11. SUBSIDENCE PREDICTIONS AND IMPACTS ON MAN MADE FEATURES

Details of the predicted subsidence parameters for each of the items of infrastructure are provided in **Appendix A**. The following sections provide a summary of predictions and the impact assessments for the SMP Area, due to the extraction of proposed Longwalls 705 to 710. The infrastructure is shown on **Plan 2** and in the separate figures referred to in this report.

11.1. ROADS

The location of roads within the SMP Area is shown in **Figure 6.5**.

11.1.1. HW2 Hume Highway

The predicted profiles of incremental and cumulative systematic subsidence, tilt and strain along the centreline of the southbound carriageway of the HW2 Hume Highway, resulting from the extraction of the proposed longwalls, are detailed in **Appendix A**.

Predictions for HW2 Hume Highway

A summary of the maximum predicted values of cumulative systematic subsidence, tilt and strain along the alignment of the southbound carriageway, after the extraction of each proposed longwall, is provided in **Table 11.1**.

Table 11.1 - Maximum Predicted Cumulative Systematic Subsidence, Tilt and Strain along the Alignment of Southbound Carriageway Resulting from the Extraction of Longwalls 705 to 710

Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Tilt (mm/m)	Maximum Predicted Cumulative Tensile Strain (mm/m)	Maximum Predicted Cumulative Compressive Strain (mm/m)
After LW705	1305	5.1	0.5	1.0
After LW706	1410	5.5	0.7	1.2
After LW707	1490	5.5	0.7	1.3
After LW708	1495	5.8	0.8	1.4
After LW709	1495	5.8	1.0	1.4
After LW710	1495	5.8	1.0	1.4

The highway will also be subjected to travelling tilts and strains as the extraction faces of the proposed longwalls pass beneath it. A summary of the maximum predicted travelling tilts and strains at the highway, during the extraction of each proposed longwall, is provided in **Table 11.2**.

Table 11.2 - Maximum Predicted Travelling Tilts and Strains at HW2 Hume Highway during the Extraction of Longwalls 705 to 710

Longwall	Maximum Predicted Travelling Tilt (mm/m)	Maximum Predicted Travelling Tensile Strain (mm/m)	Maximum Predicted Travelling Compressive Strain (mm/m)
During LW705	3.3	0.5	0.3
During LW706	3.2	0.4	0.3
During LW707	3.1	0.4	0.3
During LW708	3.0	0.4	0.3
During LW709	2.9	0.4	0.3
During LW710	3.0	0.4	0.3

Impact Assessments for HW2 Hume Highway

Illawarra Coal and the Roads and Traffic Authority of NSW (RTA) are jointly developing detailed risk management strategies for effectively managing potential mine subsidence impacts to the Hume Highway due to the mining of Longwalls 701 to 704 at Appin Colliery.

A technical committee has been coordinated to develop the risk management strategies. This technical committee includes representatives from the RTA, IC, the Department of Primary Industries, the Mine Subsidence Board and consultants who specialise in the fields of geotechnical engineering, pavement engineering, structural engineering, traffic management, mine subsidence, risk assessment and project management. The technical committee has been developing management strategies for over 5 years.

The following sub-sections provide details of the potential impacts to the Hume Highway and management measures that have been developed by the technical committee to ensure the safe operation of the highway during mining.

Pavement

The HW2 Hume Highway has been constructed with an asphaltic pavement on a slag road base and stabilised crushed sandstone sub-base. While the asphaltic pavement is considered flexible, the stabilised sandstone sub-base and some isolated sections of the slag layer have some stiffness and strength.

The stiffness of the bound sandstone pavement is unlike most pavements that have previously experienced mine subsidence impacts in the Southern Coalfield. The technical committee has identified a potential risk that mine subsidence movements may result in stepping failure of the pavement due to the presence of the stiff bound sandstone layer. Stepping failures have occurred as a result of mine subsidence on two occasions on the F6 Freeway.

Road Pavement Drainage

The maximum predicted change in crossfall across the pavement due to mine subsidence movements is 0.52%. By comparison, the crossfall in the existing Highway is typically 3.0%.

There are two transition points within the SMP Area; one on the southbound carriageway above Longwall 708 and one of the northbound carriageway above Longwall 709. The rate of transition in crossfall occurs over a relatively short distance compared to the predicted rate of change in crossfall and it is expected that the point of transition will not move significantly.

While it is recommended that an assessment be made by the technical committee to determine the potential impact of mine subsidence on crossfalls on the pavement, it is considered unlikely that the changes to pavement crossfalls would present a significant impact to the safe operation of the Highway. Management of risks associated with mine subsidence impacts on pavement drainage will be provided for in the infrastructure risk management plan for Longwalls 705 to 710.

Median Drainage

Two local sag points have been identified within the proposed subsidence area, as shown in **Figure 6.4**. Sag Point 2 is located beyond the limit of subsidence of the proposed Longwalls 705 to 710.

Sag Point 1 is located directly above Longwall 705. Predictions of subsidence have been made every 30 metres along the median. It has been found that the point of maximum subsidence along the median in the vicinity of Sag Point 1 will be located within 30 metres of Sag Point 1.

It is therefore possible that mine subsidence may result in a shift of the location of the sag point by a distance of less than 30 metres. While some ponding may develop in the grassed median adjacent to the drop down pit at Sag Point 1, the differential subsidence between Sag Point 1 and the point of predicted maximum subsidence will be less than 50 mm. This impact can be readily corrected by regrading of the median in the vicinity of the drop down drainage pits.

While it is recommended that an assessment be made by the technical committee to determine the potential impact of mine subsidence on median drainage, it is unlikely that the changes to median drainage would present a significant impact to the safe operation of the Highway. Management of risks associated with mine subsidence impacts on shifts in sag point will be provided for in the infrastructure risk management plan for Longwalls 705 to 710.

For further details on predictions and impact assessments for the HW2 Hume Highway refer **Appendix A**.

11.1.2 Highway Creek Crossings

The locations of the highway culverts are shown in **Figure 6.4**. A summary of the maximum predicted values of systematic subsidence, tilt and strain at the culverts, resulting from the extraction of the proposed longwalls, is provided in **Table 11.3**.

Table 11.3 - Predicted Systematic Subsidence, Tilt and Strain at the Highway Culverts Resulting from the Extraction of Longwalls 702 to 710

Label	Diameter (mm)	Maximum Predicted Subsidence (mm)	Maximum Predicted Cumulative Tilt (mm/m)	Maximum Predicted Tensile Strain (mm/m)	Maximum Predicted Compressive Strain (mm/m)
H-C2	1800	1340	2.4	0.4	0.4
H-C3	1800	1360	2.3	0.4	0.3
H-C4	1200	1375	1.8	0.4	0.3
H-C5	1200	945	1.3	0.4	0.3
H-C6	1200	380	4.5	0.8	0.1
H-C7	1200	60	0.5	< 0.1	< 0.1
H-C8	1200	< 20	< 0.1	< 0.1	< 0.1

The values provided in the above table are the maximum predicted parameters within a 20 metre radius of each culvert, including the predicted movements resulting from the extraction of Longwalls 702 to 704. The predicted tilts are the maximum values at the completion of any or all longwalls, whichever are the greatest. The predicted strains are the maximum values which occur at anytime during or after the extraction of the proposed longwalls.

Although the Highway is situated generally on the side of a ridge, it passes over a number of small creek valleys. Experience at nearby Appin and West Cliff Collieries indicates that closure and upsidence has occurred in small creek valleys on the plateau areas above the Nepean River valley.

The highway culverts are located within drainage lines and could, therefore, also experience valley related movements resulting from the extraction of the proposed longwalls. A summary of the maximum predicted upsidence and closure movements at these culverts, after the extraction of the proposed longwalls, is provided in **Table 11.4.**

Table 11.4 - Maximum Predicted Upsidence and Closure Movements at the Highway Culverts

Location	Diameter (mm)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
H-C2	1800	95	55
H-C3	1800	125	100
H-C4	1200	90	60
H-C5	1200	60	45
H-C6	1200	35	30
H-C7	1200	< 20	< 20
H-C8	1200	< 20	< 20

No culverts are expected to experience significant impacts due to systematic subsidence, as shown by the parameters given in **Table 11.3**. The predicted levels of upsidence and closure are also very low. The predicted strains due to closure are expected to have little impact on the concrete culverts as they are typically orientated perpendicular to the culverts, across their strongest axis.

It is anticipated that the subsidence induced tilts will not significantly affect the drainage flows in the culverts, which are all less than 1% in grade. Similar comments would apply to other drainage structures associated with the Highway.

There are a number of culverts and other smaller drainage structures that do not lie within creek alignments. These structures are less likely to experience non-systematic movements, though some sections may experience them. It is possible that these movements would be sufficient to result in some cracking. Cracking of small pipe sections due to mine subsidence is rarely observed in the Southern Coalfield. This is because the pipe sections are relatively short in length and are able to accommodate some ground movements without impact.

Continuous structures, such as kerbs and table drains are considered more prone to cracking. Large drainage structures, such as culverts, are also more susceptible to impact. The potential impact to all culverts is manageable by monitoring and by carrying out mitigatory or remedial measures. The ground movements will occur gradually as mining progresses, which will provide adequate time to rectify the Highway at appropriate stages to maintain the safe operation of the Highway. Management of risks associated with mine subsidence impacts on culverts will be provided for in the infrastructure risk management plan for Longwalls 705 to 710.

11.1.3. Highway Cuttings

The locations of the highway cuttings are shown in **Figure 6.4**. A summary of the maximum predicted values of systematic subsidence, tilt and strain at the cuttings, resulting from the extraction of the proposed longwalls, is provided in **Table 11.5**.

Table 11.5 - Predicted Systematic Subsidence, Tilt and Strain at the Highway Cuttings Resulting from the Extraction of Longwalls 702 to 710

Location	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Tensile Strain (mm/m)	Maximum Predicted Compressive Strain (mm/m)
Highway Cutting 1	< 20	< 0.1	< 0.1	< 0.1
Highway Cutting 2	1190	2.5	0.4	0.6
Highway Cutting 3	1500	7.0	1.2	1.7
Highway Cutting 4	1375	6.8	1.0	1.4
Highway Cutting 5	1335	6.3	1.0	1.7

The values provided in the above table are the maximum predicted parameters within a 20 metre radius of each end and mid-length of each cutting, including the predicted movements resulting from the extraction of Longwalls 702 to 704. The predicted tilts are the maximum values at the completion of any or all longwalls, which ever are the greatest. The predicted strains are the maximum values which occur at anytime during or after the extraction of the proposed longwalls.

Cuttings 3 to 5 are located directly above proposed Longwalls 705 to 710 and these cuttings are relatively small in height and well battered from the pavement. The cuttings consist of clay and weathered shale, which are unlikely to represent a safety risk should any material become loose. It is recommended, however, that a geotechnical assessment be carried out of the cuttings, with recommendations for any preventive or protective works or monitoring measures. Management of risks associated with mine subsidence impacts on culverts will be provided for in the infrastructure risk management plan for Longwalls 705 to 710.

11.1.4 Road Embankments

It is possible that mine subsidence may result in some movements to road embankments. This is of particular concern in fill areas over natural watercourses where closure and upsidence may occur. There are currently no known issues concerning the stability of the road embankments within the affected area. Adverse movements of batters may cause longitudinal cracking in the pavement and, in the extreme, embankment failure.

With regards to the proposed Longwalls 705 to 710, it is expected that the embankments will experience very minor impacts, as the predicted amount of subsidence is very low. There have been no reports of impacts to road embankments as a result of previous mining beneath major roads. It is, however, recommended that the embankments should be monitored periodically while mining occurs.

Management of risks associated with mine subsidence impacts on embankments will be provided for in the infrastructure risk management plan for Longwalls 705 to 710.

11.1.5 Twin Bridges over the Nepean River at Douglas Park

The Twin Bridges along the HW2 Hume Highway cross over the Nepean River at Douglas Park are located approximately 1.9 kilometres south of the finishing (western) end of Longwall 705, at their closest points to the proposed longwalls.

The Twin Bridges over the Nepean River at Douglas Park are located well outside the general SMP Area. The bridges could experience small differential far-field horizontal movements as a result of mining the proposed longwalls. It is for this reason that the Bridges have been included within the SMP Area.

It is likely that the management measures that have been developed for the Bridges will remain in operation during the mining of proposed Longwalls 705 to 710 until such time that all parties are satisfied that no further mining-related movements are being observed. It is noted that the Bridges experienced no adverse impacts as a result of mining Longwall 701.

11.1.6 Moreton Park Road Bridge (South)

The Appin longwalls will approach to within 600 metres of Moreton Park Road Bridge (South) during the mining of Longwall 703. Subsequent longwalls including the proposed Longwalls 705 to 710 will mine further away from the Bridge. The Bridge is located approximately 1 kilometre south of the finishing (western) end of Longwall 705, at its closest point.

It is likely that the management measures that have been developed for the Bridge will remain in operation during the mining of proposed Longwalls 705 to 710 until such time that all parties are satisfied that no further mining-related movements are being observed. It is noted that the Bridge experienced no adverse impacts as a result of mining Longwall 701.

11.1.7 Moreton Park Road Bridge (North)

Moreton Park Road Bridge (North) crosses over the HW2 Hume Highway and is located approximately 400 metres north of Longwall 710, at its closest point to the proposed longwalls.

The technical committee will undertake detailed investigations and assessments of potential impacts to the Bridge in a similar manner to the methods undertaken for Moreton Park Road Bridge (South). Given that the Bridge is located approximately 400 metres from the closest longwall, it is likely that the management measures will be similar to those currently employed for Moreton Park Road Bridge (South).

Management of risks associated with mine subsidence impacts on the Bridge will be provided for in the infrastructure risk management plan for Longwalls 705 to 710.

11.1.8. Highway Rest Area Buildings and Associated Infrastructure

There are 4 building structures (Refs. C17a to C17d) which are associated with a Rest Area along the HW2 Hume Highway. The location of the rest area is shown in **Figure 6.5**.

The maximum predicted systematic subsidence parameters for each rest area building structure are provided in **Appendix A**. A summary of the maximum predicted systematic subsidence, tilt and strains for the rest area building structures, at any time during or after the extraction of the proposed longwalls, is provided in **Table 11.6**.

Table 11.6 - Maximum Predicted Systematic Subsidence, Tilt and Strain for the Rest Area Building Structures Resulting from the Extraction of Longwalls 702 to 710

Location	Structure	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Tensile Strain (mm/m)	Maximum Predicted Compressive Strain (mm/m)
Rest Area	C17a	1040	1.9	1.4	< 0.1
	C17b	1005	1.7	1.5	< 0.1
	C17c	1065	3.2	1.5	< 0.1
	C17d	1235	4.5	1.4	< 0.1

The Rest Area structures are constructed of lightweight steel supports and are unlikely to experience adverse impacts as a result of mine subsidence.

It is possible that the on-site waste system and associated sewerage pipework could experience some adverse impacts, though extensive experience of mining beneath waste systems in the Southern Coalfield suggests that the probability of impacts is rare. Management of risks associated with the Rest Area will be provided for in the infrastructure risk management plan for Longwalls 705 to 710.

11.1.9. Local Roads

The locations of the local roads within the SMP Area are shown in **Figure 6.5**. The predictions and impact assessments for these roads are provided in the following sections.

Predictions for Local Roads

A summary of the maximum predicted values of cumulative systematic subsidence, tilt and strain along the alignments of Moreton Park and Menangle Roads, after the extraction of each proposed longwall, is provided in **Table 11.7**.

Table 11.7 - Maximum Predicted Cumulative Systematic Subsidence, Tilt and Strain along the Alignments of the Local Roads Resulting from the Extraction of Longwalls 702 to 710

Location	Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Tilt (mm/m)	Maximum Predicted Cumulative Tensile Strain (mm/m)	Maximum Predicted Cumulative Compressive Strain (mm/m)
Moreton Park Road	After LW705	1350	5.2	1.1	1.8
	After LW706	1430	4.7	1.1	1.8
	After LW707	1440	6.4	1.1	1.8
	After LW708	1440	5.6	1.1	1.8
	After LW709	1440	6.4	1.1	1.8
	After LW710	1440	7.9	1.1	2.2
Menangle Road	After LW705	< 20	< 0.1	< 0.1	< 0.1
	After LW706	40	0.2	< 0.1	< 0.1
	After LW707	975	6.3	1.0	1.7
	After LW708	1325	4.3	1.0	1.1
	After LW709	1420	5.2	1.0	1.0
	After LW710	1450	5.5	1.0	1.2

The values provided in the above table are the maximum predicted cumulative systematic subsidence parameters which occur along the roads within the general SMP Area, including the predicted movements resulting from the extraction of Longwalls 702 to 704.

These roads will also be subjected to travelling tilts and strains as the extraction faces of the proposed longwalls pass beneath them. A summary of the maximum predicted travelling tilts and strains at the roads, during the extraction of each proposed longwall, is provided in **Table 11.8**.

Table 11.8 - Maximum Predicted Travelling Tilts and Strains at the Local Roads during the Extraction of Longwalls 705 to 710

Location	Longwall	Maximum Predicted Travelling Tilt (mm/m)	Maximum Predicted Travelling Tensile Strain (mm/m)	Maximum Predicted Travelling Compressive Strain (mm/m)
Moreton Park Road	During LW705	3.5	0.5	0.4
	During LW706	3.2	0.4	0.3
	During LW707	3.3	0.5	0.4
	During LW708	2.9	0.4	0.3
	During LW709	3.6	0.5	0.4
	During LW710	3.7	0.5	0.4
Menangle Road	During LW705	< 0.1	< 0.1	< 0.1
	During LW706	0.1	< 0.1	< 0.1
	During LW707	2.9	0.4	0.3
	During LW708	3.0	0.4	0.3
	During LW709	2.8	0.4	0.3
	During LW710	2.6	0.3	0.2

Impact Assessments for Local Roads

It is unlikely that the predicted systematic tilts at the local roads within the SMP Area would result in any significant changes in surface water drainage, as the maximum predicted change in grade is less than 1% and is much less than the typical existing gradients along the alignment of the local roads. It is possible, however, that there could be some very localised changes in surface water drainage, where the greater tilts coincide with flat sections of the local roads, however, these changes are not expected to be significant.

The maximum predicted systematic tensile and compressive strains at the local roads within the SMP Area, at any time during or after the extraction of the proposed longwalls, are 1.3 mm/m and 2.3 mm/m, respectively. The minimum radii of curvatures associated with the maximum predicted tensile and compressive strains are 12 kilometres and 6.5 kilometres, respectively.

The local public roads are of flexible construction with bitumen seals and the private roads are typically unsealed. It is expected that the local roads within the SMP Area would be able to tolerate strains of these magnitudes without significant impacts. It is possible that minor cracking could occur in some places along the local roads, due to localised concentrations of tensile strains, and that minor rippling of the local roads surface could occur in other places, due to localised concentrations of compressive strains.

As the magnitudes of the maximum predicted strains are relatively low, any such impacts are likely to be infrequent occurrences and of a minor nature. It is recommended that any impacts are remediated using normal road maintenance techniques. With these remediation measures implemented, it is expected that the local roads can be maintained in a safe and serviceable condition throughout the mining period.

Impact Assessments for Local Roads Based on Increased Predictions

If the predicted systematic tilts were increased by factors of up to 2 times, the maximum predicted tilt at the local roads within the SMP Area would be 16 mm/m (i.e.1.6%), or a change in grade of 1 in 65. It would still be unlikely that the predicted tilts would result in significant changes in surface water drainage, as the maximum predicted change in gradient is still less than the typical existing gradients along the alignment of the local roads within the SMP Area.

If the maximum predicted systematic strains were increased by factors of up to 2 times, the likelihood and extent of cracking in the local road surfaces would increase accordingly. As the magnitudes of the maximum predicted strains are relatively low, however, it would still be expected that any impacts could be easily repaired using normal road maintenance techniques. With these remediation measures implemented, it is expected that the local roads can be maintained in a safe and serviceable condition throughout the mining period.

11.2. RAILWAYS

11.2.1. Main Southern Railway

Predictions for Main Southern Railway

The location of the Main Southern Railway and the associated infrastructure within the SMP Area are shown in **Figure 6.4**. The predictions and impact assessments for these items of infrastructure are provided in the following sections.

A summary of the maximum predicted values of cumulative systematic subsidence, change in grade and ground strain along the alignment of the railway, after the extraction of each proposed longwall, is provided in **Table 11.9**.

Table 11.9 - Maximum Predicted Cumulative Systematic Subsidence, Change in Grade and Ground Strain along the Railway Resulting from the Extraction of Longwalls 702 to 710

Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Change in Grade (%)	Maximum Predicted Cumulative Tensile Ground Strain (mm/m)	Maximum Predicted Cumulative Compressive Ground Strain (mm/m)
After LW705	1275	0.42	0.7	1.1
After LW706	1365	0.63	0.8	1.4
After LW707	1450	0.65	1.0	1.7
After LW708	1455	0.60	1.1	1.6
After LW709	1455	0.47	1.1	1.6
After LW710	1455	0.58	1.1	1.6

The values provided in the above table are the maximum predicted cumulative systematic subsidence parameters which occur along the railway within the general SMP Area, including the predicted movements resulting from the extraction of Longwalls 702 to 704.

A summary of the maximum predicted values of cumulative systematic horizontal movement across the alignment of the railway, change in cant and long twist, after the extraction of each proposed longwall, is provided in **Table 11.10**.

Table 11.10 - Maximum Predicted Cumulative Horizontal Movement across the Railway, Change in Cant and Long Twist Resulting from the Extraction of Longwalls 702 to 710

Longwall	Maximum Predicted Cumulative Horizontal Movement Across the Alignment (mm)	Maximum Predicted Change in Cant (mm)	Maximum Predicted Long Twist over 13.2 m Baylengths (mm)
After LW705	95	9	1.0
After LW706	70	7	1.0
After LW707	60	6	0.9
After LW708	60	6	0.9
After LW709	65	6	1.0
After LW710	60	6	0.9

The values provided in the above table are the maximum predicted cumulative systematic subsidence parameters which occur along the railway within the general SMP Area, including the predicted movements resulting from the extraction of Longwalls 702 to 704.

A summary of the maximum predicted loss in rail Stress Free Temperature (SFT), after the extraction of each proposed longwall, based on a transfer of ground strain to rail strain varying between 5% and 100%, is provided in **Table 11.11**.

Table 11.11 - Maximum Predicted Loss in Rail SFT Resulting from the Extraction of Longwalls 702 to 710

Stage of Mining	Transfer of Ground Strain to Rail Strain				
	5%	25%	50%	75%	100%
After LW705	5	20	35	55	75
After LW706	5	20	45	65	90
After LW707	5	25	50	75	100
After LW708	5	25	45	70	95
After LW709	5	25	45	70	90
After LW710	5	25	45	70	90

It is estimated that the Main Southern Railway will experience additional subsidence greater than 20 mm, resulting from the extraction of Longwalls 705 to 710, between Chainage 70.237 and 74.252 kilometres. The maximum predicted subsidence along the railway, after the extraction of all proposed longwalls, of 1455 mm is expected to occur above Longwall 705, near Chainage 73.085 kilometres.

Impact Assessments for Main Southern Railway

Illawarra Coal and ARTC are jointly developing detailed risk management strategies for effectively managing potential mine subsidence impacts to the Main Southern Railway due to the mining of Longwalls 703 and 704 at Appin Colliery. This consultation has been conducted in conjunction with Xstrata Tahmoor Colliery, who also plans to mine directly beneath the railway at Tahmoor.

An assessment of potential impacts and development of risk management measures will be undertaken jointly by ARTC and Illawarra Coal through the rail technical committee. It is noted that by the time Appin Colliery extracts Longwall 705 beneath the railway, the technical committee will have benefited from the collective experiences of mining Longwalls 703 to 704 at Appin Colliery and Longwalls 25 to 27 at Tahmoor Colliery. It is therefore expected that the management strategies and plans will be fully developed prior to the mining of the proposed Longwall 705 to 710.

The following sub-sections provide details of the potential impacts to the Main Southern Railway and management measures that have been developed by the rail technical committee to ensure the safe operation of the railway during mining.

<u>Changes in Track Geometry</u>

Mine subsidence will result in changes to track geometry. Changes to track geometry are described using a number of parameters:

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

The Australian Rail Track Corporation's (ARTC) Base Operating Standards for Track Geometry provide allowable deviations in track geometry. Predictions of systematic subsidence, tilt and horizontal movement have been at 5 metre intervals along the railway to calculate each track geometry parameter at any stage of mining. A summary of the maximum predicted changes in geometry are shown in **Table 11.12**. Predicted changes in cant and long twist along the railway are provided in **Appendix A**.

Table 11.12 - Predicted Maximum Changes in Track Geometry due to Systematic Subsidence

Track Geometry parameter	Measured	Maximum allowable deviation before first speed limit applied*	Maximum allowable deviation before trains are stopped*	Predicted Maximum Deviation due to Systematic Subsidence
Top	Mid-ordinate vertical deviation over a 10 m chord	25 mm	45 mm	< 2
Line	Mid-ordinate horizontal deviation over a 10 m chord	20 mm	60 mm	< 2
Change in Cant	Deviation from design superelevation across rails spaced 1.435 m apart	30 mm	75 mm	9
Long Twist	Changes in Cant over a 13.2 m chord	30 mm	65 mm	1

*Note: Maximum allowable deviations are specified in current ARTC Base Operating Standards for Track Geometry. Please note that these standards are currently under review. Any changes are unlikely to represent a significant change from the current standard.

It can be seen from **Table 11.12** that the predicted changes in track geometry are an order of magnitude less than the maximum allowable deviations specified in the ARTC standards, if systematic subsidence occurs. For example, the maximum allowable change in cant is 75 mm over a length of 1.435 metres before the trains are stopped. In mining terminology, this represents a tilt of approximately 50 mm/m, which is substantially greater than the predicted maximum tilts of 7 mm/m due to mine subsidence.

For further detail on changes in track geometry refer **Appendix A**.

<u>Rail Stress</u>

Mine subsidence will result in changes to rail stress unless preventive measures are implemented. If no action is taken, it is likely that the rails will become unstable as a result of mine subsidence. The maximum predicted change in stress free temperature is 100 degrees if 100 % of predicted ground strains are transferred into the rails. By comparison a change in stress free temperature of approximately 14 degrees is sufficient to warrant immediate preventative action on a track with concrete sleepers.

Management of rail stress during active mine subsidence has been the primary focus of the rail technical committee. Traditionally, rail stress has been managed in Australia and overseas by rail strain or stress monitoring. Once measured changes in rail stress reach defined triggers, the stress is dissipated by unclipping the rails from the sleepers, cutting the rails and adding or removing steel to the rails as required, followed by re-stressing the rails back to their desired stress. This process is effective but it is labour intensive and very difficult to undertake on busy tracks such as the Main Southern Railway, particularly if the frequency of required rail re-stressing is likely to be less than weekly, as would be expected during the mining of Longwalls 705 to 710.

For this reason, the rail technical committee proposes to use a combination of rail expansion switches and zero toe load clips to dissipate mining and temperature related rail stress during mining. Rail expansion switches consist of a tapered joint in the track, which allow the rails to slide independently. Maximum allowable displacements of expansion switches vary between different types of switches and the ones proposed for use to manage mine subsidence are approximately 300 mm. Expansion switches are standard rail equipment and operate in non-subsidence applications in Australia and overseas to accommodate, for example, differential thermal movements between bridges and natural ground.

For further detail on rail stress refer **Appendix A.**

Changes in Track Gradient

The predicted changes in grade (i.e. tilts) along the alignment of the Main Southern Railway, resulting from the extraction of the proposed longwalls, are provided in **Appendix A**. The greatest predicted changes in grade, at each stage of mining, occur where the railway enters and exits the subsidence bowl. The maximum predicted change in grade along the railway at any stage in mining is 0.65% (6.5 mm/m rising northbound).

The Main Southern Railway climbs steadily in a northbound direction from Douglas Park towards Menangle. The regional high point on the railway is located above Longwall 704, near Chainage 73.452 kilometres. The existing gradients along the alignment of the railway, within the SMP Area, varies between +1.4% (i.e. 14 mm/m rising northbound) and -1.8% (i.e. 18 mm/m falling northbound). The existing gradients have been determined from the 1 metre surface level contours which were generated from an aerial laser scan of the area.

The gradients along the alignment of the railway, before and after the extraction of the proposed longwalls, are also provided in **Appendix A**. The maximum predicted gradients along the alignment of the railway within the SMP Area, after the extraction of the proposed longwalls, are similar to those which existed before mining. In overall terms, the predicted changes gradient along the alignment of the railway are relatively small and are not expected to result in any significant impacts on the operation of the railway.

11.2.2. Railway Creek Crossings

Predictions and Impact Assessments for the Railway Creek Crossings

The locations of the railway culverts are shown in **Figure 6.4**. A summary of the maximum predicted values of systematic subsidence, tilt and strain at the culverts, resulting from the extraction of the proposed longwalls, is provided in **Table 11.13**.

Table 11.13 - Predicted Systematic Subsidence, Tilt and Strain at the Railway Culverts Resulting from the Extraction of Longwalls 702 to 710

Label	Chainage (km)	Dia. (mm)	Maximum Predicted Subsidence (mm)	Maximum Predicted Cumulative Tilt (mm/m)	Maximum Predicted Tensile Strain (mm/m)	Maximum Predicted Compressive Strain (mm/m)
R-C4	70.870	1000	1345	1.9	0.4	1.2
R-C5	70.508	2000	1305	2.1	0.4	0.3
R-C6	69.868	1000	1350	1.7	0.4	0.3
R-C7	69.446	1000	1315	1.7	0.4	0.3
R-C8	69.000	1300	1345	2.4	0.4	1.6
R-C9	68.621	2x450	1210	1.4	0.4	0.3
R-C10	67.934	600	530	6.0	0.8	0.2

The values provided in the above table are the maximum predicted parameters within a 20 metre radius of each culvert, including the predicted movements resulting from the extraction of Longwalls 702 to 704. The predicted tilts are the maximum values at the completion of any or all longwalls, which ever are the greatest. The predicted strains are the maximum values which occur at anytime during or after the extraction of the proposed longwalls.

Culverts R-C4, C5, C8, C9 and C10 are located within drainage lines and could, therefore, also experience valley related movements resulting from the extraction of the proposed longwalls. A summary of the maximum predicted upsidence and closure movements at these culverts, after the extraction of the proposed longwalls, is provided in **Table 11.14**.

Table 11.14 - Maximum Predicted Upsidence and Closure Movements at the Railway Culverts

Label	Chainage (km)	Diameter (mm)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
R-C4	70.870	1000	105	55
R-C5	70.508	2000	85	60
R-C8	69.000	1300	100	55
R-C9	68.621	2 x 450	80	50
R-C10	67.934	600	40	30

All of the watercourses that cross the path of the railway within the SMP Area appear to pass through one of the culverts. There do not appear to be any watercourses within the SMP Area that have been infilled during the construction of the railway.

It is expected that mining-induced systematic tilts will not significantly impact the drainage flows in the culverts as the changes in grade are expected to be less than 1%. It is, however, recommended that the culverts be cleared of ballast prior to mining.

The potential impacts on railway infrastructure at creek crossings are manageable by monitoring and mitigatory or remedial measures. Management of risks associated with mine subsidence impacts on culverts will be provided for in the management plan for Longwalls 705 to 710.

For further detail on impact assessments for the railway creek crossings refer **Appendix A**.

11.2.3. Railway Cuttings

Predictions and Impact Assessments for the Railway Cuttings

The locations of the railway cuttings are shown in **Figure 6.4**. A summary of the maximum predicted values of systematic subsidence, tilt and strain at the cuttings, resulting from the extraction of the proposed longwalls, is provided in **Table 11.15**.

Table 11.15 - Predicted Systematic Subsidence, Tilt and Strain at the Railway Cuttings Resulting from the Extraction of Longwalls 702 to 710

Cutting No.	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Tensile Strain (mm/m)	Maximum Predicted Compressive Strain (mm/m)
Railway Cutting 1	< 20	0.1	< 0.1	< 0.1
Railway Cutting 2	1340	1.9	0.4	1.1
Railway Cutting 3	1345	4.9	1.0	1.7
Railway Cutting 4	1325	4.2	1.1	0.3
Railway Cutting 5	1450	6.6	1.1	1.5

The values provided in the above table are the maximum predicted parameters within a 20 metre radius of each end and mid-length of each cutting, including the predicted movements resulting from the extraction of Longwalls 702 to 704. The predicted tilts are the maximum values at the completion of any or all longwalls, which ever are the greatest. The predicted strains are the maximum values which occur at anytime during or after the extraction of the proposed longwalls.

Cuttings 3 to 5 are located directly above proposed Longwalls 705 to 710 and these cuttings are relatively small in height and well battered from the track. The cuttings consist of clay and weathered shale, which are unlikely to represent a safety risk should any material become loose. It is recommended, however, that a geotechnical assessment be carried out of the cuttings, with recommendations for any preventive works or monitoring measures.

The potential impacts to all cuttings are considered manageable by monitoring and mitigatory or remedial measures to maintain the safe operation of the Railway. Management of risks associated with mine subsidence impacts on cuttings will be provided for in the management plan for the proposed Longwalls 705 to 710.

For further detail on impact assessments for the railway cuttings refer **Appendix A**.

11.3. SYDNEY CATCHMENT AUTHORITY INFRASTRUCTURE

The locations of the Sydney Catchment Authority infrastructure in the vicinity of the proposed longwalls are shown in **Figure 6.6**. The predictions and impact assessments for the Sydney Catchment Authority infrastructure are provided in the following sections.

11.3.1. Predictions and Impact Assessments for the Upper Canal

The Upper Canal is situated east of the general SMP Area and is located at a distance of 500 metres east of Longwall 705, at its closest point to the proposed longwalls. The Upper Canal is located outside the predicted 20 mm subsidence contour and is unlikely, therefore, to be subjected to any significant systematic subsidence movements resulting from the extraction of the proposed longwalls, even if the predicted movements were increased by factors of up to 2 times.

The Upper Canal could be subjected to very small far-field horizontal movements as a result of the extraction of the proposed longwalls. Far-field horizontal movements have, in the past, been observed at similar distances as the canal is from the proposed longwalls, however, these movements tend to be bodily movements associated with very low levels of strain. It is unlikely, therefore, that the Upper Canal would be impacted by far-field horizontal movements resulting from the extraction of the proposed longwalls, even if the predicted movements were increased by factors of up to 2 times.

It is expected that Upper Canal would remain in a serviceable condition during and after the extraction of the proposed Longwalls 705 to 710.

11.3.2. Predictions and Impact Assessments for the Wrought Iron Aqueducts

The Upper Canal crosses Mallaty Creek, Leafs Gully and Nepean Creek via 3 wrought iron aqueducts, the locations of which are shown in **Figure 6.6**. A summary of the maximum predicted total subsidence, upsidence and closure movements at these aqueducts, after the extraction of the proposed longwalls, is provided in **Table 11.16**.

Table 11.16 - Maximum Predicted Total Subsidence Upsidence and Closure Movements at the Wrought Iron Aqueducts Resulting from the Extraction of Longwalls 702 to 710

Wrought Iron Aqueduct	Crossing	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
A4	Mallaty Creek	< 5	5	5
A5	Leafs Gully	< 5	5	10
A6	Nepean Creek	< 5	< 5	< 5

It is recommended that the predicted movements at the Wrought Iron Aqueducts, resulting from the extraction of the proposed longwalls, are reviewed by the SCA and that any necessary mitigation measures are implemented. Mitigation measures have been previously provided at this the Mallaty Creek Aqueduct (A4) to accommodate the predicted movements resulting from the extraction of West Cliff Longwalls 29 to 33.

The wrought iron aqueducts across Mallaty Creek, Leafs Gully, Nepean Creek could be subjected to very small far-field horizontal movements as a result of the extraction of the proposed longwalls. The far-field horizontal movements at these aqueducts are expected to be bodily movements associated with very low levels of strain and are unlikely, therefore, to result in a significant impact, even if the predicted movements were increased by factors of up to 2 times.

With the implementation of any necessary management strategies, it is expected that wrought iron aqueducts can be maintained in a safe and serviceable condition during and after the extraction of the proposed Longwalls 705 to 710.

11.3.3. Predictions and Impact Assessments for the Concrete Aqueducts

The Upper Canal crosses 2 unnamed creeks via two concrete aqueducts, referred to as Aqueducts C and D, the locations of which are shown in **Figure 6.6**. A summary of the maximum predicted total subsidence, upsidence and closure movements at these aqueducts, after the extraction of the proposed longwalls, is provided in **Table 11.17**.

Table 11.17 - Maximum Predicted Total Subsidence Upsidence and Closure Movements at the Concrete Aqueducts Resulting from the Extraction of Longwalls 702 to 710

Concrete Aqueduct	Crossing	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
C	Unnamed Creek 1	< 5	5	15
D	Unnamed Creek 2	< 5	10	20

It is recommended that the predicted movements at the Concrete Aqueducts, resulting from the extraction of the proposed longwalls, are reviewed by the SCA and that any necessary mitigation measures are implemented. Mitigation measures have been provided at concrete Aqueducts C and D to accommodate the predicted movements resulting from the extraction of West Cliff Longwalls 29 to 33.

The concrete aqueducts could be subjected to very small far-field horizontal movements as a result of the extraction of the proposed longwalls. The far-field horizontal movements at the concrete aqueducts are expected to be bodily movements associated with very low levels of strain and are unlikely, therefore, to result in impact, even if the predicted movements were increased by factors of up to 2 times.

It is expected that concrete Aqueducts C and D would remain in a safe and serviceable condition during and after the extraction of the proposed Longwalls 705 to 710.

11.3.4. Predictions and Impact Assessments on the Culverts and Flumes

The culverts and flumes along the Upper Canal are located outside the predicted 20 mm subsidence contour and are unlikely, therefore, to be subjected to any significant systematic subsidence movements resulting from the extraction of the proposed longwalls, even if the predicted movements were increased by factors of up to 2 times.

The culverts and flumes are located in small drainage ditches, which have very small effective valley heights, and are unlikely, therefore, to be subjected to any significant valley related movements resulting from the extraction of the proposed longwalls, even if the predicted movements were increased by factors of up to 2 times.

The culverts and flumes could be subjected to very small far-field horizontal movements as a result of the extraction of the proposed longwalls. The far-field horizontal movements at the culverts and flumes are expected to be bodily movements associated with very low levels of strain and are unlikely, therefore, to result in impact, even if the predicted movements were increased by factors of up to 2 times.

It is expected that culverts and flumes would remain in a serviceable condition during and after the extraction of the proposed Longwalls 705 to 710.

11.3.5. Predictions and Impact Assessment for the Maintenance Road and Bridges

The maintenance road associated with the Upper Canal is located outside the predicted 20 mm subsidence contour and is unlikely, therefore, to be subjected to any significant systematic subsidence movements resulting from the extraction of the proposed longwalls, even if the predicted movements were increased by factors of up to 2 times.

There are a number of bridges where the maintenance road crosses the drainage lines, the locations of which are shown in **Figure 6.5**. All of the bridges are located outside the general SMP Area. A summary of the maximum predicted total subsidence, upsidence and closure movements at the bridges, after the extraction of the proposed longwalls, is provided in **Table 11.18**.

Table 11.18 - Maximum Predicted Total Subsidence, Upsidence and Closure Movements at the Bridges Resulting from the Extraction of Longwalls 702 to 710

Bridge	Crossing	Maximum Predicted Subsidence (mm)	Maximum Predicted Upsidence (mm)	Maximum Predicted Closure (mm)
RB4	Mallaty Creek	< 5	5	5
RB5	Leafs Gully	< 5	5	10
RB6	Nepean Creek	< 5	< 5	< 5

It is recommended that the predicted movements at the bridges, resulting from the extraction of the proposed longwalls, are reviewed by the SCA and that any necessary mitigation measures are implemented.

With the implementation of any necessary mitigation measures, it is expected that the bridges can be maintained in a safe and serviceable condition during and after the extraction of the proposed Longwalls 705 to 710.

11.3.6. Predictions and Impact Assessments for Devines Tunnel

Devines Tunnel Nos. 1 and 2 are located outside the general SMP Area and are at distances of 500 metres and 570 metres, respectively, to the east of Longwall 705 and 706, respectively, at their closest point to the proposed longwalls. It is unlikely, therefore, that the tunnels would be subjected to any significant systematic subsidence movements resulting from the extraction of the proposed longwalls, even if the predictions were increased by factors of 2 times.

The tunnels could be subjected to very small far-field horizontal movements as a result of the extraction of the proposed longwalls. Far-field horizontal movements have, in the past, been observed at similar distances as the tunnels are from the proposed longwalls, however, these movements tend to be bodily movements associated with very low levels of strain. It is unlikely, therefore, that the tunnels would be impacted by far-field horizontal movements resulting from the extraction of the proposed longwalls.

It is expected that Devines Tunnels Nos. 1 and 2 would remain in a safe and serviceable condition during and after the extraction of the proposed Longwalls 705 to 710.

11.4 WATER AND GAS PIPELINES

The United Utilities treated water gravity main, the Alinta EGP and AGN Natural Gas Pipelines and the Gorodok Ethane Pipeline are all located within an easement located east of the SMP Area, the location of which is shown in **Figure 6.6**.

The pipeline easement is located outside the predicted 20 mm subsidence contour and it is unlikely, therefore, that the water and gas pipelines would be subjected to any significant systematic subsidence movements resulting from the extraction of the proposed longwalls, even if the predicted movements were increased by factors of up to 2 times.

The pipeline easement is located at a distance of 1.7 kilometres east of Longwalls 705 and 710, at its closest point to the proposed longwalls. It would be unlikely, therefore, that the water and gas pipelines would be subjected to any significant valley related upsidence and closure movements resulting from the extraction of the proposed longwalls, even if the predicted movements were increased by factors of up to 2 times.

The water and gas pipelines could be subjected to very small far-field horizontal movements as a result of the extraction of the proposed longwalls. Far-field horizontal movements have, in the past, been observed at similar distances as the easement is from the proposed longwalls, however, these movements tend to be bodily movements associated with very low levels of strain. It is unlikely, therefore, that the water and gas pipelines would be impacted by far-field horizontal movements resulting from the extraction of the proposed longwalls, even if the predicted movements were increased by factors of up to 2 times.

11.5 ELECTRICAL SERVICES

The electrical infrastructure within the SMP Area comprise a 66 kV powerline, a number of 11 kV powerlines and low voltage consumer lines, all of which are owned by Integral Energy. The locations of the powerlines within the SMP Area are shown in **Figure 6.7**. The predictions and impact assessments for the powerlines are provided in the following sections.

11.5.1 Powerlines

The locations of the powerlines within the SMP Area are shown in **Figure 6.7**. The predictions and impact assessments for the powerlines are provided in the following sections.

A summary of the maximum predicted values of cumulative systematic subsidence, tilt along and tilt across the alignments of the 66 kV powerline and 11 kV powerline Branches 1 to 3, after the extraction of each proposed longwall, is provided in **Table 11.19**.

Table 11.19 - Maximum Predicted Cumulative Systematic Subsidence, Tilt Along and Tilt Across the Alignments of the Powerlines Resulting from the Extraction of Longwalls 702 to 710

Location	Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Tilt along Alignment (mm/m)	Maximum Predicted Cumulative Tilt across Alignment (mm/m)
66 kV Powerline	After LW708	< 20	< 0.1	0.1
	After LW709	290	1.3	3.8
	After LW710	970	5.1	3.6
11 kV Powerline (Branch 1)	After LW705	1345	5.3	4.7
	After LW706	1410	6.5	3.2
	After LW707	1415	6.4	2.9
	After LW708	1415	5.5	3.0
	After LW709	1415	5.9	4.4
	After LW710	1415	4.8	5.6
11 kV Powerline (Branch 2)	After LW705	1250	5.1	2.8
	After LW706	1320	5.7	3.1
	After LW707	1350	6.2	3.5
	After LW708	1430	5.9	3.3
	After LW709	1500	5.6	3.1
	After LW710	1510	5.7	3.2
11 kV Powerline (Branch 3)	After LW705	< 20	< 0.1	0.1
	After LW706	65	0.4	0.5
	After LW707	985	4.7	4.8
	After LW708	1330	4.6	5.5
	After LW709	1425	5.4	4.0
	After LW710	1450	5.7	3.5

The values provided in the above table are the maximum predicted cumulative systematic subsidence parameters which occur along the powerlines within the general SMP Area, including the predicted movements resulting from the extraction of Longwalls 702 to 704.

The powerlines will also be subjected to travelling tilts and strains as the extraction faces of the proposed longwalls pass beneath them. A summary of the maximum predicted travelling tilts at the 66 kV powerline and the 11 kV powerline Branches 1 to 3, during the extraction of the proposed longwalls, is provided in **Table 11.20**.

Table 11.20 - Maximum Predicted Travelling Tilts at the Powerlines during the Extraction of the Proposed Longwalls 705 to 710

Location	Longwall	Maximum Predicted Travelling Tilt (mm/m)
66 kV Powerline	During LW709	0.9
	During LW710	2.7
11 kV Powerline (Branch 1)	During LW705	3.5
	During LW706	3.2
	During LW707	3.2
	During LW708	3.1
	During LW709	3.4
	During LW710	3.0
11 kV Powerline (Branch 2)	During LW705	2.6
	During LW706	2.9
	During LW707	3.3
	During LW708	3.2
	During LW709	3.0
	During LW710	3.0
11 kV Powerline (Branch 3)	During LW705	< 0.1
	During LW706	0.2
	During LW707	2.9
	During LW708	3.0
	During LW709	2.8
	During LW710	2.6

11.5.2. Impact Assessments for the Powerlines

The cables along the 66 kV powerline, 11 kV powerlines and low voltage consumer lines are not affected by ground strains, as they are supported by the poles above ground level. The cables can, however, be affected by the changes in the bay lengths, i.e. the distances between the poles at the height of the cables, which result from mining induced differential subsidence, horizontal ground movements and lateral movements at the tops of the poles caused by tilting of the poles. The stabilities of the poles can also be affected by the tilting of the poles and the changes in the catenary profiles of the cables.

Refer **Appendix A** for further detail on subsidence, tilts and strains for the powerlines.

11.5.3. Impact Assessments for the Powerlines Based on Increased Predictions

If the predicted tilts were increased by factors of up to 2 times, the maximum predicted tilt at the powerlines within the SMP Area would be 16 mm/m. As described previously, overhead powerlines can typically tolerate tilts of up to 20 mm/m at the poles, without significant impacts on the cables or poles. It is unlikely, therefore, that the powerlines would experience significant impacts resulting from the extraction of the proposed longwalls, even if the predicted tilts were exceeded by factors of up to 2 times. It is possible, however, that the likelihood of impacts where the consumer lines connect to the houses would increase accordingly.

11.6. OPTICAL FIBRE CABLES

The optical fibres cable generally follows the alignments of the HW2 Hume Highway and the Main Southern Railway within the SMP Area, the locations of which are shown in **Figure 6.8**. The predictions and impact assessments for the optical fibre cables are provided in the following sections.

11.6.1 Predictions for the Optical Fibre Cables

A summary of the maximum predicted values of cumulative systematic subsidence, tilt and strain along the alignment of the optical fibre cables, after the extraction of each proposed longwall, is provided in **Table 11.21**.

Table 11.21 - Maximum Predicted Cumulative Systematic Subsidence, Tilt and Strain along the Optical Fibre Cable Resulting from the Extraction of Longwalls 702 to 710

Location	Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Tilt (mm/m)	Maximum Predicted Cumulative Tensile Strain (mm/m)	Maximum Predicted Cumulative Compressive Strain (mm/m)
Telstra Railway	After LW705	1270	4.6	0.8	1.2
	After LW706	1350	6.7	1.0	1.6
	After LW707	1430	6.5	1.1	1.6
	After LW708	1450	5.7	1.1	1.6
	After LW709	1450	4.6	1.2	1.6
	After LW710	1450	5.6	1.2	1.6
Telstra Highway	After LW705	1325	4.8	1.4	1.5
	After LW706	1410	6.2	1.2	2.3
	After LW707	1490	6.1	1.2	1.9
	After LW708	1495	5.9	1.2	1.7
	After LW709	1495	5.8	1.2	1.7
	After LW710	1495	5.8	1.2	1.7
Optus	After LW705	1320	4.7	1.3	1.1
	After LW706	1410	6.2	1.5	1.7
	After LW707	1490	6.1	1.5	1.5
	After LW708	1495	5.9	1.5	1.5
	After LW709	1495	5.7	1.5	1.4
	After LW710	1495	5.6	1.5	1.4
Powertel	After LW705	1290	5.8	0.6	1.4
	After LW706	1405	5.7	0.8	1.3
	After LW707	1490	5.0	0.8	1.2
	After LW708	1495	5.5	1.5	1.4
	After LW709	1495	5.8	0.9	1.4
	After LW710	1495	5.7	1.3	1.9
NextGen	After LW705	1315	4.9	0.5	0.9
	After LW706	1410	6.2	0.7	1.9
	After LW707	1490	6.0	0.9	1.5
	After LW708	1495	5.9	0.9	1.5
	After LW709	1495	5.8	1.0	1.4
	After LW710	1495	5.8	1.0	1.4

The cables will also be subjected to travelling tilts and strains as the extraction faces of the proposed longwalls pass beneath them. A summary of the maximum predicted travelling tilts and strains at the optical fibre cables, during the extraction of each proposed longwall, is provided in **Table 11.22**.

Table 11.22 - Maximum Predicted Travelling Tilts and Strains at the Optical Fibre Cables during the Extraction of Longwalls 705 to 710

Location	Longwall	Maximum Predicted Travelling Tilt (mm/m)	Maximum Predicted Travelling Tensile Strain (mm/m)	Maximum Predicted Travelling Compressive Strain (mm/m)
Telstra Railway	During LW705	3.0	0.4	-0.3
	During LW706	3.1	0.4	-0.3
	During LW707	3.0	0.4	-0.3
	During LW708	3.0	0.4	-0.3
	During LW709	2.8	0.4	-0.3
	During LW710	2.9	0.4	-0.3
Telstra Highway	During LW705	3.4	0.5	0.4
	During LW706	3.2	0.4	0.3
	During LW707	3.1	0.4	0.3
	During LW708	3.0	0.4	0.3
	During LW709	2.9	0.4	0.3
	During LW710	3.0	0.4	0.3
Optus	During LW705	3.4	0.5	0.4
	During LW706	3.2	0.4	0.3
	During LW707	3.2	0.4	0.3
	During LW708	3.0	0.4	0.3
	During LW709	2.9	0.4	0.3
	During LW710	3.1	0.4	0.3
Powertel	During LW705	3.3	0.4	0.3
	During LW706	3.1	0.4	0.3
	During LW707	2.9	0.4	0.3
	During LW708	2.9	0.4	0.3
	During LW709	2.9	0.4	0.3
	During LW710	3.0	0.4	0.3
NextGen	During LW705	3.3	0.5	0.3
	During LW706	3.2	0.4	0.3
	During LW707	3.1	0.4	0.3
	During LW708	3.0	0.4	0.3
	During LW709	2.9	0.4	0.3
	During LW710	3.0	0.4	0.3

The optical fibre cables cross a number of drainage lines and could be subjected to valley related movements in these locations. A summary of the maximum predicted upsidence and closure movements at the drainage line crossings, after the extraction of all the proposed longwalls, is provided in **Table 11.23**.

Table 11.23 - Maximum Predicted Upsidence and Closure Movements at the Drainage Line Crossings Resulting from the Extraction of Longwalls 702 to 710

Crossing	Telstra Railway	Telstra Railway	Optus	Powertel	NextGen	Effective Valley Height (m)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
1						5	< 20	< 20
2						5	< 20	< 20
3						5	20	< 20
4						5	40	30
5						5	40	35
6						5	85	40
7						5	115	55
8						5	105	55
9						5	90	55
10						5	105	60
11						5	90	60
12						5	90	60
13						5	80	60
14						5	80	60
15						5	80	60
16						5	80	60
17						5	80	55
18						5	100	55
19						5	120	55
20						5	80	60
21						5	85	50
22						5	85	50
23						5	60	40
24						5	70	45
25						5	60	35
26						5	< 20	< 20
27						5	25	25
28						5	< 20	< 20
29						5	< 20	< 20

11.6.2 Impact Assessments for the Optical Fibre Cable

The optical fibre cables within the SMP Area are direct buried and, therefore, will not be affected by the tilts resulting from the extraction of the proposed longwalls. The cables, however, are likely to experience the ground strains resulting from the extraction of the proposed longwalls.

Refer **Appendix A** for further detail for the optical fibre cable.

11.6.3 Impact Assessments for the Optical Fibre Cable Based on Increased Predictions

If the predicted systematic movements along the optical fibre cables were increased by factors of up to 2 times, the maximum predicted systematic tensile strain along the cables would still be less than 4 mm/m and unlikely, therefore, to result in a significant impacts on the cables. It would be possible, however, that elevated strains could occur at any anchor points along the cable during the extraction of the proposed longwalls. In addition to this, the maximum predicted compressive strains along the cables would be greater than 4 mm/m and could, therefore, be of sufficient magnitude to result in attenuation or transmission loss. It is expected, however, that the cables could be maintained in serviceable conditions by monitoring using OTDR and the implementation of suitable mitigation measures if elevated strains were detected.

If the predicted upsidence and closure movements along the optical fibre cables were increased by factors up to 2 times, the likelihood of impacts at the drainage line crossings would increase accordingly. It should be noted, however, that the method used to predict the valley related movements adopts very conservative prediction curves and it is unlikely, therefore, that these movements would be exceeded by any more than 15 %. In addition to this, the cables can be maintained in serviceable conditions by monitoring using OTDR and the implementation of suitable mitigation measures if elevated strains were detected.

11.7. TELECOMMUNICATIONS SERVICES

The locations of the telecommunications services within the SMP Area are shown in **Figure 6.8**. The predictions and impact assessments for the telecommunications services are provided in the following sections.

11.7.1 Copper Telecommunications Cables

Predictions for Copper Telecommunications Cables

The copper telecommunications cables within the SMP Area generally follow the alignments of Moreton Park Road, Menangle Road, the Main Southern Railway and the HW2 Hume Highway, refer **Figure 6.8**.

A summary of the maximum predicted values of cumulative systematic subsidence, tilt and strain along the copper telecommunications cables, after the extraction of each proposed longwall, is provided in **Table 11.24**.

Table 11.24 - Maximum Predicted Cumulative Systematic Subsidence, Tilt and Strain along the Copper Telecommunications Cables Resulting from the Extraction of Longwalls 702 to 710

Location	Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Tilt (mm/m)	Maximum Predicted Cumulative Tensile Strain (mm/m)	Maximum Predicted Cumulative Compressive Strain (mm/m)
Copper Cables	After LW705	1350	5.2	1.1	1.8
	After LW706	1430	6.3	1.1	1.8
	After LW707	1490	6.5	1.1	1.8
	After LW708	1495	6.0	1.1	1.8
	After LW709	1495	6.4	1.1	1.8
	After LW710	1495	7.9	1.1	2.2

The values provided in the above table are the maximum predicted cumulative systematic subsidence parameters which occur along the copper telecommunications cables within the general SMP Area, including the predicted movements resulting from the extraction of Longwalls 702 to 704.

The cables will also be subjected to travelling tilts and strains as the extraction faces of the proposed longwalls pass beneath them. A summary of the maximum predicted travelling tilts and strains at the copper telecommunications cables, during the extraction of each proposed longwall, is provided in **Table 11.25**.

Table 11.25 - Maximum Predicted Travelling Tilts and Strains at the Copper Telecommunications Cables during the Extraction of Longwalls 705 to 710

Location	Longwall	Maximum Predicted Travelling Tilt (mm/m)	Maximum Predicted Travelling Tensile Strain (mm/m)	Maximum Predicted Travelling Compressive Strain (mm/m)
Copper Cables	During LW705	3.5	0.5	0.4
	During LW706	3.2	0.4	0.3
	During LW707	3.3	0.5	0.4
	During LW708	3.0	0.4	0.3
	During LW709	3.6	0.5	0.4
	During LW710	3.7	0.5	0.4

Impact Assessments for the Copper Telecommunications Cables

The copper telecommunication cables along Moreton Park Road, Menangle Road, other local roads and some consumer lines are aerial cables and, therefore, are not affected by ground strains, as they are supported by the poles above ground level.

The aerial cables can, however, be affected by the changes in the bay lengths, i.e. the distances between the poles at the height of the cables, which result from mining induced differential subsidence, horizontal ground movements and lateral movements at the tops of the poles caused by tilting of the poles. The stabilities of the poles can also be affected by the tilting of the poles and the changes in the catenary profiles of the cables.

Refer **Appendix A** for further details for the cables.

Impact Assessments for the Copper Telecommunications Cables Based on Increased Predictions

If the predicted systematic movements along the copper telecommunications cables were increased by factors of up to 2 times, the predicted systematic tilts along the aerial cables would still be less than 20 mm/m and the predicted tensile strains along the direct buried cables would still be less than 4 mm/m. It would still be unlikely, therefore, that there would by any significant impacts on the copper telecommunications cables, even if the predictions were exceeded by factors of up to 2 times.

It would be possible, however, that elevated strains could occur at any anchor points along the direct buried cables during the extraction of the proposed longwalls. It is unlikely at the magnitudes of the predicted systematic strains, however, that there would be a significant impact on the copper telecommunication cables at any anchor points, even if the predictions were exceeded by a factor of up to 2 times.

11.7.2 Mobile Phone Towers

Predictions for Mobile Phone Towers

The locations of the mobile phone tower sites are shown in **Figure 6.8**. A summary of the maximum predicted values of systematic subsidence, tilt and strain at the tower sites within the SMP Area, at any time during or after the extraction of the proposed longwalls, is provided in **Table 11.26**.

Table 11.26 - Maximum Predicted Systematic Subsidence, Tilt and Strain at the Mobile Phone Tower Sites within the SMP Area Resulting from the Extraction of the Proposed Longwalls

Tower Site	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative or Travelling Tilt (mm/m)	Maximum Predicted Cumulative or Travelling Tensile Strain (mm/m)	Maximum Predicted Cumulative or Travelling Compressive Strain (mm/m)
A	1125	2.1	0.3	0.3
B	1295	1.8	0.3	0.2

The values provided in the above table are the maximum predicted parameters within a 20 metre radius of each site, including the predicted movements resulting from the extraction of Longwalls 702 to 704. The predicted tilts and strains are the maximum values which occur anytime during or after the extraction of the proposed longwalls.

Impact Assessments for Mobile Phone Towers

The maximum predicted systematic tilt at the mobile phone tower sites is 2.1 mm/m (i.e. 0.2%), or a change in grade of 1 in 475. The maximum predicted tilt is very small and unlikely, therefore to affect the structural integrity or serviceability of the shed structures containing the equipment for the towers.

It is possible, however, that subsidence and tilt could affect the microwave link dishes which link each mobile phone tower site, as these are very sensitive to angular deviations. Based on the maximum predicted subsidence at the tower sites of 1300 mm over a minimum line of site distance of, say, 2 kilometres, the predicted angular deviation resulting from subsidence along is less than 0.1 degrees. The angular deviation resulting from the maximum predicted tilt at the tower sites of 2.1 mm/m is approximately 0.1 degrees.

The maximum angular deviation due to both subsidence and tilt at the tower sites is, therefore, approximately 0.2 degrees. It is expected that the angular deviation of the microwave dishes can be managed by making any necessary adjustments to the lines of sight as Longwalls 706 and 709 mine beneath the tower sites.

The maximum predicted systematic tensile and compressive strains at the mobile phone sites, resulting from the extraction of the proposed longwalls, are both 0.3 mm/m and the associated minimum radius of curvature is 50 kilometres.

The confidence levels assigned to the prediction of strain at a point are less than those assigned to the prediction of subsidence and tilt at a point. It is possible, therefore, that the actual strains at the mobile phone tower sites could be greater or less than those predicted.

It is expected, however, that the actual systematic strains at the mobile phone tower sites would be within the maximum predicted systematic tensile and compressive strains within the SMP Area, which are 1.3 mm/m and 2.3 mm/m, respectively.

11.8 GILBULLA CONFERENCE CENTRE

The Gilbulla Conference Centre comprises three main building structures (Refs. B14a, B14d and B14j), six associated rural building structures (Refs. B14b, B14e, B14k, B14m, B14n and B14o) and one house (Ref. B14c). The locations of all the building structures are shown in **Figure 6.9** and provided in **Appendix A**.

The predictions and impact assessments for the main conference centre building structures (Refs. B14a, B14d and B14j) are provided in the following sections. The predictions and impact assessments for the associated rural building structures and house are provided below.

11.8.1 Main Conference Centre Building Structures

Predictions for Main Conference Centre Building Structures

Predictions of systematic subsidence, tilt, curvature and strain have been made at the centroid and at the vertices of each main conference centre building structure, 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.

At these points, the maximum predicted values of systematic subsidence, tilt, curvature and strain have been determined, during and after the extraction of each proposed longwall, for each main conference centre building structure. An additional strain of 0.2 mm/m has been added to the magnitude of the predicted strains, where the predicted subsidence is greater than 20 mm, to account for the scatter which is generally observed in strain profiles.

A summary of the maximum predicted systematic subsidence, tilt and strains for the main conference centre building structures within the SMP Area, at any time during or after the extraction of the proposed longwalls, is provided in **Table 11.27**.

Table 11.27 - Maximum Predicted Systematic Subsidence, Tilt and Strain for the Main Conference Centre Building Structures Resulting from the Extraction of Longwalls 702 to 710

Location	Structure	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Tilt (mm/m)	Maximum Predicted Cumulative Tensile Strain (mm/m)	Maximum Predicted Cumulative Compressive Strain (mm/m)
Gilbulla	B14a	< 20	0.1	0.1	< 0.1
Conference	B14d	50	0.4	0.1	< 0.1
Centre	B14j	< 20	0.3	0.1	< 0.1

The main conference centre building structures are located 260 metres north of proposed Longwall 710, at their closest points to the proposed longwalls. It is unlikely, therefore, that these structures would be subjected to any significant travelling tilts or strains.

Impact Assessments for the Main Conference Centre Building Structures

The maximum predicted systematic tilt at the main conference centre building structures is 0.4 mm/m (i.e. < 0.1%), or a change in grade of 1 in 2500. The maximum predicted systematic tilts are very small and unlikely, therefore, to result in any significant impacts on these structures.

The maximum predicted systematic strains at the main conference centre building structures is 0.1 mm/m tensile and the associated minimum radius of curvature is greater than 150 kilometres. It is expected that the measured strains at these structures would less than survey tolerance and unlikely, therefore, to result in any significant impacts on these structures.

Impact Assessments for the Main Conference Centre Building Structures Based on Increased Predictions

If the predicted systematic tilts were increased by factors of up to 2 times, the maximum predicted systematic tilts at the main conference centre building structures would still be less than 1% and unlikely, therefore, to result in any significant impact on these structures.

If the predicted systematic strains were increased by factors of up to 2 times, the maximum predicted systematic strains at the main conference centre building structures would still be less than survey tolerance and unlikely, therefore, to result in any significant impact on these structures.

11.9 FARM LAND AND FACILITIES

The following sections provide the subsidence predictions and impact assessments for the farm land and facilities within the SMP Area, due to the extraction of the proposed Longwalls 705 to 710.

11.9.1 Rural Building Structures

There are 393 rural building structures (Structure Type R) that have been identified within the SMP Area, which include farm sheds, garages and other non-residential structures such as the Gilbulla Conference centre. The locations of the rural building structures are shown in **Appendix A**. The impact assessments for the rural building structures within the SMP Area are provided in the following sections.

Predictions for the Rural Building Structures

The maximum predicted subsidence and the impact assessments for tilt and strain for each rural building structure within the SMP Area are provided in **Appendix A**. A summary of the maximum predicted subsidence and tilts for the rural building structures within the SMP Area, after the extraction of each proposed longwall, is provided in **Table 11.28**. A summary of the maximum predicted curvatures and systematic strains for the rural building structures within the SMP Area, after the extraction of each proposed longwall, is provided in **Table 11.29**.

Table 11.28 - Summary of the Maximum Predicted Subsidence and Tilts for the Rural Building Structures within the SMP Area after the Extraction of Each Proposed Longwall

Longwall	Predicted Subsidence (mm)				Predicted Tilt (mm/m)			
	< 500	≥ 500 & < 1000	≥ 1000 & < 1500	≥ 1500	< 5	≥ 5 & < 7	≥ 7 & < 10	≥ 10
After LW705	356	14	23	0	385	8	0	0
After LW706	336	28	29	0	384	9	0	0
After LW707	309	35	49	0	375	18	0	0
After LW708	270	44	79	0	361	32	0	0
After LW709	232	46	115	0	373	20	0	0
After LW710	182	67	144	0	377	16	0	0

Table 11.29 - Summary of the Maximum Predicted Curvatures and Systematic Strains for the Rural Building Structures within the SMP Area after the Extraction of Each Proposed Longwall

Longwall	Predicted Curvature (1/km)				Predicted Systematic Strain (mm/m)					
	< 0.05	≥ 0.05 & < 0.10	≥ 0.10 & < 0.15	≥ 0.15	< 0.25	≥ 0.25 & < 0.5	≥ 0.5 & < 1.0	≥ 1.0 & < 1.5	≥ 1.5 & < 2.0	≥ 2.0
After LW705	352	24	9	8	334	17	20	12	9	1
After LW706	334	37	10	12	322	11	34	13	12	1
After LW707	306	46	24	17	294	16	39	22	21	1
After LW708	263	62	45	23	251	19	50	38	34	1
After LW709	213	89	59	32	184	50	67	56	35	1
After LW710	181	102	69	41	143	72	67	75	35	1

Impact Assessments for the Rural Building Structures

The majority of the rural building structures within the SMP Area are of lightweight construction. It has been found from longwall mining experience, that tilts less than 10 mm/m (i.e. Category A to Category C) generally do not result in any significant impacts on rural building structures.

It is unlikely, therefore, that the maximum predicted tilts at the rural building structures within the SMP Area would be of sufficient magnitude to result in any significant impacts on the stability of these structures. It is possible, however, that the larger predicted tilts could result in some minor serviceability impacts, including door swings and issues with roof gutter and pavement drainage. It is expected, that any impacts on the rural building structures as a result of tilts of these magnitudes could easily be remediated using normal building maintenance techniques.

Refer **Appendix A** for further detail on impact assessments for rural building structures.

Impact Assessments for the Rural Building Structures Based on Increased Predictions

If the predicted systematic subsidence parameters were to be increased by factors of 1.25 to 2 times, the potential impacts on the rural building structures would increase accordingly. A summary of the impact assessments for tilt and strain for the rural building structures based on increased predictions are provided in **Table 11.30**.

Table 11.30 - Summary of Tilt and Strain Impact Assessments for the Rural Building Structures within the SMP Area Based on Increased Predictions

Increased Prediction	Number of Structures. with Tilt Impact Assessment for Increased Predictions				Number of Structures with Strain Impact Assessment for Increased Predictions					
	Cat A	Cat B	Cat C	Cat D	Cat 0	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
x 1.25	327	57	9	0	319	57	9	8	0	0
x 1.50	294	73	26	0	301	70	10	12	0	0
x 1.75	262	65	57	9	283	80	16	14	0	0
x 2.00	242	60	75	16	265	87	26	15	0	0

If the predicted systematic tilts were increased by a factor of 1.5 times, 26 rural building structures within the SMP Area (i.e. 7% of the total) would be assessed to experience a Category C tilt impact. As described previously, tilts less than 10 mm/m (i.e. Category A to Category C) generally do not result in any significant impacts on rural building structures. It is possible, however, that the some structures could experience minor serviceability impacts, including door swings and issues with roof gutter and pavement drainage. It would still be expected, however, that any impacts on the rural building structures as a result of tilt could easily be remediated using normal building maintenance techniques.

If the predicted systematic strains were increased by a factor of 1.5 times, 80 rural building structures within the SMP Area (i.e. 20% of total) would be assessed to experience a Category 1 or 2 strain impact (i.e. very slight or slight impact) and 12 rural building structures (i.e. 3% of total) would be assessed to experience a Category 3 strain impact (i.e. moderate impact). Based on the experience at Tahmoor Colliery, it would still be expected that all structures would remain safe and that the impacts could be repaired using normal building maintenance techniques.

11.9.2 Tanks

There are 243 tanks (Structure Type T) that have been identified within the SMP Area. The locations of the tanks are provided in **Appendix A**. The impact assessments for the tanks within the SMP Area are provided in the following sections.

Predictions for the Tanks

Predictions of systematic subsidence, tilt and strain have been made at the centroid and at points located around the perimeter of each tank, as well as at points located at a distance of 20 metres from the perimeter of each tank. The maximum predicted systematic subsidence parameters for each tank within the SMP Area are provided in **Appendix A**. The tanks are located across the SMP Area and, therefore, are subjected to the full range of predicted systematic subsidence movements.

Impact Assessments for the Tanks

Tilt can affect the serviceability of tanks by altering the water levels in the tanks, which can in turn affect the minimum level of water which can be released from the taps. The maximum predicted systematic tilt at the tanks within the SMP Area of 6.8 mm/m represents a change in grade of less than 1% and is unlikely, therefore, to result in a significant impact on the serviceability of the tanks.

The maximum predicted systematic tensile and compressive strains at the tanks are 1.2 mm/m and 2.0 mm/m, respectively. The ground strains are unlikely to be transferred into the tanks where they are founded on a ground slab or on the natural ground. In these cases, it is unlikely that the tanks would be impacted by the predicted systematic strains.

Refer **Appendix A** for further detail on impact assessments at the tanks.

Impact Assessments for the Tanks Based on Increased Predictions

If the predicted systematic subsidence parameters at the tanks were increased by factors of up to 2 times, the maximum predicted tilt at the tanks would be 14 mm/m, which is slightly greater than 1% and unlikely, therefore, to result in a significant impact on the serviceability of the tanks.

It would be unlikely that the ground strains would be transferred into the tanks themselves, even if the predicted systematic strains were increased by factors of up to 2 times. The likelihood of impacts on the associated buried water pipelines would increase accordingly. At these magnitudes of predicted strain, however, it would be expected that any impacts would still be of a minor nature and could be easily repaired. With these remediation measures in place, it would be unlikely that there would be a significant impact on the pipelines associated with the tanks.

11.9.3 Fences

There are a number of fences within the SMP Area which are constructed in a variety of ways, generally using either timber or metal materials. The fences are located across the SMP Area and are likely to be subjected to the full range of predicted systematic subsidence parameters.

Wire fences can be affected by tilting of the fence posts and by changes of tension in the fence wires due to strain as mining occurs. These types of fences are generally flexible in construction and can usually tolerate tilts of up to 10 mm/m and strains of up to 5 mm/m without significant impacts. It is unlikely, therefore, that the wire fences within the SMP Area would be impacted by the predicted systematic subsidence parameters resulting from the extraction of the proposed longwalls. Any impacts on the wire fences which occur as the result of mining are likely to be of a minor nature and relatively easy to remediate by re-tensioning the fencing wire, straightening the fence posts, and if necessary, replacing some sections of fencing.

Colorbond and timber paling fences are more rigid than wire fences and, therefore, are more susceptible to impacts resulting from mine subsidence movements. It is possible that these types of fences could be impacted at the magnitudes of predicted systematic strain. Any impacts on Colorbond or timber paling fences are expected to be of a minor nature and relatively easy to remediate or, where necessary, affected sections of fence replaced.

The assessed impacts on the fences resulting from the predicted systematic subsidence parameters can be managed with the implementation of suitable management strategies.

Refer **Appendix A** for predicted systematic subsidence parameters for the tanks.

11.9.4 Farm Dams

There are 286 farms dams (Structure Type D) that have been identified within the SMP Area. The locations of the farm dams are shown in **Appendix A**. The predictions and impact assessments for the farm dams are provided in the following sections.

Predictions for the Farm Dams

Predictions of systematic subsidence, tilt and strain have been made at the centroid and at points located around the perimeter of each farm dam, as well as at points located at a distance of 20 metres from the perimeter of each farm dam.

The maximum predicted values of systematic subsidence, tilt and strain have been determined for each farm dam within the SMP Area, during and after the extraction of each proposed longwall. The maximum predicted systematic subsidence parameters at each farm dam are provided in **Appendix A**.

The 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 systematic subsidence movements and, therefore, are not significant.

Impact Assessments for the Farm Dams

Refer **Appendix A** for maximum predicted strains at the farm dams.

The maximum predicted systematic tilt at the farm dams within the SMP Area, at any time during or after the extraction of the proposed longwalls, is 7.9 mm/m (i.e.: 0.8%), or a change in grade in 1 in 125. 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 them to overflow, or affect the stability of the dam walls.

The maximum predicted changes in freeboard at the farm dams within the SMP Area were conservatively determined by applying the maximum predicted systematic tilts along the longest sides of the dams. The maximum predicted changes in freeboard at the farm dams are provided in **Appendix A**.

The maximum predicted change in freeboard at the farm dams is 500 mm, which occurs at Dam B11d03 after the extraction of proposed Longwall 710. The predicted changes in freeboard are relatively small and unlikely to result in any significant impacts on the stability of the dam walls, or any significant reductions in the capacities of the farm dams.

The maximum predicted systematic tensile and compressive strains at the farm dams within the SMP Area, at any time during or after the extraction of the proposed longwalls, are 1.3 mm/m and 2.3 mm/m, respectively. The minimum radii of curvatures associated with the maximum predicted systematic tensile and compressive strains at the farm dams are 12 kilometres and 6.5 kilometres, respectively.

Farm dams, such as those identified within the SMP Area, 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 impact, because of their inherent elasticity. It is unlikely, therefore, that the maximum predicted systematic strains, resulting from the extraction of the proposed longwalls, would result in a significant impact on the farm dams within the SMP Area.

It is possible, however, that some minor cracking or leakage of water may occur in the farm dam walls which are subjected to the higher strains, though any minor cracking or leakages can be easily 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 and that any loss would flow into the tributary in which the dam was formed and not result in a significant impact on the environment.

There is a possibility that high concentrations of strain could occur at faults, fissures and other geological features, or points of weaknesses 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 could occur, but the likelihood of this occurring is very small. In the unlikely event that these impacts occur, they can be easily remediated using well established dam construction and maintenance techniques. With the implementation of the appropriate remediation measures, there is unlikely to be a significant impact on the ongoing operations of the farm dams within the SMP Area or on the downstream environment.

Impact Assessments for the Farm Dams Based on Increased Predictions

If the predicted systematic tilts at the farm dams were increased by factors of up to 2 times, the maximum change in freeboard would be 1000 mm, which is still relatively small and unlikely, therefore, to affect the stability of the dam walls. The capacities of the farm dams subjected to the greatest tilts would, however, decrease accordingly.

If the predicted systematic strains at the farm dams were increased by factors of up to 2 times, the maximum predicted tensile strain would still be less than 3 mm/m and unlikely, therefore, to result in a significant impact on the farm dams. It is possible that some minor impacts could occur at the farm dams subjected to the larger strains, such as minor cracking or leakages, which are expected to be easily identified and remediated as required. With the implementation of the appropriate remediation measures, there is unlikely to be a significant impact on the ongoing operations of the farm dams within the SMP Area or on the downstream environment.

11.10. GROUNDWATER BORES

The locations of the registered groundwater bores in the vicinity of the proposed longwalls are shown in **Figure 6.2**. The predictions and impact assessments for these bores are provided in the following sections.

11.10.1. Predictions for the Registered Groundwater Bores

A summary of the maximum predicted values of systematic subsidence, tilt and strain at the registered groundwater bores within the general SMP Area, at any time during or after the extraction of the proposed longwalls, is provided in **Table 11.31**.

Table 11.31 - Maximum Predicted Systematic Subsidence, Tilt and Strain at the Groundwater Bores within the SMP Area Resulting from the Extraction of the Proposed Longwalls

Registered Groundwater Bore	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative or Travelling Tilt (mm/m)	Maximum Predicted Cumulative or Travelling Tensile Strain (mm/m)	Maximum Predicted Cumulative or Travelling Compressive Strain (mm/m)
GW102584	635	3.6	0.4	0.1
GW104154	1045	3.3	0.3	0.4
GW104602	< 20	0.1	< 0.1	< 0.1
GW104661	120	1.1	0.1	< 0.1
GW105339	1010	5.0	1.1	0.2
GW105376	330	3.7	0.7	< 0.1
GW105388	1225	1.2	0.3	0.3
GW105534	425	3.7	0.5	< 0.1
GW105574	< 20	0.1	< 0.1	< 0.1
GW106574	925	2.1	0.4	0.2
GW106675	< 20	0.1	< 0.1	< 0.1
GW108312	1055	4.5	1.2	0.2

The values provided in the above table are the maximum predicted parameters within a 20 metre radius of each bore, including the predicted movements resulting from the extraction of Longwalls 702 to 704. The predicted tilts and strains are the maximum values which occur anytime during or after the extraction of the proposed longwalls.

11.10.2. Impact Assessments for the Groundwater Bores

The registered groundwater bores are located across the SMP Area and are directly mined beneath by the proposed longwalls. It is likely that differential horizontal displacements will occur at the different strata horizons over the depths of these bores, which could result in reduced capacities or, in some cases, blockage of the bores. It is also possible, that fracturing or bed separation in the strata could result in the migration of water from near surface aquifers into other aquifers that lie beneath them.

Any impacts on the registered ground water bores as a result of the extraction of the proposed longwalls can be readily managed until such a time as the Mine Subsidence Board (MSB) can re-establish them. Should the capacities of the bores be reduced to unacceptable levels during the mining period, Illawarra Coal will provide alternative supplies of water until the time which the MSB can repair the existing bores, extend the bores to a greater depth, or establish new bores.

11.11. QUARRY SITES

There are 2 shale quarry sites identified within the SMP Area, above Longwalls 707 and 710, the locations of which are shown in **Figure 6.9**. It is possible, that the subsidence movements resulting from the extraction of the proposed longwalls could dislodge marginally stable rocks or lose boulders on the quarry faces.

It is recommended that access should be restricted to the quarry faces as the proposed longwalls are mined beneath the sites. It is also recommended that the owners and workers are made fully aware of the potential of rock falls occurring during and after the extraction of the longwalls beneath the sites. The quarry faces should be visually monitored on a regular basis throughout the mining period.

11.12. ARCHAEOLOGICAL SITES

The archaeological sites that have been identified within the SMP Area are shown in **Figure 6.10**. The predictions and impact assessments for these archaeological sites are provided in the following sections.

11.12.1. Predictions for the Archaeological Sites

A summary of the maximum predicted values of systematic subsidence, tilt and strain at the archaeological sites within the SMP Area, at any time during or after the extraction of the proposed longwalls, is provided in **Table 11.32**.

Table 11.32 - Maximum Predicted Systematic Subsidence, Tilt and Strain at the Archaeological Sites within the SMP Area Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative or Travelling Tilt (mm/m)	Maximum Predicted Cumulative or Travelling Tensile Strain (mm/m)	Maximum Predicted Cumulative or Travelling Compressive Strain (mm/m)
Foot Onslow Creek AS 1	1400	1.8	0.4	0.9
Foot Onslow Creek IA 1	1085	1.9	0.4	0.3
Foot Onslow Creek IA 2	1025	2.8	1.1	0.2
Foot Onslow Creek IA 3	1025	5.0	1.2	0.2
Foot Onslow Creek IA 4	1390	1.7	0.4	1.4
Foot Onslow Creek IA 5	1505	6.8	0.4	1.8
Foot Onslow Creek IA 6	1420	1.8	0.4	0.3
Moreton Park Road 4	1275	5.4	1.0	0.5
Moreton Park Road 5	1135	5.1	1.3	0.4
Mountbatten 1	810	2.9	0.3	0.3
Mountbatten 2	1230	1.9	0.3	0.2
Nepean River 4	95	0.8	0.1	< 0.1
Nepean River 5	70	0.6	< 0.1	< 0.1
Nepean River 6	120	0.8	< 0.1	< 0.1
Nepean River 7	785	3.3	0.4	0.1
Nepean River 8	< 20	< 0.1	< 0.1	< 0.1
Unit d Ground Axe Paddock	885	3.7	0.4	0.3
Unit e Rubbish Dump	1095	3.4	1.2	0.2
Upper Nepean Hand Stencils	125	0.8	< 0.1	< 0.1

The values provided in the above table are the maximum predicted parameters within a 20 metre radius of each site, including the predicted movements resulting from the extraction of Longwalls 702 to 704. The predicted tilts and strains are the maximum values which occur at anytime during or after the extraction of the proposed longwalls.

11.12.2. Impact Assessments for the Archaeological Sites

There are 13 open sites with scattered artefacts and isolated finds within the SMP Area, being *Foot Onslow Creek AS 1*, *Foot Onslow Creek IA 1* to *IA 6*, *Moreton Park Road 4* and *5*, *Mountbatten 1* and *2*, *Nepean River 8* and *Unit d Ground Axe Paddock*. Open sites can potentially be affected by cracking in the surface soils as the result of mine subsidence movements. It is unlikely, however, that the scattered artefacts or isolated finds themselves would be impacted by surface cracking.

There is one scarred tree site, being *Nepean River 7*, which is located above the chain pillar between Longwalls 704 and 705, at the eastern ends of these longwalls. It has been observed from past longwall mining experience, that trees are not impacted by mine subsidence movements at depths of cover greater than 500 metres, such as at Appin Colliery. It is unlikely, therefore, that the scarred tree would be impacted as the result of the extraction of the proposed longwalls.

There is one recorded grinding groove site within the SMP Area, being *Unit e Rubbish Dump*, which is located adjacent to Moreton Park Road, directly above Longwall 704. It should be noted, that the grinding groove could not be located on site by Biosis and that it is possible that this site has been covered by soil, or that this site has been incorrectly classified. Refer to **Appendix E** for further details on the grinding groove site.

Although the grinding groove site could not be located, predictions and impact assessments for the site have been provided. The maximum predicted systematic tensile and compressive strains at this site are 1.2 mm/m and 0.2 mm/m, respectively, and the associated minimum radii of curvature are 12.5 kilometres and 75 kilometres, respectively.

The remaining four archaeological sites within the SMP Area are shelters with deposits or midden, being *Nepean River 4* to *6* and *Upper Nepean Hand Stencils*. Biosis (2008) suggest that the *Upper Nepean Hand Stencils* are not likely to be of Aboriginal origin. 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 any artwork. The main mechanisms which could potentially result in impacts on sandstone shelters are the systematic strains and curvatures.

The shelters are situated within the valley of a tributary to the Nepean River and are located at distances of between 260 metres and 560 metres south of Longwall 705, at their closest points to the proposed longwalls. The maximum predicted systematic strain at the shelters is 0.1 mm/m tensile and the associated minimum radius of curvature is 150 kilometres. The predicted maximum systematic strains are very small and are unlikely, therefore, to result in any significant impacts on the shelters with art.

The shelter with art (*Upper Nepean Hand Stencils*) could also experience valley related movements as the result of the extraction of the proposed longwalls. The maximum predicted upsidence and compressive strains due to the closure movements are expected to occur near the base of the valley and are not expected to be significant in the locations of the shelters, which are located along the valley sides.

The likelihood of impact on shelters with art located outside of extracted longwalls are considerably less than those which are located directly above extracted longwalls. 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 shelter with art, resulting from the extraction of the proposed longwalls, is low.

Further details of the potential impacts on archaeological sites are provided in **Appendix E**.

11.12.3. Impact Assessments for the Archaeological Sites Based on Increased Predictions

If the predicted systematic subsidence movements were increased by factors of up to 2 times at the open sites, the likelihood and extent of fracturing of the uppermost bedrock and, hence, the likelihood and extent of cracking in the surface soils would increase accordingly. Any cracking in the surface soils would still expected to be of a relatively minor nature which could be easily remediated.

If the predicted systematic subsidence parameters were increased by a factor 2 times at the scarred tree site, it would still be unlikely that any significant impacts would occur at the site.

If the predicted systematic strains were increased by factors of up to 2 times at the grinding groove site, the likelihood and extent of fracturing at the site would increase accordingly. It would still be expected, however, that any required preventive measures at the grinding groove site would not significantly change.

If the predicted systematic strains were increased by factors of up to 2 times at the overhang sites, the maximum predicted systematic strains at the sites would still be in the order of 0.2 mm/m and, therefore, not significant. It would be unlikely, therefore, that the potential for impacts at these sites would increase significantly.

11.13. SURVEY CONTROL MARKS

There are a number of survey control marks within the vicinity of the proposed longwalls, the locations of which are shown in **Figure 6.2**. The predictions and impact assessments for the survey control marks are provided in the following sections.

11.13.1. Predictions for the Survey Control Marks

There are 23 survey control marks located within the general SMP Area. A summary of the maximum predicted values of systematic subsidence and horizontal movement at these survey control marks, at any time during or after the extraction of the proposed longwalls, is provided in **Table 11.33**.

Table 11.33 - Maximum Predicted Systematic Subsidence and Horizontal Movement at the Survey Control Marks within the General SMP Area Resulting from the Proposed Longwalls

Survey Mark	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Horizontal Movement (mm)
PM 25150	1325	100
PM 25153	1440	65
PM 60537	1210	40
PM 60538	1100	45
PM 60539	1330	95
PM 60540	1160	40
PM 60541	1040	90
PM 60542	20	< 20
PM 61513	90	< 20
PM 66381	1345	35
PM 67986	150	20
PM 87183	145	< 20
PM 87186	970	40
PM 87187	20	< 20
SS 16098	< 20	< 20
SS 16320	435	50
SS 16325	995	95
SS 16326	875	50
SS 37523	1105	25
SS 67659	30	< 20
SS 9471	< 20	< 20
SS 97734	130	< 20
TS 10421	1410	40

The values provided in the above table are the maximum predicted parameters within a 20 metre radius of each survey control mark, including the predicted movements resulting from the extraction of Longwalls 702 to 704.

11.13.2. Impact Assessments for the Survey Control Marks

It will be necessary on the completion of the proposed longwalls, when the ground has stabilised, to re-establish any survey control marks that are required for future use. Consultation between IC and the Department of Lands will be required to ensure that these survey control marks are reinstated at the appropriate time, as required.

11.13.3. Impact Assessments for the Survey Control Marks Based on Increased Predictions

If the predicted systematic subsidence parameters were increased by factors of up to 2 times, the extent of the remediation measures would not significantly increase. If the predicted far-field horizontal movements were increased by factors up to 2 times, it is likely that additional survey control marks further a field would be affected and, therefore, could require re-establishment. It is anticipated that with the appropriate remediation measures implemented, that it would be unlikely that there would be a significant impact on the survey control marks resulting from the extraction of the proposed longwalls.

11.14. RESIDENTIAL ESTABLISHMENTS

11.14.1 Houses

There are 115 houses located within the SMP Area, of which 71 are single-storey houses with lengths less than 30 metres (Type H1), 30 are single-storey houses with lengths greater than 30 metres (Type H2), 10 are double-storey houses with lengths less than 30 metres (Type H3) and four are double-storey houses with lengths greater than 30 metres (Type H4).

The locations of the houses within the SMP Area are shown in **Appendix A**. The impact assessments for the houses within the SMP Area are provided in the following sections.

Predictions for the Houses

A summary of the maximum predicted subsidence and tilts for the houses within the SMP Area, after the extraction of each proposed longwall, is provided in **Table 11.34**. A summary of the maximum predicted curvatures and systematic strains for the houses within the SMP Area, after the extraction of each proposed longwall, is provided in **Table 11.35**.

Table 11.34 - Summary of the Maximum Predicted Subsidence and Tilts for the Houses within the SMP Area after the Extraction of Each Proposed Longwall

Longwall	Predicted Subsidence (mm)				Predicted Tilt (mm/m)			
	< 500	≥ 500 & < 1000	≥ 1000 & < 1500	≥ 1500	< 5	≥ 5 & < 7	≥ 7 & < 10	≥ 10
After LW705	106	4	5	0	114	1	0	0
After LW706	102	6	7	0	115	0	0	0
After LW707	95	8	12	0	111	4	0	0
After LW708	83	12	20	0	108	7	0	0
After LW709	74	10	31	0	111	4	0	0
After LW710	56	22	37	0	109	6	0	0

Table 11.35 - Summary of the Maximum Predicted Curvatures and Systematic Strains for the Houses within the SMP Area after the Extraction of Each Proposed Longwall

Longwall	Predicted Curvature (1/km)				Predicted Systematic Strain (mm/m)					
	< 0.05	≥ 0.05 & < 0.10	≥ 0.10 & < 0.15	≥ 0.15	< 0.25	≥ 0.25 & < 0.5	≥ 0.5 & < 1.0	≥ 1.0 & < 1.5	≥ 1.5 & < 2.0	≥ 2.0
After LW705	105	3	2	5	100	6	2	5	2	0
After LW706	97	7	4	7	96	3	8	5	3	0
After LW707	88	7	6	14	87	2	13	10	3	0
After LW708	77	9	8	21	76	4	16	14	5	0
After LW709	60	14	10	31	58	9	21	21	6	0
After LW710	46	16	16	37	42	14	25	27	7	0

Impact Assessments for the Houses

The predicted systematic tilts at the houses, at any time during or after the extraction of the proposed longwalls, are less than 7 mm/m (i.e. Category A or B). It has been found from past longwall mining experience that tilts less than 7 mm/m generally do not result in any significant impacts on houses.

It is unlikely, therefore, that the maximum predicted tilts at the houses within the SMP Area would be of sufficient magnitude to result in any significant impacts on the stability of these structures. It is possible, however, that the larger predicted tilts could result in some minor serviceability impacts, including door swings and issues with roof gutter and wet area drainage. It is expected, that any impacts on the houses as a result of tilts of these magnitudes could easily be remediated using normal building maintenance techniques.

Refer **Appendix A** for further detail on impact assessments for houses.

Impact Assessments for the Houses Based on Increased Predictions

If the predicted systematic subsidence parameters were to be increased by factors of 1.25 to 2 times, the potential impacts on the houses would increase accordingly. A summary of the impact assessments for tilt and strain for the houses based on increased predictions are provided in **Table 11.36**.

Table 11.36 - Summary of Tilt and Strain Impact Assessments for the Houses within the SMP Area Based on Increased Predictions

Increased Prediction	Number of Houses with Tilt Impact Assessment for Increased Predictions				Number of Houses with Strain Impact Assessment for Increased Predictions					
	Cat A	Cat B	Cat C	Cat D	Cat 0	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
x 1.25	92	20	3	0	54	28	30	3	0	0
x 1.50	85	21	9	0	51	23	34	7	0	0
x 1.75	77	15	20	3	45	21	34	15	0	0
x 2.00	74	12	23	6	44	18	31	21	1	0

If the predicted systematic tilts were increased by a factor of 1.5 times, no houses would be assessed to experience a Category D tilt impact. If the predicted systematic tilts were increased by a factor of 2 times, six houses (i.e. 5 % of total) would be assessed to experience Category D tilt impacts. It is possible, in these cases, that the houses would experience serviceability impacts, including door swings, and issues with roof gutter and wet area drainage.

If the predicted systematic strains were increased by a factor of 1.5 times, there would be seven houses which would be assessed to experience Category 3 strain impacts. It is possible that these houses would experience moderate impacts, which would be required to be remediated during the mining period. Based on the experience at Tahmoor Colliery, it would still be expected that all houses would remain safe and that the impacts could be repaired using normal building maintenance techniques.

Refer **Appendix A** for further detail on houses.

11.14.2. Swimming Pools

There are 42 privately owned swimming pools (Structure Type P) which have been identified within the SMP Area, the locations of which are provided in **Appendix A**.

Predictions of systematic subsidence, tilt and strain have been made at the centroid and at the corners of each pool, as well as eight equally spaced points placed radially around the centroid and corners at a distance of 20 metres. The maximum predicted systematic subsidence parameters for each pool within the SMP Area are provided in **Appendix A**. The pools are located across the SMP Area and, therefore, are subjected to the full range of predicted systematic subsidence movements.

Refer **Appendix A** for further detail on swimming pools.

11.14.3. Tennis Courts

There are 7 privately owned tennis courts (Structure Type TC) which have been identified within the SMP Area, the locations of which are provided in **Appendix A**.

Predictions of systematic subsidence, tilt and strain have been made at the centroid and at the corners of each tennis court, as well as eight equally spaced points placed radially around the centroid and corners at a distance of 20 metres. The maximum predicted systematic subsidence parameters for each tennis court within the SMP Area are provided in **Appendix A**. The tennis courts are located across the SMP Area and, therefore, are subjected to the full range of predicted systematic subsidence movements.

Refer **Appendix A** for further detail on tennis courts.

11.14.4. On-Site Waste Water Systems

The residences on the rural properties within the SMP Area have on-site waste water systems. The predicted systematic subsidence parameters at the on-site waste water systems are similar to those at the houses which they serve, which are summarised in **Appendix A**, as these are the maximum values which occur within 20 metres of the houses.

A summary of the maximum predicted systematic subsidence parameters at the on-site waste water systems, at any time during or after the extraction of the proposed longwalls, whichever is the greater, is provided in **Table 11.37**.

Table 11.37 - Maximum Predicted Systematic Subsidence Parameters at the On-Site Waste Water Systems Resulting from the Extraction of the Longwalls 702 to 710

Location	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Systematic Tensile Strain (mm/m)	Maximum Predicted Systematic Compressive Strain (mm/m)
On-site Waste Water Systems	1470	6.1	1.6	2.0

It is possible, however, that the buried pipelines associated with the on-site waste water tanks could be impacted by the predicted systematic strains if they are anchored by the tanks or other structures in the ground. Any impacts are expected to be of a minor nature, including leaking pipe joints, and could be easily repaired. With the implementation of these remediation measures, it would be unlikely that there would be any significant impacts on the pipelines associated with the on-site waste water systems.

Refer **Appendix A** for further detail on on-site waste water systems.

11.14.5. Concrete Pavements

A number of the houses within the SMP Area have concrete driveways or footpaths. The predicted subsidence parameters at the concrete pavements are similar to those at the houses, which is summarised in **Appendix A**, as these predictions are the maximum values within 20 metres of the houses.

Residential concrete pavements are typically constructed with tooled joints which do not have the capacity to absorb compressive movements. It is possible that some of the smaller concrete footpaths in the locations of the larger predicted compressive strains could buckle upwards if there are insufficient movement joints in the pavements. It is expected, however, that the buckling of footpaths and pavements would not be common, at these magnitudes of predicted strain, and could be easily repaired.

Refer **Appendix A** for further detail on concrete pavements.

11.15. THE LIKELIHOOD OF IRREGULAR PROFILES

Wherever faults, dykes and abrupt changes in geology are present at the surface, it is possible that irregularities in the subsidence profiles could occur. Similarly, where surface rocks are thinly bedded, and where cross-bedded strata exist close to the surface, it is possible for surface buckling to occur, leading to irregular movements. By far the greatest number of irregularities in subsidence profiles, however, can be explained by the presence of surface incisions such as gorges, river valleys and creeks.

The geological structures which have been identified at seam level are shown in **Figure 4.3**. The geological features identified at seam level within the SMP Area include a series of dykes which cross between the middle and the western ends of the proposed and a number of faults which cross between the middle and the eastern ends of the proposed longwalls. It is uncommon for these geological features at seam level to extend through to the surface and result in changed subsidence parameters.

It is possible that anomalous movements could occur as a result of the extraction of the proposed longwalls, as these have occurred in the past in the Southern Coalfield. Given the relatively low density of surface features within the SMP Area, the probability of an anomalous movement coinciding with a surface feature sensitive to these movements is assessed as low. Further details on anomalous movements are provided in **Appendix A**.

Irregularities also occur in shallow mining situations, where the collapsed zone, above the extracted seam, extends all the way to the surface. This type of irregularity is generally only seen where the depth of cover is less than 100 metres, which does not occur above the proposed longwalls.

Irregular profiles can also occur where longwall mining is carried out beneath previous workings such as bord and pillar extractions. In such situations, the stooks left in the upper seam can collapse, when mining occurs beneath them, leading to localised subsidence and irregular subsidence profiles. There are no earlier workings above the proposed longwalls and this kind of irregularity will not occur in this case.

11.16. PREDICTED REGIONAL HORIZONTAL MOVEMENTS

In addition to the systematic movements that have been predicted above and adjacent to the proposed longwalls and the predicted valley related movements along the rivers and drainage lines, it is also likely that some far-field horizontal movements will also be experienced during the extraction of these longwalls.

Far-field horizontal movements result from the redistribution of horizontal in situ stress in the strata around the collapsed zones above the extracted voids. Such movements are, to some extent, predictable and occur whenever significant excavations occur at the surface or underground.

An empirical database of observed incremental far-field horizontal movements has been compiled using monitoring data primarily from the Southern Coalfield, from Collieries including Appin, Bellambi, Dendrobium, Newstan, Tower and West Cliff. The far-field horizontal movements resulting from longwall mining were generally observed to be orientated towards the extracted longwalls. At very low levels of far-field horizontal movements, however, there was a high scatter in the orientation of the observed movements.

Refer **Appendix A** for further detail on predicted horizontal movements.

11.17. OTHER POTENTIAL IMPACTS

The following sections discuss other potential impacts resulting from the extraction of the proposed longwalls.

11.17.1. The Likelihood of Surface Cracking in Soils and Fracturing of Bedrock

As subsidence occurs, surface cracks will generally appear in the tensile zone, i.e. within 0.1 to 0.4 times the depth of cover from the longwall perimeters. Most of the cracks will occur within a radius of approximately 0.1 times the depth of cover from the longwall perimeters. The cracks will generally be parallel to the longitudinal edges of the longwalls.

It is also possible that surface cracks could occur above and parallel to the moving longwall extraction faces, i.e. at right angles to the longitudinal edges of the longwalls, as the subsidence trough develops. This cracking is, however, likely to be transient, since the tensile phase, which causes the cracks to open up, is generally followed by a compressive phase, that partially closes them.

Fracturing of exposed sandstone or near surface bedrock is likely to occur coincident with the maximum tensile strains, but open fractures could also occur due to buckling of surface beds that are subject to compressive strains. Fracture widths tend to increase as the depth of cover reduces and only minor fracturing, if any, is expected above the proposed longwalls, where the depths of cover vary between 470 and 620 metres.

Fractures are less likely to be observed in exposed bedrock where tensile strain levels are low, typically less than 0.5 mm/m, as has been predicted within the SMP Area. A joint spacing of ten metres is not unusual for Hawkesbury Sandstone and, therefore, fractures at the existing joints could be as wide as 10 mm, based the maximum predicted systematic tensile strain of 1.1 mm/m resulting from the extraction of the proposed longwalls.

Surface cracking in soils as the result of systematic subsidence movements is not commonly seen at depths of cover greater than 500 metres, such as at Appin Colliery, and any cracking that has been observed has generally been isolated and of a minor nature. Any significant cracking in the surface soils could be easily remediated, where required, by infilling with soil or other suitable materials, or by locally regrading and recompacting the surface.

11.17.2 The Likelihood of Gas Emissions at the Surface

It is known that the mining of coal causes fracturing of the strata above the coal seam and this may result in the liberation of methane and other gases. Methane, being a lighter gas, would tend to move upwards to fill the voids in the rock mass and diffuse towards the surface through any continuous cracks or fissures.

Some strata, however, have lower permeability and are able to act as barriers to water and gas movements. One such barrier is the Bald Hill Claystone, which separates the Hawkesbury and Bulgo Sandstones and inhibits the movement of water and gas.

If the claystone were to be fractured by subsidence of the strata it is possible that some gas and/or water could move upwards through the cracks. It is also possible that water could move downwards through the cracks, but an increase in moisture content of the claystone would cause it to swell and seal off the cracks, thus inhibiting further gas or water movements. However, the likelihood of fracturing the Bald Hill Claystone from the extraction of Longwalls 705 to 710 is very low.

Gas emissions at the surface have typically occurred within river valleys such as the Nepean, Cataract and George Rivers, although some gas emissions have also been observed in smaller creeks and in water bores. Analyses of gas compositions indicate that the coal seam is not the direct and major source of the gas and that the most likely source is the Hawkesbury Sandstone (APCRC, 1997).

It is possible that gas emissions could affect water quality, where they occur along the watercourses within the SMP Area. The potential impacts of gas emissions on water quality are discussed in **Section 9**.

It is also possible that gas emissions at the surface could result in localised vegetation die back. This occurred at Tower Colliery over small areas in the base of the Cataract River Gorge, as a result of gas emissions directly above Longwalls 10 and 14. These impacts were limited to small areas of vegetation. The gas emissions have declined and the affected areas have successfully revegetated. For further detail on the potential impact of gas emissions of flora and fauna refer **Appendix D**.

It should also be noted that the emission of gases at the surface tends to be short-lived temporary events and result in minor impacts that are readily managed.

11.17.3 The Potential Impacts of Ground Vibration on Structures due to Mining

The settlement of the ground resulting from systematic subsidence is generally a gradual and progressive movement, the effect of which is not apparent to an observer at the surface. The major breakage and collapse of strata into the voids left by the extraction of the seam occur in the layer immediately above the seam. Above that level, the breakage and collapse of the strata reduces to become a bending and sagging of the upper layers of rock with less sudden and much smaller movements occurring. In some instances, the movements can be concentrated at faults or other points of weakness in the strata with minor stepping at the surface.

Any major collapse below ground would result in some vibration in the layers of rock above it, which might be felt as a minor effect at the surface. This effect is generally only noticeable where the depth of cover is less than 100 metres, which does not occur above the proposed longwalls.

It is possible, therefore, as the proposed longwalls are mined and the strata subsides, for some vibrations to be felt at the surface, though these are more likely to occur directly above or close to the longwalls. The levels of vibration would, however, generally be very low and would not be of sufficient amplitude to result in a significant impact on the natural features or items of infrastructure. The impact due to vibration resulting from the extraction of the proposed longwalls is expected to be negligible.

11.17.4 The Potential of Noise at the Surface due to Mining

It would be very unusual for noise to be noticed at the surface due to longwall mining at depths greater than 100 metres. As systematic subsidence occurs and the near surface rocks are affected by tensile and compressive strains, the rocks open up at joints and planes of weakness and displace due to rotation and shear.

Generally the movements are gradual and cannot be noticed by an observer at the surface. These movements are also generally shielded by the more plastic surface soils which tend to distribute the strains more evenly and insulate against any sounds from below.

In some cases, the stresses in the rock can build up to the point that the rock suddenly shears to form a new fracture and if the rock is exposed or has only a thin covering of surface soil, the noise resulting from the fracturing can be heard at the surface. Normally the background level of noise in the countryside is high enough to ensure that the sound is not noticed, although in the stillness of night, it might occasionally be noticed when it occurs in close proximity. The impact of noise at the surface resulting from the extraction of the proposed longwalls is not expected to be significant.