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# Centennial Mandalong Pty Ltd

# SURFACE WATER ASSESSMENT

Mandalong Southern Extension Project

**August 2013**

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## Mandalong Southern Extension Project

**August 2013**

Prepared by
Umwelt (Australia) Pty Limited

on behalf of
Centennial Mandalong Pty Ltd

| | |
|---|---|
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| Report No: | **2943/R01/FINAL** |
| Date: | **August 2013** |

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# Executive Summary

The Mandalong Southern Extension Project is located to the south of the existing Mandalong Mine, operated by Centennial Mandalong Pty Ltd (Centennial Mandalong), west of the Sydney to Newcastle F3 Freeway.

This project is known as the Mandalong Southern Extension Project (the Project). As part of the Project, Centennial Mandalong is proposing to expand the existing Mandalong Mine underground mining operations.

This Surface Water Assessment has been prepared by Umwelt (Australia) Pty Limited (Umwelt) in support of an Environmental Impact Statement (EIS) required under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

This Surface Water Assessment considers the following aspects of the Project:

- extraction of up to 6 million tonnes per annum (Mtpa) of run of mine (ROM) coal from the West Wallarah and Wallarah-Great Northern Seams through the mining of 40 new longwall panels, ranging in lengths from approximately 1.0 kilometre to 3.7 kilometres, typically orientated in an approximately east-west direction, using a combination of continuous miner and longwall mining methods; and

- construction of an access road approximately 1.8 kilometres in length extending from Mandalong Road to the proposed new surface infrastructure area.

The Project has the potential to impact on the following:

- catchment area boundaries;

- watercourse stability and associated water quality;

- remnant ponding;

- flood regimes; and

- water quantity for downstream water users and the environment.

The assessment undertaken by Umwelt identified that no significant adverse impacts on catchment areas and watercourse alignments are likely within the Southern Extension Area as a result of the predicted subsidence.

In addition, the assessment of the predicted subsidence identified no significant adverse impacts on the predicted remnant ponding within the Project Area. Minor changes to the remnant ponding were identified primarily within existing watercourses (i.e. not within pasture areas), which will require regular inspection as part of an ongoing monitoring program. If necessary, mitigation works may be implemented to return the remnant ponding to the current (i.e. pre-mining) condition.

It is considered that the potential impacts of the predicted subsidence on the stability of watercourses within the Southern Extension Area are typically minor. Where the modelling indicated the potential decrease in bed and bank stability (i.e. a potential increase in scouring watercourse bed and banks), a program of monitoring is proposed, with the potential for in channel mitigation works if necessary.

An analysis of flood regimes within the Southern Extension Area included detailed hydrodynamic modelling of Schedule 2 and higher watercourses, for a range of design storm events up to and including the 100 year Average Recurrence Interval (ARI) design event.

The analysis indicated that increases to the maximum modelled flood depth for the 100 year ARI design storm event as a consequence of the predicted subsidence of up to 0.4 metres within the main channels of the watercourses modelled are possible. These increases were generally limited to the immediate vicinity of the proposed longwall panels, as well as upstream of the proposed access road where flood flows are constricted by the conceptual crossing over Morans Creek. The modelled impacts on flood depths were typically limited to approximately 100 metres downstream of the conceptual road crossing over Morans Creek. It is understood that the final design of the Morans Creek crossing will include drainage structures sufficient to minimise the local impacts on flooding.

The analysis indicated that the predicted subsidence had no significant impact on the duration of flooding at the boundary of the Southern Extension Area, with minor flood events remaining in channel, and no discernible increase to the time out of bank for larger flood events. This indicates that the potential for flooding impacts on the agricultural value of the surrounding properties is negligible.

The analysis indicated that the predicted subsidence is unlikely to have a significant impact on the habitability or access to dwellings within the Southern Extension Area, with all of the identified dwellings within the Southern Extension Area outside of modelled flood extent for the 100 year ARI design storm event, and no identified dwellings that are currently outside of the modelled flood extent for the 100 year ARI design storm event becoming inundated as a result of the predicted subsidence.

To ensure that the Project has a minimal impact on the surface water environment of the surrounding area, a monitoring program is proposed that includes ongoing monitoring of erosion and sediment controls, subsidence impacts on second order and higher watercourses, watercourse stability, water quality and visual flow monitoring.

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# APPENDICES

# 1.0 Introduction

Mandalong Mine is an existing underground coal mine operation located in the Lake Macquarie Local Government Area (LGA) approximately 130 kilometres north of Sydney near Morisset in New South Wales (NSW) (refer to **Figure 1.1**). The mine was purchased from Powercoal in August 2002 by Centennial Mandalong Pty Ltd (Centennial Mandalong), which is a wholly owned subsidiary of Centennial Coal Company (Centennial).

Underground longwall mining operations commenced at Mandalong Mine in January 2005 under the provisions of Development Consent DA 97/800. Since this time, Centennial Mandalong has extracted up to 6 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal from the West Wallarah Seam utilising a combination of longwall and continuous mining methods. Mandalong Mine represents a major component to the success of Centennial, producing approximately 30 per cent of the company's annual ROM coal.

Centennial Mandalong expects to have extracted the final approved longwall panel in the West Wallarah Seam at Mandalong Mine in 2018. As part of the life of mine (LOM) planning process at Mandalong Mine, Centennial Mandalong obtained Exploration Licence (EL) 6317 in 2005 over an area referred to as the Mandalong Southern Extension Area. This exploration area comprises approximately 4700 hectares of land immediately south of the existing Mandalong Mine. The exploration drilling program, which commenced in 2010, identified additional economic coal reserves within the West Wallarah Seam and the Wallarah-Great Northern (WGN) Seam that are high in heat energy and low in ash content, making the coal ideal for electricity generation.

The Mandalong Southern Extension Project (the Project) proposes to extend Mandalong Mine's existing underground mining operations into the area covered by EL 6317 in order to access, develop and extract the additional coal reserves identified within the West Wallarah Seam and WGN Seam at a rate of up to 6 Mtpa of ROM coal. The Project also proposes to continue the utilisation of existing surface infrastructure integral to the mining operation in terms of coal delivery, handling and transport (refer to **Figure 1.2**).

This Surface Water Assessment Report has been prepared by Umwelt (Australia) Pty Limited (Umwelt) to support an Environmental Impact Statement (EIS) for the Project required under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

This assessment has been undertaken in consideration of the Department of Planning and Infrastructure (DP&I) Director-General's Environmental Assessment Requirements (DGRs) for the Project (refer to **Section 2.0**).

## 1.1 The Proposed Project

The key aspects of the Project relevant to this surface water assessment are as follows:

- the Mandalong Southern Extension Project (referred to hereafter as the Project) proposes to extend Mandalong Mine's existing underground operations into the area covered by EL 6317 (hereafter referred to as the Southern Extension Area) which lies to the south of the existing mining operation, in order to access, develop and extract additional coal reserves identified within the West Wallarah Seam and WGN Seam at a rate of up to 6 Mtpa of ROM coal;

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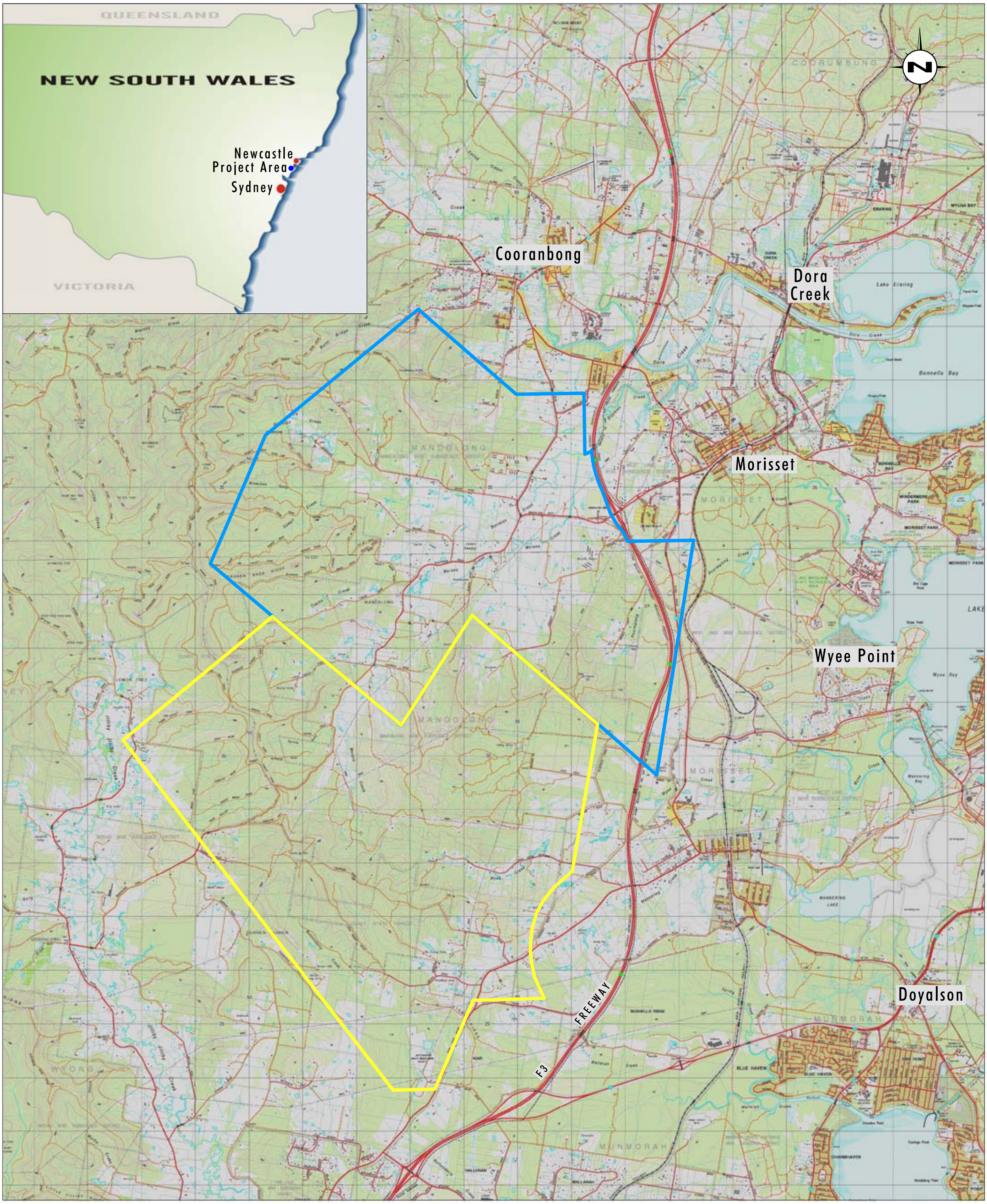


Source: LPMA (2006), Centennial Mandalong (2012)

0 1.0 2.5 5.0km
1:100 000

## Legend

Southern Extension Area
Existing Centennial Mandalong Operations

FIGURE 1.1

**Locality Map**

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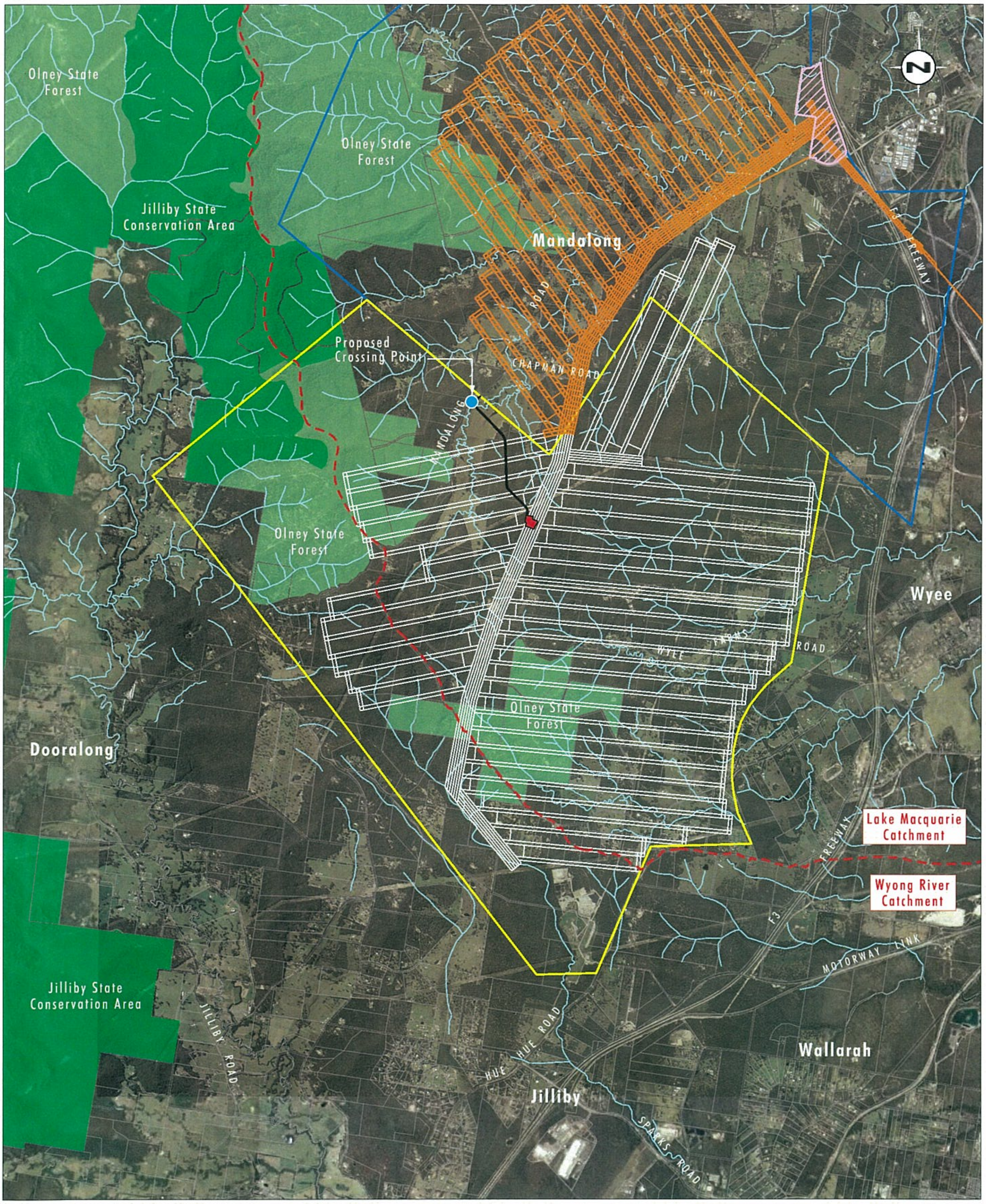


Source: Centennial Mandalong (2012) - Aerial Photograph, LPI - Cadastre and Hydrolines

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**Legend**

- Southern Extension Area
- Existing Centennial Mandalong Lease Area
- Existing Mandalong Mine Access Site Surface Infrastructure
- Proposed Surface Infrastructure
- Current and Proposed Northern Longwalls
- Proposed Southern Longwalls
- Proposed Access Road
- Drainage Line
- State Forest
- Conservation Area
- Catchment Boundary

FIGURE 1.2

**Current and Proposed Centennial Operations**

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- extract up to 6 Mtpa of ROM coal from the West Wallarah and WGN Seams through the mining of 40 new longwall panels, ranging in lengths from approximately 1.0 kilometre to 3.7 kilometres, typically orientated in an approximately east-west direction, using a combination of continuous miner and longwall mining methods; and

- construction of an access road approximately 1.8 kilometres in length extending from Mandalong Road to the proposed new Mandalong South Surface Site.

The Southern Extension Area covers an area of approximately 4500 hectares, with the land being privately owned rural land as well as Olney State Forest, Jilliby State Conservation Area and Crown Land (Commonwealth) (refer to **Figure 1.2**).

The proposed longwall panels are located within the catchment area of Lake Macquarie and the Wyong River (refer to **Figure 1.2**). The longwall panels will be accessed from headings which continue from the existing Mandalong Mine to the north of the Southern Extension Area.

## 1.2 Potential Surface Water Impacts

The aim of this surface water assessment is to define the potential impacts on flooding and drainage as a result of the Project. Key features of the Project which may potentially impact on surface waters are assessed in this report and include:

- subsidence resulting from underground mining; and

- associated access road and crossing of Morans Creek.

The potential subsidence impacts that will impact on surface water resources is primarily vertical subsidence displacement as no connective cracking is predicted with the Project (refer to Section 12.3 of the Subsidence Assessment Report; Ditton Geotechnical Services, 2012).

The surface water impact assessment has been undertaken for the Mandalong Southern Extension Area (**Figure 1.1**).

## 1.3 Structure of the Report

This surface water assessment report has been prepared to support the EIS for the Project and identifies and assesses the potential impacts on surface water arising from the Project. The report is structured as follows:

- **Section 2.0** outlines the surface water planning context for the Project;

- **Section 3.0** of this report provides information on the existing surface water resources within the Southern Extension Area;

- **Section 4.0** presents the potential surface water impacts of the Project and proposed surface water management strategies; and

- **Section 5.0** provides a discussion of the monitoring, licensing and reporting requirements for the Project.

# 2.0 Planning Context

This surface water assessment has been prepared to support the EIS being prepared as part of a development application under Part 4 of the EP&A Act. The relevant planning instruments and guidelines for the surface water assessment are summarised below.

## 2.1 Planning Instruments and Guidelines

The Project is subject to the relevant requirements of the following water planning policies/plans and legislation regarding surface water impacts associated with the Project:

- *Water Management Act 2000*;
- *Water Act 1912*;
- *Protection of the Environment Operations Act 1997* (POEO Act);
- State Water Management Outcomes Plan (SWMOP) (Department of Natural Resources (DNR), undated);
- Hunter-Central Rivers Catchment Action Plan (CAP);
- Guidelines for Management of Stream/Aquifer Systems in Coal Mining Developments – Hunter Region (Department of Infrastructure Planning and Natural Resources (DIPNR), 2005);
- River Hydrology and Energy Relationships - Design Notes for the Mining Industry (DWE 2007);
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Australia and New Zealand Environment and Conservation Council (ANZECC) Guidelines 2000);
- Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009;
- Water Sharing Plan for the Central Coast Unregulated Water Sources 2009; and
- Water Sharing Plan for the Jilliby Jilliby Creek Water Source 2003.

The relevant requirements of these plans and regulations regarding this surface water assessment are addressed in this report.

## 2.2 Director Generals Environmental Assessment Requirements

In addition to the aforementioned planning provisions, guidelines and legislation, the Director-General of the DP&I has provided DGRs for the Project which identify key issues for consideration in the EIS. **Table 2.1** summarises those DGRs which relate to surface water and are subsequently addressed in this report. Only underlined sections of the DGRs presented below are assessed as part of this surface water assessment, with the other DGRs assessed as part of separate studies also supporting the EIS.

## Table 2.1 - DGRs for Surface Water Resources

| DGRs | Section of Report/Comments |
|---|---|
| • detailed assessment of potential impacts on the quality and quantity of existing surface and ground water resources, including:<br>▪ detailed modelling or potential groundwater impacts; and<br>▪ impacts on riparian, ecological, geo-morphological and hydrological values of watercourses, including environmental flows. | Discussion and analysis of historical surface water quality and quantity is included in **Section 3.0**.<br>Analysis of potential impacts on water quality and quantity of surface water resources is included in **Section 4.0**.<br>Groundwater modelling and impacts on riparian, ecological, geo-morphological values addressed as part of a separate study. |
| • a detailed assessment of potential impacts of the project on:<br>▪ the quantity and quality or regional water supplies, and in particular the supply of water to the Gosford-Wyong Water Supply Scheme;<br>▪ regional water supply infrastructure; and<br>▪ impacts on affected licensed water users and basic landholder rights. | Analysis of existing water quality and quantity included in **Sections 3.2** and **3.3**.<br>Analysis of potential impacts on water quality and quantity included in **Sections 4.1** and **4.2**.<br>Assessment of regional water supply infrastructure is addressed as part of a separate study.<br>Assessment of potential impacts on landholder rights included in **Section 4.6**. |
| • a detailed site water balance, including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply infrastructure and water storage structures; | Addressed as part of a separate study. |
| • an assessment of proposed water discharge quantities quality/ies against receiving water quality and, if relevant, flow objectives. | Addressed as part of a separate study. |
| • identification of any licensing requirements or other approvals under the Water Act 1912 and/or Water Management Act 2000. | Discussed in **Section 5.0**. |
| • demonstration that water for the construction and operation of the development can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant Water Sharing Plan (WSP). | Addressed as part of a separate study. |
| • a description of the measures proposed to ensure the development can operate in accordance with the requirements of any relevant WSP or water source embargo. | Addressed as part of a separate study. |

## Table 2.1 - DGRs for Surface Water Resources (cont.)

| DGRs | Section of Report/Comments |
| --- | --- |
| • <u>a detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts.</u> | Addressed as part of a separate study. |
| • <u>a detailed flood impact assessment, taking into consideration:</u><br>▪ predicted subsidence effects and identification of impacts on local and regional flood regimes; and<br>▪ resultant impacts on agricultural land use, transport, services, habitability, public safety and other environmental consequences, including any measures proposed to mitigate potential flood impacts. | Existing flood conditions assessment in **Section 3.4**.<br>Assessment of potential impacts of subsidence on water quality, quantity, stability and flooding discussed in **Sections 4.1** to **4.4**. |

# 3.0 Existing Surface Water Environment

The following is a summary of the existing surface water environment within the Southern Extension Area. The catchment areas and watercourses, existing water quality and quantity estimations, and modelled existing flood regimes are discussed below.

## 3.1 Catchment Areas and Watercourses

The Southern Extension Area lies predominantly within the catchment of Lake Macquarie, with the southern portion of the Southern Extension Area within the Wyong River catchment (refer to **Figure 3.1**).

The Southern Extension Area intersects five sub catchment areas: Morans Creek, Wyee Creek and Mannering Creek flowing to Lake Macquarie, Buttonderry Creek and Jilliby Creek flowing to the Wyong River (refer to **Figure 3.1** and **Table 3.1**). For Morans Creek, Wyee Creek and Mannering Creek, hydraulic modelling was undertaken for the sections of each watercourse upstream of the Sydney to Newcastle F3 Freeway (refer to **Figure 3.1**) as this location provides a suitable hydraulic control point downstream of the Project Area, whilst the analysis of each watercourse was limited to the Southern Extension Area and the immediate surrounds. For Buttonderry Creek and Jilliby Creek, the analysis was limited to the section of each watercourse within the area of the predicted subsidence and extended downstream beyond the predicted subsidence extent.

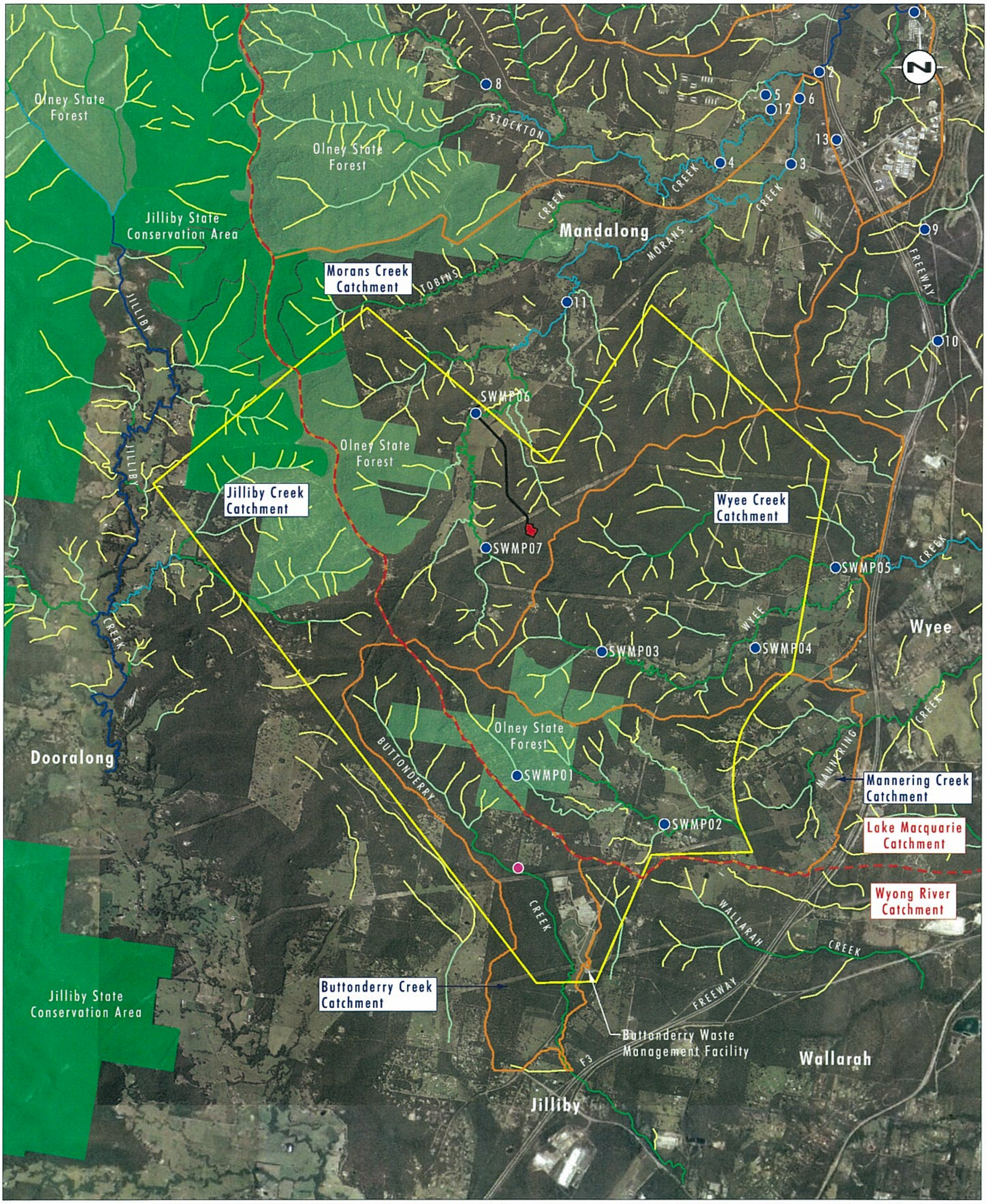
In characterising the watercourses in the area, consideration is given to the Strahler ordering system presented in the DIPNR Guidelines (now the NSW Office of Water (NOW)) (DIPNR 2005). Watercourse ordering is a hierarchical numbering system based on the degree of branching within a waterway and provides an indication of the complexity of a creek system.

The Strahler ordering system begins at the origin of a waterway, the initial watercourse being a first order watercourse. The watercourse remains first order until joining another watercourse. The confluence of two first order waterways results in a second order watercourse and the watercourse remains second order until joining a second order or higher order watercourse. After the confluence of two second order watercourses, the subsequent downstream waterway is designated a third order watercourse and so on moving downstream. Where lower order waterways join higher order waterways, the higher order numbering is unaffected, i.e. the watercourse resulting from the confluence of a first or second order watercourse with a third order watercourse will remain a third order watercourse.

The DIPNR Guidelines (DIPNR 2005) classify waterway orders into three schedules linked to their ordering. The schedules are as follows:

- Schedule 1 – usually intermittent and consisting of first or second order waterways;
- Schedule 2 – third and higher order waterways that drain into primary catchment rivers; and
- Schedule 3 – these watercourses are major rivers, including their primary tributaries and associated alluvial groundwater zones.

Key characteristics of each of the catchment areas within the Southern Extension Area are summarised within **Table 3.1**.




**Source:** Centennial Mandalong (2012) - Aerial Photograph, LPI - Hydrolines

## Legend

- Southern Extension Area
- Sub-catchment Boundary
- Proposed Surface Infrastructure
- Proposed Access Road
- Water Quality Monitoring Location
- State Forest
- Conservation Area
- Catchment Boundary
- Approximate Location of Observed Ponding

Stream Order:

- 1st Order
- 2nd Order
- 3rd Order
- 4th Order
- 5th Order

FIGURE 3.1

**Watercourses and Catchments**

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## Table 3.1 - Summary of Sub Catchment Areas

| Catchment | Sub Catchment | Watercourse ID | Schedule (Order)[1] | Catchment (ha) | |
|---|---|---|---|---|---|
| | | | | Total | Southern Extension Area |
| Lake Macquarie | Morans Creek | 6 | 2 (3rd) | 2,930 | 1,274 |
| | Wyee Creek | 1, 2 & 3 | 2 (3rd) | 1,522 [2] | 1,216 |
| | Mannering Creek | 4 | 2 (3rd) | 990 [2] | 639 |
| Wyong River | Buttonderry Creek | 5 | 2 (3rd) | 634 [2] | 505 |
| | Jilliby Creek | -[3] | 2 (3rd) | ~10,000 | 661 |

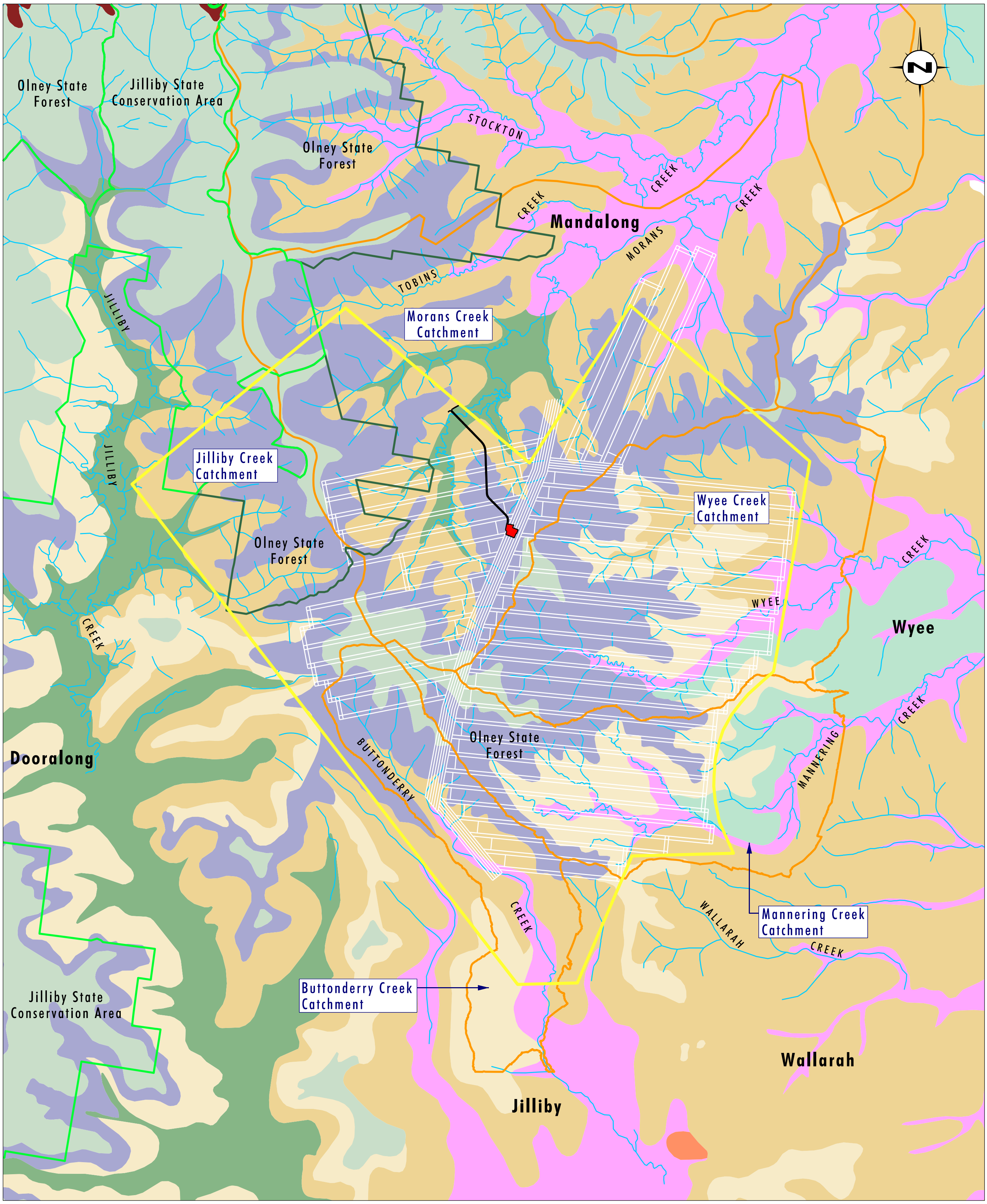
Notes: 1. DIPNR Guidelines (DIPNR 2005).
2. Total catchment area upstream of the Sydney to Newcastle F3 Freeway.
3. Jilliby Creek main channel not located within Southern Extension Area.

The Southern Extension Area typically includes six soil landscapes (Department of Land and Water Conservation (DLWC) 1993), the extents of which are included in **Figure 3.2** with the typical soil landscape properties summarised in **Table 3.2**. The upper slopes of the Southern Extension Area are predominantly Mandalong and Woodburys Bridge soil landscapes, with the footslopes predominantly Gorokan soil landscapes. The floodplain areas are typically Yarramalong, Wyong and Doyalson soil landscapes. All of the soils landscapes within the Southern Extension Area typically exhibit between moderate and very high erodibility, with a corresponding erosion hazard between slight to moderate and extreme (refer to **Table 3.2**). Erodibility describes the susceptibility of soil to mobilise as a result of rainfall and runoff, erosion hazard describes the likelihood for erosion to occur within a given area.

## Table 3.2 - Soil Landscapes in the Southern Extension Area

| Soil Landscape | Typical Terrain | Dominant Topsoil | Erodibility | Erosion Hazard [1] |
|---|---|---|---|---|
| Watagan | Hill tops | Friable dark brown loam (WN1)<br>Hardsetting yellowish brown sandy clay loam (WN2) | Very high | Extreme |
| Mandalong | Upper slopes | Hardsetting stony brown sandy clay loam (ML1) | Moderate to High | Very High |
| Woodburys Bridge | | Dark brown pedal fine sandy loam (WO1) | Moderate | Moderate |
| Gorokan | Footslopes | Loose dark brown loamy sand (GK1) | High | Moderate to High |
| Yarramalong | Floodplains | Loose brown sands (YA1) | Moderate to High | Slight to High |
| | | Brown pedal loam (YA2) | Moderate | Slight to High |
| Wyong | | Brownish black pedal loam (WY1) | Moderate | Slight to Moderate |
| Doyalson | | Brown loose loamy sand (DO1) | Moderate to High | Moderate |

Note: Erosion Hazard category for grazing conditions.
Source: Soil Landscapes for Gosford - Lake Macquarie, DLWC (1993).




Source: Centennial Mandalong (2012), DLWC (1993), LPI - Hydrolines

0 1 2 3km

1:70 000

## Legend

- Southern Extension Area
- Sub-catchment Boundary
- Proposed Surface Infrastructure
- Proposed Longwalls
- Proposed Access Road
- Drainage Line
- State Forest
- Conservation Area

Soil Landscapes:

- Disturbed Terrain
- Doyalson Soil Landscape
- Gorokan Soil Landscape
- Mandalong Landscape
- Sydney Town Landscape
- Watagan Landscape
- Woodburys Landscape
- Wyong Landscape
- Yarramalong Landscape

FIGURE 3.2

**Soil Landscapes**

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### 3.1.1 Morans Creek

Morans Creek (refer to **Figure 3.3**; Watercourse 6), located in the Lake Macquarie catchment, flows in an approximately north-easterly direction through the Southern Extension Area, before flowing into Stockton Creek approximately 4 kilometres north of the Southern Extension Area. Stockton Creek flows into Dora Creek west of Morisset, which flows into Lake Macquarie.

Approximately 1274 hectares (43 per cent of the total catchment area) of Morans Creek lies within the Southern Extension Area (refer to **Table 3.1**).

Catchment elevations range from 260 metres Australian Height Datum (mAHD) within the southern sections of the catchment to 30 mAHD at the northern end of the Southern Extension Area. Current (i.e. pre-mining) ponding areas, which occur after prolonged rainfall and/or flooding, were observed during June 2011, primarily within second order tributaries of Morans Creek (refer to **Plate 3.1**).

In contrast to the sections of Morans Creek in the vicinity of the approved Mandalong Mine to the north of the Southern Extension Area, the portion of the Morans Creek catchment area within the Southern Extension Area is predominantly well forested, with sandy soils and some rocks ranging in size up to approximately 200 millimetres in diameter (refer to **Plate 3.2**).

The soil landscapes within the Morans Creek catchment include Watagan and Mandalong soil landscapes within upper slope areas, Gorokan soil landscapes within the footslope areas and Yarramalong and Wyong soil landscapes within the floodplain area (refer to **Figure 3.2**).

Previous flood modelling of Morans Creek was undertaken by Umwelt as part of the Mandalong Valley Flood Study (the Flood Study) (Hughes Truman 2004). The Flood Study and associated modelling was approved by the then DIPNR (now referred to as NOW).

### 3.1.2 Wyee Creek

Wyee Creek (refer to **Figure 3.3**; Watercourses 1 to 3) generally flows in an easterly direction to the north of Wyee before flowing into Mannering Bay at the southern end of Lake Macquarie (refer to **Figure 3.1**). Three 3rd order branches of Wyee Creek lie within the Southern Extension Area (identified as Watercourse 1, 2 and 3) (refer to **Figure 3.3**), with the southernmost branch (Watercourse 3) having the clearest defined bed and banks of the three branches (despite the same Strahler stream order) (refer to **Table 3.1**). The catchment area of Wyee Creek within the Southern Extension Area is approximately 1520 hectares (80 per cent of the catchment area upstream of the Sydney to Newcastle F3 Freeway lies within the Southern Extension Area) (refer to **Figure 3.1** and **Table 3.1**).

Wyee Creek catchment area has a maximum elevation of approximately 200 mAHD in the western portion of the catchment. The catchment slopes generally to the east, falling to a minimum elevation of approximately 20 mAHD at the Sydney to Newcastle F3 Freeway, east of the Southern Extension Area.

The catchment areas of Wyee Creek range from well forested with medium to large trees, thin under scrub and minimal groundcover within the upper catchment areas, to areas largely cleared for use as livestock pasture within the lower catchment areas. Approximately 72 hectares of Olney State Forest lies within the catchment area of Wyee Creek (refer to **Figure 3.1**).

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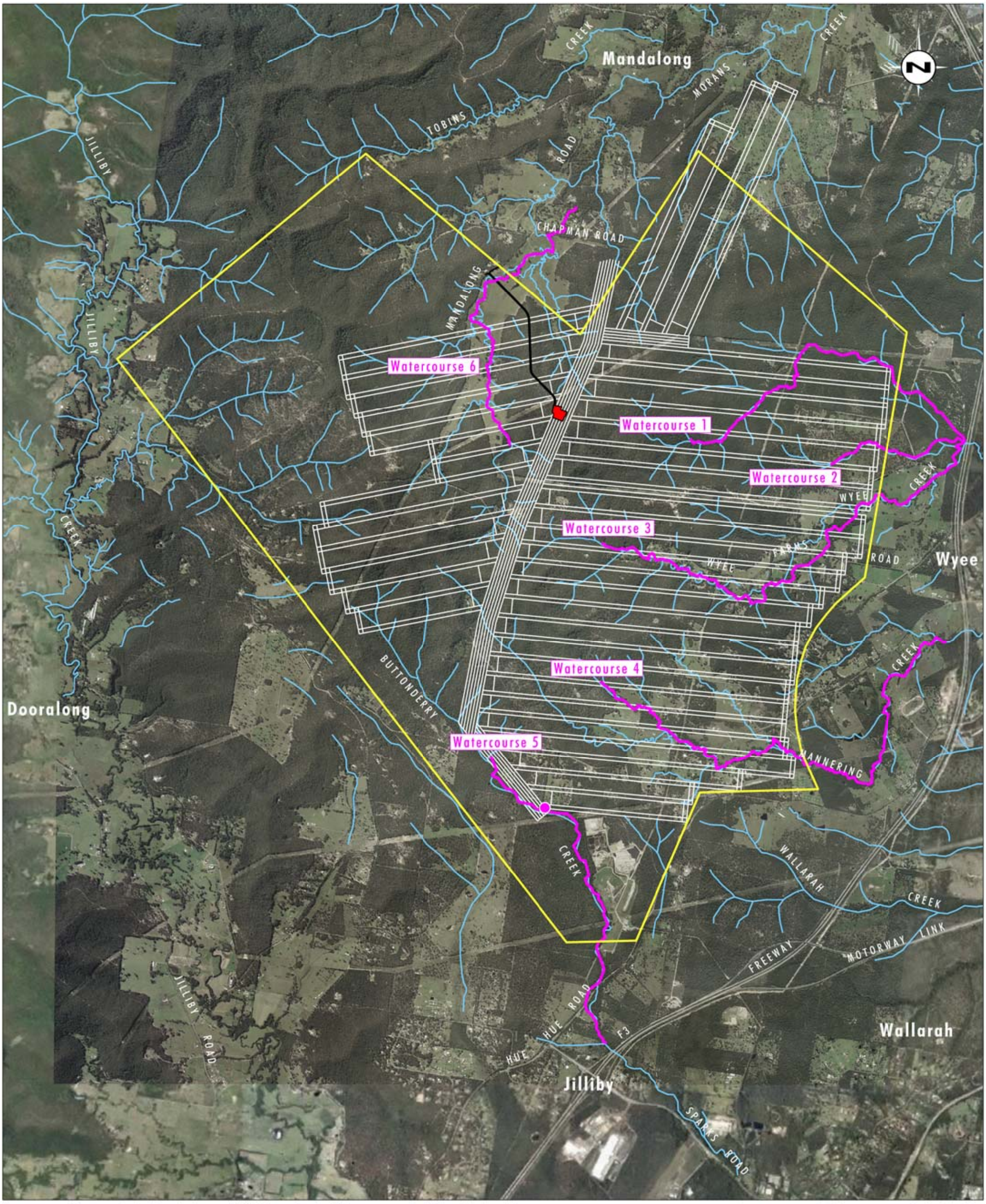


Source: Centennial Mandalong (2012) - Aerial Photograph, LPI - Hydrolines

## Legend

- Southern Extension Area
- Proposed Surface Infrastructure
- Proposed Longwalls
- Proposed Access Road
- Drainage Line
- Water Course
- Approximate Location of Observed Existing Ponding

FIGURE 3.3

**Watercourse Extents and Locations**

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PLATE 3.1
Existing Ponding Area within Morans Creek System
(June 2011)

PLATE 3.2
Typical Section of the Morans Creek Catchment Area
(June 2011)

Within the upper, forested catchment area, the bed of Wyee Creek typically consists of well graded sands and gravels overlaying clays with occasional rock bars and minimal groundcover vegetation (refer to **Plate 3.3**). Within the upper catchment areas, some sections of Wyee Creek have been subject to scouring as a result of the construction of road culverts, bridges and other structures which concentrate flows and increase local flow velocities. An example of a scoured section of Wyee Creek is illustrated in **Plate 3.4**, which shows Wyee Creek looking downstream from the Wyee Farms Road culverts. Bank stabilisation works installed to reduce further scouring are also evident.

Within the lower catchment areas, Wyee Creek is typically grassed with a broad U-shaped cross section (refer to **Plate 3.5**). As in the upper catchment areas, construction of road crossings, including culverts and bridges, have resulted in the scouring of the Wyee Creek bed and banks at some locations into a steep sided trapezoidal channel (refer to **Plate 3.6**).

The soil landscapes within the Wyee Creek catchment include Watagan and Mandalong soil landscapes within upper slope areas, Gorokan soil landscapes within the footslope areas and Yarramalong and Wyong soil landscapes within the floodplain area (refer to **Figure 3.2**).

### 3.1.3 Mannering Creek

Mannering Creek (refer to **Figure 3.3**; Watercourse 4) generally flows in an easterly direction (refer to **Figure 3.1**) before being intercepted upstream of Mannering Dam east of Wyee and diverted into Wyee Creek to the north by way of a diversion drain downstream of the Southern Extension Area. The diversion is intended to prevent the flow of clean water into the Mannering Lake, which is currently used as an ash dam for Vales Point Power Station.

The catchment area of Mannering Creek within the Southern Extension Area is approximately 639 hectares (65 per cent of the total catchment area) (refer to **Table 3.1**).

The catchment of Mannering Creek ranges in elevation from approximately 260 mAHD in the west to approximately 30 mAHD in the east of the Southern Extension Area.

The catchment of Mannering Creek ranges from well forested with medium to large trees, thin under scrub and minimal groundcover to areas largely cleared for use as livestock pasture. The forested areas are generally located within the upper catchment areas, including a portion (approximately 14 per cent of the catchment area within the Southern Extension Area and surrounds) of the Olney State Forest (refer to **Figure 3.1**).

Mannering Creek typically consists of well graded sands and gravels overlaying clays with occasional rock bars and minimal vegetation (refer to **Plate 3.7**). Some sections of the creek bed exhibit some indication of recent scouring, including undercutting of the outer banks (refer to **Plate 3.8**). Road crossings, including culverts and bridges, have also resulted in the scouring of Mannering Creek bed and banks (refer to **Plate 3.9**).

The soil landscapes within the Mannering Creek catchment include Watagan, Mandalong and Woodburys Bridge soil landscapes within upper slope areas, Gorokan soil landscapes within the footslope areas and Wyong and Doyalson soil landscapes within the floodplain area (refer to **Figure 3.2**).

PLATE 3.3
Typical Section of Wyee Creek, Upper Catchment Area
(June 2011)

PLATE 3.4
Bank Stabilisation Works within Wyee Creek, Looking Downstream from Wyee Farms Road
(June 2012)

PLATE 3.5
Typical Section of Wyee Creek, Lower Catchment Area
(June 2011)

PLATE 3.6
Scouring within Lower Catchment Area of Wyee Creek, Looking Downstream from Schofield Road
(June 2011)

PLATE 3.7
Typical Section of Mannering Creek
(June 2011)

PLATE 3.8
Evidence of Scouring within Mannering Creek
(June 2011)

PLATE 3.9
Scouring of Mannering Creek, Looking Downstream from Hue Hue Road
(June 2012)

PLATE 3.10
Typical Section of Buttonderry Creek
(June 2011)

### 3.1.4 Buttonderry Creek

Buttonderry Creek (refer to **Figure 3.3**; Watercourse 5) flows in a southerly direction to the west of the Buttonderry Waste Management Facility, and flows into the Wyong River approximately 6 kilometres south of the Southern Extension Area (refer to **Figure 3.1**).

Approximately 505 hectares (80 per cent of the total catchment area) of Buttonderry Creek lies within the Southern Extension Area (refer to **Table 3.1**).

The Buttonderry Creek catchment ranges in elevation from approximately 260 mAHD in the north to approximately 20 mAHD at the southern boundary of the Southern Extension Area, adjacent to the Buttonderry Waste Management Facility. Within the Southern Extension Area, the catchment is predominantly forested with a thick canopy of medium sized trees with minimal underbrush (refer to **Plate 3.10**).

Sections of Buttonderry Creek indicates some ongoing scouring, including bank erosion and deposition of sandy sediment within the creek bed (refer to **Plate 3.11**). There is also an existing ponded area (refer to **Plate 3.12**) within the main channel of Buttonderry Creek in the south of the Southern Extension Area (refer to **Figure 3.1**).

The soil landscapes within the Buttonderry Creek catchment include Watagan, Mandalong and Woodburys Bridge soil landscapes within upper slope areas, Gorokan soil landscapes within the footslope areas and Wyong soil landscapes within the floodplain area (refer to **Figure 3.2**).

### 3.1.5 Jilliby Creek

Jilliby Creek flows in a southerly direction west of the Southern Extension Area (refer to **Figure 3.1**). Whilst the main fifth order channel lies outside of the Southern Extension Area, three second order tributaries and a section of a third order tributary lie within the western portion of the Southern Extension Area (refer to **Figure 3.1**), with a catchment area within the Southern Extension Area of approximately 660 hectares.

The Jilliby Creek catchment ranges in elevation from approximately 200 mAHD in the south-west to approximately 30 mAHD at the Project Boundary to the west. Within the Southern Extension Area, the catchment is predominantly forested, including approximately 385 hectares of Olney State Forest. The lower slopes are typically pasture improved for animal grazing.

The upper slopes of the Jilliby Creek catchment include Watagan, Mandalong and Woodburys Creek soil landscapes, with the lower slopes including Gorokan and Yarramalong soil landscapes (refer to **Figure 3.2**).

## 3.2 Surface Water Quality

The environmental value of water within a watercourse is typically defined in terms of water quantity and water quality. In order to assess the existing background water quality within the Southern Extension Area, Centennial Mandalong has undertaken monthly water quality monitoring for a wide range of water quality parameters (refer to **Appendix 2** Table 2.1), including key indicator parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), turbidity, Total Suspended Solids (TSS), Total Nitrogen (TN), Total Phosphorous (TP), manganese (Mn), iron (Fe), aluminium (Al), and a range of total and dissolved metals. Water quality sampling is currently being undertaken at seven locations within the Southern Extension Area, with the first samples collected in June 2011. The locations of monitoring points are shown on **Figure 3.1** and described in **Table 3.3**.

PLATE 3.11
Bank Erosion and Deposition of Sediment within Buttonderry Creek
(June 2011)

PLATE 3.12
Existing Ponding Area within Buttonderry Creek
(June 2011)

**Table 3.3 - Surface Water Quality Monitoring Locations**

| ID | Location |
|---|---|
| SWMP01 | Mannering Creek within the Olney State Forest |
| SWMP02 | Mannering Creek at Hue Hue Road |
| SWMP03 | Wyee Creek at the end of Wyee Farms Road |
| SWMP04 | Wyee Creek at Wyee Farms Road Bridge |
| SWMP05 | Wyee Creek near junction of Schofield Road and Manhire Road |
| SWMP06 | Morans Creek adjacent to Mandalong Road near the northern Project Area boundary |
| SWMP07 | Upper catchment area of Morans Creek |

The ANZECC guidelines (ANZECC 2000) provide tools for the assessment and management of ambient water quality according to designated environmental values, providing a reference against which observed water quality parameters can be compared in order to determine the condition of watercourses in the Southern Extension Area.

The ANZECC guidelines provide default trigger values to characterise water quality in natural watercourses. The trigger values can be used to estimate the ecological integrity of the water resource. However, the ANZECC guidelines also indicate the preferred use of site specific trigger values, based on reference values, generally based on pre-development water qualities.

The ANZECC Guidelines provide default water quality trigger values that are applicable to catchments to location (by region), flow direction and elevation. The default trigger values are to be used where insufficient data is available to develop site specific trigger values. The watercourses within the Southern Extension Area are at an elevation below 150 mAHD and flow eastwards, so the relevant trigger values from the ANZECC guidelines are therefore those for lowland coastal flowing rivers in NSW. The default trigger values for freshwater ecosystems are summarised in **Table 3.4**. The ANZECC guidelines recommend a minimum of two years of continuous monthly data to establish site specific trigger values. The analysis in this assessment is based on 19 months of observed water quality data (June 2011 to December 2012) and as such is not sufficient to establish site specific trigger values. Water quality monitoring will continue to be undertaken during the approval process and until operations begin, enabling the potential establishment of baseline water quality at the site for a period in excess of two years and the establishment of site specific trigger values. For this surface water assessment the default ANZECC trigger values have been adopted (where available) as a basis of comparison for water quality within the Southern Extension Area. The use of ANZECC default triggers will be revised when a minimum of two years of monitoring results are available. ANZECC trigger values are not available for all water quality parameters currently monitored. The observed water quality monitoring results for the key parameters pH, EC, TDS, turbidity, TSS, TN, TP, Mn, Fe and Al are presented in **Graphs 3.1** to **3.10**. The graphs also include the relevant ANZECC guideline values (to enable comparison of the observed water quality ranges to the default trigger values, refer to **Table 3.4**). A summary table of all the observed water quality data including total and dissolved metals is included in **Appendix 2**.

## Table 3.4 - ANZECC Default Trigger Values

| Water Quality Parameter | Unit | Trigger Values |
|---|---|---|
| pH | - | 6.5 to 8.5 |
| EC | µS/cm | 125 to 2,200 |
| TDS | mg/L [1] | < 1,400 |
| Turbidity | NTU [2] | 6 to 50 |
| TSS | mg/L [3] | < 40 |
| TN | µg/L | <350 |
| TP | µg/L | <25 |
| Mn | µg/L [3] | < 10 |
| Fe | µg/L [3] | < 10 |
| Al | mg/L | <0.2 |

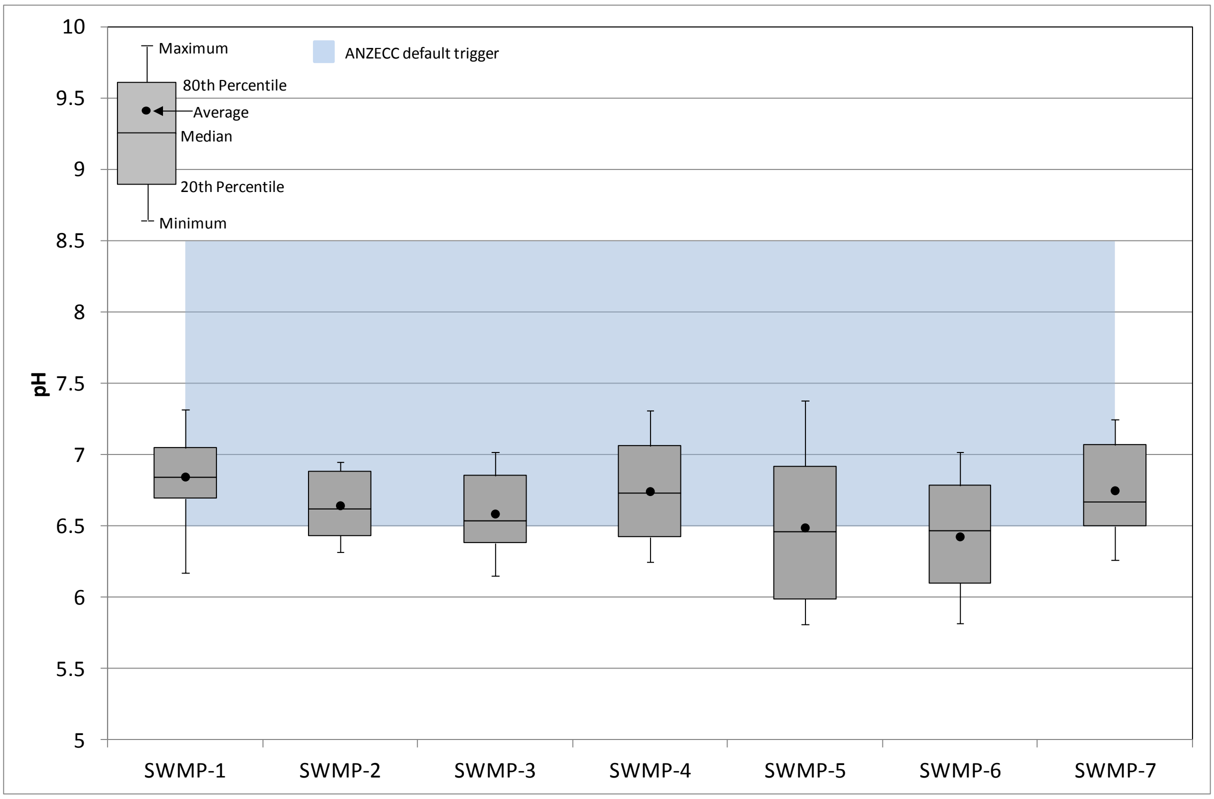
Notes: 1. TDS adapted from EC for Lowland Rivers, assuming TDS (mg/L) = 0.67 × EC (µS/cm).
2. The conversion from turbidity (NTU) to TSS (mg/L) is material specific, but typically 1 mg/L = 1 to 1.5 NTU.
3. Aquaculture default trigger values as no default trigger value provided for aquatic ecosystems.

Source: ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Lowland coastal flowing rivers in NSW).

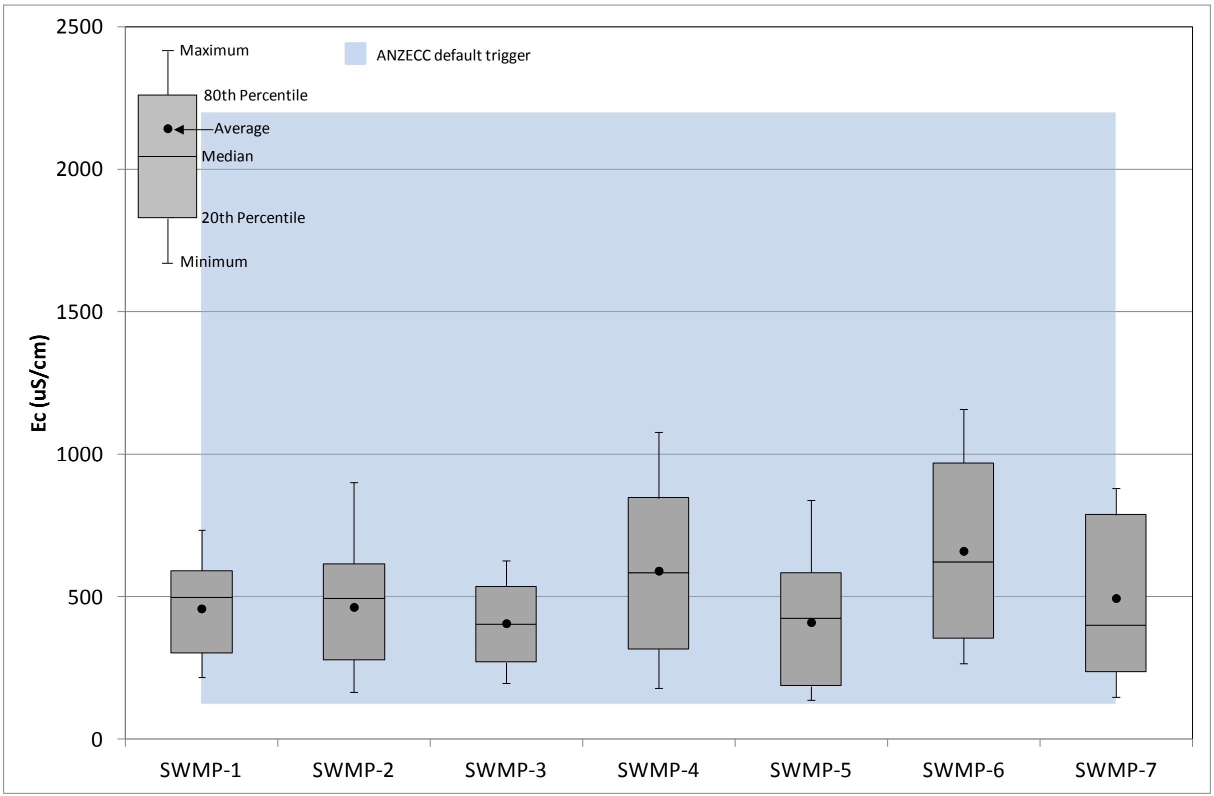
The graphs illustrate the following with regards to observed key water quality parameters:

- pH is typically neutral to slight acidic, with measured pH values typically at the lower end or below the ANZECC default trigger range (refer to **Graph 3.1**).
- EC is within the ANZECC default trigger range and consistently at the lower end of the range (refer to **Graph 3.2**).
- TDS is below the ANZECC default trigger value across all monitoring points (refer to **Graph 3.3**).
- Turbidity values frequently exceed the ANZECC default trigger value, with SWMP-6 experiencing very high turbidity values during August, September and October 2011 when observations steadily increased, peaking in October 2011 at 269 NTU (refer to **Graph 3.4**). Soils within Morans Creek catchment have a high erosivity (refer to **Section 3.1.4**) which may be a factor in these high values.
- TSS values tend to remain within the ANZECC default trigger value, with the exception of SWMP-5 and SWMP-6 (refer to **Graph 3.5**). At SWMP-5, a peak TSS of 98 mg/L was recorded in November 2012. As with turbidity, higher values of TSS were recorded at SWMP-6 for August, September and October 2011, peaking at 364 mg/L in October 2011.
- TN is on average above the ANZECC default trigger value for all monitoring locations (refer to **Graph 3.6**). The TN measurements at SWMP-4 includes a spike of 7.5 mg/L in September 2011.
- TP is on average above the ANZECC default trigger value for all monitoring locations except for SWMP-1 and SWMP-6 (refer to **Graph 3.7**).
- Both filtered and total Mn is below the ANZECC default trigger value across all monitoring locations (refer to **Graph 3.8**).

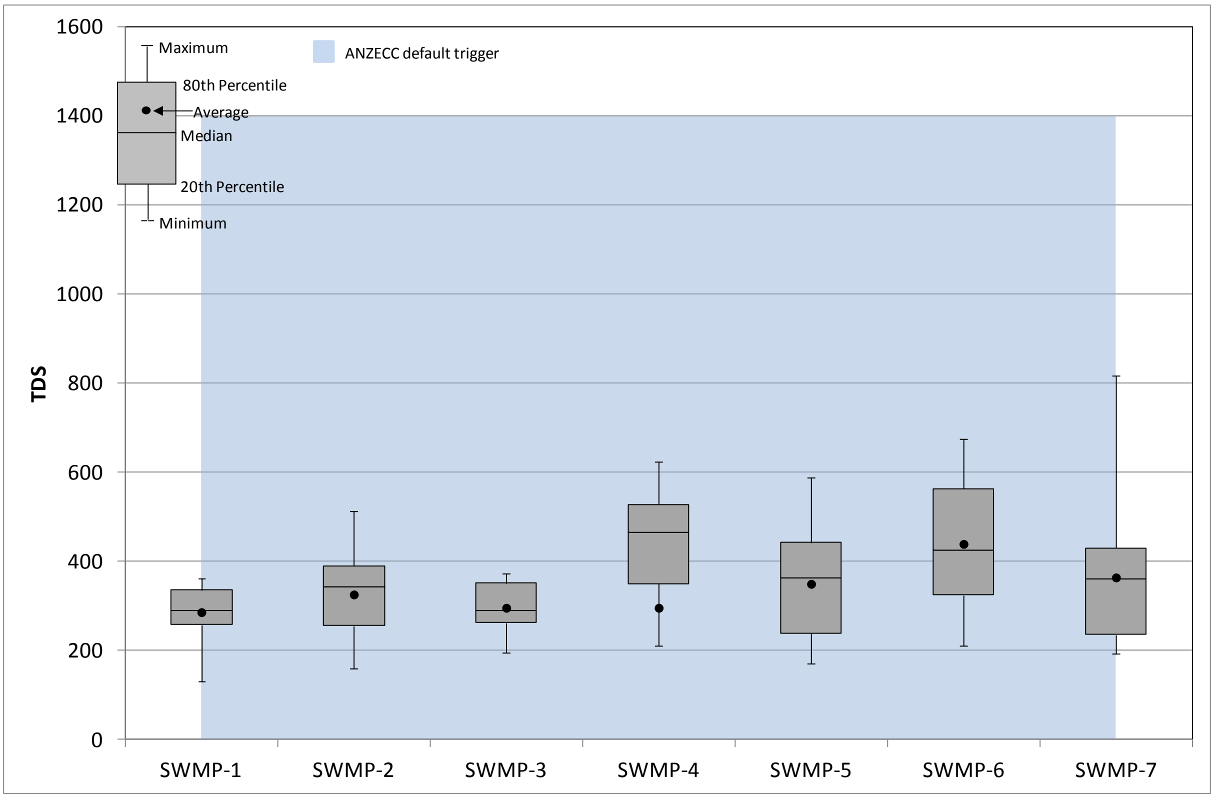
- Filtered Fe is below the ANZECC default trigger value across all monitoring locations (refer to **Graph 3.9**) whilst total FE for SWMP-4 peaks at 13.6 μg/L in October 2012, SWMP-5 peaks at 11.8 μg/L in May 2012 and SWMP-7 peaks at 15.2 μg/L in August 2012.
- Al is on average above the ANZECC default trigger value for all monitoring locations (refer to **Graph 3.10**).



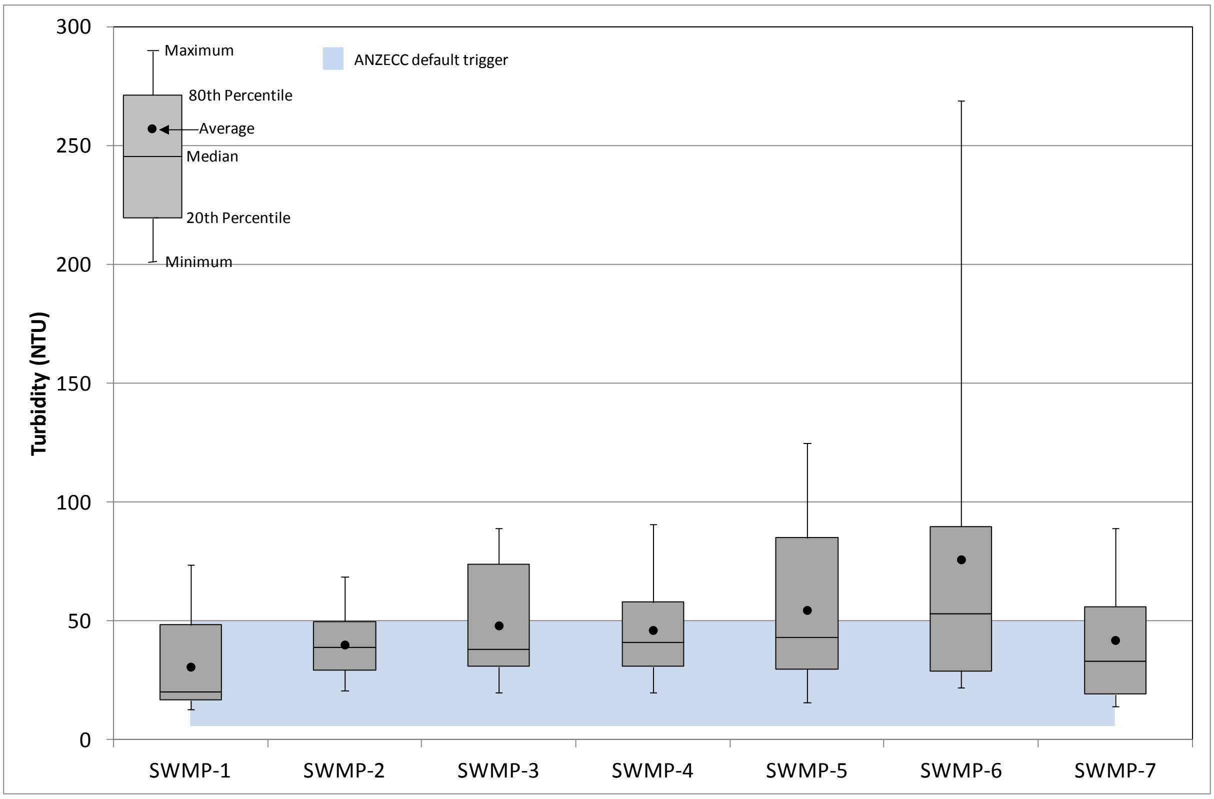

**Graph 3.1 – pH**



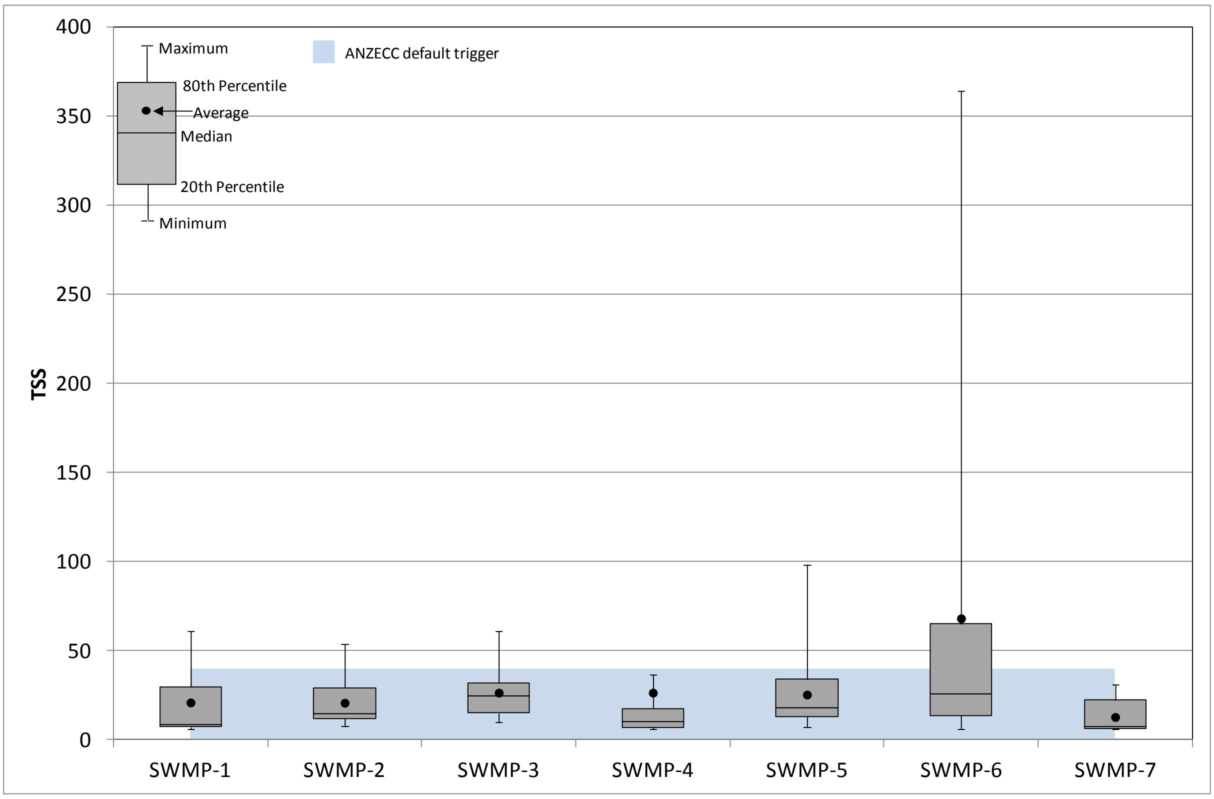

**Graph 3.2 - Electrical Conductivity**



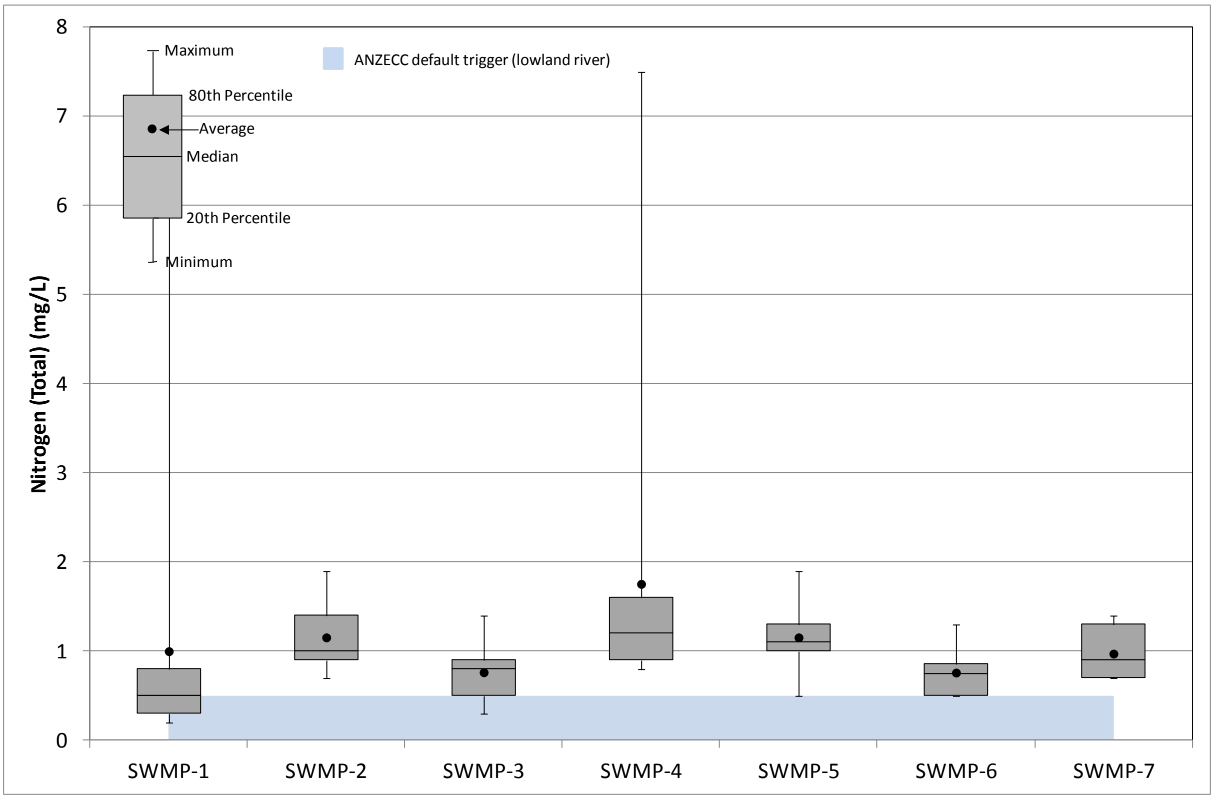

**Graph 3.3 - Total Dissolved Solids**



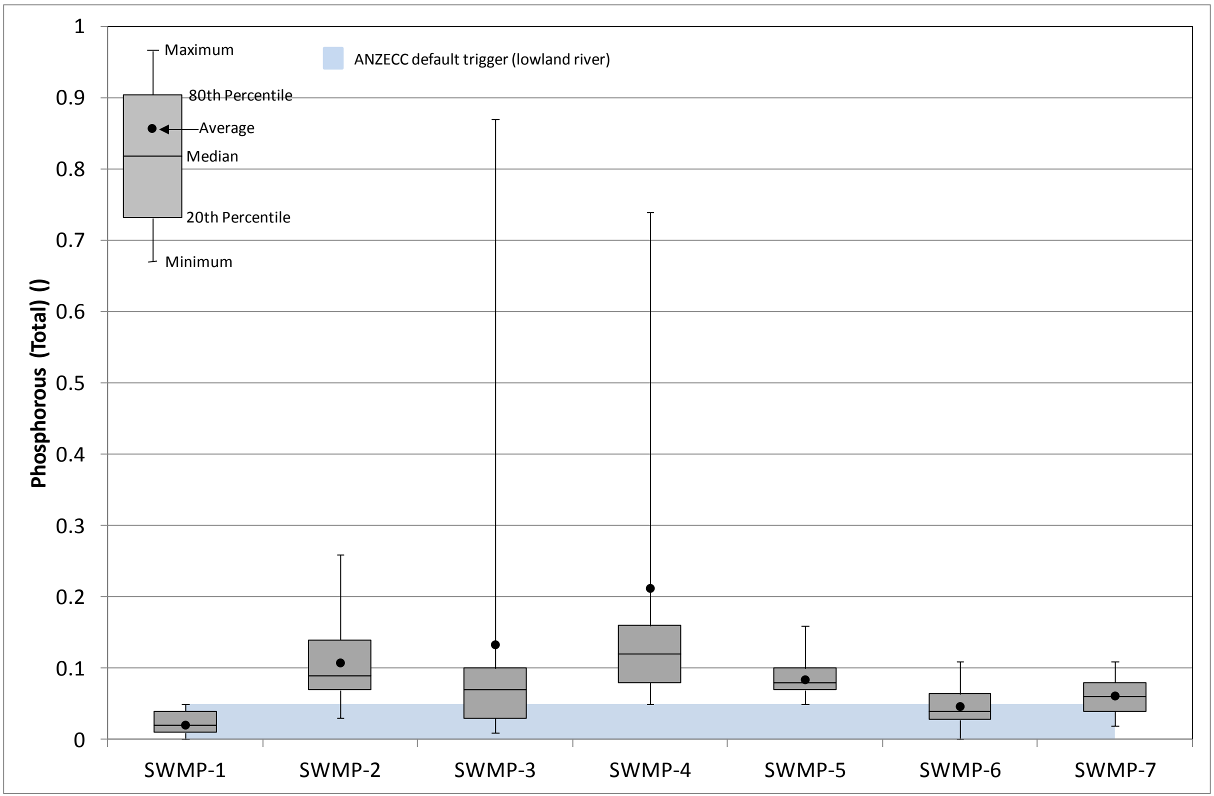

**Graph 3.4 - Turbidity**



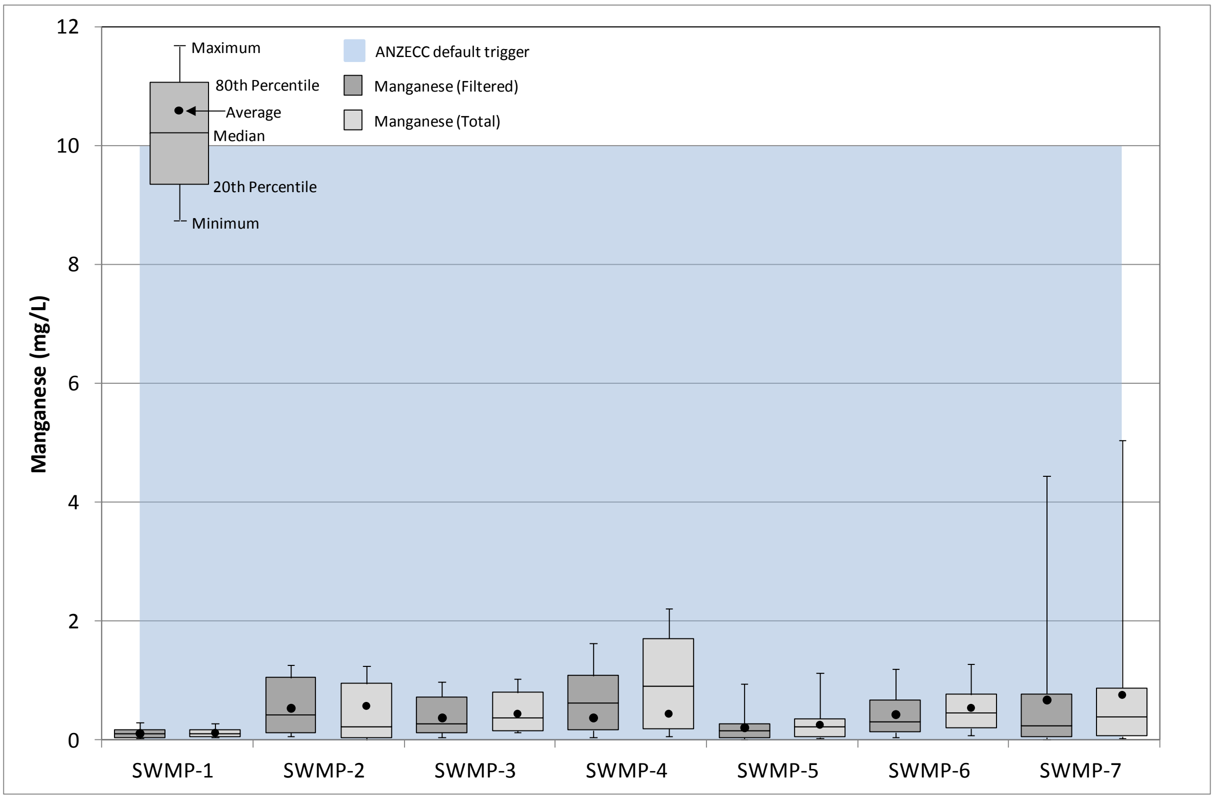

**Graph 3.5 - Total Suspended Solids**



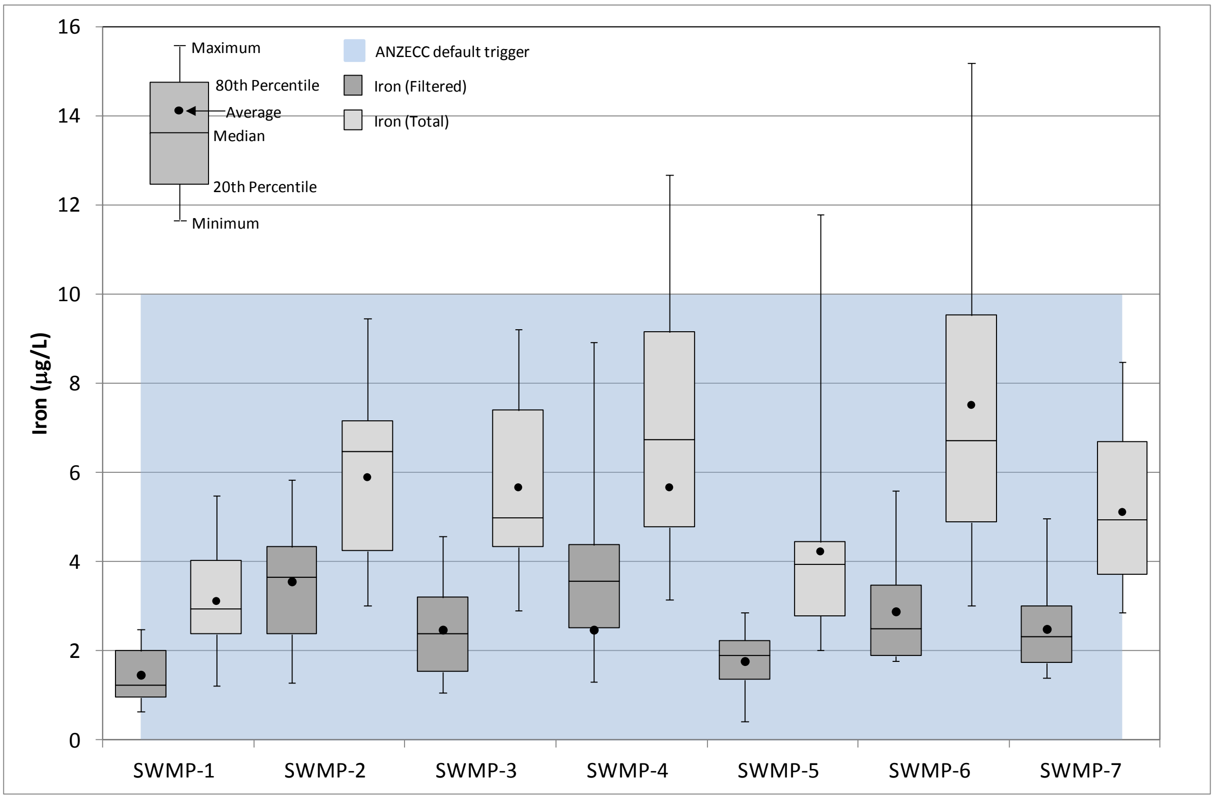

**Graph 3.6 - Total Nitrogen**



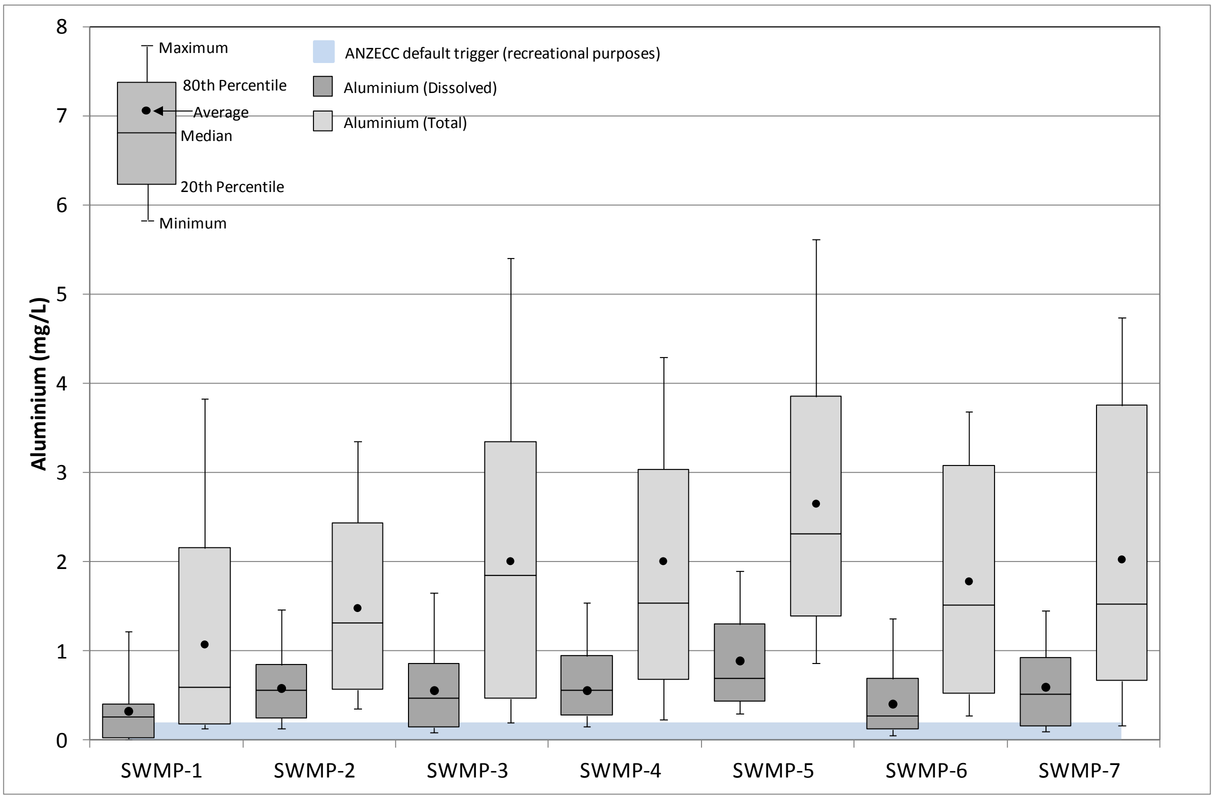

**Graph 3.7 - Total Phosphorous**




**Graph 3.8 – Manganese**




**Graph 3.9 - Iron**




**Graph 3.10 - Aluminium**

## 3.3 Water Quantity

No observed streamflow data is available for the watercourses within the Southern Extension Area. There is, however, one historical streamflow gauge located on Wyee Creek approximately 2.6 kilometres east of the Southern Extension Area and an existing streamflow gauge within Jilliby Creek located approximately 6 kilometres south of the Southern Extension Area. The Wyee Creek gauge (ID 211001) recorded daily records of water level and flows and was operational from 1958 until 1980. The limited data set available for the Wyee Creek gauge makes the estimation of typical annual flows for the watercourse within the Southern Extension Area problematic.

The Jilliby Creek gauge (ID 211010), operated by NOW has been active since 1972 and records daily water levels and flows. The Project occupies only a small fraction of the catchment upstream of the Jilliby Creek gauge, making the use of the Jilliby Creek gauge to estimate historical flows within the Southern Extension Area is of limited value.

## 3.4 Flood Regimes

Hydrodynamic flood models were used as part of this assessment to estimate the flood response of the existing conditions of six watercourses within the Southern Extension Area (refer to **Figure 3.3**) for several design storm events (refer to **Appendix 1**). Morans Creek was modelled using the existing Flood Study (Hughes Trueman, 2004) two dimensional (2D) model, extended to include sections of the Southern Extension Area. The flood response of the other creeks was estimated using new one dimensional (1D) models developed for watercourses of third order (Schedule 2) and higher (refer to **Figure 3.1**), with consideration of the requirements of DIPNR (2005).

**Figure 3.4** illustrates that the maximum modelled 100 year Average Recurrence Interval (ARI) storm event flood depths for the existing conditions in Morans Creek and **Figure 3.5** illustrates that the maximum modelled 100 year ARI storm event flood depths for the existing conditions in the three tributaries of Wyee Creek, Mannering Creek and Buttonderry Creek within the Southern Extension Area and in the proposed underground mining area. The upper reaches of Jilliby Creek are typically first and second order watercourses (i.e. Schedule 1) within the vicinity of the proposed underground mine (refer to **Figure 3.1**), and therefore were not included in the hydraulic modelling.

The one year ARI storm event flood extent for existing conditions in Morans Creek is included in **Figure 3.6**. Flood hazard categories for the existing conditions within Morans Creek in response to the 100 year ARI design storm event are included in **Figure 3.7**. The additional detail for Morans Creek, to the north and downstream of the Southern Extension Area boundary, is included to assist in the assessment of the potential impacts of the proposed access road crossing over Morans Creek (refer to **Section 4.4.2**).

The Mandalong area has a history of flooding. Anecdotal evidence, in addition to historical flood reports addressed in the Flood Study (Hughes Trueman 2004), in the form of photographs of flood events has been provided by Tina Swann, a local resident. Photographs of the June 2007 flood event are provided on **Figure 3.8**, including the approximate location and orientation of each photograph. Within the Mandalong Valley, it is estimated that the June 2007 flood event was between a 50 year and 100 year ARI flood event. Photograph one was taken at the property adjacent to Mandalong Road and Chapman Road (refer to **Figure 3.8**) and shows a broad area of flooding towards the vicinity

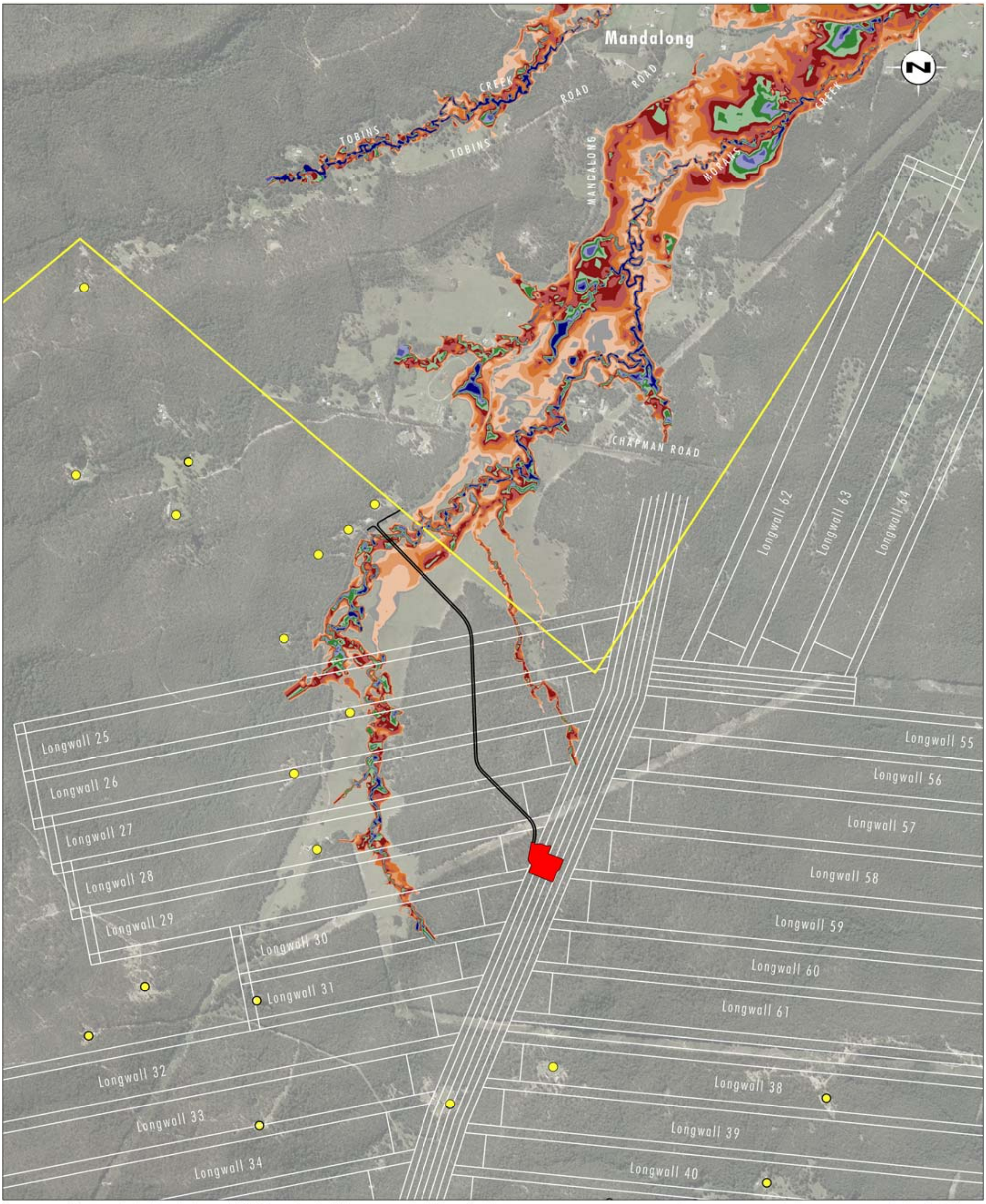
of the proposed crossing of Morans Creek, similar to that indicated by the maximum flood extent indicated in **Figure 3.4**. Photograph two shows flooding over Mandalong Road where it crosses a tributary of Morans Creek (refer to **Figure 3.8**). This location was used as an inflow point for the hydrodynamic modelling, which shows a similar extent of flooding over Mandalong Road (refer to **Figure 3.4**). Photographs three, four and five all show flooding within Morans Creek and the overbank areas, to similar extents as those shown in **Figure 3.4**.

## 3.5 Downstream Water Users

It is understood that watercourses within the Southern Extension Area are ephemeral, with periods of limited or no flow during periods of low rainfall. The ephemeral nature would suggest that dependence on flows within these watercourses to downstream agricultural users is likely to be limited.

However, the Southern Extension Area is within an area covered by the Jilliby Creek (2003), Central Coast Unregulated (2009) and Hunter Unregulated (2009) Water Sources Water Sharing Plans.

Jilliby Creek has a total catchment area of approximately 10,000 hectares, approximately 505 hectares (5 per cent) of which lies within the Southern Extension Area (refer to **Table 3.1**). The Water Sharing Plan for the Jilliby Creek Water Source (2003) allows for basic landholder rights of 0.51 mega litres (ML)/day, with a further 1016 ML/year available for extraction under extraction licences.




Source: Centennial Mandalong (2012) - Aerial Photograph, LPI - Cadastre

0 0.5 1.0 1.25km
1:25 000

**Legend**

- Southern Extension Area
- Proposed Surface Infrastructure
- Proposed Longwalls
- Proposed Access Road
- Dwellings

**Water Depth (metres)**

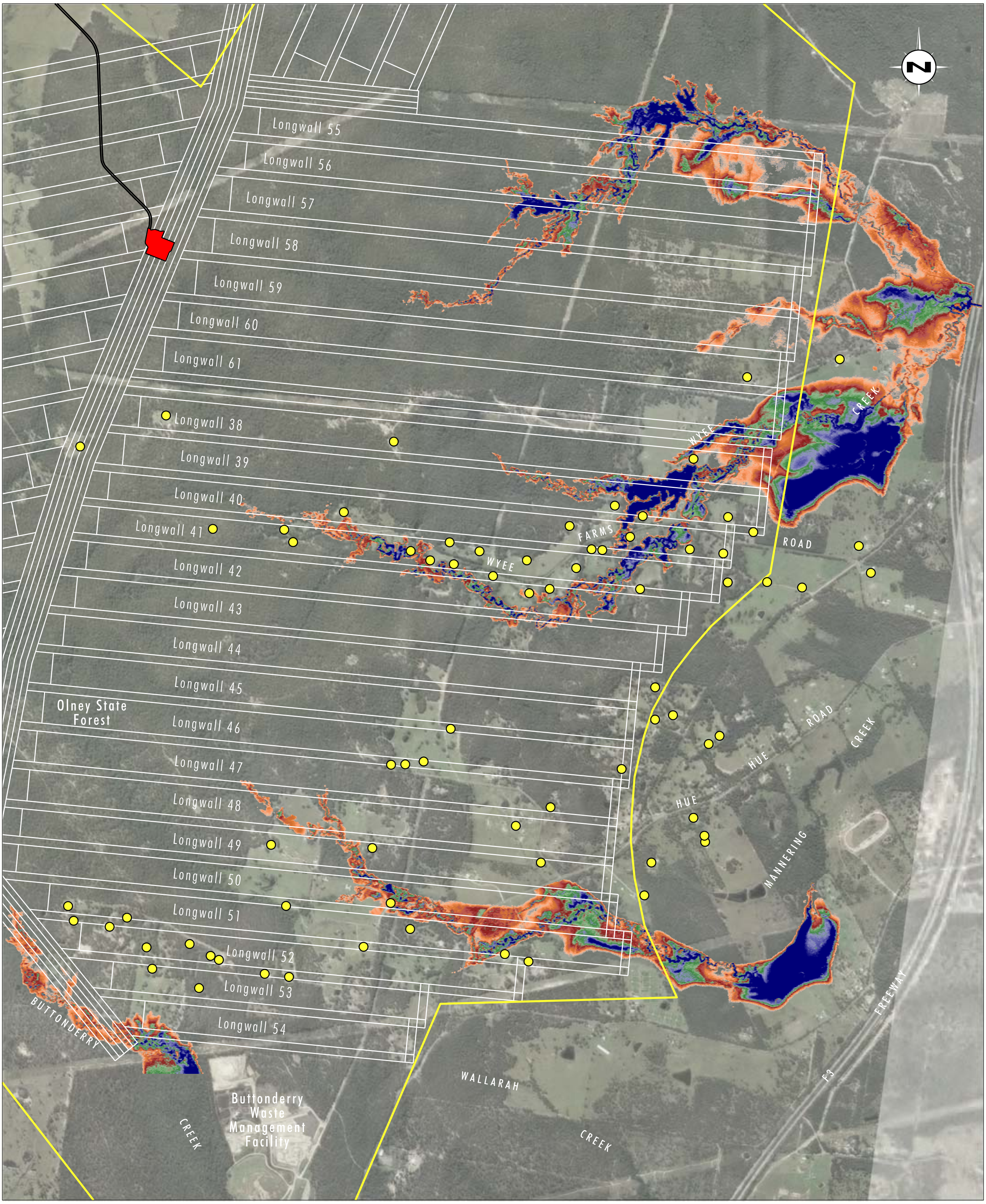
- Range [0.001 : 0.100]
- Range [0.100 : 0.300]
- Range [0.300 : 0.500]
- Range [0.500 : 0.700]
- Range [0.700 : 0.900]
- Range [0.900 : 1.100]
- Range [1.100 : 1.300]
- Range [1.300 : 1.500]
- Range [1.500 : 1.700]
- Range [1.700 : 1.900]
- Range [>1.900]

FIGURE 3.4

**100 year ARI Storm Event Maximum Flood Depths for Morans Creek (Existing Conditions)**

File Name (A4): R01/2943_017.dgn
20121213 16.39

Umwelt
Environmental Consultants




**Source:** Centennial Mandalong (2012) - Aerial Photograph, LPI - Cadastre

## Legend

- Southern Extension Area
- Proposed Surface Infrastructure
- Proposed Longwalls
- Proposed Access Road
- Dwellings

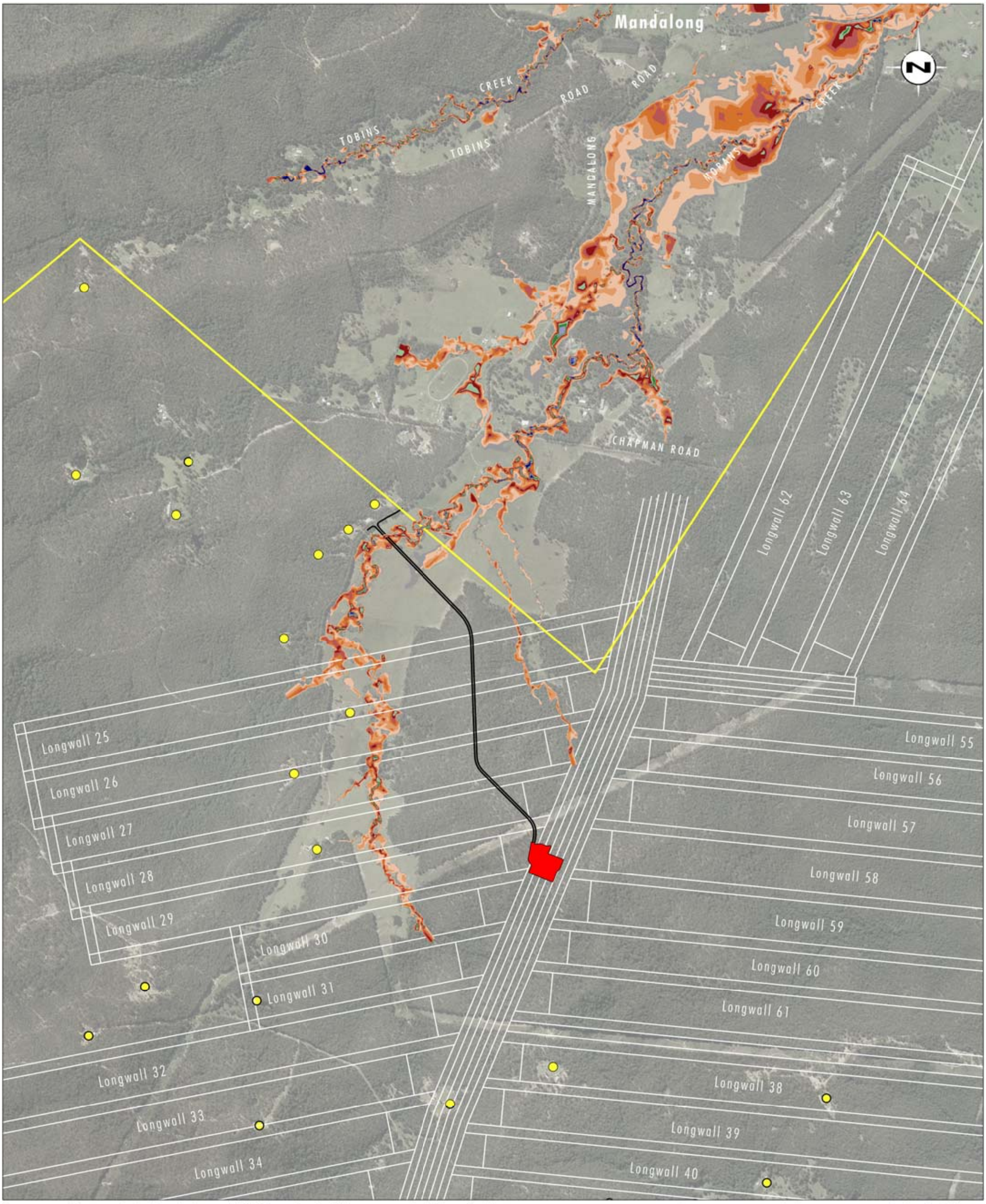
## Water Depth (metres)

- Range [0.001 : 0.100]
- Range [0.100 : 0.300]
- Range [0.300 : 0.500]
- Range [0.500 : 0.700]
- Range [0.700 : 0.900]
- Range [0.900 : 1.100]
- Range [1.100 : 1.300]
- Range [1.300 : 1.500]
- Range [1.500 : 1.700]
- Range [1.700 : 1.900]
- Range [>1.900]

FIGURE 3.5

**100 year ARI Storm Event Maximum Flood Depths for Wyee Creek, Mannering Creek and Buttonderry Creek (Existing Conditions)**

File Name (A4): R01/2943_016.dgn
20130121 11.15




Source: Centennial Mandalong (2012) - Aerial Photograph, LPI - Cadastre

0 0.5 1.0 1.25km
1:25 000

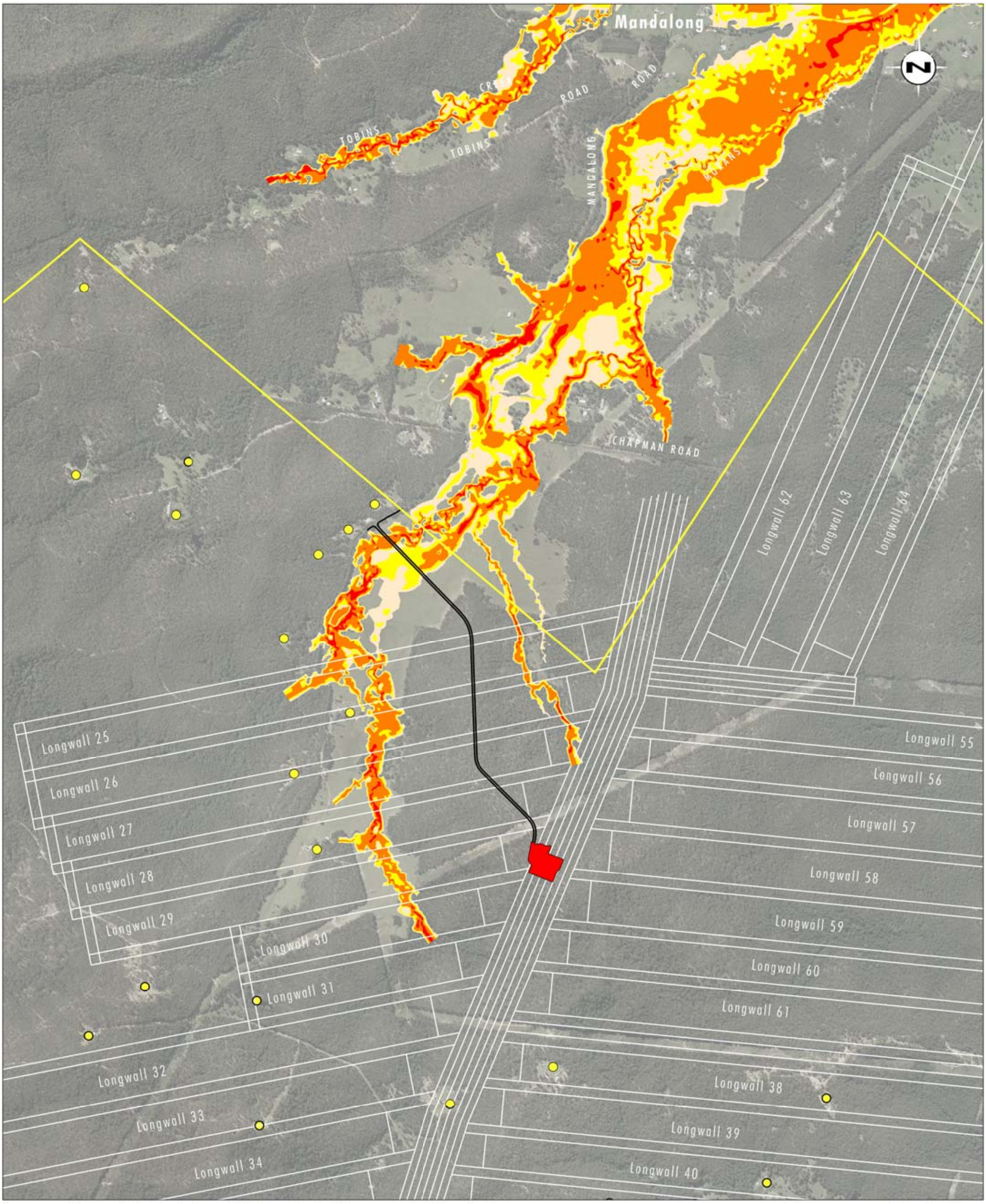
**Legend**
- Southern Extension Area
- Proposed Surface Infrastructure
- Proposed Longwalls
- Proposed Access Road
- Dwellings

**Water Depth (metres)**
- Range [0.001 : 0.100]
- Range [0.100 : 0.300]
- Range [0.300 : 0.500]
- Range [0.500 : 0.700]
- Range [0.700 : 0.900]
- Range [0.900 : 1.100]
- Range [1.100 : 1.300]
- Range [1.300 : 1.500]
- Range [1.500 : 1.700]
- Range [1.700 : 1.900]
- Range [>1.900]

FIGURE 3.6

1 year ARI Storm Event
Maximum Flood Depths for Morans Creek
(Existing Conditions)

Umwelt
Environmental Consultants




Source: Centennial Mandalong (2012) - Aerial Photograph, LPI - Cadastre

0 0.5 1.0 1.25km
1:25 000

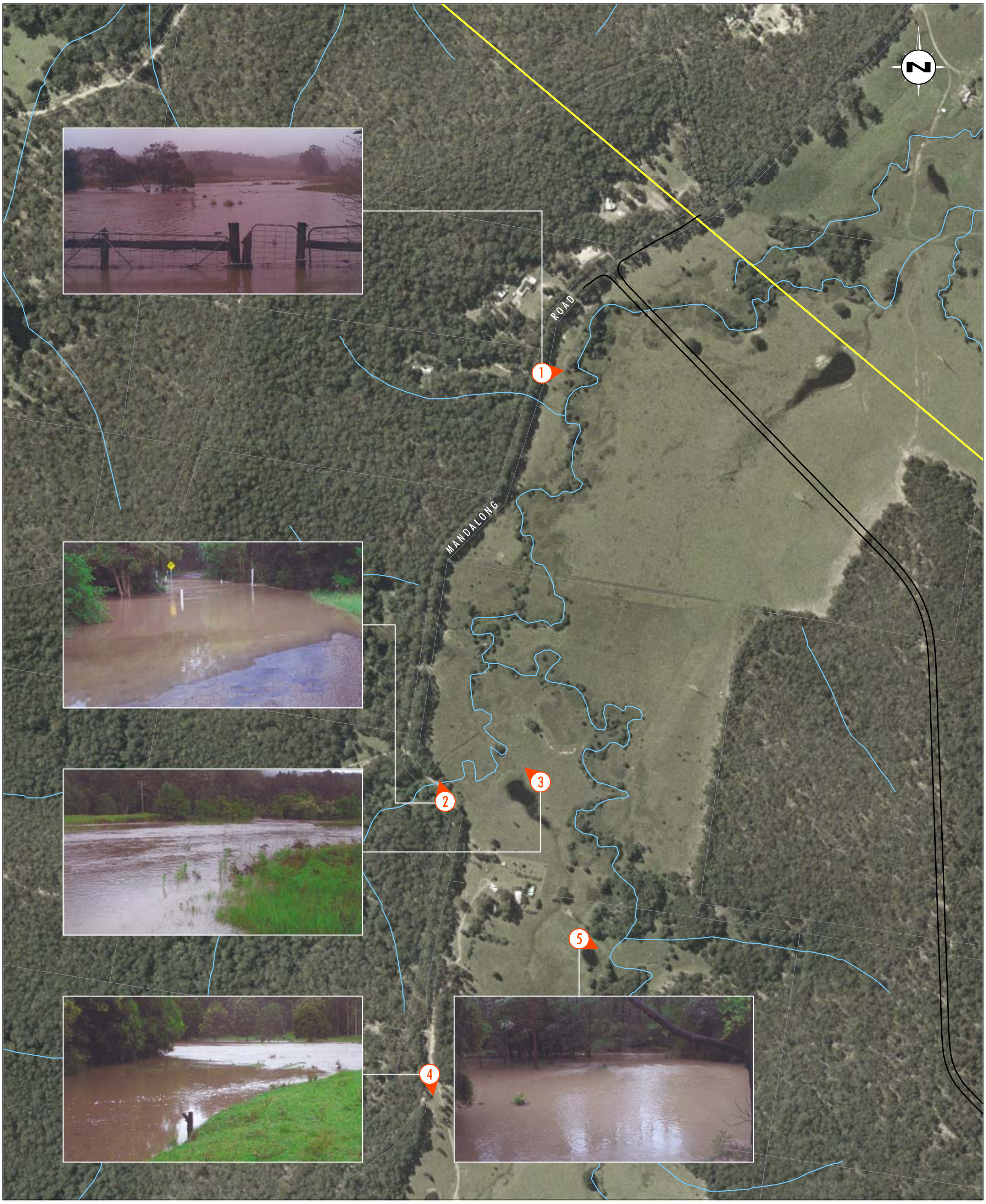
**Legend**
- Southern Extension Area
- Proposed Surface Infrastructure
- Proposed Longwalls
- Proposed Access Road
- Dwellings

**Hazard Category**
- Low Hazard - Uncalssified hazard
- Low Hazard - Vehicles unstable
- High Hazard - Wading unsafe
- High Hazard - Damage to light structures

FIGURE 3.7

**100 year ARI Storm Event**
**Maximum Flood Hazard Categories for Morans Creek, (Existing Conditions)**

File Name (A4): R01/2943_030.dgn
20121214 8.57




**Source:** Centennial Mandalong (2012) - Aerial Photograph,
LPI - Cadastre and Hydrolines

0 100 200 400m
1:7500

## Legend

- Southern Extension Area
- Proposed Access Road
- Drainage Line
- 4 Photo Location

FIGURE 3.8

June 2007 Flood Photographs
(Courtesy of Tina Swann)

The Wyong River has a total catchment area of approximately 44,000 hectares, including approximately 634 hectares (1.4 per cent) of Buttonderry Creek catchment within the Southern Extension Area (refer to **Table 3.1**) and immediate surrounds. Wyong River is used as a town water supply, accounting for approximately 89 per cent of extractions from the river (Wyong River water source - Report Card, August 2009). Surface water entitlements total 38,782 ML/year within the Wyong River water source. The Water Sharing Plan for the Central Coast Unregulated Water Sources (2009) allows for access to water within the Wyong River catchment area under basic landholder rights for up to 0.24 ML/day, with extraction licenses covering a total of 3984 unit shares of the Wyong River water source.

Morans Creek, Wyee Creek and Mannering Creek are located within the catchment area of Lake Macquarie (refer to **Table 3.1**), which has a total catchment area of approximately 153 $km^2$, 3130 hectares of which are within the Southern Extension Area (approximately 0.02 per cent). The Southern Extension Area is located within the South Lake Macquarie extraction management unit of the Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources (2009). The Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources (2009) allows access to water within South Lake Macquarie for basic landholder rights of 0.07 ML/day, with extraction licences totalling 169 unit shares in the South Lake Macquarie water source of a 169 ML/year total surface water entitlement. The surface water entitlement is used almost entirely for irrigation purposes.

# 4.0 Surface Water Impacts and Management Methods

This section of the surface water assessment reviews the potential impacts of the Project on surface water resources and the proposed management of any identified potential impacts. The assessment approach and methodology are discussed in **Appendix 1**.

The Project has the potential to impact on the following:

- catchment area boundaries;
- watercourse stability and associated water quality;
- remnant ponding;
- flood regimes; and
- water quantity for downstream water users and the environment.

The potential of each of these impacts and any proposed management methods are outlined in **Sections 4.1** to **4.5**.

## 4.1 Catchment Areas

The predicted subsidence has the potential to alter catchment boundaries. Analysis of the subsidence predictions for the Project (Ditton 2012) indicates that the proposed underground mining will result in maximum predicted vertical subsidence of up to approximately 1.35 metres in some areas, but will not significantly alter the catchment boundaries from those that currently exist as shown on **Figure 3.1**.

## 4.2 Watercourse Stability

The existing characteristics of the watercourses within the Southern Extension Area have the potential to be impacted as a result of changes to the profiles of the watercourses as a result of the predicted subsidence. The characteristics of the watercourses will be potentially influenced by changes to longitudinal grades, and associated flow velocities and tractive stresses. Changes to the stability of a watercourse can result in increased scouring, changed channel geometry or rerouting of the watercourse. The potential for changes to the stability of the watercourses within the Southern Extension Area therefore need to be examined to allow for appropriate monitoring and management options to be implemented as required.

The assessment of potential impacts on watercourse stability considers changes to longitudinal grades by longsection analysis (refer to **Section 4.2.1**) and changes to bank full velocities and tractive stresses (refer to **Section 4.2.2**). The outcomes of the watercourse stability assessment is summarised in **Section 4.2.3**.

### 4.2.1 Longsection Analysis

Changes to longitudinal grades as a result of the predicted subsidence can provide an initial indication of locations which may experience a change to current (i.e. pre-mining) scouring or remnant ponding conditions (refer to **Section 4.3**) within a watercourse. These changes are typically the result of increases or decreases in the longitudinal grades due to the predicted subsidence.

The existing landform and predicted subsided landform longsections for the three branches of Wyee Creek (Watercourse 1, Watercourse 2 and Watercourse 3), Mannering Creek (Watercourse 4), Buttonderry Creek (Watercourse 5) and Morans Creek (Watercourse 6) are presented in **Charts 4.1** to **4.6**. Potential scouring locations are marked on the longsections based on changes to channel grade due to the predicted subsidence. During the inspections of the watercourses within the Southern Extension Area, it was noted that several sections of watercourses were subject to scouring of the bed and banks (refer to **Section 3.1**), often in apparent response to the construction of road culverts. It should be noted that these potential scouring locations are typically extensions to existing locations of potential scouring, either observed (refer to **Sections 3.1.1** to **3.1.5**) or estimated from the longsections of the existing landform (refer to **Charts 4.1** to **4.6**). In addition, potential remnant ponding locations are marked on the longsections. Remnant ponding impacts are discussed further in **Section 4.3**. The location and extent of each of the watercourse longsections is included in **Figure 4.1**.

**Chart 4.1** shows the longsections for Morans Creek (Watercourse 6) within the Southern Extension Area and surrounds for both the existing landform and predicted subsided landform. The comparison of the existing and predicted subsided longsections for Morans Creek (refer to **Chart 4.1**) indicates the potential for increased remnant ponding in the vicinity of proposed Longwalls 25 and 30, with the potential for increased scouring to occur in the vicinity of proposed Longwall 25. The approximate locations of these potential remnant ponding and scouring points are illustrated on **Figure 4.1**.

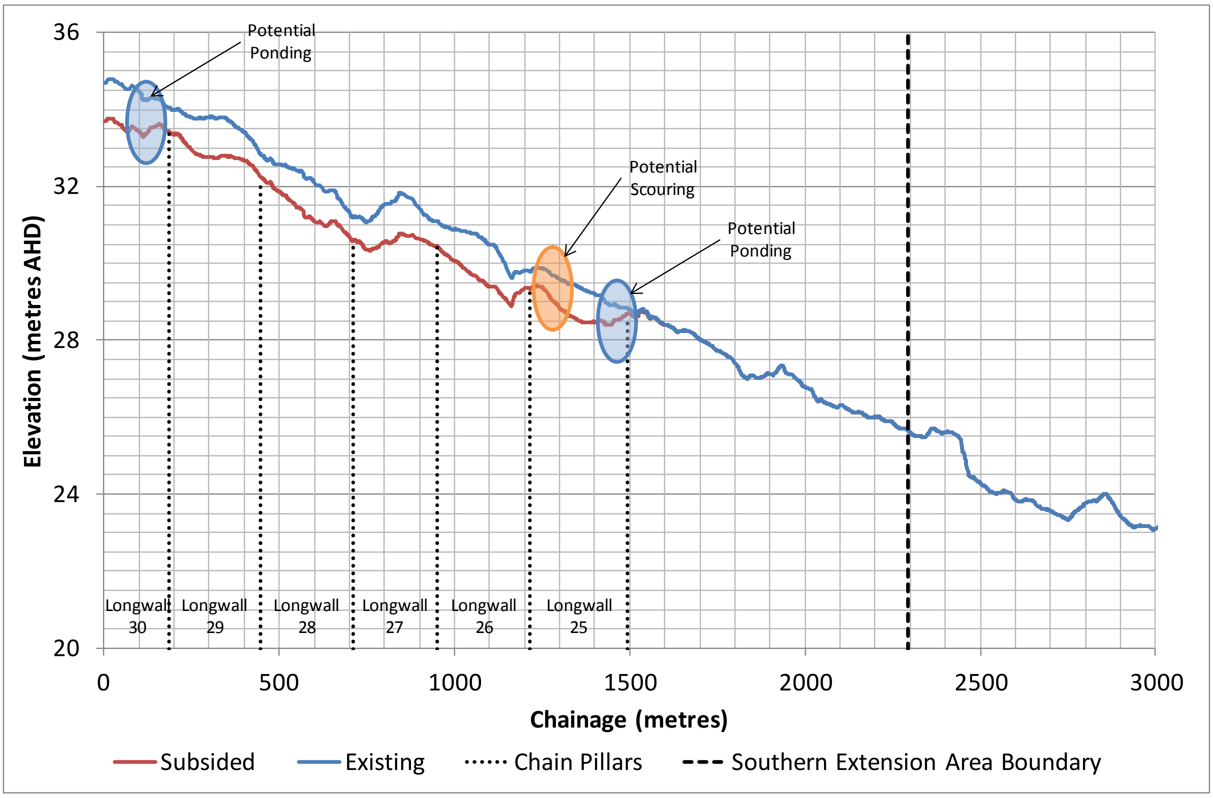
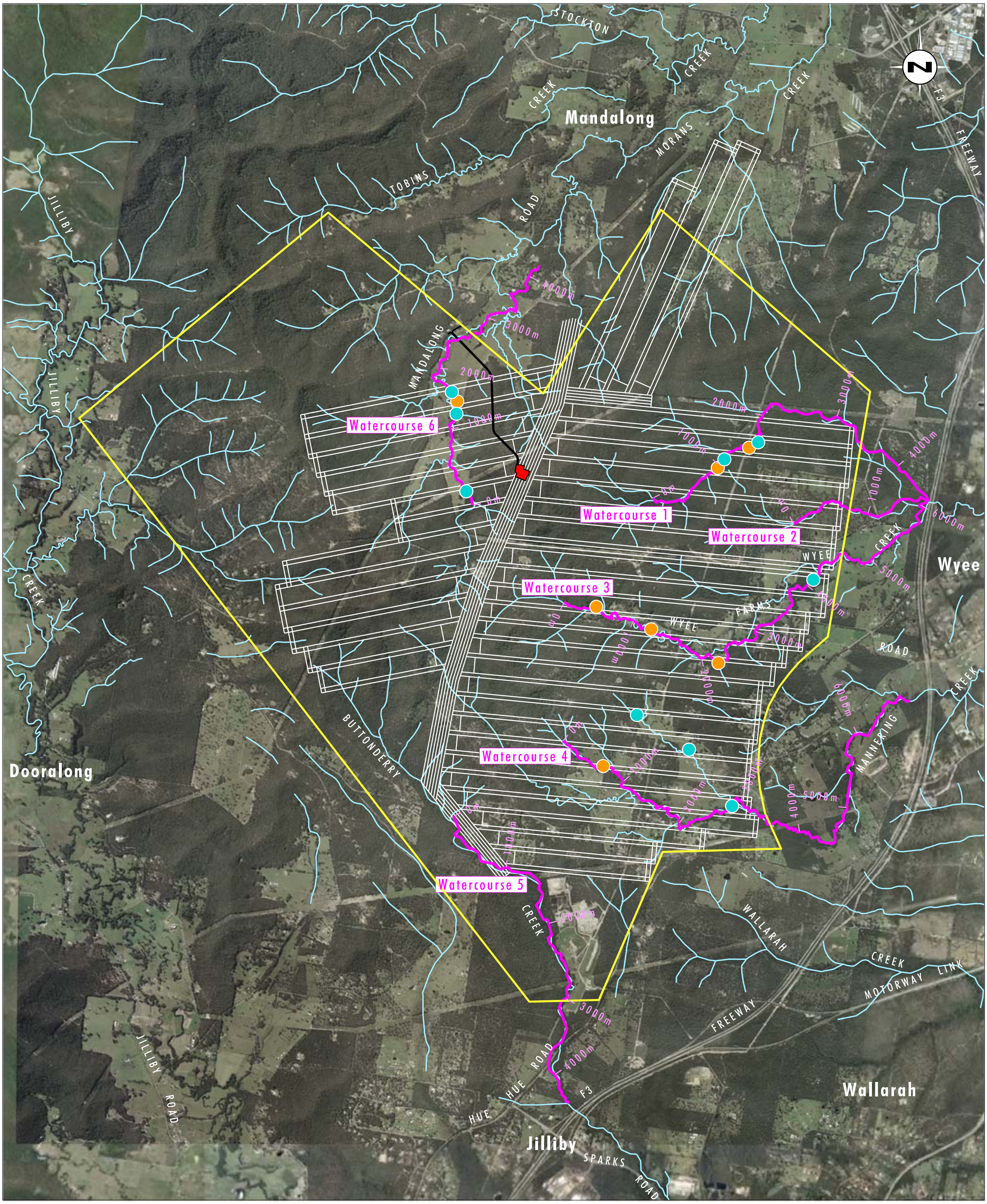



**Chart 4.1 - Longitudinal Grade of Morans Creek (Watercourse 6)**




Source: Centennial Mandalong (2012) - Aerial Photograph, LPI - Hydrolines

0 1.0 2.0 2.5km
1:60 000

## Legend

- Southern Extension Area
- Proposed Surface Infrastructure
- Proposed Longwalls
- Proposed Access Road
- Drainage Line
- Water Course
- Predicted Scouring Location
- Predicted Ponding Location

FIGURE 4.1

**Long Section Locations and Monitoring Points**

File Name (A4): R01/2943_032.dgn
20121214 9.04

**Charts 4.2**, **4.3** and **4.4** show the longsections for the three branches of Wyee Creek within the Southern Extension Area and surrounds for both the existing landform and the predicted subsided landform. The locations of potential changes to scouring and remnant ponding are evident on these charts. **Chart 4.2** indicates that within Watercourse 1 of Wyee Creek there is potential for alternating sections of scouring and remnant ponding above Longwall 56 and Longwall 57. No significant changes to the existing scouring and remnant ponding conditions are expected within Watercourse 2 of Wyee Creek (refer to **Chart 4.3**). **Chart 4.4** indicates that within Watercourse 3 of Wyee Creek there is potential for increased scouring within the watercourse in the vicinity of proposed Longwalls 40, 41 and 43, with a potential remnant ponding area identified in the vicinity of proposed Longwall 38. The approximate locations of these potential remnant ponding and scouring points are illustrated on **Figure 4.1**.

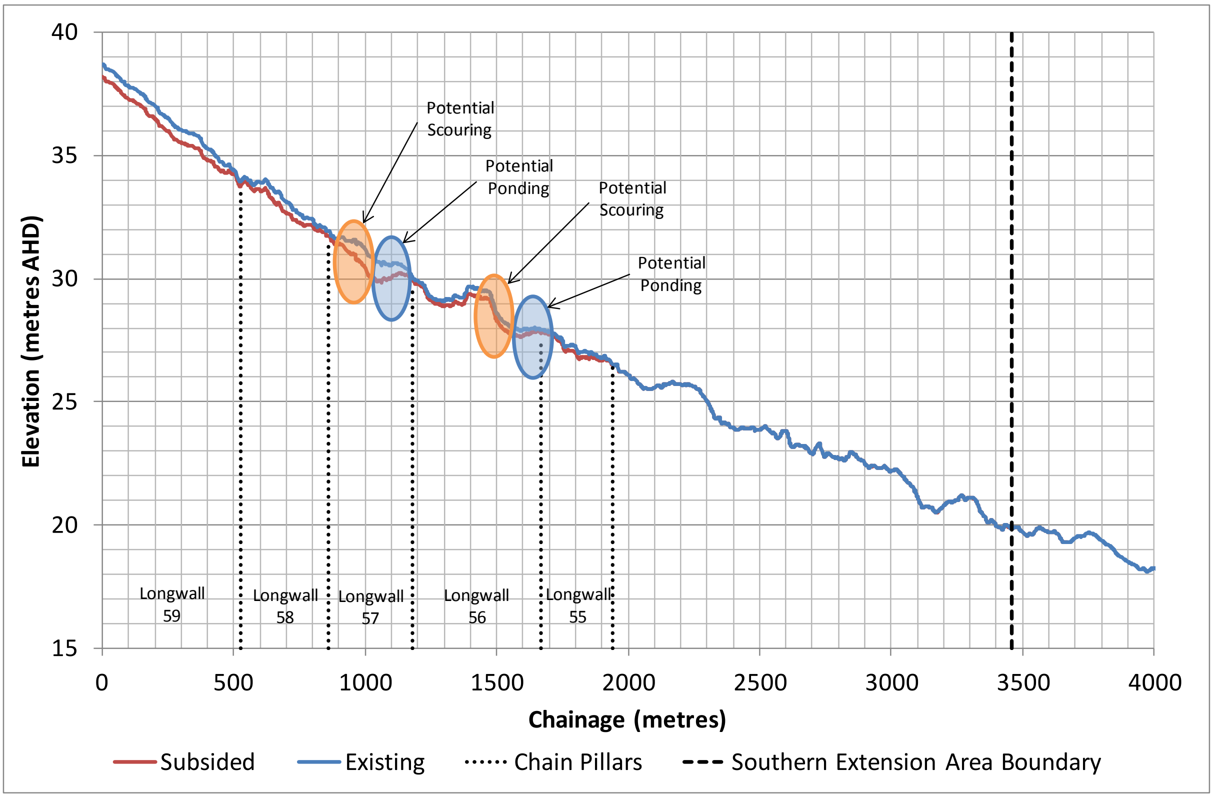



**Chart 4.2 - Longitudinal Grade of Wyee Creek (Watercourse 1)**

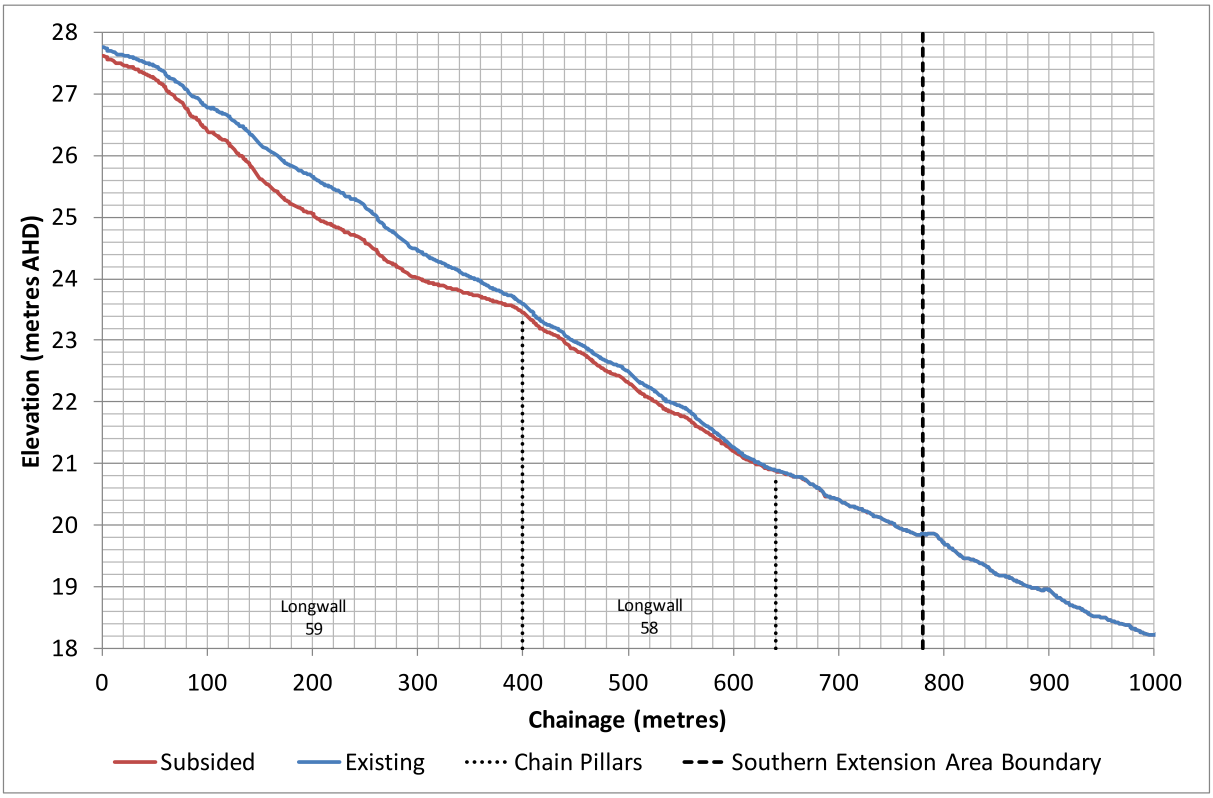



**Chart 4.3 - Longitudinal Grade of Wyee Creek (Watercourse 2)**

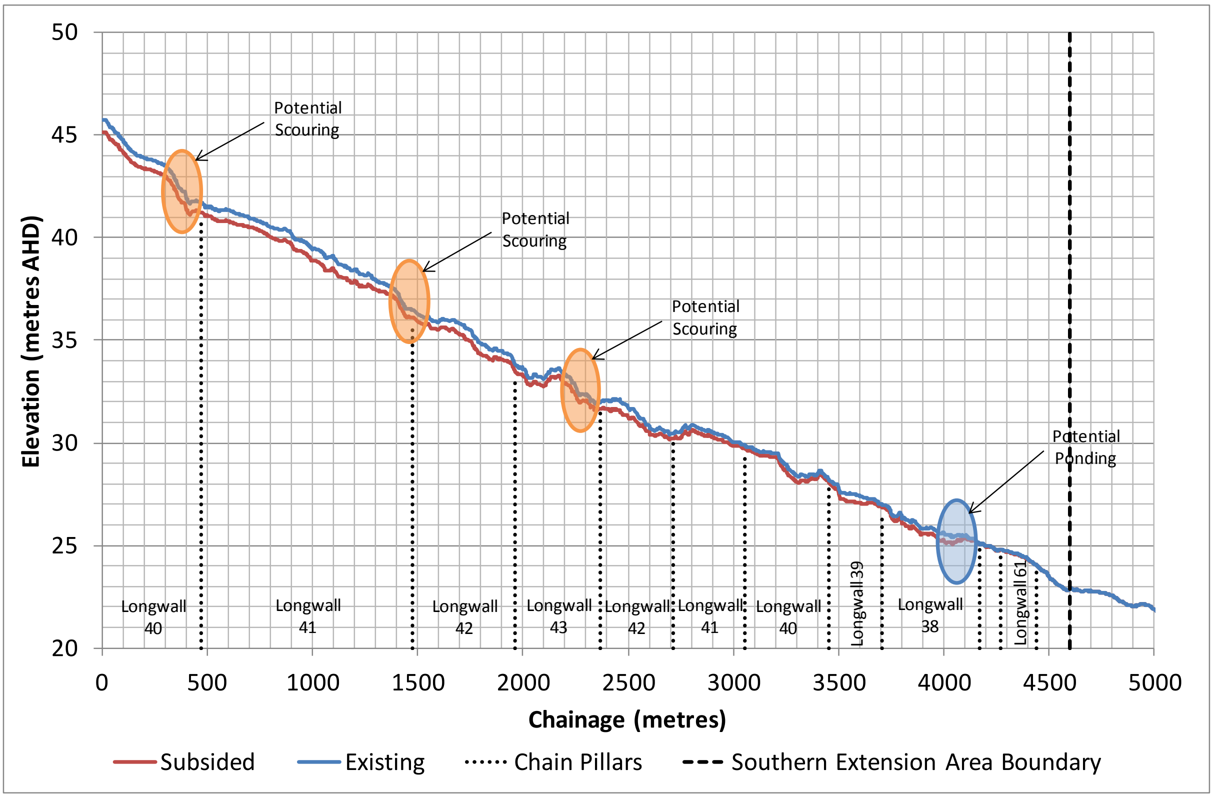



**Chart 4.4 - Longitudinal Grade of Wyee Creek (Watercourse 3)**

**Chart 4.5** shows the longsections for Mannering Creek (Watercourse 4) within the Southern Extension Area for both the existing landform and predicted subsided landform. The longsections indicate that within Manning Creek (Watercourse 4), there is the potential for an increase in the existing scour between proposed Longwalls 48 and 49, and the potential for and additional remnant ponding area in the vicinity of proposed Longwall 50. The approximate locations of these potential scouring points and remnant ponding are illustrated on **Figure 4.1**.

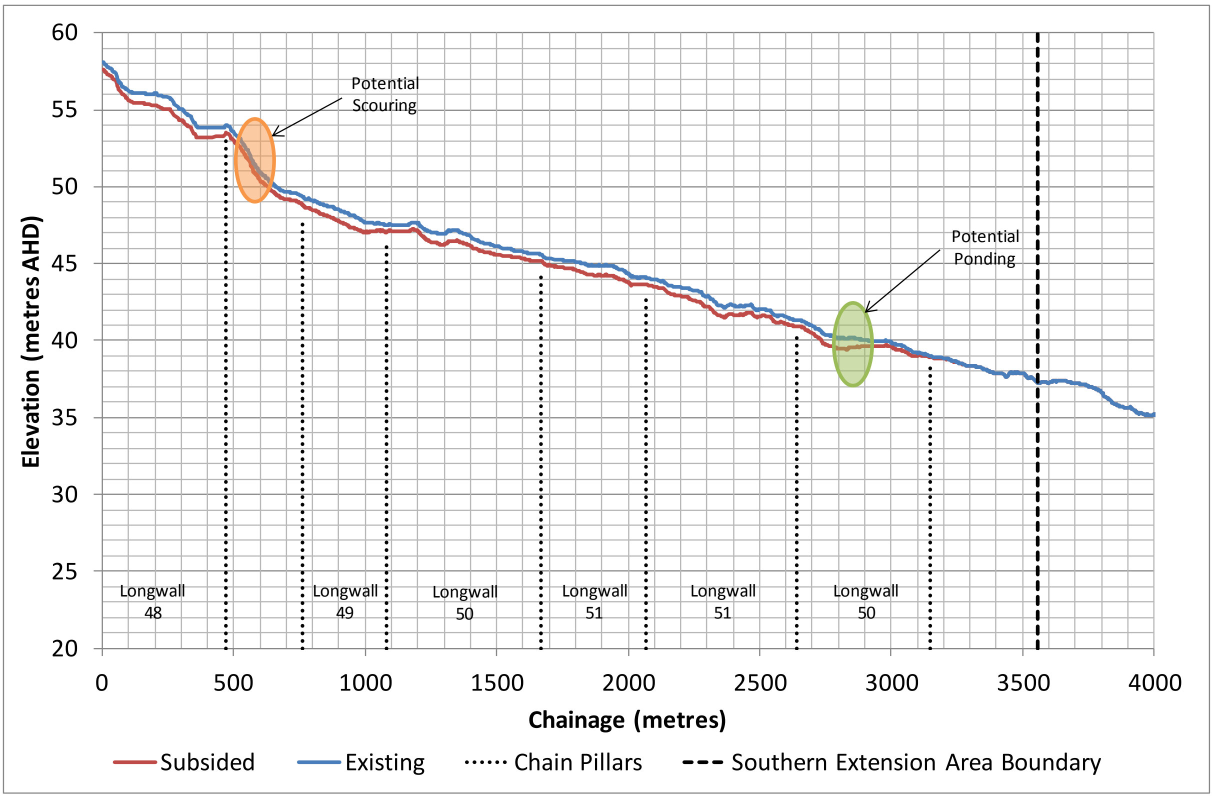



**Chart 4.5 - Longitudinal Grade of Mannering Creek (Watercourse 4)**

**Chart 4.6** shows the longsections for Buttonderry Creek (Watercourse 5) within the Southern Extension Area for both the existing landform and predicted subsided landform. The longsections indicate only very minor changes to the watercourse longsections as a result of the predicted subsidence, up to 135 millimetres within the watercourse longsection in the area adjacent to proposed Longwall 54.

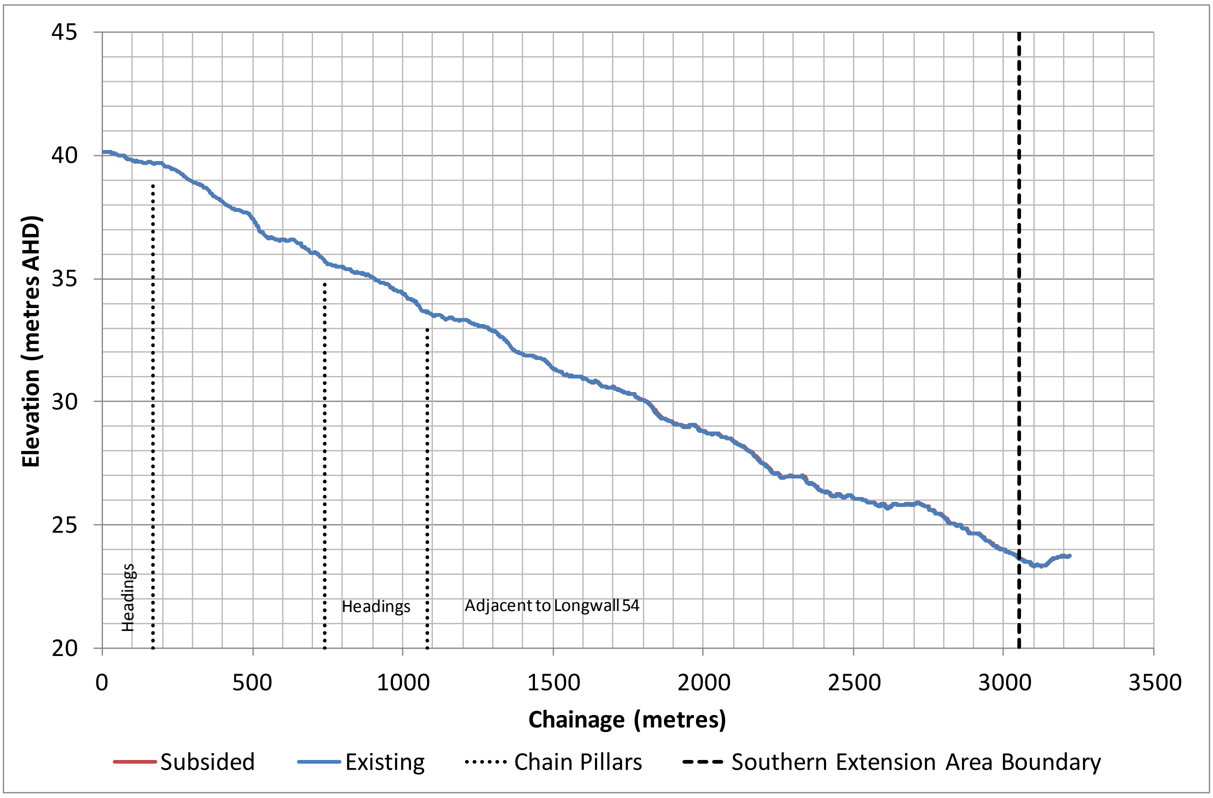



**Chart 4.6 - Longitudinal Grade of Buttonderry Creek (Watercourse 5)**

The location of potential changes in longitudinal grade which may result in potential changes to existing scouring, new areas of scouring, or current (i.e. pre-mining) remnant ponding conditions, as highlighted on **Charts 4.1** to **4.6**, should be included in any ongoing watercourse monitoring program and may require remediation works (refer to **Sections 4.5** and **5.0**).

It should be noted that the potential scouring locations included in **Charts 4.1** to **4.6** and **Figure 4.1** are typically within locations that are potentially unstable under existing conditions (refer to **Section 3.1**).

### 4.2.2 Velocities and Tractive Stresses

The longterm stability of the bed and banks of a watercourse is influenced by the flow energy within the watercourse. The flow energy is typically estimated using modelled flow velocities and tractive stresses (i.e. the force of the water on the bed and banks of a watercourse) throughout the modelled watercourse in response to a bank full flow event. The bank full flow event is classed as the design event that results in maximum flow depths that are approximately equal to the top of bank of the watercourse, typically the one year or two year (ARI) design event.

Subsidence, as a result of underground mining, has the potential to result in changes to the longitudinal grades of watercourses. The changes to longitudinal grade can alter the hydraulic response of flows within a watercourse, potentially resulting in changes to flow velocities and tractive stresses that in turn could increase scouring of the bed and banks of the watercourse.

The potential impacts on watercourse stability as a result of the predicted subsidence were assessed using modelled changes in the approximate bank full flow velocity and tractive stress (refer to **Appendix 1**) and results of the longitudinal grade analysis (refer to **Section 4.2.1**).

The potential impact of changes to modelled velocities and tractive stresses on the stability of a watercourse were estimated using stability thresholds. The stability thresholds allow for flows to be categorised as *stable*, *marginally stable* or *unstable*. The thresholds depend on bed and bank material and vegetation coverage.

Based on the observations from the field inspections, bed materials appear to range from fine gravels to graded loam and cobbles. The thresholds for tractive stress and flow velocity shown in **Table 4.1** have been selected as indicative thresholds for determining stability state of each watercourse.

**Table 4.1 - Tractive Stress and Velocity Thresholds**
**(Adapted from Fischenich (2001))**

| Flow Metric | Stable | Marginally Stable | Unstable |
|---|---|---|---|
| Velocity | < 0.75 m/s | 0.75 m/s to 1.15 m/s | > 1.15 m/s |
| Tractive Stress | < 3.6 N/m$^2$ | 3.6 N/m$^2$ to 18.2 N/m$^2$ | > 18.2 N/m$^2$ |

The analysis of potential impacts on bank full velocities and tractive stresses for Morans Creek, Wyee Creek, Mannering Creek and Buttonderry Creek are provided in **Sections 4.2.2.1** to **4.2.2.4**.

#### 4.2.2.1 Morans Creek (Watercourse 6)

The modelled approximate bank full (for this watercourse identified by modelling as the one year ARI design storm event) velocity and tractive stress within Morans Creek (refer to **Figure 3.2**) for the existing landform and predicted subsided landform, are included in **Charts 4.7** and **4.8**. These charts also include indicative stability thresholds (adapted from Fischenich (2001), refer to **Table 4.1**) and the approximate location of the proposed longwalls and the boundary of the Southern Extension Area.

Morans Creek was modelled using a 2D hydrodynamic model (refer to **Appendix 1**) as such the tractive stress plot included in **Charts 4.7** and **4.8** shows the tractive stress *per unit width* of the channel centre line. This measure provides an estimate of the maximum tractive stress within the watercourse profile and has been used to assess potential impacts on tractive stresses.

From **Charts 4.7** and **4.8**, it can be seen that there is little difference in the modelled bank full velocities and tractive stresses for Morans Creek, with modelled velocities and tractive stresses typically consistent between the existing landform and predicted subsided landform. The modelling indicates that the potential impact of the proposed infrastructure on the modelled bank full velocities and tractive stresses is minor, with only minor changes to the modelled velocities and tractive stresses within the immediate vicinity of the proposed access road, with no change in stability categories.

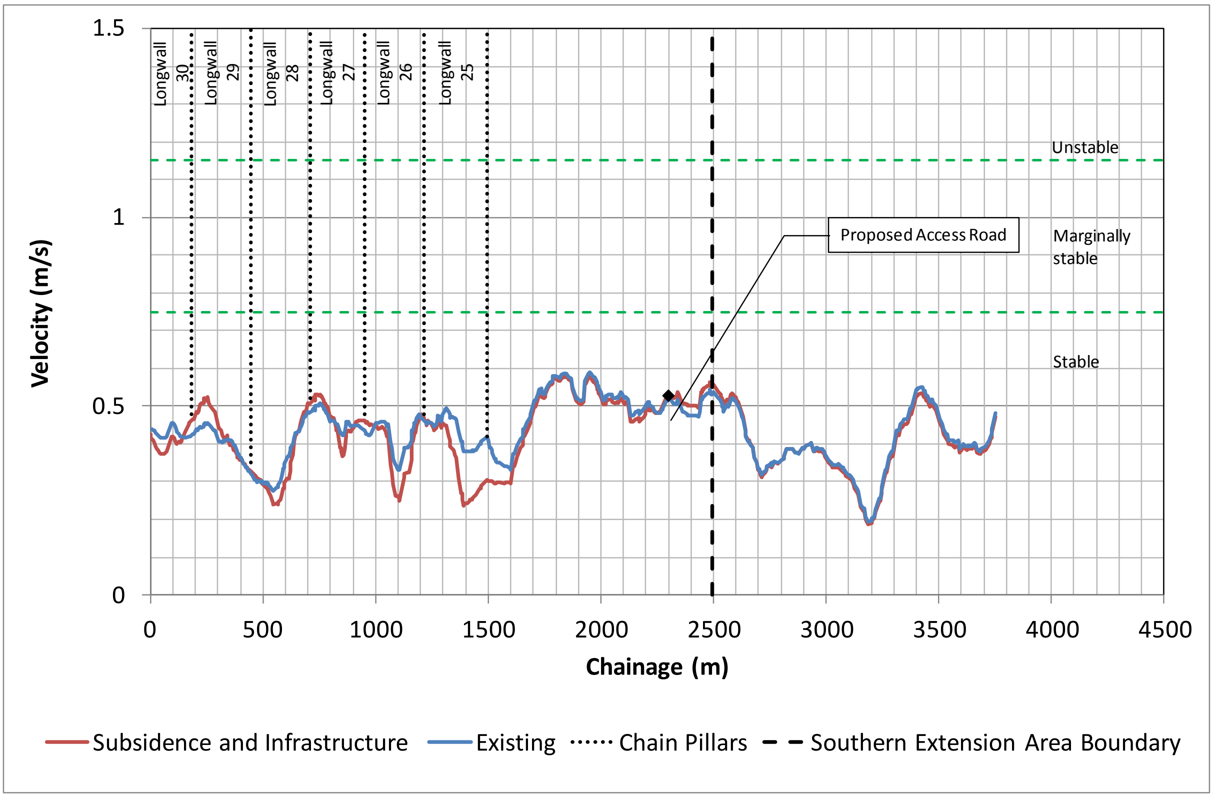



**Chart 4.7 - Morans Creek (Watercourse 6) - Modelled Velocity**

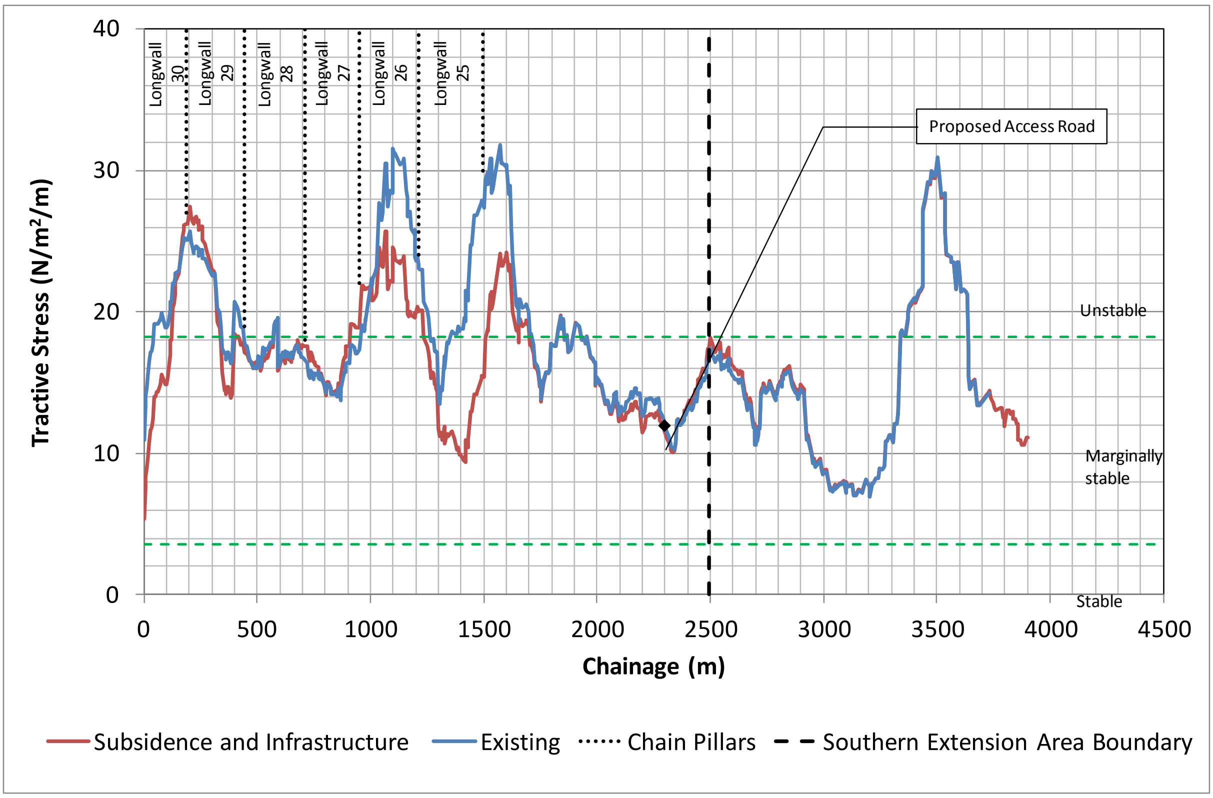



**Chart 4.8 - Morans Creek (Watercourse 6) - Modelled Tractive Stress**

#### 4.2.2.2 Wyee Creek

**Wyee Creek (Watercourse 1)**

The modelled approximate bank full (for Wyee Creek identified by modelling as the two year ARI design storm event) velocity and tractive stress within northern branch of Wyee Creek (Watercourse 1) (refer to **Figure 3.2**) for the existing landform and predicted subsided landform are presented in **Charts 4.9** and **4.10** respectively.

From **Chart 4.9** it is evident that the maximum modelled velocity for the bank full event shows minimal difference in velocities between the existing landform and predicted subsided landform with the exception of two locations, i.e. at approximately 1100 metres (in the vicinity of Longwall 57) and approximately 1900 metres (in the vicinity of Longwall 55). The modelled decrease in velocity at these locations is reflected in the modelled maximum tractive stress (refer to **Chart 4.10**), which also indicates an additional location where the modelled tractive stresses decreases at approximately 900 metres (in the vicinity of Longwall 57).

In terms of the modelled maximum velocities, only the modelled decrease at approximate chainage 1100 metres is estimated to result in a change in stability category from *unstable* to *stable* (refer to **Chart 4.9**). This pattern is repeated in the modelled tractive stress (refer to **Chart 4.10**).

**Chart 4.9** indicates that the modelled decrease in maximum velocity that occurs at approximately 1900 metres occurs at a location that is already estimated to be *unstable*, i.e. the stability category at this location is unlikely to change as a result of the predicted subsidence. The analysis of the maximum modelled tractive stress at this location also indicates that the stability category is unlikely to differ from the existing conditions (refer to **Chart 4.10**).

The modelling of the maximum tractive stresses indicates a decrease in the stability category at an approximate chainage of 900 metres, with the estimated stability category at this location changing from *unstable* to *marginally unstable* (refer to **Chart 4.10**).

Those locations where the modelling indicates a decrease or no change to the stability category in the areas identified by the longitudinal grade changes are shown in **Chart 4.2**. No specific monitoring locations are identified for Watercourse 1.

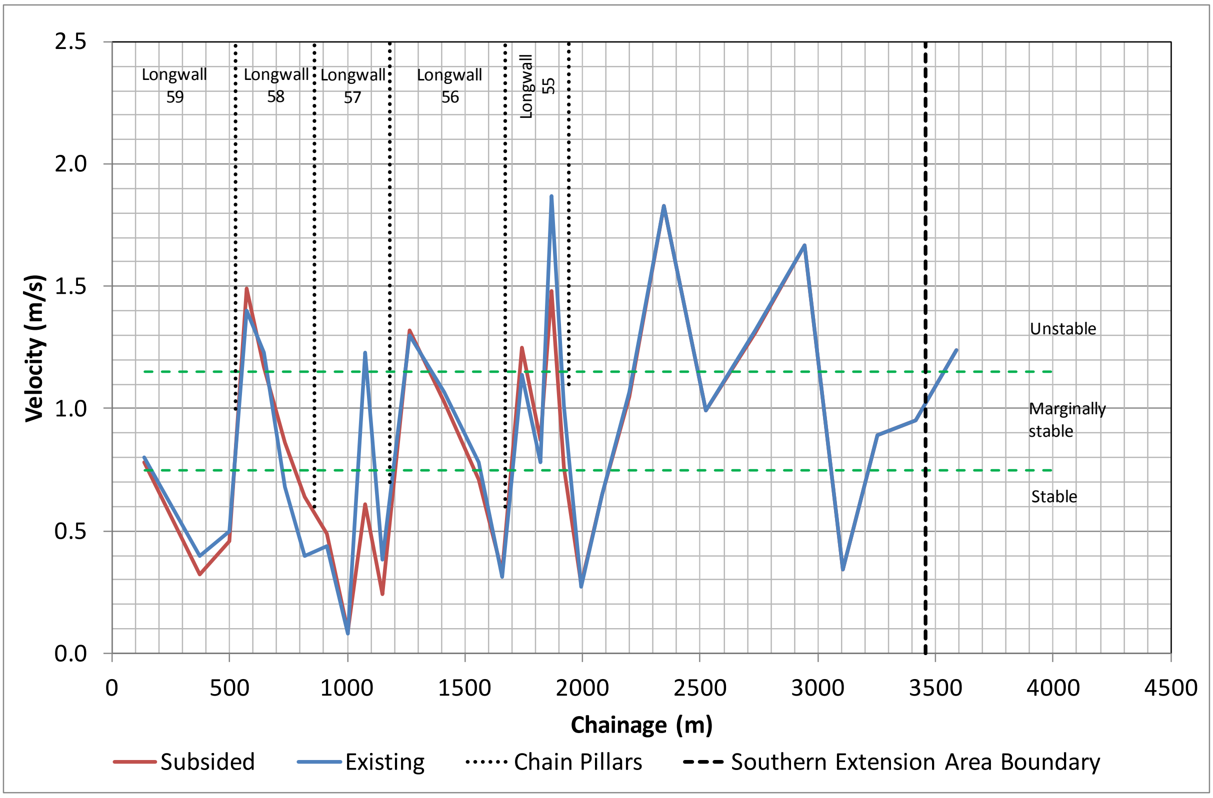



**Chart 4.9 - Wyee Creek (Watercourse 1) - Modelled Velocity**

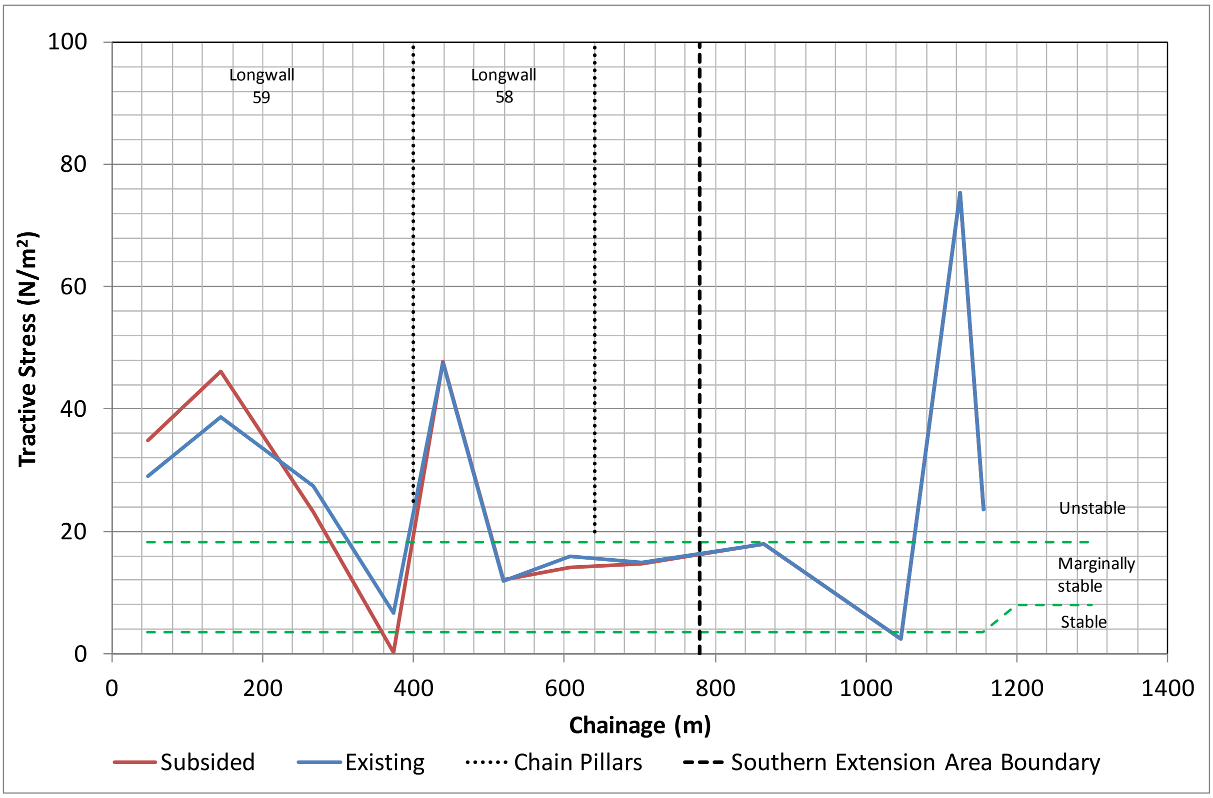



**Chart 4.10 - Wyee Creek (Watercourse 1) - Modelled Tractive Stress**

### Wyee Creek (Watercourse 2)

The modelled approximate bank full (identified by modelling as the two year ARI design storm event) velocity and tractive stress within middle branch of Wyee Creek (Watercourse 2) (refer to **Figure 3.2**) for the existing landform and predicted subsided landform are presented in **Charts 4.11** and **4.12**. These charts also include indicative stability thresholds and the approximate location of the proposed longwalls and the boundary of the Southern Extension Area.

From **Charts 4.11** and **4.12**, it can be seen that there is little difference in the modelled bank full velocities and tractive stresses for Watercourse 2 when comparing the existing landform and predicted subsided landform, with no predicted increase in the estimated stability categories throughout the modelled section. The only predicted change in stability category within the modelled section of Watercourse 2 is a decrease in the tractive stress stability category at the chainage of approximately 370 metres (refer to **Chart 4.12**). At this point, the modelled bank full flows are estimated to change from *marginally stable* under the existing conditions, to *stable* as a result of the predicted subsidence.

As there are no increases in stability categories indicated by the modelling no specific monitoring points have been identified for Watercourse 2.

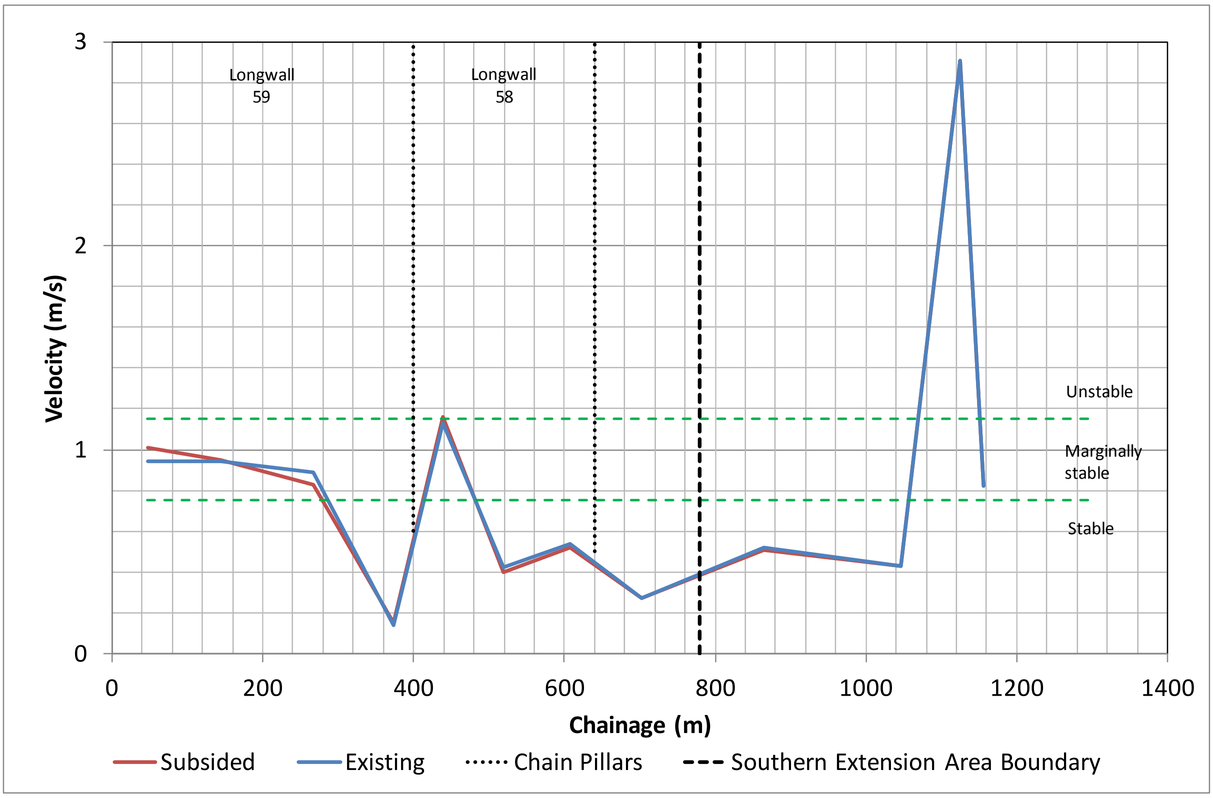



**Chart 4.11 - Wyee Creek (Watercourse 2) - Modelled Velocity**

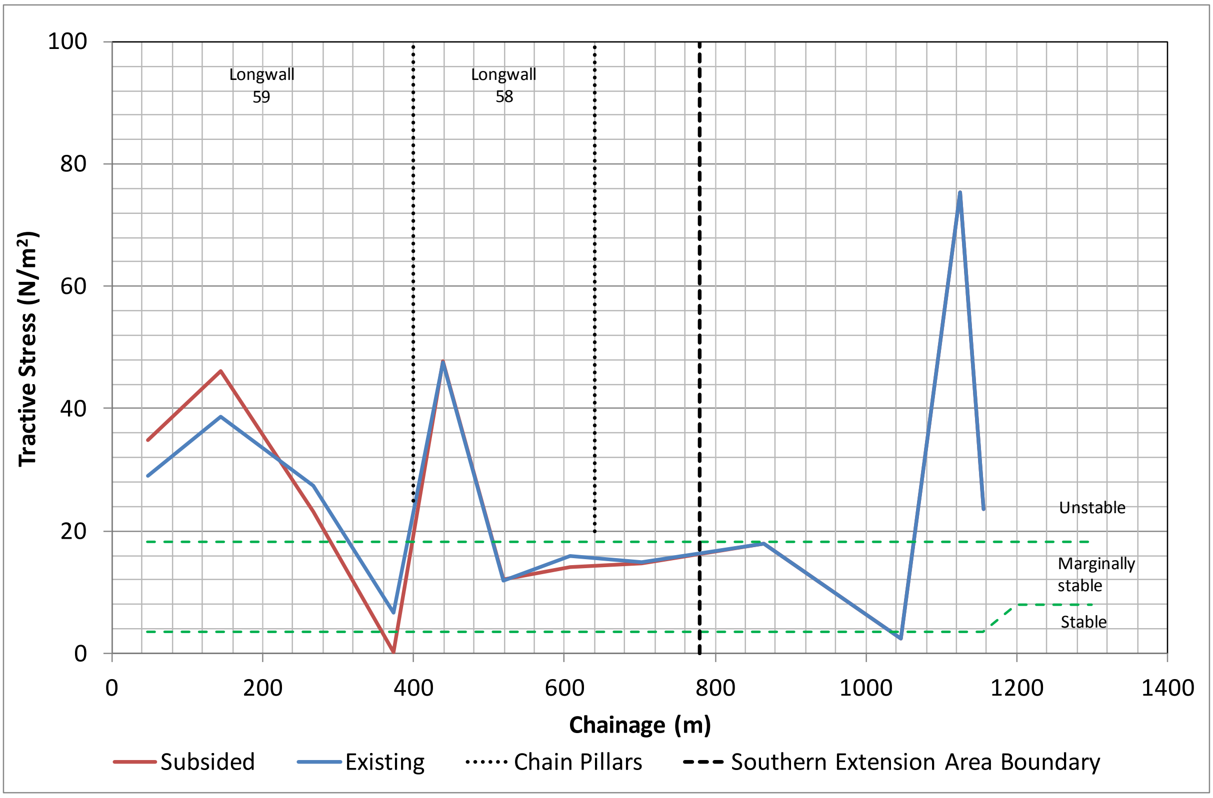



**Chart 4.12 - Wyee Creek (Watercourse 2) - Modelled Tractive Stress**

## Wyee Creek (Watercourse 3)

The modelled approximate bank full (identified by modelling as the two year ARI design storm event) velocity and tractive stress within the southern branch of Wyee Creek (Watercourse 3) (refer to **Figure 3.2**) for the existing landform and predicted subsided landform are presented in **Charts 4.13** and **4.14**. These charts also include indicative stability thresholds and the approximate location of the proposed longwalls, and the boundary of the Southern Extension Area.

From **Charts 4.13** and **4.14**, it can be seen that there is little difference in the modelled bank full velocities and tractive stresses for Watercourse 3 when comparing the existing landform and predicted subsided landform. Estimated increases in instability, both in terms of velocity and tractive stress, are identified at approximate chainage 550 metres (refer to **Charts 4.13** and **4.14**). At approximately 550 metres, the modelling indicates that the estimated velocity stability category is estimated to increase from *marginally stable* to *unstable* as a result of the predicted subsidence (refer to **Charts 4.13**), whilst the estimated tractive stress category is likely to increase from *stable* to *unstable* (refer to **Charts 4.14**). It is therefore likely that ongoing monitoring will be required and potential mitigation works may be necessary at this location. The location of the proposed monitoring points are included on **Figure 4.1**. If required, erosion protection measures may be necessary to limit scouring of the bed and banks of the watercourse (refer to **Section 4.5**).

The locations where the modelling indicates an increase in stability category correlate with the locations identified by the longitudinal grade changes in **Chart 4.2**.

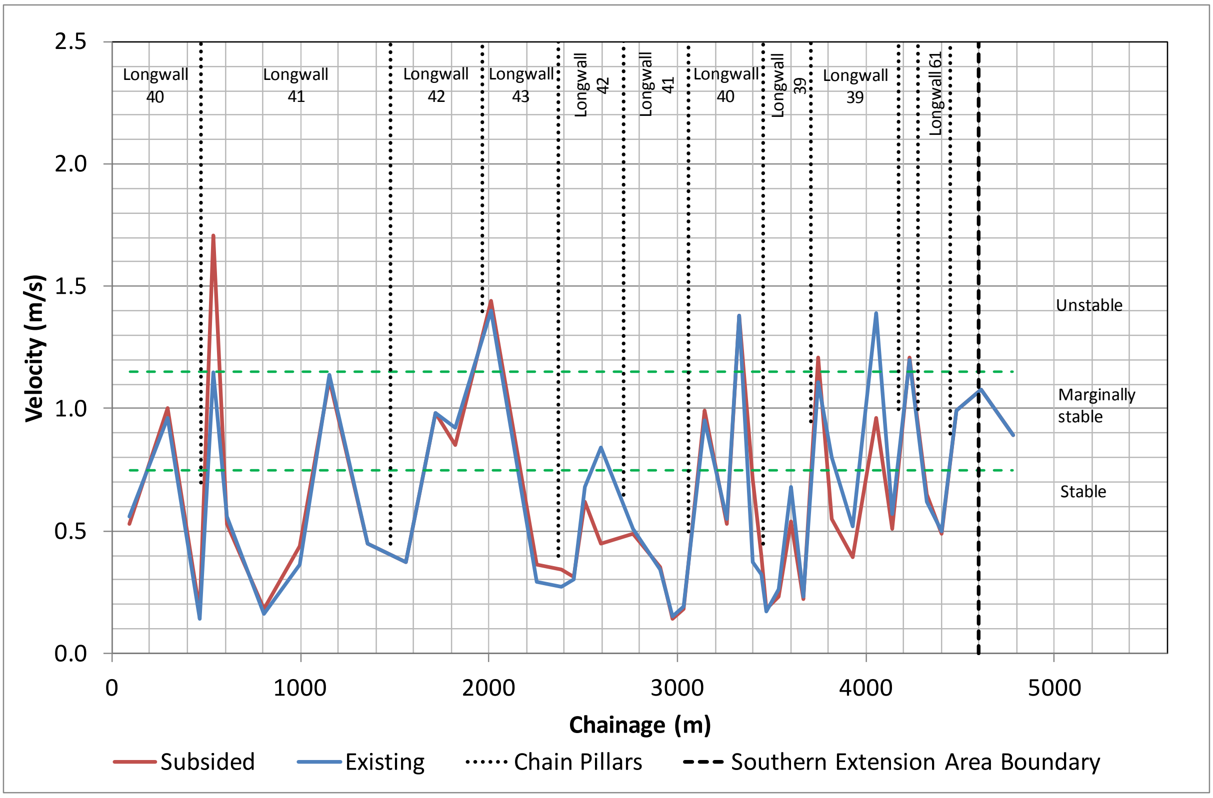



**Chart 4.13 - Wyee Creek (Watercourse 3) - Modelled Velocity**

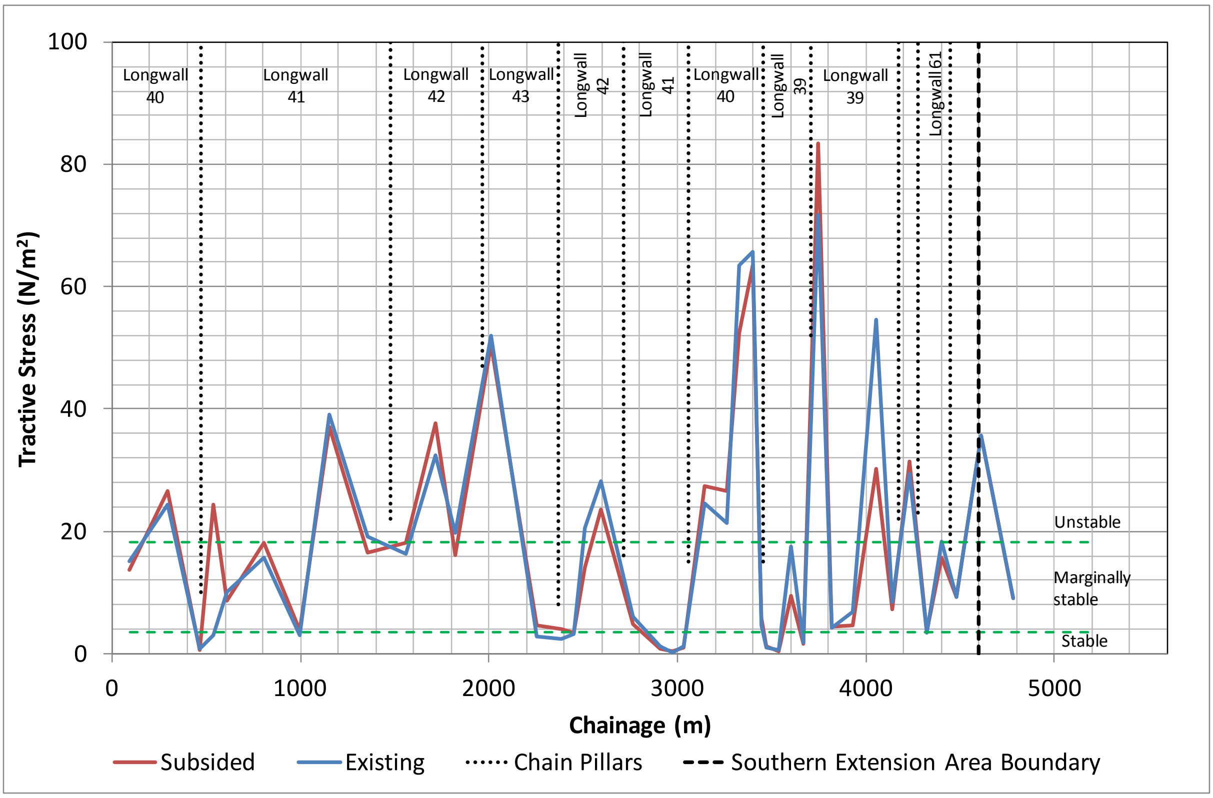



**Chart 4.14 - Wyee Creek (Watercourse 3) - Modelled Tractive Stress**

#### 4.2.2.3 Mannering Creek (Watercourse 4)

The modelled approximate bank full (for Mannering Creek identified as the two year ARI design storm event) velocity and tractive stress within Mannering Creek (Watercourse 4) (refer to **Figure 3.2**) for the existing landform and predicted subsided landform are included in **Charts 4.15** and **4.16**. These charts also include indicative stability thresholds and the approximate location of the proposed longwalls and the edge of the Project Area.

From **Charts 4.15** and **4.16**, it can be seen that there is little difference in the modelled bank full velocities and tractive stresses for Watercourse 4. Estimated increases in instability, in terms of tractive stress, were identified at approximately 1700 (refer to **Chart 4.16**). Modelling indicates that at approximately 1100 metres the tractive stress category will increase from *stable to marginally stable* (refer to **Chart 4.16**). It is therefore likely that mitigation works (i.e. erosion protection / bank stabilisation) will be required at this location in addition to proposed monitoring at the locations shown on **Figure 4.1** and discussed in **Section 5.0**.

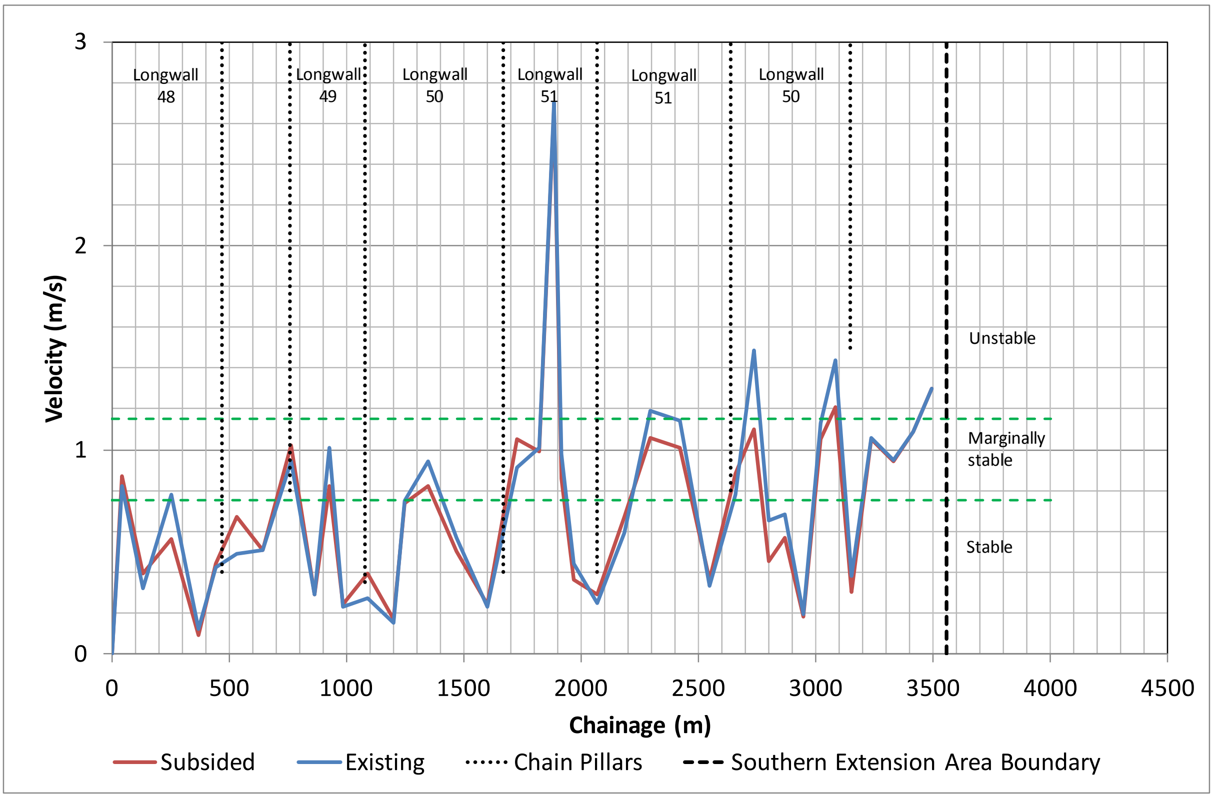



**Chart 4.15 - Mannering Creek (Watercourse 4) - Modelled Velocity**

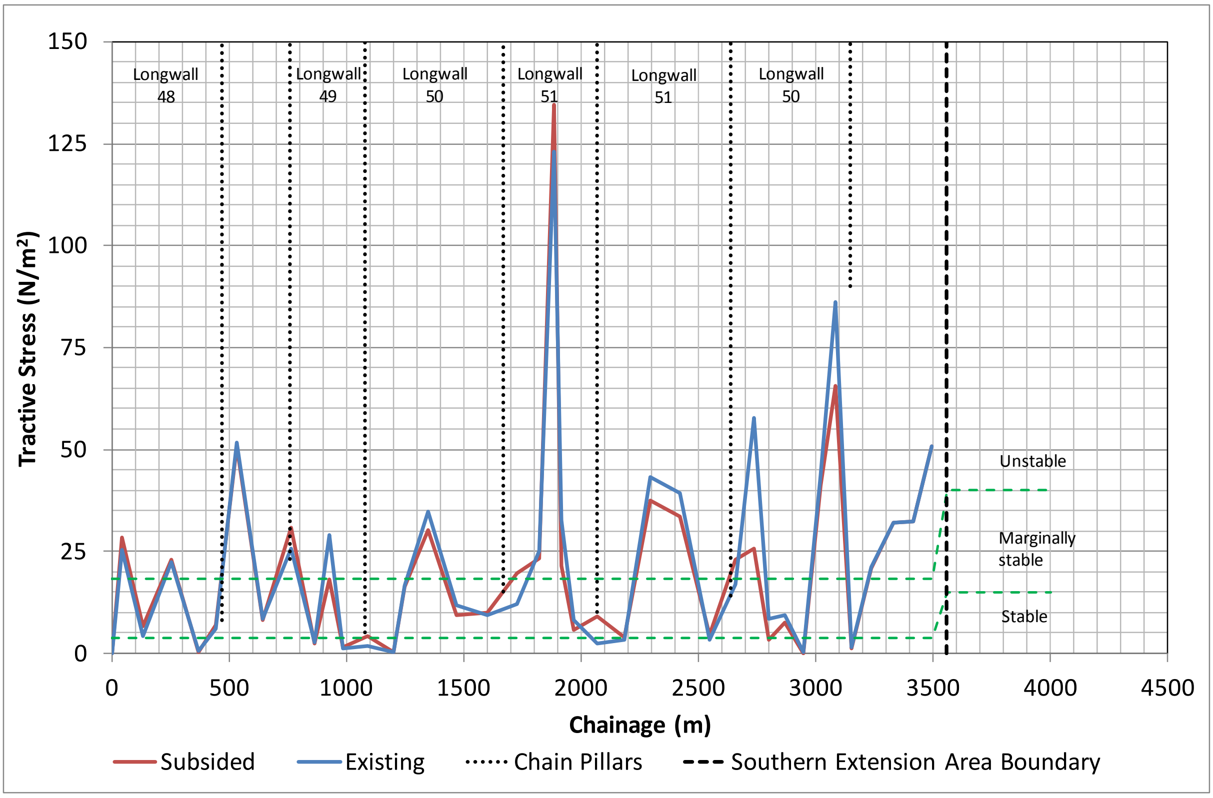



**Chart 4.16 - Mannering Creek (Watercourse 4) - Modelled Tractive Stress**

### 4.2.2.4 Buttonderry Creek (Watercourse 5)

The modelled approximate bank full (for Buttonderry Creek identified as the two year ARI design storm event) velocity and tractive stress within Buttonderry Creek (Watercourse 5) (refer to **Figure 3.2**) for the existing landform and predicted subsided landform are presented in **Charts 4.17** and **4.18**. These charts also include indicative stability thresholds and the approximate location of the proposed longwalls and the boundary of the Southern Extension Area.

From **Charts 4.17** and **4.18**, it is evident that there is almost no difference in the modelled bank full velocities and tractive stresses for Watercourse 5 when comparing the existing landform to the predicted subsided landform. As such no specific monitoring points have been identified for Buttonderry Creek.

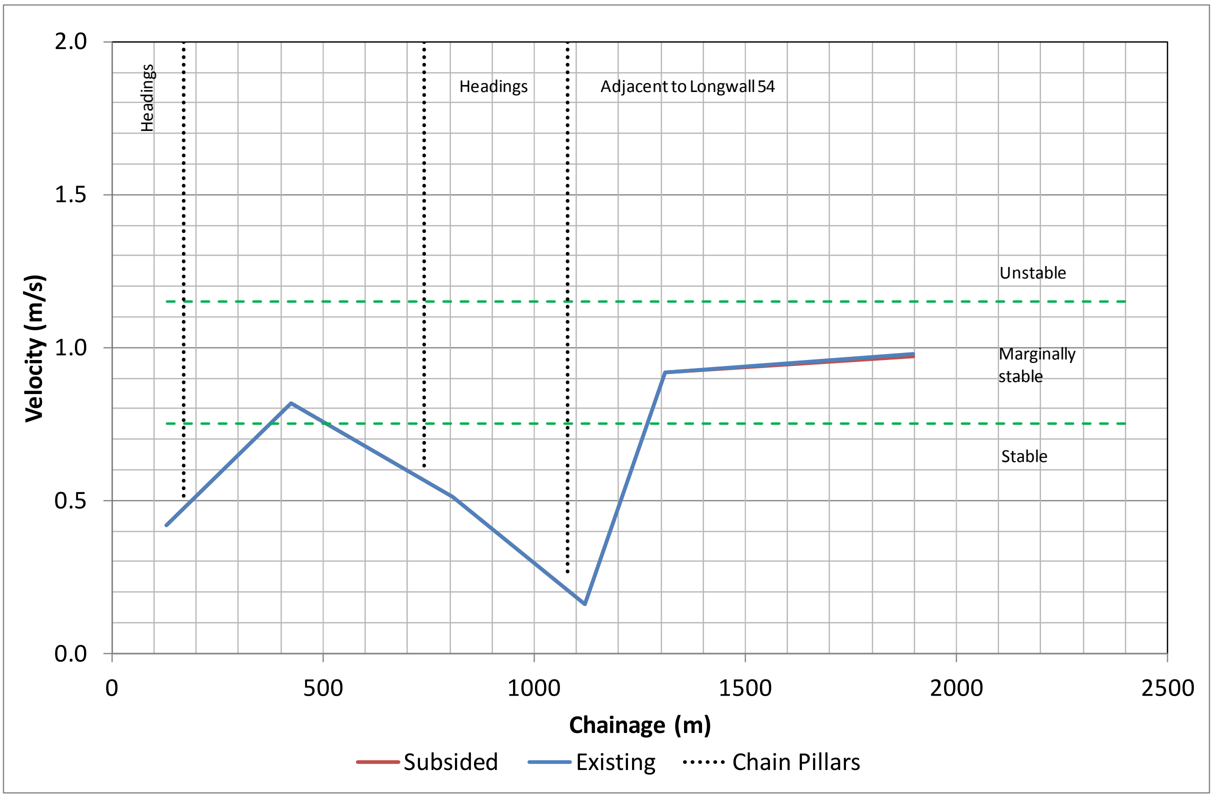



**Chart 4.17 - Buttonderry Creek (Watercourse 5) - Modelled Velocity**

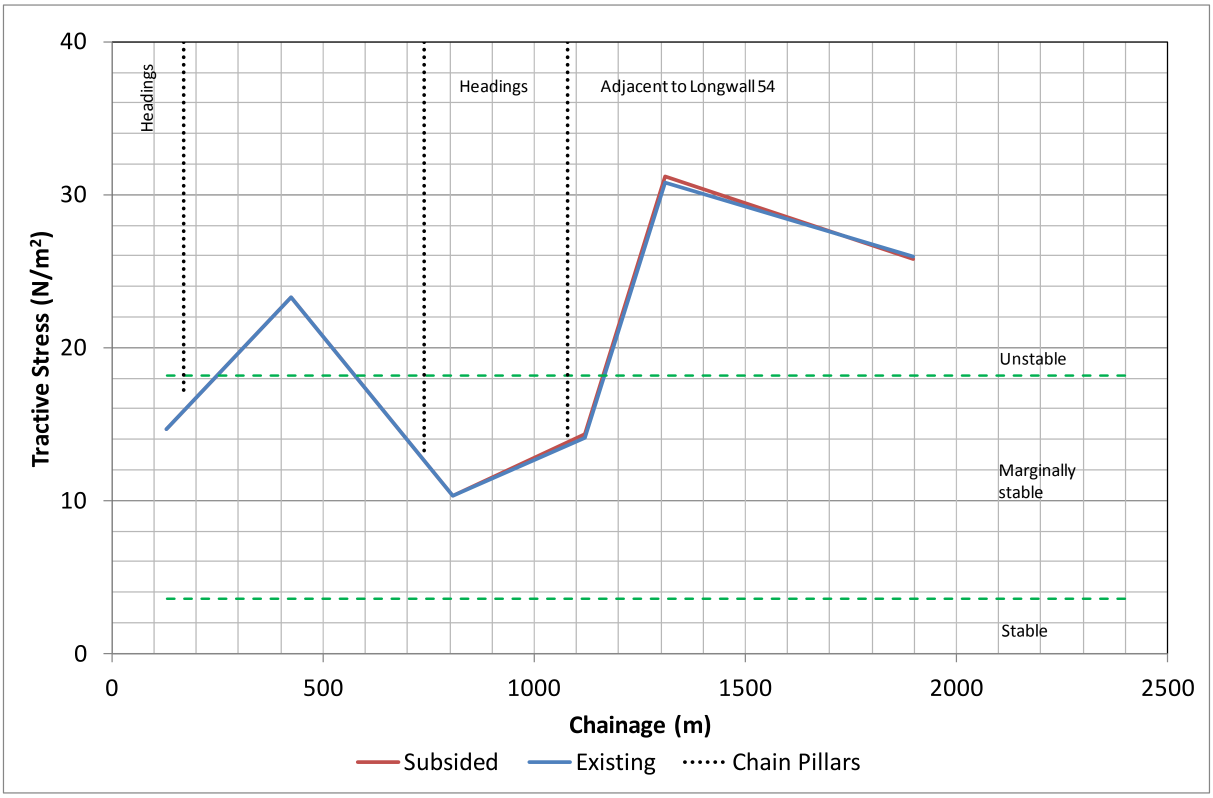



**Chart 4.18 - Buttonderry Creek (Watercourse 5) - Modelled Tractive Stress**

### 4.2.3 Summary of Watercourse Stability Impacts

The analysis of the watercourse longsections and modelled velocities and tractive stresses indicates that within:

- Morans Creek there is a potential for:
  - minimal change in modelled scouring of bed and banks with the exception of sections where longitudinal grade of the creek bed increases as a result of the predicted subsidence (e.g. in the vicinity of Longwall 25);
  - drainage mitigation works to be undertaken, if increases in remnant ponding are identified during subsidence monitoring (refer to **Section 5.2**); and
  - watercourse stabilisation works to be undertaken, if increased bed and bank scouring is observed during subsidence monitoring (refer to **Section 5.2**).
- Wyee Creek there is a potential for:
  - increased potential for scouring within Watercourse 3 are expected as a result of the predicted subsidence;
  - drainage mitigation works to be undertaken, if increases in remnant ponding are identified during subsidence monitoring (refer to **Section 5.2**); and
  - watercourse stabilisation works to be undertaken, if increased bed and bank scouring is observed during subsidence monitoring (refer to **Section 5.2**).
- Mannering Creek there is a potential for:
  - minimal change in the modelled scouring of watercourse bed and banks, however some sections within Mannering Creek are expected to have increased longitudinal grades as a result of the predicted subsidence;
  - drainage mitigation works to be undertaken, if increases in remnant ponding are identified during subsidence monitoring (refer to **Section 5.2**); and
  - watercourse stabilisation works to be undertaken, if increased bed and bank scouring is observed during subsidence monitoring (refer to **Section 5.2**).
- Buttonderry Creek there is a potential for:
  - no expected change in the modelled scouring of watercourse bed and banks.

## 4.3 Remnant Ponding

Predicted subsidence impacts resulting from the Project have the potential to affect remnant ponding in Morans Creek, Wyee Creek, Buttonderry Creek, Mannering Creek and Jilliby Creek catchments.

Analysis of remnant ponding for the current conditions (i.e. pre-mining) indicates that remnant ponding, that occurs after prolonged rainfall and/or flooding, is typically confined to existing flow paths (refer to **Figure 4.2**), in particular:

- Morans Creek - increased remnant ponding in the vicinity of Longwalls 25 and 25;
- Wyee Creek:
  - increased remnant ponding in the vicinity of Longwalls 56 and 57 within Watercourse 1; and
  - increased remnant ponding in the vicinity of Longwall 38 within Watercourse 3.

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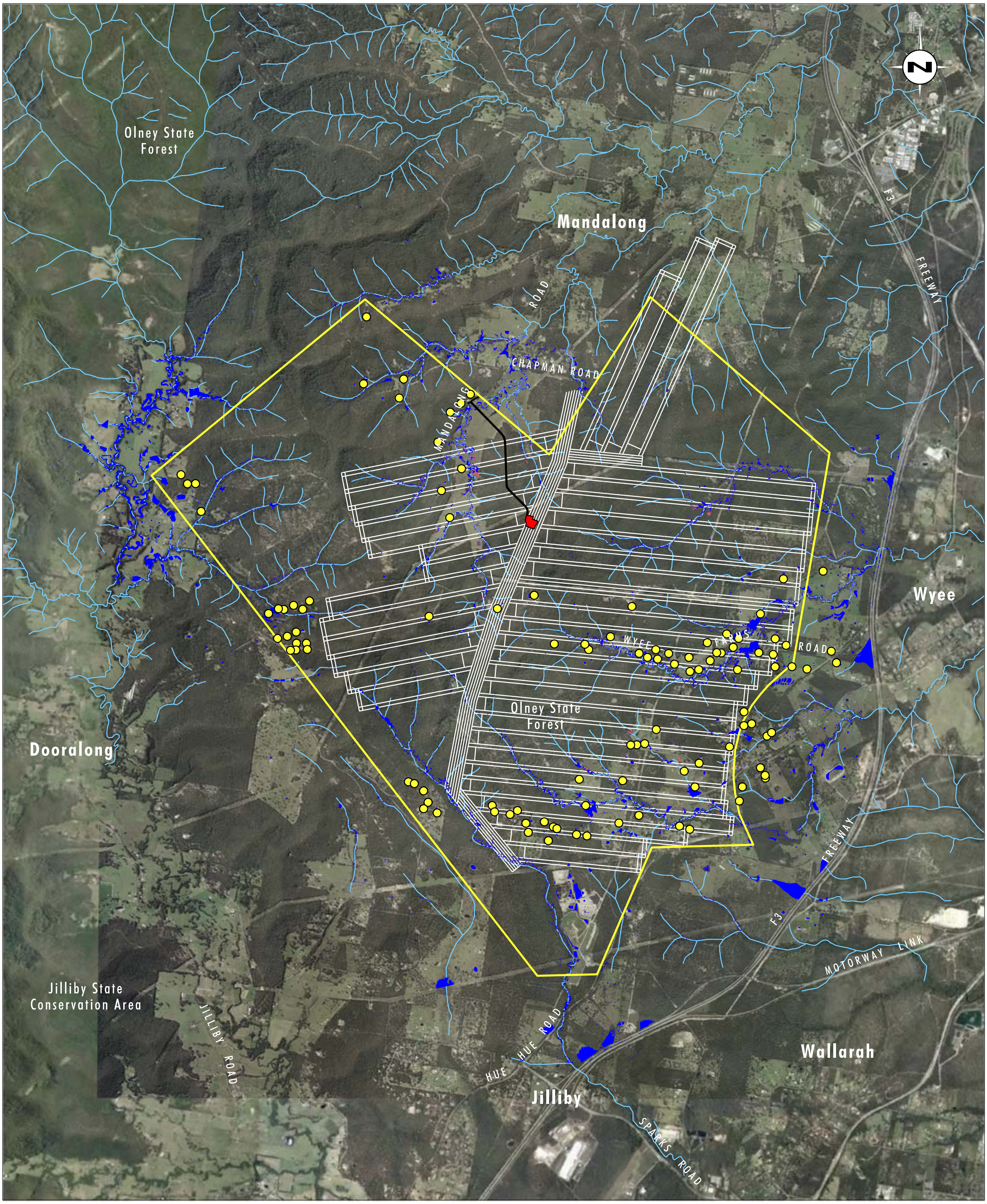


**Source:** Centennial Mandalong (2012) - Aerial Photograph, LPI - Hydrolines
**Note:** Ponding areas only shown within extent of LIDAR based DTM

0 1 2 3km
1:70 000

## Legend

- Southern Extension Area
- Proposed Surface Infrastructure
- Proposed Longwalls
- Proposed Access Road
- Drainage Line
- Dwellings
- Pre Mining Remnant Ponding
- Post Mining (P16) Remnant Ponding

FIGURE 4.2

**Remnant Ponding**

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20121218 13.47

- Mannering Creek - increased remnant ponding in the vicinity of Longwall 50.

Analysis indicates that the remnant ponding area for the current conditions is approximately 182 hectares. An assessment of the predicted subsided landform indicates negligible changes to the remnant ponding in the area to be undermined are likely (refer to **Figure 4.2**) with an increase in remnant ponding area of 3.6 hectares predicted (i.e. an increase of less than 2 per cent). The analysis indicates that potential impacts on remnant ponding are confined to existing flow paths and paddocks, with no predicted impact on access routes to, or within, properties (and residences) within the Southern Extension Area.

The largest potential increase to remnant ponding is predicted to occur within the upstream reaches of the Morans Creek and Mannering Creek catchments (refer to **Figure 4.2**). At these locations, local drainage works may be required to alleviate the increased ponding (refer to **Section 4.5**).

The locations of the proposed monitoring points for potential changes in remnant ponding are included in **Figure 4.1** and discussed in **Section 5.0**.

## 4.4 Flood Regimes

Changes to the flood regimes (flood response) of the Southern Extension Area and surrounds are a potential consequence of the predicted subsidence and proposed infrastructure. This section presents the results of flood modelling and potential impacts as a result of the Project. The modelling methods used are outlined in **Appendix 1**.

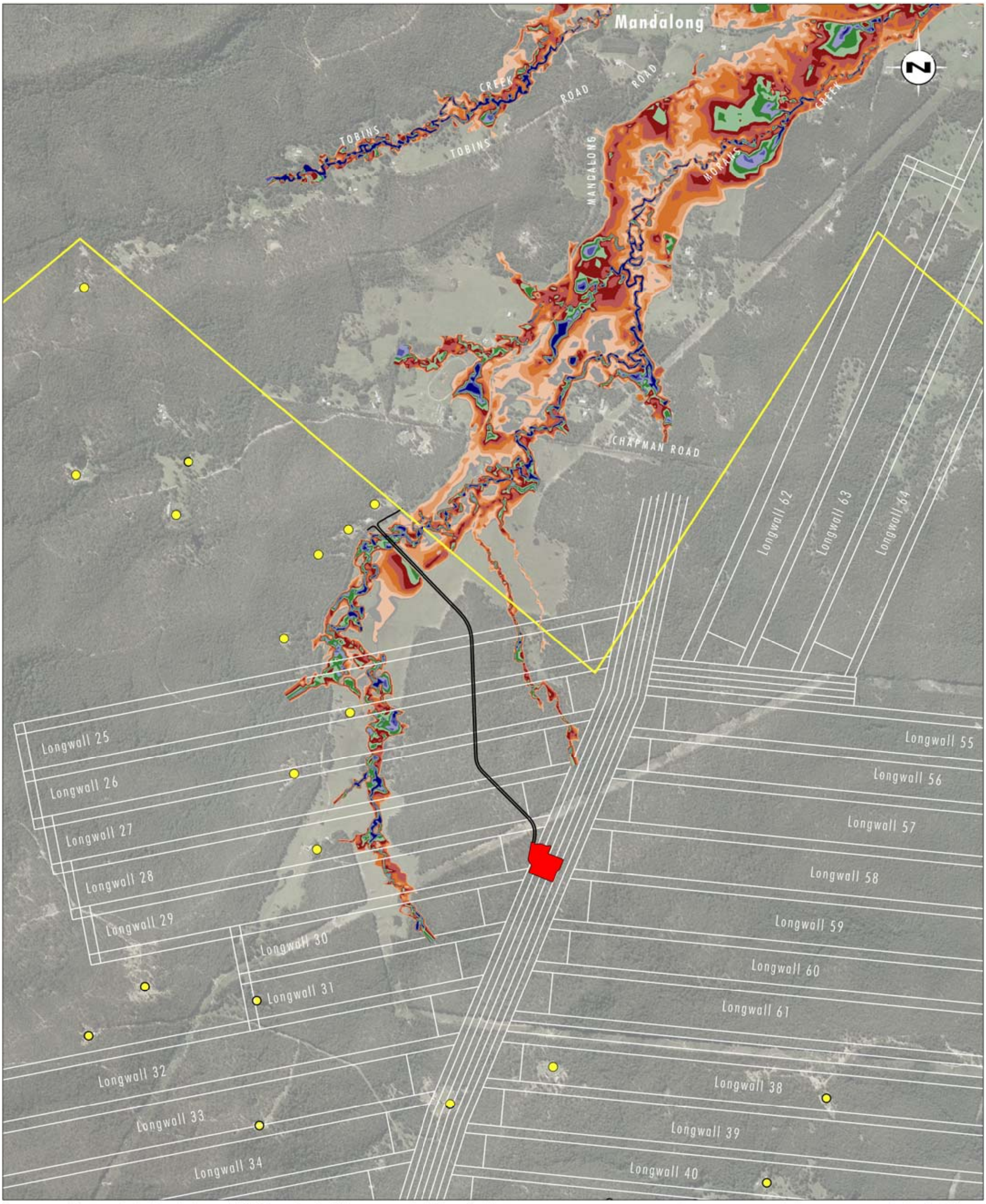
The potential impacts of the predicted subsidence on the flood regimes of the watercourses within the Southern Extension Area were assessed using the potential changes in both maximum flood depths and flood hazard categories (DIPNR 2005) (refer to **Appendix 1**). The modelled flood regimes of the Southern Extension Area for the predicted subsided landform were compared to the modelled flood regimes of the existing conditions within Morans Creek, Wyee Creek, Mannering Creek and Buttonderry Creek (refer to **Section 3.4**).

The maximum modelled flood depths for the 100 year ARI storm event for the existing conditions in Morans Creek are shown in **Figure 3.4**, with those for Wyee Creek, Mannering Creek and Buttonderry Creek shown in **Figure 3.5.**

**Figure 4.3** shows the maximum modelled flood depths for the 100 year ARI design storm event for the subsided conditions in Morans Creek and **Figure 4.4** shows the maximum modelled flood depths for the one year ARI design storm event for the subsided conditions in Morans Creek. **Figure 4.5** shows the maximum modelled flood hazard categories within Morans Creek for the 100 year ARI design storm event.

**Figure 4.6** shows the maximum modelled flood depths for the 100 year ARI design storm event for the predicted subsided landform in the three modelled branches of Wyee Creek, Mannering Creek and Buttonderry Creek within the Southern Extension Area.

Comparing the modelled flood response for the predicted subsided landform to that of the existing conditions (indicates that for the 100 year ARI design storm event (refer to **Figure 3.5**), maximum modelled flood depths increase by a maximum of between 0.1 metre and 0.4 metre. These increases are primarily contained within the main flow channels of the watercourses. Further detailed analyses of the modelled flood regime impacts are included in **Sections 4.4.1** to **4.4.4**.




**Source:** Centennial Mandalong (2012) - Aerial Photograph, LPI - Cadastre

0 0.5 1.0 1.25km
1:25 000

**Legend**
- Southern Extension Area
- Proposed Surface Infrastructure
- Proposed Longwalls
- Proposed Access Road
- Dwellings

**Water Depth (metres)**
- Range [0.001 : 0.100]
- Range [0.100 : 0.300]
- Range [0.300 : 0.500]
- Range [0.500 : 0.700]
- Range [0.700 : 0.900]
- Range [0.900 : 1.100]
- Range [1.100 : 1.300]
- Range [1.300 : 1.500]
- Range [1.500 : 1.700]
- Range [1.700 : 1.900]
- Range [>1.900]

FIGURE 4.3

**100 year ARI Storm Event
Maximum Flood Depths for Morans Creek,
(Subsided Landform)**

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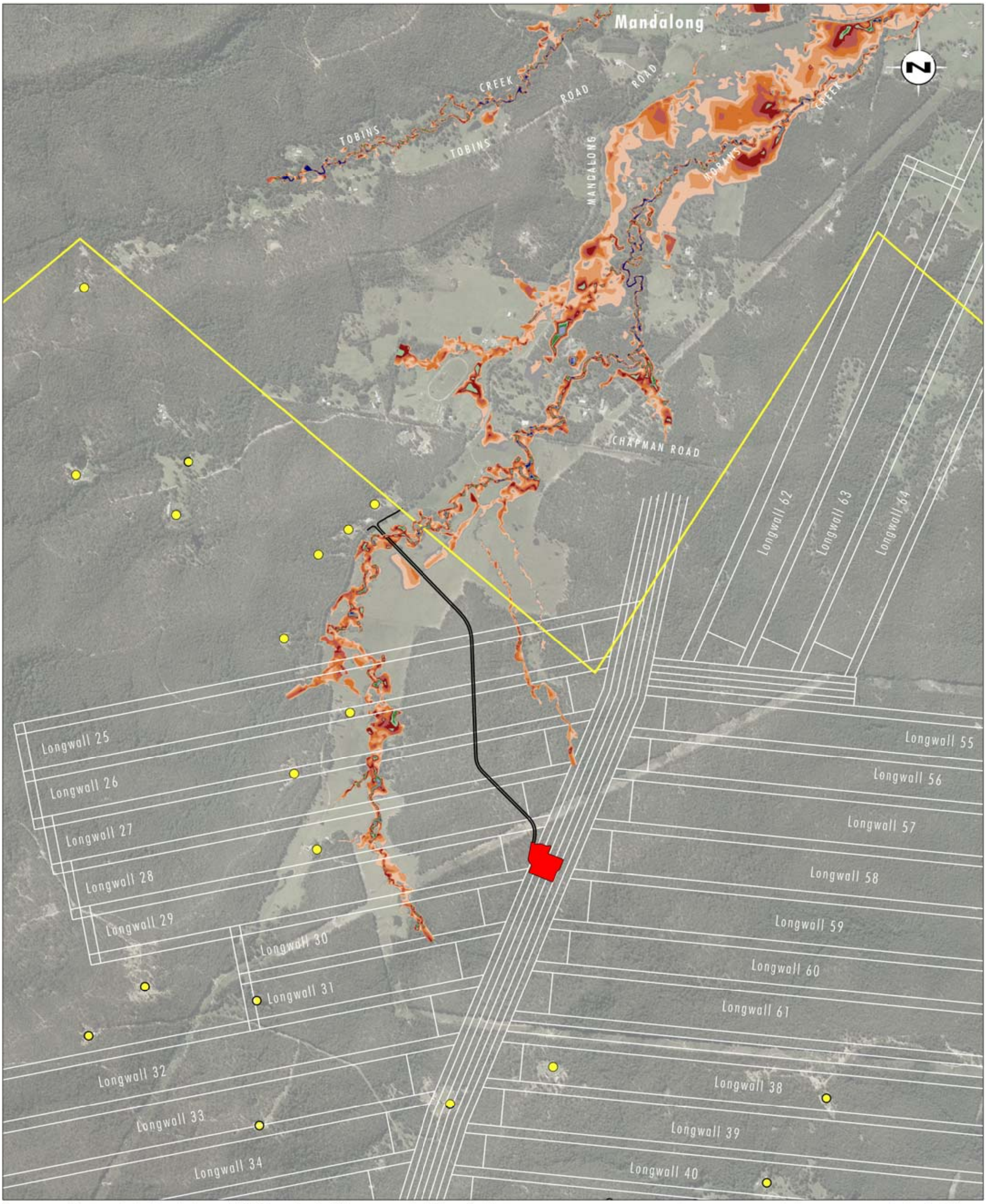


Source: Centennial Mandalong (2012) - Aerial Photograph, LPI - Cadastre

0 0.5 1.0 1.25km
1:25 000

**Legend**

- Southern Extension Area
- Proposed Surface Infrastructure
- Proposed Longwalls
- Proposed Access Road
- Dwellings

**Water Depth (metres)**

- Range [0.001 : 0.100]
- Range [0.100 : 0.300]
- Range [0.300 : 0.500]
- Range [0.500 : 0.700]
- Range [0.700 : 0.900]
- Range [0.900 : 1.100]
- Range [1.100 : 1.300]
- Range [1.300 : 1.500]
- Range [1.500 : 1.700]
- Range [1.700 : 1.900]
- Range [>1.900]

FIGURE 4.4

**1 year ARI Storm Event
Maximum Flood Depths for Morans Creek,
(Subsided Landform)**

File Name (A4): R01/2943_025.dgn
20121214 9.38

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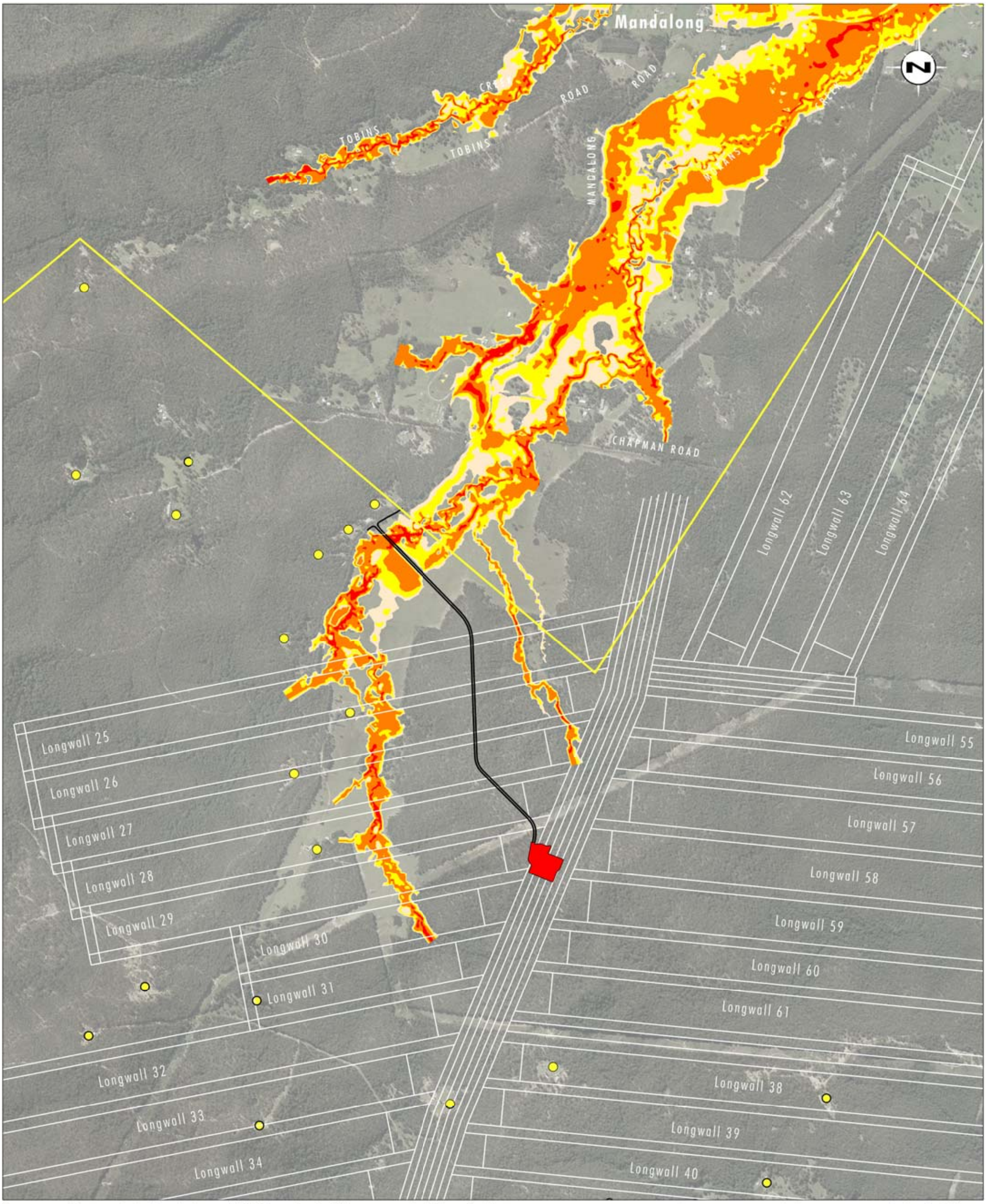



Source: Centennial Mandalong (2012) - Aerial Photograph, LPI - Cadastre

0 0.5 1.0 1.25km
1:25 000

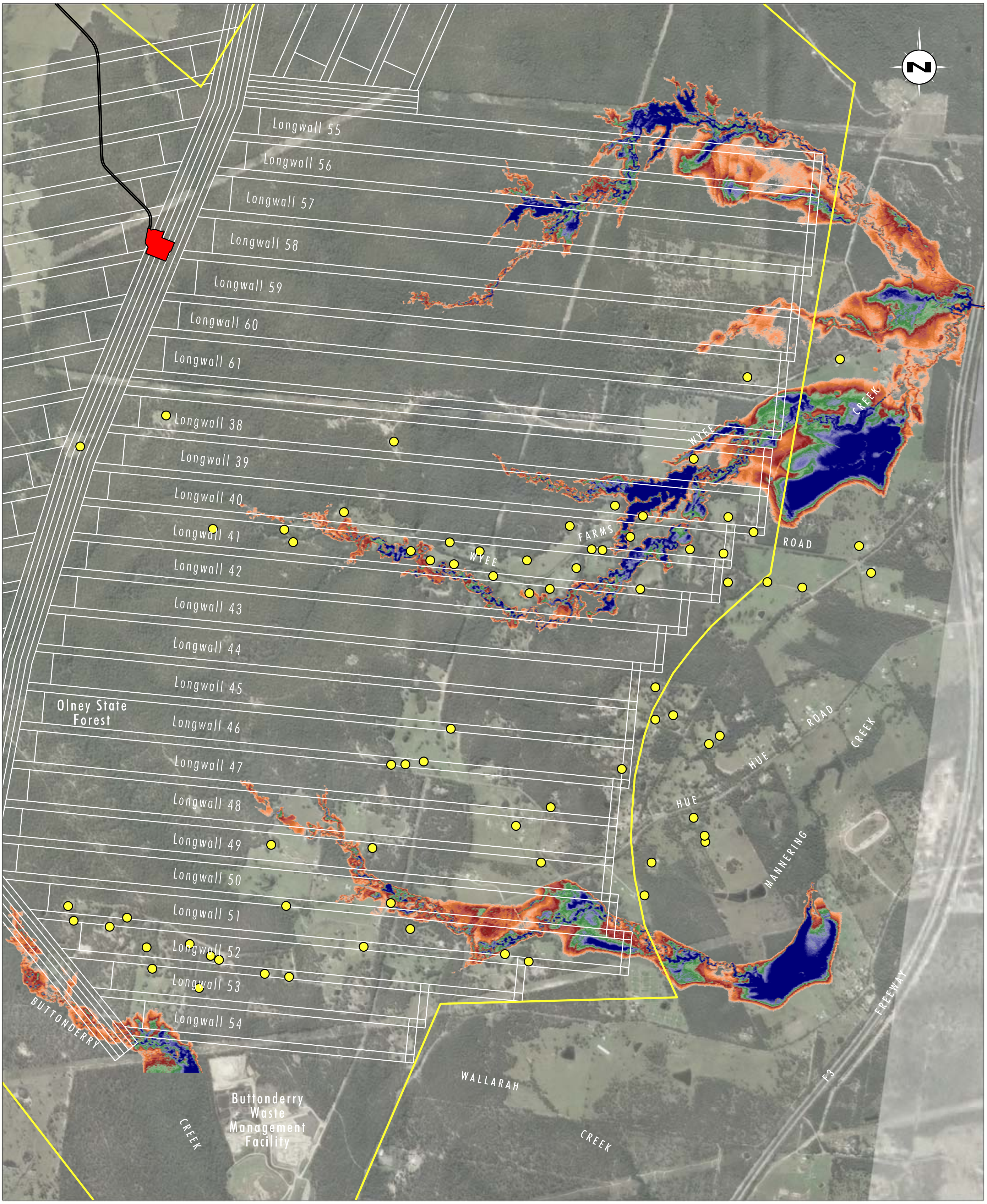
**Legend**
- Southern Extension Area
- Proposed Surface Infrastructure
- Proposed Longwalls
- Proposed Access Road
- Dwellings

**Hazard Category**
- Low Hazard - Uncalssified hazard
- Low Hazard - Vehicles unstable
- High Hazard - Wading unsafe
- High Hazard - Damage to light structures

FIGURE 4.5

100 year ARI Storm Event
Maximum Hazard for Morans Creek,
(Subsided Landform)

File Name (A4): R01/2943_029.dgn
20121214 9.45




Source: Centennial Mandalong (2012) - Aerial Photograph, LPI - Cadastre

0 0.5 1.0 1.5km
1:30 000

## Legend

- Southern Extension Area
- Proposed Surface Infrastructure
- Proposed Longwalls
- Proposed Access Road
- Dwellings

## Water Depth (metres)

- Range [0.001 : 0.100]
- Range [0.100 : 0.300]
- Range [0.300 : 0.500]
- Range [0.500 : 0.700]
- Range [0.700 : 0.900]
- Range [0.900 : 1.100]
- Range [1.100 : 1.300]
- Range [1.300 : 1.500]
- Range [1.500 : 1.700]
- Range [1.700 : 1.900]
- Range [>1.900]

FIGURE 4.6

**100 year ARI Storm Event
Maximum Flood Depths for Wyee Creek, Mannering Creek and Buttonderry Creek (Subsided Landform)**

File Name (A4): R01/2943_028.dgn
20121214 9.43

Comparing the modelled flood extents for the predicted subsided landform (refer to **Figures 4.3** and **4.6**) to that of the existing conditions (refer to **Figures 3.4** and **3.5**) indicates that for the 100 year ARI design storm event, there is no change expected in the habitability of identified dwellings within the Southern Extension Area in response to the predicted subsidence. The modelling indicates that no dwellings are currently identified as being inside the flood extent for the 100 year ARI design storm event under the existing conditions (refer to **Figures 3.4** and **3.5**) or within the modelled flood extent for the 100 year ARI design storm event for the predicted subsided landform (refer to **Figures 4.3** and **4.4**). However, three residences are close to the 100 ARI design storm event level and will need to be confirmed with actual survey data prior to undermining as part of the Subsidence Management Plan process.

### 4.4.1 Morans Creek

#### Flood Depths

**Chart 4.19** presents the maximum modelled flood depths throughout the modelled section of Morans Creek (Watercourse 6) for the one year and 100 year ARI design storm events. The modelling indicates that, for the 100 year ARI design storm, changes to the maximum modelled flood depths range from approximately 0.1 metre (at approximately 270 metres; in the vicinity of proposed Longwall 29) up to an increase of approximately 0.4 metre (at approximately 1100 metres; upstream of the proposed access road). The modelling also indicates a similar range of changes to the maximum modelled flood depths for other design storm events, including the one year (also illustrated in **Chart 4.19**), 10 year and 20 year ARI design storm events. The maximum modelled increase in flood depths from the predicted subsidence occurs upstream of the proposed access road (refer to **Chart 4.19**). It is important to note that the modelled effects of both the access road (which includes the conceptual Morans Creek crossing) and predicted subsidence are almost undetectable approximately 100 metres downstream of the Southern Extension Area (refer to **Chart 4.19**).

The modelled increases in flood depths (up to 0.38 metre; refer to **Chart 4.19**) result in only minor increases in the maximum flood extent (refer to **Figure 4.3**) for the 100 year ARI design storm event. For the minor storm event (one year ARI design storm event), the modelled increase in flood depths remain predominantly in channel.

The potential impacts of the proposed access road alone (i.e. including the conceptual Morans Creek crossing and with no subsidence upslope) were also assessed. It was found that the increases in maximum modelled flood depth in the vicinity of the proposed access road were approximately 0.36 metre, and are therefore comparable to that shown in **Chart 4.19**.

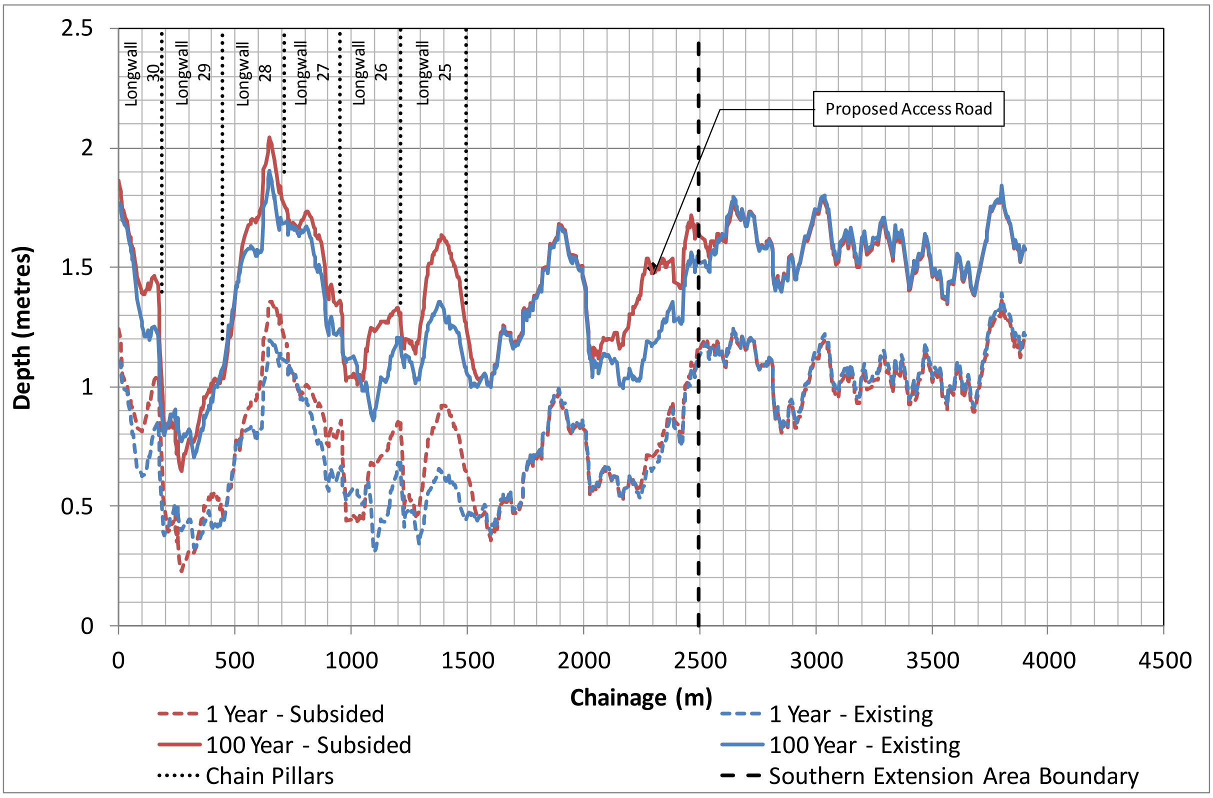



**Chart 4.19 - Morans Creek (Watercourse 6) - Modelled Flood Depths**

## Flood Duration

**Chart 4.20** presents the depth hydrograph for Morans Creek at the northern boundary of the Southern Extension Area. Modelling indicates that despite the increase in the maximum modelled flood depths for the one year and 100 year ARI design storm events (refer to **Chart 4.19**), no changes to the out of channel flood duration are expected, remaining at approximately 4.3 hours for the 100 year ARI design storm event for both the existing and subsided landforms (refer to **Chart 4.20**). This would suggest that the potential for impacts on access to, and agricultural use of, the surrounding land is minimal.

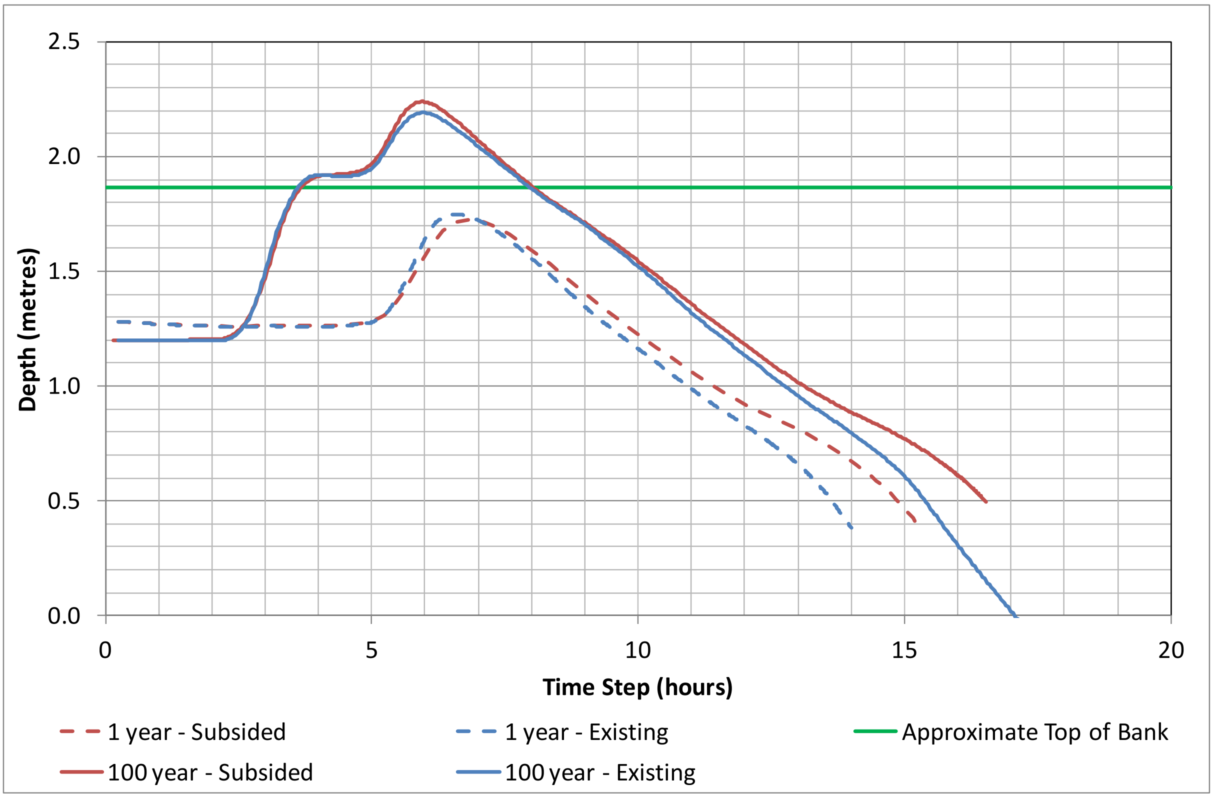



**Chart 4.20 - Morans Creek (Watercourse 6) - Modelled Depth Hydrograph**

### Flood Hazard Categories

The maximum modelled flood hazard category for Morans Creek (Watercourse 6) for the 100 year ARI storm events for the predicted subsided landform are presented in **Figure 4.5**, with the corresponding flood hazard categories for the existing landform illustrated in **Figure 3.5**. As the flood hazard category is determined from a combination of flood depth and velocity, the changes to the flood hazard category between the existing landform and predicted subsided landform are a consequence of the modelled changes to the modelled flood depths (refer to **Figure 4.3**) and velocities (refer to **Chart 4.7**). Comparing the existing landform to predicted subsided landform 100 year ARI design storm event maximum flood hazard categories, it is evident that at some locations increases to the modelled flood hazard category for the 100 year ARI design storm event do occur (refer to **Figure 4.5**). These increases are typically extensions to existing areas of higher flood hazard categories rather than newly created areas of higher flood hazard categories.

The identified dwellings and their access routes within the Southern Extension Area are outside of the modelled flood extent for the 100 year ARI design storm event for both the existing landform and with the predicted subsidence. As such the modelling indicates that the Project (refer to **Figures 3.7** and **4.4**) is unlikely to have significant impacts on the access and habitability of dwellings within the Morans Creek area.

### 4.4.2 Wyee Creek

#### 4.4.2.1 Wyee Creek (Watercourse 1)

#### Flood Depths

**Chart 4.21** presents the maximum modelled flood depths throughout the modelled section of the northern branch of Wyee Creek (Watercourse 1) for the two year (i.e. bank full) and 100 year ARI design storm events. The modelling indicates that, for the 100 year ARI design storm event, changes to the maximum modelled flood depths range from a decrease of approximately 0.3 metre (at 1060 metres). The modelling also indicates a similar range of changes to the maximum modelled flood depth for other design storm events, including the two year (also presented in **Chart 4.21**), 10 year and 20 year ARI design storm events.

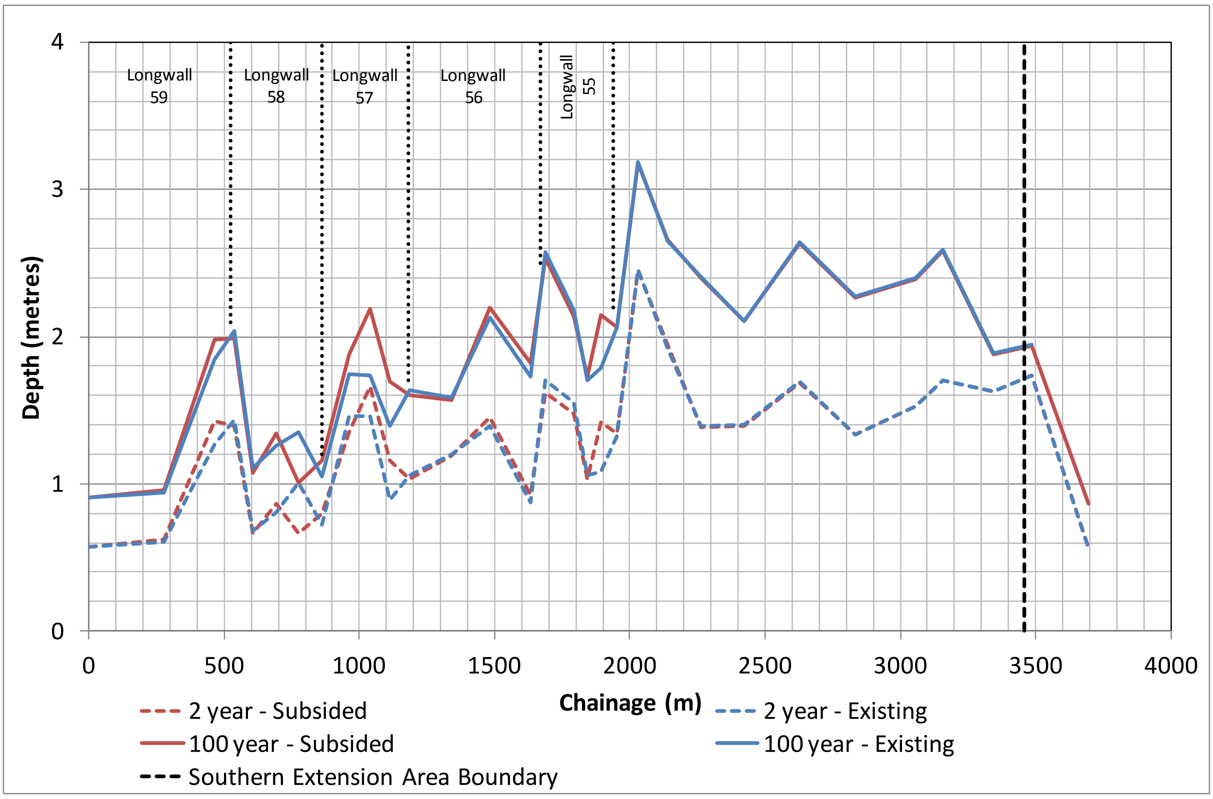



**Chart 4.21 - Wyee Creek (Watercourse 1) - Modelled Flood Depths**

#### Flood Duration

**Chart 4.22** presents the depth hydrograph for Wyee Creek (Watercourse 1) at the eastern boundary of the Southern Extension Area. The modelling indicates that despite the increase in the maximum modelled flood depths for the one year and 100 year ARI design storm events (refer to **Chart 4.21**), changes to the flood duration are relatively minor, decreasing from approximately 4.5 hours to 4.4 hours for the 100 year ARI design storm event as a result of the predicted subsidence, with negligible out of channel impacts (refer to **Chart 4.22**). As such the modelling indicates that the potential for impacts on access to, and agricultural use of, the surrounding land is minimal.

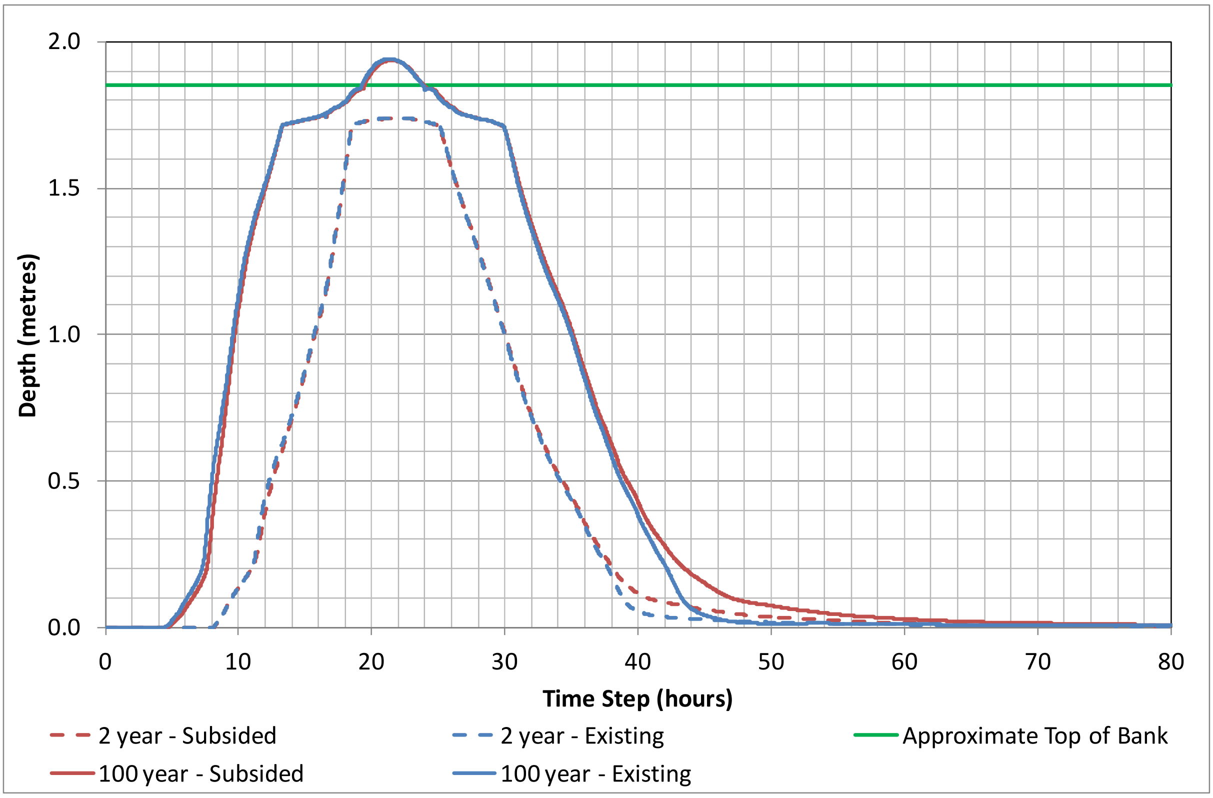



**Chart 4.22 - Wyee Creek (Watercourse 1) - Modelled Depth Hydrograph**

## Flood Hazard Categories

The maximum modelled flood hazard category for the northern branch of Wyee Creek (Watercourse 1) for the two year and 100 year ARI design storm events for both the existing landform and predicted subsided landform are illustrated in **Chart 4.23**. As the flood hazard category is determined from a combination of flood depth and velocity, the changes to the flood hazard category between the existing landform and predicted subsided landforms are a consequence of the modelled changes to the modelled flood depths (refer to **Chart 4.21**) and velocities (refer to **Chart 4.9**). From **Chart 4.23**, it is evident that local increases to the flood hazard category are predicted typically increasing from Category 3 (*wading unsafe*) to Category 4 (*damage to light structures*). These increases are within the upper catchment area of Watercourse 1 (refer to **Figure 4.1**), and are not within the vicinity of any identified dwellings or their access routes.

Modelled changes to the flood hazard categories indicate that there is unlikely to be significant impacts on the access to, and habitability of, dwellings within the Southern Extension Area (refer to **Chart 4.23**).

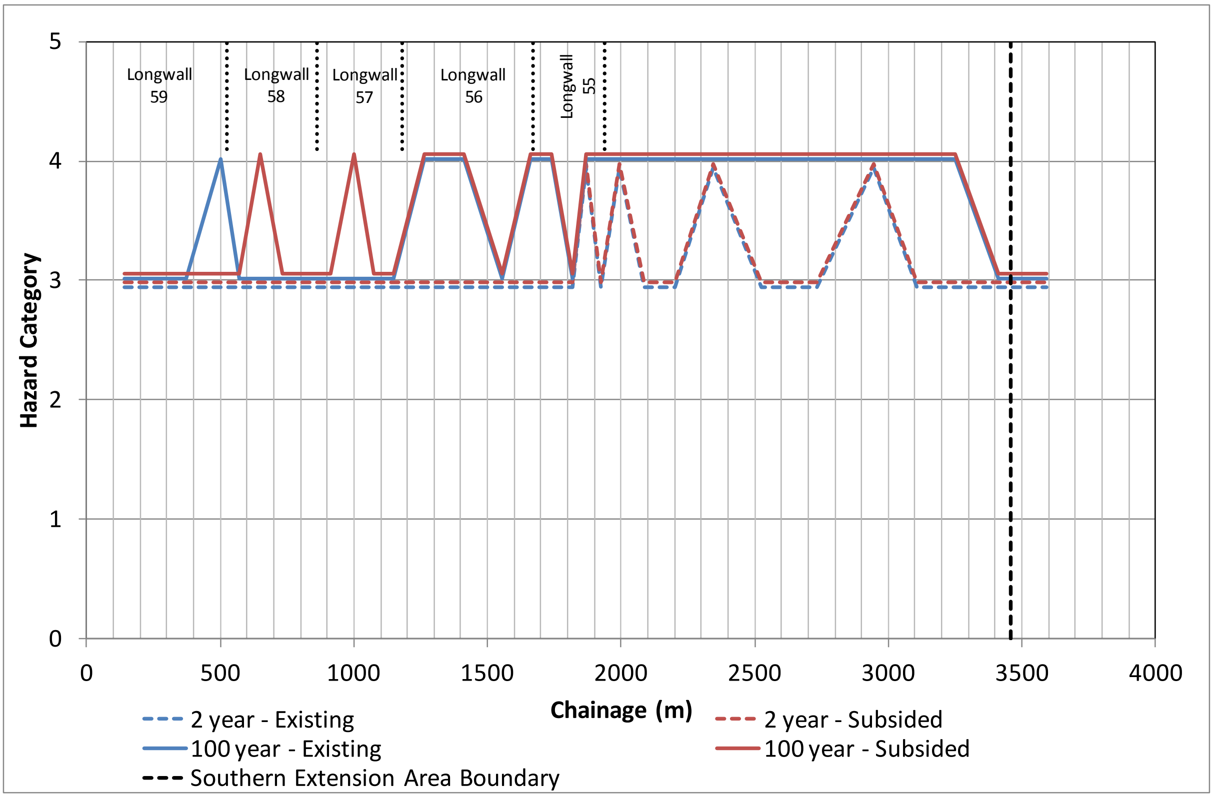



**Chart 4.23 - Wyee Creek (Watercourse 1) - Modelled Hazard Categories**

### 4.4.2.2 Wyee Creek (Watercourse 2)

#### Flood Depths

**Chart 4.24** presents the maximum modelled flood depths for the middle branch of Wyee Creek (Watercourse 2) for the two year (i.e. bank full) and 100 year ARI design storm events. Modelling indicates that for the 100 year ARI design storm event, changes to the maximum modelled flood depths of up to an increase of approximately 0.2 metre (at approximately 340 metres) are possible. The modelling also indicates a similar range of changes to the maximum modelled flood depth for other design storm events, including the two year, 10 year and 20 year ARI design storm events.

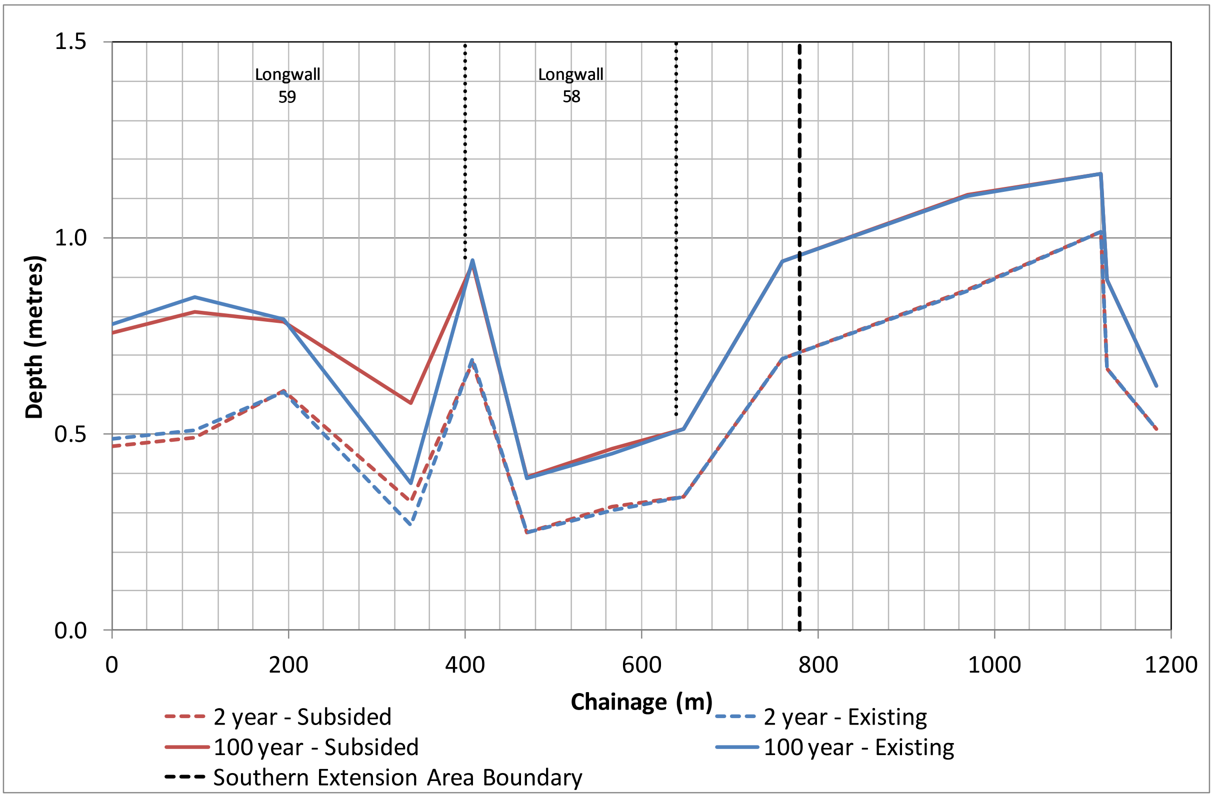



**Chart 4.24 - Wyee Creek (Watercourse 2) - Modelled Flood Depth**

## Flood Duration

**Chart 4.25** shows the depth hydrograph for Wyee Creek (Watercourse 2) at the eastern boundary of the Southern Extension Area. The modelling indicates that despite the increase in the maximum modelled flood depths for the one year and 100 year ARI design storm events (refer to **Chart 4.24**), changes to the flood duration are relatively minor, remaining at approximately 4.3 hours and 14.3 hours for the two year (bank full) and 100 year ARI design storm events respectively (refer to **Chart 4.25**). As such the modelling indicates that the potential for impacts on access to, and agricultural use of, the surrounding land is negligible.

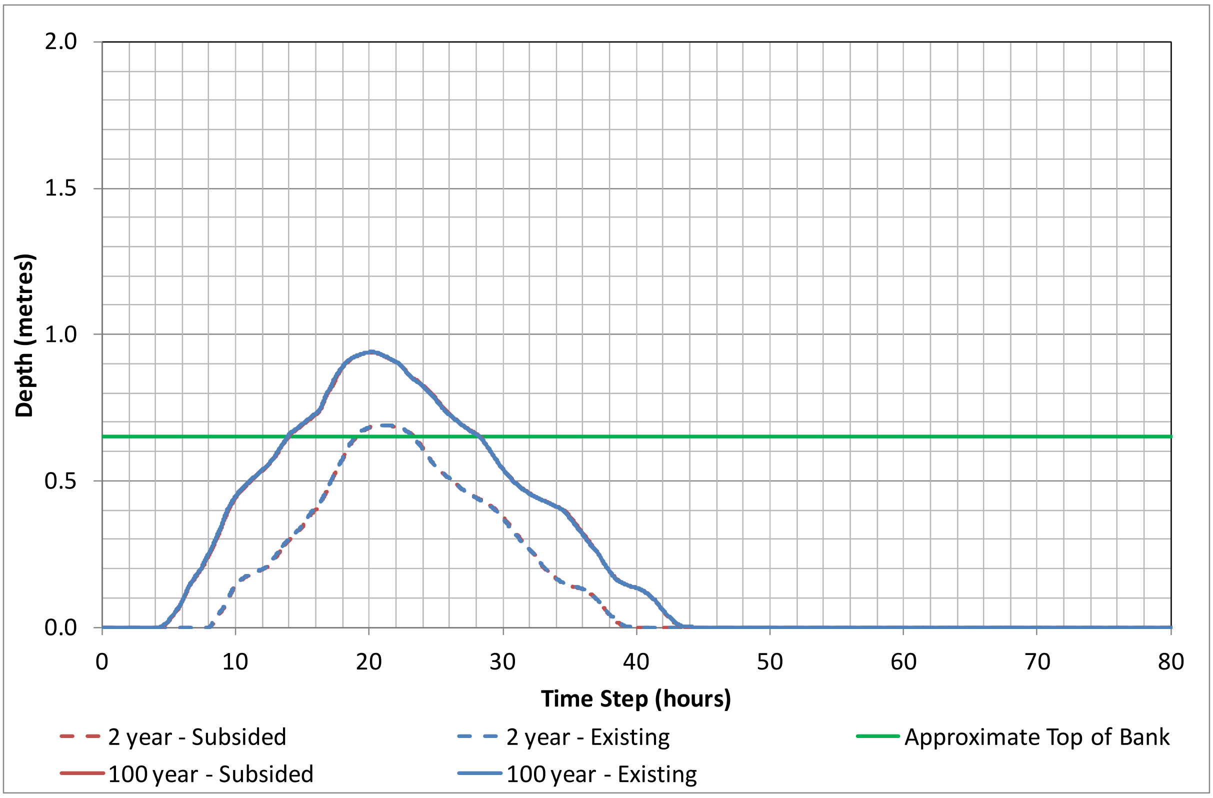



**Chart 4.25 - Wyee Creek (Watercourse 2) - Modelled Depth Hydrograph**

## Flood Hazard Categories

The maximum modelled flood hazard category for the middle branch of Wyee Creek (Watercourse 2) for the two year and 100 year ARI storm events for both the existing landform and predicted subsided landform are presented in **Chart 4.26**. As the flood hazard category is determined from a combination of flood depth and velocity, the changes to the flood hazard category between the existing landform and predicted subsided landform are a consequence of the modelled changes to the modelled flood depths (refer to **Chart 4.24**) and velocities (refer to **Chart 4.11**). From **Chart 4.26**, it is evident that local increases to the flood hazard category are expected, typically increasing from Category 2 (*vehicles unstable*) to Category 3 (*wading unsafe*) for the 100 year ARI storm event. The modelling suggests that these increases are extensions of existing areas of Category 3 flood hazard category.

The modelled changes to the flood hazard categories are not within the vicinity of any identified dwellings or their access routes within the Southern Extension Area. As such the modelling indicates that there is unlikely to be significant impacts on the access to, and habitability of, dwellings within the Southern Extension Area, including Schofield Road (refer to **Chart 4.26**).

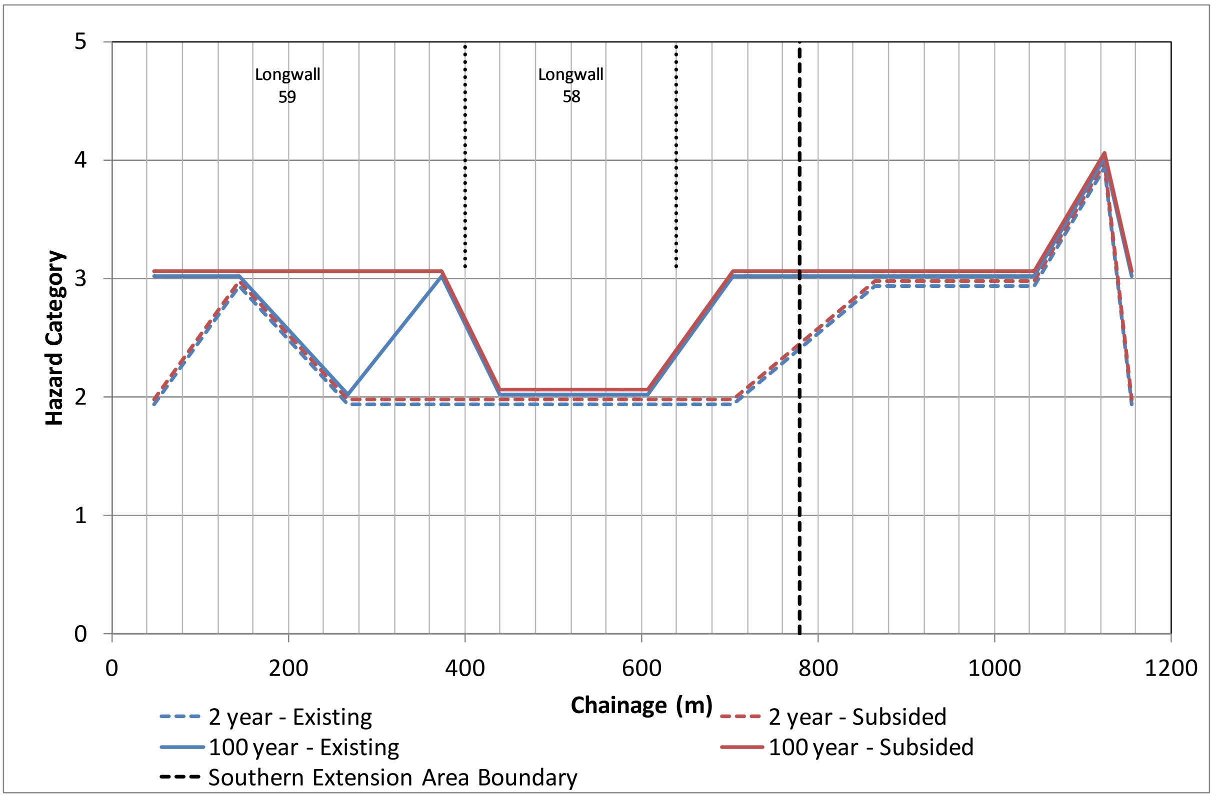



**Chart 4.26 - Wyee Creek (Watercourse 2) - Modelled Flood Hazard Categories**

### 4.4.2.3 Wyee Creek (Watercourse 3)

**Flood Depths**

**Chart 4.27** illustrates the maximum modelled flood depths throughout the modelled section of the southern branch of Wyee Creek (Watercourse 3) for the two year (i.e. bank full) and 100 year ARI design storm events. The modelling indicates that, for the 100 year ARI design storm event, changes to the maximum modelled flood depths range from a decreases of approximately 0.2 metre (at approximately 510 metres and approximately 2300 metres) up to an increase of approximately 0.2 metre (at approximately 3600 metres). The modelling also indicates a similar range of changes to the maximum modelled flood depth for other design storm events, including the two year, 10 year and 20 year ARI design storm events.

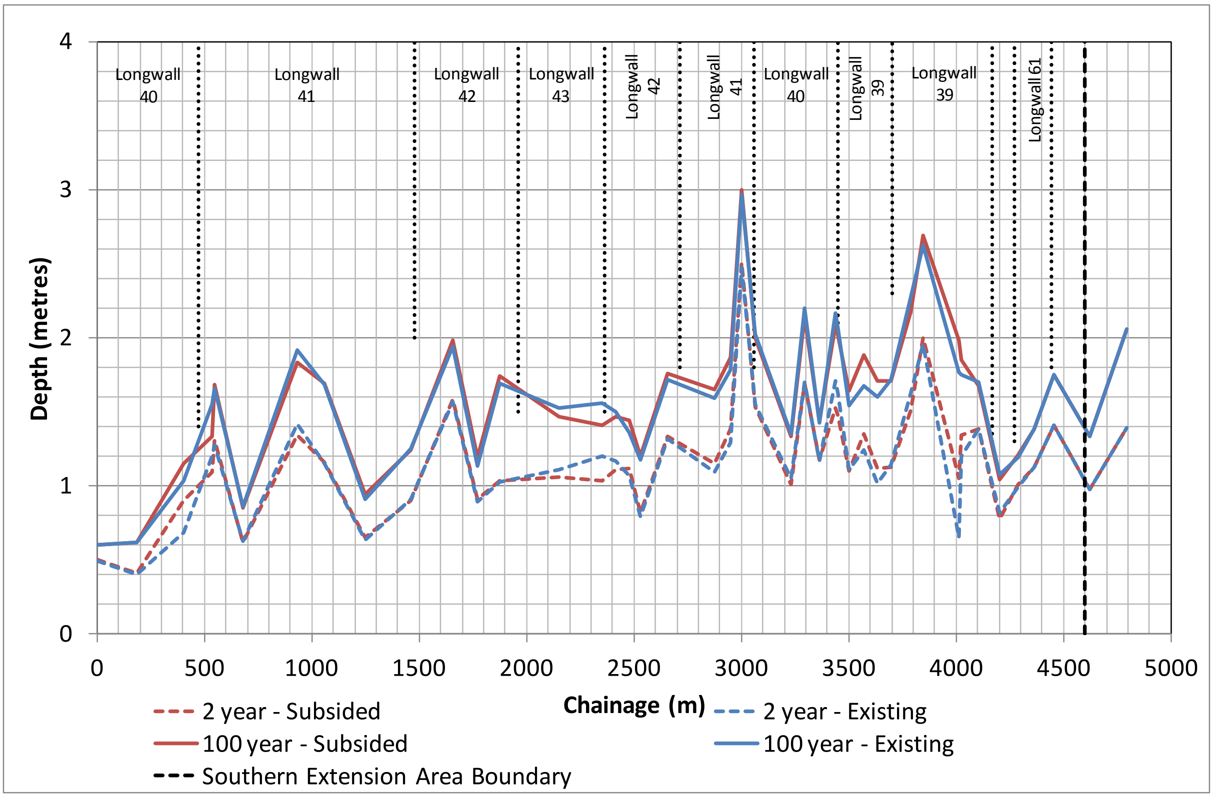



**Chart 4.27 - Wyee Creek (Watercourse 3) - Modelled Flood Depth**

## Flood Duration

**Chart 4.28** shows the depth hydrograph for Wyee Creek (Watercourse 3) at the eastern boundary of the Southern Extension Area. Modelling indicates that despite the increase in the maximum modelled flood depths for the one year and 100 year ARI design storm events (refer to **Chart 4.27**), changes to the flood duration are relatively minor, increasing from approximately 7.6 hours to 7.7 hours for the one year ARI design storm event and 17.6 hours to 17.7 hours for the 100 year ARI design storm event (refer to **Chart 4.28**). As such the modelling indicates that the potential for impacts on access to, and agricultural use of, the surrounding land is minimal.

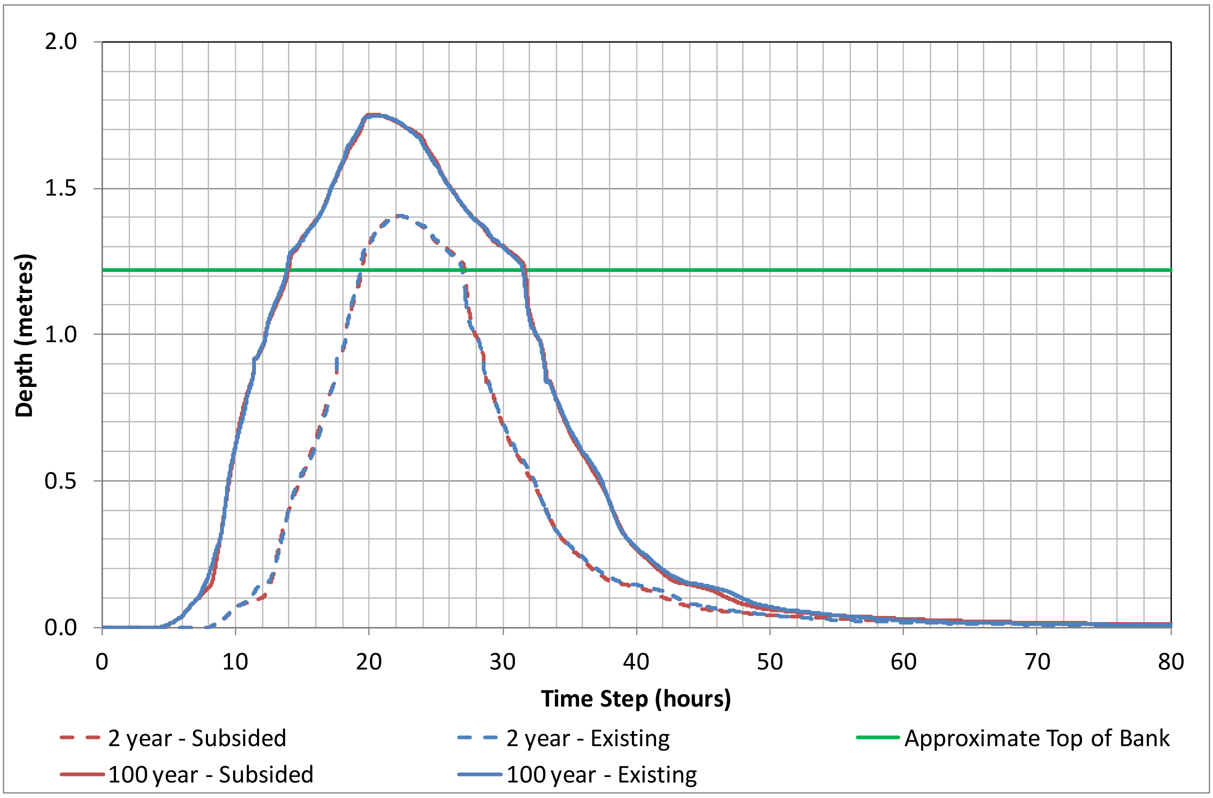
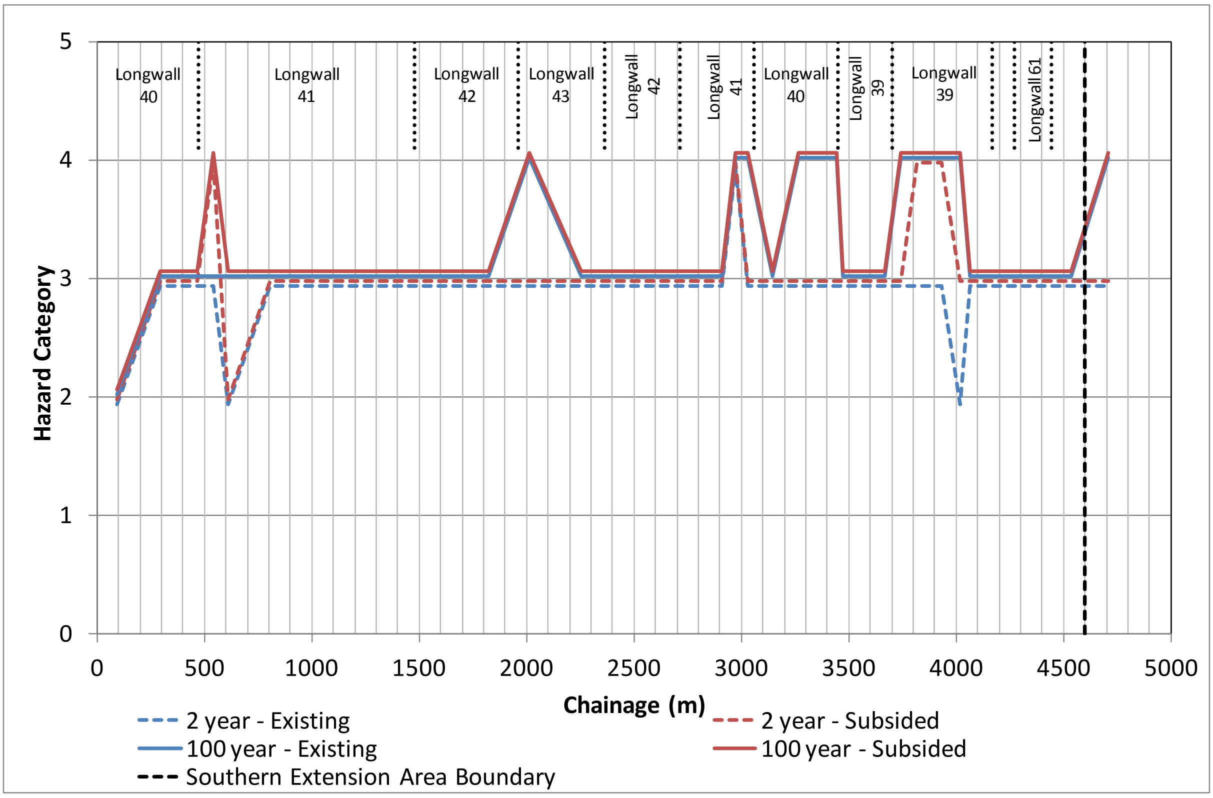



**Chart 4.28 - Wyee Creek (Watercourse 3) - Modelled Depth Hydrograph**

## Flood Hazard Categories

The maximum modelled flood hazard category for the southern branch of Wyee Creek (Watercourse 3) for the two year and 100 year ARI storm events for both the existing landform and predicted subsided landform are presented in **Chart 4.29**. As the flood hazard category is determined from a combination of flood depth and velocity, the changes to the flood hazard category between the existing and predicted subsided landform are a consequence of the modelled changes to the modelled flood depths (refer to **Chart 4.29**) and velocities (refer to **Chart 4.13**). From **Chart 4.29**, it is evident that local increases to the flood hazard category are expected, typically increasing from Category 3 (*wading unsafe*) to Category 4 (*damage to light structures*) for the 100 year ARI storm event. These increases tend to be extensions of existing areas of Category 4 flood hazard category.

The modelled changes to the flood hazard categories are not immediately adjacent to any dwellings or their access routes within the Southern Extension Area. As such the modelling indicates that there is unlikely to be significant impacts on the access and habitability of dwellings within the Southern Extension Area, including Wyee Farms Road (refer to **Chart 4.29**).



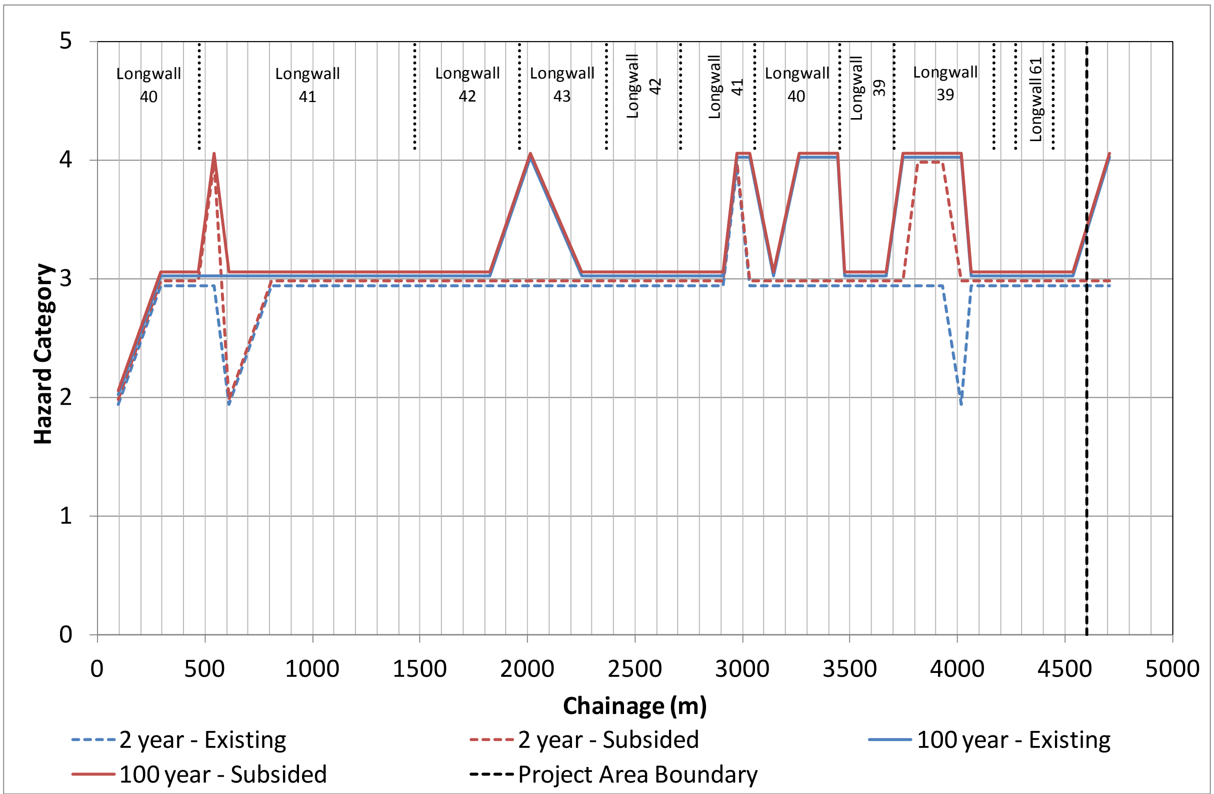




**Chart 4.29 - Wyee Creek (Watercourse 3) - Modelled Flood Hazard Categories**

### 4.4.3 Mannering Creek

#### Flood Depths

**Chart 4.30** presents the maximum modelled flood depths throughout the modelled section of Mannering Creek (Watercourse 4) for the two year (i.e. bank full) and 100 year ARI design storm events. Modelling indicates that for the 100 year ARI design storm changes to the maximum modelled flood depths range from a decrease of approximately 0.2 metre (at approximately 2050 metres) up to an increase of approximately 0.3 metre (at approximately 1950 metres). The modelling also indicates a similar range of changes to the maximum modelled flood depth for other design storm events, including the two year (also presented in **Chart 4.30**), 10 year and 20 year ARI design storm events.

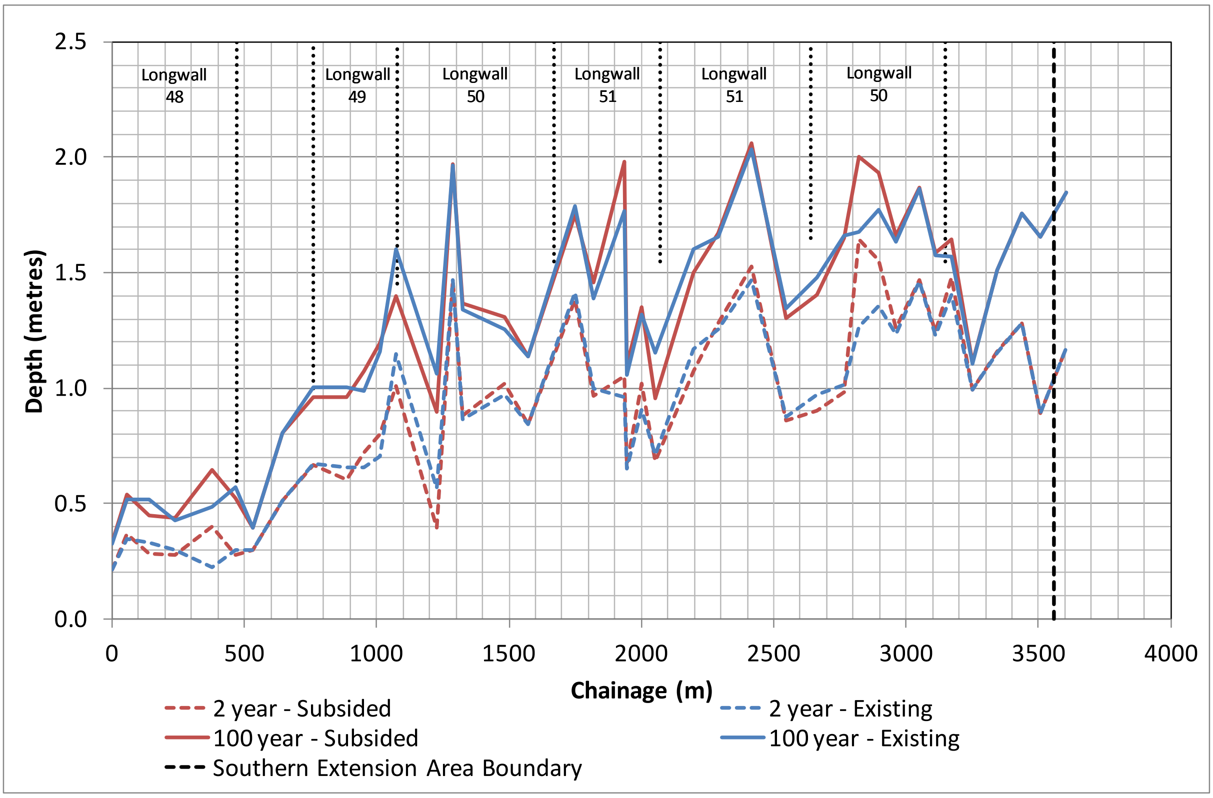



**Chart 4.30 - Mannering Creek (Watercourse 4) - Modelled Flood Depth**

#### Flood Duration

**Chart 4.31** shows the depth hydrograph for Mannering Creek (Watercourse 4) at the eastern boundary of the Southern Extension Area. The modelling indicates that despite the increase in the maximum modelled flood depths for the one year and 100 year ARI design storm events (refer to **Chart 4.30**), changes to the flood duration are relatively minor, increasing from approximately 12.7 hours to 12.8 hours for the 100 year ARI design storm event (refer to **Chart 4.31**). As such the modelling indicates that the potential for impacts on access to, and agricultural use of, the surrounding land is minimal.

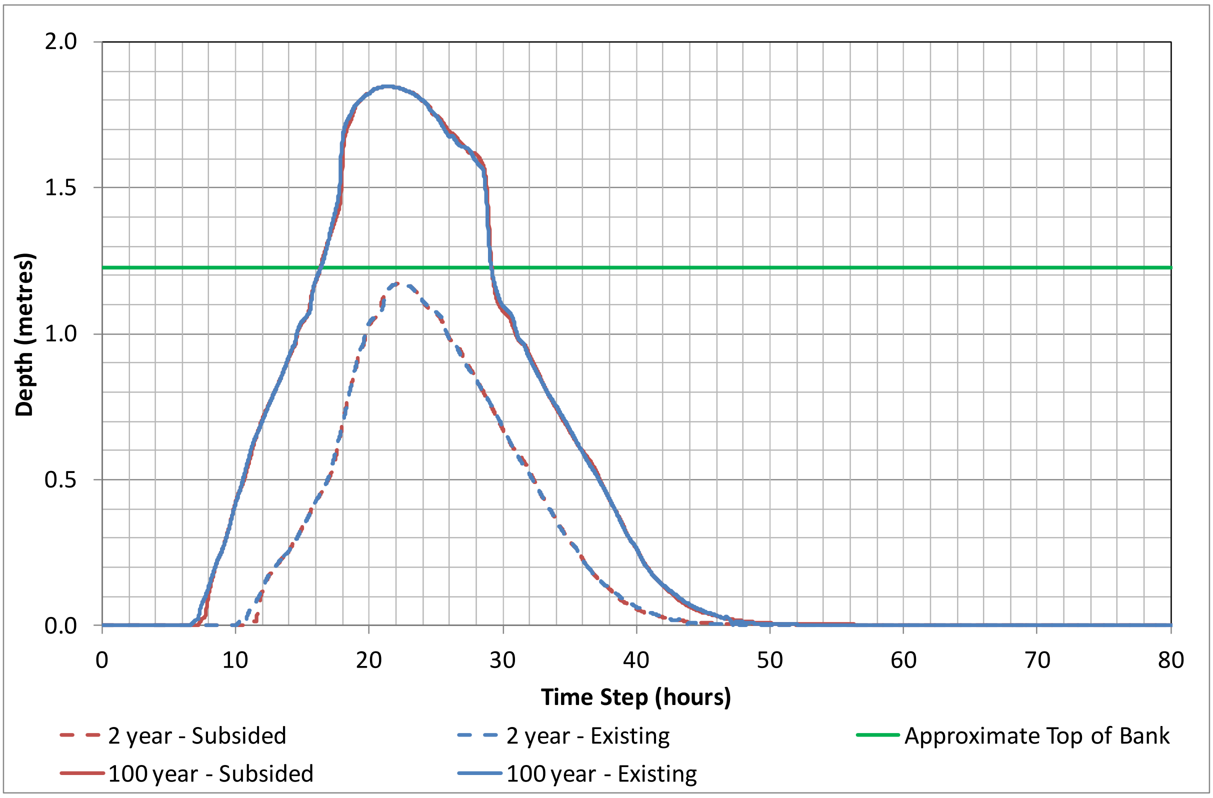



**Chart 4.31 - Mannering Creek (Watercourse 4) - Modelled Depth Hydrograph**

## Flood Hazard Categories

The maximum modelled flood hazard category for Mannering Creek (Watercourse 4) for the two year and 100 year ARI storm events for both the existing landform and predicted subsided landform are illustrated in **Chart 4.32**. As the flood hazard category is determined from a combination of flood depth and velocity, the changes to the flood hazard category between the existing and predicted subsided landform are a consequence of the modelled changes to the modelled flood depths (refer to **Chart 4.30**) and velocities (refer to **Chart 4.15**). From **Chart 4.32**, it is evident that local increases to the flood hazard category are expected, typically increasing from Category 3 (*wading unsafe*) to Category 4 (*damage to light structures*) for the 100 year ARI design storm event. No identified dwellings or their access routes occur within the vicinity of this modelled increase in flood hazard category.

The modelled changes to the flood hazard indicate that there is unlikely to be significant impacts on the access to, and habitability of, dwellings within the Southern Extension Area, including along Hue Hue Road and Toepfers Road (refer to **Chart 4.32**).

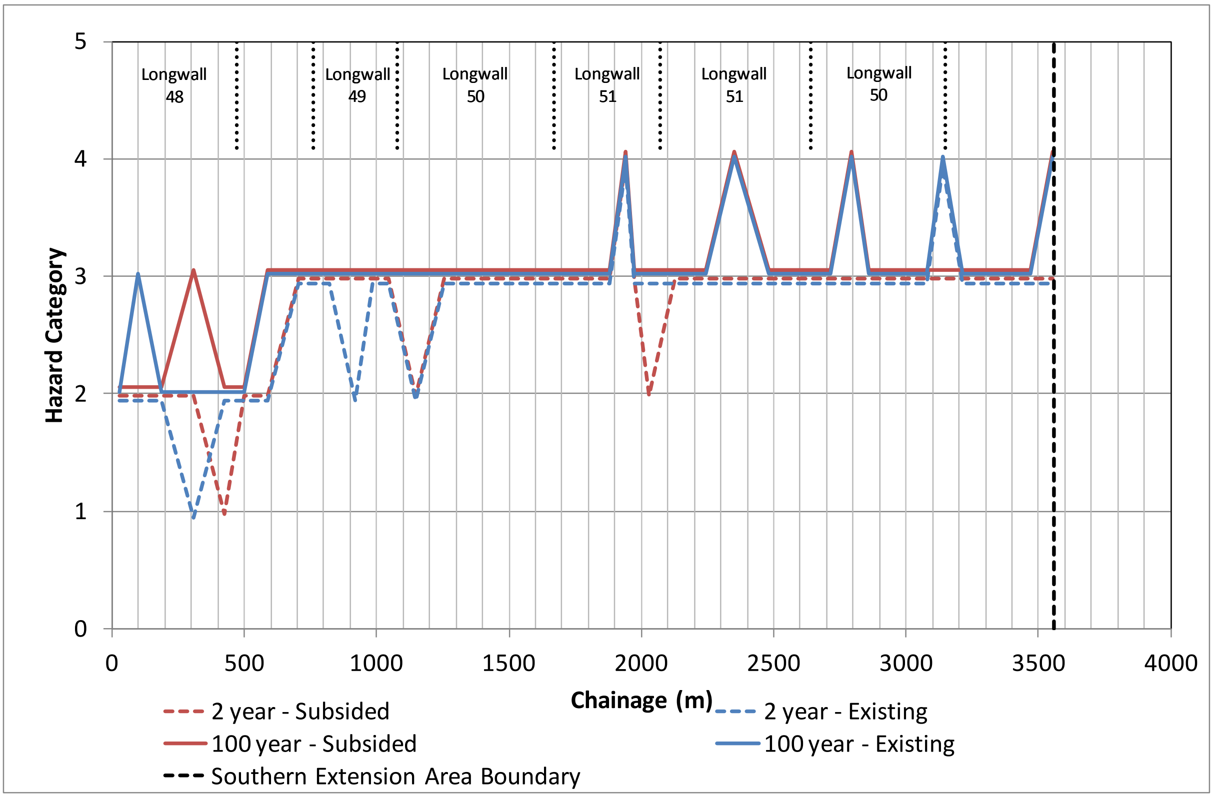



**Chart 4.32 - Mannering Creek (Watercourse 4) - Modelled Flood Hazard Categories**

### 4.4.4 Buttonderry Creek

#### Flood Depths

**Chart 4.33** presents the maximum modelled flood depths throughout the modelled section of Buttonderry Creek (Watercourse 5) for the two year (i.e. bank full) and 100 year ARI design storm events. The modelling indicates that there is no discernable change to the modelled flood depths throughout Buttonderry Creek.

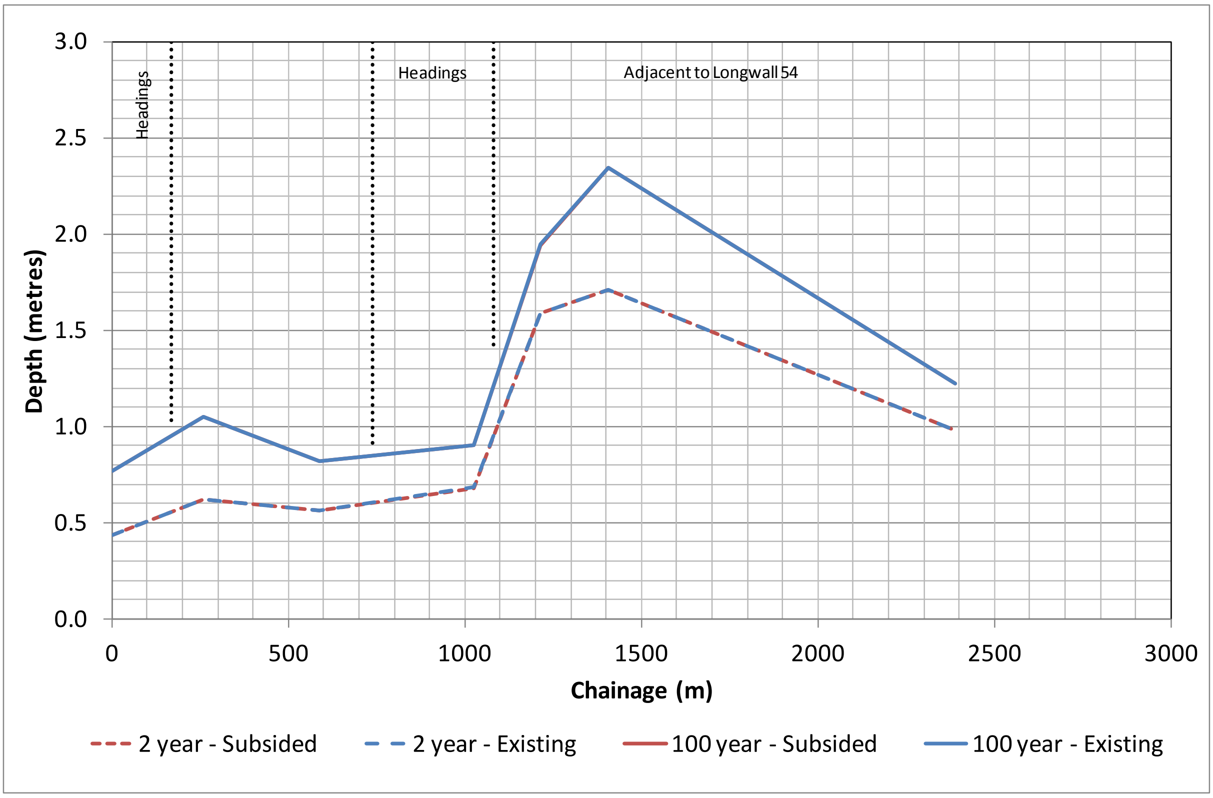



**Chart 4.33 - Buttonderry Creek (Watercourse 5) - Modelled Flood Depth**

## Flood Duration

There was no discernable change in the maximum modelled flood depth on Buttonderry Creek (Watercourse 5) in response to the subsided landform, which is reflected in the flow hydrograph at the southern limit of the extraction area, which indicates that the out of bank duration remains at approximately 2.1 hours and 14.5 hours for the 2 year (bank full) and 100 year ARI design storm events respectively(refer to **Chart 4.34**). As such the modelling indicates that the predicted subsidence will have negligible impact on agricultural land use.

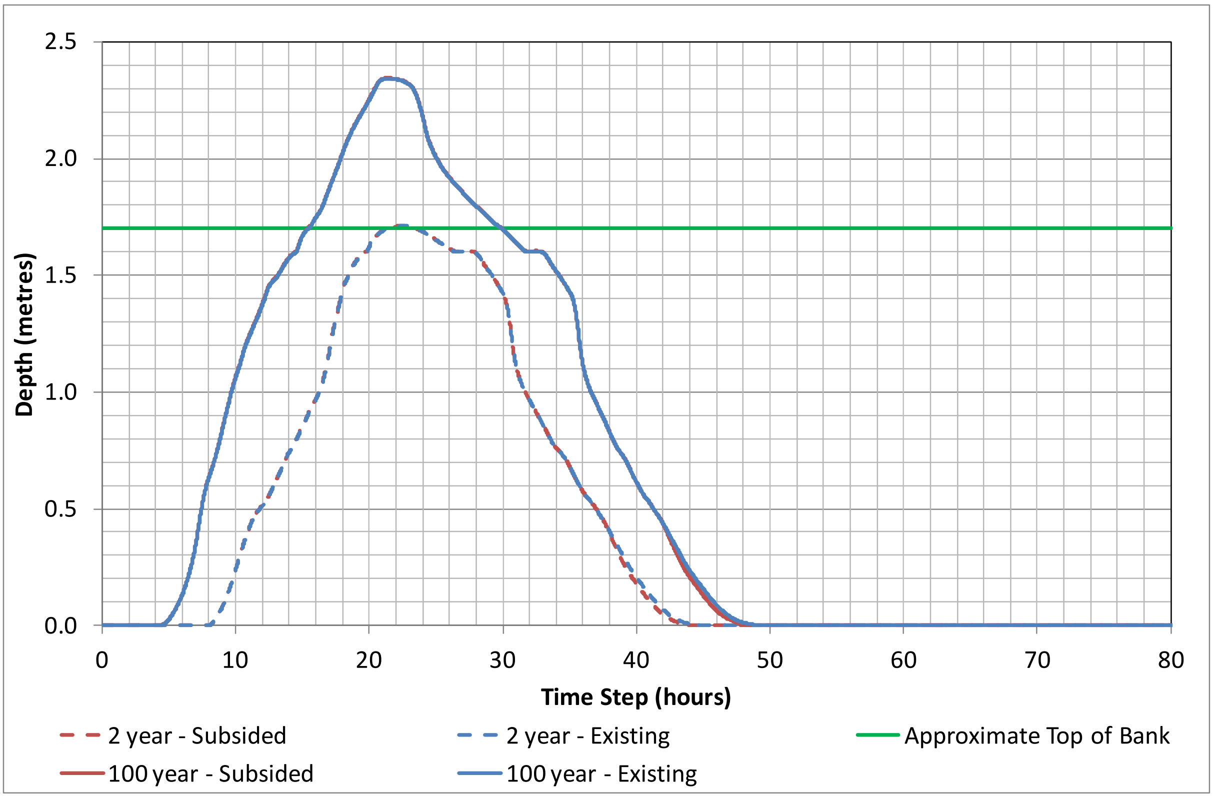



**Chart 4.34 - Buttonderry Creek (Watercourse 5) - Modelled Depth Hydrograph**

## Flood Hazard Categories

The maximum modelled flood hazard category for Buttonderry Creek (Watercourse 5) for the two year and 100 year ARI design storm events for both the existing landform and predicted subsided landform is illustrated in **Chart 4.35**. From **Chart 4.35**, it is evident that there are no discernible changes in the modelled flood hazard category for Buttonderry Creek.

As such the modelling indicates that there will be negligible changes to access routes within the Buttonderry Creek catchment area.

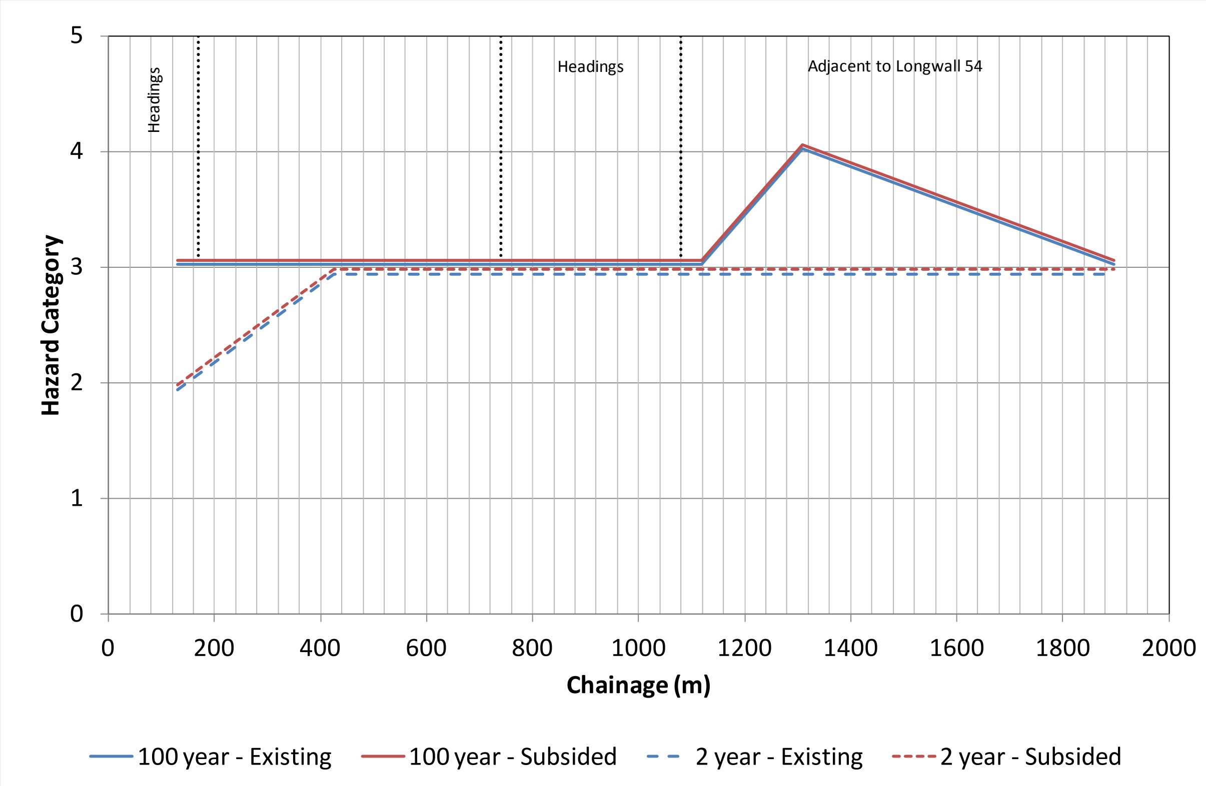



**Chart 4.35 - Buttonderry Creek (Watercourse 5) - Modelled Flood Hazard Categories**

## 4.5 Proposed Monitoring and Remediation Protocols

Taking into consideration the existing surface water regime, associated topography and previous experience at the existing Mandalong Mine, it is considered likely that only minor remediation works will be required consisting of erosion protection measures. However, a comprehensive monitoring regime will be required to be implemented to monitor major drainage lines and those locations identified in **Figure 4.1** for potential subsidence impacts.

The required controls and protocols will utilise standard erosion and sediment control techniques to manage surface water during any remediation (refer to **Section 4.5.2**).

Similarly, due to the steepness of the catchment areas and surrounding topography and vegetation it is not considered practical to divert runoff from upstream catchment areas around potential impacts areas if works are required. As such it is proposed that all remediation works are managed in stream.

It is recommended to refine and implement procedures as part of the Subsidence Management Plan for the Project drainage line remedial works. These procedures may include but not be limited to:

- monitoring of vertical and horizontal subsidence along second and third order drainage lines as determined in consultation with the Department of Industry and Investment (DII) (formerly Department of Primary Industries (DPI));
- visual inspection and recording (including photographic records at least every 50 metres) of stream bed and bank condition and riparian vegetation along second and third order drainage lines, including collection of baseline data and monitoring during and post mining operations;

- sediment and erosion controls;
- soil stabilisation measures, where appropriate;
- revegetation techniques and maintenance; and
- velocity reduction controls.

### 4.5.1 Erosion and Sediment Controls

Any necessary subsidence remediation works will require suitable erosion and sediment controls. All erosion and sediment control measures will be carried out in accordance with the relevant guidelines for erosion and sediment control, including:

- *Managing Urban Stormwater Soils and Construction* (the Blue Book) *Volume 1* (Landcom 2004) and *Volume 2C Unsealed Roads* (Department of Environment and Climate Change (DECC) 2008); and
- where relevant to a standard consistent with *Draft Guidelines for the Design of Stable Drainage Lines on Rehabilitated Mine Sites in the Hunter Coalfields* (DIPNR, undated).

The general erosion and sediment control principals proposed to be incorporated into the construction of mitigation works during the Project include:

- construction of erosion and sediment controls prior to the commencement of any substantial construction works;
- construction and regular maintenance of sediment fences downslope of disturbed areas;
- use of soil amelioration/stabilisation methods where appropriate;
- seeding and controlled fertilising of disturbed areas to provide for rapid grass cover. Areas will be seeded with a grass mix specific to the needs of the area to be grassed;
- regular inspection of all works and immediately following rainfall events of a magnitude sufficient to generate runoff to ensure erosion and sediment controls are performing adequately; and
- provision for the immediate repair or redesign of erosion and sediment controls which are identified as not performing adequately.

In addition to the above erosion and sediment control measures, construction plans will detail the specific inspection, maintenance and revegetation requirements for each works area where subsidence remediation works are required.

## 4.6 Summary of Impacts

The potential impacts of the Project on surface water resources has been minimised by the iterative process Centennial has undertaken to develop the mine design to minimise potential impacts on surface waters, including the natural and built environment.

The surface water assessment of the predicted subsidence impacts indicates that the catchment boundaries of the creek systems to be undermined will not change significantly.

The existing environment has already undergone scouring as a result of constructed features, including culverts and bridges, however increases to scouring may further degrade water quality. Monitoring of watercourses within the impacted area and the implementation of appropriate mitigation measures area proposed to reduce the potential of additional scouring. Specifically, monitoring will be required and mitigation measures may be required within Wyee Creek (Watercourse 3) as a result of an increase in the modelled tractive stresses (refer to **Section 4.2.2.2** and **Chart 4.13**) in response to the predicted subsidence.

If subsidence remediation works are required, erosion and sediment control measures will be included to ensure that there will be minimal impact on downstream water qualities.

It is also considered that the potential for any significant change to remnant ponding or storage of surface runoff is minimal. A series of monitoring points have been identified to monitor potential drainage grade changes and remnant ponding (refer to **Sections 4.2** and **4.3**, and **Figure 4.1**). The remnant ponding monitoring points include three locations each within the Morans Creek, Wyee Creek and Mannering Creek (refer to **Figure 4.1**).

The modelling indicates that the potential impacts of the predicted subsidence on the flooding regimes within the Southern Extension Area and its surrounds are typically limited to areas that are currently subject to flooding as a result of the 100 year ARI design storm event. The modelling indicated that maximum modelled flood depths could increase up to 0.4 metre for the 100 year ARI design storm event as a result of the predicted subsidence. These increases are generally contained within the main channel sections of the modelled watercourses, with limited changes to the modelled flood extents and out of bank flooding duration. As a result, the potential impacts on the habitability and accessibility of dwellings within the Southern Extension Area is minimal, as are the potential impacts on the agricultural areas. The modelling also indicated that no significant impacts to road and transport is expected as a result of the predicted subsidence.

The watercourses within the Southern Extension Area do not have a persistent long-term baseflow, sustaining small flows during dry periods and ceasing to flow during drought periods. As such the long-term predicted losses to baseflows are expected to have negligible impacts on the streamflow conditions within these watercourses.

As a result of the limited potential for changes to water quantities, including annual flow volumes, baseflows and environmental flows, downstream users are unlikely to experience significant changes to water availability as a consequence of the proposed mining operation.

On this basis it is considered that the proposed development will not result in adverse cumulative impacts on water use, flows or qualities in the areas surrounding the Project.

# 5.0 Monitoring, Licensing and Reporting

The monitoring proposed in **Sections 5.1** to **5.5** will be detailed in the management plans for the Project to be prepared if approval is granted. The monitoring programs will provide details on monitoring frequency, analysis and reporting methods.

The monitoring that has been used as the baseline data for the Project (refer to **Section 3.0**) will continue to be collected in order to establish a comprehensive data set to inform the review of monitoring data, allowing any potential impacts of the Project to be identified.

## 5.1 Erosion and Sediment Controls

Where subsidence rehabilitation works are required erosion and sediment controls will be monitored during the works period in accordance with the Blue Book (Landcom 2004 and DECC 2008) including regular inspections and inspection after rainfall events causing runoff (refer to **Section 4.5.2**).

## 5.2 Subsidence Monitoring

Centennial Mandalong has an established subsidence monitoring program and management plans for the existing approved Mandalong Mine. The established subsidence monitoring program will be continued within the Southern Extension Area, with inspections of 2nd order and higher watercourses proposed to be undertaken on a regular basis to ensure that watercourses within the subsidence affectation zone are not adversely impacted by remnant ponding and scouring.

It is considered that the predicted subsidence impacts will not result in any substantial remnant ponding or drainage realignment within the Southern Extension Area. However, a number of monitoring points have been identified based on the long section analysis (refer to **Section 4.3**). If monitoring identifies that remediation works are required, remediation works will need to maintain channel grades and take into consideration channel stabilities and existing channel characteristics.

If necessary, remediation works have the potential to generate short term impacts on water quality while the remediation works are being undertaken and stable vegetated post mining landforms are being achieved. Potential water quality impacts with respect to downstream water users and ecosystems will principally be a consequence of increased sediment generation and export of sediment off site. To mitigate the potential impact it is proposed to implement a number of erosion and sediment control measures (refer to **Section 4.5.1**).

## 5.3 Watercourse Stability Monitoring

Based on the predicted subsidence impacts on watercourses within the Southern Extension Area, Centennial Mandalong proposes to monitor watercourses within the undermined area, in particular at those locations identified as potential scouring points in **Section 4.3** and shown in **Figure 4.1**.

Monitoring will be undertaken immediately prior to the undermining of the areas, with additional inspection of these locations following rainfall events of a magnitude sufficient to generate runoff (an appropriate rainfall trigger will be identified during the preparation of the monitoring program) and monitoring undertaken post mining. Annual watercourse stability reports will be prepared with the key findings reported in the Annual Environmental Management Report (AEMR) for the Project. Monitoring and remediation procedures will include monitoring of:

- any bed control points;
- areas where subsidence may increase the erosive potential above the determined threshold limits potentially causing channel erosion/instability; and
- monitoring may include long section and cross section surveys, photographic records and/or methods outlined in Australian Rivers Assessment System (AUSRIVAS).

## 5.4 Surface Water Quality Monitoring

Surface water quality monitoring is currently undertaken at various locations throughout the Southern Extension Area (refer to **Section 3.2**). For the Project, ongoing surface water quality monitoring will include the continuation of water quality monitoring at the current locations and include testing for the water quality parameters included within the current monitoring program (refer to Table 2.1 in **Appendix 2**). The water quality records will also include a visual assessment of the flow conditions at the time of sampling.

## 5.5 Flow Monitoring

Flow monitoring on the various creeks potentially impacted on by the Project will be undertaken by visual inspections during water quality sampling (refer to **Section 5.4**). The observations should note any changes to the conditions of the watercourse bed and banks, including scouring. The visual inspections will be used to inform the assessment of water quality data.

## 5.6 Licensing Requirements

The *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009* applies to the areas in the vicinity of the Southern Extension Area including all surface water flows from the Southern Extension Area and alluvial groundwater in the Lake Macquarie catchment (Morans Creek, Wyee Creek and Mannering Creek) and Wyong River catchment (Buttonderry Creek and Jilliby Creek). Therefore, the surface waters of the Southern Extension Area are governed by the *Water Management Act 2000.*

The Groundwater Impact Assessment (GHD, 2012) indicates that alluvial groundwater levels are not expected to drop more than 0.1 metres. As such it is understood that no surface water take will occur as a result of the proposed underground mining and no surface water licences will be required for this component of the Project.

## 5.7 Reporting

Results from the proposed monitoring programs (refer to **Sections 5.1** to **5.6**) will be reported in the AEMR and available to the public on the Centennial website.

# 6.0 References

ANZECC/ARMCANZ, 2000, *National Water Quality Management Strategy: Australian and New Zealand Guidelines for Fresh and Marine Water Quality*.

Department of Environment and Climate Change (DECC), 2008, *Managing Urban Stormwater: Soils and Construction, Volume 2C Unsealed Roads*.

Department of Infrastructure, Planning and Natural Resources (DIPNR), 2005, *Floodplain Development Manual, The Management of Flood Liable Land*.

Department of Infrastructure, Planning and Natural Resources (DIPNR), 2005, *Management of Stream / Aquifer Systems in Coal Ming Developments, Hunter Region.*

Department of Infrastructure, Planning and Natural Resources (DIPNR), undated, *Draft Guidelines for the Design of Stable Drainage Lines on Rehabilitated Minesites in the Hunter Coalfields*.

Department of Land and Water Conservation, 1993, *Soil Landscapes for Gosford - Lake Macquarie*.

Ditton Geotechnical Services Pty Ltd, 2012. *Predicted Final; Subsidence Contours for Option 7 (P15): Optimum Longwall Panel and Chain Pillar Widths for ALTS & Subsidence Control*, prepared for Centennial Coal Mandalong Pty Ltd.

Fischenich, C, 2001, *Stability Thresholds for Stream Restoration Materials*, US Army Engineer and Research Development Center.

GDH, 2013 Groundwater Impact Assessment, Mandalong Southern Extension Project, prepared for Centennial Mandalong Pty Ltd

Hughes Trueman 2004. *Flood Study: Mandalong Coal Mine*, prepared for Department of Infrastructure, Planning and Natural Resources.

Landcom, 2004, *Managing Urban Stormwater: Soils and Construction, Volume 1*.

# APPENDIX 1

Assessment Method

# Appendix 1 - Assessment Approach

## 1.1 Scope of Surface Water Assessment

In response to the Director-General's Requirements (DGRs) (refer to **Section 2.2**), this Surface Water Assessment includes consideration of the existing and potential impacts of the Project on:

- catchment area boundaries;
- watercourse stability and associated water quality;
- remnant ponding;
- flood regimes; and
- water quantity for downstream water users and the environment.

The assessment methodology for each of these components is outlined below.

## 1.2 Airborne Laser Survey Data

Airborne Laser Survey (ALS) data was sourced in March 2012 by Centennial Mandalong Pty Ltd. ALS data was used to develop a high resolution Digital Terrain Model (DTM) for the existing landform within the Project Area and immediate surrounding area which includes existing approved mining operations.

## 1.3 Subsidence Predictions

Subsidence predictions for the mine plan for the proposed Project were provided by Ditton Geotechnical Service Pty Ltd. The predicted subsidence was used to subside the DTM developed for the Project Area using ALS data, to reflect the potential impacts of subsidence on the local terrain. The DTM was used to estimate the potential impacts on flooding and drainage as a result of the predicted subsidence.

## 1.4 Modelling Methodology

One dimensional (1D) and two dimensional (2D) hydrodynamic modelling was used to estimate the potential surface water impacts of the Project on the surrounding area. This modelling utilised the detailed DTMs constructed for the existing and predicted subsided landforms.

### 1.4.1 Hydrodynamic Modelling

The nature of the watercourses within the Project Area combined with the level of model detail required to adequate capture the predicted subsidence and infrastructure have meant that both 1D and 2D hydrodynamic models have been used.

The 1D XP-Storm modelling package describes a watercourse on terms of a series of nodes and links. The links of the model describes the watercourse geometry, including cross sectional profile and longitudinal slope. The links are joined by nodes, which are also used as points of interface between the upslope runoff and watercourse routing. The 1D XP-Storm model was used in this study to simulate the flood response of:

- Three tributaries of Wyee Creek (Watercourses 1, 2 and 3);
- Mannering Creek (Watercourse 4); and
- Buttonderry Creek (Watercourse 5).

The 2D hydrodynamic RMA-2 model uses a finite element mesh to describe the terrain of the modelled area at a variable resolution, suitable to capture the hydraulically important details. The finite element mesh typically consists of nodes (points) that describe a detailed network of triangular elements. The nodes are locations where the various 2D hydraulic equations are computed for each time step, which can then be interpolated across the mesh elements to provide a highly detailed estimate of the flood response of a floodplain. The RMA-2 package is typically applied to broad floodplains.

A 2D hydrodynamic RMA-2 model was previously developed for Morans Creek as part of the Mandalong Valley Flood Study (Hughes Truman 2004). The 2D model has been used for subsequent surface water assessments and ongoing subsidence management plans, covering Morans Creek (e.g. Umwelt 2012). The previously developed RMA-2 model was extended to include the upper reaches of Morans Creek (Watercourse 6). The 2D RMA-2 model was used to estimate the potential flood impacts of the proposed access road off Chapman Road, which crosses Morans Creek outside of the proposed mining area but still within the boundary of EPL 6317. The 2D model was also used to estimate the potential subsidence impacts on the flood flows within Morans Creek.

The high resolution DTM (refer to **Section A1.2**) was used to developed both the 1D and 2D models. The models allow for the estimation of the flood response of both the existing conditions or predicted subsidence impacts.

The hydrodynamic models were used to estimate the flood response of watercourses within the Project Area and to identify any potential downstream impacts for four design storm events, including:

- approximate bankfull event, typically the one year or two year Average Recurrence Interval (ARI) design event;
- 10 year ARI design event;
- 20 year ARI design event; and
- 100 year ARI design event.

ARI refers to the average interval (in years) between design storms of a specific magnitude. For example, a 10 year ARI storm is expected to occur once for every 10 years of observed data, assuming a sufficiently long observation period (of the order of several hundred years). This does not mean the event will occur once every 10 years, and in fact such events tend to cluster within flood dominated periods as a result of large scale climate cycles.

The bank full flood event, defined as the design flood event that results in flow depths that are approximately equal to the top of bank of a watercourse, are used for the estimation of the potential changes to tractive stresses within the main watercourse channel sections. The estimation of tractive stress within the modelled watercourses allows for the determination of locations which have the potential to undergo increased erosion or scouring as a conseqence of the changes to the watercourses.

The outputs of the models were used to generate flood maps and charts, which allow for the comparison of the pre and post-mining flood depths, velocities and flood hazard categories. The models also allow for the estimation of potential changes to tractive stesses within each watercourse thalweg during approximately bank full flows. The differences in the main text between the resolution of the charts (refer to Section 4) is primarily the different resolutions of the 2D model (Morans Creek) and the 1D models (Wyee Creek, Mannering Creek and Buttonderry Creek). However, it is considered that the modelling has been undertaken as a suitable resolution to inform the assessment of potential impacts and associated monitoring and mitigation works.

### 1.4.2 Remnant Ponding

Remnant ponding refers to the areas which retain surface water for an extended period of time following a rainfall event. They are typically local depressions which do not gravity drain, i.e. not free draining. Subsidence has the potential to alter the existing pattern of remnant ponding, potentially impacting on the existing amenity of properties within EL 6317, including farm dams, pasture areas and access routes. The changes to remnant ponding can also impact on existing ecosystems.

The potential changes to the pattern of remnant ponding was estimated using the high resolution DTM (refer to **Section 3.2.1**) and predicted subsidence (refer to **Section 3.2.2**), and Geographic Information System (GIS) tools that identify areas within the DTMs that are not free draining. It should be noted that the remnant ponding analysis does not include minor drainage structures, such as subsurface drains, that may be in place to alleviate local ponding issues.

### 1.4.3 Watercourse Stability

The hydrodynamic model results provide an opportunity to estimate the potential changes to the bed and bank stability of the modelled watercourses in response to the predicted subsidence. Changes to the landform as a result of predicted subsidence can result in changes to flow velocities and tractive stresses within a watercourse, which can change the existing pattern of erosion and deposition within a watercourse.

The potential impact of changes to modelled velocities and tractive stresses on the stability of a watercourse are estimated using stability thresholds. The stability thresholds allow for flows to be categorised as *stable*, *marginally stable* or *unstable*. The thresholds depend on bed and bank material and vegetation coverage.

Based on the observations from the field inspections, bed materials appear to range from fine gravels to graded loam and cobbles. The thresholds for tractive stress and flow velocity shown in **Table 1** have been selected as indicative thresholds for determining stability state of each watercourse.

**Table 1 - Permissible Tractive Stress and Velocity, Adapted from Fischenich (2001)**

| Flow Metric | Stable | Marginally Stable | Unstable |
|---|---|---|---|
| Velocity | < 0.75 m/s | 0.75 m/s to 1.15 m/s | > 1.15 m/s |
| Tractive Stress | < 3.6 N/m$^2$ | 3.6 N/m$^2$ to 18.2 N/m$^2$ | > 18.2 N/m$^2$ |

# APPENDIX 2

Water Quality Data

## Table 2.1 - List of Surface Water Quality Parameters

| | | | |
|---|---|---|---|
| pH (Field) | Iron (Total) | Nitrogen (Ammonia) | C10-C14 |
| pH | Lead (Total) | Nitrogen (Total) | C15-C28 |
| TSS | Lithium | Nitrogen Organic TKN | C29-C36 |
| TDS | Magnesium (Dissolved) | Phosphorous (Total) | Dissolved Ba |
| COD | Manganese (Dissolved) | Phenolics | Dissolved Pb |
| Ec | Manganese (Total) | Anioinic Surfactants | Dissolved Ag |
| Oil & Grease | Mercury | Acidity to low pH | Dissolved B |
| Manganese (Filtered) | Molybdemon (Dissolved) | Acidity to high pH | Dissolved Hg |
| Iron (Filtered) | Molybdemon (Total) | Alkalinity to CO | Hex Cr |
| Turbidity (NTU) | Nickel (Dissolved) | Alkalinity to HCO | Dissolved Li |
| Aluminium (Dissolved) | Nickel (Total) | Alkalinity to OH | Dissolved Sn |
| Aluminium (Total) | Potassium | Langelier Saturation | Dissolved Ti |
| Antimony | Selenium (Dissolved) | Hardness (Total) | Dissolved Sb |
| Arsenic (Dissolved) | Selenium (Total) | Dissolved Oxygen | Dissolved Silica |
| Arsenic (Total) | Silica | BOD | Dissolved Calcium |
| Barium | Silver | NOx | Dissolved Potassium |
| Beryillium (Dissolved) | Sodium | TOC | Dissolved Sodium |
| Beryillium (Total) | Sulphur (Total) | DOC | Total Anions |
| Boron | Sulphur Sulphate (Total) | Fe 2+ | Total Cations |
| Cadmium (Dissolved) | Sulphide | Fe 3+ | Ionic Balance |
| Cadmium (Total) | Tin | Redox Potential | Chlorine Free |
| Calcium | Titanium | Fluoride (Total) | Thermotolerant coliforms |
| Chromium (Dissolved) | Uranium | Cyanide (Total) | Total coliform |
| Chromium (Total) | Vanadium (Dissolved) | Chlorine | E Coli |
| Chloride | Vanadium (Total) | Dissolved Sulfur as S | Dissolved Sulfate |
| Cobalt (Dissolved) | Zinc (Dissolved) | Hydroxide Alkalinity as CaCO3 | |

**Table 2.2 - Surface Water Quality (June 2011 to June 2012)**
**(Summary of results for water quality parameters with near continuous records)**

| Parameter | ANZECC Trigger Values | | | Mannering Creek | | Wyee Creek | | | Morans Creek | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lowland | Upland | | SWMP01 | SWMP02 | SWMP03 | SWMP04 | SWMP05 | SWMP06 | SWMP07 |
| pH | 6.5 to 8.5 | 6.5 to 8.0 | Minimum | 6.17 | 6.32 | 6.15 | 6.25 | 5.81 | 5.82 | 6.26 |
| | | | Average | 6.85 | 6.65 | 6.59 | 6.75 | 6.49 | 6.43 | 6.75 |
| | | | Maximum | 7.32 | 6.95 | 7.02 | 7.31 | 7.38 | 7.02 | 7.25 |
| EC (µS/cm) | 125 to 2,200 | 30 to 350 | Minimum | 218 | 167 | 196 | 181 | 140 | 266 | 149 |
| | | | Average | 460 | 465 | 408 | 592 | 412 | 662 | 496 |
| | | | Maximum | 736 | 902 | 628 | 1080 | 839 | 1160 | 883 |
| Turbidity (NTU) | 6 to 50 | 2 to 25 | Minimum | 13.0 | 21.0 | 19.8 | 19.8 | 16.0 | 21.9 | 14.1 |
| | | | Average | 30.8 | 40.1 | 48.2 | 46.2 | 54.7 | 76.0 | 42.0 |
| | | | Maximum | 73.7 | 68.5 | 89.3 | 90.9 | 125.0 | 269.0 | 88.9 |
| TDS (mg/L) | < 1,400 [1] | < 230 [1] | Minimum | 130 | 160 | 196 | 210 | 172 | 212 | 193 |
| | | | Average | 286 | 326 | 296 | 453 | 350 | 439 | 364 |
| | | | Maximum | 362 | 514 | 372 | 676 | 588 | 676 | 818 |
| TSS (mg/L) | < 40 [2] | | Minimum | < 5.0 | < 5.0 | < 5.0 | < 5.0 | < 5.0 | 6.0 | < 5.0 |
| | | | Average | 21.0 | 20.8 | 26.5 | 15.6 | 25.1 | 68.2 | 12.8 |
| | | | Maximum | 61.0 | 54.0 | 61.0 | 42.0 | 98.0 | 364.0 | 31.0 |
| Mn (µg/L) | < 10 [3] | | Minimum | 0.04 | 0.06 | 0.04 | 0.05 | 0.02 | 0.05 | 0.02 |
| | | | Average | 0.12 | 0.54 | 0.38 | 0.57 | 0.12 | 0.38 | 0.41 |
| | | | Maximum | 0.29 | 1.26 | 0.97 | 1.52 | 0.30 | 1.14 | 1.87 |
| Fe (µg/L) | < 10 [3] | | Minimum | 0.64 | 1.28 | 1.06 | 1.31 | 0.77 | 1.77 | 1.39 |
| | | | Average | 1.47 | 3.56 | 2.48 | 3.19 | 1.89 | 2.97 | 2.32 |
| | | | Maximum | 2.48 | 5.84 | 4.57 | 5.63 | 2.86 | 5.59 | 3.59 |
| Al (mg/L) | < 0.2 [4] | | Minimum | 0.1 | 0.4 | 0.2 | 0.2 | 0.9 | 0.3 | 0.2 |
| | | | Average | 1.1 | 1.5 | 2.0 | 2.1 | 2.7 | 1.8 | 2.0 |
| | | | Maximum | 3.8 | 3.4 | 5.4 | 5.0 | 5.6 | 3.7 | 4.7 |

**Table 2.2 - Surface Water Quality (June 2011 to June 2012) (cont.)**
**(Summary of results for water quality parameters with near continuous records)**

| Parameter | ANZECC Trigger Values | | | Mannering Creek | | Wyee Creek | | | Morans Creek | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lowland | Upland | | SWMP-1 | SWMP-2 | SWMP-3 | SWMP-4 | SWMP-5 | SWMP-6 | SWMP-7 |
| Ba (mg/L) | < 1 [4] | | Minimum | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 |
| | | | Average | 0.0 | 0.1 | 0.1 | 0.1 | 0.0 | 0.1 | 0.1 |
| | | | Maximum | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Chloride (mg/L) | < 400 [4] | | Minimum | 41.0 | 31.0 | 40.0 | 37.0 | 22.0 | 60.0 | 28.0 |
| | | | Average | 123.1 | 131.0 | 103.5 | 181.8 | 101.9 | 206.4 | 145.9 |
| | | | Maximum | 217.0 | 256.0 | 169.0 | 304.0 | 206.0 | 363.0 | 245.0 |
| Sulphur Sulphate (mg/L) | | | Minimum | 7.0 | 4.0 | 8.0 | 4.0 | 0.0 | 9.0 | 2.0 |
| | | | Average | 17.5 | 13.1 | 13.9 | 16.7 | 13.4 | 17.7 | 11.2 |
| | | | Maximum | 22.0 | 22.0 | 22.0 | 26.0 | 26.0 | 26.0 | 17.0 |
| TN (mg/L) | 0.5 | | Minimum | 0.2 | 0.7 | 0.3 | 0.8 | 0.5 | 0.5 | 0.7 |
| | | | Average | 1.0 | 1.2 | 0.8 | 1.8 | 1.2 | 0.8 | 1.0 |
| | | | Maximum | 6.2 | 1.9 | 1.4 | 7.5 | 1.9 | 1.3 | 1.4 |
| TP (mg/L) | 0.05 | | Minimum | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 |
| | | | Average | 0.0 | 0.1 | 0.1 | 0.2 | 0.1 | 0.0 | 0.1 |
| | | | Maximum | 0.1 | 0.3 | 0.9 | 0.7 | 0.2 | 0.1 | 0.1 |
| Hardness (mg/L as $CaCO_3$) | soft < 60<br>moderate < 120<br>hard < 180 | | Minimum | 17.0 | 11.0 | 17.0 | 13.0 | 11.0 | 26.0 | 13.0 |
| | | | Average | 64.1 | 54.2 | 60.6 | 68.6 | 53.8 | 78.2 | 55.7 |
| | | | Maximum | 126.0 | 96.0 | 115.0 | 116.0 | 108.0 | 138.0 | 102.0 |

**Table 2.2 - Surface Water Quality (June 2011 to June 2012) (cont.)**
**(Summary of results for water quality parameters with near continuous records)**

| Parameter | ANZECC Trigger Values | | | Mannering Creek | | Wyee Creek | | | Morans Creek | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lowland | Upland | | SWMP-1 | SWMP-2 | SWMP-3 | SWMP-4 | SWMP-5 | SWMP-6 | SWMP-7 |
| NOx (mg/L) | | | Minimum | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | Average | 0.7 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | Maximum | 5.8 | 0.4 | 0.1 | 0.1 | 0.3 | 0.1 | 0.1 |

| Key: | Value Below Lowland Range | Value Above Upland Range | Value Above Lowland Range | Value Above Recreational Range |
|---|---|---|---|---|

Notes: 1. TDS = 0.37*EC.
2. TSS trigger value from freshwater aquaculture.
3. Mn, Fe trigger values from ANZECC Toxicant guidelines for the protection of aquiculture species.
4. Al, Ba and Cl values from ANZECC Toxicant guidelines for recreational purposes.

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