# BULLI SEAM OPERATIONS

# APPENDIX P
# STREAM RISK ASSESSMENT

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APPENDIX P

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# STREAM RISK ASSESSMENT


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# P1 INTRODUCTION

The Bulli Seam Operations (the Project) is located approximately 25 kilometres (km) north-west of Wollongong in New South Wales (NSW). The Project involves the continuation of underground mining operations at the Appin Mine and West Cliff Colliery with development to extend to the north (Appin Area 7 and West Cliff Area 5), east (North Cliff), west (Appin West [Area 9] and Appin Area 8) and south (Appin Areas 2 and 3 Extended). A description of the Project is provided in Section 2 in the Main Report of the Environmental Assessment (EA).

As part of the Director-General's Environmental Assessment Requirements (EARs), the EA must include an assessment of potential impacts of the Project taking into consideration the findings and recommendations of the Southern Coalfield Inquiry (SCI). The findings of the SCI are documented in the report *Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield - Strategic Review* (herein described as the Southern Coalfield Panel Report [SCPR]) (NSW Department of Planning [DoP], 2008).

In June 2009, the Minister for Planning released the NSW Planning Assessment Commission's *Metropolitan Coal Project Review Report* (May, 2009) (herein described as the Metropolitan PAC Report). The Metropolitan Coal Project was the first mining proposal in the Southern Coalfield to be assessed under Part 3A of the *Environmental Planning and Assessment Act, 1979* (EP&A Act) since the SCPR was published in 2008.

Of relevance to this Project, the Metropolitan PAC Report concludes (page 132):

> *The Panel considers that it would be desirable if future proposals for mining in the Southern Coalfield were required to take account of the SCI recommendations as modified by this report in preparing the Project Application and the subsequent EA.*

Specifically, Recommendations 2, 3 and 11 of the Metropolitan PAC Report state (pages 135, 136 and 138):

> ***Recommendation 2***
>
> *The Panel recommends that the concept of RMZs enunciated in the SCI report be incorporated into a broader risk framework that includes:*
>
> - *Identifying natural features likely to be at risk of negative environmental consequences from subsidence impacts.*
> - *Assessing the potential risk to those features from the mining proposal.*
> - *Identifying the options for dealing with any significant risk.*
> - *Determining which of these options will form part of the management plan.*
> - *Monitoring the subsidence impacts, consequences for the feature, and outcomes from the management strategies.*
> - *Contingency options and planning to deal with exceedances, and*
> - *Auditing of the risk management process.*
>
> ***Recommendation 3***
>
> *The Panel recommends that the steps set out in Section 6.2 of this review for assessing risk be considered for inclusion in future requirements for the assessment of proposals for mining in the Southern Coalfield to ensure that appropriate information on risks to significant natural features is available in the EA.*
>
> ***Recommendation 11***
>
> *The Panel recommends that until objective measures or policy guidance are available, adoption of an approach to significance and protection be adopted that is characterised by a case by case assessment of the values attributed to the watercourse, the options for protecting these values and the feasibility and costs of doing so. A suggested set of values is included in Section 7.4.1 of this report.*

This Stream Risk Assessment has been prepared based on data provided by Gilbert & Associates, Heritage Computing, Bio-Analysis, FloraSearch, Biosphere Environmental Consultants, Mine Subsidence Engineering Consultants (MSEC) and Gillespie Economics.

## P2 FRAMEWORK AND ASSESSMENT APPROACH

The Metropolitan PAC Report indicates (page 79) that the Panel spent time considering a risk assessment approach for subsidence impact and environmental consequences in relation to natural features and the approach is described in Section 6.2 of the Metropolitan PAC Report (quoted below).

> *The following steps are suggested as a means of ensuring that adequate relevant information is available to the decision maker. They should also assist the Proponent and the regulators to focus their attention early on key issues for preparation of proposals and the identification of problems.*
>
> *Step 1. Identify the mine characteristics and types of subsidence impacts likely to be experienced in the Project Area. Mine characteristics include depth, geology, mining method, mining height, mine layout and percentage extraction.*
>
> *Step 2. Identify significant natural features that might be at risk from the subsidence impacts that could be expected from the proposal. In the case of the Southern Coalfield, a checklist of features that require consideration could be developed based on the SCI Report. It should include at least rivers and significant streams, upland swamps, endangered ecological communities, threatened species habitat, major cliff lines and Aboriginal Heritage. A full description of these features is required, including any characteristics that may be relevant in assessing potential subsidence-related impacts and consequences for the feature or parts of the feature.*
>
> *Step 3. Assess any features identified in Step 2 that warrant special significance status[27] in any proposed risk management plan.*
>
> *Step 4. Using the criteria set out in the SCI Report for deriving RMZ boundaries, draw a Risk Management Zone around those features from Step 2 and Step 3 and assess the risk to the feature (or relevant part of the feature)[28], and*
>
> *Step 5. Proposed risk management plans will be required:*
>
> - *For those features of special significance identified in Step 3 where a risk of impact is a real possibility.[29].*
> - *For those features identified in Step 2 where a risk of significant impact is a real possibility.[30]*
>
> *Risk management plans should identify:*
>
> *(i) the options for managing the risk based on one or a combination of avoidance, mitigation, remediation or tolerance and taking account of any assessment of special significance of the feature;*
>
> *(ii) where relevant, the potential costs of those options;*
>
> *(iii) a preferred option;*
>
> *(iv) where relevant, a monitoring regime that will detect impact, measure actual impact against predicted impact and measure the effectiveness of the management strategies adopted;*
>
> *(v) contingency plans for dealing with the situation where actual impact exceeds predicted impact; and*
>
> *(vi) auditing of the implementation and effectiveness of the risk management plan.*

[27] *'Special Significance Status' is based on an assessment of a natural feature that determines the feature to be so special that it warrants a level of consideration (and possibly protection) well beyond that accorded to others of its kind. It may be based on a rigorous assessment of scientific importance, archaeological and cultural importance, uniqueness, meeting a statutory threshold or some other identifiable value or combination of values.*

[28] *The Panel notes that it would be desirable to develop a two-stage risk assessment process for Step 4 to ensure that those features from steps 2 and 3 that are unlikely to meet the risk and impact thresholds in Step 5 are not required to undergo a stage 2 detailed risk assessment.*

[29] *'Real Possibility' in this context means that the risk of occurrence needs to be more than remote, but no so high as to require a finding of 'more likely than not'. A risk of occurrence of between 5 and 15 percent is probably an appropriate starting point for consideration.*

[30] *A lower level of acceptable impact will apply to features of special significance and the threshold for requiring preparation of a risk management plan will therefore also be lower.*

The framework and assessment approach to streams has been conducted consistent with the steps described in Section 6.2 of the Metropolitan PAC Report.

# P3 STEP 1 - MINE PARAMETERS AND LIKELY TYPES OF SUBSIDENCE IMPACTS

The Project mine parameters (depth, geology, mining method, mining height, mine layout and percentage extraction) and likely types of subsidence impacts are described below. Further detail is provided in Section 2 in the Main Report of the EA and the Subsidence Assessment (Appendix A of the EA).

## P3.1 MINE PARAMETERS

***Depth/Mining Height***

In the Project extent of longwall mining area, the Bulli Seam is located between approximately 300 metres (m) (in the south-east) and 850 m (in the north-west) below the surface and is the uppermost seam of the Illawarra Coal Measures.

The minimum depth of cover between each stream assessed in this report and the Bulli Seam ranges from approximately:

- 350 m (Stokes Creek reach 2) to 450 m (Dahlia Creek reach 2) in North Cliff;
- 405 m (Stokes Creek reach 1) to 445 m (Georges River reach 2 and Mallaty Creek) in West Cliff Area 5;
- 300 m (Tributary to Cataract Reservoir 2) to 430 m (Tributary to Cataract River 2) in Appin Areas 2 and 3 Extended;
- 425 m (Nepean River reach 2) to 595 m (Tributary to Navigation Creek 2) in Appin Area 7;
- 430 m (Harris Creek) to 700 m (Apps Gully) in Appin West (Area 9); and
- 345 m (Nepean River reach 1) to 665 m (Tributary to Racecourse Creek 2) in Appin Area 8.

***Geology***

Above the Bulli Seam, the stratigraphy of the area consists of a sequence of sandstone, shale and claystone units within the Narrabeen Group, which are in turn, overlain by the Hawkesbury Sandstone.

The Wianamatta Group is stratigraphically located above the Hawkesbury Sandstone and has been eroded from a significant portion of the Southern Coalfield. However, within the Project area the Wianamatta Group outcrops generally north-west of the Nepean River and Georges River and ranges in thickness from 0 m (where the Hawkesbury Sandstone is exposed) to greater than 150 m across the Razorback Range.

There are a number of known major structures (e.g. faults or fault systems) in the vicinity of the Project extent of longwall mining area and their locations are provided in Appendix A of the EA.

***Mining Method***

The longwall utilises a shearer to cut a slice of coal from the coal face (generally up to 1 m thick) and the broken coal is then transferred to the coal conveyors via an armoured face conveyor. The longwall utilises a series of hydraulic roof supports to provide a working area for the shearer and the machine operators. Once each slice of coal is removed from the longwall face, the hydraulic roof supports are moved forward, allowing the roof and a section of the overlying strata to collapse behind the longwall machine (referred to as forming the 'goaf'). In order to start each new panel, the longwall is separated into components and re-assembled in the installation roadway of the next panel.

***Mine Layout***

The Project general arrangement is shown on Figure 2-1 in the Main Report of the EA. The Project extent of longwall mining area has been divided into several domains corresponding to the location of each of the extent of longwall mining areas, namely:

- West Cliff Area 5 and Appin Area 7 (north domain - contiguous with the current operations);
- North Cliff (east domain);
- Appin West (Area 9) and Appin Area 8 (west domain); and
- Appin Areas 2 and 3 Extended (south domain).

The four domains are shown on Figures 2-8 to 2-11 in the Main Report of the EA. These general arrangements show the Project future development of the mining operations.

***Percentage Extraction***

The Bulli Seam varies from less than 1.5 m to approximately 3.6 m in thickness beneath the stream systems within the Project extent of longwall mining area (increasing from the south to the north-west) and it is expected that its full thickness would be extracted during the Project underground operations.

## P3.2 LIKELY TYPES OF SUBSIDENCE IMPACTS

Subsidence is the vertical and horizontal movement of the land surface as a result of the extraction of underlying coal. Likely types of subsidence impacts (i.e. any physical change to the fabric or structure of the ground, its surface, or man-made features) as a result of systematic (*conventional*) or non-systematic (*non-conventional*) subsidence effects include surface and sub-surface cracking, buckling, dilating and/or tilting.

The predicted systematic and non-systematic subsidence effects for streams and associated risk of impact and environmental consequences are discussed in Step 4 (Section P6). A detailed Subsidence Assessment is presented in Appendix A of the EA.

# P4 STEP 2 – IDENTIFICATION AND CHARACTERISATION OF STREAMS

The identification and characterisation of streams described in Sections P4.1 to P4.9 below is based on desktop analysis and site inspections. Stream mapping is provided in Attachment PA. Site inspections were also conducted for a representative sample of streams in the Project area by various specialists to inform the EA studies including MSEC, Gilbert & Associates, Bio-Analysis, FloraSearch and Biosphere Environmental Consultants (refer to Appendices A, C, D, E and F, respectively).

It is recognised that there are limitations associated with the assessment of each of the characteristics considered. Notwithstanding, the information provided is considered suitable for the purpose of the risk assessment. As described in Section P7, future monitoring/survey would be conducted to provide additional information that would be incorporated in Stream Risk Management Plans (RMPs) to be included in future Extraction Plans for specific mining domains.

## P4.1 IDENTIFICATION OF STREAMS

As described in Section 6.2 of the Metropolitan PAC Report, Step 2 requires the identification of significant natural features including rivers and significant streams.

The SCPR recommended that EAs for project applications lodged under Part 3A of the EP&A Act identify and assess significant natural features located within 600 m of the edge of secondary extraction (SCPR Recommendation 4). Rivers and significant streams located above the extent of longwall mining area and within 600 m of the edge of secondary extraction[1] are identified in Attachment PB.

In relation to significant watercourses, the SCPR states:

> *The Southern Coalfield's significant natural features include rivers and higher order streams, …*

and

> *RMZs for watercourses should be applied to all streams of 3rd order or above, in the Strahler stream classification.*

Attachment PB includes relevant rivers as named on the Appin, Bargo, Bulli, Camden, Campbelltown and Picton 1:25,000 topographic mapping (Lands Department, 2000) and streams of third order or above according to the Strahler stream classification system consistent with the SCPR.

A total of 47 rivers and significant streams (herein referred to as streams) have been identified (Attachment PB).

The streams have been grouped in Attachment PB according to mining domain (i.e. North Cliff, West Cliff Area 5, Appin Areas 2 and 3 Extended, Appin Area 7, Appin West [Area 9] and Appin Area 8). Each stream identified is listed in Attachment PB and their locations are shown on Plans 1 to 4 in Attachment PC. Some streams have been separated into reaches for the purpose of the risk assessment. This includes the Georges River (two reaches, Plans 1 and 4 in Attachment PC), Nepean River (three reaches, Plans 1 and 3 in Attachment PC), Dahlia Creek (two reaches, Plan 2 in Attachment PC) and Stokes Creek (three reaches, Plans 1 and 2 in Attachment PC). A total of 53 reaches have been delineated.

[1] For the purpose of this assessment, the edge of secondary extraction has conservatively been taken to be the "extent of longwall mining area" boundary as shown on Plans 1 to 4 in Attachment PC.

The approximate length of each stream reach situated within the extent of longwall mining area and within 600 m of the edge of secondary extraction is provided in Attachment PB.

Fourteen of the stream reaches identified have previously been subject to subsidence in some or all of their reach (Attachment PB). The approximate length of the stream reach previously undermined or subject to subsidence is provided in Attachment PB.

The characteristics of each stream reach are summarised below from Attachments PA and PB.

## P4.2 TOPOGRAPHIC CHARACTERISTICS

### P4.2.1 Stream Order

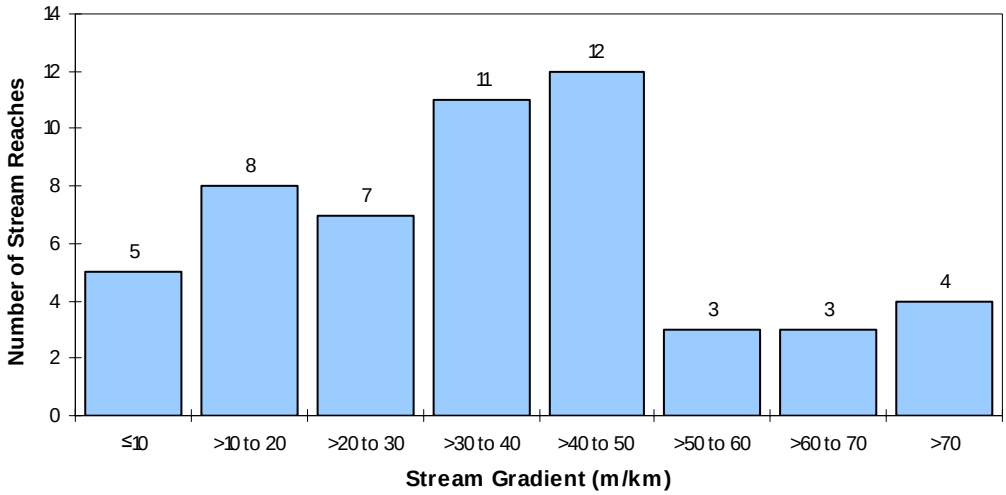
The maximum order of each stream reach according to the Strahler stream classification system has been identified and provided in Attachment PB. Streams of lower than third order are included on the basis that they are named rivers or the stream located within the extent of longwall mining area or within 600 m of the boundary of secondary extraction comprises some reaches of third order or above.

In summary, one stream reach is classified as first order according to the Strahler stream classification system, three stream reaches as second order, 35 as third order, nine as fourth order, one as fifth order, one as sixth order and three as seventh order (Attachment PB).

### P4.2.2 Average Stream Gradient

The average stream gradient was determined for each stream reach by calculating the change in elevation over the relevant reach and dividing by the length of the reach. The average stream gradient ranges from less than 1 metre per kilometre (m/km) to 95 m/km (Attachment PB). In summary, 22 reaches have an average stream gradient greater than 40 m/km. Some 58 percent (%) of the stream reaches have an average stream gradient of 40 m/km or less. The ranges of delineated average stream gradients are presented in Chart P-1.

**Chart P-1**
**Distribution of Average Stream Gradients**



### P4.2.3 Geomorphic Type

A geomorphic classification has been developed by Gilbert & Associates to characterise the geomorphic attributes of the streams. The classification scheme has been based loosely on the River Styles framework as described in the paper by Brierley *et al.* (2002) and is considered to be indicative only.

The classification scheme is based on four groups of geomorphic attributes:

1. Valley type – confined, partially confined and alluvial.
2. Floodplain development – no floodplains, irregular floodplain and floodplain pockets less than 25% of stream fringed by floodplains; moderate floodplain development – between 25% and 75% of stream fringed by floodplains; high floodplain development – greater than 75% of stream fringed by floodplains.
3. Bed materials and mobility – bedrock comprising rock outcrop or boulderfield beds with no or minimal/infrequent mobile sediments in some sections; sand bed comprising cohesionless sandy sediments; cohesive bed comprising silty, sandy bed materials with significant cohesion and/or organic materials.
4. Physical features – pools and rockbars and chutes; cascades and waterfalls; boulderfields; pools and riffles in alluvial/mobile streams; uniform streams with no or insignificant pool development; swamps and/or chain of ponds wide shallow streams with significant in-stream vegetation and persistent swamps or wide shallow pools with ill defined channels.

In applying the classification scheme to the stream reaches, the classification which is dominant over the full length of the stream reach has been selected.

The geomorphic attributes of the stream reaches are classified in Attachment PB.

### P4.2.4 Key In-Stream/Visual Amenity Features

Stream mapping has identified key in-stream/visual amenity features including rockbars, waterfalls, pools, riffles and boulderfields. The features identified are included in Attachment PB. Stream mapping results are provided in Attachment PA.

## P4.3 HYDROLOGIC CHARACTERISTICS

### P4.3.1 Stream Catchment Area

Stream catchment areas have been delineated and calculated by Gilbert & Associates for each of the 53 stream reaches and are provided in Attachment PB. The catchment areas are based on the total upstream catchment area reporting to the downstream point of each stream reach[2].

In summary, of the 53 delineated stream reaches, approximately 85% of the stream reaches have a catchment area of less than 20 square kilometres ($km^2$) (Attachment PB). Eight have a catchment area of greater than 20 $km^2$ (Attachment PB). The four reaches with the largest catchment areas are the Cataract River (220 $km^2$), Nepean River reach 1 (999 $km^2$), Nepean River reach 2 (1,219 $km^2$) and Nepean River reach 3 (1,233 $km^2$) (Attachment PB). The ranges of delineated stream reach catchment areas are presented in Chart P-2.

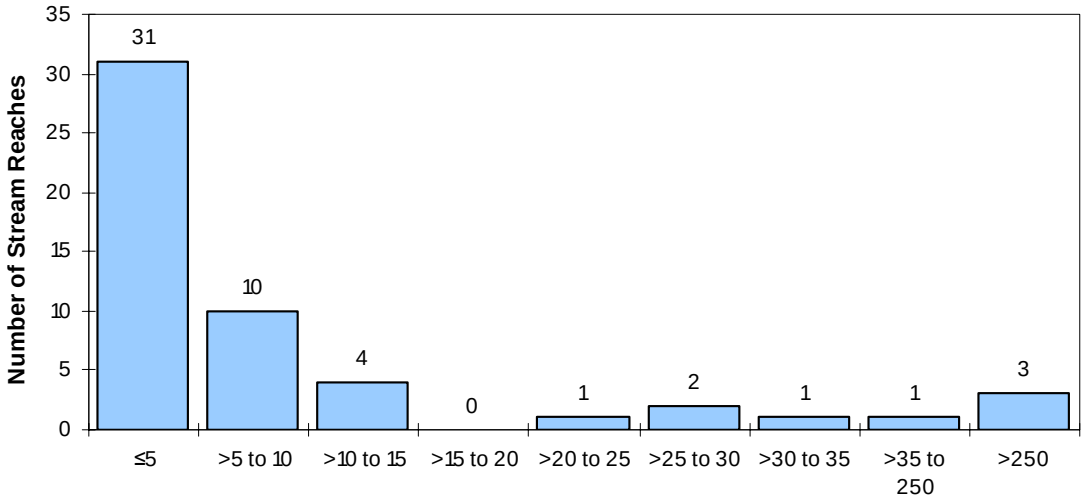
### P4.3.2 Permanence of Flow

The permanence of flow of each stream reach has been categorised in Attachment PB as: (a) perennial; (b) intermittent and/or ephemeral; or (c) perennial – intermittent/ephemeral if the permanence of flow changed over the stream reach being assessed. Streams were categorised as perennial based on the mapping of perennial watercourses on the 1:25,000 topographic mapping (Lands Department, 2000). Streams not mapped as perennial were categorised as intermittent and/or ephemeral.

In summary, some 11 stream reaches were categorised as perennial, 37 reaches as intermittent and/or ephemeral, and five reaches as perennial to intermittent/ephemeral (Attachment PB).

[2] Where the stream reach extend more than 600 m from the edge of secondary extraction the end of the reach is taken at the 600 m boundary. Where the stream terminates at another stream within 600 m from the edge of secondary extraction the end of the reach is taken at the stream confluence.

**Chart P-2**
**Distribution of Catchment Areas**




### P4.3.3 Stream Regulation History

Natural flows in many Australian streams have been regulated or altered, for example, through the extraction of water, the placement of dams and weirs, and discharges into streams.

Attachment PB identifies Sydney Catchment Authority (SCA)-controlled dams/weirs known to be situated upstream of the stream reaches, as well as reaches subject to the NSW Department of Environment and Climate Change (DECC) licensed water discharges. In summary, SCA-controlled dams/weirs are known to be situated upstream of four stream reaches (i.e. Cataract River and Nepean River reaches 1, 2 and 3) and nine stream reaches are subject to DECC licensed water discharges (i.e. Georges River reach 2, Mallaty Creek, Nepean River reaches 1, 2 and 3, Ousedale Creek, Harris Creek, Matahill Creek and Clements Creek).

In addition to the above, a number of water extraction licences are known to have been issued by the NSW Department of Water and Energy (DWE), for example, along the Nepean River between Pheasants Nest Weir and Menangle Weir and along the Georges River (Appendix C of the EA).

### P4.3.4 Importance to Catchment Yield

The importance of the stream reach to catchment yield has been assessed as either low, moderate or high based on the catchment area of the stream reach relative to the overall area of the closest parent watercourse in Attachment PB.

The parent watercourses are O'Hares Creek, Punchbowl Creek and Woronora River in North Cliff, the Georges River and Nepean River in West Cliff Area 5, the Cataract River in Appin Areas 2 and 3 Extended, the Nepean River, Foot Onslow Creek and Navigation Creek in Appin Area 7, the Nepean River, Matahill Creek, Navigation Creek and Racecourse Creek in Appin West (Area 9) and the Nepean River and Racecourse Creek in Appin Area 8.

In summary, 33 of the individual reaches were assessed as low, 11 as moderate and nine as having high importance to catchment yield (Attachment PB).

### P4.3.5 Significance to Water Supply

The significance of each stream reach to water supply has been assessed as a percentage of the reaches' contribution to the relevant water supply catchment area in Attachment PB. The relevant water supply catchments are the Woronora Dam catchment, the Cataract Dam catchment and the Broughtons Pass Weir catchment.

In summary, two reaches (i.e. Tributary to the Woronora River and Woronora River) contribute approximately 17% to the Woronora Dam catchment and two reaches (Tributary to Cataract Reservoir 1 and Tributary to Cataract Reservoir 2) contribute approximately 5.3% to the Cataract Dam catchment (Attachment PB). Of the seven reaches that contribute to the Broughtons Pass Weir catchment, six reaches contribute approximately 33.9% to the Cataract River which flows to the Broughtons Pass Weir and the seventh reach, the Cataract River contributes 100% to the Broughtons Pass Weir (Attachment PB).

As indicated in Section P6.4.4, while streams can experience cracking and associated diversion of a portion of surface flow into the network of cracks, this flow returns to the surface at the downstream end of the cracks (i.e. there is negligible loss of flow in the stream system) (Appendix C of the EA). As a result, the Project would not result in a material reduction in catchment yield reaching the Cataract Dam, Woronora Dam or Broughtons Pass Weir.

## P4.4 ECOLOGICAL SIGNIFICANCE

### P4.4.1 Environmental Quality (Observed/Existing Disturbance)

Attachment PB presents an assessment of the environmental quality of the stream reaches as either pristine, modified or severely modified based on the following:

- Pristine - majority of vegetation within upstream catchment is intact, limited disturbances within catchment area (e.g. fire tracks, exploration activities).
- Modified - majority of riparian vegetation intact, agricultural/other disturbances within catchment areas.
- Severely Modified - moderate to high disturbance of riparian vegetation, agricultural/other disturbances to catchment area and/or disturbance to channel/flow (e.g. weirs, dams, discharges).

This qualitative assessment has been based on known disturbances in consideration of the information provided in the Surface Water Assessment (Appendix C of the EA) and Terrestrial Flora Assessment (Appendix E of the EA) and the inspection of aerial photographs provided in Attachment PC.

In summary, 16 reaches were assessed as being pristine, 18 reaches as modified and 19 as severely modified (Attachment PB). It should be noted that some streams assessed as pristine (e.g. Wallandoolla Creek and Lizard Creek) have previously been subject to mine subsidence effects such as fracturing and iron staining.

### P4.4.2 Flora and Fauna Surveys

Aquatic and terrestrial flora and fauna surveys have been conducted for the Project and these surveys included representative sampling of stream and adjacent riparian and/or gully habitats. Flora and fauna sites surveyed relevant to the list of streams are provided in Attachment PB. Details of the survey methodologies are provided in the Aquatic Ecology Assessment (Appendix D of the EA), Terrestrial Flora Assessment (Appendix E of the EA) and Terrestrial Fauna Assessment (Appendix F of the EA).

A number of aquatic and terrestrial flora and fauna surveys and reports have been conducted in recent years in the general locality of the Project and were reviewed as part of the surveys and assessments (Appendices D, E and F of the EA). This information has also informed the assessment of the ecological significance of the streams.

### P4.4.3 Endangered Ecological Communities

Some vegetation communities mapped along streams (Appendix E of the EA) represent Endangered Ecological Communities listed under the NSW *Threatened Species Conservation Act, 1999* (TSC Act) or Commonwealth *Environment Protection and Biodiversity Conservation Act, 1999* (EPBC Act) (as at 1 July 2009). This includes vegetation mapped as Cumberland Plain Woodland, River-flat Eucalypt Forest on Coastal Floodplains, Western Sydney Dry Rainforest in the Sydney Basin Bioregion, and Sandstone/Shale Transition Forest. Based on the mapping provided in Appendix E of the EA, these communities have all been conservatively include in Attachment PB as being associated with streams. It is considered by FloraSearch however that the Cumberland Plain Woodland, Western Sydney Dry Rainforest in the Sydney Basin Bioregion, and Sandstone/Shale Transition Forest are not riparian communities in that they do not rely on water from streams.

### P4.4.4 Threatened Species Records

Threatened flora and fauna records for each stream and adjacent riparian and/or gully habitats have been identified and provided in Attachment PB. The records of threatened species are based on the results of the Aquatic Ecology Assessment (Appendix D of the EA), Terrestrial Flora Assessment (Appendix E of the EA) and Terrestrial Fauna Assessment (Appendix F of the EA).

In summary, 13 threatened species were identified by the Project surveys or are known aquatic fauna records for the area as reported in Appendix D of the EA. Table P-1 lists the threatened species and indicates whether the species records are from the stream or adjacent riparian and/or gully habitats. Notwithstanding these records, it is recognised that all streams and adjacent riparian and/or gully habitats in the Project area provide potential habitat for a range of threatened species, as discussed in Section P4.4.5.

### P4.4.5 Stream Specialists

The DECC (2009a) considers that a number of species either depend on rivers/creeks for survival, or have a stronghold in rivers/creeks but are also found in other types of habitat. This includes species listed as threatened under the TSC Act or EPBC Act and those of regional significance based on Rare or Threatened Australian Plants (ROTAP) status as well as knowledge within the DECC. These species are listed and discussed in Attachment PD.

**Table P-1**
**Threatened Species Records**

| Species | Stream | |
|---|---|---|
| | Riparian and/or Gully Habitat | Stream Habitat |
| *Leucopogon exolasius* | O'Hares Creek<br>Cataract River | - |
| *Pomaderris adnata* | O'Hares Creek | - |
| *Pultenaea aristata* | Woronora River | - |
| Sydney Hawk Dragonfly | - | Nepean River reach 1 (historic record for the Nepean River near Maldon Bridge) |
| Macquarie Perch | - | Georges River reach 2 (based on records approximately 15 km downstream of the Project area)<br>Cataract River (Project survey records)<br>Nepean River reaches 1 to 3 (based on records downstream of Pheasant's Nest Weir) |
| Red-crowned Toadlet | Cobbong Creek<br>Cataract River | - |
| Powerful Owl | Nepean River reach 2 | - |
| Black-chinned Honeyeater | Allens Creek | - |
| Koala | Georges River reach 2 | - |
| Eastern Pygmy Possum | O'Hares Creek | - |
| Grey-headed Flying Fox | Woronora River<br>Georges River reach 2<br>Tributary to Cataract Reservoir 1<br>Nepean River reach 2<br>Allens Creek | - |
| Eastern Bentwing-bat | Georges River reach 1<br>Georges River reach 2 | - |
| Large-footed Myotis | - | Cataract River |

## P4.5 ASSOCIATED LANDUSE

### P4.5.1 Dharawal State Conservation Area

The Dharawal State Conservation Area is located within the Project area (Figure 2-1 in the Main Report of the EA). The Dharawal State Conservation Area is heavily vegetated and is generally undisturbed in comparison to agricultural and development centres in the west of the Project area (Figure 1-2 in the Main Report of the EA).

As shown in Attachment PB, nine stream reaches are located within the Dharawal State Conservation Area, namely Cobbong Creek, Dahlia Creek reaches 1 and 2, O'Hares Creek, Stokes Creek reaches 1, 2 and 3 (reaches 2 and 3 being partially within the conservation area) and two tributaries of O'Hares Creek.

The following excerpts of relevance are from the *Dharawal Nature Reserve and Dharawal State Conservation Area Plan of Management* (NSW National Parks and Wildlife Service [NPWS], 2006):

> *Dharawal Nature Reserve (NR) and Dharawal State Conservation Area (SCA) are contiguous and share related objectives of management and management policies, whereby management of the reserves will focus on natural and cultural heritage management, self-reliant passive recreation opportunities, education and research.*
>
> *Prior to its reservation, the majority of the area of the two reserves was Crown land under the care, control and management of the Sydney Water Corporation and its predecessors. It remains a Schedule Two Special Area (O'Hares Creek Special Area) under the Sydney Water Catchment Management Act 1998 and is also subject to the Sydney Catchment Management (General) Regulation 2000.*
>
> *Underground coal mining in the O'Hares Creek Special Area preceded reservation under the National Parks and Wildlife Act 1974 and this use will continue as an existing interest in the state conservation area for some time. The state conservation area and nature reserve boundary reflects the existing mining and exploration interests rather than any difference in conservation values of the two reserves.*
>
> *While the O'Hares Creek Special Area has not been developed for water supply purposes, the Sydney Catchment Authority retains a statutory and joint management role in the protection and management of the Special Area. This interest is protected under Section 185 of the National Parks and Wildlife Act 1974. This section states that nothing in this Act affects the operation of any of the provisions of the Sydney Water Catchment Management Act 1998 in relation to lands within a nature reserve or state conservation area in so far as those provisions relate to catchment areas or special areas. The Authority's concurrence is required for the granting of any lease, license, easement, or right of way over lands within the Special Area.*
>
> *…*
>
> *A number of coal mining leases and authorisations to prospect currently exist within the state conservation area and will continue to operate. In order to accommodate these existing interests, the majority of the area has been reserved as a state conservation area. This state conservation area category provides for the continuation of existing mineral and petroleum exploration and extraction. The balance of the area has been reserved as nature reserve with the boundary being determined by existing mining and exploration interests rather than any difference in the conservation significance of the area.*
>
> *The National Parks and Wildlife Service has had a long-standing interest in the area. In 1978, following advice from the then Metropolitan Water Sewage and Drainage Board that the catchment would not be developed for water supply purposes, the NSW Premier announced the Government's intention to establish a state recreation area over the majority of the catchment. However, this proposal did not progress following negotiations involving the National Parks and Wildlife Service, the then Department of Mineral Resources (coal resources), the then Department of Lands (clay and shale extraction leases) and the Australian Army (military training).*
>
> *…*

*Both Dharawal Nature Reserve and Dharawal State Conservation Area overlie the extensive Southern Coalfields and have a history of underground mining and associated surface activities. The majority of the area of the two reserves was reserved as a state conservation area to protect conservation values while continuing to accommodate mining and mineral exploration. As such, existing mining interests encompass almost the entire extent of Dharawal State Conservation Area and mining and surface exploration operations will continue until the interests expire. Mining interests are likely to persist for some time as over 30 years of coal reserves are estimated to remain in the area.*

### P4.5.2 Dharawal Nature Reserve

The Dharawal Nature Reserve is located more than 1 km outside of the south-eastern extent of the Project area (Figure 2-1 in the Main Report of the EA). No nature reserves are located within the Project area.

### P4.5.3 Sydney Catchment Authority Special Areas and Drinking Water Catchments

The Project area coincides with three of the SCA's Special Areas, namely Woronora Special Area, Metropolitan Special Area and O'Hares Creek Special Area.

Of the 53 stream reaches, two are located within the Woronora Special Area, nine within the Metropolitan Special Area and nine within the O'Hares Creek Special Area (Attachment PB).

The Woronora Special Area and Metropolitan Special Area are covered by the *Drinking Water Catchments Regional Environmental Plan No 1* (Drinking Water Catchments REP) which commenced on 1 January 2007. The Drinking Water Catchments REP applies to land within the 'hydrological catchment', which comprises a number of sub-catchments which contribute to Sydney's (and surrounding regional centres) water supply, including the Upper Nepean River and Woronora River catchments.

As described in Section P4.5.1 above, unlike the Woronora Special Area and Metropolitan Special Area, the O'Hares Creek Special Area has not been developed for water supply purposes however remains a Schedule Two Special Area under the *Sydney Water Catchment Management Act, 1998.*

### P4.5.4 Other

In addition to the information provided in Sections P4.5.1 to P4.5.3, Attachment PB provides the zoning of land within which stream reaches are situated according to the Local Environmental Plan maps for the Wollondilly Shire, Wollongong City and Campbelltown City Councils. The majority of reaches are situated on land that has been categorised as water catchment or rural/agricultural landscape (Attachment PB).

## P4.6 COMMUNITY VALUE

Community value (i.e. the value the community attributes to protection) has been explored for streams using Choice Modelling.

Choice Modelling is a non-market valuation study, conducted to obtain estimates of NSW and Illawarra community values for key potential environmental and social impacts of the Project. Choice Modelling involves the design and implementation of a questionnaire that contains a number of choice sets that describe the environmental outcomes of alternative policy scenarios in terms of changing levels of a set of environmental and social attributes. By observing and modelling how people choose their preferred policy scenario in response to the changes in the levels of the attributes, it is possible to determine how they trade-off between the attributes. That is, it is possible to determine the value that respondents hold for additional amounts of an attribute.

The Choice Modelling study for the Project involved:

- defining the key environmental and socio-economic attributes of relevance to the Project;
- designing the Choice Modelling questionnaire with the aid of focus groups, including alternative questionnaire designs to test the concerns raised in the Metropolitan PAC Report;
- compiling the Choice Modelling experimental design;
- sampling the views of 663 households in the Illawarra Region and 2,302 households in the rest of NSW via completion of the questionnaires;
- analysing the data collected using conditional logit and random parameter logit econometric techniques; and
- estimating implicit prices for the environmental and social attributes included in the study.

Review of the literature on coal mining in the Southern Coalfield and meetings with Illawarra Coal Holdings Pty Ltd (ICHPL) elicited the following potential environmental attributes in relation to streams: cracking of stream beds in affected sections of streams; draining of pools in affected sections of streams; reduced water flow in sections of affected streams; iron staining in affected sections of streams; ecological impacts in affected sections of streams and loss of water from the catchment. These five attributes all related to the cracking of stream beds as a result of mine subsidence. Consequently, these impacts were amalgamated into a single attribute, length of stream affected, with the nature of effects described as including cracking, draining of pools, reduced water flow in streams, iron staining and ecological impacts.

While loss of water from the catchment, via stream bed cracking, has been raised in some policy documents and the media, in relation to the mining in the Southern Coalfield, scientific evidence suggests that there is negligible loss of water from catchments as a result of underground mining at moderate to high depths of cover such as experienced in the area of the Project.

At the substantial depths of cover at the Project, there would not be connective cracking from the ground surface to the mined seam (Appendix B of the EA). In addition, while a stream bed with an exposed rock base can experience cracking in response to subsidence to a depth of 10 to 20 m, there is no potential for the loss of shallow water to the mine because there is no continuity of fractures from the surface to the mine (Appendix B of the EA). A portion of surface water flows may be diverted through the rock fractures beneath the stream bed, with emergence further downstream. As a result, the Project would result in negligible adverse consequences to the quantity of water reaching the Cataract Dam, Woronora Dam or Broughtons Pass Weir.

In this regard, the Metropolitan PAC Report states (page iii):

> *The potential loss of catchment yield was a strongly contested issue that could not be resolved beyond doubt on the information available. However, the Panel's view is that the risk of any significant loss is very low unless a major geological discontinuity is encountered during mining that provides a direct hydraulic connection between the surface and the mine workings. This is considered unlikely.*

In addition, the Metropolitan PAC Report states (page 50):

> *7.3.4. Panel's Resolution on Yield to Woronora Reservoir*
>
> *… the local and regional groundwater conditions coupled with the mine parameters, would suggest that the likelihood of water being lost from the surface water system as a consequence of mining, and then by-passing Woronora Reservoir, is very low. This conclusion accords with the findings of the Southern Coalfield Inquiry, viz:*
>
> > *No evidence was presented to the Panel to support the view that subsidence impacts on rivers and significant streams, valley infill or headwater swamps, or shallow or deep aquifers have resulted in any measurable reduction in runoff to the water supply system operated by the Sydney Catchment Authority or to otherwise represent a threat to the water supply of Sydney or the Illawarra region.*[37]
>
> *[37] Page 2 of Southern Coalfield Inquiry Report*

The Choice Modelling study results indicate that for streams, respondents were on average willing to pay $5.64 million (M) per kilometre of stream protected. The Choice Modelling study results provide some indication of community value. The Choice Modelling results have been utilised in the trade-off analysis presented in Section P7.3 and detailed in Appendix L of the EA.

## P4.7 RECREATIONAL VALUE

A number of streams are accessible and provide aesthetic and/or recreational values to the public. Attachment PB identified streams that are accessible to the public. In summary, 43 stream reaches are accessible to the public, while ten stream reaches are generally inaccessible to the public being situated in SCA Special Areas (Attachment PB).

## P4.8 STREAM PHOTOS

A catalogue of photos of streams has been compiled from stream surveys and inspections and they are provided in Attachment PC.

## P4.9 REGIONAL SIGNIFICANCE OF STREAMS

In relation to the assessment of significance, the Metropolitan PAC Report states (pages 75-76):

> *… The SCI report lamented that there was a lack of guidance for Proponents on how to determine the relative significance and value of natural features where multiple examples exist within a Project Area or region. It suggested that there should be clear delineation of the priorities of both Government and the community for the protection and values of such features.*
>
> *It would certainly make it much easier for Proponents and governments to have a checklist of natural features, a value for conservation of each and then a regional scale of relative significance for each of these natural features against which the individual examples in the Project Area could be rated. However, the attainability of this is questionable.*

and (page 57):

> *…There are several methods used in Australia to categorise rivers and streams. The most pertinent in the NSW context is River Styles (Brierley et al, 2002). Application of the River Styles Framework across the region would allow appraisal of the regional significance of Waratah Rivulet and its values. In the absence of such an appraisal, the regional significance of the Rivulet and its values cannot be reliably assessed. …*

Recommendation 12 in the Metropolitan PAC Report also relevantly states (page 138):

> *The Panel also recommends that the relevant Government agencies explore the use of established techniques for assessment of waterways (see Section 6.4.2 of this report) to assist in determination of significance of watercourses under threat of impact from mining proposals.*

In relation to streams in the Project area, the following aspects are considered of relevance to regional significance:

- Map 7 from the SCPR (Attachment PE) shows the regional distribution of first to seventh order streams. Map 7 indicates that there are few sixth and seventh order streams in the region. Sixth and seventh order streams in the region include the Cataract River (sixth order) and Nepean River (reaches 1, 2 and 3) (seventh order).
- The Nepean River is one of the major coastal river systems of NSW (Appendix C of the EA).
- In relation to contribution to the water supply catchments, the Cataract River contributes 100% of the Broughtons Pass Weir catchment.
- In relation to threatened species, an historic record of the Sydney Hawk Dragonfly exists for the Nepean River near Maldon Bridge. In addition, the Macquarie Perch has been recorded in the Cataract River during the Project surveys and there are records of the species in the Nepean River downstream of Pheasant's Nest Weir and the Georges River approximately 15 km downstream of the Project area.
- A number of streams are accessible and provide aesthetic and/or recreational values to the public (Attachment PB).

The identification of streams of special significance is discussed in Section P5.

## P5 STEP 3 – ASSESSMENT OF FEATURES THAT WARRANT SPECIAL SIGNIFICANCE STATUS

In relation to 'special significance' the Metropolitan PAC Report provides the following (page 42):

> *'Special Significance Status' is based on an assessment of a natural feature that determines the feature to be so special that it warrants a level of consideration (and possibly protection) well beyond that accorded to others of its kind. It may be based on a rigorous assessment of scientific importance, archaeological and cultural importance, uniqueness, meeting a statutory threshold or some other identifiable value or combination of values.*

Further, the Metropolitan PAC Report states (page 55):

> *In the current circumstances, the discussions as to significance and the appropriate protection to be afforded to a particular watercourse will come down to a case by case assessment of the values attributed to the watercourse, …*

The Metropolitan PAC Report also recognised that in the absence of quantifiable measures and an objective threshold, conclusions about 'special significance' would be subjective.

The Nepean River has an estimated overall length of approximately 180 km and is one of the major coastal river systems of NSW. The headwaters of the Nepean River are situated approximately 100 km south of Sydney. In its headwaters, the Nepean River flows north into the Nepean Dam, which supplies water for Sydney. The river flows north of the Metropolitan Special Area and into the Project area, where the dominant landuses are agriculture, small urban settlements and industry (Appendix C of the EA). There are 11 weirs located on the Nepean River that regulate the natural flow behaviour. The river has been segmented into a series of 'weir lakes' rather than a freely flowing river (Hawkesbury Nepean Catchment Management Authority, 2009). Near Penrith the Nepean River is joined by the Warragamba River. The Nepean River flows through the Nepean Gorge, which is considered a significant section of the river, having the Greater Blue Mountains World Heritage Area on its east and west banks (Hawkesbury Nepean Catchment Management Authority, 2009). At the junction of the Grose River near Yarramundi, the Nepean River becomes the Hawkesbury River.

The Hawkesbury Nepean River is considered to be an iconic waterway and an important ecological and community asset (Commonwealth Department of the Environment, Water, Heritage and the Arts [DEWHA], 2009). The river supplies water to Sydney's 4.3 million people as well as supporting agricultural production (DEWHA, 2009).

Based on the Metropolitan PAC Report's description of special significance, the authorities may consider the Nepean River as a stream that warrants special significance status.

Within the Project area, the Nepean River is characterised by an irregular (meandering and straight) channel which has formed within sandstone gorges (Warner, 1983). Extensive river channel modification, including dredging and construction of several weirs to improve riparian access to flow has resulted in the creation of a series of long, slow moving ponds over sections of the Nepean River (University of Wollongong, 2007).

Menangle Weir, which is near the northern (downstream) limit of the Project area creates a pond some 10 km long, extending to the Douglas Park Causeway. The Douglas Park Causeway creates another pond which extends further upstream to near the Allens Creek-Nepean River confluence.

In addition to the flow dampening effect of these in-stream ponds, flow in this section of the Nepean River is highly regulated as a result of operation of the Upper Nepean Water Supply scheme (which incorporates four major dams on the Cataract, Cordeaux, Avon and Nepean Rivers and several weirs, tunnels and a pumping station which are used to supply water to the Sydney Metropolitan area). During dry weather, flows downstream of the Upper Nepean Water Supply Scheme dams comprise almost entirely water released for water supply and environmental purposes.

Stream impact minimisation criteria have been applied to the Nepean River for the Project. Specifically, the longwall layout shown on Figures 2-8 to 2-11 in the Main Report of the EA would be designed not to directly undermine the Nepean River (reaches 1, 2 and 3). In addition, a 200 millimetre (mm) closure threshold has been applied to the longwall layout to avoid significant fracturing of rockbars that could result in the draining of associated pools along Nepean River reach 1 (i.e. the section of the Nepean River that is upstream of the inundation area associated with the Douglas Park Causeway and which is upstream of the Allens Creek confluence). The stream impact minimisation criteria are described in Section P6.2.

# P6 STEP 4 – RISK IDENTIFICATION AND ASSESSMENT

## P6.1 RISK MANAGEMENT ZONES

As shown on Plans 1 to 4 in Attachment PF, a Risk Management Zone (RMZ) has been applied to each stream. The RMZ boundary is based on the definition prescribed in the SCPR (i.e. 400 m surface lateral distance from the outside extremity of the stream or by a 40 degree (°) angle from the vertical down to the coal seam which is proposed to be extracted, whichever is greater).

Consistent with the SCPR recommendation, RMZs have been applied to all streams of third order or above according to the Strahler stream classification system.

Of relevance, the Metropolitan PAC Report states (page 54):

> *… The SCI Report provides some guidance by recommending that RMZs should be applied to all streams of 3rd order or above in the Strahler stream classification[38]. Whilst the SCI was at pains to point out that this was not, of itself, a determination of 'significance' (nor did it suggest a need to exclude mining) it did mean that careful assessment may lead to management consequences.*
>
> *[38] SCI Report, page 112, Section 5.4.2*

## P6.2 LONGWALL LAYOUT DESIGN OBJECTIVES

As discussed in Section P3.1, the Project underground mining areas have been divided into several domains corresponding to the location of each of the extent of longwall mining areas.

The longwall layout shown on Figures 2-8 to 2-11 in the Main Report of the EA is herein referred to as the EA Base Plan Longwalls. The EA Base Plan Longwalls on Figures 2-8 to 2-11 in the Main Report of the EA has been designed to meet specific impact minimisation criteria for streams, cliffs and major infrastructure items. The objectives of these impact minimisation criteria are further described below.

There are a number of alternative longwall layouts which may also meet these design objectives. Sensitivity analyses of alternative longwall layouts are included in the Subsidence Assessment (Appendix A of the EA). The final detailed design of the longwall layouts would be subject to review and approval as part of the Extraction Plan developed in consultation with the relevant authorities and to the satisfaction of the DoP.

***West Cliff Area 5***

Stream impact minimisation criteria have been applied to two streams in West Cliff Area 5, namely the Georges River (reach 2) and Stokes Creek (reach 1).

The longwall layout at West Cliff Area 5 would be designed to avoid significant fracturing of rockbars that could result in the draining of associated pools along Georges River and Stokes Creek. Achievement of this criteria would also result in a significant reduction of subsidence effects on sections of the streams between each rockbar feature (Appendix A of the EA).

Detailed stream mapping including the identification of rockbars along the Georges River (reach 2) and Stokes Creek (reach 1) is provided in Attachment PA.

***Appin Area 7***

Stream impact minimisation criteria have been applied to the Nepean River in Appin Area 7. The longwall layout would be designed not to directly undermine the Nepean River (reaches 2 and 3). This would result in a reduction in potential subsidence effects (Appendix A of the EA).

The longwall layout at Appin Area 7 would be designed to minimise impacts such as cliff falls along the Nepean River by applying a minimum setback distance of (Appendix A of the EA):

- 50 m from the top of mapped cliff lines; and
- 50 m from the transition from steep slope to the Nepean River alluvium/colluvium zone.

Minimum setback distances of a $35^{o}$ angle of draw from the Menangle Weir and road/rail bridges across the Nepean River would also be applied to the longwall layout to maintain the structural integrity of the weir and road/rail bridges. Further details are provided in Appendix A of the EA.

***Appin West (Area 9)***

Stream impact minimisation criteria have been applied to the Nepean River at Appin West (Area 9).

The longwall layout in Appin West (Area 9) would be designed to avoid significant fracturing of rockbars that could result in the draining of associated pools along the Nepean River (reach 1) upstream of the inundation area associated with the Douglas Park Causeway (i.e. upstream of the Allens Creek confluence). Achievement of this criteria would also result in a significant reduction of subsidence effects on sections of the Nepean River between each rockbar feature (Appendix A of the EA).

Detailed stream mapping including the identification of rockbars along the Nepean River is provided in Attachment PA.

The longwall layout at Appin West (Area 9) would be designed to minimise impacts such as cliff falls along the Nepean River, by applying a minimum setback distance of 50 m from the top of mapped cliff lines.

A minimum setback distance of a 35° angle of draw from the Douglas Park Twin Bridges (where the Hume Highway crosses the Nepean River) would be also applied to the longwall layout design to maintain the structural integrity of the bridge. Further details are provided in Appendix A of the EA.

***Appin Area 8***

Stream impact minimisation criteria have been applied to the Nepean River in Appin Area 8.

The longwall layout at Appin Area 8 would be designed to avoid significant fracturing of rockbars that could result in the draining of associated pools along the Nepean River (reach 1), upstream of the inundation area associated with the Douglas Park Causeway (i.e. upstream of the Allens Creek confluence). Achievement of this criteria would also result in a significant reduction of subsidence effects on sections of the Nepean River (reach 1) between each rockbar feature (Appendix A of the EA).

Detailed stream mapping including the identification of rockbars along the Nepean River (reach 1) is provided in Attachment PA.

The longwall layout at Appin Area 8 would be designed to minimise impacts such as cliff falls along the Nepean River, by applying a minimum setback distance of 50 m from the top of mapped cliff lines.

A minimum setback distance of a 35° angle of draw from the Moolbung Bridge[3] (where the Hume Highway crosses Allens Creek) has also been applied to the longwall layout design to maintain the structural integrity of the bridge. Further details are provided in Appendix A of the EA.

***Appin Areas 2 and 3 Extended***

Stream impact minimisation criteria have been applied to three streams in Appin Areas 2 and 3 Extended, namely the Cataract River, Lizard Creek and Georges River.

The longwall layout at Appin Areas 2 and 3 Extended would be designed to avoid impacts such as significant fracturing of rockbars that could result in the draining of associated pools along the Cataract River and Lizard Creek. Achievement of this criteria would also result in a significant reduction of subsidence effects on sections of the streams between each rockbar feature (Appendix A).

The longwall layout would also be designed not to directly undermine the headwater reach of the Georges River labelled as “perennial” on the 1:25,000 topographic mapping (Lands Department, 2000). This would result in a reduction in potential subsidence effects within the Georges River (reach 1) (Appendix A of the EA).

Detailed stream mapping including the identification of rockbars along the Cataract River, Lizard Creek and Georges River (reach 1) is provided in Attachment PA.

The final detailed design of the longwall layouts which extend into the Cataract and Broughtons Pass Notification Areas (Figure 2-11 in the Main Report of the EA) would conform to the requirements of the Dams Safety Committee (DSC).

Appropriate setback distances from the Cataract Reservoir dam wall and the Broughtons Pass Weir have also been applied to the longwall layout design to maintain the structural integrity of the dam wall and weir.

ICHPL would seek separate DSC approval prior to mining within the notification areas. Further details are provided in Appendix A of the EA.

***North Cliff***

Stream impact minimisation criteria have been applied to three streams at North Cliff, namely O’Hares Creek, Stokes Creek and Woronora River.

The longwall layout at North Cliff would be designed to avoid significant fracturing of rockbars that could result in the draining of associated pools along O’Hares Creek and Stokes Creek downstream of Longwall 5a (Figure 2-9 in the Main Report of the EA) (i.e. reach 2). Achievement of this criteria would also result in a significant reduction of subsidence effects on sections of the streams between each rockbar feature (Appendix A of the EA).

The longwall layout would also be designed to not directly undermine the headwater reach of the Woronora River labelled as “perennial” on the 1:25,000 topographic mapping (Lands Department, 2000). This would result in a reduction in potential subsidence effects in this reach of the Woronora River (Appendix A of the EA).

Detailed stream mapping including the identification of rockbars along O’Hares Creek, Stokes Creek (reach 2) and Woronora River is provided in Attachment PA.

[3] Also known as Moolgun Bridge.

## P6.3 SYSTEMATIC AND NON-SYSTEMATIC SUBSIDENCE PREDICTIONS

Systematic subsidence predictions for each stream based on the EA Base Plan longwalls are provided in Attachment PB, including:

- Total Maximum Subsidence (mm).
- Total Maximum Tilt (millimetres per metre [mm/m]).

The subsidence and tilt predictions for each stream are illustrated on the long sections in Attachment PG.

The above total maximum subsidence and tilt predictions are used to inform and assess the potential risk of subsidence impacts and associated environmental consequences on streams in Section P6.4.

Non-systematic subsidence predictions for each stream based on the EA Base Plan longwalls are provided in Attachment PB, including:

- Maximum Predicted Upsidence (mm).
- Maximum Predicted Closure (mm).

The method for calculation of upsidence and closure is closely related to the equivalent valley height for each stream. As a result, streams located in more incised valleys are generally subject to more upsidence and closure movements than a stream located in a broader valley. The maximum equivalent valley heights (MEVHs) for each stream (based on the stream long section) are provided in Attachment PB. There is inherent conservatism included in the calculation by using the MEVH, as the equivalent valley height typically varies along the stream.

The change in equivalent valley height and the MEVH along each stream long section, and associated predicted upsidence and closure movements, are illustrated on long sections in Attachment PG.

The above maximum predicted upsidence and closure movements are used to inform and assess the potential risk of subsidence impacts and associated environmental consequences on streams in Section P6.4.

## P6.4 RISK OF IMPACT RESULTING IN ENVIRONMENTAL CONSEQUENCES

Longwall mining results in subsidence movements at the surface above and adjacent to longwall mining activities. These movements and the resulting patterns of fractures at the surface have been described by MSEC in Appendix A of the EA. The following summary from Appendix A of the EA provides background on the types of subsidence effects that can cause impacts and environmental consequences to surface water resources.

The physical effects of subsidence at the surface are:

- Vertical (downward) and horizontal displacements of the surface which are referred to as **vertical subsidence** and **horizontal subsidence**.
- Changes in surface slope, which is referred to as **tilt**.
- Changes in the horizontal distance between two points on the surface which is referred to as **tensile strain** if the distance between the two points increases and **compressive strain** if the distance between the two points decreases.

In addition to the above systematic (or conventional) effects, there are also particular effects which occur when subsidence occurs in incised valleys and gorges typical of the Southern Coalfield which are referred to as non-systematic (or un-conventional) effects.

These include:

- **Upsidence** is the reduced downward subsidence, or the relative uplift within a valley which results from the dilation or buckling of near surface strata at or near the base of the valley.
- **Valley Closure** is the reduction in the horizontal distance between the valley sides.
- **Compressive Valley Strains** occur within the bases of valleys as the result of valley closure and upsidence movements. **Tensile Valley Strains** also occur at the tops of the valleys as the result of valley closure movements.

MSEC (Appendix A of the EA) has developed a database of pool and rockbar sites that have experienced mining induced upsidence and valley closure movements in the Southern Coalfield. MSEC (Appendix A of the EA) note that there have been no observed pool flow diversion and pool water level impacts observed where the predicted total valley closure was less than 200 mm. MSEC also notes that there are numerous instances where pools have been subject to valley closure movements greater than, and sometimes substantially greater than 200 mm, without reports of flow diversion and pool level impacts. The 200 mm closure value has been adopted as a reference valley closure magnitude below which it is expected that flow diversion and pool water level impacts are unlikely to occur. The currently available database is however relatively small and the adoption of a 200 mm valley closure criteria is viewed as an indicator of low probability of flow diversion and pool level impacts.

Attachment PB indicates the length of each stream reach predicted to experience greater than 200 mm closure, as well as the length of each reach previously subject to greater than 200 mm closure.

The impacts of subsidence on flow and water quality in streams would depend on its geomorphic nature and hydrological characteristics. The character of streams in the Project Application area varies significantly in terms of (Appendix C of the EA):

- Scale – for example, the Nepean River reach 3 has a catchment area of approximately 1,233 $km^2$ (at the downstream extent of the Project area) compared to the Tributary to Carriage Creek 2 which has a catchment area of approximately 0.5 $km^2$ (Attachment PB).
- Geology and geomorphic character – ranging between catchments dominated by Hawkesbury Sandstone which are typically deeply incised gullies that follow a strata-controlled alignment dominated by rockbars, pools and boulders with sparse fine sediment deposits; and those formed in Wianamatta Group shales which typically follow an alignment and have a cross-sectional form determined by alluvial processes (Attachment PB).
- Level of development – ranging from highly regulated and modified watercourses such as the Nepean River to streams in largely undisturbed catchments such as Stokes Creek in the Dharawal State Conservation Area.

Watercourses where sufficient valley closure occurs would experience dilation fracturing and shearing of rock strata and development of a fracture network beneath the stream bed (Appendix C of the EA). This would result in the diversion of a portion of stream flow via the fracture network and a reduction in water level in pools as they drain via hydraulic connections with the fracture network. There is also likely to be reduced continuity of flow between affected pools during dry weather. The capacity of the fracture networks to convey flows via the subsurface network is variable but relatively small when compared to moderate and high flow conditions and would have a negligible effect on flows in streams. Where the stream is experiencing low flow conditions it is likely that a higher proportion or all of the surface flow would be re-directed into the fractured strata.

### P6.4.1 Typical Environmental Consequences for Streams in Incised Valleys in Hawkesbury Sandstone Areas

In the Hawkesbury Sandstone areas, streams in plateau areas are typically open, dish-shaped drainage lines with ill-defined bed and banks. Upland swamps frequently occur within these areas often culminating at a low rockbar, step or shelf. Further downstream, the streams typically plunge via a series of drops and waterfalls into the incised sections in the deeper valleys. The character of the streams changes with the confined incised valley and gorges which make up the dissected plateau areas into a series of rockbars, pools and boulder strewn reaches. The beds of the streams in these reaches are dominated by hard exposed rock with loose alluvium limited to the longer and deeper pools where flow energy is lower. Significant rainfall events result in rapid, flashy runoff which results in highly turbulent, shallow flows with high velocity particularly over and downstream of rockbars. Velocities would reduce in the deeper longer pools which would act as sediment traps.

Past experience indicates that (Appendix A of the EA), where subsidence and in particular valley closure and upsidence in the streams formed in the Hawkesbury Sandstone is sufficient to cause fracturing of rockbars and development of dilation and cracking along the prominent drainage lines, the following environmental consequences are expected (Appendix C of the EA):

- diversion of a portion of stream flow along the stream length via the created fracture network;
- re-emergence of surface flow downstream of the affected area;

- reduced frequency of pools overflowing and lower pool water levels during dry weather;
- reduced and periodic loss of interconnection between pools during dry weather;
- small changes in bed gradients and limited potential for scouring at locations where tilts considerably increase the natural pre-mining stream gradients;
- localised and transient increases in iron concentrations and other minerals due to flushing from freshly exposed fractures in the sandstone rocks;
- creation and/or enhancement of existing iron rich springs; and
- drainage of strata gas[4].

The primary environmental consequences described above have the potential to result in secondary consequences, such as impacts on the ecological and aesthetic condition of waterways, mainly through diversion of surface flow and reduced water quality.

Over time fracture networks are likely to at least partially fill with sediment leading to some natural restoration of previously diverted underflow.

### P6.4.2 Typical Environmental Consequences for Streams in Alluvial Valleys in Wianamatta Group Shale Areas

The streams in alluvial valleys in Wianamatta Group shale areas are typically formed in relatively shallow open valleys. The nature of the substrates in these areas generally allow the sediments to be subject to subsidence movements without creating the interconnected dilation type of cracking that occurs in the Hawkesbury Sandstone terrains (Appendix A of the EA). Past experience indicates that subsidence impacts on streams formed in the Wianamatta Group shale terrain typically include localised and relatively isolated cracking of bed sediments; creation of transient and permanent pools in subsidence depressions; and/or alteration to existing pools and small-scale bed and bank scour due to local increases in bed and bank slope (Appendix C of the EA).

The predominance of clay rich (cohesive) bed sediments in these watercourses means that subsidence induced cracks are more likely to self-seal over time when compared to streams bedded in the Hawkesbury Sandstone. There is unlikely to be any significant diversion of flow, with any localised diversion being of a temporary nature (Appendix A of the EA). The predominance of cohesive bed sediments also means that bed and bank erosion is expected to be slow relative to that which may occur in more sandy soil profiles. The rate of morphological change (due to subsidence effects) toward a new equilibrium is also likely to be relatively slow and may be masked by earlier disturbances associated with clearing in these catchments (Appendix C of the EA).

Transient strata gas emissions can occur in these streams and would be evident as bubbling in either existing pools or slow moving water bodies.

### P6.4.3 Environmental Consequences of Subsidence on In-Stream Pools

The impacts of subsidence on the hydrological behaviour of in-stream pools would depend on the nature of the pools and the catchments that they occur in. The nature and distribution of pools in the Project area varies significantly. In-stream pools tend to occur in the mid and lower sections of streams and comprise either local depressions in the bedrock or ponds formed behind prominent rockbars. Natural pools (i.e. not including those formed by man made weirs such as on the Nepean River) mapped in the Project area typically vary in size from a few metres to over 300 m in length and from 0.1 to over 2 m in depth (Attachment PA). The rate of water level decline in affected pools and the frequency with which these pools are likely to be dry or experience low water levels would vary depending on: the size and depth of pools; the frequency and persistence of low and no flows entering the pool from the upstream catchment; the particular geological conditions of the pool bedrock and rockbars which control water levels in most pools; and the magnitude of valley closure and upsidence movements experienced in the affected reach of the watercourse (Appendix C of the EA).

The water balance of in-stream pools is dominated by upstream runoff inflow and overflow. Evaporation from the surface is typically a small component of the water balance as is seepage and incident rainfall. A number of rockbar controlled pools in un-mined areas have however been observed to have significant underflow through their controlling downstream rockbar.

[4] Release of methane-rich strata gases from overburden sequences above the coal seam.

Subsidence associated with longwall mining has affected a number of pools in the Southern Coalfield most notably by reducing water level persistence during low flow periods. The mechanism for this is the creation of a fracture network beneath the bed of a stream as a result of the dilation effects of upsidence and shearing/compressive effects of valley closure. This pattern of fractures provides a pathway for subsurface diversion (underflow) of low flows downstream. The diverted flows return to the surface near the downstream end of the fracture system which does not extend beyond the extent of subsidence.

Observation of past subsidence impacts on in-stream pools indicates a variable response with some pools experiencing lesser impacts than others.

Results of pool modelling presented in Appendix C of the EA indicate that the frequency that pools would be full or near full might decrease by a few percent in some cases and up to 50% in others. Small, shallow pools in small catchments which become well connected to extensive subsidence induced fracture networks are most likely to experience periods of drying. Small, deeper pools in large catchments with strong low flow persistence are less likely to be affected by subsidence induced bed fracturing. Streams formed in the Hawkesbury Sandstone terrains of the Project area typically contain a wide range of different pool sizes and types and experience has shown a range of different effects occur in response to subsidence induced dilation fracturing with some pools retaining water through dry periods (Appendix C of the EA).

### P6.4.4 Environmental Consequences of Subsidence on Water Supply Quantity

The risk of the quantity of water reaching the Woronora Dam, Cataract Dam and Broughtons Pass Weir being reduced as a consequence of subsidence-induced cracking has been assessed.

At the substantial depths of cover at the Project, connective cracking from the ground surface to the mined seam is not expected (Appendix B of the EA). Although stream beds with exposed rock base can experience subsidence induced fracturing to a depth of 10 to 20 m, there is considered to be negligible potential for the loss of surface water to the mine due to the lack of continuity of fractures from the surface to the mine (Appendix B of the EA).

As described in Sections P6.4.1 to P6.4.3 above, a portion of surface water flows may be diverted through the rock fractures beneath the stream bed, with emergence further downstream. As a result, the Project would not result in adverse consequences to the quantity of water reaching the Cataract Dam, Woronora Dam or Broughtons Pass Weir.

In this regard, the Metropolitan PAC Report states (page iii):

> *The potential loss of catchment yield was a strongly contested issue that could not be resolved beyond doubt on the information available. However, the Panel's view is that the risk of any significant loss is very low unless a major geological discontinuity is encountered during mining that provides a direct hydraulic connection between the surface and the mine workings. This is considered unlikely.*

and (page 50):

> *7.3.4. Panel's Resolution on Yield to Woronora Reservoir*
>
> *… the local and regional groundwater conditions coupled with the mine parameters, would suggest that the likelihood of water being lost from the surface water system as a consequence of mining, and then by-passing Woronora Reservoir, is very low. This conclusion accords with the findings of the Southern Coalfield Inquiry, viz:*
>
> > *No evidence was presented to the Panel to support the view that subsidence impacts on rivers and significant streams, valley infill or headwater swamps, or shallow or deep aquifers have resulted in any measurable reduction in runoff to the water supply system operated by the Sydney Catchment Authority or to otherwise represent a threat to the water supply of Sydney or the Illawarra region.*[37]

[37] *Page 2 of Southern Coalfield Inquiry Report*

Appendix A of the EA indicates that while the predicted subsidence movements at the Broughtons Pass Weir are small, cracking has been previously observed in the vicinity of the weir as the result of previous longwall mining (undertaken at a distance of approximately 300 m from the weir). ICHPL would develop management strategies for the weir, in consultation with the SCA, to manage the potential impacts on the weir as the result of the extraction of the longwalls. These management strategies may include ground monitoring at the weir and a Trigger Action Response Plan (TARP).

### P6.4.5 Environmental Consequences of Subsidence on Water Supply Quality

The Drinking Water Catchments REP commenced on 1 January 2007 and *State Environmental Policy 58 - Protecting Sydney's Water Supply* was repealed. The Drinking Water Catchments REP applies to land within the 'hydrological catchment', which comprises a number of sub-catchments which contribute to Sydney's (and surrounding regional centres) water supply, including the Upper Nepean River and Woronora River catchments (clause 6).

The aims of the Drinking Water Catchments REP are detailed in clause 3:

*This plan aims:*

*(a) to create healthy water catchments that will deliver high quality water while sustaining diverse and prosperous communities, and*

*(b) to provide the statutory components in Sustaining the Catchments that, together with the non-statutory components in Sustaining the Catchments, will achieve the aim set out in paragraph (a), and*

*(c) to achieve the water quality management goals of:*

*(i) improving water quality in degraded areas and critical locations where water quality is not suitable for the relevant environmental values, and*

*(ii) maintaining or improving water quality where it is currently suitable for the relevant environmental values.*

The Minister may take into account clauses 25 and 26 of the Drinking Water Catchments REP in deciding whether or not to approve the Project under Part 3A of the EP&A Act.

Clause 25 provides:

*25 Recommended practices and performance standards of the Sydney Catchment Authority*

*(1) Any development or activity proposed to be carried out on land to which this plan applies should incorporate any current recommended practices and performance standards endorsed or published by the Sydney Catchment Authority that relate to the protection of water quality (the Authority's current recommended practices and standards).*

*(2) If any development or activity does not incorporate the Authority's current recommended practices and standards, the development or activity should demonstrate to the satisfaction of the consent authority or determining authority how the practices and performance standards proposed to be adopted will achieve outcomes not less than the Authority's current recommended practices and standards.*

Clause 26 provides:

*26 Development consent cannot be granted unless neutral or beneficial effect on water quality*

*A consent authority must not grant consent to the carrying out of development under Part 4 of the Act on land in the hydrological catchment unless:*

*(a) it has considered whether the proposed development will have a neutral or beneficial effect on water quality, and*

*(b) it is satisfied that the carrying out of the proposed development would have a neutral or beneficial effect on water quality.*

Potential impacts on water quality as a result of the Project subsidence impacts would be localised (e.g. localised changes in water quality in the Nepean, Georges and Woronora Rivers and their tributaries). Although mine subsidence effects can result in isolated, episodic pulses in iron, manganese, aluminium and electrical conductivity, these pulses have not had any measurable effect on water quality on downstream reservoirs (Appendix C of the EA). The Project is not expected to impact on the performance of Woronora Reservoir, Cataract Reservoir or Broughtons Pass Weir.

ICHPL proposes to remediate sections of the streams included in Attachment PB where subsidence has resulted in significant fracturing of rockbars that results in surface flow diversion and draining of pools. The rockbars are shown on the stream mapping provided in Attachment PA. As a result, the degree of impact on water quality as a result of the Project would be limited in time.

In addition, ICHPL has committed to funding a number of researches, offset and compensatory measures including measures relevant to water quality (Section P7.3.4).

Of relevance to impacts on water supply quality, the Metropolitan PAC Report states (page 60):

> *The Panel notes that surface water monitoring undertaken by the Proponent suggests such water quality impacts appear to be both localised and transient, with negligible downstream impacts on the water quality of Woronora Reservoir stored waters. SCA supports this contention. However the Panel considers that it is the redirection of flows and disconnection of pre-existing aquatic regimes together with the localised impacts of water quality changes that have significant potential to affect aquatic systems.*

This is further supported by the findings of the SCPR (DoP, 2008) which states:

> *No evidence was presented to the Panel to support the view that subsidence impacts on rivers and significant streams, valley infill or headwater swamps, or shallow or deep aquifers have resulted in any measurable reduction in runoff to the water supply system operated by the Sydney Catchment Authority or to otherwise represent a threat to the water supply of Sydney or the Illawarra region.*

# P7 STEP 5 – RISK MANAGEMENT PLANS AND ACCEPTABILITY OF ENVIRONMENTAL CONSEQUENCES

## P7.1 PREPARATION OF RISK MANAGEMENT PLANS

ICHPL would prepare Stream RMPs for all of the streams listed in Attachment PB that are situated within the extent of longwall mining area and within 600 m of the boundary of secondary extraction.

The RMPs would be included in future Extraction Plans for specific mining domains. Consistent with the Metropolitan PAC Report, the RMPs would identify:

*(i) the options for managing the risk based on one or a combination of avoidance, mitigation, remediation or tolerance and taking account of any assessment of special significance of the feature;*

*(ii) where relevant, the potential costs of those options;*

*(iii) a preferred option;*

*(iv) where relevant, a monitoring regime that will detect impact, measure actual impact against predicted impact and measure the effectiveness of the management strategies adopted;*

*(v) contingency plans for dealing with the situation where actual impact exceeds predicted impact; and*

*(vi) auditing of the implementation and effectiveness of the risk management plan.*

Development of the RMP and the approach proposed to be taken for aspects (i) to (vi) above is described below. Specifically, Sections P7.2 to P7.7 present preliminary information upon which the RMPs would be based. The information presented in Sections P7.2 to P7.7 is preliminary on the basis that the Project Approval conditions (if the Project is approved by the Minister for Planning) and the final mine plan(s) would further inform the selection of particular risk management options that would be presented in future Extraction Plan(s).

## P7.2 REVIEW OF RISK OF IMPACTS AND ENVIRONMENTAL CONSEQUENCES

In addition to the RMP components listed in (i) to (vi) in Section P7.1 above, a review of the risk of impacts and environmental consequences presented in this Stream Risk Assessment would be conducted and presented in the RMPs. The updated risk assessment would be based on the final mine plan (which would be consistent with any Project Approval conditions and informed by relevant monitoring data). This review would represent an expanded/further informed assessment of streams to that presented in Steps 1 to 4 (described in Sections P3 to P6).

A preliminary monitoring programme has been developed for the streams based on the findings of Step 4 (Risk of Impacts and Environmental Consequences) and is described in Section P7.5. The monitoring programme has been designed to provide additional information on the streams, which would be used to inform the review of the risk of impacts and environmental consequences described above.

## P7.3 RISK MANAGEMENT OPTIONS AND COSTS

The Metropolitan PAC Report describes some of the important factors that need to be considered in the question of acceptability of environmental consequences for streams. The Metropolitan PAC Report state (page 55):

> *There are many streams of 3rd order and above in the Southern Coalfield and protecting them all from consequences induced by subsidence impacts would cause mining to cease. If mining is to proceed then a way must be found to determine which streams will be protected from consequences, which streams can be impacted but have consequences eliminated or mitigated by preventative or remediation techniques, and which streams (or part of streams) will simply be allowed to suffer damage.*
>
> *Ideally there would be an objective test based on a set of defined and measureable values that would make this task easy. Some possible assessment techniques exist (see Section 7.4.2 below), but they have not been applied in this context. The Panel recommends that the relevant government agencies explore the possible use of these techniques as a tool to assist in the determination of significance of watercourses under threat from mining proposals. Alternatively there could be an unambiguous policy position articulated that would guide decision makers in individual cases.*
>
> *As neither the test or the policy exist at present, the Panel is faced with identifying a set of values that might attach to a stream meeting the SCI threshold and that would assist in determining the nature and level of any protection that might be recommended. The list of values below is drawn from the EA, government agency submissions, public submissions and the SCI Report. It does not purport to cover all possible values, but it is the Panel's view that the main ones are included:*
>
> - *Importance to catchment yield*
> - *Significance to water supply*
> - *Scale of the watercourse*
> - *Permanence of flow*
> - *Water quality*
> - *Ecological importance*
> - *Environmental quality (pristine, modified, severely modified)*
> - *Visual amenity (eg cascades runs, pools etc)*
> - *Community value (value the community attributes to protection)*
> - *Regional significance*
>
> *Other factors that need to be considered are whether there are techniques available to prevent consequences or to remediate them effectively.*
>
> *In the current circumstances, the discussions as to significance and the appropriate protection to be afforded to a particular watercourse will come down to a case by case assessment of the values attributed to the watercourse, the options for protecting those values and the feasibility and costs of doing so.*
>
> *Inevitably there is an element of subjectivity in this decision process. …*

Preliminary consideration of the avoidance, mitigation, remediation and/or tolerance options for each stream is provided below based on the outcomes of Step 4. The final impact avoidance, mitigation, remediation and/or tolerance options selected for each stream would be informed by the updated risk assessment and presented in future Extraction Plans, to be consistent with any Project Approval issued by the Minister for Planning.

### P7.3.1 Avoidance

Consistent with the Metropolitan PAC Report statement, '*There are many streams of 3rd order and above in the Southern Coalfield and protecting them all from consequences induced by subsidence impacts would cause mining to cease.*', it is not considered feasible to avoid subsidence impacts or environmental consequences to all streams.

As described in Section P6.2, stream impact minimisation criteria have been applied to a number of streams in the Project area. Specifically, the longwall layout would be designed:

- To avoid significant fracturing of rockbars that could result in the draining of associated pools along particular stream reaches. Achievement of this criteria would also result in a significant reduction of subsidence effects on sections of stream between each rockbar feature (Appendix A of the EA).

- Not to directly undermine particular stream reaches. This would result in a reduction in potential subsidence effects (Appendix A of the EA).

A number of environmental impact reduction alternatives have been considered to examine the relative costs and benefits. The alternatives comprise modifying the mine layout (e.g. by adjusting mining parameters or adjusting the mine plan to set back from key features) to achieve various environmental outcomes for streams. Alternative mine plans are provided in Attachment PH.

A range of alternatives to the EA Base Plan Longwalls were examined (Table P-2). Analysis indicates that all of the environmental impact minimisation scenarios would result in a net cost to society and would therefore be considered to be economically inefficient (Appendix L of the EA).

**Table P-2**
**Summary of Project Environmental Impact Reduction Alternatives**

| Code | Description |
|---|---|
| C1 | Longwall setbacks from additional North Cliff domain streams 3rd order and above. |
| C3 | Longwall setbacks from additional Appin Areas 2 and 3 Extended domain streams 3rd order and above. |
| C4 | *Combination of C1 and C3.* |
| C9 | Longwall setbacks from additional West Cliff Area 5, Appin Area 7, Appin Area 9 and Appin Area 8 streams 3rd order and above. |
| C10 | *Combination of C4 and C9.* |

Source: Appendix L of the EA.

Potential stream mitigation and remediation measures have been developed and are discussed in Section P7.3.2.

### P7.3.2 Mitigation

The Metropolitan PAC Report (page 37) indicates there are four common mitigation options to reduce the impacts of subsidence on features:

> *Mitigation involves measures undertaken to reduce the impacts of subsidence on features. Four common options are:*
>
> *1. Restriction of ground movement: The magnitude of ground movement can be controlled by restricting mining height and/or restricting excavation width and/or increasing the width of pillars between panels. Mining layouts in which percentage extraction is restricted for the purpose of controlling subsidence are referred to in general as partial extraction mining systems. This is achieved by restricting the width of individual panels and separating panels by pillars of sufficient width so as to limit interaction between the panels. … Ground movement at the site of a feature may also be restricted by designing the mine layout so as to position the feature in a specific part of the subsidence trough. This measure is not usually feasible where the natural feature extends over a considerable distance or meanders.*
>
> *2. Isolation of ground movement: This involves isolating a feature from ground strains and shear displacements. Measures which are employed include uncovering buried structures (such as pipelines) and constructing slots at strategic locations adjacent to a feature, with the intention that ground strain will concentrate at the slots. The success of slots is dependent on a number of factors including selecting the correct locations and directions for the slots, having access to these sites, and constructing the slots a sufficient time in advance of mining. The slots may be cut mechanically or formed by drilling a pattern of closely spaced, large diameter drill holes. This control measure is still in a development stage and is generally considered to be an expensive option. It was trialed at Waratah Rivulet but the full array of slot holes could not be drilled in the allocated time frame. However, it has shown promising results in the limited number of cases where it has been employed (eg at Marnhyes Hole on the Georges River).*

3. *Maintenance responses: This involves measures which aim to maintain the physical state and function of a feature, albeit that it may be impacted by subsidence during the mining process. Examples include increasing flow volume in a fractured section of a watercourse in order to maintain surface flow at pre-mining levels, and installing support in overhangs and cliff faces prior to undermining.*

4. *Preservation responses: Archaeological artefacts which may be at risk from mine subsidence may be removed on a temporary or permanent basis prior to undermining, or logged and recorded in a visual format for posterity.*

Potential mitigation options for streams have been considered and are discussed below.

*P7.3.2.1 Restriction of Ground Movement*

As described above, the magnitude of ground movement can be controlled by adjusting the mining parameters.

In relation to mining parameters and potential impacts on streams at the nearby Metropolitan Colliery, the Metropolitan PAC Report states (page 11):

> *The proposed longwall panel width is 163m, reducing to 133m within the Dam Safety Committee's Notification Area for Woronora Reservoir. These widths are small by industry standards today, with most longwall panel widths falling in the range of 250 to 400m. The dimensions of the Metropolitan Colliery longwall panels are comparable with those of pillar extraction layouts utilised extensively in the past in the Southern Coalfield.*

Further to the potential setback options described in Section P7.3.1, alternative mine plans have been used to examine the relative costs and benefits of modifying the mine layout by narrowing the longwall panel void widths to 163 m. The following alternative mine plans were examined:

- **Mine Plan Option A1** – altering the North Cliff domain mine layout to utilise 163 m wide longwall panel voids.
- **Mine Plan Option A2** – altering the Appin Areas 2 and 3 Extended domain mine layout to utilise 163 m wide longwall panel voids.
- **Mine Plan Option A3** – altering both the North Cliff and Appin Areas 2 and 3 Extended domain mine layouts to utilise 163 mm wide longwall panel voids.

Gillespie Economics has undertaken an analysis of the relative costs and environmental benefits of narrowing the longwall panel void widths to 163 m. The analysis conducted by Gillespie Economics indicates that with the inclusion of the social community values estimated via the Choice Modelling Study, adjusting the mine parameters is not economically efficient and results in a net cost to society.

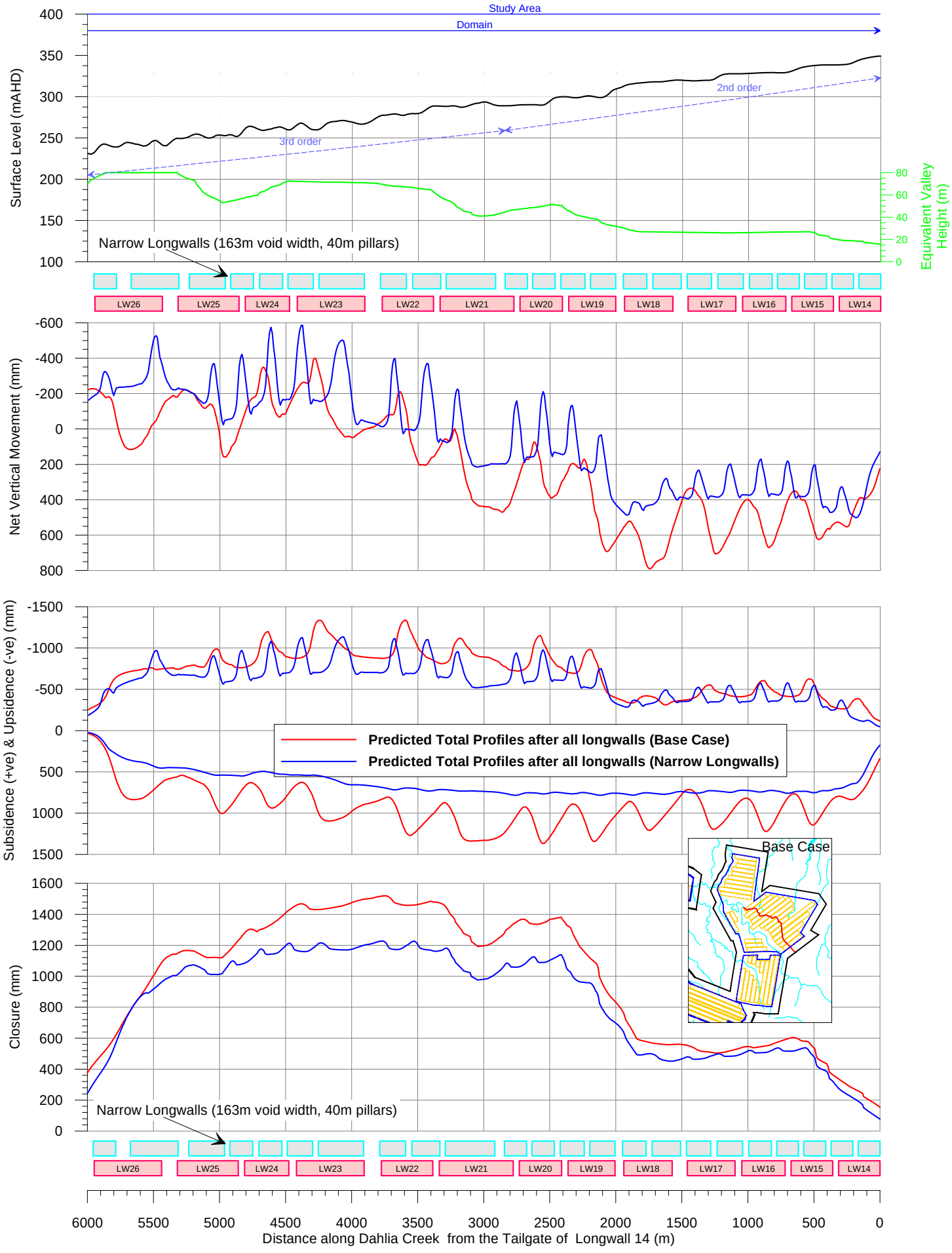
Adopting the 163 m wide longwall panel voids would result in substantial cost and would still result in subsidence predicted to be greater than 200 mm closure. For example, MSEC in Appendix A of the EA compares the subsidence, upsidence and closure profiles obtained using the 163 m wide longwall panel voids against the subsidence, upsidence and closure profiles obtained for the base case mine layout for Dahlia Creek, Wallandoola Creek and Allens Creek. The analysis is shown in Figures P-1, P-2 and P-3, respectively.

The analysis indicates that use of the 163 m wide longwall panel voids would not significantly alter the environmental consequences expected to be experienced (i.e. there would not be a material reduction in the length of stream predicted to experience greater than 200 mm of closure).

*P7.3.2.2 Isolation of Ground Movement*

As described in Section P7.3.1, the isolation of ground movement is a potential mitigation option to reduce the impacts of subsidence on streams.

# North Cliff - Longwalls 1 to 36 Dahlia Creek
# Comparison of Subsidence, Upsidence and Closure Profiles




Mine Subsidence Engineering Consultants

**Fig. P-1**

# Appin Area 3 - Longwalls 303 to 313 Wallandoola Creek
# Comparison of Subsidence, Upsidence and Closure

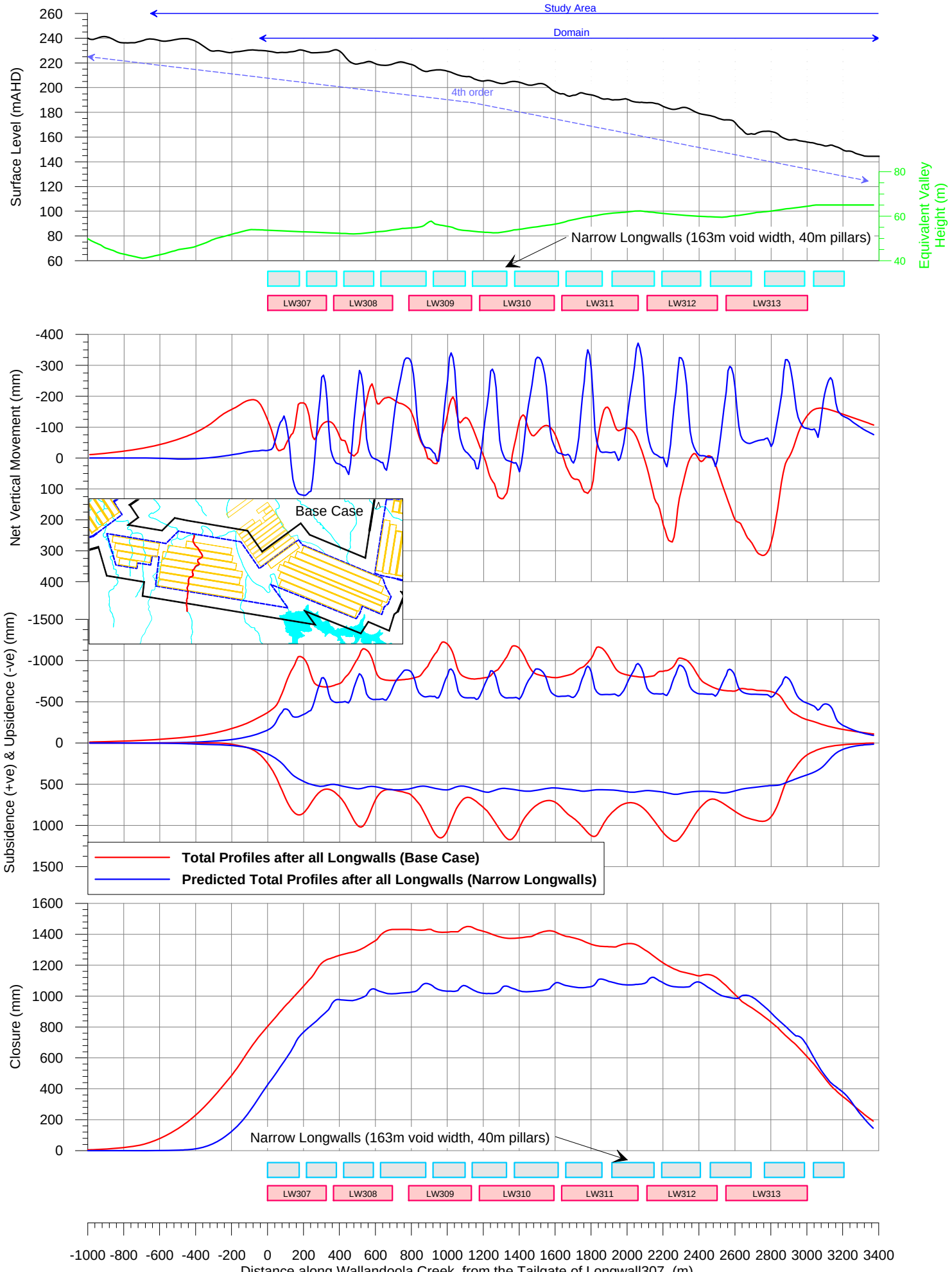



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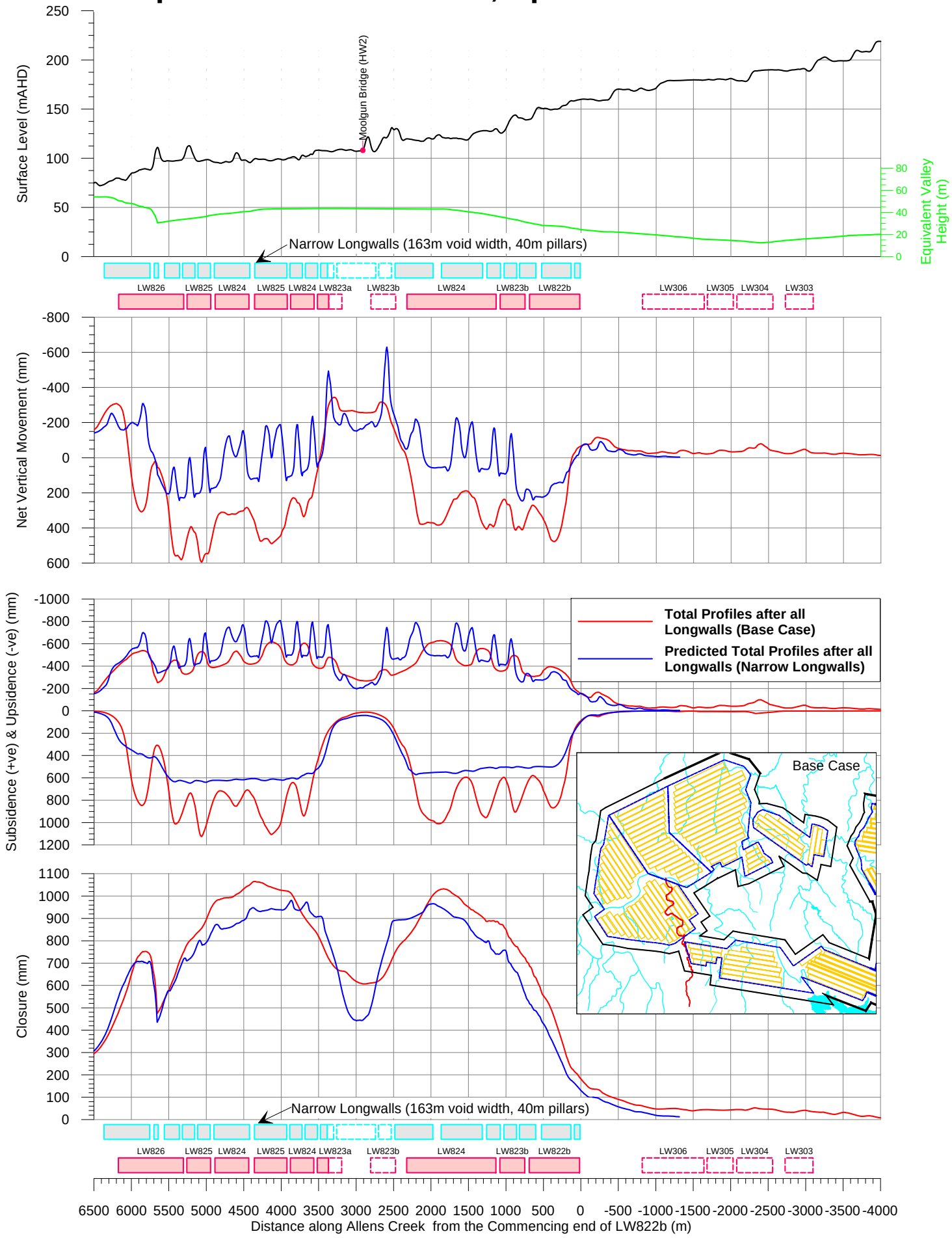
**Fig. P-2**

# Appin Area 3 - Longwalls 303 to 313 & Appin Area 8 - Longwalls 800 to 827 Allens Creek Comparison of Subsidence, Upsidence and Closure




Mine Subsidence Engineering Consultants

**Fig. P-3**

The Metropolitan PAC Report states in relation to the isolation of ground movement (page 37):

> 2. *Isolation of ground movement: This involves isolating a feature from ground strains and shear displacements. Measures which are employed include uncovering buried structures (such as pipelines) and constructing slots at strategic locations adjacent to a feature, with the intention that ground strain will concentrate at the slots. The success of slots is dependent on a number of factors including selecting the correct locations and directions for the slots, having access to these sites, and constructing the slots a sufficient time in advance of mining. The slots may be cut mechanically or formed by drilling a pattern of closely spaced, large diameter drill holes. This control measure is still in a development stage and is generally considered to be an expensive option. It was trialed at Waratah Rivulet but the full array of slot holes could not be drilled in the allocated time frame. However, it has shown promising results in the limited number of cases where it has been employed (eg at Marnhyes Hole on the Georges River).*

The construction of slots parallel to or around a particular feature is considered to be the isolation of ground movement measure of most relevance to streams. However, as recognised by the Metropolitan PAC Report, this control measure is still in a development stage.

The construction of slots to minimise impacts on rockbars would be considered on a case by case basis. Site specific design would be required in the case it is selected to be employed. Any use of the slots would be proposed in the RMPs to be prepared and included in Extraction Plans.

### *P7.3.2.3 Maintenance Responses*

Maintenance responses typically involve measures which aim to maintain the physical state and function of a feature, albeit that it may be impacted by subsidence during the mining process. Maintenance responses include remediation measures.

The Metropolitan PAC Report describes remediation as follows (page 36):

> *Remediation refers to the activities associated with partially or fully repairing or rehabilitating impacts and, as such, is a measure for controlling the consequences of an impact.*

In relation to remediation, the Metropolitan PAC Report states (page 38):

> *There are a variety of remediation options available to respond to subsidence impacts.*
>
> *These include backfilling and/or grouting of cracks and fracture networks, stabilisation of slopes and drainage and erosion control measures. Fractures may also infill naturally in watercourses that have a moderate to high sediment load; otherwise they may have to be grouted.*
>
> *Grout can be either cement-based or composed of various plastics or resins (e.g. polyurethane) and is injected under pressure into fracture networks. The degree of success of grouting is dependent on the accessibility of the site, on the type of grouting materials which are used and on timing.*
>
> *In the case of watercourses, it is not yet feasible to remediate an entire upsidence fracture network. Hence, remediation efforts in the Southern Coalfield have to date focused on sealing the fracture network at strategic locations, such as rock bars. At these sites, the fracture network can extend some distance laterally under the toe of valleys and be overlain by talus. It can also be covered by boulder beds within watercourses. These types of settings restrict access for grout injection equipment. If the site of fracturing is affected by a number of mining panels, several episodes of grouting may be required over a number of years. In the interim, mitigation measures are required to sustain surface water flows if the local ecology is not to be impacted.*

Recommendation 34 of the Metropolitan PAC Report states (page 147):

> ***Recommendation 34***
>
> *The Panel recommends that remediation be required where subsidence impacts cause diversion of flows or drainage of pools with the objective of restoring flows and pool holding capacity to pre-mining levels as quickly as possible. The Panel notes that more than one remedial effort may be required at an individual feature (eg a rock bar) given that the total impacts are expected to be associated with successive longwalls. The Panel recommends that approval conditions should require close monitoring of impacts from all longwalls likely to affect such key features.*

ICHPL has successfully remediated a series of impacted pools on the Georges River. Stream remediation measures have also been implemented at the Metropolitan Colliery on Waratah Rivulet (Helensburgh Coal Pty Ltd [HCPL], 2008). A summary of these methods from Appendix C of the EA and their possible application to different situations is provided in Table P-3.

These and other techniques would continue to be developed in Australia and overseas in both environmental restoration and civil/industrial applications. The full range of available techniques would be considered in the design of future stream remediation programmes.

As described in Section P6.2, a 200 mm closure threshold has been applied to the longwall layouts to avoid significant fracturing of rockbars on O'Hares Creek, Stokes Creek (reaches 1 and 2), Cataract River, Lizard Creek, Georges River reach 2 and the Nepean River reach 1. As a result, it is not anticipated that stream remediation measures would be required for these stream reaches, other than that required for contingency measures.

Achievement of the 200 mm criteria on the abovementioned streams would also result in a significant reduction of subsidence effects on sections of stream between each rockbar feature (Appendix A of the EA). Notwithstanding, stream remediation measures (e.g. grouting) would be conducted on rivers and stream reaches of third order and above where subsidence results in the draining of pools in stream sections between controlling rockbars, where the remediation measures are considered technically feasible.

Further, the longwall layout would be designed not to directly undermine the Nepean River (reaches 2 and 3) and the headwater reaches of the Georges River (i.e. Georges River reach 1) and Woronora River labelled as "perennial" on the 1:25,000 topographic mapping (Lands Department, 2000). This would result in a reduction in potential subsidence effects (Appendix A of the EA). Notwithstanding, it is anticipated that some stream remediation works would likely be required (particularly the Georges and Woronora Rivers).

**Table P-3**
**Summary of Proposed Stream Remediation Techniques**

| Restoration Technique | Description | Applications and Limitations |
|---|---|---|
| Hand grouting | Sealing of cracks exposed on the surface using hand applicators. A variety of sealants can be used including sealants that can be applied under water. | Limited to surface cracks which can be accessed using hand held application equipment. |
| Shallow pattern grouting | Drilling shallow holes using small hand held drilling equipment and low pressure injection of a grout using a portable pump. Grouts used successfully on the Georges River incorporated a cement mix that can be used with or without additives (e.g. bentonite). | Used to seal shallow fractures in rockbars and pools. Applicable to sensitive areas where access for larger equipment is problematic. Better results can be obtained if the target fractures are dewatered. |
| Deep pattern or curtain grouting | Drilling deeper holes using traditional air and or reverse circulation drilling rigs. Higher pressure grouting techniques can also be used. Grouts used successfully on the Georges River incorporated a cement-bentonite mix. | Used to seal fracture networks at greater depths. Can seal larger and deeper fractures. Larger equipment may necessitate constructing access tracks. Less suitable for remote or difficult access sites. |
| Deep angle hole cement grouting | Remote directional drilling techniques can be used to access otherwise inaccessible sites. The same grouting methods as deep pattern or curtain grouting outlined above can be used. | Specialised technique which can be used in situations where drill access is available close to target site. |
| Polyurethane grouting | Use of expanding polyurethane grouts to seal fracture networks. Polyurethane, which is a rapid setting grout that sets under water, is pumped into closely spaced drill holes (pattern drilling) and fractures filled systematically from "bottom up". | Technique used successfully on Waratah Rivulet by HCPL. Can be used under water and under low flow conditions. Can be used to fill large aperture fractures in stages. |

Source: BHP Billiton Illawarra Coal (2006); HCPL (2008).

Where fracturing of controlling rockbars results in surface flow diversion and draining of pools, ICHPL proposes to remediate the controlling rockbars (and associated pools) on all rivers and stream reaches

of third order and above. The rockbars associated with these stream reaches are shown on the stream mapping provided in Attachment PA.

In addition, where subsidence results in surface flow diversion and draining of pools in stream sections between controlling rockbars, ICHPL proposes to implement stream remediation measures on rivers and stream reaches of third order and above, where the remediation measures are technically feasible.

The estimated costs associated with stream remediation are explained in Appendix L of the EA and would be further detailed in RMPs to be included in Extraction Plans. The areas identified as potentially requiring stream remediation measures would be targeted during monitoring to determine the magnitude and extent of any environmental consequences.

Regular visual monitoring would be conducted to identify any stream areas subject to excessive erosion and sedimentation. Where monitoring indicates the potential for excessive erosion or sediment migration, specific mitigation measures would be employed. Potential management measures include:

- filling of cracks and minor erosion holes in the bed or banks of watercourses;
- installation of sediment fences downslope of subsidence-induced erosion areas;
- stabilisation of erosion areas using rock or other appropriate materials;
- stabilisation of banks subject to soil slumping; and
- revegetation using brush matting, seeding or tubestock.

Potential rehabilitation measures for impacts on vegetation include the implementation of weed control measures (e.g. mechanical removal or the application of approved herbicides) and the planting of endemic plant species. Any active planting would utilise flora species characteristic of the particular vegetation community in that area and would utilise seed collected from the local area.

#### *P7.3.2.4 Preservation Responses*

Preservation responses (such as relocation of specific items) are not considered applicable to streams. However, certain preservation measures may be appropriate to reduce impacts to stream features during the abovementioned mitigation works and these would be detailed in the RMPs.

### P7.3.3 Tolerance

In relation to tolerance, a 'tolerable risk' is defined in the Metropolitan PAC Report (page xv) as:

> *risk which is accepted in a given context based on the current values of society.*

Further, the Metropolitan PAC Report states (page 38):

> *Toleration of subsidence impacts usually requires that no action be taken to control or remediate the impacts. This practice is common in very deep mines (because subsidence effects are restricted and dissipate gradually over a large area) and at locations that have no significant sub-surface and surface features.*

As described in Section P7.6, Contingency Plans would be included in RMPs to describe the process and measures that would be implemented in the event that actual subsidence impacts exceed those authorised through the Extraction Plan and Project Approval.

### P7.3.4 Offset Options

In relation to offsets, Recommendation 10 of the SCPR states:

> *10. Consideration should be given to the increased use within Part 3A project approvals of conditions requiring environmental offsets to compensate for either predicted or non-predicted impacts on significant natural features, where such impacts are non-remediable.*

Further, Recommendation 37 of the Metropolitan PAC Report states (page 148):

> ***Recommendation 37***
>
> *The Panel recommends that a comprehensive suite of options be developed to deal with the situation where outcomes for environmental consequences or predicted impacts are not met. The appropriate options should be incorporated into approval conditions for the Project and measures such as compensation and offsets should be considered in this context.*

The statements quoted below from the SCPR and Metropolitan PAC Report are of relevance to the offset measures proposed.

In relation to research and the prediction of subsidence effects and impacts, the Metropolitan PAC Report states (page 35):

> *The 'disconnect' between the prediction of effects and of impacts related to closure and upsidence warrants further research. In response to the findings of the SCI, the Australian Coal Association Research Program (ACARP) has recently awarded funding of $500,000 to MSEC to undertake further research in this regard[26]. The Panel considers that in the interim, if the Metropolitan Coal Project proceeds, approval conditions should have a specific focus on the monitoring of upsidence and closure impacts and the mine plan must be capable of modification to manage these impacts within predetermined levels.*
>
> *[26] Effects of Geology on Closure and Upsidence Movements and Impacts in Valleys. ACARP Project C18015*

and (page 139):

> ***Recommendation 13***
>
> *The Panel recommends that further research be undertaken with a view to improving the prediction of subsidence induced consequences in significant watercourses in an endeavour to improve assessment of potential effects on the values attributed to these watercourses.*

In relation to stream remediation, Recommendation 14 of the SCPR states:

> *14. The coal mining industry should undertake additional research into means of remediating stream bed cracking, including:*
>
> *a. crack network identification and monitoring techniques;*
>
> *b. all technical aspects of remediation; and*
>
> *c. administrative aspects of remediation, in particular, procedures for ensuring the maintenance and security of grout seals in the long term.*

Table P-4 summarises a number of Project research, offset and compensatory measures developed for the Project.

## P7.4 PREFERRED RISK MANAGEMENT OPTION

The following summarises ICHPL's currently preferred risk management options based on consideration of the risk assessment of environmental consequences and the potential management options (avoidance, mitigation, tolerance and offset options):

- Implementation of stream impact minimisation criteria. The longwall layout would be designed to avoid significant fracturing of rockbars that could result in the draining of associated pools along particular stream reaches. Achievement of this criteria would also result in a significant reduction of subsidence effects on sections of stream between each rockbar feature (Section P6.2).
- Implementation of stream impact minimisation criteria. The longwall layout would be designed not to directly undermine particular stream reaches. This would result in a reduction in potential subsidence effects (Section P6.2).
- Implementation of maintenance responses (e.g. stream grouting and erosion control) to maintain the physical state and function of streams (Section P7.3.2.3).
- Implementation of the monitoring programme to obtain additional baseline information to further inform the risk of subsidence impacts and environmental consequences (Section P7.5).
- Implementation of the Project research, offset and compensatory measures (Section P7.3.4).

A summary of the preferred risk management options is provided in Table P-5.

**Table P-4**
**Summary of Project Research, Offset and Compensatory Measures**

| Activity | Financial Contribution |
|---|---|
| ***Research Programmes*** | |
| **Swamps:**<br>• The possible mechanisms for subsidence impacts on swamp hydrology across a range of swamp types, terrain and mining operations. The objective is to improve predictability of impacts on swamp hydrology.<br>• The relationship between changes in swamp hydrology and environmental consequences. The two key issues here are severity and duration of the hydrologic disturbance. Both are relevant to considering whether mitigation or remediation measures might play a role in management of mining impacts.<br>• The possibilities of using remediation techniques and the circumstances in which they may be applicable.<br>• Developing a suite of indicators that could form the basis of an accepted stratified approach to monitoring impacts and consequences on upland swamps.<br>• The value that the community places on both the catchment protection and conservation roles of upland swamps. | $250,000 |
| **Streams:**<br>• Non-conventional subsidence effects and associated environmental consequences in significant watercourses.<br>• Techniques for remediating stream bed cracking. | $250,000 |
| ***Catchment Condition Work*** | |
| • Financial contribution towards rehabilitation and revegetation works within the Dharawal State Conservation Area or SCA controlled catchments. | $50,000/year of longwall mining in the relevant domains |
| • Financial contribution to management within the Dharawal State Conservation Area or SCA controlled catchments:<br>– Pest Control - pest control programmes for pests such as the Red Fox, European Rabbit, Feral Deer, Feral Pig and Feral Cat.<br>– Weed Control - weed control programmes for weeds such as Pampas Grass, African Love Grass, Lantana, African Boxthorn, Bridal Veil Creeper, Prickly Pear, Onion Grass and Blackberry.<br>– Fire Management - fire management programmes. | $25,000/year of longwall mining in the relevant domains |
| **Total** | **$1,775,000** |

**Table P-5**
**Summary of Preferred Risk Management Options**

| Streams | Stream Impact Minimisation Criteria[1] | Management Measures[1] | Exceeding Prediction | Contingency |
|---|---|---|---|---|
| • O'Hares Creek.<br>• Stokes Creek (reaches 1 and 2).<br>• Cataract River.<br>• Lizard Creek.<br>• Georges River (reach 2).<br>• Nepean River (reach 1). | • Minor fracturing of controlling rockbars, with negligible diversion of water from associated pools.<br>• Potential for fracturing of stream bed and consequent stream flow diversion in stream reaches between controlling rockbars. The potential for this impact is considered to be low in stream reaches where the above criteria has been applied (i.e. the application of the above criteria at controlling rockbars is expected to significantly reduce potential impacts to intervening stream reaches as evidenced by the analysis of the EA Base Plan Longwalls presented in Appendix A).<br>• Localised[3] impacts on stream water quality.<br>• Strata gas release. | • Longwall layout design to achieve a maximum predicted closure of 200 mm at controlling rockbars.<br>• Implementation of stream remediation measures on rivers and stream reaches of third order and above where subsidence results in the diversion of stream flow in stream reaches between controlling rockbars, and where the stream features are such that the remediation measures are considered technically feasible (e.g. where there was pre-mining flow and the substrate is suitable for grouting). The need for and the effort required for successful remediation is expected to be significantly less than that required for streams without setbacks. | • Fracturing of controlling rockbar resulting in increased leakage from associated pools.<br>• Remediation measures implemented are not successful.<br>• Impacts on stream water quality more than localised. | • Implementation of additional stream remediation measures.<br>• Implementation of offset and compensatory measures. |
| • Georges River (reach 1) – includes perennial[2] reaches that are less than 3rd order.<br>• Woronora River (perennial[2] reaches) – includes perennial[2] reaches that are less than 3rd order. | • Fracturing of controlling rockbars and/or stream bed, resulting in the diversion of some stream flow, however to a reduced degree when compared to streams with full extraction.<br>• Localised[3] impacts on stream water quality.<br>• Strata gas release. | • Stream not directly undermined.<br>• Implementation of stream remediation measures (i.e. grouting) at controlling rockbars to return stream flow to pre-mining characteristics. The need for and the effort required for successful remediation is expected to be significantly less than that required for streams without setbacks.<br>• Implementation of stream remediation measures in stream reaches between controlling rockbars where remediation measures are technically feasible (e.g. where there was pre-mining flow and the substrate is suitable for grouting). | • Remediation measures implemented are not successful.<br>• Impacts on stream water quality more than localised. | • Implementation of additional stream remediation measures.<br>• Implementation of offset and compensatory measures. |

**Table P-5 (Continued)**
**Summary of Preferred Risk Management Options**

| Streams | Stream Impact Minimisation Criteria[1] | Management Measures[1] | Exceeding Prediction | Contingency |
|---|---|---|---|---|
| • Nepean River (reaches 2 and 3) – includes reaches of the Nepean River within the Douglas Park Causeway and Menangle Weir inundation areas. | • Localised[3] impacts on stream water quality.<br>• Strata gas release.<br>• Minimise impacts such as cliff falls along the Nepean River. | • Stream not directly undermined.<br>• Along the Nepean River apply a minimum setback distance (i.e. whichever gives the greater distance from the Nepean River) of:<br>– 50 m from the top of mapped cliff lines; and<br>– 50 m from the transition from steep slope to the Nepean River alluvium/colluvium zone.<br>• Minimum setback distance of a 35$^{o}$ angle of draw from the Menangle Weir and road/rail bridges across the Nepean River would also be applied to the longwall layout to maintain the structural integrity of the weir and road/rail bridges.<br>• A minimum setback distance of a 35$^{o}$ angle of draw from the Douglas Park Twin Bridges (where the Hume Highway crosses the Nepean River) would also be applied to the longwall layout design to maintain the structural integrity of the bridge. | • Impacts on stream water quality more than localised.<br>• Cliff falls. | • Implementation of stream remediation measures (e.g. remediation of bank erosion with techniques such as tree planting) where technically feasible.<br>• Implementation of offset and compensatory measures. |

**Table P-5 (Continued)**
**Summary of Preferred Risk Management Options**

| Streams | Stream Impact Minimisation Criteria[1] | Management Measures[1] | Exceeding Prediction | Contingency |
|---|---|---|---|---|
| • All other streams. | • Fracturing of controlling rockbars and/or stream bed, resulting in the diversion of some stream flow, including increased leakage from pools.<br>• Localised[3] impacts on stream water quality.<br>• Strata gas release. | • Implementation of stream remediation measures (i.e. grouting) on stream reaches of third order and above at controlling rockbars to return stream flow to pre-mining characteristics.<br>• Implementation of stream remediation measures on stream reaches of third order and above in stream reaches between controlling rockbars, where remediation measures are technically feasible (e.g. where there was pre-mining flow and the substrate is suitable for grouting). | • Remediation measures implemented are not successful.<br>• Impacts on stream water quality more than localised. | • Implementation of additional stream remediation measures.<br>• Implementation of offset and compensatory measures. |

1 Controlling rockbars on each stream are identified on stream mapping provided in Appendix P.

2 As mapped on 1:25,000 topographic mapping (Lands Department, 2000).

3 Estimated to include the extent of subsidence effects plus in the order of 600 m downstream (after HCPL, 2008).

## P7.5 STREAM MONITORING

In relation to monitoring, Recommendations 5, 15, 16 and 34 of the Metropolitan PAC Report state (pages 136, 139, 140 and 147):

> ***Recommendation 5***
>
> *The Panel recommends that approval conditions for the current Project should have a specific focus on the monitoring of upsidence and valley closure impacts and that the mine plan be capable of modification to manage the consequences arising out of these impacts within predetermined levels.*
>
> ***Recommendation 15***
>
> *The Panel recommends that a monitoring regime be established to contribute to the predictability of consequences for watercourses from subsidence impacts. This regime should cover a representative sample of watercourses and should include Tributary B.*
>
> ***Recommendation 16***
>
> *The Panel recommends that groundwater monitoring regimes proposed by the SCI are incorporated into approval conditions, including requirements (detailed in Section 8.5) for:*
>
> - *shallow piezometer installations for the monitoring of groundwater levels/pressures within significant upland swamps, drainages and any connected alluvium;*
>
> *…*
>
> ***Recommendation 34***
>
> *The Panel recommends that remediation be required where subsidence impacts cause diversion of flows or drainage of pools with the objective of restoring flows and pool holding capacity to pre-mining levels as quickly as possible. The Panel notes that more than one remedial effort may be required at an individual feature (eg a rock bar) given that the total impacts are expected to be associated with successive longwalls. The Panel recommends that approval conditions should require close monitoring of impacts from all longwalls likely to affect such key features.*

A preliminary stream monitoring programme has been developed based on the outcomes of Step 4 (risk assessment and environmental consequences). Key components of the programme are described in Table P-6.

It is proposed that a detailed monitoring programme be provided in a Catchment Monitoring Programme to be prepared to the satisfaction of the DoP. Similar to the risk assessment conducted for the Project, the Catchment Monitoring Programme would be reviewed and updated in accordance with any updated risk assessment.

TARPs would be prepared and included in the RMPs in future Extraction Plans. The TARP would assist in the identification, assessment and response to impacts (including impacts greater than predicted). The triggers would be based on comparison of baseline and impact monitoring results. The TARP would provide for detailed implementation of the framework provided in Table P-5 and that authorised by the Project Approval.

## P7.6 CONTINGENCY PLANS

The monitoring programme described in Section P7.5 would facilitate the implementation of contingency measures, where actual subsidence impacts for streams exceed predictions. Table P-5 outlines the preferred risk management options and associated contingency measures should impacts exceed predictions.

The contingency plan process would involve:

- Implementation of the TARP described in Section P7.5, specifically:
  - Implementation of the stream monitoring programme.
  - Collection of monitoring data.
  - Analysis of results, including:
    - Assessment against monitoring triggers described in a TARP developed for streams in the mining domain and included in relevant Extraction Plans.
    - Assessment of any trends in the data that may indicate changes are occurring.
    - Assessment of any impacts against predictions.
    - Root cause analysis of any change or impact.
    - Specialist input to analysis of results, as required.
  - Reporting.

**Table P-6**
**Stream Monitoring Programme Overview**

| Parameter | Monitoring Sites | Description |
|---|---|---|
| Surface Water Flow | • Nepean River<br>  - Menangle Weir gauging station.<br>  - Maldon Weir gauging station.<br>• Georges River<br>  - Gauging station to be established downstream of the Cataract Scout Park in Appin Area 2.<br>  - gauging station to be established at Wedderburn downstream of West Cliff Area 5 Extended.<br>• Flow monitoring sites to be established at local mine-area scale covering all rivers and third order streams and above. | • The mine area specific flow monitoring would be developed progressively over the Project life.<br>• Gauging stations would be established at least two years prior to the commencement of extraction within each catchment.<br>• Where stream conditions allow (e.g. existence of a suitable control site), gauging stations would be established both upstream and downstream of the main subsidence impact zones. Where this is not practicable, monitoring stations would be established as close to these locations as practicable.<br>• Gauging stations would be designed and constructed to provide suitable minimum low flow resolution and accuracy. Interim targets of ± 0.1 megalitres per day (ML/day) resolution and ± 10% accuracy in flow rate over the flow range 0.5 to 10 ML/day are proposed.<br>• Flow monitoring would contribute to the quantitative understanding of the pre-mine catchment via the use of baseline models and inform the success criteria for remediation works.<br>• Additional pluviometers would be established as the monitoring network expands to provide reliable rainfall information required to interpret and model the dynamics of catchments.<br>• Specific monitoring, aimed at quantifying local flow diversion phenomena, would also be established. The monitoring results would be used to identify the need and subsequent success of remediation measures. |
| Pool Water Level | • At representative pools in potentially impacted stream reaches (i.e. where closure movements are predicted to be greater than 200 mm) of rivers and third order streams and above. | • The programme would be developed progressively over the Project life.<br>• Pool level monitoring would commence at least two years prior to the commencement of mining in the catchment.<br>• Pool monitoring would be conducted on 10 to 20% of the pools in the potentially impacted reaches.<br>• Pools would be selected for monitoring in consideration of their environmental values, including ecological aspects.<br>• Pool level monitoring would contribute to the quantitative understanding of the pre-mine pool water balance dynamics via the use of baseline models and inform the success criteria for remediation works.<br>• As described above, additional pluviometers would be established as the monitoring network expands to provide reliable rainfall information required to interpret and model the dynamics of stream pools.<br>• Specific monitoring, aimed at quantifying local flow diversion phenomena, would also be established. The monitoring results would be used to identify the need for and subsequent success of any remediation measures. |

**Table P-6 (Continued)**
**Stream Monitoring Programme Overview**

| Parameter | Monitoring Sites | Description |
|---|---|---|
| Surface Water Quality<br>(refer to Figure 14 in Appendix C of the EA for existing water quality site locations) | • Nepean River (sites NR100, NR2, NR40 and NR60).<br>• Georges River (sites GR1, GR19 and GR100).<br>• Woronora River (sites WOWQ1 and WOWQ2).<br>• O'Hares Creek (sites OH1 and OH2).<br>• Stokes Creek (sites SC1 and SC2).<br>• Dahlia Creek (sites DC1 and DC2).<br>• Cataract River (sites CAT1 and Weir 5).<br>• Cataract Tributaries (site LCT1).<br>• Wallandoola Creek (site WA1).<br>• Lizard Creek (site LZ1).<br>• Cascade Creek (site CAS1).<br>• Foot Onslow Creek (site FO1).<br>• Navigation Creek (site NAV1).<br>• Racecourse Creek (site RC1).<br>• Clements Creek (site CLC1).<br>• Allens Creek (site AC1).<br>• Carriage Creek (site CAR1).<br>• Stonequarry Creek (site Stone1).<br>• Additional representative sites on third order streams and above in all extent of longwall mining areas. | • The mine area specific water quality monitoring would be developed progressively over the Project life.<br>• Water quality monitoring would be conducted at all flow monitoring sites and at pool level monitoring sites.<br>• Water quality monitoring would provide at least two years of data prior to the commencement of extraction within each catchment.<br>• Sampling intensity would be selected to characterise the expected variability in water quality with a nominal minimum monthly sampling frequency.<br>• Water samples would be analysed by an appropriately accredited laboratory for the standard suite of parameters. |
| Stream Remediation | • At sites on rivers and third order stream reaches and above where remediation works have been implemented. | • A programme would be developed to monitor the performance of the remediation works implemented for the Project. Examples of the type of monitoring parameters relevant to this programme include:<br>- Quantification of local flow diversion.<br>- Monitoring of remediation methods (e.g. quantity of grout injection).<br>- Effectiveness of environmental controls implemented during remediation works.<br>- Permeability testing.<br>- Water quality monitoring.<br>- Pool water level monitoring.<br>- Other environmental monitoring (e.g. aquatic ecosystem monitoring). |

- Where subsidence impacts or environmental consequences are found to be consistent with predictions, implementation of risk management options described in the RMPs.
- Where subsidence impacts or environmental consequences are found to exceed predictions, identification of options for management, mitigation and/or offset, developed in consultation with stakeholders. The options include:
  - mitigation measures such as those described in Section P7.3.2; or
  - offset options such as those described in Section P7.3.4.
- Implementation of chosen management options.
- Monitoring to assess effectiveness of contingency measures implemented.
- Identification of any required changes to RMPs.
- Consultation with regulatory authorities and landholders.

### P7.7 AUDITING

An independent audit would be conducted to assess the implementation and effectiveness of the RMPs. The audit would be conducted annually for two years and every five years thereafter following the commencement of any RMPs for particular mining domains.

The audit would:

- be conducted by a suitably qualified, experienced, and independent person whose appointment has been endorsed by the DoP;
- assess the performance of the RMP;
- review the adequacy of the RMP management options and monitoring programmes; and
- if necessary, recommend actions or measures to improve the performance of the RMP and the adequacy of the RMP management options and monitoring programmes.

ICHPL would submit a copy of the audit report, with responses to any recommendations made by the audit, to the DoP within four months of audit commissioning.

## P8 REFERENCES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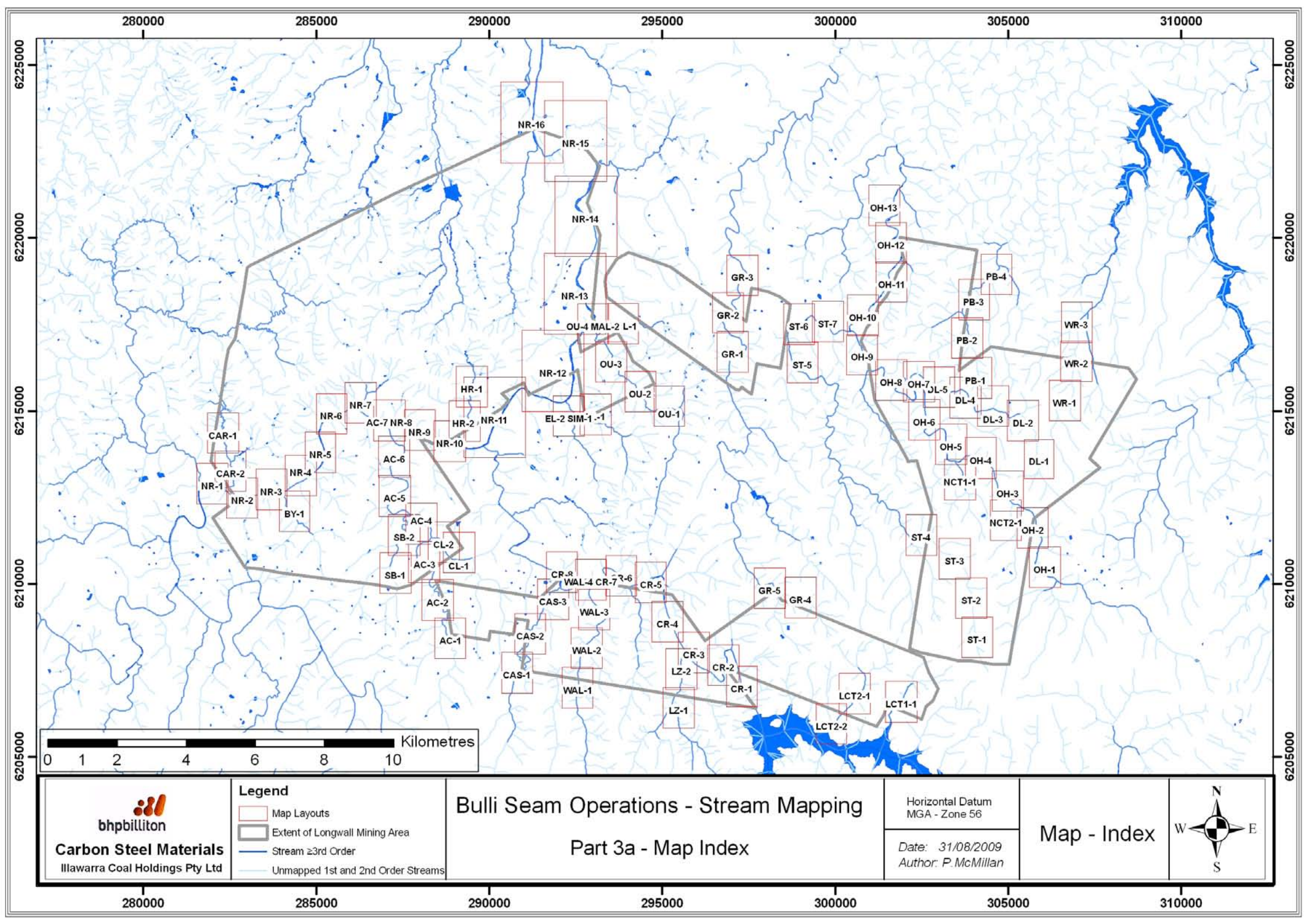
# ATTACHMENT PA

# STREAM MAPPING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Kilometres
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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Map Layouts
Extent of Longwall Mining Area
Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Bulli Seam Operations - Stream Mapping
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Date: 31/08/2009
Author: P.McMillan
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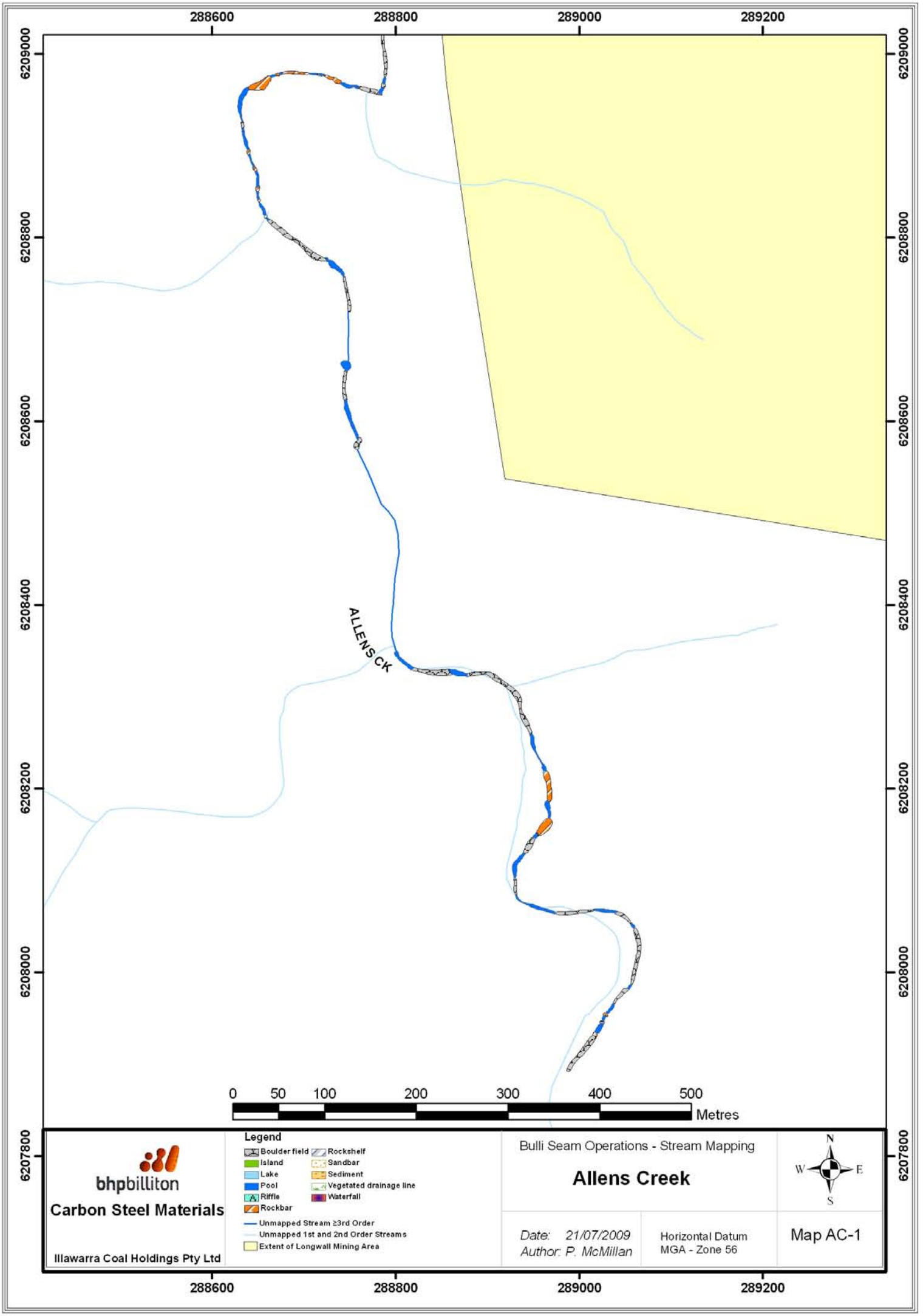
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Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
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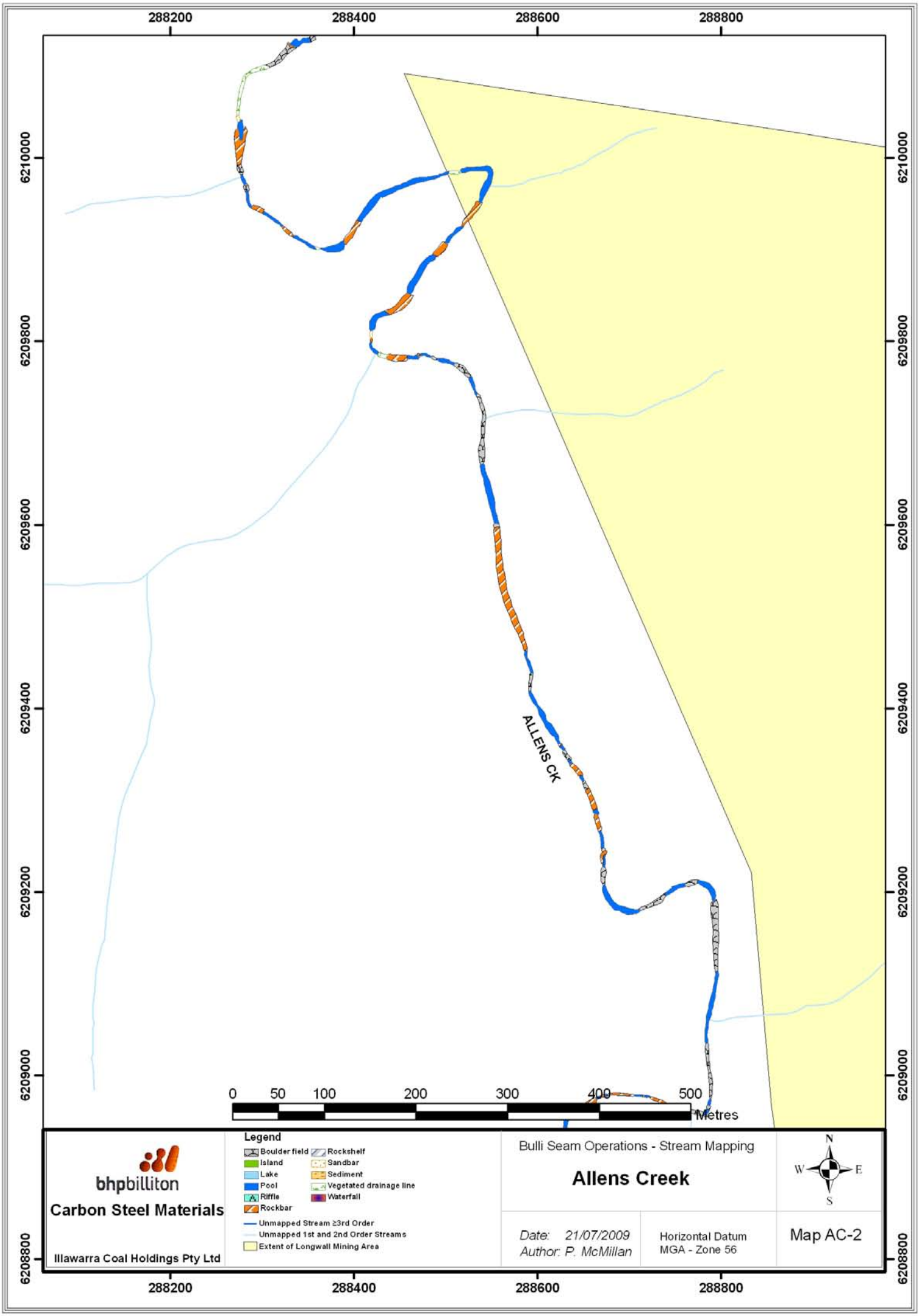
Date: 21/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map AC-1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Metres
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Bulli Seam Operations - Stream Mapping
Allens Creek
Date: 21/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
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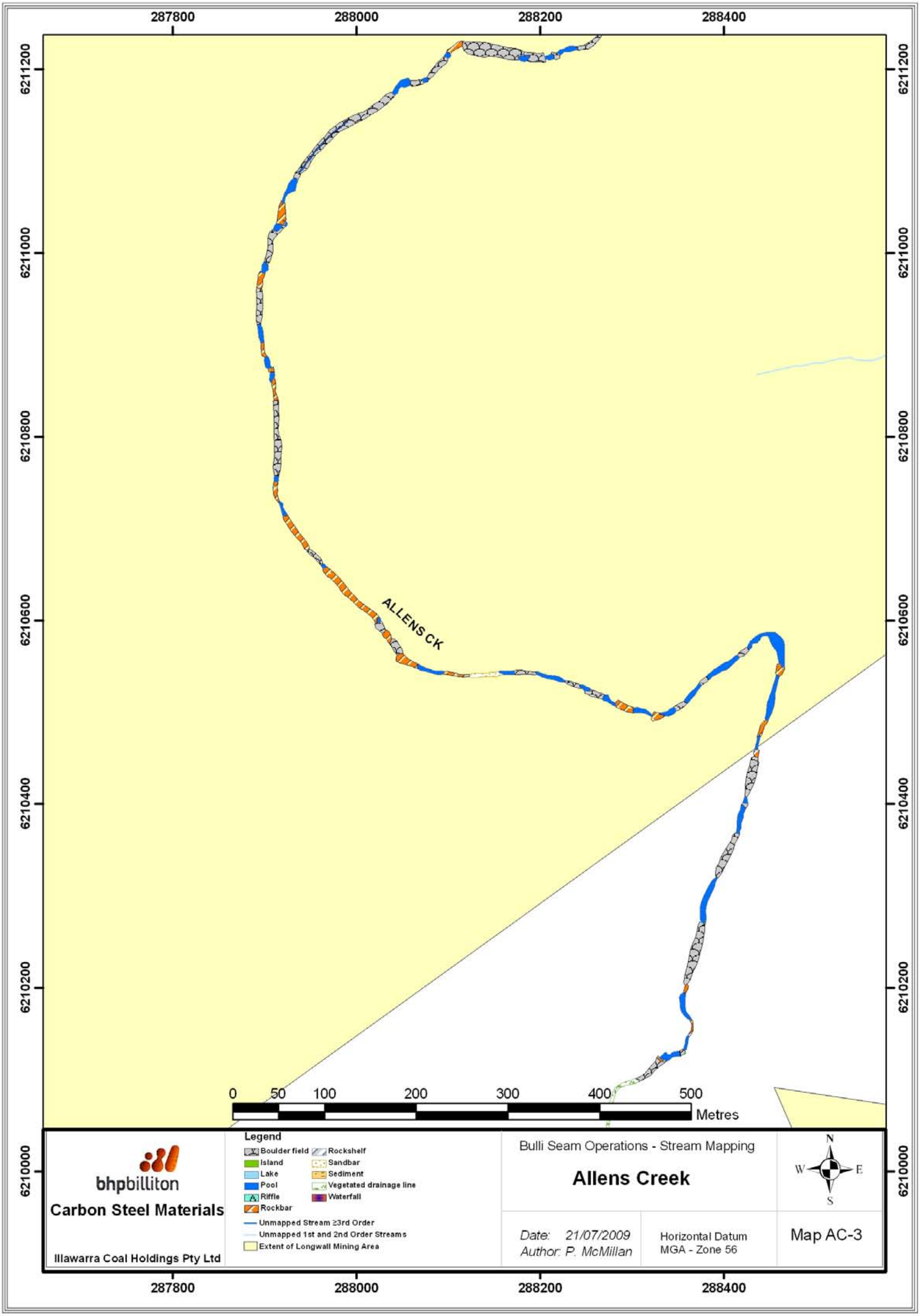
Map AC-2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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
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Rockshelf
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Lake
Sediment
Pool
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Waterfall
Rockbar
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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Allens Creek
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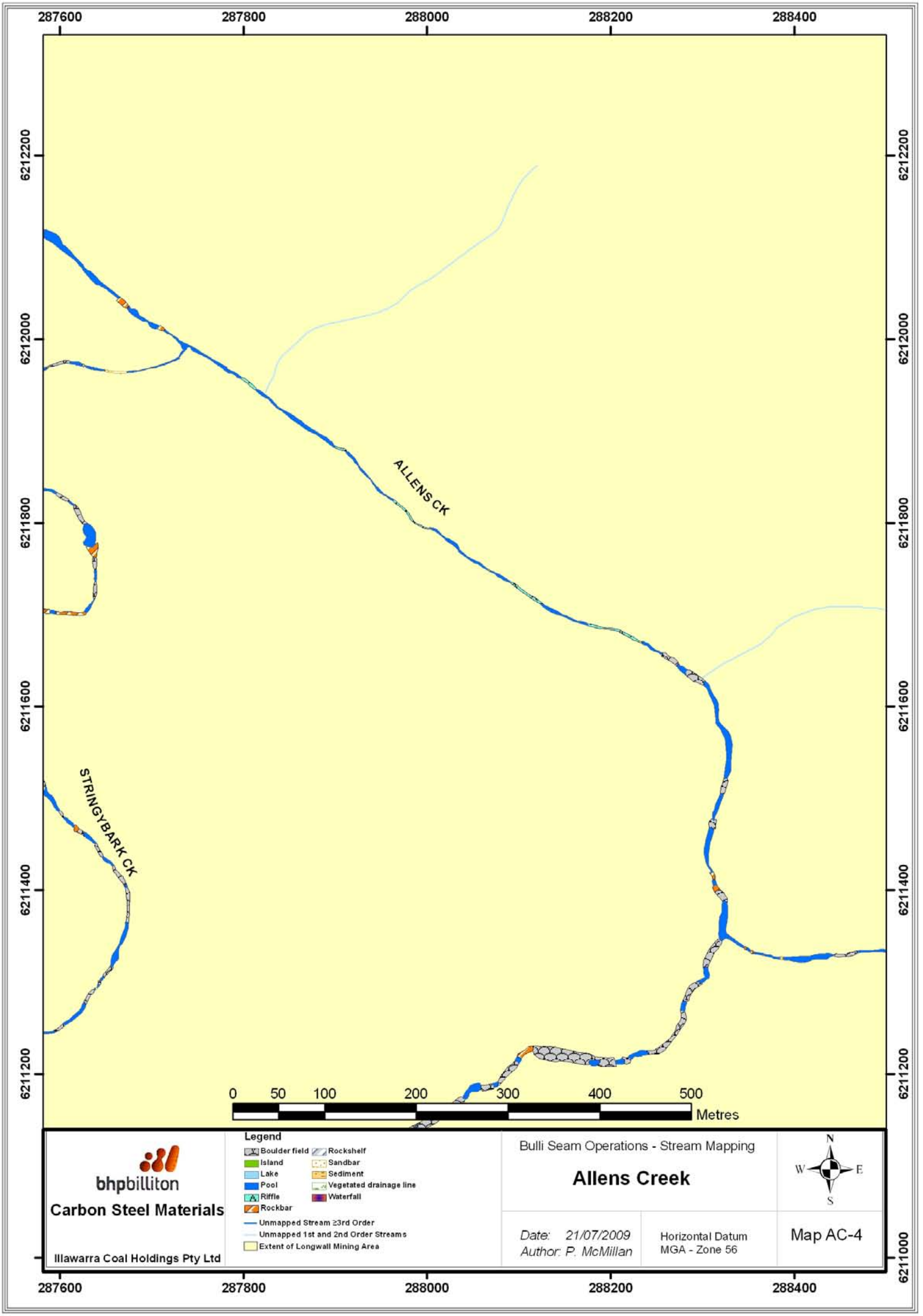
Date: 21/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map AC-3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Metres
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Illawarra Coal Holdings Pty Ltd
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Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Allens Creek
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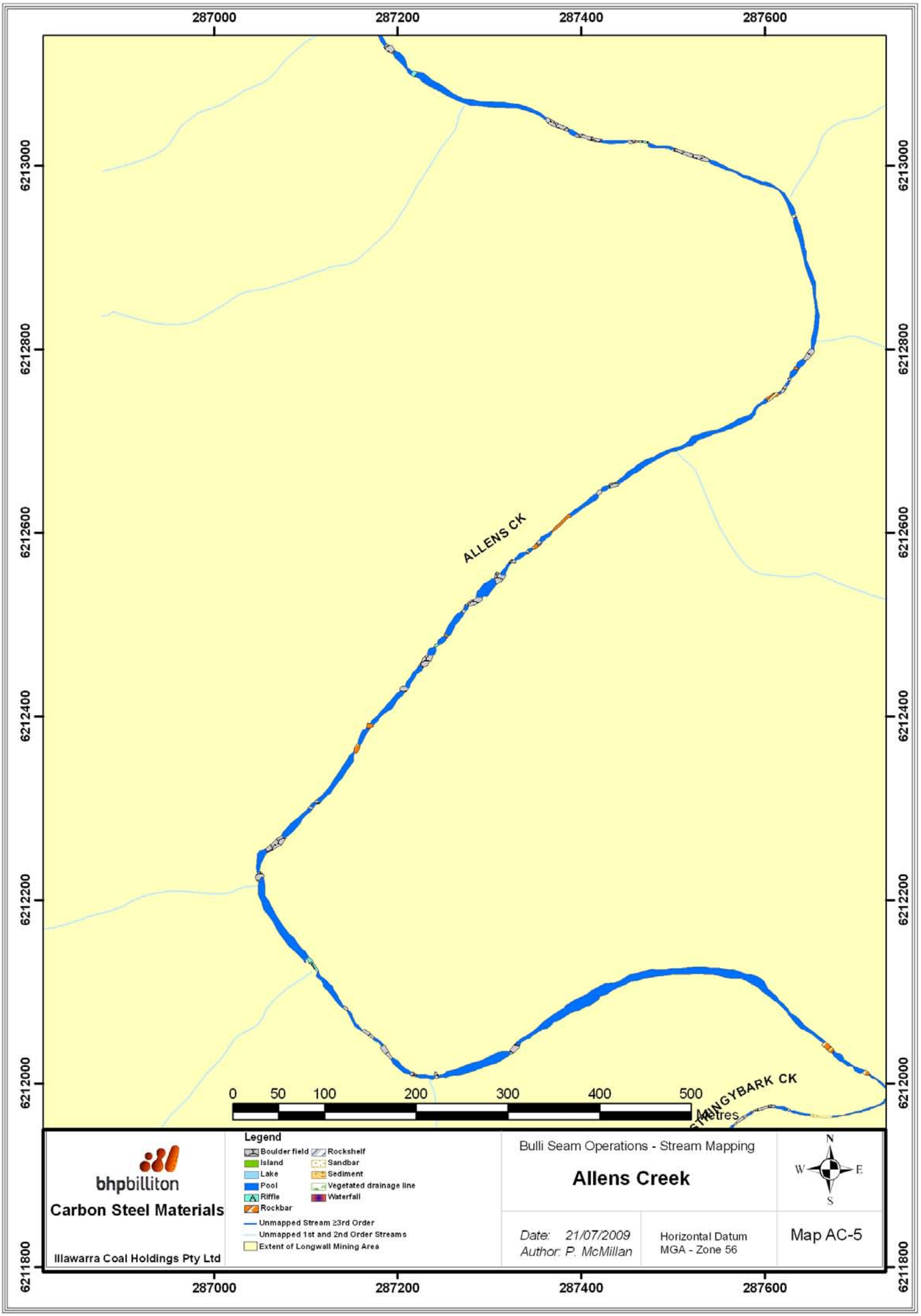
Date: 21/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map AC-4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Metres
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Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
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Date: 21/07/2009
Author: P. McMillan
Horizontal Datum
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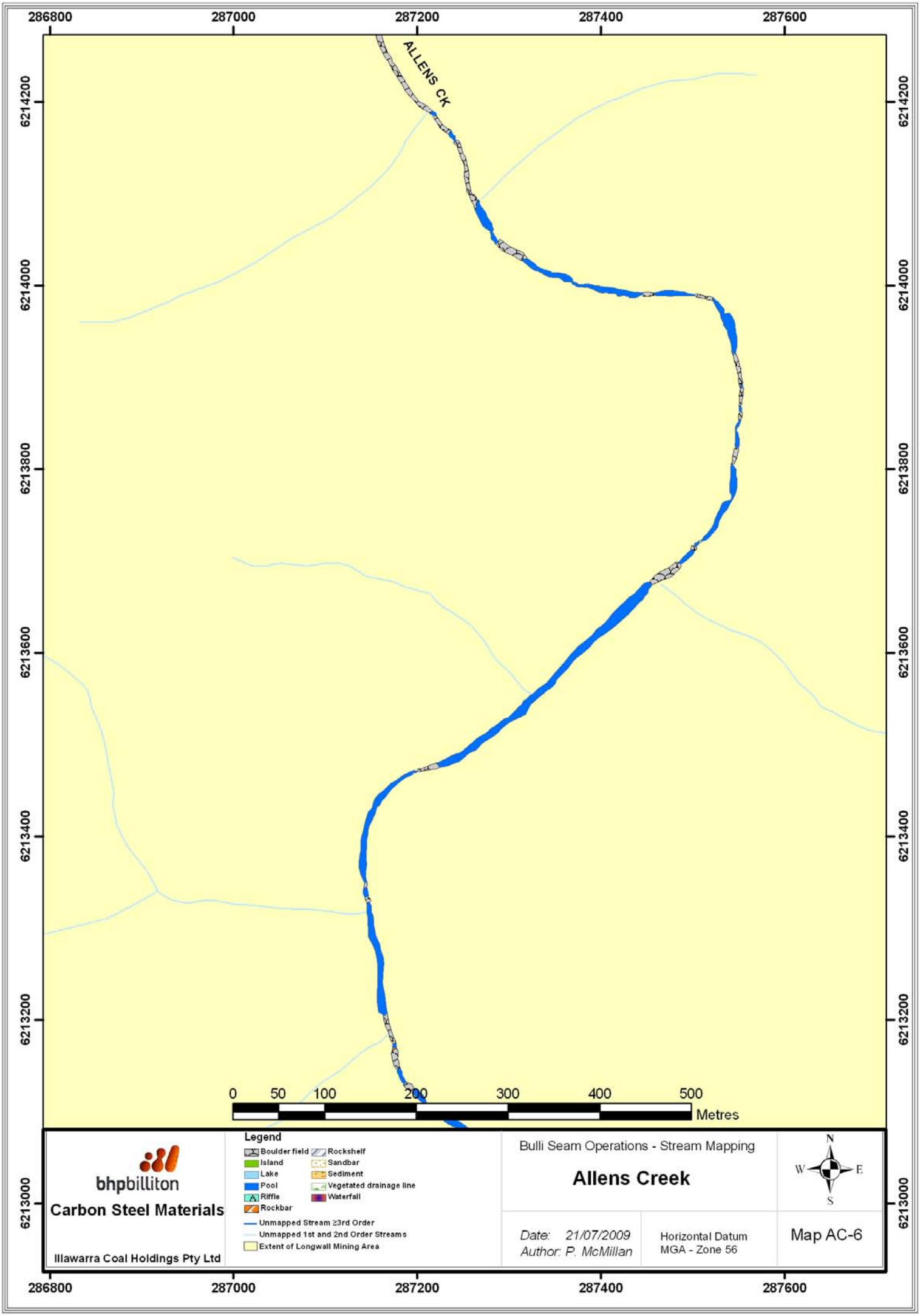
Map AC-5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Metres
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Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
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Date: 21/07/2009
Author: P. McMillan
Horizontal Datum
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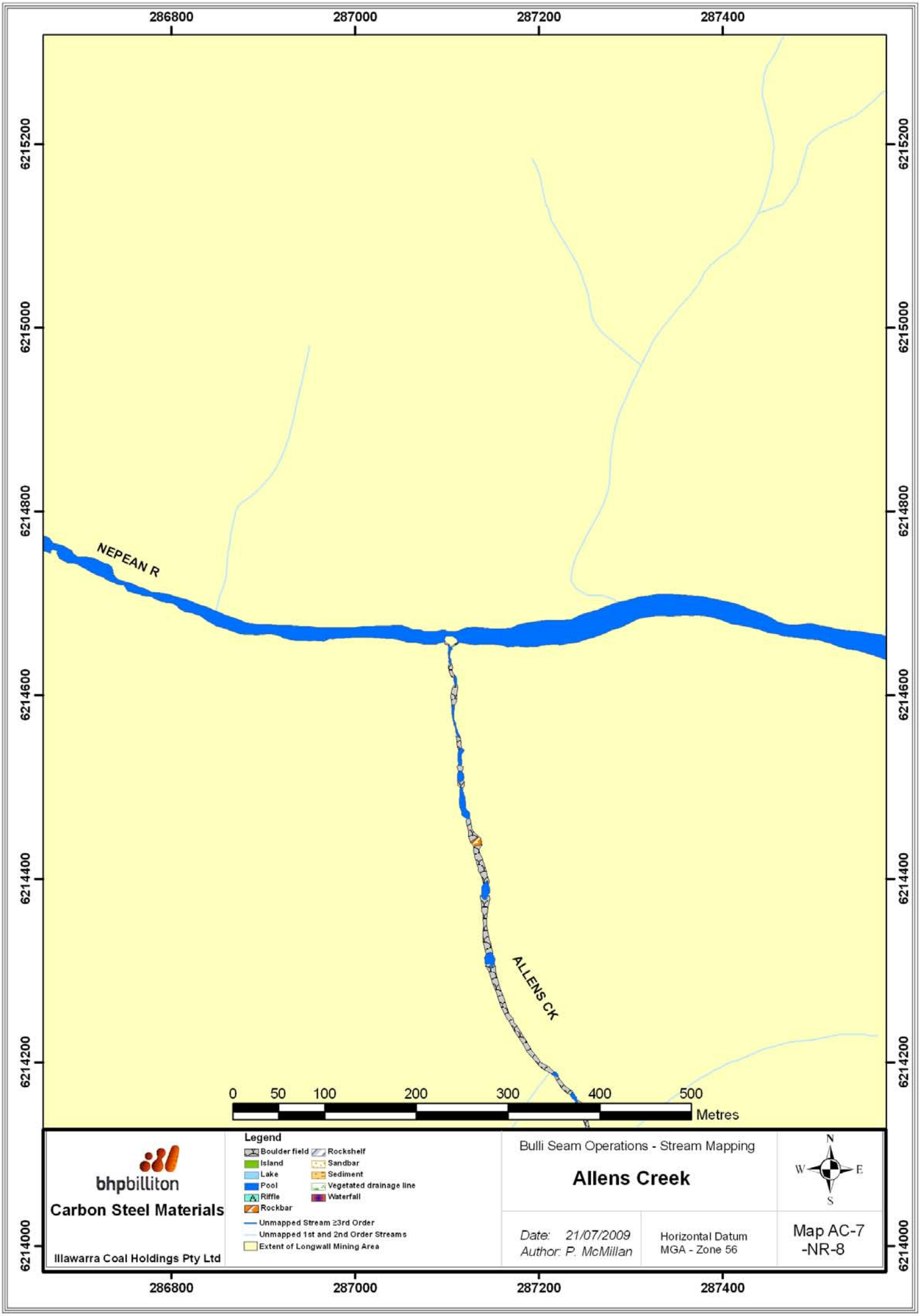
Map AC-6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Metres
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Carbon Steel Materials
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Legend
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Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Allens Creek
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Date: 21/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map AC-7
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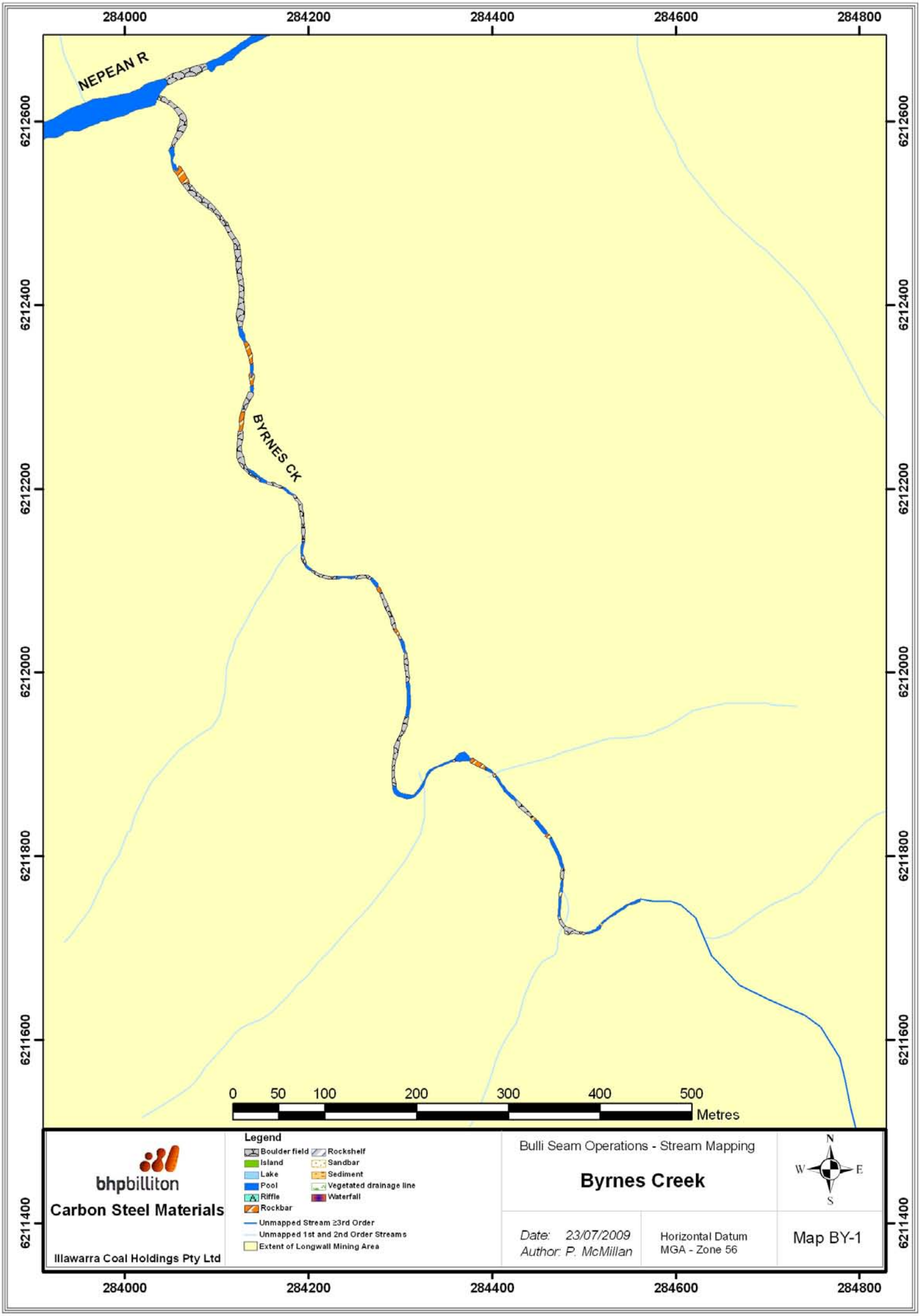
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Carbon Steel Materials
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Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
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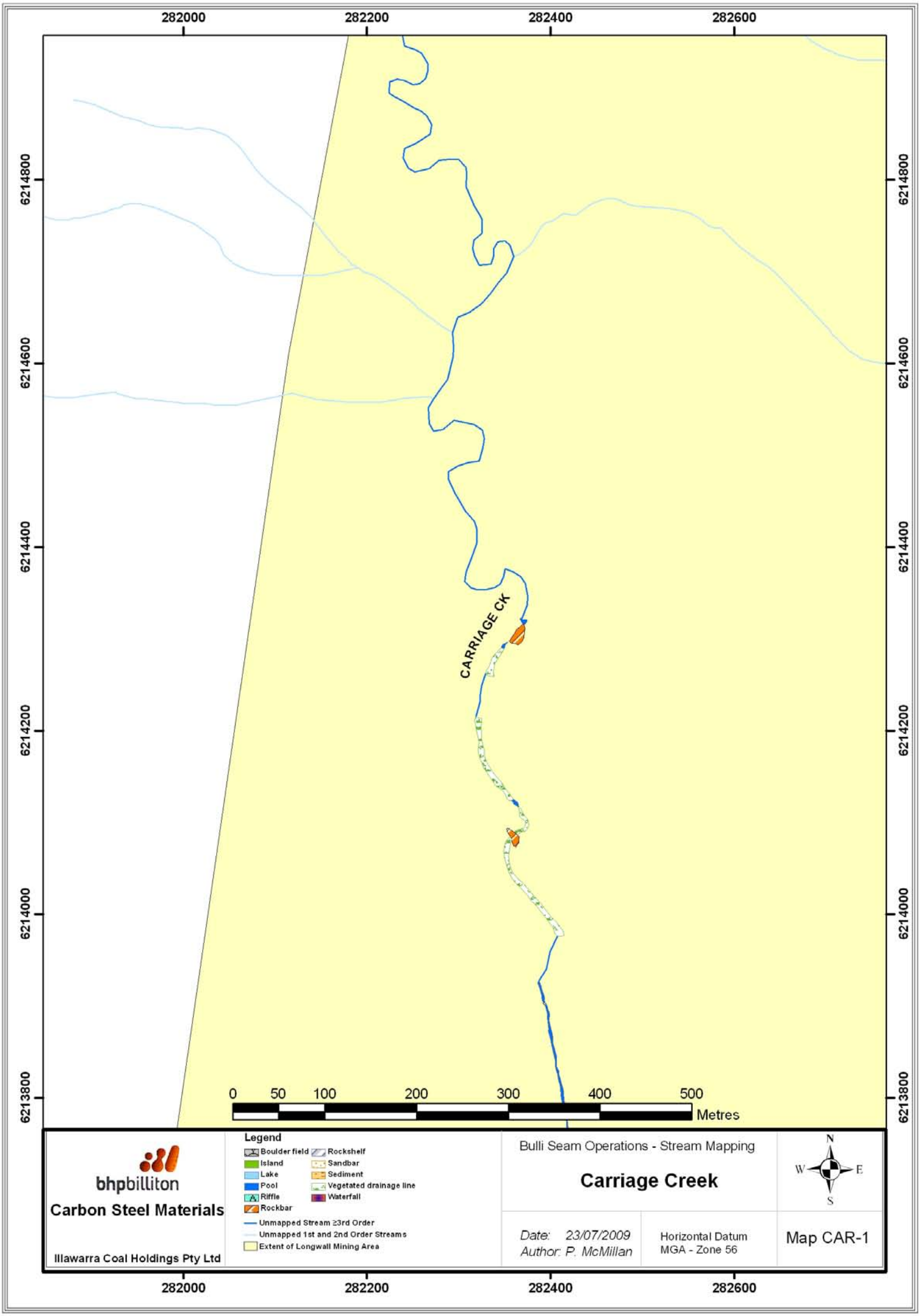
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map BY-1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Lake
Sediment
Pool
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Waterfall
Rockbar
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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
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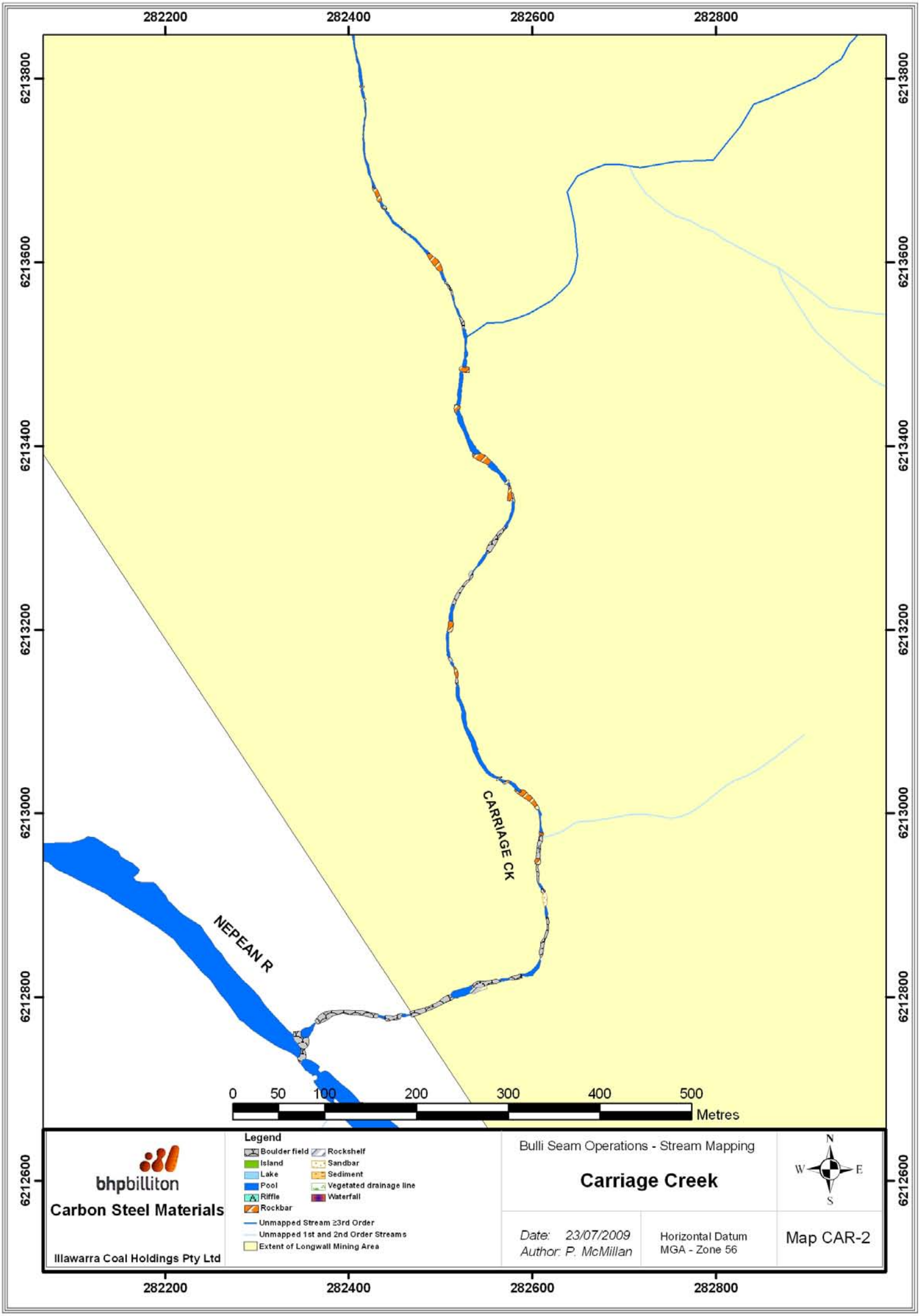
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map CAR-1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Metres
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Rockshelf
Island
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Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
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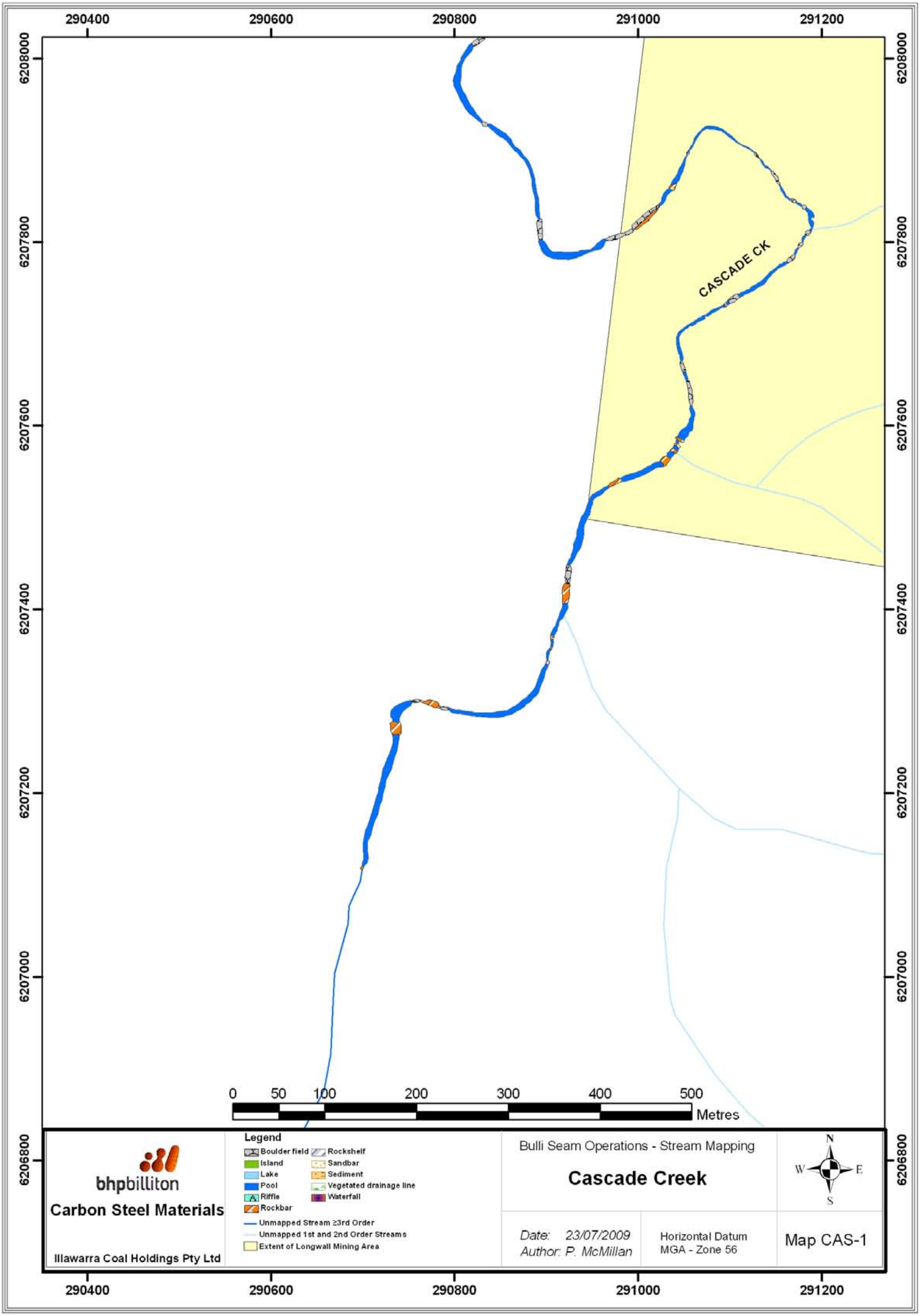
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map CAR-2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Carbon Steel Materials
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Legend
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Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
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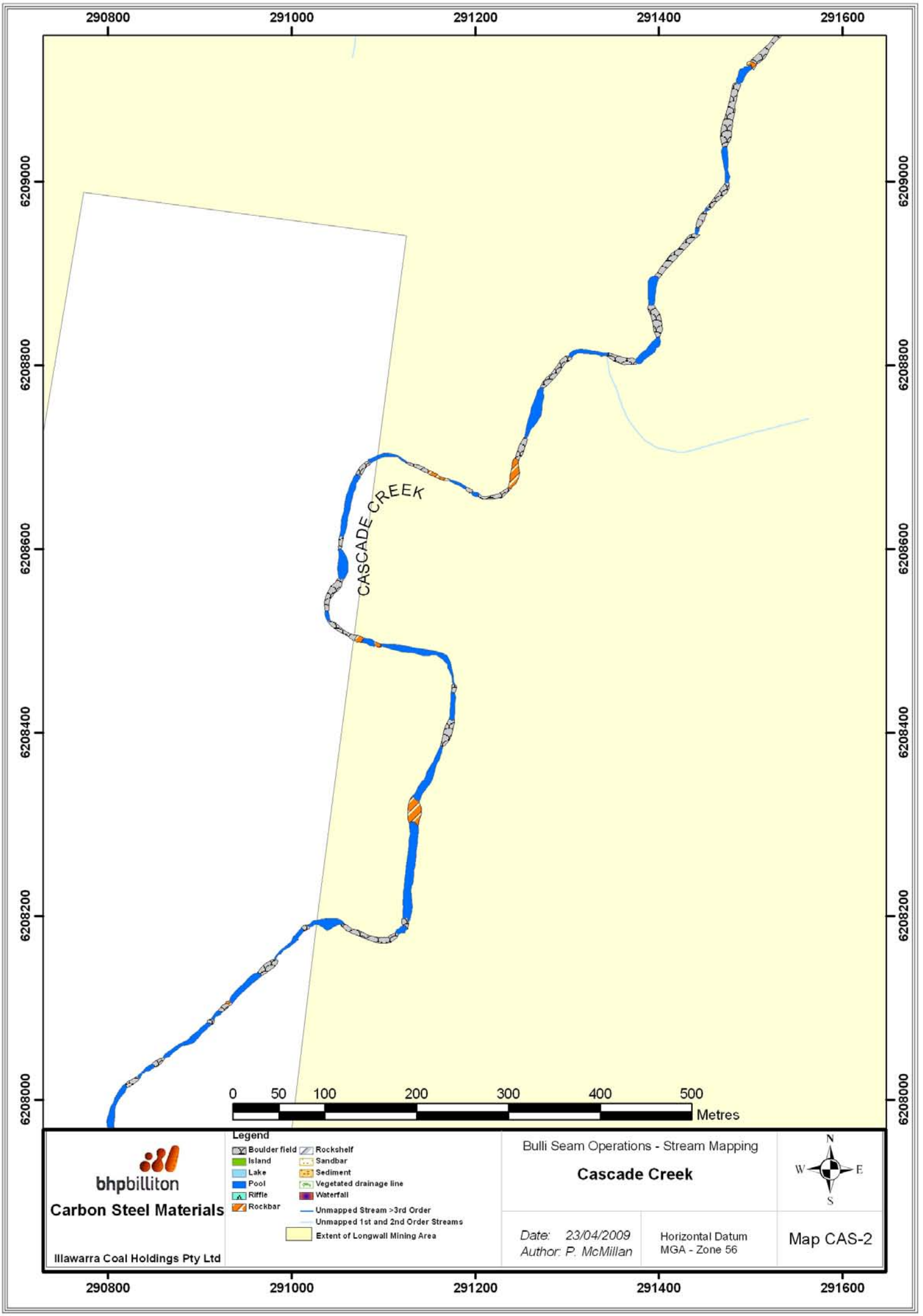
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map CAS-1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Metres
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Island
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Pool
Riffle
Rockbar
Rockshelf
Sandbar
Sediment
Vegetated drainage line
Waterfall
Unmapped Stream >3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Bulli Seam Operations - Stream Mapping
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Date: 23/04/2009
Author: P. McMillan
Horizontal Datum
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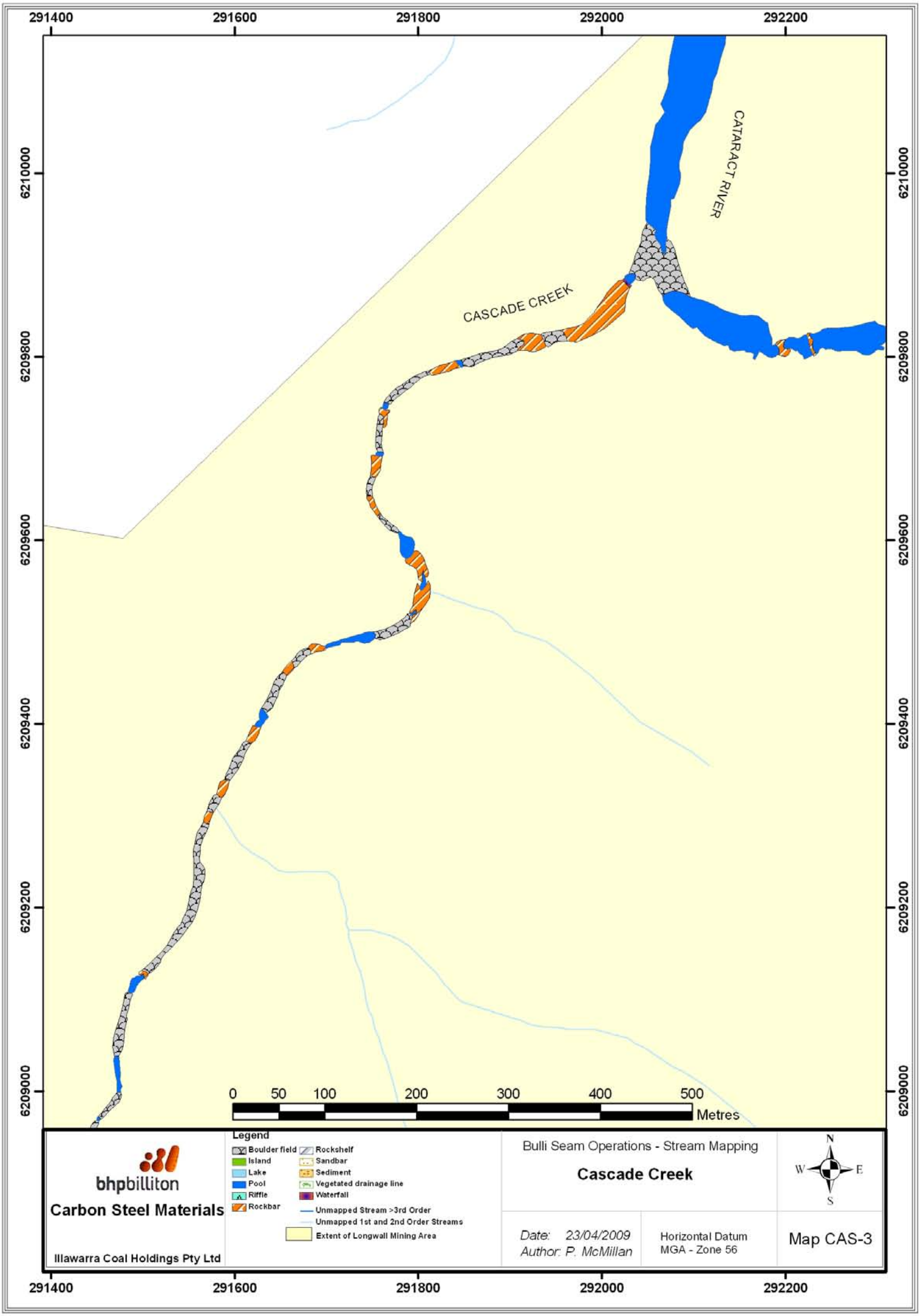
Map CAS-2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Island
Lake
Pool
Riffle
Rockbar
Rockshelf
Sandbar
Sediment
Vegetated drainage line
Waterfall
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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Bulli Seam Operations - Stream Mapping
Cascade Creek
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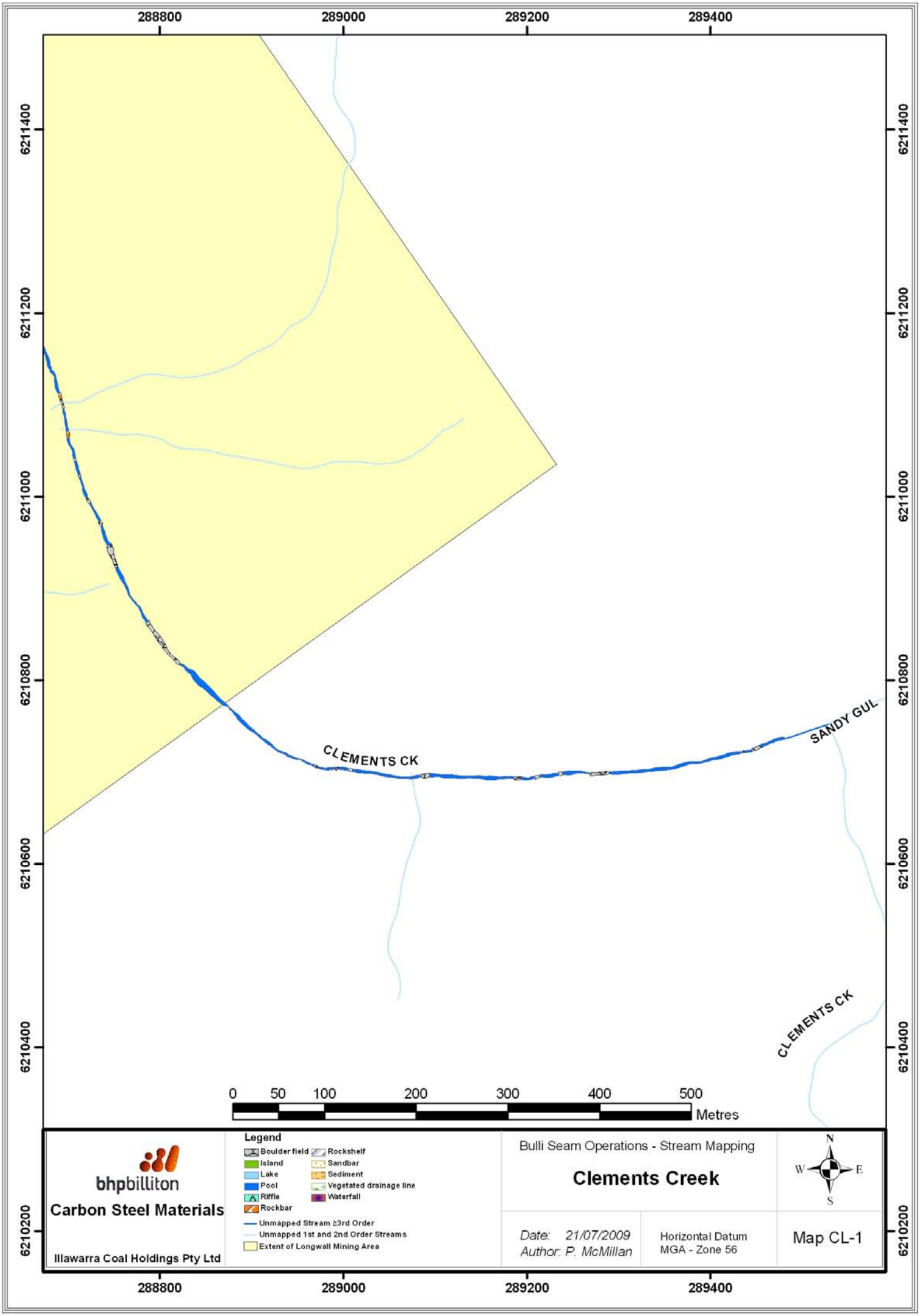
Date: 23/04/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map CAS-3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CLEMENTS CK
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Metres
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Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
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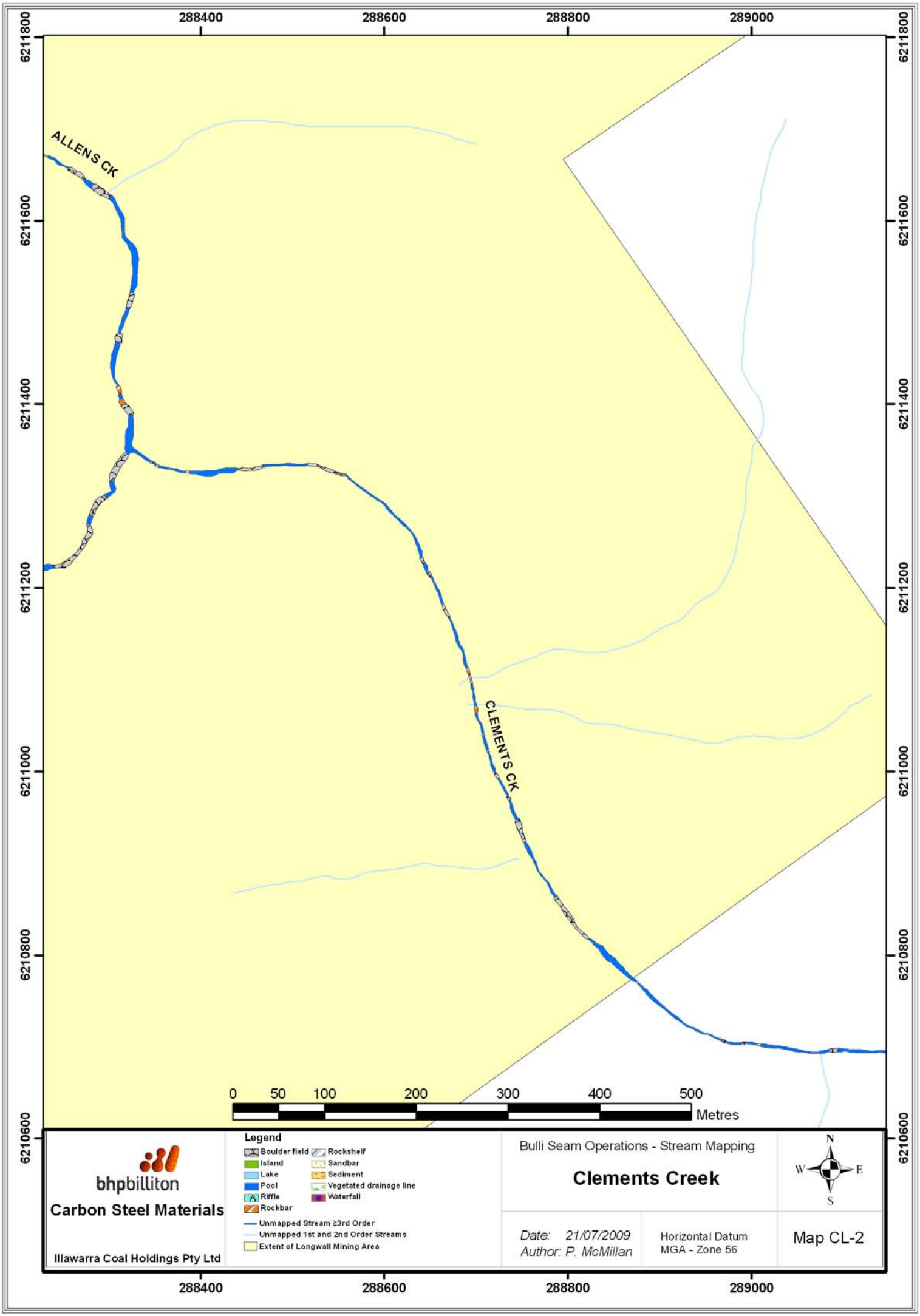
Date: 21/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map CL-1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Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
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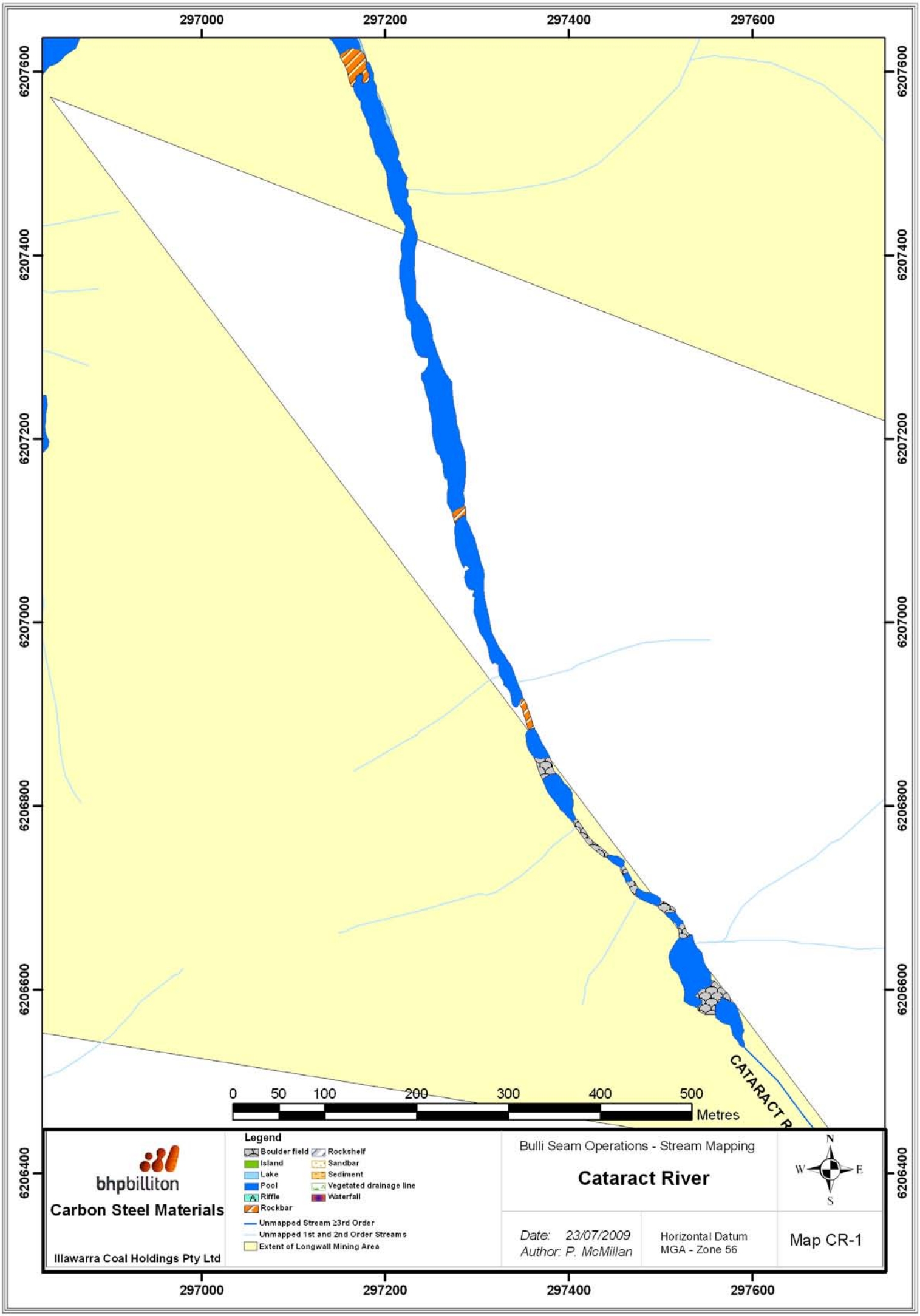
Date: 21/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map CL-2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Sediment
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Waterfall
Rockbar
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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
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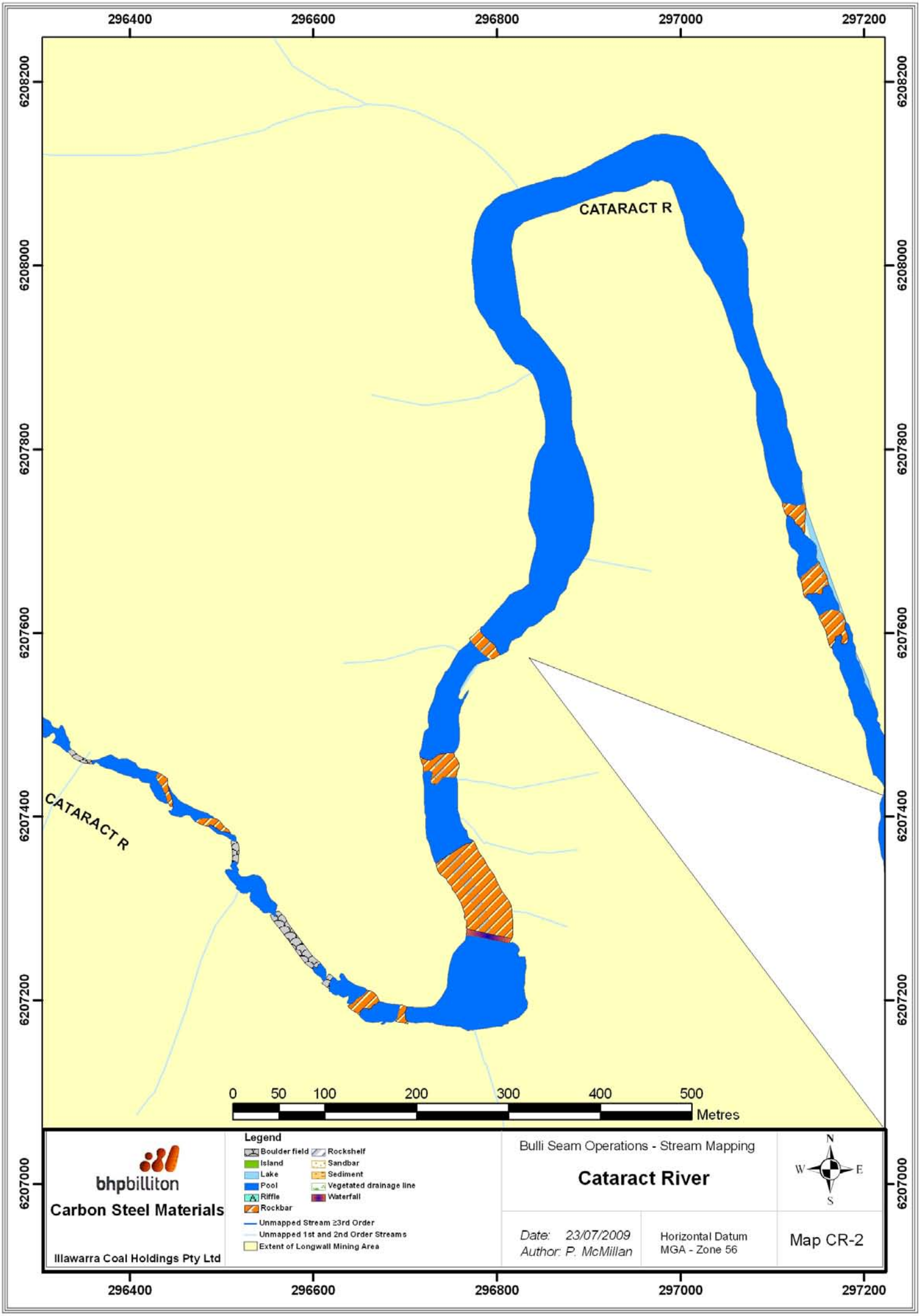
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map CR-1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Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Cataract River
N
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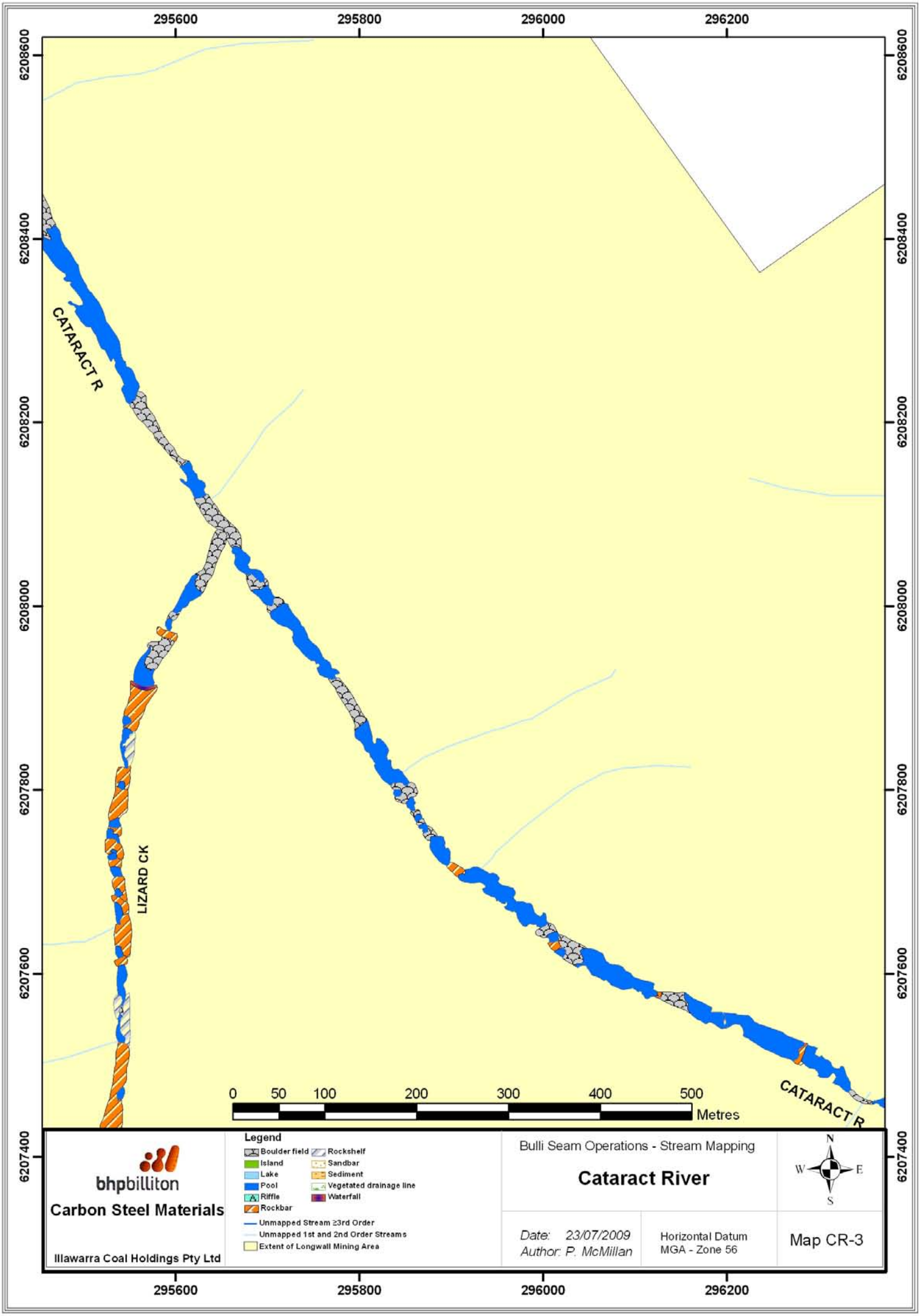
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map CR-2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Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Cataract River
N
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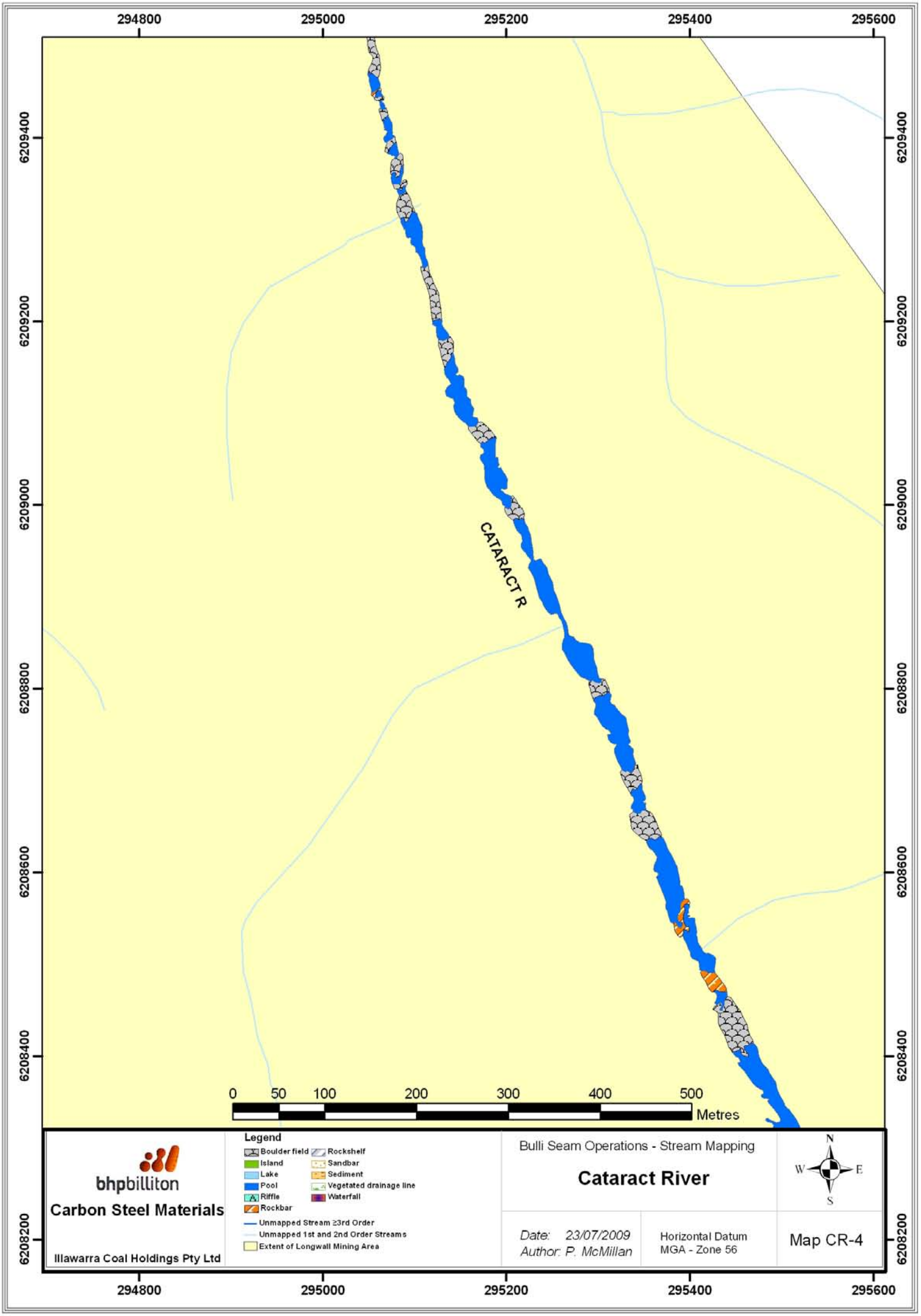
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map CR-3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bhpbilliton
Carbon Steel Materials
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Boulder field
Rockshelf
Island
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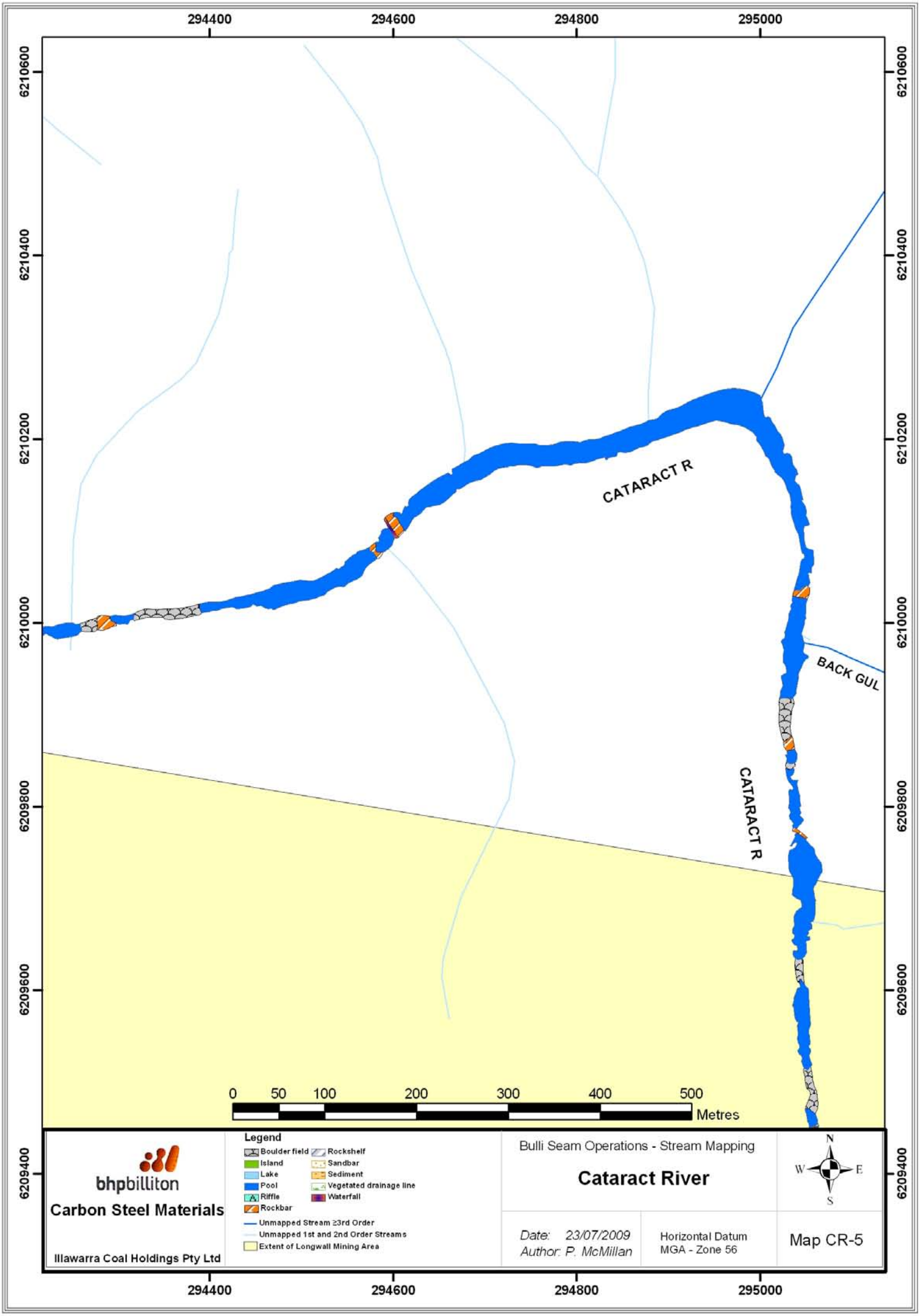
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Cataract River
N
W
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map CR-4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Carbon Steel Materials
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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Cataract River
N
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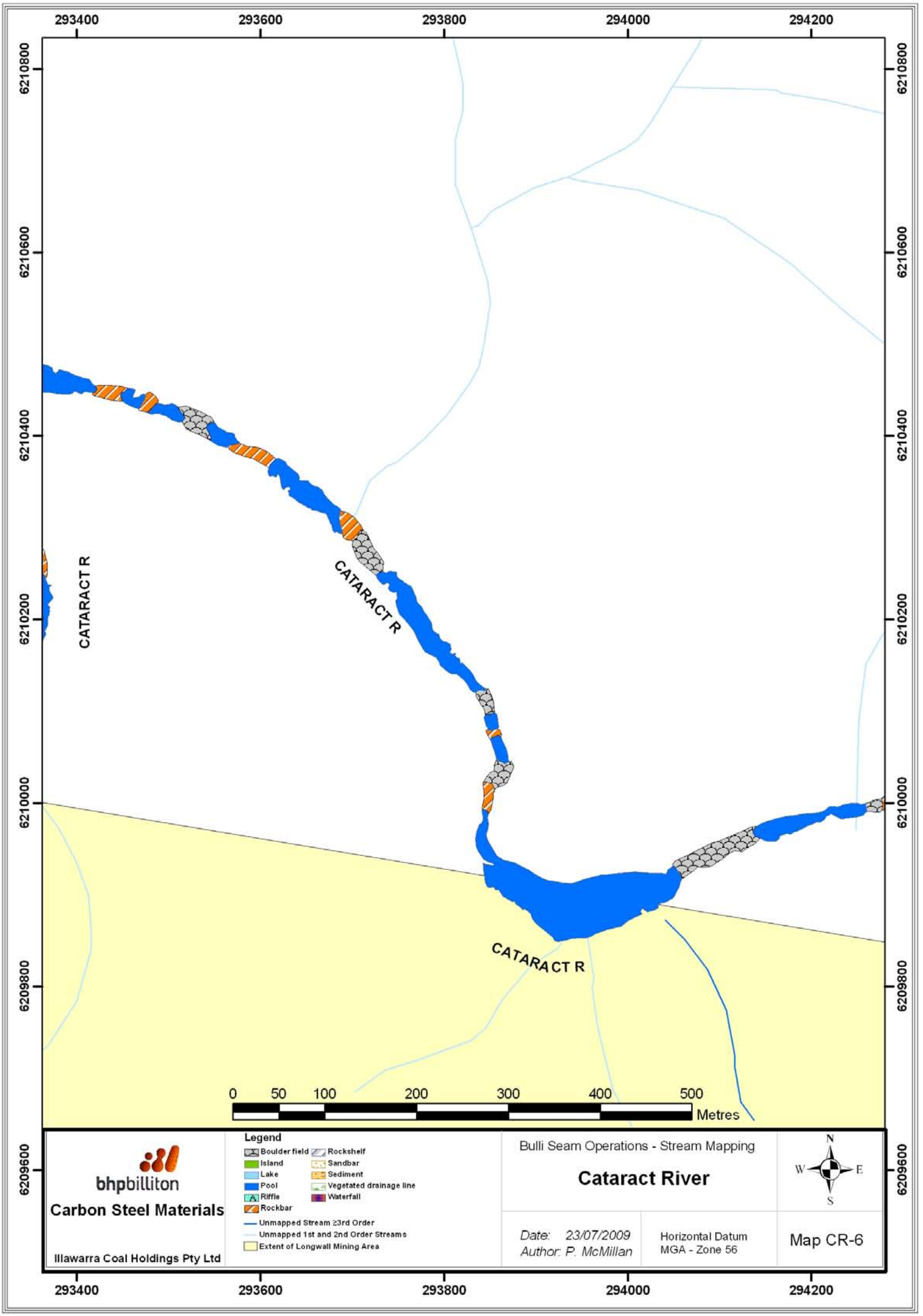
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map CR-5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Metres
bhpbilliton
Carbon Steel Materials
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Legend
Boulder field
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Sediment
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Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
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Cataract River
N
W
E
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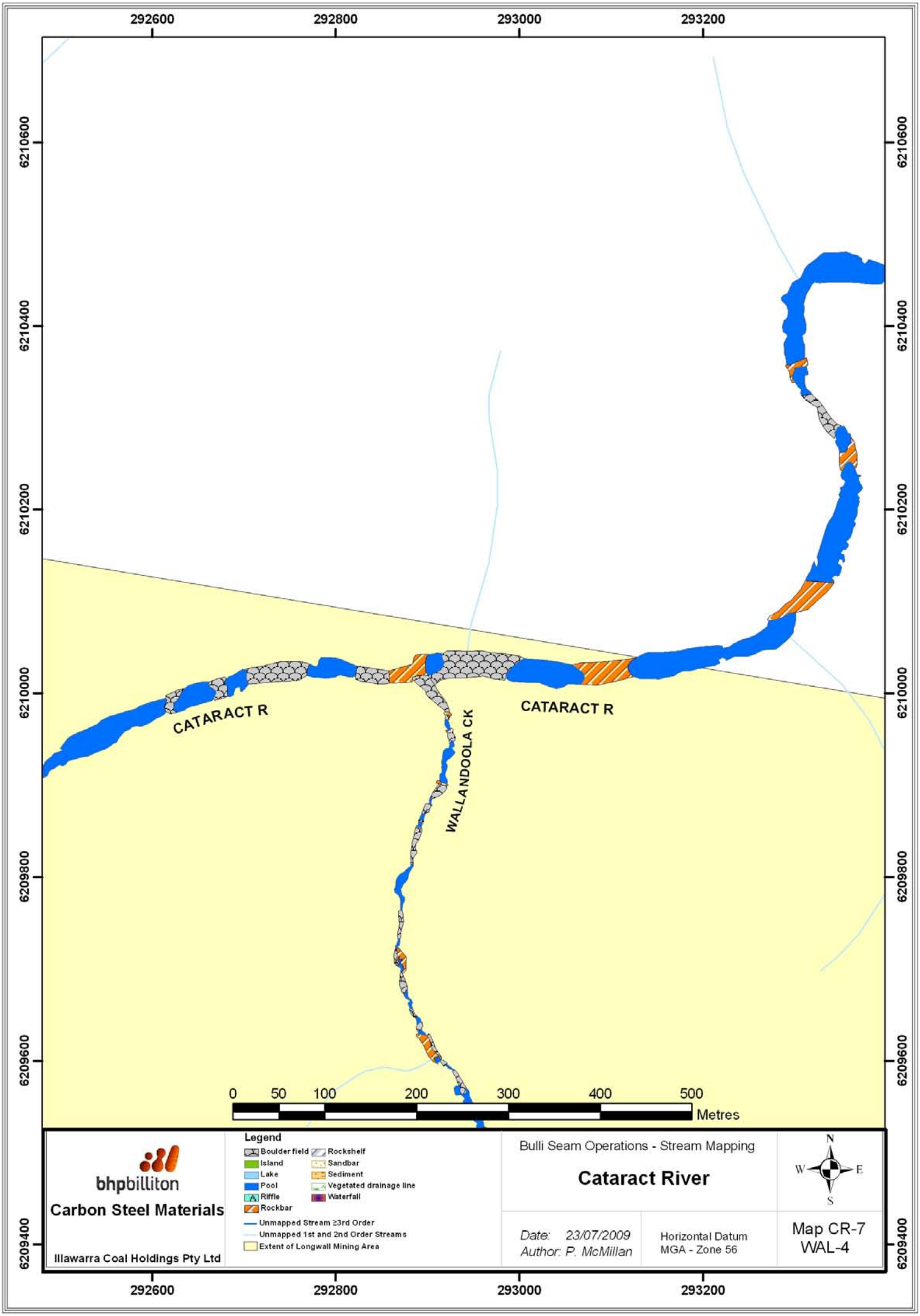
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map CR-6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Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
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Cataract River
N
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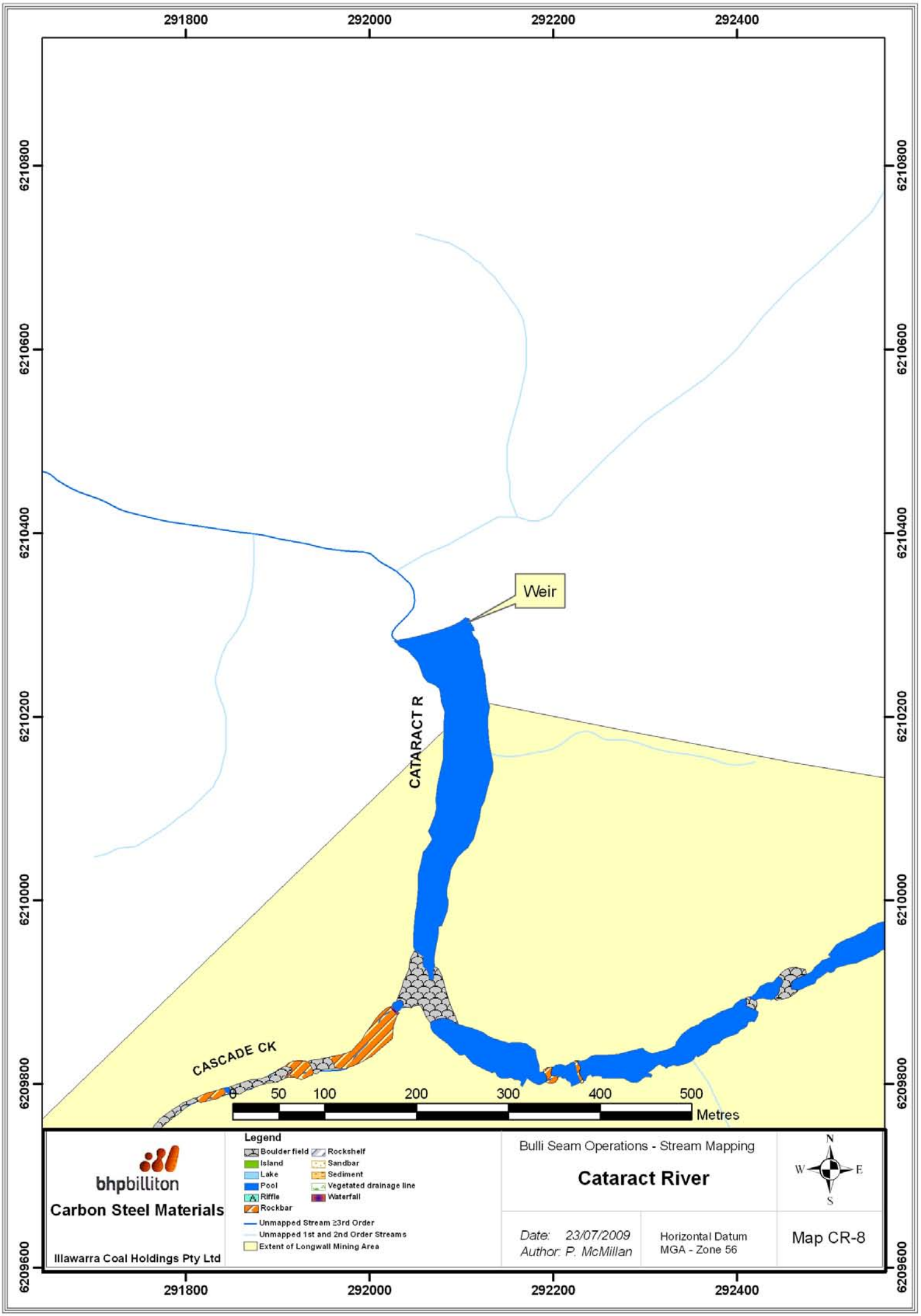
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map CR-7
WAL-4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Metres
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Bulli Seam Operations - Stream Mapping
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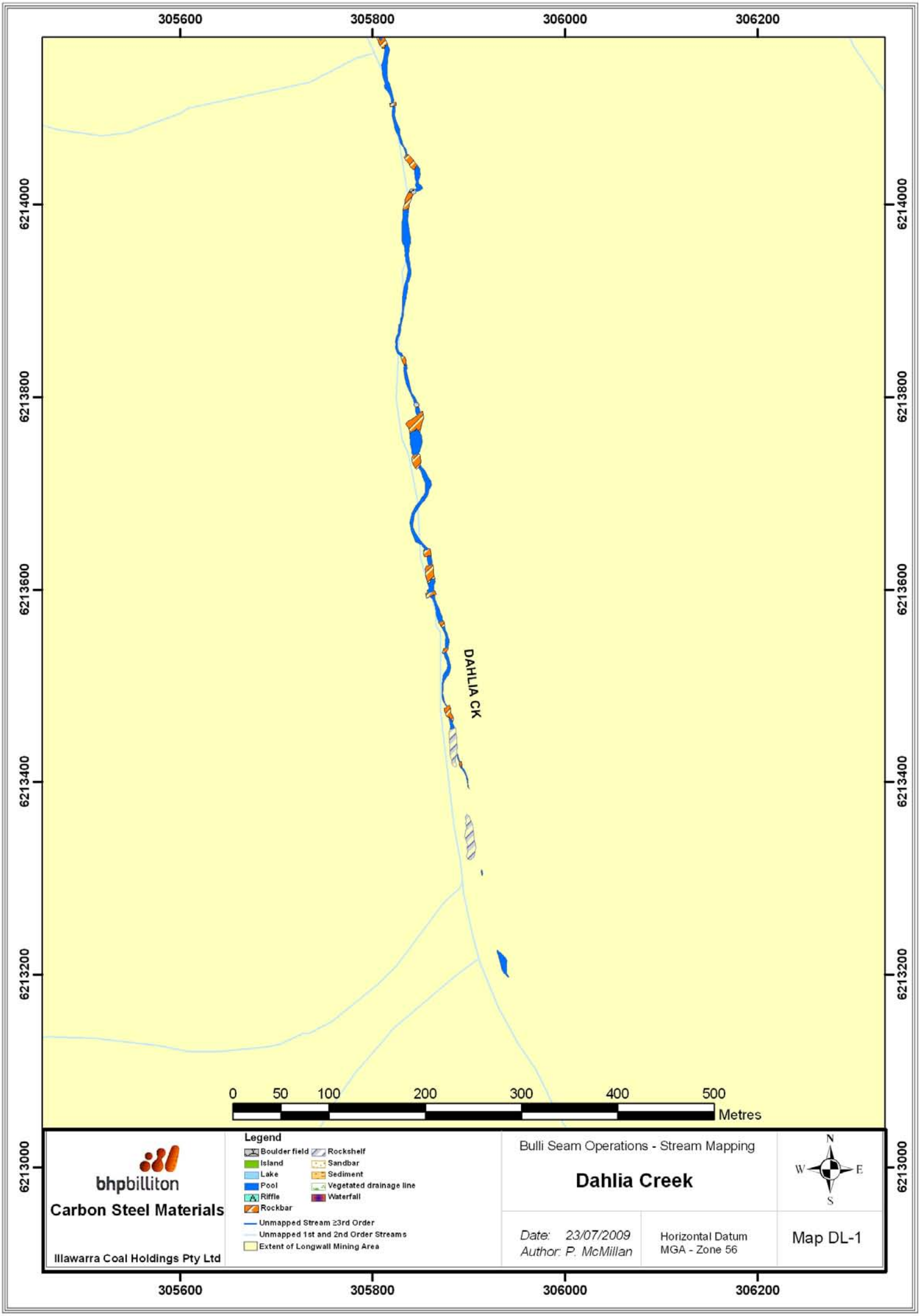
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map CR-8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Carbon Steel Materials
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Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Dahlia Creek
N
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E
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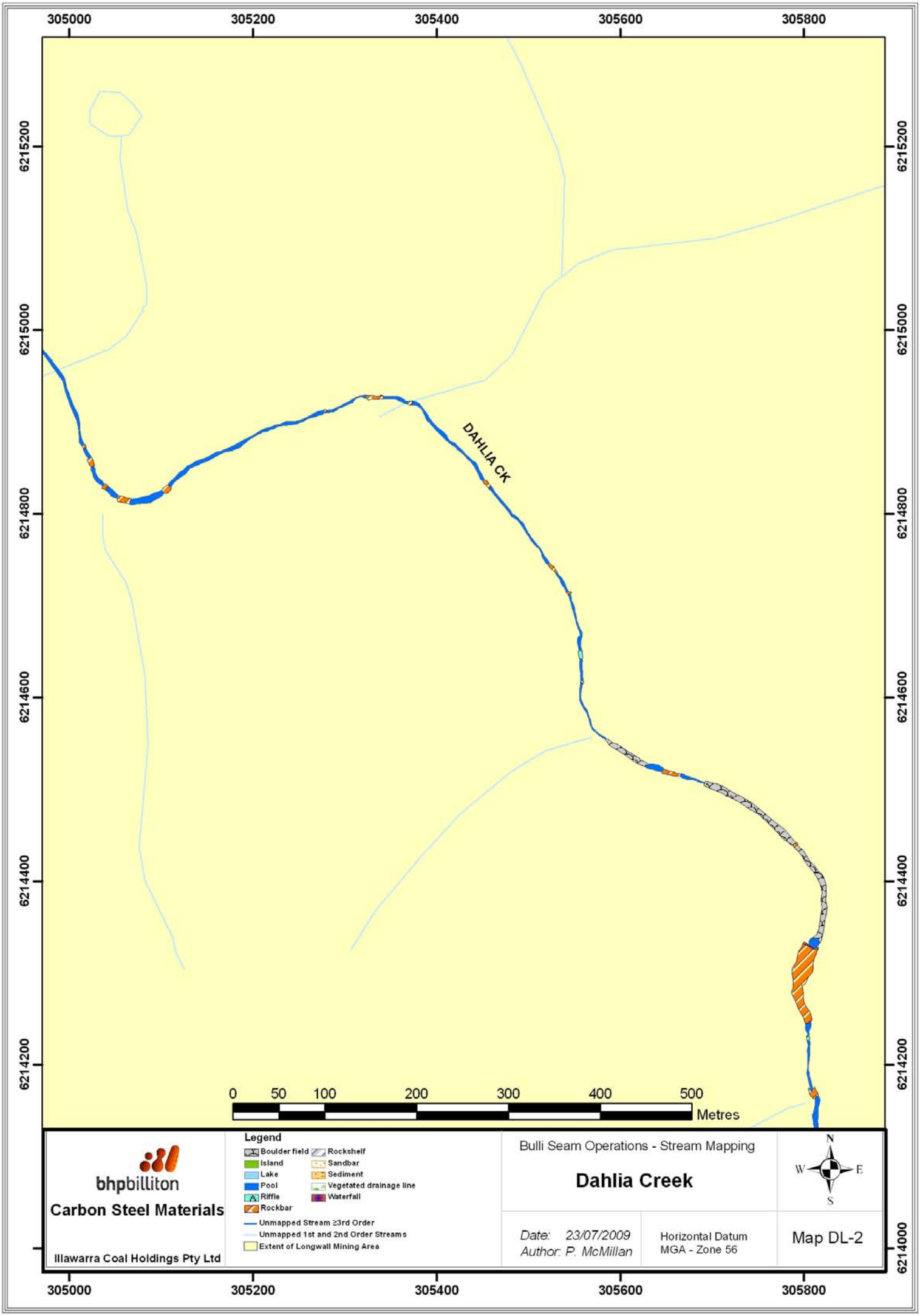
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map DL-1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Rockshelf
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Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Dahlia Creek
N
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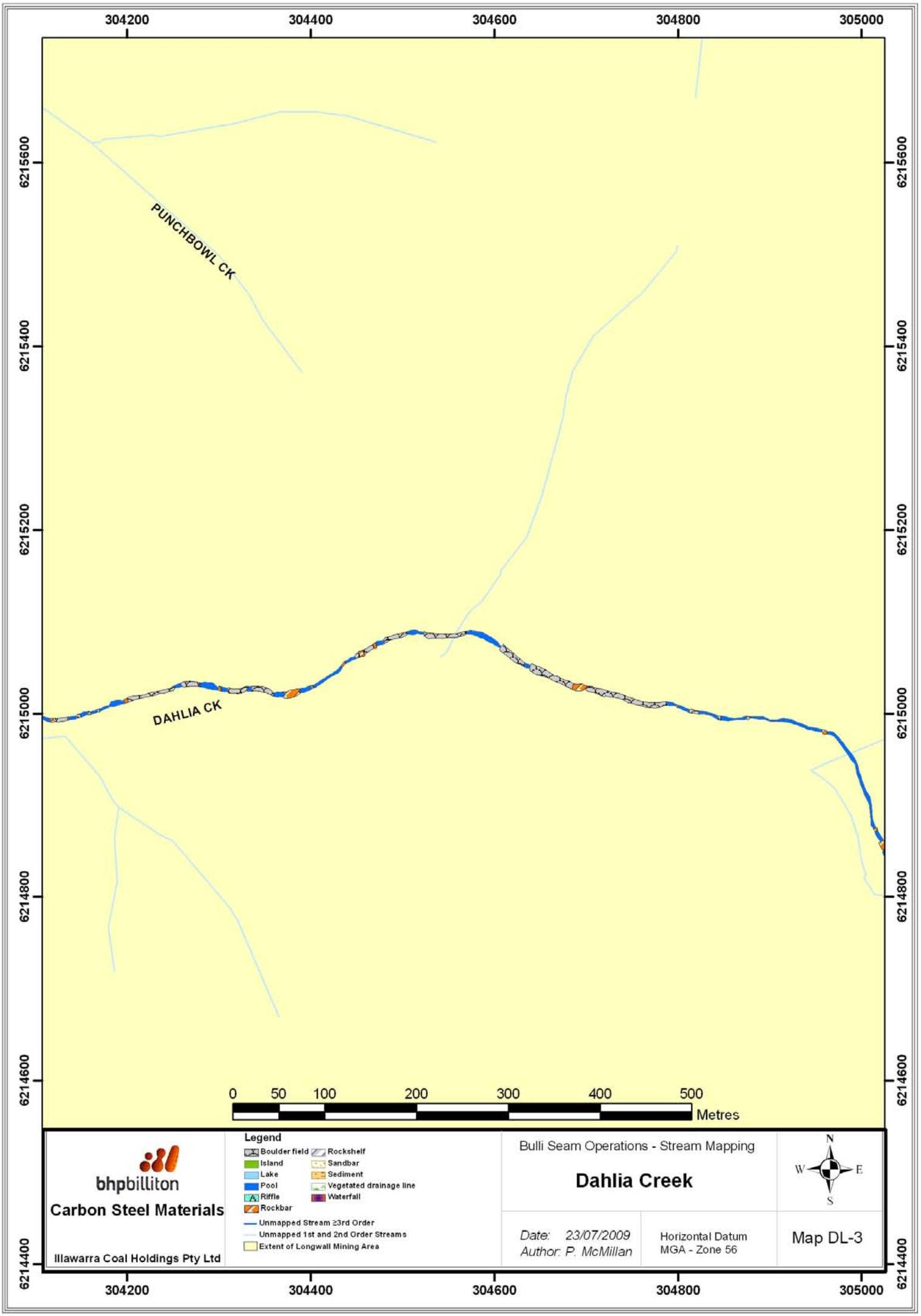
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map DL-2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Metres
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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Dahlia Creek
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E
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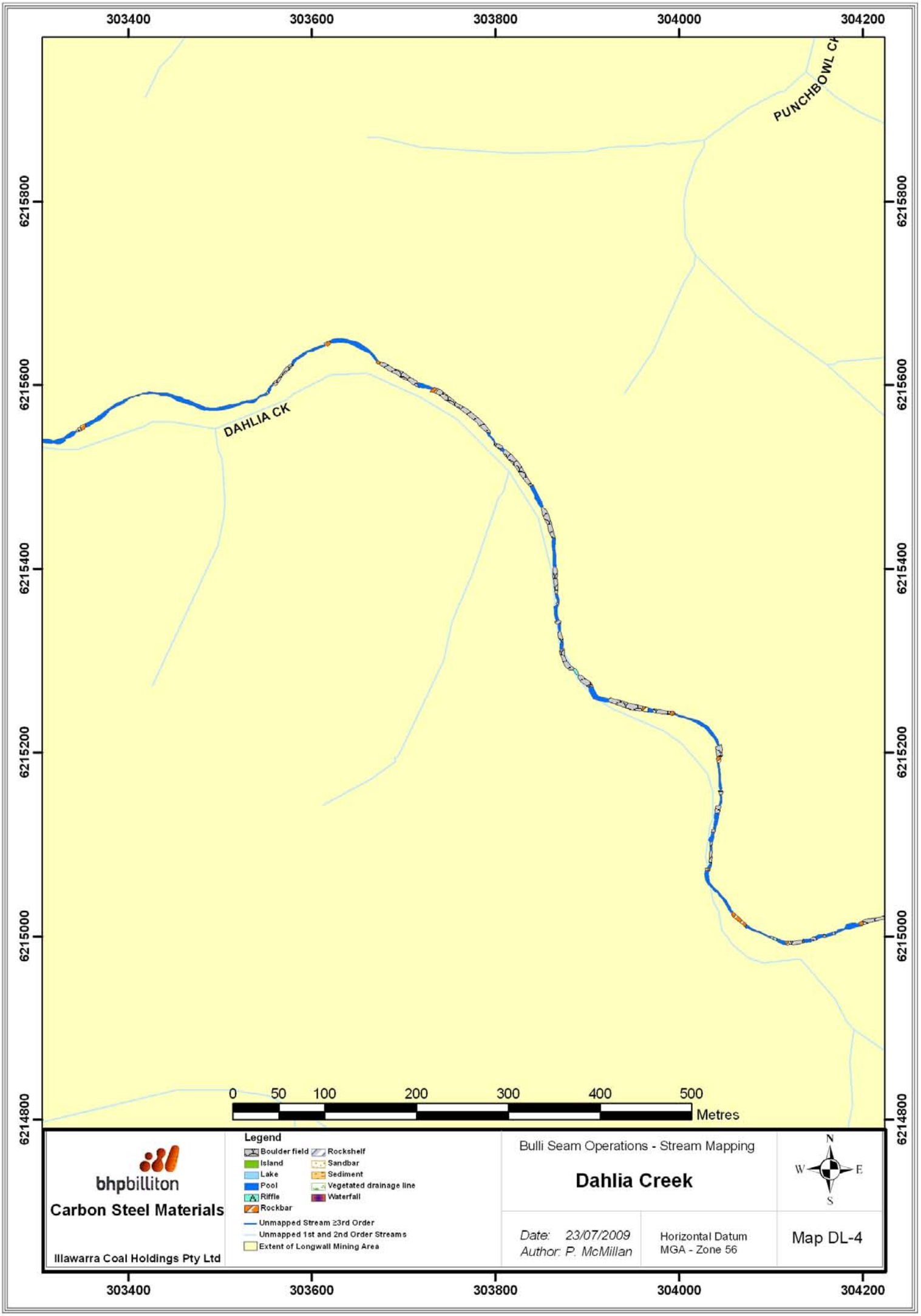
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map DL-3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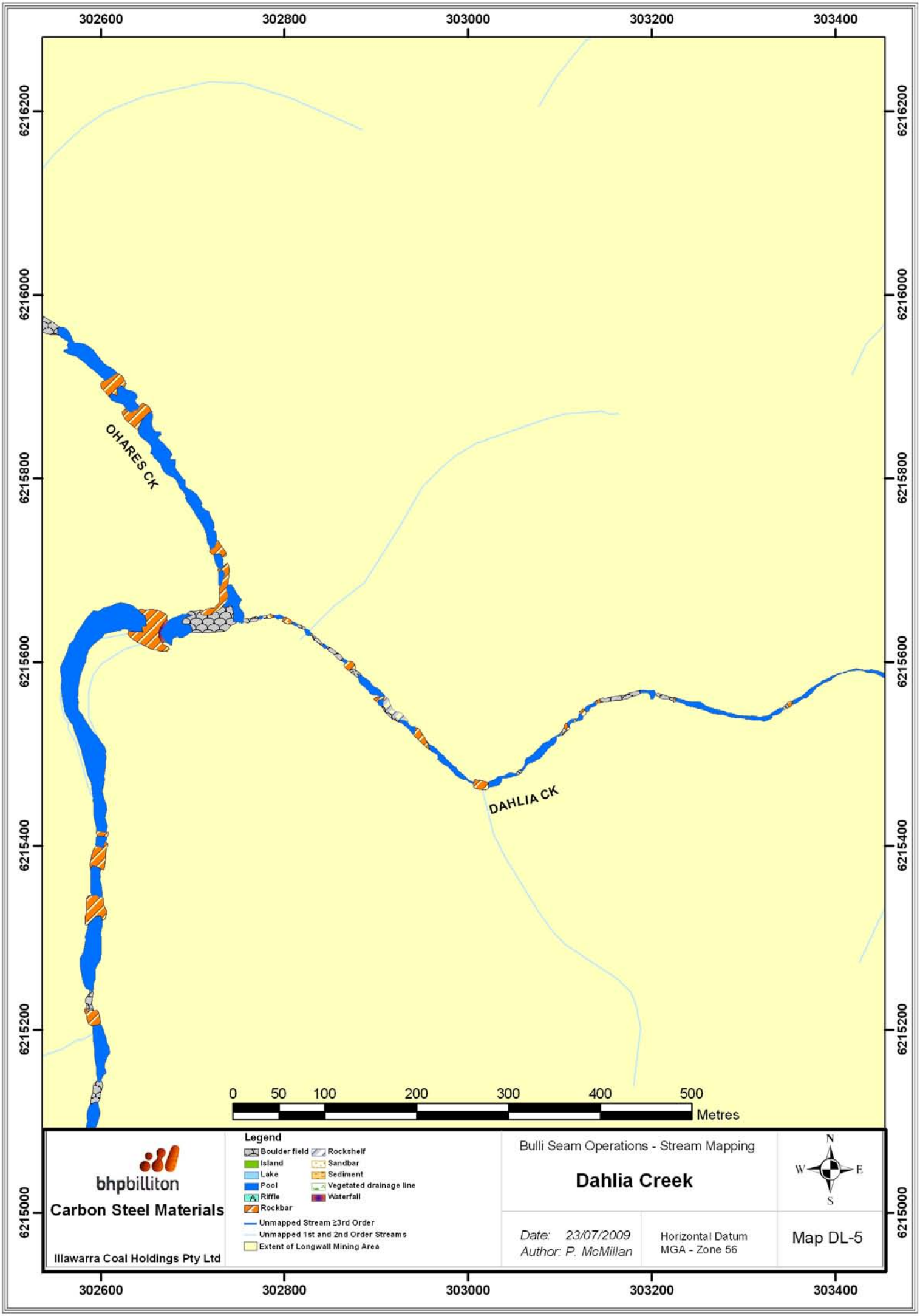
Metres
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Dahlia Creek
N
W
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map DL-4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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Dahlia Creek
N
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E
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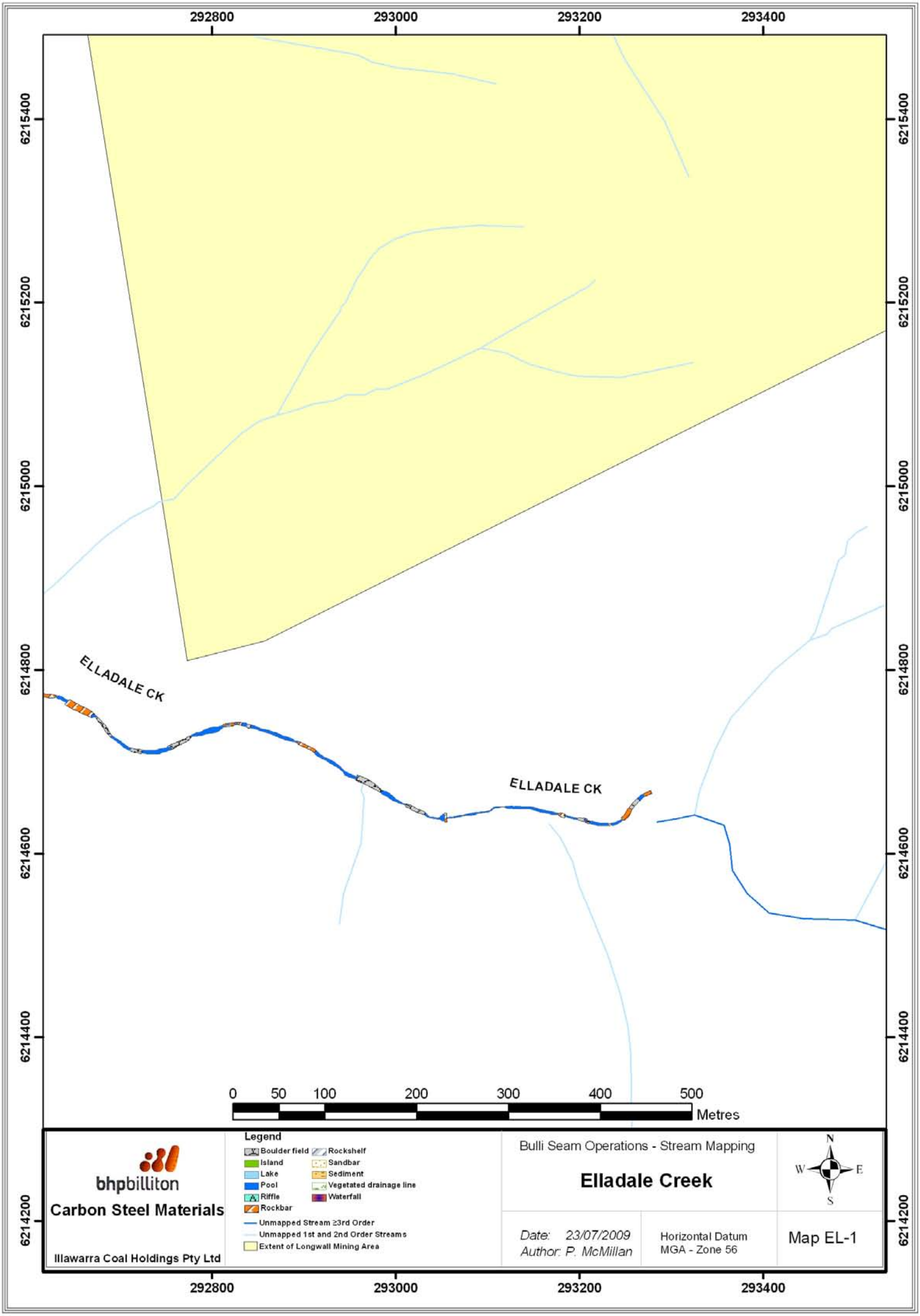
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map DL-5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Carbon Steel Materials
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Legend
Boulder field
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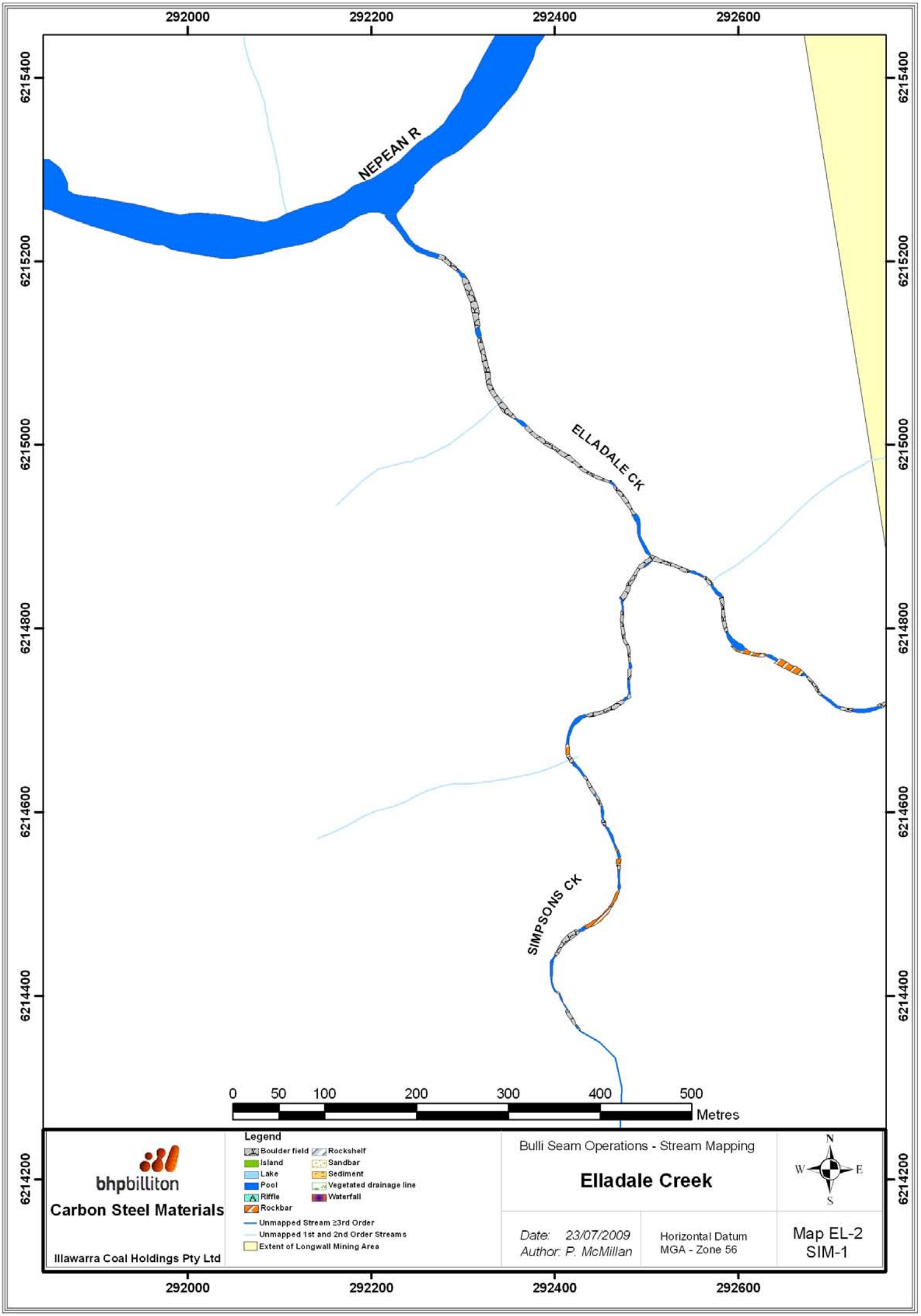
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Elladale Creek
N
W
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map EL-1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Carbon Steel Materials
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Legend
Boulder field
Rockshelf
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Sandbar
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Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Elladale Creek
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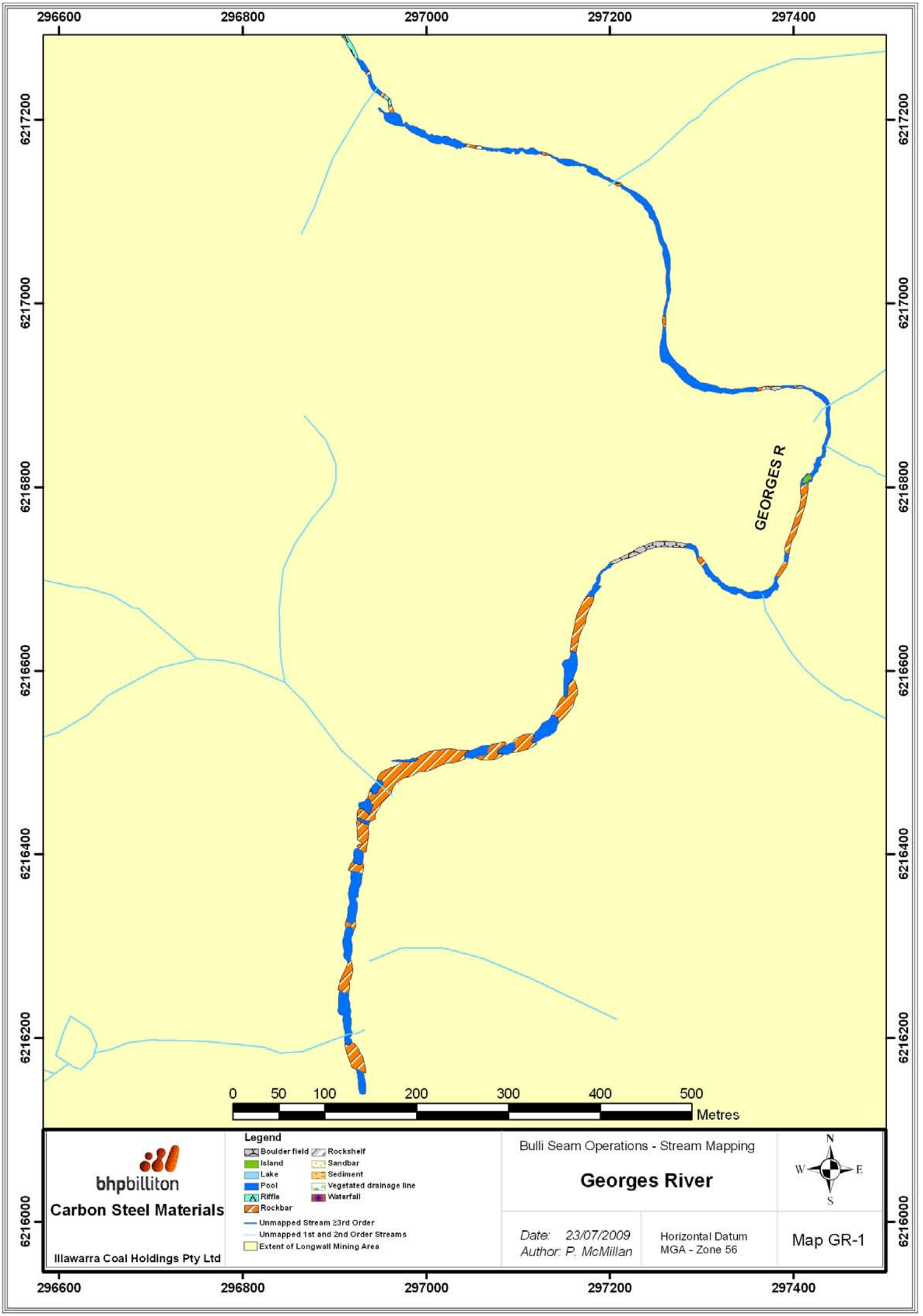
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map EL-2
SIM-1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Carbon Steel Materials
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Legend
Boulder field
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Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
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N
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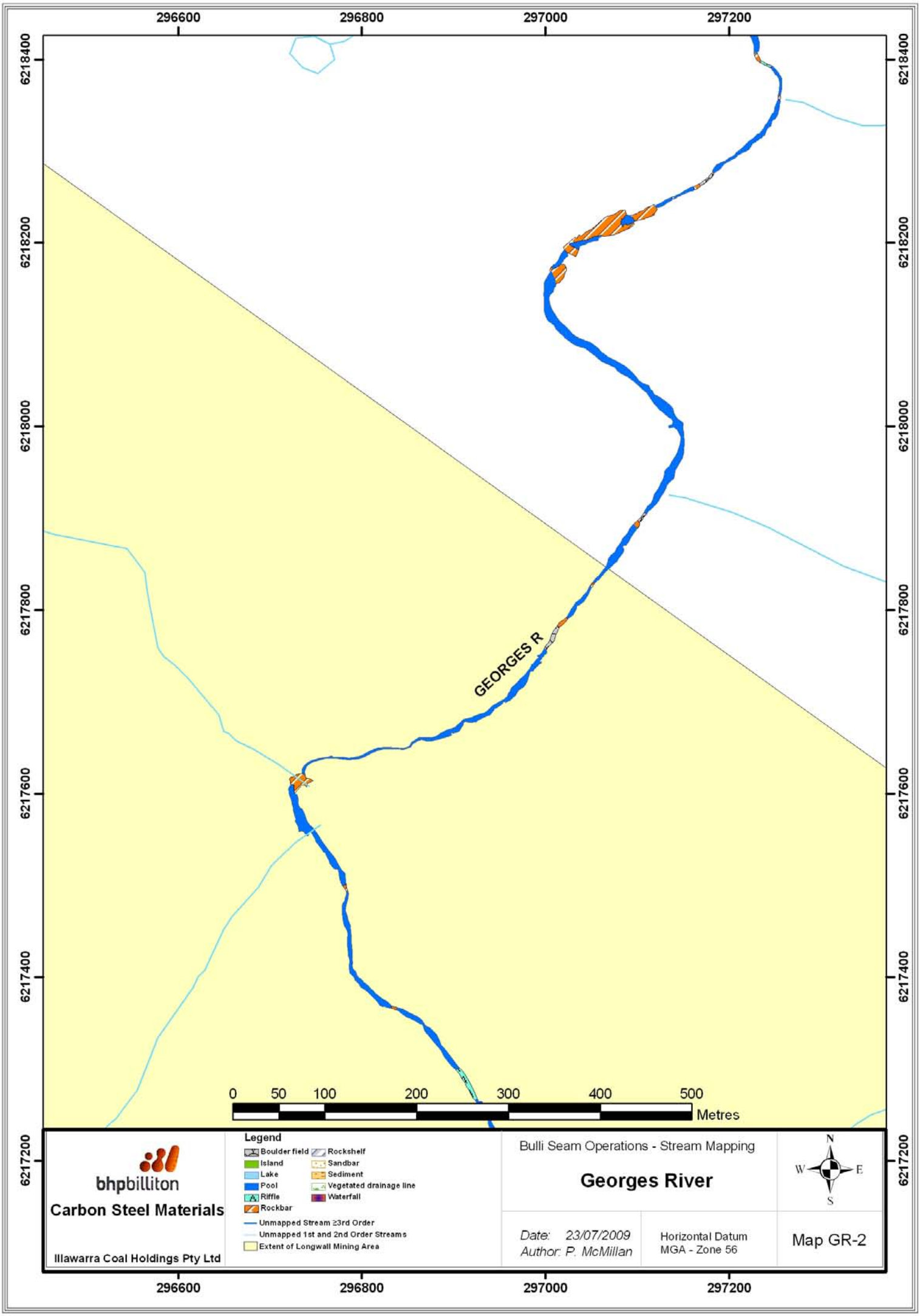
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map GR-1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Carbon Steel Materials
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Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Georges River
N
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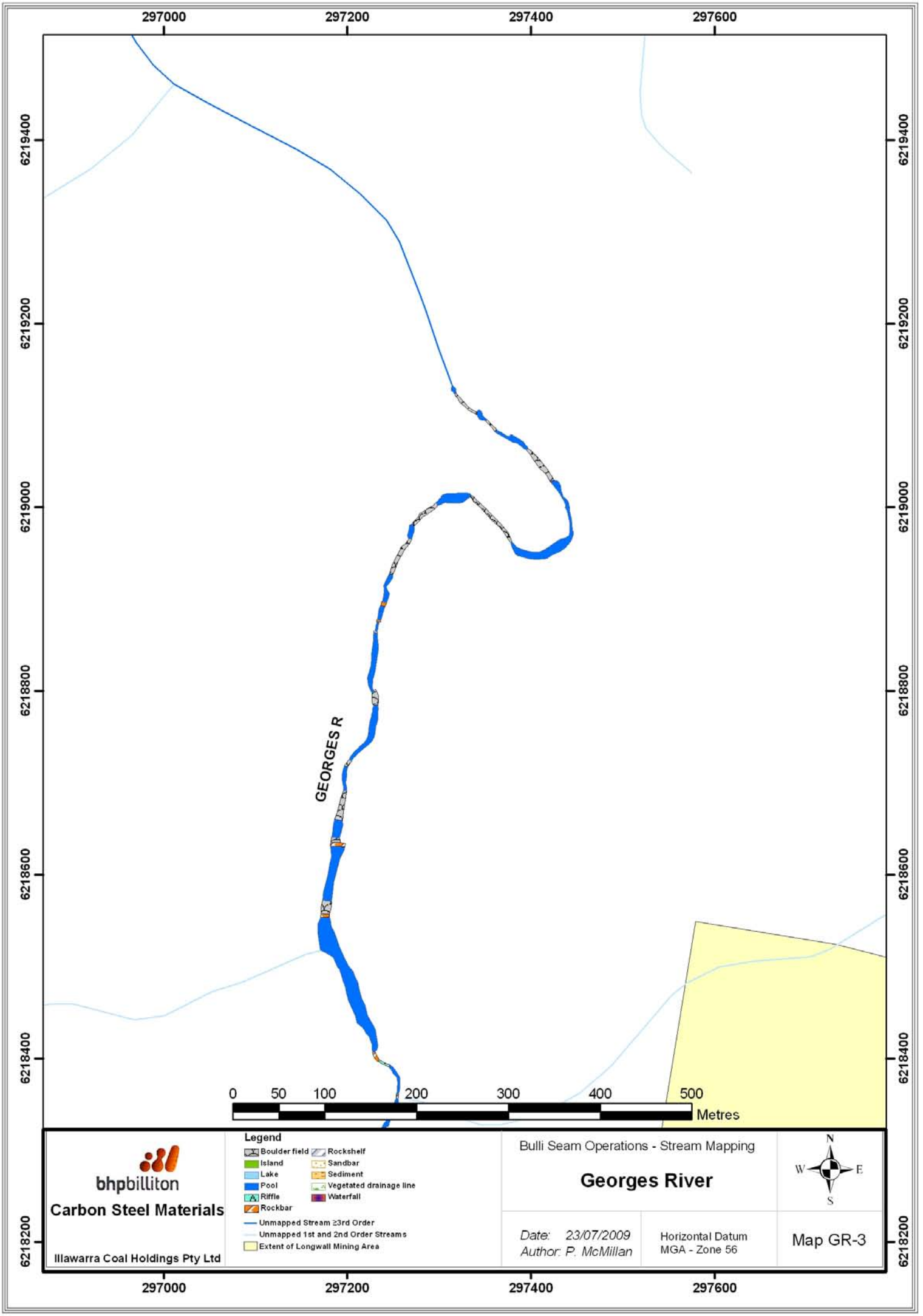
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map GR-2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Legend
Boulder field
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Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Georges River
N
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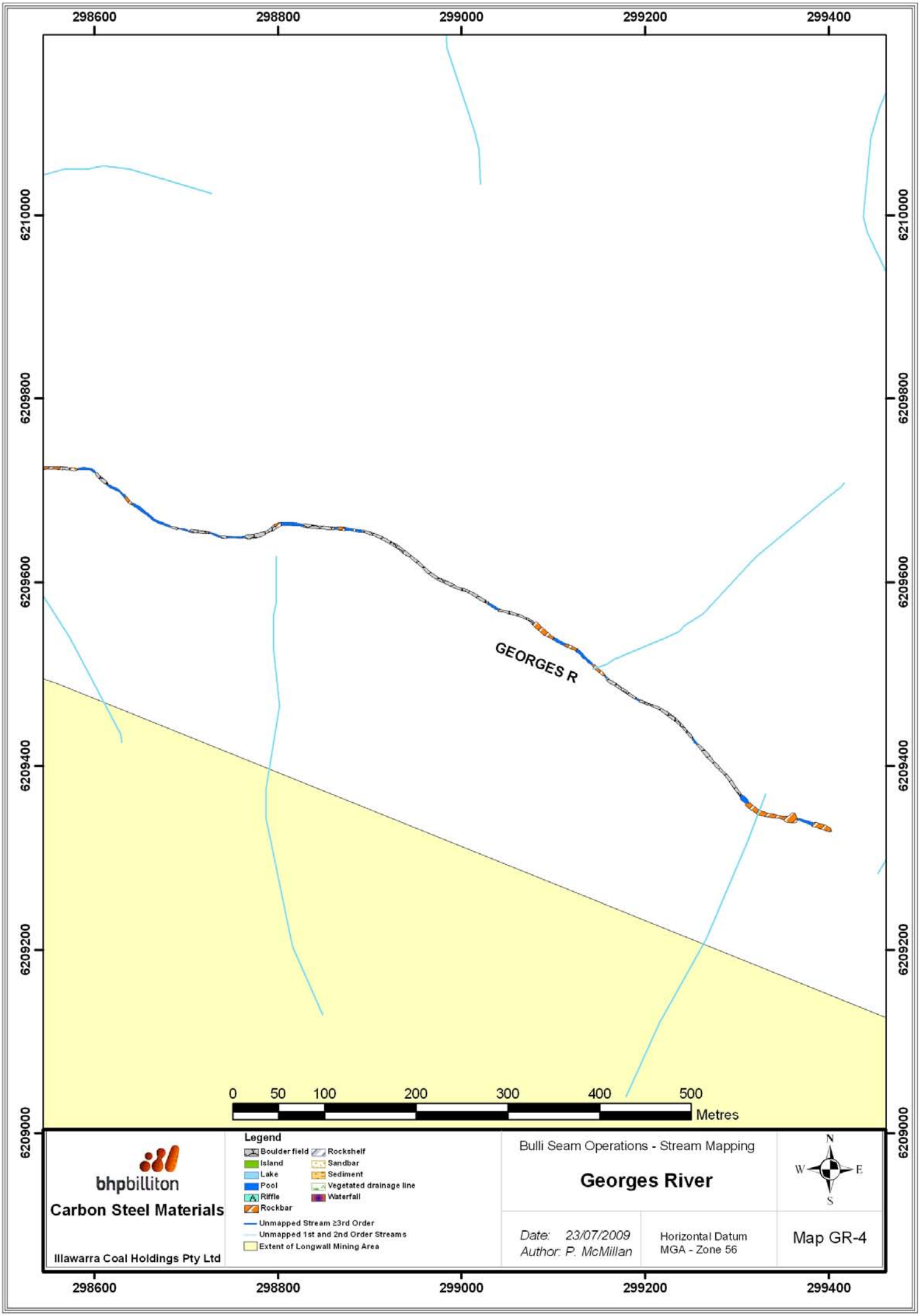
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map GR-3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Metres
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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Georges River
N
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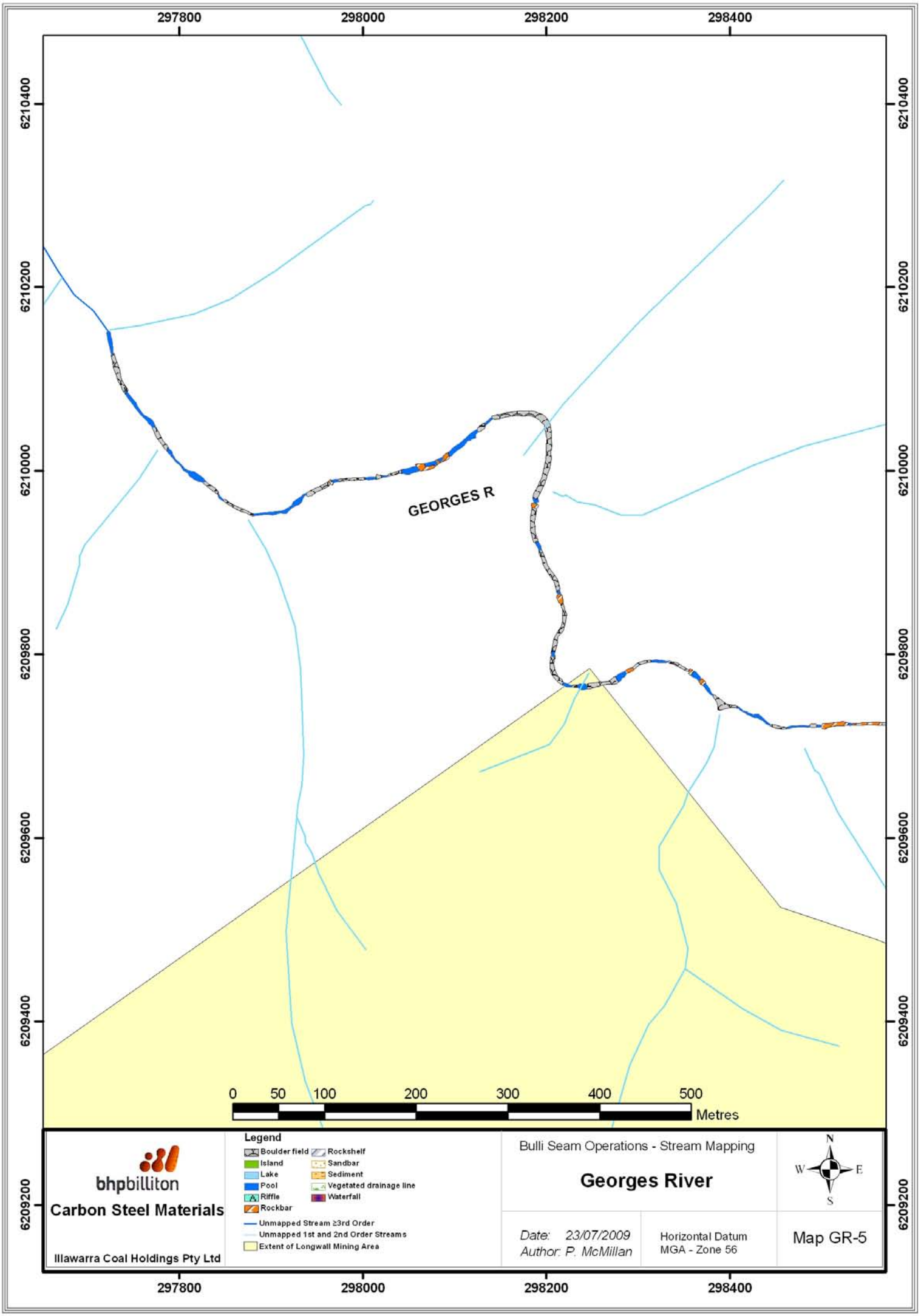
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map GR-4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Metres
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
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Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
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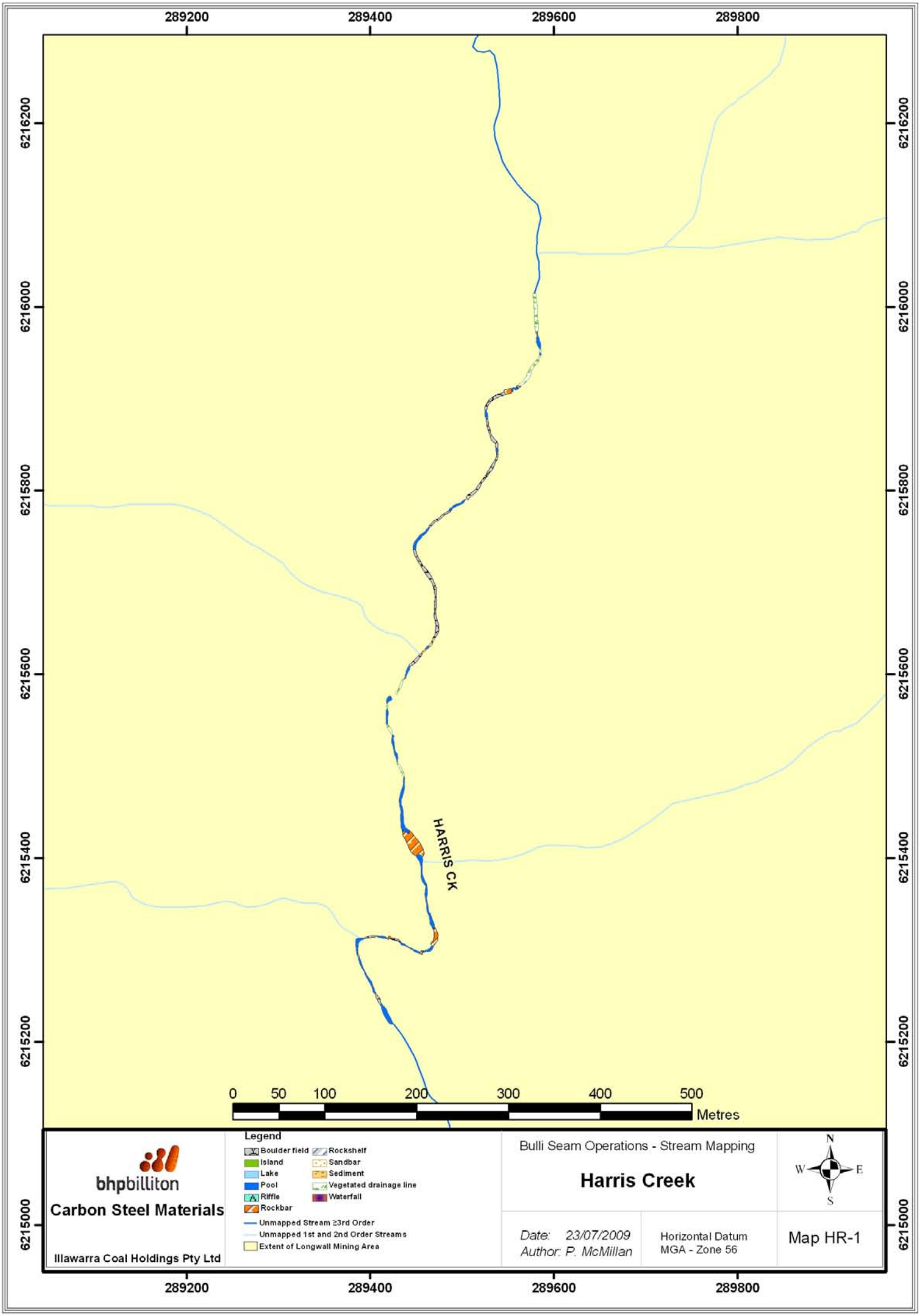
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map GR-5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Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Bulli Seam Operations - Stream Mapping
Harris Creek
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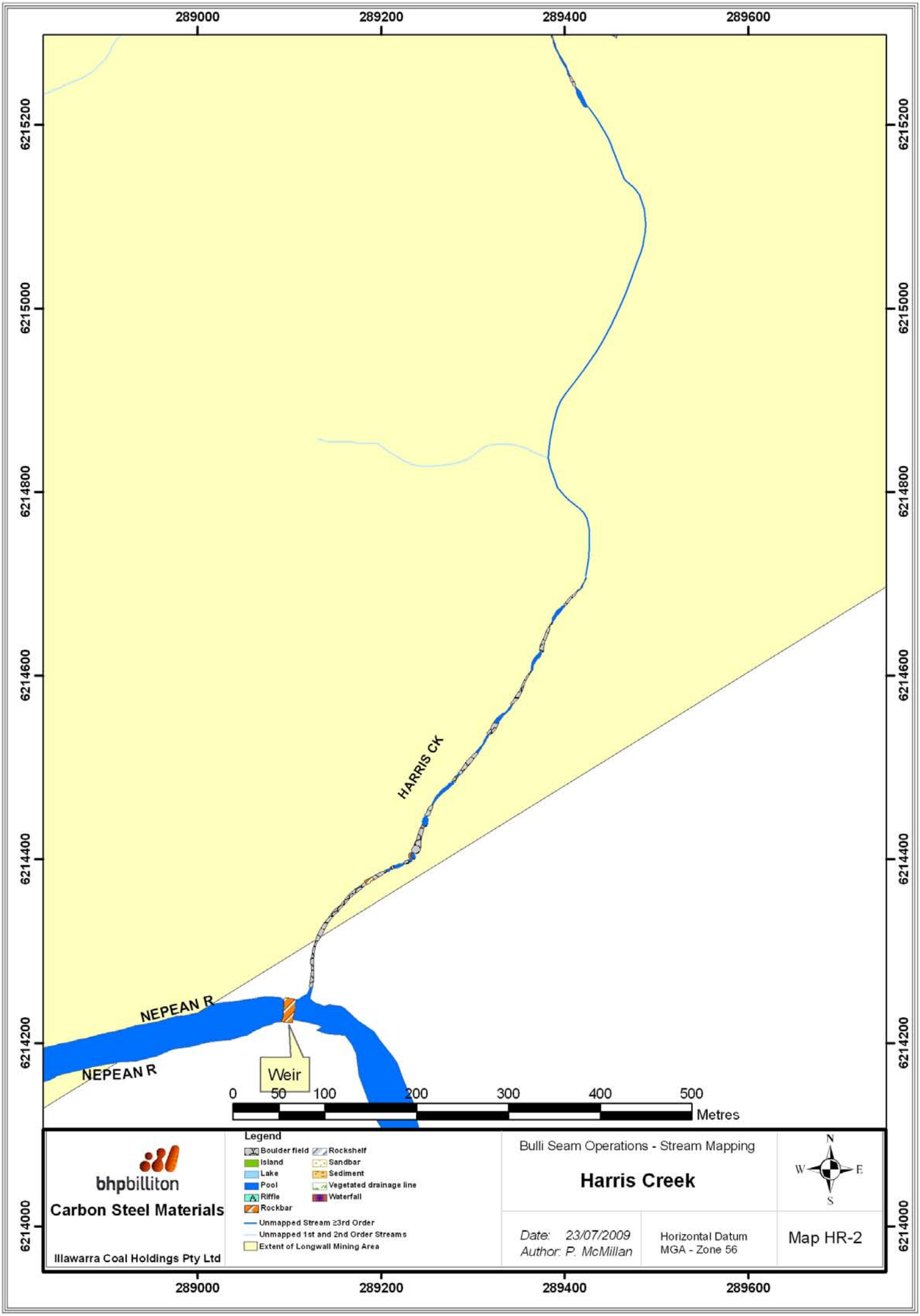
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map HR-1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Metres
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
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Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Harris Creek
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
N
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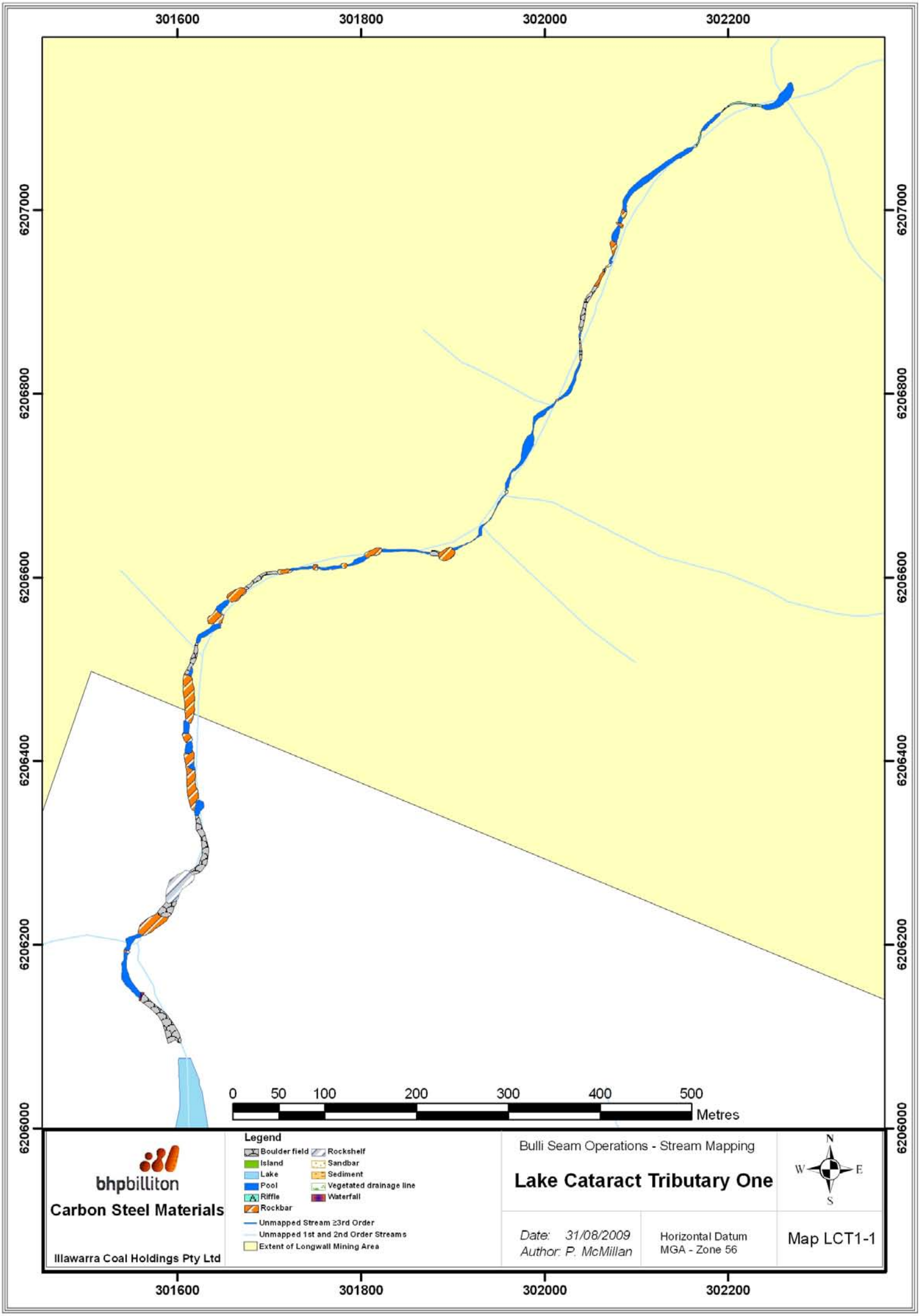
E
S
Map HR-2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Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Lake Cataract Tributary One
Date: 31/08/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map LCT1-1
N
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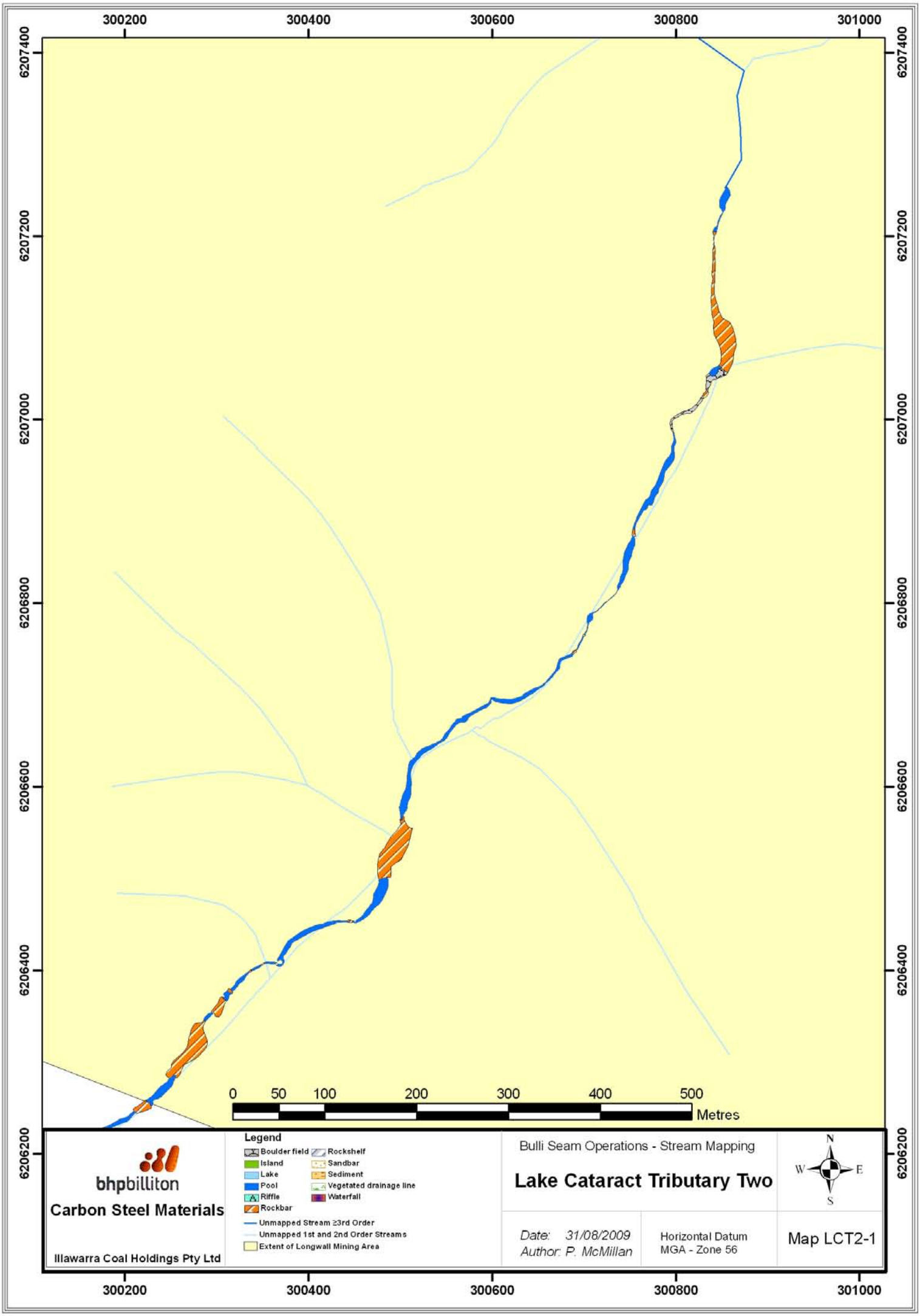
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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
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Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Lake Cataract Tributary Two
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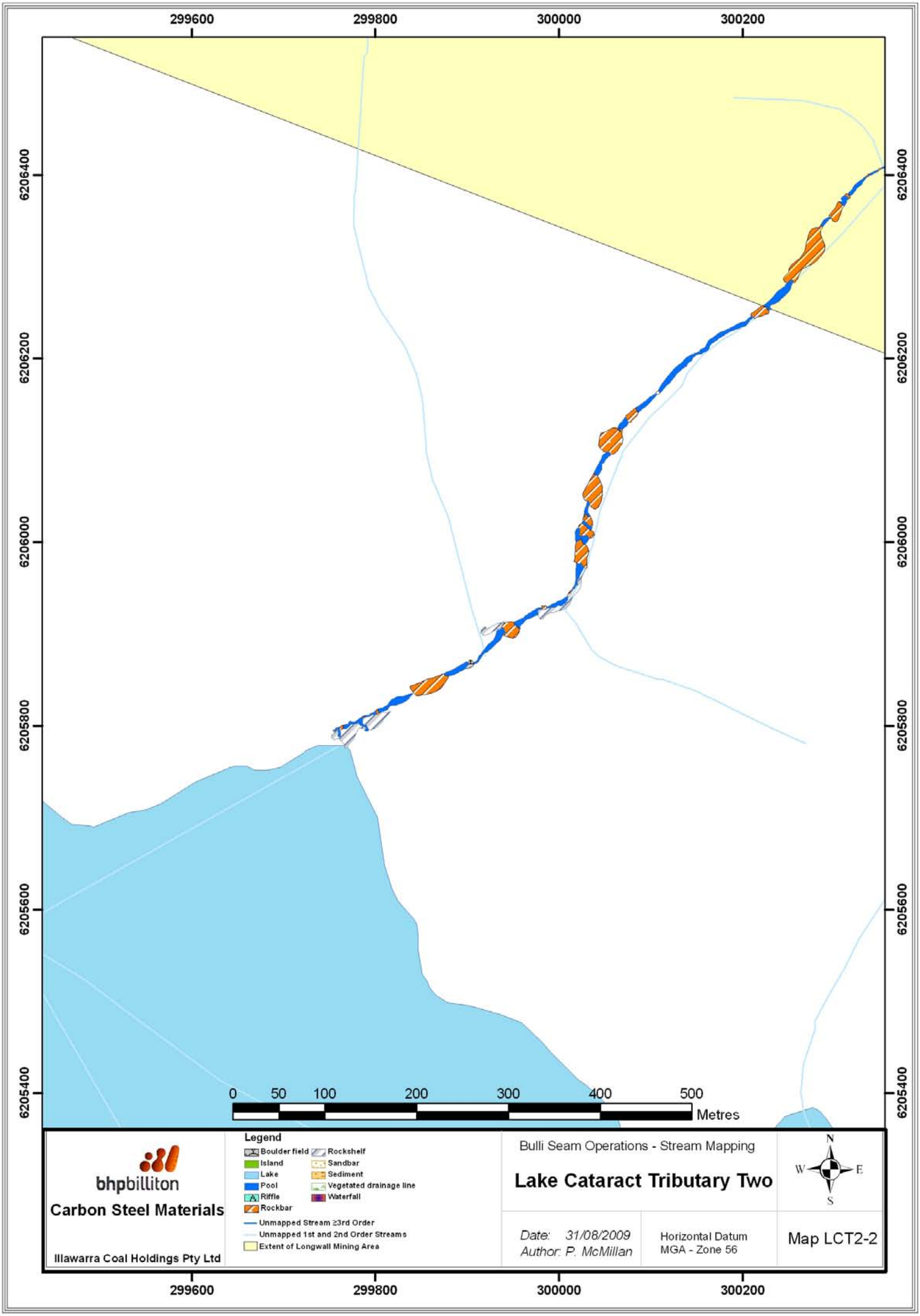
E
S
Date: 31/08/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map LCT2-1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Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Bulli Seam Operations - Stream Mapping
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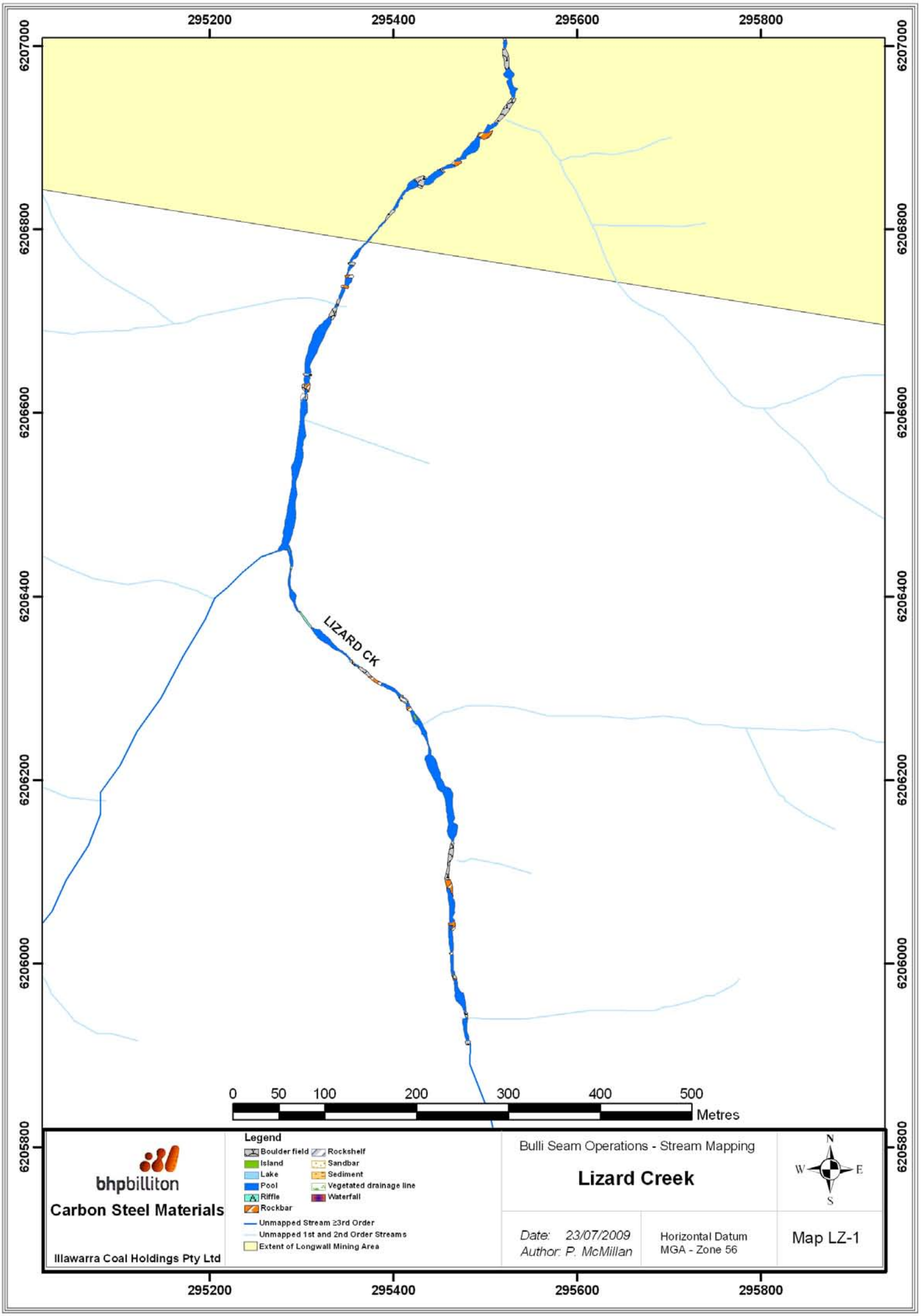
Date: 31/08/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map LCT2-2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Carbon Steel Materials
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Boulder field
Rockshelf
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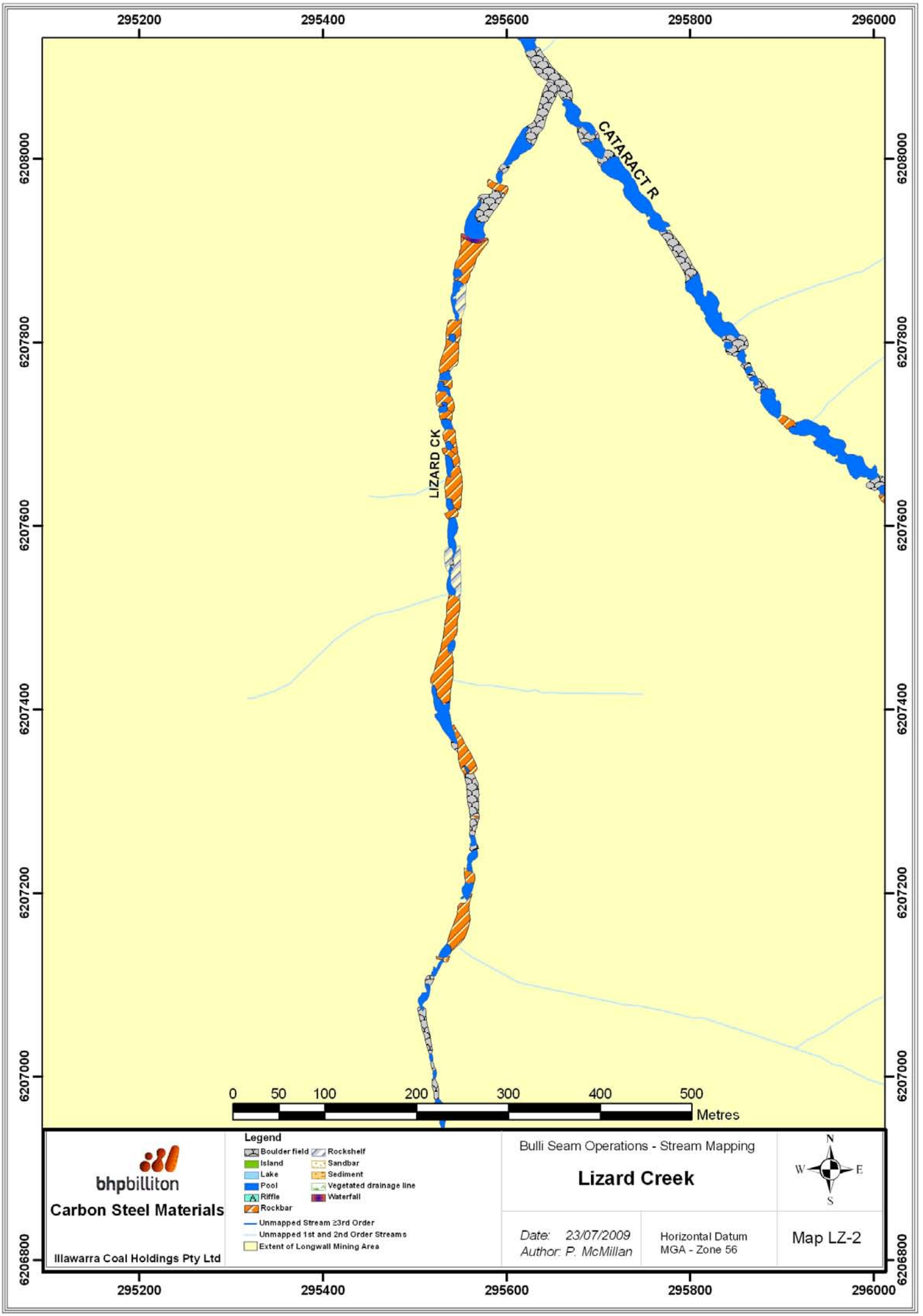
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Lizard Creek
N
W
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map LZ-1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Boulder field
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Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Bulli Seam Operations - Stream Mapping
Lizard Creek
N
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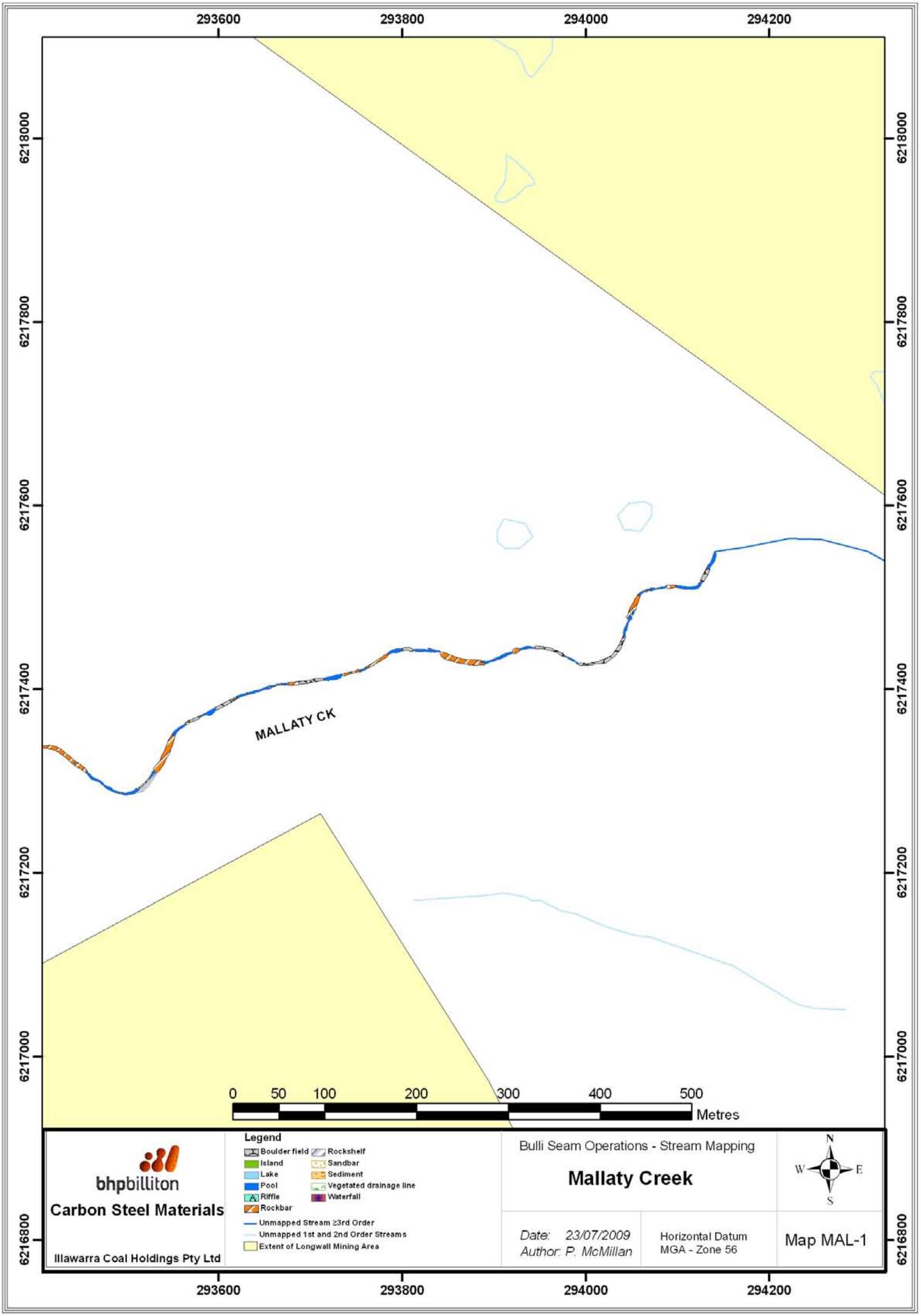
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map LZ-2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Metres
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Carbon Steel Materials
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Boulder field
Rockshelf
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Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
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N
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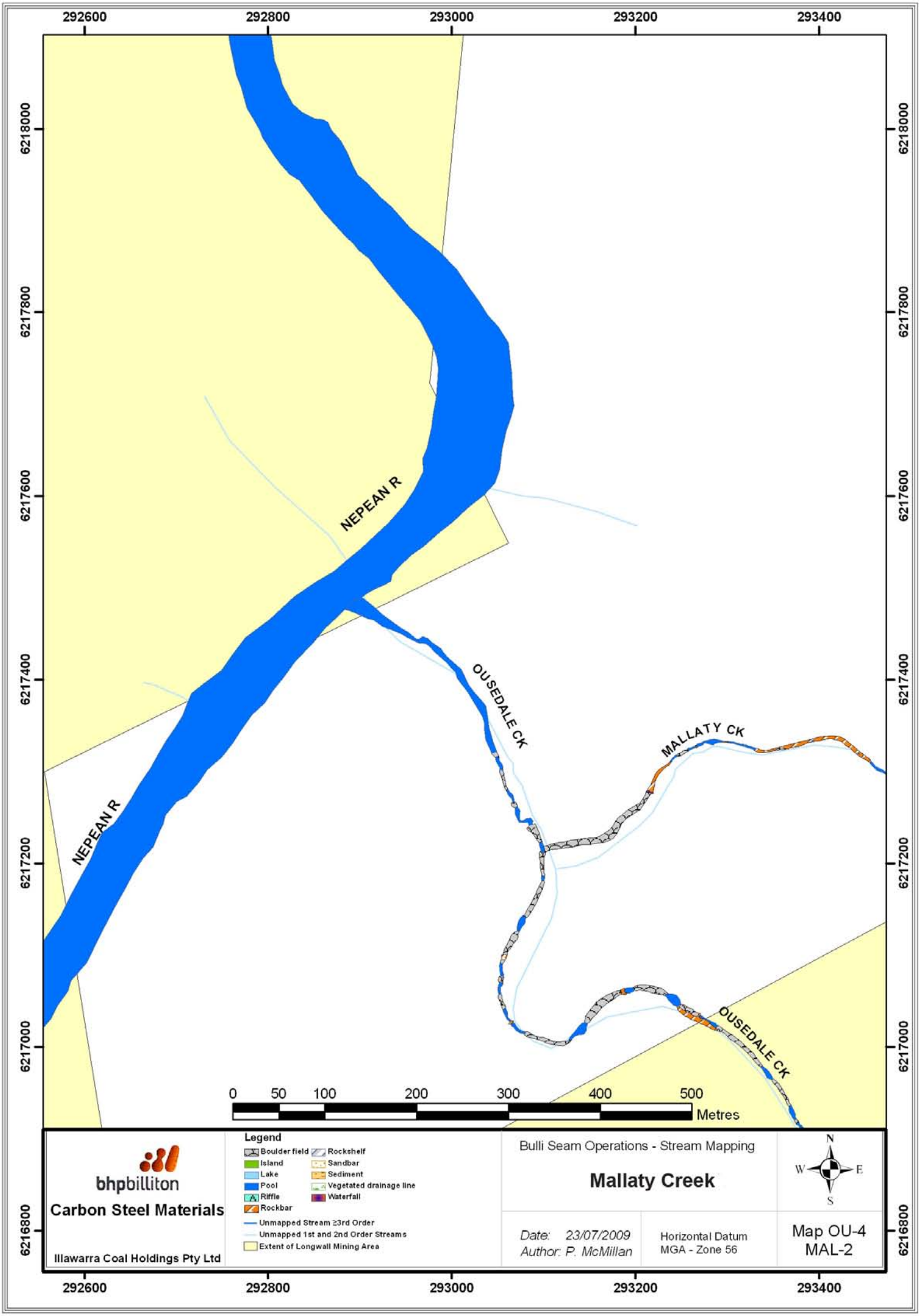
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map MAL-1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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Mallaty Creek
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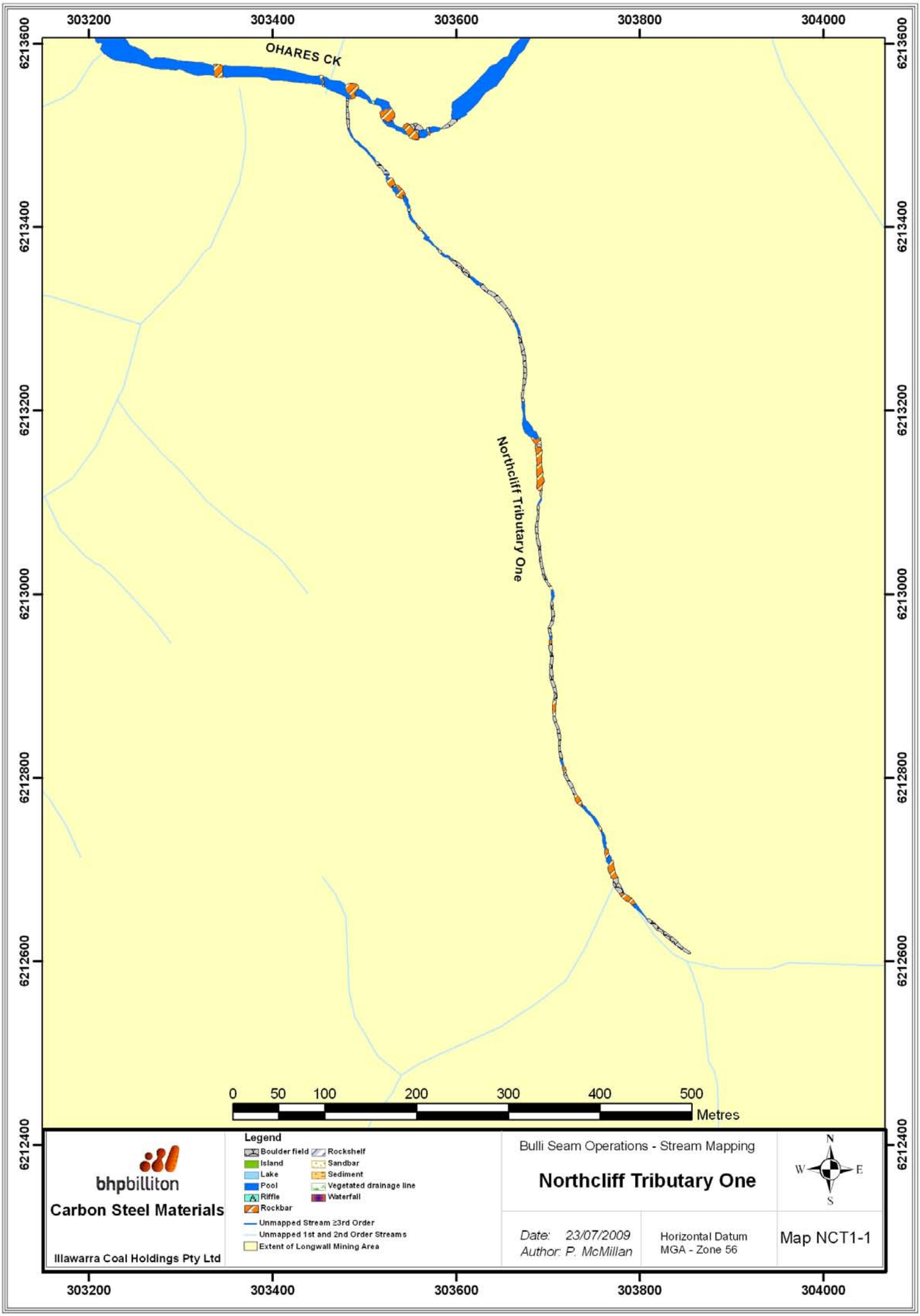
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map OU-4
MAL-2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Northcliff Tributary One
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200
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400
500
Metres
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Northcliff Tributary One
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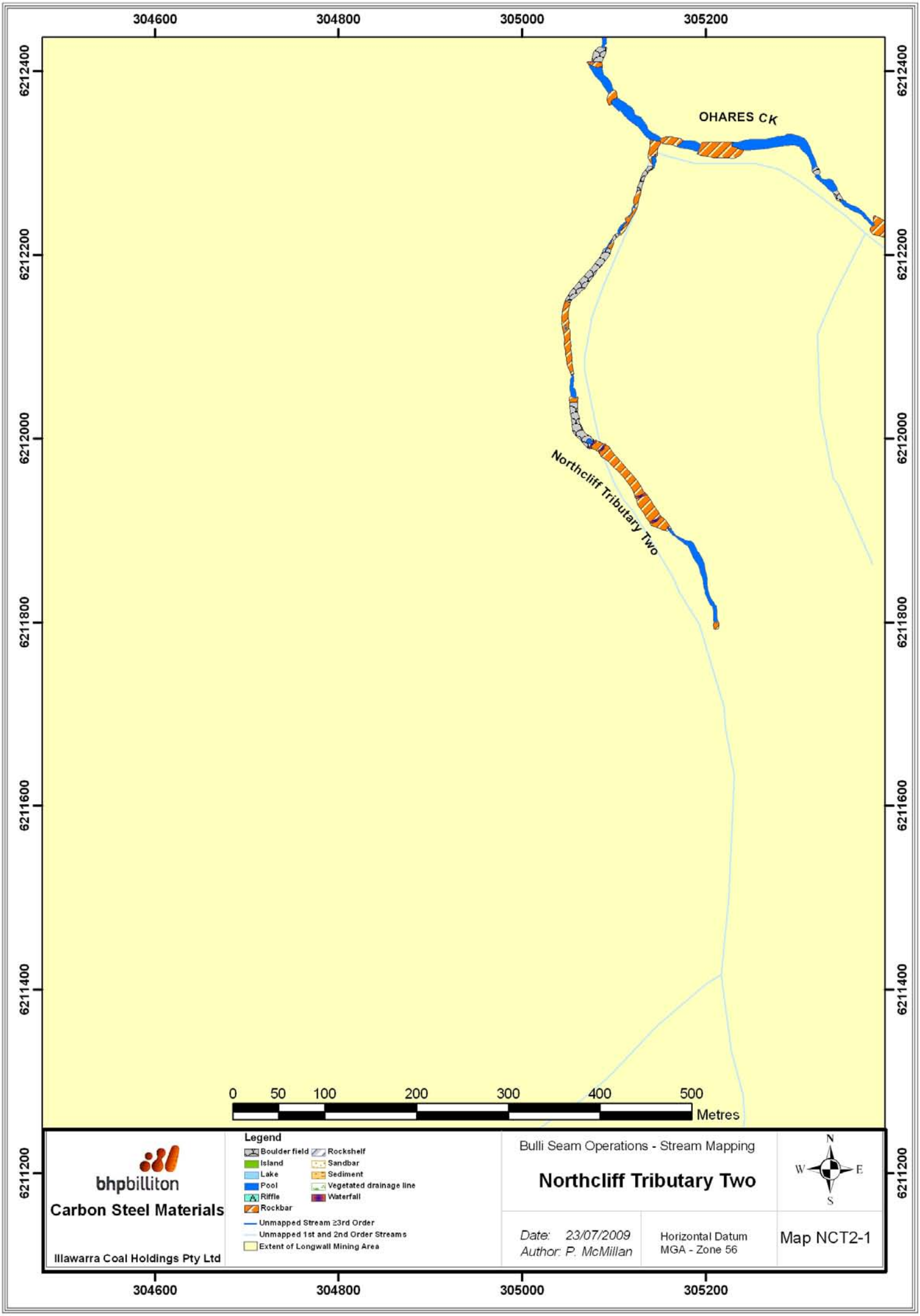
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map NCT1-1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Metres
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Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Northcliff Tributary Two
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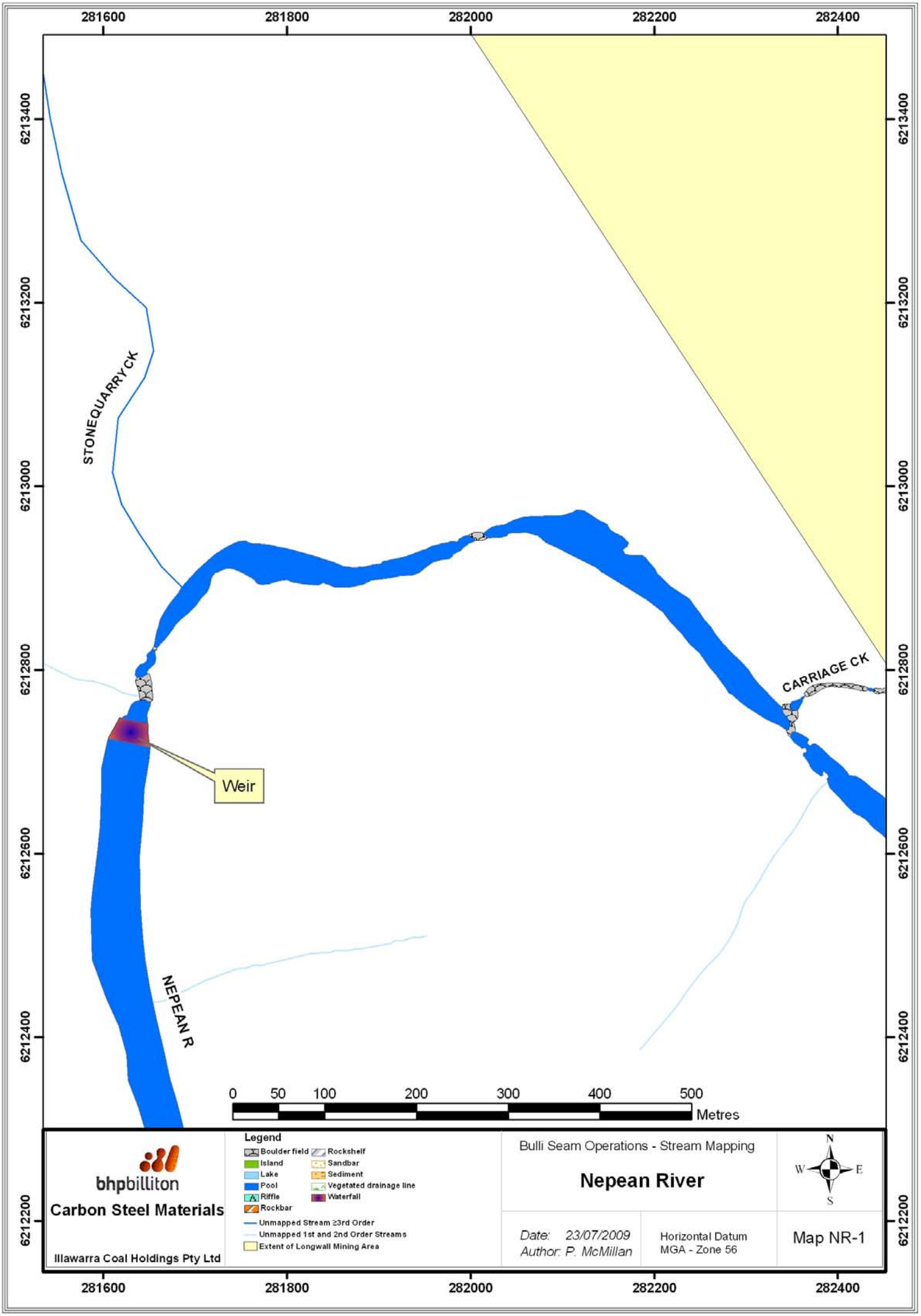
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map NCT2-1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CARRIAGE CK
Weir
NEPEAN R
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Metres
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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Nepean River
N
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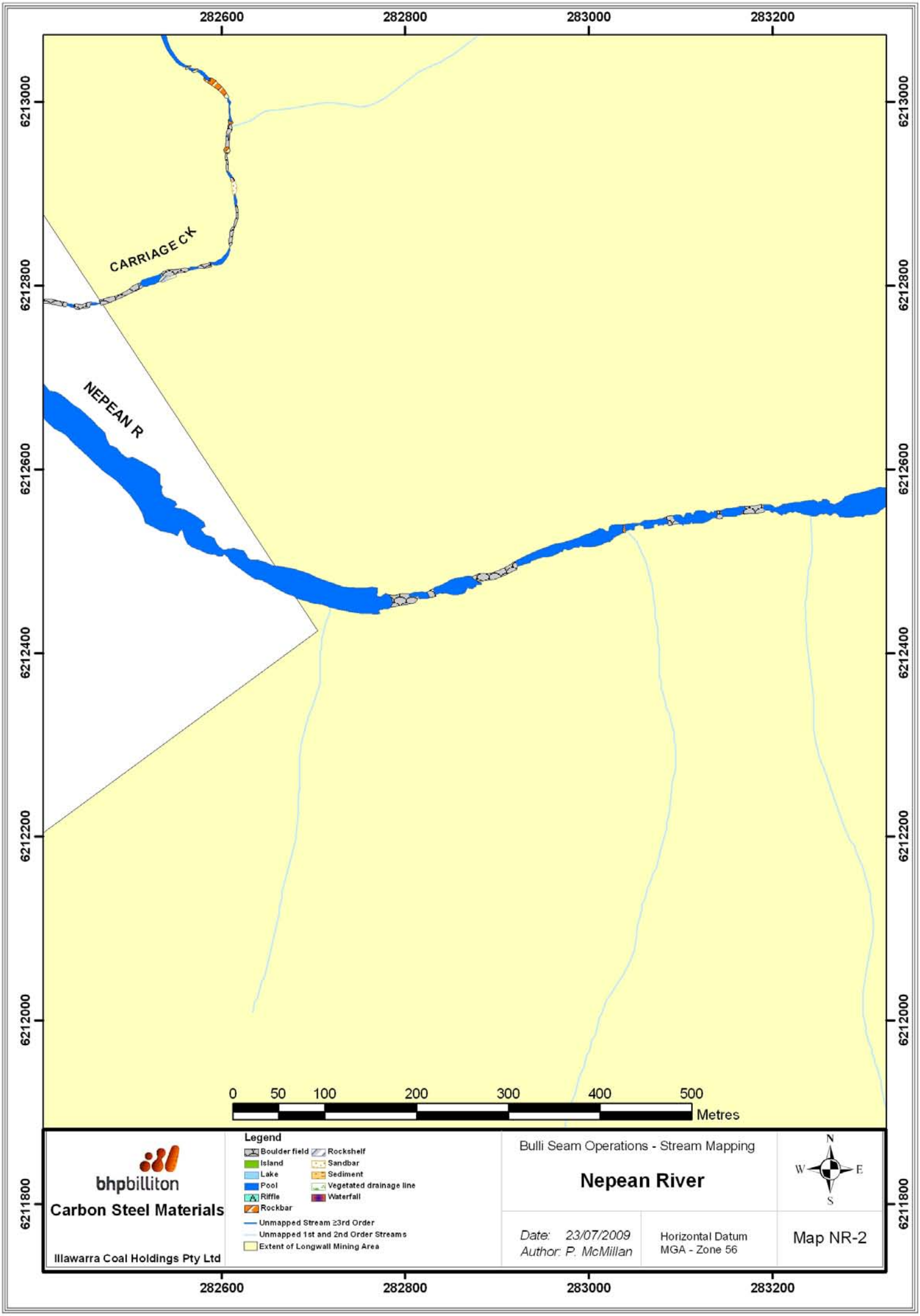
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map NR-1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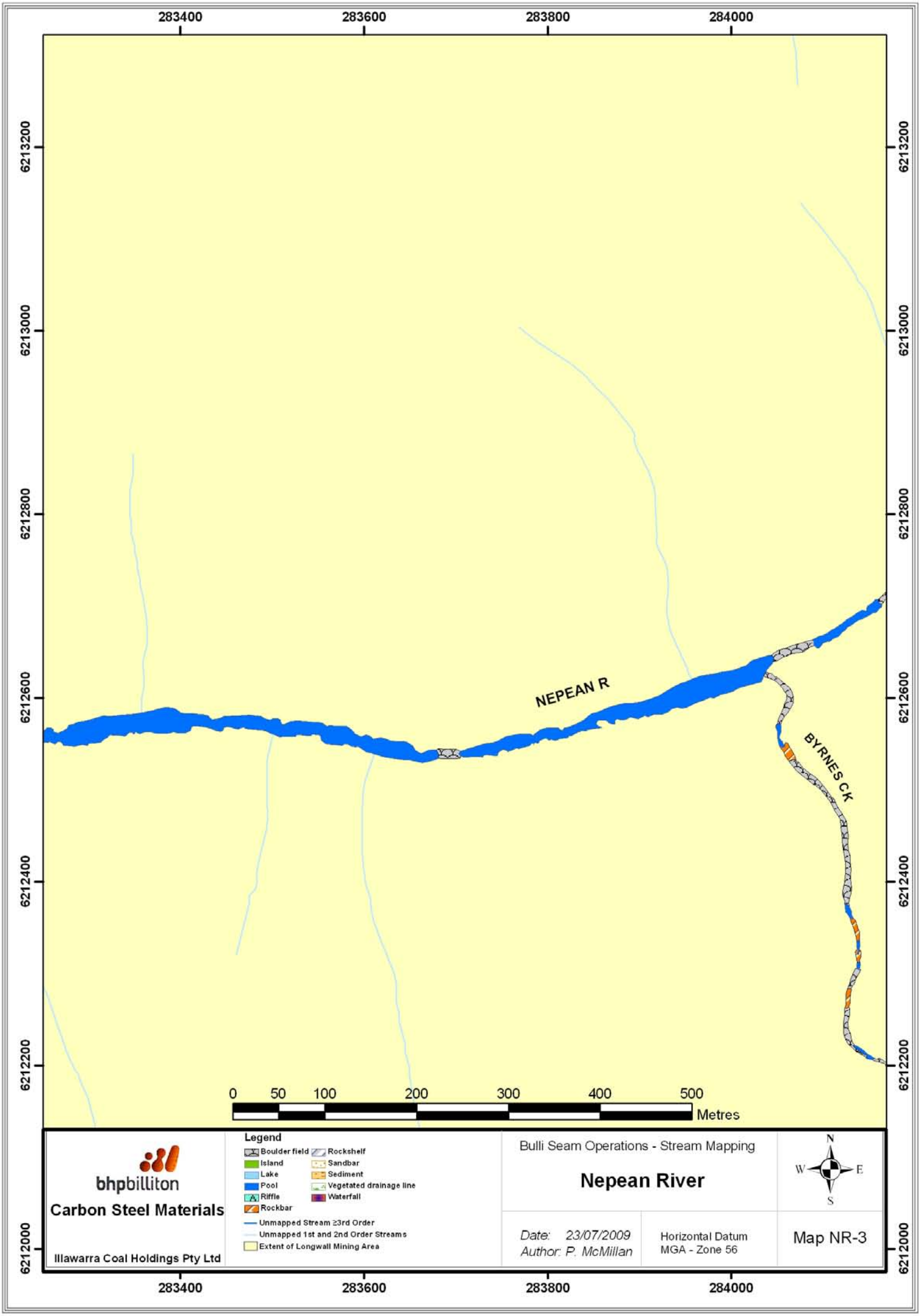
Metres
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Nepean River
N
W
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map NR-2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Metres
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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Nepean River
N
W
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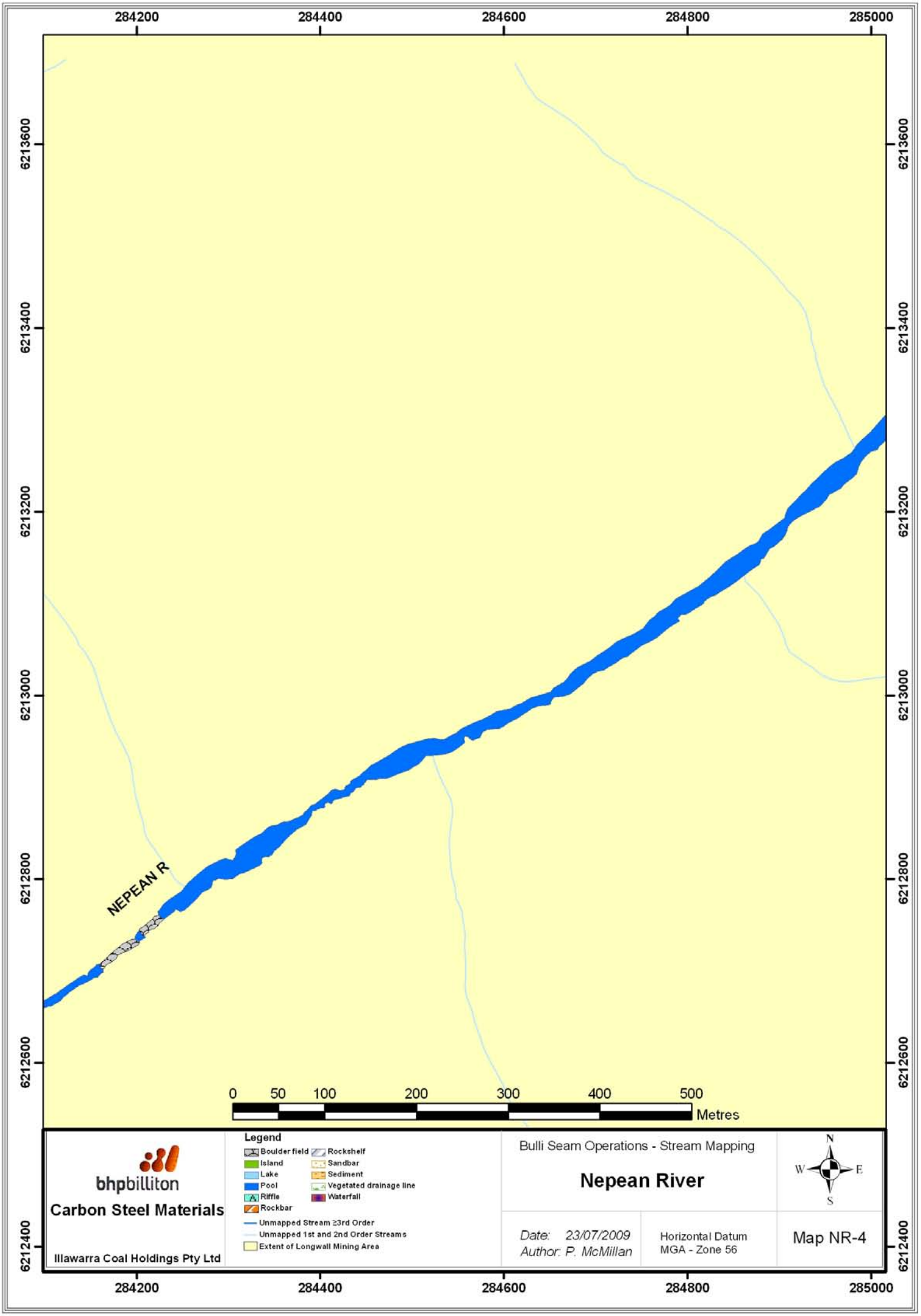
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map NR-3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Metres
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Legend
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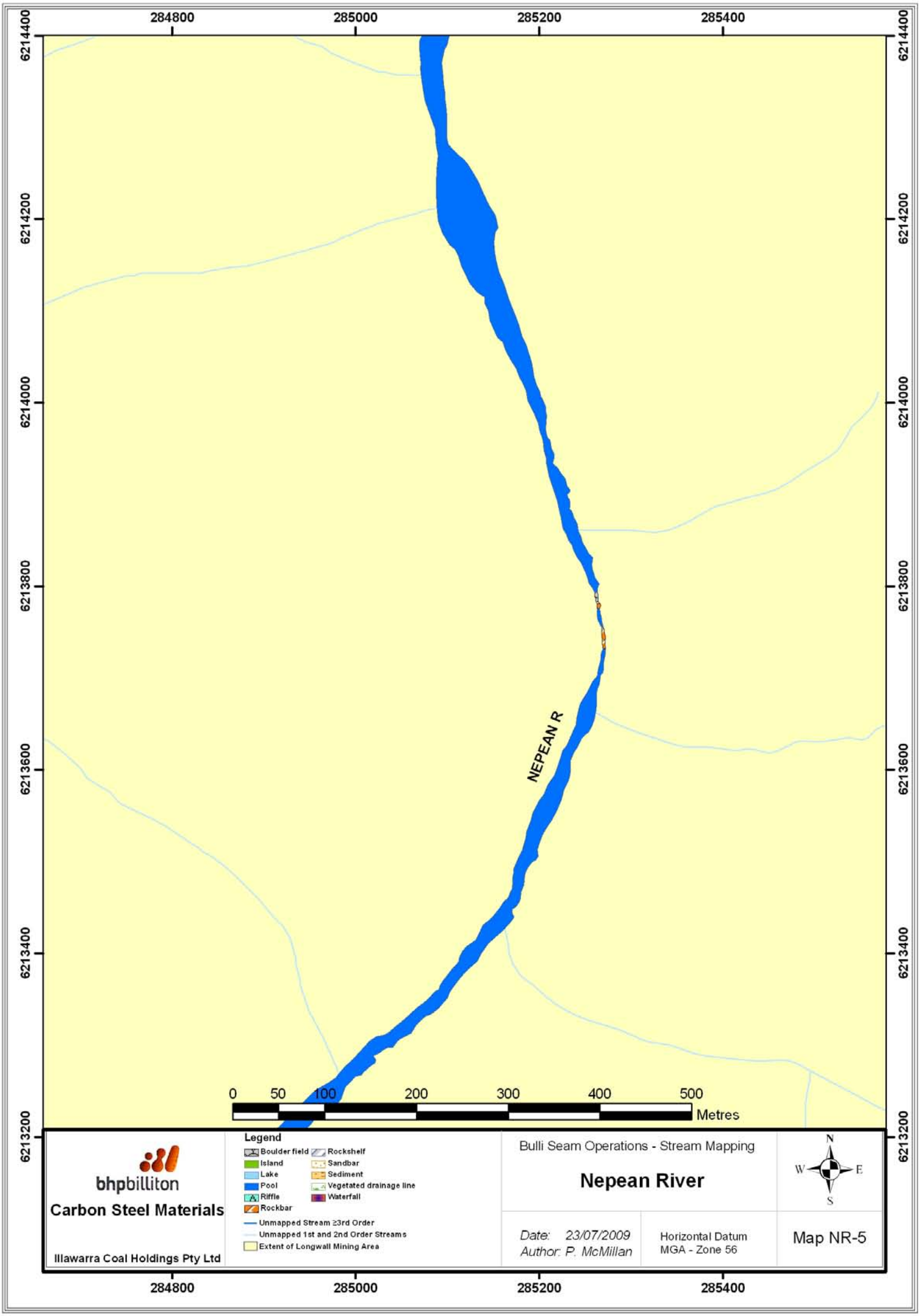
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Nepean River
N
W
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map NR-4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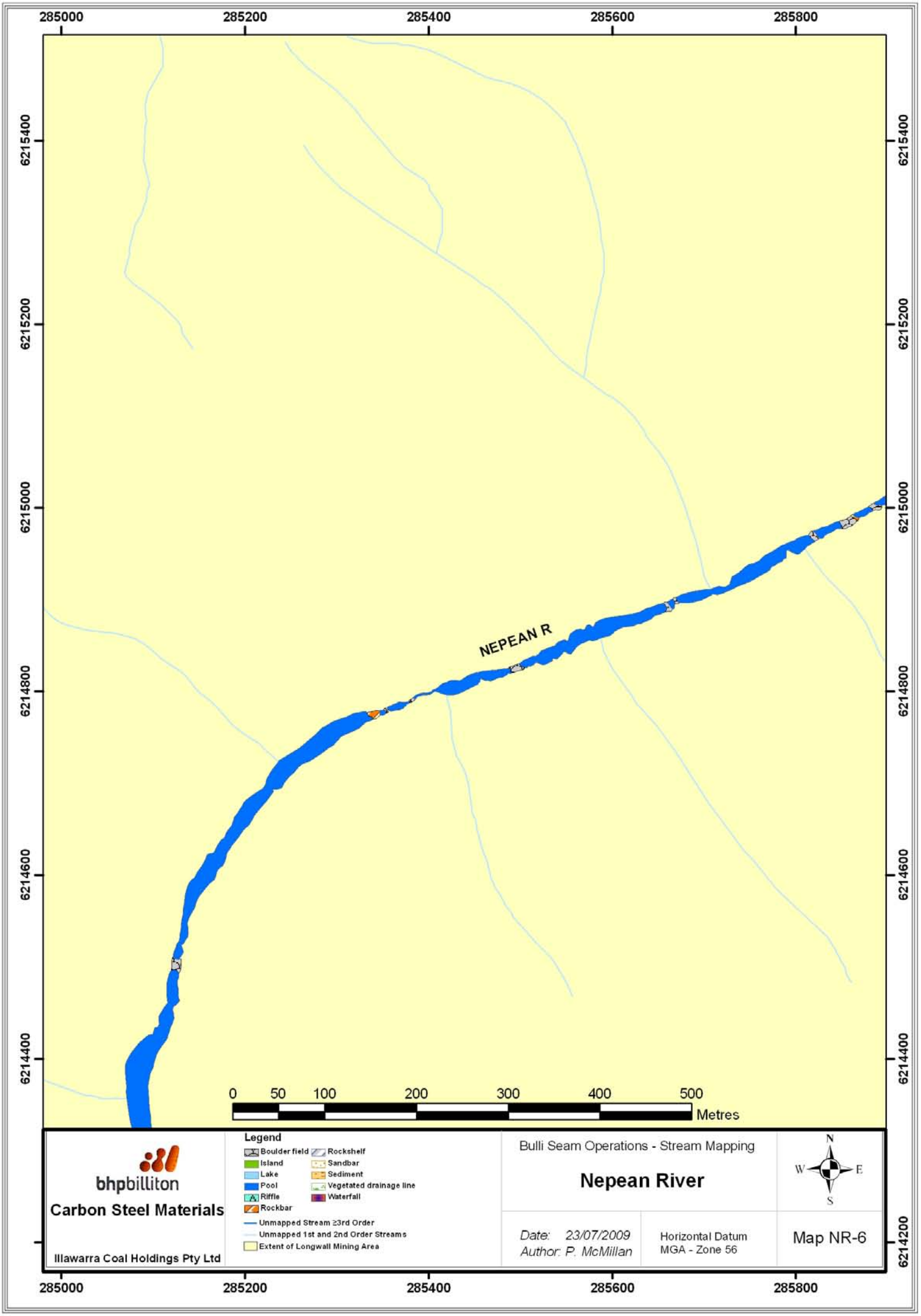
Metres
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Nepean River
N
W
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map NR-5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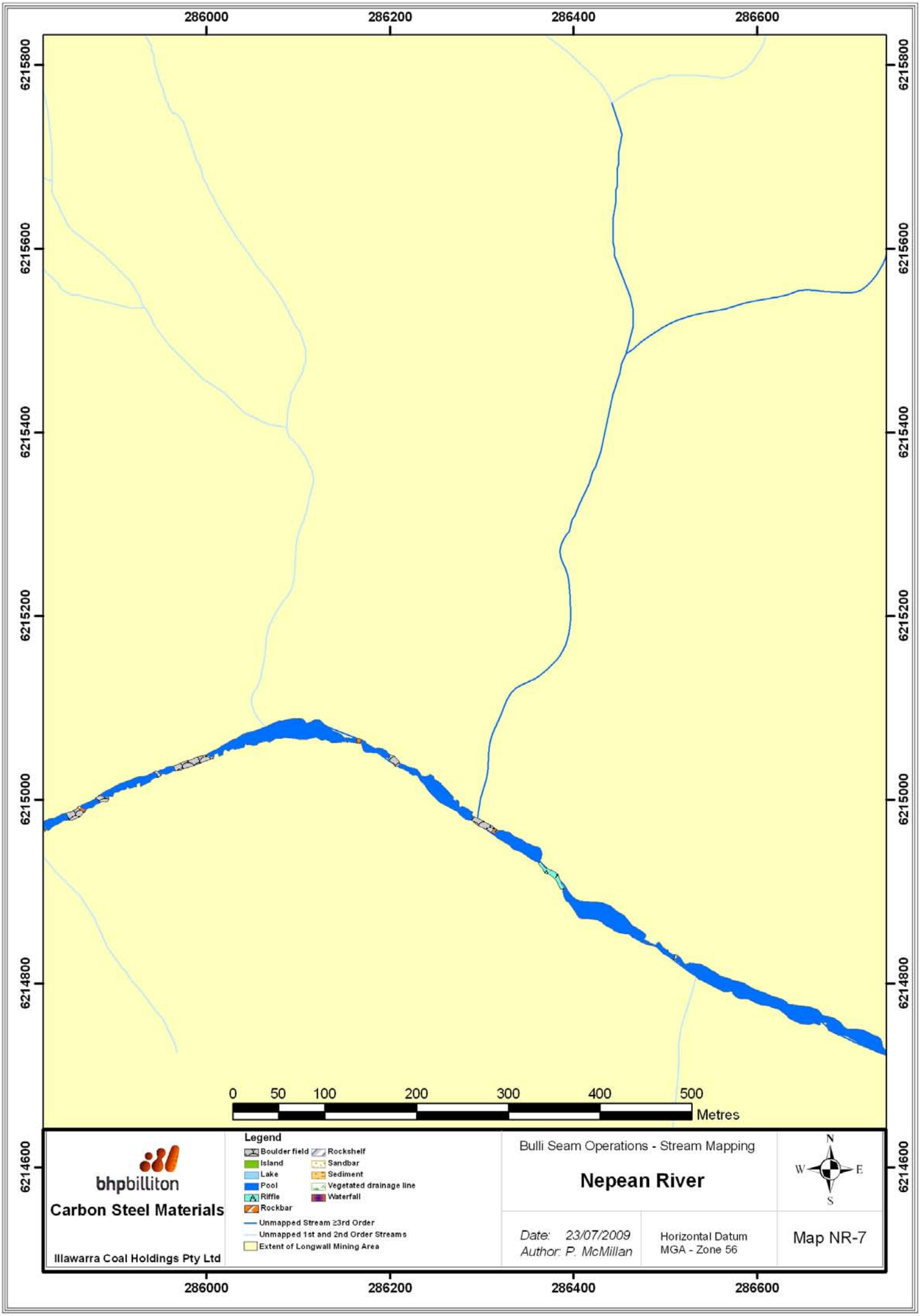
Metres
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Nepean River
N
W
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map NR-6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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Nepean River
N
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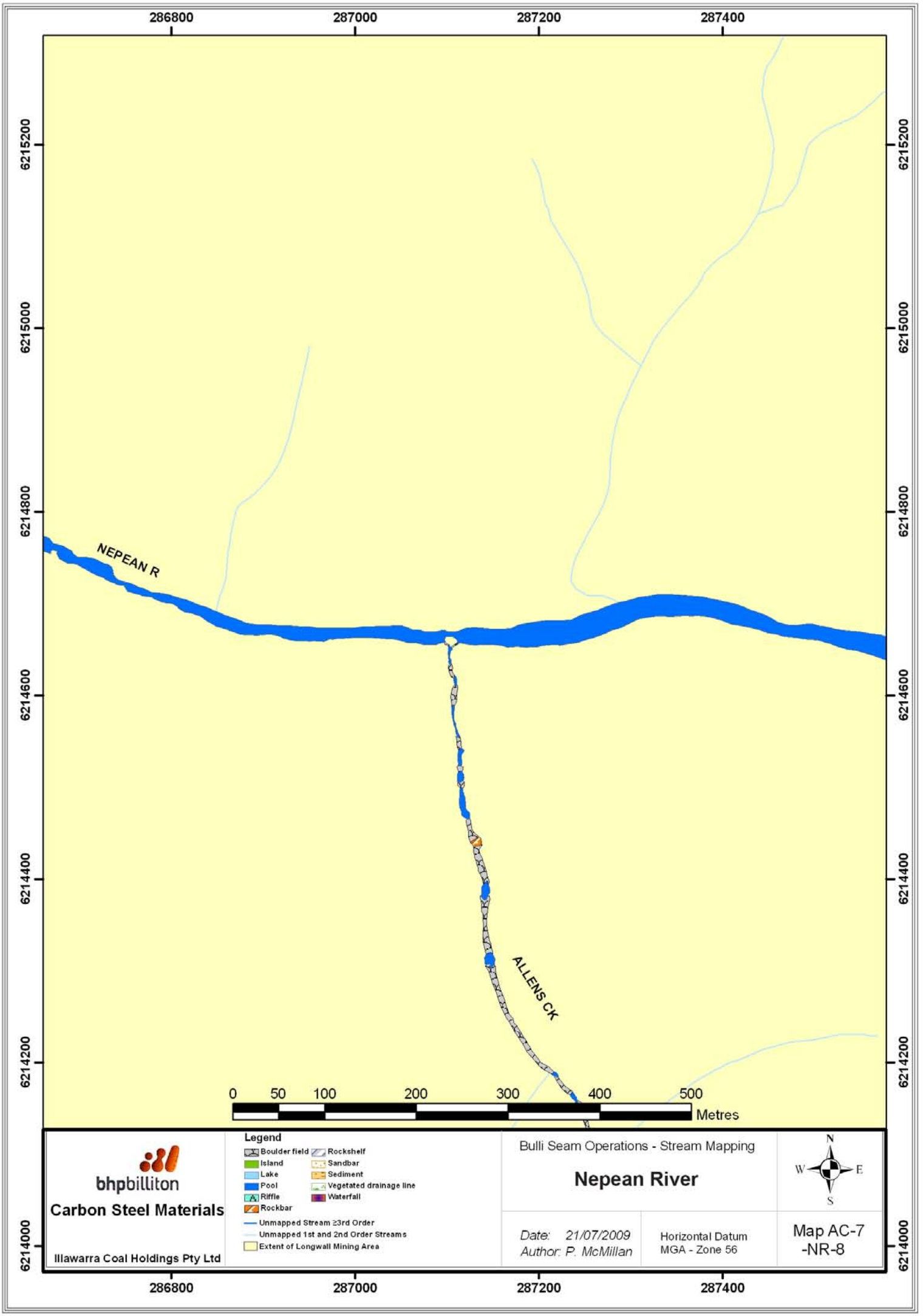
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map NR-7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Metres
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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Nepean River
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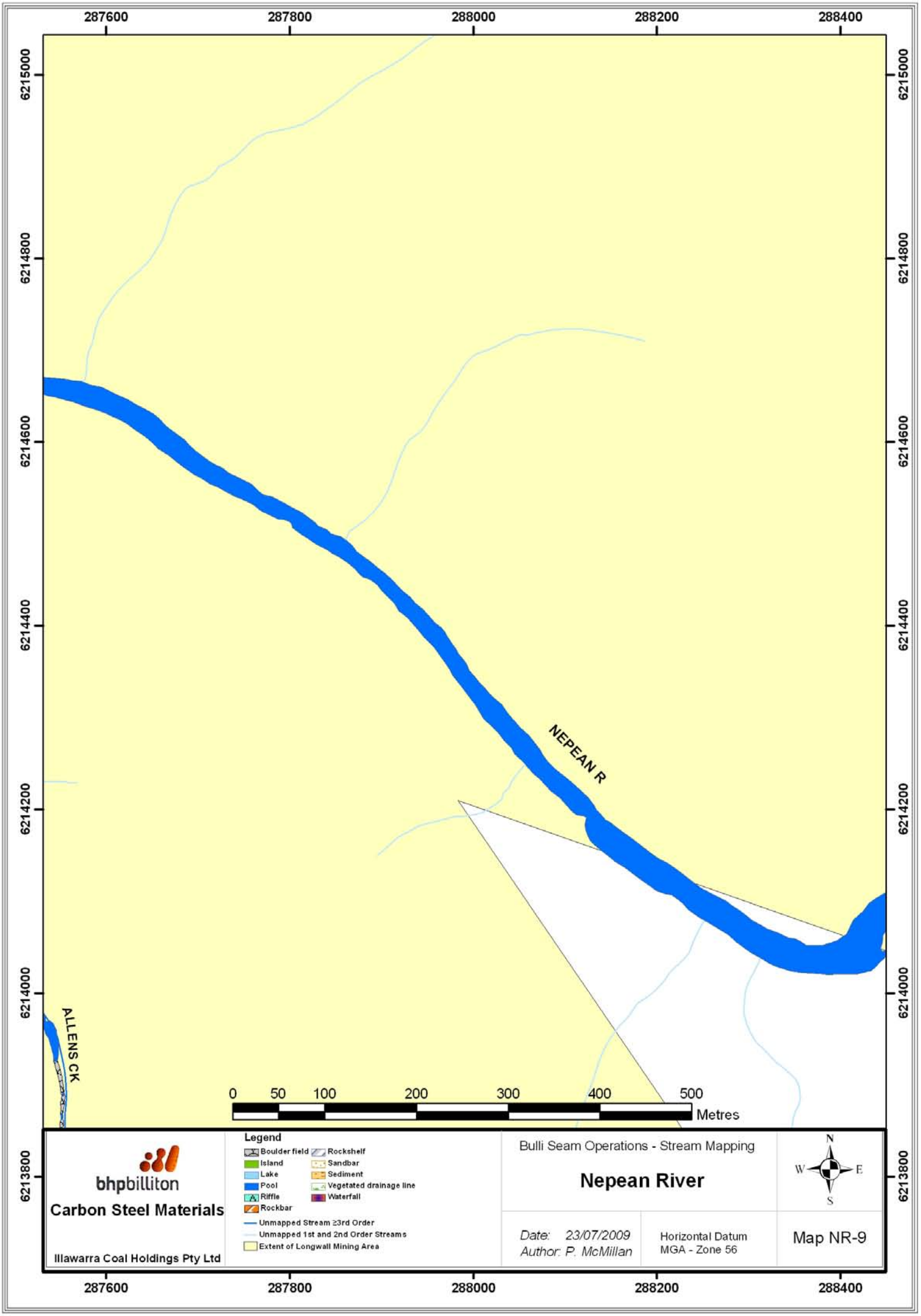
S
Date: 21/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map AC-7
-NR-8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Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Bulli Seam Operations - Stream Mapping
Nepean River
N
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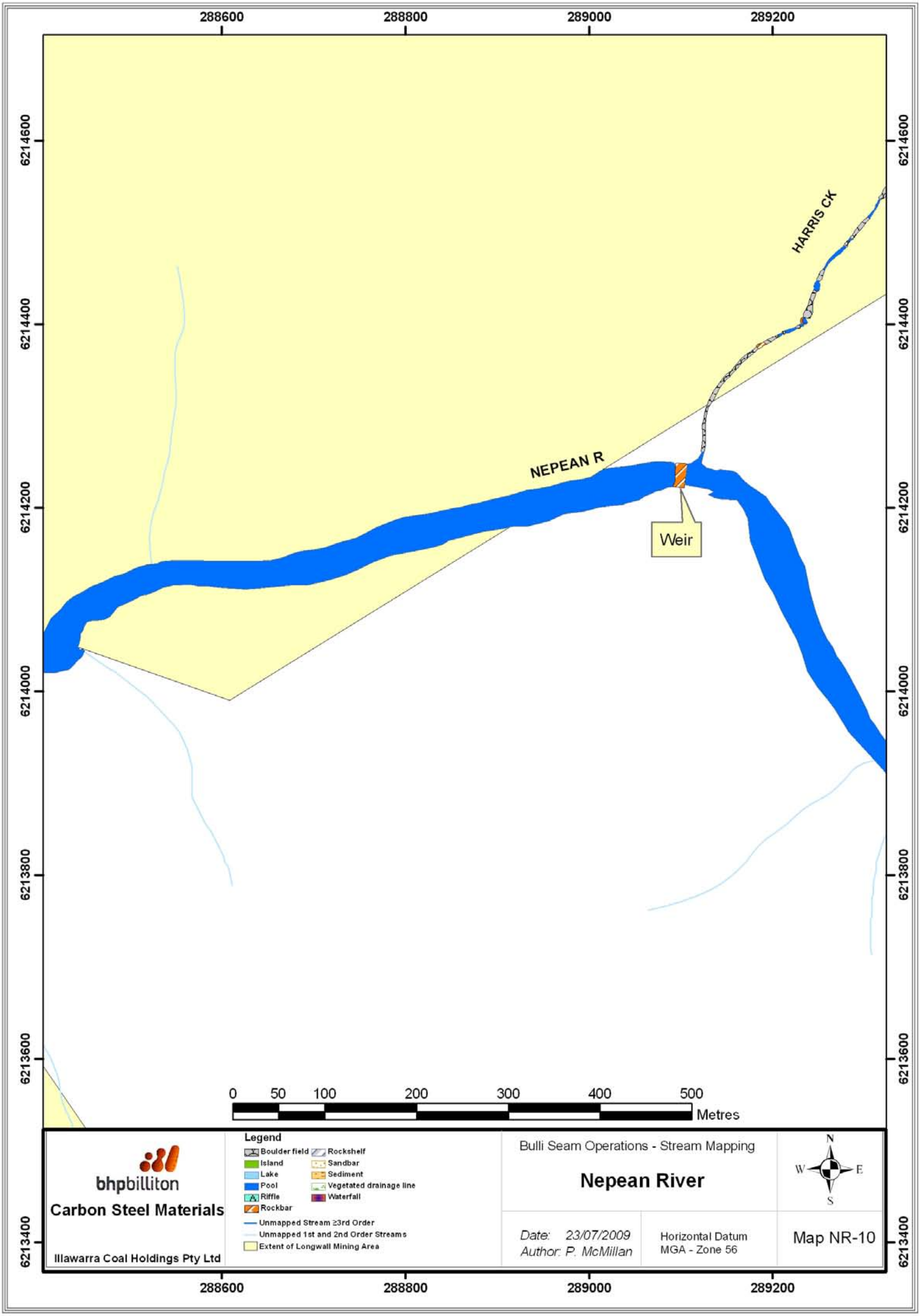
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map NR-9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Metres
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Bulli Seam Operations - Stream Mapping
Nepean River
N
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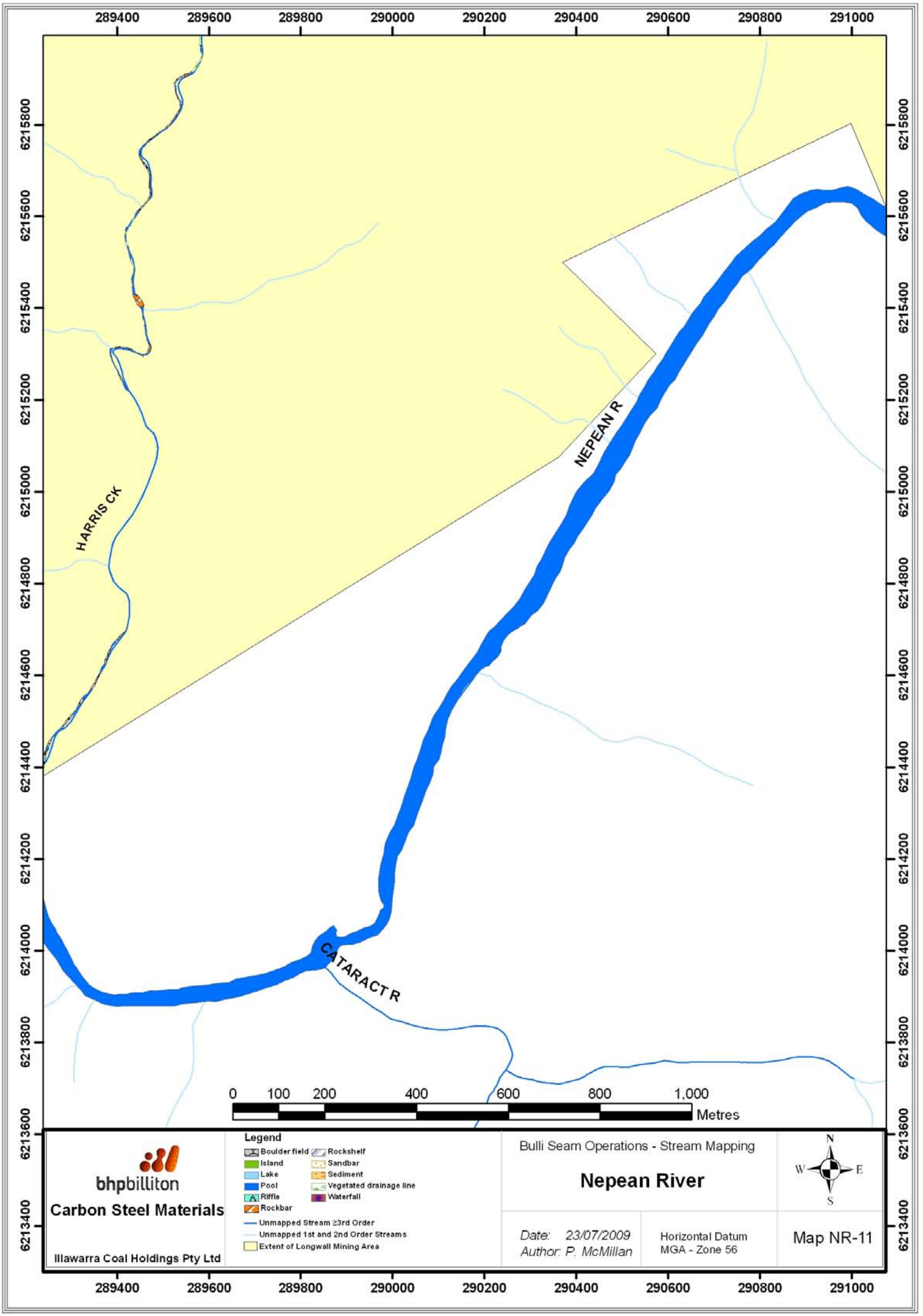
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map NR-10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NEPEAN R
CATARACT R
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1,000
Metres
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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
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Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Nepean River
N
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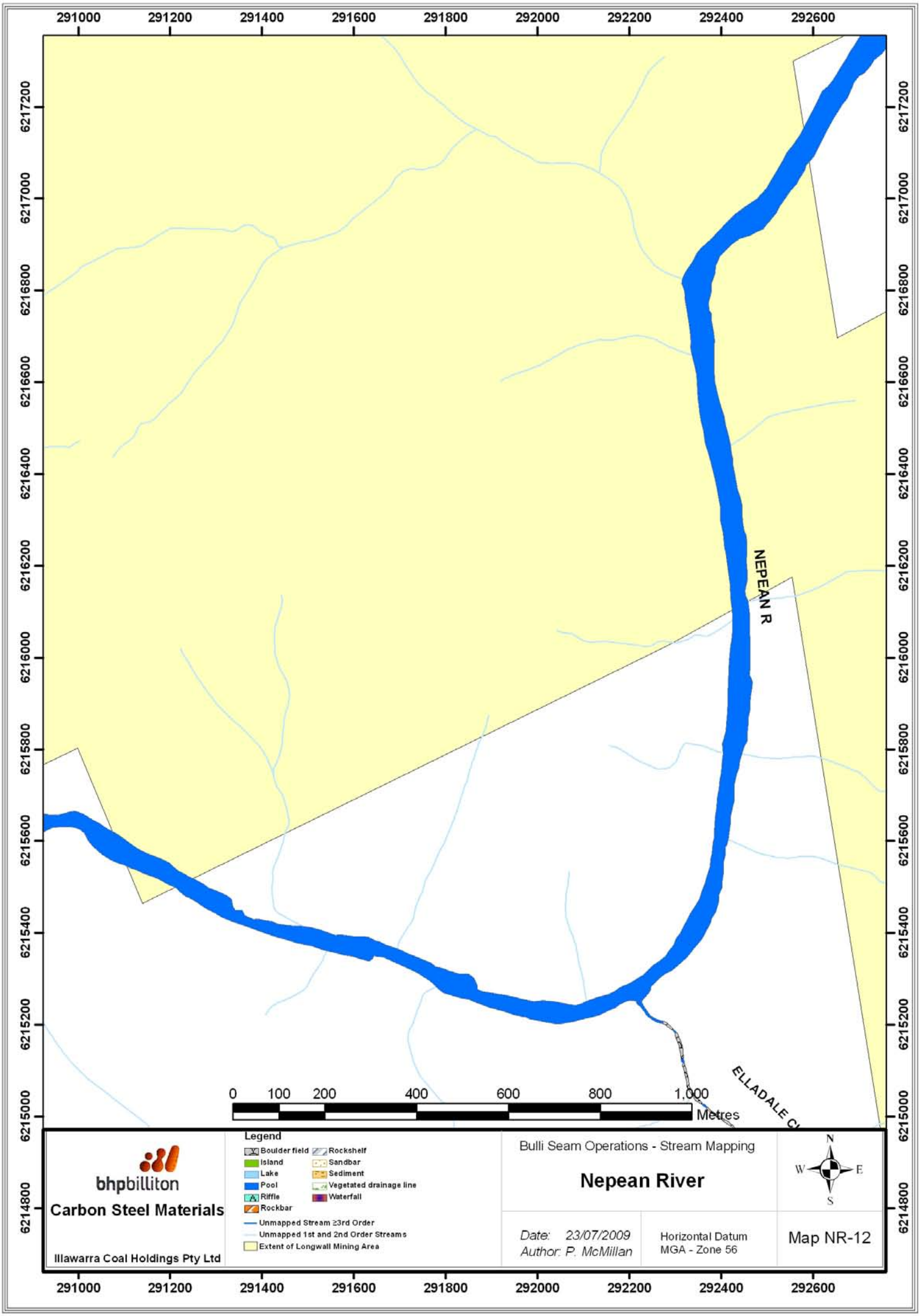
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map NR-11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Metres
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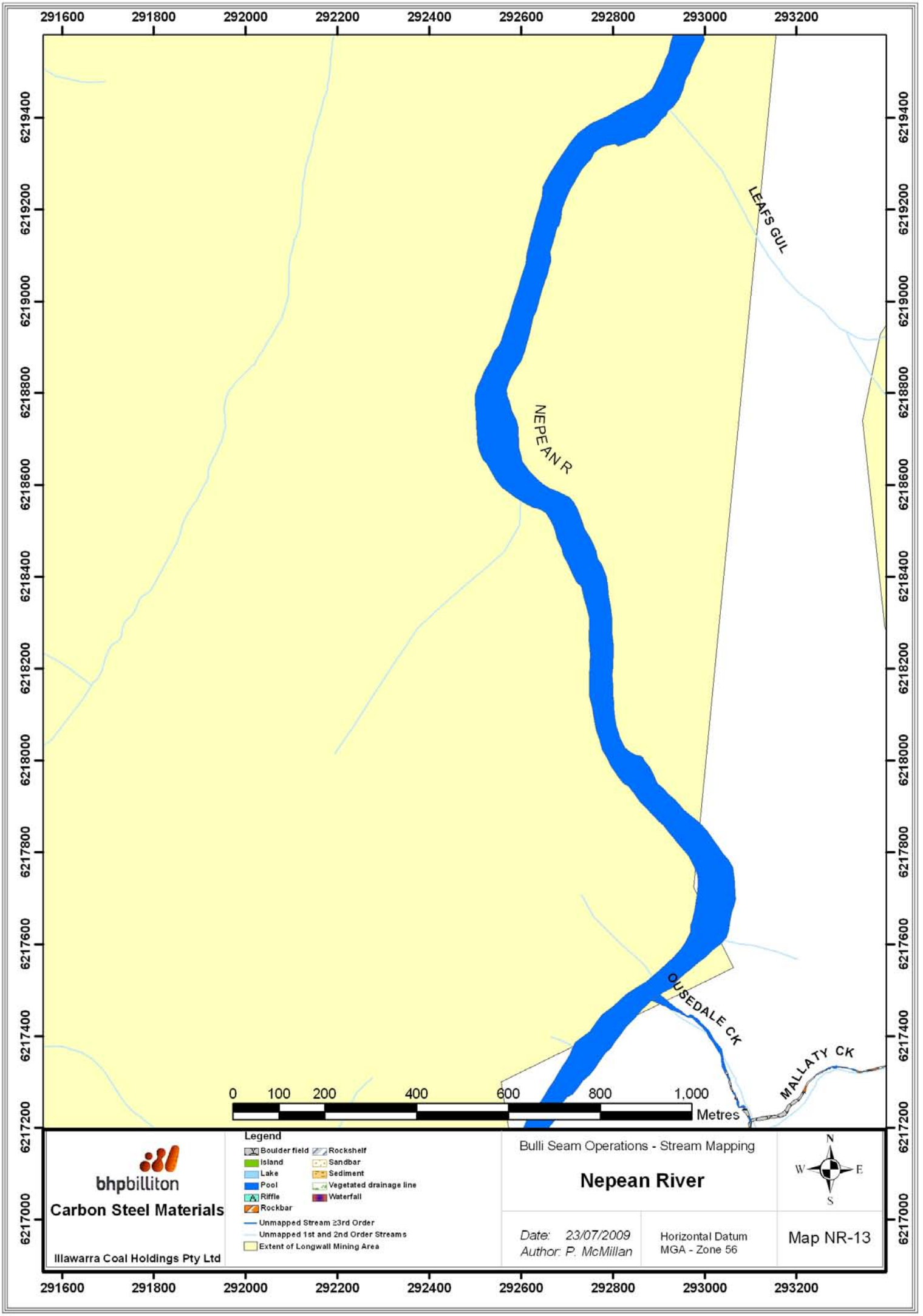
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Nepean River
N
W
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map NR-12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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
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Sediment
Pool
Vegetated drainage line
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Waterfall
Rockbar
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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Nepean River
N
W
E
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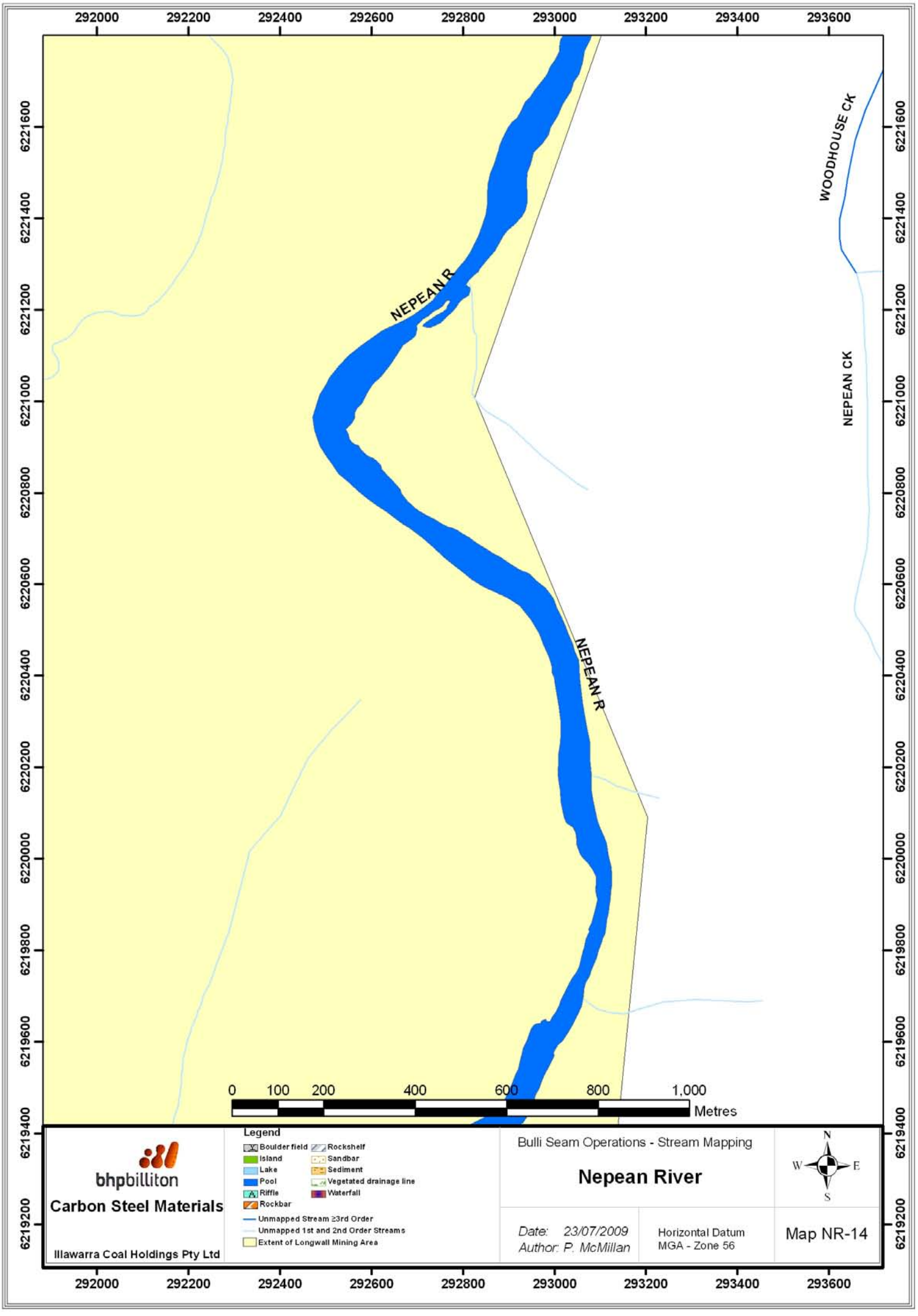
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map NR-13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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
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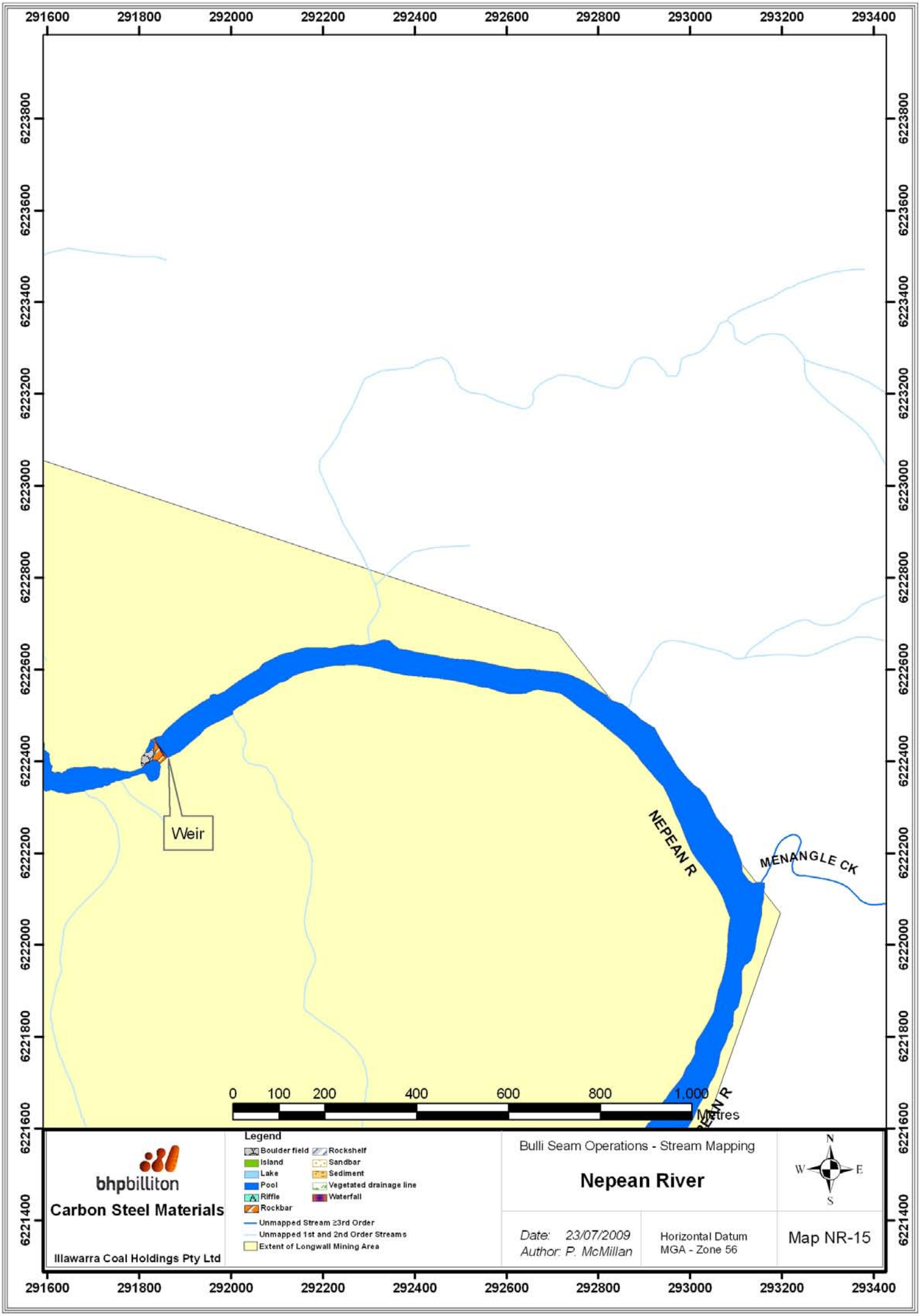
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Nepean River
N
W
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map NR-14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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
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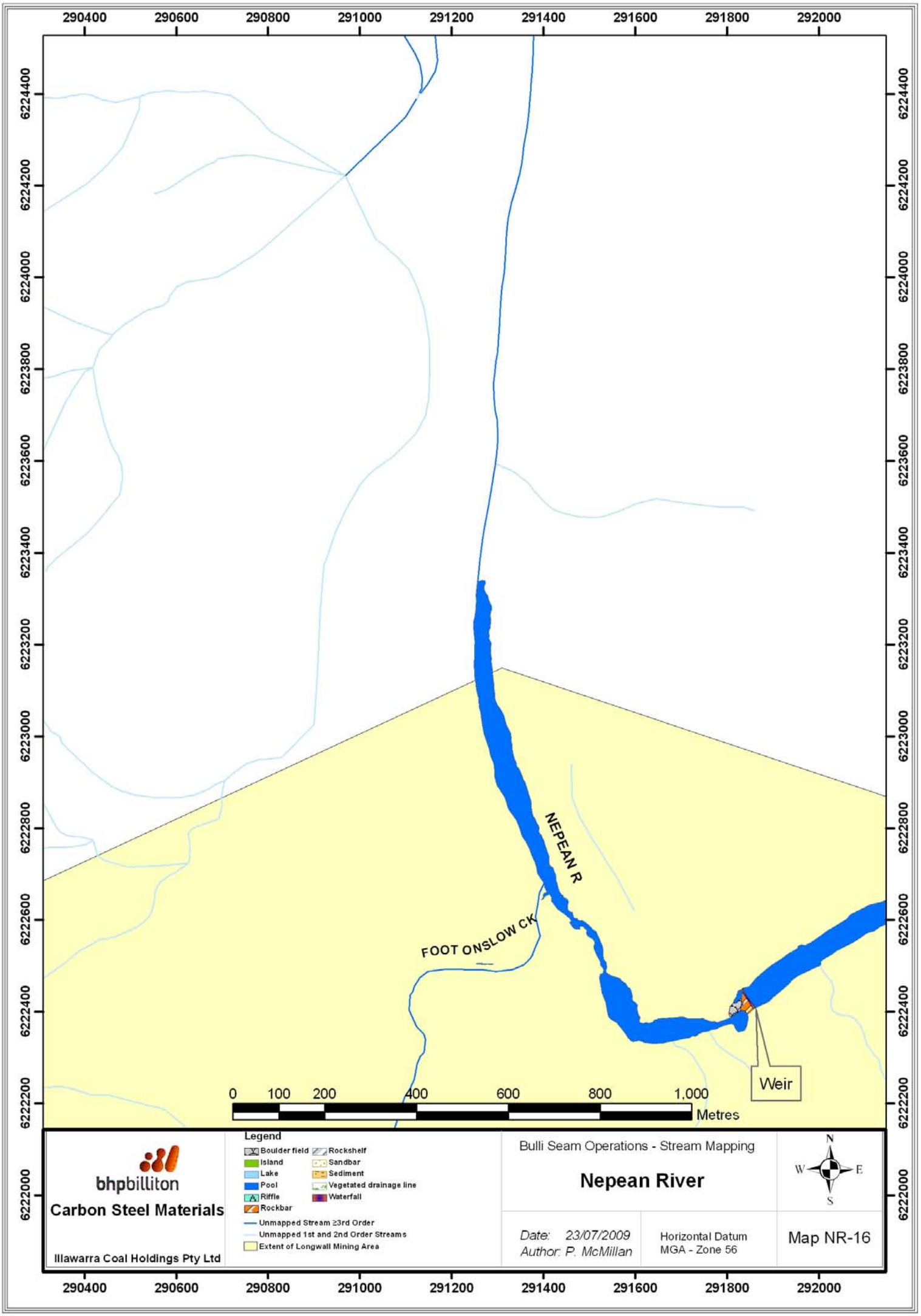
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Nepean River
N
W
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map NR-15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Metres
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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
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N
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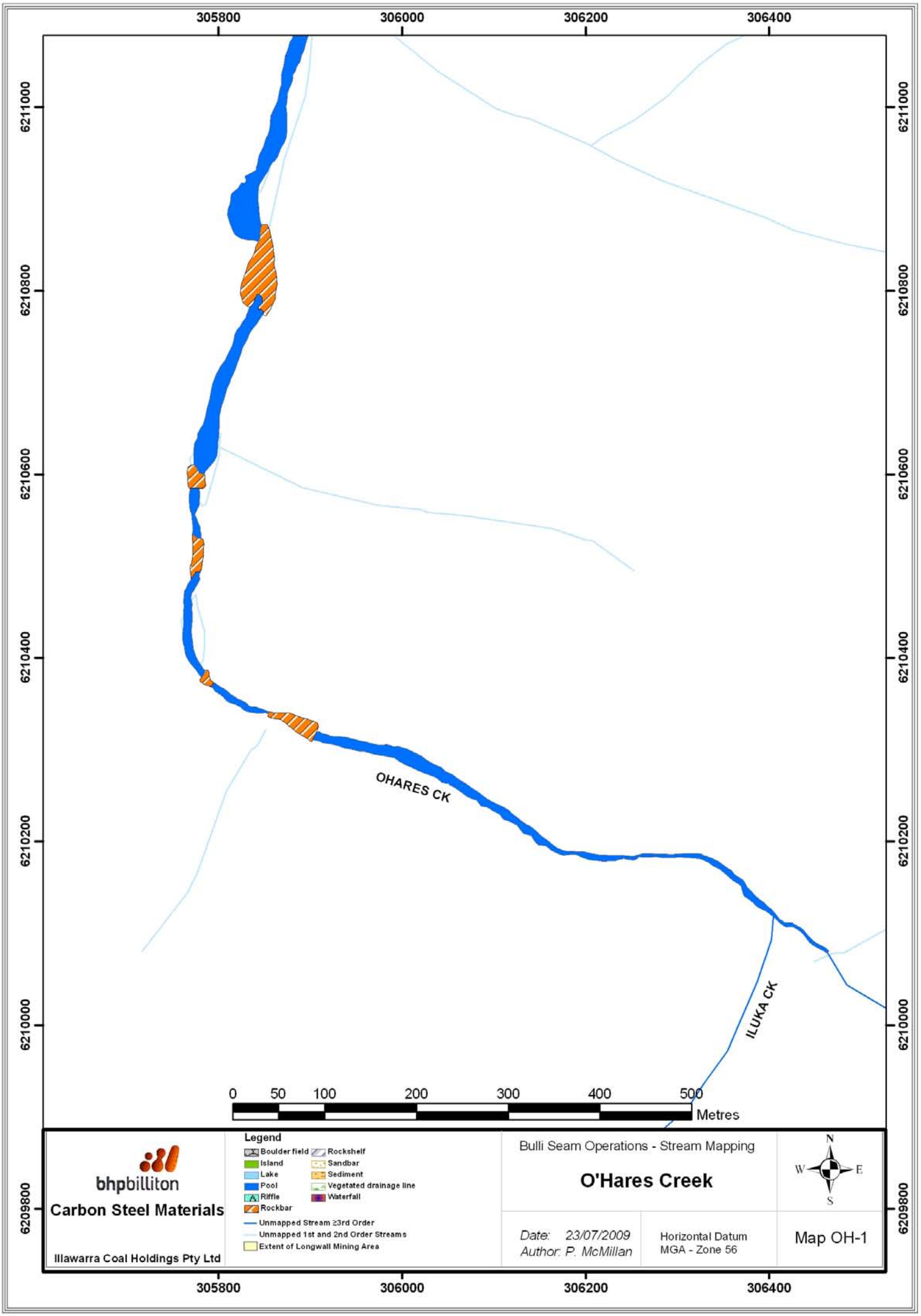
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map NR-16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Metres
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
O'Hares Creek
N
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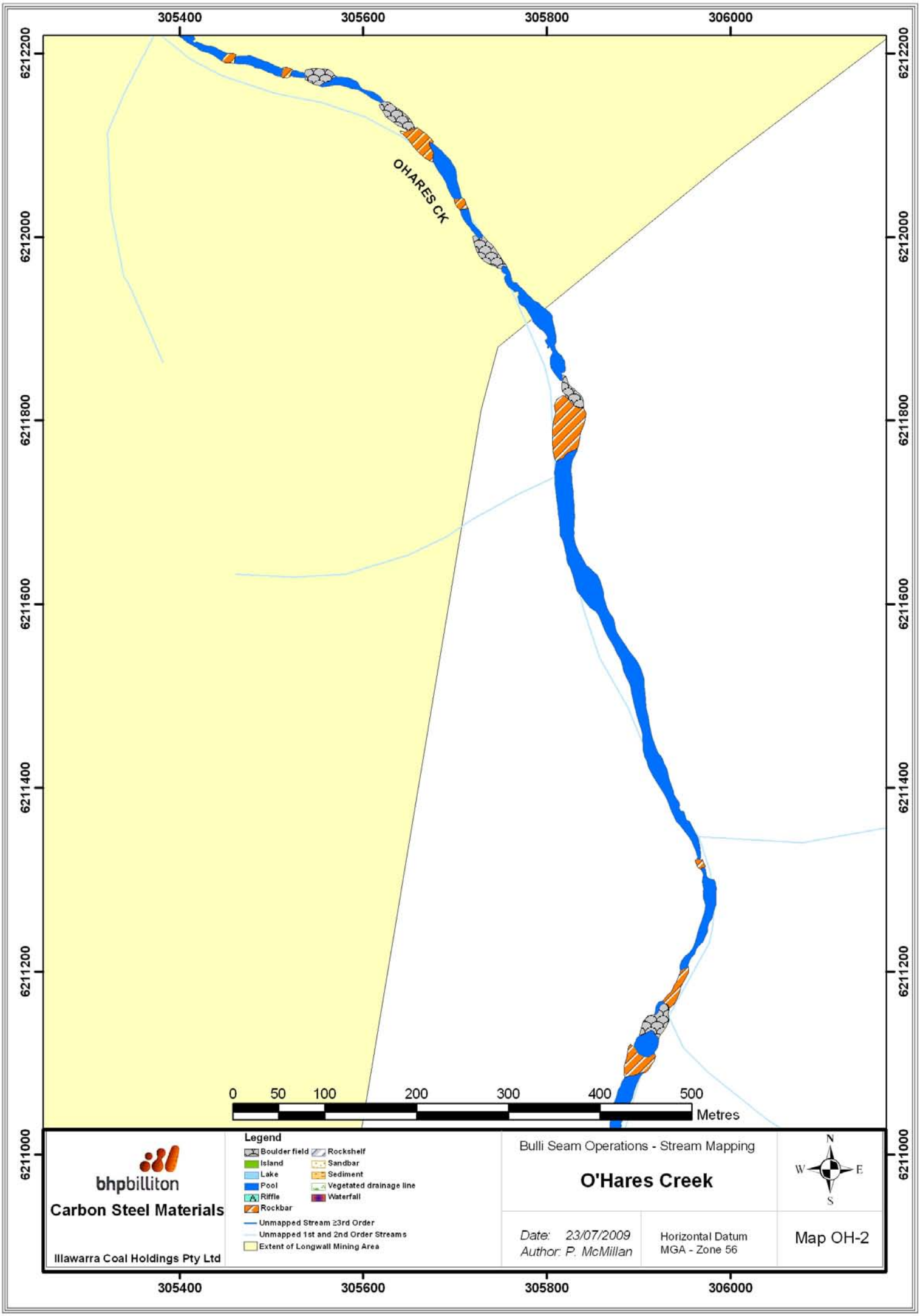
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map OH-1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Metres
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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
O'Hares Creek
N
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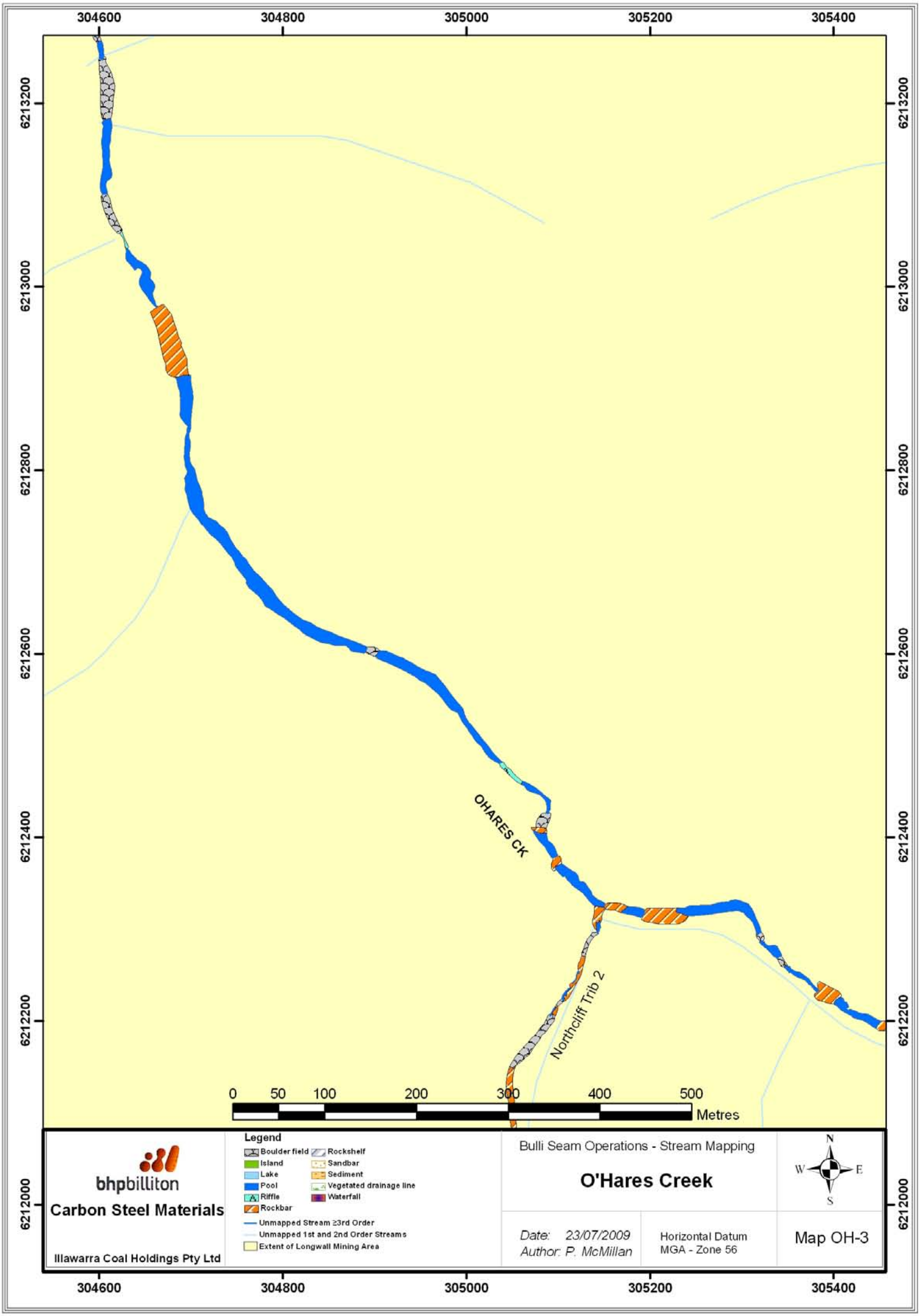
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map OH-2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bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
O'Hares Creek
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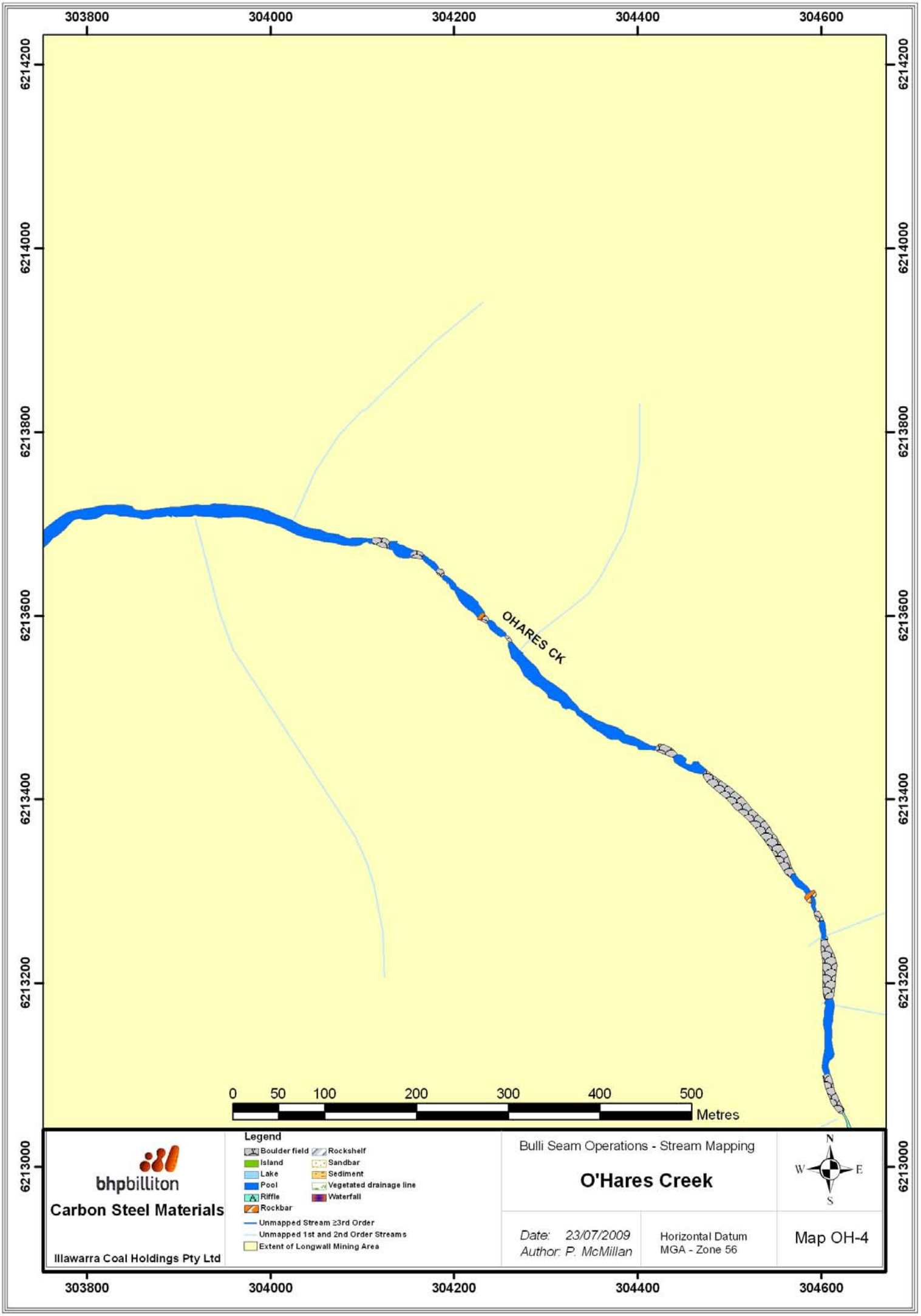
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map OH-3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Carbon Steel Materials
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Legend
Boulder field
Rockshelf
Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
O'Hares Creek
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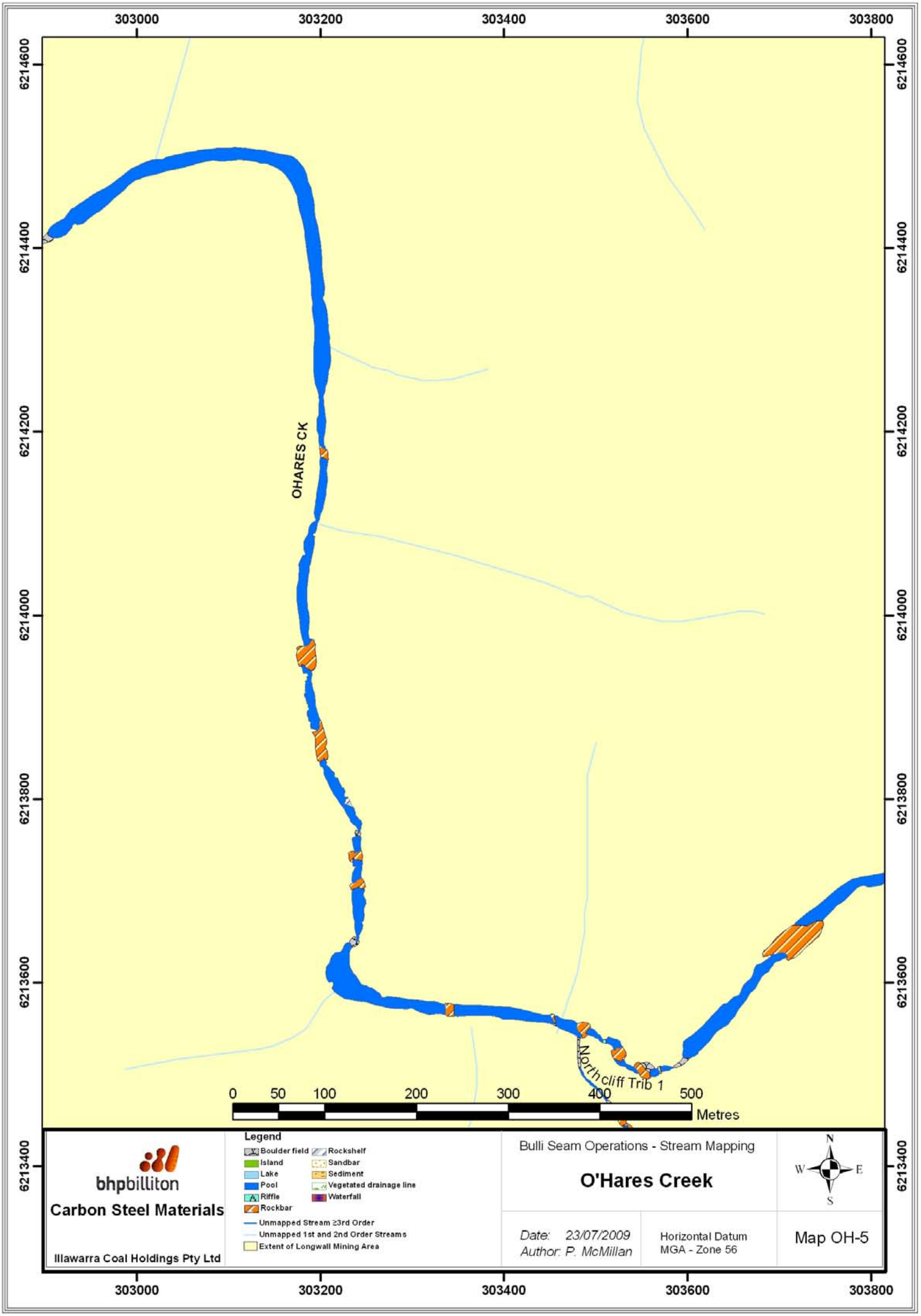
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map OH-4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Boulder field
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Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
O'Hares Creek
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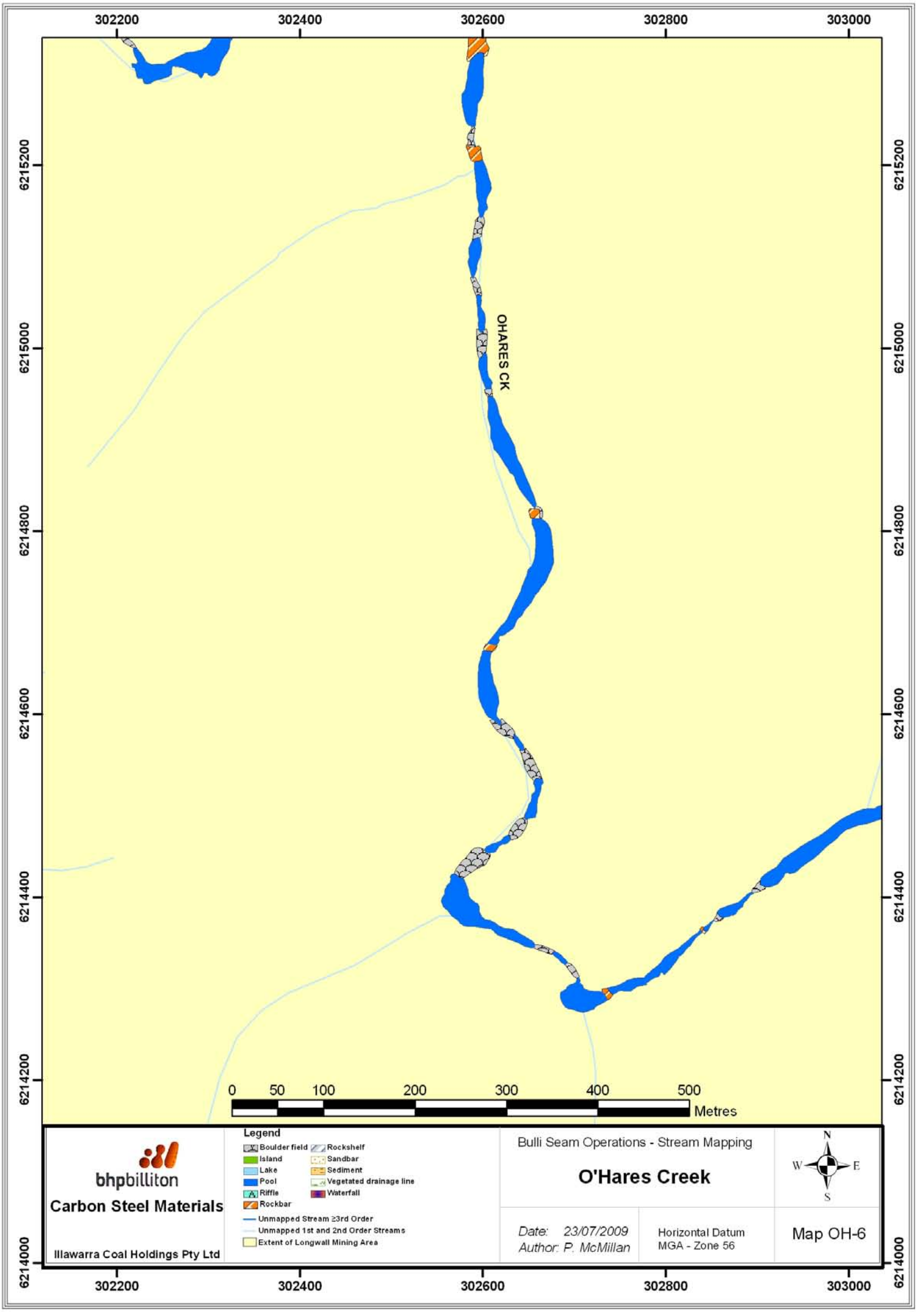
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map OH-5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Legend
Boulder field
Rockshelf
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Sandbar
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Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
O'Hares Creek
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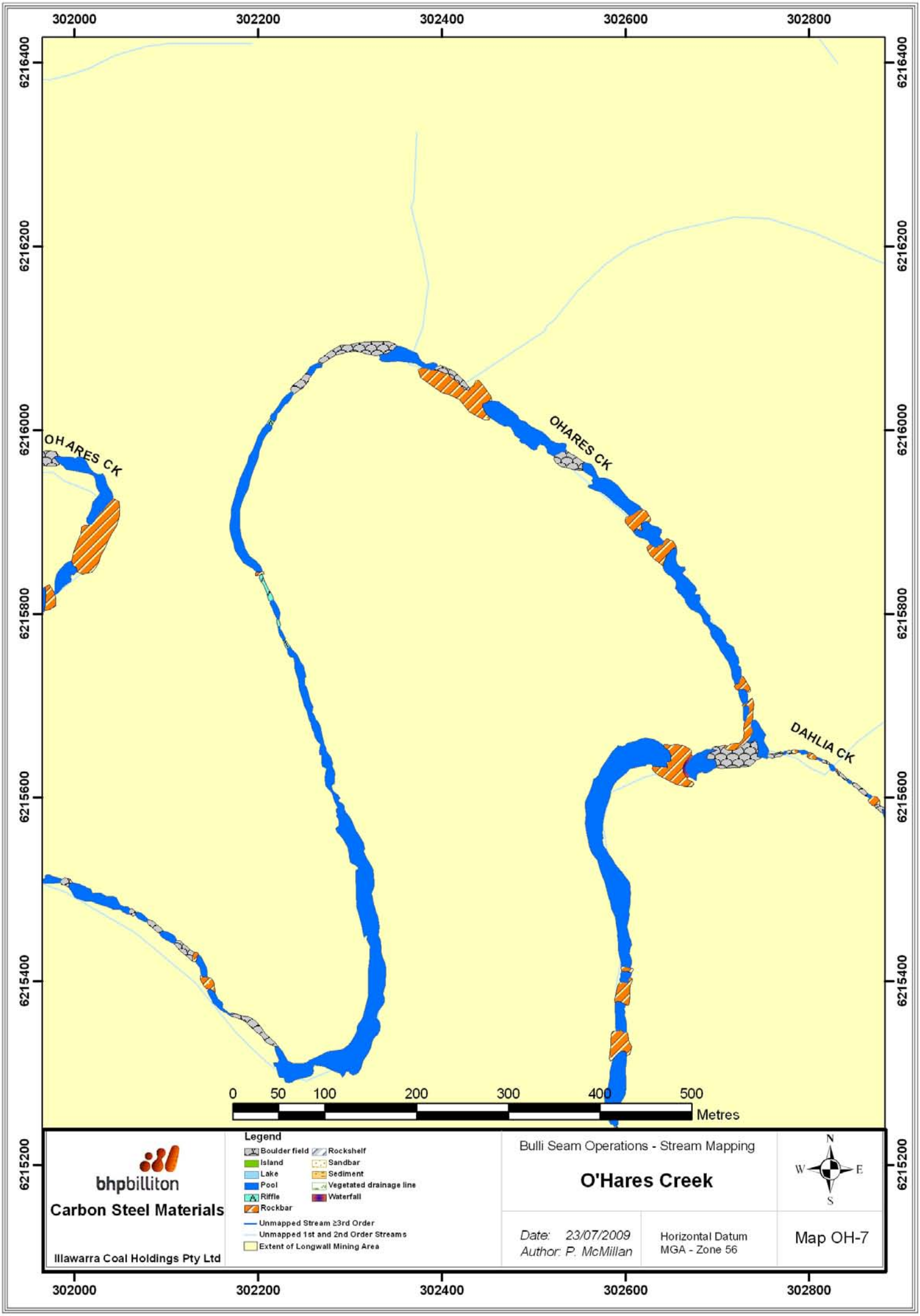
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map OH-6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Boulder field
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Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
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O'Hares Creek
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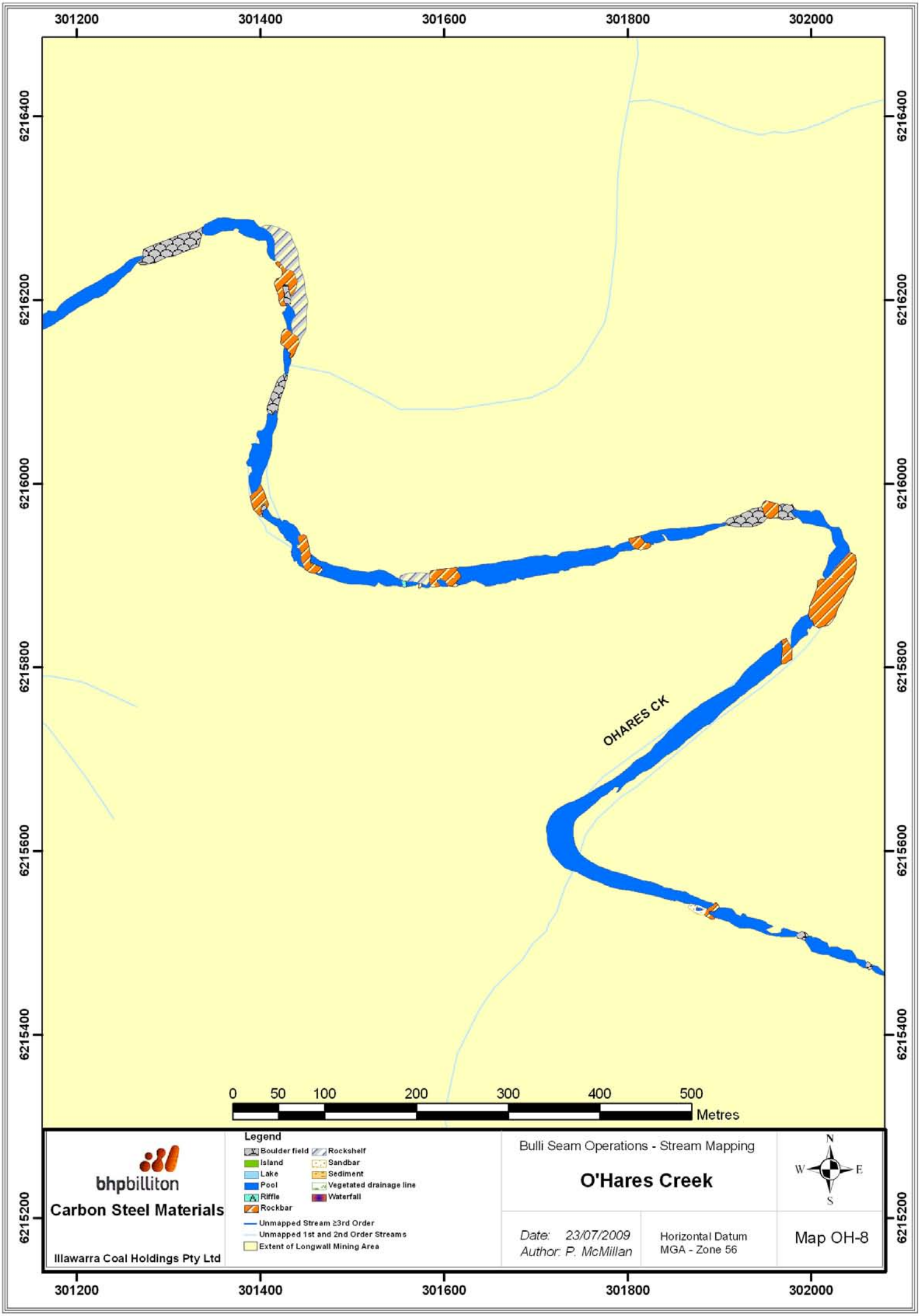
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map OH-7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Carbon Steel Materials
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Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
O'Hares Creek
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
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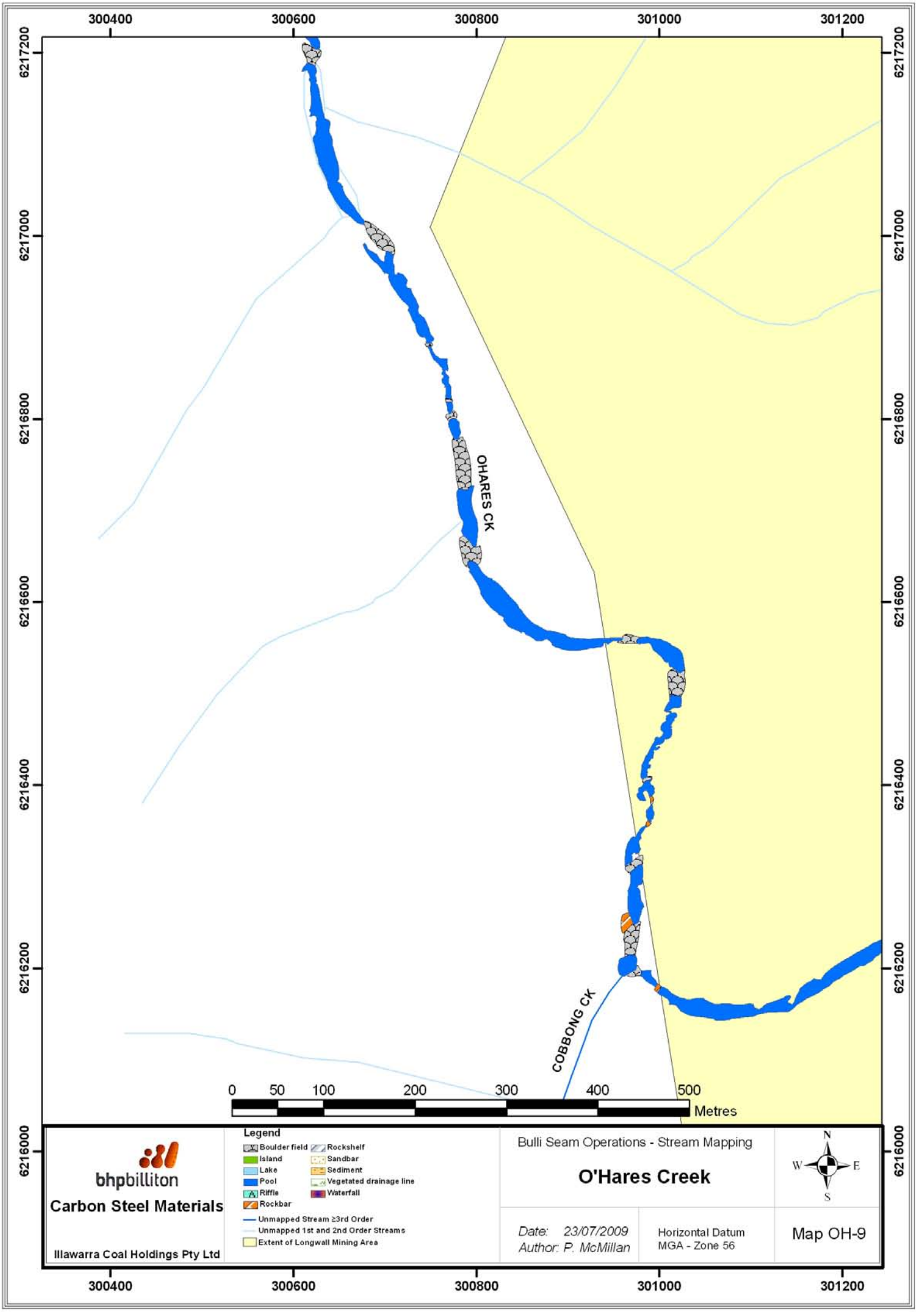
Map OH-8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Pool
Vegetated drainage line
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Waterfall
Rockbar
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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
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O'Hares Creek
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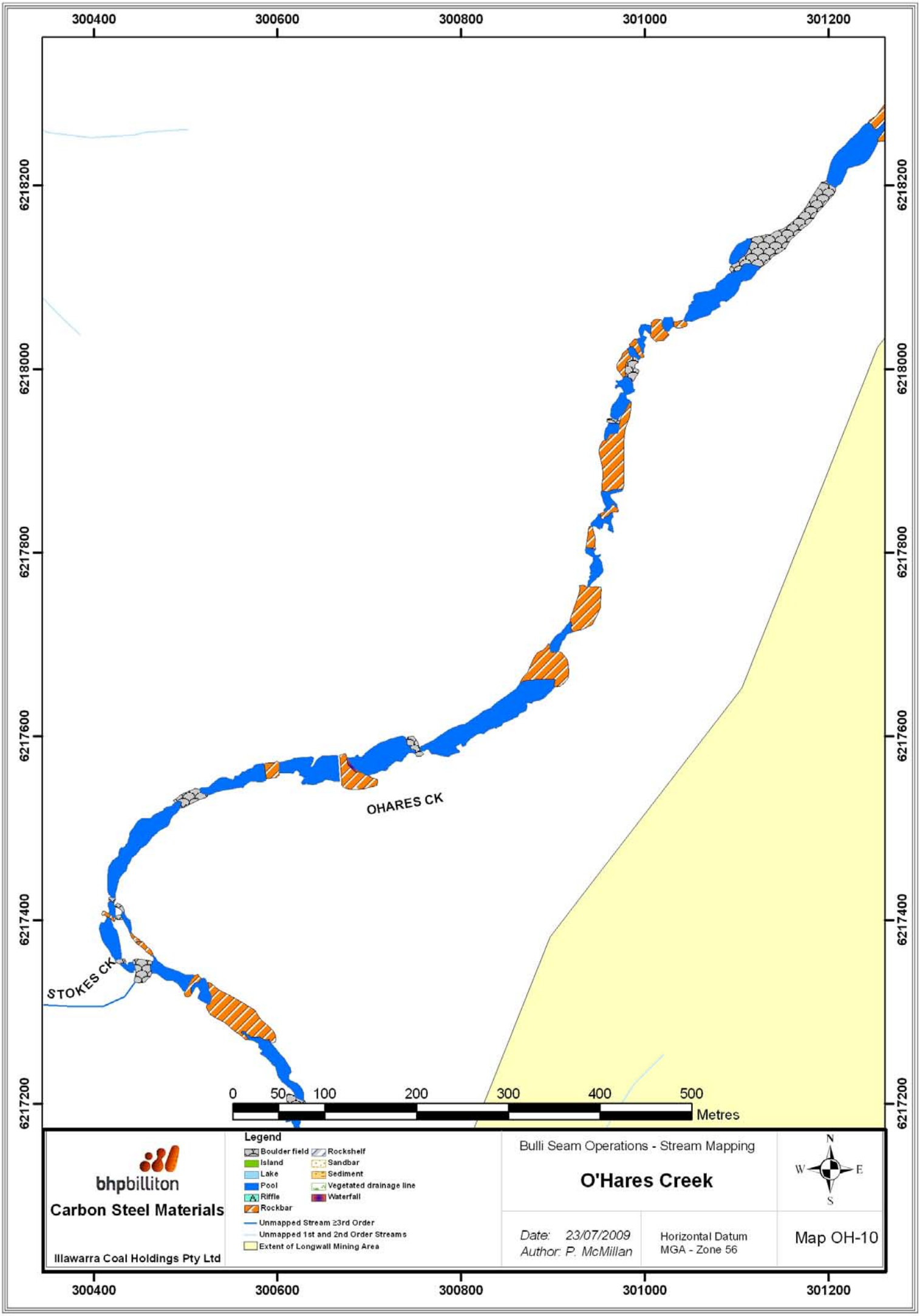
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map OH-9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Waterfall
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Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Bulli Seam Operations - Stream Mapping
O'Hares Creek
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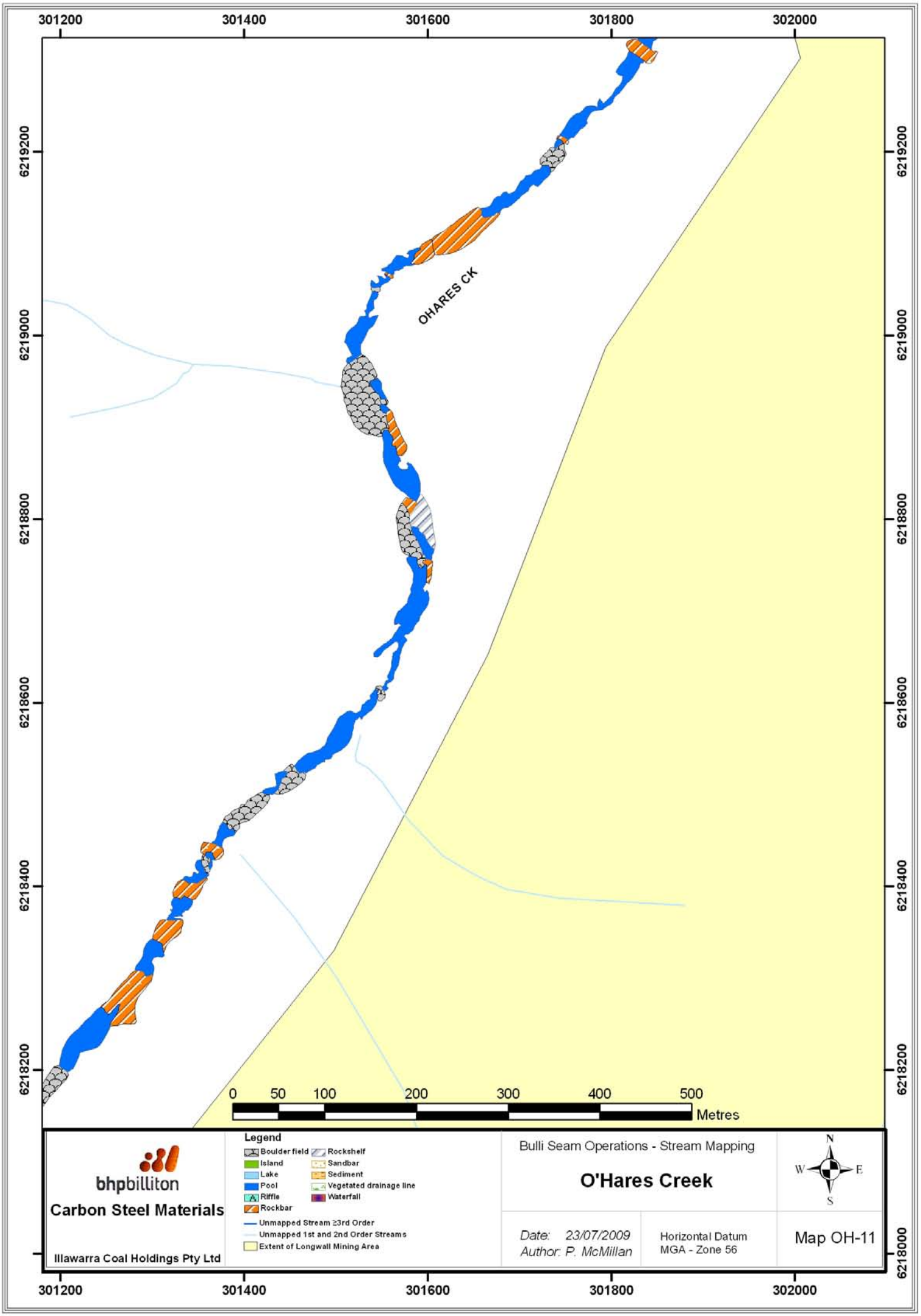
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map OH-10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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
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Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
O'Hares Creek
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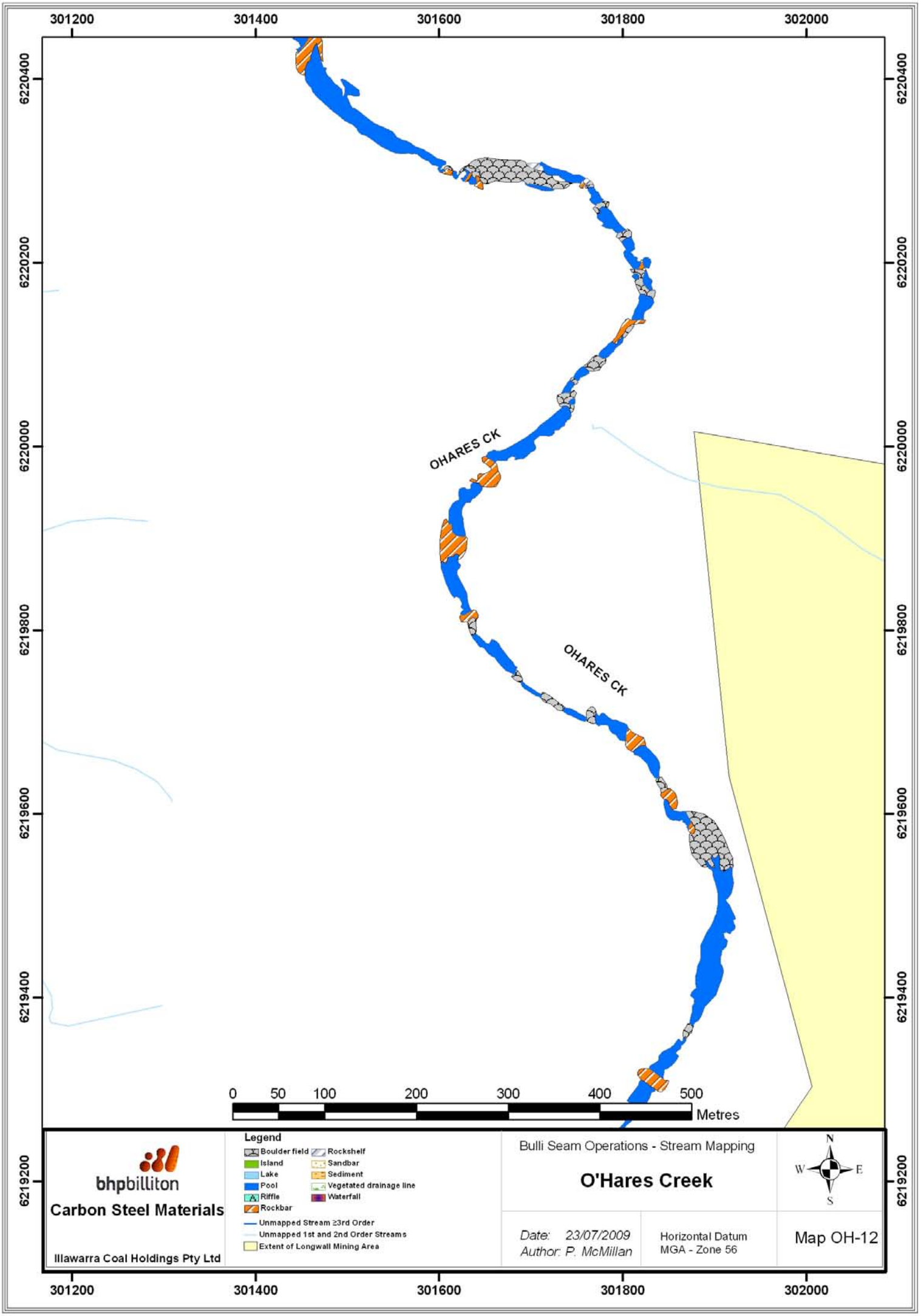
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map OH-11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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
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Vegetated drainage line
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Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
O'Hares Creek
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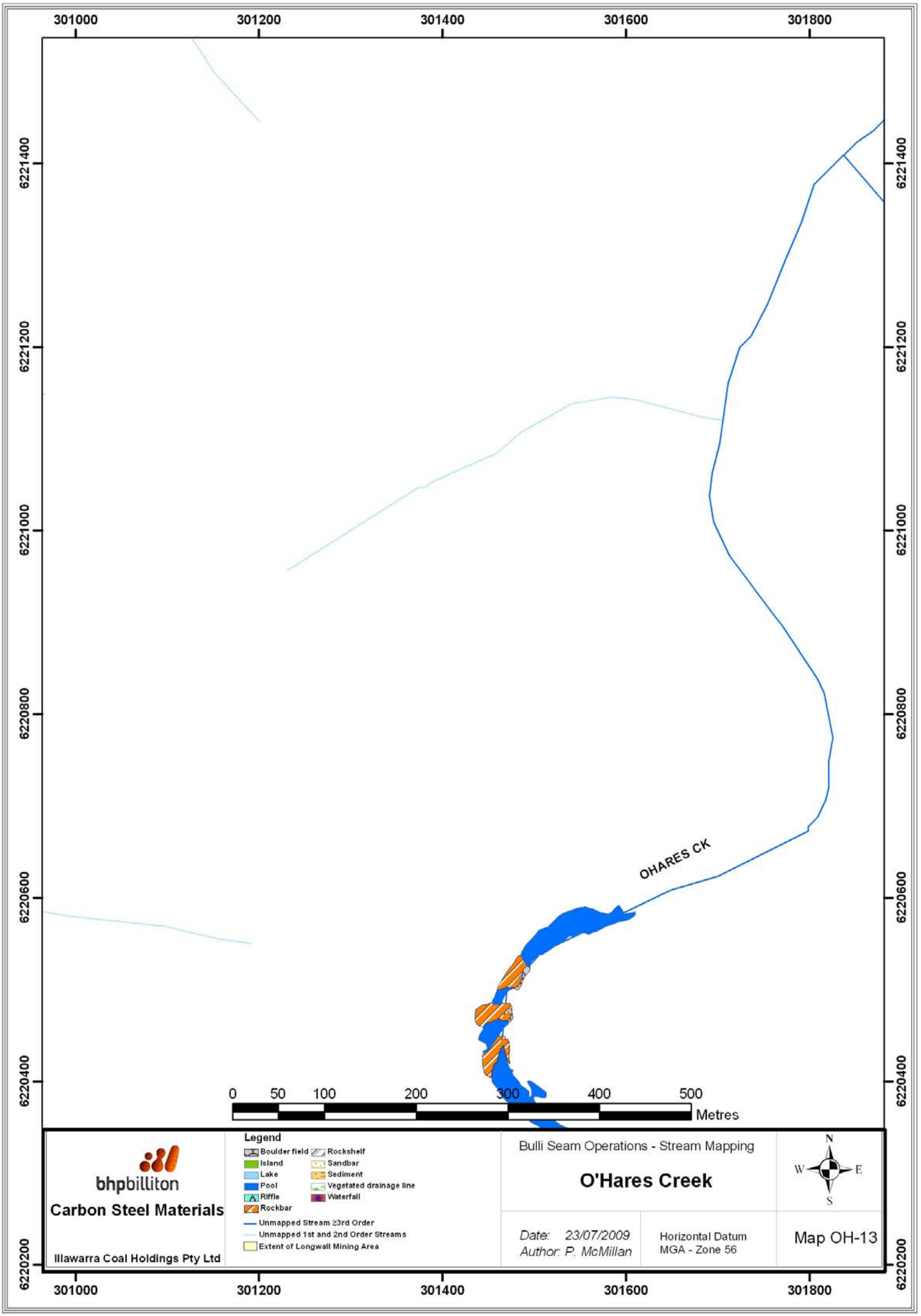
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map OH-12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Legend
Boulder field
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Island
Sandbar
Lake
Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Bulli Seam Operations - Stream Mapping
O'Hares Creek
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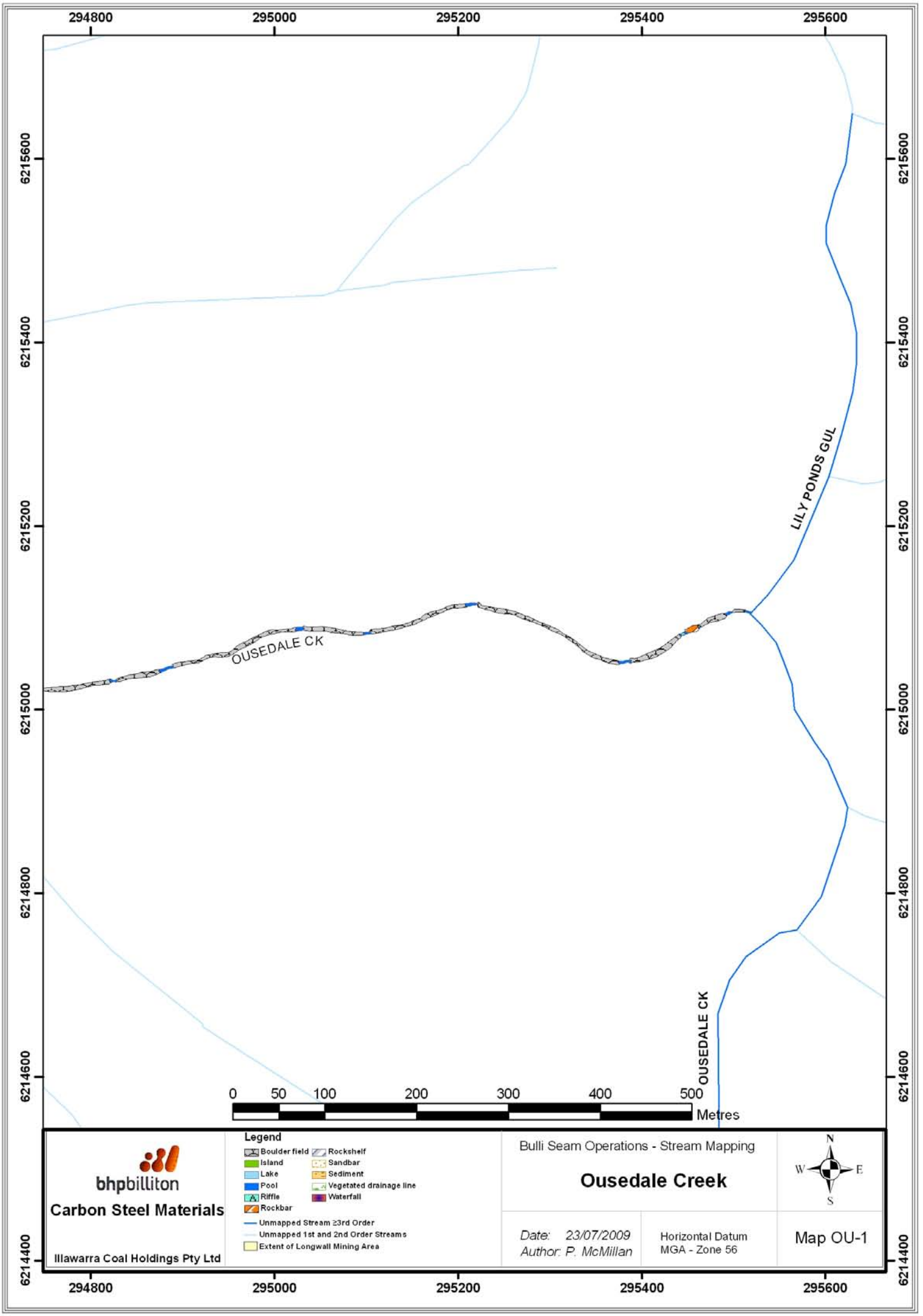
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map OH-13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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
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Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Ousedale Creek
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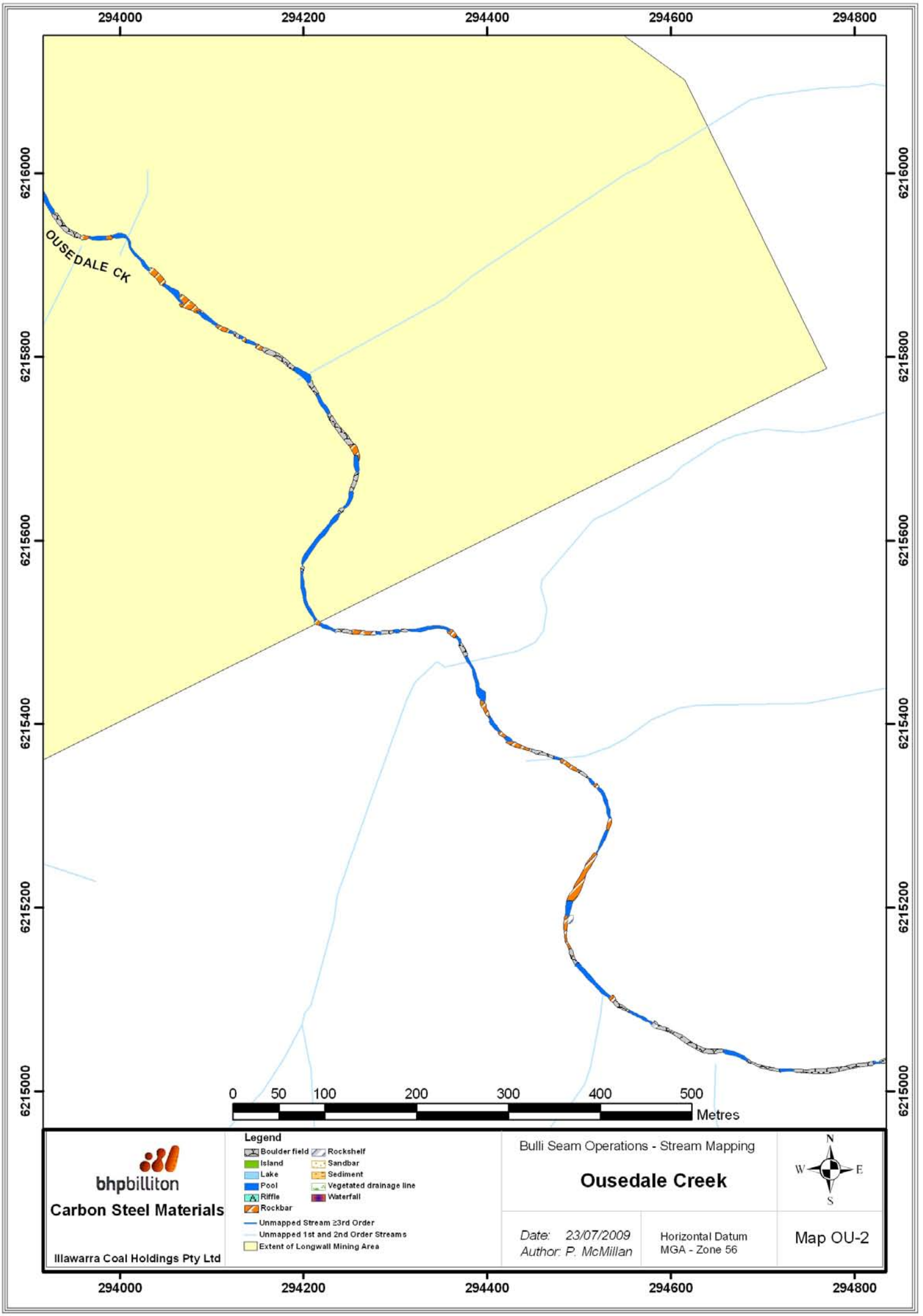
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map OU-1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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
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Sandbar
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Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Ousedale Creek
N
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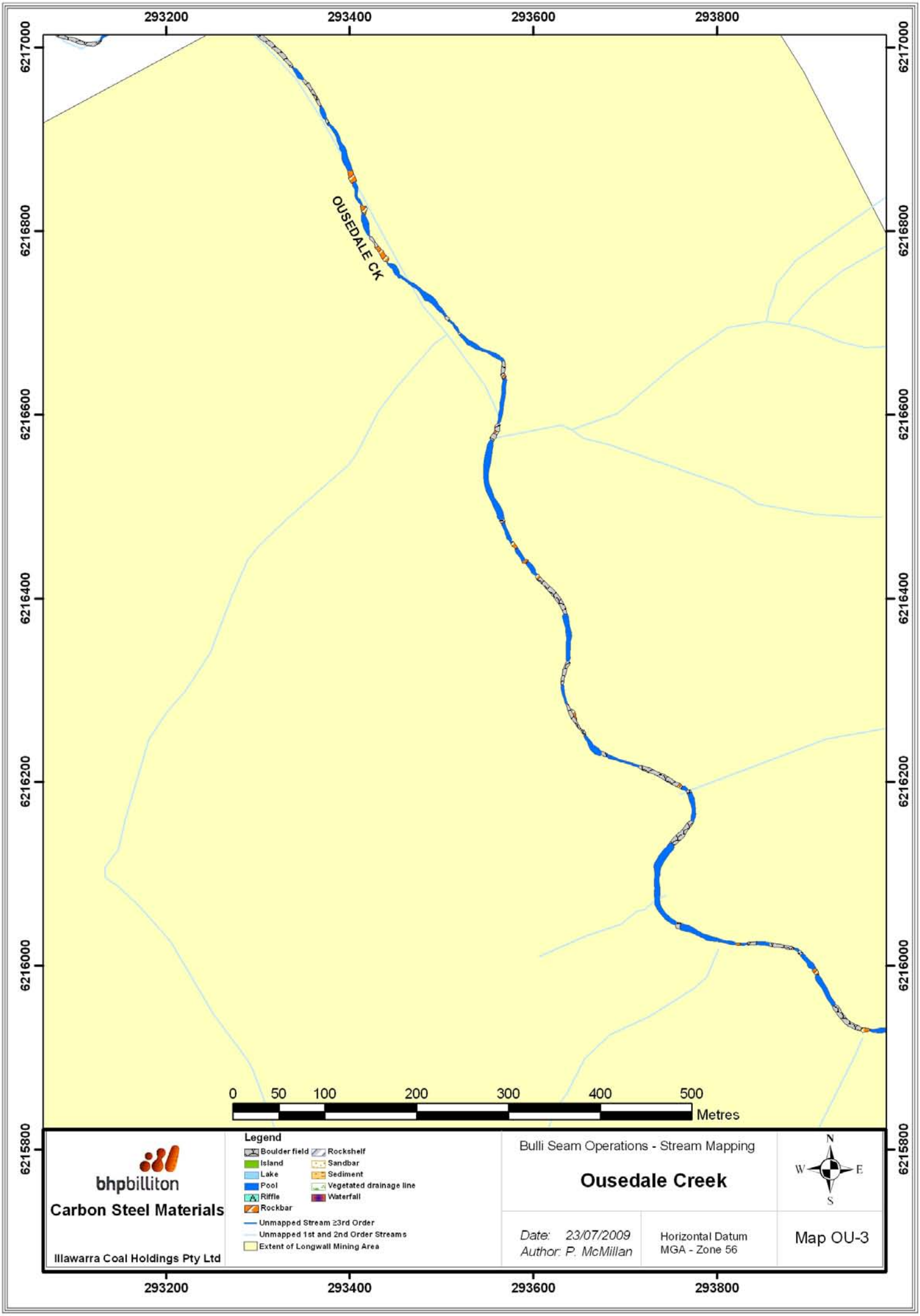
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map OU-2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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
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Boulder field
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Pool
Vegetated drainage line
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Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Ousedale Creek
N
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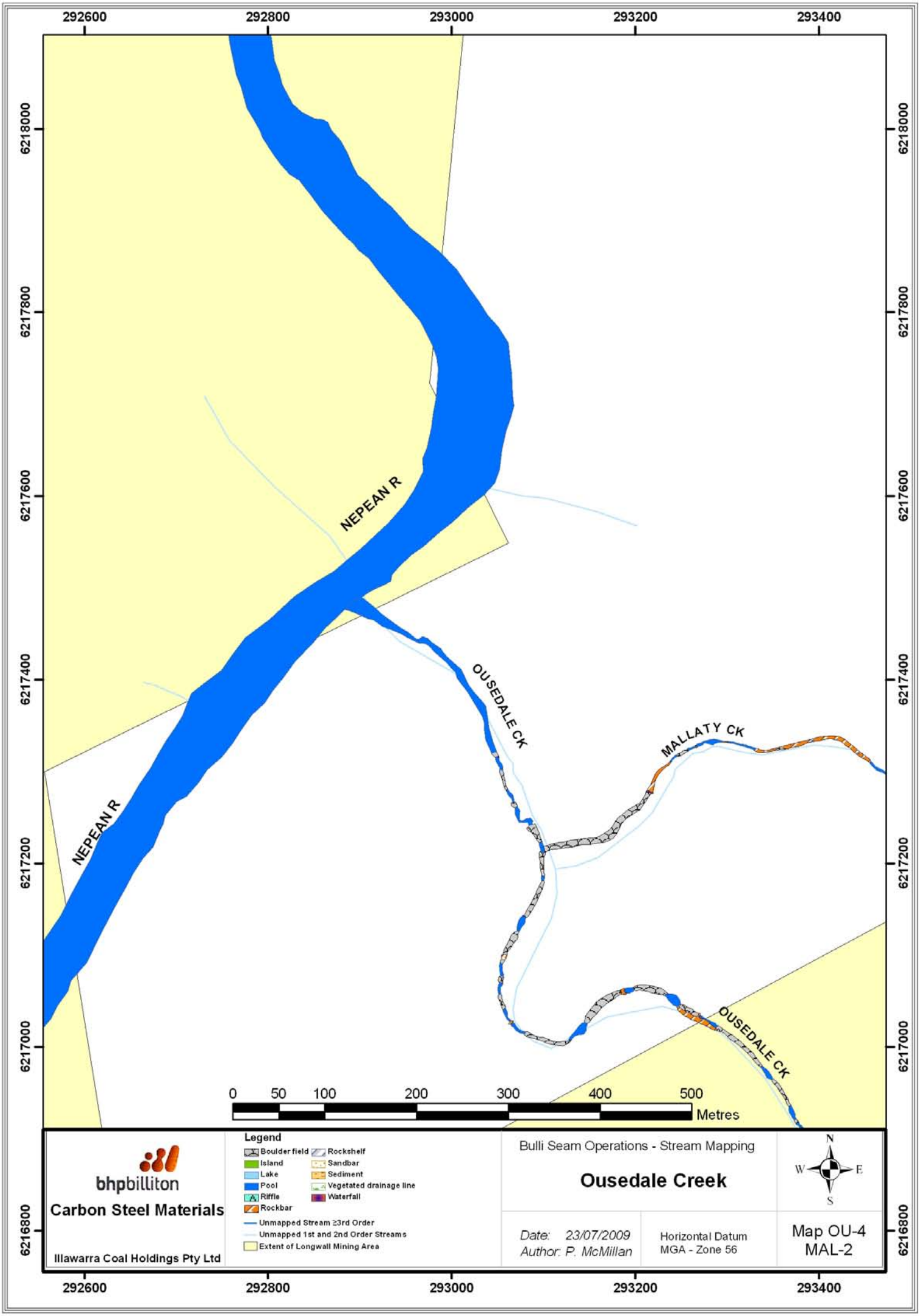
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map OU-3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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
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Pool
Vegetated drainage line
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Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
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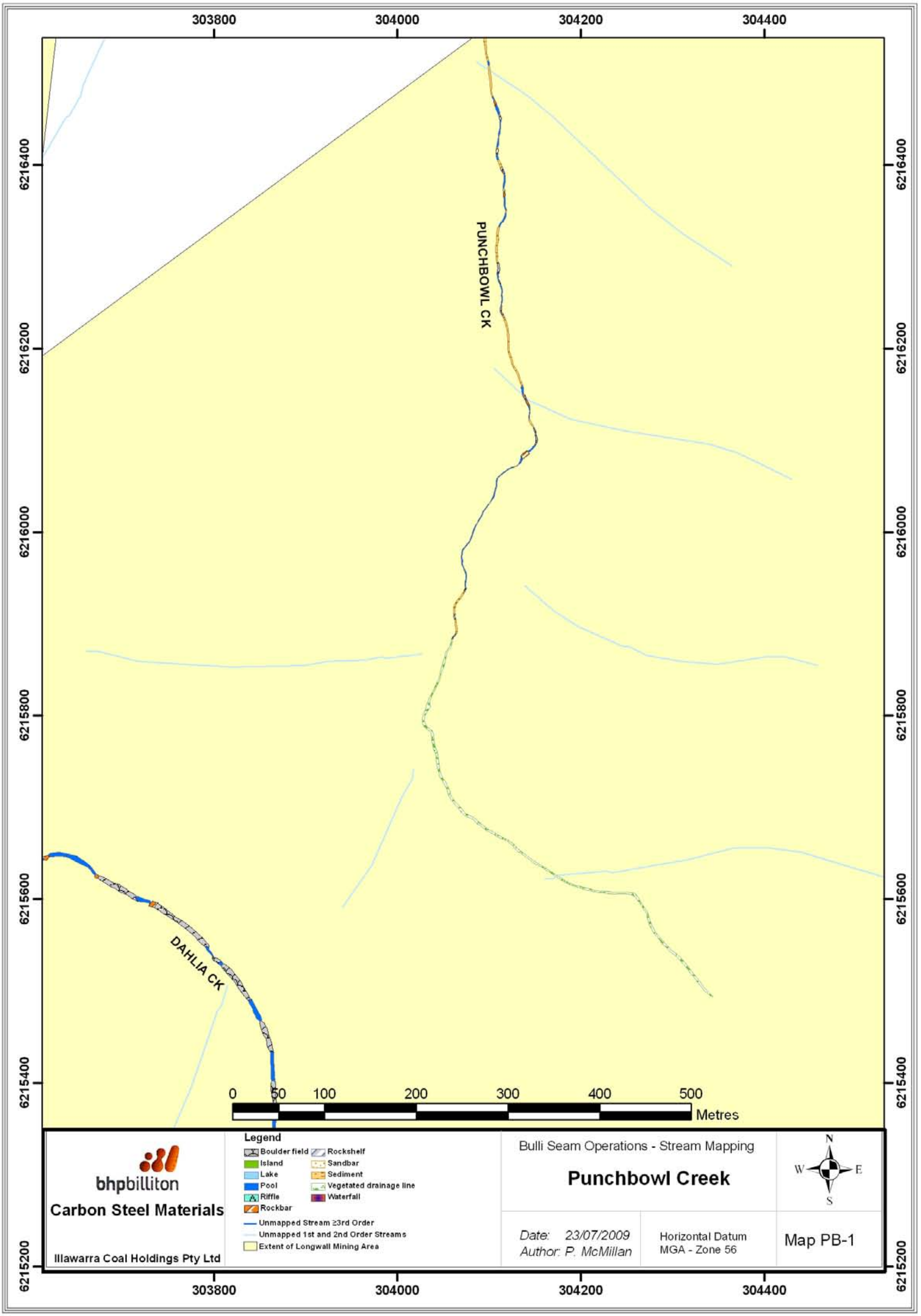
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map OU-4
MAL-2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Pool
Vegetated drainage line
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Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Bulli Seam Operations - Stream Mapping
Punchbowl Creek
N
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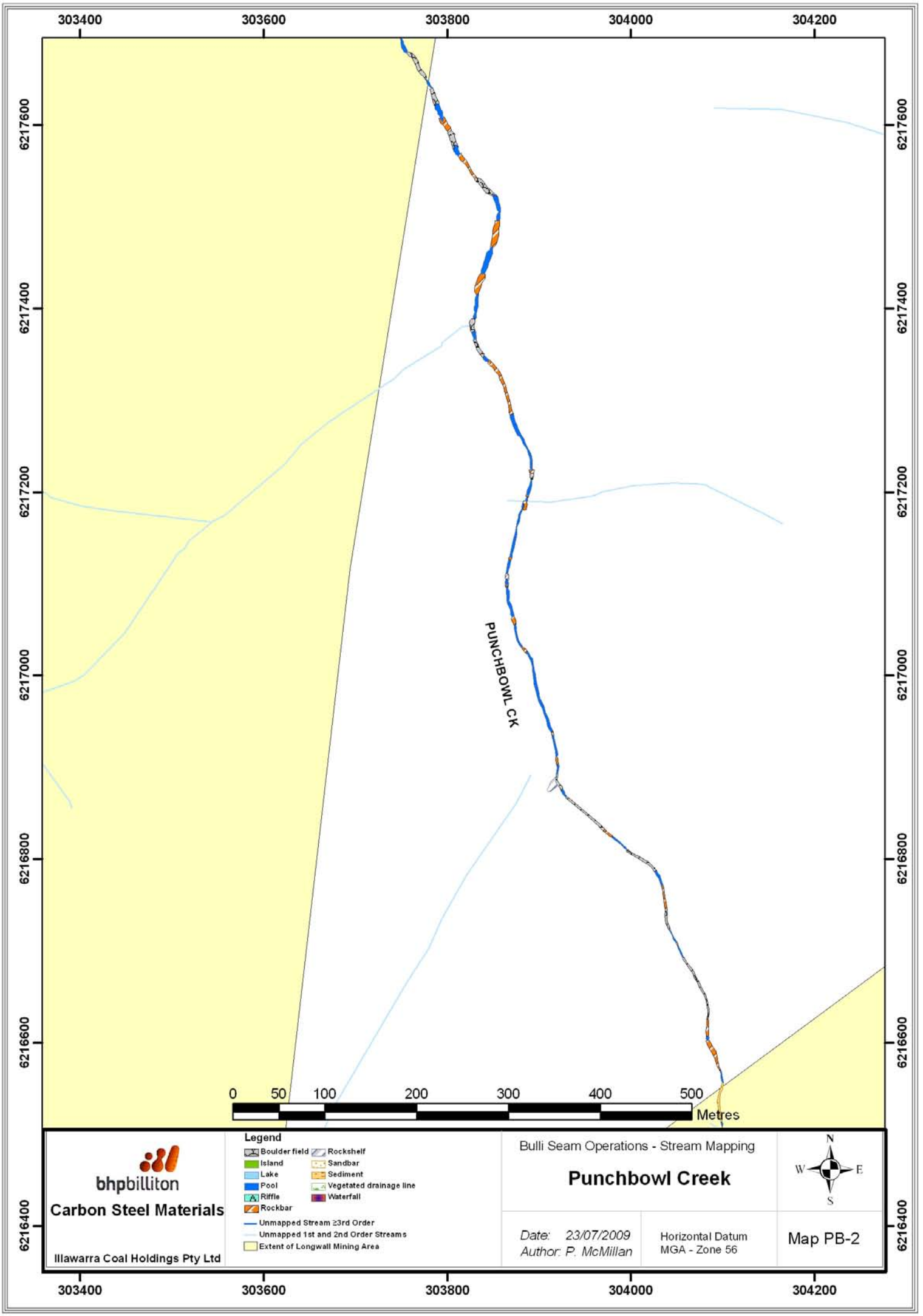
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map PB-1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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
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Boulder field
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Sediment
Pool
Vegetated drainage line
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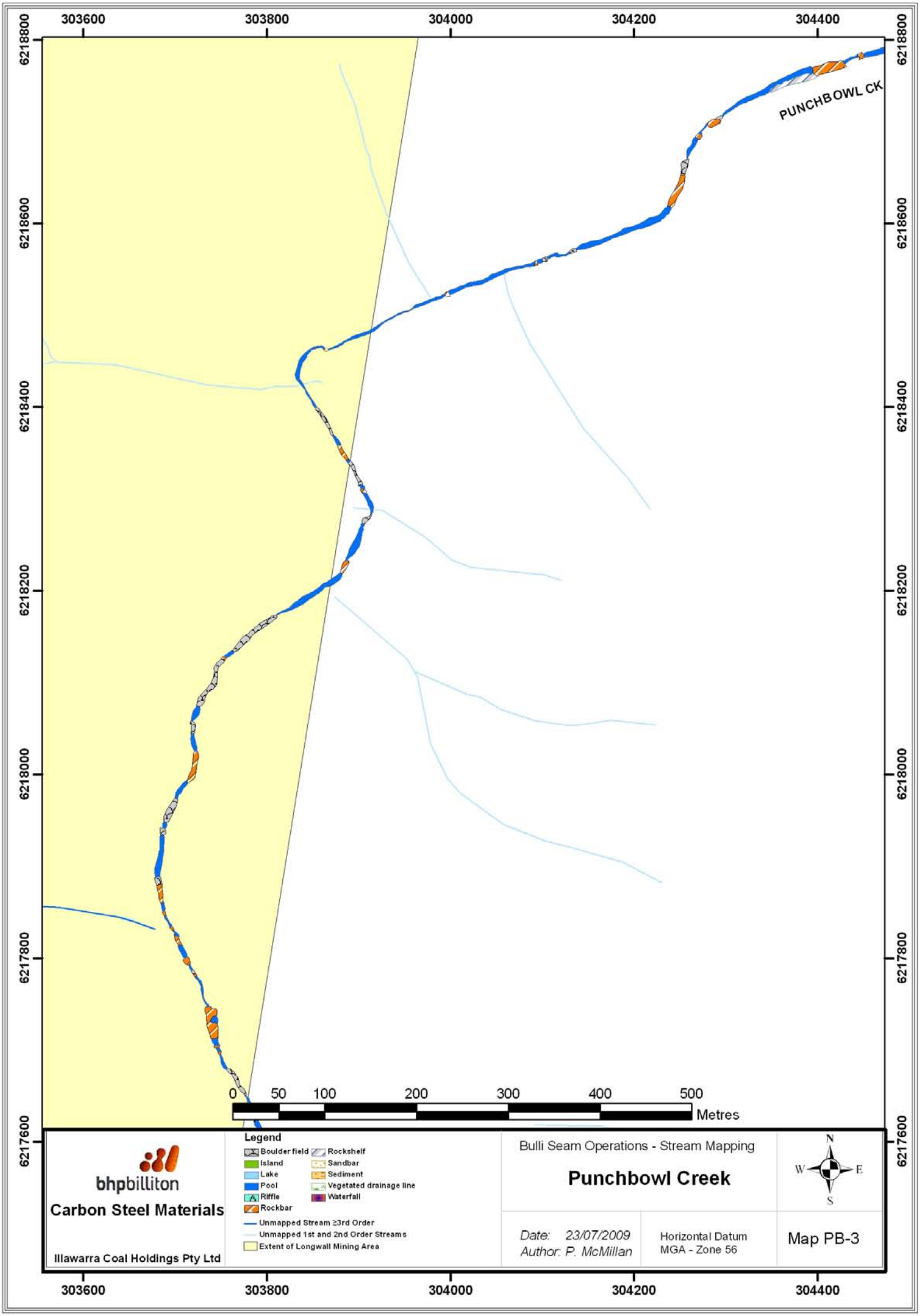
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Punchbowl Creek
N
W
E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map PB-2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Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
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Boulder field
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Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
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Punchbowl Creek
N
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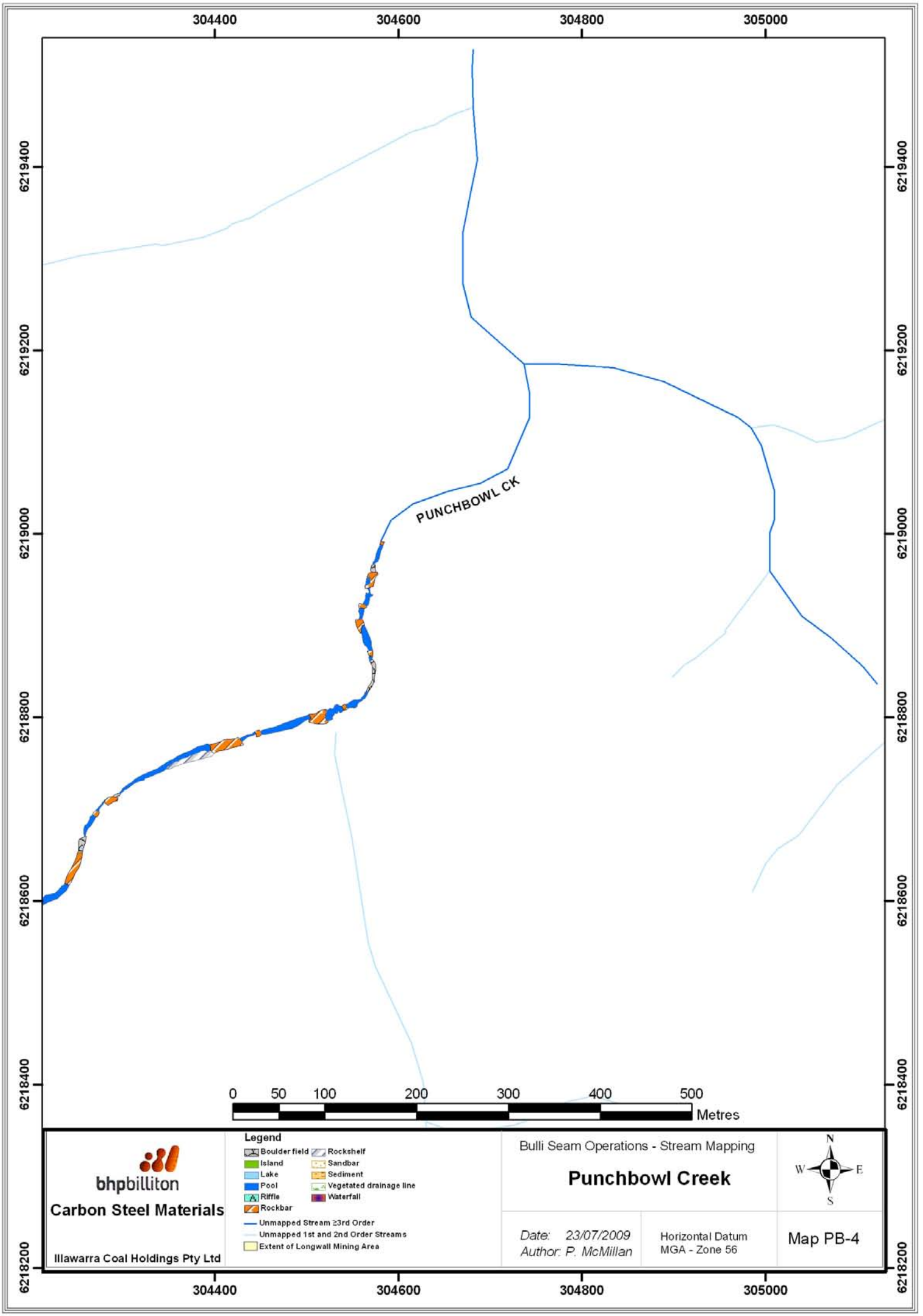
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map PB-3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Metres
bhpbilliton
Carbon Steel Materials
Illawarra Coal Holdings Pty Ltd
Legend
Boulder field
Rockshelf
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Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
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Punchbowl Creek
N
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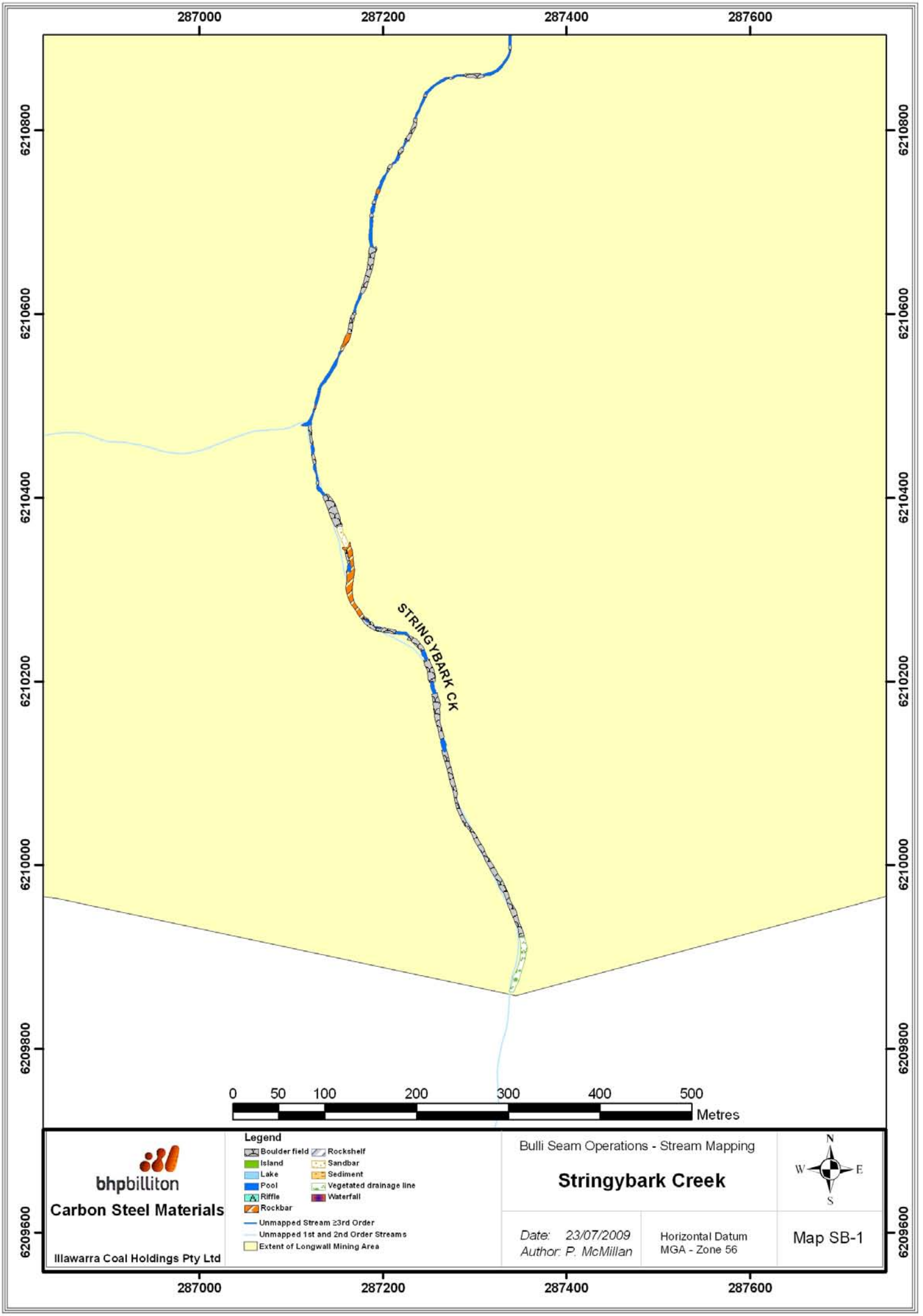
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map PB-4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Sediment
Pool
Vegetated drainage line
Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Stringybark Creek
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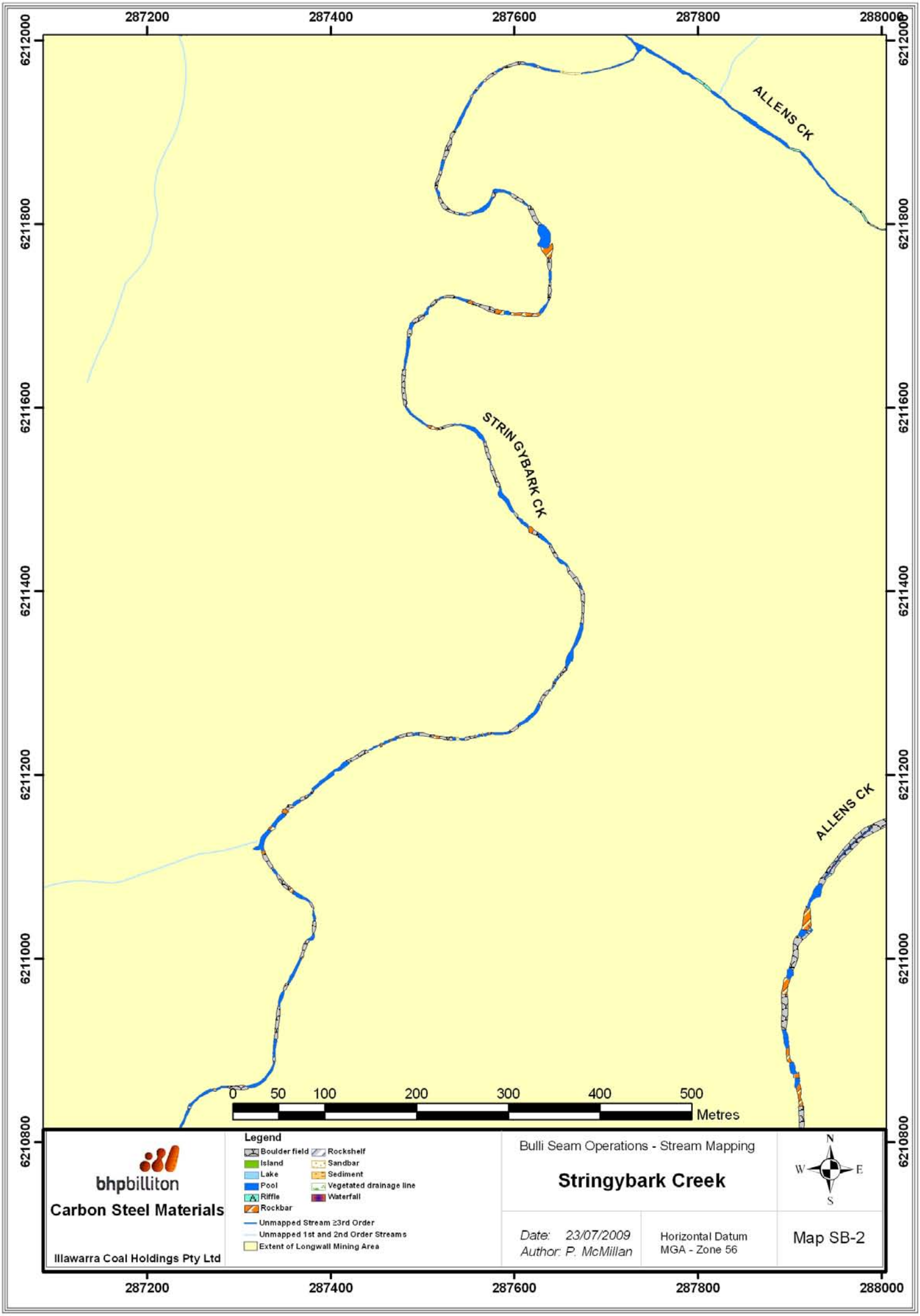
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map SB-1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Extent of Longwall Mining Area
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Author: P. McMillan
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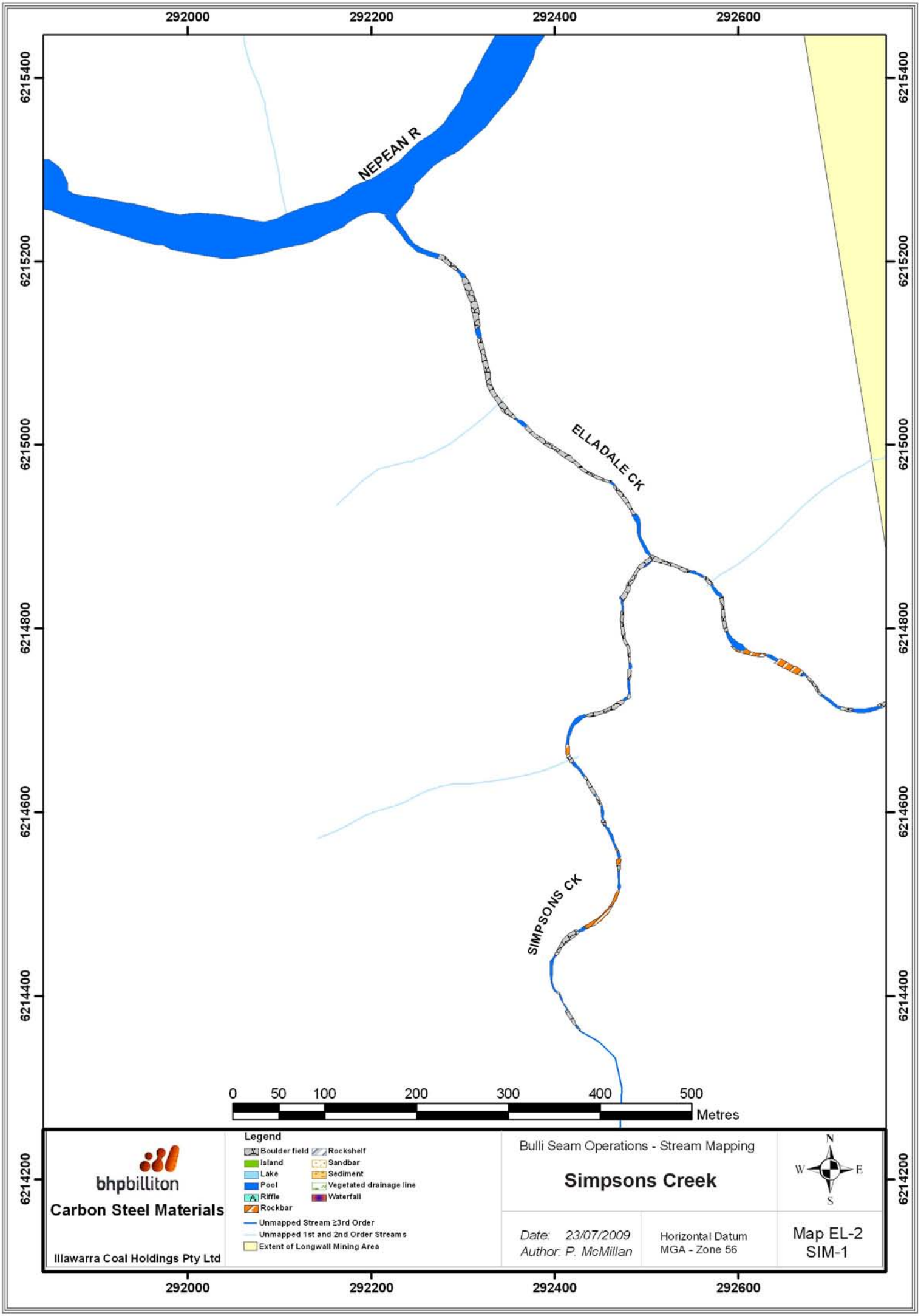
Map SB-2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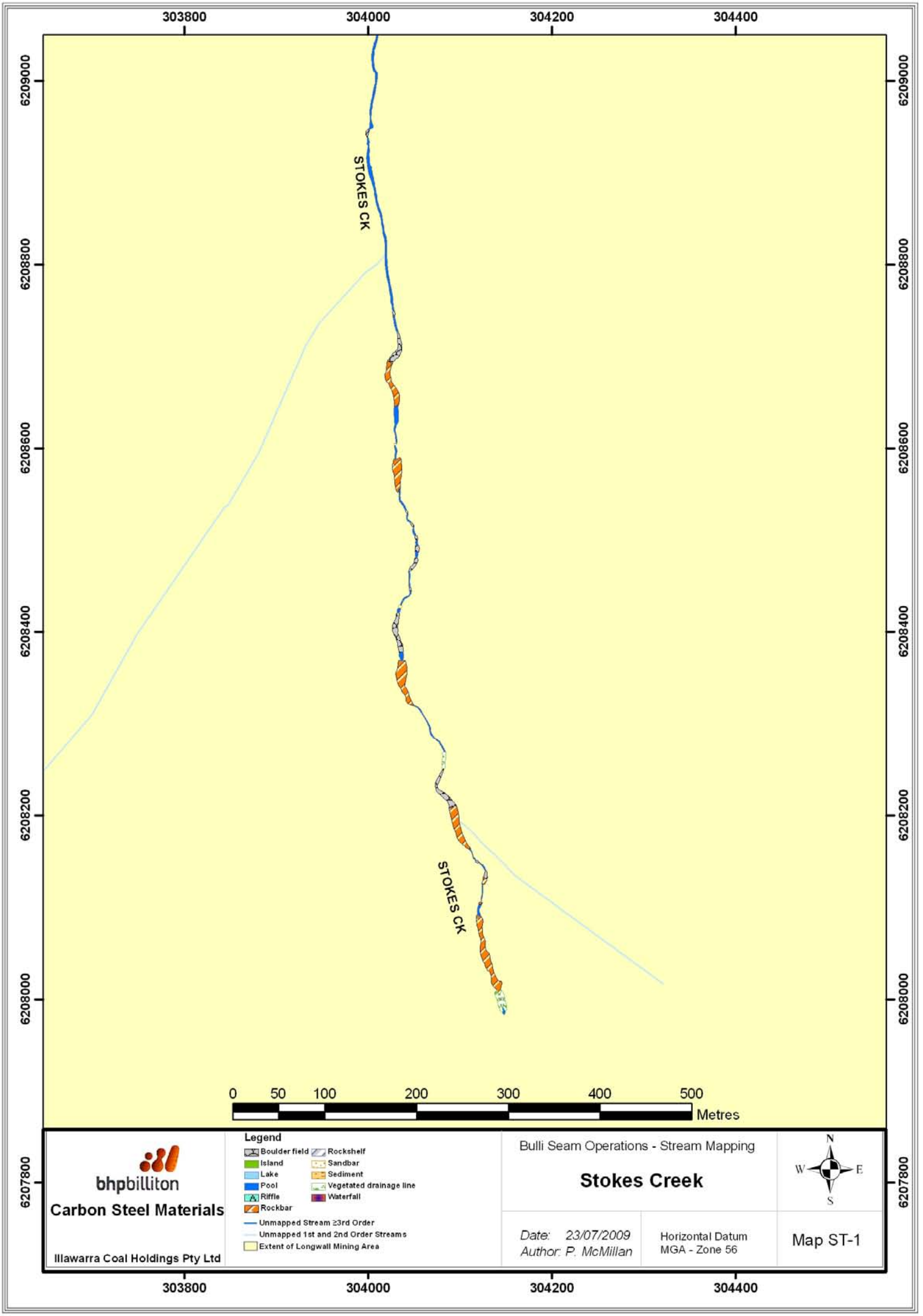
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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
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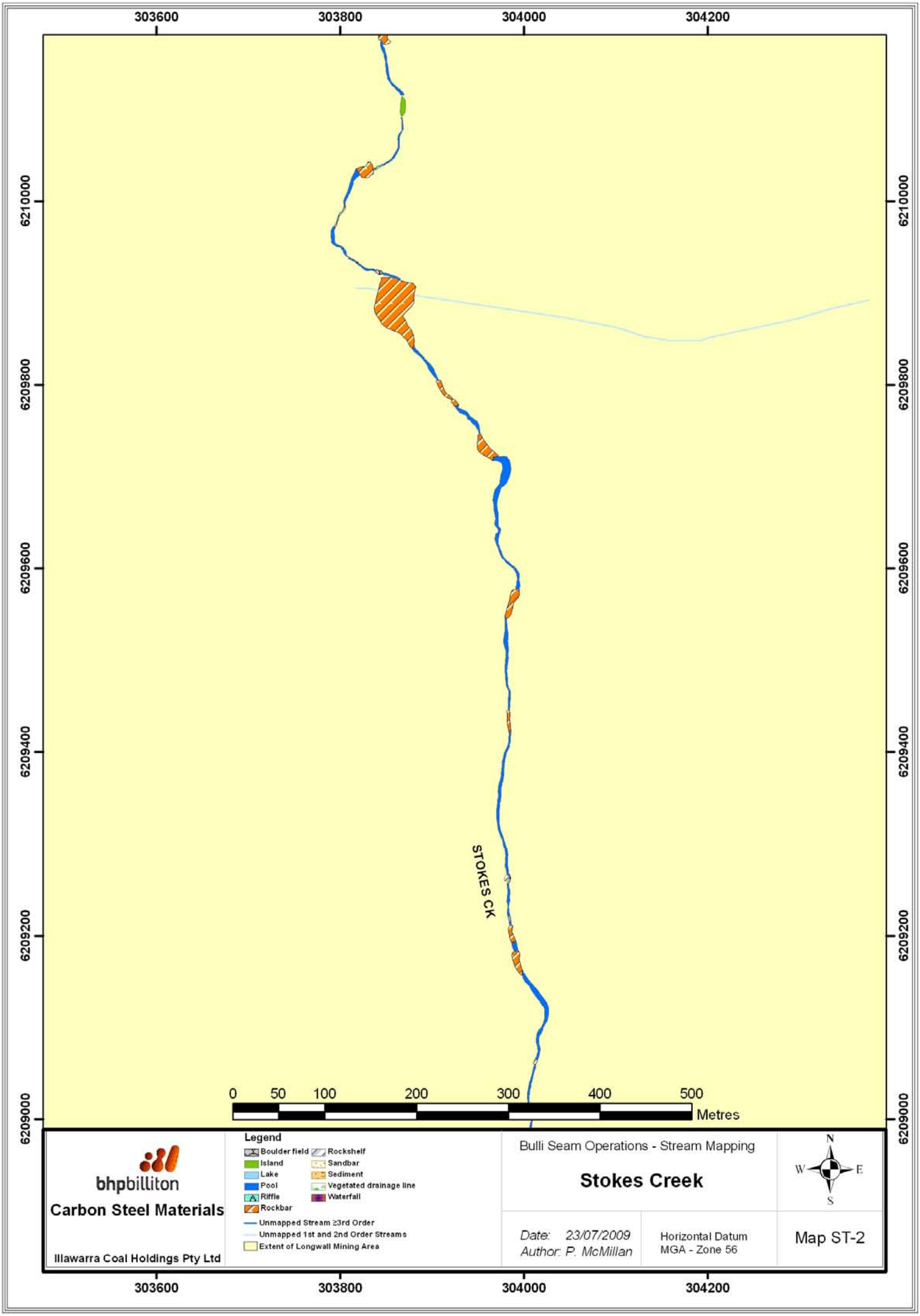
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map ST-1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Waterfall
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Bulli Seam Operations - Stream Mapping
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Date: 23/07/2009
Author: P. McMillan
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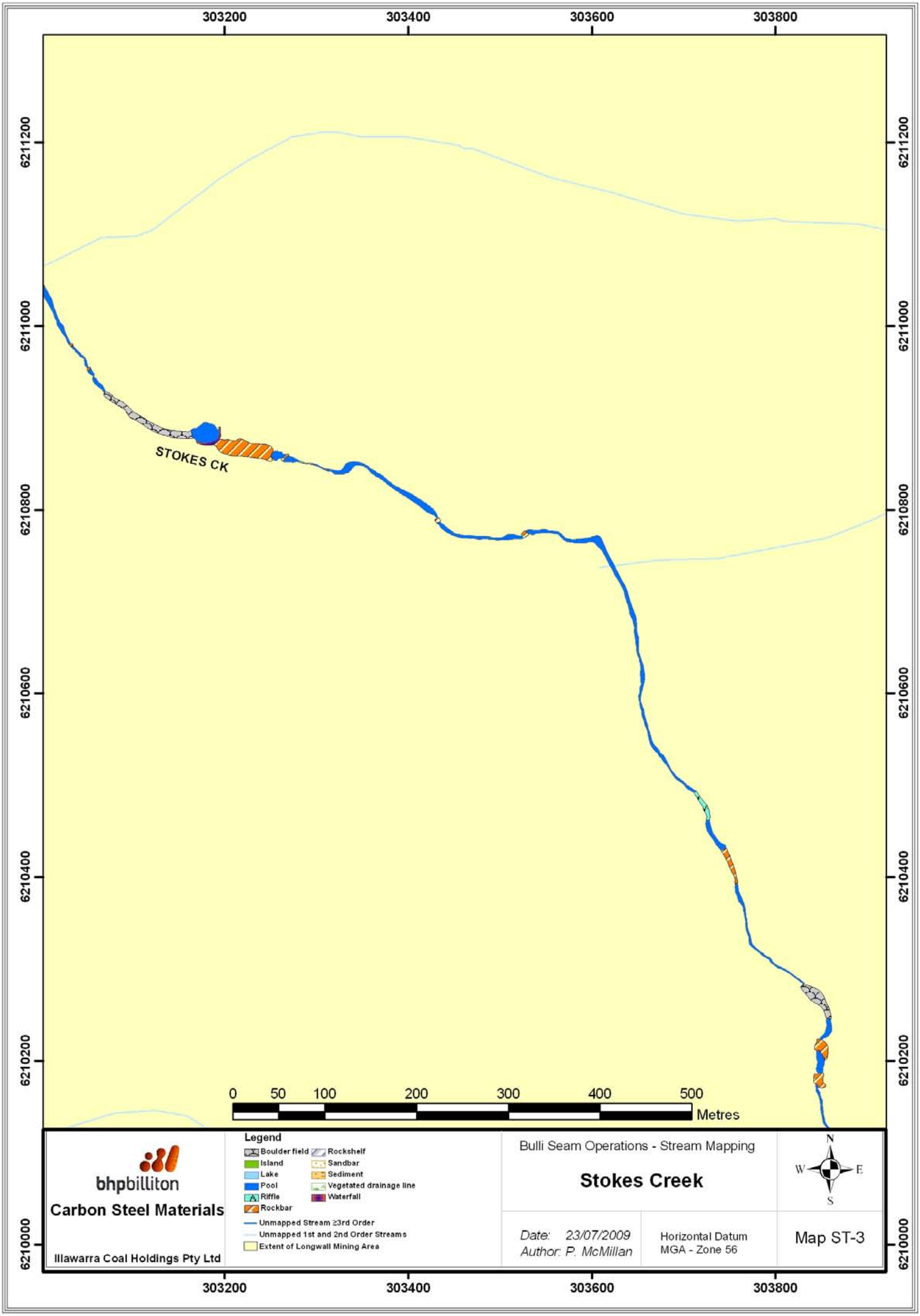
Map ST-2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Waterfall
Rockbar
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Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
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Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
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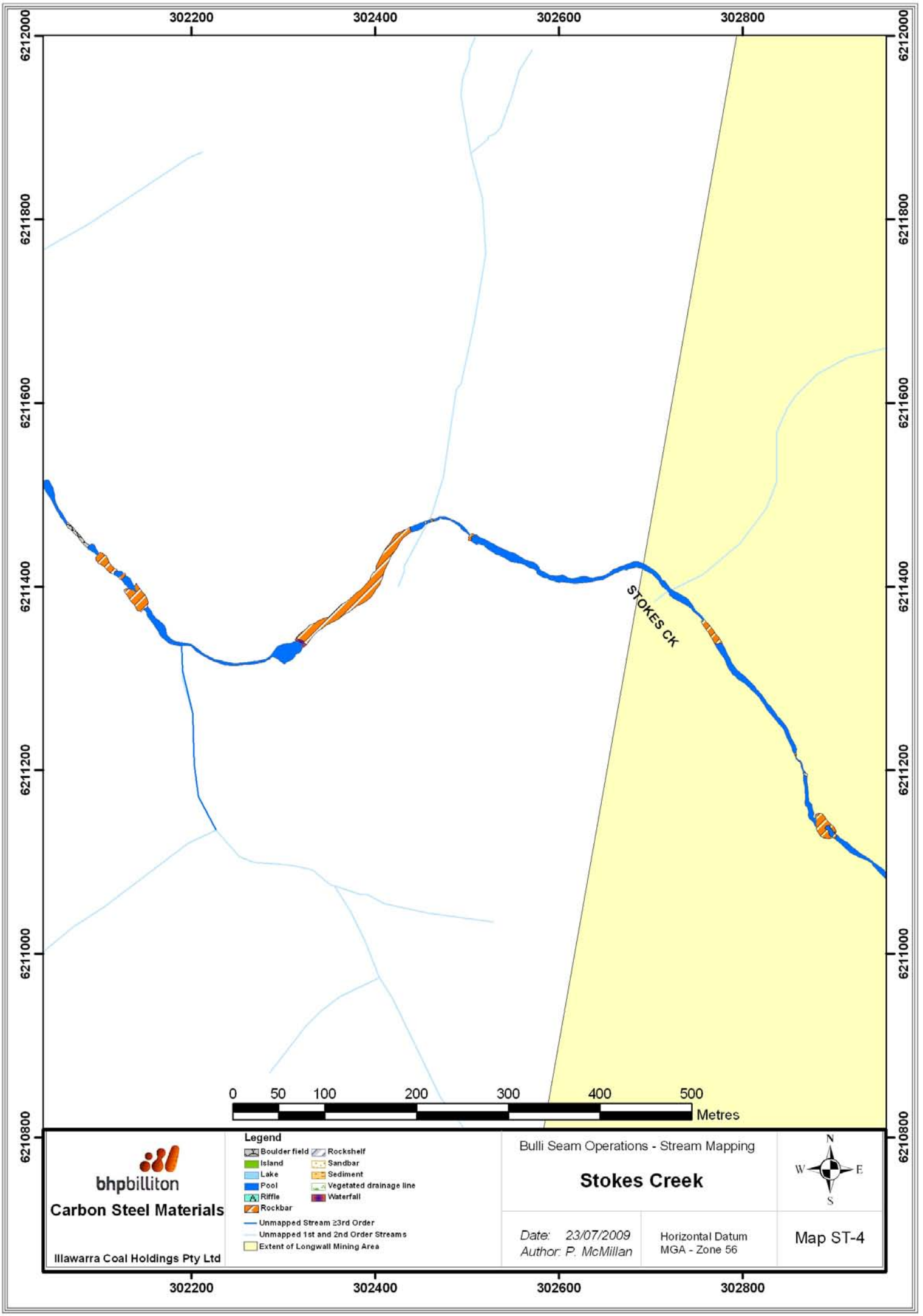
Map ST-3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Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
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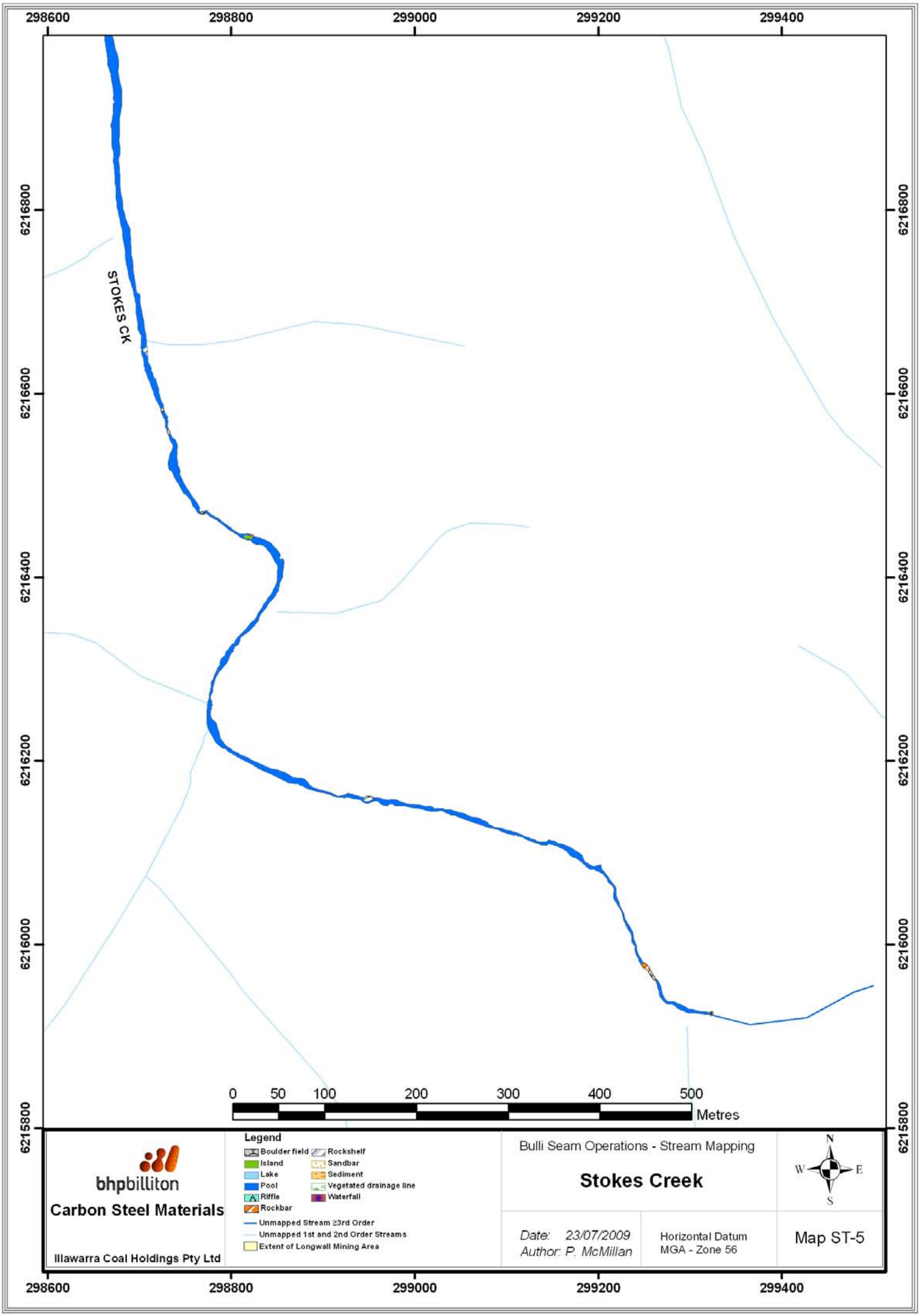
Map ST-4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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
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Date: 23/07/2009
Author: P. McMillan
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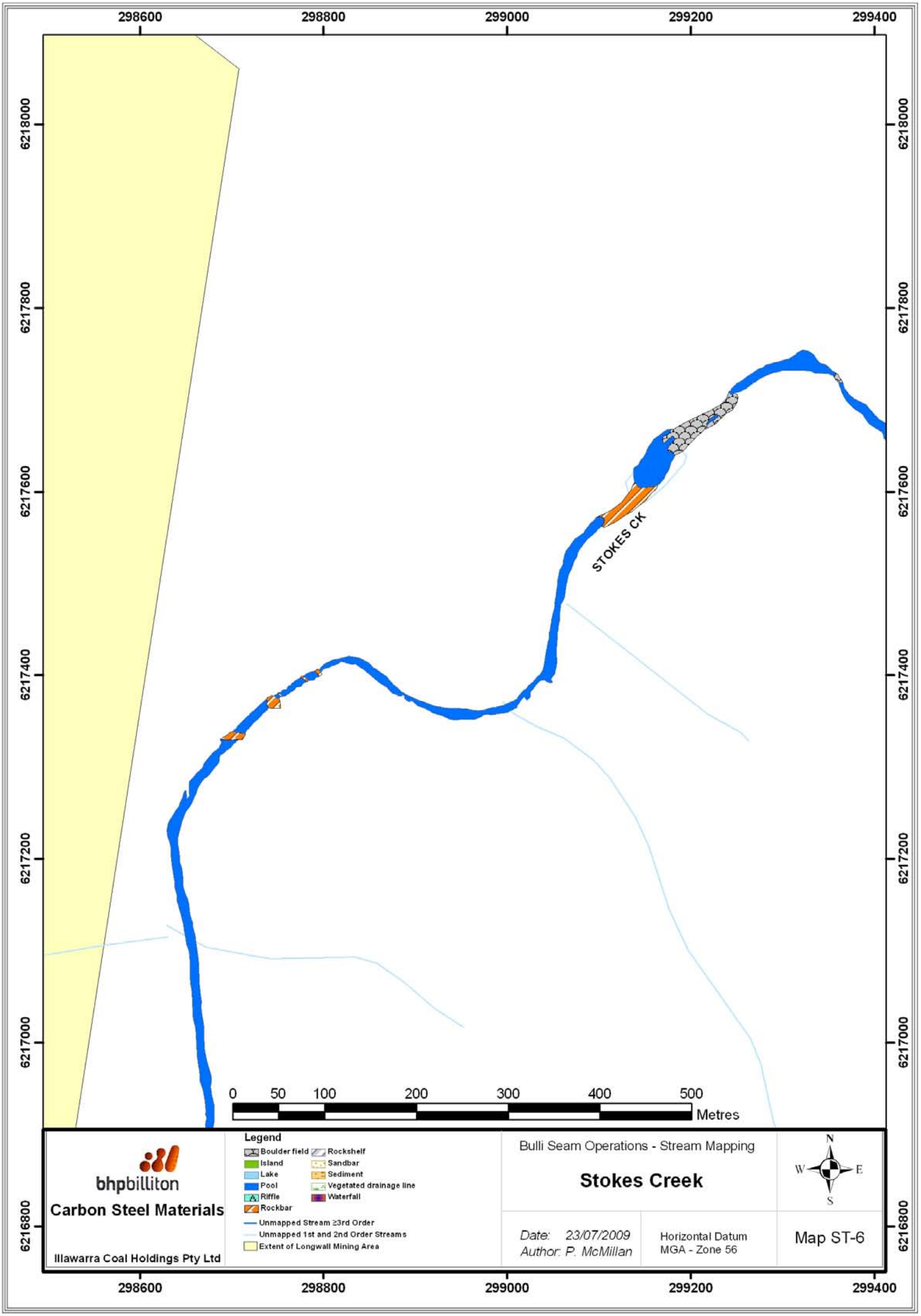
Map ST-5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Extent of Longwall Mining Area
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Carbon Steel Materials
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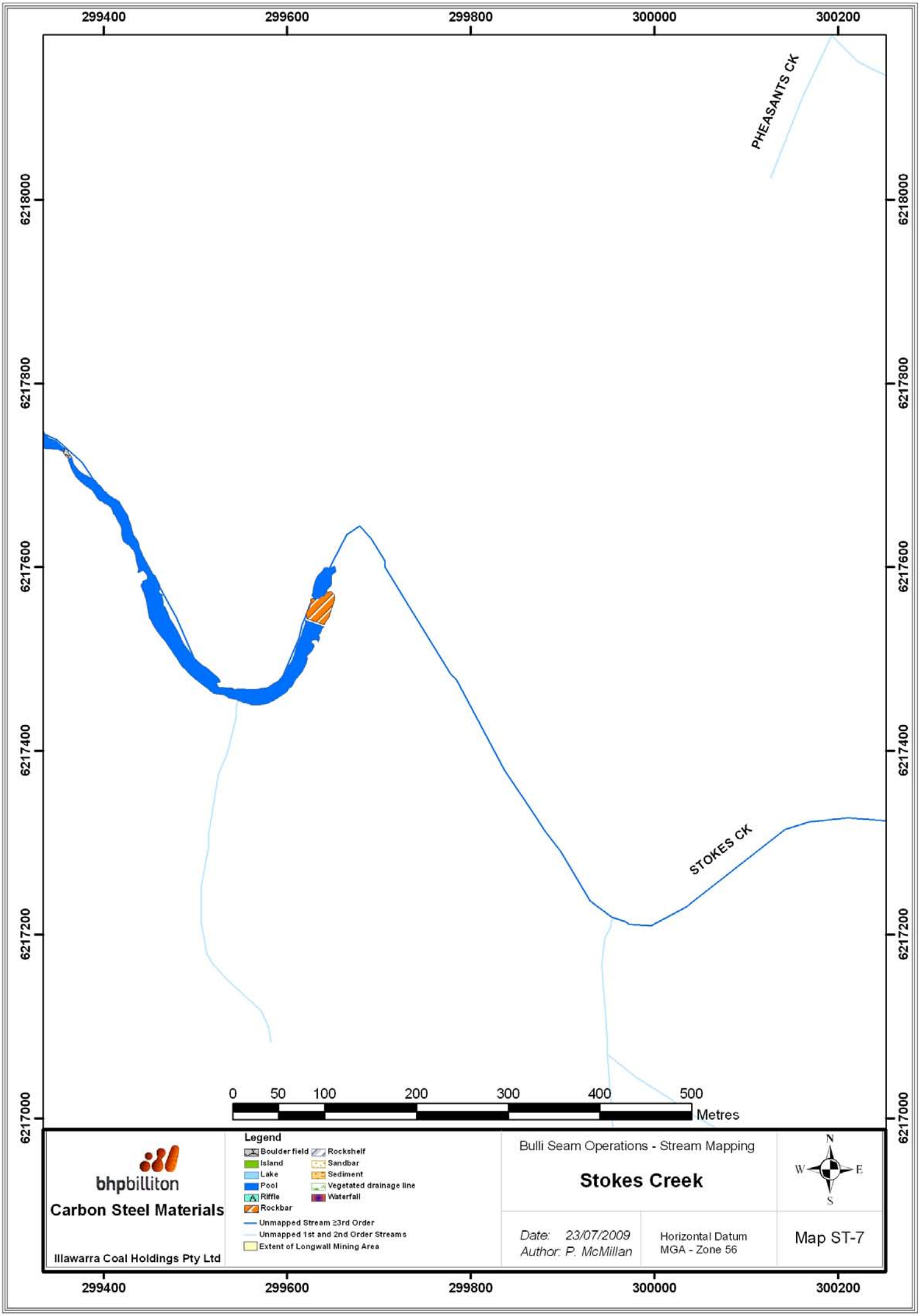
Map ST-6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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
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Date: 23/07/2009
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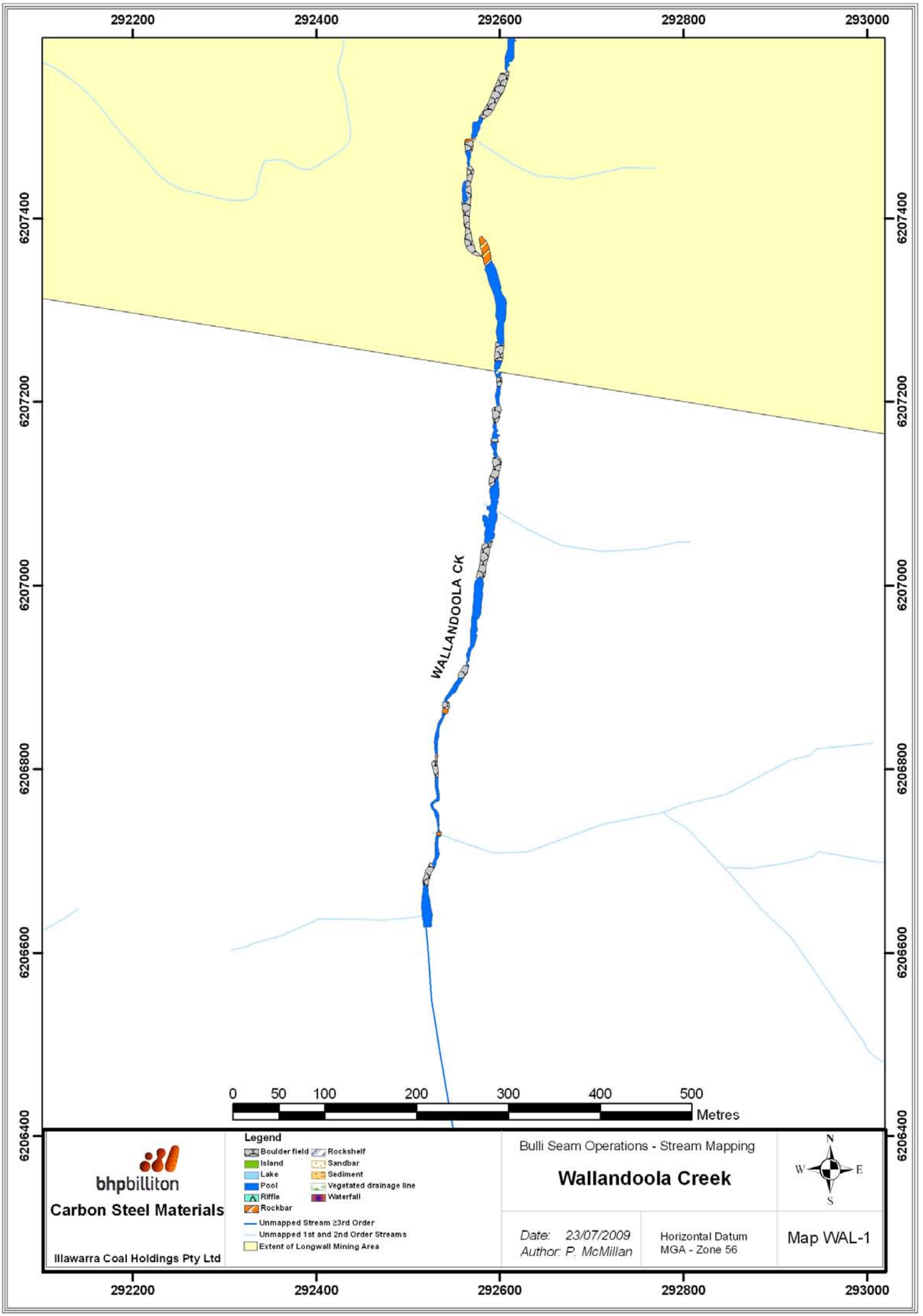
Map ST-7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Vegetated drainage line
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Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Wallandoola Creek
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Date: 23/07/2009
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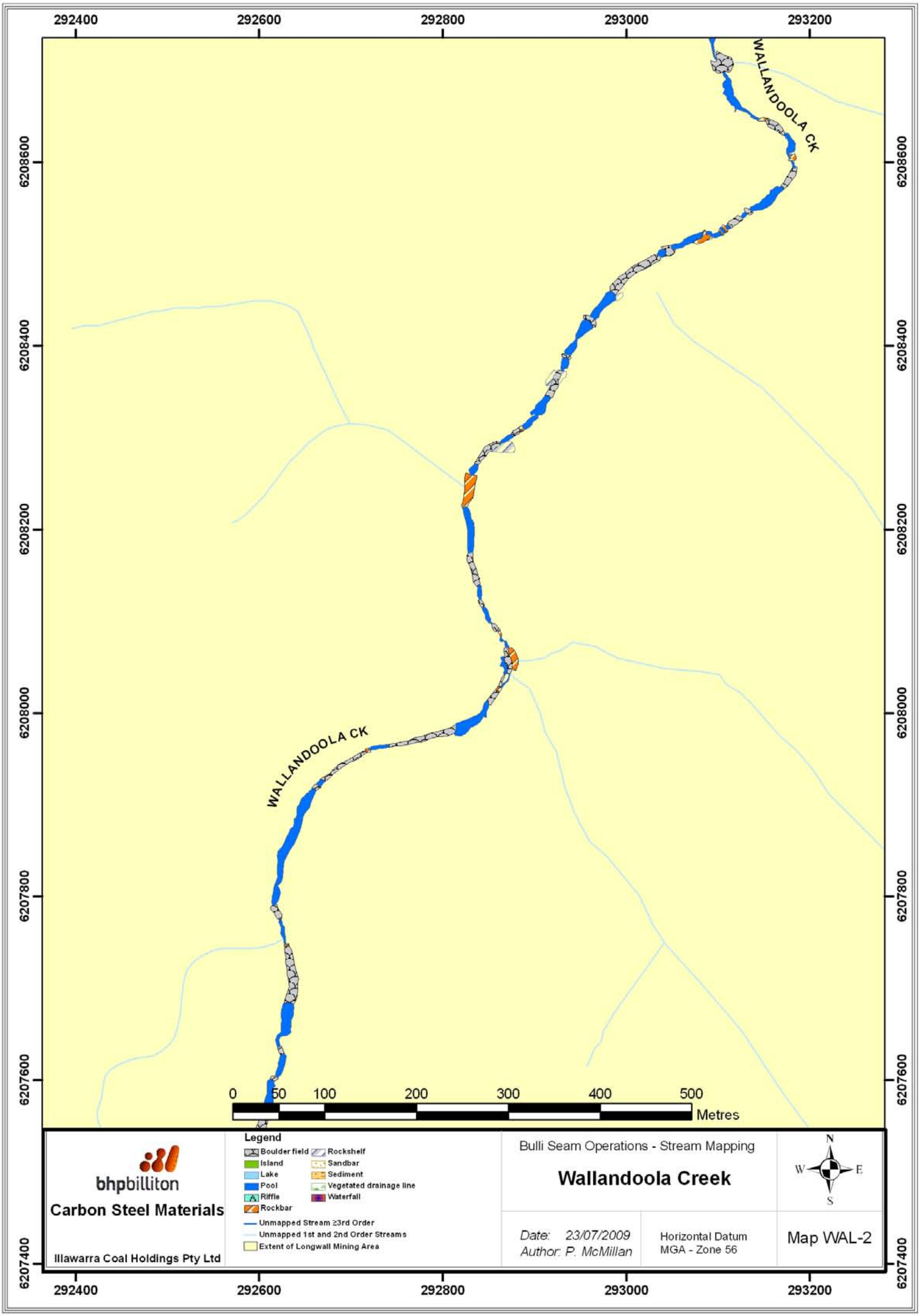
Map WAL-1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Vegetated drainage line
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Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Wallandoola Creek
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Date: 23/07/2009
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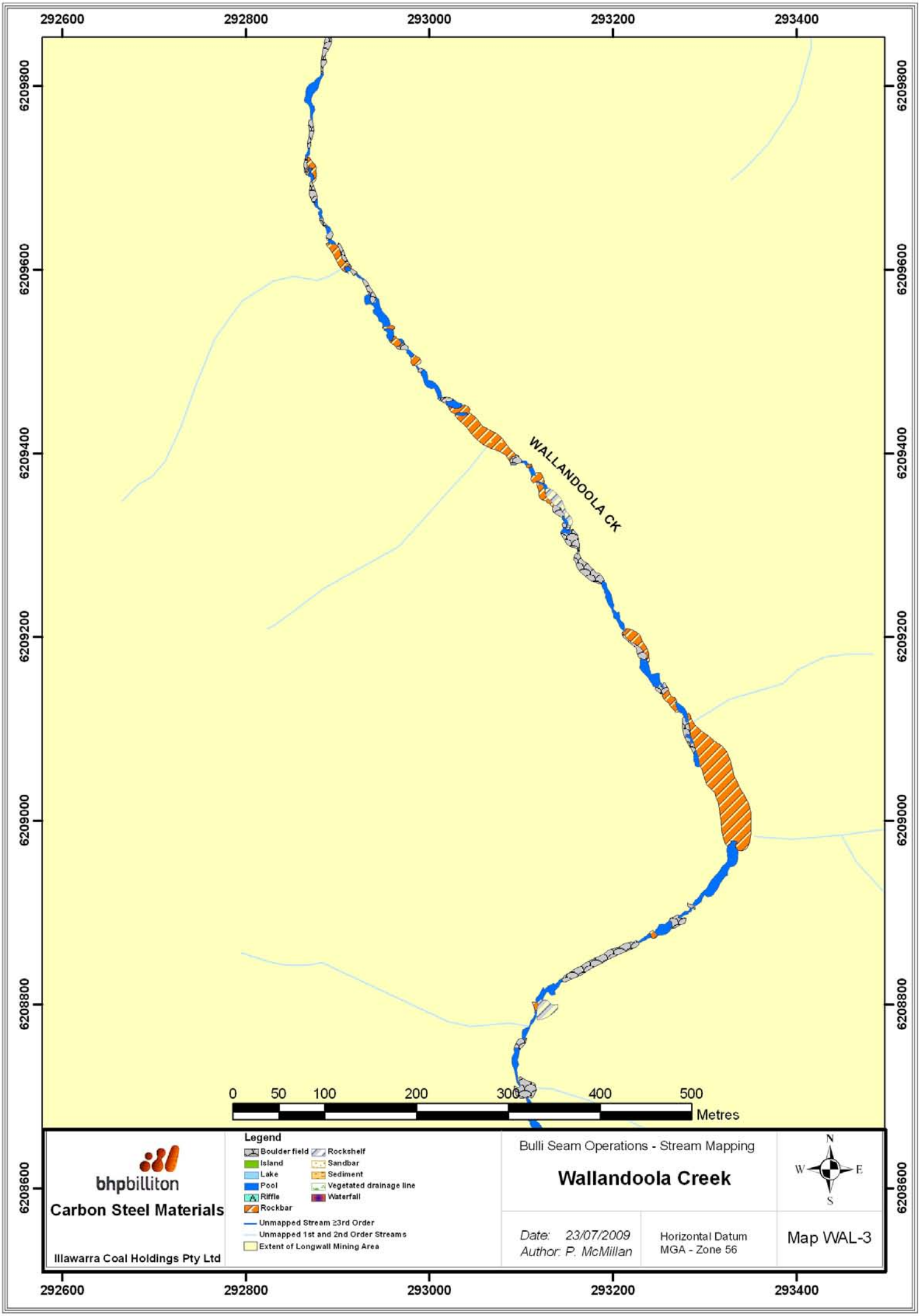
Map WAL-2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Vegetated drainage line
Riffle
Waterfall
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Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Wallandoola Creek
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Date: 23/07/2009
Author: P. McMillan
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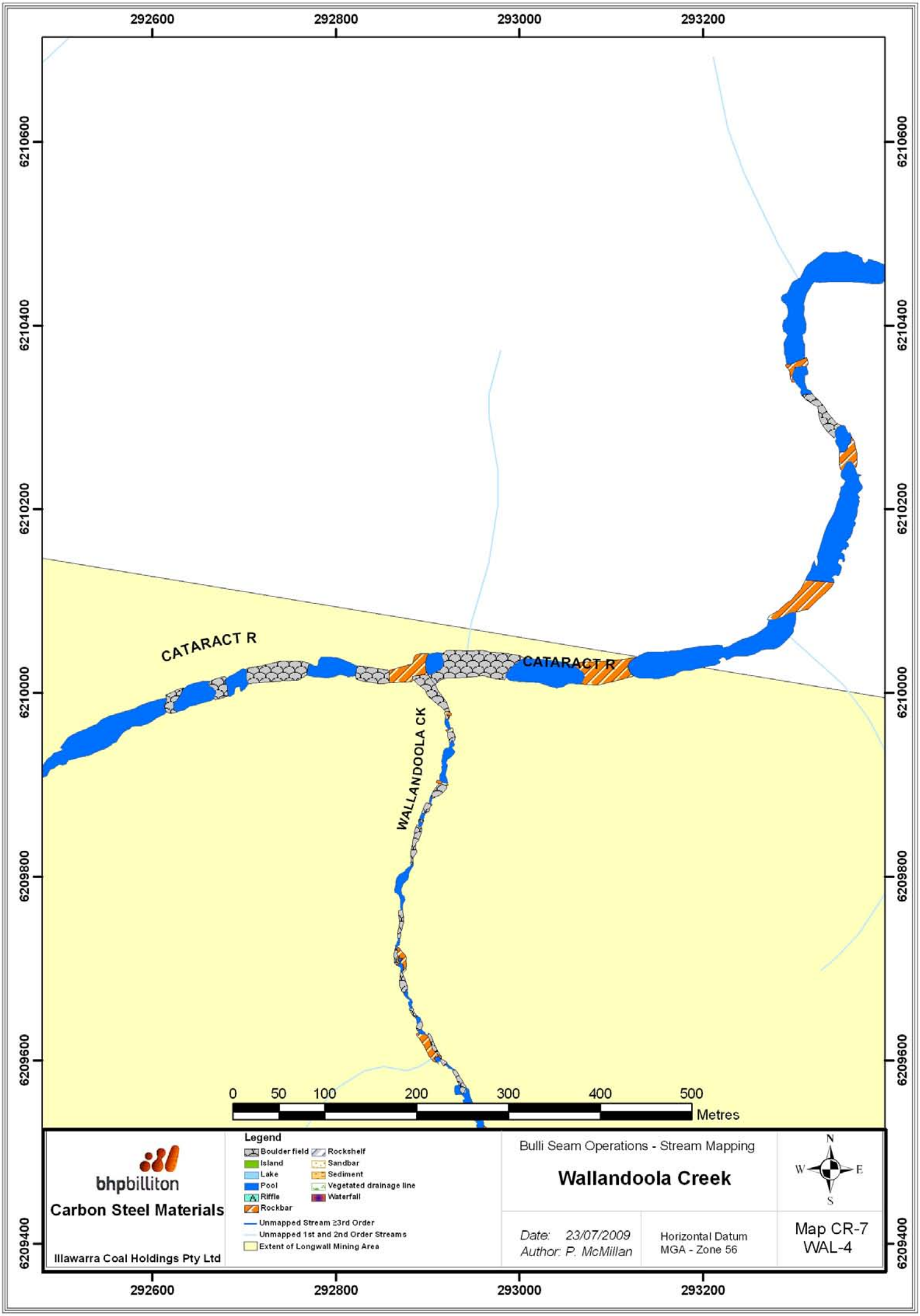
Map WAL-3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Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Wallandoola Creek
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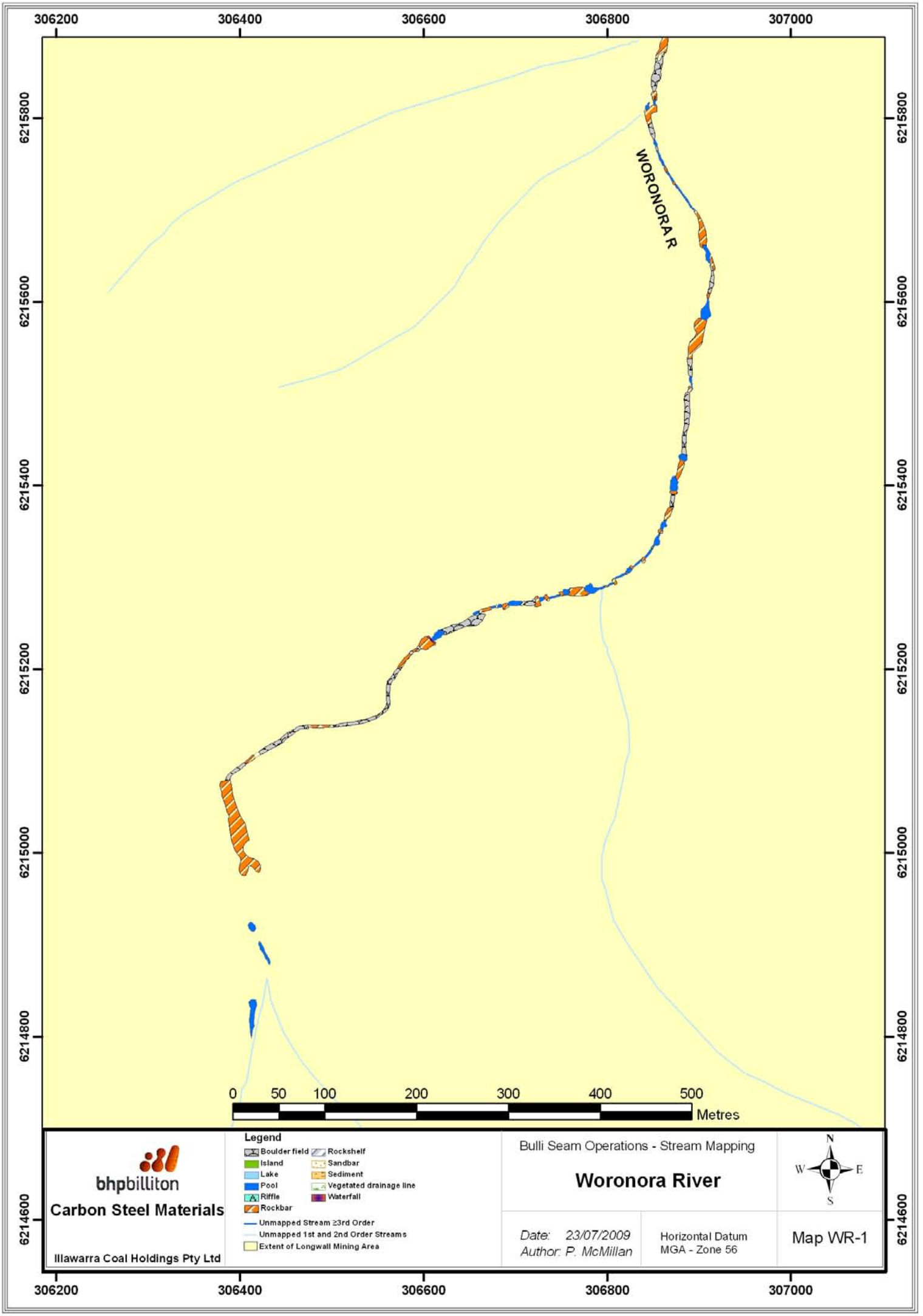
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map CR-7
WAL-4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Extent of Longwall Mining Area
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Date: 23/07/2009
Author: P. McMillan
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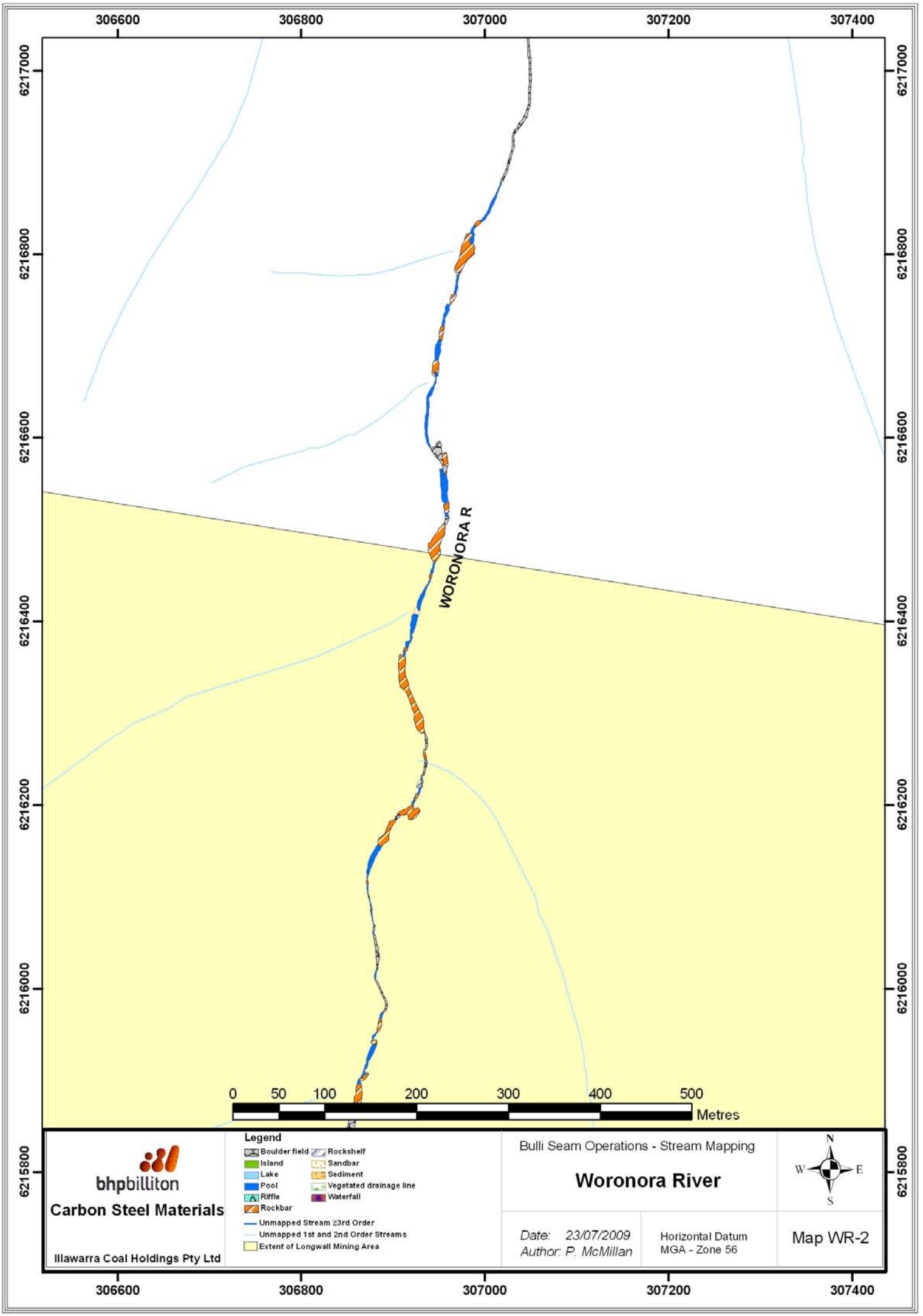
Map WR-1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Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Woronora River
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Date: 23/07/2009
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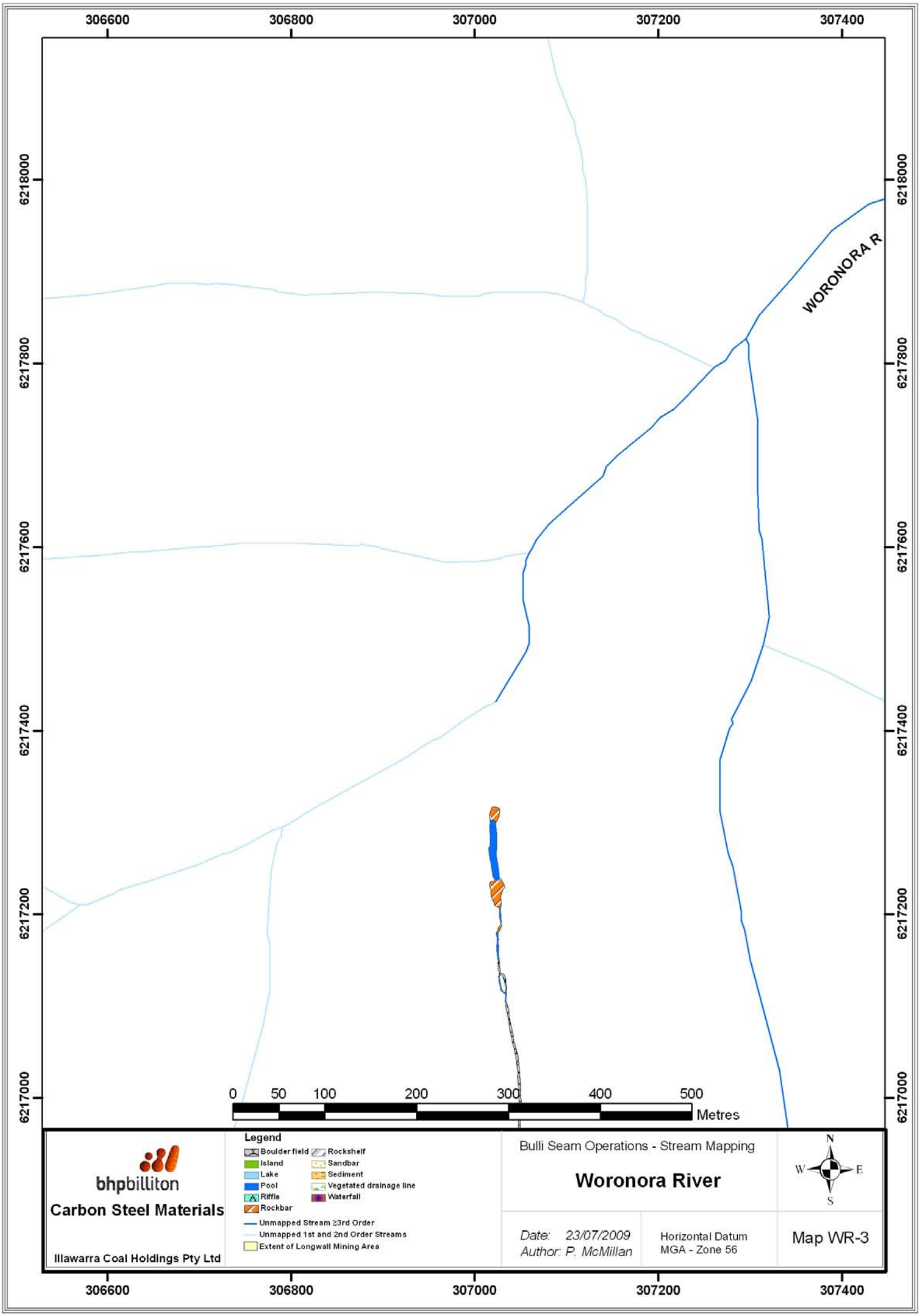
Map WR-2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Riffle
Waterfall
Rockbar
Unmapped Stream ≥3rd Order
Unmapped 1st and 2nd Order Streams
Extent of Longwall Mining Area
Bulli Seam Operations - Stream Mapping
Woronora River
N
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E
S
Date: 23/07/2009
Author: P. McMillan
Horizontal Datum
MGA - Zone 56
Map WR-3

ATTACHMENT PB

STREAM MATRIX

# Attachment PB
# Stream Matrix

| Characterisation | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| River or Significant Stream | Named? | Approximate Stream Length within Extent of Longwall Mining Area (km) | Approximate Stream Length within 600 m of Extent of Longwall Mining Area (km) | Stream History | | Maximum Strahler Stream Order | Average Stream Gradient (m/km) | Geomorphic Type | Visual Amenity/Key Features (e.g. riffles, pools, etc.) | Stream Catchment Area ($km^2$) | Permanence of Flow / Flow Regime | Stream Regulation | | Importance to Catchment Yield |
| | | | | Previously Subject to Subsidence | Distance (km) Previously Undermined/Affected by Subsidence | | | | | | | SCA Regulated Flow | DECC Regulated Flow (e.g. EPL Discharges) | |
| **North Cliff** | | | | | | | | | | | | | | |
| Cobbong Creek | Y | 0.5 | 2.9 | N | - | 3 | 46 | V1,FP1,B1,DF3 | N/D | 3.5 | I-E | N | N | L |
| Dahlia Creek Reach 1 | Y | 2.9 | 2.9 | N | - | 3 | 21 | V1,FP1,B1,DF1/DF3/DF6 | B, P, R, RB, RS | 5.3 | I-E | N | N | M |
| Dahlia Creek Reach 2 | Y | 3.0 | 3.6 | N | - | 2 | 22 | V2,FP2,B1/B2,DF1/D5 | B, P, R, RB, RS, W | 2.8 | I-E | N | N | L |
| O'Hares Creek | Y | 9.8 | 16.6 | N | - | 4 | 7.5 | V1,FP1,B1,DF1/DF3 | B, P, R, RB, RS, SB, W | 6.0 | P | N | N | M |
| Punchbowl Creek | Y | 0.6 | 1.8 | N | - | 3 | 55 | V1,FP1,B1,DF1/DF3 | B, P, RB, RS, SB | 6.1 | P/I-E | N | N | M |
| Stokes Creek Reach 2 | Y | 2.8 | 3.4 | N | - | 2 | 16 | V1,FP1,B1,DF1/DF3 | B, I, P, R, RB, RS, W | 11.1 | I-E | N | N | M |
| Stokes Creek Reach 3 | Y | 1.5 | 1.8 | N | - | 1 | 41 | V2,FP1,B1,DF1 | B, P, RB, RS, SB, V | 2.2 | I-E | N | N | L |
| Tributary to O'Hares Creek 1 | N | 1.0 | 1.0 | N | - | 3 | 40 | V1,FP1,B1,DF1 | B, P, RB, S | 2.5 | I-E | N | N | L |
| Tributary to O'Hares Creek 2 | N | 0.4 | 0.4 | N | - | 3 | 75 | V1,FP1,B1,DF1 | N/D | 1.4 | I-E | N | N | L |
| Tributary to Punchbowl Creek | N | 0.6 | 0.6 | N | - | 3 | 61 | V1,FP1,B1,DF1 | N/D | 4.5 | I-E | N | N | H |
| Tributary to Woronora River | N | 0.7 | 0.6 | N | - | 3 | 20 | V1,FP1,B1,DF1/DF3 | N/D | 4.8 | I-E | N | N | M |
| Woronora River | Y | 1.9 | 2.5 | N | - | 2 | 45 | V1,FP1,B1,DF1/DF3 | B, P, RB, RS, SB | 8.0 | P | N | N | H |
| **West Cliff Area 5** | | | | | | | | | | | | | | |
| Georges River Reach 2 | Y | 3.4 | 5.9 | Y - West Cliff/Appin Area 2 | 7.1 | 4 | 11 | V2,FP2,B1,DF1/DF3 | B, I, P, R, RB | 27.2 | P | N | Y | M |
| Mallaty Creek | Y | 0.3 | 2.0 | Y - West Cliff | 0.2 | 3 | 33 | V2,FP2,B2,DF1/DF3 | B, P, R, RB, RS | 3.3 | I-E | N | Y | L |
| Stokes Creek Reach 1 | Y | 2.0 | 4.2 | Y - West Cliff | 3.3 | 4 | 9 | V1,FP1,B1,DF1 | B, I, P, R, RB, RS | 27.8 | P | N | N | M |
| **Appin Areas 2 and 3 Extended** | | | | | | | | | | | | | | |
| Georges River Reach 1 | Y | N/A | 1.0 | Y - West Cliff/Appin Area 2 | 7.1 | 3 | 36 | V1,FP1,B1,DF3/DF1 | B, P, RB | 5.1 | P | N | N | M |
| Cataract River | Y | 11.5 | 14.8 | Y - Tower | 4.8 | 6 | 18 | V1,FP1,B1,DF1/DF2 | B, P, RB, W | 220.0 | P | Y | N | H |
| Cascade Creek | Y | 3.9 | 5.1 | N | - | 3 | 40 | V1,FP1,B1,DF1/DF3 | B, P, RB, W | 11.0 | P/I-E | N | N | M |
| Lizard Creek | Y | 1.6 | 2.2 | Y - Bellambi West | 9.0 | 5 | 46 | V1,FP1,B1,DF1/DF3/DF6(upstream) | B, P, R, RB, RS, W | 21.0 | P | N | N | M |
| Wallandoola Creek | Y | 3.4 | 4.0 | Y - Bellambi West | 4.0 | 4 | 13 | V1,FP1,B1,DF1/DF3/DF6(upstream) | B, P, RS, RB | 32.0 | P | N | N | M |
| Wallandoola East Creek | N | 2.6 | 2.6 | Y - Appin Area 3 | 1.2 | 3 | 43 | V1,FP1,B1,DF1/DF3 | N/D | 4.0 | I-E | N | N | L |
| Tributary to Cataract Reservoir 1 | N | 0.8 | 1.2 | N | - | 3 | 50 | V2,FP2,B1,DF1/DF3/DF6 | B, P, R, RB, RS, W | 2.7 | I-E | N | N | L |
| Tributary to Cataract Reservoir 2 | N | 1.7 | 2.3 | N | - | 3 | 36 | V2,FP2,B1,DF6/DF1 | B, P, RB, RS | 4.2 | I-E | N | N | L |
| Tributary to Cataract River 1 | N | 0.3 | 0.3 | Y - Appin Area 2 | 0.5 | 3 | 43 | V1,FP1,B1,DF1/DF3 | N/D | 1.5 | I-E | N | N | L |
| Tributary to Cataract River 2 | N | N/A | 0.1 | Y - Appin Area 2 | 0.9 | 3 | 33.3 | V2,FP1,B1,DF1/DF3 | N/D | 1.8 | I-E | N | N | L |
| **Appin Area 7** | | | | | | | | | | | | | | |
| Foot Onslow Creek | Y | 5.6 | 5.6 | N | - | 3 | 17 | V2/V3,FP3,B2/B3,DF4/DF5 | N/D | 5.6 | P/I-E | N | N | H |
| Navigation Creek | Y | 5.4 | 6.0 | N | - | 4 | 31 | V2/V3,FP3,B2/B3,DF4/DF5 | N/D | 15.0 | P/I-E | N | N | H |
| Nepean River Reach 2 | Y | 14.5 | 19.0 | Y - Tower | 1.0 | 7 | <1 | V1,FP1,B1,DF4 | P, RB | 1,219.0 | P | Y | Y | H |
| Nepean River Reach 3 | Y | 3.0 | 3.6 | N | - | 7 | <1 | V1,FP2,B1,DF4 | P | 1,232.8 | P | Y | Y | H |
| Ousedale Creek | Y | 1.6 | 2.7 | Y - Appin Area 1 | 5.1 | 4 | 35 | V2,FP2,B1/B2,DF1/DF3 | B, P, R, RB, RS | 5.1 | I-E | N | Y | L |
| Tributary to Navigation Creek 1 | N | 3.6 | 3.6 | N | - | 3 | 28 | V3,FP3,B2/B3,DF5 | N/D | 2.3 | I-E | N | N | L |
| Tributary to Navigation Creek 2 | N | 0.9 | 0.9 | N | - | 3 | 62 | V2/V3,FP3,B2,DF5 | N/D | 2.2 | I-E | N | N | L |
| Tributary to Navigation Creek 3 | N | 0.3 | 0.3 | N | - | 3 | 83 | V2,FP3,B2/B3,DF5 | N/D | 0.7 | I-E | N | N | L |
| Tributary to Navigation Creek 4 | N | 1.1 | 1.1 | N | - | 3 | 60 | V3,FP3,B2/B3,DF5 | N/D | 1.1 | I-E | N | N | L |
| Tributary to Navigation Creek 5 | N | 1.2 | 1.6 | N | - | 3 | 41 | V3,FP3,B2/B3,DF5 | N/D | 1.0 | I-E | N | N | L |
| Elladale Creek | Y | N/A | 1.5 | Y - Appin Area 1 | 3.3 | 3 | 42 | V1,FP1,B1,DF1/DF3 | B, P, RB, S | 7.7 | I-E | N | N | L |
| Simpsons Creek | Y | N/A | 0.8 | Y - Appin Area 4 | 2.2 | 3 | 64 | V1,FP1,B1,DF1/DF4 | B, P, RB | 3.9 | I-E | N | N | L |
| **Appin West (Area 9)** | | | | | | | | | | | | | | |
| Apps Gully | Y | 1.6 | 1.6 | N | - | 3 | 47 | V1,FP1,B1,DF1 | N/D | 1.1 | I-E | N | N | L |
| Harris Creek | Y | 2.9 | 2.9 | N | - | 3 | 18 | V2,FP2,B1/B2,DF1/DF4 | B, P, RB, S, V | 1.7 | I-E | N | Y | L |
| Matahill Creek | Y | 1.3 | 2.7 | N | - | 3 | 75 | V2,FP2,B2/B3,DF4 | N/D | 3.7 | I-E | N | Y | L |
| Tributary to Nepean River 1 | N | 1.4 | 1.4 | N | - | 3 | 57 | V2,FP2,B1/B3,DF1 | N/D | 2.7 | I-E | N | N | L |
| Tributary to Nepean River 2 | N | 0.2 | 0.2 | N | - | 3 | 50 | V1,FP2,B1/B3,DF1/DF5 | N/D | 0.9 | I-E | N | N | L |
| **Appin Area 8** | | | | | | | | | | | | | | |
| Allens Creek | Y | 6.8 | 6.8 | N | - | 4 | 14 | V2,FP2,B1,DF1/DF3 | B, P, R, RB, SB, V | 10.0 | P/I-E | N | N | L |
| Byrnes Creek | Y | 1.6 | 1.6 | N | - | 3 | 42 | V1/V2,FP1,B1,DF3/DF1 | B, P, RB, S | 3.9 | I-E | N | N | L |
| Carriage Creek | Y | 3.3 | 3.3 | N | - | 4 | 40 | V2,FP2,B1/B2,DF1/DF4 | B, P, RB, RS, SB, V | 5.8 | I-E | N | N | L |
| Clements Creek | Y | 0.9 | 1.5 | N | - | 3 | 29 | V1,FP1,B1,DF1/DF3 | B, P, RB, S | 1.3 | I-E | N | Y | L |
| Nepean River Reach 1 | Y | 7.7 | 8.9 | N | - | 7 | <1 | V1,FP1,B1,DF4 | B, P, R, RB, W | 999.0 | P | Y | Y | H |
| Racecourse Creek | Y | 3.7 | 4.6 | N | - | 4 | 25 | V2,FP2,B2/B3,DF4/DF5 | N/D | 11.4 | I-E | N | N | H |
| Stringybark Creek | Y | 2.4 | 2.4 | N | - | 3 | 31 | V1/V2,FP2,B1,DF1/DF3 | B, P, RB, SB, V | 4.0 | I-E | N | N | L |
| Tributary to Carriage Creek 1 | N | 0.7 | 0.7 | N | - | 3 | 25 | V2,FP2,B1/B3,DF1/DF5 | N/D | 1.7 | I-E | N | N | L |
| Tributary to Carriage Creek 2 | N | 0.2 | 0.6 | N | - | 3 | 40 | V2,FP2,B1/B3,DF1/DF5 | N/D | 0.5 | I-E | N | N | L |
| Tributary to Racecourse Creek 1 | N | 2.3 | 2.3 | N | - | 3 | 21 | V1/V2,FP1/FP2,B2/B3,DF4/DF5 | N/D | 2.0 | I-E | N | N | L |
| Tributary to Racecourse Creek 2 | N | 0.2 | 0.2 | N | - | 3 | 95 | V2,FP2,B2/B3,DF4/DF5 | N/D | 0.7 | I-E | N | N | L |

# Attachment PB
# Stream Matrix

| River or Significant Stream | Characterisation (continued) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Significance to Water Supply | | | Environmental Quality (Existing/Observed Disturbance) | Ecological Importance | | | | Stream Location | | Land Zoning | Public Accessibility | Stream Photos | Stream Mapping | Stream Risk Management Zone |
| | Percentage of Woronora Dam Catchment Area | Percentage of Cataract Dam Catchment Area | Percentage of Broughtons Pass Weir Catchment Area | | Fauna, Flora and Aquatic Survey Sites | EECs Present in Riparian Zone | Threatened Species Recorded during Project Surveys and/or Described in Aquatic Ecology Assessment | | Relevant DECC Area | Relevant SCA Special Area | | | | | |
| | | | | | | | Records within Streams | Records Adjacent to Streams in Riparian or Gully Habitats | | | | | | | |
| **North Cliff** | | | | | | | | | | | | | | | |
| Cobbong Creek | - | - | - | P | - | - | - | RCT (PS) | DSCA | O | WC | Y | - | - | Refer to Plan 2 |
| Dahlia Creek Reach 1 | - | - | - | P | AS | - | - | - | DSCA | O | WC | Y | Refer Plate 1 | Refer Map DL-1 to DL-2 | Refer to Plan 2 |
| Dahlia Creek Reach 2 | - | - | - | P | AS | - | - | - | DSCA | O | WC | Y | Refer Plate 2 | Refer Map DL-2 to DL-4 | Refer to Plan 2 |
| O'Hares Creek | - | - | - | M | AS, FLQ, FLRM, FLS, FS | - | - | LE (PS), PoA (PS), EPP (PS) | DSCA | O | WC | Y | Refer Plate 3 | Refer Map OH-1 to OH-13 | Refer to Plan 2 |
| Punchbowl Creek | - | - | - | P | - | - | - | - | - | - | WC | Y | Refer Plate 4 | Refer Map PB-1 to PB-4 | Refer to Plan 2 |
| Stokes Creek Reach 2 | - | - | - | M | AS, FLS | - | - | - | DSCA (partial) | O | WC | Y | Refer Plate 5 | Refer Map ST-1 to ST-2 | Refer to Plan 2 |
| Stokes Creek Reach 3 | - | - | - | M | AS | - | - | - | DSCA (partial) | O | WC | Y | - | Refer Map ST-2 to ST-4 | Refer to Plan 2 |
| Tributary to O'Hares Creek 1 | - | - | - | P | - | - | - | - | DSCA | O | WC | Y | Refer Plate 6 | Refer Map NCT1-1 | Refer to Plan 2 |
| Tributary to O'Hares Creek 2 | - | - | - | P | - | - | - | - | DSCA | O | WC | Y | - | - | Refer to Plan 2 |
| Tributary to Punchbowl Creek | - | - | - | P | - | - | - | - | - | - | WC | Y | - | - | Refer to Plan 2 |
| Tributary to Woronora River | 6.3% | - | - | P | FS | - | - | - | - | W | SEP | N | - | - | Refer to Plan 2 |
| Woronora River | 10.7% | - | - | P | FLS | - | - | PuA (PS), GFF (PS) | - | W | SEP, WC | N | Refer Plate 7 | Refer Map WR-1 to WR-3 | Refer to Plan 2 |
| **West Cliff Area 5** | | | | | | | | | | | | | | | |
| Georges River Reach 2 | - | - | - | SM | AS, FLQ, FS, FT | SST | MP (HR) | EBB (PS), GFF (PS), K (PS) | - | - | NU, OS, R | Y | Refer Plate 8 | Refer Map GR-1 to GR-3 | Refer to Plan 1 |
| Mallaty Creek | - | - | - | M | - | SST | - | - | - | - | NU, R, SU | Y | Refer Plate 9 | Refer Map MAL-1 | Refer to Plan 1 |
| Stokes Creek Reach 1 | - | - | - | M | FT | - | - | - | DSCA | O | WC | Y | Refer Plate 10 | Refer Map ST-5 to ST-7 | Refer to Plan 1 |
| **Appin Areas 2 and 3 Extended** | | | | | | | | | | | | | | | |
| Georges River Reach 1 | - | - | - | M | FS | - | - | EBB (PS) | - | - | R | Y | Refer Plate 11 | Refer Map GR-4 to GR-5 | Refer to Plan 4 |
| Cataract River | - | - | 100.0% | SM | AS, FLQ, FLRM, FLS, FS, FT | - | LFM (PS), MP (PS,HR) | LE (PS), RCT (PS) | - | M | WC | Y | Refer Plate 12 | Refer Map CR-1 to CR-8 | Refer to Plan 4 |
| Cascade Creek | - | - | 5.2% | P | AS, FLS, FS | SST | - | - | - | M | WC | N | Refer Plate 13 | Refer Map CAS-1 to CAS-3 | Refer to Plan 4 |
| Lizard Creek | - | - | 10.0% | P | AS | - | - | - | - | M | WC | N | Refer Plate 14 | Refer Map LZ-1 to LZ-2 | Refer to Plan 4 |
| Wallandoola Creek | - | - | 15.2% | P | - | - | - | - | - | M | WC | N | Refer Plate 15 | Refer Map WAL-1 to WAL-4 | Refer to Plan 4 |
| Wallandoola East Creek | - | - | 1.9% | P | AS, FLRM, FLS | - | - | - | - | M | WC | N | - | - | Refer to Plan 4 |
| Tributary to Cataract Reservoir 1 | - | 2.1% | - | P | FS | - | - | GFF (PS) | - | M | WC | N | Refer Plate 16 | Refer Map LCT1-1 | Refer to Plan 4 |
| Tributary to Cataract Reservoir 2 | - | 3.2% | - | P | AS | - | - | - | - | M | WC | N | Refer Plate 17 | Refer Map LCT2-1 to LCT2-2 | Refer to Plan 4 |
| Tributary to Cataract River 1 | - | - | 0.7% | P | - | - | - | - | - | M | WC | N | - | - | Refer to Plan 4 |
| Tributary to Cataract River 2 | - | - | 0.9% | M | - | SST | - | - | - | M | WC | N | - | - | Refer to Plan 4 |
| **Appin Area 7** | | | | | | | | | | | | | | | |
| Foot Onslow Creek | - | - | - | SM | AS | REF | - | - | - | - | R | Y | - | - | Refer to Plan 1 |
| Navigation Creek | - | - | - | SM | - | REF | - | - | - | - | AL, R, RL | Y | - | - | Refer to Plan 1 |
| Nepean River Reach 2 | - | - | - | SM | AS, FS, FT | REF, SST | MP (HR) | GFF (PS), PO (PS) | - | - | NU, OS, R, SU | Y | - | Refer Map NR-8 to NR-15 | Refer to Plan 1 |
| Nepean River Reach 3 | - | - | - | SM | AS, FS | REF, SST | MP (HR) | - | - | - | NU, R, SU | Y | - | Refer Map NR-15 to NR-16 | Refer to Plan 1 |
| Ousedale Creek | - | - | - | M | FS | REF, SST | - | - | - | - | R, SU | Y | Refer Plate 18 | Refer Map OU-1 to OU-4 | Refer to Plan 1 |
| Tributary to Navigation Creek 1 | - | - | - | SM | - | - | - | - | - | - | AL, RL | Y | - | - | Refer to Plan 1 |
| Tributary to Navigation Creek 2 | - | - | - | SM | - | - | - | - | - | - | RL | Y | - | - | Refer to Plan 1 |
| Tributary to Navigation Creek 3 | - | - | - | SM | - | - | - | - | - | - | AL | Y | - | - | Refer to Plan 1 |
| Tributary to Navigation Creek 4 | - | - | - | SM | - | REF | - | - | - | - | AL, R | Y | - | - | Refer to Plan 1 |
| Tributary to Navigation Creek 5 | - | - | - | SM | FT | - | - | - | - | - | AL, R | Y | - | - | Refer to Plan 1 |
| Elladale Creek | - | - | - | M | AS | SST | - | - | - | - | R | Y | Refer Plate 19 | Refer Map EL-1 to EL-2 | Refer to Plan 1 |
| Simpsons Creek | - | - | - | M | AS | SST | - | - | - | - | R | Y | Refer Plate 20 | Refer Map SIM-1 | Refer to Plan 1 |
| **Appin West (Area 9)** | | | | | | | | | | | | | | | |
| Apps Gully | - | - | - | M | - | CPW, SDR | - | - | - | - | AL, RL | Y | - | - | Refer to Plan 3 |
| Harris Creek | - | - | - | M | - | - | - | - | - | - | R, Res, SU | Y | Refer Plate 21 | Refer Map HR-1 to HR-2 | Refer to Plan 3 |
| Matahill Creek | - | - | - | SM | - | REF | - | - | - | - | R | Y | - | - | Refer to Plan 3 |
| Tributary to Nepean River 1 | - | - | - | M | - | SST | - | - | - | - | R | Y | - | - | Refer to Plan 3 |
| Tributary to Nepean River 2 | - | - | - | M | - | - | - | - | - | - | R | Y | - | - | Refer to Plan 3 |
| **Appin Area 8** | | | | | | | | | | | | | | | |
| Allens Creek | - | - | - | M | FS, FT | - | - | BCH (PS), GFF (PS) | - | - | R | Y | Refer Plate 22 | Refer Map AC-1 to AC-7 | Refer to Plan 3 |
| Byrnes Creek | - | - | - | M | - | SST | - | - | - | - | R | Y | Refer Plate 23 | Refer Map BY-1 | Refer to Plan 3 |
| Carriage Creek | - | - | - | SM | AS | SST | - | - | - | - | AL, I, R, SU | Y | Refer Plate 24 | Refer Map CAR-1 to CAR-2 | Refer to Plan 3 |
| Clements Creek | - | - | - | M | AS | - | - | - | - | - | R | Y | Refer Plate 25 | Refer Map CL-1 to CL-2 | Refer to Plan 3 |
| Nepean River Reach 1 | - | - | - | SM | AS | - | MP (HR), SHD (HR) | - | - | - | I, R | Y | Refer Plate 26 | Refer Map NR-1 to NR-8 | Refer to Plan 3 |
| Racecourse Creek | - | - | - | SM | AS | CPW,REF, SDR | - | - | - | - | AL | Y | Refer Plate 27 | - | Refer to Plan 3 |
| Stringybark Creek | - | - | - | M | FT | - | - | - | - | - | R | Y | Refer Plate 28 | Refer Map SB-1 to SB-2 | Refer to Plan 3 |
| Tributary to Carriage Creek 1 | - | - | - | SM | - | SST | - | - | - | - | I, R, SU | Y | - | - | Refer to Plan 3 |
| Tributary to Carriage Creek 2 | - | - | - | SM | - | - | - | - | - | - | AL, R | Y | - | - | Refer to Plan 3 |
| Tributary to Racecourse Creek 1 | - | - | - | SM | - | - | - | - | - | - | AL | Y | - | - | Refer to Plan 3 |
| Tributary to Racecourse Creek 2 | - | - | - | SM | - | - | - | - | - | - | AL | Y | - | - | Refer to Plan 3 |

# Attachment PB
# Stream Matrix

| River or Significant Stream | Predicted Subsidence Effects | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Minimum Depth of Cover (m) | Sensitivity to Valley Closure/Upsidence | Systematic Subsidence Parameters (EA Base Plan [Section 2 of the EA]) | | Stream Long Section - Tilt and Grade | Maximum Equivalent Valley Height (MEVH) (m) | Easting (at MEVH) | Northing (at MEVH) | Non-Systematic Subsidence Parameters (EA Base Plan [Section 2 of the EA]) | | Stream Long Section - Equivalent Valley Height, Upsidence and Closure | Length of Stream with greater than 200 mm Closure (km) | Length of Stream Previously Subject to more than 200 mm Closure (km) |
| | | Geological Formation | Total Maximum Subsidence Predicted (mm) | Total Maximum Predicted Tilt (mm/m) | | | | | Maximum Predicted Upsidence (mm) | Maximum Predicted Closure (mm) | | | |
| **North Cliff** | | | | | | | | | | | | | |
| Cobbong Creek | 385 | Hawkesbury Sandstone | 370 | 2.8 | - | 58 | 300900 | 6216075 | 250 | 410 | Refer Figure 200-31 | 1.6 | 0.0 |
| Dahlia Creek Reach 1 | 390 | Hawkesbury Sandstone | 1,340 | 5.3 | - | 89 | 303325 | 6215525 | 1,340 | 1,520 | Refer Figure 200-30 | 3.3 | 0.0 |
| Dahlia Creek Reach 2 | 450 | Hawkesbury Sandstone | 1,370 | 5.2 | - | 51 | 305550 | 6214650 | 1,155 | 1,380 | Refer Figure 200-30 | 2.8 | 0.0 |
| O'Hares Creek | 360 | Hawkesbury Sandstone | 40 | 0.4 | - | 145 | 301925 | 6219525 | 225 | 260 | Refer Figure 200-28 | 2.0 | 0.0 |
| Punchbowl Creek | 435 | Hawkesbury Sandstone | 1,145 | 5.7 | - | 107 | 304250 | 6218625 | 940 | 1,135 | Refer Figure 200-35 | 2.4 | 0.0 |
| Stokes Creek Reach 2 | 350 | Hawkesbury Sandstone | 55 | 0.4 | - | 54 | 302100 | 6211425 | 135 | 215 | Refer Figure 200-32 | 0.2 | 0.0 |
| Stokes Creek Reach 3 | 355 | Hawkesbury Sandstone | 780 | 5.6 | - | 29 | 304075 | 6208225 | 270 | 385 | Refer Figure 200-32 | 0.7 | 0.0 |
| Tributary to O'Hares Creek 1 | 370 | Hawkesbury Sandstone | 1,090 | 8.1 | - | 71 | 303700 | 6213000 | 915 | 1,105 | Refer Figure 200-29 | 1.0 | 0.0 |
| Tributary to O'Hares Creek 2 | 375 | Hawkesbury Sandstone | 675 | 4.3 | - | 111 | 302050 | 6219275 | 1,030 | 885 | - | 0.5 | 0.0 |
| Tributary to Punchbowl Creek | 395 | Hawkesbury Sandstone | 1,315 | 5.1 | - | 75 | 302975 | 6217525 | 1,340 | 1,515 | - | 1.0 | 0.0 |
| Tributary to Woronora River | 440 | Hawkesbury Sandstone | 75 | 0.7 | - | 60 | 307450 | 6216475 | 115 | 305 | - | 0.2 | 0.0 |
| Woronora River | 425 | Hawkesbury Sandstone | 350 | 1.4 | - | 53 | 306950 | 6216500 | 195 | 465 | Refer Figure 200-34 | 1.1 | 0.0 |
| **West Cliff Area 5** | | | | | | | | | | | | | |
| Georges River Reach 2 | 445 | Hawkesbury Sandstone | 150 | 1.2 | - | 37 | 297325 | 6219100 | 130 | 215 | Refer Figure 200-26 | 0.2 | 0.0 |
| Mallaty Creek | 445 | Wianamatta Group and Hawkesbury Sandstone | 1,180 | 3.9 | - | 28 | 294750 | 6217475 | 420 | 590 | Refer Figure 200-12 | 1.1 | 0.3 |
| Stokes Creek Reach 1 | 405 | Hawkesbury Sandstone | 90 | 0.7 | - | 69 | 299050 | 6216150 | 140 | 305 | Refer Figure 200-33 | 1.0 | 0.3 |
| **Appin Areas 2 and 3 Extended** | | | | | | | | | | | | | |
| Georges River Reach 1 | 390 | Hawkesbury Sandstone | 220 | 1.6 | - | 37 | 297850 | 6209975 | 495 | 380 | Refer Figure 200-27 | 1.2 | 0.4 |
| Cataract River | 305 | Hawkesbury Sandstone | 120 | 0.6 | - | 87 | 295525 | 6208275 | 185 | 290 | Refer Figure 200-19 | 1.3 | 0.5 |
| Cascade Creek | 400 | Hawkesbury Sandstone | 575 | 4.2 | - | 53 | 292075 | 6209900 | 310 | 335 | Refer Figure 200-23 | 1.0 | 0.0 |
| Lizard Creek | 345 | Hawkesbury Sandstone | 30 | 0.2 | - | 84 | 295575 | 6207925 | 150 | 200 | Refer Figure 200-20 | 0.0 | 0.0 |
| Wallandoola Creek | 370 | Hawkesbury Sandstone | 1,190 | 6.3 | - | 65 | 292850 | 6209725 | 1,225 | 1,450 | Refer Figure 200-22 | 3.8 | 0.0 |
| Wallandoola East Creek | 415 | Hawkesbury Sandstone | 1,175 | 7.3 | - | 30 | 294025 | 6209900 | 525 | 525 | Refer Figure 200-21 | 2.3 | 0.0 |
| Tributary to Cataract Reservoir 1 | 305 | Hawkesbury Sandstone | 1,295 | 10.4 | - | 18 | 300375 | 6206425 | 395 | 315 | Refer Figure 200-25 | 1.2 | 0.0 |
| Tributary to Cataract Reservoir 2 | 300 | Hawkesbury Sandstone | 1,205 | 9.0 | - | 28 | 302400 | 6207175 | 380 | 400 | Refer Figure 200-24 | 0.5 | 0.0 |
| Tributary to Cataract River 1 | 355 | Hawkesbury Sandstone | 70 | 0.9 | - | 60 | 297025 | 6208325 | 250 | 435 | - | 0.3 | 0.0 |
| Tributary to Cataract River 2 | 430 | Hawkesbury Sandstone | 30 | 0.2 | - | 46 | 295000 | 6210250 | 100 | 150 | - | 0.0 | 0.0 |
| **Appin Area 7** | | | | | | | | | | | | | |
| Foot Onslow Creek | 525 | Wianamatta Group | 1,435 | 5.0 | Refer Figure PG-01 | 26 | 290625 | 6219525 | 650 | 635 | Refer Figure 200-13 | 3.8 | 0.0 |
| Navigation Creek | 570 | Wianamatta Group | 1,440 | 6.2 | - | 36 | 288300 | 6218200 | 440 | 770 | Refer Figure 200-14 | 1.3 | 0.0 |
| Nepean River Reach 2 | 425 | Hawkesbury Sandstone | 590 | 3.1 | - | 75 | 292550 | 6218825 | 565 | 755 | Refer Figure 200-02 | 10.4 | 2.1 |
| Nepean River Reach 3 | 520 | Hawkesbury Sandstone | 125 | 0.6 | - | 23 | 291300 | 6223750 | 110 | 85 | Refer Figure 200-03 | 0.0 | 0.0 |
| Ousedale Creek | 445 | Hawkesbury Sandstone | 1,240 | 6.0 | - | 49 | 292900 | 6217475 | 315 | 415 | Refer Figure 200-11 | 3.6 | 0.1 |
| Tributary to Navigation Creek 1 | 550 | Wianamatta Group | 1,440 | 3.6 | - | 38 | 288700 | 6217725 | 695 | 930 | - | 2.7 | 0.0 |
| Tributary to Navigation Creek 2 | 595 | Wianamatta Group | 1,550 | 4.2 | - | 30 | 287875 | 6219050 | 505 | 460 | - | 0.8 | 0.0 |
| Tributary to Navigation Creek 3 | 590 | Wianamatta Group | 1,350 | 0.9 | - | 19 | 288375 | 6219650 | 325 | 365 | - | 0.1 | 0.0 |
| Tributary to Navigation Creek 4 | 605 | Wianamatta Group | 1,355 | 2.1 | Refer Figure PG-02 | 23 | 288050 | 6220475 | 485 | 360 | - | 0.8 | 0.0 |
| Tributary to Navigation Creek 5 | 620 | Wianamatta Group | 320 | 2.5 | - | 21 | 288300 | 6221500 | 135 | 210 | - | 0.1 | 0.0 |
| Elladale Creek | 460 | Hawkesbury Sandstone | 315 | 1.8 | - | 42 | 292375 | 6215025 | 320 | 395 | Refer Figure 200-10 | 0.6 | 0.6 |
| Simpsons Creek | 470 | Hawkesbury Sandstone | 1,505 | 6.7 | - | 39 | 292500 | 6214900 | 515 | 420 | - | 5.9 | 5.9 |
| **Appin West (Area 9)** | | | | | | | | | | | | | |
| Apps Gully | 700 | Wianamatta Group | 1,490 | 3.7 | Refer Figure PG-03 | 50 | 284950 | 6218100 | 695 | 1,195 | Refer Figure 200-17 | 1.8 | 0.0 |
| Harris Creek | 430 | Wianamatta Group and Hawkesbury Sandstone | 1,385 | 3.7 | - | 31 | 289125 | 6214225 | 550 | 535 | Refer Figure 200-09 | 1.0 | 0.0 |
| Matahill Creek | 660 | Wianamatta Group | 1,365 | 5.5 | - | 61 | 285325 | 6219525 | 720 | 1,245 | Refer Figure 200-15 | 1.6 | 0.0 |
| Tributary to Nepean River 1 | 460 | Wianamatta Group and Hawkesbury Sandstone | 1,090 | 2.6 | - | 60 | 286300 | 6214975 | 495 | 785 | - | 1.2 | 0.0 |
| Tributary to Nepean River 2 | 505 | Wianamatta Group and Hawkesbury Sandstone | 1,155 | 2.8 | - | 19 | 286450 | 6215500 | 400 | 285 | - | 0.1 | 0.0 |
| **Appin Area 8** | | | | | | | | | | | | | |
| Allens Creek | 425 | Hawkesbury Sandstone | 1,125 | 5.3 | - | 54 | 287125 | 6214425 | 625 | 1,065 | Refer Figure 200-06 | 6.5 | 0.0 |
| Byrnes Creek | 400 | Wianamatta Group and Hawkesbury Sandstone | 895 | 4.0 | - | 66 | 284025 | 6212625 | 725 | 855 | Refer Figure 200-05 | 1.7 | 0.0 |
| Carriage Creek | 405 | Wianamatta Group and Hawkesbury Sandstone | 775 | 3.6 | - | 34 | 282500 | 6212800 | 300 | 385 | Refer Figure 200-04 | 1.6 | 0.0 |
| Clements Creek | 420 | Hawkesbury Sandstone | 955 | 3.3 | - | 54 | 289125 | 6210700 | 640 | 1,055 | Refer Figure 200-08 | 1.0 | 0.0 |
| Nepean River Reach 1 | 345 | Hawkesbury Sandstone | 60 | 0.3 | - | 80 | 282825 | 6212475 | 270 | 370 | Refer Figure 200-01 | 7.1 | 0.0 |
| Racecourse Creek | 630 | Wianamatta Group | 1,120 | 4.5 | Refer Figure PG-04 | 65 | 283700 | 6217675 | 680 | 1,105 | Refer Figure 200-16 | 4.2 | 0.0 |
| Stringybark Creek | 440 | Hawkesbury Sandstone | 910 | 3.7 | - | 34 | 287550 | 6211725 | 485 | 675 | Refer Figure 200-07 | 2.4 | 0.0 |
| Tributary to Carriage Creek 1 | 455 | Wianamatta Group | 905 | 3.7 | - | 21 | 282525 | 6213525 | 445 | 335 | - | 0.5 | 0.0 |
| Tributary to Carriage Creek 2 | 510 | Wianamatta Group | 95 | 0.5 | - | 58 | 281900 | 6215250 | 260 | 435 | - | 0.2 | 0.0 |
| Tributary to Racecourse Creek 1 | 635 | Wianamatta Group | 1,110 | 2.3 | - | 60 | 283900 | 6216825 | 700 | 1,235 | Refer Figure 200-18 | 2.3 | 0.0 |
| Tributary to Racecourse Creek 2 | 665 | Wianamatta Group | 600 | 2.3 | - | 63 | 283750 | 6217725 | 595 | 875 | - | 0.2 | 0.0 |

## Stream Matrix Definitions

| No. | Item | Definition |
|---|---|---|
| *Characterisation* | | |
| 1 | River or Significant Stream | Identifies the rivers and significant streams located above the extent of longwall mining area and within 600 metres (m) of the edge of secondary extraction.<br><br>This includes relevant rivers as named on the Appin, Bargo, Bulli, Camden, Campbelltown and Picton 1:25,000 topographic maps produced by the New South Wales (NSW) Department of Information Technology and Management - Land Information Centre and streams of third order or above according to the Strahler stream classification system.<br><br>The rivers and significant streams (herein referred to as streams) have been grouped according to mining domain (i.e. North Cliff, West Cliff Area 5, Appin Areas 2 and 3 Extended, Appin Area 7, Appin West [Area 9] and Appin Area 8).<br><br>The locations of the streams are shown on Plans 1 to 4 in Attachment PC.<br><br>Some streams have been separated into reaches for the purpose of the risk assessment. This includes the Georges River (reaches 1 and 2), Nepean River (reaches 1, 2 and 3), Dahlia Creek (reaches 1 and 2) and Stokes Creek (reaches 1, 2 and 3). |
| 2 | Named? | Identifies the streams that are named on the Appin, Bargo, Bulli, Camden, Campbelltown and Picton 1:25,000 topographic maps produced by the NSW Department of Information Technology and Management - Land Information Centre.<br><br>*Legend:*<br><br>N = No.<br><br>Y = Yes. |
| 3 | Approximate Stream Length within Extent of Longwall Mining Area (km) | Length of stream within the extent of longwall mining area shown on Plans 1 to 4 in Attachment PC. Length given in kilometres (km).<br><br>*Legend:*<br><br>N/A = Stream not located within the extent of longwall mining area. |
| 4 | Approximate Stream Length within 600 m of Extent of Longwall Mining Area (km) | Length of stream within 600 m of the extent of longwall mining area shown on Plans 1 to 4 in Attachment PC. |
| 5 | Stream History – Previously Subject to Subsidence | Stream reaches previously subject to subsidence as a result of longwall mining in some or all of its reach.<br><br>*Legend:*<br><br>N = No.<br><br>Y = Yes – (relevant longwall mining area provided). |
| 6 | Stream History – Distance (km) Previously Undermined/Affected by Subsidence | The approximate length of the stream reach previously undermined (refer to Plans 1 to 4 in Attachment PC).<br><br>The approximate length of Wallandoola East Creek subject to subsidence is provided based on back predictions of closure as a result of mining at Appin Area 2. |
| 7 | Maximum Strahler Stream Order | Maximum stream order determined in accordance with the Strahler stream classification system using the Appin, Bargo, Bulli, Camden, Campbelltown and Picton 1:25,000 topographic maps produced by the NSW Department of Information Technology and Management - Land Information Centre.<br><br>Streams of lower than third order are included on the basis that they are named rivers or the stream located within the extent of longwall mining area or within 600 m of the boundary of secondary extraction comprises some reaches of third order or above. |

## Stream Matrix Definitions (Continued)

| No. | Item | Definition |
|---|---|---|
| 8 | Average Stream Gradient (m/km) | The average stream gradient determined for each stream reach by calculating the change in elevation over the relevant reach and dividing by the length of the reach. Gradient given in metres per kilometre (m/km).<br><br>Note: stream profiles for a selection of streams are shown on long sections provided in Attachment PG. |
| 9 | Geomorphic Type | A geomorphic classification has been developed by Gilbert & Associates to characterise the geomorphic attributes of the streams. The classification scheme has been based loosely on the River Styles framework as described in the paper by Brierley *et al*. (2002).<br><br>The classification scheme is based on four groups of geomorphic attributes, namely: valley type; floodplain development; bed materials and mobility; and dominant physical features.<br><br>*Legend:*<br><br><u>Valley Type:</u><br><br>V1 = Confined.<br><br>V2 = Partially Confined.<br><br>V3 = Alluvial.<br><br><u>Floodplain Development:</u><br><br>FP1 = No floodplains.<br><br>FP2 = Irregular floodplain and floodplain pockets less than 25% of stream fringed by floodplains.<br><br>FP3 = Moderate floodplain development – between 25% and 75% of stream fringed by floodplains.<br><br>FP4 = High floodplain development – greater than 75% of stream fringed by floodplains.<br><br><u>Bed Materials and Mobility:</u><br><br>B1 = Bedrock comprising rock outcrop or boulderfield beds with no or minimal/infrequent mobile sediments in some sections.<br><br>B2 = Sand bed comprising cohesionless sandy sediments.<br><br>B3 = Cohesive bed comprising silty, sandy bed materials with significant cohesion and/or organic materials.<br><br><u>Dominant Physical Features:</u><br><br>DF1 = Pools and rockbars and chutes.<br><br>DF2 = Cascades and waterfalls.<br><br>DF3 = Boulderfields.<br><br>DF4 = Pools and riffles in alluvial/mobile streams.<br><br>DF5 = Uniform streams with no or insignificant pool development.<br><br>DF6 = Swamps and/or chain of ponds wide shallow streams with significant in-stream vegetation and persistent swamps or wide shallow pools with ill defined channels.<br><br>In applying the classification scheme to the stream reaches, the classification which is dominant over the full length of the stream reach has been selected. |

## Stream Matrix Definitions (Continued)

| No. | Item | Definition |
|---|---|---|
| 10 | Visual Amenity/Key Features (e.g. riffles, pools, etc.) | Identifies key in-stream/visual amenity features based on stream mapping provided in Attachment PA.<br>*Legend:*<br>B = Boulderfield.<br>I = Island.<br>P = Pool.<br>R = Riffle.<br>RB = Rockbar.<br>RS = Rockshelf.<br>S = Sediment.<br>SB = Sandbar.<br>V = Vegetated Drainage Line.<br>W = Waterfall.<br>N/D = Not determined. |
| 11 | Stream Catchment Area ($km^2$) | Catchment area based on the total upstream catchment area reporting to the downstream point of each stream reach. Catchment area given in square kilometres ($km^2$). |
| 12 | Permanence of Flow/Flow Regime | Categorises the permanence of flow of each stream reach.<br>Streams were categorised as perennial based on the mapping of perennial watercourses on the 1:25,000 topographic maps produced by the NSW Department of Information Technology and Management – Land Information Centre.<br>Streams not mapped as perennial were categorised as intermittent and/or ephemeral.<br>Streams were categorised as perennial to intermittent-ephemeral if the permanence of flow changed over the stream reach being assessed.<br>*Legend:*<br>P = Perennial.<br>I-E = Intermittent and/or Ephemeral.<br>P/I-E = Perennial – Intermittent/Ephemeral. |
| 13 | Stream Regulation – SCA Regulated Flow | Identifies whether any Sydney Catchment Authority (SCA)-controlled dams and/or weirs are known to be situated upstream of the stream reaches, namely, the Cataract Dam, Broughtons Pass Weir and Pheasants Nest Weir.<br>*Legend:*<br>N = No.<br>Y = Yes. |
| 14 | Stream Regulation – DECC Regulated Flow (e.g. EPL Discharges) | Identifies reaches subject to NSW Department of Environment and Climate Change (DECC) licensed water discharges (i.e. via Environmental Protection Licences) based on the DECC public register for licences, applications and notices under the *Protection of the Environment Operations Act, 1997* (as at July 2009).<br>*Legend:*<br>N = No.<br>Y = Yes. |

## Stream Matrix Definitions (Continued)

| No. | Item | Definition |
|---|---|---|
| 15 | Importance to Catchment Yield | Assesses the importance of the stream reach to catchment yield based on the catchment area of the stream reach [Item 11] relative to the overall area of the closest parent watercourse.<br>The parent watercourses are O'Hares Creek, Punchbowl Creek and Woronora River in North Cliff, the Georges River and Nepean River in West Cliff Area 5, the Cataract River in Appin Areas 2 and 3 Extended, the Nepean River, Foot Onslow Creek and Navigation Creek in Appin Area 7, the Nepean River, Matahill Creek, Navigation Creek and Racecourse Creek in Appin West (Area 9) and the Nepean River and Racecourse Creek in Appin Area 8.<br>*Legend:*<br>L = Low.<br>M = Moderate.<br>H = High. |
| 16 | Significance to Water Supply – Percentage of Woronora Dam Catchment Area | The significance of each stream reach to the Woronora Dam Catchment presented as a percentage. Calculated by dividing the catchment area of the stream reach [Item 11] by the catchment area of the Woronora Dam (75 $km^2$). |
| 17 | Significance to Water Supply – Percentage of Cataract Dam Catchment Area | The significance of each stream reach to the Cataract Dam Catchment presented as a percentage. Calculated by dividing the catchment area of the stream reach [Item 11] by the catchment area of the Cataract Dam (130 $km^2$). |
| 18 | Significance to Water Supply – Percentage of Broughtons Pass Weir Catchment Area | The significance of each stream reach to the Broughtons Pass Weir Catchment presented as a percentage. Calculated by dividing the catchment area of the stream reach [Item 11] by the catchment area of the Broughtons Pass Weir (211 $km^2$).<br>The Broughtons Pass Weir is situated on the Cataract River and therefore contributes 100% to the weir. |
| 19 | Environmental Quality (Existing/Observed Disturbance) | Provides a qualitative assessment of the environmental quality of the stream reach based on known disturbances in consideration of the information provided in the Surface Water Assessment (Appendix C of the EA) and Flora Assessment (Appendix E of the EA) and the inspection of aerial photographs provided in Attachment PD and available on Google Earth.<br>*Legend:*<br>P = Pristine - majority of vegetation within upstream catchment is intact, limited disturbances within catchment area (e.g. fire tracks, exploration activities).<br>M = Modified - majority of riparian vegetation intact, agricultural/other disturbances within catchment areas.<br>SM = Severely Modified - moderate to high disturbance of riparian vegetation, agricultural/other disturbances to catchment area and/or disturbance to channel/flow (e.g. weirs, dams, discharges). |
| 20 | Ecological Importance – Flora, Fauna and Aquatic Survey Sites | The flora, fauna and aquatic surveys for the Project included representative sampling of stream and adjacent riparian and/or gully habitats. The flora, fauna and aquatic survey sites on or adjacent to the stream reaches are identified.<br>Aquatic ecology survey sites have been included for the stream reach in which they were conducted.<br>Terrestrial flora survey sites have been included on the basis of being located within the riparian zone of a stream reach.<br>Terrestrial fauna survey sites have been included on the basis of being located either in the stream (water habitat) or adjacent to the stream either in riparian or gully forest habitat).<br>Details of the survey methodologies are provided in the Aquatic Ecology Assessment (Appendix D of the EA), Terrestrial Flora Assessment (Appendix E of the EA) and Terrestrial Fauna Assessment (Appendix F of the EA). |

## Stream Matrix Definitions (Continued)

| No. | Item | Definition |
|---|---|---|
| 20 (Cont.) | Ecological Importance – Flora, Fauna and Aquatic Survey Sites (Cont.) | A systematic fauna survey site was undertaken in gully forest habitat along the Georges River between reaches 1 and 2. This site location has subsequently been included in both reaches of the Georges River.<br>*Legend:*<br>- = No survey sites within the water habitat of the stream or in the riparian zone<br>Fauna<br>FT = Targeted Survey Site<br>FS = Systematic Survey Site<br>Flora<br>FLS = Spot Sampling Site<br>FLRM = Random Meander<br>FLQ = Quadrat<br>Aquatic Ecology<br>AQ = Aquatic Ecology Sampling Site |
| 21 | Ecological Importance –EECs Present in Riparian Zone | Identifies vegetation communities identified within the riparian zone of stream reaches that represent Endangered Ecological Communities (EECs) listed under the NSW *Threatened Species Conservation Act, 1999* (TSC Act) or Commonwealth *Environment Protection and Biodiversity Conservation Act, 1999* (EPBC Act) (Appendix E of the EA) (as at 1 July 2009).<br>*Legend:*<br>CPW = Cumberland Plain Woodland (TSC Act)<br>REF = River-flat Eucalypt Forest on Coastal Floodplains (TSC Act)<br>SDR = Western Sydney Dry Rainforest in the Sydney Basin Bioregion (TSC Act)<br>SST = Sandstone/Shale Transition Forest (TSC Act and EPBC Act)<br>- = riparian vegetation does not represent any Endangered Ecological Communities listed under the TSC Act or EPBC Act |
| 22 | Ecological Importance – Threatened Species Recorded During Project Surveys and/or Described in Aquatic Ecology Assessment – Records within Streams | Identifies threatened species recorded in streams by the Project surveys (Appendices D, E and F of the EA) or based on historic records described in the Aquatic Ecology Assessment.<br>The Macquarie Perch was recently collected in the Georges River, near its confluence with Punchbowl Creek (S. Carter, pers. comm., 12 December 2008), which is approximately 15 km downstream of the Project area. A record for this species has been included for the Georges River reach 2.<br>The Macquarie Perch was recorded "downstream of Pheasants Nest Weir" in the Nepean River (Gerhke and Harris, 1996). A record for this species has been included for Nepean River reaches 1, 2 and 3.<br>An historic record for the Sydney Hawk Dragonfly near Maldon Bridge has been included for Nepean River reach 1.<br>*Legend:*<br>SHD = Sydney Hawk Dragonfly<br>MP = Macquarie Perch<br>LFM = Large-footed Myotis<br>(HR) = Historic record described in Aquatic Ecology Assessment<br>(PR) = Record from Project surveys<br>- = no threatened species records from Project surveys or historic records as described in the Aquatic Ecology Assessment. |

## Stream Matrix Definitions (Continued)

| No. | Item | Definition |
|---|---|---|
| 23 | Ecological Importance – Threatened Species Recorded During Project Surveys and Described in Aquatic Ecology Assessment – Records adjacent to Stream in Riparian or Gully Habitats | Identifies threatened species recorded in riparian and/or gully habitats adjacent to the stream reaches by the Project surveys (Appendices D, E and F of the EA).<br>Threatened flora species records have been included on the basis of being located within the riparian zone of a stream reach.<br>Threatened fauna species records have been included on the basis of being located either in riparian or gully forest habitat adjacent to the stream reach.<br>The Eastern Bentwing-bat was recorded in Gully Forest habitat along the Georges River between reaches 1 and 2. A record for this species has subsequently been included in both reaches of the Georges River.<br>*Legend:*<br>LE = *Leucopogon exolasius*<br>PoA = *Pomaderris adnata*<br>PuA = *Pultenaea aristata*<br>BCH = Black-chinned Honeyeater<br>EBB = Eastern Bentwing-bat<br>EPP = Eastern Pygmy Possum<br>GFF = Grey-headed Flying Fox<br>K = Koala<br>PO = Powerful Owl<br>RCT = Red Crowned Toadlet<br>(PS) = Record from Project surveys<br>- = no threatened species records from Project surveys |
| 24 | Stream Location – Relevant DECC Area | Identifies stream reaches located within the Dharawal State Conservation Area. No nature reserves are located within the Project Area.<br>*Legend:*<br>DSCA = Dharawal State Conservation Area.<br>- = Not located within Dharawal Sate Conservation Area. |
| 25 | Stream Location – Relevant SCA Special Area | Identifies stream reaches located within the SCA Special Areas.<br>*Legend:*<br>M = Metropolitan Special Area.<br>O = O'Hares Creek Special Area.<br>W = Woronora Special Area.<br>- = Stream not located within SCA Special Area. |
| 26 | Land Zoning | Identifies the zoning of land within which the stream reaches are situated according to the Local Environmental Plan maps for the Wollondilly Shire, Wollongong City and Campbelltown City Councils. These zonings have been summarised into three categories in the legend below.<br>*Legend*:<br>AL = Agricultural Landscape<br>I = Industrial<br>NU = Non-Urban<br>OS = Local Open Space and/or Regional Open Space Reservation<br>R = Rural<br>Res = Residential<br>RL = Rural Living<br>SEP = Special Environmental Protection<br>SU = Special Use (Other than Water Catchment)<br>WC = Water Catchment |

## Stream Matrix Definitions (Continued)

| No. | Item | Definition |
|---|---|---|
| 27 | Public Accessibility | Identifies stream reaches that are accessible to the public (i.e. all stream reaches with the exception of those located in the Metropolitan and Woronora Special Areas). |
| 28 | Stream Photos | Refers to plates with aerial view and photographs for a selection of stream reaches, included in Attachment PD.<br>*Legend:*<br>- = Stream photos not compiled. |
| 29 | Stream Mapping | Refers to stream mapping of each reach provided in Attachment PA. The stream mapping identifies key in-stream/visual amenity features.<br>*Legend:*<br>- = Stream mapping not conducted. |
| 30 | Stream Risk Management Zone | Refers to Plans 1 to 4 in Attachment PC showing the Risk Management Zone applied to each stream reach. |
| *Predicted Subsidence Effects* | | |
| 31 | Minimum Depth of Cover (m) | The minimum depth of cover between each stream reach and the underlying coal seam. |
| 32 | Sensitivity to Valley Closure/Upsidence – Geological Formation | Geological formation within the stream bed as shown on DPI Geological Series Sheet 9029-9129.<br>Stream beds of Hawkesbury Sandstone have a greater sensitivity to valley closure and upsidence than stream beds of Wianamatta Group shales. |
| 33 | Systematic Subsidence Parameters (EA Base Plan [Section 2 of the EA]) – Total Maximum Subsidence Predicted (mm) | Maximum predicted vertical movement of a point at the surface in millimetres (mm).<br>Refer to Appendix A of the EA for further detail. |
| 34 | Systematic Subsidence Parameters (EA Base Plan [Section 2 of the EA]) – Total Maximum Predicted Tilt (mm/m) | Maximum predicted change in the slope of the land surface as a result of differential subsidence, where 1 millimetre per metre (mm/m) is equivalent to 0.1% change in grade.<br>Refer to Appendix A of the EA for further detail. |
| 35 | Stream Long Section - Tilt and Grade | Refers to a figure included in Attachment PG which shows the tilt [Item 34] and the change in grade across a long section along the stream.<br>*Legend:*<br>- = Long section showing tilt and grade not completed for this stream. |
| 36 | Maximum Equivalent Valley Height (MEVH) (m) | The average height of the two valley sides above the base of the valley, within a distance from the base of the valley equal to half the depth of cover at the base of the valley.<br>Refer to Appendix A of the EA for further detail. |
| 37 | Easting (at MEVH) | Coordinate taken at point along stream with MEVH [Item 36].<br>Coordinate provided in MGA (Zone 56). |
| 38 | Northing (at MEVH) | Coordinate taken at point along stream with MEVH [Item 36].<br>Coordinate provided in MGA (Zone 56). |
| 39 | Non-Systematic Subsidence Parameters (EA Base Plan [Section 2 of the EA]) – Maximum Predicted Upsidence (mm) | The maximum predicted reduced subsidence, bulging or net uplift movement within the base of a valley.<br>Refer to Appendix A of the EA for further detail. |

## Stream Matrix Definitions (Continued)

| No. | Item | Definition |
|---|---|---|
| 40 | Non-Systematic Subsidence Parameters (EA Base Plan [Section 2 of the EA]) – Maximum Predicted Closure (mm) | The maximum predicted reduction in the horizontal distance between the valley sides.<br>Refer to Appendix A of the EA for further detail. |
| 41 | Stream Long Section - Equivalent Valley Height, Upsidence and Closure | Refers to a figure included in Attachment PG which shows the equivalent valley height [Item 36], upsidence [Item 39] and closure [Item 40] across a long section along the stream.<br>*Legend:*<br>- = Long section showing equivalent valley height, upsidence and closure not completed for this stream. |
| 42 | Length of Stream with greater than 200 mm Closure (km) | Total length of stream reach that is predicted to be subject to closure greater than 200 mm [Item 40]. |
| 43 | Length of Stream Previously Subject to more than 200 mm Closure (km) | Length of stream reach that is currently subject to greater than 200 mm closure as a result of subsidence due to previous longwall mining. |

# ATTACHMENT PC

# STREAMS – AERIAL PHOTOS AND PLATES

# Plate 1: Dahlia Creek Reach 1

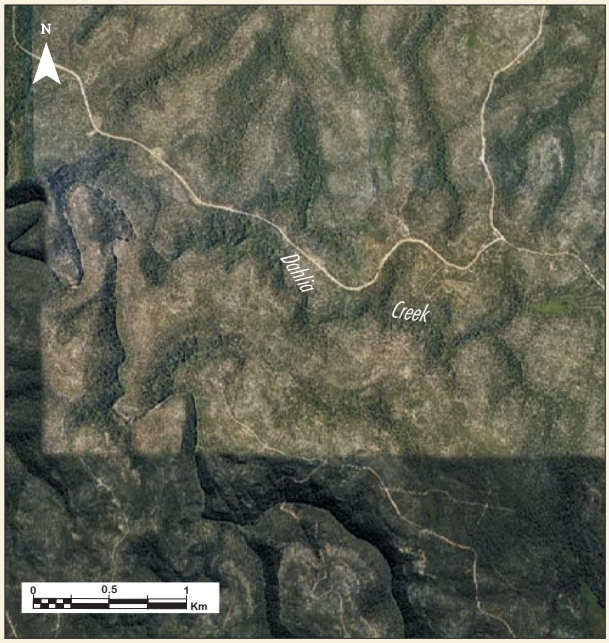



Photo A: November 2008

Photo B: December 2008

Photo C: December 2008

Photo D: December 2008

*Source: Google Earth (2009)*

# Plate 2: Dahlia Creek Reach 2

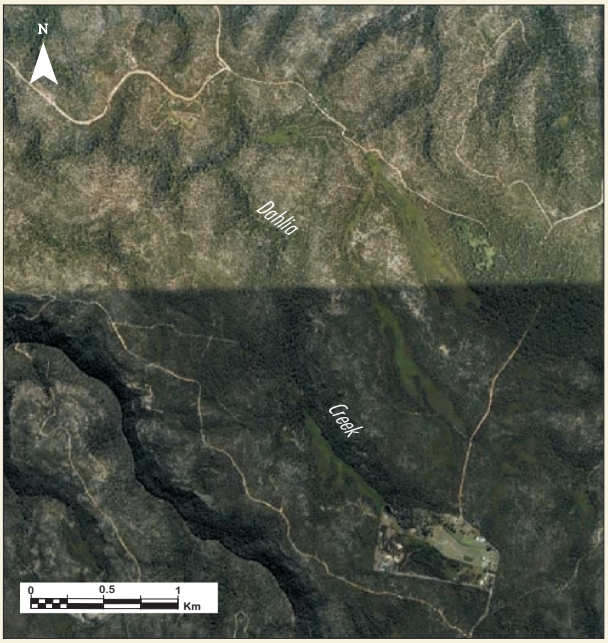



Photo A: July 2008

Photo B: July 2008

Photo C: July 2008

Photo D: July 2008

*Source: Google Earth (2009)*

# Plate 3: O'Hares Creek

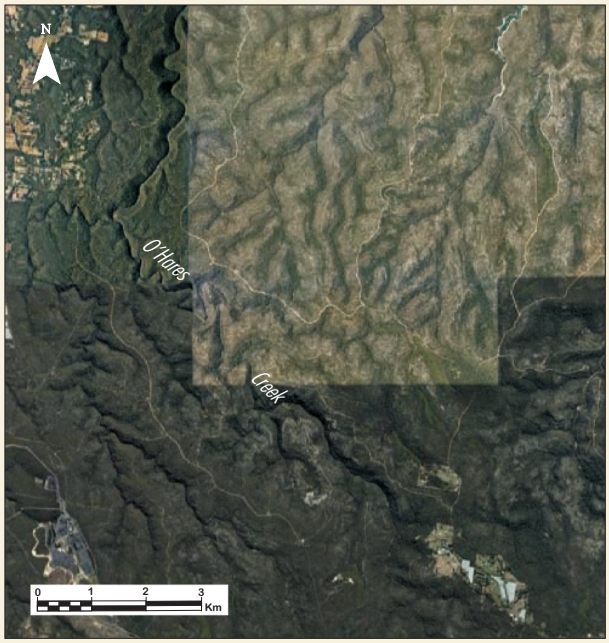



Photo A: August 2008

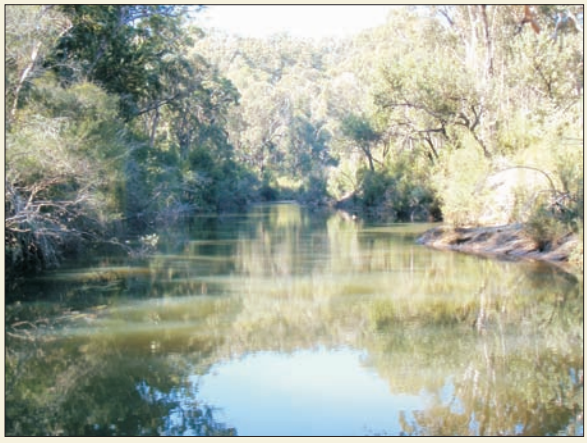


Photo B: September 2008

Photo C: October 2008

Photo D: November 2008

*Source: Google Earth (2009)*

# Plate 4: Punchbowl Creek


Photo A: January 2009

Photo B: January 2009

Photo C: January 2009

Photo D: January 2009

*Source: Google Earth (2009)*

# Plate 5: Stokes Creek Reach 2

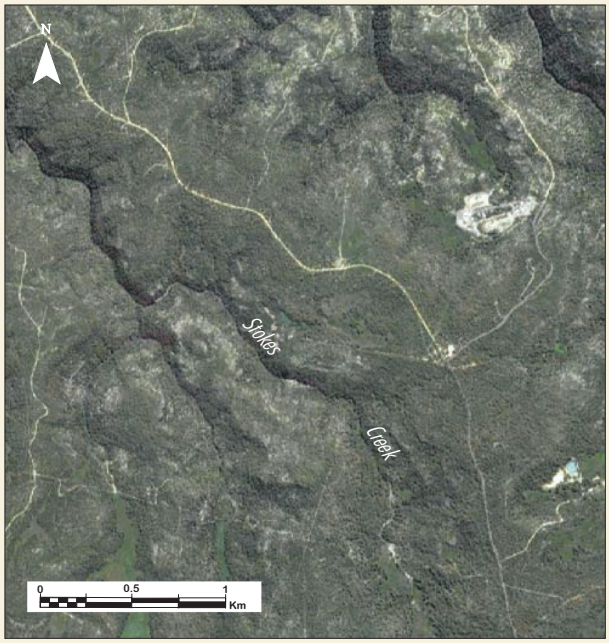



Photo A: January 2009

Photo B: January 2009

Photo C: January 2009

Photo D: January 2009

*Source: Google Earth (2009)*

# Plate 6: O'Hares Creek Tributary 1

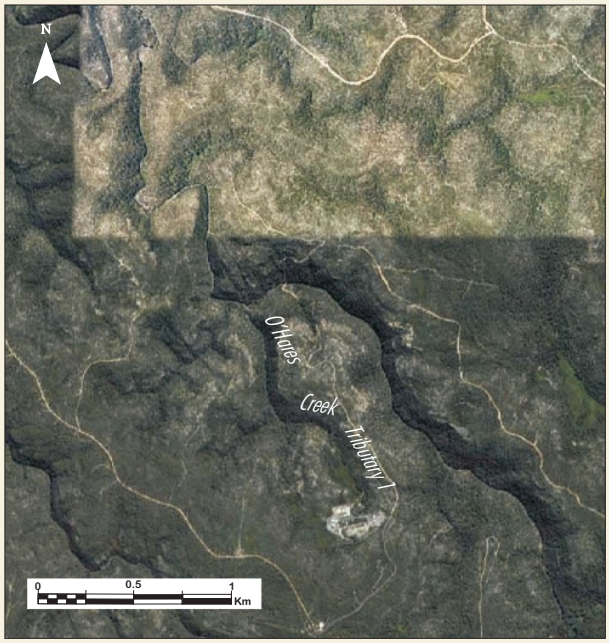



Photo A: March 2009

Photo B: March 2009

Photo C: March 2009

Photo D: March 2009

*Source: Google Earth (2009)*

# Plate 7: Woronora River

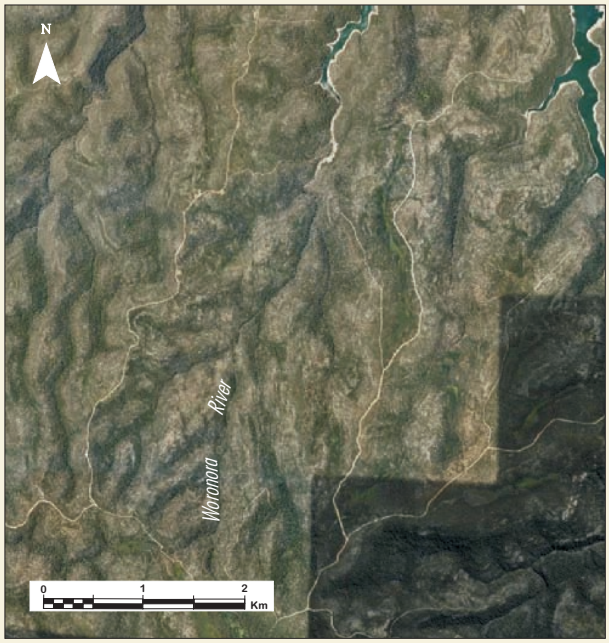



Photo A: January 2009

Photo B: February 2009

Photo C: February 2009

Photo D: February 2009

*Source: Google Earth (2009)*

# Plate 8: Georges River Reach 2


Photo A: September 2007

Photo B: September 2007

Photo C: October 2007

Photo D: October 2007

*Source: Google Earth (2009)*

# Plate 9: Mallaty Creek


Photo A: November 2007

Photo B: December 2007

Photo C: March 2008

Photo D: February 2009

*Source: Google Earth (2009)*

# Plate 10: Stokes Creek Reach 1


Photo A: November 2008

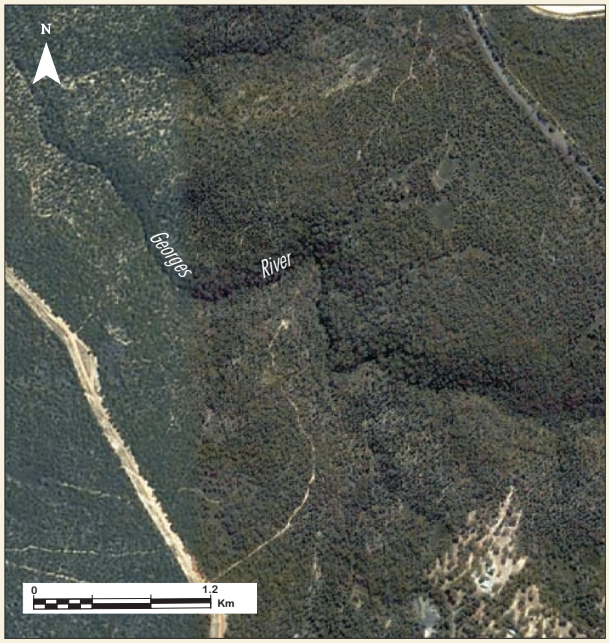
Photo B: November 2008

Photo C: November 2008

Photo D: November 2008

*Source: Google Earth (2009)*

# Plate 11: Georges River Reach 1



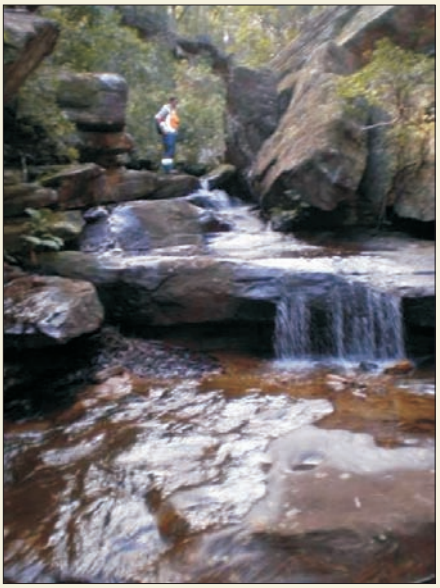



Photo A: May 2008

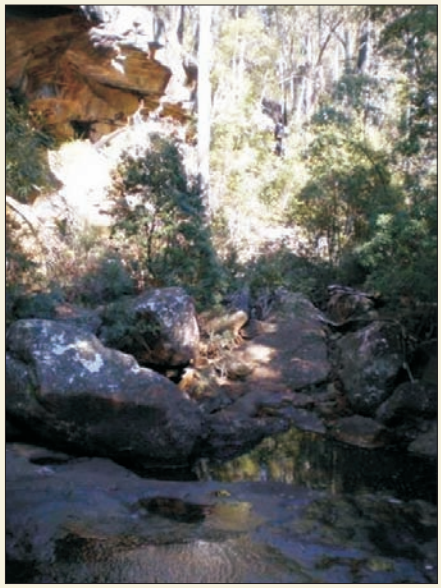


Photo B: May 2008

Photo C: May 2008

Photo D: May 2008

*Source: Google Earth (2009)*

# Plate 12: Cataract River

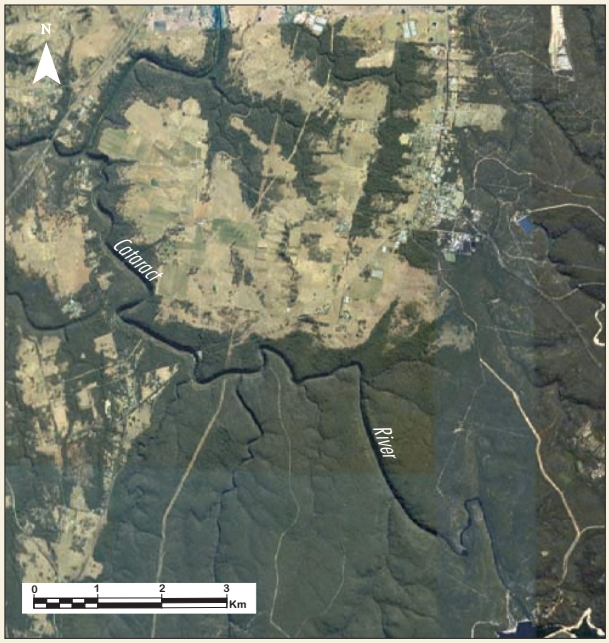



Photo A: February 2009

Photo B: February 2009

Photo C: February 2009

Photo D: March 2009

*Source: Google Earth (2009)*

# Plate 13: Cascade Creek

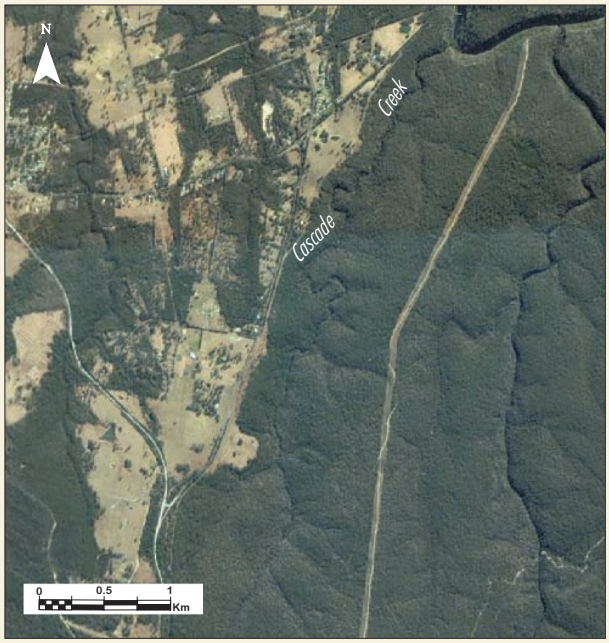



Photo A: November 2008

Photo B: November 2008

Photo C: December 2008

Photo D: December 2008

*Source: Google Earth (2009)*

# Plate 14: Lizard Creek

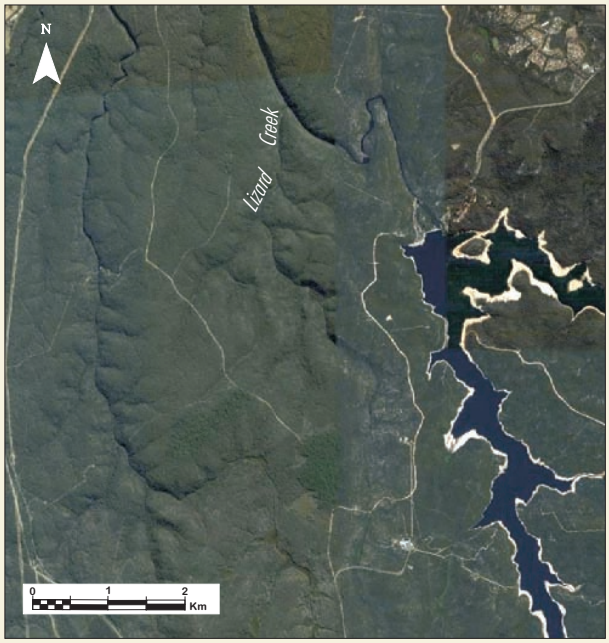



Photo A: December 2008

Photo B: December 2008

Photo C: December 2008

Photo D: December 2008

*Source: Google Earth (2009)*

# Plate 15: Wallandoola Creek

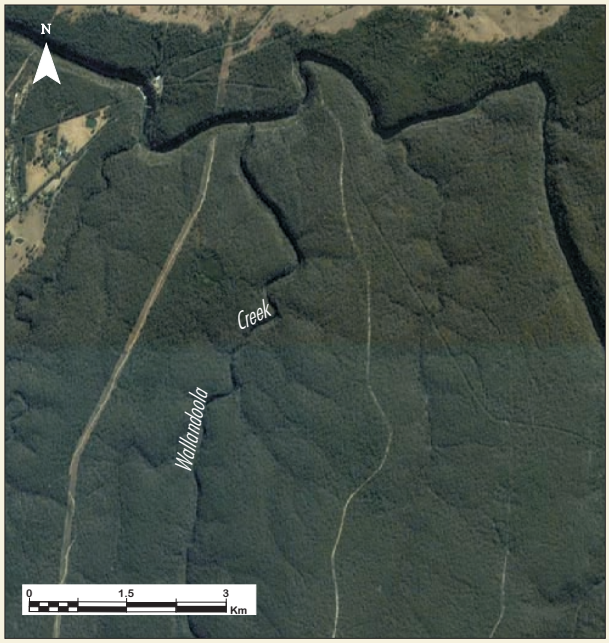



Photo A: December 2008

Photo B: December 2008

Photo C: December 2008

Photo D: December 2008

*Source: Google Earth (2009)*

# Plate 16: Cataract Reservoir Tributary 1

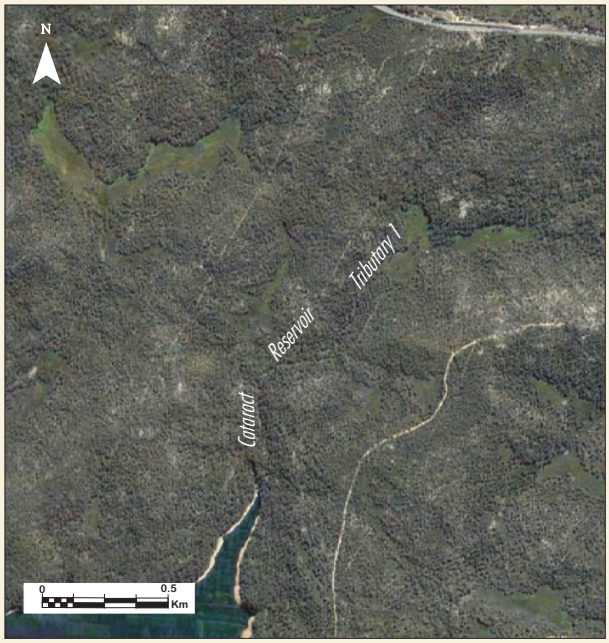



Photo A: March 2009

Photo B: March 2009

Photo C: March 2009

Photo D: March 2009

*Source: Google Earth (2009)*

# Plate 17: Cataract Reservoir Tributary 2


Photo A: March 2009

Photo B: March 2009

Photo C: March 2009

Photo D: March 2009

*Source: Google Earth (2009)*

# Plate 18: Ousedale Creek


Photo A: February 2009

Photo B: February 2009

Photo C: February 2009

Photo D: February 2009

*Source: Google Earth (2009)*

# Plate 19: Elladale Creek


Photo A: March 2009

Photo B: March 2009

Photo C: March 2009

Photo D: March 2009

*Source: Google Earth (2009)*

# Plate 20: Simpsons Creek


Photo A: March 2009

Photo B: March 2009

Photo C: March 2009

Photo D: March 2009

*Source: Google Earth (2009)*

# Plate 21: Harris Creek

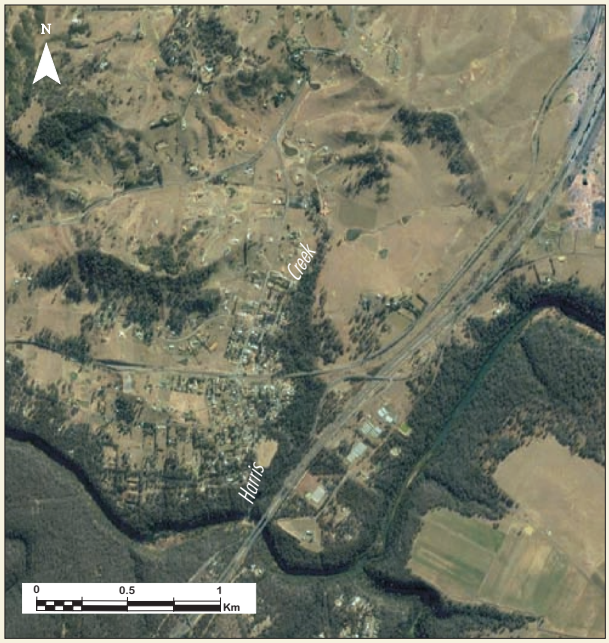



Photo A: February 2009

Photo B: February 2009

Photo C: February 2009

Photo D: February 2009

*Source: Google Earth (2009)*

# Plate 22: Allens Creek

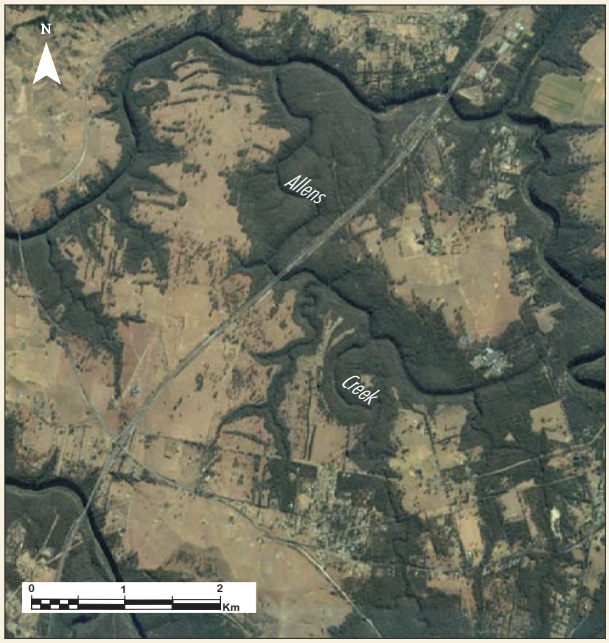



Photo A: January 2009

Photo B: January 2009

Photo C: January 2009

Photo D: January 2009

*Source: Google Earth (2009)*

# Plate 23: Byrnes Creek


Photo A: March 2009

Photo B: March 2009

Photo C: March 2009

Photo D: March 2009

*Source: Google Earth (2009)*

# Plate 24: Carriage Creek

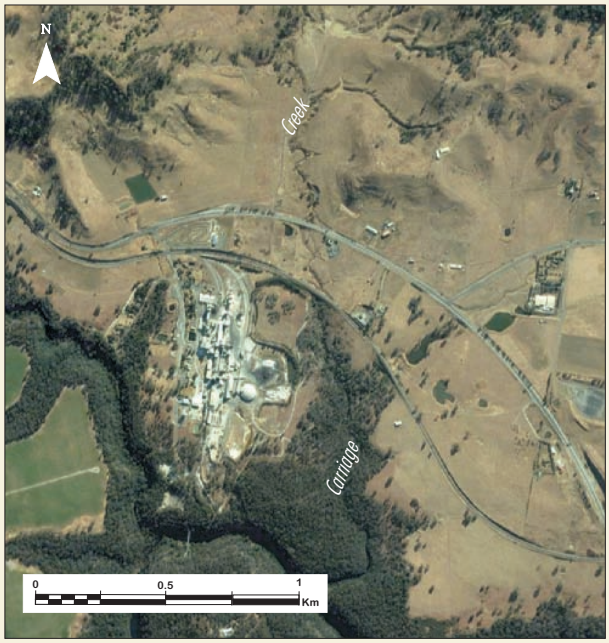



Photo A: March 2009

Photo B: March 2009

Photo C: March 2009

Photo D: March 2009

*Source: Google Earth (2009)*

# Plate 25: Clements Creek


Photo A: March 2009

Photo B: March 2009

Photo C: March 2009

Photo D: March 2009

*Source: Google Earth (2009)*

# Plate 26: Nepean River Reach 1

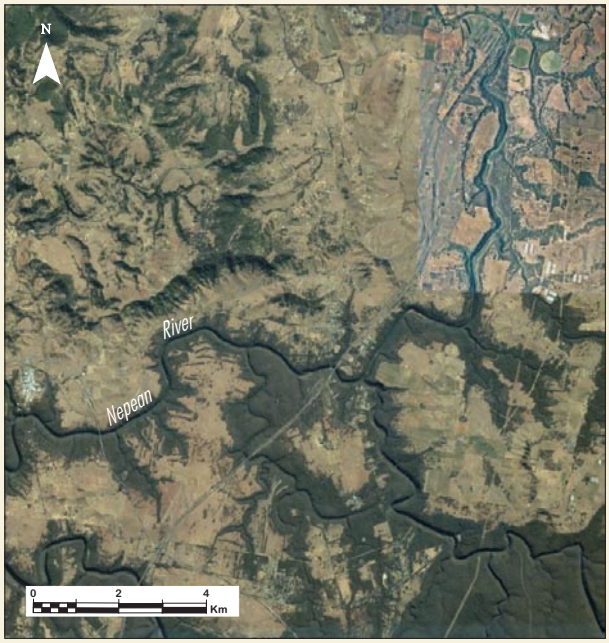



Photo A: March 2009

Photo B: March 2009

Photo C: March 2009

Photo D: March 2009

*Source: Google Earth (2009)*

# Plate 27: Racecourse Creek

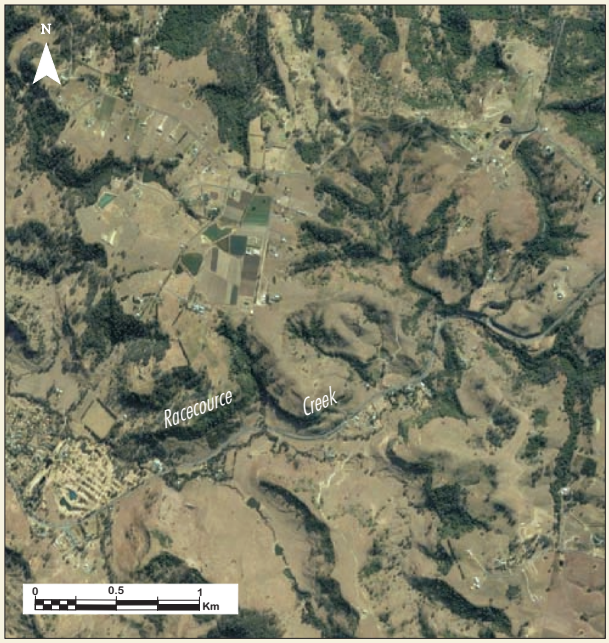



Photo A: February 2009

Photo B: February 2009

Photo C: February 2009

Photo D: February 2009

*Source: Google Earth (2009)*

# Plate 28: Stringybark Creek

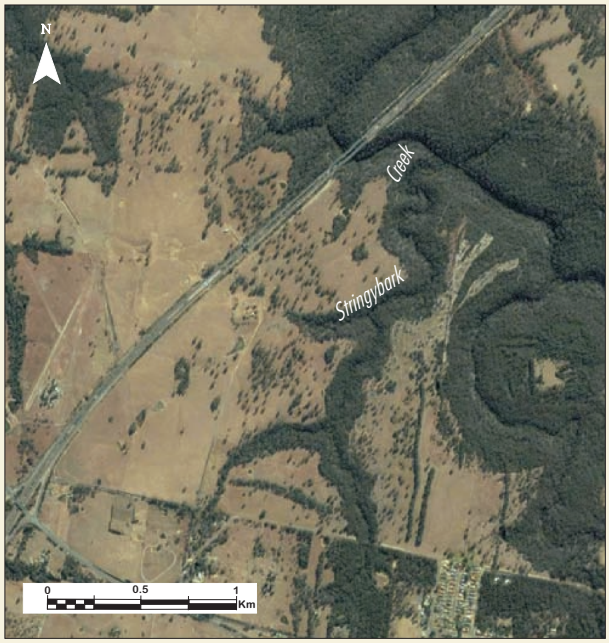



Photo A: February 2009

Photo B: February 2009

Photo C: June 2009

Photo D: June 2009

*Source: Google Earth (2009)*

# ATTACHMENT PD

# STREAM SPECIALIST SPECIES

The NSW Department of Environment and Climate Change (DECC) (2009a) consider a number of species, either threatened or of regional significance, to depend on creeks/rivers for survival. The information sourced from Appendix 1 of DECC (2009a) is provided in the columns 1 to 4 in the table below. Comments on each of the listed species in relation to the Project area are provided in column 5.

| **DECC (2009a) PRIORITY 1 SPECIES – SPECIES CONSIDERED DEPENDANT ON STREAMS** | | | | **5. COMMENT** |
|---|---|---|---|---|
| **1. Common Name** | **2. Scientific Name** | **3. Threatened/Species of Regional Significance** | **4. Habitat in Creeks or Rivers** | |
| - | *Grevillea longifolia* | Rare or Threatened Australian Plants [ROTAP] (2RC-) | Yes | *Grevillea longifolia* was recorded by the Project flora surveys in vegetation communities 2e (Exposed Sandstone Scribbly Gum Woodland), 4b (Sandstone Gully Peppermint Forest) and 5 (Sandstone Riparian Scrub). *Grevillea longifolia* grows in moist areas of sclerophyll forest, often near creeks, on Hawkesbury sandstone; chiefly the southern half of Sydney Basin, and Woronora Plateau (PlantNET, 2009). |
| - | *Lomandra fluviatilis* | ROTAP (3Rca) | Yes | *Lomandra fluviatilis* was recorded by the Project aquatic ecology and flora surveys (Appendices D and E of the Environmental Assessment [EA]). This species grows in creek beds on sandy soils (PlantNET, 2009). *Lomandra fluviatilis* was found to be relatively common (Appendix D of the EA). |
| Giant Dragonfly | *Petalura gigantea* | NSW *Threatened Species Conservation Act, 1995* [TSC Act] (E)<br>Commonwealth *Environment Protection and Biodiversity Conservation Act, 1999* [EPBC Act] (E) | Foraging | The Giant Dragonfly lives in permanent swamps and bogs, which typically comprise some free water and open vegetation (DECC, 2009b). The Giant Dragonfly is found along the east coast of NSW from the Victorian border to northern New South Wales (NSW). Known records of the Giant Dragonfly occur in the Blue Mountains and Southern Highlands, in the Clarence River catchment, and on a few coastal swamps from north of Grafton to Nadgee in the south. The Giant Dragonfly has not been recorded in the Project area. |
| Giant Burrowing Frog | *Heleioporus australiacus* | TSC Act (V)<br>EPBC Act (V) | Breeding | The northern populations of the Giant Burrowing Frog are largely confined to sandstone ridgetop habitat and broader upland valleys, where the species is associated with small headwater creek lines and slow flowing to intermittent creek lines in undisturbed areas (National Parks and Wildlife Service [NPWS], 2001a). The vegetation in these areas is typically woodland, open woodland and heath, with riparian components in and along the sides of early order streams. The species may also utilise swamps as a component of the range of habitats it is able to exploit (Appendix F of the EA). During the Project fauna surveys, the Giant Burrowing Frog was recorded at a waterbody in North Cliff. |
| Littlejohn's Tree Frog | *Litoria littlejohni* | TSC Act (V)<br>EPBC Act (V) | Breeding | The Littlejohn's Tree Frog appears to be restricted to sandstone woodland and heath communities at mid to high altitude (NSW Scientific Committee, 2000). The Littlejohn's Tree Frog occurs along permanent rocky streams with thick fringing vegetation associated with eucalypt woodlands and heaths among sandstone outcrops (DECC, 2009c). During the Project surveys, this species was recorded opportunistically at one site in open woodland (Coastal Sandstone Gully Forest). |

| DECC (2009a) PRIORITY 1 SPECIES – SPECIES CONSIDERED DEPENDANT ON STREAMS | | | | 5. COMMENT |
|---|---|---|---|---|
| 1. Common Name | 2. Scientific Name | 3. Threatened/Species of Regional Significance | 4. Habitat in Creeks or Rivers | |
| Platypus | *Ornithorhynchus anatinus* | Regional significance | Breeding, Foraging, Shelter | Mainly nocturnal, the Platypus forages on stream biota such as insect larvae, freshwater shrimp or adult insects on the surface of the water (DEC, 2002). Out of the water, the Platypus spends most of its time in burrows which have been dug into the river bank, with their entrances usually above water level (DEC, 2002). The Platypus uses a number of short resting burrows (3 to 5 metres [m] long) as protection from predators and temperature extremes.<br><br>Platypus surveys were undertaken for the Project at sites on the Georges River, Cataract River and Nepean River. A Platypus was recorded in the Georges River within the West Cliff Area 5 domain. In April 2009, a Platypus was also recorded at the Appin East pit top discharge point to Georges River by Illawarra Coal Holdings Pty Ltd (ICHPL) employees (Appendix F of the EA). Potential habitat for the Platypus may occur in streams other than the Georges River, although extensive surveys within the Stokes Creek catchment, O'Hares Creek catchment and the upper Georges River catchment by Grant *et al.* (2008) did not identify any Platypus (Appendix F of the EA).<br><br>Prior to the Project surveys there were only a few relatively recent reports of platypuses occurring in the upper Georges River or its tributary streams (Grant *et al.*, 2008). Grant (2002) surveyed the upper reaches of the Georges River, between the Cataract Scout Camp and The Woolwash, at the junction with O'Hares Creek, near Campbelltown. The 2002 survey yielded no definite observations or captures of platypuses in the upper Georges River, but reported several tentative sightings (Grant, 2002). In 2004, an animal was apparently found trapped in a rock hole in the sandstone less than a kilometre upstream of Freres Crossing at Campbelltown in March, 2004 (reported to Dr Rob Close UWS by Tina and Paul Hines) (Appendix F of the EA). |

DECC (2009a) consider a number of species, either threatened or of regional significance, to have a stronghold in creeks/rivers, but are also found in other types of habitat elsewhere. The information sourced from Appendix 1 of DECC (2009a) is provided in the columns 1 to 4 in the table below. Comments on each of the listed species in relation to the Project area are provided in column 5.

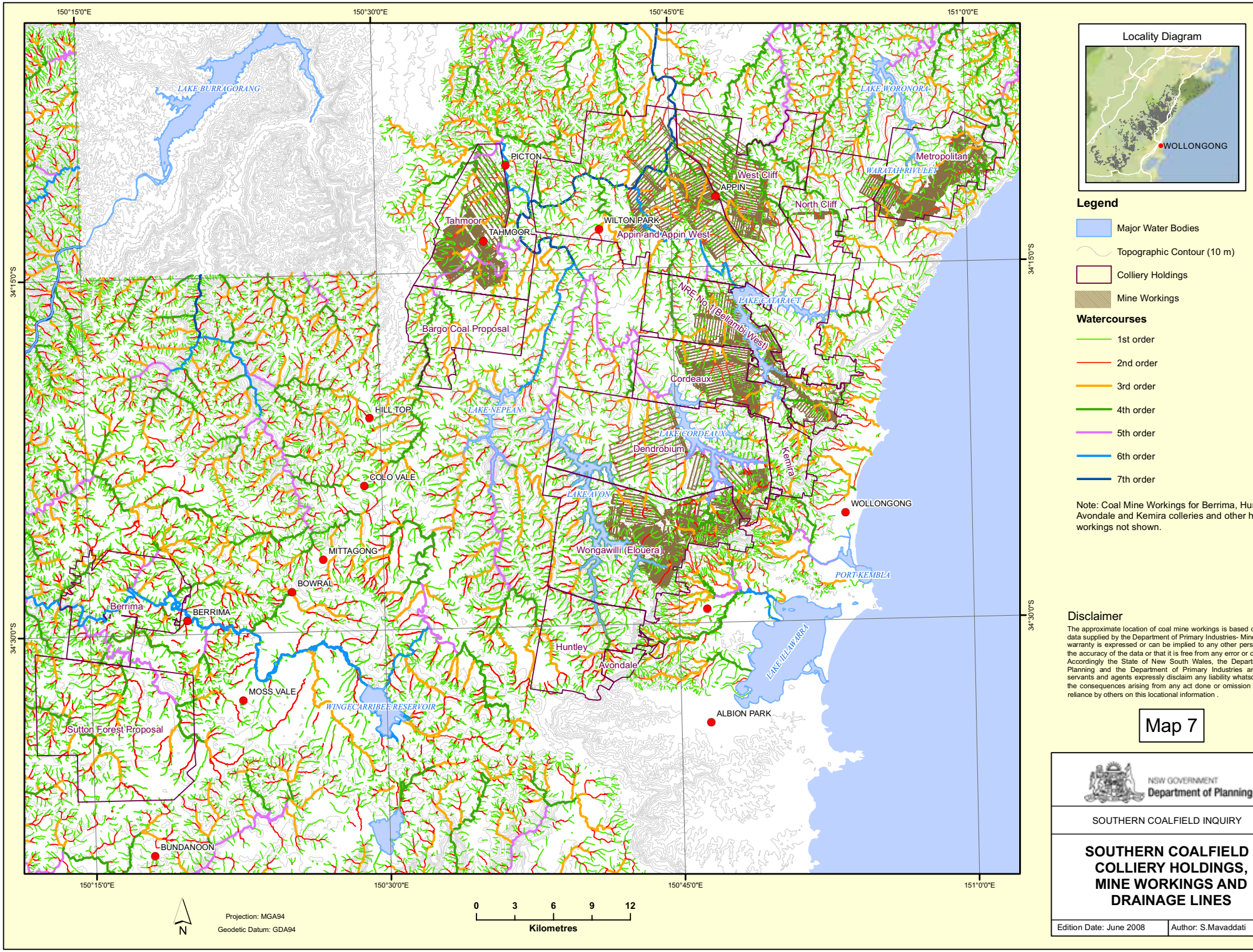
| DECC (2009a) PRIORITY 2 SPECIES – SPECIES WITH A STRONGHOLD IN CREEKS/RIVERS | | | | 5. COMMENT |
|---|---|---|---|---|
| **1. Common Name** | **2. Scientific Name** | **3. Threatened/Species of Regional Significance** | **4. Habitat in Creeks or Rivers** | |
| - | *Epacris purpurascens* var. *purpurascens* | TSC Act (V)<br>ROTAP (2KC-) | Yes | *Epacris purpurascens* var. *purpurascens* was recorded by the Project flora surveys in vegetation communities 3a, 3b, 4c, 5 and 6 (moist gullies on shale - sandstone soils).<br>*Epacris purpurascens* var. *purpurascens* is abundant in Appin Area 3 Extended in the area between Cascade and Wallandoola Creeks, particularly in the cleared 330 kilovolt power line easement paralleling Fire Road 12. Populations in this area are estimated at many tens of thousands, if not hundreds of thousands of plants. It also occurs commonly in the bushland on either side of the power line, although at much lower densities. The population extends abundantly along the power line easement to the south as far as the Picton Road across areas that have been undermined previously. It also extends across the Cataract River in the power line easement to the north. Much lower numbers occur east of Wallandoola Creek. The Rigid Heath is also widespread, but relatively uncommon on St Marys Towers near Douglas Park in Appin Area 8. This species greatly favours sandstone dominant shale/sandstone transition soils in the study area (Appendix E of the EA). |
| - | *Leucopogon exolasius* | TSC Act (V)<br>EPBC Act (V)<br>ROTAP (2VC-) | Yes | *Leucopogon exolasius* was recorded by the Project flora surveys in vegetation communities 3a, 4a, 4b, 4c and 5 (sandstone gullies and riparian habitats) on the Woronora Plateau. The species was found to be widespread but rare. It was located on O'Hares Creek in Dharawal State Conservation Area near the North Cliff domain of the Project and on the Cataract River in Appin Areas 2 and 3 Extended. It occurred in small groups of 1 to about 20 plants (Appendix E of the EA). |
| - | *Astrotricha crassifolia* | TSC Act (V)<br>EPBC Act (V)<br>ROTAP (2VC-) | Yes | *Astrotricha crassifolia* grows on dry ridgetops to 300 m altitude (Benson and McDougall, 1993) and is associated with very rich heath, or dry sclerophyll woodland (Henwood and Makinson, 1992). However, Bangalay Botanical Surveys (2008) found it was most common in moist locations in sandstone gullies in the Woronora catchment (Appendix E of the EA). |
| - | *Monotoca ledifolia* | ROTAP (3RCa) | Yes | *Monotoca ledifolia* was not recorded by the Project flora surveys. *Monotoca ledifolia* grows in exposed sites in dry sclerophyll forest and shrubland on sandstone in the Woronora Plateau and Blue Mountains area (PlantNET, 2009). |

| DECC (2009a) PRIORITY 2 SPECIES – SPECIES WITH A STRONGHOLD IN CREEKS/RIVERS | | | | 5. COMMENT |
|---|---|---|---|---|
| **1. Common Name** | **2. Scientific Name** | **3. Threatened/Species of Regional Significance** | **4. Habitat in Creeks or Rivers** | |
| Red-crowned Toadlet | *Pseudophryne australis* | TSC Act (V) | Breeding | The Red-crowned Toadlet is known only from Triassic sandstones of the Sydney Basin, being found in steep escarpment areas and plateaus, as well as low undulating ranges with benched outcroppings (NPWS, 2001b). Within these geological formations, this species mainly occupies the upper parts of ridges, usually being restricted to within about 100 m of the ridgetop (*ibid*.). The Red-crowned Toadlet may also occur on plateaus or more level rock platforms along the ridgetop, however this area is usually less preferred than the first talus slope areas below the upper escarpment or just below benched rock platforms (NPWS, 2001b).<br><br>Favoured microhabitats for shelter sites are under flat sandstone rocks ('bush-rock') either resting on bare rock or damp loamy soils (NPWS, 2001b). Red-crowned Toadlets have also been found under logs on soil, beneath thick ground litter, particularly near large trees and in horizontal rock crevices near the ground (*ibid*.). Red-crowned Toadlets do not usually live along permanent flowing watercourses occurring in gullies, instead preferring permanently moist soaks or areas of dense ground vegetation or litter along or near headwater stream beds (NPWS, 2001b). These are the non-perennial first or second order drainage systems that are adjacent to ridges, are ephemeral in nature, and commonly called 'feeder-creeks' (*ibid*.). These drainage systems channel water from the ridges, benches, cliffs and talus slopes to the perennial streams in the gullies below. Such watercourses are dry or reduced to scattered shallow pools or ponds for much of the year, and have sustained flow for only a few weeks following thunderstorms (NPWS, 2001b).<br><br>The main vegetation communities found in association with this species are open woodland and heath communities that are typical for Hawkesbury and Narabeen geology (NPWS, 2001b). Tree cover, when present, is usually open and low (10 to 20 m) and with a xeromorphic understorey (*ibid*.).<br><br>During the Project surveys, this species was recorded in riparian habitat, gully forest habitat and opportunistically in Coastal Sandstone Ridgetop Heath. |
| Large-footed Myotis | *Myotis adversus* | TSC Act (V) | Foraging | The Large-footed Myotis will live in most habitat types (including mangroves, paperbark swamps, riverine monsoon rainforest, wet and dry sclerophyll forest, open woodland and River Red Gum woodland), as long as they are close to water (Richards, 1998; Churchill, 1998; NPWS, 2000). Riparian habitat is thought to be preferred (Duncan *et al.*, 1999).<br><br>Colonies of the Large-footed Myotis roost during the day, predominantly in caves or their substitutes (such as mines and tunnels), however have also been known to roost in tree hollows and disused bird nests (NPWS, 2000). |

| DECC (2009a) PRIORITY 2 SPECIES – SPECIES WITH A STRONGHOLD IN CREEKS/RIVERS | | | | 5. COMMENT |
|---|---|---|---|---|
| **1. Common Name** | **2. Scientific Name** | **3. Threatened/Species of Regional Significance** | **4. Habitat in Creeks or Rivers** | |
| Large-footed Myotis (Continued) | | | | The Large-footed Myotis forage most commonly over water, raking its surface with the sharp claws of their large feet to catch aquatic insects and small fish, which make up most of their diet (Richards, 1998; Churchill, 1998; NPWS, 2000). The Large-footed Myotis may also forage aerially and may forage individually or hunt together (*ibid.*).<br><br>During the Project surveys, this species was recorded at two riparian sampling sites, one on the Cataract River and one on a minor un-named tributary of the Nepean River. |

# ATTACHMENT PE

# SOUTHERN COALFIELD – COLLIERY HOLDINGS, MINE WORKINGS AND DRAINAGE LINES




Locality Diagram




**Legend**

- Major Water Bodies
- Topographic Contour (10 m)
- Colliery Holdings
- Mine Workings

**Watercourses**

- 1st order
- 2nd order
- 3rd order
- 4th order
- 5th order
- 6th order
- 7th order

Note: Coal Mine Workings for Berrima, Huntley, Avondale and Kemira colleries and other historic workings not shown.

## Disclaimer

The approximate location of coal mine workings is based on digital data supplied by the Department of Primary Industries- Minerals. No warranty is expressed or can be implied to any other person as to the accuracy of the data or that it is free from any error or omission. Accordingly the State of New South Wales, the Department of Planning and the Department of Primary Industries and their servants and agents expressly disclaim any liability whatsoever for the consequences arising from any act done or omission made in reliance by others on this locational information .

Map 7

NSW GOVERNMENT
Department of Planning

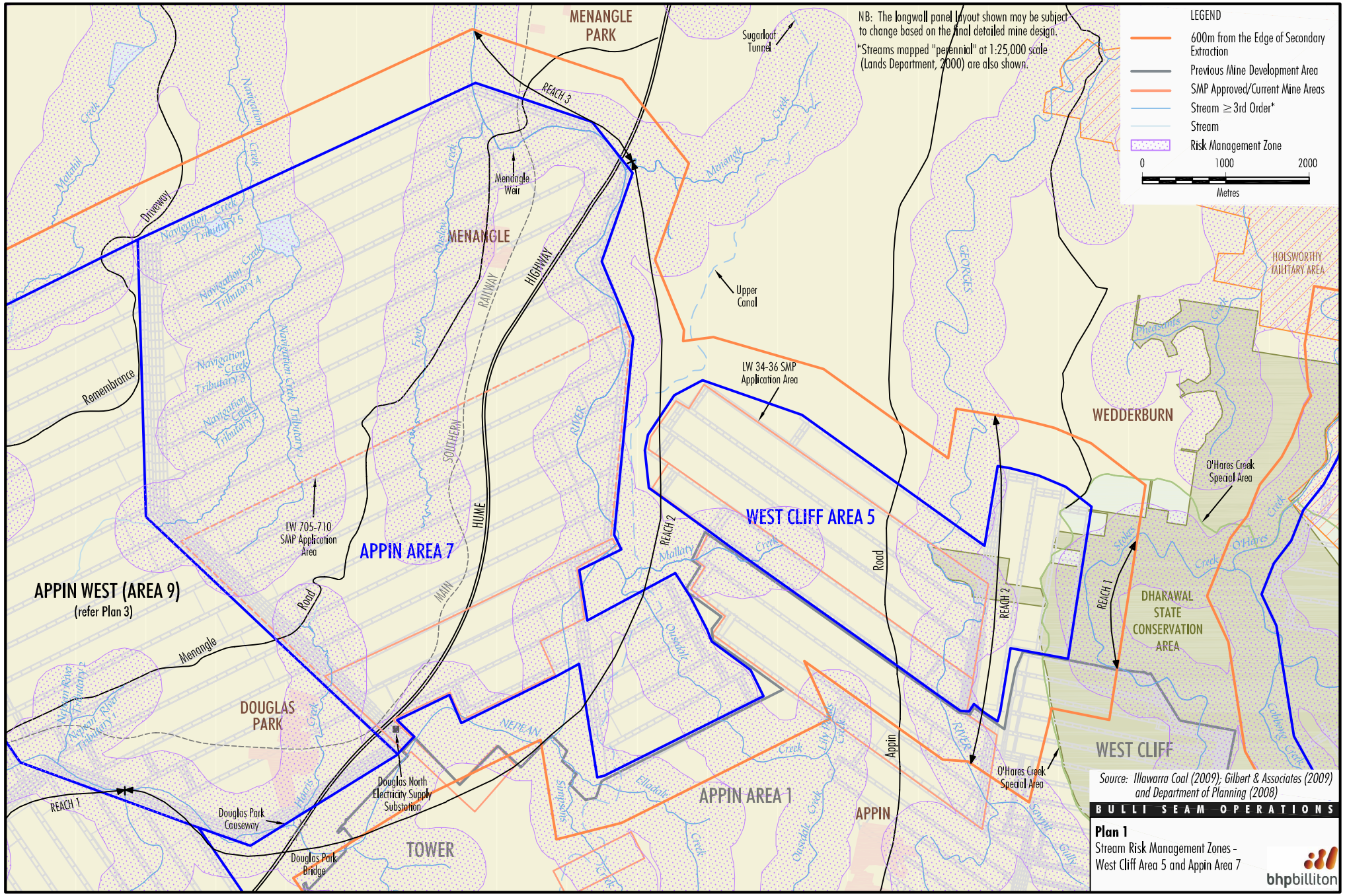
SOUTHERN COALFIELD INQUIRY

# SOUTHERN COALFIELD - COLLIERY HOLDINGS, MINE WORKINGS AND DRAINAGE LINES

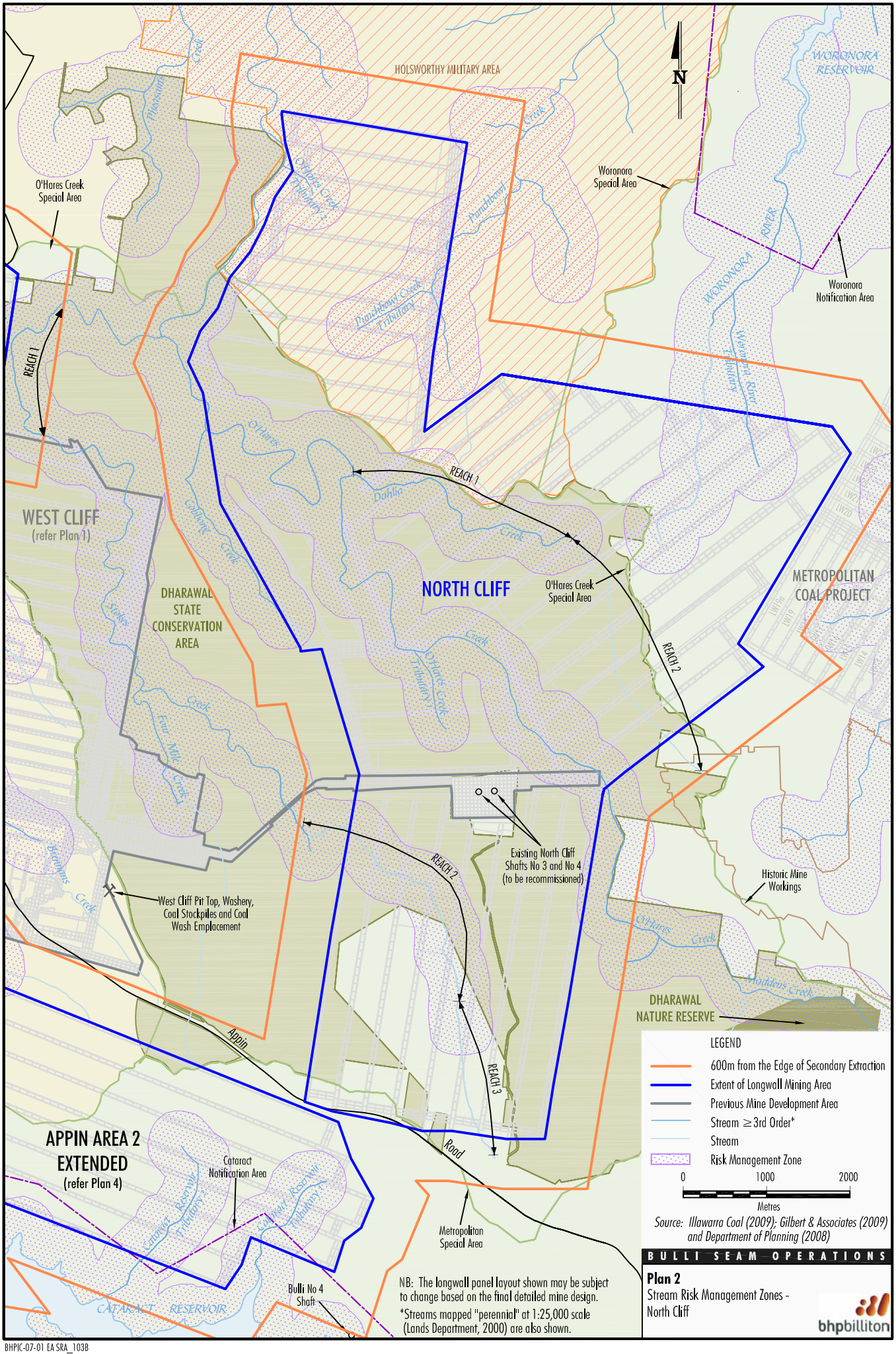
| Edition Date: June 2008 | Author: S.Mavaddati |
|---|---|

# ATTACHMENT PF

# STREAM RISK MANAGEMENT ZONES




BHPIC-07-01 EA SRA_105B

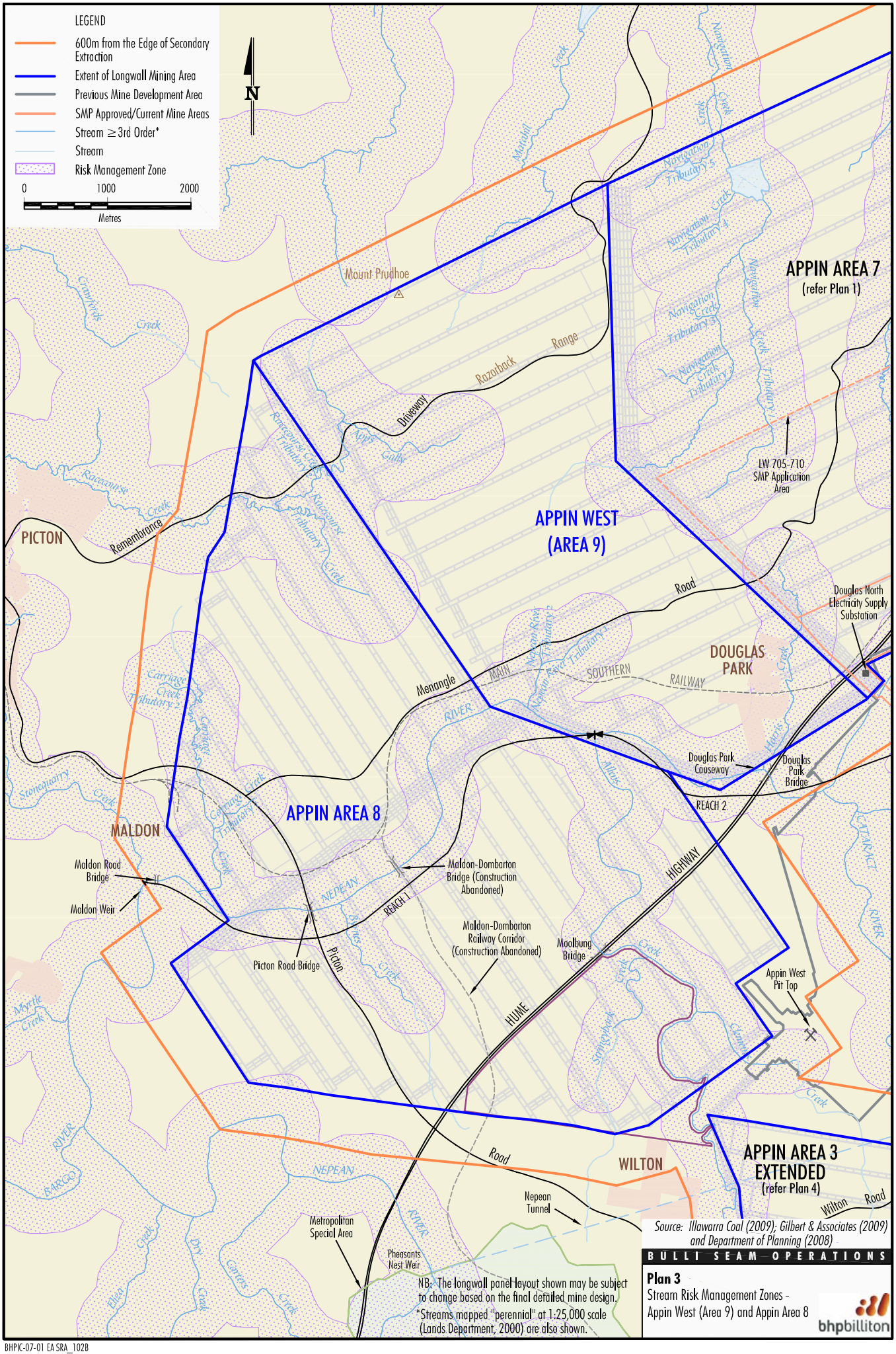



BULLI SEAM OPERATIONS

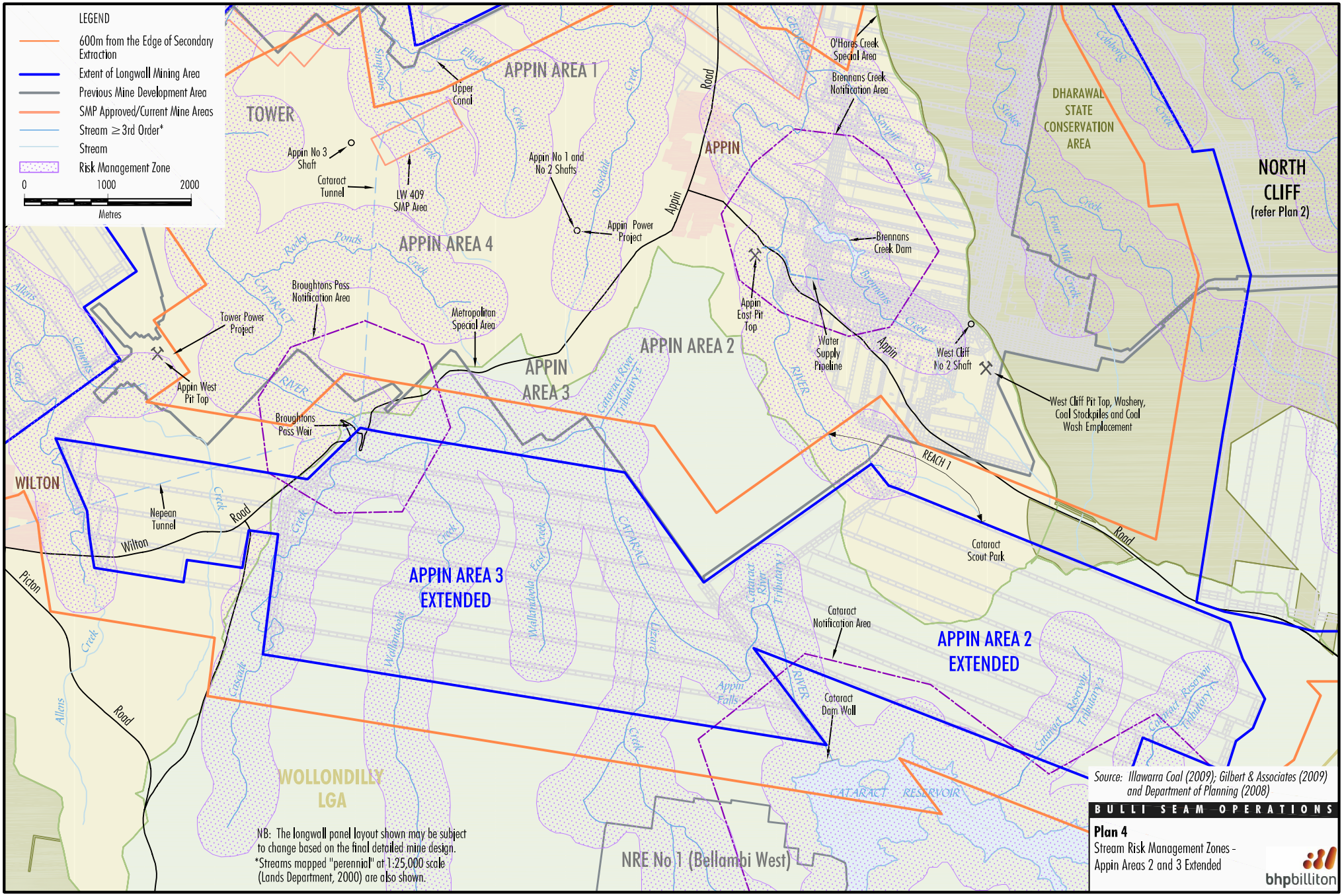
**Plan 2**
Stream Risk Management Zones - North Cliff

bhpbilliton

BHPIC-07-01 EA SRA_103B




BHPIC-07-01 EA SRA_102B




NB: The longwall panel layout shown may be subject to change based on the final detailed mine design.
*Streams mapped "perennial" at 1:25,000 scale (Lands Department, 2000) are also shown.

*Source: Illawarra Coal (2009); Gilbert & Associates (2009) and Department of Planning (2008)*

BULLI SEAM OPERATIONS

**Plan 4**
Stream Risk Management Zones - Appin Areas 2 and 3 Extended

bhpbilliton

BHPIC-07-01 EA SRA_104B

ATTACHMENT PG

STREAMS – LONG SECTIONS

# Appin Area 7 - Longwalls 703 to 724 Foot Onslow Creek
# Predicted Profiles of Subsidence, Tilt and Grade

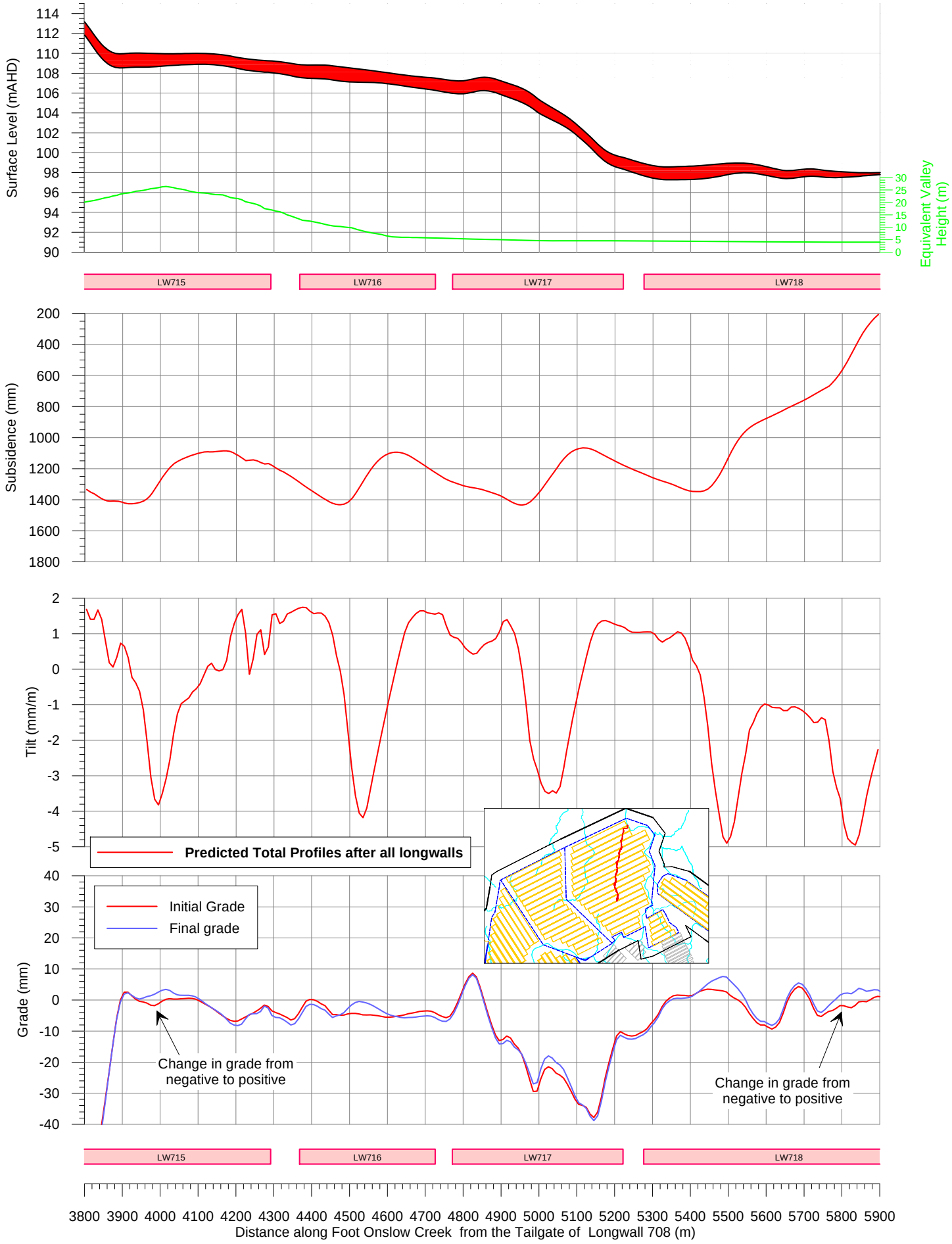



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**Fig. PG-01**

# Appin Area 7 - Longwalls 703 to 724 Navigation Creek Tributary 4
# Predicted Profiles of Subsidence, Tilt and Grade

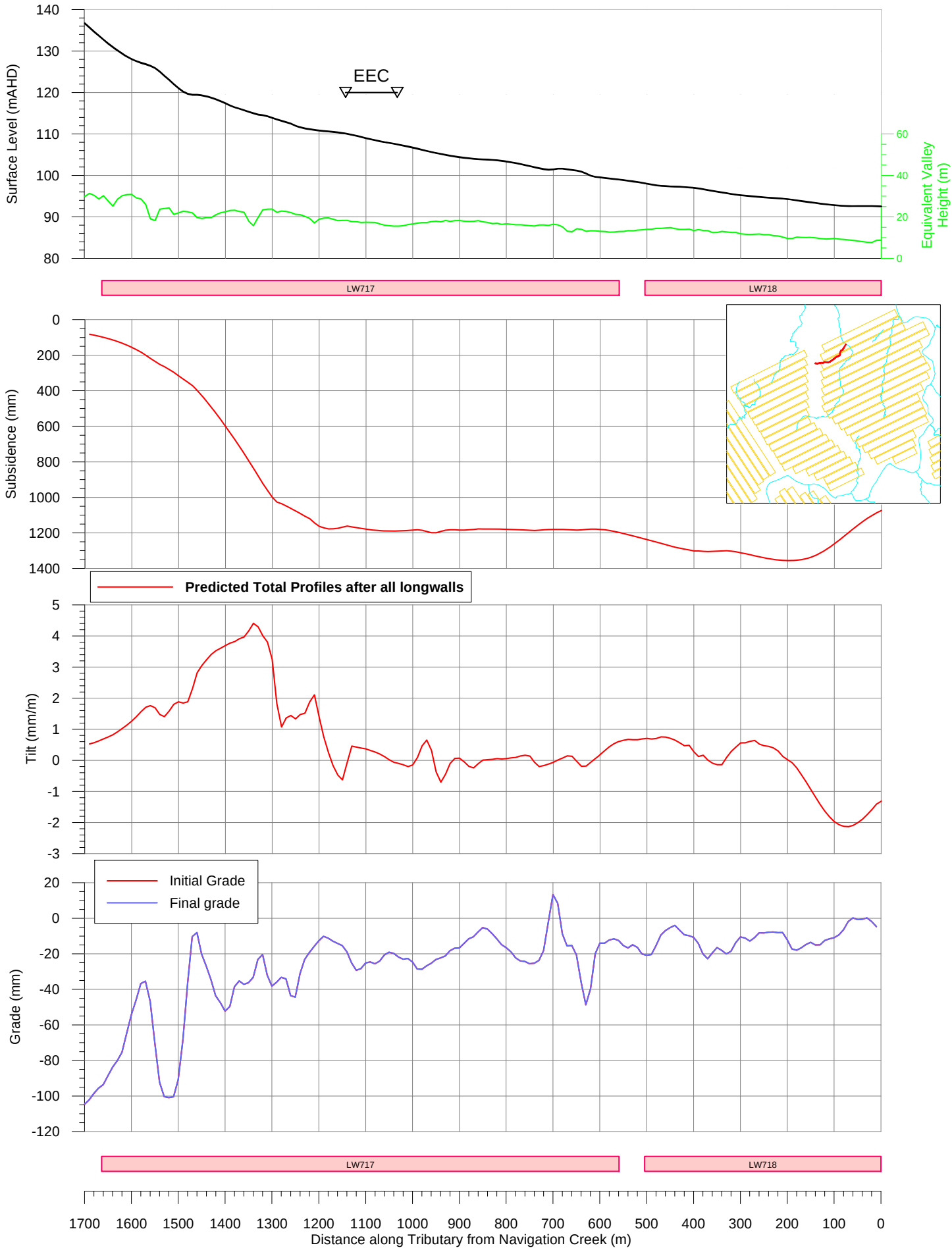


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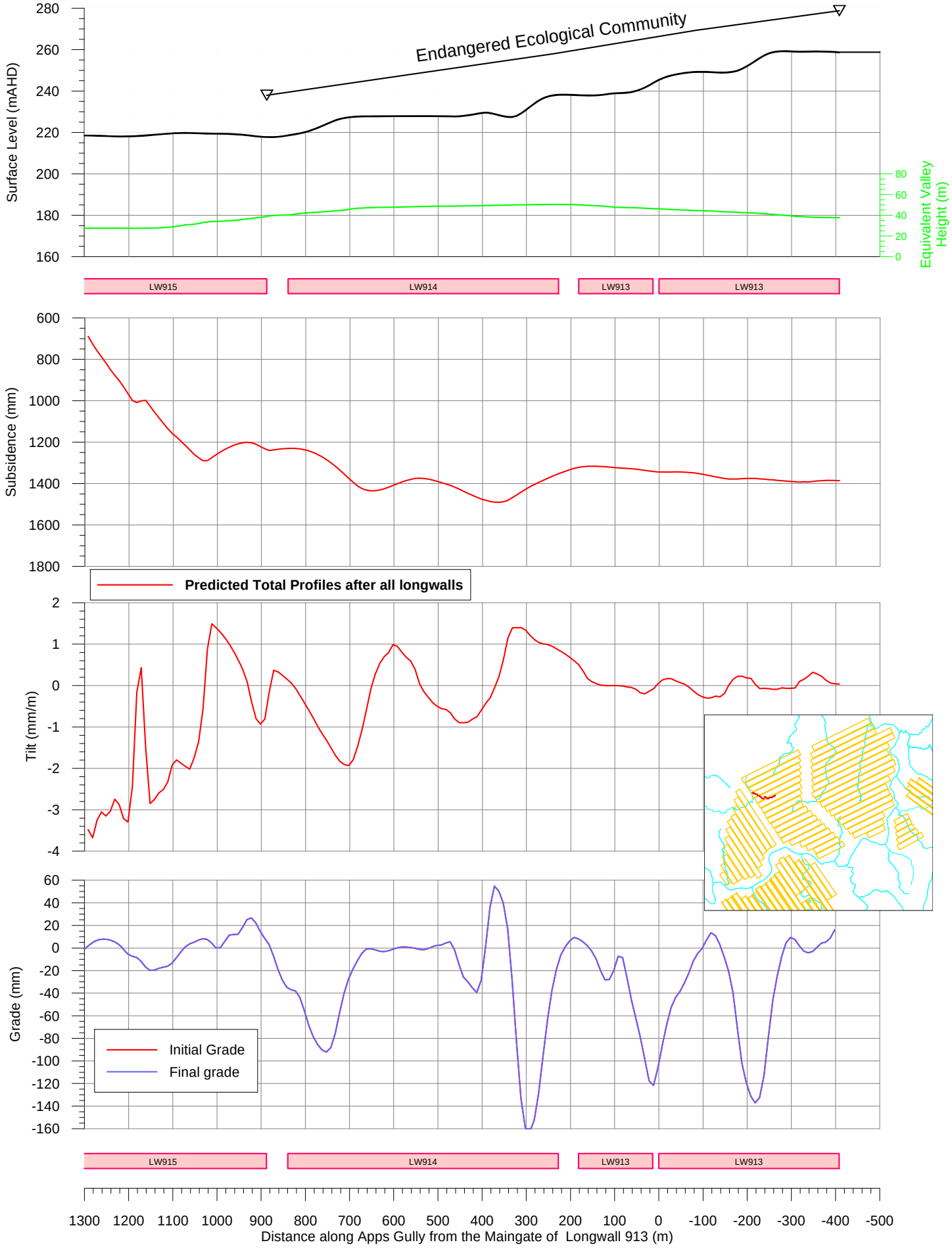
**Fig. PG-02**

# Appin Area 9 - Longwalls 901 to 918 Apps Gully
# Predicted Profiles of Subsidence, Tilt and Grade




Mine Subsidence Engineering Consultants

**Fig. PG-03**

# Appin Longwalls 800 to 827 & 901 to 918 Racecourse Creek
# Predicted Profiles of Subsidence, Tilt and Grade

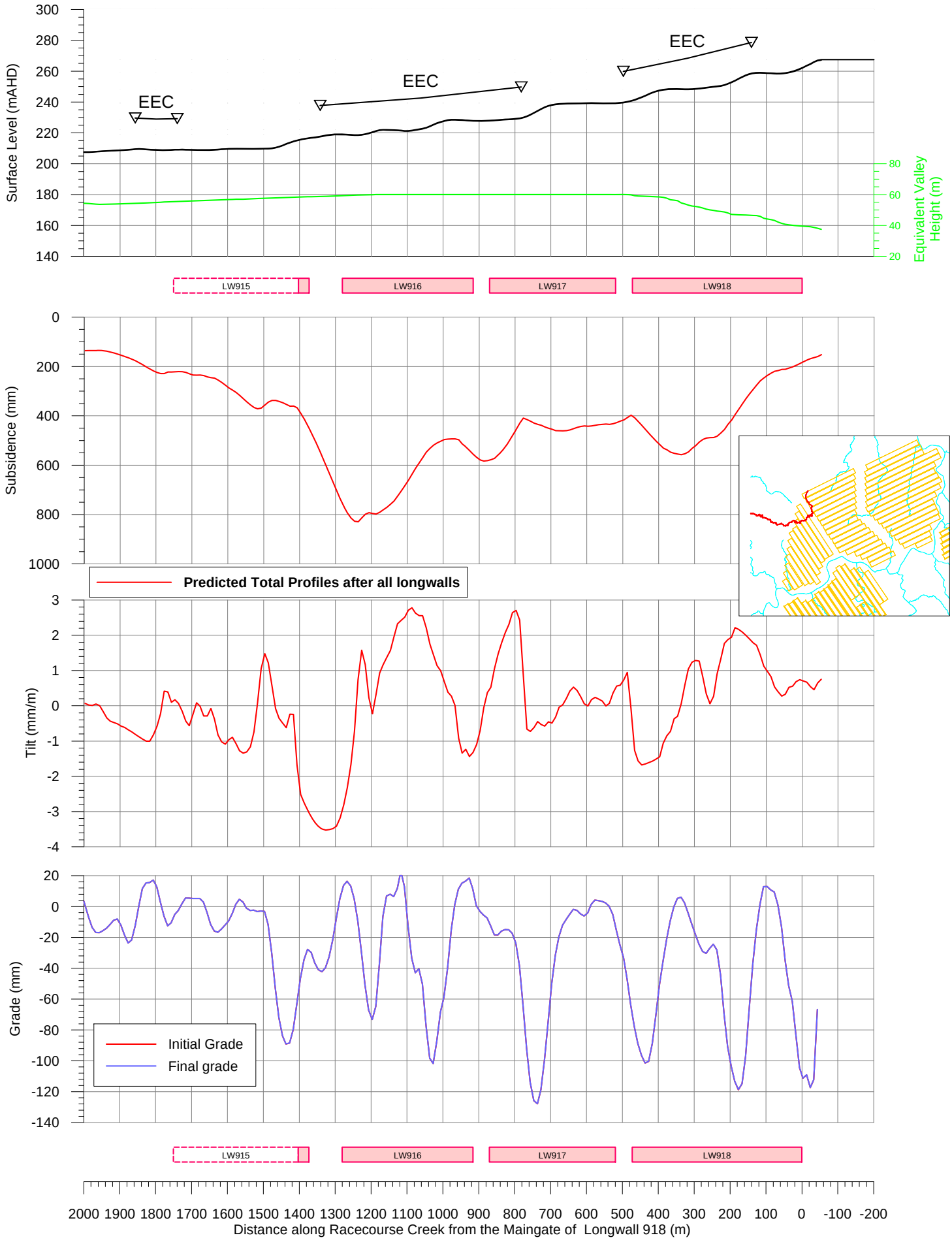



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**Fig. PG-04**

# Appin Area 7 to 9 - Nepean River Section 1
# Predicted Profiles of Subsidence, Upsidence and Closure

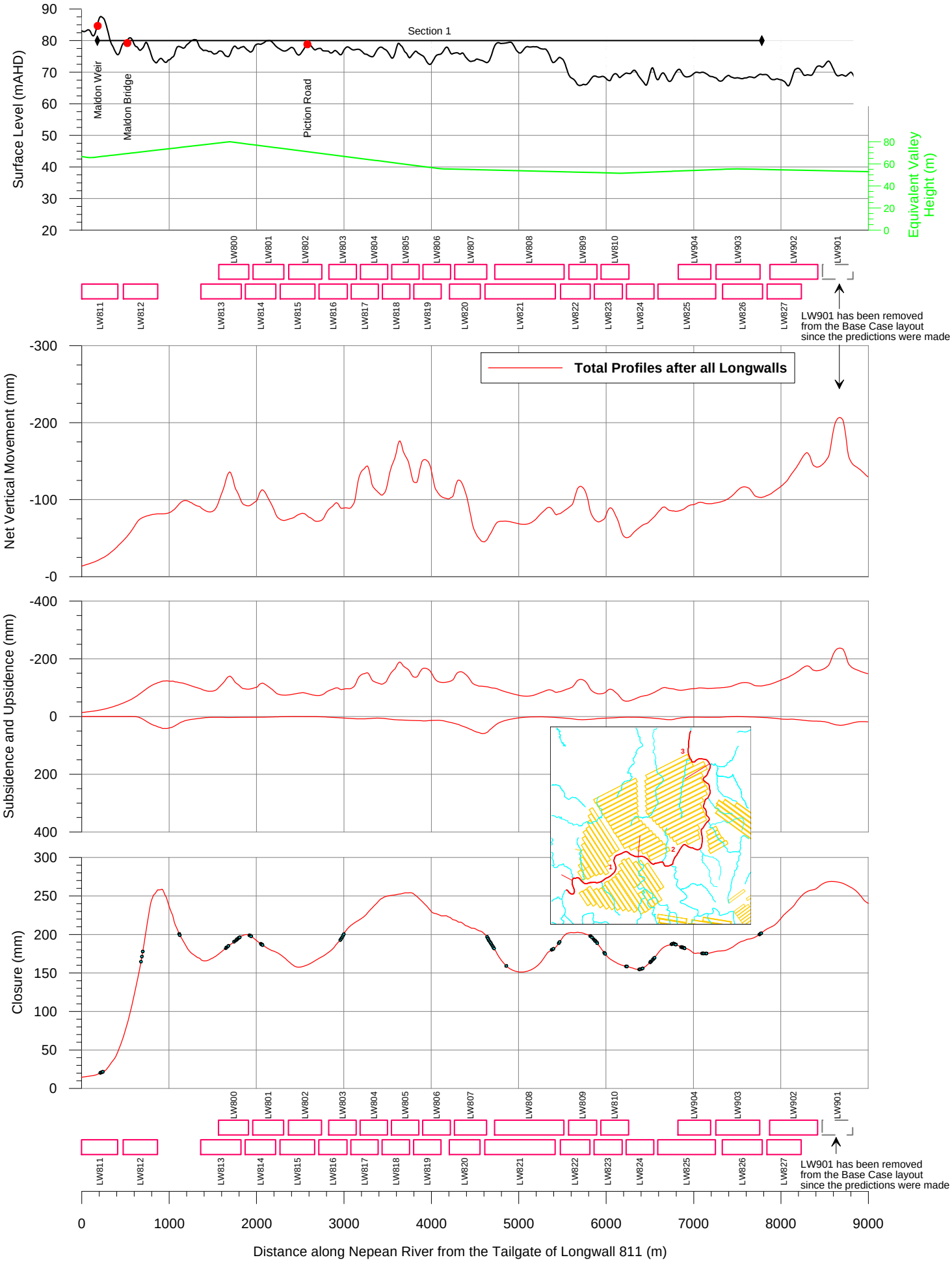


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**Fig. 200-01**

# Appin Area 7 to 9 - Nepean River Section 2
# Predicted Profiles of Subsidence, Upsidence and Closure

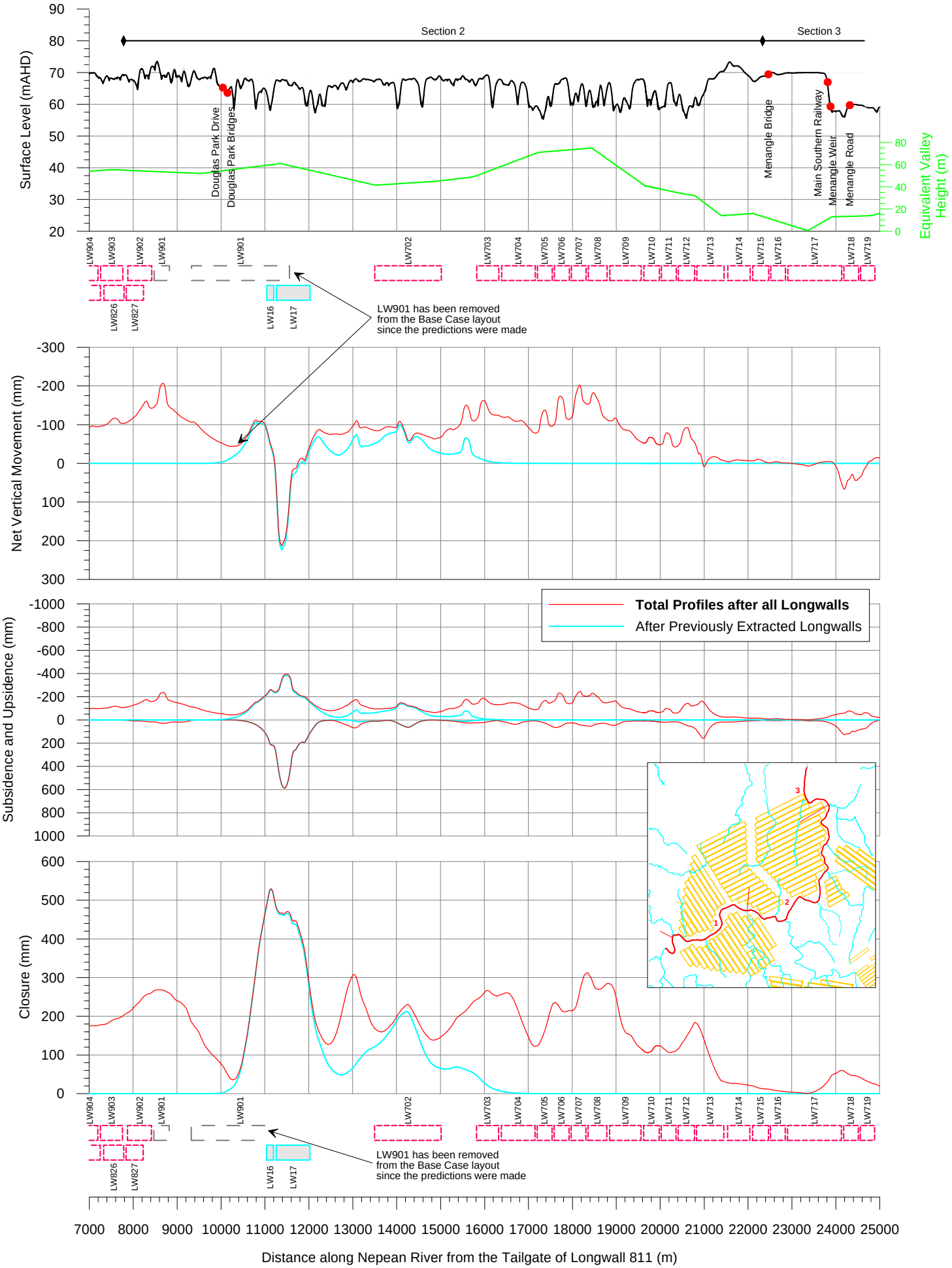


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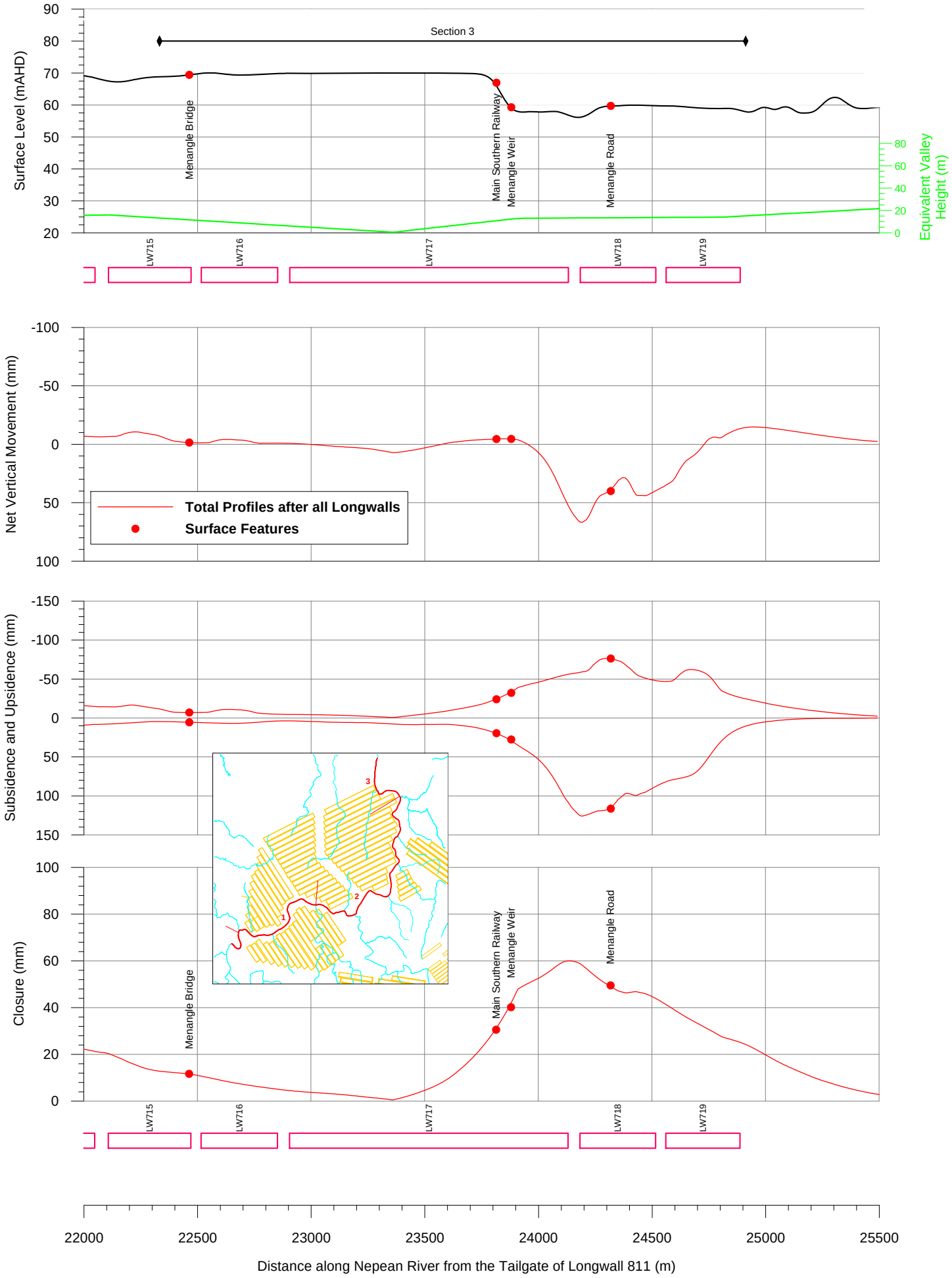
**Fig. 200-02**

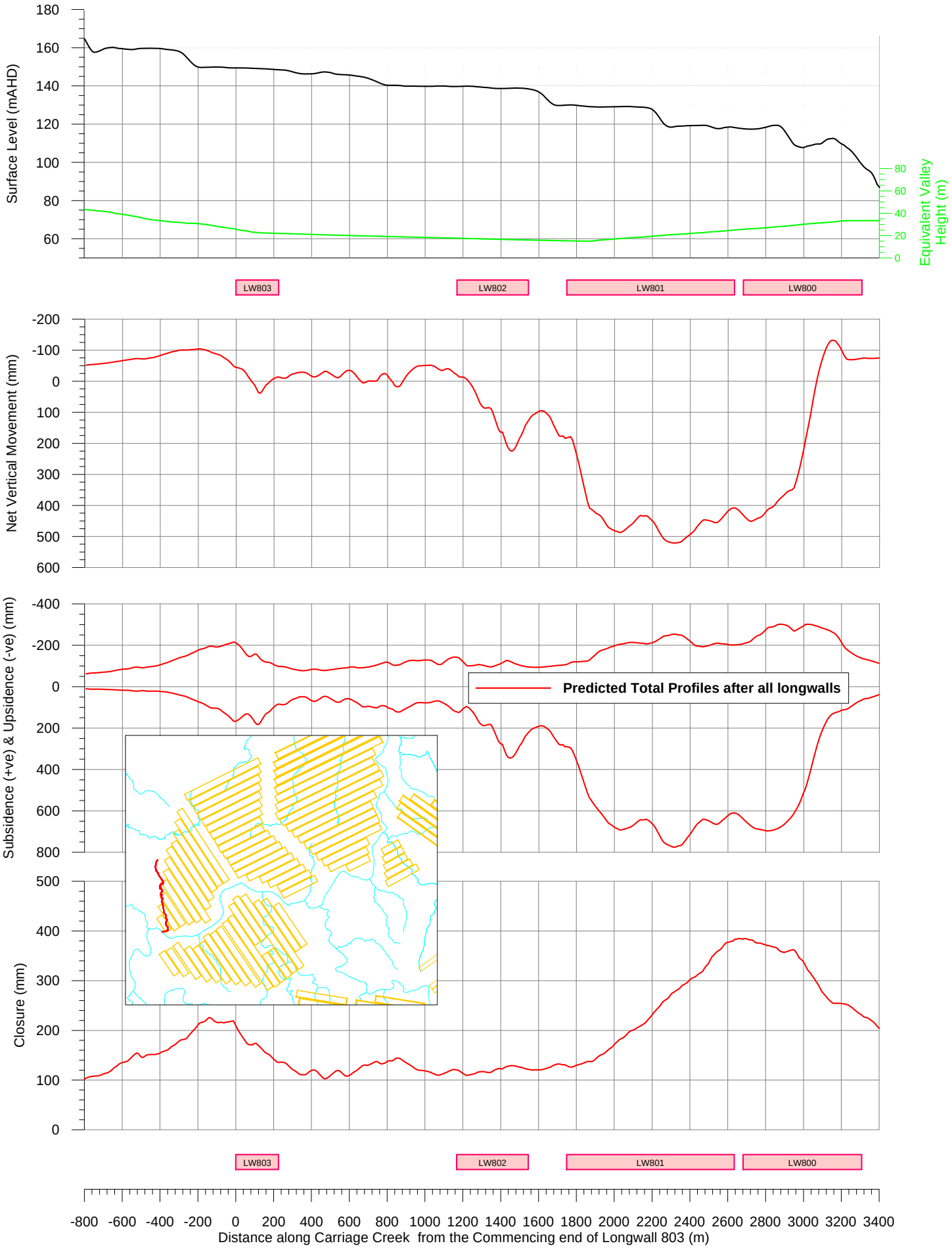
# Appin Area 7 to 9 - Nepean River Section 3
# Predicted Profiles of Subsidence, Upsidence and Closure




Mine Subsidence Engineering Consultants

**Fig. 200-03**

# Appin Area 8 - Longwalls 800 to 827 Carriage Creek
# Predicted Profiles of Subsidence, Upsidence and Closure




Mine Subsidence Engineering Consultants

**Fig. 200-04**

# Appin Area 8 - Longwalls 800 to 827 Byrnes Creek
# Predicted Profiles of Subsidence, Upsidence and Closure

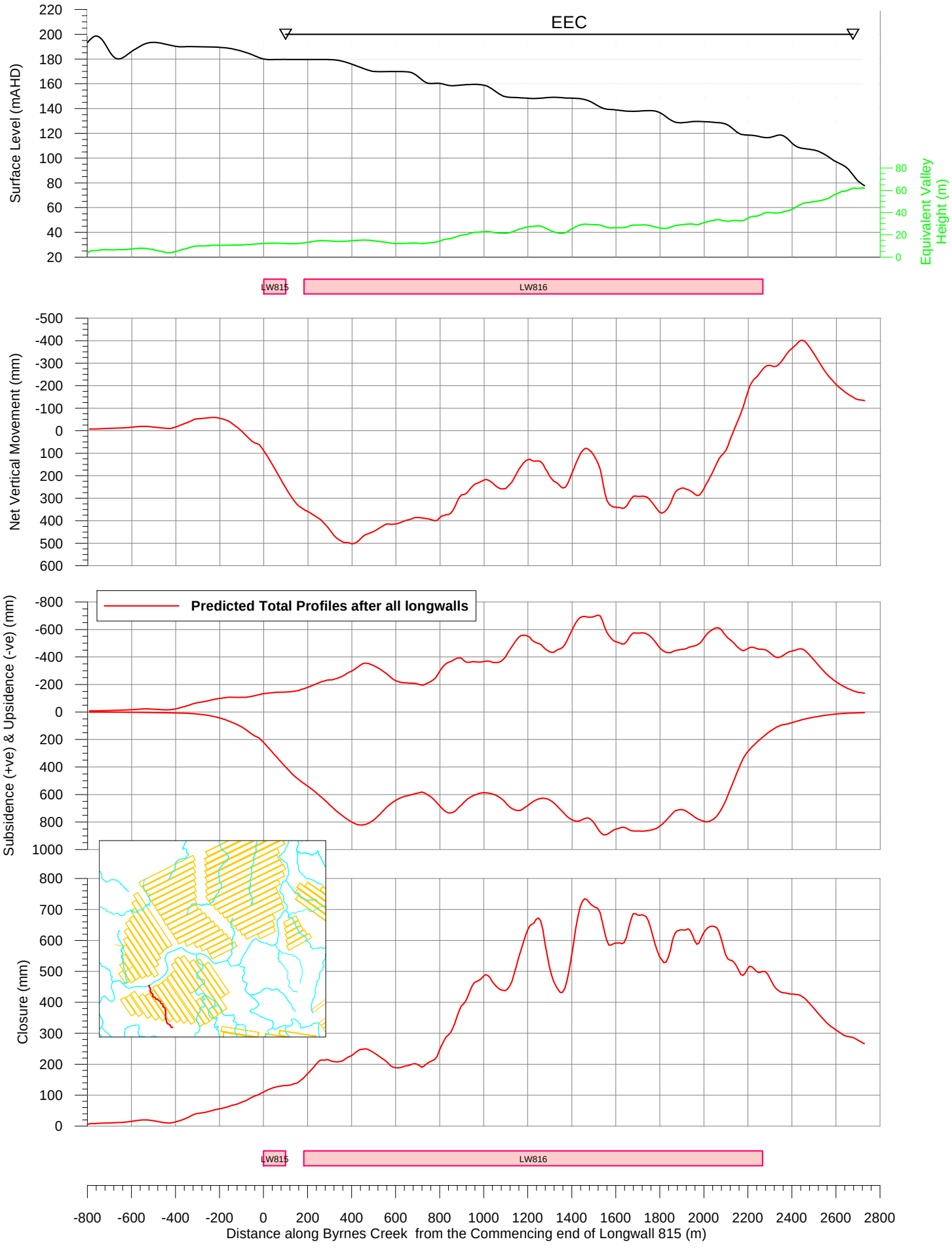



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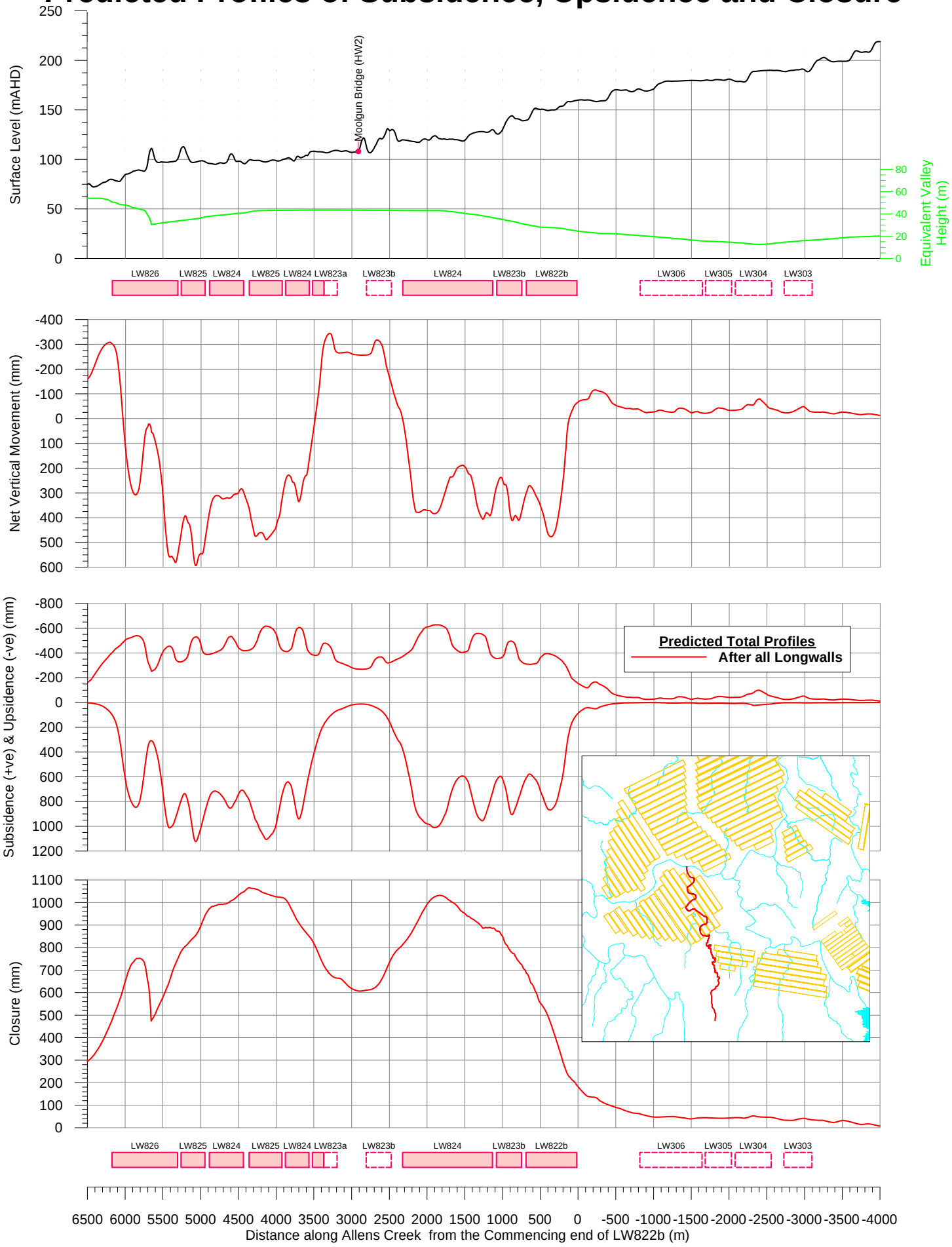
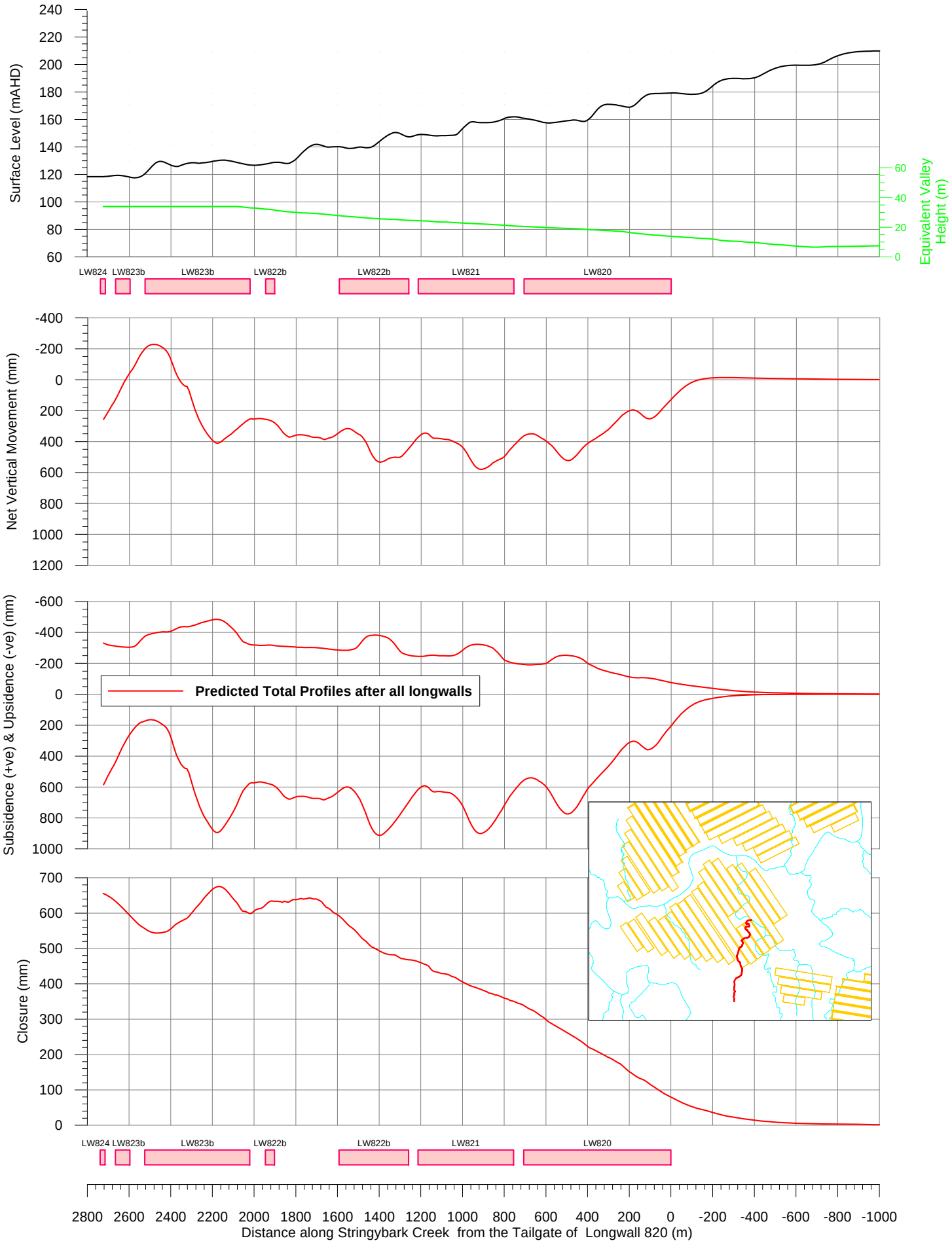
**Fig. 200-05**

# Appin Area 3 - Longwalls 303 to 313 &
# Appin Area 8 - Longwalls 800 to 827 Allens Creek
# Predicted Profiles of Subsidence, Upsidence and Closure



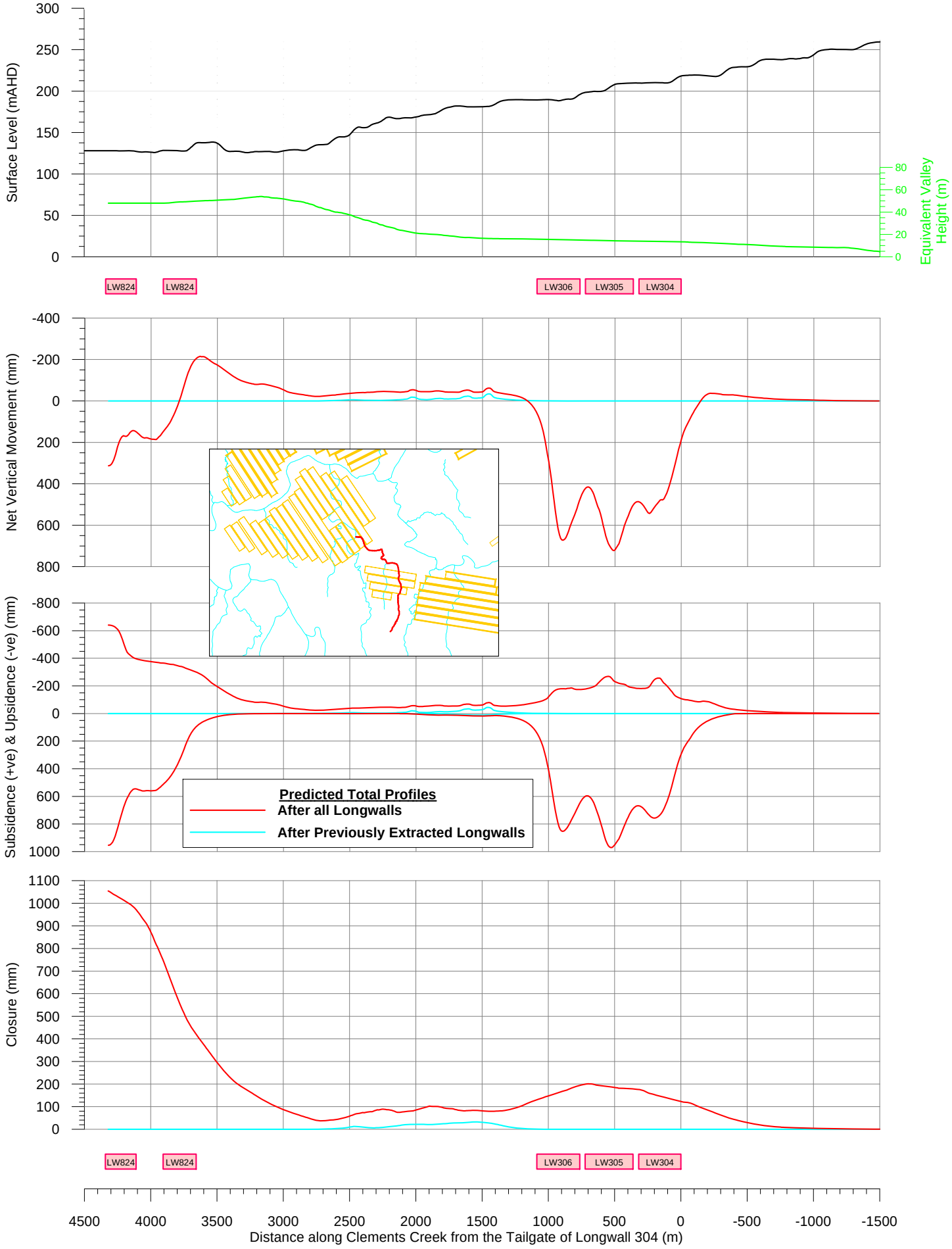
# Appin Area 8 - Longwalls 800 to 827 Stringybark Creek
# Predicted Profiles of Subsidence, Upsidence and Closure




Mine Subsidence Engineering Consultants

**Fig. 200-07**

# Appin Area 8 Longwalls 800 to 827 & Appin Area 3 Longwalls 303 to 313 - Clements Creek Predicted Profiles of Subsidence, Upsidence and Closure




Mine Subsidence Engineering Consultants

**Fig. 200-08**

# Appin Area 7 and Area 9 Harris Creek
# Predicted Profiles of Subsidence, Upsidence and Closure

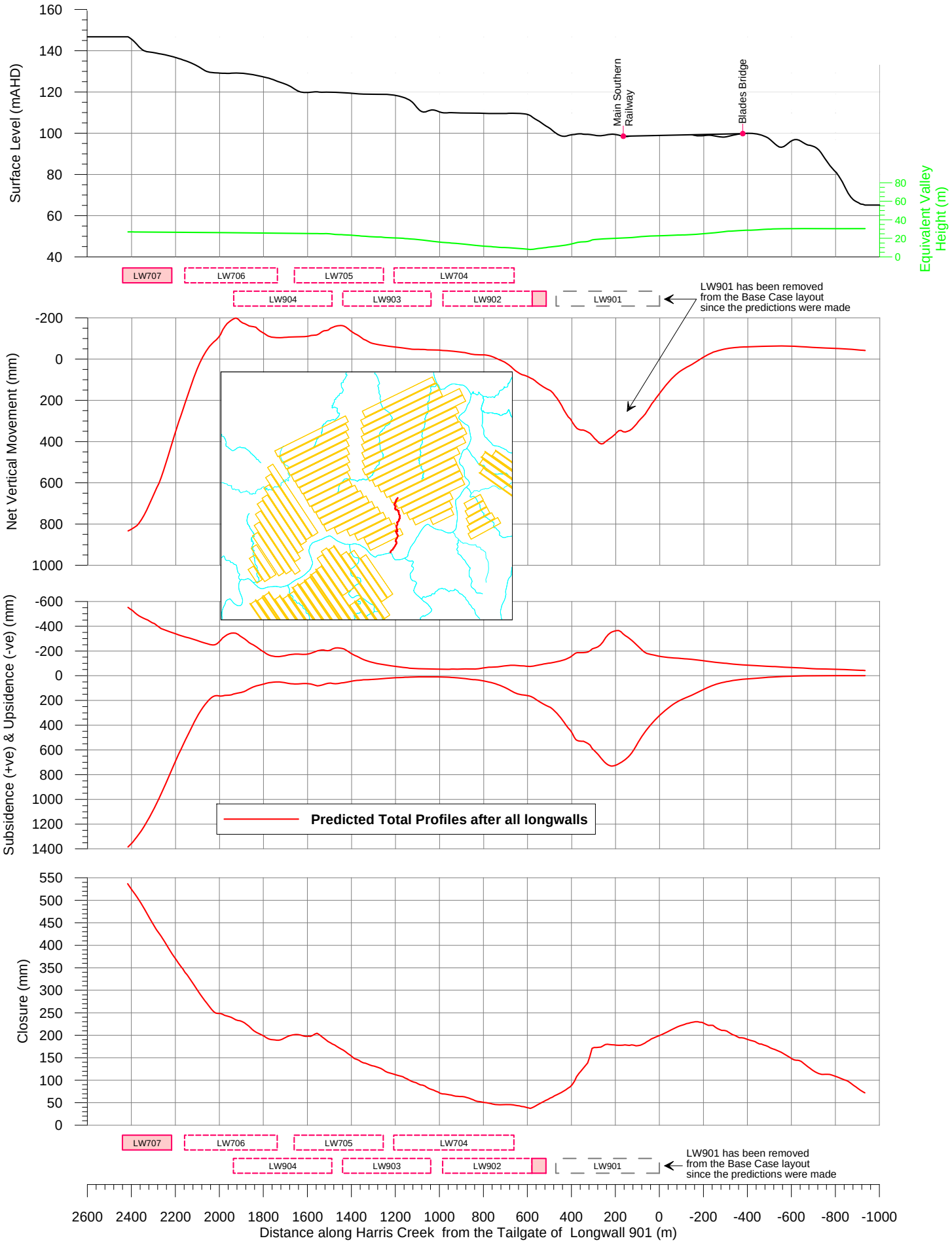



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**Fig. 200-09**

# Appin Area 7 - Longwalls 703 to 719 Elladale Creek
# Predicted Profiles of Subsidence, Upsidence and Closure

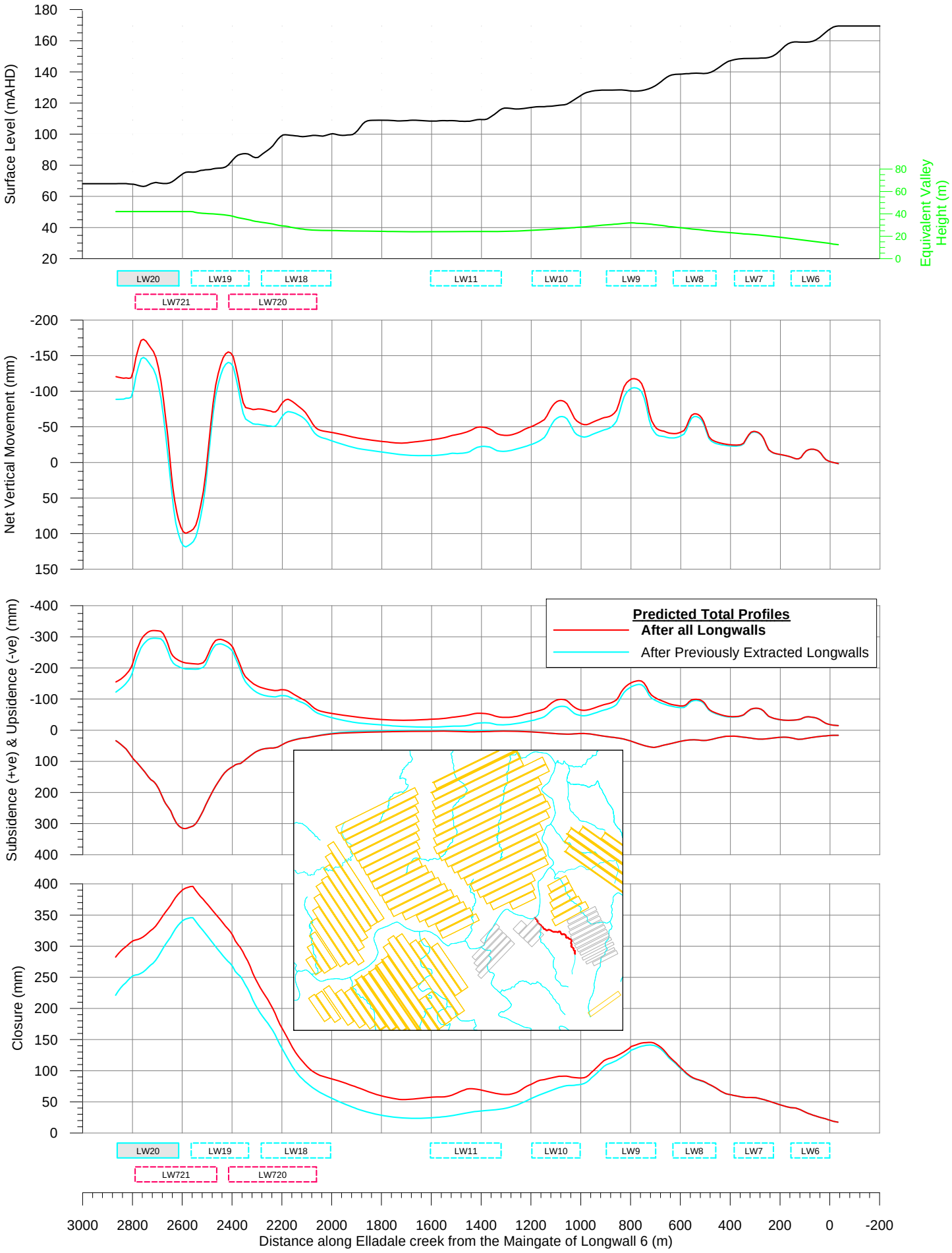


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**Fig. 200-10**

# Appin Area 7 - Longwalls 702 to 719 Ousedale Creek
# Predicted Profiles of Subsidence, Upsidence and Closure

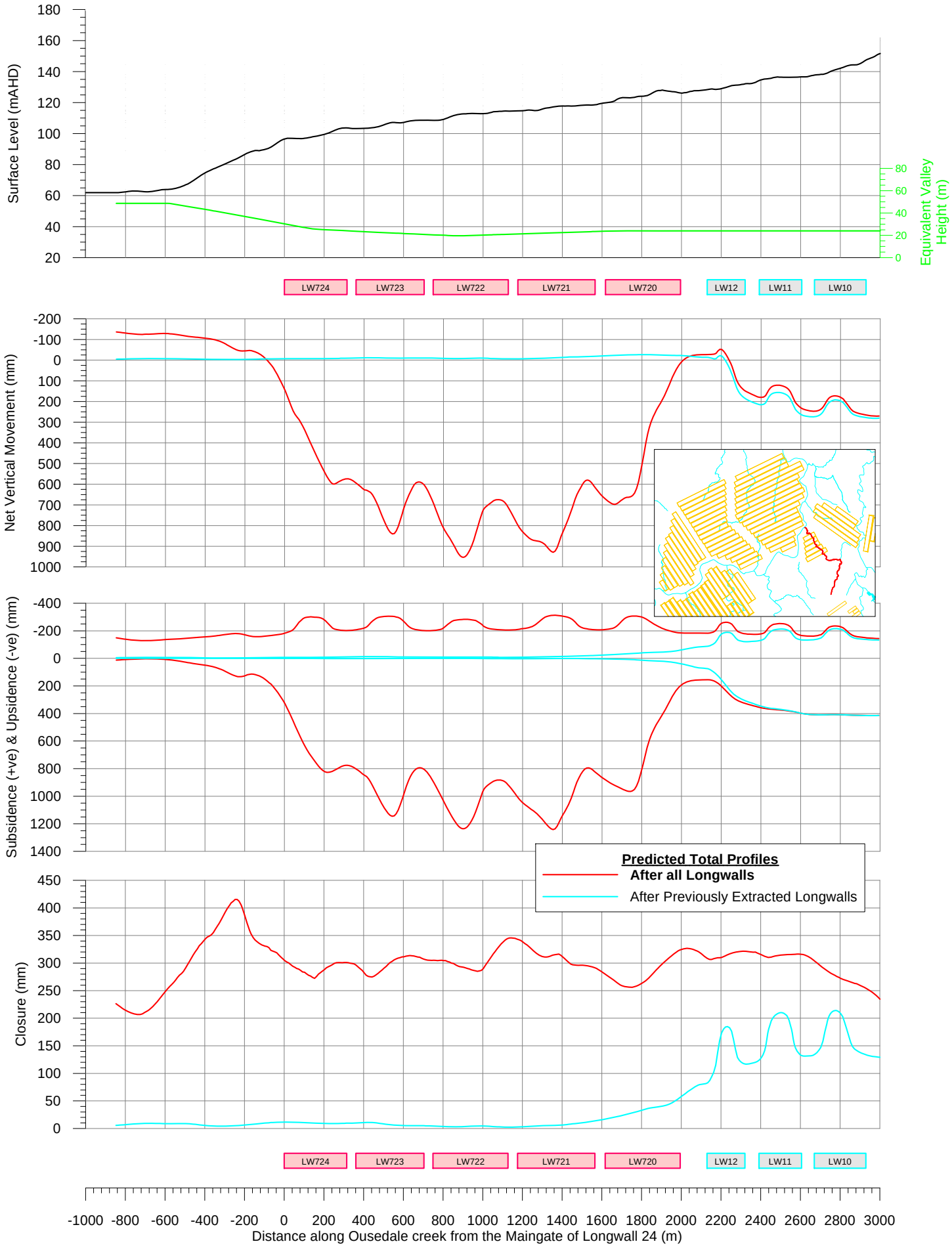
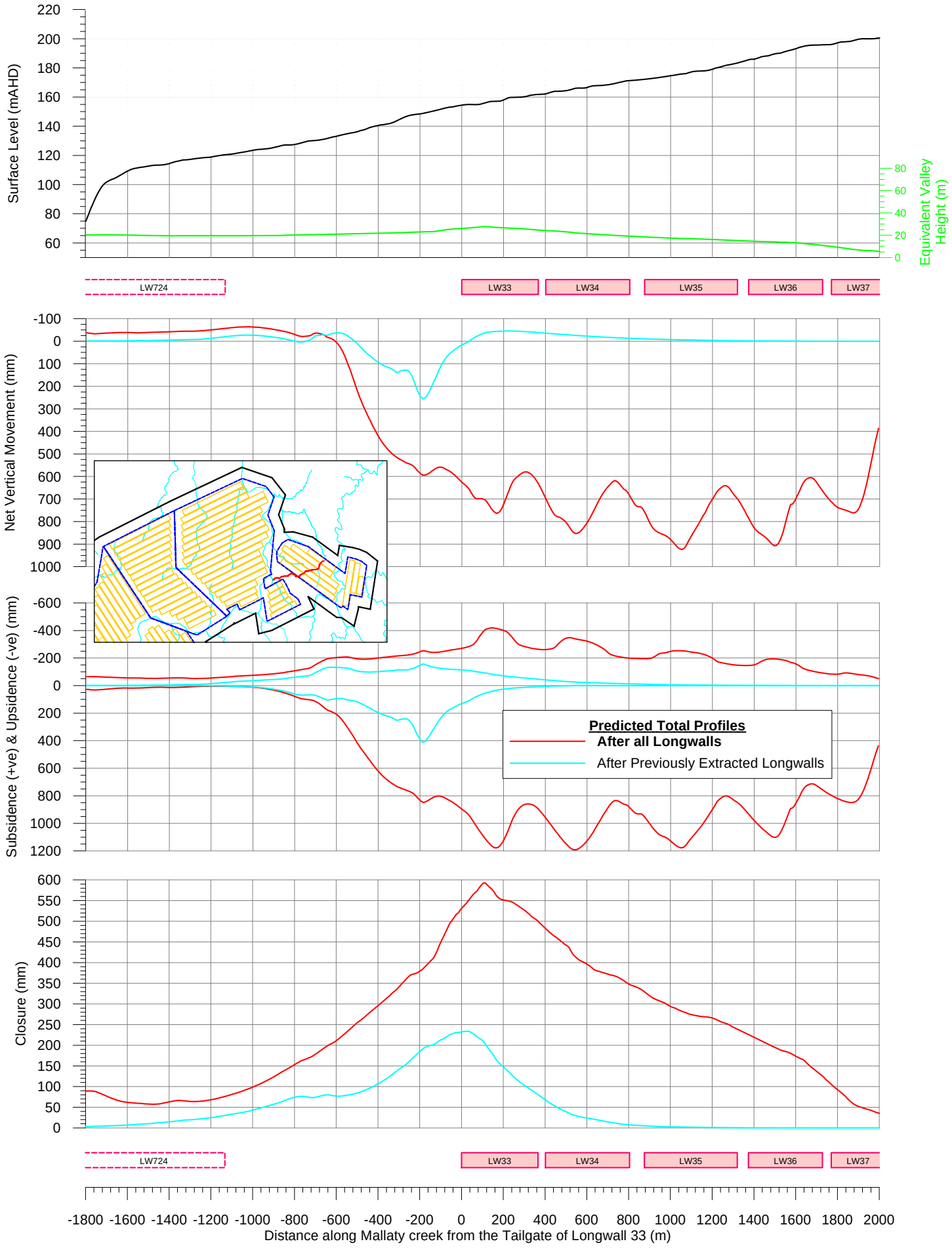





**Fig. 200-11**

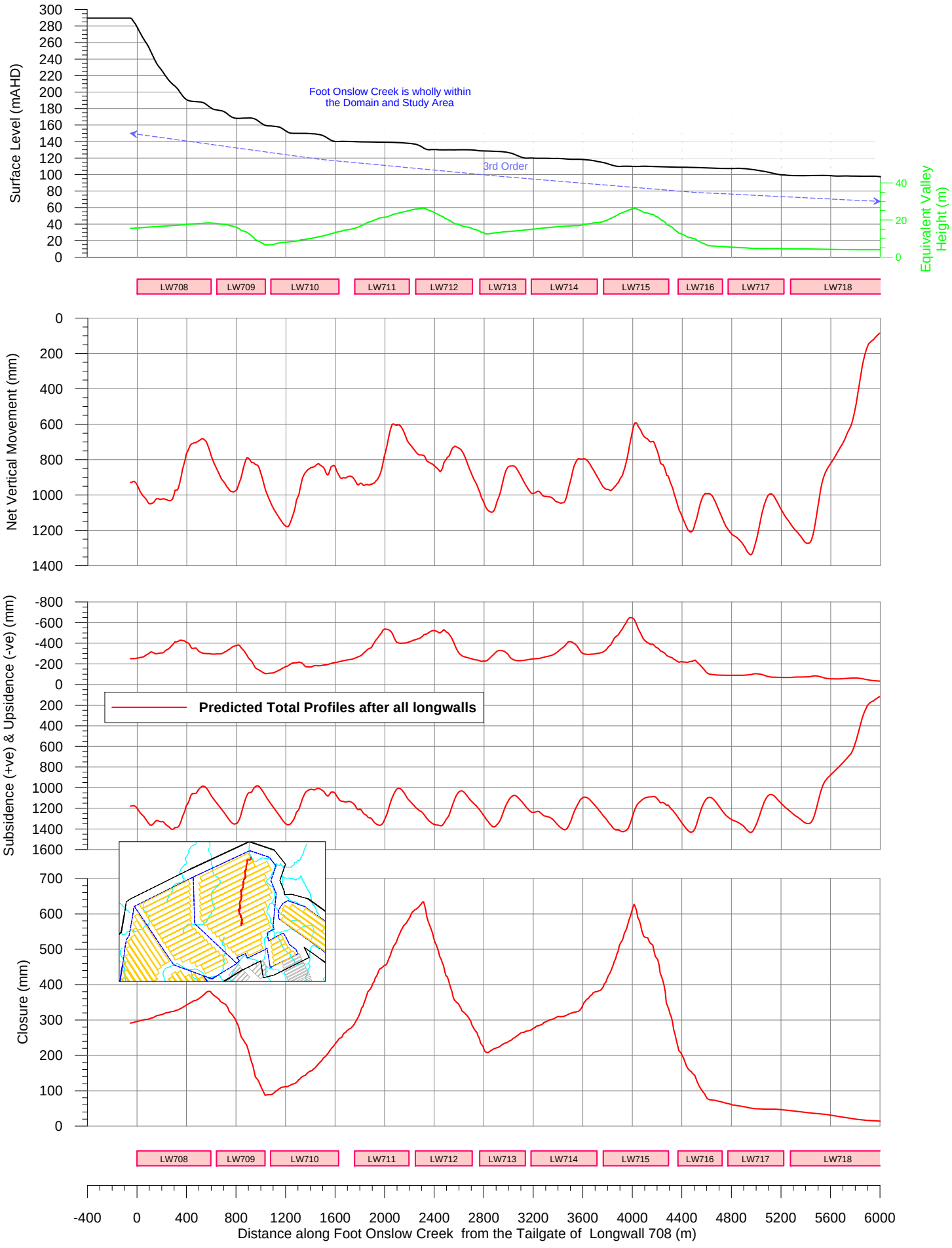
# West Cliff Area 5 - Longwalls 33 to 37 & 5E1 to 5E3 Mallaty Creek
# Predicted Profiles of Subsidence, Upsidence and Closure




Mine Subsidence Engineering Consultants

**Fig. 200-12**

# Appin Area 9 - Longwalls 901 to 918 Foot Onslow Creek
# Predicted Profiles of Subsidence, Upsidence and Closure




Mine Subsidence Engineering Consultants

**Fig. 200-13**

# Appin Area 7 and Area 9 Navigation Creek
# Predicted Profiles of Subsidence, Upsidence and Closure

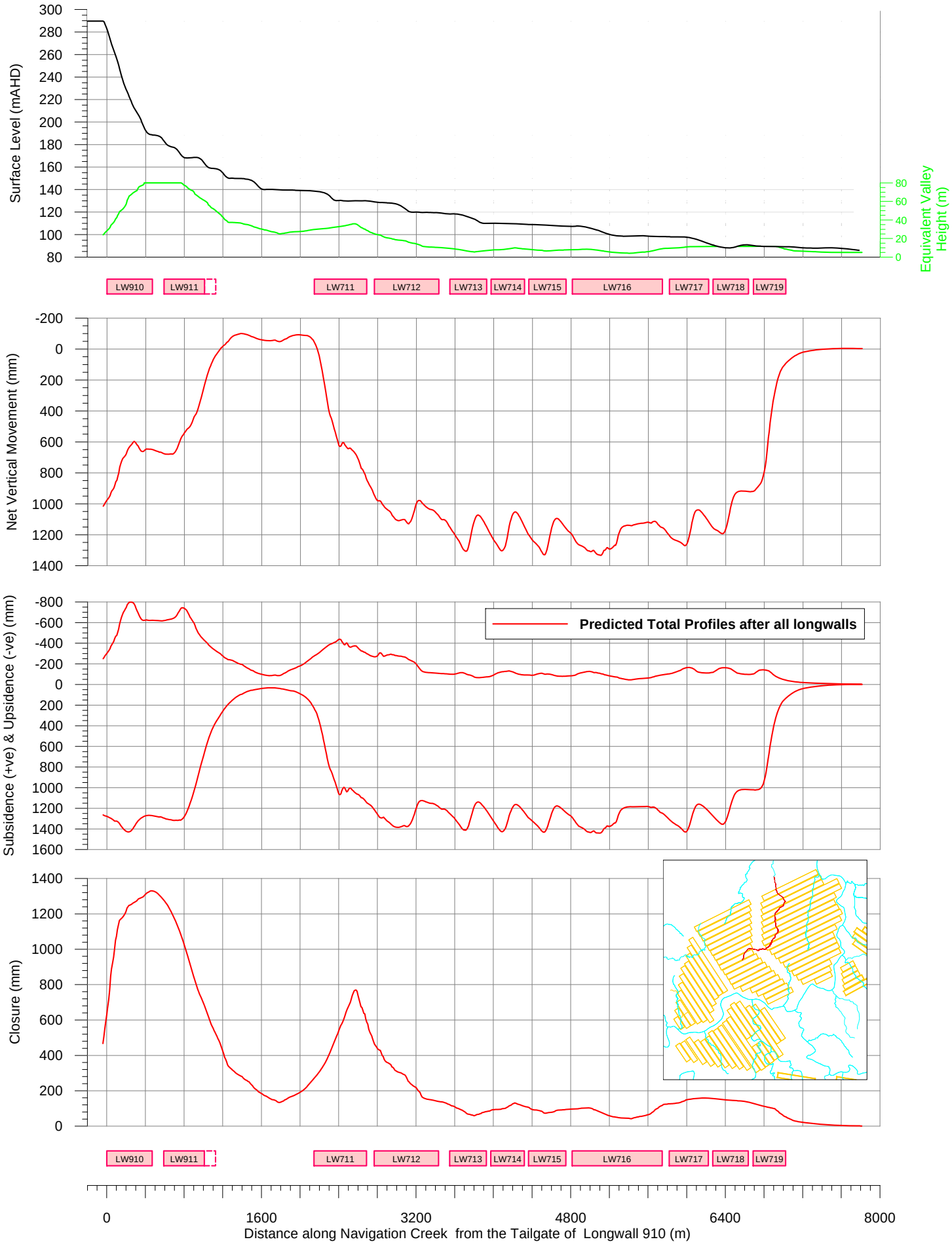



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**Fig. 200-14**

# Appin Area 9 - Longwalls 901 to 918 Matahill Creek
# Predicted Profiles of Subsidence, Upsidence and Closure

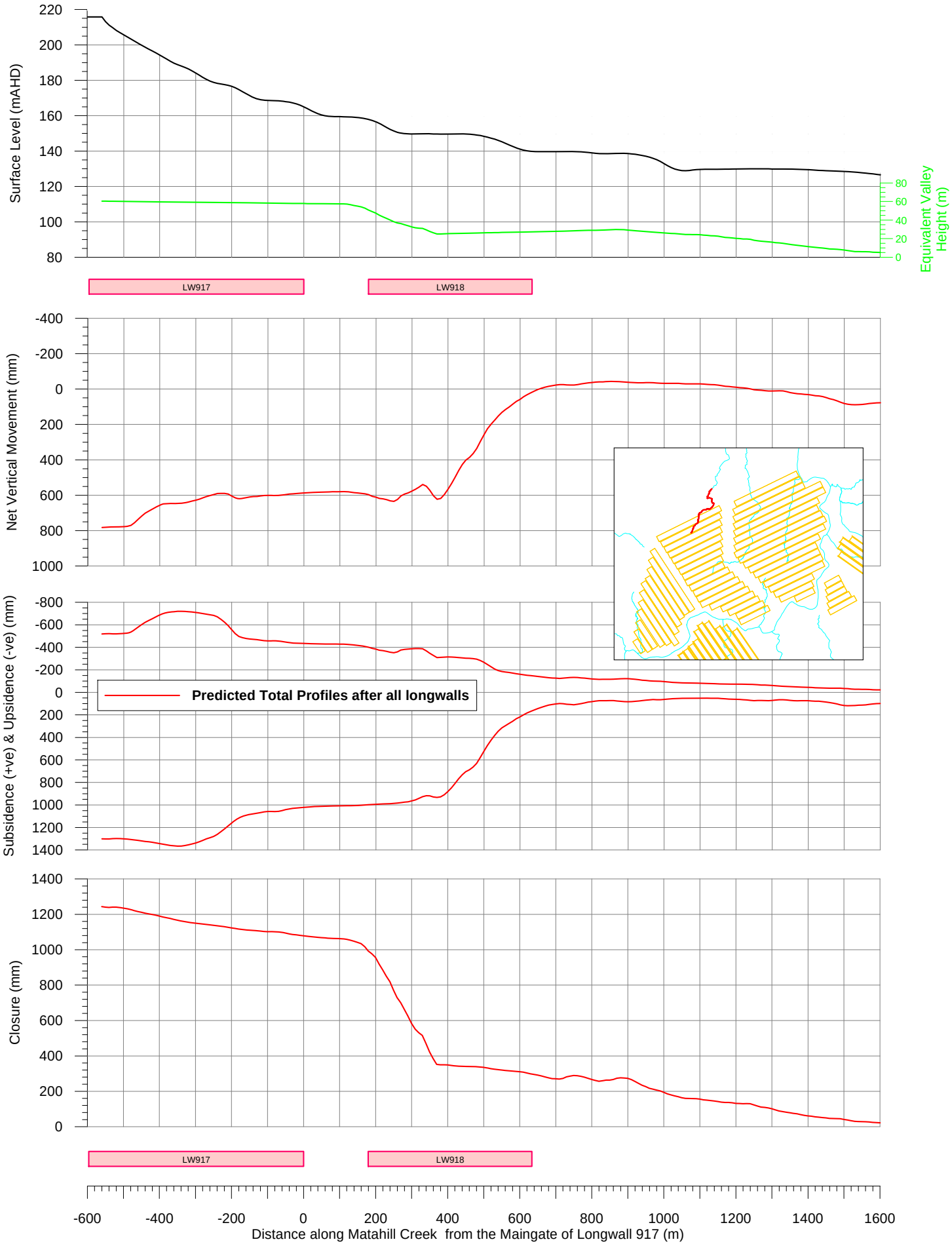


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**Fig. 200-15**

# Appin Area 8 - Longwalls 800 to 827 & Appin Area 9 - Longwalls 901 to 918 Racecourse Creek Predicted Profiles of Subsidence, Upsidence and Closure

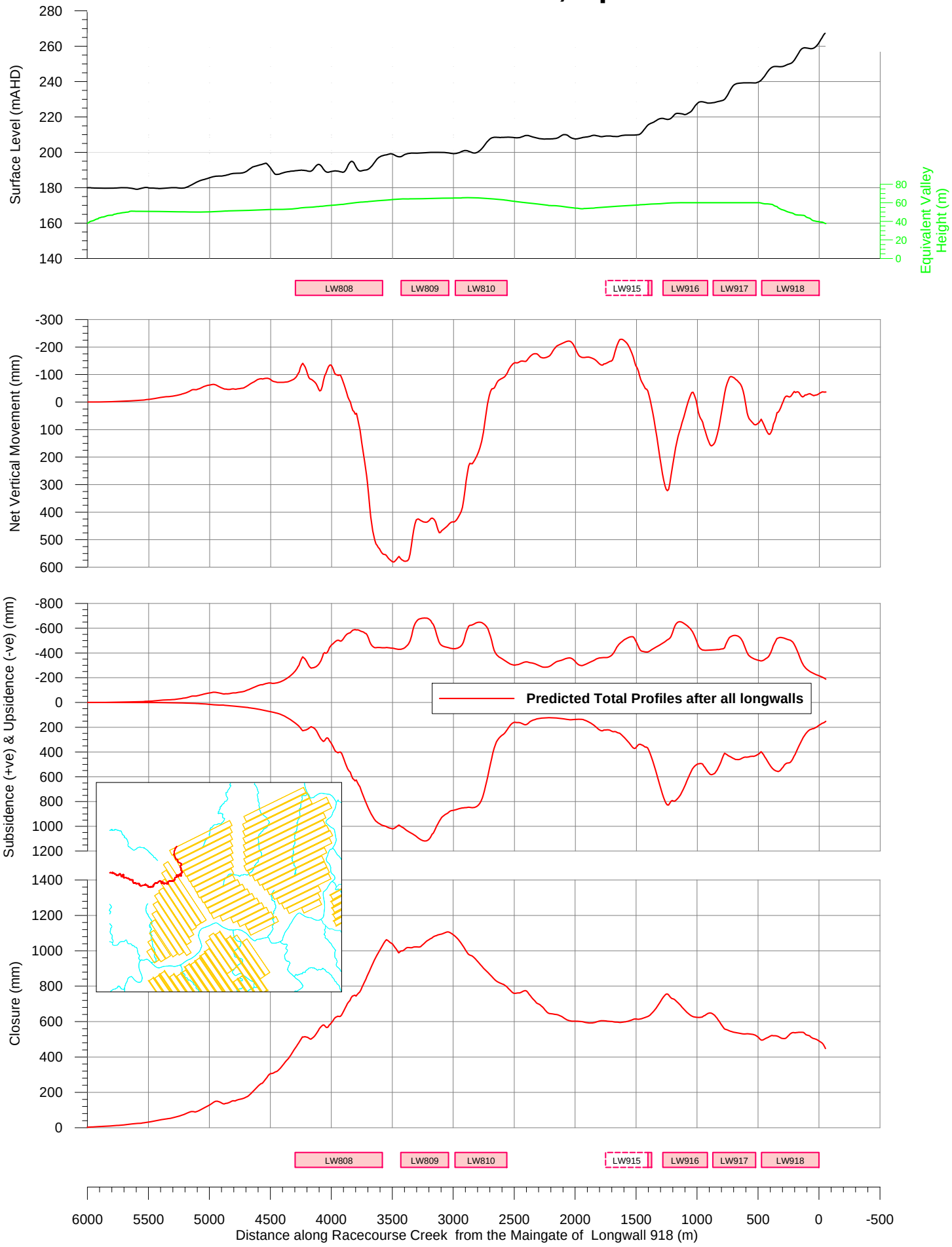


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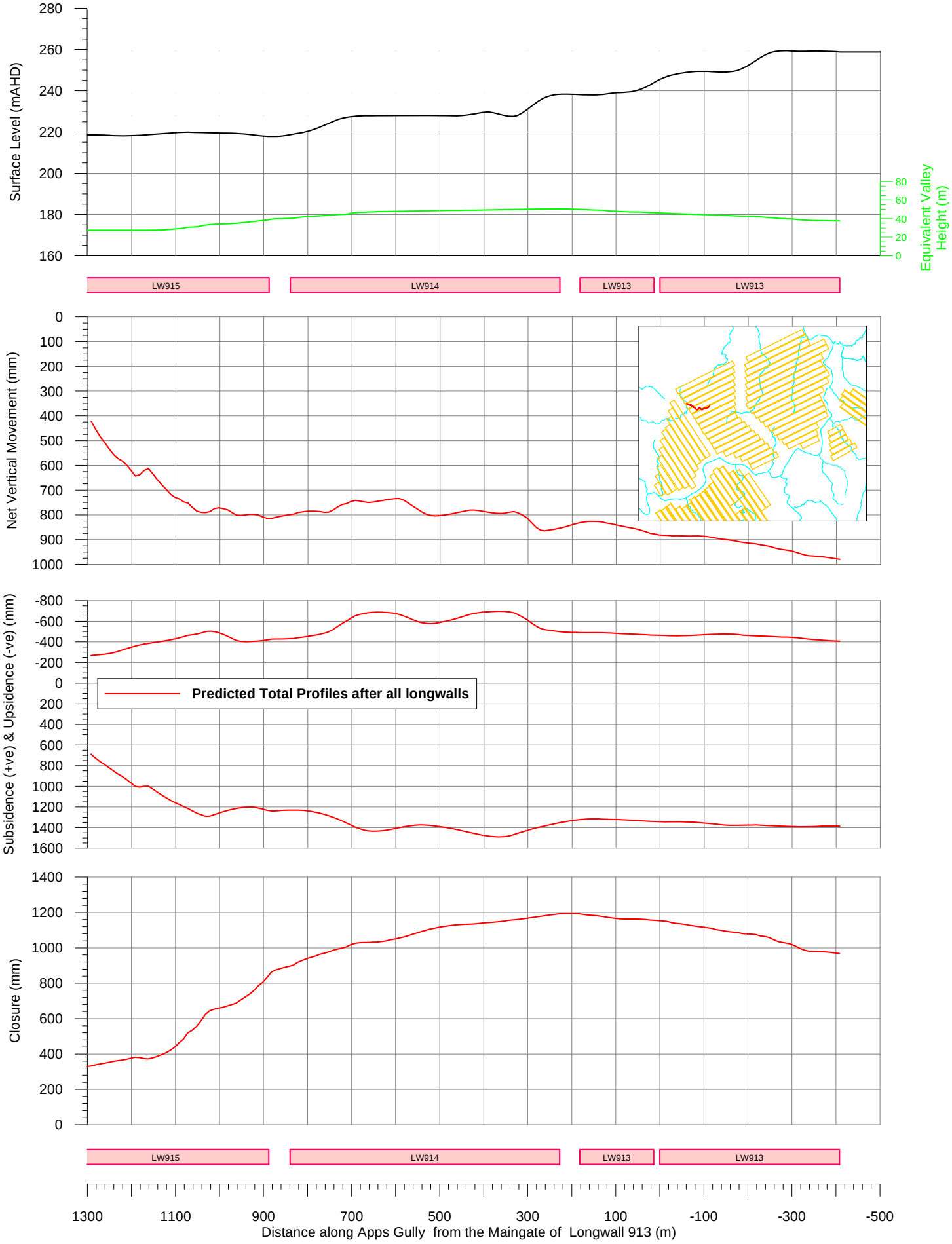
**Fig. 200-16**

# Appin Area 9 - Longwalls 901 to 918 Apps Gully
# Predicted Profiles of Subsidence, Upsidence and Closure




Mine Subsidence Engineering Consultants

**Fig. 200-17**

# Appin Area 8 - Longwalls 800 to 827 &
# Appin Area 9 - Longwalls 901 to 918 Racecourse Creek Tributary
# Predicted Profiles of Subsidence, Upsidence and Closure

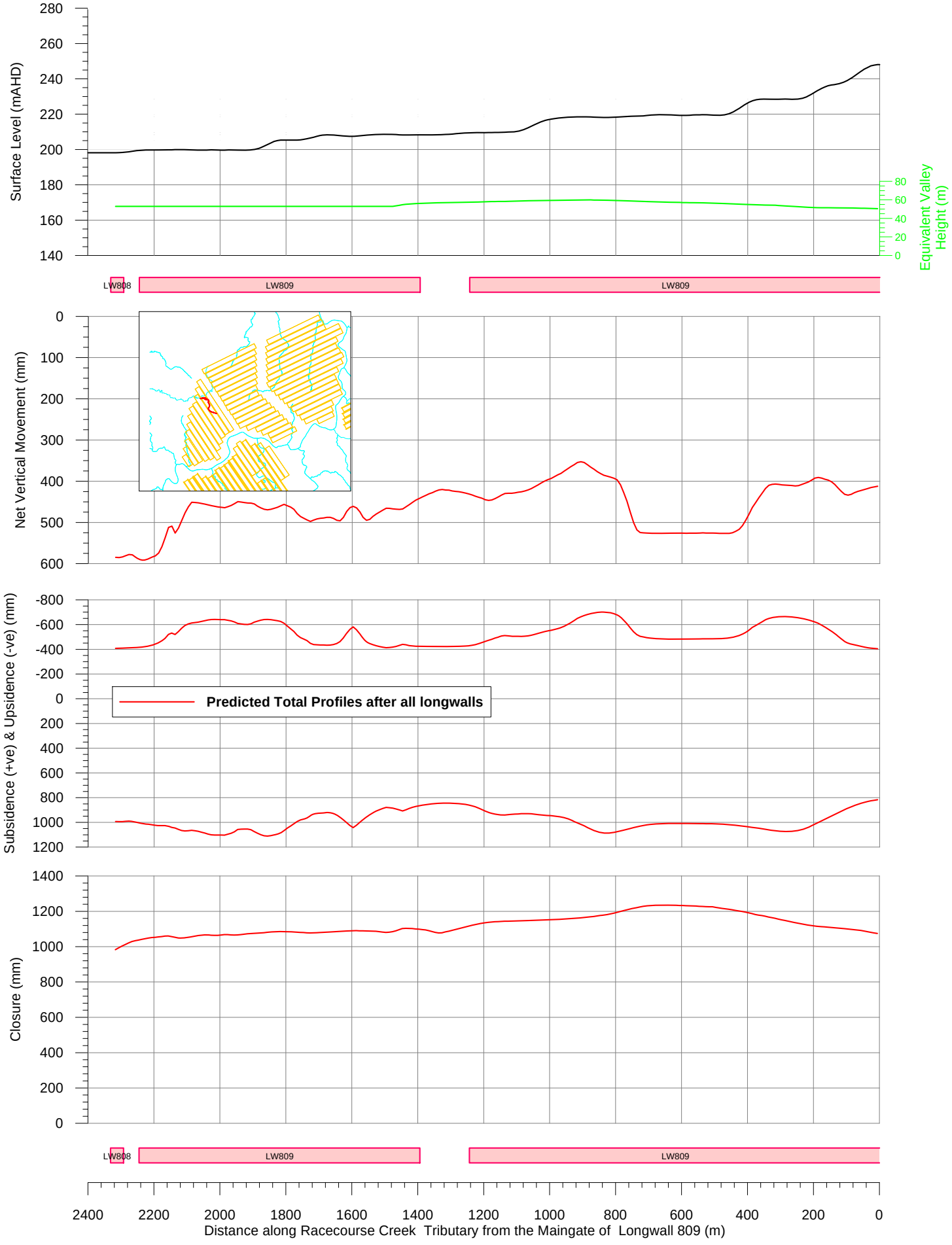



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**Fig. 200-18**

# Appin Area 2 Longwalls 30, 231 to 237 & Appin Area 3 - Longwalls 303 to 313 Cataract River Predicted Profiles of Subsidence, Upsidence and Closure

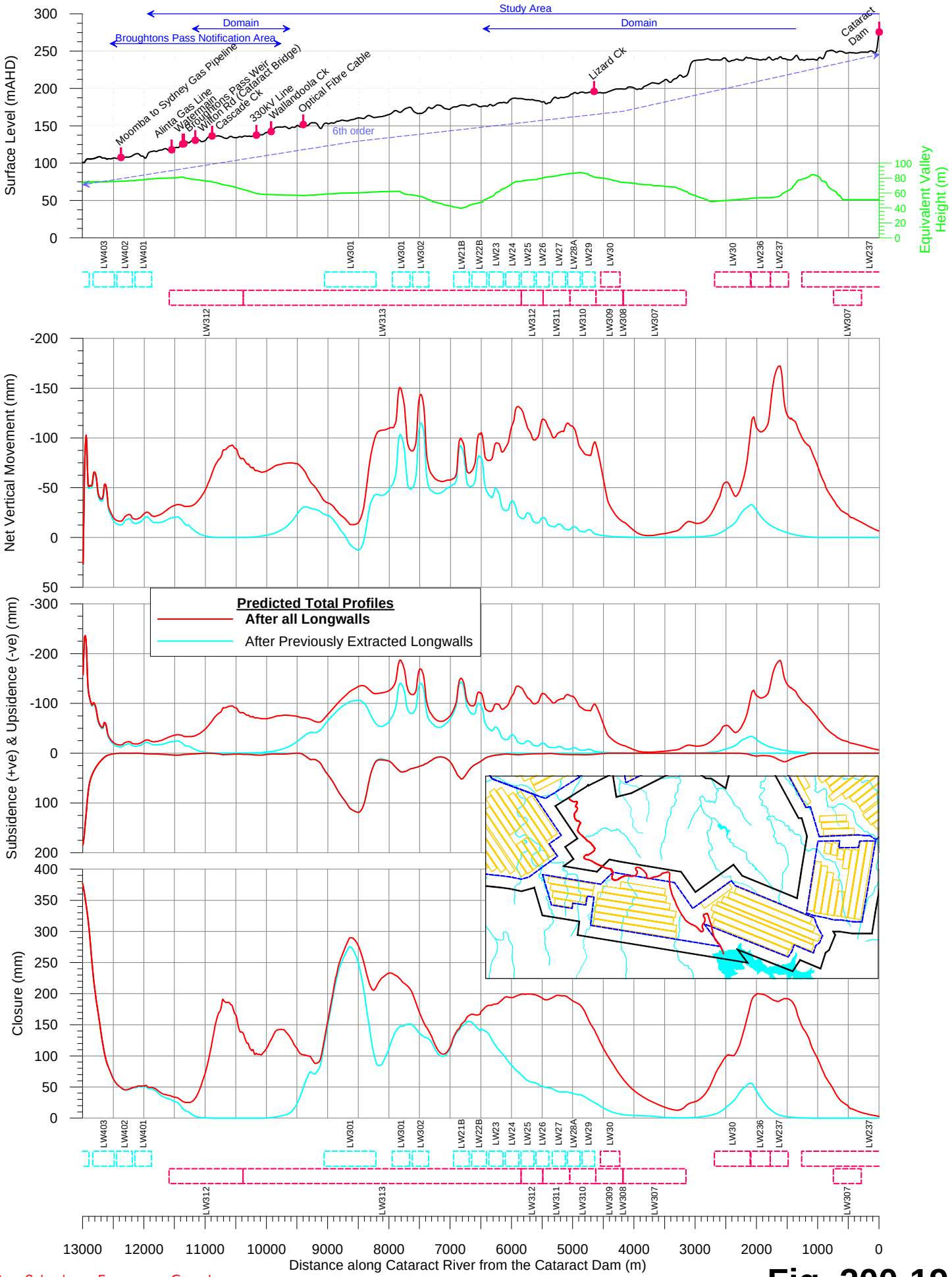


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**Fig. 200-19**

# Appin Area 3 - Longwalls 303 to 313 Lizard Creek
# Predicted Profiles of Subsidence, Upsidence and Closure

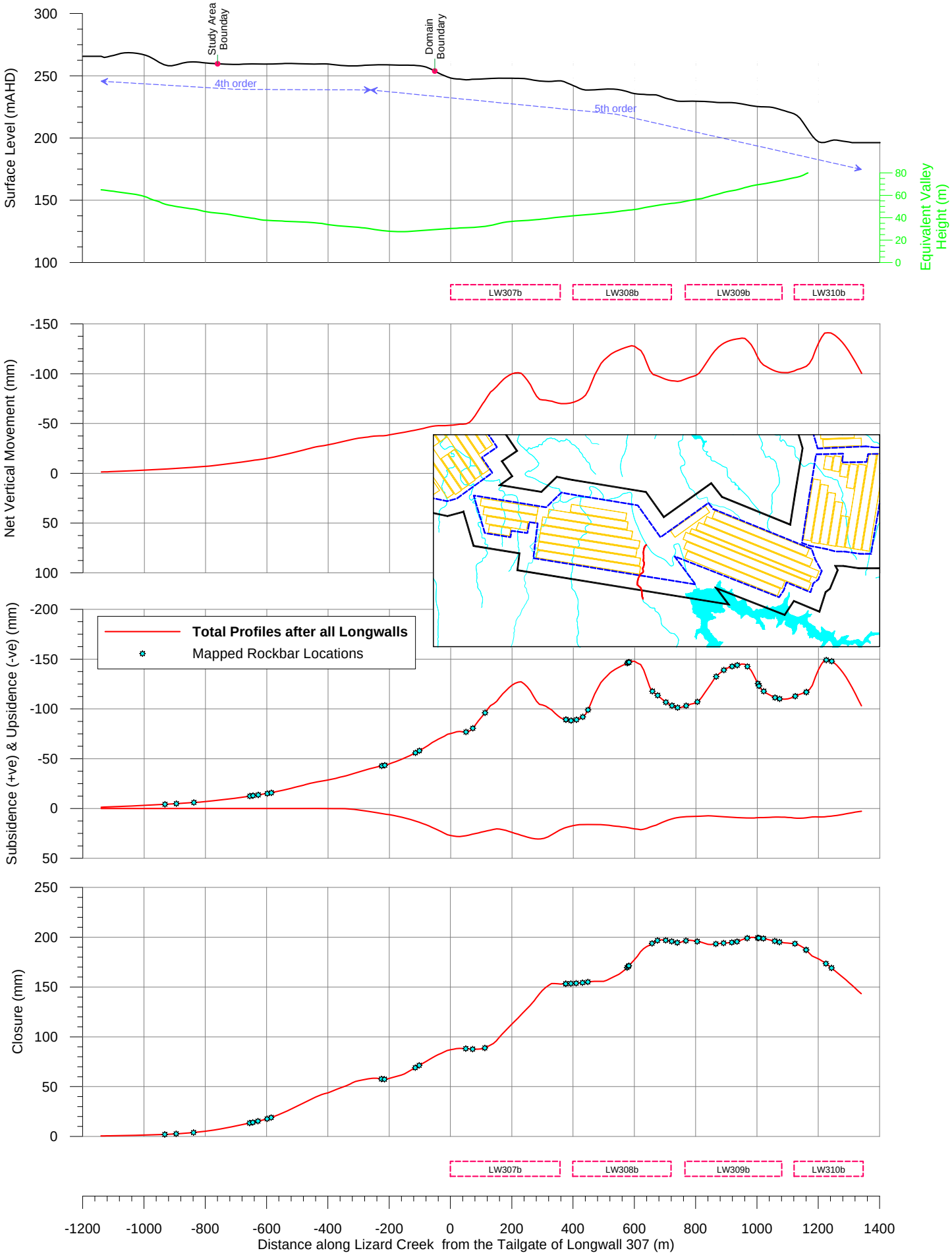


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**Fig. 200-20**

# Appin Area 3 - Longwalls 303 to 313 Wallandoola East Creek
# Predicted Profiles of Subsidence, Upsidence and Closure

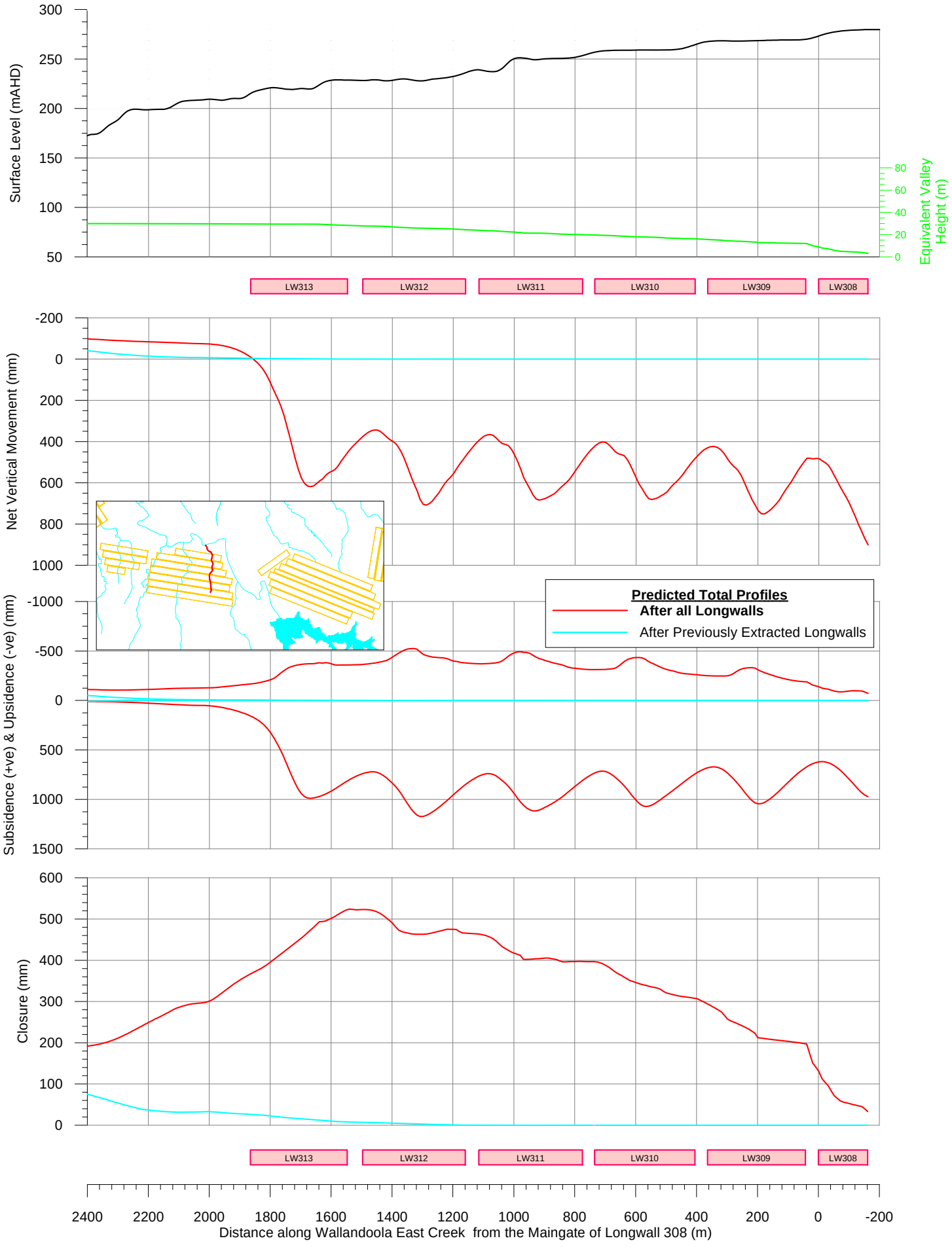


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**Fig. 200-21**

# Appin Area 3 - Longwalls 303 to 313 Wallandoola Creek
# Predicted Profiles of Subsidence, Upsidence and Closure

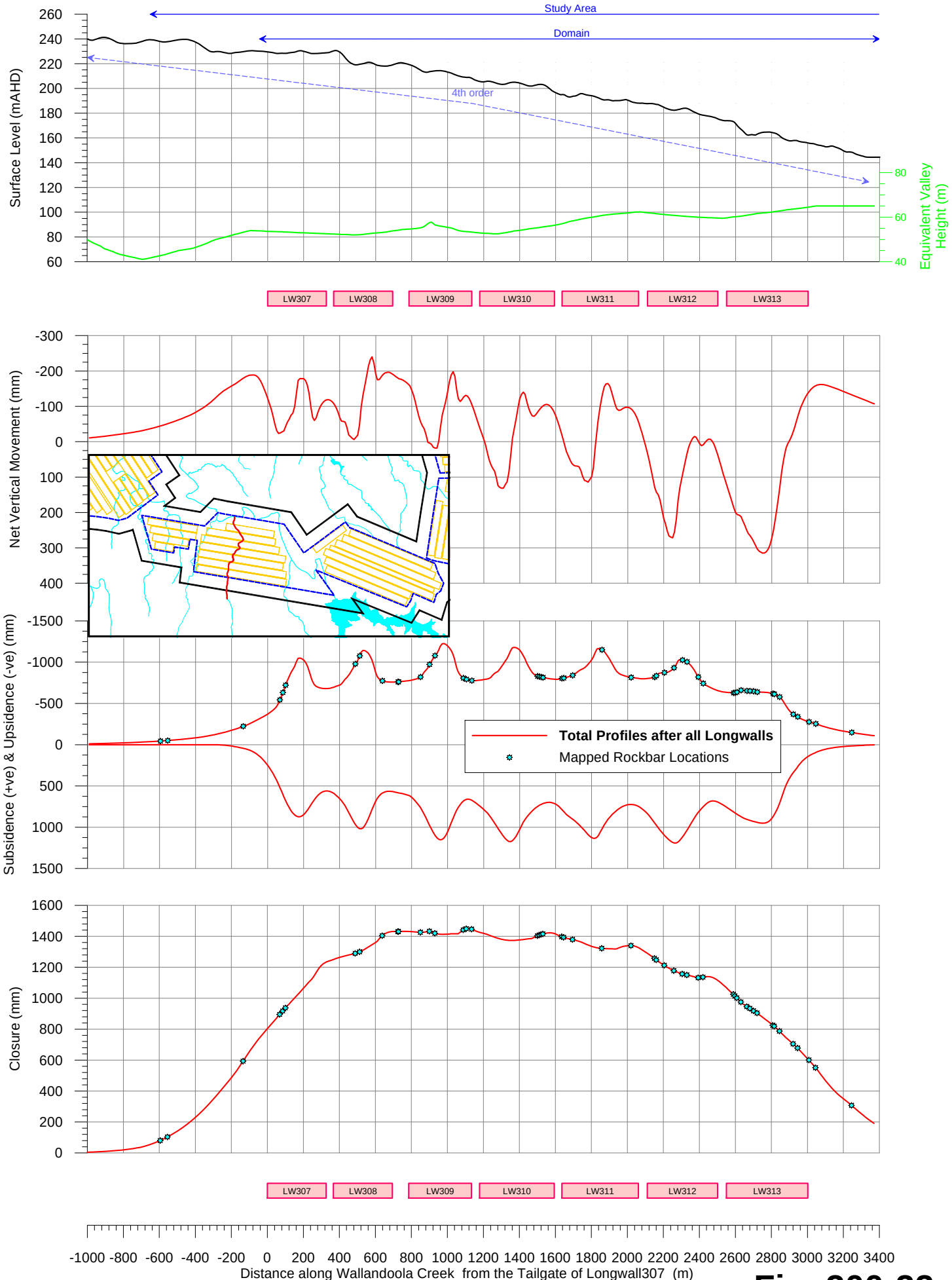


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**Fig. 200-22**

# Appin Area 3 - Longwalls 303 to 313 Cascade Creek
# Predicted Profiles of Subsidence, Upsidence and Closure

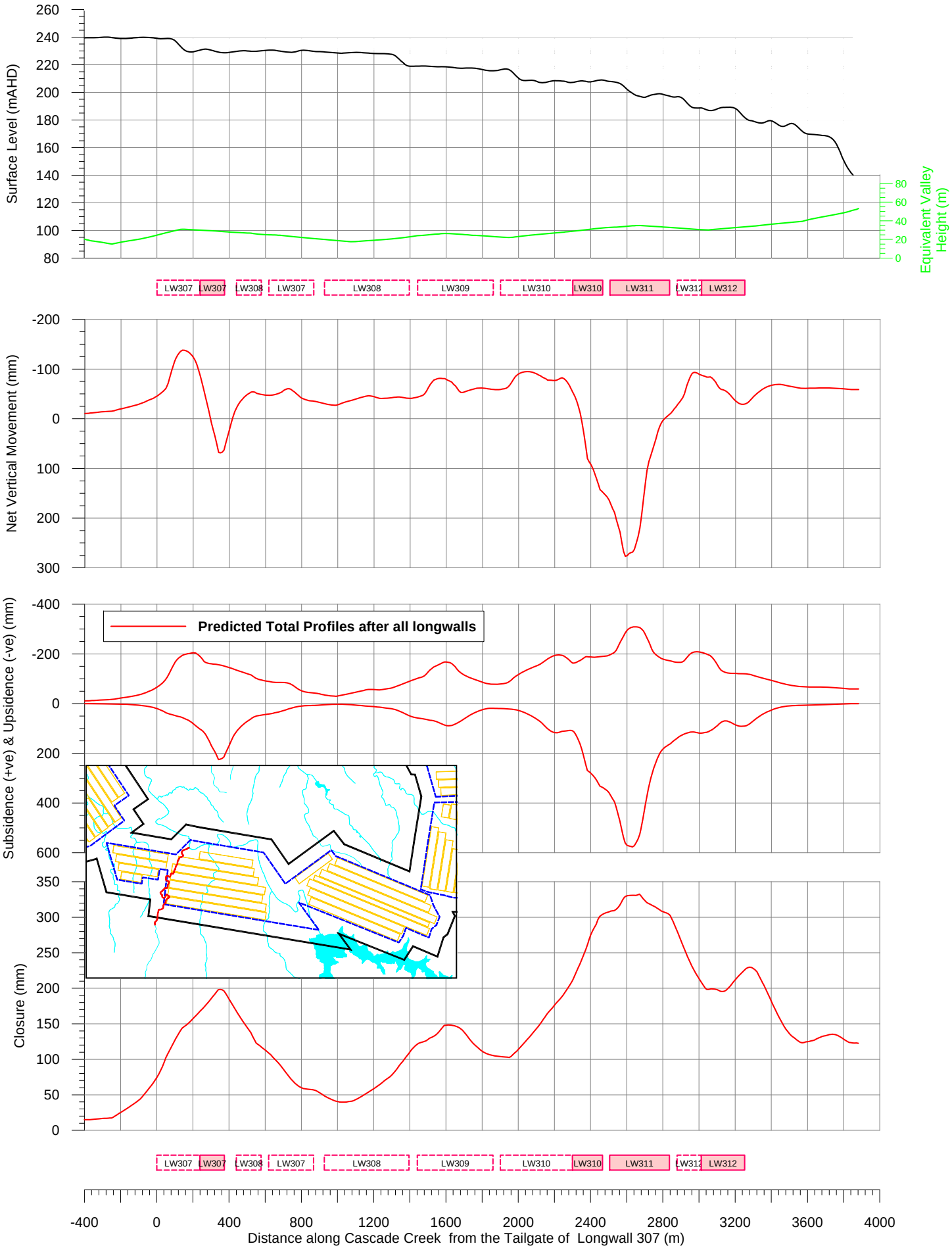


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**Fig. 200-23**

# Appin Area 2 - Longwalls 231 to 237
# Cataract Reservoir Tributary 2
# Predicted Profiles of Subsidence, Upsidence and Closure

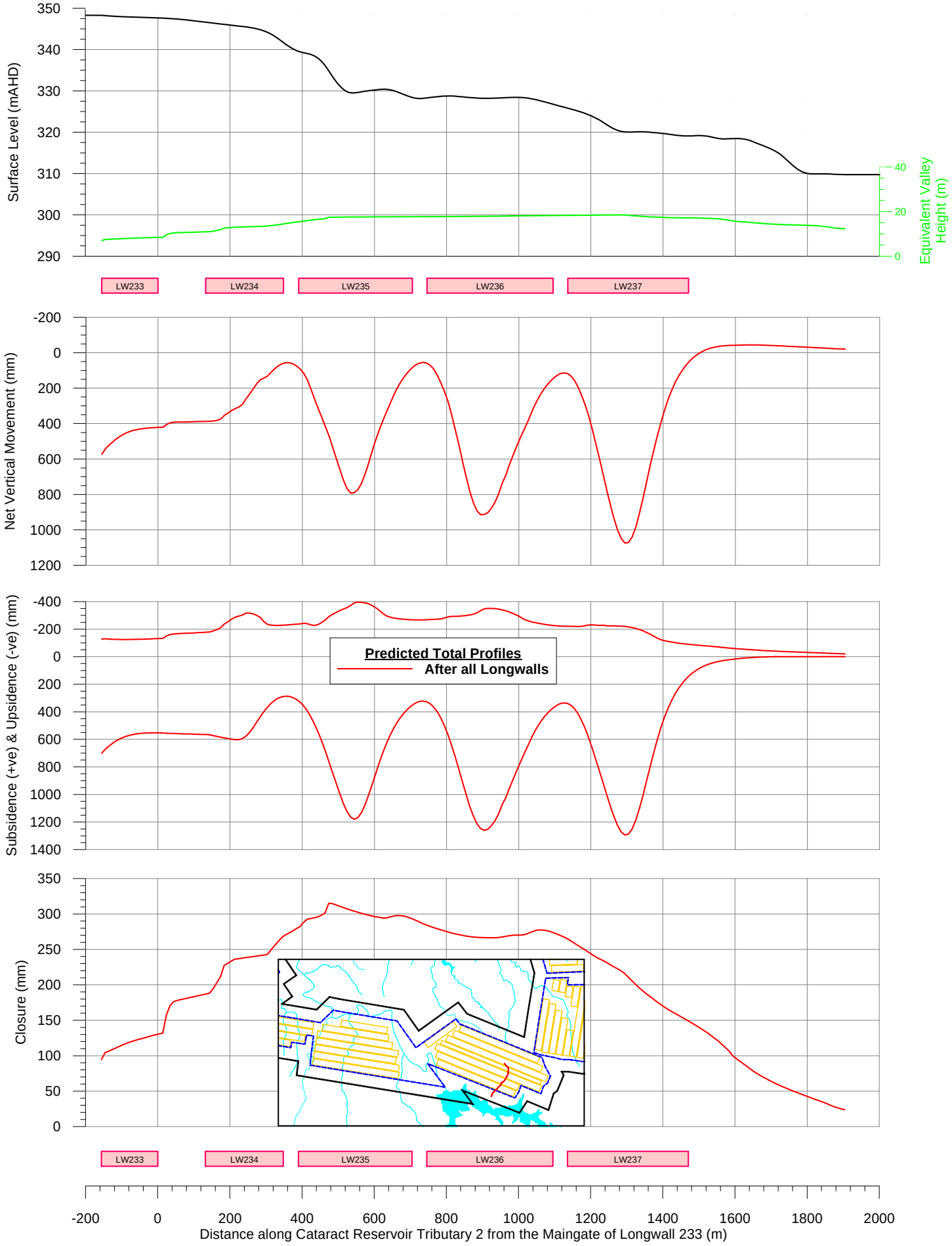


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**Fig. 200-24**

# Appin Area 2 - Longwalls 231 to 237
# Cataract Reservoir Tributary 1
# Predicted Profiles of Subsidence, Upsidence and Closure

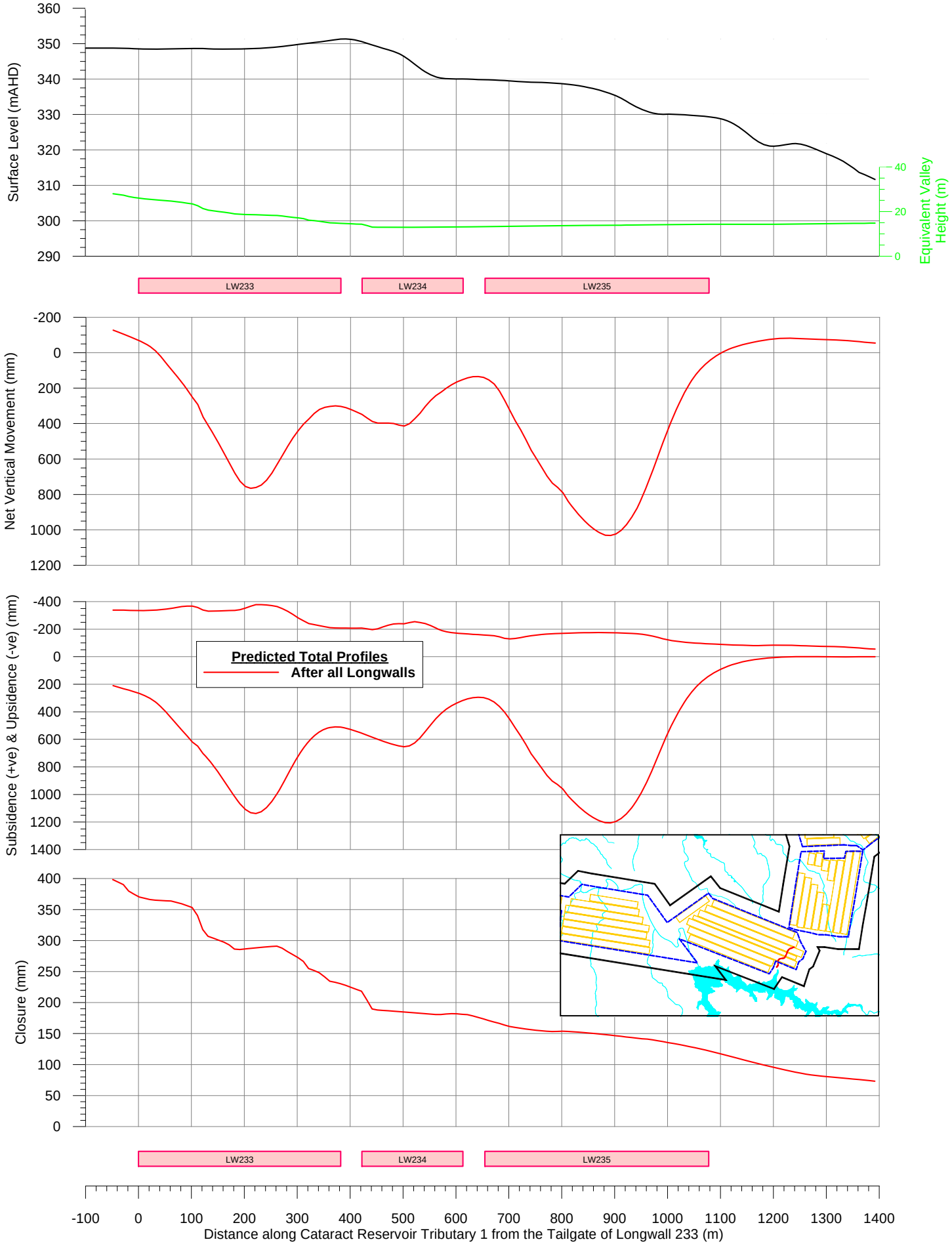


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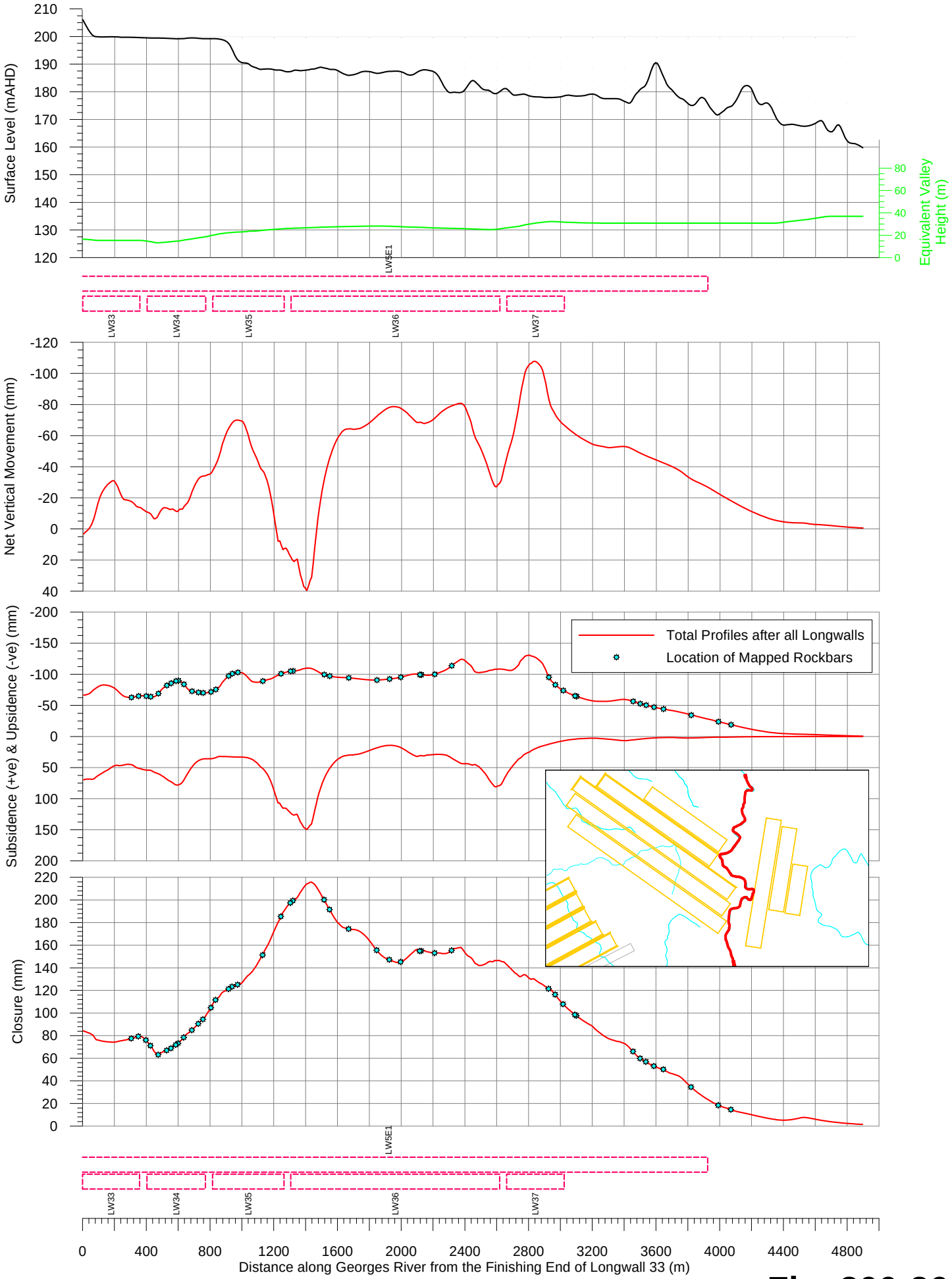
**Fig. 200-25**

# West Cliff Area 5 Longwalls 34 to 37 & 5E3 to 5E1 Georges River
# Predicted Profiles of Subsidence, Upsidence and Closure




Mine Subsidence Engineering Consultants

**Fig. 200-26**

# Appin Area 2 - Longwalls 30 & 231 to 237 Georges River
# Predicted Profiles of Subsidence, Upsidence and Closure

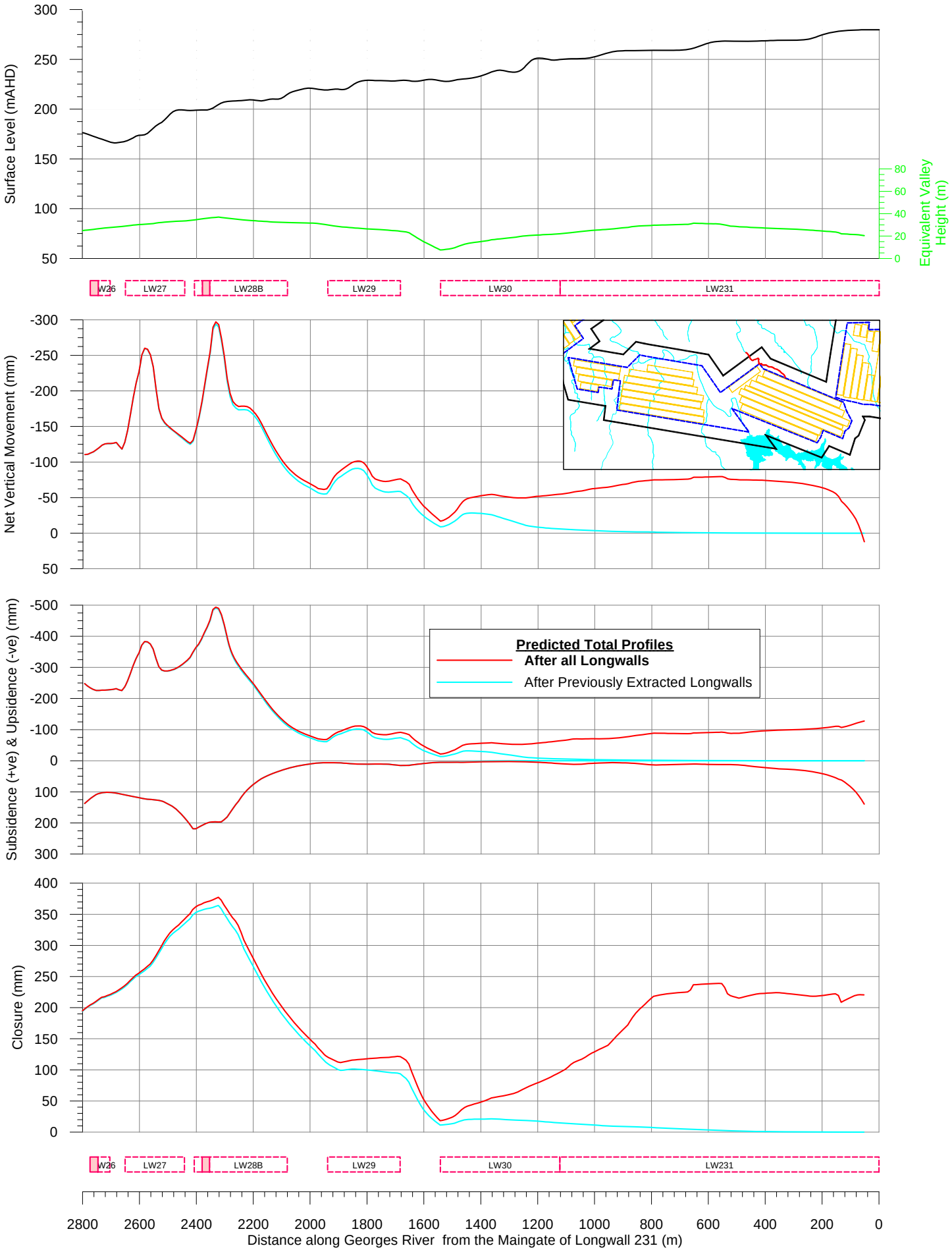



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**Fig. 200-27**

# North Cliff - Longwalls 1 to 36 O'Hares Creek
# Predicted Profiles of Subsidence, Upsidence and Closure


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**Fig. 200-28**

# North Cliff - Longwalls 1 to 36 O'Hares Creek Tributary
# Predicted Profiles of Subsidence, Upsidence and Closure

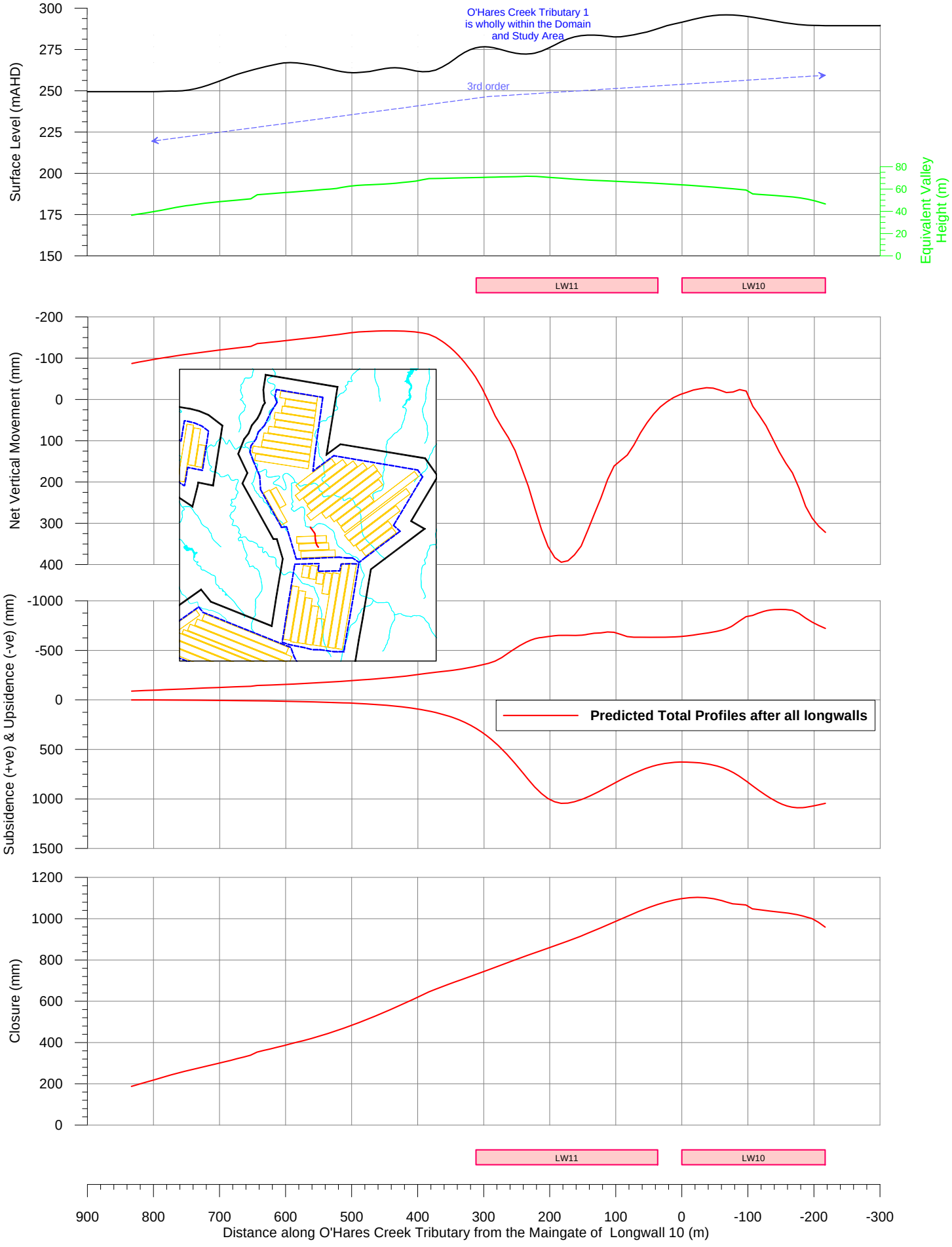


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**Fig. 200-29**

# North Cliff - Longwalls 1 to 36 Dahlia Creek
# Predicted Profiles of Subsidence, Upsidence and Closure

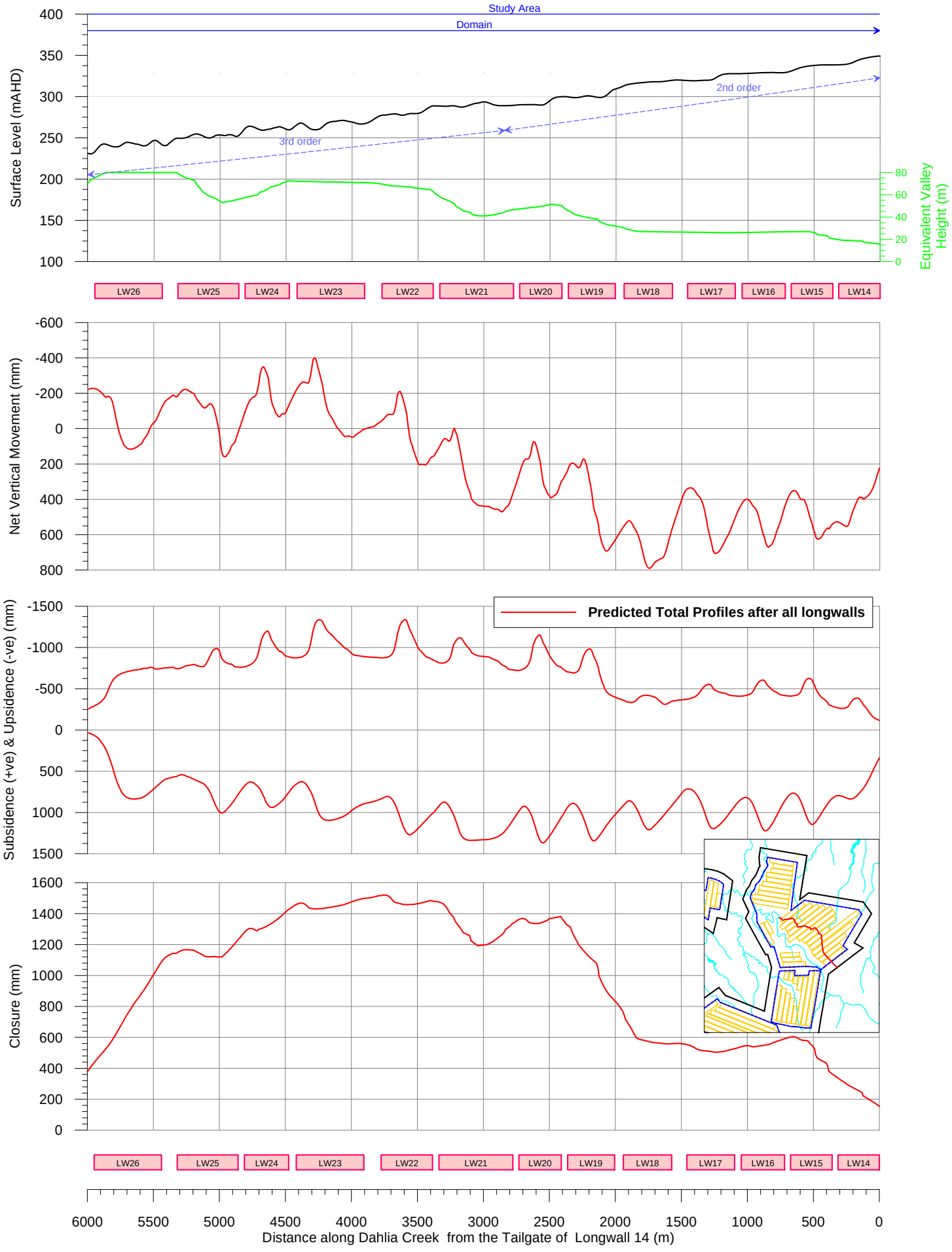


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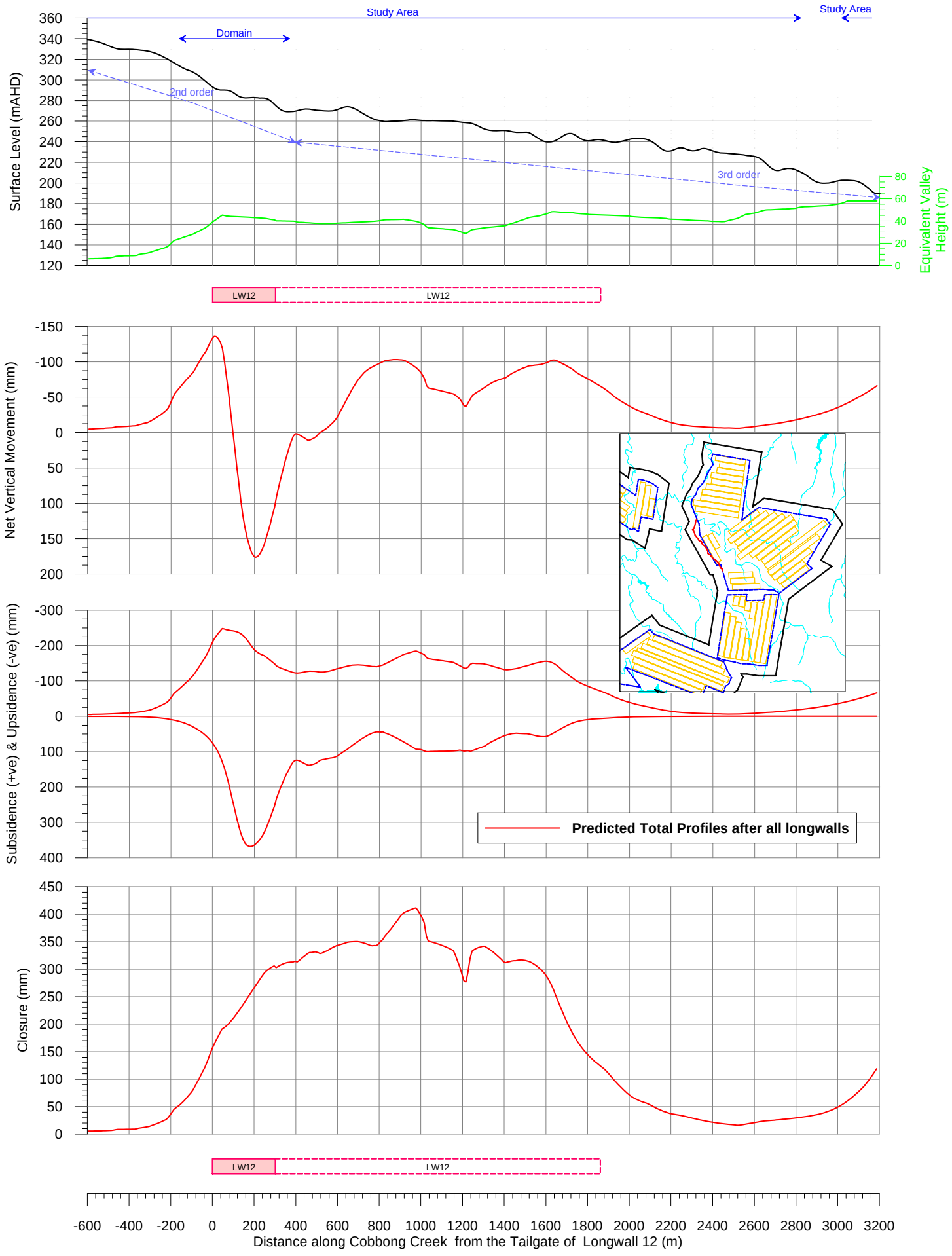
**Fig. 200-30**

# North Cliff - Longwalls 1 to 36 Cobbong Creek
# Predicted Profiles of Subsidence, Upsidence and Closure



# North Cliff - Longwalls 1 to 36 Stokes Creek
# Predicted Profiles of Subsidence, Upsidence and Closure

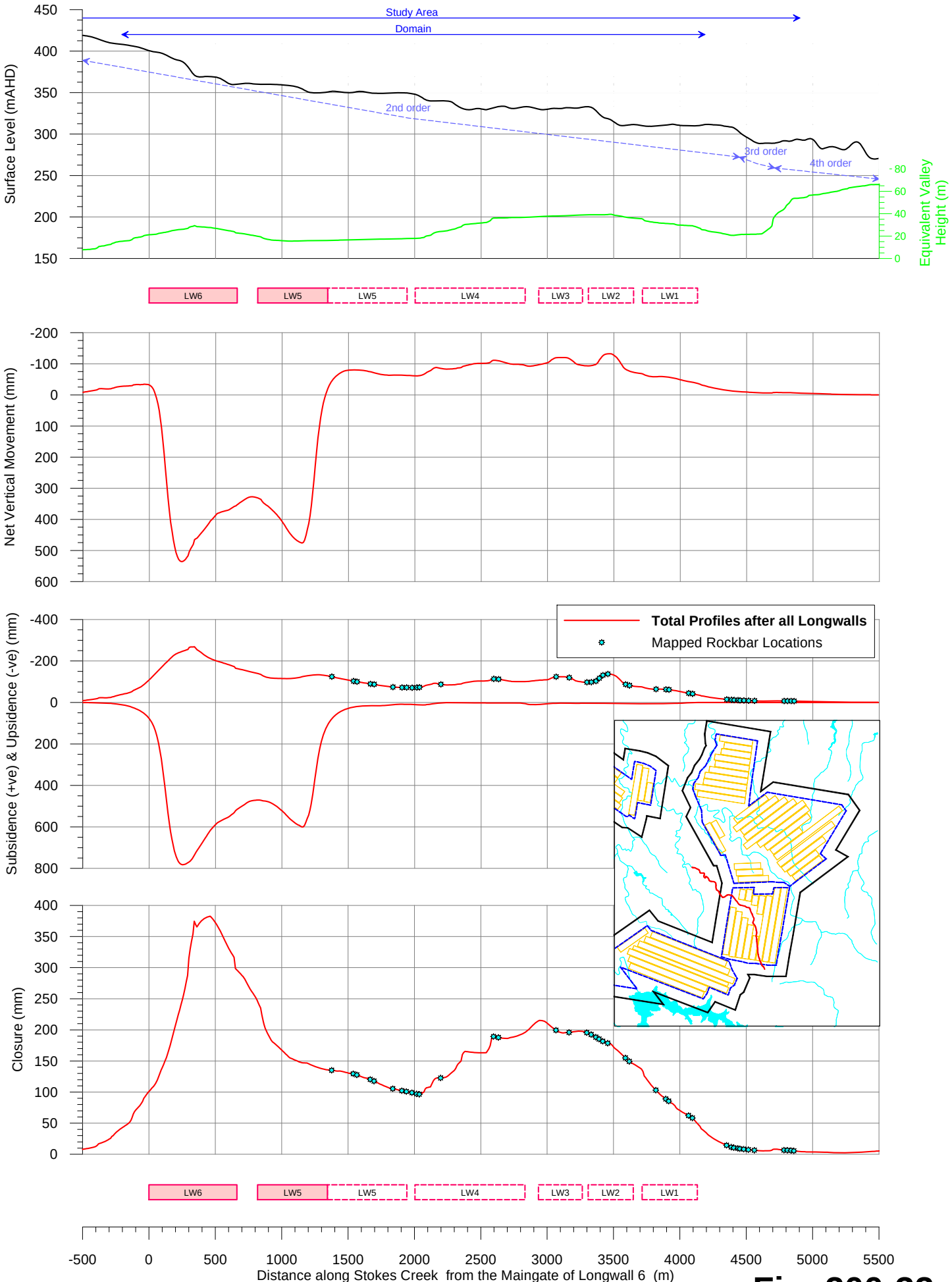



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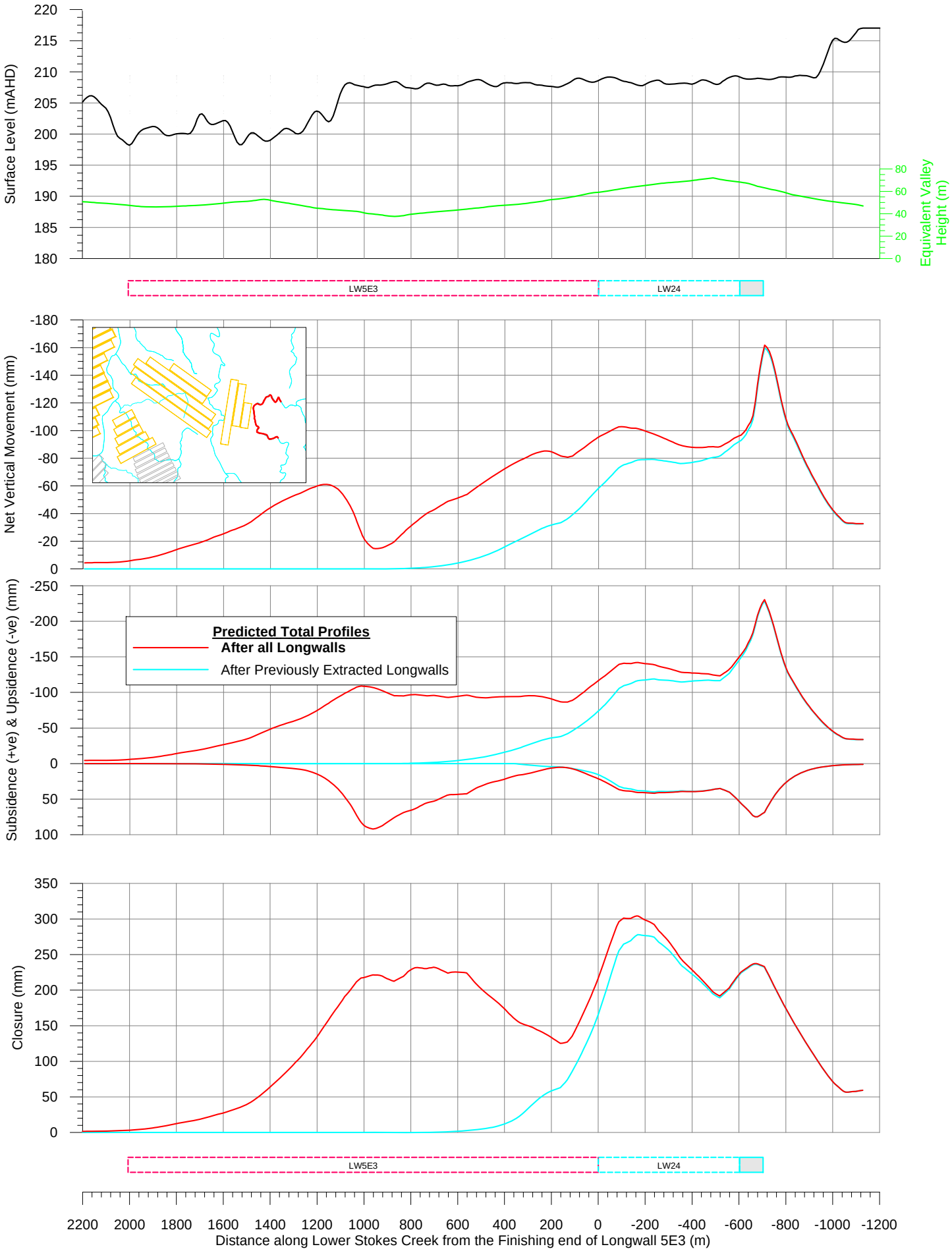
**Fig. 200-32**

# West Cliff Area 5 - Longwalls 33 to 37 & 5E1 to 5E3
# Lower Stokes Creek
# Predicted Profiles of Subsidence, Upsidence and Closure



# North Cliff - Longwalls 1 to 36 Woronora River
# Predicted Profiles of Subsidence, Upsidence and Closure


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**Fig. 200-34**

# North Cliff - Longwalls 1 to 36 Punchbowl Creek
# Predicted Profiles of Subsidence, Upsidence and Closure


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**Fig. 200-35**

# ATTACHMENT PH

# TRADE-OFF ANALYSIS – ALTERNATIVE MINE PLANS

I:\Projects\IllawarraCoal-SouthCoastPart3A\MSEC404-SthCoastPt3A\AcadData\MSEC404-1201.dwg

MINE SUBSIDENCE ENGINEERING CONSULTANTS
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# ILLAWARRA COAL

## LONGWALL OFFSETS AT APPIN AREAS 8 & 9

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 19-Aug-2009 | 1:40000 | MSEC404-1201 | B |

**LEGEND**
- ECONOMIC COAL
- STERILISED COAL
- WATERCOURSES
- 3rd ORDER STREAMS
- 4th ORDER STREAMS
- 5th ORDER STREAMS
- 6th ORDER STREAMS
- 7th ORDER STREAMS

**OPTIONS C7 and C8**
LONGWALL SETBACKS TO ACHIEVE 200mm TARGET CLOSURE AT STREAMS 3RD ORDER AND ABOVE

**LEGEND**
- BASECASE LONGWALL LAYOUT
- EXTENT OF LONGWALL MINING AREA

STUDY AREA

AREA 7 — LW 719, LW 718, LW 717, LW 716, LW 715, LW 714, LW 713, LW 712, LW 711, LW 710, LW 709, LW 708, LW 707, LW 706, LW 705, LW 704, LW 703, LW 702

AREA 9 — LW 918, LW 917, LW 916, LW 915, LW 914, LW 913, LW 912, LW 911, LW 910, LW 909, LW 908, LW 907, LW 906, LW 905, LW 904, LW 903, LW 902, LW 901

AREA 8 — LW 810, LW 809, LW 808, LW 807, LW 806, LW 805, LW 804, LW 803, LW 802, LW 801, LW 800, LW 824, LW 823a, LW 822a, LW 821, LW 820, LW 819, LW 818, LW 817, LW 816, LW 815, LW 814, LW 813, LW 812, LW 811, LW 827, LW 826, LW 825, LW 822b, LW 823b

AREA 3 — LW 306, LW 305, LW 304, LW 303

TOWER

DOUGLAS PARK WEIR

MALDON WEIR

431m, 476m, 458m, 509m, 686m, 1377m, 1335m, 1438m, 806m, 2050m, 771m, 491m, 871m, 534m, 182m, 233m, 143m, 130m, 376m, 784m, 370m, 293m, 430m, 419m, 782m, 1328m, 870m, 850m, 342m, 1859m, 241m, 142m, 3127m, 1099m, 1549m, 299m, 1115m, 630m

LW901 has been removed from the Base Case Layout since the predictions were made.

Grid to MGA co-ordinates

I:\Projects\IllawarraCoal-SouthCoastPart3A\MSEC404-SthCoastPt3A\AcadData\MSEC404-1202.dwg

LEGEND

BASECASE LONGWALL LAYOUT

EXTENT OF LONGWALL MINING AREA

LEGEND

ECONOMIC COAL

STERILISED COAL

WATERCOURSES

3rd ORDER STREAMS

4th ORDER STREAMS

5th ORDER STREAMS

6th ORDER STREAMS

7th ORDER STREAMS

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bhpbilliton

# ILLAWARRA COAL

## LONGWALL OFFSETS AT APPIN AREA 7 & WEST CLIFF

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 19-Aug-2009 | 1:40000 | MSEC404-1202 | B |

**OPTIONS C5 and C6**
LONGWALL SETBACKS TO achieve 200mm TARGET CLOSURE AT STREAMS 3RD ORDER AND ABOVE

STUDY AREA

290 000

295 000

300 000

6 220 000

6 215 000

AREA 7

AREA 9

AREA 8

WEST CLIFF

NORTH CLIFF

STUDY AREA

TOWER

APPIN

MENANGLE WEIR

DOUGLAS PARK WEIR

BRENNANS CREEK DAM

Marhnyes Hole

Jutts Crossing

LW901 has been removed from the Base Case layout since the predictions were made.

Grid to MGA co-ordinates

LW 918 LW 917 LW 916 LW 915 LW 914 LW 913 LW 912 LW 911 LW 910 LW 909 LW 908 LW 907 LW 906 LW 905 LW 904 LW 903 LW 902 LW 901

LW 719 LW 718 LW 717 LW 716 LW 715 LW 714 LW 713 LW 712 LW 711 LW 710 LW 709 LW 708 LW 707 LW 706 LW 705 LW 704 LW 703 LW 702

LW 724 LW 723 LW 722 LW 721 LW 720

LW 37 LW 36 LW 35 LW 34 LW 33

LW 5E1 LW 5E2 LW 5E3

LW30 LW29 LW28 LW27 LW12

LW 824 LW 823a LW 822a LW 821 LW 820 LW 827 LW 826 LW 825

400m 676m 573m 439m 1003m 537m 127m 601m 75m 674m 772m 420m 433m 587m 122m 509m 1428m 287m 968m 449m 218m 351m 362m 202m 425m 529m 1104m 259m 345m 430m 234m 73m 542m 194m 198m 295m 317m 338m 416m 116m 300m 45m 377m 1035m

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# ILLAWARRA COAL

## LONGWALL OFFSETS AT APPIN AREAS 2 & 3

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 19-Aug-2009 | 1:40000 | MSEC404-1203 | B |

**OPTION C3**
LONGWALL SETBACKS TO achieve 200mm TARGET CLOSURE AT STREAMS 3RD ORDER AND ABOVE

LEGEND
- BASECASE LONGWALL LAYOUT
- EXTENT OF LONGWALL MINING AREA

LW901 has been removed from the Base Case layout since the predictions were made.

STUDY AREA

TOWER

APPIN

AREA 8

AREA 3

AREA 2

NORTH CLIFF

DOUGLAS PARK WEIR

BROUGHTONS PASS WEIR

SCA WEIR

BRENNANS CREEK DAM

CATARACT DAM

MARHNYES HOLE

JUTTS CROSSING

JORDANS PASS

CATARACT TUNNEL

NEPEAN TUNNEL

BELLAMBI MINES

LW 901, LW 902, LW 827, LW 826, LW 825, LW 824b, LW 823b, LW 822b, LW 306, LW 305, LW 304, LW 303, LW 312, LW 311, LW 310, LW 309, LW 313, LW 308, LW 307, LW 30, LW 232, LW 233, LW 234, LW 235, LW 236, LW 237, LW 231, LW10, LW9, LW2b, LW3b, LW1, LW2a, LW3a, LW4a

287m, 304m, 211m, 61m, 176m, 176m, 1186m, 1205m, 1142m, 1268m, 1086m, 1034m, 1050m, 323m, 372m, 403m, 397m, 380m, 345m, 1106m, 371m, 181m, 454m, 393m, 229m, 322m, 321m, 209m, 425m, 210m, 441m

LEGEND
- ECONOMIC COAL
- STERILISED COAL
- WATERCOURSES
- 3rd ORDER STREAMS
- 4th ORDER STREAMS
- 5th ORDER STREAMS
- 6th ORDER STREAMS
- 7th ORDER STREAMS

Grid to MGA co-ordinates

6 215 000, 6 210 000, 6 205 000, 290 000, 295 000, 300 000

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# ILLAWARRA COAL

## LONGWALL OFFSETS AT NORTH CLIFF

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 22-July-2009 | 1:40000 | MSEC404-1204 | B |

**OPTION C1**
LONGWALL SETBACKS TO ACHIEVE 200mm TARGET CLOSURE AT STREAMS 3RD ORDER AND ABOVE

LEGEND
- BASECASE LONGWALL LAYOUT
- EXTENT OF LONGWALL MINING AREA

LEGEND
- ECONOMIC COAL
- STERILISED COAL
- WATERCOURSES
- 3rd ORDER STREAMS
- 4th ORDER STREAMS
- 5th ORDER STREAMS
- 6th ORDER STREAMS
- 7th ORDER STREAMS

300 000
305 000
6 220 000
6 215 000
6 210 000

WEST CLIFF
NORTH CLIFF
APPIN
METROPOLITAN MINES
STUDY AREA
STUDY AREA
AREA 2

LW36 LW35 LW34 LW33 LW32 LW31 LW30 LW29 LW28 LW27
236m 412m 672m 269m 525m 969m 644m

LW26 LW25 LW24 LW23 LW22 LW21 LW20 LW19 LW18 LW17 LW16 LW15 LW14 LW13 LW12 LW11 LW10 LW9
1049m 1492m 1249m 1519m 1422m 1501m 801m 194m 986m 560m 1712m 821m 881m 520m

LW2b LW3b LW4b LW5b LW1 LW2a LW3a LW4a LW5a LW6 LW7 LW8

LW 231 LW 232 LW 233 LW 234 LW 235 LW 236 LW 237

N

Grid to MGA co-ordinates