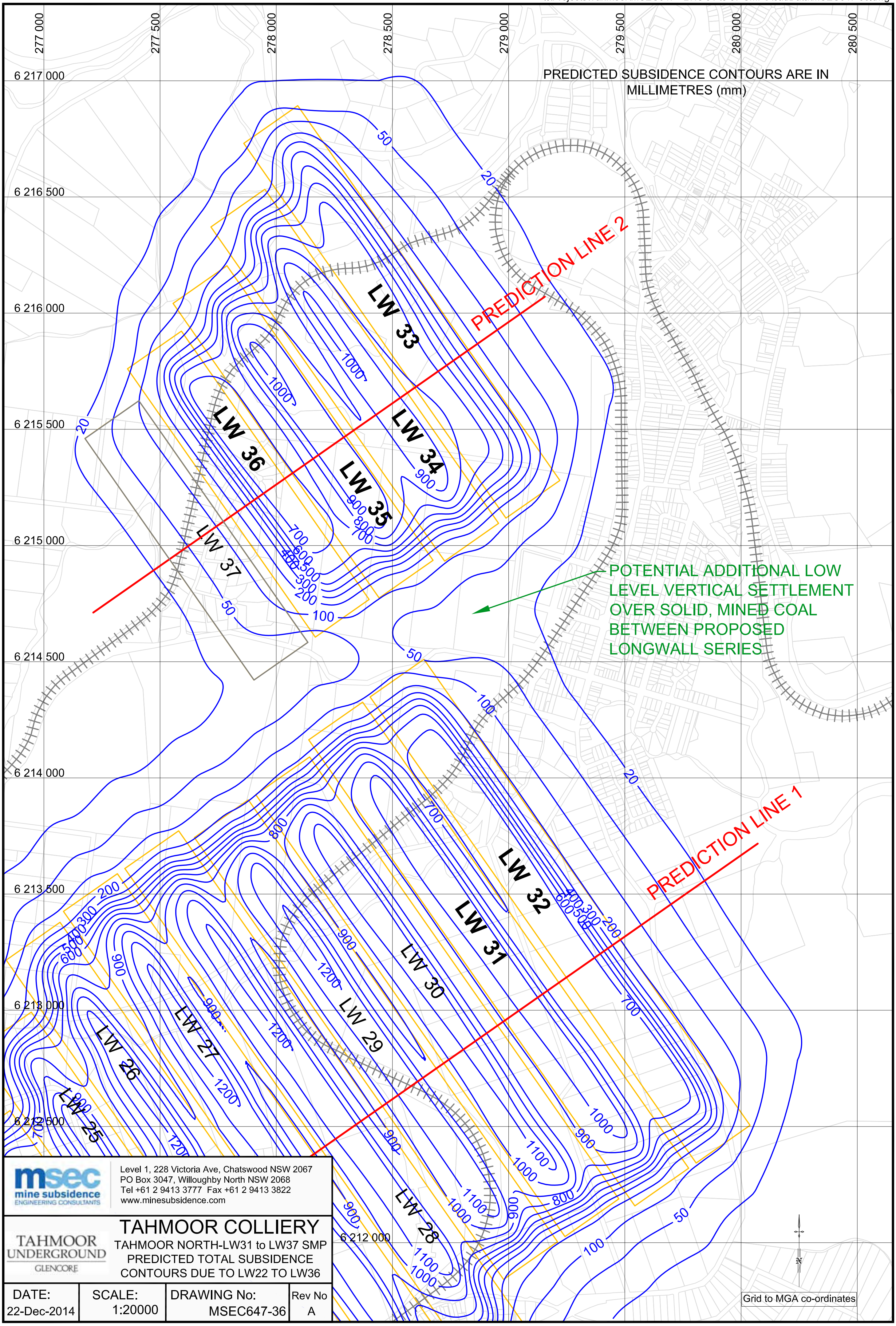

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH-LW31 to LW37 SMP
PREDICTED TOTAL SUBSIDENCE CONTOURS DUE TO LW22 TO LW36

DATE:	SCALE:	DRAWING No:	Rev No
22-Dec-2014	1:20000	MSEC647-36	A

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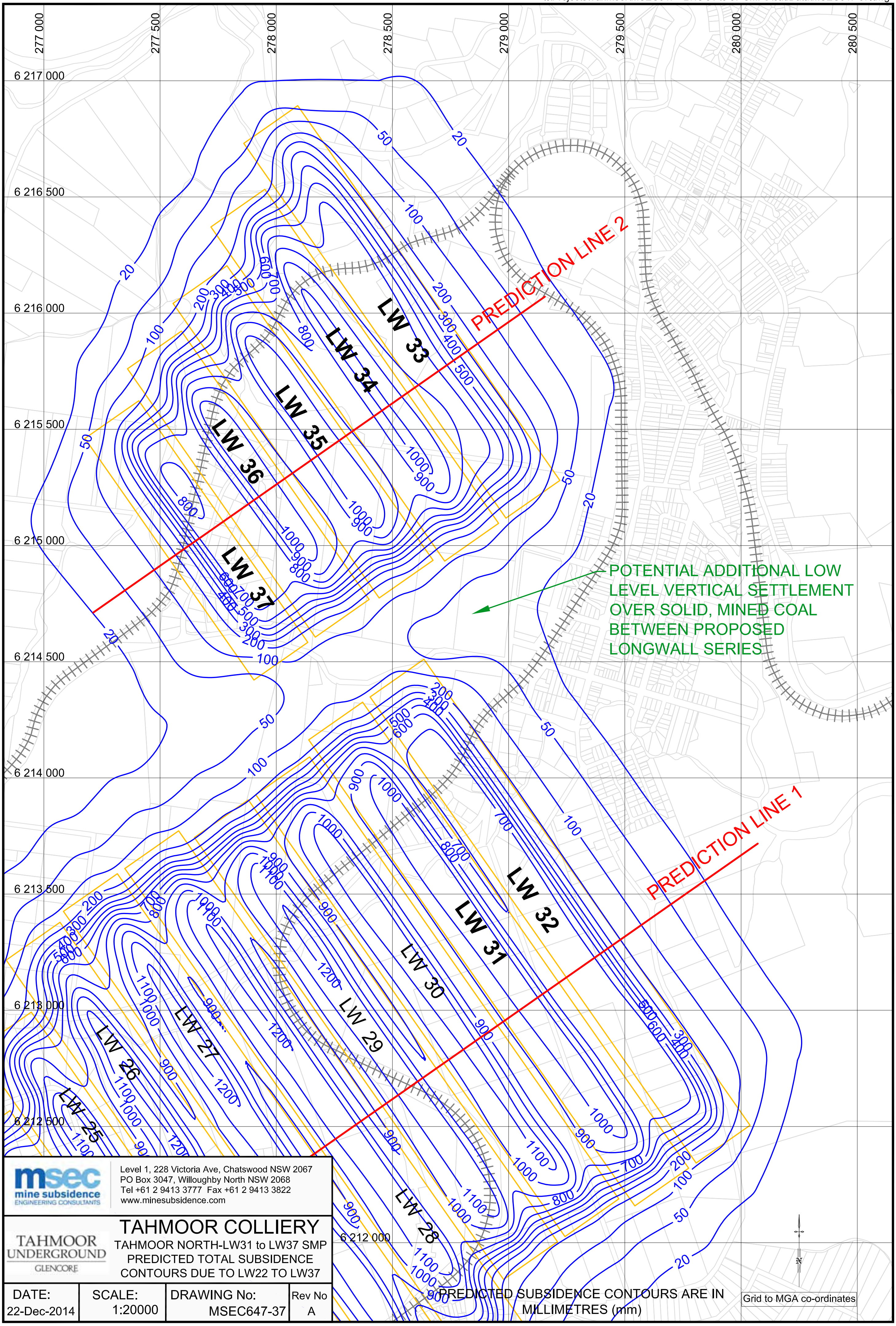

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH-LW31 to LW37 SMP
PREDICTED TOTAL SUBSIDENCE CONTOURS DUE TO LW22 TO LW37

DATE:	SCALE:	DRAWING No:	Rev No
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PREDICTED SUBSIDENCE CONTOURS ARE IN MILLIMETRES (mm)

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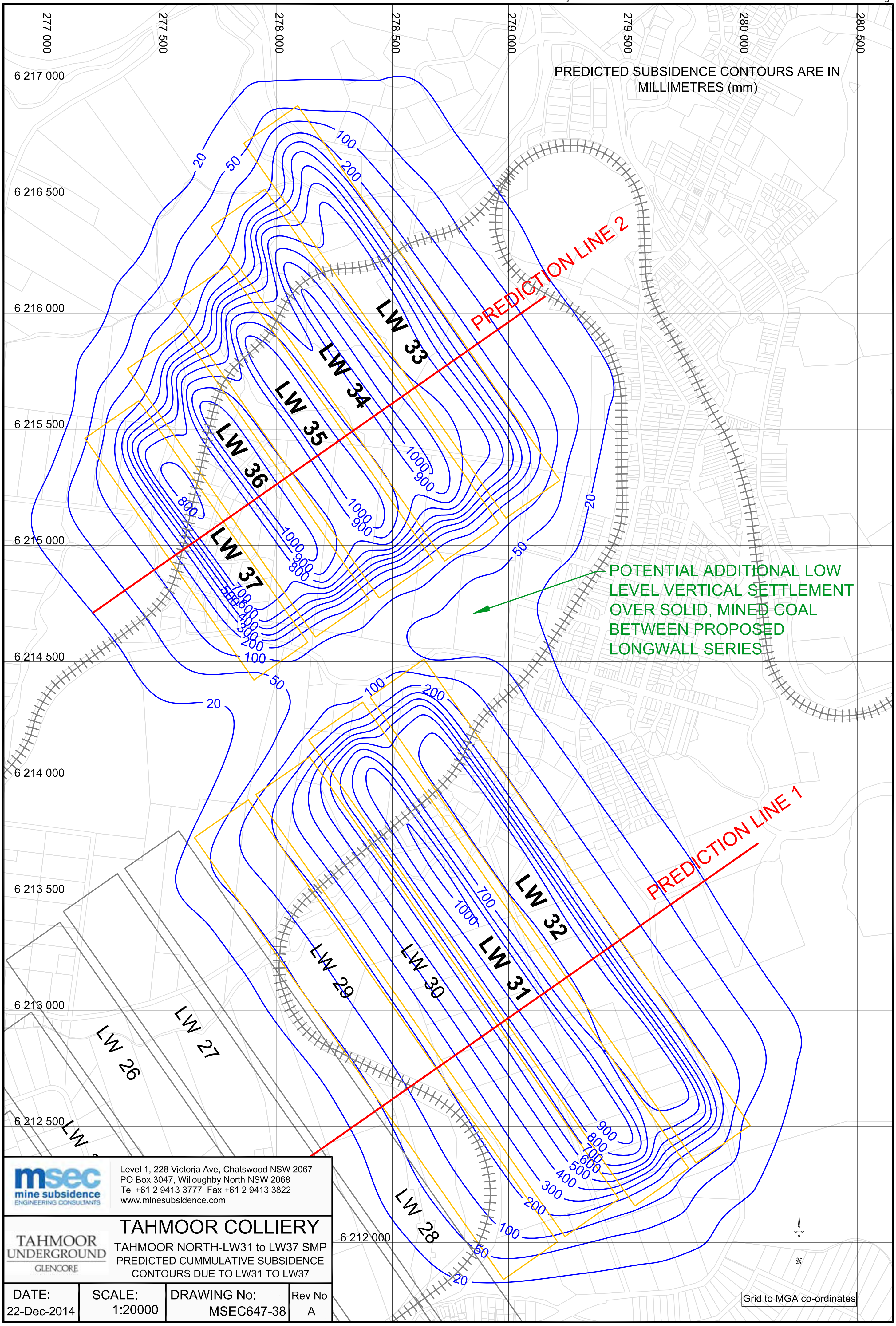

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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH-LW31 to LW37 SMP
PREDICTED CUMMULATIVE SUBSIDENCE CONTOURS DUE TO LW31 TO LW37

DATE:	SCALE:	DRAWING No:	Rev No
22-Dec-2014	1:20000	MSEC647-38	A