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Bowmans Creek Geomorphology Review

Ashton Coal Project

Ashton Coal Operations Limited

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Prepared for

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Executive Summary

Ashton Coal Operations Limited (ACOL) initiated a review of the geomorphology baseline assessment for Bowmans Creek due to stream bed changes resulting flooding in June 2007. The baseline assessment is required as a condition of consent for the Ashton Coal Project and provides a benchmark survey of Bowman's Creek geomorphology and a pre-mining hydrological assessment.

The next stage of longwall mining for ACOL involves mining beneath Bowman's Creek and an associated alluvial aquifer. In order to minimise subsidence impacts to Bowmans Creek and associated alluvial aquifer, a mine plan has been developed that adopts narrower panels beneath Bowmans Creek ("miniwalls") to significantly reduce vertical subsidence.

This report presents the results of the updated baseline assessment and also aims to ensure that the statutory requirements of ACP will be met through the proposed stream monitoring program in light of the mine plan changes to incorporate miniwalls into the underground mine design.

This report presents the following information:

- Updated monitoring program and methodology following changes to the mine plan; and
- Updated baseline monitoring data and a discussion of observed changes along Bowmans Creek.

The baseline data has been reviewed to confirm that it still provides an adequate representation of the pre-mining condition of Bowmans Creek. It was found that:

- Some minor, natural variation in channel form is occurring as is typical for a meandering stream;
- The flood event experienced in June 2007 was not a significant flood for Bowmans Creek, and as such, relatively minor changes to the stream morphology are apparent. Bank scour and erosion from this event, whilst visually apparent, have not significantly altered the channel form or pool-riffle sequence.

This report also presents an updated monitoring program methodology to address the development consent conditions for the stream monitoring program based on changes to the mine plan. This methodology will enable the identification of mine impacts to the creek in accordance with Condition 3.20 of the ACP Development Consent. Sufficient detail is provided in this report to allow adequate repetition of the monitoring methodology over time, and in accordance with the proposed monitoring schedule.

It is noted that one of the key difficulties in interpreting the results of future monitoring will be to differentiate the impacts of mining versus natural variation of the stream through normal climatic variations, erosion and deposition processes or upstream influences. Major flood events present more potential for large changes to the stream compared to the low levels of subsidence predicted as a result of the proposed mine plan.

If mining-induced impacts are identified, remedial measures will need to be determined based on the degree, extent and type of impacts identified. The design of remedial works, where required, should aim to:

- Provide long-term stability of the stream channel, banks and surrounding floodplain;
- Avoid hard engineering structures where possible;
- Allow the stream to naturally migrate in its channel boundaries;
- Maintain and support the existing pool-riffle sequence along the stream;
- Include the use of woody debris to support stream habitat; and
- Use vegetation to support and protect riparian banks rather than hard-engineering solutions.

List of Abbreviations

mAHD	metres Australian Height Datum
RL	relative level
AEP	Annual exceedance probability
ACP	Ashton Coal Project
km	kilometres
km^2	square kilometres
m^3/s	cubic metres per second
ACP	Ashton Coal Project

1.0 Introduction

1.1 Background

The Ashton Coal Project (ACP) is located approximately 14 kilometres (km) northwest of Singleton in the Hunter Valley region of New South Wales. It includes both an open cut and an underground mine and associated surface infrastructure. A locality plan is presented in Figure 1.

The layout of the Ashton underground mine is shown in Figure 2. The mine plan has been revised since the original environmental impact assessment (HLA, 2001). Detailed monitoring and modelling of subsidence and impacts to groundwater has resulted in the mine plan being revised to incorporate a serries of miniwalls below Bowmans Creek and its associated alluvial aquifer.

In accordance with the development consent conditions, a pre-mining baseline assessment was conducted in 2006. This assessment included detailed survey of Bowmans Creek from the New England Highway to its junction with the Hunter River (Pegasus Technical, 2006) and an assessment of the current geomorphologic design and stability of the creek (ERM, 2006).

In June 2007, as a result of an east coast low and in conjunction with widespread flooding across the Hunter Valley, high flows in Bowmans Creek and backwater flooding from the Hunter River occurred across the site. Marine Pollution Research (2008) observed flood erosion damage to Bowmans Creek during fieldwork associated with the aquatic ecology monitoring program in late June 2008.

Therefore, Ashton Coal considered that additional surveys were necessary to update the baseline survey information prior to underground mining of Bowmans Creek associated with longwalls and miniwalls 5 to 9 (LW/MW 5-9).

This review has been prepared to summarise the changes experienced as a result of the recent flooding, and update the proposed monitoring program based on both these changes, and changes to the underground mine layout.

1.2 Scope and Objectives

This report presents the results of the updated baseline assessment and also aims to ensure that the statutory requirements of Ashton Coal can be met through the proposed stream monitoring program as a result of the recent mine plan changes to incorporate miniwalls into the underground mine design.

This report presents the following information:

- Updated monitoring program methodology to address the development consent conditions for the stream monitoring program based on changes to the mine plan; and
- Updated baseline monitoring data and a discussion of observed changes along Bowmans Creek.

1.3 Statutory Requirements

The Bowmans Creek monitoring program was developed in direct response to the following condition of the ACP Development Consent (Ref DA No. 309-11-2001-i):

3.20 The Applicant is to conduct a detailed Stream Monitoring Program on Bowmans Creek developed in consultation with DIPNR and DPI - Fisheries. This monitoring is to commence at commencement of construction, or as otherwise directed by the Director-General, and is to be supported with visual records as well as technical records.

The River monitoring program shall include, but not be limited to:

a) *a detailed benchmark survey of the affected length of Bowmans Creek, and the reaches from the nearest upstream bedrock control point from the effective zero point of subsidence to the nearest downstream control point from the effective zero point of subsidence (usually measured by the 20 mm limit of subsidence). This survey is to be completed at least one year prior to mining affecting the stream channel system, or as otherwise directed;*

b) *pre-mining assessment including:*

   i. *identification of stable bedrock control points along the affected reach, and the nature and extent of bedrock control points.*

   ii. *identification of stable cross sectional survey control points along the affected reach.*

   iii. *identification of chain pillar survey control points to establish the change in vertical reduced levels and bed gradient change.*

   iv. *identification of stable control monitoring points to establish bedload transport through the affected reach.*

   v. *assessment of the extent of existing pool-riffle sequences, rock bar and cobble chute pools and bed gradient steepening through riffle sequences.*

   vi. *assessment of bank stability provision by existing vegetation galleries along the affected reach of Bowmans Creek.*

   vii. *the extent, floristics and structure of any existing wetlands or standing pools along the length of the affected reach of Bowmans Creek.*

   viii. *existing water quality and exchange/discharge rates of local groundwaters (both alluvial and underlying bedrock) to Bowmans Creek; and,*

   ix. *monitoring to benchmark fish, macroinvertebrates and aquatic habitat; water velocities and flow rates; and current geomorphological design and stability of the creek.*

c) *immediate post-mining monitoring (at least twice in the period within one year of each longwall pass under Bowmans Creek), including:*

   i. *extent of change in level and gradient from each control point identified in the pre-mining survey.*

   ii. *extent of change in cross section between each survey control point identified in the pre-mining survey.*

   iii. *change in pool-riffle sequence, depth and width of pools, location of breakout points for flood waters from the subsided troughs overlying each extracted longwall panel.*

   iv. *change in stream power relations through each chain pillar and chute/riffle sequence along the extent of the affected stream.*

   v. *obstruction to fish passage through reverse gradient slopes on the downstream face of each subsidence trough.*

   vi. *cumulative changes in stream power and tractive stress along the affected reach.*

   vii. *impacts on existing vegetation communities along Bowmans Creek from subsidence or other impacts, and potential impacted areas from potential breakout points along the channel (such as the southern length of subsidence overlying longwall panels 5, 6 and 7 beyond the incised meander of Bowmans Creek); and*

   viii. *monitoring to assess impacts to fish, fish passage, macroinvertebrates and aquatic habitat; water velocities and flow rates; and geomorphological design and stability of the creek.*

d) *long term monitoring on a bi-annual basis extending for at least five years after longwall mining has been completed under Bowmans Creek;*

   i. *changes in bed gradients, control point locations, pool/riffle locations and chute depths and energies along the affected reach of the creek.*

   ii. *changes in bedload transport rates, bed material sorting/imbrication, bedrock control exposure and energy relations in the affected reach of the creek.*

iii. *drainage of local groundwaters into and water quality changes in each pool of Bowmans Creek, including an assessment of pool maintenance periods during dry periods resulting from discharge of local groundwaters into Bowmans Creek.*

iv. *vegetation community changes along the length of the affected channel.*

v. *long term changes in biological communities within the affected reach of the creek; and*

vi. *monitoring to assess impacts to fish, fish passage, macroinvertebrates and aquatic habitat; water velocities and flow rates; and geomorphological design and stability of the creek.*

The baseline assessment and ongoing monitoring program aims to ensure that compliance with the above condition is achieved. For matters in the above which relate specifically to aquatic ecology, riparian vegetation and groundwater interactions, it is noted that these aspects are outside the scope of this report and are addressed by the following monitoring regimes:

- Aquatic ecology monitoring: currently being conducted biannually with the most recent being in Autumn 2008 (Marine Pollution Research); and
- Groundwater monitoring and investigations. Detailed investigation of Bowmans Creek alluvium has recently been completed by Aquaterra (2008).

2.0 Desktop Review

2.1 Environmental Impact Statement (2001)

Patterson Britton (2001) prepared an assessment of Bowmans Creek as part of the initial development application proposal which involved a diversion of Bowmans Creek around the underground project area. This report was prepared in support of the EIS (HLA, 2001).

Whilst the diversion was later dropped from the proposal, the document contains relevant information on Bowmans Creek.

2.2 Pre-mining Baseline Assessment (2006)

ERM prepared a pre-mining baseline assessment of Bowmans Creek prior to the commencement of underground mining and to prepare a program for ongoing monitoring of fluvial geomorphology of Bowmans Creek.

The report was prepared to address the relevant consent conditions noted in the Development Application consent conditions as they relate to the approval for the extraction of the Pikes Gully Seam within longwall panels 1 to 4. It also establishes the baseline for ongoing monitoring during and after the potential mining of longwall panels 5 to 8.

The following methodology was employed for preparation of the baseline assessment (ERM, 2006):

- Review of existing literature for Bowmans Creek;
- Review of literature addressing contemporary river processes in New South Wales coastal rivers pre- and post-European settlement;
- Inspection of modern and historical aerial photographs of the site, with particular attention to any changes in channel position, plan-form, morphology and riparian vegetation;
- Field inspection of general landscape and creek features, including evidence of river bank erosion, channel bed lowering, in-channel debris accumulation, cattle trampling, gravel bars, divided flow, impacts of bridges, crossings and fences, and pool and riffle locations in relation to meanders;
- In-situ measurements of dissolved oxygen, electrical conductivity, pH, temperature, total dissolved solids and turbidity;
- Use of surveyed cross profiles to determine channel gradient, width, depth, cross sectional area and width to depth ratios;
- HEC-RAS modelling to identify critical hydraulic control points and characterise stream hydraulics under various flow events;
- Establishment of photo monitoring and stream condition monitoring locations and baseline recording at these locations; and
- Development of a monitoring program to meet the requirements of the consent conditions regarding stream monitoring of Bowmans Creek.

2.3 Bowmans Creek

2.3.1 Catchment Description

Bowmans Creek is a major tributary of the Hunter River that drains a catchment of $265km^2$. It flows in a predominantly southerly direction until it joins the Hunter River about 56 kilometres from its headwaters.

The catchment of Bowmans Creek comprises terrain of varying slope that flattens with distance downstream from the catchment divide. The catchment can be characterised by steeply sloping terrain in the upper section with peak elevations 830mAHD (at Big Brother) which transitions to form a relatively flat and open floodplain that extends downstream of the village of Ravensworth. Bowmans Creek has little to no riparian vegetation along its full reach and the majority of the catchment is cleared of native vegetation with the exception of the steep slopes in the upper catchment. Land use throughout the catchment is dominated by agriculture (grazing) and coal mining. Immediately upstream of the New England Highway Bridge, Bowman Creek is joined by Bettys Creek and Swamp Creeks.

Between the New England Highway and the junction of Bowmans Creek and the Hunter River, the catchment is relatively narrow (approximately 2 to km wide). It extends to the ridgeline over LW1-4 in the east and partially over Ravensworth and to the west.

2.3.2 Physical Characteristics

Upstream of the New England Highway Bridge, Bowmans Creek follows a meandering path through a relatively narrow alluvial floodplain. The channel typically has a "v-shape" formed by the natural floodplain topography. The stream exhibits a pool and riffle sequence formed by gravel shoals and in-channel gravel point bars. The bed of the channel is lined by cobbles with occasional outcropping of bedrock.

In the area downstream of the New England Highway Bridge, the channel becomes increasingly incised within the alluvial floodplain. Close to the junction with the Hunter River, the channel is incised up to twelve metres below the banks and surrounding floodplain.

The channel banks are alternately steep, gently sloping and terraced, with no clear pattern to channel form evident within the study area. The steepest bank is generally located on the outside of bends, as is typical of a meandering stream. Occasional outcrops of bedrock are evident along the length of the creek. With downstream progression, the channel bed graded from cobble lining with a gravely silty substrate to a silty sand substrate.

A channel is considered to be meandering if its sinuosity is greater than 1.5. The sinuosity ratio is the distance between two points on the stream, measured along the channel thalweg, divided by the distance between the two points measured in a straight line. The channel of Bowmans Creek from the New England Highway Bridge to the junction with the Hunter River is 6km and the straight line distance is 3.04km. This equates to an overall sinuosity ratio of 1.97 and hence Bowmans Creek can be considered to be meandering.

The pool and riffle sequence at Bowmans creek downstream of the New England Highway is formed by gravel shoals and in-channel gravel point bars. The meanders of the creek exhibit an alteration of bends and straight reaches of 100m to 300m in length. Pools are typically narrow and slow flowing, with fine bed sediments and asymmetrical cross sections. Riffles are located on the high parts of the bed at low discharges. They are typically steep-banked, wide, shallow and fast flowing with coarser sediments and symmetrical cross sections, though most comprise vegetated pebble bars.

Examination of the contours and sections indicates that some profiles exhibit unpaired terracing, suggesting lateral migration of the channel may have occurred in these reaches. However, most profiles appear to be constrained on one bank and therefore only exhibit terracing on the opposite bank. This is supported by the findings of aerial photograph interpretation (ERM, 2006) with three small billabong formations indicating past channel migration that occurred well before 1983.

2.3.3 Hydrology and Flooding Behaviour

The local area has an average rainfall of 724mm per annum. A flow gauging station is located within the study area and has been operating since approximately 1993 (Foy Brook, Station No. 210130). The creek is perennial although it reportedly ceases to flow during severe droughts.

The floodplain within the study area can be best described a partly confined valley setting (ie discontinuous floodplains) although some transition to a laterally unconfined valley setting has occurred in the southern portion of the site.

Patterson Britton (2001) report that flooding in the upper Hunter River has occurred on numerous occasions. During the 1955 flood, the Hunter River reached a peak level of 64.2mAHD in the vicinity of Ashton Coal. In this event, a substantial proportion of the ACP site downstream from the New England Highway was inundated. At the same time, rainfall in the Bowmans Creek catchment led to the concentration of runoff along Bowmans Creek. Large flows were distributed downstream and flooded extensive areas of the Bowmans Creek floodplain. Available records suggest that a peak flood level of 67.8mAHD occurred on the upstream side of the New England Highway Bridge during the 1955 flood.

Although inundation of the ACP would be most influenced by major flooding of the Hunter River, there is also potential for inundation of the site due to flooding of Bowmans Creek. Flooding of the site can be dominated by either runoff from the Bowmans Creek or backwater inundation due to flooding in the Hunter River, or both simultaneously.

A comparison of 1955 recorded versus predicted peak flood levels for the site shows that backwater effects from the Hunter River dominate flooding behaviour across the southern section of the mine site (Patterson Britton 2001). In the event of a 1 in 100 year Average Recurrence Interval (ARI) design flood occurring in the Hunter River and Bowmans Creek simultaneously, Patterson Britton concluded that floodwaters from the Hunter River would "back-up" along Bowmans Creek to a point about 3.7km upstream from the confluence.

Desktop review of flood flows presented in previous reports found differences in the values adopted for catchment discharge during design flood events. A review of the approaches used was undertaken and it was concluded that the methodology adopted by Patterson Britton (2001) represents a more comprehensive analysis of the potential catchment discharge and the values presented in that report should be adopted for any future determination of changes to stream power and channel velocities. Patterson Britton used long term gauging data from upstream of the site (Gauge No 210042), catchment modelling using RAFTs and verification of results using the Probabilistic Rational Method to determine peak catchment discharge for a range of design events. ERM (2006) used only the short-term data available from Stream Gauge 210130 (less than 15 years data) to estimate the 1 in 2 year and 1 in 10 year Average Recurrence Interval (ARI) peak flow and noted the limitations of using this limited data set.

Values of catchment discharge that may be adopted for future hydraulic modelling and assessment (*in lieu* of additional hydrological assessment) are presented in Table 1.

Table 1 – Catchment Discharge

Design Flood Event (ARI)	Peak Discharge (m^3/s)
1 in 100 year[1]	844
1 in 50 year[2]	695
1 in 20 year[1]	546
1 in 10 year[2]	408
1 in 5 year[1]	340
1 in 2 year[2]	209
1 in 1 year[1]	120

1. *These values have been sourced from Patterson Britton (2001) and independently checked as part of this review using the Probabilistic Rational Method*
2. *Values have been determined using the Probabilistic Rational Method to provide a complete the data set*

In June 2007 as a result of an East Coast Low, widespread flooding occurred within the Hunter Valley, including Bowmans Creek. Comparison of daily stream flow gauging data for Foy Brook indicates that the peak flow recorded during this event was 17,826ML/day (206m^3/s). Comparison of this recorded flow to design flood flows shown in the table above indicates that the flooding experienced in Bowmans Creek in June 2007 was of only a relatively minor nature and approximately equivalent to the 1 in 2 year ARI design flood event for Bowmans Creek.

Recent climatic conditions in the Hunter Region have been dominated by drought conditions over the last 5 to 10 years. The years in this period have received below average to significantly below the annual average rainfalls, and as such the existing morphology of the stream is likely to reflect this climatic influence. It is likely that Bowmans Creek existing channel formation is strongly influenced by low flows and that overall rates of sediment transport are currently quite low. This is supported by visual inspections which note extensive sand and gravel deposits. With a return to normal or above average rainfall conditions, an increase in sediment mobilisation and alterations in channel form are highly probable.

3.0 Monitoring Program

3.1 Objectives

As outlined by ERM (2006) the overall objective of the monitoring program will be to detect subsidence impacts to Bowmans Creek and achieve compliance with the requirements Condition 3.26 of the development consent.

This report presents the results of the updated baseline monitoring by Pegasus Technical (2008) and Maunsell. The data presented and methodology used aimed to ensure the baseline data required for comparison purposes in the immediate post-mining and long-term post mining monitoring periods is sufficient to enable the identification of subsidence related impacts.

3.2 Monitoring Schedule

The schedule required for monitoring is set out in the development consent and includes both an immediate post-mining and long term post-mining monitoring phase to be conducted. The wording of the consent states that monitoring will be conducted "*at least twice in the period within one year of each longwall pass under Bowmans Creek".* However, approximately two panels will be completed per year, as shown in the schedule below).

Table 2 – Indicative Mining Schedule

Longwall Extraction Schedule		
Panel	**Commencement**	**Completion**
LW/MW 5	November 2009	May 2010
LW/MW 6	June 2010	December 2010
MW 7	December 2010	April 2011
MW 8	May 2011	September 2011
LW/MW 9	October 2011	April 2012

Therefore monitoring will be conducted twice per year, commencing in 2010 (i.e. following the completion of LW/MW 5). Where possible, the monitoring will be timed as soon as practicable after the completion of each panel (i.e. prior to additional impacts being incurred following by the subsequent panel).

The biannual monitoring is required to continue for five-years following the completion of panel 9.

3.3 Methodology Overview

The monitoring aims to enable assessment of impacts (resulting from subsidence) to Bowmans Creek as required by the Development Consent. Monitoring parameters identified in the consent and the methodology by which they will be assessed is summarised in Table 3.

Table 3 – Monitoring Methodology Overview

Impact	Assessment methodology
Immediate Post-mining Monitoring	
Change in level and gradient from each control point identified in the pre-mining survey	Re-survey and comparison of levels to baseline
Change in cross section between each survey control point identified in the pre-mining survey	Re-survey and comparison of levels to baseline
Change in pool-riffle sequence, depth and width of pools	Re-survey and comparison of pool locations (note that total depth is naturally variable and width a function of prevailing flow conditions)
Location of breakout points for flood waters from the subsided troughs overlying each extracted longwall panel.	Re-survey and analysis of contour data to identify flood breakout points
Change in stream power relations through each chain pillar and chute/riffle sequence along the extent of the affected stream	Hydraulic modelling and comparison of stream power values at each cross section
Development of reverse gradient slopes on the downstream face of each subsidence trough (potential obstruction to fish passage).	Re-survey and comparison of longitudinal gradient to baseline.
Cumulative changes in stream power and tractive stress along the affected reach	Hydraulic modelling and comparison of overall stream power values
Development of potential breakout points along the channel (such as the southern length of subsidence beyond the incised meander of Bowmans Creek)	Re-survey and analysis of top of bank levels and subsidence monitoring survey.
Monitoring to assess impacts to water velocities and flow rates, geomorphological status and stability of the creek.	Hydraulic modelling, field inspection and photographic monitoring.
Long-term monitoring	
Changes in bed gradients, control point locations, pool/riffle locations and chute depths and energies along the affected reach of the creek.	As above
Changes in bedload transport rates, bed material sorting/imbrication, bedrock control exposure and energy relations in the affected reach of the creek.	Field observations and photographic monitoring, hydraulic monitoring.
Monitoring to assess impacts to water velocities and flow rates; and geomorphological design and stability of the creek.	As above

3.4 Survey Monitoring

Baseline surveys have been conducted in 2006 and 2008 by Pegasus Technical and will form the basis of ongoing survey monitoring. These surveys included:

- Establishment and survey of detailed channel cross sections;
- Identification and survey of stable bedrock control points;
- Longitudinal sections along the thalweg; and
- Identification of pool locations, widths and depths.

Survey control marks in the form of galvanised steel posts have been placed on each side of the creek bank at monitoring cross sections to provide a permanent point of reference. These survey monitoring cross sections have been placed at bedrock control points or maximum intervals of 250 metres where bedrock controls do not exist. The location of the survey control marks (Eastings, Northings and current relative level (RL) in metres Australia Height Datum (mAHD)) are listed in Appendix A. These points will form as a permanent point of reference to measure indicative creek level movements. The survey control points provide the start and finish points for each detailed cross-section.

The beginning, end, and major change in grade of each bedrock control point along the thalweg have been surveyed as part of the baseline, and will continue to be monitored using the same methodology.

At four well spaced locations along the creek, a series of cross sections at 15 metre intervals has been established to assist in the future monitoring of changes in channel cross-section due to bedload movement through these reaches.

Areas identified as having either: pool-riffle sequences, rock bar and cobble chute pools and bed gradient steepening through riffle sequences have been surveyed and a longitudinal section plot of the thalweg produced. The locations of the survey shots are taken at changes in grade or no further apart than 50m.

Any pools found during the survey by Pegasus were located and shown on a plan indicating the pool depths and widths.

The location of the survey monitoring cross sections is shown in Figure 3.

3.5 Photographic Monitoring

ERM (2006) established 17 photo monitoring points at which, photos were taken both viewed upstream, downstream and perpendicular to the channel. These locations were reviewed as part of this report and the need for additional photo monitoring points considered in light of the amended mine plan.

As part of this review, an additional 9 monitoring points were added to the monitoring methodology. The existing points and additional points are shown in Figure 4. GPS coordinates of the location each photo was taken and the directional bearing is provided in Appendix B.

3.6 Field Observations

The monitoring methodology recommended by ERM (2006) included the documentation of field observations of the following:

- Stream banks:
  - Topography;
  - Soils;
  - Vegetative Cover;
- Midstream:
  - Bed material/sorting;
  - Hydrology (pools, depths); and
  - Aquatic flora and fauna.

However, repetition of these observations is problematic in that they rely heavily on the interpretation and observations of individuals. Furthermore, some of the above factors are unlikely to change over time as a result of mining, can be influenced by other anthropogenic or seasonal factors and/or overlap with other more comprehensive monitoring programs (i.e. aquatic flora and fauna).

Generally the photographic monitoring and detailed survey monitoring is sufficient to identify morphological changes in Bowmans Creek without subjective observations being recorded on the above factors. Therefore, documented field observations are not recommended for the ongoing monitoring program other than key observations on gross channel, bank or vegetative changes.

3.7 Hydraulic Modelling

Hydraulic modelling was undertaken by ERM (2006) using HEC-RAS to estimate flow characteristics, velocities, energy and stream power for a number of flow conditions. Post-mining, the hydraulic modelling will be repeated using the post-subsidence survey cross sections and the catchment discharges presented in Table 1. The results will then be used to estimate changes in stream power at each individual cross section used to determine the likely long-term response of the channel to subsidence.

Stream power is commonly used as a theoretical basis for evaluating bedload transport and can assist in the understanding of fluvial form and behavioural characteristics – particularly channel patterns and meander dynamics and changes induced as a result of human activities (Worthy 2005). Stream power represents the energy available to transport sediment in a stream and is defined as:

$$W = \gamma Q s$$

W = stream power per unit length of channel (W/m)
γ = specific weight of water (9810 N/m^3)
Q = discharge (m^3/s)
s = energy slope (m/m)

Using the results of the hydraulic modelling, stream power will provide a useful index for describing the erosive capacity of the stream and observing any changes in the ability of Bowmans Creek to transport bedload. The prediction of potential changes in stream behaviour will depend on the bed particle size and whether each individual section (in a pre-mining context) is either:

- Stable (no cross-sectional change – available energy is sufficient to transport all the material delivered from upstream);
- Aggrading (energy available to move sediments is less than the volume of sediments arriving from upstream); or
- Degrading (not enough sediments are arriving to consume the available energy (or stream power) and is therefore eroding).

Qualitative results to changes in stream power for bank full flows are summarised in Table 4.

Table 4 – Likely Impacts to Changing Stream Power

Pre-mining Cross Section	Stream Power Change	Likely Action
Stable	Increase	Initiation of erosion
	Decrease	Initiation of sedimentation
Aggrading	Increase	Section may become stable or start to degrade
	Decrease	Increasing rate of sedimentation
Degrading	Increase	Increasing rate of erosion
	Decrease	Section may become stable or start to aggrade.

In addition to observing changes in stream power, thalweg sections for pre and post mining will be compared to reveal changes in bed gradients and areas of aggradation and degradation. Noting that over time, aggrading sections tend to become steeper and degrading sections flatter. The comparison of these longitudinal sections will be particularly focused on the identification of nick points and/or head-cutting within the stream bed.

3.8 Monitoring Limitations & Key Considerations

It is noted that the processes of erosion and deposition of sediment in streams is a natural one, and that these natural patterns can be altered by anthropogenic influences such as clearing, land use. Channels are generally stable for long periods of time, until a flow event of sufficient size occurs to alter the channel morphology.

It is expected that other than changes in surface levels as a result of subsidence, changes in channel morphology (either natural, subsidence induced, or as a result of other anthropogenic causes) between monitoring events may not become apparent unless there has been a significant flow event between surveys.

Furthermore, care should be taken not to assume that any major changes in channel morphology are a result of subsidence where a significant flow event has occurred. However, key changes in stream cross section and longitudinal grade should be observed to ensure subsidence is not resulting in:

- A loss of pool-riffle structure during low flows
- Increase in bank instability and collapse – resulting in excess sediment input into the system
- Loss of stream meanders and increase in grade (and resulting increase in stream power)

These changes would potentially result in impacts to aquatic and riparian ecology and downstream water quality.

4.0 Monitoring Results

4.1 Overview

Following a flood event in June 2007 (in conjunction with widespread flooding of the Hunter River) the baseline survey was repeated by Pegasus Technical in July 2008. Aquatic ecologists from Marine Pollution Research noted in their ecological monitoring events that this flood event had caused resulted in the following impacts along Bowmans Creek within the study area:

- Bank instability and/or collapse
- Mud deposition
- Severe scouring of groundcovers
- Fallen riparian trees

Therefore, to ensure that survey information for Bowmans Creek provided a representative baseline prior to mining beneath Bowmans Creek, the baseline physical survey of Bowmans Creek was repeated using the methodology discussed in Section 3.4.

In addition to the repetition of the baseline survey, field inspections of the general condition of Bowmans Creek and photo monitoring were also undertaken. The results of this monitoring and comparison to the 2006 Baseline Assessment is detailed below.

4.2 Cross Section Geometry

Despite anecdotal observations of bank collapse and instability and channel scour as a result of the 2007 floods, survey monitoring of the cross sections did not reveal significant changes in cross section geometry for most of the survey monitoring sections.

Data for each of the survey monitoring cross sections from 2006 and 2008 were compared and are plotted in Appendix C. Some apparent differences in cross section geometry visible in these plots are partially the result of differences in the location of survey levels. Maximum vertical changes in channel level are shown in Table 5.

Table 5 – Summary of observed differences in cross section survey

Cross-section	Description of change	Approx change in RL (m)
XS A	Scour of channel invert	-0.6
XS D	Deposition in channel	+0.4
XS E2	Scour of channel invert	-0.1
XS E3	Deposition on LHS Bank – small terrace formed	+0.3
XS E	Deposition on LHS Bank – increase in terrace	+0.2
XS E4	Deposition on LHS Bank – increase in terrace	+0.4
XS E5	Deposition on LHS Bank – increase in terrace	+0.2
XS E6	Deposition on LHS Bank – increase in terrace Alterations to RHS bank geometry	+0.3
XS F	Alterations to LHS bank geometry	-
XS H	Deposition in channel	+0.2
XS I	Scour of midstream bar	-0.3
XS L	Possible lateral channel migration (2.5 metres to RHS) (may also be result of survey point selection)	-
XS N3	Deposition in channel	+0.4
XS O	Channel invert scour	-0.3
XS P	Deposition in channel	+0.2
XS Q3	Channel scour	-0.4
XS Q	Minor base channel widening	-
XS Q6	Overall change in geometry – LHS bank slump.	-
XS T	Scour and shift of channel invert	-0.1
XS U	Scour at base of RHS bank	-0.7
XS V5	Bank collapse on LHS and scour of channel bed	-0.5
XS V6	Scour of channel invert	-0.6
XS W	Scour of channel invert	-0.5
XS X	Scour of channel invert (may be lack of survey data points)	-0.9
XS Z	Scour of channel invert	-0.4

4.3 Longitudinal Profile

Survey longsections along the creek thalweg have been carried out and compared. Thalweg survey locations are located along sections of the creek that will travel through subsidence troughs as shown in Figure 3.

4.4 Pool Riffle Sequence

There were 44 distinct pools identified in the ponding survey by Pegasus Technical in March 2006 compared to 12 pools July 2008.

Review of the survey and photographic monitoring conducted in 2006 and it is noted that this survey was undertaken during drought conditions and there was little, if any, flow in Bowmans Creek at that time. Any surface water in the creek occurred largely in a series of largely disconnected pools. Where surface flow through riffles did occur, it was typically very small.

In 2008, surface water flows were significantly greater and observations during site inspection by Maunsell noted continuous surface water was present for the entire length and that it was difficult to differentiate between pool and riffle in terms of stream depth or width. Visually, the only indications apparent were changes in surface velocity.

Water depths between the two surveys are significantly different, as demonstrated by the water depth at the rock pool a short distance downstream of the New England Highway. In 2006, this pool was the third distinct surface water pool along the stream with a surface water level of only 61.6mAHD. In 2008, Pegasus noted this location as still being within the first pool along the stream (i.e. the former survey pools 1, 2 and 3 had merged) and the surface water level was 62.6mAHD.

The ponding survey conducted in 2006 provides a good indication of the deepest locations along the stream length and where the pre-mining pool locations occur. The comparison between the number of pools picked up in the 2006 and 2008 surveys also clearly indicates that the overall length and number of pools will change depending on the prevailing climate and that as flows and water depths increase:

- Pools merge and increase in length and width;
- Riffles become less evident; and
- Eventually relatively continuous flow is experienced along the entire reach.

Therefore a key consideration when assessing the impact of mining on pool and riffle sequences will be to note the overall flow conditions at the time of survey. Analysis of post-mining levels through the chain pillars and subsidence troughs, particularly along the thalweg sections, may prove more useful in the determination of mining impacts to pool location and formation. It is noted however that comparison of survey information along the thalweg, as produced in the attached figures, demonstrates that some natural variation in pool formation is already occurring.

4.5 Hydrology and Stream Flow

Following review of the cross-sectional survey, the degree of observed changes in overall cross section geometry (area, width depth) were not concluded to be sufficient to impact the overall hydraulic properties of Bowmans Creek during flood events.

However, repetition of the pre-mining hydraulic modelling previously conducted (ERM, 2006) will be required to update the baseline results based on the adopted catchment discharge values above. This should be included in the first post mining monitoring round to investigate any changes in energy gradient and sediment transport as a result of mining.

5.0 Summary

This report presents the results of the updated baseline assessment and also aims to ensure that the statutory requirements of Ashton Coal can be met through the proposed stream monitoring program as a result of the recent mine plan changes to incorporate miniwalls into the underground mine design.

Based on proposed changes to the Ashton Coal mine plan, which adopts miniwalls beneath the creek to minimise subsidence and recent flood flows, the baseline data has been reviewed to confirm that it still provides an adequate representation of the pre-mining condition of Bowmans Creek. It was found that:

- Some minor variation in channel form is occurring as is typical for a meandering stream;
- The flood event experienced in June 2007 was not a significant flood for Bowmans Creek, and as such, relatively minor changes to the stream morphology are apparent. Bank scour and erosion from this event, whilst visually apparent, have not significantly altered the channel form or pool-riffle sequence.

Maunsell have prepared an updated monitoring program methodology to address the development consent conditions for the stream monitoring program based on changes to the mine plan. This methodology is detailed in the report, and will enable the identification of mine impacts to the creek in accordance with Condition 3.20 of the ACP Development Consent. Sufficient detail is provided in this report to allow adequate repetition of the monitoring methodology over time, and in accordance with the proposed monitoring schedule.

It is noted that one of the key difficulties in interpreting the results of future monitoring will be to differentiate the impacts of mining versus variation of the stream through normal erosion and deposition processes. Recent climatic conditions in the Hunter Region have been dominated by drought conditions over the last 5 to 10 years and Bowmans Creek existing channel formation is strongly influenced by low flows. With a return to normal or above average rainfall conditions, an increase in sediment mobilisation and alterations in channel form are highly probable.

It will therefore be important to record the flow conditions in the intervening period between monitoring events and particularly major flow events. Major flood events present more potential for large changes to the stream compared to the low levels of subsidence predicted as a result of the LW/MW 5-9 mine plan.

If mining-induced impacts are identified, remedial measures will need to be determined based on the degree, extent and type of impacts identified. The design of remedial works, where required, should aim to:

- Provide long-term stability of the stream channel, banks and surrounding floodplain;
- Avoid hard engineering structures where possible;
- Allow the stream to naturally migrate in its channel boundaries;
- Maintain and support the existing pool-riffle sequence along the stream;
- Include the use of woody debris to support stream habitat; and
- Use vegetation to support and protect riparian banks rather than hard-engineering solutions.

References

ERM (2006) **Bowmans Creek Geomorphology Pre-mining Assessment**, report prepared for Ashton Coal Operations Pty Ltd, Environmental Resources Management Australia Pty Ltd, (Reference 0048641) Pyrmont Australia.

HLA Envirosciences (2001) **Environmental Impact Statement, Ashton Coal Project**. Prepared for White Mining Limited, HLA Envirosciences, Warabrook, NSW Australia.

Marine Pollution Research (2008) **Ashton Coal Subsidence Management Plan Longwalls 5 to 9: Aquatic Ecology Aspects**, prepared for Ashton Coal Operations Pty Ltd. Marine Pollution Research Pty Ltd.

Patterson Britton (2001) **Ashton Mine Project Camberwell, Proposed Diversion of Bowmans Creek** prepared for White Mining Limited. Patterson Britton and Partners.

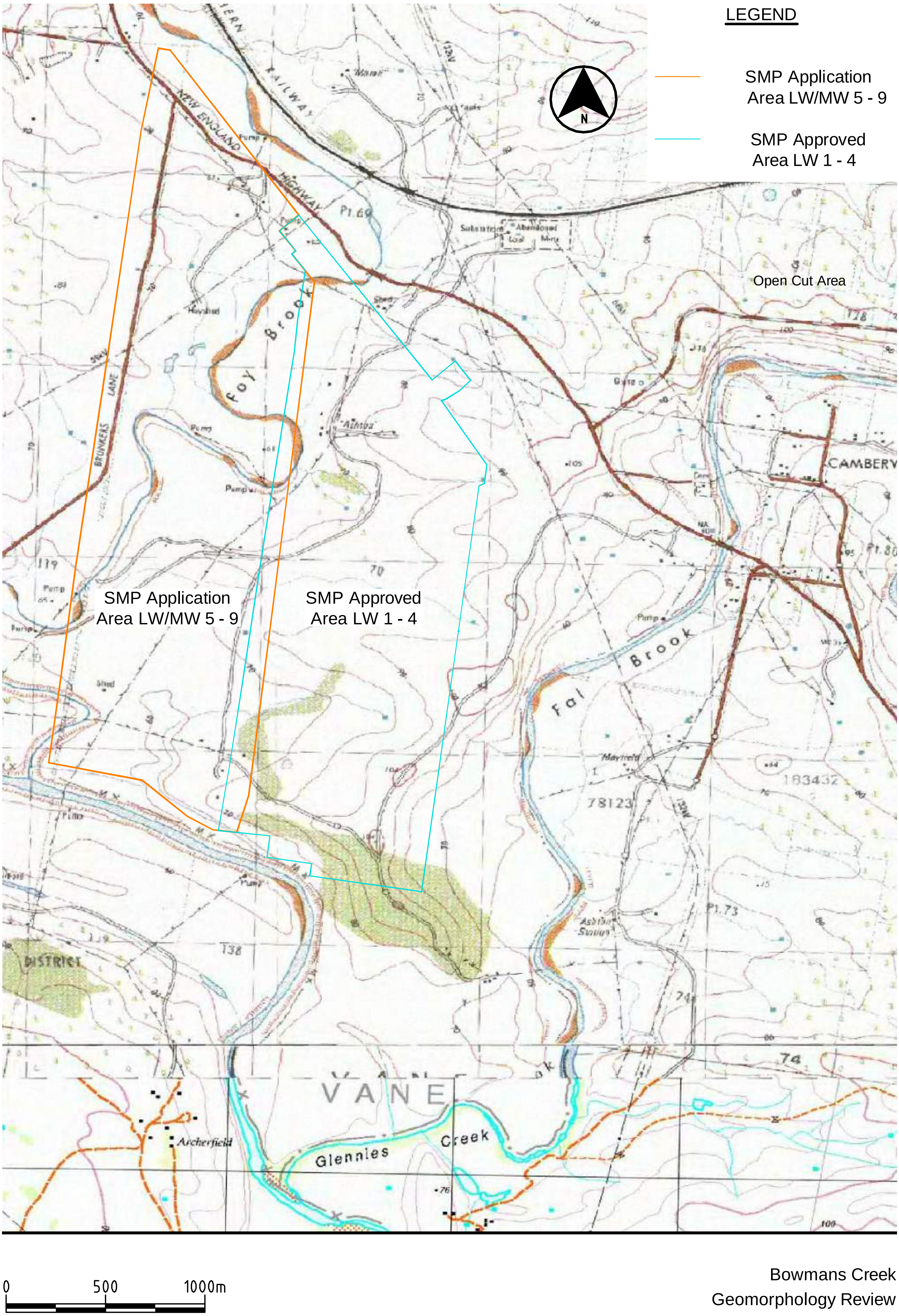
Pegasus Technical (2006) **Ashton Coal Operations Bowmans Creek Monitoring Program: 2008 Survey Report. Prepared** for Ashton Coal Operations Limited. Pegasus Technical

Pegasus Technical (2008) **Ashton Coal Operations Bowmans Creek Monitoring Program: 2008 Survey Report. Prepared** for Ashton Coal Operations Limited. Pegasus Technical

Worthy M (2005) High-resolution total stream power estimates for the Cotter River Namadgi National Park, Australian Capital Territory **Regolith 2005: Ten years of CRC LEME pp.338-343**. Proceedings of the CRC LEME Regional Regolith Symposia 2005.

Figures

MAUNSELL | AECOM



K:\60045376_BCRKGEOM\5. CADD\5.3 Working\AUTOCAD\FIGURES\60045376_Figure 1 Locality Plan.dwg Thursday, October 30, 2008

Bowmans Creek
Geomorphology Review

Figure 1 - Locality Plan

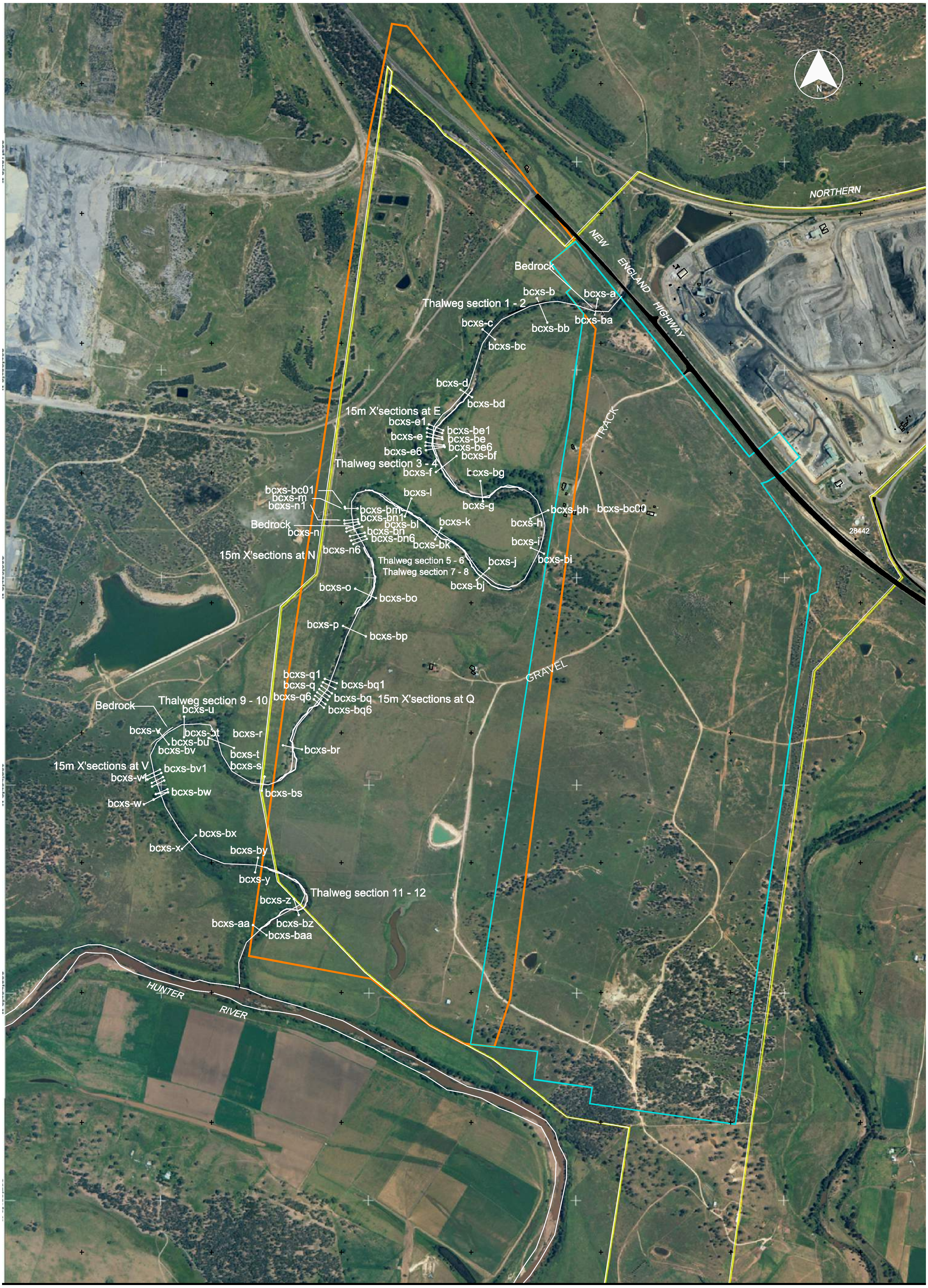
MAUNSELL | AECOM

Cad ref: K:\60045376_BCRKGEOM\5. CADD\5.3 Working\AUTOCAD\FIGURES\60045376_Figure 2 Proposed Mine Plan.dwg

0 150 300 450 600 750m

Bowmans Creek
Geomorphology Review

Figure 2 - Ashton Underground Mine Layout



Friday, October 31, 2008

K:\60045376_BCRKGEOM\5. CADD\5.3 Working\AUTOCAD\FIGURES\60043883_Figure 3 Bowman Creek Survey Monitoring Locations.dwg

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Bowmans Creek
Geomorphology Review

Figure 3 - Survey Monitoring Locations

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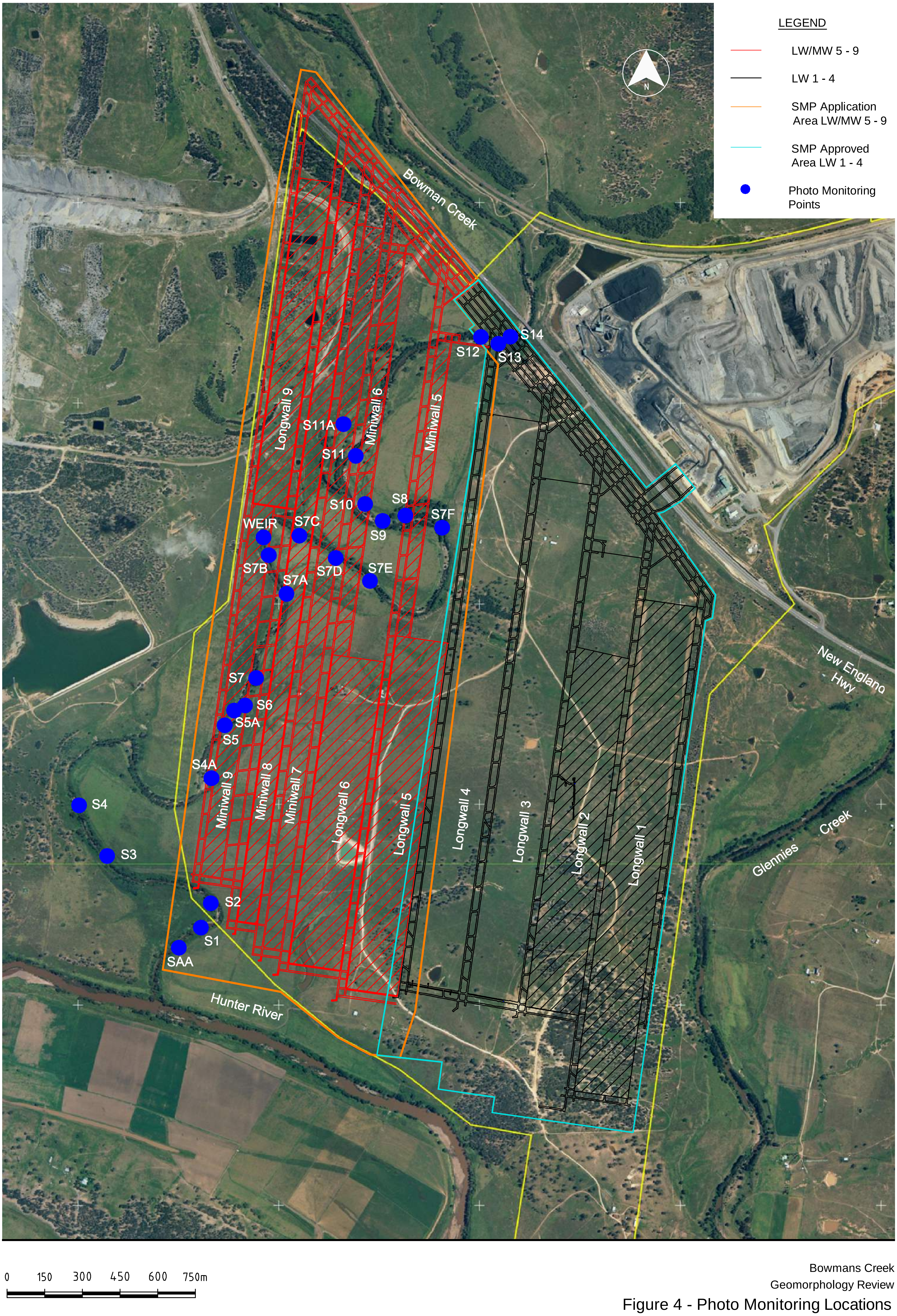

Cad ref: K:\60045378_BCRKGEOM\5. CADD\5.3 Working\AUTOCAD\FIGURES\... Figure 4 Bowmans Creek Photo Monitoring Locations.dwg

Bowmans Creek
Geomorphology Review

Figure 4 - Photo Monitoring Locations

Appendix A Survey Control Marks

Appendix B Survey Control Marks

POINT	NORTHING	EASTING	RL	CODE
4	6405746.193	319480.719	107.929	ssm28442
5	6405864.379	318652.09	88.044	BC00
6	6405870.036	317513.146	62.731	BC01
7	6406671.09	318487.281	66.766	BCXS-A
8	6404259.431	317159.419	61.53	BCXS-AA
9	6406673.767	318253.142	65.639	BCXS-B
10	6406609.819	318477.25	66.213	BCXS-BA
11	6404220.551	317211.845	61.169	BCXS-BAA
12	6406579.775	318293.167	65.893	BCXS-BB
13	6406514.852	318092.121	64.367	BCXS-BC
14	6406292.432	318003.483	65.086	BCXS-BD
15	6406130.391	317889.473	63.919	BCXS-BE
16	6406164.587	317892.414	63.458	BCXS-BE1
17	6406154.042	317888.332	63.408	BCXS-BE2
18	6406138.403	317888.003	63.833	BCXS-BE3
19	6406107.625	317894.562	63.982	BCXS-BE4
20	6406103.099	317896.955	63.913	BCXS-BE5
21	6406100.371	317898.006	63.903	BCXS-BE6
22	6406065.933	317943.647	64.666	BCXS-BF
23	6405969.578	318035.638	64.162	BCXS-BG
24	6405856.836	318296.893	65.804	BCXS-BH
25	6405689.692	318280.402	63.697	BCXS-BI
26	6405588.53	318021.539	63.441	BCXS-BJ
27	6405744.569	317861.438	60.845	BCXS-BK
28	6405833.168	317744.237	60.369	BCXS-BL
29	6405863.966	317562.419	59.906	BCXS-BM
30	6405793.578	317580.049	60.617	BCXS-BN
31	6405822.224	317563.93	60.173	BCXS-BN1
32	6405812.646	317565.219	60.153	BCXS-BN2
33	6405804.886	317569.018	60.541	BCXS-BN3
34	6405770.606	317589.499	60.831	BCXS-BN4
35	6405757.308	317591.765	60.617	BCXS-BN5
36	6405518.895	317633.149	62.697	BCXS-BO
37	6405371.392	317594.409	61.843	BCXS-BP
39	6405140.447	317454.31	60.787	BCXS-BQ
40	6405191.328	317482.476	61.316	BCXS-BQ1
41	6405169.847	317476.662	61.303	BCXS-BQ2
42	6405152.144	317463.264	60.995	BCXS-BQ3
43	6405126.915	317446.868	60.943	BCXS-BQ4
44	6405110.488	317438.74	60.873	BCXS-BQ5
45	6405096.683	317433	60.854	BCXS-BQ6
46	6404936.192	317348.42	59.995	BCXS-BR

POINT	NORTHING	EASTING	RL	CODE
47	6404776.799	317193.461	61.088	BCXS-BS
48	6404979.906	316988.917	57.848	BCXS-BT
49	6404983.187	316893.944	57.749	BCXS-BU
50	6404955.434	316834.878	60.558	BCXS-BV
51	6404858.508	316801.284	60.579	BCXS-BV1
52	6404845.419	316806.45	60.602	BCXS-BV2
53	6404829.686	316812.559	60.55	BCXS-BV3
54	6404816.382	316817.563	60.582	BCXS-BV4
55	6404771.008	316832.117	60.362	BCXS-BV5
56	6404782.666	316830.296	60.521	BCXS-BV6
57	6404771.008	316832.117	60.677	BCXS-BW
58	6404605.12	316938.941	60.451	BCXS-BX
59	6404518.992	317178.87	60.147	BCXS-BY
60	6404298.568	317335.956	61.254	BCXS-BZ
61	6406553.824	318043.936	64.279	BCXS-C
62	6406320.973	317958.745	63.558	BCXS-D
63	6406140.413	317830.177	63.348	BCXS-E
64	6406188.095	317837.056	63.451	BCXS-E1
65	6406172.614	317830.876	63.132	BCXS-E2
66	6406156.073	317829.298	63.069	BCXS-E3
67	6406118.815	317824.785	63.398	BCXS-E4
68	6406105.685	317824.177	63.556	BCXS-E5
69	6406088.062	317825.784	63.413	BCXS-E6
70	6406004.141	317863.913	64.79	BCXS-F
71	6405891.584	318045.412	64.63	BCXS-G
72	6405861.122	318158.553	64.328	BCXS-GH
73	6405824.078	318228.121	63.818	BCXS-H
74	6405712.873	318229.723	63.666	BCXS-I
75	6405633.774	318069.276	62.857	BCXS-J
76	6405789.233	317884.817	62.991	BCXS-K
77	6405902.218	317769.625	63.804	BCXS-L
78	6405899.112	317615.989	60.718	BCXS-LM
79	6405863.797	317514.989	62.772	BCXS-M
80	6405774.589	317519.95	63.464	BCXS-N
81	6405817.983	317511.112	62.859	BCXS-N1
82	6405805.337	317512.197	62.959	BCXS-N2
83	6405787.268	317519.4	62.996	BCXS-N3
84	6405757.244	317533.198	63.51	BCXS-N4
85	6405740.2	317537.866	63.351	BCXS-N5
86	6405726.859	317546.013	62.88	BCXS-N6
87	6405645.107	317637.988	60.875	BCXS-NO
88	6405554.98	317553.354	62.571	BCXS-O
89	6405411.53	317506.414	61.114	BCXS-P
90	6405168.13	317415.029	59.238	BCXS-Q

POINT	NORTHING	EASTING	RL	CODE
91	6405207.731	317436.274	59.615	BCXS-Q1
92	6405194.607	317429.101	59.486	BCXS-Q2
93	6405180.901	317422.946	59.372	BCXS-Q3
94	6405155.456	317407.022	58.904	BCXS-Q4
95	6405142.807	317398.966	58.739	BCXS-Q5
96	6405128.588	317394.24	58.018	BCXS-Q6
97	6404951.723	317274.724	61.009	BCXS-R
98	6404831.484	317204.336	59.714	BCXS-S
99	6404941.683	317086.227	59.886	BCXS-T
100	6405062.389	316894.219	60.072	BCXS-U
101	6405007.056	316795.036	60.525	BCXS-V
102	6404814.764	316718.514	65.842	BCXS-V1
103	6404805.036	316721.807	65.411	BCXS-V2
104	6404784.219	316727.798	65.154	BCXS-V3
105	6404774.08	316730.424	64.936	BCXS-V4
106	6404759.505	316734.397	65.055	BCXS-V5
107	6404743.389	316738.459	65.125	BCXS-V6
108	6404724.589	316738.965	65.726	BCXS-W
109	6404552.839	316885.828	59.988	BCXS-X
110	6404462.539	317167.515	59.843	BCXS-Y
111	6404348.043	317339.226	54.728	BCXS-YZ1
112	6404376.606	317362.575	50.207	BCXS-YZ2
113	6404435.694	317253.167	60.061	BCXS-YZ3
114	6404360.117	317317.191	58.791	BCXS-Z
1032	6405746.676	317598.137	61.427	BCXS-BN6

Appendix B Photo Monitoring Locations

Appendix C Photo Monitoring Locations

Site Name	Site Type	Easting	Northing	Photo Bearings		
		MGA Zone 56		Upstream	Across	Downstream
AA	Existing	317208	6404229	40°	326°	270°
1	Existing	317296	6404309	100°	165°	205°
2	Existing	317335	6404406			
BX	Existing	316922	6404595	270°	225°	170°
3	Existing	316861	6404671	330°	35°	90°
4	Existing (not found)	316810	6404797	300°	240°	165°
4A	New	317338	6404905	315°	233°	205°
5	Existing	317391	6405116	55°	120'°	185°
5A	New	317463	6405155	55°	120'°	185°
6LHS	Existing	317472	6405195	325°	275°	220°
6RHS	Existing	317428	6405175			
7	Existing	317516	6405304	320°	270°	210°
7A	New	317637	6405640	320°	260°	180°
7B	New	317566	6405794	315°	245°	275°
Weir	New	317545	6405865	315°	245°	275°
7C	New	317688	6405872	90°	355°	315°
7D	New	317833	6405783	114°	35°	307°
7E	New	317970	6405691	138°	30°	302°
7F	New	318254	6405907	283°	-	170°
8	Existing	318111	6405952	195°	130°	80°
9	Existing	318020	6405931	230°	160°	95°
10	Existing	317950	6405998	285°	225°	170°
11	Existing	317913	6406190	355°	300°	225°
11A	Existing	317864	6406317	100°	170°	240°
12	Existing	318412	6406664	110°	175°	240°
13LHS	Existing	318500	6406628	60°	350°	280°
13RHS	Existing	318489	6406654	105°	155°	225°
14	Existing	318522	6406661	80°	140°	200°

Appendix C Cross Section Comparison

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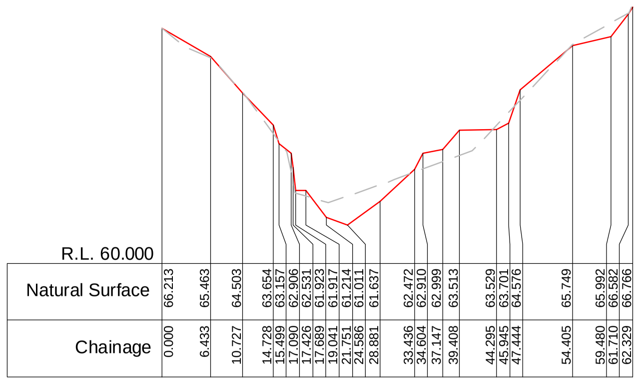
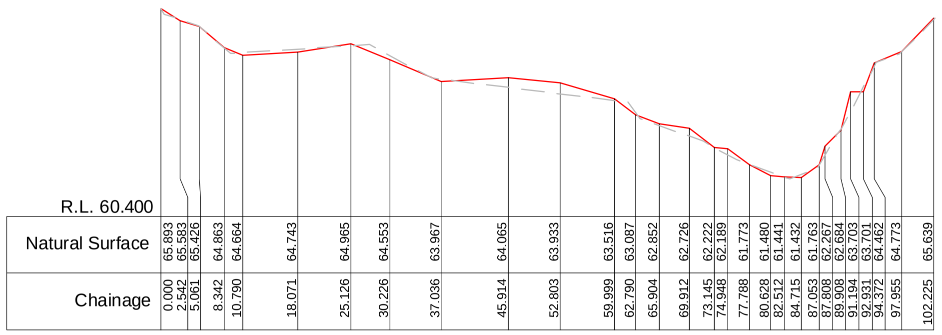


BCXS-BA CROSS SECTION

SCALES: HORIZ 1: 1000
VERT 1: 200



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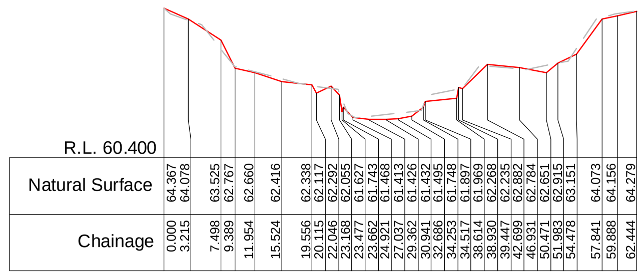

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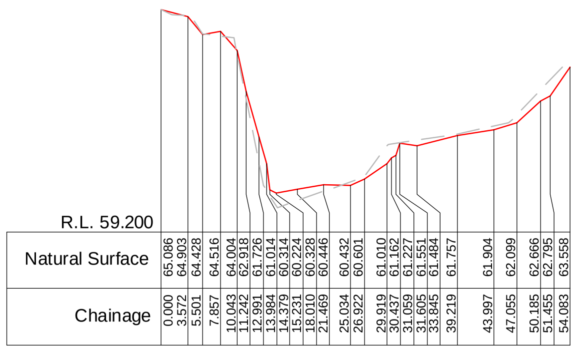

BCXS-BD CROSS SECTION

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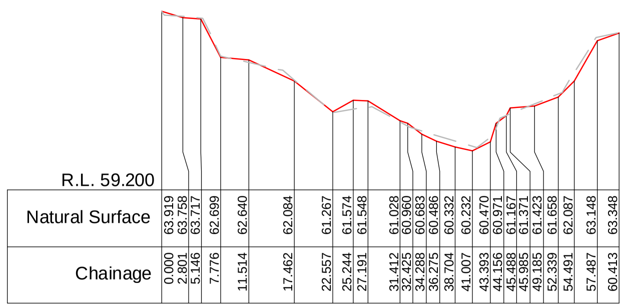

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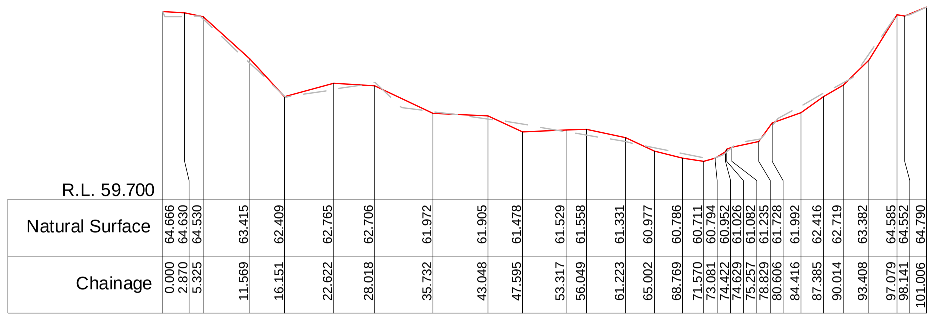

BCXS-BF CROSS SECTION

SCALES: HORIZ 1: 1000
VERT 1: 200

LEGEND
2005 SURFACE
2008 SURFACE

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Bowmans Creek
Geomorphology Review
Appendix - Cross sections BA - BF

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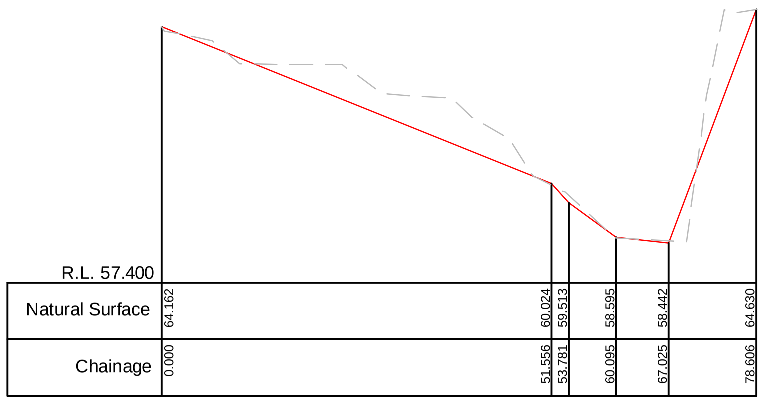

BCXS-BG CROSS SECTION

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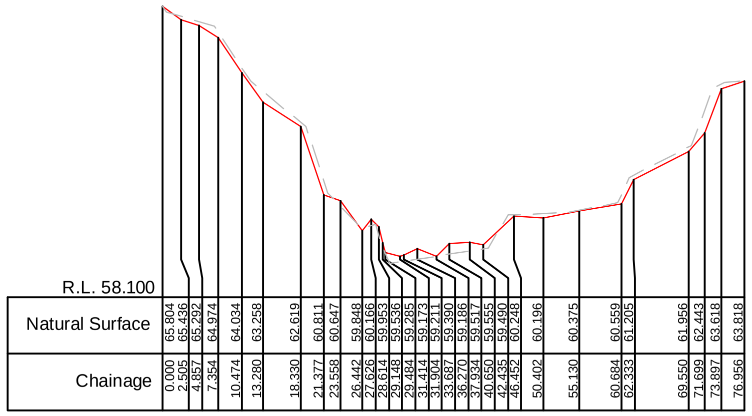

BCXS-BH CROSS SECTION

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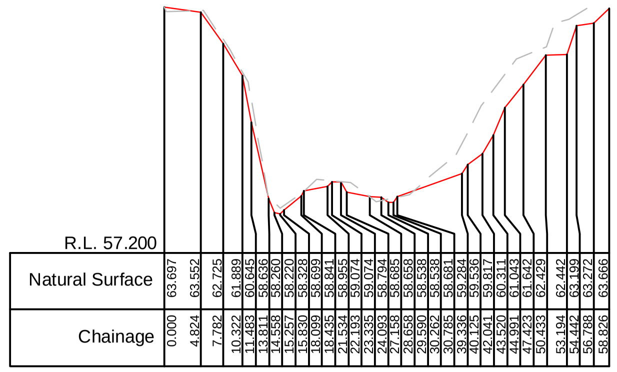

BCXS-BI CROSS SECTION

SCALES: HORIZ 1: 1000
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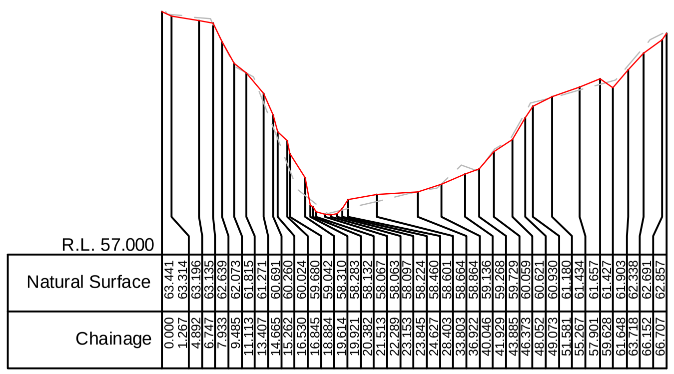

BCXS-BJ CROSS SECTION

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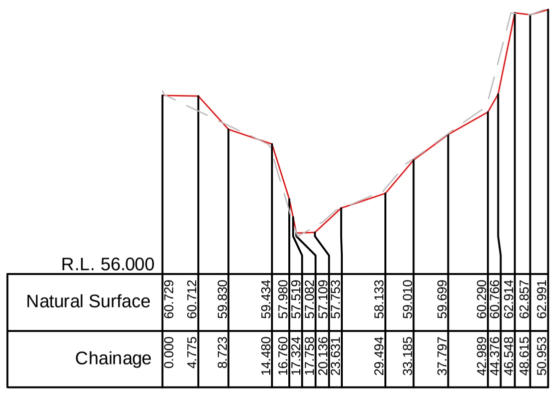

BCXS-BK CROSS SECTION

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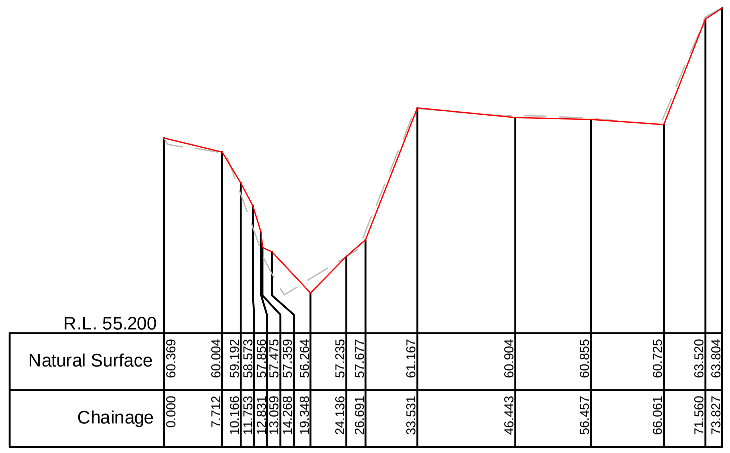
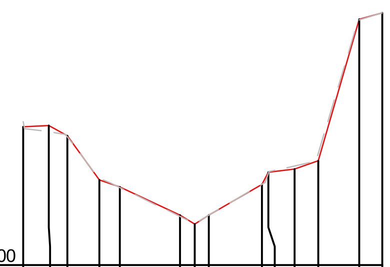


BCXS-BL CROSS SECTION

SCALES: HORIZ 1: 1000
VERT 1: 200

LEGEND
- - - - 2006 SURVEY
—— 2008 SURVEY

MAUNSELL | AECOM

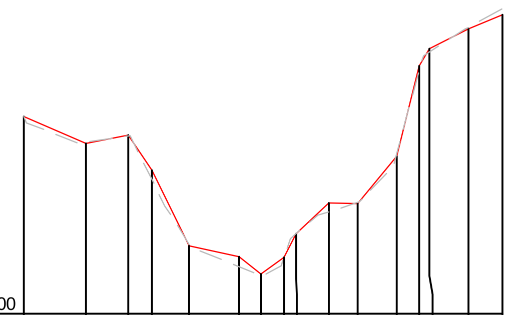


R.L. 56.100

Chainage	Natural Surface
0.000	59.771
3.313	59.792
5.792	59.529
10.077	58.362
12.787	58.174
20.736	57.424
22.622	57.191
24.514	57.436
31.498	58.244
32.950	58.561
35.866	58.641
38.957	58.875
44.442	62.610
47.457	62.772

BCXS-BM CROSS SECTION

SCALES: HORIZ 1: 1000
VERT 1: 200

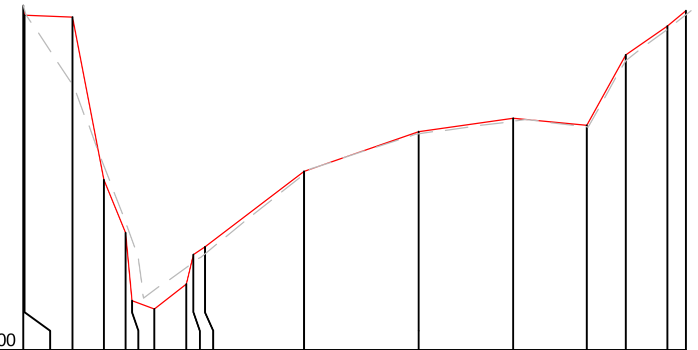


R.L. 55.400

Chainage	Natural Surface
0.000	60.617
8.232	59.901
13.795	60.122
16.919	59.186
21.893	57.192
28.451	56.905
31.344	56.453
34.355	56.882
35.980	57.517
40.323	58.321
44.143	58.316
49.277	59.555
52.253	61.952
53.555	62.414
58.758	62.926
63.223	63.306

BCXS-BN CROSS SECTION

SCALES: HORIZ 1: 1000
VERT 1: 200

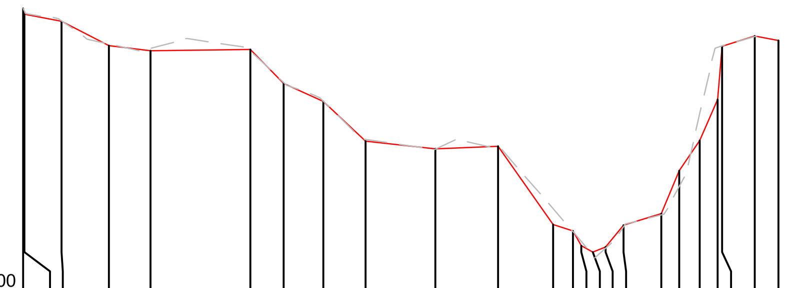


R.L. 53.600

Chainage	Natural Surface
0.000	62.697
0.141	62.444
6.519	62.391
10.608	58.092
13.488	56.694
14.400	54.891
17.346	54.669
21.582	55.331
22.451	56.121
23.971	56.326
37.125	58.322
52.283	59.366
64.768	59.717
74.514	59.534
79.688	61.400
85.240	62.158
87.623	62.571

BCXS-BO CROSS SECTION

SCALES: HORIZ 1: 1000
VERT 1: 200

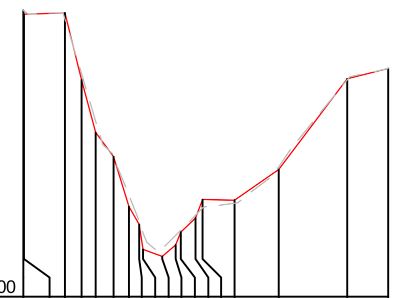


R.L. 54.400

Chainage	Natural Surface
0.000	61.843
0.170	61.689
5.026	61.498
11.368	60.855
16.809	60.722
30.008	60.763
34.473	59.858
39.702	59.391
45.255	58.328
54.449	58.130
62.809	58.192
70.090	56.128
72.705	55.966
73.806	55.570
75.295	55.413
77.011	55.544
79.396	56.123
84.354	56.423
86.719	57.565
89.434	58.357
91.837	59.438
92.411	60.848
96.717	61.114
99.838	61.002

BCXS-BP CROSS SECTION

SCALES: HORIZ 1: 1000
VERT 1: 200

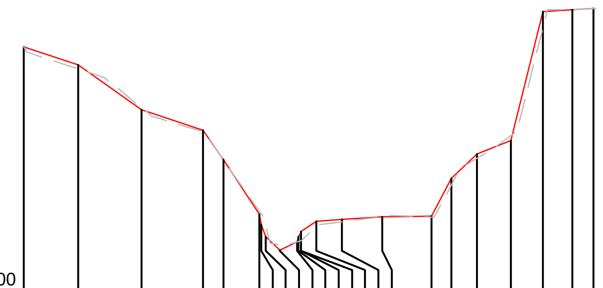


R.L. 53.200

Chainage	Natural Surface
0.000	60.787
0.081	60.676
5.481	60.720
7.730	58.943
9.551	57.557
11.943	56.899
13.941	55.579
15.291	55.104
15.800	54.450
18.360	54.263
20.120	54.568
20.840	54.911
22.773	55.280
23.889	55.771
27.979	55.750
33.767	56.562
42.877	58.967
48.236	59.238

BCXS-BQ CROSS SECTION

SCALES: HORIZ 1: 1000
VERT 1: 200



R.L. 53.600

Chainage	Natural Surface
0.000	59.995
7.214	59.517
15.571	58.332
23.739	57.784
26.415	57.013
31.170	55.523
31.394	55.299
32.055	54.973
33.898	54.632
35.150	54.842
36.339	54.981
36.651	55.087
36.699	55.116
38.668	55.378
42.079	55.434
47.443	55.507
53.955	55.516
56.550	56.513
59.986	57.171
64.409	57.515
68.708	60.923
72.586	60.968
75.371	61.009

BCXS-BR CROSS SECTION

SCALES: HORIZ 1: 1000
VERT 1: 200

LEGEND
2006 SURVEY
2008 SURVEY

K:\60045376_BCRKGEOM\5. CADD\5.3 Working\AUTOCAD\FIGURES\...Cross Sections.dwg

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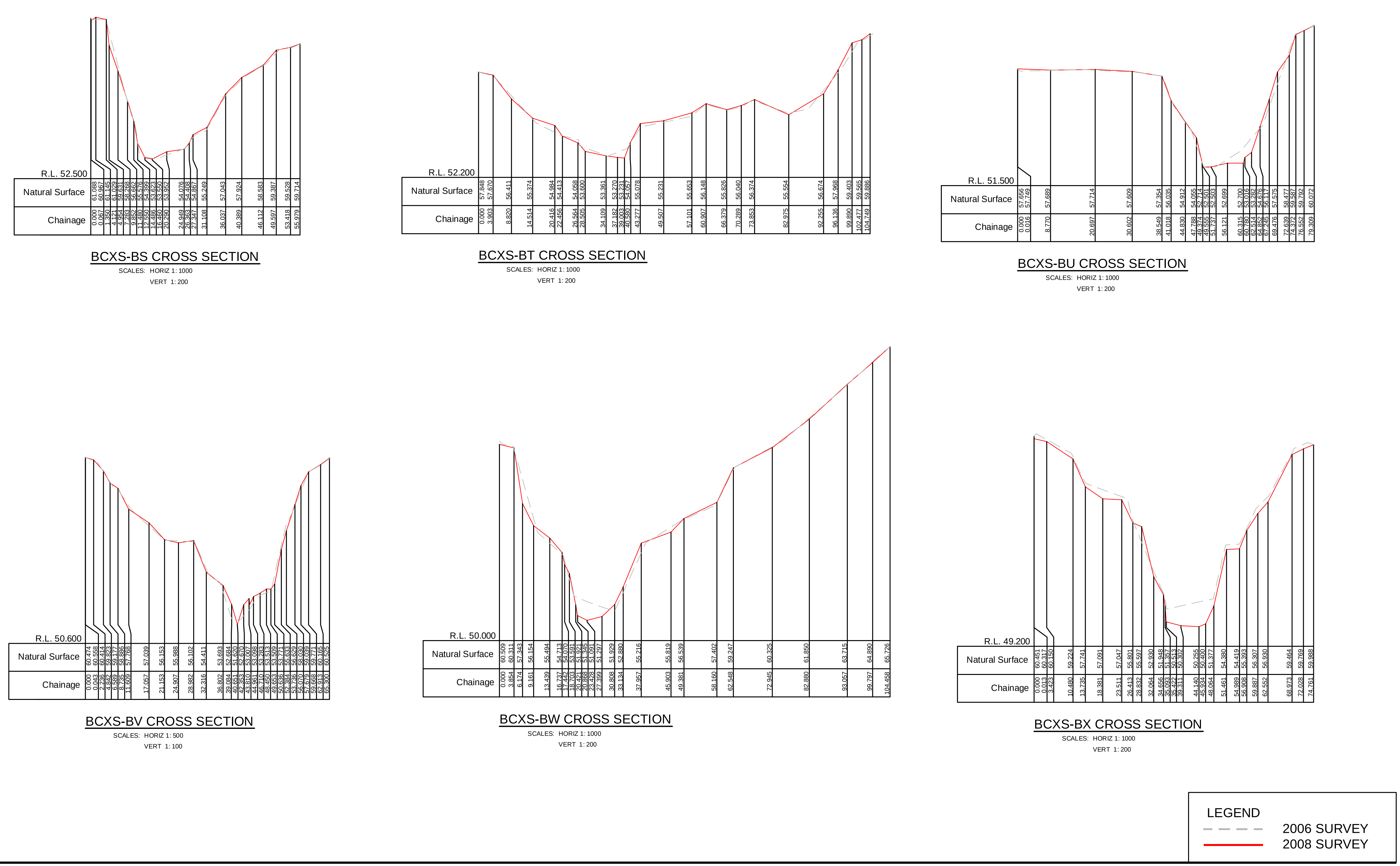
Bowmans Creek
Geomorphology Review
Appendix - Cross Sections BM - BR

MAUNSELL | AECOM



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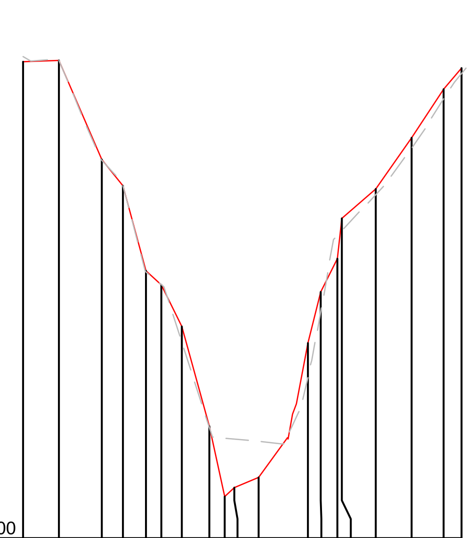
Bowmans Creek
Geomorphology Review

Appendix - Cross Sections BS - BX

R.L. 47.400

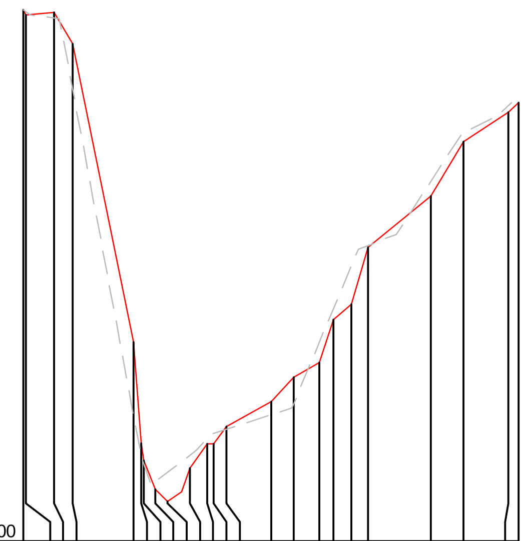


Chainage	Natural Surface
0.000	60.009
4.743	60.052
10.390	57.421
13.216	56.728
16.252	54.469
18.313	54.107
21.004	53.009
24.649	50.356
26.619	48.492
27.892	48.733
31.144	49.002
37.651	52.558
39.336	53.916
41.541	54.797
42.130	55.860
46.588	56.641
51.408	57.998
55.617	59.285
57.941	59.843

BCXS-BY CROSS SECTION

SCALES: HORIZ 1: 1000
VERT 1: 200

R.L. 47.200

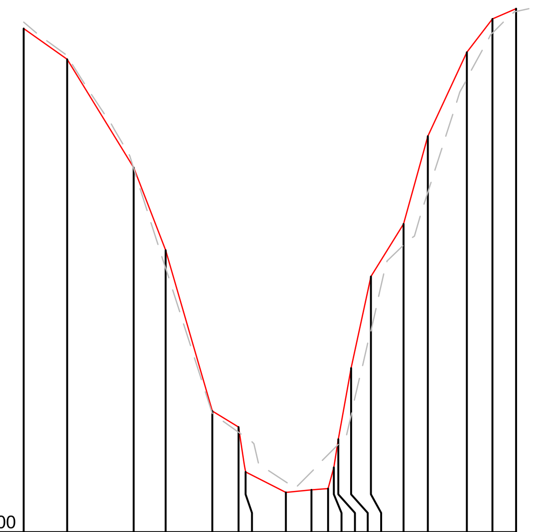


Chainage	Natural Surface
0.000	61.254
0.221	61.121
4.044	61.179
6.489	60.351
14.555	52.472
15.567	49.796
15.889	49.328
17.425	48.571
19.024	48.250
21.932	49.128
24.282	49.777
25.060	49.781
26.834	50.225
32.748	50.896
35.700	51.536
39.057	51.917
40.893	53.064
43.266	53.459
45.462	54.975
53.813	56.332
58.117	57.770
64.056	58.550
65.357	58.791

BCXS-BZ CROSS SECTION

SCALES: HORIZ 1: 1000
VERT 1: 200

R.L. 47.700



Chainage	Natural Surface
0.000	61.000
5.811	60.182
14.595	57.336
18.836	55.139
24.960	50.896
28.464	50.476
29.374	49.292
34.723	48.748
38.079	48.812
40.327	48.850
41.099	49.397
41.702	50.153
43.385	52.023
45.950	54.454
50.258	55.840
53.544	58.163
58.674	60.370
62.047	61.254
65.228	61.530

BCXS-AA CROSS SECTION

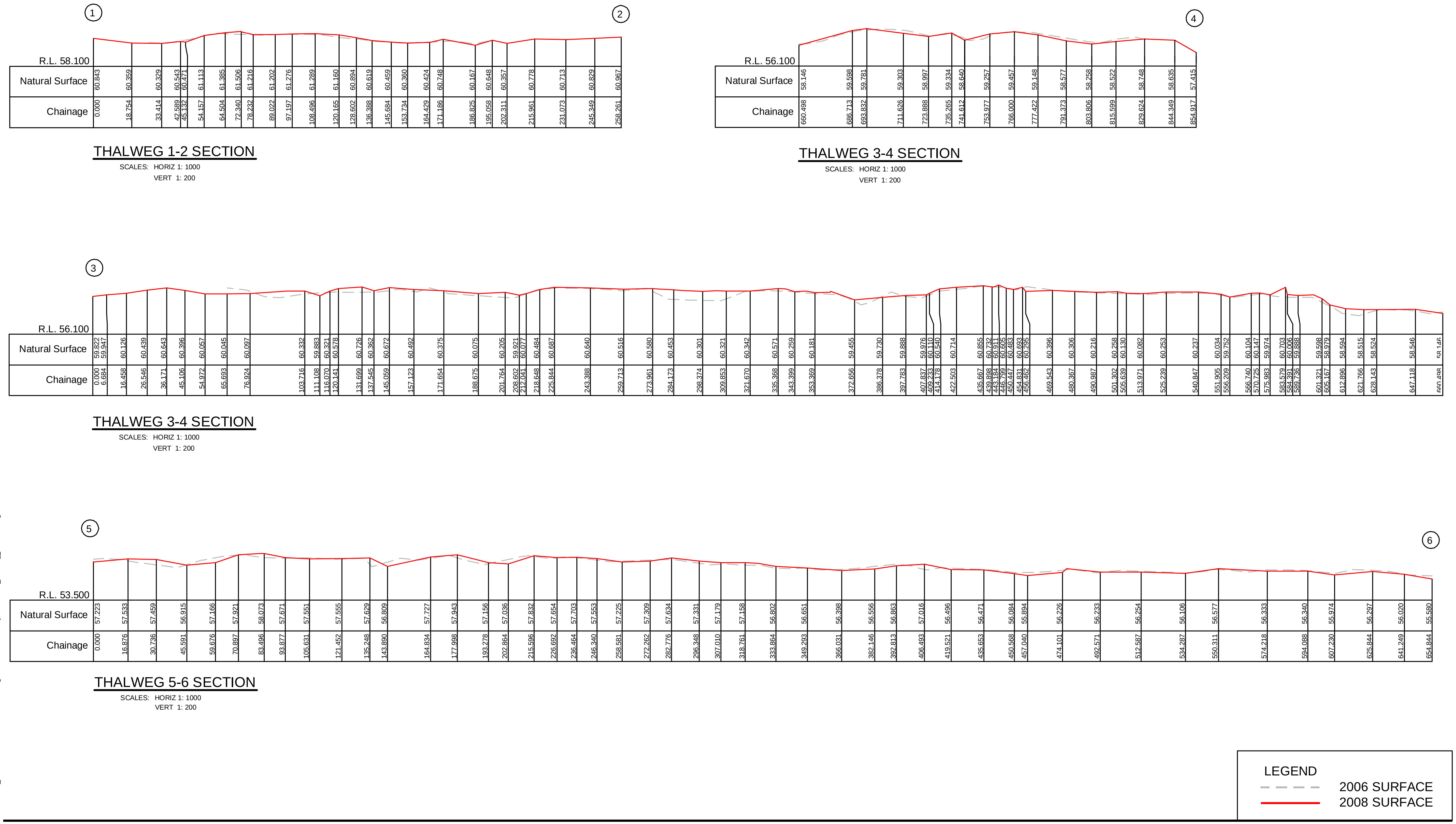
SCALES: HORIZ 1: 1000
VERT 1: 200

LEGEND

- - - - 2006 SURVEY
—— 2008 SURVEY

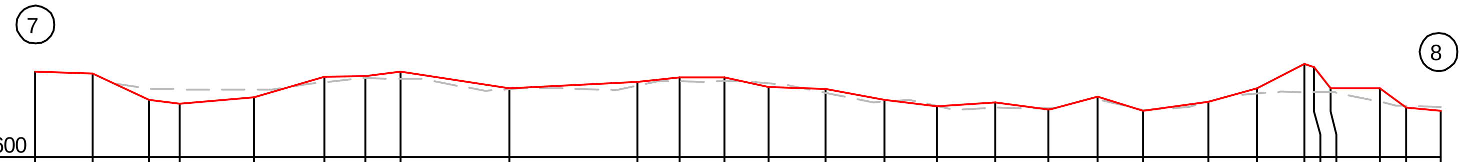
Bowmans Creek
Geomorphology Review

Appendix - Cross Sections BY - BAA



Bowmans Creek
Geomorphology review

Appendix - Thalweg Sections 1 - 6

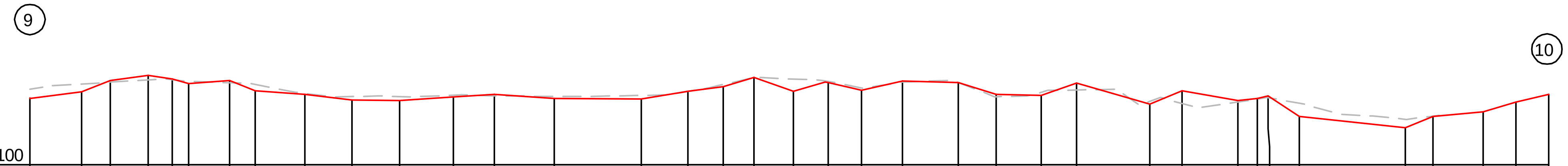


R.L. 52.600

Chainage	Natural Surface
0.000	56.368
12.734	56.270
25.125	55.126
31.943	54.944
48.240	55.226
63.794	56.123
72.828	56.168
80.624	56.354
104.540	55.618
132.709	55.905
142.030	56.105
152.011	56.094
161.637	55.683
174.264	55.604
187.282	55.127
198.733	54.845
211.596	55.018
223.273	54.680
234.161	55.263
244.267	54.634
258.639	55.039
269.294	55.621
279.811	56.709
281.921	56.559
285.580	55.619
296.376	55.626
302.160	54.785
309.775	54.638

THALWEG 7-8 SECTION

SCALES: HORIZ 1: 1000
VERT 1: 200

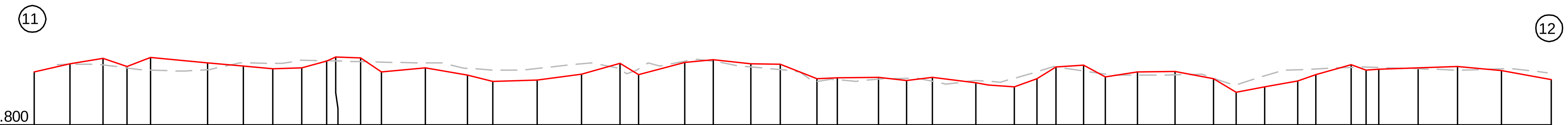


R.L. 50.100

Chainage	Natural Surface
0.000	53.755
14.191	54.116
22.093	54.732
32.592	55.012
39.153	54.823
43.686	54.563
55.048	54.743
62.091	54.185
75.726	53.984
88.708	53.654
101.814	53.626
116.603	53.834
127.982	53.985
144.493	53.765
168.437	53.738
181.255	54.140
191.052	54.402
199.450	54.911
210.321	54.150
219.894	54.638
229.058	54.201
240.393	54.700
255.712	54.641
266.210	53.985
278.534	53.908
288.323	54.604
308.522	53.433
317.394	54.163
332.705	53.638
338.050	53.756
341.111	53.887
349.749	52.765
378.886	52.156
386.548	52.777
400.288	53.029
409.380	53.542
418.353	53.965

THALWEG 9-10 SECTION

SCALES: HORIZ 1: 1000
VERT 1: 200



R.L. 45.800

Chainage	Natural Surface
0.000	49.095
11.185	49.615
21.415	49.948
28.969	49.436
36.180	49.994
54.066	49.663
65.213	49.473
74.315	49.302
83.419	49.345
91.158	49.774
93.953	50.029
101.755	49.973
108.171	49.095
121.832	49.336
134.968	48.899
142.828	48.496
156.748	48.574
170.552	48.943
182.469	49.621
188.273	48.926
202.692	49.691
211.556	49.869
223.287	49.604
232.437	49.588
243.873	48.674
250.208	48.724
263.056	48.768
271.880	48.560
279.891	48.754
293.394	48.426
305.436	48.155
312.454	48.680
318.342	49.398
326.941	49.510
333.793	48.778
343.743	49.101
355.473	49.110
367.456	48.664
374.535	47.812
383.442	48.176
393.668	48.521
399.367	48.915
410.283	49.532
414.950	49.198
418.958	49.260
431.147	49.353
443.433	49.420
457.213	49.176
472.682	48.622

THALWEG 11-12 SECTION

SCALES: HORIZ 1: 1000
VERT 1: 200

LEGEND
- – – – 2006 SURFACE
- —— 2008 SURFACE

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Bowmans Creek
Geomorphology Review

Appendix - Thalweg Sections 7 - 12

Appendix D Photo Monitoring Comparison

View Upstream July 2006

View Opposite July 2008

View Downstream July 2008

View Upstream July 2006

View Opposite July 2008

View Downstream July 2008

View Upstream July 2006

View Opposite July 2008

View Downstream July 2008

View Upstream July 2006

View Opposite July 2008

View Downstream July 2008


View Upstream July 2006


View Weir (opposite) July 2008


View Downstream July 2008

View Upstream July 2006

View Opposite July 2008

View Downstream July 2008

View Upstream July 2006

View Opposite July 2008

View Downstream July 2008

View Upstream July 2006

View Opposite July 2008

View Downstream July 2008

View Upstream July 2006

View Downstream July 2008

View Upstream July 2006

View Downstream July 2008


View Upstream May 2006


View Upstream July 2008


View Across May 2006


View Across July 2008


View Downstream May 2006


View Downstream July 2008

View Upstream May 2006

View Upstream July 2008

View Across May 2006

View Across July 2008

RHS View Downstream May 2006

LHS View Downstream July 2008


View LHS Upstream May 2006


View RHS Upstream July 2008


View LHS Across May 2006


View RHS Across July 2008


View LHS Downstream May 2006


View RHS Downstream July 2008

View Upstream May 2006

View Across May 2006

View Downstream May 2006

View Upstream July 2008

View Across July 2008

View Downstream July 2008


View Upstream May 2006


View Upstream July 2008


View Across May 2006


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