6. Subsidence

This section deals specifically with the issue of subsidence. It was identified through the Risk Assessment and Prioritisation of Issues process as being one of the most important issues associated with the W2CP, in terms of the potential impact on the environment, community perception, and the potential consequences of subsidence on other environmental factors such as flooding, water supply systems and groundwater.

6.1 Context

The issue of mine subsidence and its potential impact on residential structures, water catchment and groundwater regimes in the Wallarah 2 Coal Project (W2CP) area has been recognised from the outset as being a key factor for consideration in the mine design process. Similarly, any disruption to the water regime that would result in water ingress into the proposed mine workings has been identified as a major risk that must also be addressed through appropriate mine design. Both Strata Control Technology Pty Limited and Mine Subsidence Engineering Consultants Pty Limited undertook the subsidence assessment for the project in conjunction with the W2CP study team. The combined use of these two leading consultants for the subsidence assessment for this project demonstrates the proponent's desire to ensure that this issue is comprehensively addressed.

Subsidence will result in a range of potential impacts. Borehole data indicate that the overburden (material from the roof of the coal seam to the surface) in the W2CP area is relatively fine grained, comprising mainly shales, mudstones, siltstones and sandstones with fewer massive conglomerate units than commonly exist in these Newcastle Coal Measures to the north. This local geological setting is important as it reduces the risk of anomalous subsidence and enhances the accuracy of subsidence predictions.

The effect of mine subsidence is not only a key issue in relation to impacts on properties and residences, it also has other potential implications for the natural and built environments.

A key potential impact of subsidence is the effect on the surface drainage patterns in the area, particularly for a 1-in-100 year flood event. The effect of subsidence is likely to alleviate the existing flood hazard (determined from floodwater depth and velocity) in some areas, while other areas will be adversely affected.

The issues that relate to subsidence that have been addressed within this EA are:

- implications for the regional water supply scheme;
- effect on drainage and flooding behaviour;
- mechanisms for impact mitigation and management;
- effect on infrastructure and built environment features; and
- ecological and other environmental impacts.

The basis for this assessment is provided in this Chapter while the full subsidence report, which includes a detailed assessment of individual natural features and surface infrastructure, is provided in Appendix A. This analysis in turn has been incorporated into other areas of assessment such as water supply issues, groundwater, flooding, ecology and heritage. These issues are discussed in Chapters 7 to 15. This Chapter provides general background information necessary to understand the mechanics of subsidence, general methods of subsidence predictions and then details of the W2CP subsidence model and results.

6.1.1 The Longwall Mining Process

An understanding of the process of underground coal extraction, and in this case longwall mining, is necessary in order to understand the principles of subsidence. Longwall mining is a term given to a particular type of underground coal extraction. All underground mines use mechanised extraction equipment and often in combination with hydraulic roof supports in order to safely extract the coal. In the case of longwall mining, blocks of coal are delineated by developing a series of parallel roadways, or tunnels, within the coal seam. These longwall blocks or "panels" are typically around 150 to 300 m wide, 1,000 to 3,500 m long and 2 m to 5 m thick. Once the block is developed, a coal shearer is installed which progressively extracts the block by cutting slices back and forth along the entire exposed face of the coal seam in the block. The overhead rock strata that remains after the coal is extracted in the working area is called the roof. The roof in the longwall working area is supported by a series of hydraulic supports or longwall chocks which move with the shearer in order to shield the workers and the face equipment from falling strata.

The coal is removed from the mine by a system of conveyors which run along the face of the block being extracted, then down one side to the main roadways leading out of the mine. A plan of part of a typical longwall coal mine layout is shown in Figure 6.1 and a photograph of typical longwall face equipment is shown in Figure 6.2.

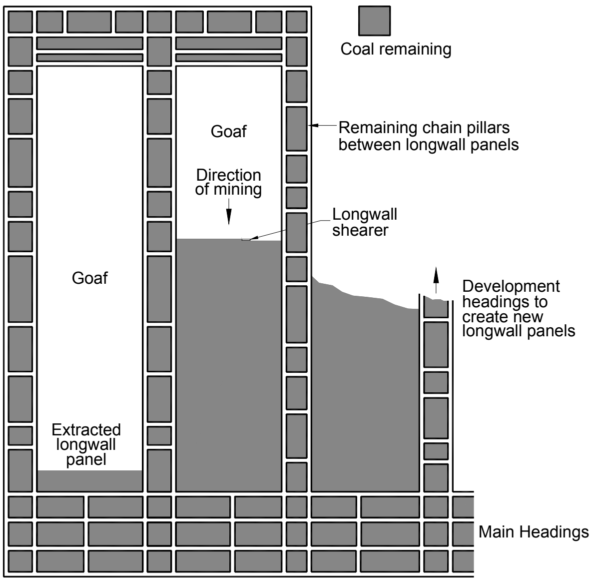

Figure 6.1 Typical Plan View of a Series of Longwall Panels

Figure 6.2 Typical Longwall Face Equipment

After each slice of coal is removed, the hydraulic roof supports, the face conveyor and the shearer are moved forward. Figure 6.2 shows a close up of the arrangement of machinery on a typical longwall face, with the hydraulic roof supports on the left hand side and the coal face on the right hand side of the picture. The drum in the background is the rotating cutting head of the coal shearer and the chain conveyor can be seen in the foreground.

Before the extraction of a longwall panel commences, continuous mining equipment extracts coal to form roadways (known as headings) around the longwall panel. These roadways form the mine ventilation passages and provide access for people, machinery, electrical supply, communication systems, water pump out lines, compressed air lines and gas drainage lines. Those roadways which provide access from the mine entrance to the longwall panel, are referred to as the main headings. Once the main headings have been established additional roadways, known as gateroads, are driven on both sides of the longwall panel and are connected together across the end of the longwall panel.

The longwall face equipment is established at the end of the panel that is remote from the main headings and coal is extracted within the panel as the longwall equipment moves towards the main headings. Typically, a longwall face retreats at a rate of 50 metres to 100 metres per week, depending on the seam thickness and mining conditions. The coal between the gateroads and between the main headings is left in place as pillars to protect the roadways as mining proceeds. The pillars between the gateroads are referred to as chain pillars.

If the width of an extracted panel of coal is small and the rock above the seam is sufficiently strong, it is possible that the roof will not collapse and hence no appreciable subsidence will occur at the surface. However, to maximise the utilisation of coal resources and for other economic reasons, wide panels of coal are generally extracted and, in most cases, the roof is unable to support itself.

Longwall panel widths between 250 m and 300 m are becoming common as collieries strive towards more cost-efficient production and some collieries are now considering longwall widths of 400 metres or more. In the case of the W2CP, panel width will vary from as narrow as 120 m initially to 150 m within the Hue Hue Mine Subsidence District and then from 150, 170 and 200 m below the flood plain depending on depth of cover and then up to 250 m wide beneath the forested areas in the western area of the mine.

6.1.2 Subsidence Mechanisms

As longwall coal mining takes place, the roof immediately above the seam is allowed to collapse into the void that is left as the face retreats. This void is referred to as the goaf. Miners working along the coalface, operating the machinery, are shielded from the collapsing strata by the canopy of the hydraulic roof supports. As the roof collapses into the goaf behind the roof supports, the fracturing, settlement and sagging of the overlying rocks progresses upward and attenuates toward the surface to form surface subsidence. This is depicted in Figure 6.3. It should be noted that this figure depicts the strata immediately above the coal seam rather than any surface expression.

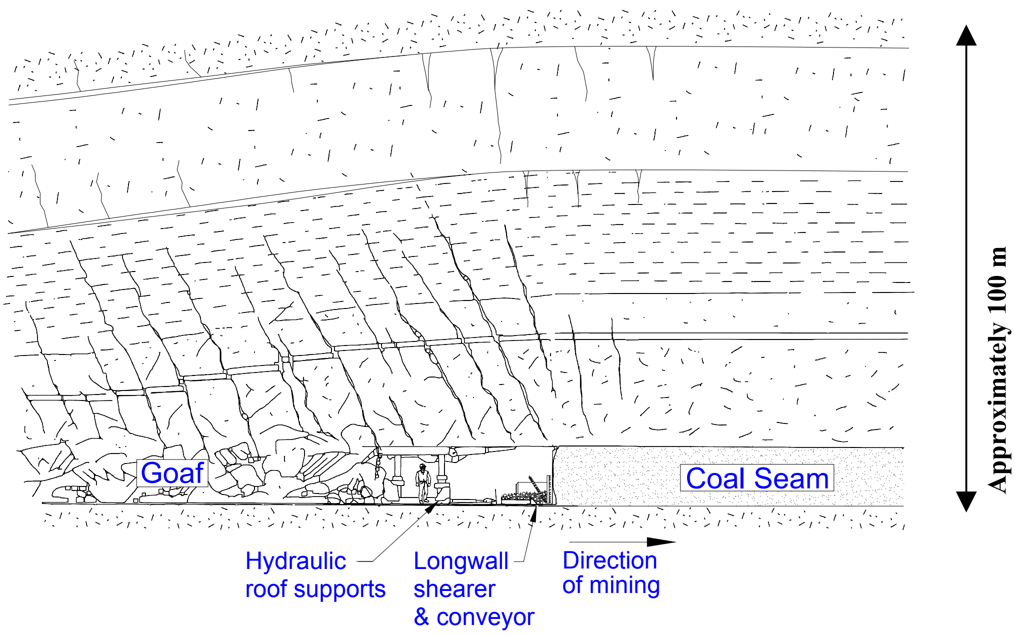

Figure 6.3 Cross Section of a Typical Longwall Face

The subsidence of the surface is considerably less than the thickness of coal removed, due to the bulking effect of the collapsed strata. The extent of the settlement at the surface is therefore dependent upon the strength and nature of the rocks overlying the coal seam.

When a panel has a width that is small relative to the depth of the seam below the surface, the overlying rocks have a tendency to bridge across the goaf by arching between the solid abutments on each side of the panel, thus reducing the amount of subsidence.

As the panel width is increased, however, the overlying rocks are less able to maintain a self-supporting arch across the goaf and a limiting panel width is reached where no support is available and maximum subsidence will occur. This limiting panel width is referred to as the critical width and is usually taken to be approximately 1.4 times the depth of cover.

Where several panels are mined in a series and chain pillars are left between the panels, the maximum subsidence will not occur unless each panel is at least of critical width. The chain pillars may crush or distort as the adjacent panels are extracted, but they do not totally collapse and can therefore provide a considerable amount of support to the overlying strata, thereby reducing the surface subsidence.

Where large super-critical areas are extracted (an area that is more extensive than the critical width), the maximum possible subsidence is typically 55% to 65% of the extracted seam thickness, but, because chain pillars are normally left in place, and provide some support, this maximum possible subsidence is rarely reached.

Where the width-to-depth ratios of the panels in a series are sub-critical, the amount of subsidence in each panel is also determined by the extent of interaction between panels, which are further influenced by the widths of the chain pillars. In this situation, the first panel in a series will generally exhibit the least subsidence and the second and subsequent panels will exhibit greater subsidence due to disturbance of the strata caused by mining the preceding panels and consequential redistribution of stresses within the strata.

The subsidence at the surface does not occur suddenly but develops progressively as the coal is extracted within the area of influence of the extracted panel.

Consequently when extraction of coal from a panel is commenced, there is no immediate surface subsidence, but as the coal within the panel is extracted and the resulting void increases in size, subsidence develops gradually above the goaf area. As further adjacent panels are extracted, additional subsidence may occur, above the previously mined panel or panels. As mining continues, a point is reached within the panel where a maximum value of subsidence occurs and despite further extraction of the particular panel this level of subsidence is not increased. However, a point is also reached where a maximum value of subsidence is observed over the series of panels irrespective of whether more panels are later extracted.

The development of subsidence at any point on the land surface can be seen to be a very complex mechanism and represents the cumulative effect of a number of separate movements. To control the impact of these effects, various combinations of panel width, chain pillar size and extraction height are employed as a fundamental part of modern mine design.

6.1.3 Overview of Systematic Subsidence Movements

The normal ground movements resulting from the extraction of longwalls are referred to as systematic subsidence movements. These movements are described by the following parameters:

- **Subsidence** usually refers to vertical displacement of a point, but subsidence of the ground actually includes both vertical and horizontal displacements.

Subsidence is usually expressed in units of *millimetres (mm)*. The actual ability of vertical subsidence to cause impacts is normally quite low but would be relatively more significant where it creates the potential for non-flood prone structures to become flood prone.

- **Tilt** is the change in the slope of the ground as a result of differential subsidence, and is calculated as the difference in subsidence between two points divided by the distance between those points. Tilt is usually expressed in units of *millimetres per metre (mm/m)*. The main impact of tilt is on structures and drainage with these impacts mitigated, and/or rectified, through the role of the Mine Subsidence Board.

- **Strain** is calculated as the change in horizontal distance between two points on the ground, divided by the original horizontal distance between them. Strain is typically expressed in units of *millimetres per metre (mm/m)*. **Tensile Strains** occur where the distance between two points increases and **Compressive Strains** occur where the distance between two points decreases. The main impact of strain is to produce surface fractures and cracking, which if excessive, may adversely impact upon surface structures. These impacts are mitigated, and/or rectified, through the role of the Mine Subsidence Board.

6.1.4 Overview of Non-Systematic Subsidence Movements

Non-systematic subsidence movements include regional horizontal movements, upsidence, closure and rock mass disturbance.

- **Far Field Horizontal Movements** tend to be horizontal movements towards the extracted goaf area and are accompanied by very low levels of strain. Movements of this type are usually expressed in millimetres (mm). The impacts that result from these movements are generally confined to large rigid structures and steep natural features such as cliffs or gorges and rarely impact on surface infrastructure or small rigid structures such as buildings.

- **Upsidence** is the reduced subsidence or the net vertical movement that may occur within the base of a valley, and is typically expressed in units of *millimetres (mm)*. It results from the buckling of near-surface strata in the base of the valley, resulting in the observed subsidence being generally less than that which would normally be expected in flat terrain. While valley bulging is a natural phenomenon resulting from the formation and ongoing development of the valley, the impact of mining may be to accelerate this process. The effects of upsidence are much more apparent in dramatic geomorphological features such as steep sided gorges with rock bar floors than in broader alluvium filled valleys.

- **Closure** is the reduction in the horizontal distance between the valley sides, and is expressed in units of *millimetres (mm)*. Closure may result from the redistribution of, and increase in, the horizontal stresses in response to longwall extraction. The effects of closure are also much more apparent in dramatic geomorphological features such as steep sided gorges with rock bar floors than in broader alluvium filled valleys.

- **Rock mass disturbance** is the impact that the caving process may have on the strata above the area where longwall extraction has taken place. The vertical and horizontal fracture systems that develop immediately above the longwall goaf dissipate toward the surface, as shown in Figure 6.4**.** The main potential impacts associated with the rock mass disturbance are the possible disruption of aquifers and/or surface water regimes. These may occur if the vertical fracture system is continuous and intersects an aquifer or propagates through to the surface. The potential for any significant impact on the surface water regime is usually confined to areas of shallow cover above coal extraction operations where there is insufficient thickness of strata to enable the vertical fracture systems to dissipate before connecting with the surface.

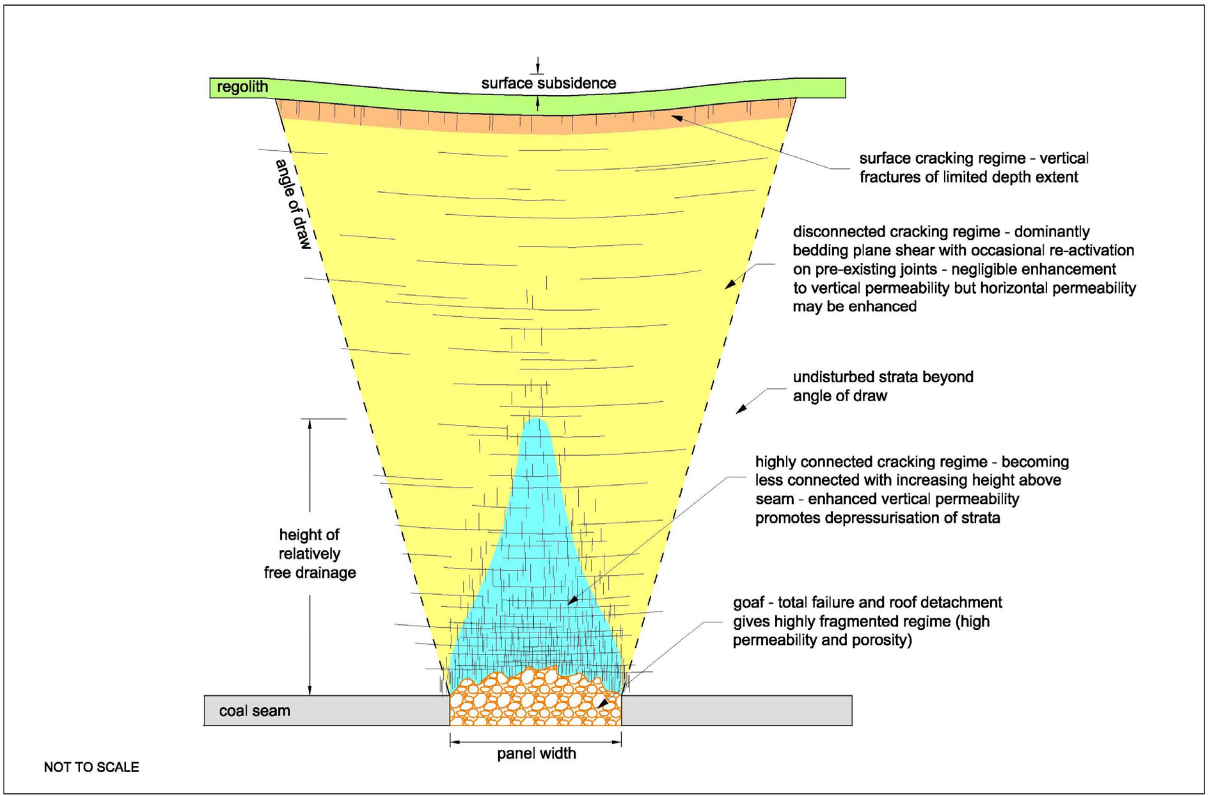

Figure 6.4 Diagrammatic Representation of Subsided Strata

6.2 Guidelines and Statutory Requirements

As with all coal mines in NSW, the W2CP will be subject to a range of legislative requirements in addition to the initial planning approval under Part 3A of the Environmental Planning and Assessment Act. These relate specifically to authorities to extract coal under the Mining Act 1992 and Mining Regulation 2003, mine subsidence and management, compensation and conditions under the mining lease granted by the Minister for Mineral Resources.

6.2.1 Mine Subsidence Districts

In recognition of likely future mining, the Hue Hue Mine Subsidence District was proclaimed in December 1985. This district overlies the initial area of the W2CP mine plan, and requires that mining-induced ground movement effects on dwellings be limited to:

- ❒ Maximum ground strain 3 mm/m; and

- Maximum ground tilt 4 mm/m

The proposed mine plan has provided for restricted panel widths of 120-175 m within the Hue Hue Mine Subsidence District and immediately adjacent areas. Not only have the panel widths and geometries been carefully designed, the proposed extraction height beneath the Hue Hue area has been significantly reduced to ensure that the final surface subsidence effects will comply with the aforementioned limits so as to enable the effective management of subsidence impacts on structures.

Similarly, when mining beneath the Dooralong Valley floodplain, the mine design has been selected to reduce the effects of vertical subsidence. In the case of the Yarramalong Valley, this risk has been substantially mitigated by shortening the length of the longwall blocks so that it will not be significantly affected by mining. The risk has been avoided in the case of the Wyong River by excluding longwall panels under or in immediate proximity to the river.

The Wyong Mine Subsidence District was proclaimed in 1997 in recognition of the significant resource underlying the Wyong State Forest, the Dooralong Valley and the Yarramalong Valley. Initially, no specific ground movement limits applied, with single storey buildings less than 30 m in length on bearers and joists automatically approved, and longer structures or structures on slabs approved on their merits provided that they were designed to withstand tilt and strain predictions provided by the then Department of Mineral Resources. In 2000 the WACJV indicated their intention to limit tilts to 4 mm/m. The Mine Subsidence Board adopted this as an interim guideline, and a number of houses were built to that specification. Future houses in this district will be required to meet tilt and strain criteria supplied by the Mine Subsidence Board, on the basis of advice from WACJV, and to be consistent with the extraction of longwall blocks up to 255 m wide and working heights of up to 4.5 m.

While construction that has, or will have, taken place after the proclamation of the Wyong Mine Subsidence District should permit effective extraction of the underlying coal reserves, a percentage of the buildings constructed prior to this would be at risk of suffering damage. As discussed below, this does not mean that such damage would not be covered by the Mine Subsidence Board.

6.2.2 Mine Subsidence Compensation Act 1961

The Mine Subsidence Compensation Act 1961 established the Mine Subsidence Board (MSB). It also puts in place the Mine Subsidence Board Compensation Fund and a process for repairing damage caused to improvements (such as houses, extensions, sheds and infrastructure) by subsidence following the extraction of coal. This fund is fully financed by the coal mining industry by a production-based levy imposed on every coal mine in NSW.

The stated mission of the MSB is to mitigate the effects of mine subsidence on the community by promoting compatibility between surface developments and underground coal mining, restoring damaged improvements and managing the compensation fund. The MSB provides expert advice to property owners, government departments and authorities, local councils, community organisations and industries within Mine Subsidence Districts, and throughout NSW. This advice aims to provide compatibility between surface development and underground mining. To this end, the Board controls building and other surface development in Mine Subsidence Districts, setting building and construction requirements that provide protection from subsidence damage. These requirements cover the nature and class of improvements, including height, type of building materials used and the method of construction

All properties that may be affected by subsidence will be inspected prior to mining. The inspections are undertaken independently of the mine by MSB Inspectors and usually occur within 12 months prior to expected subsidence occurring at the property. The inspections are undertaken in the presence of the landowner and copies of the reports are made available to the landowner. These inspections provide a detailed account of the condition of the land improvements in order to determine what, if anything, needs to be repaired or replaced following mining. If any damage is caused by the extraction of coal then it will be fully corrected at no cost to the landowner.

Repair work is organised by the MSB in close consultation with the landowner. Follow-up inspections are carried out as required.

6.2.3 Subsidence Management Plan Process

As a result of the NSW Government's revised subsidence management approval process, all potential mining-induced subsidence impacts are dealt with via an approval required by the conditions of the mining lease. The revised approval process requires the preparation of a Subsidence Management Plan and its approval by the Director-General of the Department of Industry & Investment.

Subsidence Management Plans (SMPs) are a requirement of all underground coal mines, whether they are new projects or existing operations. SMPs are required to be prepared every seven years or sooner if changes to the mine plan occur, to address sequential phases of the proposed mining process. The plans must be based on a full land use description and impact assessment. Physical landforms and surface infrastructure are addressed, along with ecosystems, items of potential heritage or archaeological significance and other social and economic factors including stakeholder consultation. An initial detailed assessment has been undertaken by MSEC which is contained in Appendix A.

The onus is on the company to demonstrate how it proposes to manage any subsidence which may be caused by underground mining. Applicants must advertise their intention to develop a draft SMP in a local and a State-wide newspaper, identify and consult with all directly affected landholders and local councils and take their views into account. Applicants must readvertise when the draft SMP is finalised and submitted to the Department of Industry and Investment – Mineral Resources. The advertisements must contain details of where the SMP can be accessed by the public.

Subsidence management planning can be undertaken at the same time as an operator draws up a mine plan, making it a more cohesive approach which allows companies to plan between 2 and 7 years ahead.

6.3 Subsidence Modelling for W2CP

6.3.1 Initial Subsidence Modelling

Subsidence, tilt and strain predictions were initially prepared by Waddington Kay & Associates (now Mine Subsidence Engineering Consultants, or MSEC) in December

2001, based upon the mine layout that was proposed in November 2001. The method used to prepare these subsidence predictions was the Incremental Profile Method (IPM).

The IPM is an empirical method that is based on extensive measurement of mine subsidence that has taken place over mined areas for more than fifty years, and has been continually refined to suit a wide variety of mine layouts with differing geological conditions in NSW and Queensland coalfields. The IPM has the capacity to provide detailed site specific "empirical" predictions of subsidence, tilt and strain over a series of mined panels with differing panel and pillar widths, depths of cover and extracted seam thicknesses. It has been exhaustively reviewed during a number of inquiries and reviews and is regarded as the best method available for the empirical prediction of subsidence parameters.
The W2CP proposal however is unique in a number of ways, in that:

- it involves the longwall extraction of coal at depths well beyond those previously mined in the Newcastle Coalfield, and more typical of the depth of mining in the Southern Coalfield;

- Southern Coalfield mines usually extract approximately 3.0 m of coal whereas the W2CP proposal includes plans to extract up to 4.5 m;

- the Southern Coalfield seams are usually bounded above and below by reasonably strong strata whereas the near-seam strata in the W2CP area are relatively weaker; and

- In the traditional mining areas of the Newcastle Coalfield the overburden often contains thick strong conglomerate units which tend to reduce surface subsidence. The overburden in the W2CP area consists of finer gained sandstones and shales with minor conglomerates.

Therefore, since no empirical subsidence data were available that reflected the proposed mining conditions for the W2CP, some of the initial IPM predictions were based on the Newcastle Coalfield subsidence prediction curves, whilst others were based through necessity on the Southern Coalfields subsidence prediction curves.

To ensure that the use of these empirical data would be fully representative of the geological response to mining in the Wyong area, further studies were initiated to undertake a detailed review of the predictions.

In February 2003, Strata Control Technology Pty Ltd (SCT) was engaged to undertake numerical modelling to compare against the differences, if any, which may have resulted from the use of empirical data from the Southern Coalfield to predict subsidence in the Newcastle Coalfield.

This numerical modelling suggested that surface subsidence above the proposed layouts in the valley area would exceed that based on the initial empirical predictions.

A review of the information gained from the studies to date was undertaken. The aim of this review was to draw upon the respective capabilities of the empirical and numerical models to develop a methodology with an improved predictive capability. As a result of this review, a mechanistically modified empirical model was developed that reflected the site-specific rock mass behaviour in satisfactorily predicting the surface subsidence associated with the extraction of Southern Coalfield geometries within a Newcastle Coalfield geological environment.

The W2CP achieved this by incorporating advanced computer modelling techniques developed by Strata Control Technology Pty Ltd, with current empirical modelling methods developed by Mine Subsidence Engineering Consultants Pty Ltd through an exhaustive process of validation and back analysis. The specialist subsidence report is contained in full in Appendix A, and summarised below.

6.3.2 Preliminary Layout Assessments

The SCT numerical modelling component of this study confirmed that surface subsidence results form a complex interaction between longwall geometry, rock mass characteristic, extraction height and chain pillar behaviour, and enabled the standard IPM empirical prediction curves to be calibrated or supplemented to reflect the likely response to mining in the W2CP area.

The calibrated IPM Model was then used to predict systematic subsidence profiles for varying longwall geometries and varying seam extraction heights.

Four preliminary assessment options were considered to provide a basis for designing a final mine layout. These were:

Option 1 – comprised four longwalls, the first having a 125 m void width, and the remainder having 155 m void widths. The proposed chain pillars were 65 m wide. The depth of cover varied between 350 and 450 m, and the proposed extracted seam thickness was 4.0 m.

Option 2 – comprised four longwalls having 200 m void widths. The area between each longwall comprised a 30 m chain pillar, a 5 m heading, 100 m of solid coal, a 5 m heading, and a 30 m chain pillar, which provided a total distance of 170 m between the longwalls. The depth of cover varied between 350 and 450 m, and the proposed extracted seam thickness was 4.5 m.

Option 3 – comprised six longwalls having 125 m void widths. The longwalls were grouped into three pairs. A 40 m chain pillar was used between the longwalls within each pair. The area between the longwall pairs comprised a 40 m chain pillar, a 5 m heading, 100 m of solid coal, a 5 m heading, and a 40 m chain pillar, which provided a total distance of 190 m between the longwall pairs. The depth of cover varied between 350 and 450 m, and the proposed extracted seam thickness was 4.5 m.

Option 4 – comprised six longwalls having 150 m void widths. The longwalls were grouped into three pairs. A 40 m chain pillar was used between the longwalls within each pair. The area between the longwall pairs comprised a 40 m chain pillar, a 5 m heading, 100 m of solid coal, a 5 m heading, and a 40 m chain pillar, which provided a total distance of 190 m between the longwall pairs. The depth of cover varied between 350 and 450 m, and the proposed extracted seam thickness was 3.5 m.

The predicted systematic subsidence, tilt and strain profiles for each option are overlaid in Figure 6.5.

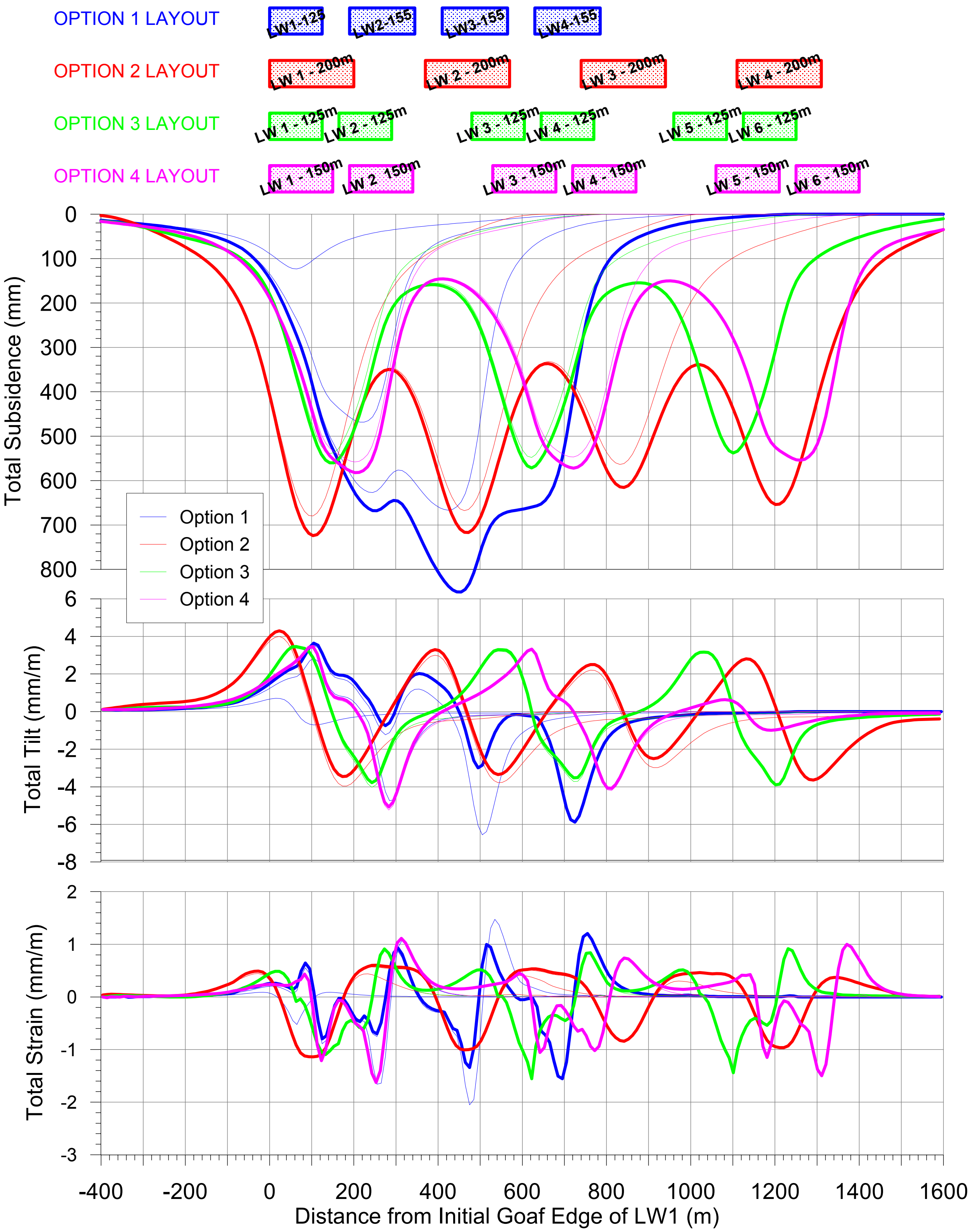

Figure 6.5 Comparison of Predicted Systematic Subsidence Profiles, Options 1-4

It can be seen from the above figure that the maximum predicted total tilts and total strains are similar for the four options. Option 1, however, gives a slightly higher transient tilt and strains above Longwall 3 and gives a slightly higher final tilt above Longwall 4.

6.3.3 Iterative Design Process

The preliminary layout assessments provided a clear insight into the speed and the detail with which the IPM could evaluate various combinations of panel geometry and extraction height to enable planners to quickly review the impacts of a complex matrix of design options.

Consequently, a number of iterative changes to the mine design were made to enable the subsidence parameters relevant to particular structures and features to be controlled.

On the basis of these assessments a layout was developed which was then run with three different extraction heights 3.5 m, 4.0 m and 4.5 m. The results of these runs were then used to further optimise the layout by varying the extraction height in certain areas to offer additional control of surface affects in line with particular environmental sensitivities.

The proposed layout, showing the proposed extraction heights, is shown in Figure 6.6. This design was developed in recognition of the Hue Hue and Wyong Mine Subsidence Districts, as well as to adhere to the public commitment that the proposed mine would avoid adverse impacts on the water supply catchments.

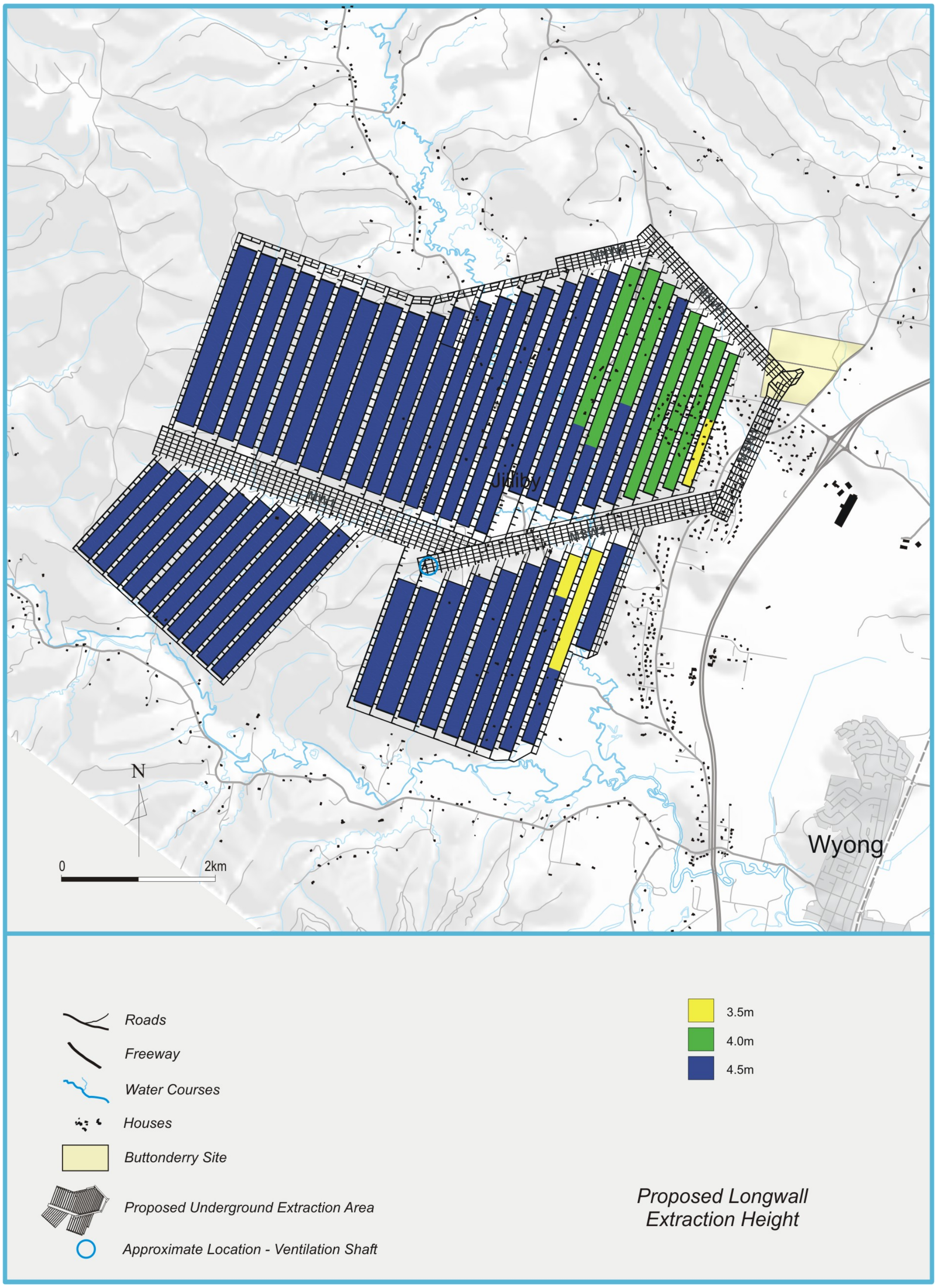

Figure 6.6 Mine Layout Showing Areas of Various Extraction Heights

6.4 Subsidence Predictions

The predicted systematic subsidence parameters were determined along four prediction lines, labelled Lines 1, 2, 3 and 4, all of which were orientated transversely to the proposed longwalls. The locations of the prediction lines are shown in Figure 6.7.

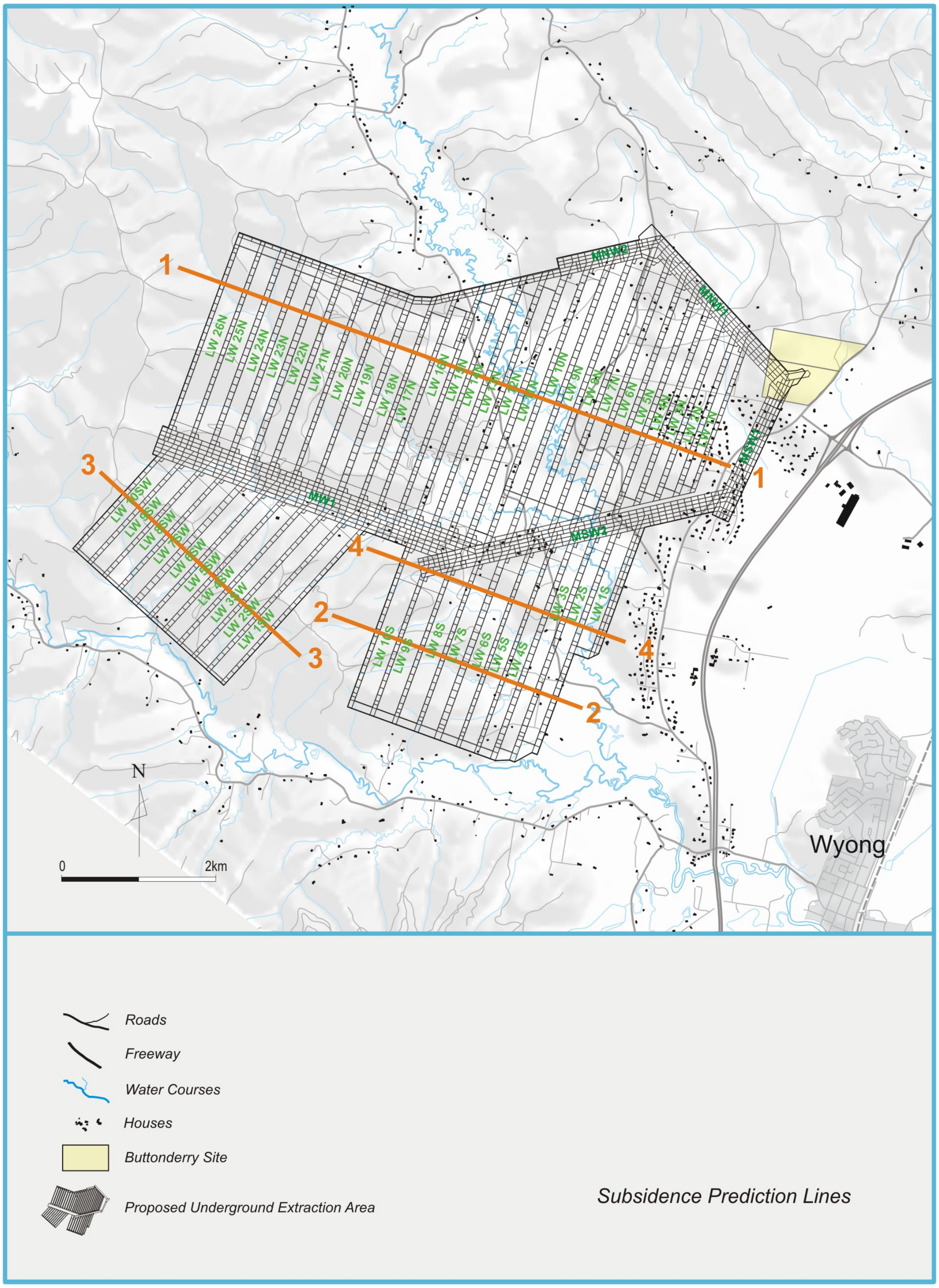

Figure 6.7 Location of Prediction Lines 1 to 4

The predicted profiles of systematic subsidence, tilt and strain along Prediction Lines 1, 2, 3 and 4 are shown in Figure 6.8, Figure 6.9, Figure 6.10, Figure 6.11 respectively.

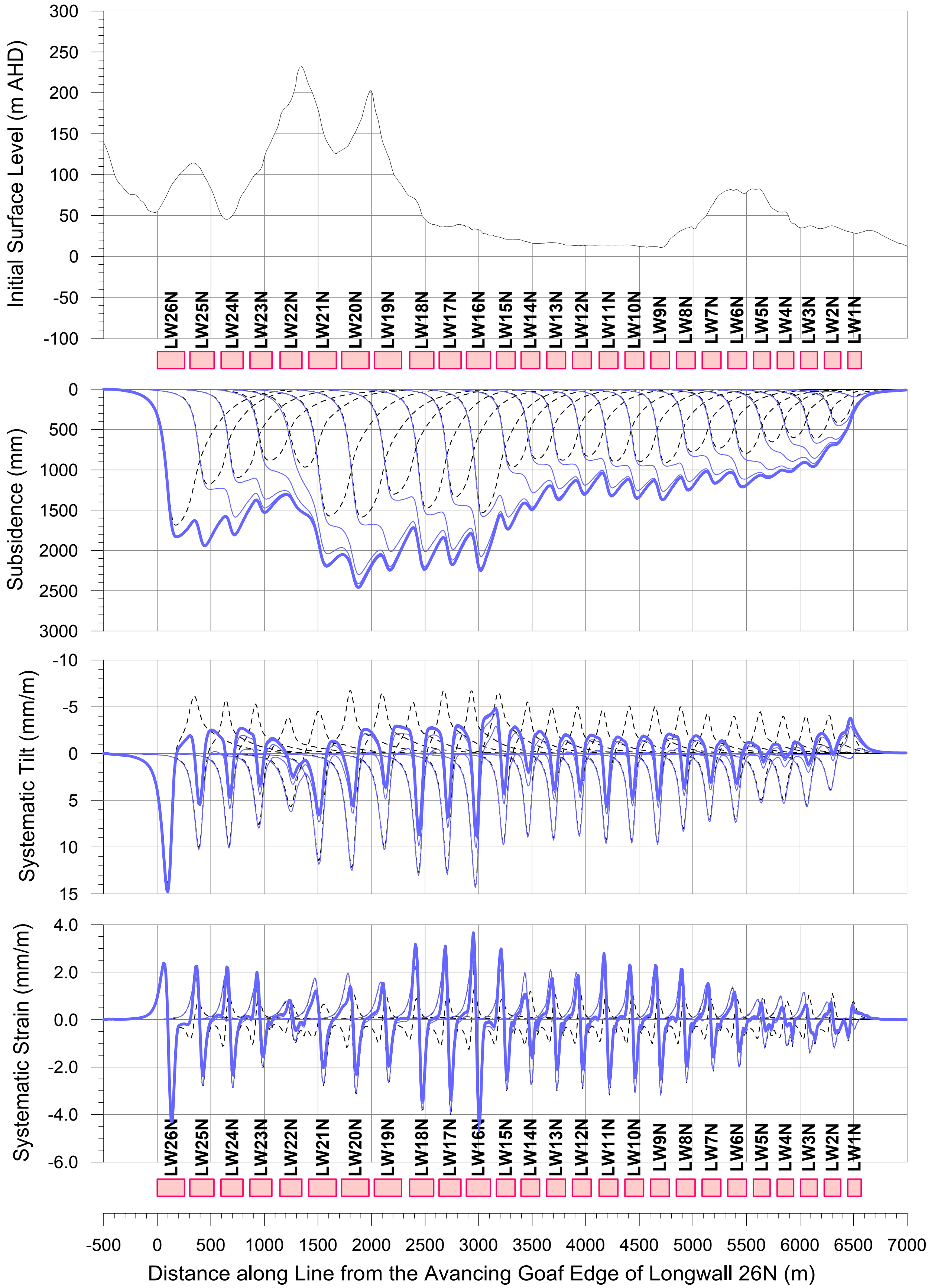

Figure 6.8 Predicted Subsidence, Systematic Tilt and Systematic Strain Profiles, Prediction Line 1

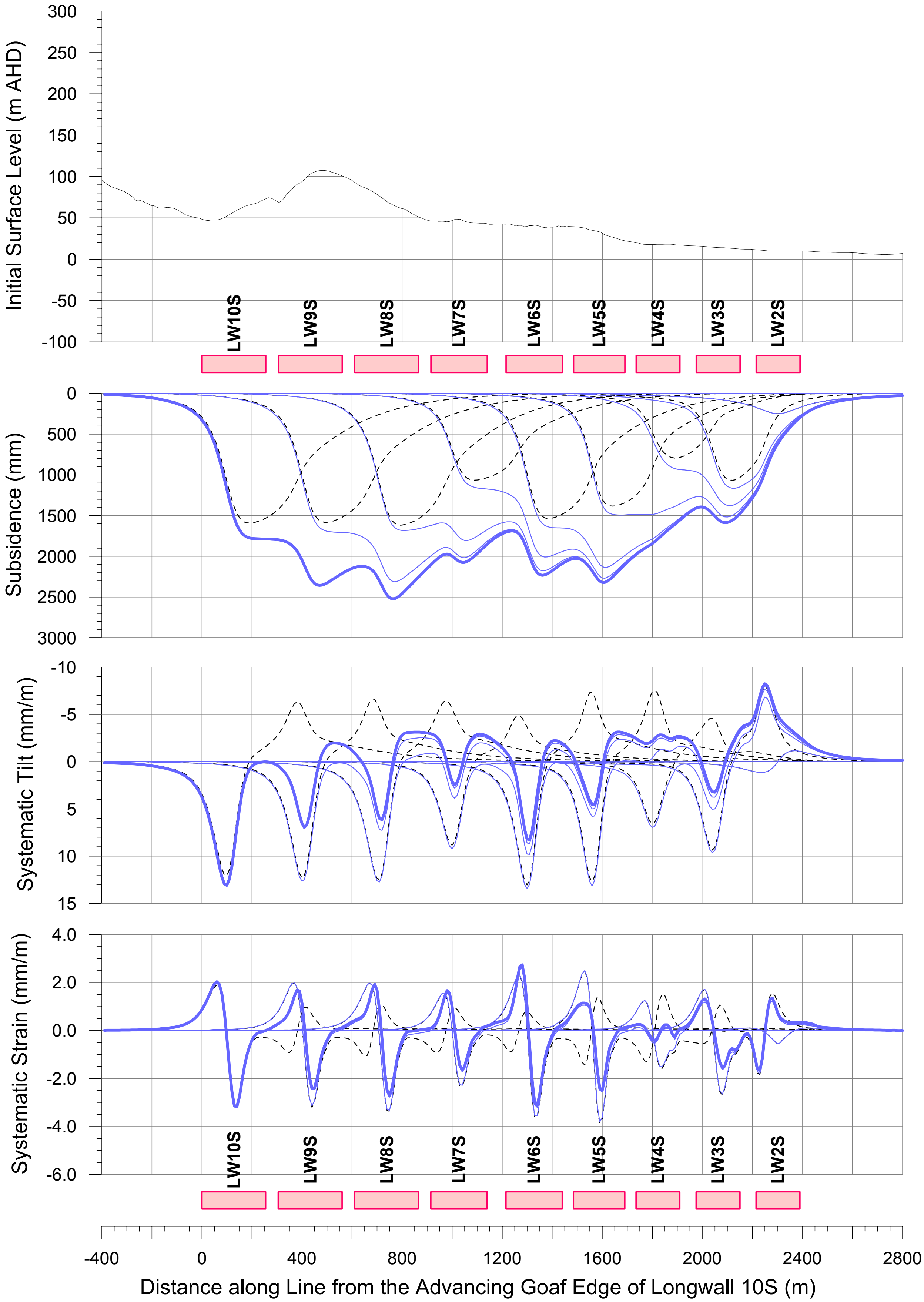

Figure 6.9 Predicted Subsidence, Systematic Tilt and Systematic Strain Profiles, Prediction Line 2

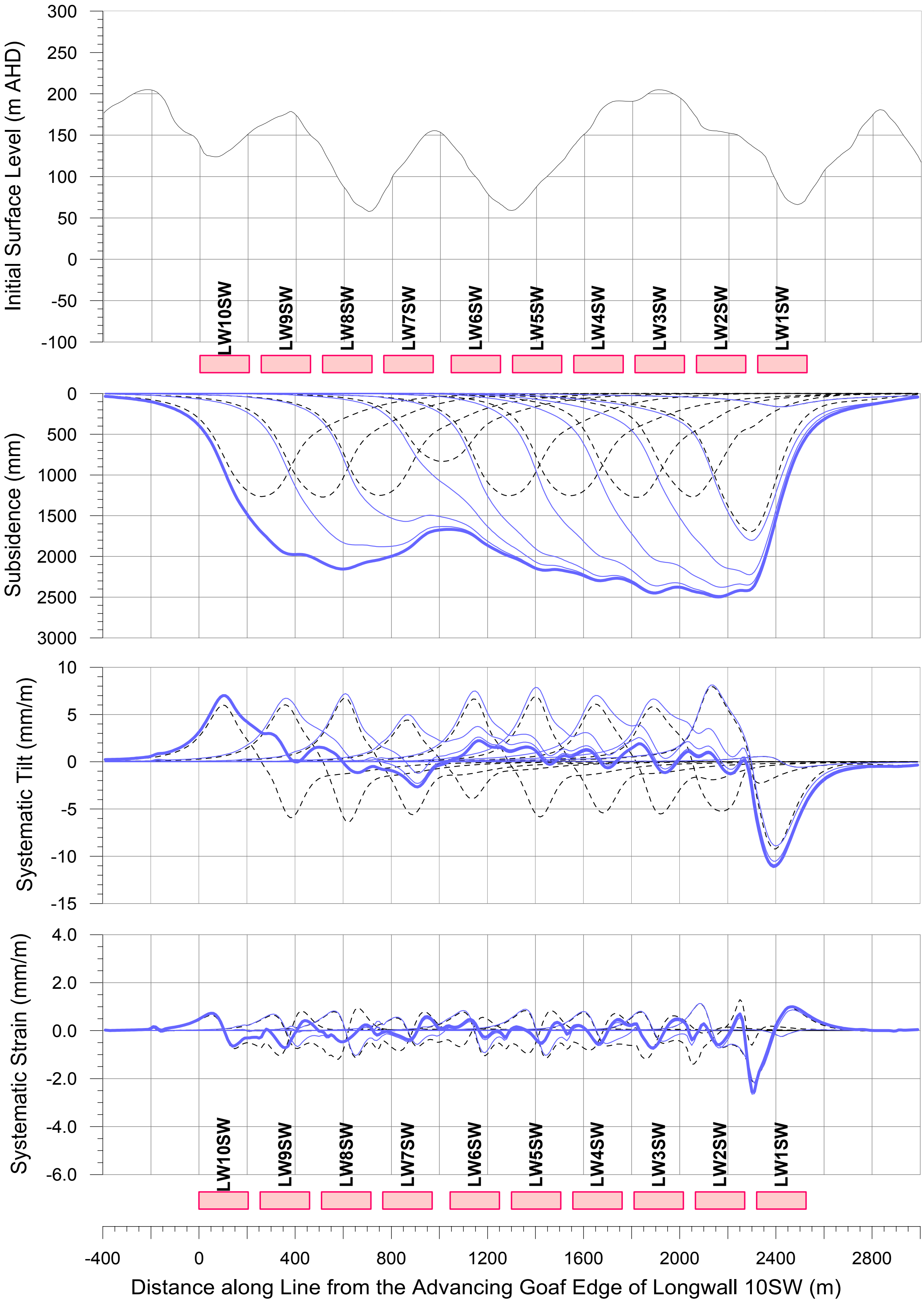

Figure 6.10 Predicted Subsidence, Systematic Tilt and Systematic Strain Profiles, Prediction Line 3

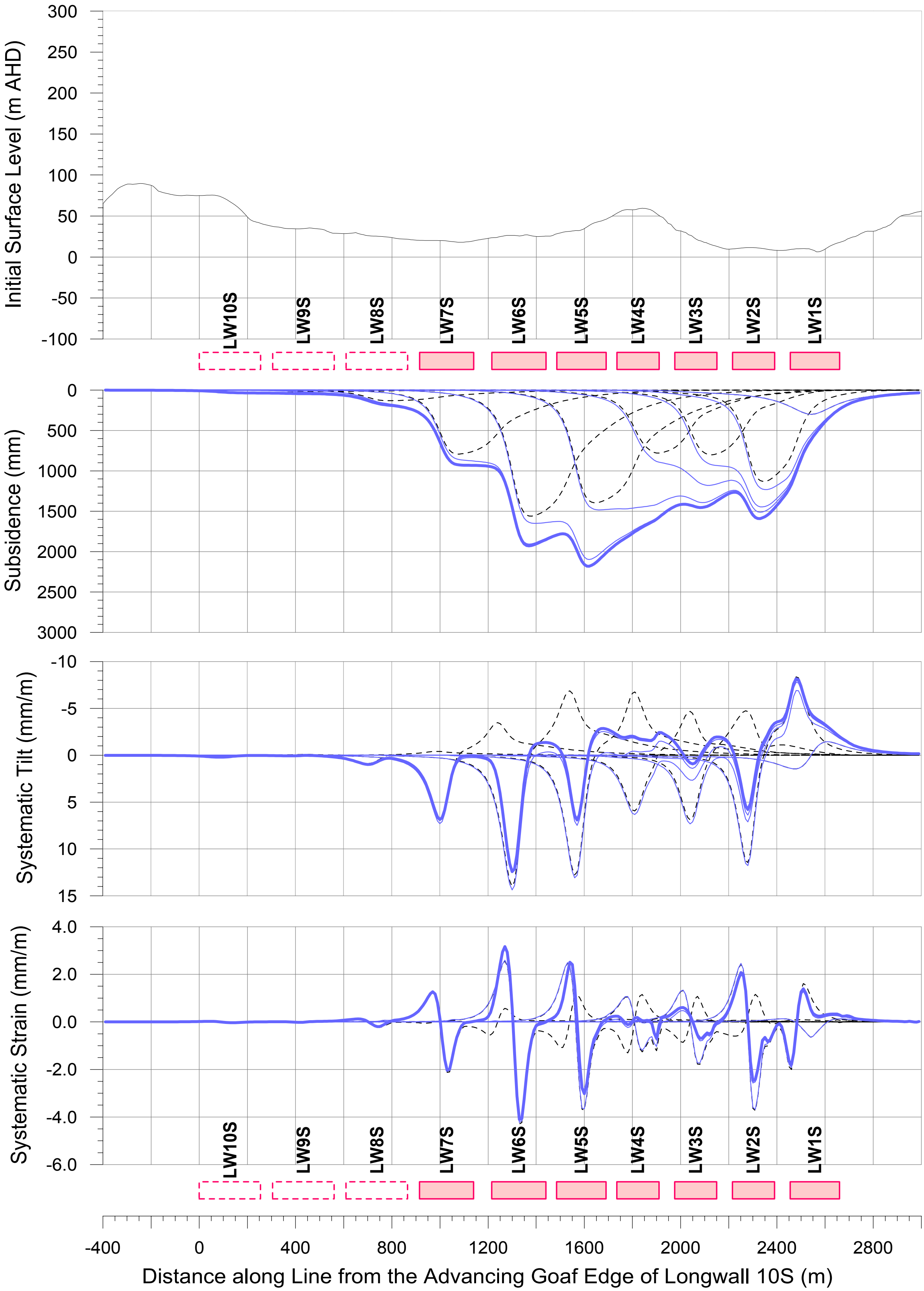

Figure 6.11 Predicted Subsidence, Systematic Tilt and Systematic Strain Profiles, Prediction Line 4

The variations in the maximum predicted subsidence parameters along the prediction lines are the result of the variations in the proposed longwall widths, chain pillar widths, topography, depths of cover, and proposed seam extraction heights.

6.4.1 Predicted Systematic Subsidence Parameters

The predicted total systematic subsidence, tilt, tensile strain and compressive strain contours, at the completion of the proposed longwalls, are shown in Figures 6.12, 6.13, 6.14 and 6.15 respectively.

The extraction of each successive longwall reduces the maximum predicted tilt and strains above the maingate of the previously extracted longwall. The maximum predicted total tilts and strains as subsequent panels are extracted therefore, are less than the maximum predicted transient tilts and strains at the completion of individual longwall blocks.

It should be noted that within the Hue Hue Mine Subsidence District, the maximum predicted total strains and tilts at the completion of mining, are consistent with criteria prescribed for that district.

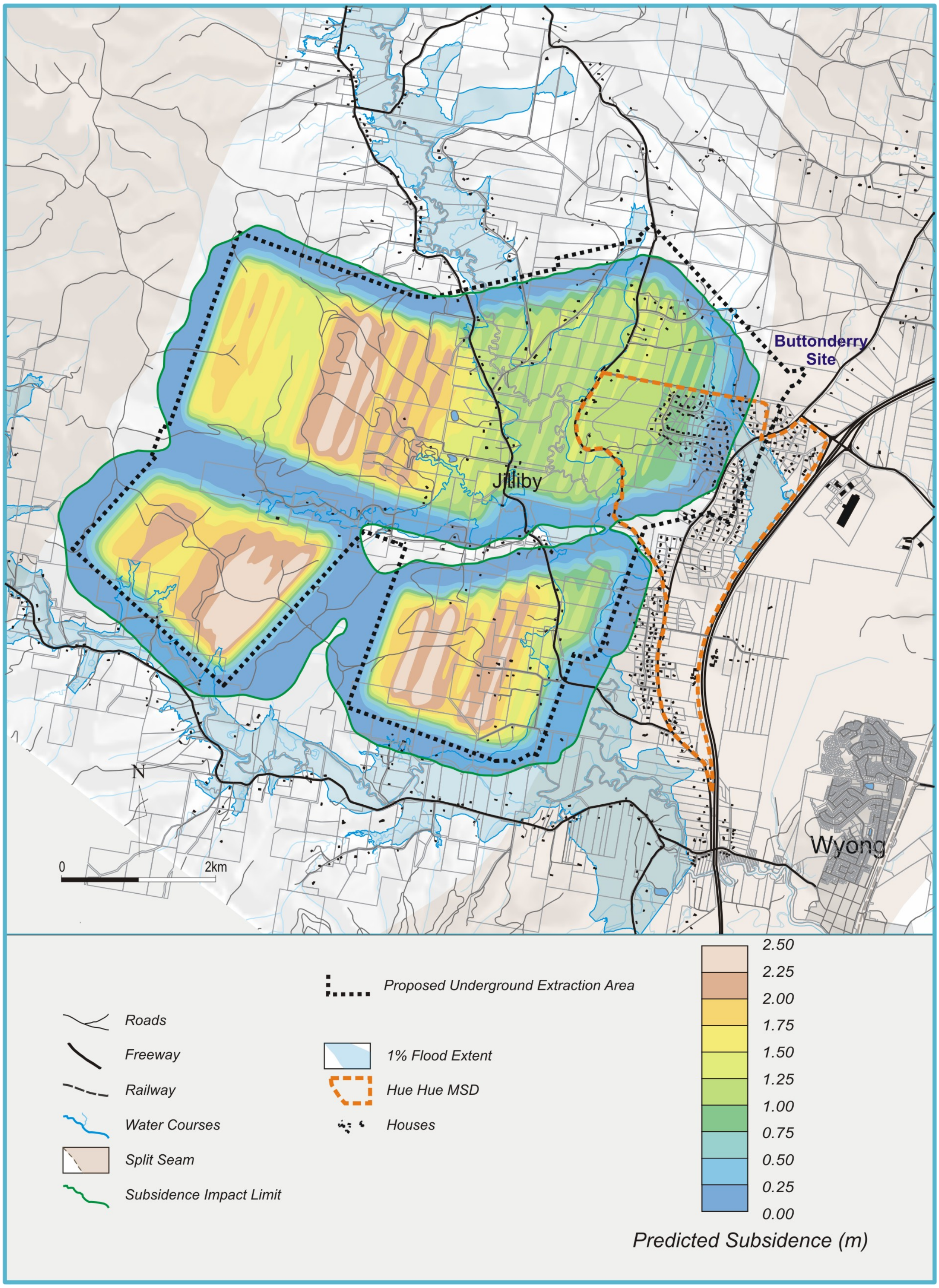

Figure 6.12 Predicted Total Subsidence

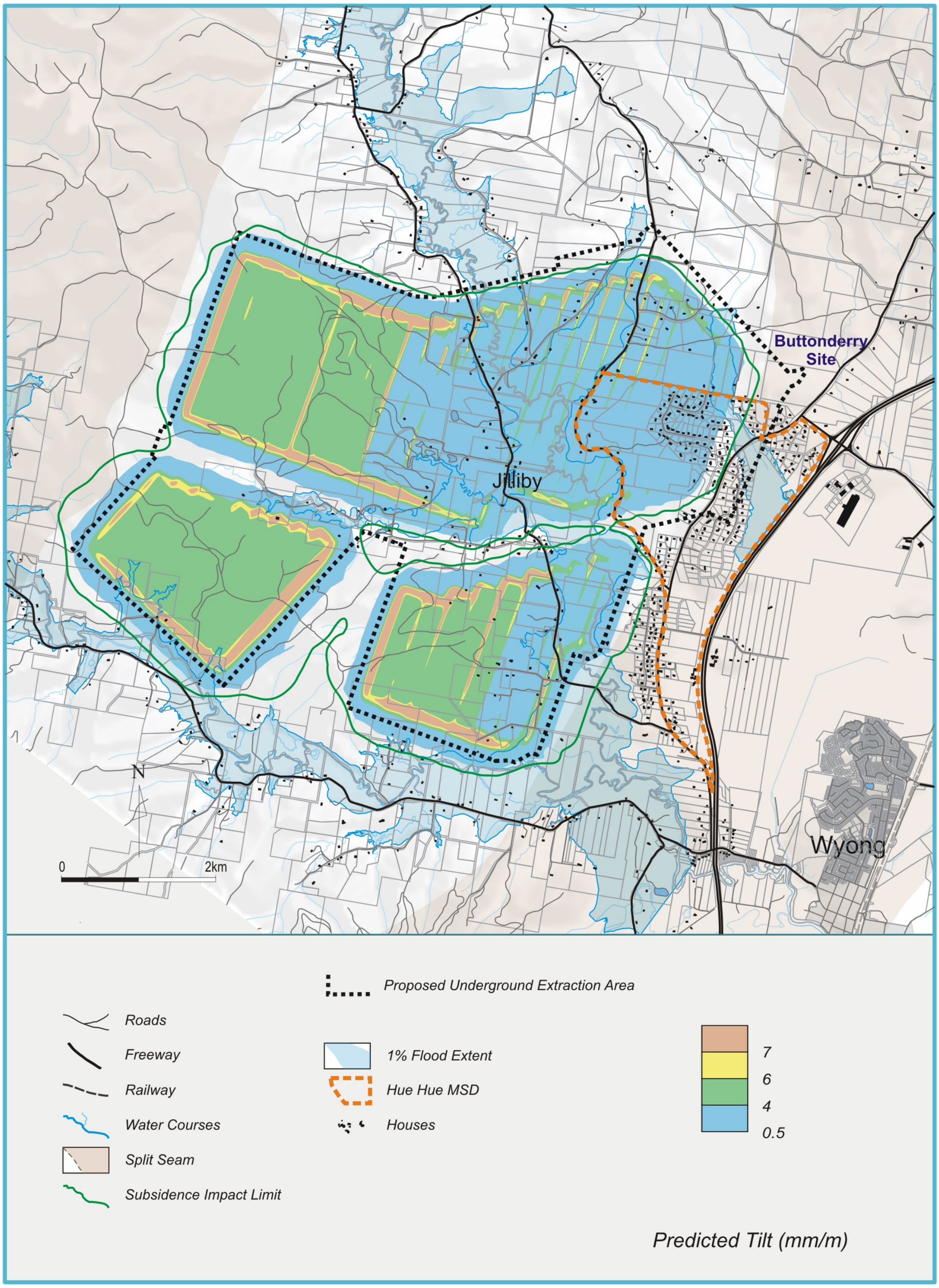

Figure 6.13 Predicted Total Tilt

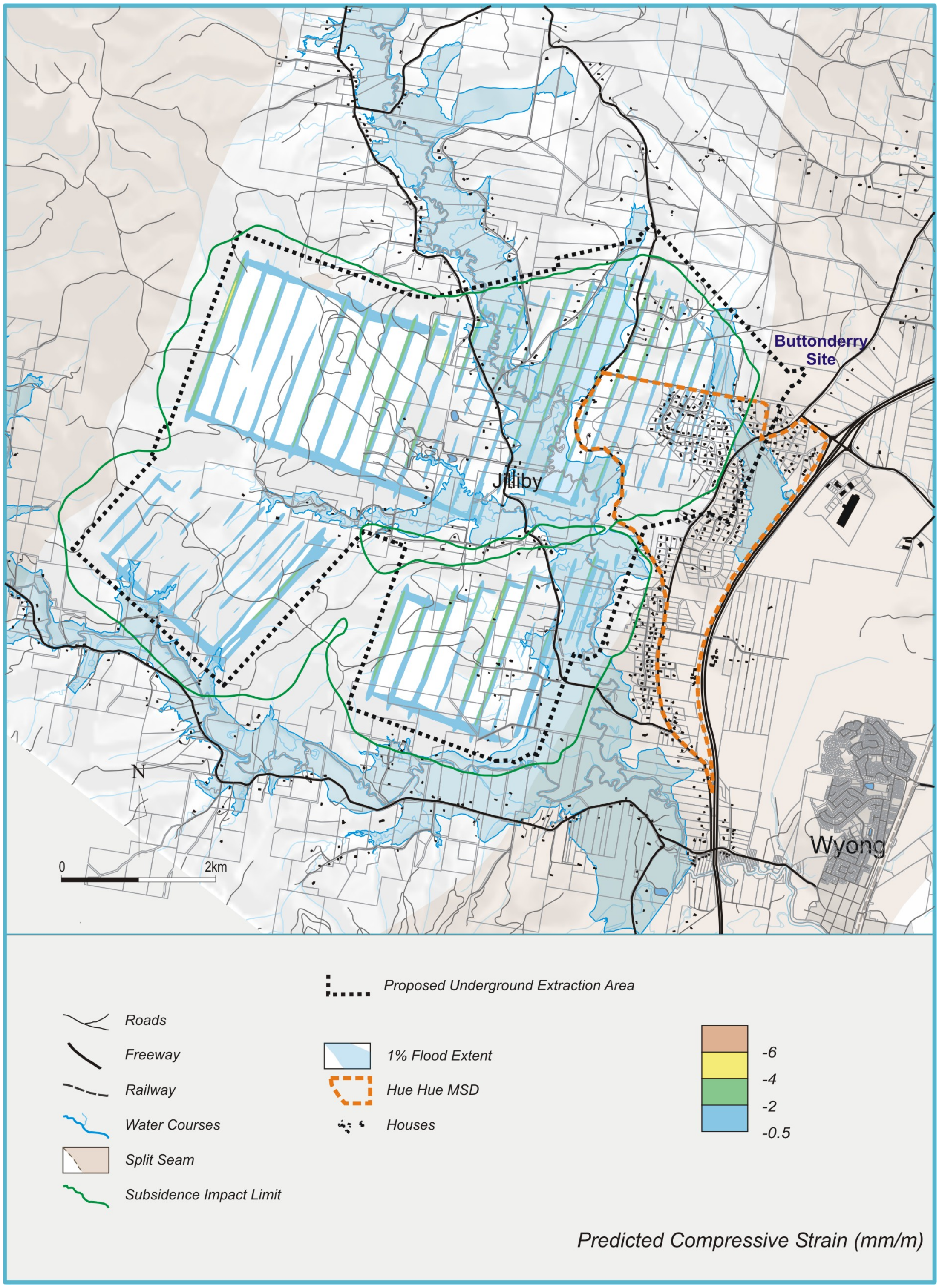

Figure 6.14 Predicted Total Compressive Strain

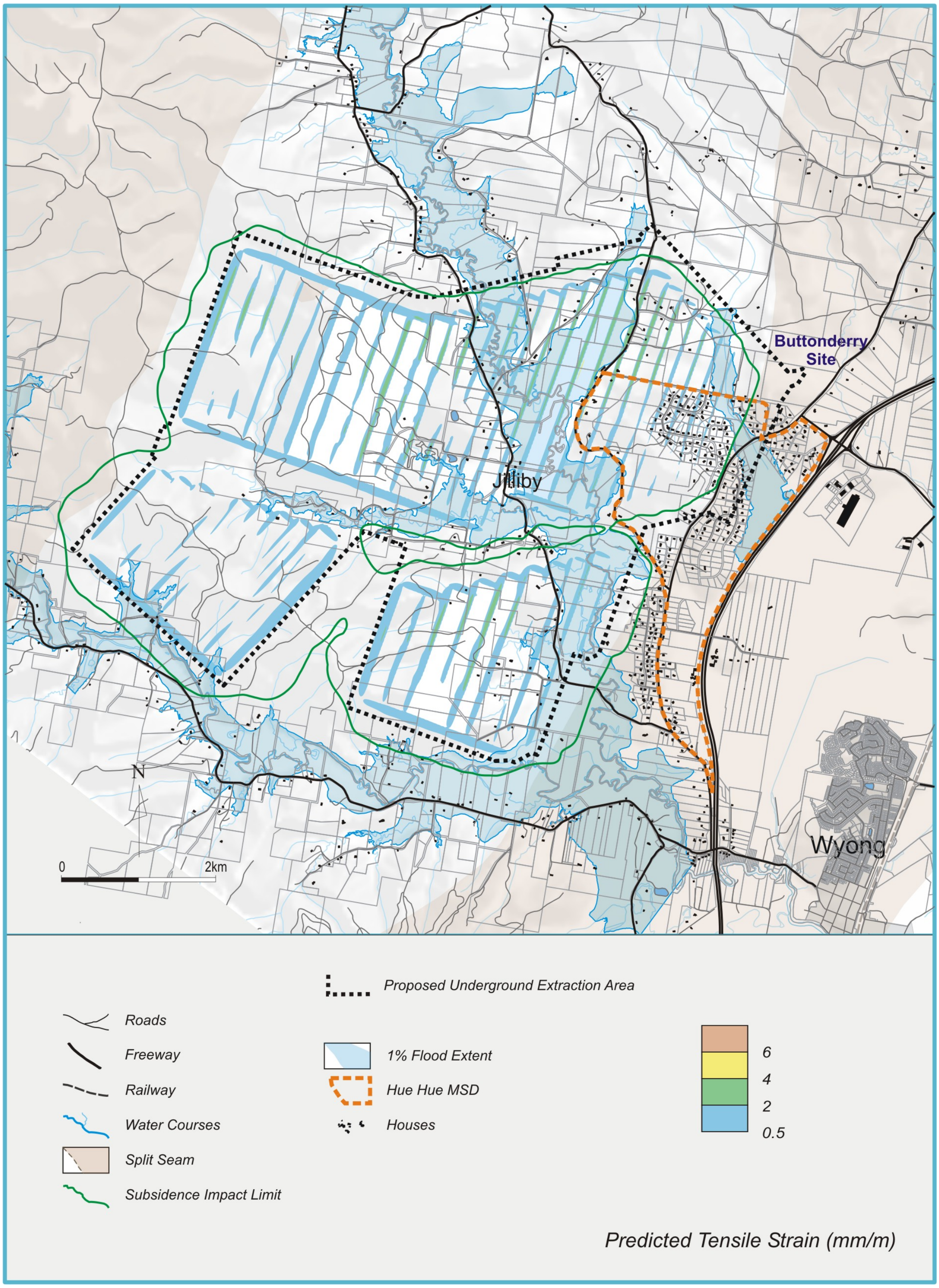

Figure 6.15 Predicted Total Tensile Strain

6.5 Subsidence Effects

The WACJV recognises that the proposed mine layout must address key concerns and issues associated with longwall mining and subsidence. Final approval from I&I NSW to commence longwall extraction in the W2CP area will be conditional upon the development and submission of a detailed Subsidence Management Plan (SMP) by WACJV. This SMP will involve a detailed assessment of the potential impacts of mine subsidence in the proposed mine area together with details of how they will be mitigated and managed to meet the expectations of the various stakeholders. In preparing the SMP, emphasis will be placed on the significance of the impact rather than the specific magnitude of the effect alone.

This assessment of subsidence impacts has sought to provide:

- realistic predictions of the character and magnitude of mining induced movement; and
- input data to assist relevant specialist impact assessment studies.

This has been achieved through the development of a mechanistically based modelling process that provides predictions for a 'worst case' scenario. Empirical data gathered during the mining process will be used to back analyse these predictions, revise them where necessary, and underpin further optimisation of the mine layout if required.

6.5.1 Vertical Subsidence

The main potential impact of vertical subsidence is upon the flood implications within the existing flood prone areas of Dooralong and Yarramalong Valleys. This results from a combination of increasing and decreasing flood retention capacity, flood depth and duration.

While Wyong Shire Council currently seeks that all dwellings in Mine Subsidence Districts be located such that their floor levels are at least 600 mm above the 100 year flood level, WACJV recognises that subsidence has the potential to modify this free-board as well as increase the inundation potential of non-habitable structures, roads and other elements of infrastructure. Consequently a number of mine layouts were modelled to determine the sensitivity of flood impacts to vertical subsidence. The output of this modelling has provided direct input into flood modelling to assess the impact on the 100 yr flood extent line, relative flood levels and various inundation issues in the Dooralong Valley and Hue Hue Creek areas. The detailed results of these studies are contained within the ERM flood study report, and will act as a key element in the preparation of the Subsidence Management Plan. That SMP will contain specific management strategies for structures that are deemed to be at risk.

6.5.2 Ground Movement

The main impact of ground movement is the effect of strains and tilts on relatively rigid structures such as houses. The Hue Hue Mine Subsidence District is the only portion of the proposed mine area for which specific limits apply for mining induced ground movements. These limits are 3 mm/m of strain and 4 mm/m of tilt. The iterative design process described in this report has been used to ensure that the current mine layout will comply with these legislative requirements.

All of the houses that have been built in the Hue Hue Mine Subsidence District since it was proclaimed in 1985 have been designed to criteria that will safeguard against structural damage if they experience ground movements of these magnitudes. In the event that any impacts do occur, the Mine Subsidence Board (MSB) will rectify them. In addition, any houses that were constructed prior to the proclamation of the

Mine Subsidence District are similarly covered and any damage will be rectified by the MSB at no cost to the landowner.

The WACJV has used available information and compiled an exhaustive database containing the accurate location and construction details of buildings in the entire proposed mine area to serve as a key element in the preparation of the Subsidence Management Plan. That plan will contain specific management strategies for structures that are deemed to be at risk. The SMP will benefit from additional property knowledge and appreciation of detailed issues gained during consultation with landowners.

Similarly, public infrastructure such as transmission lines, pipelines, roads and cables, which cross the proposed mine area, have been identified for detailed consideration in the Subsidence Management Plan. Initial discussions with representatives of the owners of such assets have been undertaken to gain a full appreciation of the possibilities and limitations that may exist in managing potential effects. No insurmountable issues have been identified at this stage.

6.5.3 Upsidence and Closure

When topographically significant and relatively narrow river valleys are affected by mine subsidence, the observed subsidence in the base of the creek or river is generally less than the level that would normally be expected in flat terrain. This reduced subsidence is due to the floor of the valley moving upwards and this phenomenon is referred to as valley bulging or upsidence. At the same time, the sides of the valley are observed to move towards the centre of the valley. The reduced distance across the valley is referred to as valley closure.

The local reduction in subsidence, or upsidence, is generally accompanied by localised changes in ground movement (tilt, curvature) and permeability to a depth of up to 10 m below the base of the valley. The reduction in width across the valley, or closure, is generally accompanied by high compressive strains in the centre of the valley. In the case of escarpments and wide river gorges the movements may be limited to the cliffs that are closest to the extracted area.

Valley bulging is a natural phenomenon resulting from the formation and ongoing development of the valley. The impact of mining may be to accelerate this process. The process of valley formation is a relatively slow one and is further complicated by the weathering of the strata in the sides of the valley, which results in rock falls and a gradual widening of the valley over geological time.

The effects of upsidence and closure are much more apparent in dramatic geomorphological features such as steep sided gorges with rock bar floors than in broad alluvium filled valleys such as in the W2CP area.

Research undertaken by MSEC has included reviews of previous experience of longwall mining in the Cataract, Georges, Nepean and Bargo Rivers to assist in evaluating the likely impact of these effects in the W2CP area.

The water flows in the Cataract, Georges and Bargo Rivers are dependent on bed gradients, rock bars and pools and the riverbeds are perched above the local groundwater levels. A downstream weir, however, predominantly controls the water level in the Nepean River, and the riverbed is permanently flooded along its entire length. Consequently, the alluvials in that riverbed are fully flooded or saturated.

Exploration drilling in the W2CP indicates the presence of alluvial deposits of up to 40 m deep in the Wyong River, Little Jilliby Jilliby Creek and Jilliby Jilliby Creek valleys. This indicates that experience of longwall mining in the Nepean River is more applicable to the W2CP area than case histories relating to features such as Cataract Gorge.

It is expected that a shallow zone in the bedrock beneath these saturated riverbeds may fracture, buckle, or uplift due to the valley closure and upsidence movements creating a zone of increased permeability in the upper few metres of rockhead. However, since this will occur beneath the saturated alluvial deposits the fracture zone will fill as it develops with little or no effect to the ground water level. Similarly, since this permeability zone will develop quite gradually, and its volume will be small compared to the volume of the overlying saturated alluvium, the impact on overall stream flow will be insignificant.

It is also worthwhile noting that whilst longwall mining has occurred directly beneath the Cataract, Georges, Nepean and Bargo Rivers, no longwall extraction is proposed directly beneath the Wyong River or lower sections of Jilliby Creek.

6.5.4 Rock Mass Disturbance

The main impacts that may potentially emerge from rock mass disturbance are the disruption of aquifers and/or surface water regimes. These may occur where mining induced fracture systems that develop above the longwall goaf intersect an aquifer or propagate through to the surface. Surface fracturing such as this, however, is mainly confined to areas of relatively shallow depths of cover.

The numerical modelling that has been undertaken as part of this study, indicates that the caving related fracturing extends to approximately 200 m above the seam, beyond which the disturbance to the strata is limited to bedding plane shear and localised, non-continuous fracturing. Whilst some enhanced permeability is anticipated in the near surface strata as a result of subsidence related cracking at rockhead (see Section 6.5.3), there is no evidence of connectivity with the deeper, mining induced fracture systems. This is not unexpected since the two fracture systems will be vertically separated by 200-300 m of strata. To further evaluate this possibility however, further studies using acoustic scanner results from key boreholes were undertaken to determine the possible existence of natural fracture networks that may contribute to future connectivity. These investigations failed to identify any such zones that could facilitate large-scale shear movements which may connect to the mine.

Although no significant aquifers have been identified in the proposed mine area, the numerical modelling results prepared by SCT were forwarded to Mackie Environmental Research Pty Ltd to assess the effect of mining induced fracturing on the groundwater regime. That modelling, analysed in conjunction with acoustic scanner results also sought to confirm that mining induced fracturing is unlikely to result in excessive water ingress to the proposed mine workings. The detailed results of these studies are contained within the Mackie Environmental Research groundwater study report (Appendix B).

6.5.5 Far Field Horizontal Movements

Far field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain. Impacts attributed to this form of movement result from differential displacement and are therefore confined to large rigid structures and steep natural features such as cliffs or gorges. These movements generally do not result in impacts on surface infrastructure, or small rigid structures such as buildings.

These horizontal surface movements are associated with the phenomenon of bedding plane slip and although they are very small in magnitude, they have been detected over 1 km beyond the mining zone. They may occur if bedding planes with sufficiently low frictional properties, such as claystones, experience sufficient horizontal stress relief to enable them to experience shear failure. Since these planes are typically on the verge of their stability equilibrium, only minor changes in the stress field are therefore required to initiate some degree of movement.

South Coast experience suggests that while mining in the W2CP area will be expected to result in some activation of such planes, the impact on low lying areas is not likely to be noted, particularly where there is a covering of Quaternary sediments and no significant relief to create differential movement across rigid man made structures or natural features. The greatest likelihood of potential far field horizontal effects from subsidence would be confined to the high relief areas in the western part of the proposed mining area.

6.6 Subsidence Related Impacts

Subsidence has the potential to lead to other impacts. While each of these issues is discussed in detail in the following chapters, a summary is provided below.

6.6.1 Groundwater

Three principal domains of groundwater have been identified within the region – the unconsolidated alluvial aquifers hosted within the Yarramalong and Dooralong valleys and coastal areas, the shallow weathered rock zone, and the more regional Narrabeen Group of sedimentary rocks overlying the Wallarah–Great Northern (WGN) seam. Other than the surface unconsolidated alluvium, the remaining strata are considered to be aquitards (very poor groundwater transmission characteristics) or aquicludes (impermeable).

The numerical modelling results prepared by SCT have been used by Mackie Environmental Research to assess the effect of mining induced fracturing on the groundwater regime. The resultant ground water model, discussed in Chapter 8, has confirmed that mining induced fracturing is highly unlikely to adversely affect streams and alluvial aquifers.

6.6.2 Surface Water

Mining in or under any catchment usually has negligible impacts on water supplies. This has been the experience throughout NSW as evidenced by numerous technical reports to both the Southern Coalfields Inquiry into longwall mining and the Expert Panel into Coal Mining in the Wyong LGA. The factors involved in the prevention and mitigation of potential impacts on water supply catchments are complex, but include factors such as geology, depth of mining, extraction height (thickness of coal seam section to be mined), overburden rock type and behaviour, surface hydrology and topography.

Underground mining can cause vertical subsidence, which in itself does not affect the water yield of a catchment but can affect flood levels near subsided areas and, to a small extent, peak flows. Shallow mining under weak overburden layers can result in fracturing that can cause loss of groundwater and surface flows to aquifers or to the mine void. However, in the case of the W2CP the coal seams are very deep and overburden comprises strong, relatively unfractured rock with no significant aquifers so that the scenario of loss of surface flow or groundwater through fractures would be extremely unlikely if not impossible.

6.6.3 Houses and Structures

The proposed mine layout that has resulted from the iterative design process, using the W2CP subsidence prediction curves, is consistent with relevant requirements for both the Hue Hue and Wyong Mine Subsidence Districts and the Mine Subsidence Board of NSW (MSB). Should damage occur to any land improvements, repairs will be carried by the MSB at no cost to the land owners.

A detailed assessment has been undertaken by MSEC (refer Appendix A) on each house and structure within the mining area. This assessment has included a range of potential impacts based on a revised method of impact classification as described in Table 6.1.

Table 6.1 Revised Classification based on the Extent of Repairs

Repair Category	Extent of Repairs
Nil	No repairs required
R0 **Adjustment**	One or more of the following, where the damage does not require the removal or replacement of any external or internal claddings or linings:- - Door or window jams or swings, or - Movement of cornices, or - Movement at external or internal expansion joints.
R1 **Very Minor Repair**	One or more of the following, where the damage can be repaired by filling, patching or painting without the removal or replacement of any external or internal brickwork, claddings or linings:- - Cracks in brick mortar only, or isolated cracked, broken, or loose bricks in the external façade, or - Cracks or movement < 5 mm in width in any external or internal wall claddings, linings, or finish, or - Isolated cracked, loose, or drummy floor or wall tiles, or - Minor repairs to any services or gutters.
R2 **Minor Repair**	One or more of the following, where the damage affects a small proportion of external or internal claddings or linings, but does not affect the integrity of external brickwork or structural elements:- - Continuous cracking in bricks < 5 mm in width in one or more locations in the total external façade, or - Slippage along the damp proof course of 2 to 5 mm anywhere in the total external façade, or - Cracks or movement ≥ 5 mm in width in any external or internal wall claddings, linings, finish, or - Several cracked, loose or drummy floor or wall tiles, or - Replacement of any services.

Repair Category	Extent of Repairs
R3 Substantial Repair	One or more of the following, where the damage requires the removal or replacement of a large proportion of external brickwork, or affects the stability of isolated structural elements:- - Continuous cracking in bricks of 5 to 15 mm in width in one or more locations in the total external façade, or - Slippage along the damp proof course of 5 to 15 mm anywhere in the total external façade, or - Loss of bearing to isolated walls, piers, columns, or other load-bearing elements, or - Loss of stability of isolated structural elements.
R4 Extensive Repair	One or more of the following, where the damage requires the removal or replacement of a large proportion of external brickwork, or the replacement or repair of several structural elements:- - Continuous cracking in bricks > 15 mm in width in one or more locations in the total external façade, or - Slippage along the damp proof course of 15 mm or greater anywhere in the total external façade, or - Relevelling of building, or - Loss of stability of several structural elements.
R5 Re-build	Extensive damage to house where the MSB and the owner have agreed to rebuild as the cost of repair is greater than the cost of replacement.

There are 242 houses that have been identified within the mining area. A summary of the predicted movements and the assessed impacts for each house within the study area is provided in Table D.01 in Appendix A. The distribution of the assessed impacts for the houses within the Study Area is provided in Table 6.2.

Table 6.2 Assessed Impacts for the Houses within the Study Area

Group	Repair Category			
	No Claim or R0	R1 or R2	R3 or R4	R5
All houses (total of 242)	200 (83 %)	29 (12 %)	12 (5 %)	≈ 1 (< 0.5 %)

By way of sensitivity analysis, if the predicted tilts were increased by factors of up to 2 times, the predicted maximum tilts would be less than 7 mm/m at 193 of the houses (i.e. 80 %) at the completion of mining. It would still be expected that only minor serviceability impacts would occur at these houses, as the result of tilt, which could be remediated using normal building techniques.

The predicted maximum tilts would be between 7 mm/m and 10 mm/m at 24 houses (i.e. 10 %) and would be greater than 10 mm/m at 25 houses (i.e. 10 %) at the completion of mining. It would be expected that greater serviceability impacts would occur at these houses which would require more substantial remediation measures including, in some cases, relevelling of the building structures.
It is expected, in all cases, that the houses within the Study Area would remain safe as the result of the mining induced tilts.

Similarly, if the predicted curvatures and strains were increased by factors of up to 2 times, it would still be expected that the houses would remain safe. The impacts would develop slowly, allowing preventive measures to be undertaken and, where required, relocation of residence if any structures were deemed to become unsafe.

Management strategies will be developed as part of Property Subsidence Management Plans or the Extraction Plans, to manage the potential for impacts to the residential and non-residential structures. The management strategies would include the following where access is provided to the property:

- identification of structures and their forms of construction prior to mining;
- identification by a suitably qualified building inspector of any structures or structural elements that may be potentially unstable prior to mining;
- implementing any mitigation measures, where necessary to address specific identified risks to public safety;
- undertaking detailed monitoring of ground movements at or around structures, where necessary to address specific identified risks to public safety;
- periodic inspections of structures that are considered to be at higher risk. These may include:
  - structures in close proximity to steep slopes where recommended by a geotechnical or subsidence engineer;
  - structures identified as being potentially unstable where recommended by a structural or subsidence engineer; and
  - pool fences.
- coordination and communication with landowners and the Mine Subsidence Board during mining.

With these strategies in place, it is expected that the houses would remain safe throughout the mining period.

6.6.4 Public Infrastructure

Public infrastructure such as transmission lines, pipelines, roads and cables, which cross the proposed mine area, have been identified in the Subsidence Assessment contained in Appendix A. These items will be further detailed in the Subsidence Management Plan and will include updated predictive modelling once subsidence monitoring data is available. Initial discussions with representatives of the owners of such assets have been undertaken to gain a full appreciation of the possibilities and limitations that may exist in managing potential effects. No insurmountable issues have been identified at this stage.

Two transmission lines operated by TransGrid cross the proposed mine area. Calculations of subsidence, tilt and strain at each tower and bay length changes between the towers were issued to and discussed with TransGrid in 2006, 2007 and 2008. The proposed mine layout and the predicted levels of mine subsidence movements at the transmission lines and towers has not changed significantly since January 2007. Preliminary investigations indicated that all but two of these towers can be managed quite readily, with the remaining two tension towers requiring special consideration. Neither of these towers however is affected until some 20 years into the mine life, so it would be premature to develop a detailed management plan at this stage. Further detailed investigations will be undertaken during the Subsidence Management Plan process which allows for sufficient time to undertaken any necessary mitigation works to tower structures well in advance of mining.

Smaller local and domestic power lines, optical fibre and telecommunications infrastructure, farm infrastructure, water tanks, public amenities, local roads, F3 Freeway and bridges have been identified and assessed. As detailed in Appendix A, none of this infrastructure is expected to be adversely impacted by mine subsidence.

6.6.5 Soils

The impact on soils above the underground extraction area will be indirect through the effects of subsidence. Impacts on the soil structure and material that could potentially arise as a result of subsidence are limited to the physical characteristics of the soil material, the chemical composition will not be altered.

Potential physical effects that may be experienced include:

- Hardsetting soil surfaces are more likely to crack as a result of subsidence than other soil materials that have a high plasticity or loosely consolidated;
- Cracks in the soil surface, if left unrehabilitated, may have the potential to cause erosion;
- Where subsidence results in localised pooling of water that would not otherwise occur, the wet-strength of the soil material may be of importance; and
- In situations where a steep slope is tilted, there may be the potential for some slumping to occur in susceptible soil materials.

Above the mining area are six different soil landscapes, and numerous different soil materials, which are described in detail in Section 15.4. Each of the soil materials possess different physical and chemical properties, as summarised in Table 6.3. The higher risk areas for soil disturbance occurs in the more elevated terrain within Wyong State Forest. More low lying flood plain areas tend to contain loose unconsolidated alluvial material which have a low risk of soil disturbance due to subsidence with the exception of some creek banks.

It is primarily the physical limitations and erosional characteristics of the soil materials that will render some more susceptible to subsidence related impacts than others. For example, soil materials such as categories ml2, er5, and wo3 that have a high plasticity, are less likely to show signs of cracking, whereas soils with hardsetting surfaces are more likely to develop cracks as the ground tilts and strains. The potential risks of subsidence to each of the soil types is also summarised in the table below, along with the rehabilitation techniques, which are further described in detail in the following section.

Table 6.3 Summary of Soil Characteristics Above the W2CP Mining Area

Soil Material	Physical Limitations					Erosion			Potential Risks from W2CP Underground Extraction	Areas Identified for Possible Monitoring	Possible Rehabilitation Techniques
	High Plasticity	Low wet Strength	Shrink-swell	Organic Matter	Stoniness	Sodicity	Erodibility	Hardsetting surface			
Mandalong Soil Landscape											
ml1									Cracking of Hardsetting surfaces which may lead to erosion.	Banks of Jilliby Jilliby Ck and Myrtle Ck.	Filling in cracks and revegetating area of disturbance.
ml2									Changes of water flow may exacerbate existing erosion.	Banks of Jilliby Jilliby Ck and Myrtle Ck.	Erosion control and revegetating disturbed area.
ml3									Changes of water flow may exacerbate existing erosion.	Banks of Jilliby Jilliby Ck and Myrtle Ck.	Erosion control and revegetating disturbed area.
Watagan Soil Landscape											
wn1									None	None	None
wn2									Changes of water flow may exacerbate existing erosion.	Scattered ridge tops throughout mining area.	Erosion control and revegetating disturbed area.
wn3									None	None	None
wn4									None	None	None
wn5									None	None	None
wn6									None	None	None
Erina Soil Landscape											
er1									None	None	None
er2									Cracking of Hardsetting surfaces which may lead to erosion.	Small section on western perimeter of mining area.	Filling in cracks and revegetating area of disturbance.

Table 6.3 Summary of Soil Characteristics Above the W2CP Mining Area

Soil Material	Physical Limitations					Erosion			Potential Risks from W2CP Underground Extraction	Areas Identified for Possible Monitoring	Possible Rehabilitation Techniques
	High Plasticity	Low wet Strength	Shrink-swell	Organic Matter	Stoniness	Sodicity	Erodibility	Hardsetting surface			
er3									Changes of water flow may exacerbate existing erosion.	Small section on western perimeter of mining area.	Erosion control and revegetating disturbed area.
er4									Changes of water flow may exacerbate existing erosion.	Small section on western perimeter of mining area.	Erosion control and revegetating disturbed area.
er5									None	Small section on western perimeter of mining area.	None
er6									None	Small section on western perimeter of mining area.	None
Woodburys Bridge Soil Landscape											
wo1									None	None	None
wo2									Cracking of Hardsetting surfaces which may lead to erosion.	Scattered locations adjacent to creeklines.	Filling in cracks and revegetating area of disturbance.
wo3									Changes of water flow may exacerbate existing erosion.	Scattered locations adjacent to creeklines.	Erosion control and revegetating disturbed area.
wo4									Changes of water flow may exacerbate existing erosion.	Scattered locations adjacent to creeklines.	Erosion control and revegetating disturbed area.
Yarramalong Soil Landscape											
ya1									Changes of water flow may exacerbate existing erosion.	Banks of Jilliby Jilliby Ck and Myrtle Ck.	Erosion control and revegetating disturbed area.
ya2									Cracking of Hardsetting surfaces which may lead to erosion.	Banks of Jilliby Jilliby Ck and Myrtle Ck.	Filling in cracks and revegetating area of disturbance.
ya3									Changes of water flow may exacerbate existing erosion.	Banks of Jilliby Jilliby Ck and Myrtle Ck.	Erosion control and revegetating disturbed area.
ya4									Changes of water flow may exacerbate existing erosion. Loss of structural integrity.	Banks of Jilliby Jilliby Ck and Myrtle Ck.	Erosion control and revegetating disturbed area. Repair foundations.

Table 6.3 Summary of Soil Characteristics Above the W2CP Mining Area

Soil Material	Physical Limitations					Erosion			Potential Risks from W2CP Underground Extraction	Areas Identified for Possible Monitoring	Possible Rehabilitation Techniques
	High Plasticity	Low wet Strength	Shrink-swell	Organic Matter	Stoniness	Sodicity	Erodibility	Hardsetting surface			
Gorokan Soil Landscape											
gk1						Widespread Occurrence	Widespread Occurrence		Changes of water flow may exacerbate existing erosion.	Isolated occurrences.	Erosion control and revegetating disturbed area.
gk2						Widespread Occurrence	Widespread Occurrence	Widespread Occurrence	Cracking of Hardsetting surfaces which may lead to erosion.	Isolated occurrences.	Filling in cracks and revegetating area of disturbance.
gk3	Widespread Occurrence						Widespread Occurrence		Changes of water flow may exacerbate existing erosion.	Isolated occurrences.	Erosion control and revegetating disturbed area.
gk4	Widespread Occurrence	Localised Occurrence				Widespread Occurrence	Widespread Occurrence		Changes of water flow may exacerbate existing erosion.	Isolated occurrences.	Erosion control and revegetating disturbed area.

Limitation not an issue   Widespread Occurrence   Localised Occurrence

Source – Table adapted from Table 4.1 of Department of Conservation and Land Management *Soil Landscapes of the Gosford – Lake Macquarie 1:100 000 Sheet,* 1993.

Note - For detailed descriptions of the soil materials refer to Section 16.4.

6.7 Rehabilitation Techniques

Despite the expectation that no surface cracking or other visible land disturbance would occur in the valley areas and limited if any within the forested hills of the Wyong State Forest and Jilliby State Conservation Area, any detected mining related disturbances to the soil surface, whether on privately owned or public land will be repaired by the W2CP. The rehabilitation techniques used will be site specific, and will often depend on the location, level of disturbance, accessibility of equipment, and landowner input. Techniques that are commonly used are described in the following sections.

6.7.1 Filling Cracks

In locations where cracks have been identified as a result of mining, there are a number of options for repairing the damage. The method selected will depend largely on the degree of disturbance, and may include:

- If the cracks are only minor and there is no risk of erosion gullies developing from the crack, it may be allowed to naturally fill in. No active works may be required;
- The cracks may be filled with surrounding material, if suitable material can be found without causing unnecessary additional disturbance; or
- If there is no suitable material available in the surrounding vicinity, clean, weed-free fill material of a similar composition will be brought in.

Repair of cracks may be done either by hand using a shovel, or with small equipment. This will depend on the size of the crack, sensitivity of the surrounding area to the use of machinery, accessibility for machines, and the landowners request.

Following filling of cracks, revegetation may be required.

6.7.2 Revegetation

If instances of surface soil cracks, erosion or slumping are detected as a result of subsidence, revegetation may be required to stabilise the surface. Depending on the degree of damage and erosion that could potentially result, the surface will be quickly stabilised by sowing a grass seed mix similar in composition to the immediately surrounding area. In some cases however, where the area of disturbance is small and there is no risk of erosion, the area may be left to naturally revegetate.

In areas where the damage has occurred on steep slopes, spray seeding with an application of straw, anionic bitumen, seed and fertilizer may be required. This is an active form of revegetation as it provides an instantaneous cover in the form of straw which is effectively bound to the surface by the bitumen. The seed mix consists of fast growing improved pasture species combined with a heavy fertiliser application. This provides a quick and substantial grass cover which, when combined with the straw enhances erosion control and provides organic matter to the surface soil material. The application is however, limited to smaller areas that are accessible by road registered truck mounted spray equipment.

6.7.3 Erosion Control

Areas where there is the risk of erosion as a result of subsidence, sediment fences will be constructed downslope of the exposed site. The purpose of the fence is to filter runoff from disturbed areas, trapping the sediment and allowing filtered water to pass through. The reason for using a filter fabric instead of a straw bale filter is the ease of removing trapped material to be returned to the original site. Sediment fences will be maintained until a self sustaining and stable land cover exists over the exposed or disturbed site. Such work is likely to be limited to high voltage transmission tower sites.

6.8 Monitoring

The majority of the land above the mining area is held by private entities, and access to properties will be by negotiation with each landowner. In areas where access is granted, and in public areas, monitoring and inspections as described in the following section will be carried out to identify any areas where rehabilitation works are required. The monitoring program will be further refined and more detailed in the Subsidence Management Plans that are to be prepared for the mining area following granting of project approval, and are prepared on an individual property basis.

6.8.1 Inspections

Based on the assessment of soil types that could potentially display subsidence related impacts in certain locations, areas have been identified that will be regularly inspected to detect any locations where rehabilitation works may be required, for example any signs of cracking, new erosion channels, or slumping of land.

Inspections will involve a traverse of the mining area at the identified locations (dependant on permission to access) to search for any signs of subsidence related damage. In the event that an area of subsidence related damage is found, the exact location will be recorded using a GPS, and expert advise employed regarding the rehabilitation of the area in consultation with the affected landowner.

Based on previous mining experience, pre-mining inspections are carried out to identify any areas where erosion or cracking etc already exists, to assist in determining whether any future surface disturbances are related to the W2CP or some other influence as well as to determine and correct any underlying erosional cause.

Following the commencement of underground extraction, previously identified areas will be re-inspected approximately six months after the longwall has passed. It is expected that all subsidence related effects will occur in this six month period. Following the first post-mining inspections, annual visits will be routine for a five year period. This is to ensure that if there are any erosional effects that are slow and more gradual, then sufficient time is provided for the management process of inspection and undertaking any necessary rectification works.

Should impacts be evident after this period then mitigation works will still be undertaken. All works will be carried out at no cost to the landowner either private or public.

6.8.2 Subsidence Data Collection

In general, subsidence monitoring will be conducted monthly of the panel crosslines and centrelines using either insitu survey pegs or remote sensing marker points. The design of the monitoring layout will be to allow effective comparison between predicted and measured subsidence parameters for each panel and at each surface feature. Structures and utilities will be separately monitored in accordance with DII-MR requirements but will likely include separate survey targets.

Subsidence data will be collected in 3-D coordinates to determine vertical movement, strain and tilt parameters at each peg or marker point. The monitoring program will also include visual inspections, mapping and photographic record.

6.8.3 Recording and Reporting of Monitoring Results

The survey lines will be installed at least one month before longwall extraction occurs to allow at least one baseline survey to be completed. The baseline survey will include the pre-inspections for any structures within the zone of influence of each panel which is then provided to both the land owner and Department of Industry and Investment (I&I NSW).

Reports will then be prepared on a quarterly basis for each longwall panel as well as an annual end of panel report and provided to the DII-MR. Both hard and soft copies will be provided and will include subsidence measurements in Excel format, details of visual inspections, copies of photographs and a mine plan showing areas extracted during the reporting period.