Tasman Extension Project

Environmental Impact Statement

APPENDIX C

SURFACE WATER ASSESSMENT

Resource Strategies

DONALDSON COAL
Part of Gloucester Coal

Tasman Extension Project

Surface Water Assessment

Prepared for

DONALDSON COAL

Part of Gloucester Coal

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Summary

Background

This Surface Water Assessment reviews the existing surface water hydrology and water quality characteristics on the creeks within the Tasman Extension Project (the Project) area, and provides an assessment of the potential impacts of mining on the surface water systems. The proposed Project involves the continued underground mining of the Fassifern Seam (mainly under the headwaters of Blue Gum Creek) and underground mining of the West Borehole Seam (mainly under the headwaters of Surveyors Creek, with minor encroachments into the catchments of Burkes Creek and Wallis Creek). These catchments all drain in various directions from the Sugarloaf Range.

Existing Conditions

The Project area contains two distinctly different landforms; steep rocky hillsides (slopes up to 60%) with relatively shallow soils and rock outcrops, and lower slopes (slopes in the range of 2% to 20%) with deeper soils. Within the Project area, the catchment of Surveyors Creek is largely undisturbed except for a number of cleared easements for high voltage power lines. There is no evidence of wildfires for the last two decades. The creeks that drain the Project area exhibit a range of geomorphic forms that reflect the interaction of the underlying geology and soils, stream gradient, channel sediments and flow regime.

No licensed surface water extractions have been identified on any of the creeks that drain from the Project area.

In the absence of any flow gauging on the creeks in the Project area, the flow regimes in the various sub-catchments have been estimated using the Australian Water Balance Model (AWBM), while peak flow rates have been estimated using the Probabilistic Rational Method (PRM).

Parameters for AWBM were derived from flow records from six catchments in the Hunter Valley and Central Coast with comparable topography, land-use and climate to Surveyors Creek. The model was then used to generate sequences of daily flow for seven representative catchments within the Project area using 125 years of representative historic daily rainfall and areal potential evapotranspiration.

Model results indicate that runoff is likely to be slightly higher from steep rocky headwater catchments than from lower sections with deeper soils. Flow is highly dependent on the rainfall regime over a particular year, and can range from 9% to over 500% of average annual runoff for the driest and wettest years on record respectively. A more typical range that is likely to be encountered during mining would be a 10^{th} percentile (1 in 10 dry) year with runoff of about 20% of average annual runoff and a 90^{th} percentile (1 in 10 wet) year with runoff of about 200% of average annual runoff.

Donaldson Coal undertakes monthly monitoring of temperature pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), turbidity and sulphate at 12 locations on Blue Gum Creek and Surveyors Creek. In addition, water samples from the area in the immediate vicinity of Tasman Underground Mine are monitored quarterly for a range of common anions and cations. Water quality data from nearby locations were also sourced from the NSW Office of Water and publically available reports from the Hunter Expressway project which crosses both Blue Gum Creek and Surveyors Creek downstream of the areas that would be affected by the

Project. The water quality data shows variability attributable to catchment geology and land use, but no direct impact as a result of the existing operation of the Tasman Underground Mine. Notwithstanding the relatively pristine nature of the catchments, the water quality data indicates that the water quality does not comply with the applicable ANZECC 'default' trigger values. Revised 'trigger' values for EC, pH and turbidity are proposed based on the monitored data. Insufficient data for metals concentrations is available to justify varying the 'trigger' from the default values in the ANZECC Guidelines.

Mining and Subsidence Impacts

In order to minimise the impacts of subsidence, Donaldson Coal proposes to implement the Subsidence Control Zones (SCZs) along potentially affected creek lines, steep slopes and areas of identified riparian EECs. Routine monitoring would be undertaken along creek lines and in the zones near the edge of extraction panels that are most likely to experience cracking. Repairs to any significant cracks would be undertaken using procedures currently employed at other Donaldson Coal mines.

Various aspects of potential impacts of subsidence are considered in the *Subsidence Assessment* (Appendix A to the EIS), the *Groundwater Assessment* (Appendix B) and the *Geomorphology Assessment* (Appendix D) as well as this *Surface Water Assessment*.

The *Geomorphology Assessment* assessed the existing geomorphic condition, resilience and recovery potential of the creeks and identified the migration of existing knickpoints as the key threatening process to geomorphic character. Analysis of the predicted changes in post-mining creek bed slopes indicates that all of the creek sections subject to the greatest change in slope are located in areas considered to have 'insignificant' risk to geomorphic character.

This assessment, relating to potential surface water impacts associated with the Project, concludes that:

- Subsidence would not have any significant effect on drainage patterns, catchment yield or flow regimes.
- Groundwater lowering associated with mining is predicted to lead to a minor reduction in groundwater baseflow into one of the headwater tributaries of Surveyors Creek, but this would have no measurable effect on the flow regime in Surveyors Creek itself.
- Changes in bed slope are unlikely to have any significant impact in reducing or increasing the volume of the observed pools. Accordingly, the water retained within the pools and the overall water-balance of these pools (in terms of seepage and evaporation losses) is not expected to change significantly.

In view of the above, it is concluded that the Project would not have any impact on environmental flows, basic landholder rights or licensed water users.

Although the mine layout and subsidence control zones are intended to minimise the subsidence impacts on the catchment of Surveyors Creek, the cracking of sandstone in areas that lie outside the SCZs may lead to changes in shallow sub-surface flow paths and consequently lead to an increase in iron concentration and lowering of pH. However, these effects have not been observed at either of the underground mines in the area operated by Donaldson Coal. The subsidence effects on the landform and the creeks are not expected to lead to significant surface erosion or channel scour that would lead to a significant change in suspended sediment concentrations.

Pit Top Water Management

The water management systems for the pit-top area would provide for separation of groundwater inflow to the workings, runoff from 'dirty' areas of the site (coal stockpile area, mine portal, etc) and other areas of the site. Mine water would be directed into the Mine Water Storage Dam (5 ML) from which water would be drawn for re-use underground. 'Dirty' stormwater would be directed into the Surface Water Storage Dam (4 ML storage plus 2 ML surcharge) from which water would be drawn for dust suppression and the truck wheel wash. The water balance assessment shows that there would be surpluses of both groundwater inflow to the mine workings and surface runoff from the 'dirty' areas of the pit-top. All operational water requirements are expected to be met from these sources except for:

- Potable supply for the offices and bath-house (provided by water cart) with roof runoff used for toilet flushing;
- Possible requirement for some supplementary supply by water-cart to meet water requirements for the initial construction phase.

Excess mine inflow and 'dirty' runoff would be directed into a bore for storage in old historic mine workings that lie beneath the pit-top area (assessed capacity 7,000 ML). Over the life of the mine a total of about 5,450 ML is expected to be transferred to the old mine workings.

The potential surface water impacts associated with the pit-top area are:

- A reduction of about 4 ML/year (1%) in average annual flow in the adjacent tributary of Surveyors Creek. This is attributable to the retention of runoff from the 'dirty' sections of the site for pollution control purposes;
- The minor risk of overflow from the Surface Water Storage Dam in the event of a storm of greater than 20 years average recurrence interval. Under such circumstances the volume of overflow would be minor compared to the flow in the creek at the time and is not expected to have any significant impact on downstream water quality.
- All mine water would either be re-used for underground operational purposes or stored in historic old mine workings that lie beneath the pit-top area. There would be no discharge of mine water to surface waters.

Monitoring, Management, Mitigation Measures and Licensing Requirements

Water quality monitoring would be undertaken with the objective of detecting any significant changes in surface water quality that would warrant remedial measures on the catchment. Water quality monitoring would continue at the five existing monitoring sites on Surveyors Creek and its tributaries that would potentially affected by mine operations. Subject to access restrictions, it is recommended that two additional water quality monitoring sites be established to monitor any water quality changes associated with possible surface cracking on the steeper slopes. The monitoring results would be compared to the trigger values proposed in the Surface Water Assessment. Further investigation of the cause would be undertaken if readings outside the range occurred on more than two successive occasions. Under those circumstances, further investigation would be undertaken to ascertain whether the cause was related to mining activities and, if so, what mitigation actions would need to be taken.

It is recommended that a flow gauging station be established on Surveyors Creek tributary S2 where it crosses between Panels 26 and 27. If a suitable site can be identified and access granted, it would also be desirable to establish a gauging station on Surveyors Creek Tributary S2 downstream of the junction with Tributary S2G.

After flow and rainfall data has been collected for three years, and every year thereafter until the catchment is undermined, the data should be analysed to re-calibrate the rainfall runoff model. Once the catchment has been undermined, the observed runoff would be compared to the modelled runoff for the catchment using model parameters derived for pre-mining conditions. Any departure of greater than 10% from the predicted annual flow from the catchment using pre-mining model parameters would lead to further investigation to establish the cause and identify appropriate remedial actions.

The main surface water subsidence impacts that may require management are impacts associated with surface cracking, ponding and scouring. The *Subsidence Assessment* sets out the details of a subsidence monitoring program that include survey lines, visual inspections, mapping along each watercourse and establishing permanent reference points on the creeks.

The site water balance analysis indicates that the capture and re-use of ‘dirty’ runoff for pollution control purposes would reduce the annual runoff to Surveyors Creek by about 4 ML/year compared to existing conditions. As this ‘take’ of water is for pollution control purposes, an access licence under the Water Management Act 2000 is not required.

If the Project is approved, Donaldson Coal would apply for a revision of EPL 12483 or the granting of a new EPL for the additional components associated with the Project. The EPL would include conditions for management and monitoring of stormwater runoff and effluent disposal.

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List of Abbreviations

AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment and Conservation Council
ARI	Average recurrence interval
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AWBM	Australian Water Balance Model
BOD_5	Five day biochemical oxidation demand
BoM	Bureau of Meteorology
CAP	Catchment Action Plan
CCC	Cessnock City Council
CHPP	Coal Handling and Processing Plant
CMA	Catchment Management Authority
DEC	Department of Environment and Conservation (now OEH)
DECCW	Department of Environment, Climate Change and Water (now OEH and NOW)
DGRs	Director-General's Requirements
DgS	Ditton Geotechnical Services
DIPNR	Dept of Infrastructure, Planning and Natural Resources (now DP&I)
DLWC	Department of Land & Water Conservation (now OEH)
DP&I	Department of Planning and Infrastructure
DP&I	Department of Planning and Infrastructure (formerly the Department of Planning (DoP)
EEC	Endangered Ecological Communities
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EP&A Act	Environmental Planning and Assessment Act 1979
EPL	Environmental Protection License
GIS	Geographic Information System
ha	hectare
kL	kilolitre
km	kilometre
LGA	Local Government Area
LMCC	Lake Macquarie City Council
LOOCV	Leave-One-Out Cross Validation

m	metres
ML	megalitre
mm	millimetre
NOW	New South Wales Office of Water
NSW	New South Wales
OEH	Office of Environment and Heritage
PoEO Act	Protection of the Environment Operations Act 1997
PRM	Probabilistic Rational Method
RMS	Roads and Maritime Services (formerly RTA)
ROM	Run-of-mine
SCZ	Subsidence Control Zone
SWA	Surface Water Assessment
SWMOP	State Water Management Outcomes Plan
WM Act	Water Management Act 2000
WMP	Water Management Plan
WSP	Water Sharing Plan
WSPHUAWS	Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009
µS	microSiemens

1 INTRODUCTION

1.1 Background

This Surface Water Assessment has been prepared by Evans & Peck on behalf of Donaldson Coal Pty Ltd ("Donaldson Coal"). This document is to form part of the Specialist Consultant Studies Compendium prepared in support of the Environmental Impact Statement (EIS) for the proposed Tasman Extension Project ("the Project").

1.2 Project Description

1.2.1 Existing Operations

The Tasman Underground Mine is owned and operated by Donaldson Coal, and is located approximately 20 kilometres (km) from the Port of Newcastle (**Figure 1**) within the Newcastle Coalfield. The Tasman Underground Mine was approved (DA 274-9-2002) in 2002, and operations commenced in late 2006.

Other Donaldson Coal operations in the Newcastle Coalfield include (**Figure 1**):

- Donaldson Open Cut Mine which commenced operations in January 2001 and is scheduled to finish mining by 2013; and
- Abel Underground Mine which commenced in early 2008.

All coal from these mines is delivered to the Bloomfield Coal Handling and Processing Plant (CHPP) for processing and transport by rail to the Port of Newcastle or to other customers. The Bloomfield CHPP is located within the Bloomfield Colliery lease adjoining the northern boundary of the Donaldson Mine lease area (**Figure 1**).

1.2.2 Proposed Tasman Extension Project

The proposed Project involves the extension of underground mining operations at the Tasman Underground Mine for an additional operational life of 15 years. This would include continued underground mining of the Fassifern Seam and underground mining of the West Borehole Seam. The mining processes would involve a combination of total and partial pillar extraction methods. The Project would require the development of a new pit-top and associated run-of-mine (ROM) coal handling infrastructure located immediately south of George Booth Drive.

In summary, the Project would involve:

- extending the existing underground mining operation to extract up to 1.5 million tonnes of coal a year for 15 years;
- developing new pit-top facilities, including coal handling, administration and service infrastructure;
- decommissioning and rehabilitating the existing pit-top facilities; and
- transporting coal from the mine by public and private roads to Bloomfield CHPP for processing.

For the purposes of this report the "Project area" is taken to be the area covered by the existing Tasman Underground Mine and the Project as shown on **Figure 1**.

The potential surface water impacts associated with the Project relate to:

- Underground mining operations and associated groundwater dewatering, leading to potential changes to surface water flow regime;
- Subsidence from underground mining operations, leading to the potential for changes to runoff from the catchments and changes to the flow regime and water quality in the creeks draining from the Project area; and
- Operations at the pit-top facilities area, including the management of mine water (potentially saline) and the management of stormwater runoff from areas used for the stockpiling and loading of coal.

1.3 Location

The existing Tasman Underground Mine pit-top is located immediately south of George Booth Drive, Seahampton, approximately 2.5 km by road west of the Newcastle Freeway (F3). As shown on **Figure 1**, the Project would extend the area of underground mining to the west and the north of the existing operation. The Project is located in the Cessnock and Lake Macquarie Local Government Areas (LGAs).

The existing underground mine operations in the Fassifern Seam and pit-top facilities are predominantly located in the headwaters of Blue Gum Creek which drains in a north-easterly direction from Mount Sugarloaf and the Sugarloaf Range, and eventually drains into Hexham Swamp at the Pambalong Nature Reserve approximately 8 km north-east of Mount Sugarloaf. Underground mining also extends under a small area of the catchment of Slatey Creek which drains to Lake Macquarie via Cockle Creek. As mining of the Fassifern Seam continues, mining would also encroach into an area on the eastern edge of the Surveyors Creek catchment surrounding Mount Sugarloaf.

As shown on **Figure 2**, the Project would involve underground mining of the West Borehole Seam in an area predominantly located to the west of the Sugarloaf Range and south of George Booth Drive. This area drains in a northerly direction to Surveyors Creek, a tributary of Wallis Creek which drains to the Hunter River near Maitland. A small area in the south east corner of the mine area encroaches into the catchment of Burkes Creek which drains to Lake Macquarie via Cockle Creek. Another small area in the south-west corner of the mine area encroaches into the catchment of a small un-named tributary which drains to an existing water storage, the 'Colliery Dam', which overflows to Wallis Creek.

1.4 Objectives

The objectives of this Surface Water Assessment are to:

- Document the existing catchment conditions and the flow regime and water quality in the creeks draining from the Project area;
- Assess the impacts of any changes in the flow and water quality resulting from the proposed Project, and the mitigation actions necessary to minimise the impacts; and
- Identify appropriate monitoring and management measures necessary to verify the predicted impacts of the Project and initiate any additional mitigation measures.

1.5 Report Structure

The assessment of potential impacts on surface water is closely related to other physical processes within the catchment particularly subsidence, interaction with the groundwater system and the impact of subsidence on fluvial processes. Accordingly, this report draws on information provided in the following related reports:

- *Subsidence Predictions and General Impact Assessment for the Tasman Extension Project* (Ditton Geotechnical Services, 2012) which forms Appendix A to the EIS. For purposes of this report this Appendix is referred to as "the *Subsidence Assessment"*.
- *Tasman Extension Project Groundwater Assessment* (RPS Aquaterra, 2012) which forms Appendix B to the EIS. For purposes of this report this Appendix is referred to as "the *Groundwater Assessment"*.
- *Tasman Mine Extension Stream Risk and Impact Assessment: Fluvial Geomorphology* (Fluvial Systems, 2012) which forms Appendix D to the EIS. For purposes of this report this Appendix is referred to as "the *Geomorphology Assessment"*.

In order to accommodate the interactions between the physical processes assessed in each of these reports and this *Surface Water Assessment*, and to allow existing and post-mining conditions to be directly related, the report has been structured in the following manner:

- **Sections 2, 3 and 4** 'set the scene' in terms of the regulatory and physical context;
- **Section 5** provides an analysis and interpretation of the direct impacts of subsidence on the creeks system, and the proposed measures to manage and minimise the consequences of subsidence;
- **Section 6** provides an analysis of the flow characteristics of the creeks within the Project area and the predicted impacts of mining on surface runoff and interaction with the groundwater system;
- **Section 7** presents an analysis of the surface water quality in the creeks that drains from the Project area and an assessment of any impacts on water quality associated with the existing underground mining at the Tasman Underground Mine and the proposed Project;
- **Section 8** describes the proposed water management system for the pit-top area including the management of mine water and surface runoff;
- **Section 9** presents an assessment of the overall water balance for the mine.
- **Section 10** summarises the potential impacts associated with the mine and draws on material previously presented in Sections 5 – 9; and
- **Sections 11 and 12** summarise the mitigation and management measures together with the proposed monitoring, licensing and reporting procedures.

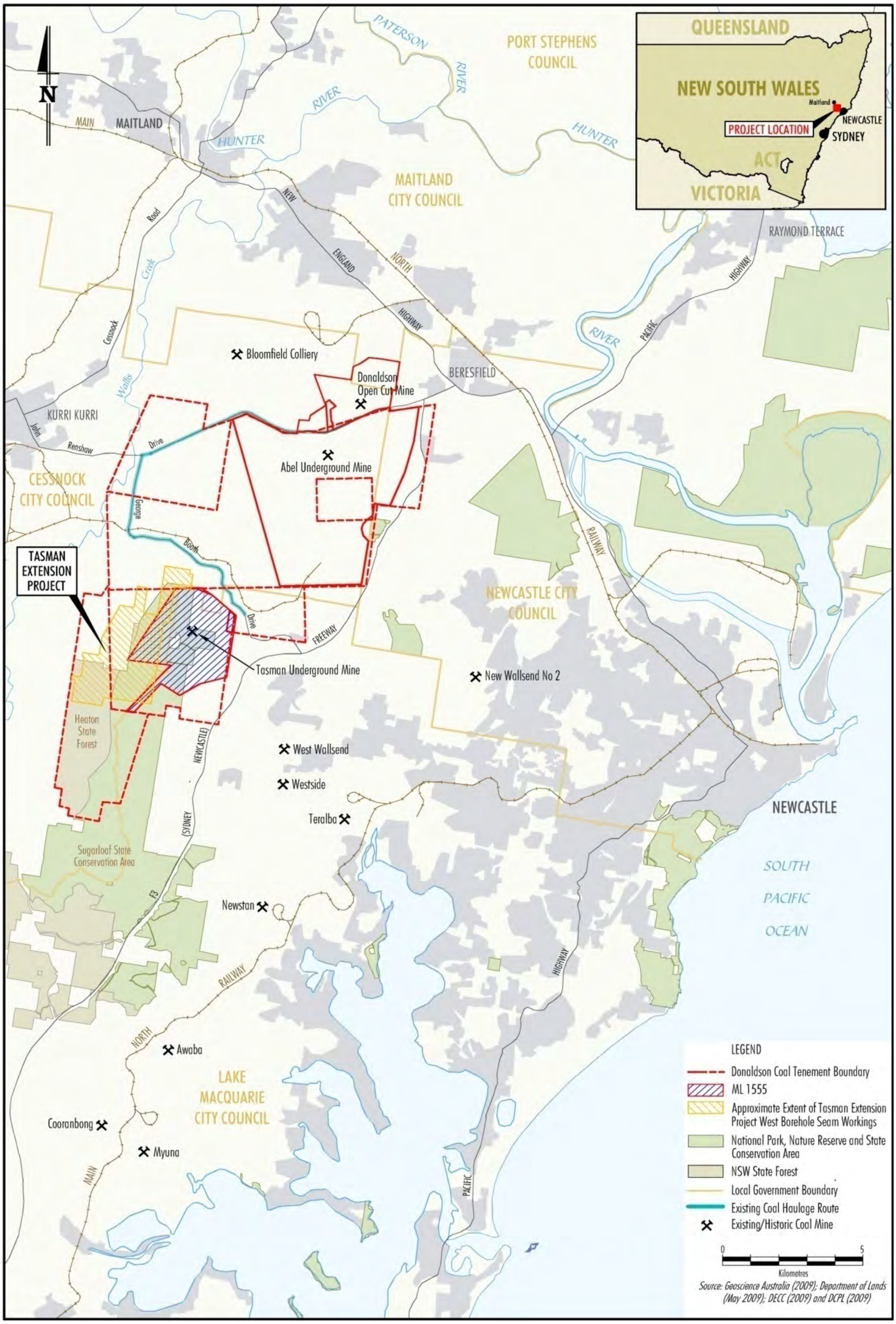

Figure 1: Regional Location

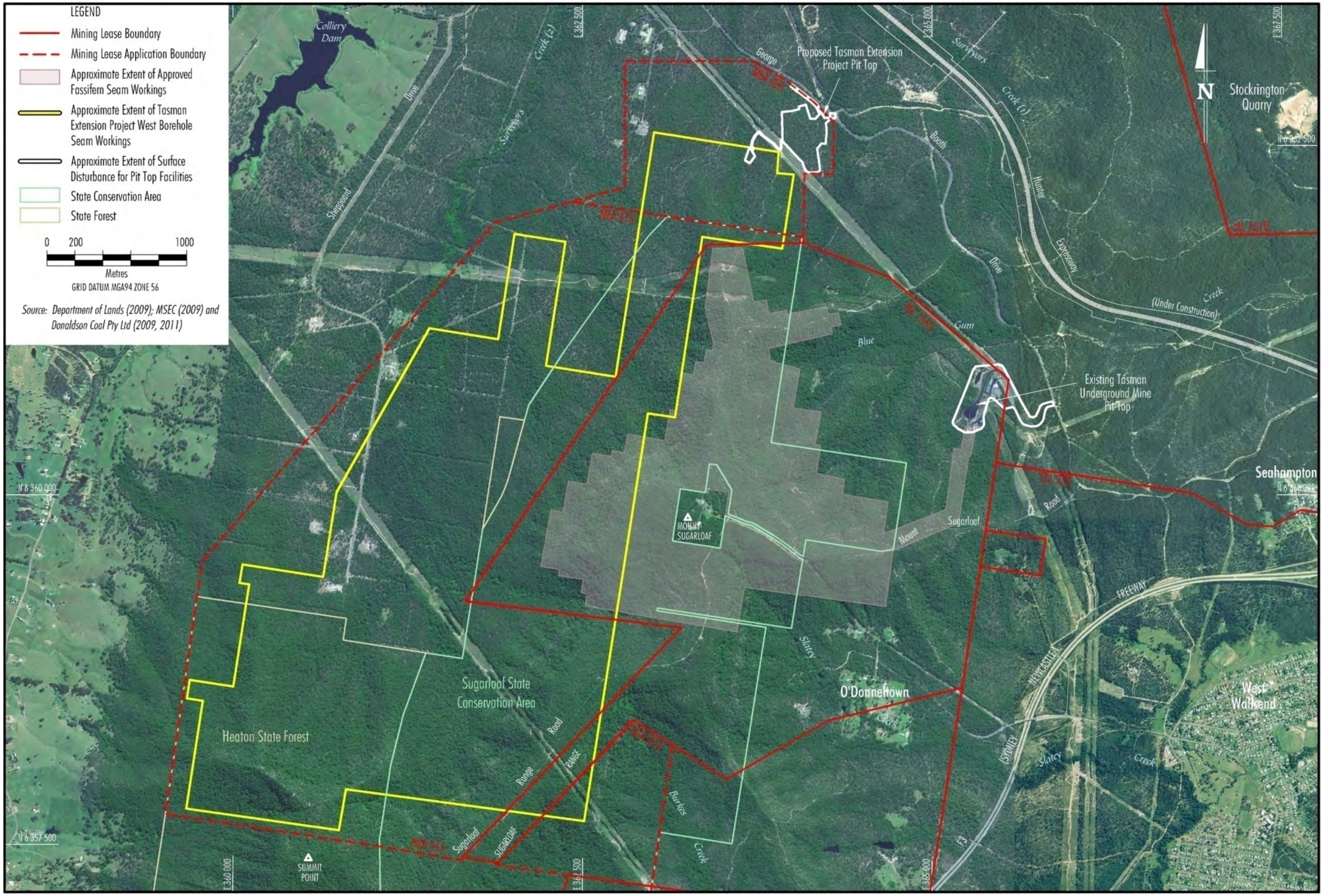

Figure 2:
Indicative Project Areas
(Source: Donaldson Coal, 2012)

Material in this report has been arranged so that maps and full page figures are located at the end of each section. Where necessary a blank page is included to ensure that each new section starts on a right hand page when the report is copied double sided.

2 DIRECTOR-GENERAL'S REQUIREMENTS

The Director-General's Requirements (DGRs) for the environmental assessment of the Project under Section 78A (8A) of the *Environmental Planning and Assessment Act 1979* (EP&A Act) State Significant Development were provided in a letter from the Department of Planning & Infrastructure (DP&I) on 14 December 2011.

Table 2.1 provides a summary of the DGRs relating to surface water. **Table 2.1** also indicates where the specific issues have been addressed within this document. **Appendix 4** to this Surface Water Assessment also identifies the surface water related Agency requirements and provides a cross reference to where each requirement has been addressed.

Table 2.1: DGRs Related to Surface Water

	Requirement	Reference
General Requirements	The EIS must include a: ▪ detailed description of the development including environmental protection;	▪ Section 5 Subsidence ▪ Section 6 Flow regime ▪ Section 7 Water quality ▪ Section 8 Water management
	▪ risk assessment of the potential environmental impacts of the development, identifying the key issues for further assessment;	▪ EIS Section 4
	▪ detailed assessment of the key issues specified below, and any other significant issues identified in this risk assessment, which includes: - a description of the existing environment, using sufficient baseline data;	▪ Section 4 Catchment characteristics ▪ Section 6 and Appendix 1 Flow regime ▪ Section 7 and Appendix 2 Surface water quality
	- an assessment of the potential impacts of all stages of the development, including any cumulative impacts, taking into consideration relevant guidelines, policies, plans and statutes; and	▪ Section 5 Subsidence ▪ Section 10 Surface water
	- a description of the measures that would be implemented to avoid, minimise and if necessary, offset the potential impacts of the development, including proposals for adaptive management and/or contingency plans to manage any significant risks to the environment; and	▪ Section 5 Subsidence ▪ Section 8 Water management ▪ Section 9 Site water balance
Key Issues: Subsidence	The EIS must include a detailed quantitative and qualitative assessment of the potential conventional and non-conventional subsidence impacts of the development that includes:	
	▪ the identification of the natural and built features (both surface and sub-surface) within the area that could be affected by subsidence, and an assessment of the respective values of these features using any relevant statutory or policy documents;	▪ EIS Appendix A ▪ Section 5 Subsidence
	▪ a detailed assessment of the potential environmental consequences of these effects and impacts on both the natural and built environment, paying particular attention to those features that are considered to have significant economic, social, cultural or environmental values; and	▪ EIS Appendix A ▪ Section 5 Subsidence ▪ Section 6 Flow regime ▪ Section 7 Water quality ▪ Section 8 Water management

	Requirement	Reference
	▪ a detailed description of the measures that would be implemented to avoid, minimise, remediate and/or offset subsidence impacts and environmental consequences (including adaptive management and proposed performance measures);	▪ EIS Appendix A ▪ Section 5 Subsidence
Key Issues: **Water Resources**	The EIS must include: ▪ a detailed assessment of potential impacts on the quality and quantity of existing surface water resources, including:	▪ Section 10.4 Water quality
	- impacts on affected licensed water users and basic landholder rights; and	▪ Section 10.5 Water Sharing Plan
	- impacts on riparian, ecological, geo-morphological and hydrological values of watercourses, including environmental flows;	▪ Section 10.5 Water Sharing Plan
	▪ 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;	▪ Section 9 Water balance
	▪ identification of any licensing requirements or other approvals under *the Water Act 1912* and/or *Water Management Act 2000;*	▪ Section 3.1.1 ▪ Section 12.2 Licensing and approvals
	▪ 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);	▪ Section 3.2.5 ▪ Section 9 Site water balance
	▪ 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;	▪ Section 10.5 Water Sharing Plan
	▪ a detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface water impacts;	▪ Section 8 Water management system ▪ Section 9 Site water balance ▪ Section 11 Mitigation and management measures

3 RELEVANT LEGISLATION, POLICY AND GUIDELINES

A variety of legislation, policies, regulations and guidelines contain relevant considerations for the assessment of the surface water related aspects for the Project. Key issues to be addressed in finalising the details of the Project are set out below.

3.1 Legislation

3.1.1 Water Act 1912 and Water Management Act 2000

The aim of the *Water Management Act 2000* (WM Act) is to provide for the sustainable and integrated management of the water sources of New South Wales (NSW) for the benefit of both present and future generations. The *Water Act 1912* and the WM Act contain provisions for the licensing of water capture and use. If any dams are proposed as part of the water management, consideration must be given to whether the dams need to be licensed.

Donaldson Coal currently holds a bore licence (Licence Number 20BL171792) under the existing approval for the purposes of mining and dewatering at the Tasman Underground Mine, which allows extraction of no more than 75 megalitres (ML) in a 12 month period (commencing 1 July).

The *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009* is relevant to the Project. Refer to **Section 3.2.5** below for more details.

3.1.2 Protection of the Environment Operations Act 1997

The NSW *Protection of the Environment Operations Act 1997* (PoEO Act) and the NSW Protection of the *Environment Operations (General) Regulation 2009* set out the general obligations for environmental protection. The PoEO Act is relevant to the Project as it contains requirements relating to the prevention of the pollution of waters.

The existing Tasman Underground Mine currently operates under Environmental Protection Licence (EPL) 12483. If the Project is approved, Donaldson Coal would apply for a revision of EPL 12483 or the granting of a new EPL for the additional components associated with the Project. Under section 89K(1)(e) of the EP&A Act, if the Project is approved as State Significant Development, an EPL under the PoEO Act cannot be refused and is to be substantially consistent with any Development Consent granted under Division 4.1 of Part 4 of the EP&A Act.

3.2 Policies and Plans

Relevant issues related to NSW State Government natural resource management policies and guidelines that have been considered in relation to surface water management for the Project are set out below.

3.2.1 NSW Water Quality and River Flow Objectives: Hunter River Catchment

The *Water Quality and River Flow Objectives for the Hunter River Catchment* (DECCW, 2006) sets out a range of general principles as well as specific objectives for different parts of the landscape. This includes the following objectives for mainly forested areas:

- Protection of water quality for aquatic ecosystems, visual amenity and recreation in line with the guidelines set out in ANZECC (2000).
- Protection of the following features of natural flow regimes:
  - Protect pools in dry times;
  - Protect natural low flows;
  - Maintain natural flow variability.

The *Water Quality and River Flow Objectives for the Hunter River Catchment* notes that local water quality varies naturally because of various factors, including the type of land the waters are draining (e.g. soils, slope), or rainfall and runoff patterns (e.g. ephemeral or permanent streams). Different land use and land management practices also affect water quality. It recognises that local water quality objectives must take account of these variations, particularly for the environmental value of aquatic ecosystems.

The document also recognises that "*the ANZECC 2000 Guidelines move away from setting fixed single number water quality criteria, and emphasise water quality criteria that can be determined on a case by case basis, according to local environmental conditions. This is done through the use of local reference data and risk based decision frameworks. The ANZECC 2000 Guidelines establish default trigger values that are set conservatively and can be used as a benchmark for assessing water quality. Further refinement of the trigger values may be needed to take account of local conditions, especially for aquatic ecosystems and particularly in places, or for issues, requiring priority action.*"

Potential impacts to flow regimes and water quality associated with the Project are assessed **Section 6** and **Section 7** respectively.

3.2.2 State Water Management Outcomes Plan

The WM Act provides for the establishment of the State Water Management Outcomes Plan (SWMOP) to set out the over-arching policy context, targets and strategic outcomes for the development, conservation, management and control of the State's water sources.

This SWMOP promotes the objects of the WM Act and its water management principles and seeks to give effect to the NSW Government's salinity strategies. The SWMOP provides for the protection and enhancement of the environmental services provided by aquatic ecosystems while delivering a framework for the use of water to meet human needs, including more secure access licences. It details the Government's commitment to manage the linkages between environment, human health, communities and industries.

The Project is consistent with the objectives of the SWMOP, both within the Project and area and on downstream users, as the mine is designed to achieve performance measures through subsidence control zones for creeks (refer **Section 5**) to protect the creek system from potential impacts associated with subsidence, and therefore, maintain the flow regime.

3.2.3 Hunter-Central Rivers Catchment Action Plan

The *Hunter-Central Rivers Catchment Action Plan* ("the CAP") (Hunter-Central Rivers CMA, 2007) makes the distinction between:

- management targets (on-ground natural resource management that will be funded through the Catchment Management Authority (CMA)), and
- guiding principles (statements that reflect how natural resources should be managed in our region).

In relation to mining and extractive industries, the stated aim of the CAP is to minimise the impacts of mining and extractive operations on natural resources and ensure appropriate rehabilitation of affected land. The key guiding principles relating to mining are:

1. Every precaution should be taken to ensure that surface water flows are not lost or diverted due to subsidence or geological cracking caused by extraction. Where surface water is lost or diverted, offsets or mitigating actions should be provided.
2. An aquifer's highest beneficial use or an inter-connected groundwater dependent ecosystem's requirements should not be significantly reduced.
3. A water management plan (WMP) should be completed and approved before the commencement of mining operations. This WMP should apply to the full lifespan of the mine including after closure. The WMP would show how mining will be conducted so that water resources are managed sustainably. Development and approval of the WMP should be open and transparent.
4. Mining should not occur where the alteration of hydrological regimes adversely impacts significant threatened species habitat and where the impact cannot be managed or offset.

The Project is consistent with these principles, and should the Project be approved, a comprehensive WMP would be prepared for the life of the Project.

3.2.4 Wallis-Fishery Creeks Total Catchment Management Strategy

The *Wallis-Fishery Creek Total Catchment Management Strategy* (Hunter Catchment Management Trust, 2000), which was prepared by the former Trust that was absorbed into the CMA, pre-dates the CAP. The Strategy identifies similar issues to those canvassed in the CAP. In particular the Strategy identifies water quality associated with increased turbidity, nutrients and salinity caused by clearing, grazing, mining and runoff as key issues in the Wallis Creek catchment.

The priority strategy for water quality management is the determination and adoption of target values for water quality parameters for different reaches of the creeks, including Wallis Creek, in line with the *Water Quality and River Flow Objectives: Hunter River Catchment* (DECCW, 2006).

3.2.5 Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009

The Wallis Creek Water Source, in which Surveyors Creek is located, is defined as one of a number of water source units within the Hunter Extraction Management Unit as defined in the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources.* In addition, Burkes Creek is defined as one of a number of water source units within the North Lake Macquarie Water Source in the broader Lake Macquarie Extraction Management Unit of the Water Sharing Plan.

Relevant provisions of the Plan that relate to the Wallis Creek and Surveyors Creek catchment and require consideration in relation to the Project are:

- The Plan identifies the following share components under various rights and licence conditions in the Wallis Creek Water Source:
  - domestic and stock rights - 39 ML/day;
  - share component of domestic and stock access licences - 2 ML/year;
  - share component of unregulated river access licences - 490 unit shares; and
  - share component of aquifer access licences - 0 unit shares.
- For Water Access Licences with no existing conditions, no flow classes are established for Wallis Creek. However, from Year 6 of the Plan (2015), the taking of water from pools will only be permitted when there is a visible inflow and outflow. Where higher or more stringent flow conditions currently exist on licences, these conditions will continue.
- From Year 6 of the Plan the conditions relating to the requirement for visible inflow and outflow from a pool also apply to:
  - access licences taking water from the alluvial sediments (other than those specifically identified [Clause 68 of the Plan]); and
  - access licences that nominate a runoff harvesting dam.
- No total daily extraction limits have been established or assigned in the Wallis Creek Water Source.

From a surface water perspective, the main considerations relate to accounting for any impact of the underground mining on flows in the tributaries of Surveyors Creek and any surface water taken for operational purposes that is not otherwise accounted for under harvestable rights regulations or for pollution control purposes.

3.2.6 Hunter River Salinity Trading Scheme

The Hunter River Salinity Trading Scheme was established by the *Protection of the Environment Operations (Hunter River Salinity Trading Scheme) Regulation 2002* under the PoEO Act with the objective of maintaining the average salinity in the Hunter River below 900 microSiemens per centimetre (µS/cm). The scheme operates by a system of 'credits' that allow saline discharge to the Hunter River in times of high flow when dilution of the saline discharge by the flow in the river will ensure that salinity is maintained below 900 µS/cm Different flow ranges for discharge of saline water have been established for three sectors:

- Upper Sector – upstream of Denman;
- Middle Sector – between Denman and Glennies Creek; and

- Lower Sector – between Glennies Creek and Singleton.

The scheme does not apply to the Hunter River downstream of Singleton and is therefore not relevant to the Project.

3.3 Technical and Policy Guidelines

The assessment of the key issues has also taken into account the following technical and policy guidelines:

- *Managing Urban Stormwater: Soils & Construction – Volume 1* (Landcom, 2004) (taken into account in the design of the Surface Runoff Storage Dam at the new pit-top area).
- *Managing Urban Stormwater: Soils & Construction– Volume 2E: Mines and Quarries* (DECC, 2008) (taken into account in the design of the Surface Runoff Storage Dam at the new pit-top area).
- *Environmental Guideline: Use of Effluent by Irrigation* (DEC, 2004a) (for the design of the effluent irrigation system at the new pit-top area).
- *Australian Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000) (to determine water quality 'trigger' values).
- *Using the ANZECC Guideline and Water Quality Objectives in NSW* (DEC, 2006) (to determine water quality 'trigger' values).

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4 CATCHMENT CHARACTERISTICS

4.1 Land Use

The land within the Project area is highly forested (approximately 95%) and includes the Sugarloaf State Conservation Area and Heaton State Forest, as illustrated in **Figure 2**. The Sugarloaf State Conservation Area is within the area covered by the Lower Hunter Regional Conservation Plan (DECCW, 2009). A vegetation corridor exists linking the Sugarloaf Range to the Watagan Mountains in the south.

The Project area includes a number of cleared easements for high voltage electricity transmission lines radiating from a major sub-station located to the east of the Newcastle Freeway near Killingworth. The approved mining for the Fassifern Seam includes an area surrounding the Mount Sugarloaf lookout including mining under Mount Sugarloaf Road and Sugarloaf Range Road.

Within the Project area, the catchment of Surveyors Creek is largely undisturbed with no evidence of wildfires for two decades (Fluvial Systems, 2012). Downstream of the Project area the catchment of Surveyors Creek located upstream of George Booth Drive is cleared or partially-cleared for rural residential development and there are many existing tracks (Fluvial Systems, 2012).

Ten private land holders own rural residential land that overlies the extent of the proposed workings in the West Borehole Seam.

4.2 Topography

The Project area contains two distinctly different landforms:

- Steep slopes radiating from Mount Sugarloaf (412 metres Australian Height Datum [m AHD]), Summit Point and the Sugarloaf Ridge (>300 m AHD). Slopes vary from relatively flat on the ridge tops (2-5%) to steep mid-slopes of up to 60% and 20% on the foot-slopes above about 100 m AHD.
- Moderate to low slopes (2-20%) below about 100 m AHD that occur predominantly in the northern and western portion of the Surveyors Creek catchment located to the south of George Booth Drive.

The land overlying the extent of the proposed underground workings in the West Borehole Seam ranges in elevation from 40 m to 370 m AHD.

4.3 Soil Landscapes

The soil landscape units within the Project area, as shown in **Figure 3**, reflect the underlying topography and comprise three main units (Matthei, 1995) of relevance to this report, as described below.

4.3.1 Sugarloaf soil landscape unit (Su)

The Sugarloaf soil landscape unit is found on the steep slopes around Mount Sugarloaf, Summit Point and the Sugarloaf Range. Soils derived from the underlying sandstone and shales vary from shallow to moderately deep with bedrock outcrops on the crests and benches, and sandstone floaters on the side slopes. A variant of this unit is recognised on the crest of the ridge running along the Sugarloaf Ridge between Mount Sugarloaf and Summit Point. Some land represented by this unit would be subject to any subsidence that occurs as a result of underground mining. No construction is proposed on this landscape unit.

4.3.2 Killingworth soil landscape unit (Ki)

The Killingworth soil landscape unit is found on the foot-slopes below about 100 m AHD to the north and east of Mount Sugarloaf and to the north of Summit Point. Soils, which vary from shallow to moderately deep, are moderately erodible when exposed. Small areas of this soil landscape unit located to the north of Mount Sugarloaf and Summit Point would be subject to any subsidence that occurs as a result of underground mining. The existing pit-top facilities are located on this soil landscape unit as well as the new pit-top facilities.

4.3.3 Beresfield soil landscape unit (Be)

The Beresfield soil landscape unit occurs on the broad relatively flat areas of the Surveyors Creek catchment located on the western side of the Project area. Soils are moderately deep and moderately erodible.

4.3.4 Acid Sulphate Soils

There are no areas identified as having acid sulphate potential within the Project area.

4.4 Drainage Systems

Figure 4 shows the drainage catchments within and surrounding the Project area. Two drainage systems that emanate from Mount Sugarloaf and the Sugarloaf Range are of primary relevance to this report:

- **Blue Gum Creek** which drains in a north-easterly direction from Mount Sugarloaf and discharges to the Hexham Swamp at the Pambalong Nature Reserve. The pit-top facilities for the existing Tasman Underground Mine and most of its associated underground mining occur within the section of the Blue Gum Creek catchment to the south of George Booth Drive. The catchment area of Blue Gum Creek is about 4 square kilometres [km^2] at George Booth Drive and about 18 km^2 where it drains into Hexham Swamp.
- **Tributaries of Surveyors Creek** which drain in northerly and westerly directions across George Booth Drive (catchment area about 19 km^2 at this point) and eventually join Wallis Creek near John Renshaw Drive about 4 km north of the northern boundary of the extraction area for the Project. Wallis Creek discharges into the Hunter River near Maitland about 10 km downstream of the Surveyors Creek junction, at which point Wallis Creek has a total catchment area of 211 km^2.

In addition to these main catchments, the Project area includes small areas of other creek systems draining from the Sugarloaf Range:

- An area of about 65 hectares (ha) in the headwaters of Slatey Creek which overlies the approved area for mining of the Fassifern Seam for the existing Tasman Underground Mine;
- An area of about 90 ha in the south-east corner of the footprint for the Project that lies within the headwaters of Burkes Creek which drains to Lake Macquarie via Cockle Creek.

- An area of about 125 ha in the south-west corner of the footprint for the Project that lies within the headwaters of a small un-named tributary which drains to an existing water storage, the 'Colliery Dam', which overflows to Wallis Creek.

These small headwater catchments, which drain from the Sugarloaf Range, all have similar topography, soils and forest cover to the equivalent headwater catchments of Blue Gum Creek and Surveyors Creek and can, therefore, be expected to have similar hydrologic characteristics.

4.5 Geomorphic Characteristics

The topographic and geomorphic characteristics of the section of the Surveyors Creek drainage system located upstream of George Booth Drive have been characterised on the basis of detailed field survey for the Project undertaken by Fluvial Systems (2012). Details of this survey are documented in the *Geomorphology Assessment* (Appendix D to the EIS for the Project). Relevant aspects of the report, which includes the location of the relevant geomorphic features in the study area, are summarised below.

The field survey revealed that both digital data (Land and Property Information, NSW Government) and the 1:25,000 Topographic Maps had deficiencies in representing streamlines. This problem was resolved by using field data to correct (where necessary and where data were available) the streamlines represented on the 1:25,000 topographic sheets. **Figure 5** shows the streams identified as a result of this process, the adopted naming convention and the Strahler stream order classification for the creeks within the study area. **Table 4.1** summarises the number of reaches within each order, the total length of those reaches and the stream gradients.

Table 4.1: Summary of Stream Lengths and Slopes

Creek Name	Strahler Stream Order	No of Reaches	Total Length (m)	Mean Gradient (m/km)	Maximum Gradient (m/km)
Surveyors Creek 1	1	6	4,862	56	410
	2	2	4,102	13	146
	3	1	1,682	7	58
	4	1	376	4	27
Surveyors Creek 2	1	12	11,413	99	765
	2	3	5,094	67	575
	3	1	8,551	8	26
Wallis Creek 1	1	2	1,259	121	321
	2	1	525	98	378

(Source: Table 1, Fluvial Systems, 2012)

Figure 5 shows that the majority of the area that is proposed to be undermined in the West Borehole Seam for the Project lies under Surveyors Creek 2 and its tributaries. A small area to be undermined is located under the first order section of tributary S1C while the area for the new pit-top facilities would drain to the second order section of tributary S1B. A small area to be undermined is also located under the first order sections of Wallis Creek tributaries W1 and W1A.

As shown in **Table 4.1**, the average stream gradient decreases for each increasing Strahler order class. It is noticeable, however, that the average gradient for the tributaries of Surveyors Creek 1 are lower than those in Surveyors Creek 2 and Wallis Creek tributaries which have their headwaters in the steeper slopes of the Sugarloaf Range (see **Figure 5**).

On the basis of the field survey, seven geomorphic stream types have been identified. The classification system, which is based on the River Styles® framework (Brierley and Fryirs, 2000), includes a higher level of detail than in the original River Styles® framework in order to reflect the relatively small-scale of the Surveyors Creek tributary catchments and the lack of many of the larger scale features recognised in the River Styles® framework. The structure of the classification scheme is shown in **Figure 6** while **Figure 7** shows the relevant classification of all the streams within the section of the Surveyors Creek catchment that is relevant to this report.

The field survey identified a range of geomorphic features within the area that is proposed to be subject to mining in the West Borehole Seam which reflect the interaction of the underlying geology and soils, stream gradient, channel sediments and flow regime, including:

- 54 bedrock outcrops, predominantly on the headwater sections of tributaries of Surveyors Creek 2;
- 25 cliffs on the headwaters of tributaries S2CB and S2;
- 33 headwater knickpoints and 10 valley-fill knickpoints; and
- 25 pools, predominantly on the second and higher order reaches with the majority on tributary S1B (9) and tributary S1C (8).

4.6 Existing Surface Water Users

No surface water licensed extractions have been identified on Surveyors Creek, Burkes Creek or the tributary of Wallis Creek that drains to the 'Colliery Dam'.

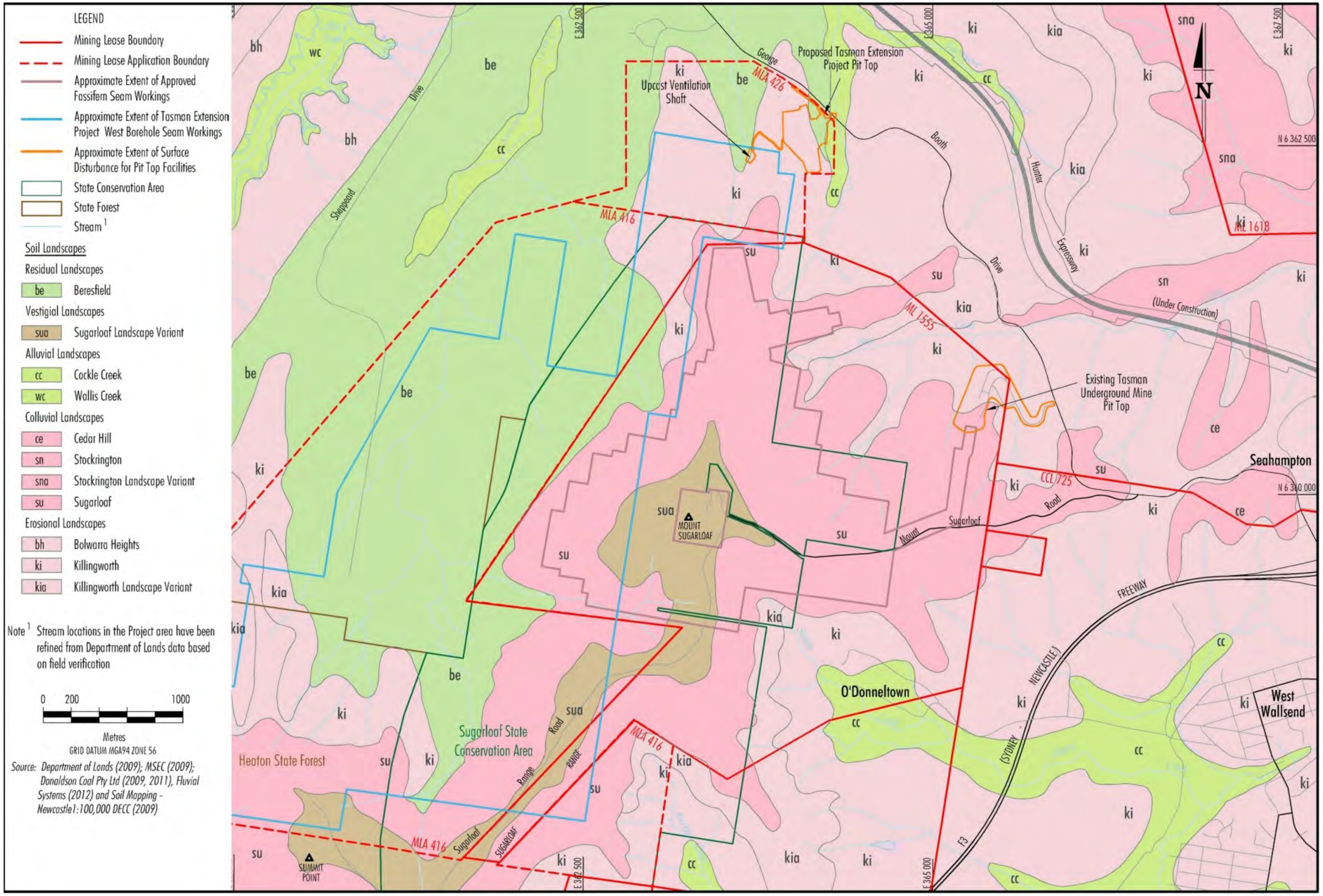


Figure 3:
Soil Landscape Units in the Project Area
(Source: Resource Strategies, 2012)

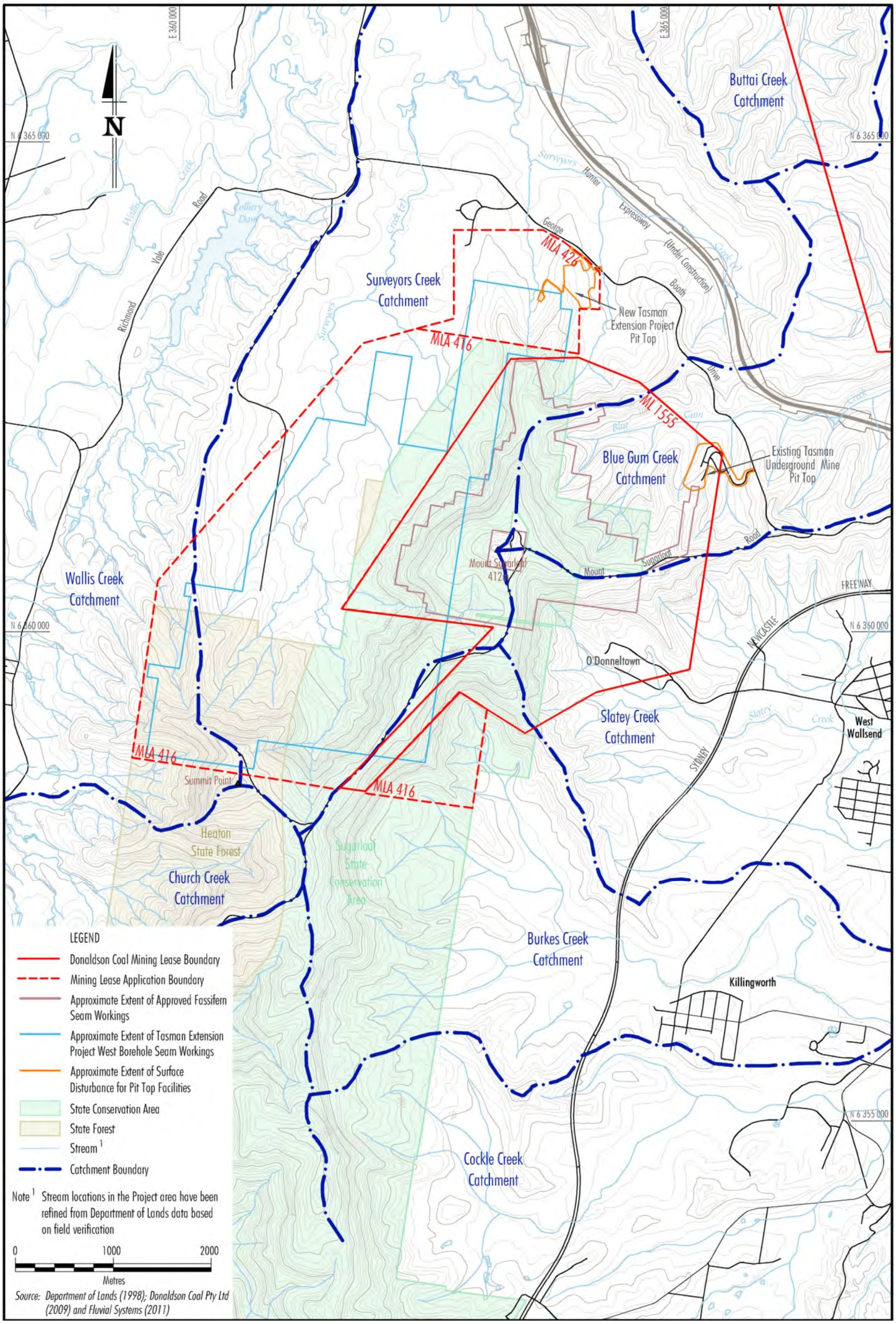


Figure 4:
Catchments in the Vicinity of the Project Area

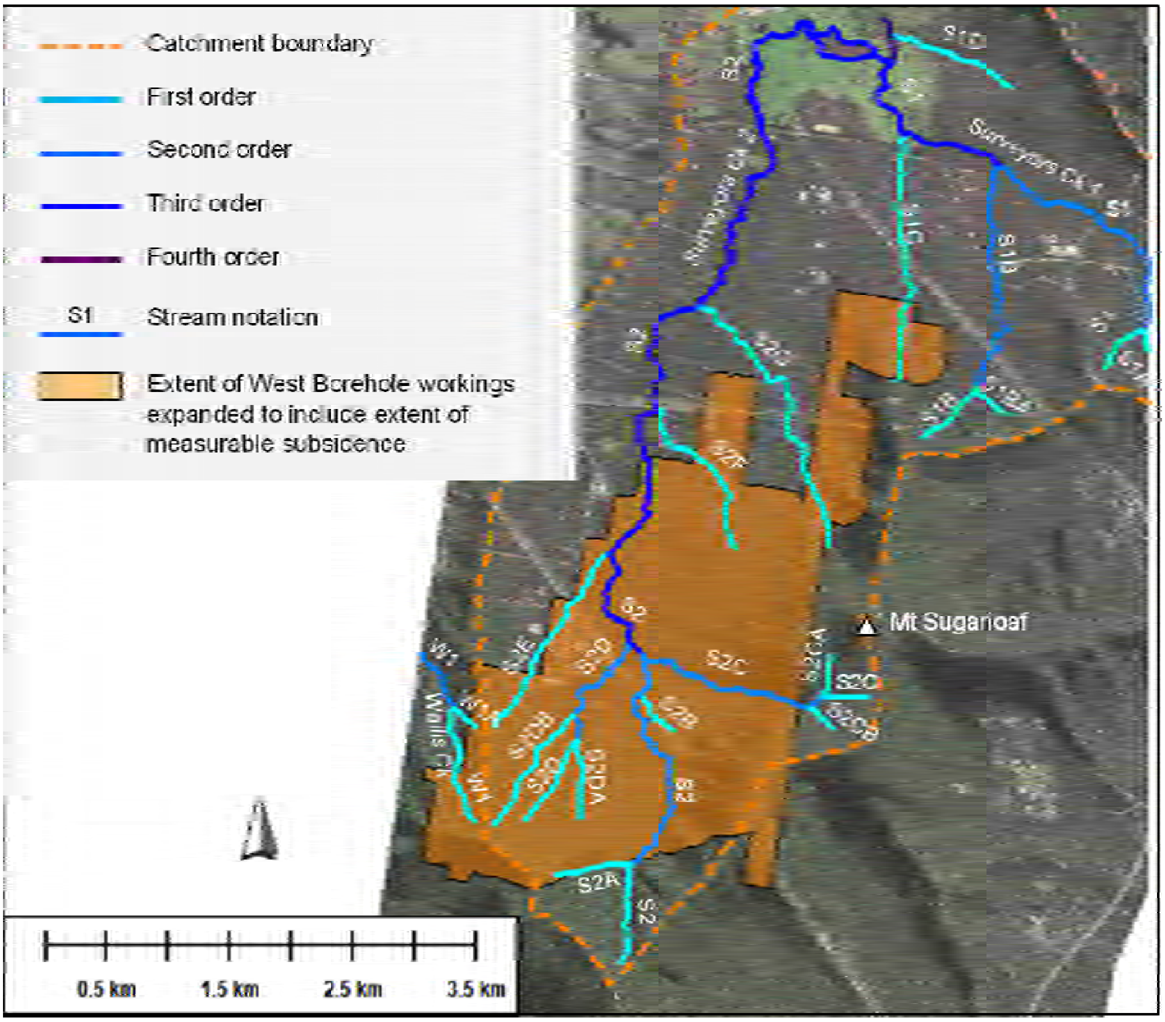


Figure 5:
Strahler Stream Order and Creek Naming
(Source: Fluvial Systems, 2012)

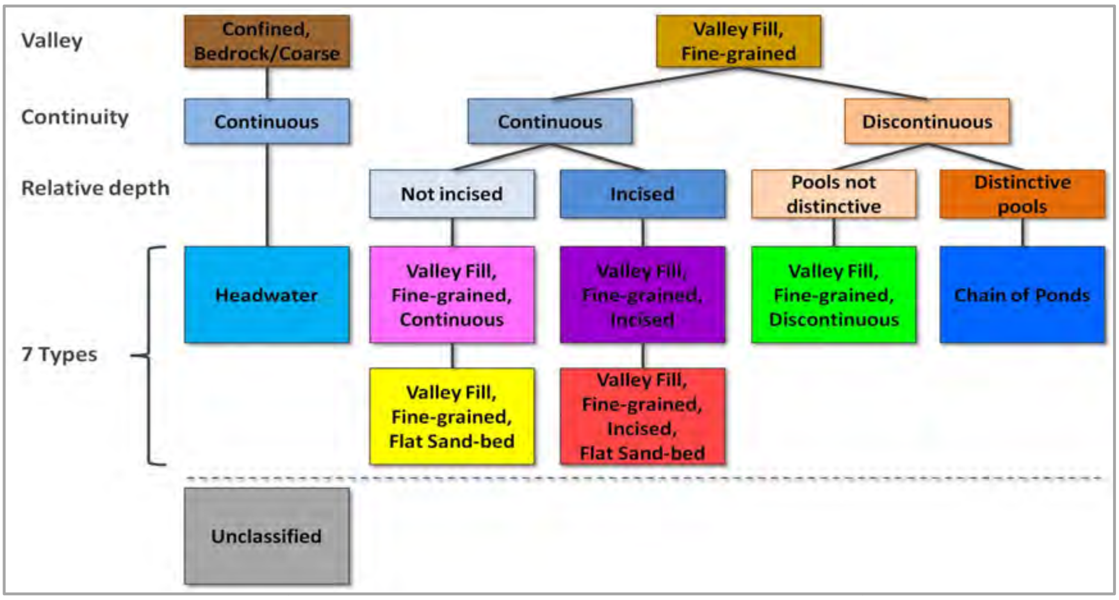


Figure 6:
Geomorphic Classification Scheme for Surveyors Creek
(Source: Fluvial Systems, 2012)

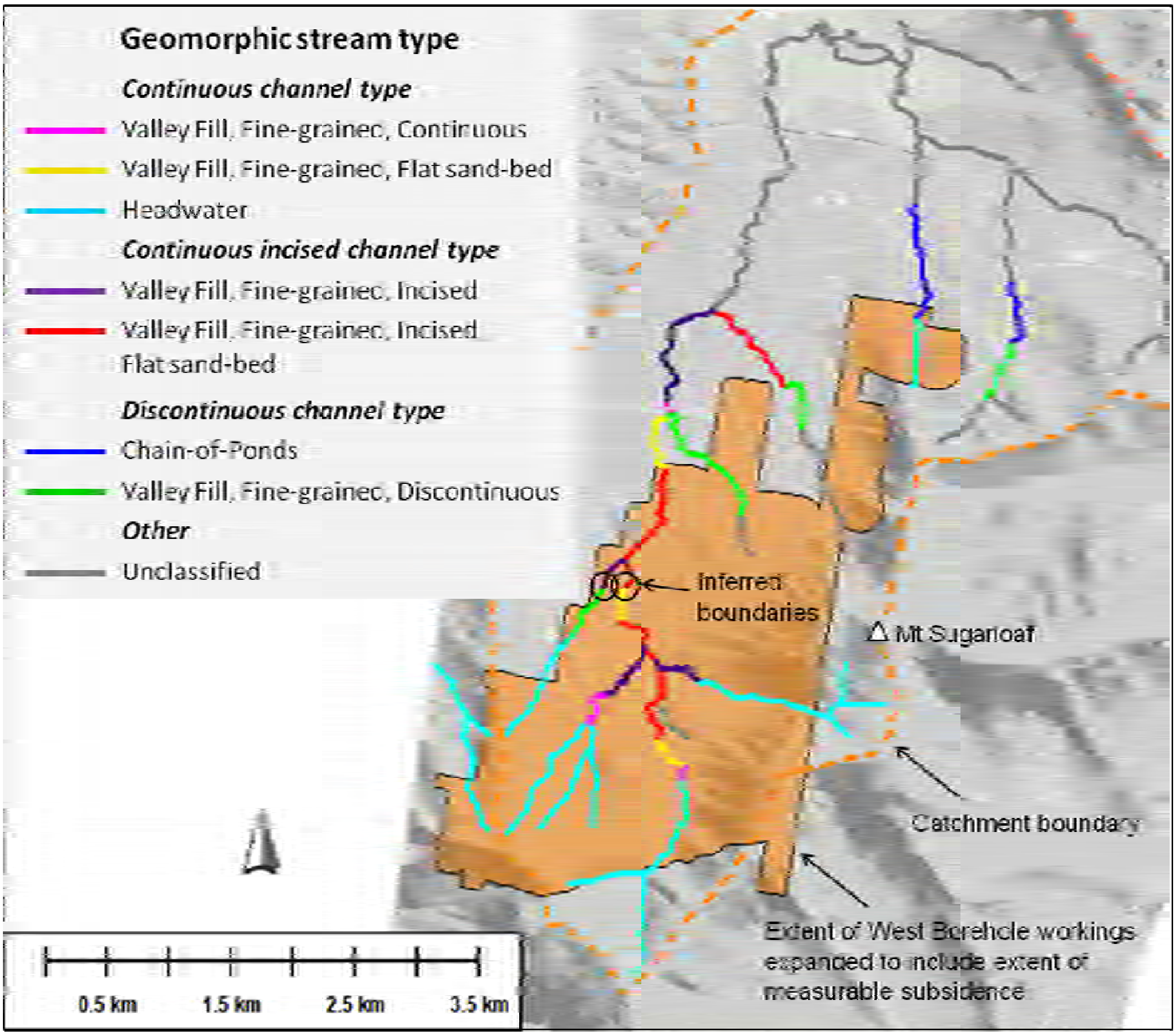


Figure 7:
Geomorphic Stream Types
(Source: Fluvial Systems, 2012)

5 SUBSIDENCE IMPACTS AND MANAGEMENT

5.1 Introduction

Coal extraction would occur using the bord and pillar mining method which allows for subsidence impacts to be managed by increasing or decreasing the amount of coal extracted in particular areas. In order to minimise impacts of subsidence on the creeks overlying the extraction area, Donaldson Coal proposes to implement the Subsidence Control Zones (SCZs) to achieve the performance measures relating to creeks, groundwater dependent endangered ecological communities (EECs) and Riparian EECs as set out in **Table 5.1**. The SCZs may involve partial extraction of coal or limiting extraction to first workings (i.e. no secondary extraction) in some areas.

Table 5.1: Performance Measures and Subsidence Control Zones for Creeks

Creek Order[1]	Performance Measure	Proposed Subsidence Control Zone
3rd and above	Negligible environmental consequences (that is, negligible diversion of flows and negligible change in the natural drainage behaviour of pools). Negligible connective cracking to underground workings.	First workings only (no secondary extraction) within 26.5° angle of draw resulting in less than 20 mm subsidence at the edge of the bank.
1st and 2nd	Not more than minor environmental consequences. Negligible connective cracking to underground workings.	Partial extraction only, with stable remnant pillars resulting in less than 300 mm of subsidence where the depth of cover to the stream is less than 80 m.
Groundwater Dependent EECs[2] and Riparian EEC[3]	Negligible environmental consequence	Partial extraction with stable remnant pillars resulting in less than 300 mm of subsidence.

Note 1 – Based on the Strahler stream ordering system

Note 2 – Coastal Warm Temperate – Subtropical Rainforest and Alluvial Tall Moist Forest

Note 3 – Hunter Lowlands Redgum Forest along 3rd order streams

The *Subsidence Assessment* prepared by Ditton Geotechnical Services (DgS, 2012) presents details of the mine subsidence impact assessment for the Project for mining in both the Fassifern Seam and West Borehole Seam. Data generated for the *Subsidence Assessment* has been used to provide an assessment of the impact of subsidence on:

- watercourse bed slopes and the potential for increased velocity; and
- the potential impact on pools and ponding.

The *Subsidence Assessment* provides details of the predicted subsidence along eight 1st order streams, three 2nd order streams and one 3rd order stream (the western branch of Surveyors Creek). The assessment indicates that, while the predicted maximum subsidence of 0.58 m to 1.27 m is likely to result in surface cracks developing within the limits of the extracted panels in areas without subsidence control, surface cracks are 'unlikely' to develop within the SCZs (as defined in **Table 5.1**).

The *Subsidence Assessment* also indicates that the potential worst-case pond depths along the 1st, 2nd and 3rd order creeks in the low-lying areas above the middle of proposed coal extraction panels may be increased by 0.5 to 1.0 m after mining. Several out-of-channel 'depressions', between 0.1 m and 0.7 m deep, may also develop above several of the extraction panels.

5.2 Watercourse Subsidence

The pre- and post-mining surface level profiles along representative creek reaches (Figures 40a to 40j in the *Subsidence Assessment*) show predicted subsidence and gradient changes along sections of Surveyors Creek and its tributaries that lie within the proposed extraction area.

The predicted level of subsidence along the watercourses when SCZs are implemented is as follows:

- Tributary S2 – Minimal impact in the downstream half of the watercourse. Some subsidence up to a maximum of 0.82 m may occur at around chainage 3,500 m (from the Junction with S2F) over a length of approximately 200 m. Subsidence of the upstream reaches is limited to 0.4 m.
- Tributary S2E – A long zone of minor subsidence is predicted in the downstream section of S2E, with subsidence of around 0.3 m between chainage 0-900 m (measured upstream from the junction with S2). The upstream reach may subside by up to 0.4 m over a length of 250 m, whilst the maximum subsidence of 1.2 m would occur over a 100 m length from chainage 1,250-1,350 m.
- Tributary S2DA/S2D – An extended zone of subsidence is predicted along the upstream 350 m section of S2DA, with an average subsidence of approximately 1.15 m. This zone lies outside the area protected by SCZs, as it is a first order stream with more than 80 m of cover. From chainage 300-1,200 m (measured from the junction of S2) there is minimal subsidence ranging up to 0.3 m. At the downstream end, there is an area of expected subsidence of up to 0.8 m over a length of about 200 m.
- Tributary S2CB/S2C – The expected subsidence is minimal, with an undulating pattern ranging up to 0.4 m of subsidence over the majority of the reach length.
- Tributary S2F – No subsidence is expected from chainage 0-600 m (measured from the junction with S2). Three distinct zones of subsidence are expected in the central and upstream reaches. Two areas of up to 1.0 m of subsidence are expected in the central reach, each spanning around 150 m. Subsidence of up to 0.5 m is expected in the upstream 200 m of the watercourse.

The maximum level of subsidence across the assessed watercourses is predicted to occur on steeper headwater creeks with up to 1.2 m on tributary S2E and up to 1.15 m on tributaries S2DA/S2D.

In terms of impacts on the flow regime the greatest impact of subsidence would be in sections where there is greatest relative change in bed slope. The absolute magnitude of subsidence is not relevant if it occurs progressively over a long distance. However, as noted in the *Geomorphology Assessment*, consideration of the significance of change in bed slope is also given in relation to the range of slopes encountered in the existing channels with similar geomorphic features.

5.3 Impact of Subsidence on Bed Slope

Further analysis of bed slope change was undertaken for tributaries S2E and S2DA/S2D which exhibit the greatest change in bed slope of all the creek profiles shown in Figures 40a to 40j of the *Subsidence Assessment*:

- Tributary S2E – the reach of greatest subsidence, between chainage 1,220 and 1,600 m (measured from the junction with tributary S2). This reach is located upstream of a pool identified in the Ge*omorphology Assessment* at approximately chainage 1,180 m (downstream of the zone of projected subsidence impacts);
- Tributaries S2DA/S2D – the reach of transition from greatest subsidence to zero subsidence which results in noticeable bed slope change (chainage 1,200 to 1,450 m measured from the junction with tributary S2).

Surface profile data from Figures 40c & 40d (tributary S2E subsidence and gradient change respectively) and Figures 40e & 40f (tributaries S2DA/S2D subsidence and gradient change respectively) were utilised for the detailed analysis of changes in bed slope in the areas of maximum change. The analysis was undertaken assuming SCZs would be implemented in accordance with **Table 5.1**.

The *Subsidence Assessment* indicates that the surface level profiles for the pre-mining (existing conditions) scenario were generated by cutting lines through a digital terrain (elevation) model of the Project site, where each line approximated the alignment of a watercourse as designated on the topographic map or in the *Geomorphology Assessment*. In some areas the watercourse line used to generate the surface profile has not followed the low point of the landscape. This has resulted in the pre-mining surface profiles having an unrealistically high degree of variability over short distances – particularly along the steeper headwater creeks. Some watercourse profiles show an increase in elevation of up to 4 m over short distances in a downstream direction (implying the presence of a deep pool), despite the fluvial geomorphic survey showing no pools in these areas. These anomalies in the derivation of the creek profiles shown in the *Subsidence Assessment* do not provide an adequate basis for assessing likely areas where changes in bed slope could lead to changes in flow velocity.

For the reaches of interest, a realistic profile of the existing creek was prepared by fitting a polynomial equation through the data points derived from a rolling average (12 consecutive data points) extracted from the ‘creek’ bed profile data provided by DgS. Changes in elevation (as defined in the data provided by DgS) were then superimposed onto the polynomial equation that defined the existing bed slope.

The most significant bed slope changes of all the watercourses are expected on tributary S2E. The section between chainage 1,200-1,600 m (upstream from the junction with tributary S2) has an existing bed slope of around 4% in the downstream portion, increasing to nearly 10% at the upstream end. The section between chainages 1,260 and 1,380 m may experience subsidence of up to 1.2 m, which would cause a steepening of the profile by up to 4% between chainages 1,330 and 1,380 m.

The downstream transition zone from subsidence to no subsidence would cause a section of decreased bed slope between chainages 1,280 and 1,320 m, including a flat section of around 30 m. The bed slope in this section decreases from 4% to 0%.

The existing bed slope in the reach of interest along tributaries S2D and S2DA (chainage 1,200 to 1,450 m from the junction with S2) varies from 2–8%. As a result of subsidence the bed slope is predicted to decrease, with a maximum decrease from 5.7% to 4.5%, which is not considered to have a significant effect on flow conditions.

5.4 Impact of Subsidence on Knickpoints

An assessment of risk to the geomorphic character to watercourses in the Project area, associated with potential subsidence impacts, was conducted by Fluvial Systems (2012). As described in the *Geomorphology Assessment*, the key threatening process to geomorphic character associated with potential subsidence impacts are considered to be the migration of existing knickpoints in areas where subsidence increases stream gradient beyond the natural range of variation.

For most of the watercourses in the Project area, the risk to geomorphic character associated with subsidence is considered to be 'insignificant', with several isolated, short sections of watercourses being assessed as 'low', 'moderate' and 'high' risk (see **Figure 8**). The highest risk sections were located on Valley-fill, Fine-grained, Discontinuous stream type on tributary S2F, as these sections were identified as having high fragility/vulnerability (due to the potential for knickpoint migration), and high relative subsidence (i.e. bed slope outside of the natural range of variation).

In relation to tributary S2E the *Geomorphology Assessment* notes five existing headwater knickpoints and one valley fill knickpoint. However the risk to geomorphic form and stream processes is considered 'insignificant' at any of the existing knickpoints and the reaches of bed slope change identified in **Section 5.3** above. Two areas of risk have been identified:

- An area of 'low' risk located about 100 m upstream of the junction with tributary S2;
- An area of 'moderate' risk located about 550 m upstream of the junction with tributary S2.

As shown on **Figure 8**, the only other areas of risk identified in the headwater creeks are located on tributary S2D approximately 170 m and 300 m upstream of the junction with tributary S2. These areas, which are assessed as 'low' risk do not correspond with the location of any existing knickpoints on this tributary.

5.5 Impact of Subsidence on Ponding

The *Subsidence Assessment* found that the potential worst-case pond depths along the 1st, 2nd and 3rd order creeks in the low-lying areas above the middle of proposed panels may be increased by 0.5-1.0 m after mining.

Ponds have been identified during the course of the geomorphic survey on tributaries S2E and S2CB/S2C only. A more detailed analysis of the impacts of subsidence on ponding has been attempted using the limited data available. The pool location chainages have been estimated based on GIS information from the fluvial geomorphology survey.

From the geomorphology field survey, two pools were identified on tributary S2E in the central and downstream sections, at approximate chainages 920 m and 1,170 m respectively:

- The pool at chainage 920 m is in an area above Panel 8 which would have a SCZ for protection of the groundwater dependent EECs. Minimal subsidence of 0.08m is predicted. This level of subsidence is unlikely to have any impact on the pool.
- The pool at chainage 1,170 m is located outside the extraction area where no subsidence is predicted.

In addition to the existing pools, a section of flat/negative bed slope is predicted due to the subsidence at about chainage 1,300 m. However, given that the predicted surface level difference across the flat section is limited to <0.05 m, it is unlikely that a pool would be formed.

Two pools were identified on the headwater section of tributary S2C in the geomorphic field survey:

- The downstream pool, located in the vicinity of 720-750 m from the junction with S2, is in an area where the predicted subsidence is about 0.1 m greater at the downstream end (implying a potential decrease in the depth of the pool). There are no details of the depth of this pool. However, if subsequent assessment indicated that this pool is significant for the ecology in the immediate vicinity, only minor works would be required to restore the capacity of the pool.
- The upstream pool, located in the vicinity of chainage 960-1,000 m, is in an area where the predicted subsidence is about 0.05 m less at downstream end (implying a potential decrease in the depth of the pool). This potential change is not considered significant. However, this pool, along with all others would be monitored and managed as part of the subsidence monitoring and management program (see **Section 5.6** and **Section 5.7**).

5.6 Subsidence Impact Management

The main surface water subsidence impacts that may require management are impacts associated with surface cracking, ponding and scouring.

The *Subsidence Assessment* concludes that the strategy of providing SCZs for all 1st and 2nd order creeks where the depth of cover is less than 80 m is expected to avoid any cracking in the beds of these creeks. In areas where no SCZs are employed, such as where 1st and 2nd order ephemeral watercourses at depths >80 m are present, surface crack repair works may need to be implemented.

The decision on whether crack repairs need to be undertaken in creeks would depend upon the perceived risk to public safety, the potential for self-healing or long-term degradation, site accessibility to effect repairs or the requirements of the stakeholder agreement. For the 1st and 2nd order creeks with cover depths >80 m, the following remediation strategies are proposed in the *Subsidence Assessment*:

- Pre-mining and post-mining inspections would be undertaken along the creeks, with the results of these inspections communicated to the stakeholders through Extraction Plans and End of Year Reports.

- Trigger Action Response Plans and remediation strategies would be developed and outlined in Extraction Plans.
- Consultation with relevant government agencies at other mine sites has suggested that natural regeneration may be the favoured management strategy in most scenarios, due to the likely level of disturbance caused by other remediation strategies, such as back filling with imported, free-draining materials from haulage trucks.

Along all 3rd order tributary sections of Surveyors Creek No. 2, surface cracking would be limited by the panel geometries and proposed buffer zones around first workings. The *Subsidence Assessment* considers it 'very unlikely' that surface cracks would develop along this section of the creek bed. However Extraction Plans would include Trigger Action Response Plans that address this issue.

To minimise the likelihood of increased scouring potential along creeks due to changes to bed slopes after mining, the following management strategies have been proposed in the *Subsidence Assessment*:

- Bed slope monitoring (combined with general subsidence monitoring along watercourse cross sections and centre lines);
- Areas that are significantly affected by scour after mining may need to be repaired and protected with mitigation works such as re-grading a section of channel and placement of scour protection on exposed areas, based on consultation with the relevant stakeholders; and
- On-going review and appraisal of any significant changes such as cracking, increased erosion, seepages and drainage path adjustments observed after each panel is extracted.

In addition, the *Geomorphology Assessment* recommends that, based on the monitoring described above, any observed significant development of knickpoints should be assessed by a suitably qualified specialist in order to determine the most appropriate control measure. The *Geomorphology Assessment* states that large wood structures (e.g. log sills) could be the most appropriate knickpoint control structures for the Project.

Notwithstanding the assessment in **Section 5.5** above that any changes in existing ponds would be minor, the *Subsidence Assessment* proposes the following management strategies to address potential impacts on ponding:

- The development of a suitable monitoring and mitigation response plan as a component of the Extraction Plan process, based on consultation with the regulatory government authorities to ensure ponding impacts on existing vegetation do not result in long-term environmental degradation.
- The review and appraisal of changes to drainage paths and surface vegetation in areas of ponding development (if they occur), after each panel is extracted.
- In the event that it is necessary to re-establish flows between sections of creek within a SCZ (as set out in **Table 5.1**) and subsided creek areas above total extraction panels, engineered channel earth works may be necessary. However, local experience to-date suggests that if increased in-channel ponding occurs it can either remain as an ‘additional’ pond along the creek or be remediated in consultation with the relevant stakeholders.

The *Subsidence Assessment* indicates that outside the SCZs, the predicted maximum subsidence of 0.58 m to 1.27 m is likely to result in cracks on the land surface. The main risk of cracking is expected within a zone extending from 9 m to 47 m from the edge of each extraction panel (160.5 m wide).

The potential impact of surface cracking on surface runoff will be mitigated by the same procedures adopted by Donaldson Coal on land overlying the Abel Underground Mine. These procedures include routine inspection of the land surface within the zone of expected cracking after coal extraction has occurred, and back-filling and rehabilitation of significant cracks. The backfilling procedure includes separately excavating each soil horizon in an area around each crack, and backfilling to restore the original soil horizons. The areas outside the SCZs predominantly comprise either Beresfield or Killingworth soil landscape units which have deeper soils than the Sugarloaf soil landscape unit, and therefore provide greater opportunity to use in-situ materials for filling of any cracks.

As a result of implementing the established procedures for monitoring for the occurrence of cracks and backfilling where required, no significant change in surface runoff is expected.

5.7 Subsidence Monitoring

The *Subsidence Assessment* sets out details of a subsidence monitoring program and management plan that addresses all aspects of subsidence. The following general monitoring program activities are suggested in relation to surface water impacts:

- Survey lines along the centre line and across the banks of Surveyors Creek Tributaries 1 (i.e. S1C) and 2 (i.e. S2C) and a number of key headwater tributaries;
- Visual inspections and mapping of any changes/damage along each watercourse to be conducted before, during, and after mining. During mining, each watercourse should be inspected after the completion of each underlying panel; and
- At locations on the creeks identified in the *Subsidence Assessment* as having the potential to be subject to significant changes in grade or changes affecting existing pools, establish permanent reference points for annual photographic recording.

The monitoring of subsidence above panels mined during the first phases of the mining would provide valuable insights into the actual subsidence as compared to the predicted subsidence. The impact of mining and subsidence along tributaries S1C and S2C (as identified by the monitoring described above), which would be mined in 2014-2015 (Panels 1-2) and 2017-2021 (Panels 12-17), respectively, can be used to guide the management of SCZs and extent of coal removal during later stages of mining beneath tributaries such as S2, S2D and S2E, to ensure impacts are minimised.

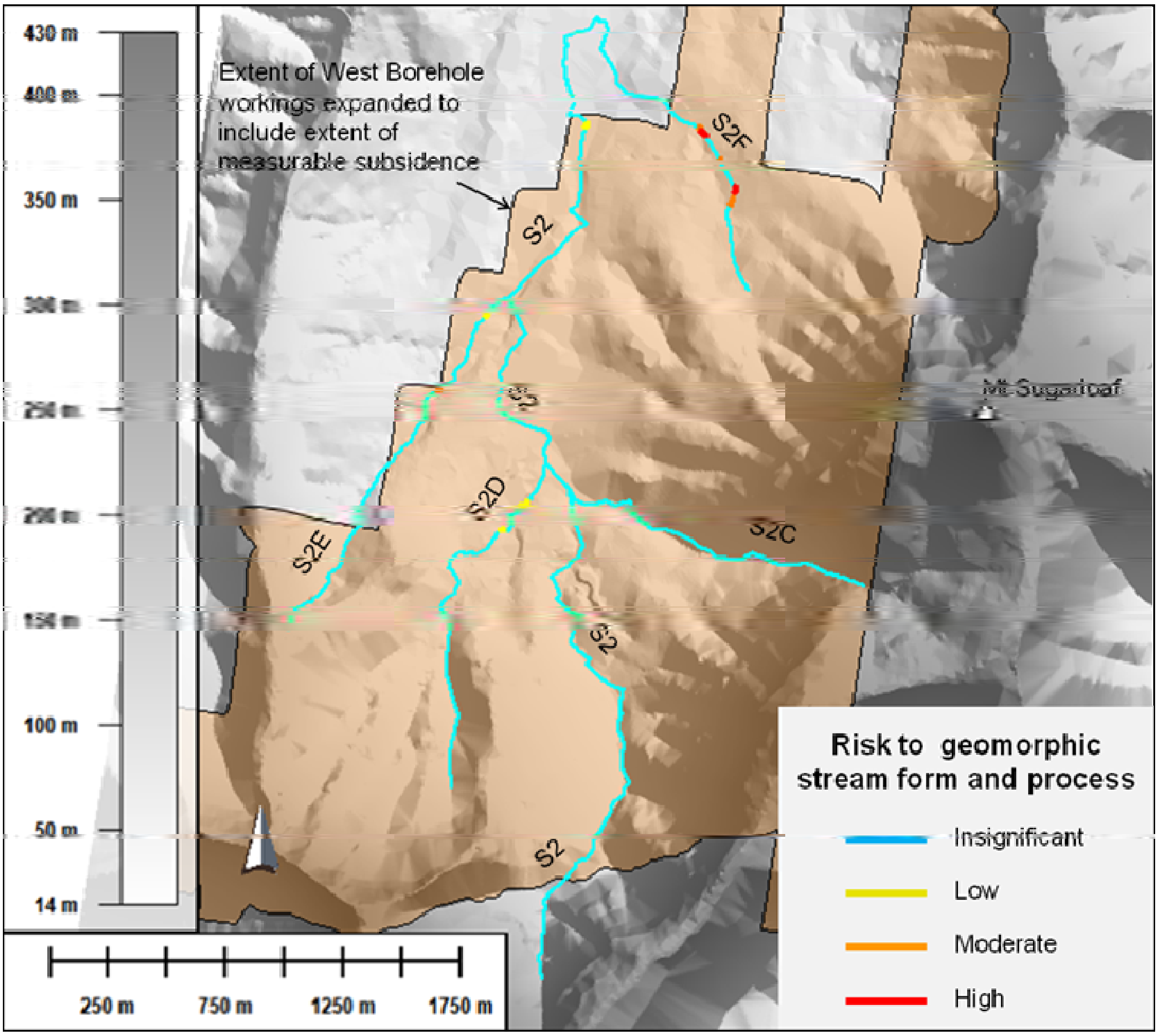


Figure 8:
Assessed Risk to Geomorphic Stream Form and Process
(Source: Fluvial Systems, 2012)

6 FLOW CHARACTERISTICS

No continuous streamflow or peak flow gauging has been undertaken on any of the creeks in the catchments of Blue Gum Creek or Surveyors Creek. Therefore, for purposes of defining the flow regime within the creek systems of relevance to this report, modelling of flow has been undertaken using two types of models.

The **Australian Water Balance Model** (AWBM) has been used to provide estimates of the daily flow characteristics of streams. These estimates provide a basis for assessing the potential impacts of subsidence on water supply to pools within the Project area and any impacts on environmental flows and the entitlements of downstream water users. AWBM is a catchment water balance program developed for Australian conditions (Boughton, 1984, Boughton and Carroll, 1993, Boughton, 2010) which represents the hydrologic response of a catchment on the basis of a series of interlinked soil stores. Model parameters that represent the characteristics of the soil stores are derived from analysis of observed daily rainfall and streamflow records, along with potential evapotranspiration for representative catchments.

Once the model parameters have been derived from observed records, the AWBM model can be used to generate sequences of daily flow using extended historic records of daily rainfall and potential evapotranspiration estimates for each month of the year. In this instance, representative AWBM model parameters for the Surveyors Creek catchment have been derived from the calibration of AWBM to monitored catchments in the Hunter Valley and Central Coast which have comparable topography, land-use and climate to Surveyors Creek, together with published model parameters for the region. The procedure adopted for application of the AWBM to the Surveyors Creek catchment is outlined in **Section 6.4** below and set out in greater detail in **Appendix 1**.

The **Probabilistic Rational Method** (PRM) has been used to estimate peak flow rates at key locations in order to assess the potential impacts of subsidence on channel form, such as channel scour or knick-point migration. The PRM (Pilgrim and McDermott, 1982) is based on extensive analysis of the relationship between the peak flow rate and the peak rainfall intensity for the same probability of occurrence. The application of the PRM to the Surveyors Creek catchment is described in **Section 6.5**.

6.1 Climate Data

AWBM requires rainfall and potential evapotranspiration data for purposes of model calibration and operation. For this study, the full historic daily rainfall records for sites in close proximity to Surveyors Creek and the catchments identified for purposes of model calibration were obtained and analysed. **Table 6.1** lists the sources of rainfall data used for model calibration or modelling of streamflow.

Appendix 1 describes the data checking procedures and corrections made to account for aggregated or missing data in the period required for modelling. Where daily rainfall data supplied by the Bureau of Meteorology (BoM) contained aggregated (typically total rainfall over 2-3 days) this was disaggregated based on the rainfall pattern at a neighbouring station. With the exception of one station (Cooranbong - Avondale) less than 2.5% of data at each station had to be disaggregated for the years selected for modelling. Where there was missing rainfall data this was in-filled with data from a neighbouring station adjusted to account for the relationship between the stations established on the basis of the period of common records. During the periods required for modelling, less than 0.5% of rainfall data was missing.

Table 6.1: Summary of Relevant BoM Rainfall Stations

Station Name	Station No.	Latitude	Longitude	Station Opened	Station Closed
Rainfall Stations used for Model Calibration					
Congewai (Greenock)	61152	32° 59' 58''	151° 17' 27''	1959	Open
Cooranbong (Avondale)	61012	33° 05' 07''	151° 27' 48''	1903	2011
Cessnock Post Office	61009	32° 49' 38''	151° 21' 58''	1903	1992
Pokolbin (Somerset)	61238	32° 48' 51''	151° 18' 09''	1962	Open
Wyee (Wyee Farms Road)	61082	33° 10' 45''	151° 26' 29''	1899	Open
Rainfall Stations used for Project Area Modelling					
Morpeth Post Office	61046	32° 43' 31''	151° 37' 43''	1884	2010
Mulbring (Vincent Street)	61048	32° 54' 10''	151° 28' 55''	1932	2007

For the purposes of assessing the flow regime in the catchments that overlie the Project area, it was necessary to utilise long term rainfall records in order to adequately characterise the effects of rainfall variation from year to year. Analysis was undertaken to assess the relationship between the rainfall statistics at the Tasman Underground Mine site (gauge located on open ground next to water storage tanks - about 35 m from the nearest tree or structure) and long term rainfall stations in the general area. Unfortunately the rainfall record from Mulbring (about 2 km west of the western boundary of Surveyors Creek) ceased in August 2007 and does not provide sufficient record for correlation against the records from Tasman Underground Mine, which commenced November 2006. Rainfall relationships between at the following stations were assessed:

- Tasman Underground Mine and Morpeth Post Office for the period (6/11/2006 – 28/2/2011).
- Mulbring and Morpeth Post Office for the period (1/1/1933 – 31/8/2007). Although Morpeth is about 20 km from the site of the Project, it provides one of the longest records available in the lower Hunter region, commencing in mid-1884. (Morpeth Post Office is not listed as one of the Bureau of Meteorology's Reference Climate Stations. However, the record contains minimal missing data, is consistent with other rainfall records in the area and is therefore considered appropriate for characterising the long term rainfall regime in the area.)

Two sets of graphs were derived:

- Correlation between rainfall depth on days of equal probability of occurrence (analysed at 0.1% intervals); and
- Relationship between cumulative total daily rainfall over the period of common record.

As summarised in **Table 6.2** and set out in more detail in **Appendix 1**, on the basis of the high degree of correlation, and the cumulative rainfall relationship, the rainfall record at Morpeth (complete years July 1885 – June 2010) has been adopted as a good representation of the long term rainfall for the catchments in the vicinity of the existing Tasman Underground Mine and the Project. A scaling factor of 1.07 (based on a line of best fit with an intercept of zero) was applied to account for slightly higher rainfall at the Tasman Underground Mine than at Morpeth.

Table 6.2: Analysis of Daily Rainfall at Tasman, Mulbring and Morpeth

Data	Stations	Coefficient	R^2
Daily Rainfall of Equal Probability	Morpeth v Tasman Underground Mine	1.068	0.994
Daily Rainfall of Equal Probability	Mulbring v Morpeth	1.070	0.999
Cumulative Daily Rainfall	Morpeth v Tasman	1.074	N/A
Cumulative Daily Rainfall	Mulbring v Morpeth	1.109	N/A

Potential evapotranspiration data was sourced from the digital version of the *Climatic Atlas of Australia: Evapotranspiration* (Version 1.0, Bureau of Meteorology, 2002). The software was used to provide the monthly areal potential evapotranspiration values specific to each catchment, based on the coordinates of the catchment centroid.

6.2 Streamflow Data

A search of the *Pinneena* database and the NSW Office of Water web site was undertaken to identify catchments in the Lower Hunter and Central Coast that were relatively small (<100 km^2) and had sufficient length of relatively complete daily flow records to provide a basis for model calibration and verification. In addition to the availability of streamflow records, catchments were identified that had a significant proportion of steep forested land.

Coincident daily streamflow and rainfall data for each catchment to be modelled was required. Streamflow data is localised and cannot be determined from other sites, therefore only complete years (July to June) of data were used. Model calibration was undertaken using the Leave-One-Out Cross Validation (LOOCV) procedure, a process which enables all available complete years of streamflow data to be utilised for parameter estimation and model validation. **Table 6.3** lists the flow and rainfall station and data periods used in the AWBM modelling.

Table 6.3: AWBM Input Data

Catchment No.	1	2	3	4	5	6
Gauging Station (Number)	Congewai Ck (210026)	Swamp Ck (210053)	Wallis Ck (210054)	Muggyrang Ck (210069)	Jilliby Ck (211004)	Jigadee Ck (211008)
Rainfall Station (Number)	Cooranbong (61012) Congewai (61152)	Cessnock Post Office (61009)	Cessnock Post Office (61009)	Pokolbin (Somerset) (61238)	Wyee (Wyee Farms Road) (61082)	Cooranbong (61012)
Catchment Area (km^2)	83	83	95	5	8	55
Period of Record Used(y)	27	11	8	20	6	16
Modelling Period (July to June)	1948 - 1959 1962 - 1964 1965 - 1979	1960 - 1971	1959 - 1964 1965 - 1966 1969 - 1970 1976 - 1977	1965 - 1969 1970 - 1971 1972 - 1973 1974 - 1982 1985 – 1991	1962 - 1963 1982 - 1987	1974 - 1976 1988 - 1991 1993 - 1994 1995 - 1996 1997 - 2006
Ave Rainfall (mm/y)	1,117	772	844	761	1,348	1,149
Ave Pot Evap (mm/y)	1,407	1,392	1,405	1,355	1,421	1,415
Ave Flow (mm/y)	397	78	215	79	205	315
% Runoff (Recorded Mean Runoff/ Recorded Mean Rainfall)	36%	10%	25%	10%	15%	27%

6.3 Daily Flow Regime Modelling of Comparable Catchments

The AWBM was utilised to generate a set of parameters describing the flow characteristics for six catchments within the lower Hunter Valley and Central Coast. Model performance was assessed using the Nash-Sutcliffe coefficient of efficiency (E) based on monthly totals (as adopted by Boughton, 2006). The modelling involved a three staged process:

- For each catchment, repeated derivations of the AWBM model parameters using the automatic calibration function of the AWBM, leaving out one year at a time.
- Using the spread-sheet version of the AWBM, apply each set of parameters to a test sample (i.e. the year of data that was left out of the calibration) and calculate the Nash-Sutcliffe coefficient of efficiency for the test sample.
- Using the full data set and manual version of the AWBM, select the model parameters using the calculated Nash-Sutcliffe coefficient values and assessment of the flow duration as a guide.

To derive parameters that would best represent the ephemeral runoff from the relatively small catchments of Surveyors Creek, the manual adjustment of parameters focussed on the high flow range immediately following rainfall. Observations recorded at the time of water quality monitoring in Blue Gum Creek since 2006 indicated that the flow is typical of that from small sandstone catchments in which a high proportion of the runoff occurs immediately after rainfall, with declining baseflow persisting for up to a week after significant rainfall. These observations were taken into account in assessing the model parameters that would reflect the runoff characteristics of the small Surveyors Creek sub-catchments.

Details of the procedures used for data selection and model calibration, including graphs comparing the observed and modelled flow duration, cumulative flow, and scatter plots are provided in **Appendix 1**. The results of the calibration process are summarised in **Table 6.4**.

Table 6.4: AWBM Results

Catchment No.	**1**	**2**	**3**	**4**	**5**	**6**
Creek (Number)	Congewai (210026)	Swamp (210053)	Wallis (210054)	Muggyrang (210069)	Jilliby (211004)	Jigadee (211008)
Adopted Average Capacity	61.8	137.0	38.0	159.3	550.0	133.0
Adopted BFI	0.210	0.180	0.250	0.250	0.280	0.160
Adopted K_{base}	0.950	0.992	0.943	0.890	0.965	0.930
Adopted K_{surf}	0.520	0.280	0.450	0.050	0.600	0.350
E (monthly totals)	0.770	0.696	0.775	0.734	0.402	0.803
R^2 (monthly totals)	0.774	0.783	0.775	0.740	0.461	0.810
Recorded Runoff (mm/y)	397	78	215	79	205	315
Modelled Runoff (mm/y)	397	78	215	79	208	318

The model results indicate that, apart from Jilliby Creek, the model provides a good representation of the average annual runoff with reasonable values of coefficient of efficiency and correlation coefficient for monthly data. The model results also indicate that the total runoff as a percentage of rainfall varies significantly between the stations.

The Jilliby Creek record appears anomalous because, for the calibration period, it has the highest rainfall of all stations but a very low proportion of runoff (15%). Published data on rainfall and average runoff from Ourimbah Creek (21%), and Wyong River (27%) (Boughton, 2010), both of which are located relatively close to Jilliby Creek, provides further evidence for the Jilliby record being anomalous.

Most of the available rainfall records were for locations near to, but outside, the catchment to be modelled. Although the rainfall stations used in the analysis could be expected to have good **statistical** correlation against rainfall within the catchment, the actual rainfall on the catchment on a particular day corresponding to the runoff record may have been significantly different. This factor limits the degree of correlation achievable in the AWBM calibration process.

6.4 Estimation of Daily Flow Regime in Surveyors Creek

6.4.1 Catchment Areas

For the purposes of characterising the flow regime of the various creek systems within the Surveyors Creek catchment, seven representative catchments were identified. **Figure 9** shows six catchments in the area of the proposed West Borehole Seam Workings. The seventh catchment (S1B – see location in **Figure 5**) drains in a northerly direction from Mt Sugarloaf and runs immediately adjacent to the new pit-top area for the Project before draining under George Booth Drive. Note that the naming convention adopted for the Surveyors Creek catchment follows that set out in the *Geomorphology Assessment* (as shown in **Figure 5**). Details of the catchments are set out in **Table 6.5**.

Table 6.5: Details of Representative Catchments

Designation	Area (km^2)	Catchment Conditions and Outlet Location
S2B	1.67	Steep forested catchment – outlet at the transition from "Headwater" to "Valley fill, Fine grained, Incised" creek style.
S2C	1.40	Steep forested catchment – outlet near pool that marks the transition from "Headwater" to "Valley fill, Fine grained, Incised" creek style.
S2D	1.08	Steep forested catchment – outlet at the transition from "Headwater" to "Valley fill, Fine grained, Incised" creek style.
S2(3)	5.32	Surveyors Creek "Tributary 2" at the downstream end of an area designated as containing Groundwater-Dependent Ecosystems.
S2(2)	8.48	Surveyors Creek "Tributary 2" just downstream of the boundary of area to be undermined.
S2(1)	13.26	Surveyors Creek "Tributary 2" at the junction of "Tributary S2G".
S1B	1.47	"Tributary S1B" just upstream of George Booth Drive where any impact from the pit-top facilities is likely to occur. No underground mining in the West Borehole Seam.

6.4.2 Climate Data

As described in **Section 6.1**, the rainfall record at Morpeth (with adjustment by factor of 1.07) provides a good statistical characterisation of the rainfall regime that could be expected on the Surveyors Creek catchment. The long term record for Morpeth (July

1885 – June 2010) was therefore adopted as the basis for modelling the expected runoff characteristics of the sub-catchments of Surveyors Creek. Although Morpeth is located approximately 20 km from the site of the Project, it provides one of the longest complete records available in the lower Hunter region and is located at a similar distance from the coast. Morpeth is, however, at a slightly lower elevation (about 10 m AHD) compared to the Surveyors Creek catchment (50-400 m AHD).

6.4.3 AWBM Parameter Selection

For the purposes of assessing the daily flow regime in Surveyors Creek, two AWBM models were set up:

- A model with parameters selected from the calibration analysis (**Section 6.2**) and published data (Refer **Appendix 1**) that were considered to provide a good representation of the surface runoff characteristics of the steep forested catchments in terms of overall percentage runoff and relatively short period of base flow following rainfall.
- A model with parameters selected from the calibration analysis and published data that were considered to provide a good representation of the runoff characteristics of catchments that also include lower gradient sections with incised alluvial channels in which more persistent baseflow would be expected.

AWBM parameters were selected based on the following considerations that are explained in further detail in **Appendix 1**:

- Parameters adopted for the six comparable catchments in the area, as listed **Table 6.4**, the LOOCV procedure and the Nash-Sutcliffe coefficient of efficiency (E);
- Appropriate average annual runoff (based on assessment of the relationship between average annual rainfall and average annual runoff for catchments in the Lower Hunter and Central Coast); and
- Recession characteristics based on the fact that most runoff from the steep headwaters catchments can be expected immediately after significant rainfall as observed in Blue Gum Creek (see **Section 6.3**). The rainfall records indicate an average of 46 days/year (13% of the time) when rainfall exceeds 5 mm/day and 28 days/year (8% of the time) when rainfall exceeds 10 mm/day. These rainfall characteristics and the steep rocky nature of the headwater catchments limit the percentage of time when significant runoff could occur.

Table 6.6 lists the AWBM parameters adopted for the two catchment types.

Table 6.6: Adopted AWBM Parameters for Surveyors Creek

	Ave Cap	BFI	K_{base}	K_{surf}
Steep forested catchments	120	0.230	0.890	0.050
Lowland creeks with forested headwaters	180	0.210	0.950	0.520

6.4.4 Existing Flow Characteristics

The parameters adopted for Surveyors Creek were used in conjunction with the long term historical climate data (125 years: July 1885 – June 2010) to create runoff models for the seven representative catchments. **Table 6.7** provides a statistical summary of the modelled runoff for the representative catchments while **Figure 10** and **Figure 11** show the flow duration graphs for two representative catchments:

- Tributary S2C which is representative of steep forested headwaters creeks; and
- Surveyors Creek tributary 2, Site S2(1) which is located downstream of all mining activity on the main tributary that would be affected by mining.

The data in **Table 6.7**, **Figure 10** and **Figure 11** illustrate the variability of runoff corresponding to:

- Average for the full record (1885 –2010);
- Minimum drought year (1964/1965);
- 10th percentile low flow year (1939/1940 or 2002/2003);
- Median year (1971/1972 or 1991/1992);
- 90th percentile high flow year (1930/1931 or 1961/1962); and
- Maximum wet year (1892/1893).

Note that different water years for median, 10th percentile and 90th percentile runoff represent the differences caused by the two runoff models for the headwater and lowland catchments.

Table 6.7: Statistics of Modelled Runoff for the Representative Catchments

	Catchment Designation (Catchment Type)						
	S2D (Steep Forested)	S2C (Steep Forested)	S1B (Steep Forested)	S2B (Steep Forested)	S2(3) (Lowland)	S2(2) (Lowland)	S2(1) (Lowland)
Area (km^2)	1.08	1.40	1.47	1.67	5.32	8.48	13.26
Ave Rainfall (mm/y)	993	993	993	993	993	993	993
Ave Pot Evaporation (mm/y)	1,412	1,412	1,412	1,412	1,412	1,412	1,412
Ave Runoff (mm/y)	221	221	221	221	172	172	172
Ave Runoff (ML/y)	239	309	325	369	912	1,454	2,274
Runoff as % of Rainfall	22%	22%	22%	22%	17%	17%	17%
Minimum (ML/y)	18	23	24	27	78	124	194
10th Percentile (ML/y)	56	73	77	87	194	309	483
Median (ML/y)	167	217	227	258	558	890	1,392
90th Percentile (ML/y)	481	624	655	744	1,983	3,161	4,942
Maximum (ML/y)	1,395	1,809	1,899	2,158	6,754	10,766	16,834

In **Figure 10** and **Figure 11** it can be seen that the flow duration graph for the complete record is a smoother line than the others, reflecting the fact that there are significantly more data points (i.e. 125 years of daily runoff values) whereas the other graphs represent flow duration over a single year and therefore contain fewer data points; which lead to greater variation around the overall trend.

The results in **Table 6.7** and **Figure 10** and **Figure 11** provide a quantitative illustration of features of the expected existing flow regime that can be deduced from the hydrologic process and climatic drivers that affect the sub-catchments draining from the land above the proposed mining in the West Borehole Seam:

- Runoff as a percentage of average annual rainfall from the steep rocky headwater catchments is likely to be slightly higher than for catchments that contain significant areas of valley fill material;
- Runoff from areas of valley fill is expected to include a larger proportion of baseflow into the creek which would be reflected in more persistent flow;
- The rainfall regime in a particular year can be expected to have a significant effect on the total annual runoff. **Table 6.8** illustrates the differences in runoff between wet and dry years expressed as a percentage of average annual runoff. The table shows that annual runoff can range from 9% of the average to over 500% (a factor of 50) for the driest and wettest years on record. A more typical range that is likely to be encountered during mining would be a 10th percentile (1 in 10 dry) year – runoff of about 20% of average and a 90th percentile (1 in 10 wet) year – runoff of about 200% of average.
- The high degree of variability of runoff between dry and wet years contrasts with the much smaller percentage variation in rainfall which is also illustrated in **Table 6.8**. As shown in the table, the difference in rainfall between a 90th percentile (wet) year and a 10th percentile (dry) year is about a factor of 2, while the difference in runoff of is a factor of 10. This 'elasticity' in the relationship between rainfall and runoff (a factor of about 5 in this instance) is a well-recognised hydrologic phenomenon (Chiew, 2006) that needs to be taken into account in this instance in making comparisons between runoff in different years.

Table 6.8: Variation of Modelled Runoff as a Percentage of Average Annual Runoff

Year	Runoff as Percentage of Average	Rainfall as Percentage of Average
Minimum	9%	46%
10th Percentile	22% - 24%	68%
Median	72% - 82%	98%
90th Percentile	188% - 204%	134%
Maximum	444% - 515%	215%

- The differences in the volume of annual runoff between years are also reflected in the proportion of time that significant flows occur. For the sake of illustration, **Table 6.9** lists the proportion of time that modelled flows exceed a notional 1 ML/day (0.012 m3/s or 12 L/s which would appear as a trickle flow). For ease of comparison, the catchments are listed in order of catchment area (listed in the second row). The table shows that, as is to be expected, the percentage of time that the flow is greater than 1 ML/day increases as the catchment size increases. It also shows significant differences between wet and dry years as can also be seen from **Figure 10** and **Figure 11**. In particular, low flows can be expected less than half as much of the average in dry years and 1.5 to 2 times the average in wet years.

Table 6.9: Percentage of Time Flow Exceeds 1 ML/Day

	Catchment Designation						
	S2D	**S2C**	**S1B**	**S2B**	**S2(3)**	**S2(2)**	**S2(1)**
Area (km^2)	1.08	1.40	1.47	1.67	5.32	8.48	13.26
Minimum Year	1%	2%	2%	2%	6%	11%	15%
10^{th} Percentile Year	2%	2%	3%	3%	9%	11%	16%
Median Year	6%	7%	7%	8%	18%	29%	39%
90^{th} Percentile Year	15%	17%	18%	19%	43%	50%	56%
Maximum Year	27%	33%	34%	37%	84%	91%	96%

6.5 Estimation of Peak Flows

Peak flows at the representative catchment outlets set out in **Table 6.5** have been estimated using the PRM for small ungauged catchments in eastern NSW as set out in Chapter 5 of *Australian Rainfall & Runoff* (Institution of Engineers Australia, 1998).

Rainfall intensity-frequency-duration data for the section of Surveyors Creek catchment located south of George Booth Drive was obtained from the Bureau of Meteorology web site (http://www.bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtml accessed 25/7/2011). The estimated time of concentration for each catchment and the corresponding rainfall intensities for a range of average recurrence intervals are set out in **Table 6.10**.

Table 6.10: Estimated Time of Concentration (Tc) and Rainfall Intensities for Representative Catchments

		Catchment Designation						
		S2D	**S2C**	**S1B**	**S2B**	**S2(3)**	**S2(2)**	**S2(1)**
Area (ha)		108	140	147	167	532	848	1,326
Tc (min)		47	52	55	55	86	103	122
Rainfall Intensity (mm/h)	0.5 Y	20.5	19.3	19.2	18.8	14.5	12.9	11.8
	1 Y	28.1	26.5	26.3	25.7	19.8	17.7	16.2
	2 Y	36.2	34.2	33.8	33.1	25.5	22.9	20.9
	5 Y	46.2	43.8	43.4	42.4	32.9	29.6	27.1
	10 Y	52.0	49.5	48.9	47.9	37.2	33.5	30.7
	20 Y	60.0	57.0	56.0	55.0	43.0	38.7	35.5
	100 Y	78.0	74.0	74.0	72.0	56.0	51.0	46.8

Peak flow estimates derived using the PRM are set out in **Table 6.11.**

Table 6.11: Estimated Peak Flows (m^3/s) for Representative Catchments

		Catchment Designation						
		S2D	S2C	S1B	S2B	S2(3)	S2(2)	S2(1)
Area (ha)		108	140	147	167	532	848	1,326
Peak Runoff (m3/s)	0.5 Y	1.2	1.4	1.5	1.6	4.0	5.8	8.2
	1 Y	2.4	2.9	3.0	3.3	8.2	11.6	16.6
	2 Y	3.6	4.4	4.6	5.1	12.5	18.0	25.6
	5 Y	5.5	6.7	7.0	7.8	19.3	27.6	39.5
	10 Y	7.0	8.7	9.0	10.0	24.7	35.5	50.9
	20 Y	9.1	11.2	11.5	12.9	32.0	45.9	65.9
	100 Y	13.1	15.9	16.6	18.4	45.6	66.2	95.0

6.6 Impact of Mining on Flow

There are four potential causes that might lead to a change in the flow regime as a result of the Project:

- Subsidence effects leading to cracking which could provide a pathway for loss of water from the catchment or creek channels; or provide alternative subsurface flow paths which bypass a section of creek;
- Subsidence effects leading to changes in the depth and surface area of water held in pools which could lead to a change in seepage and evaporation;
- Changes in groundwater levels leading to a change in the interactions between the groundwater system and the creeks;
- Reduction in the contributing catchment area as a result of the proposed stormwater retention for pollution control purposes at the pit-top area.

6.6.1 Potential Subsidence Effects on the Catchment and Creeks

Subsidence can potentially impact upon the flow regime in a number of ways, many of which, such as connective cracking to the mine workings, would be mitigated or eliminated by the proposed mine plan, particularly the establishment of SCZs that are designed to minimise the impacts of subsidence on cliff lines, steep slopes, groundwater dependent ecosystems and the creeks:

- Shallow surface cracking on the land surface is considered possible, but would be minimised by subsidence controls that limit subsidence near cliffs to a maximum of 150 mm, and to a maximum of 300 mm on steep slopes (>32.5%). The subsidence control zone for cliffs and steep slopes covers almost all of the slopes to be undermined above 100 m AHD in the upper catchment of Surveyors Creek Tributary 2. Surface cracking is considered unlikely in these areas where there is minimal soil depth available to naturally fill any cracks. Where surface cracking occurs on shallower slopes, established procedures employed at the Abel Underground mine will be used to monitor for, and repair, any significant cracks. As a result, no significant change in surface runoff is expected.

- Even where surface cracking does occur, it would be relatively shallow and may lead to the creation of alternative sub-surface flow paths, but is unlikely to lead to drainage from the surface flow regime to the deep groundwater system, or have any significant effect on the soil moisture regime.
- The implementation of SCZs would minimise subsidence along the creeks, particularly second and third order streams. The *Subsidence Assessment* concludes that surface cracks are not expected to develop where the proposed SCZs are implemented, and that it is 'very unlikely' that surface cracks would develop above first workings pillars (where subsidence magnitudes of <20 mm are expected) and 'unlikely' above partial pillar extraction panels (where subsidence magnitudes <300 mm may occur). As a result, no measurable loss of baseflow due to subsidence is expected.

There may be some minor changes to the location, depth and volume of pools as described in **Section 5.5**, but these are very unlikely to be significant in the context of catchment hydrology.

Due to the implementation of SCZs beneath the majority of second order and all third order streams, it is expected that there would be:

- minimal surface cracking,
- only a small number of areas where scouring potential would increase, and
- only a small number of pool areas that may have their shape and volume impacted by subsidence changes.

These changes are described in more detail in **Section 5** above, but are not anticipated to lead to significant changes in baseflow.

Management strategies and monitoring of the ground surface along these watercourses would ensure that any low-scale impacts are identified, managed, minimised and rectified in a timely manner.

6.6.2 Changes in Groundwater / Creek Interactions

The *Groundwater Assessment* indicates that under current conditions groundwater levels underlying the Sugarloaf Range ridgeline are at sufficient elevation to provide minor inflow to one of the headwater creeks. Elsewhere, the water table is significantly lower than the creeks and minor losses of baseflow to the groundwater system are predicted to occur.

Figure 12 has been derived from outputs from the groundwater model and shows the predicted change in baseflow as a percentage of the average annual flow for each of the representative catchments for which flow analysis is presented in **Section 6.4**.

It should be noted that the groundwater model developed for the *Groundwater Assessment* included the mining operations for the Project (in the West Borehole Seam and Fassifern Seam), West Wallsend Colliery, Abel Underground Mine, Donaldson Open Cut and Bloomfield Colliery. As such, the predicted changes in baseflow shown in **Figure 12** represent the potential cumulative impacts associated with these projects.

The positive baseflow values in **Figure 12** indicate that water is being gained by the creek and lost from the groundwater system. Note that the graphs for upstream catchments (S2B, S2C and S2D – see **Figure 9** for locations) represent changes in baseflow to individual sub-catchments, while the graphs for S2(1), S2(2) and S2(3) represent the cumulative effects at various locations along the main tributary of Surveyors Creek (S2).

The predicted changes in baseflow as a proportion of average annual runoff (see **Figure 12**) indicate that the main change would occur in the headwater creek above S2B where the existing groundwater inflow (about 0.42% of the average annual runoff) is predicted to reduce over the life of the mine to zero by about 2027. The other two headwater creeks (S2C and S2D) have bed levels above the existing water table and therefore have very minor losses to the groundwater system (0.001% of average annual runoff) which is not predicted to change as a result of mining. On the main tributary of Surveyors Creek where it leaves the area of mining (Site S2(1) on **Figure 9**) groundwater contribution is predicted to change from a net gain of about 0.07% of average annual flow at present (due to inflow above S2B) to zero by the end of mining. Even in a 1 in 10 dry year, by the end of mining the loss of groundwater baseflow from the catchment above S2B (1.6 ML/year) would only constitute about 0.3% of the flow at Site S2(1).

These predicted changes in baseflow attributable to changes in groundwater levels are negligible and would have no measurable effect on the flow regime in Surveyors Creek.

6.6.3 Reduction in Contributing Catchment Area

Stormwater runoff from the 'dirty' sections of the pit-top area (total 5.7 ha) would be captured and re-used or transferred to historic old mine workings. Other sections of the pit-top site would continue to drain off site in a similar manner to the existing situation at the existing Tasman Underground Mine pit-top. The effect of the loss of 5.7 ha of contributing catchment to tributary S1B would be to reduce the average annual runoff by about 12 ML/year (or 4% of the runoff from that sub-catchment). (Note that the increase in predicted runoff from the 'dirty' sections of the pit-top area compared to natural conditions [average 36 ML/year] is due to the replacement of the existing natural bushland with largely impervious surfaces.)

The reduction in runoff as a result of retention of all runoff from 'dirty' areas of the site would be partially offset by the sealing of the car park area (1.16 ha). Runoff from the car park would be directed into an oil/sediment trap and a bio-retention swale before being discharged into the road side drain on the southern side of George Booth Drive – which drains to tributary S1B. The runoff modelling indicates that the average annual runoff from the car-park would be about 8 ML/year.

The water balance modelling indicates that there would be an average net 'retention' of runoff of 4 ML/year in the pit-top area. This represents approximately 1% of the average annual runoff from the catchment of tributary S1B at George Booth Drive (**Table 6.7**), or approximately 0.1% of the average annual runoff from the catchments of Surveyors Creek in the Project area (**Table 6.5**). This reduction in flow in Surveyors Creek is considered negligible particularly in the context of the high variability of runoff from year to year (see **Table 6.7** and **Figure 11**)

Further detail regarding water management at the new pit-top area is provided in **Sections 8** and **Section 9**.

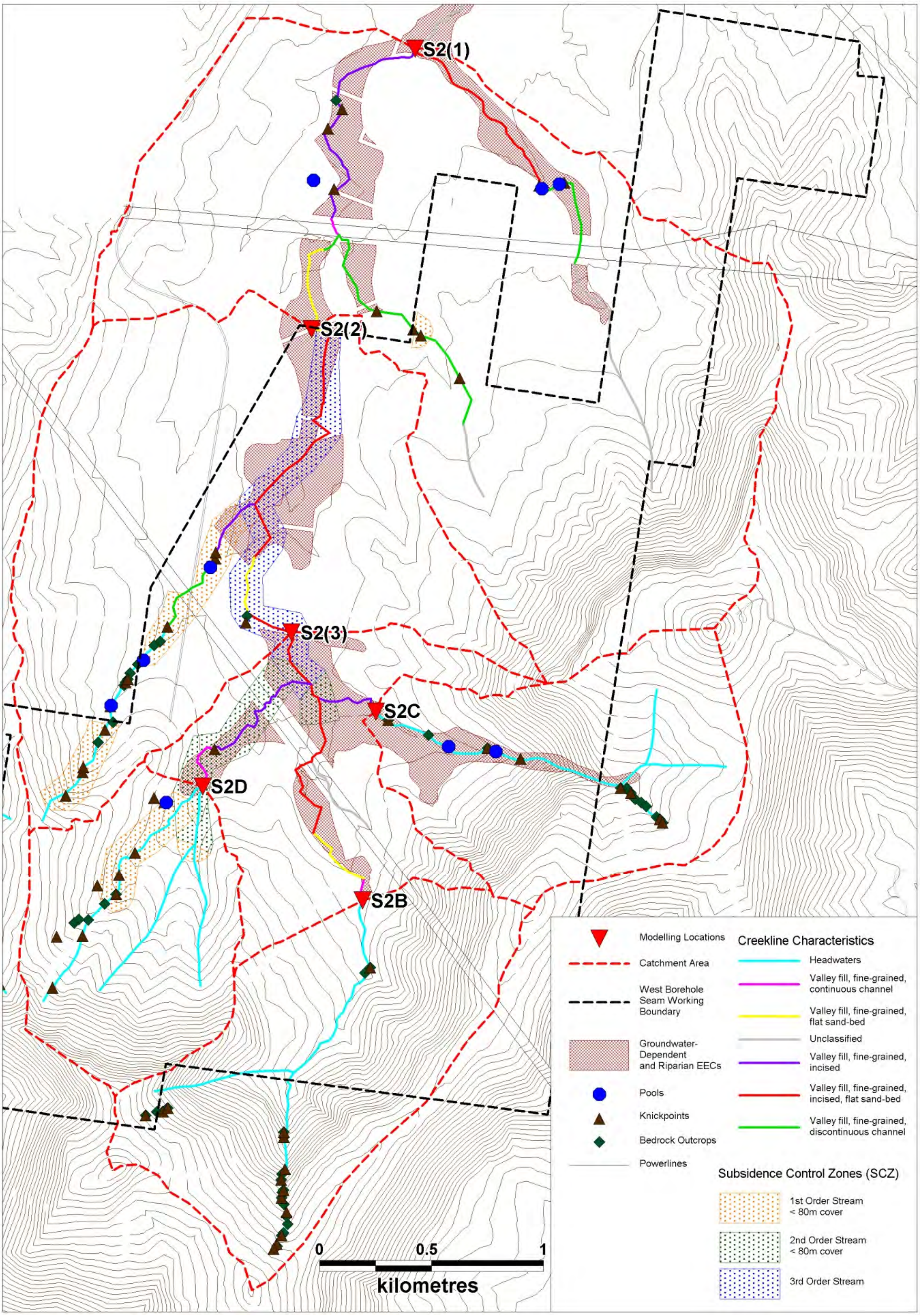
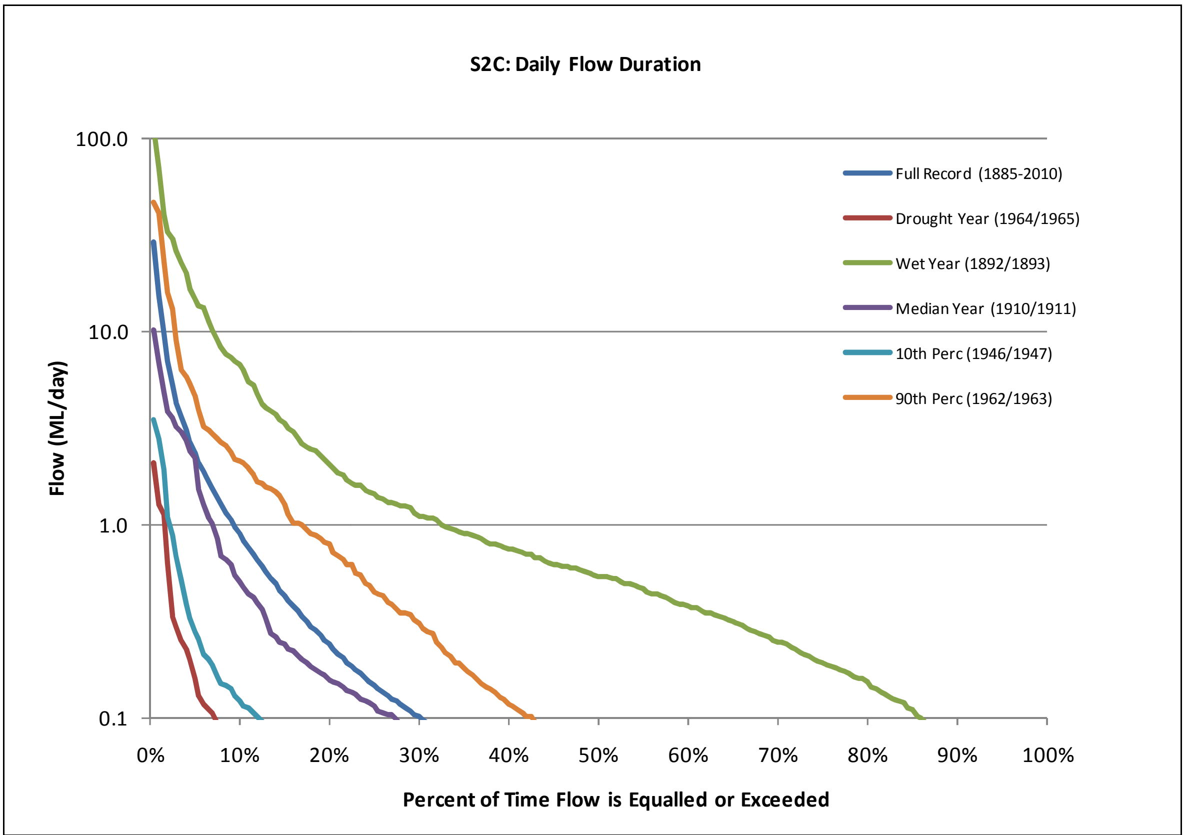


Figure 9:
Representative Catchments



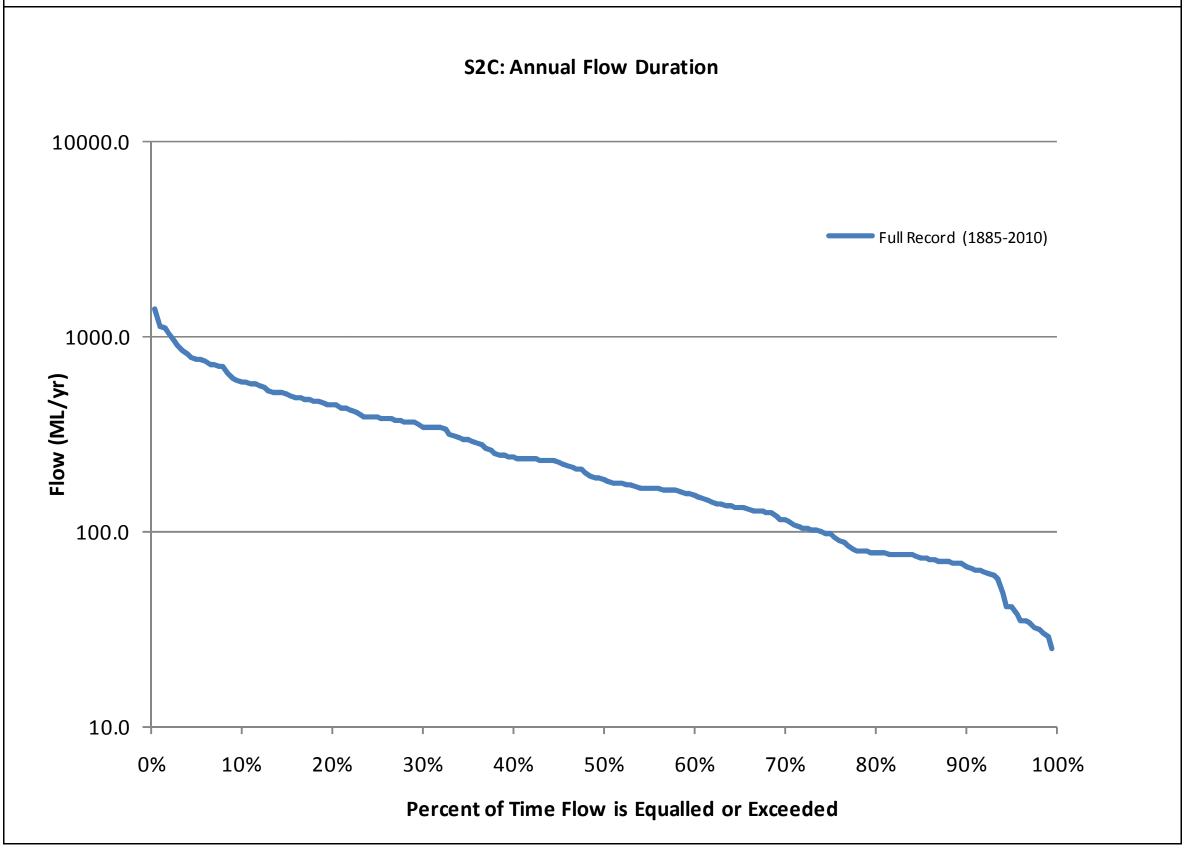
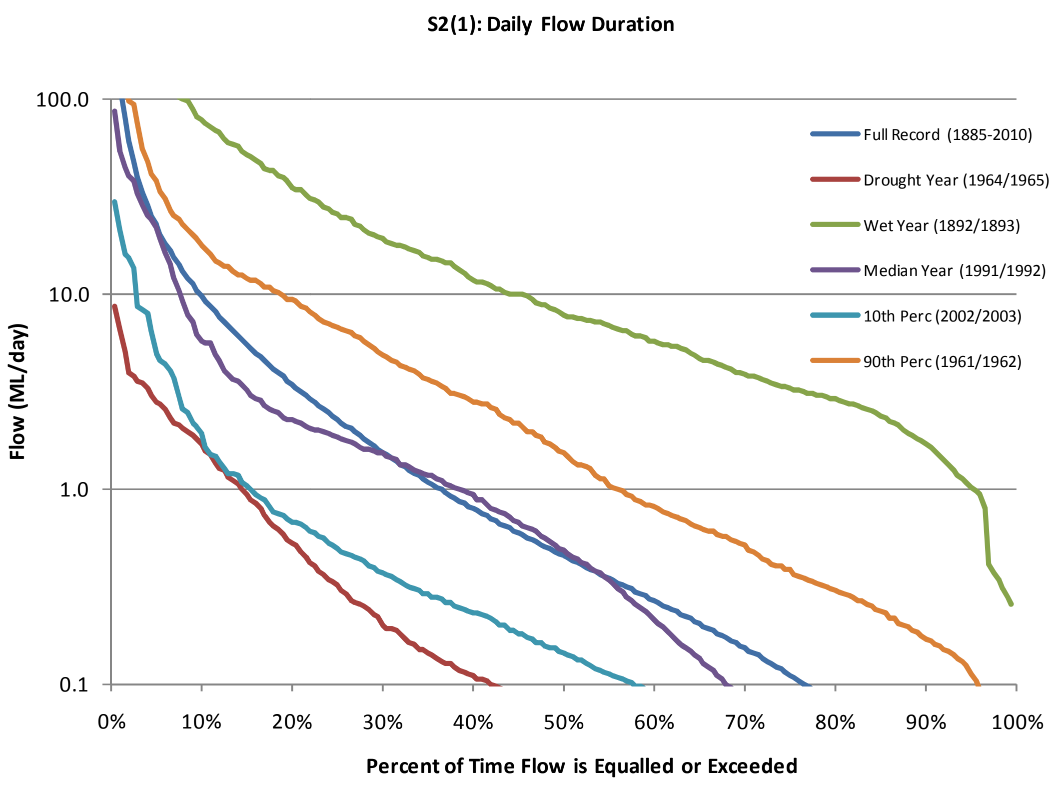


Figure 10:
Flow Duration Curves for Representative Headwater Catchment - S2C



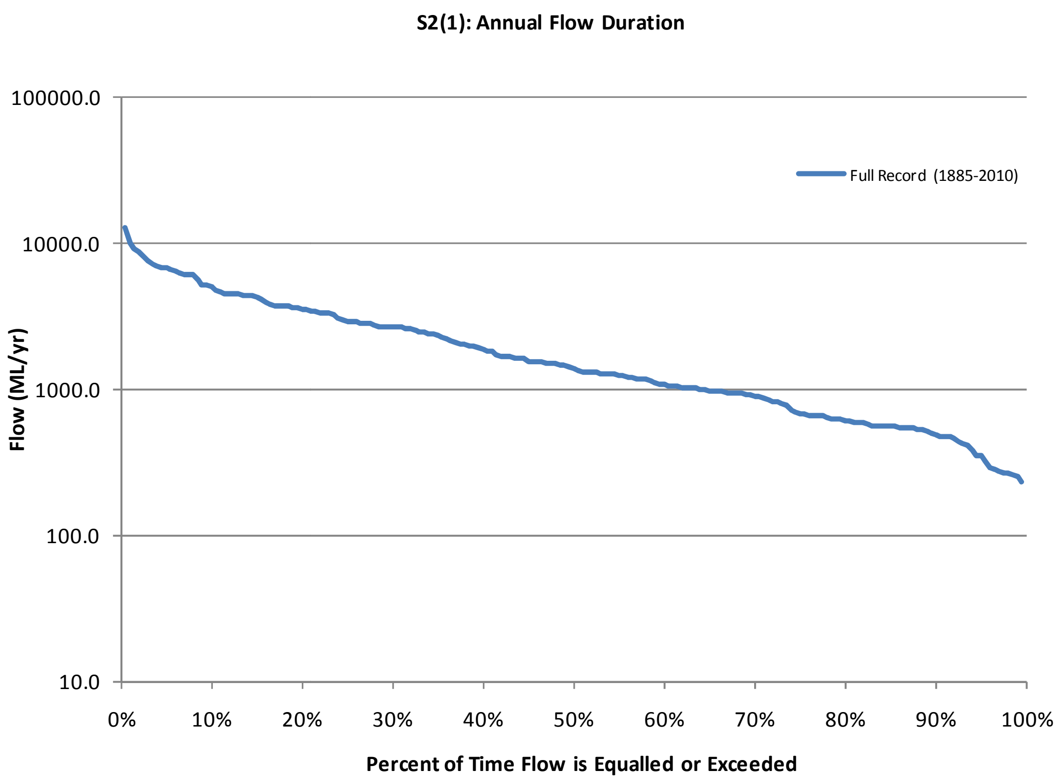


Figure 11:
Flow Duration Curves for Surveyors Creek Tributary 2 – Site S2(1)

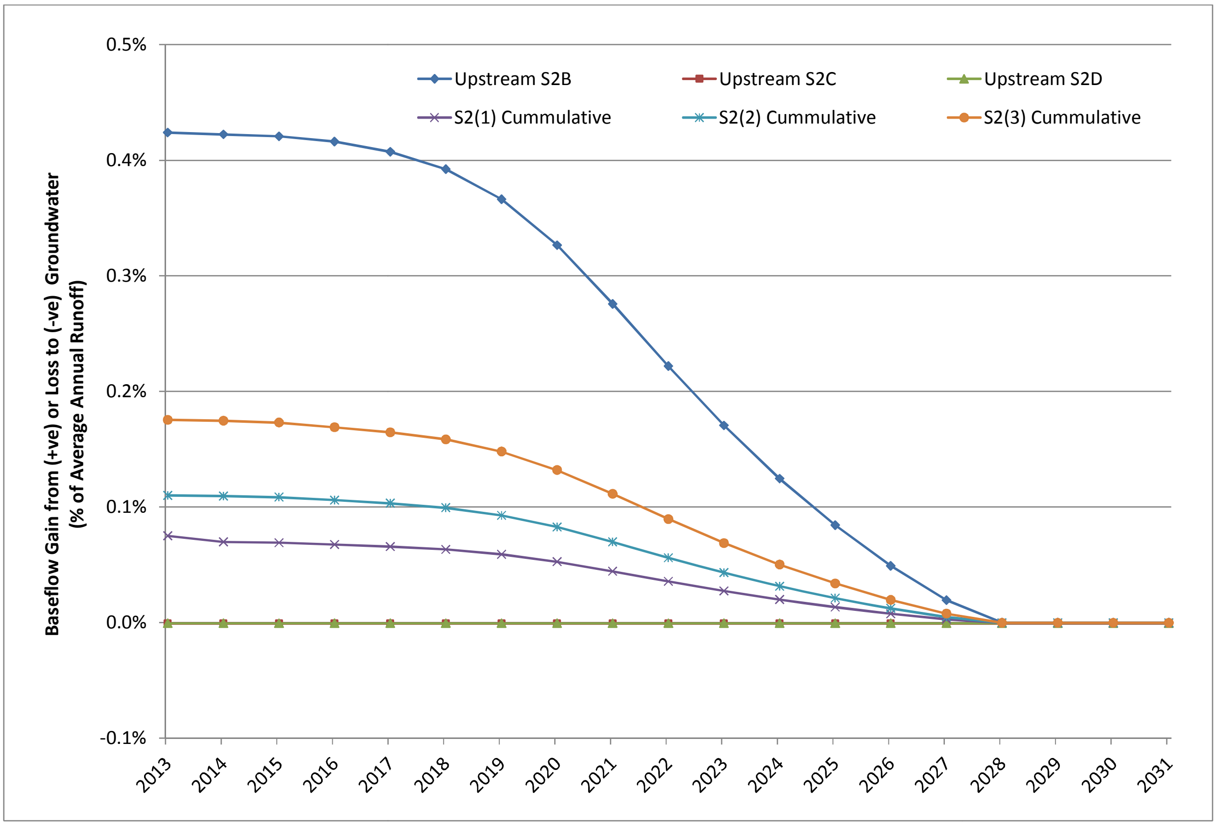


Figure 12:
Predicted Baseflow Losses/Gains in Surveyors Creek

7 WATER QUALITY

7.1 Monitoring Locations and Parameters

Table 7.1 lists the sites in the vicinity of the Project area at which water quality monitoring is regularly undertaken on behalf of Donaldson Coal in relation to the Tasman Underground Mine and the Project. **Figure 13** shows the locations of these sites.

Table 7.1: Water Quality Monitoring Sites

Site No.	Site Location	Strahler Stream Order
2	Surveyors Creek upstream of John Renshaw Drive	4
3	Surveyors Creek Tributary S2E at Sheppards Road	1
4	Surveyors Creek Tributary S2 at George Booth Drive	3
5	Surveyors Creek Tributary S1C at George Booth Drive	1
6	Surveyors Creek Tributary S1B at George Booth Drive	2
7	Blue Gum Creek Headwater Tributary 1.5 km W of George Booth Drive	1
8	Blue Gum Creek upstream of George Booth Drive	3
9	Blue Gum Creek at Stockrington Road	4
10	Blue Gum Creek at Dog Hole Road	4
BG1	Blue Gum Creek downstream of George Booth Drive	3
BG2	Blue Gum Creek Tributary 3 upstream of Tasman Underground Mine	1
BG3	Blue Gum Creek Tributary 3 upstream of Tasman Underground Mine	1

Monthly monitoring comprises temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), turbidity, sulphate and observations/comments regarding flow conditions in the creek. In addition, water samples from the area in the immediate vicinity of Tasman Underground Mine (BG1, BG2 and BG3) are monitored quarterly for a range of common anions and cations.

In addition to the routine water quality monitoring undertaken for Donaldson Coal, data from local creeks has been obtained from two other sources:

- Historic data, some dating from the 1970s, provided by the NSW Office of Water (NOW). This data relates to two sites on Wallis Creek:
  - a site labelled WC-RV on **Figure 13** located just upstream of a minor tributary which contains the 'Colliery Dam' and receives runoff from a small area in the south-west corner of the proposed mining in the West Borehole Seam; and.
  - a site located about 12 km north of the proposed Project area (not shown on **Figure 13**).
- Data collected by contractors to the Roads and Maritime Services (RMS) since July 2010 at various sites on Blue Gum Creek and Surveyors Creek where the Hunter Expressway, currently under construction, crosses these creeks.

Further reference to water quality in Wallis Creek is quoted in the *City Wide Settlement Strategy* prepared by Cessnock City Council (2003). Unfortunately the source document (Shearer, 1997) is unpublished and is not available for further assessment.

7.2 Water Quality Assessment

Water quality data collected on behalf of Donaldson Coal is summarised in **Table 7.3** and **Table 7.4**, while **Table 7.5** and **Table 7.6** summarise the data from the other sources listed above. Further data analyses and detail can be found in **Appendix 2**. It should be noted that the naming conventions adopted for monitoring sites do not relate to a particular creek system or the position along the creek.

To identify any water quality relationships that relate to topography, geology and land use, the data in **Table 7.3** and **Table 7.6** are presented in the sequence set out in **Table 7.2**. The general sequence is from upstream to downstream or with increasing potential for human-induced impacts.

Table 7.2: Hierarchy of Monitoring Sites Listed in Table 7.3 and Table 7.6

Catchment Characteristics	Sites in Table 7.3	Sites in Table 7.6
Sites where the creeks drain off steep slopes from Mount Sugarloaf or the Sugarloaf Range and the catchment is fully forested and subject to minimal human influence	Site 3, Site 7, Site 8, BG2 and BG3	
Sites where the creek drains off steep slopes from Mount Sugarloaf and onto flatter sections of creek in valley fill soils. The catchment of these sites is also fully forested and subject to minimal human influence	Site 5 and Site 6	SC1(U) and SC2(U) (also subject to influence from George Booth Drive)
Downstream sites on Surveyors Creek that are subject to human influence associated with rural residential settlement and land cleared for grazing	Site 2 and Site 4	SC3(U)
Sites on Blue Gum Creek located:		
▪ downstream of the Tasman Underground Mine pit-top facilities and George Booth Drive	BG1	BGC(U)
▪ on Stockrington Road near the Daracon Quarry	Site 9	
▪ at Dog Hole Road where there is rural residential development upstream	Site 10	
Sites on Wallis Creek arranged in order from upstream to downstream.		WC-RV, WC(U) and WC-LP

Table 7.3 and **Table 7.6** include the default 'trigger' values for lowland rivers as set out in the ANZECC Guidelines (2000) for comparison with monitored data. Further discussion in relation to the applicability of the default ANZECC 'trigger' values is provided in **Section 7.4**.

Table 7.3: Statistical Summary for Basic Water Quality Parameters – Donaldson Coal Sites

Site Name		**Site 3**	**Site 7**	**BG3**	**BG2**	**Site 5**	**Site 6**	**Site 8**	**Site 4**	**Site 2**	**BG1**	**Site 9**	**Site 10**	**ANZECC**
Creek Designation[1]		SC	BGC	BGC	BGC	SC	SC	BGC	SC	SC	BGC	BGC	BGC	**Default 'trigger values'**[2] (range)
Catchment Characteristics		Steep forested headwaters	Steep forested headwaters	Steep forested headwaters	Steep forested headwaters	Moderately-sloped headwaters	Moderately-sloped headwaters	Moderately-sloped headwaters	Mixed-steepness	Downstream of headwaters	Moderately-sloped headwaters	Slightly downstream of headwaters	Downstream of headwaters	
Potential for human influence		Minimal human influence							Rural and rural residential		George Booth Drive & Tasman Underground Mine			
EC (field) (µS/cm)	*# Samples*	*50*	*32*	*12*	*14*	*19*	*34*	*45*	*42*	*43*	*52*	*34*	*47*	**125 – 2,200**
	Mean	333	803	698	583	234	365	744	728	590	708	872	1,130	
	20th %ile	216	632	544	161	159	282	606	402	354	510	526	751	
	50th %ile	337	750	705	370	205	369	770	653	530	750	835	1,160	
	80th %ile	415	976	872	1,022	256	411	941	1,018	766	918	1,126	1,410	
pH (field)	*# Samples*	*50*	*32*	*12*	*15*	*19*	*34*	*45*	*42*	*43*	*52*	*34*	*47*	**6.5 – 8.0**
	Mean	6.6	7.2	6.9	7.0	7.0	7.4	7.2	6.8	7.1	7.1	7.4	7.3	
	20th %ile	5.9	6.9	7.0	5.8	6.6	6.9	7.0	6.4	6.7	6.8	7.2	7.1	
	50th %ile	6.3	7.2	7.3	7.0	6.9	7.5	7.3	6.7	6.9	7.1	7.5	7.2	
	80th %ile	7.3	7.6	7.5	8.1	7.4	7.9	7.4	7.2	7.3	7.4	7.7	7.4	
Turbidity (NTU)	*# Samples*	*50*	*32*	*12*	*14*	*20*	*35*	*45*	*42*	*43*	*36*	*34*	*47*	**6 – 50**
	Mean	85	68	114	166	142	139	43	60	124	136	76	62	
	20th %ile	34	13	15	12	46	25	9	16	43	16	14	8	
	50th %ile	69	21	25	32	92	49	19	36	70	34	31	22	
	80th %ile	99	61	35	148	128	105	40	84	203	88	89	54	
TSS (mg/L)	*# Samples*	*51*	*33*	*12*	*15*	*20*	*35*	*46*	*42*	*44*	*36*	*35*	*48*	**N/A**
	Mean	22	14	17	12	31	31	12	21	68	35	20	25	
	20th %ile	5	2	7	4	14	6	3	6	26	2	4	4	
	50th %ile	11	7	12	8	21	16	7	12	38	8	8	8	
	80th %ile	34	24	20	21	34	38	18	23	104	25	31	23	
TDS (mg/L)	*# Samples*	*51*	*33*	*12*	*15*	*20*	*35*	*46*	*43*	*44*	*52*	*35*	*48*	**N/A**
	Mean	288	489	414	339	253	289	447	454	368	427	538	685	
	20th %ile	230	366	335	137	173	228	361	275	263	354	392	533	
	50th %ile	275	460	402	232	234	285	467	448	375	432	514	683	
	80th %ile	324	613	500	594	317	354	544	583	450	518	640	809	

Note 1: Creek Designation> BGC = Blue Gum Creek SC = Surveyors Creek WC = Wallis Creek

Note 2: See **Section 7.4** for an explanation of the significance of ANZECC default 'trigger values'.

Table 7.4: Statistical Summary for Metals – Donaldson Coal Sites

Monitoring Site		Al (mg/L)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Mg (mg/L)	Mn (mg/L)	Zn (mg/L)
BG1	*# Samples*	*14*	*14*	*14*	*14*	*15*	*14*	*3*	*14*	*14*
	Minimum	0.06	0.00005	0.001	0.001	0.54	0.0004	3	0.026	0.006
	Average	0.62	0.00016	0.001	0.003	1.55	0.0013	9	0.104	0.058
	Maximum	1.95	0.00130	0.002	0.008	3.00	0.0030	12	0.280	0.490
BG2	*# Samples*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*
	Minimum	0.25	0.00005	0.001	0.001	0.41	0.0009	3	0.021	0.005
	Average	1.71	0.00010	0.002	0.002	1.16	0.0021	3	0.066	0.105
	Maximum	4.00	0.00017	0.003	0.004	2.70	0.0041	3	0.160	0.470
BG3	*# Samples*	*4*	*4*	*4*	*4*	*4*	*4*	*0*	*4*	*3*
	Minimum	0.07	0.00005	0.001	0.001	1.40	0.0003	-	0.098	0.007
	Average	1.33	0.00009	0.002	0.002	2.85	0.0027	-	0.510	0.010
	Maximum	4.70	0.00021	0.003	0.005	5.80	0.0060	-	1.300	0.017
Site 9	*# Samples*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*4*
	Minimum	-	-	-	-	-	-	-	-	0.095
	Average	-	-	-	-	-	-	-	-	0.644
	Maximum	-	-	-	-	-	-	-	-	1.300
ANZECC 95th %iles		0.055	0.00002	0.001	0.0014	-	0.0034	1.9	-	0.008

Table 7.5: Statistical Summary for Dissolved Oxygen – RMS Sites

Monitoring Site	Dissolved Oxygen (% saturated)		
	Minimum	Average	Maximum
BGC(U)	12	76	130
SC1(U)	56	85	115
SC2(U)	27	58	101
SC3(U)	21	70	96
WC(U)	59	85	118
ANZECC	85 - 110		

Table 7.6: Statistical Summary for Basic Water Quality Parameters – RMS and NOW Sites

Site Name		SC1(U)	SC2(U)	BGC(U)	SC3(U)	WC-RV	WC(U)	WC-LP	ANZECC
Creek Designation		SC	SC	BG	SC	WC	WC	WC	**Default 'trigger values'**[1] (range)
Catchment Characteristics		Moderately-sloped headwaters	Moderately-sloped headwaters	Moderately-sloped headwaters	Downstream of headwaters	Large catchment with steep headwaters and low slope valley	Large catchment with steep headwaters and low slope valley	Large catchment with steep headwaters and low slope valley	
Potential for human influence		George Booth Drive			Rural and urban (Mulbring)				
				Tasman Underground Mine					
EC (field) (µS/cm)	*# Samples*	*9*	*14*	*21*	*13*	*39*	*19*	*48*	**125 – 2,200**
	Mean	385	770	454	1,046	857	991	915	
	20th %ile	142	309	310	278	646	482	695	
	50th %ile	166	660	499	585	899	661	895	
	80th %ile	650	892	561	716	1,068	769	1,156	
pH (field)	*# Samples*	*9*	*14*	*22*	*13*	*8*	*19*	*40*	**6.5 – 8.0**
	Mean	5.6	6.7	7.1	7.0	7.5	7.2	7.5	
	20th %ile	5.1	6.1	6.8	6.7	7.2	6.9	7.3	
	50th %ile	5.6	6.9	7.0	7.1	7.6	7.3	7.6	
	80th %ile	6.1	7.3	7.5	7.4	7.7	7.7	7.7	
Turbidity (NTU)	*# Samples*	*9*	*14*	*22*	*13*	*9*	*19*	*48*	**6 – 50**
	Mean	257	220	310	270	5	28	63	
	20th %ile	147	10	83	57	2	14	39	
	50th %ile	156	163	177	260	2	23	63	
	80th %ile	319	281	589	472	5	41	91	
TSS (mg/L)	*# Samples*	*4*	*5*	*5*	*0*	*0*	*0*	*0*	**N/A**
	Mean	61	8	29	-	-	-	-	
	20th %ile	26	1	21	-	-	-	-	
	50th %ile	38	3	26	-	-	-	-	
	80th %ile	87	10	43	-	-	-	-	

Note 1: See **Section 7.4** for an explanation of the significance of ANZECC default 'trigger values'.

Any consideration of water quality in the headwaters of creeks draining from Mount Sugarloaf and the Sugarloaf Range must take account of the quality of groundwater seepage from the various strata that include the relevant coal seams and the potential for dewatering impact of mining. As reported in the *Groundwater Assessment*, groundwater quality in the vicinity of the existing Tasman Underground Mine was characterised in 2002 by the collection of samples from monitoring piezometers installed in seven exploration drillholes within and around the mine site. Three sampling rounds were conducted between September and December 2001, with the following findings:

- The water quality appears to be more saline in the aquifers above the Fassifern Seam (2,770-5,280 µS/cm), and to a lesser degree in the aquifers below the Fassifern Seam (2,100 µS/cm), than in the Fassifern seam itself (900 – 1,260 µS/cm).
- Most samples are slightly acidic, with pH values ranging from 6.2 to 7.4.
- One bore completed in the Fassifern seam was found to be moderately acidic, with pH around 4.7. Samples at this bore contained very high concentrations of dissolved iron, ranging from 272 to 1,245 mg/L. The bore was located very close to outcrop, where the coal seam was likely to be readily exposed to the atmosphere.
- A number of the other samples also contained high concentrations of dissolved iron, ranging up to 85 mg/L.
- The high dissolved iron suggests the likely presence of pyrite in the coal, and in conjunction with the mostly acidic pH, suggests that the mine waters could have moderate acid generating potential.

Details of the progress of mining for the Tasman Underground Mine are set out in the various Annual Environmental Management Reports (Newcastle Coal Company, 2009, 2010, 2011). Extraction of coal from the Fassifern Seam commenced in mid-2007 in an area located either side of Mount Sugarloaf Road approximately 1 km south-west of the mine portal. This area underlies headwater tributaries of both Slatey Creek (draining to the south) and Blue Gum Creek (draining to the north). Extraction progressed in a westerly direction either side of the Mount Sugarloaf Road ridge until about mid-2009, after which mining progressed in a northerly direction on the Blue Gum Creek side of the ridge that separates Blue Gum Creek from Surveyors Creek (see **Figure 4**).

Key aspects identified from the tabled summary data above are outlined below.

7.2.1 Salinity (EC) and Total Dissolved Solids (TDS)

- Because the coal measures were laid down in a marine environment, the associated groundwater typically exhibits elevated salinity, particularly in the deeper strata which have been less subject to the flushing effect of rainwater recharge at outcrop zones of the more permeable coal seams. In general, headwater creeks that drain from sandstone catchments typically exhibit elevated salinity, particularly at times of low flow when groundwater seepage comprises a higher proportion of the total flow. The difference between the 20^{th} percentile and 80^{th} percentile data in **Table 7.3** and **Table 7.6** is a reflection of this effect.

- Various strata in the vicinity of the Fassifern Seam which outcrop within the catchments that drain from Mount Sugarloaf and the Sugarloaf Range have varying electrical conductivity, with the Fassifern Seam itself generally having the lowest conductivity.
- In the case of the small sub-catchments that drain from the steep slopes of Mount Sugarloaf and the Sugarloaf Range, the monitored salinity (as represented by electrical conductivity and TDS) would be affected by:
  - the location of the monitoring point in relation to the main sources of groundwater seepage;
  - any dewatering of the contributing strata as a result of mining;
  - evaporation from the creeks and pools leading to elevated salinity during dry conditions.

Some of these effects are illustrated in **Figure 14**.

- Despite the fact that they originate from the steep slopes of Mount Sugarloaf and the Sugarloaf Range, headwater tributary sites on Blue Gum Creek (BG2, BG3, Site 7 and Site 8) exhibit significantly higher EC than the tributaries of Surveyors Creek (Site 3 shown on **Figure 14**; Sites 5 and 6 listed in **Table 7.3**).
- The historic trends in EC at sites BG1, BG3, Site 7 and Site 8 (see **Figure 14**) indicate that the higher EC in the creeks that drain into Blue Gum Creek are attributable to the catchment geology, particularly the location and quality of groundwater seepage, rather than any mine de-watering effects.
- Notwithstanding the lower EC in the upper tributaries of Surveyors Creek (Sites 3, 5 and 6), EC values on the main tributaries (Site 4 and Site 2) are generally only slightly lower than in Blue Gum Creek while Site SC2(U) has EC levels that are comparable with those at Site 7 in the headwaters of Blue Gum Creek.
- Both Blue Gum Creek and Surveyors Creek exhibit a general trend of increasing salinity from upstream to downstream with no apparent influence of the Tasman Underground Mine pit-top facilities distinguishable from the general trend on Blue Gum Creek.
- All sites on Wallis Creek exhibit a range of EC comparable to those in Surveyors Creek and Blue Gum Creek.
- All sites exhibit a range of EC that are within the range specified for the ANZECC default trigger values for lowland streams.
- However, Cessnock City Council (2003) quotes a water quality study undertaken by Shearer (1997) which found that Wallis Creek, adjacent to the abandoned Glen Ayr mine, was highly saline and therefore unsuitable for potable supply and for the maintenance of aquatic ecosystems according to the default ANZECC trigger levels current at the time (ANZECC, 1992). This observation supports the conclusion that there are localised sources of salinity within the catchments in the vicinity of the Project.

7.2.2 pH

- The data for some of the upstream tributaries (particularly Site 3 and Site SC1(U)) indicates that runoff from the steep rocky “natural” headwater catchments tends to have low pH, presumably reflecting acid conditions that are typical of sandstone geology.

- Data from monitoring sites downstream of the existing Tasman Underground Mine (i.e. Site 8 and BG1) exhibit moderately higher levels of pH, around 7.0 or slightly higher. However, monitoring sites in the same catchment but upstream of the mine (i.e. Site 7 and BG2/3) exhibit similar levels of pH, indicating that the difference in pH levels are a result of the difference in catchment characteristics and not an effect of upstream mining operations (see **Figure 15**).
- Site 6 has a relatively pristine steep forested catchment and exhibits high levels of pH, with some recordings in excess of pH 8.0. This provides further evidence that differences in pH are an effect of different catchment characteristics, rather than mining operations upstream (see Figure 4 in **Appendix 2**).
- The data indicates that there are differences in pH between catchments. None of the data indicates that there is any influence attributable to either subsidence within the catchment or influence from the Tasman Underground Mine pit-top facilities.

7.2.3 Turbidity and Total Suspended Solids (TSS)

- Given that Sites 3, 5, 6, 7 and BG2/3 are all located on relatively pristine catchments, average turbidity is high.
- Similarly, sites SC1(U), SC2(U) and BGC(U) exhibit high turbidity levels despite the fact that, apart from the natural catchment, the only potential source of turbidity is George Booth Drive.
- Notwithstanding the fact that turbidity is high at many sites, suspended solids concentrations are relatively low. This suggests that turbidity in these headwater catchments is influenced by other factors, not just suspended solids.
- At all sites monitored in Surveyors Creek and Blue Gum Creek except Site 8, turbidity is above the ANZECC default trigger value on average and only complies with the default trigger values 20% of the time.
- Sites WC-RV, WC(U) and WC-LP all exhibit consistent low levels of turbidity. Since each of these sites is situated on Wallis Creek, this indicates that Wallis Creek is generally lower in turbidity than Blue Gum Creek or Surveyors Creek. However, there is a noticeable trend in Wallis Creek with turbidity progressively increasing downstream.

7.2.4 Dissolved Oxygen

- No general trend or pattern is discernible based on the limited available dissolved oxygen data (refer to Section 1.2.2 of **Appendix 2**: Water Quality Data).
- The average values for BGC(U) and SC3(U) are below the default ANZECC trigger range.
- The minimum values for all RMS monitoring sites are below the default ANZECC trigger range.

7.2.5 Metals

Any assessment in relation to concentrations of metals is restricted by the limited quantity of data (see **Table 7.4**):

- All data entries for aluminium, cadmium, chromium and magnesium are equal to or above the default ANZECC trigger values.
- Average values for copper and zinc are above the default ANZECC trigger values. The minimum value for zinc at Site 9 in particular is above the default ANZECC trigger value.
- All values for lead, except maximum values at BG2 and BG3, are above the default ANZECC trigger values.

The previous mining in the area was in the West Borehole Seam, which is about 200 m below the Fassifern Seam (currently mined at the Tasman Underground Mine) and does not outcrop within the catchment areas that have been monitored. Access for previous mining in the West Borehole Seam occurred from areas further east. Accordingly, there does not appear to be any connection between the observed metals concentrations and previous mining activities in the catchment of Blue Gum Creek.

7.3 Cessnock LGA Catchment Study

The *Cessnock LGA Catchment Study*, which was prepared for Cessnock City Council by Shearer (1997), aimed to assess the relative health of Cessnock's local water environment through analysis of a range of factors including water quality monitoring and land use. The main findings of the study, which were derived from the *City Wide Settlement Strategy* (Cessnock City Council, 2003) (source document not published), were:

1. Areas in the north and east of the Cessnock LGA (including the catchments of Anvil Creek, Black Creek, Wallis Creek, Swamp Creek and Four Mile Creek) were found to be in relatively poor health.
2. The results of water quality monitoring indicated that water quality in the upper reaches of the Wallis Creek catchment met the ANZECC (1992) guidelines for the maintenance of aquatic ecosystems, potable water supply and agricultural use. Further downstream, water quality significantly declined, possibly as a result of agricultural land uses (intensive agricultural activities, use of fertilisers and associated soil erosion) and leachate intrusions from abandoned mine sites. Consequently, many water quality parameters exceeded the ANZECC (1992) guideline values.
3. Wallis Creek, adjacent to the abandoned Glen Ayr mine, was highly saline and therefore unsuitable for potable supply and for the maintenance of aquatic ecosystems (ANZECC, 1992). In addition, Department of Planning and Natural Resources Potential Acid Sulphate Soil Maps (1995) indicated that soils along the lower reaches of Wallis Creek have varying potential to develop into acid sulphate soils.
4. Overall, water quality monitoring, visual inspections of the Wallis Creek catchment combined with land use investigations revealed that the catchment is highly degraded when compared to other, less developed catchments in the LGA.

7.4 ANZECC Default Trigger Values

The data in **Table 7.3** and **Table 7.6** indicates that, for a significant proportion of the time, the water quality in relatively pristine catchments within the Project area does not comply with the default water quality trigger values for lowland rivers set out in the ANZECC Guidelines published in 2000 ("the Guidelines").

The Guidelines provide **default** 'trigger' values for different indicators of water quality parameters as either a '*threshold value*' or as a '*range of desirable values*'. Where an indicator is above a threshold value or outside the range of desirable values; "*there may be a risk that the environmental value will not be protected"*. The purpose of these 'trigger' values is to provide a 'trigger' for action or further investigation. They are not prescribed limits.

The Guidelines also state that:

> *"Trigger values are conservative assessment levels, not 'pass/fail' compliance criteria. Local conditions vary naturally between waterways and it may be necessary to tailor trigger values to local conditions or 'local guidelines'."*

The Guidelines also state that two years of monthly sampling is regarded as sufficient to provide an indication of the local ecosystem variability and to provide a basis for derivation of 'trigger' values appropriate to conditions in a particular creek system. For physical and chemical stressors for slightly or moderately disturbed ecosystems, such as that surrounding the Tasman Underground Mine, the Guidelines recommend the use of the 20^{th} and 80^{th} percentile values of the data obtained from an appropriate reference system as the basis for revised 'trigger' values. On the basis of the monitoring data summarised in **Table 7.3** and **Table 7.6**, appropriate trigger values for the creeks influenced by the Project are set out in **Table 7.7**.

Table 7.7: Proposed Water Quality 'Trigger' Values

Parameter	Proposed 'Trigger' Value Range
EC (µS/cm)	125 – 2,200
pH	5.0 – 8.0
Turbidity (NTU)	10 – 500

In line with the way that the ANZECC trigger values are intended to be used, the proposed trigger values in **Table 7.7** do not represent 'limits'. Rather, they represent ranges in which the majority of observations can be expected, but future observations can be expected outside this range on occasions. The 'trigger' for further investigation would be if readings outside these ranges occurred persistently in a particular location. Under those circumstances, further investigation would be required to ascertain whether the cause was related to mining activities and, if so, what mitigation actions would need to be taken.

Although the data in **Table 7.4** indicates that many water samples had concentrations of various metals that exceeded the ANZECC default 'trigger' values, there is insufficient data to justify alternative 'trigger' values for the catchments of Surveyors and Blue Gum Creeks in the short term. This should be reviewed once a larger dataset is available.

Key to Responsibility for Monitoring Sites

- Donaldson Coal
- Hunter Expressway
- NSW Office of Water

Figure 13:
Water Quality Monitoring Locations

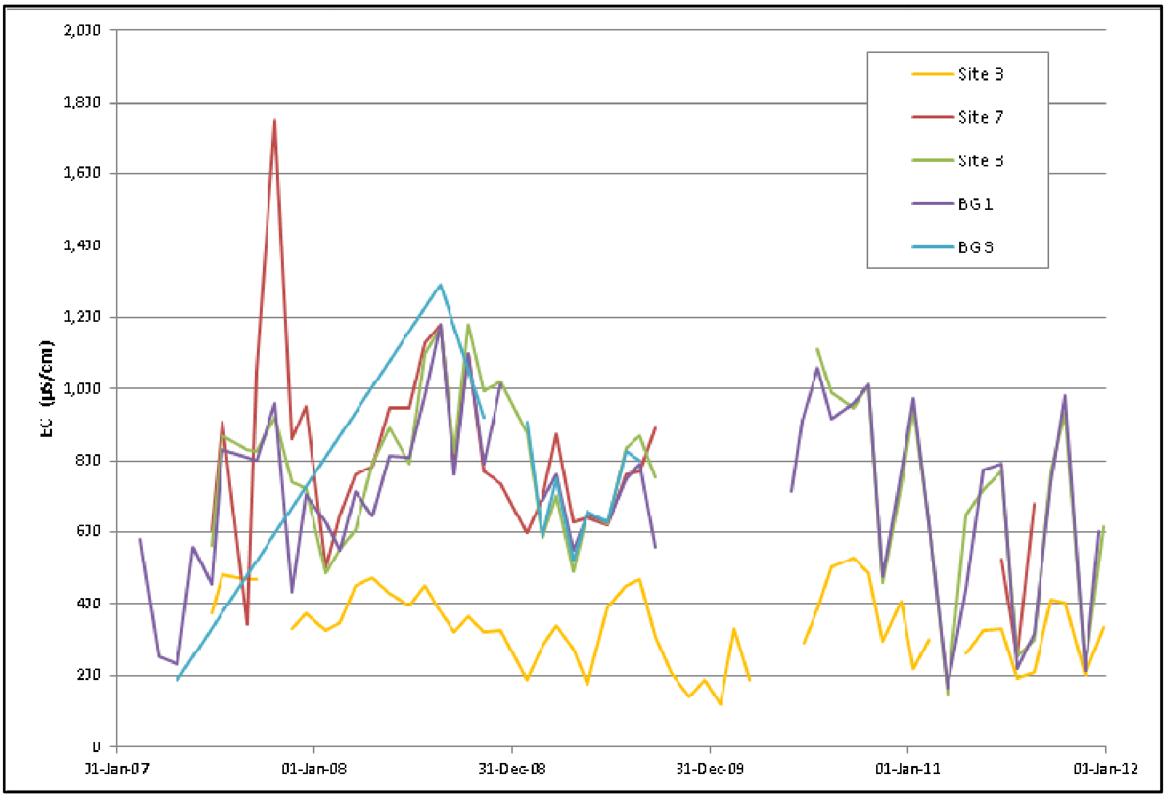


Figure 14:
Historic Variation in Electrical Conductivity at Headwater Sites

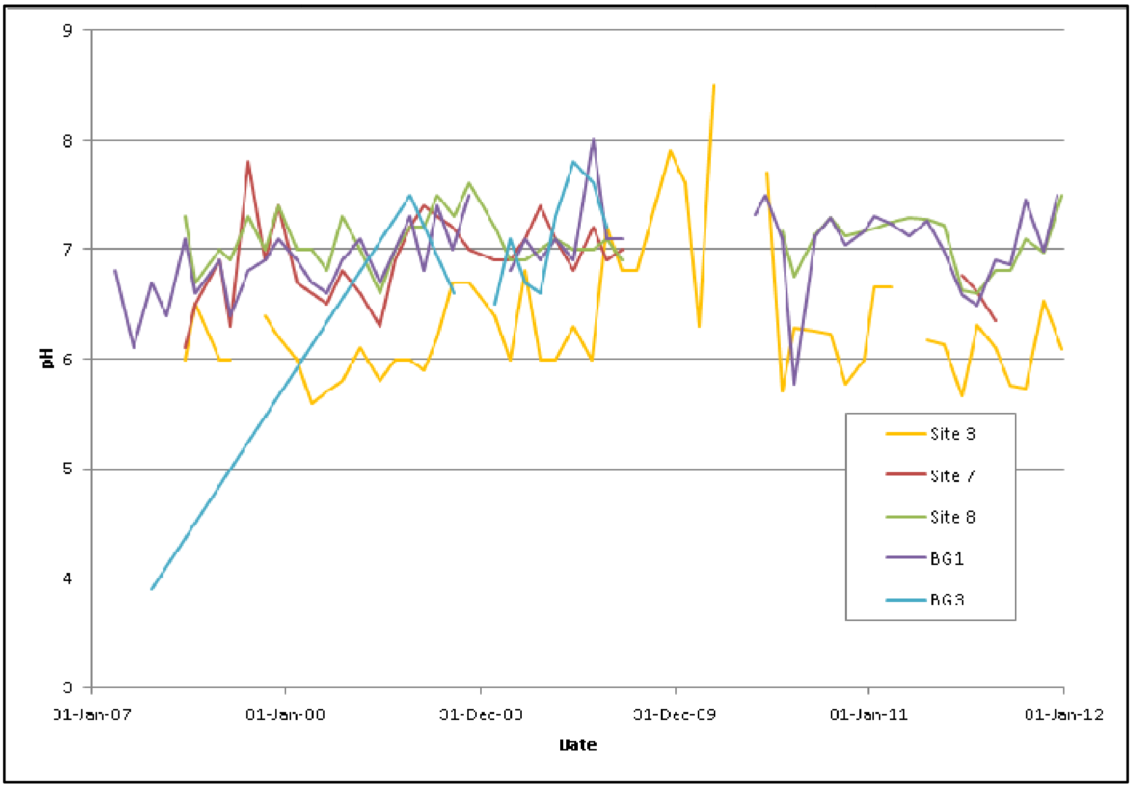


Figure 15:
Historic Variation in pH at Headwater Sites

8 WATER MANAGEMENT SYSTEM

The water management system proposed for the Project is summarised in this section and documented in detail in **Appendix 3**. The analyses provided in **Appendix 3** have been undertaken to demonstrate the ability of the water management system to provide adequate supplies of water for operational purposes and control any discharge so as to minimise the potential for off-site impacts.

It is proposed to adopt three main water management systems that would operate largely independently of each other:

1. A **pit-top stormwater management and recycling system** to collect stormwater runoff from the 'dirty' areas of the site. This water would be re-used for dust suppression and the wheel wash and any excess would be transferred to historic old workings in the West Borehole Seam.
2. A **mine water management system** that takes water pumped out of the workings. A proportion of this water would be treated and returned to the workings for underground dust suppression and processing requirements. Any excess water would be transferred to historic old workings in the West Borehole Seam.
3. The **pit-top stormwater drainage system** that would convey runoff to the existing off-site drainage systems from all areas that would not produce 'dirty' stormwater.

Figure 16 shows the general arrangement of the pit-top area including designated sub-catchments while **Figure 17** shows a schematic of the proposed water management systems. The system is described further below and an analysis of the water balance for each of the first two systems is provided in **Section 9**.

8.1 Water Sources

The two main sources of water for the Project are the surface runoff from the pit-top area and the groundwater inflow to the mine workings.

8.1.1 Pit-Top Surface Runoff

Table 8.1 summarises the characteristics of the pit-top sub-catchments (shown on **Figure 16**) which have been designated to allow appropriate treatment of surface runoff from different areas, in line with its stormwater pollution potential.

8.1.2 Groundwater Inflow

Predictions of groundwater inflow to the mine workings are provided in the *Groundwater Assessment* (Appendix B to the EIS). The predicted annual inflows to the mine are shown in **Figure 18**. Note that the flows depicted in **Figure 18** represent the total volume over a calendar year. The actual volume pumped out of the mine on a particular day can be expected to fluctuate according to localised geological conditions and operational conditions.

Table 8.1: Pit-Top Sub-Catchments

	Catchment	Area (ha)	Surface Treatment	Runoff Destination
A	Office, Mess and Car-parking areas (including water storage tanks)	1.16	Asphalt	Offsite via bio-retention swale
B	Workshop / Fuel storage / Wash-bay	0.87	Hardstand	Surface Runoff Storage Dam
C	Access Road	0.38	Asphalt	Surface Runoff Storage Dam
D	Coal Stockpile and Loading Area (inc Surface Runoff Storage Dam – 4 ML)	2.35	Hardstand	Surface Runoff Storage Dam
E	Box Cut	2.06	Gravel Road	Surface Runoff Storage Dam
F	Inert Materials Storage Area / Effluent Disposal	4.16	Natural	Offsite via grassed swale
G	Bushland - Downstream of Box Cut	3.67	Natural	Offsite
H	Bushland - North Site	4.62	Natural	Offsite
I	Mine Water Storage Dam (5ML)	0.31	Dam	Mine Water Storage Dam (5 ML)

8.2 Water Discharge

8.2.1 Groundwater

Groundwater inflow to the mine would be pumped to a 5 ML turkeys-nest Mine Water Storage Dam ('I' on **Figure 16** and **Figure 17**). Further details on the Mine Water Storage Dam are provided in **Section 8.3.2** below.

8.2.2 Pit-Top Surface Water Runoff

The pit-top sub-catchments have been designed to segregate 'clean' and 'dirty' runoff to provide the most efficient treatment process, as follows:

- **Sub-catchment 'A'**: The car park and immediate surrounds of the offices and amenities would drain via a bio-retention swale into the roadside drainage system on the southern side of George Booth Drive.
- **Sub-catchments 'B', 'C', 'D' and 'E':** Surface runoff from the 'dirty' areas of the site (coal stockpile and loading area, mine portal and the workshop area - sub-catchments 'B', 'C' and 'D') would be directed to a sump in the northern corner of the coal stockpile area from where it would overflow to the Surface Water Dam located immediately east of the coal stockpile area.

  The sump would be designed to capture coarse sediment and allow access for removal of sediment by a front-end loader. The outlet of the sump would be equipped with a baffle to retain any oil within the sump.

  Runoff from sub-catchment 'E' (haul road and box-cut) would be pumped directly to the Surface Runoff Storage Dam from a sump within the box-cut. Emergency overflow from the box-cut sump would be directed to the historic old workings.
- **Sub-catchment 'F':** The laydown area to the south of the workshop area would be used to store the inert hardware, such as pipes, mesh and conveyor belts required for mine operations. This area is not expected to be a source of any pollutants except occasional minor ground disturbance. Runoff from this area would be drained in a southerly direction around the portal via a grassed swale that runs generally along the contour and would discharge into the tributary of Surveyors Creek that drains past the eastern side of the site. A bund would be

constructed on the down-slope side of the swale to prevent surface runoff draining into the box-cut.

- The part of **Sub-catchment 'F'** located within the power-line easement would be used for spray irrigation of treated effluent from the site. As required in the DEC guideline *Use of Effluent by Irrigation* (2004a), this area has a buffer of at least 100 m from the creek.
- **Sub-catchment 'H':** The northern border of the site would remain undisturbed. This area would be allowed to continue to drain naturally to the table drain on the southern side of George Booth Drive.

8.3 Water Storages

8.3.1 Old Workings in the West Borehole Seam

The new pit-top for the Project is located vertically above historic old mine workings in the West Borehole Seam. By reference to plans of the old workings and measurement of the existing groundwater level, Donaldson Coal has established that there is at least 7,000 ML of void space in the old workings.

It is proposed to use the existing void space to store any excess water from the Mine Water Storage Dam and Surface Runoff Storage Dam, effectively making the site a 'zero discharge' site to the surface environment. As the majority of the water to be transferred to the old workings would be groundwater derived from elsewhere in the same coal seam, the water would be recycled back to the same hydrogeologic system. One or more bores would be constructed from the pit-top area to connect to the old underground workings and allow transfer of excess water.

8.3.2 Mine Water Storage Dam and Storage Tank

The Mine Water Storage Dam ('I' on **Figure 16** and **Figure 17**) is to be located adjacent to the offices and amenities area. Water from underground would be pumped direct to this dam which has been sized (5 ML) to provide balancing storage to account for variation in day to day pumping from the mine. Water from the Mine Water Storage Dam would be treated to remove sediment and oil before being disinfected and placed in a 200 kilolitre (kL) storage tank from where it would be pumped back for re-use in the underground workings. Excess water pumped into the Mine Water Storage Dam would drain by gravity to the head-works for the bore and would drain to the old workings.

8.3.3 Surface Runoff Storage Dam

The Surface Runoff Storage Dam located on the eastern side of the coal stockpile area would receive all runoff from sub-catchments 'B', 'C', 'D' and 'E', a total catchment area of 5.53 ha. Water from sub-catchment 'E' (the box-cut) would be pumped to the Surface Runoff Storage Dam while all others would drain via a sump in the northern corner of the coal stockpile area which would be designed to capture coarse sediment and oil. Water retained in the Surface Runoff Storage Dam would be re-used for dust suppression within the pit-top area and for the wheel wash. Any excess would be directed into the bore which would drain to the old historic workings immediately beneath the site.

The dam would be designed to have two zones:

- A lower storage zone (nominal capacity 4 ML) which would be used to provide water for dust suppression and wheel wash purposes. The sizing of this zone has been undertaken using the water balance model (see **Section 9.1.5**) and has taken account of the variability of rainfall-runoff and requirements for dust suppression whilst seeking to maximise the proportion of water supplied from runoff. Further details of this analysis are provided in **Appendix 3**.
- An upper surcharge zone (2 ML) which has been sized to be sufficient to retain excess runoff from a 20 year average recurrence interval storm without discharge to the natural environment.

A spillway culvert (nominal 600 mm diameter with invert at the top of the lower storage zone) would direct water retained in the surcharge zone into a discharge structure connected to the bore which drains to the old historic workings beneath the site. This structure would comprise a concrete header tank (nominal 1.8 m diameter x 2.4 m deep) with a funnel shaped base leading into a bore (provisionally sized as 225 mm diameter).

8.4 Water Requirements and Supply

8.4.1 Underground Operations

In the existing Tasman Underground Mine which uses four continuous miners, treated water is pumped underground for dust suppression and cooling purposes. Records of the volume of water required to support the operation for the period January 2009 to September 2010 indicates an average requirement of 79 kL/day. For the Project a conservative requirement of 90 kL/day has been assumed for assessment purposes.

It is anticipated that water requirements for the Project would progressively increase in line with the construction sequence set out in **Table 8.2**.

Table 8.2: Construction Activities and Estimated Water Requirements

Activity	Timing	Machinery	Water Requirements
Construction of drift	Approx 6 months Starting early 2014	Two road headers	45 (kL/day)
Development works	Ongoing Starting late 2014	Nominally two continuous miners	45 (kL/day)
Development and secondary extraction	Ongoing Starting early 2016	Nominally four continuous miners	90 (kL/day)

The following arrangements are proposed for water supply for the activities identified in **Table 8.2**:

- One of the first elements to be constructed in association with the pit-top facilities would be the Surface Runoff Storage Dam which would initially act as a sediment control dam while earthworks are being undertaken. The total volume (6 ML) is significantly larger than the volume required for sediment control in for the disturbance area (7.1 ha) in accordance with *Managing Urban Stormwater: Soils & Construction* (Landcom 2004) (1 ML for a 5 day 90th percentile storm). To meet sediment control requirements, the 2 ML surcharge zone in the dam would be emptied within 5 days of inflow (in accordance with the requirements) while the remaining 4 ML of storage zone would be retained for water supply for surface and underground construction. The Surface Runoff Storage Dam is expected to be constructed 3-6 months in advance of the construction of the drift. Any water in excess of that required for surface earthworks would be available to meet the water requirements for construction of the drift after treatment to reduce sediment concentration and provide disinfection.

- If there is insufficient water from surface runoff for the construction of the drift, potable water would be imported by tanker truck (up to two loads per day).
- Once development work commences in the coal seam, it is anticipated that groundwater inflow would commence. This water would be pumped to the Mine Water Storage Dam and, after treatment, this water would be used to meet the ongoing requirements for the development works.
- Any supplementary water supply for initial mine development work would be provided by excess surface runoff or potable supply by tanker truck.
- Once full secondary extraction commences in early 2016, it is anticipated that groundwater inflow would exceed the requirements for underground operations.

8.4.2 Dust Suppression and Wheel Wash

Water requirements for dust suppression at the existing Tasman Underground Mine site are estimated to be about 50 kL/day on a hot dry day, with an average of about 40 kL/day when the site is operating. This water is used for dust suppression on the truck access road to the coal loading area, around the workshop area and on the access road to the portal as well as top-up water for the wheel wash. No additional water is required for the coal stockpile because the coal is saturated when discharged.

The footprint of the new pit-top facilities for the Project is significantly smaller than the footprint of the existing Tasman Underground Mine pit-top facilities. Accordingly, the peak water requirement is estimated by Donaldson Coal to be approximately 30 kL/day (about 11 ML/year). This water would be drawn from the Surface Runoff Storage Dam.

Water for the wheel wash facility would also be drawn from the Surface Runoff Storage Dam. Based on experience of a similar facility at the existing Tasman Underground Mine pit-top facilities, 3.5 kL/day (1.3 ML/year) has been allowed for water loss from the wheel wash.

8.4.3 Potable Supply

Potable supply would be provided by tanker truck and stored in an on-site 200 kL tank. During 2011, the average usage of potable water at the Tasman Underground Mine (which has a similar workforce to that proposed for the Project) was approximately 15 kL/day. This water usage included water for toilet flushing.

At the new pit-top for the Project, site water for toilet flushing would be sourced from rainwater. Accordingly, the potable water usage for the new pit-top for the Project is expected to be less than 15 kL/day.

8.5 Effluent Treatment and Disposal

The wastewater treatment and effluent disposal system at the existing Tasman Underground Mine comprises an aerated wastewater treatment system that produces secondary quality effluent, and disposal of treated effluent by spray irrigation onto an area of about 6,000 m^2. This system is licensed by the EP&A under EPL 12483 for the mine.

The new pit-top for the Project would utilise a similar treatment and disposal system. Effluent would be disposed of by spray irrigation onto the open grassed area located under the power-line easement (comprising the south west section of sub-catchment 'F' on **Figure 16**.) The available land area within the easement is approximately 2 ha (20,000 m^2) which provides sufficient area (about 6,000 m^2) for effluent disposal together with the necessary buffer distances, including being more than 100 m from a drainage line (DEC, 2004a).

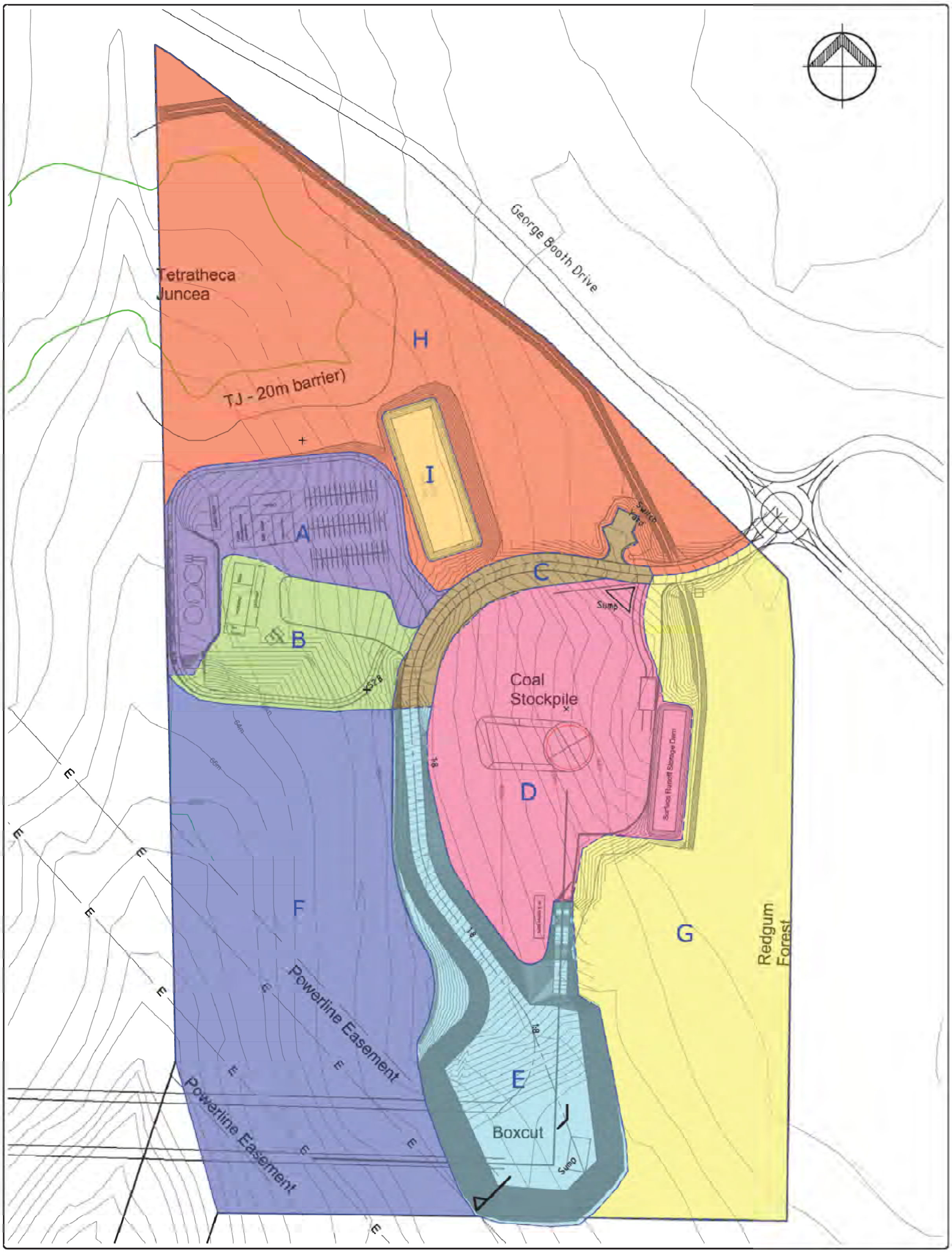


Figure 16: Tasman Extension Pit-top Layout
(Source: Ardill Payne & Partners – Drawing 7247/Fig1/A)

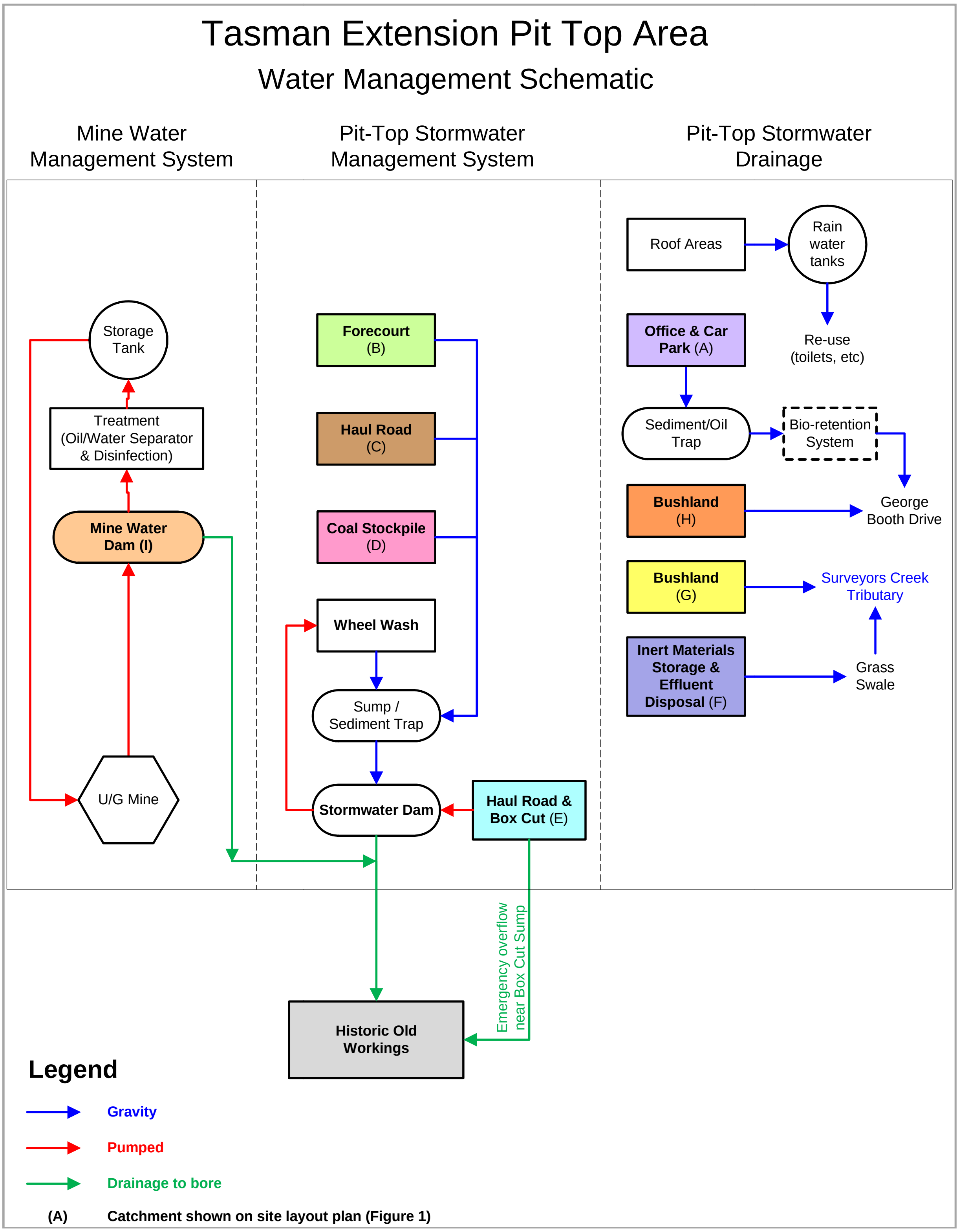


Figure 17:
Tasman Extension Project Water Management System Schematic.

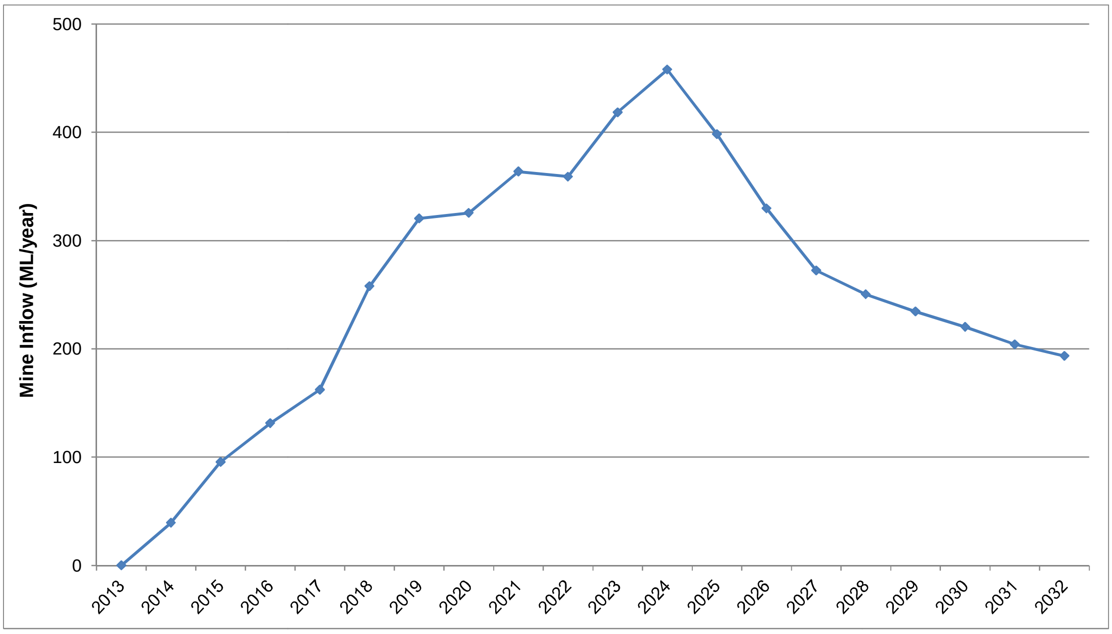


Figure 18:
Predicted Annual Groundwater Inflows

(Source: RPS Aquaterra, 2012)

9 PIT-TOP WATER BALANCE

As described in **Section 8**, the water management system for the new pit-top would include three largely independently sub-systems:

- A **pit-top stormwater management and recycling system** to manage stormwater runoff from the 'dirty' areas of the site;
- A **mine water management system** to take water pumped out of the workings and treated and returned for operational purposes;
- The **pit-top stormwater drainage system** to convey runoff from all areas that would not produce 'dirty' stormwater.

The systems are shown schematically on **Figure 17**. The water balance associated with the first two of these systems is described in **Section 9.1** and **Section 9.2** below.

9.1 Pit-Top Stormwater Recycling System Water Balance

9.1.1 Overview

The water balance associated with the stormwater management system for the 'dirty' runoff areas of the pit-top area (sub-catchments 'B', 'C', 'D' and 'E' on **Figure 16** and **Figure 17**) has been analysed using a daily water balance model with 125 years of climate data. The model accounts for:

- Different runoff characteristics of hardstand areas and the coal stockpile area;
- Storage of runoff in the Surface Runoff Storage Dam;
- Evaporation from water surfaces, the coal stockpile and hardstand area (as determined from the climate data - see below);
- An allowance for seepage loss from the Surface Runoff Storage Dam (0.5 mm/day);
- Extraction of water for dust suppression and for top-up of the wheel wash;
- Transfer of excess water via a culvert connected to a sump from which water is drained to the old historic workings via a bore; and
- Overflow to the creek in the event that the volume of runoff is sufficient to exceed the surcharge capacity of the Surface Runoff Storage Dam. (Although this is anticipated to only occur in storms in excess of 20 years average recurrence interval, this mode of overflow is allowed for in the model.)

9.1.2 Climate Data

The runoff component of the water balance analysis utilised the same rainfall and potential evapotranspiration dataset as that used for the assessment of the runoff characteristics of the catchments overlying the extraction area (as outlined in **Section 6.1** and described in further detail in **Appendix 1**). This comprises a 125 year daily rainfall record based on correlation established between the rainfall records at Tasman Underground Mine, Mulbring and Morpeth. For runoff modelling purposes monthly averages of potential evapotranspiration derived from the digital version of the *Climatic Atlas of Australia: Evapotranspiration* (Version 1.0, Bureau of Meteorology, 2002) have been used.

Because water requirements for dust suppression are largely a function of temperature and wind speed on a particular day, the estimation of these requirements have been assessed using a dataset of daily pan evaporation, which is much more variable than monthly averages of potential evapotranspiration. The daily pan evaporation record from Cessnock has been used for this purpose. For those years of the rainfall record that do not have coincident pan evaporation records, a synthetic record was created by reference to the annual rainfall. For a year without pan evaporation data the record for the year with the rainfall record closest to that of the missing year was utilised.

9.1.3 Pit-Top Runoff Estimation

Runoff was estimated using the AWBM model which is described in further detail in **Appendix 1**. The adopted model parameters for hardstand areas and the coal stockpile are listed in **Table 9.1**.

Table 9.1: Adopted AWBM Parameters for Pit-Top Runoff Estimation

Parameter	Hardstand and Sealed Areas	Coal Stockpile Area
C1	2.0	5.0
C2	0.0	10.0
C3	0.0	0.0
A1	1.0	0.5
A2	0.0	0.5
A3	0.0	0.0
K_{base}	0.96	0.96
K_{surf}	0.1	0.1

9.1.4 Water Uses and Supplementary Supply

Water uses have been based on the following assumptions:

- dust suppression: as a function of evaporation deficit (based on the work of Thompson and Visser, 2002); and
- wheel wash: average of 3.5 kL/day based on observed water use at the existing Tasman Underground Mine.

As noted in **Section 8.4.1** above, the average daily volume of groundwater inflow to the underground workings is expected to exceed the volume required for operational purposes. The water balance model assumes that any shortfall in water in the Surface Runoff Storage Dam would be met from excess water from underground.

9.1.5 Water Balance

The water balance model was run for the full 125 years of climate data from which statistics for the long term annual average water balance have been extracted along with data for years that represent median, 1:10 dry and 1:10 wet years.

Long Term Average Performance

Key long term annual average statistics from the water balance model are set out in **Table 9.2**. Note that these data are **averages** whereas the data for representative years presented below are for representative median, 1:10 dry and 1:10 wet runoff years.

Table 9.2: Average Annual Statistics from the Pit-Top Stormwater Recycling System

Average Annual Statistic	Value
Base Data	
Rainfall	993 mm/year
Open Water Evaporation	1,125 mm/year
Water demand (dust suppression and wheel wash)	13.4 ML/year
Inputs	
Runoff	36.2 ML/year
Rainfall onto surface of Surface Runoff Storage Dam	1.2 ML/year
Total	***37.5 ML/year***[1]
Water Uses and Losses	
Water supply for dust suppression and wheel wash	12.3 ML/year
Evaporation loss from Surface Runoff Storage Dam	1.3 ML/year
Seepage loss from Surface Runoff Storage Dam	0.2 ML/year
Transfer to underground	23.9 ML/year
Total	***37.5 ML/year***[1]
System Performance	
Percentage supply from runoff	92%
Transfer to underground	36.7 days/year

Note 1: Apparent discrepancy in totals due to rounding

The data in **Table 9.2** indicates that, because of the impervious nature of the sub-catchments draining to the Surface Runoff Storage Dam, the site can be expected to generate significantly more runoff than can be used for dust suppression and the wheel wash. The model results also show that the proposed discharge to the bore and the associated surcharge capacity of the Surface Runoff Storage Dam are adequate to minimise the risk of discharge to surface waters. The modelling indicates only one instance of overflow in 125 years of record. Given that during any overflow event there would be high volume flows in the receiving environment, any overflow event would be expected to result in negligible environmental consequence.

The results also indicate that the modelled long term average annual water requirement for dust suppression and the wheel wash was 13.4 ML/year which is slightly more than the estimates set out in **Section 8.4.2** (12.3 ML/year) indicating that the model is slightly conservative in the assessment of water demand.

Median, Dry and Wet Years

Because the rainfall patterns are different in years with comparable rainfall totals, the performance of the stormwater management system is illustrated in each case by three examples: the year corresponding to the runoff statistic (median, 1:10 dry and

1:10 wet) (shown bold in **Table 9.3** below) and the closest year on either side of that year, when ranked in order of annual runoff total. In each case the data for a particular year has been extracted from the full 125 years of model record and therefore realistically accounts for variation in water storage in the Surface Runoff Storage Dam at the beginning of a particular year (rather than assuming a set storage value at the start of a year).

Summary statistics for the analyses are presented in **Table 9.3** while the water level variation in the Surface Runoff Storage Dam for these years is shown in **Figure 19** to **Figure 21**.

Table 9.3: Stormwater Management System Statistics

Calendar Year	Rainfall (mm)	Runoff (ML)	Supply Shortfall (ML)	Storage Empty Days	Transfer to Bore (ML)	Transfer to Bore Days	Overflow to Creek (ML)	Overflow to Creek Days
Median Runoff Years								
1909	1,013	34.8	1.8	24	16.6	18	0.0	0
1895	**1,036**	**35.0**	**0.0**	**0**	**21.5**	**53**	**0.0**	**0**
1999	1,035	35.2	0.0	0	21.8	25	0.0	0
1:10 Dry Years								
1888	615	20.3	3.5	39	9.3	12	0.0	0
1901	**708**	**21.0**	**0.0**	**0**	**4.5**	**6**	**0.0**	**0**
1907	700	21.1	0.0	0	6.9	19	0.0	0
1:10 Wet Years								
1931	1,291	53.1	0.0	0	36.3	68	0.0	0
1927	**1,227**	**53.5**	**0.0**	**0**	**37.9**	**32**	**0.0**	**0**
1891	1,418	54.5	0.0	0	41.7	79	0.0	0

The data in **Table 9.3** and **Figure 19** to **Figure 21** illustrates the significant differences that can occur from year to year, depending on the timing of the rainfall and the volume held in storage at the beginning of the year.

In a **median year**, although the long term average indicates that 92% of the required water could be supplied from runoff, in practice there is a good chance that the system would be capable of supplying all of the required water for dust suppression and the wheel wash. In two out of the three years shown in **Table 9.3** and **Figure 19** the Surface Runoff Storage Dam never empties.

In two out of the three representative examples of a **1:10 dry year**, as shown in **Table 9.3** and **Figure 20,** the full water demand could be met from the Surface Runoff Storage Dam. In one year out of three dry years the dam could be expected to be empty for about a month. In this instance, water would be sourced from the Mine Water Storage Dam.

In all of the representative examples of a **1:10 wet year**, as shown in **Table 9.3** and **Figure 21,** the Surface Runoff Storage Dam would provide all of the water required for dust suppression and the wheel wash, although the dam may get drawn down to about 20% of its capacity at some stage. It should also be noted that in such years there are no occasions on which overflow would occur to the adjoining creek.

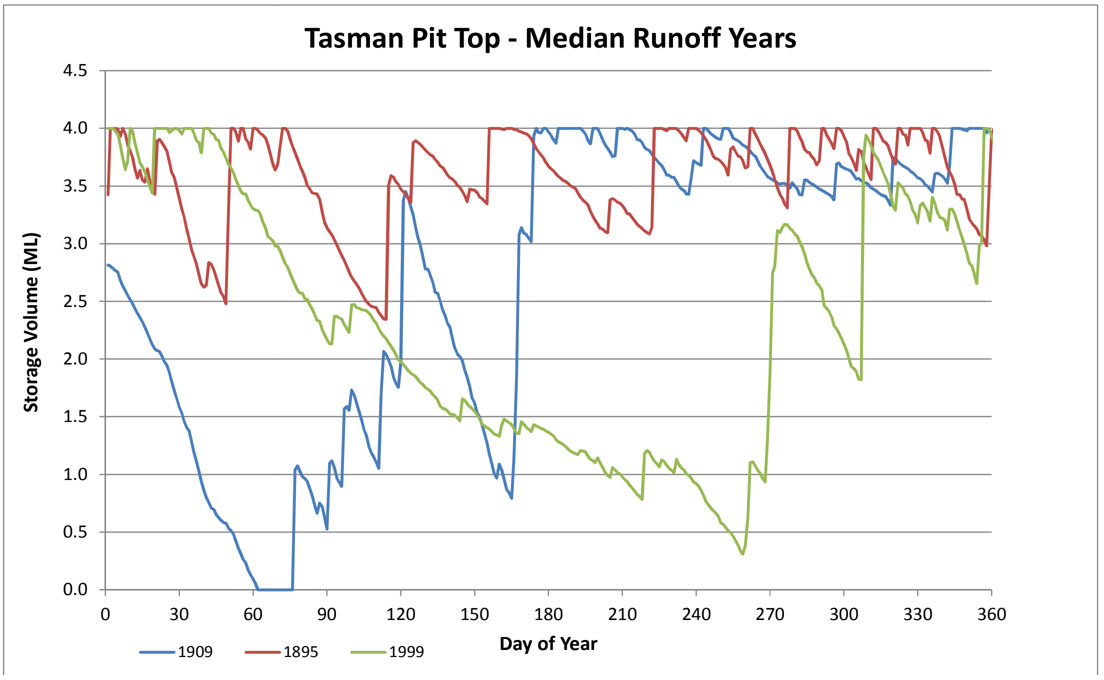


Figure 19:
Variation in Surface Runoff Storage Dam Volume for Representative Median Years

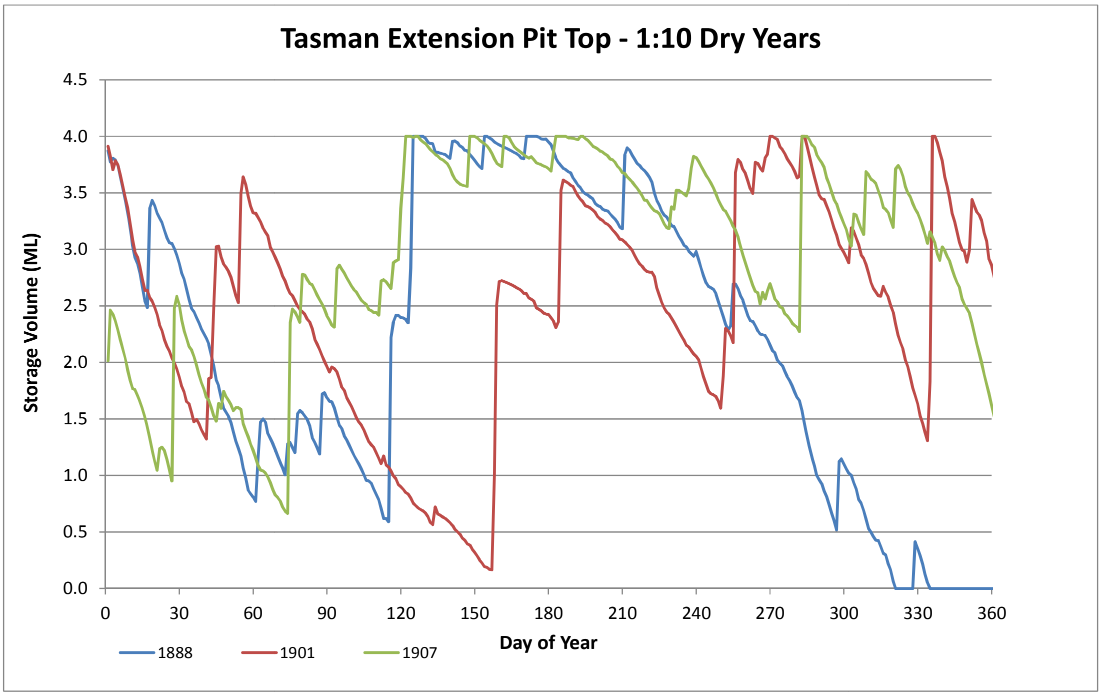


Figure 20:
Variation in Surface Runoff Storage Dam Volume for Representative 1:10 Dry Years

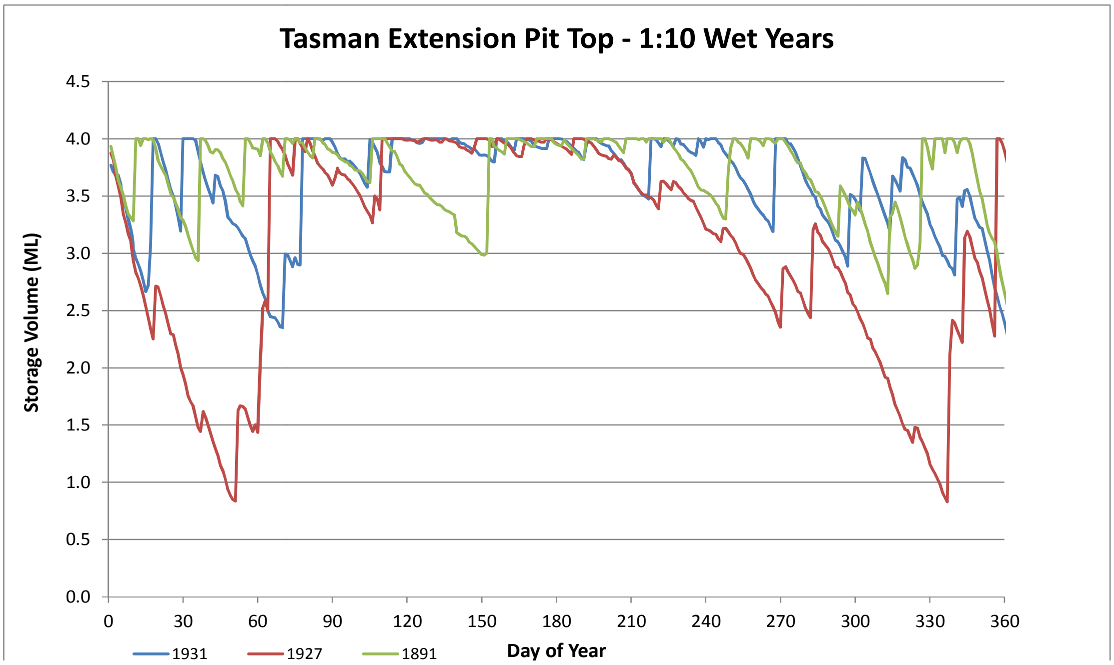


Figure 21:
Variation in Surface Runoff Storage Dam Volume for Representative 1:10 Wet Years

Sizing of the Storage Zone Capacity of the Surface Runoff Storage Dam

The full 125 years of daily climate record was used to assess the trade-off between the capacity of the storage zone in the Surface Runoff Storage Dam and the proportion of water requirements that could be met from stormwater runoff. The results of that analysis are set out in **Appendix 3** and summarised in **Section 8.3.3.**

9.2 Underground Mine Water

Predicted groundwater inflows to the mine workings are shown in **Figure 18**. The predicted inflow rises rapidly once development starts in the coal seams from zero in 2013 to 39 ML/year in 2014. Long term average inflow over the period of mining is predicted to be about 0.7 ML/day. It can be seen that the predicted inflow significantly exceeds the required water for underground operations (90 kL/day [0.09 ML/day] – refer **Table 8.2**).

Table 9.4 summarises the volumes of water that would need to be stored in the old historic workings over the life of the mine assuming that all excess water from the underground workings and from the 'dirty' areas of the surface facilities would be transferred to the old workings.

Table 9.4: Components of Groundwater Balance over the Mine Life

Source	Volume (ML)
Groundwater inflow to workings	5,035
Excess stormwater	415
Total	**5,450**

Note that, while a total of about 460 ML of water would be recycled for operational purposes, this would either be lost through evaporation (reflected in an increase in relative humidity of the exhaust air) or pumped out of the mine with the groundwater inflow.

For purposes of **Table 9.4** it has been conservatively assumed that all water for operational purposes is recycled. The estimated volume in **Table 9.4** therefore represents a conservative (upper limit) to the estimated volume of excess water generated by mine operations that would need to be stored in the old historic workings in order to achieve zero discharge from the mine to the surface environment. It can be seen that the upper limit of the estimated excess water (5,450 ML) is significantly less than the estimated storage volume available in the historic workings (7,000 ML).

10 SURFACE WATER IMPACTS

10.1 Water Demand and Supply

The analysis in **Section 9.1** and **Section 9.2** indicates that there would be surpluses of both groundwater inflow to the workings and surface runoff from the pit-top area. All operational requirements are expected to be met from these sources except for:

- Potable supply for the offices and bath-house (provided by water cart);
- Possible requirement for some supplementary supply by water-cart to meet water requirements for the initial construction phase.

In order to minimise the requirement for potable water supply, rainwater would be collected from all roofs and used for toilet flushing.

As described in **Section 8.4.1**, one of the first elements of the construction of the pit-top facilities would be the construction of the Surface Runoff Storage Dam, which would serve as a sediment dam during the construction phase. As this dam would be constructed 3-6 months in advance of the construction of the drift, it is anticipated that there would be sufficient water retained in the dam to meet the requirements for the commencement of underground operations. Any shortfall (estimated to be a maximum of 45 kL/day) would be provided by water cart from Seahampton.

From a surface water perspective, the main considerations relate to accounting for any impact of the underground mining on flows in the tributaries of Surveyors Creek and any surface water taken for operational purposes. These issues are discussed in the sections below.

10.2 Surface Water Hydrology

Section 5 and **Section 6.6** provide an assessment of the potential impact of the Project on the hydrology of the creeks that drain from the land above the extraction area. The analysis in those sections indicates that:

- Subsidence would not have any significant effect on drainage patterns, catchment yield or flow regimes.
- On the main tributary of Surveyors Creek where it leaves the area of mining (Site S2(1) on **Figure 9**) the *Groundwater Assessment* estimates a net contribution to baseflow from groundwater of about 0.07% of average annual flow at present and predicts this would change to zero by the end of mining. Even in a 1 in 10 dry year the loss would constitute only about 0.3% of the annual flow. This predicted change in baseflow attributable to changes in groundwater levels are negligible and would have no measurable effect on the flow regime in Surveyors Creek.
- The subsidence assessment indicates that changes in bed slope are unlikely to have any significant impact in reducing or increasing the volume of the observed pools. Accordingly, the water retained within the pools and the overall water balance of these pools (in terms of seepage and evaporation losses) are not expected to change significantly.

In view of the above, it is concluded that the Project would not have any impact on environmental flows, basic landholder rights or licensed water users.

10.3 Channel Geometry and Bed Slope

The *Geomorphology Assessment* identifies the migration of existing knickpoints in areas where subsidence increases stream gradient beyond the natural range of variation as the key threatening process to geomorphic character associated with potential subsidence impacts.

Section 5 provides an assessment of the impact of the predicted subsidence on channel bed slope. Detailed assessment of the channel profile data from the *Subsidence Assessment* indicates that there are small areas, particularly on tributaries S2E and S2A/S2DA where there is predicted to be noticeable change in bed slope over short distances. However, none of these changes would lead to bed slopes that are outside the range of bed slopes found in these sections of the creeks.

The *Geomorphic Assessment* indicates that, for most of the watercourses in the Project area, the risk to geomorphic character associated with subsidence is considered to be 'insignificant', with several isolated, short sections of watercourses being assessed as 'low', 'moderate' and 'high' risk. The highest risk sections were located on Valley-fill, Fine-grained, Discontinuous stream type on tributary S2F, as these sections were identified as having high fragility/vulnerability (due to the potential for knickpoint migration), and high relative subsidence (i.e. bed slope outside of the natural range of variation). The *Geomorphology Assessment* indicates that, on the basis of the existing geomorphic condition, resilience and recovery potential, all of the creek sections identified in the detailed analysis of bed slope change are considered to have 'insignificant' risk to geomorphic character.

The field survey undertaken for the *Geomorphic Assessment* identified a total of four pools within the area that is predicted to be affected by subsidence, all of which are located on or adjacent to the steep headwater sections of the creeks. The implementation of SCZs along the creeks is expected to lead to minimal impact on the existing pools. All pools would be monitored and managed as part of the subsidence monitoring and management program, and remedial action to restore pool capacity would be undertaken as necessary.

10.4 Water Quality

In order to minimise the potential for stormwater runoff from the pit-top area to impact on the water quality of Surveyors Creek tributary S1B or downstream receiving waters, a water management system has been developed (see **Section 8**) that is designed to provide zero discharge to surface waters. All runoff from the 'dirty' areas of the pit-top facilities up to and including a 20 year annual recurrence interval (ARI) storm would be retained in the Surface Runoff Storage Dam for re-use within the site. Any excess would be stored in the available void space in historic old workings that underlie the site.

Water quality monitoring associated with the existing Tasman Underground Mine (see **Section 7**) shows no significant evidence of water quality changes that might be associated with subsidence and cracking of surface rocks such as increased iron concentration or lower pH. Notwithstanding, it is possible that cracking of the surface rocks in areas outside the subsidence control zones could lead to the creation of shallow sub-surface flow pathways leading to increased iron concentrations or lower pH. Monitoring of water quality would be undertaken to detect any significant changes that might warrant remedial action such as sealing of cracks on the catchment areas.

Wastewater from the offices and bath-house would be treated in an aerated wastewater treatment system and the treated effluent would be disposed of by irrigation onto land under the power-line easement in the south-west corner of the pit-top area. The proposed treatment and disposal system is similar to the existing licensed system at the Tasman Underground Mine which has a similar workforce to that for the Project.

10.5 Water Sharing Plan

As noted in **Section 10.2** above, the implementation of Subsidence Control Zones is predicted to minimise the potential for surface cracking that might lead to loss of baseflow from the creeks. In addition, the groundwater assessment indicates that there would be a negligible loss of baseflow from Surveyors Creek as a result of changes in groundwater levels.

Stormwater runoff from the 'dirty' sections of the pit-top area (total 5.7 ha) would be captured and re-used or transferred to historic old mine workings. Other sections of the pit-top site would continue to drain off site in a similar manner to the existing situation. The effect of the loss of 5.7 ha of contributing catchment to tributary S1B has been taken into account in runoff assessment (**Section 6.6**) which shows that the reduction would be of the order of 12 ML/year. This reduction in runoff as a result of retention of all runoff from 'dirty' areas of the site would be partially offset by the sealing of the car park area (1.16 ha). The runoff modelling indicates that the average annual runoff from the car-park would be about 8 ML/year, leading to a net 'retention' of runoff of 4 ML/year. (Note that the increase in predicted runoff from the 'dirty' sections of the pit-top area compared to natural conditions [average 36 ML/year] is due to the replacement of the existing natural bushland with largely impervious surfaces.)

The net 'loss' of an average of 4 ML/year of surface runoff (about 1% of average annual runoff from catchment S1B at George Booth Drive) is necessary to prevent stormwater discharge from the new pit-top area and the associated potential impacts to Surveyors Creek. As the primary objective is pollution control, it is considered that the net 'loss' of 4 ML/year does not require a licence under the *Water Management Act 2000*.

Overall, the Project is predicted to result in no measurable change in the flow regime in Surveyors Creek or to have any impacts on existing surface water users or environmental flows.

10.6 Cumulative Impacts

The analysis and assessment of surface water related impacts has taken account of the following potential cumulative impacts:

- The *Groundwater Assessment* takes account of the potential cumulative impacts from the Project (including the proposed underground mining in West Borehole Seam and approved mining in the Fassifern Seam), West Wallsend, Abel, Donaldson Open Cut and Bloomfield. The effects from these operations are included in the predicted changes in baseflow used in this surface water assessment.

- The *Subsidence Assessment* considered the potential cumulative impacts associated with the proposed underground mining in West Borehole Seam and approved mining in the Fassifern Seam, and the subsidence predictions have been used to assess potential impacts to surface water in this assessment.

Based on the conclusions presented in **Sections 10.2** to **Section 10.5**, no material impacts to surface water flow regime or water quality in the creeks overlying the West Borehole Seam mining area are predicted due to the Project, inclusive of the potential cumulative impacts from other projects (as described above).

On the basis that no material impacts to surface water are expected due to the Project alone, no additional surface water impacts associated with the Project would be expected when considered cumulatively with other projects in the region.

The *Proposed Tasman Underground Mine Water Management Studies* (Peter Dundon and Associates, 2002) assessed the potential impacts associated with underground mining in the Fassifern Seam to surface water flow regime and water quality for the catchments overlying the Fassifern Seam mining area. During the operation of the Tasman Underground Mine, surface water monitoring has been conducted in accordance with the requirements of DA 274-9-2002 and EPL 12483, with the results reported in the Annual Environmental Management Reports, as described in Section 4.6.1 of the EIS.

No additional surface water impacts in catchments overlying the Fassifern Seam mining area are predicted due to the proposed underground mining in West Borehole Seam concurrent with the approved mining in the Fassifern Seam.

10.7 Climate Change Analysis

As described in Section 6.7.3 of the EIS, the weight of scientific opinion supports the proposition that the world is warming due to the release of emissions of carbon dioxide and other greenhouse gases from human activities including industrial processes, fossil fuel combustion, and changes in land use, such as deforestation.

The *NSW Climate Impact Profile - The Impacts of Climate Change on the Biophysical Environment of New South Wales* (DECCW, 2010) projects the following changes to the climate of the Project region by 2050:

- Increased maximum and minimum temperatures in all seasons.
- An increase in summer rainfall, with no decrease during winter. These projected changes are within the historical variation in rainfall.
- Increased evaporation due to increased projected temperatures. The projected increases in evaporation are likely to counteract the expected increases in summer rainfall across the state.
- Increased rainfall intensity for flood producing rainfall, particularly for short durations storms.

As such, there are potential cumulative impacts to surface water flow regime and water quality associated with the Project and climate change. However, based on the conclusions presented in **Sections 10.2** to **Section 10.5**, no material impacts to surface water flow regime or water quality are predicted due to the Project. On this basis, no additional surface water impacts associated with the Project would be expected when considered cumulatively with potential impacts as a result of climate change.

Climate change has the potential to impact site water management at the pit-top through changes to rainfall and evaporation. However, as described above, projected rainfall changes by 2050 for the Project region would be within the historical variation. As described in **Section 9.1**, the performance of the site water management system for the new pit-top area has been assessed using 125 years of historical rainfall data, and therefore, no further analysis is considered to be required.

Increased evaporation rates may reduce the amount of water available in the Surface Water Runoff Storage Dam for water supply requirements for surface operations. However, as noted in **Section 9.2** predicted groundwater inflow significantly exceeds the required water for underground operations, and as such, any water deficit for surface operations would be sourced from the Mine Water Storage Dam.

While increased rainfall intensity for short duration storms is predicted for 2050, this increase is expected to be gradual and has not been quantified for the early 2030s. The potential impact on water quality in Surveyors Creek as a result of any minor increased risk of overflow from the Surface Water Storage Dam is not considered significant.

11 MITIGATION AND MANAGEMENT MEASURES

Mitigation of potential surface water impacts has been addressed primarily through the design of the Project. In particular:

- SCZs are proposed so as to minimise the potential for significant changes in elevation or bed slope that might lead to cracking, increased velocity or changes in pool levels in the creeks. As a result of the implementation of the SCZs, no change is anticipated in the flow regime of the catchments that overlie the extraction area.
- All mine water would either be re-used for underground operational purposes or stored in historic old mine workings that lie beneath the pit-top area. There would be no discharge of mine water to surface waters.
- For all storms up to and including the 20 year ARI storm, potentially polluted stormwater from the 'dirty' areas of the pit-top facilities would either be reused for dust suppression and the wheel wash or stored in historic old mine workings that lie beneath the pit-top area.

The implementation of these key elements of the Project is expected to minimise the potential for water quality or flow impacts on the creeks that drain from the Project area.

Notwithstanding these measures, it is recognised that cracking of sandstone within the catchment of Surveyors Creek that lie outside the subsidence control zones could lead to changes in shallow sub-surface flow paths leading to an increase in iron concentration and lowering of pH. Water quality monitoring would be undertaken with the objective of detecting any significant changes in surface water quality that would warrant remedial measures on the catchment such as sealing of cracks in exposed sandstone.

11.1 Subsidence Impacts on Creeks

As a result of the implementation of SCZs beneath creeks, any impacts of subsidence on creeks are expected to be minimal. Mitigation of subsidence impacts on creeks is focused on the impacts relating to surface cracking, ponding and scouring. The mitigation of these impacts primarily involves the surveying, inspecting and monitoring of creek line conditions pre- and post-mining, and the utilisation of the outcomes of these strategies for early mine stages for the management of subsidence in later stages.

For 1st and 2nd order creeks with cover depths >80 m where SCZs are not employed, the management of potential cracking would involve pre- and post-mining inspections, building trigger action response plans and remediation strategies into Extraction Plans, and potentially natural regeneration where the disturbance caused by attempting remediation may be more severe than the subsidence related impact. Surface cracks may be repaired and sealed, dependent on location and ease of access.

Impacts on ponding of water along creeks would be managed by frequently reviewing changes to drainage pathways and surface vegetation along each creek, and undertaking targeted channel earth works if necessary to re-establish surface flows between sections of creek or to repair impacts on pond volumes.

Potential scour impacts would be managed by undertaking subsidence monitoring along creek centre lines and cross sections. Ongoing review and appraisal of the monitoring results would allow targeted repair of any areas of increased erosion in channel works such as localised scour protection.

The monitoring of subsidence above panels mined during the first phases of the mining would provide valuable insights into the actual subsidence as compared to the predicted subsidence. The impact of mining and subsidence along tributaries S1C and S2C (as identified by the monitoring described above), which would be mined in 2014-2015 (Panels 1-2) and 2017-2021 (Panels 12-17), respectively, can be used to guide the management of SCZs and extent of coal removal during later stages of mining beneath tributaries such as S2, S2D and S2E, to ensure impacts are minimised.

11.2 Site Water Management

As described in **Section 8,** the water management system for the pit-top area would segregate runoff of different quality and treat and/or dispose of appropriately:

- Remaining bushland area within the site (8.3 ha) would continue to drain off site without mixing with runoff from the pit-top facilities;
- Roof runoff would be re-used for toilet flushing;
- Runoff from the car-park area would drain via an oil/sediment trap and a bio-retention swale and discharge to the table drain on the southern side of George Booth Drive;
- Runoff from the laydown area (used for storage of inert materials) would be directed around the box-cut by a grassed swale and bund which would direct runoff into tributary S1B. The pollution potential of this area is confined to minor surface disturbance when equipment is picked up or set-down;
- Runoff from the effluent disposal area would drain naturally to tributary S1B via overland flow. The potential for pollution of the creek would be mitigated by the offset from the creek (>100 m) and the provision of a sufficiently large area to ensure low hydraulic loading which would not significantly impact on the runoff potential;
- All stormwater from the 'dirty' sections of the pit-top area, including the oil and spares store would be directed via a sump (for collection of coarse sediment and oil) to the Surface Runoff Storage Dam. Water in the dam would be used for dust suppression and top-up of the wheel wash. Except in the event of a storm greater than 20 years ARI, all excess stormwater would be transferred to historic old mine workings below the site.

11.3 Sediment Control

Three types of mitigation measures are proposed for control of sediment discharge:

- For the construction phase all surface runoff from disturbed areas would be directed to a sediment basin. This basin would be constructed to the ultimate size required to function as the Surface Runoff Storage Dam during mine operations, which is significantly larger (6 ML) than that required to comply with the requirements of *Managing Urban Stormwater: Soils & Construction* (Landcom, 2004) (namely 1 ML). The upper 'surcharge zone' of the Surface Runoff Storage Dam would be operated in accordance with the requirements and emptied within 5 days of the end of a storm. This would provide adequate protection against unnecessary sediment discharge during construction works.
- Minor surface disturbance may occur as equipment and materials is picked up or set-down in the laydown area used for storage of inert materials. Runoff from this area would drain via a grassed swale that would significantly reduce the potential for any sediment discharge to the creek.
- During the operational phase all trucks leaving the site would be required to travel through a wheel wash facility. This would ensure that there is minimal sediment or coal dust transported onto George Booth Drive by trucks.

11.4 Effluent Irrigation

The effluent irrigation area within the power-line easement would be designed and operated in accordance with the requirements of *Use of Effluent by Irrigation*, (DEC, 2004a). The treatment and effluent disposal system would be licensed as part of the overall Environmental Protection Licence for the mine.

12 MONITORING, LICENSING & REPORTING PROCEDURES

12.1 Monitoring

12.1.1 Surface Water Quality Monitoring

Water quality monitoring would continue at the five existing monitoring sites on Surveyors Creek and its tributaries that would potentially be affected by mine operations (see **Figure 13** for locations):

- Site 2 on Surveyors Creek upstream of George Booth Drive (just south of John Renshaw Drive);
- Site 3 on the upper reaches of Surveyors Creek Tributary S2E;
- Site 4 on Surveyors Creek Tributary 2 upstream of George Booth Drive;
- Site 5 on Surveyors Creek Tributary S1C upstream of George Booth Drive; and
- Site 6 on Surveyors Creek Tributary S1B upstream of George Booth Drive (adjacent to the pit-top area).

Subject to access restrictions it is recommended that two additional water quality monitoring sites be established to monitor any water quality changes associated with possible surface cracking on the steeper slopes. Suggested locations are:

- Tributary S2C where it crosses between Panels 12 and 13 (approximately 225 m north-east of the TransGrid 132 kV easement – near site S2C on **Figure 9**). The catchment above this point is scheduled to be undermined between 2017 and 2020 which would provide sufficient time for collection of baseline data before mining commenced.
- Tributary S2 where it crosses between Panels 26 and 27 (approximately 100 m south-west of the TransGrid 132 kV easement – near site S2B on **Figure 9**). This location is also suggested for the installation of a flow gauging station (see **Section 12.1.2** below). The catchment above this point is scheduled to be undermined between 2017 and 2023 which would provide sufficient time for collection of baseline data before mining commenced.

In addition, a water quality monitoring site would be established upstream of the new pit-top area to supplement the existing monitoring downstream (Site 6). The data from these two sites would be used to monitor any water quality changes associated with stormwater runoff from relatively undisturbed areas of the new pit-top area (e.g. sub-catchments A and F as described in **Section 8.2.2**) being directed off-site.

Water quality monitoring would include:

- Monthly field measurement of temperature, pH, EC, turbidity and dissolved oxygen;
- Monthly collection of water samples for analysis of pH, EC, TDS, TSS, Sulphate and dissolved iron; and
- Quarterly collection of water samples for analysis of turbidity, alkalinity, Chloride, Ca, Mg, Na, K, Al, As, Ba, Cd, Cr, Co, Cu, Pb, Mg, Se, Zn, Fe (dissolved and total), F, N and orthophosphorus.

Water quality monitoring would be undertaken in accordance with *Approved Methods for the Sampling and Analysis of Water Pollutant in NSW* (DEC, 2004b).

The monitoring results would be compared to the proposed trigger values in **Table 7.7**. Further investigation of the cause would be undertaken if readings outside the range occurred on more than two successive occasions. Under those circumstances, further investigation would be undertaken to ascertain whether the cause was related to mining activities and, if so, what mitigation actions would need to be taken.

Water quality monitoring results would be assessed every six months and reported annually in the Annual Environmental Review.

12.1.2 Surface Flow Monitoring

It is recommended that a flow gauging station be established on Surveyors Creek tributary S2 where it crosses between Panels 26 and 27 (approximately 100 m south-west of the TransGrid 132 kV easement). This location is also suggested for the installation of a water quality monitoring site (see **Section 12.1.1** above). This location has been identified as one where, subject to gaining access along the power transmission easement, it would allow access for any construction works necessary to create a small flow control structure and to permit access for data retrieval and equipment maintenance. If possible, a gauging site would be selected where the existing creek bed provides a natural hydraulic control. In the event that a natural control is not available, any works to create a hydraulic control would be designed to allow fish passage. A recording pluviometer should also be established within the power transmission easement to supplement the records from the meteorological station at the pit-top area.

Although some extraction of coal is scheduled to commence in the eastern corner of the catchment in 2017, the majority of extraction is not due until 2019/23 which would provide an appropriate period before mining to obtain sufficient data to calibrate the rainfall:runoff model for existing conditions. The flow gauging station would then provide flow data that could be used to verify any impact of mining on flow.

After flow and rainfall data has been collected for three years, and every year thereafter until the catchment is undermined, the data should be analysed to re-calibrate the rainfall:runoff model. Once the catchment has been undermined, the observed runoff would be compared to the modelled runoff for the catchment using model parameters derived for pre-mining conditions.

Any departure of greater than 10% from the predicted annual flow from the catchment using pre-mining model parameters would lead to further investigation to establish the cause and identify appropriate remedial actions.

If a suitable site can be identified and access granted, it would also be desirable to establish a gauging station on Surveyors Creek Tributary S2 downstream of the junction with Tributary S2G. This would allow monitoring of flow from the majority of land to be undermined. Data analysis would be undertaken in a similar manner to that outlined above in order to identify any significant changes in the flow regime as a result of mining.

The results of the flow monitoring and modelling would be presented in the Annual Environmental Management Reviews for the Project.

12.1.3 Subsidence

The *Subsidence Assessment* sets out details of a subsidence monitoring program and management plan that addresses all aspects of subsidence. The following general monitoring program activities are suggested in relation to surface water impacts:

- Survey lines along the centre line and across the banks of Surveyors Creek Tributaries 1 (i.e. S1C) and 2 (i.e. S2C) and a number of key headwater tributaries;
- Visual inspections and mapping of any changes/damage along each watercourse to be conducted before, during, and after mining. During mining, each watercourse should be inspected after the completion of each underlying panel.
- At locations on the creeks identified in the *Subsidence Assessment* as having the potential to be subject to significant changes in grade or changes affecting existing pools, establish permanent reference points for annual photographic recording.

12.1.4 Effluent Treatment and Disposal

A *Wastewater Management Plan* would be prepared for the site. The plan would include the following monitoring of the effluent treatment and disposal system:

- Monthly recording of the volume of effluent applied and comparison against site rainfall records to ensure that the hydraulic loading (including rainfall) is within the design limits.
- Monthly visual inspection of the treatment plant and effluent irrigation system. Maintenance would be carried out as required.
- Quarterly monitoring of effluent quality for BOD_5 (i.e. five day biochemical oxidation demand), suspended solids, total nitrogen, total phosphorus, and faecal coliforms;
- Annual testing of three representative soil samples of both the topsoil and subsoil in the effluent irrigation area for pH, electrical conductivity, exchangeable sodium percentage, sodium absorption ratio, cation exchange capacity and phosphorus sorption.

In the event that hydraulic overloading occurs for more than three consecutive months, a review would be undertaken of the design and operation of the effluent disposal system to identify whether additional effluent irrigation area is required.

Details of the operation of the effluent treatment and disposal system, and the associated monitoring would be presented in the Annual Environmental Management Reviews for the Project.

12.2 Licensing and Approvals

- The site water balance analysis indicates that the capture and re-use of 'dirty' runoff for pollution control purposes would reduce the annual runoff to Surveyors Creek by about 4 ML/year compared to existing conditions. As this 'take' of water is for pollution control purposes, an access licence under the *Water Management Act 2000* is not required.

- If the Project is approved, Donaldson Coal would apply for a revision of EPL 12483 or the granting of a new EPL for the additional components associated with the Project. The EPL would include conditions for management and monitoring of stormwater runoff and effluent disposal.

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Appendix 1: Flow Regime

Donaldson Coal Pty Ltd

Surface Water Assessment for the Tasman Extension Project Area

Appendix 1: Flow Regime

May 2012

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1 INTRODUCTION

The two significant creek systems that drain from the Tasman Extension Project area (the Project area) are Surveyors and Blue Gum Creeks and their tributaries. This appendix details the methodology used to assess the flow regime of Surveyors Creek, which may be subject to potential subsidence impacts associated with mining of the West Borehole Seam and has not previously been subject of an environmental assessment, as in the case of Blue Gum Creek.

There are no stream gauges on the creeks in the Project area which would allow direct analysis of the existing flow regime. Therefore, in order to characterise the flow regime for the Project area, hydrologic modelling has been undertaken based on flow data for creeks within the lower Hunter Valley and Central Coast with comparable geology, land-use and climate to the Project area.

The Australian Water Balance Model (AWBM) was selected to model the Project area flow regime as it is a well-recognised, standard model developed specifically for assessment of runoff from Australian catchments. The modelling process is described in detail in **Section 3** to **Section 5**.

2 AWBM RAINFALL-RUNOFF MODEL

AWBM is a catchment water balance model developed for Australian conditions (Boughton, 1984; Boughton and Carroll; 1993, Boughton, 2010) and is based on the principle of conservation of mass. The model uses rainfall and potential evapotranspiration data together with a representation of the hydrologic processes to generate an estimate of daily runoff from a catchment. Once the surface storage capacity of the catchment has been replenished by rainfall, runoff is generated. This is divided into surface runoff and baseflow.

Figure 1 is a schematic diagram of the model structure which is based on many decades of observed catchment behaviour. The AWBM uses three different capacities of surface storage covering partial areas of the catchment. The water balance of each surface store is calculated independently of the others. The model calculates the moisture balance of each soil store at daily time steps. At each time step, rainfall is added to each surface store and effective evapotranspiration is subtracted from each store. If the value of moisture retained in any of the three stores exceeds its capacity, the excess moisture becomes runoff. The three parameters A1, A2 and A3 represent three partial areas of surface storage capacity, i.e. the proportion of the catchment that is draining to the surface stores of set depth C1, C2 and C3, respectively. The baseflow index (BFI) dictates how much of the excess is diverted to the baseflow store via recharge, and the baseflow runoff parameter K_{base} describes the rate at which water retained in the baseflow store is released and contributes to runoff. The K_{surf} parameter dictates the rate of release of water from the surface runoff routing store.

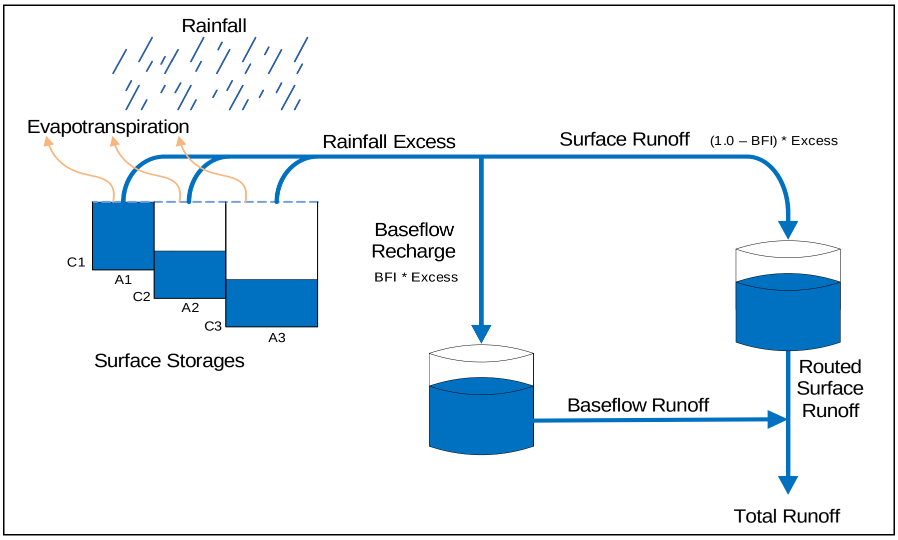


Figure 1:
Schematic of AWBM Structure

Although the model represents A1, A2 and A3 as separate storages, Boughton (2010) reports that by analysis of a number of high quality data sets, it was found that the average value of surface storage capacity was far more important for model calibration than the individual set of capacities and partial areas (where Ave = C1*A1 + C2*A2 + C3*A3). Boughton (2010) developed an average pattern that could be used to disaggregate Ave into three capacities (C1, C2 and C3 equal to 0.075*Ave, 0.762*Ave and 1.524*Ave) and three partial areas (A1 = 0.134, A2 = 0.433, A3 = 0.433).

3 STREAMFLOW AND CLIMATE DATA

This section describes the details of the streamflow, rainfall and potential evapotranspiration data used for the AWBM modelling of the Project area flow regime.

3.1 Streamflow Data

There is no continuous streamflow or peak flow data for Surveyors Creek. It was therefore necessary to model catchments from areas surrounding the Project area to generate a set of representative AWBM parameters to reproduce the flow regime for catchments in the Project area. Relatively small catchments (<100 km^2) with a significant proportion of steep forested land were selected to derive representative model parameters. The streamflow data was sourced from PINEENA (Version 9.3, NSW office of Water, 2010).

Table 1 lists the stations for which data was obtained and the year each station opened and closed. For modelling purposes, only the years (July – June) with complete runoff records were used, as gaps in streamflow data cannot be reliably estimated using other sources. Refer to **Annexure 1D** for a bar chart illustrating the periods of available data.

Table 1: Streamflow Gauging Stations and Periods of Available Record

Station Name	Station No.	Station Opened	Station Closed	No. Years (July to June) with Complete Data Record
Congewai Creek at Eglinford	210026	1948	1979	27
Swamp Creek at Kurri Kurri	210053	1958	1976	11
Wallis Creek at Richmond Vale	210054	1959	1979	8
Muggyrang Creek at Pokolbin Site 4	210069	1963	1993	20
Jilliby Creek at Olney	211004	1961	1989	6
Jigadee Creek at Avondale	211008	1969	2009	16

Figure 2 shows the location of the selected stream gauging stations and corresponding catchment boundaries while **Table 2** provides a description of the characteristics of the catchments including the topography and land-use which influence the catchment yield, peak flow rate and proportions of baseflow and surface runoff.

3.2 Rainfall Data

The model calibration process is most robust in situations in which the rainfall record is derived from a location that is representative of the catchment. Rainfall data for use in AWBM modelling was sourced from Bureau of Meteorology daily rainfall stations located in the same or nearby catchments to the flow stations listed in **Table 1**. Long term historical records for stations near the Project area were also obtained for modelling the flow regime in the Project area. The rainfall stations selected are listed in **Table 3** and their locations shown in **Figure 2**.

Table 2: Characteristics of Catchments Adopted for Analysis

No.	Catchment Latitude & Longitude	Area (km^2)	Topography	Land-Use	Flow Stn. (Number)	Flow Pattern	Gauging Stn. Relative to Project Area	Location of Rainfall Gauge Relative to Catchment
1	33° 00' 15'' 151° 19' 19''	83	Myall Range forms the northern boundary of the catchment. Mostly composed of ridges (~400-500m AHD) with steep slopes (up to 40%) and gullies. The valley (~140m AHD) has 5% slopes.	75% dense forest (incl. Watagan State Forest)	Congewai Creek (210026)	Water flows generally to the NW. Moderately dense to dense drainage patterns.	Approx. 25 km WSW of the Project site	Rainfall station 61152 is located within the catchment boundary approx. 5 km SE of the gauging station.
2	32° 50' 13'' 151° 24' 45''	83	Mostly undulating terrain with 2% slopes. Steep terrain in the southern part of the catchment with 20% slopes.	80% dense forest (incl. Aberdare State Forest) Residential areas – Kurri Kurri, Abermain Colliery, disused quarries	Swamp Creek (210053)	Water flows to the NE. Dense drainage patterns.	Approx. 10 km NW of the Project site	Rainfall station 61009 is located outside the catchment boundary approx. 11 km SW of the gauging station.
3	32° 54' 10'' 151° 27' 19''	95	Ridges along the catchment boundaries in the: East - Sugarloaf Range (~200-300 m AHD), steep 40% slopes; South (~400-450m AHD), steep 50% slopes; and West - Broken Back Ridge (~200m AHD), moderate 7% slopes.	60% dense forest (incl. Heaton State Forest, Aberdare State Forest) Residential areas – Brunkerville, Mulbring Quarries, dams (incl. Colliery Dam)	Wallis Creek (210054)	Water flows to the NE. Dense drainage patterns.	Less than 5 km W of the Project site	Rainfall station 61009 is located just outside the catchment boundary approx. 14 km W of the gauging station.
4	32° 48' 20'' 151° 15' 02''	5	Mount View Ridge forms the southern and western boundaries of the catchment (~400 m AHD). Mostly steep slopes ranging from 25% to 35%. The valley comprises undulating terrain of 3% slopes at approx. 120 m AHD.	85% dense forest 10% vineyards	Muggyrang Creek (210069)	Water flows to the NE. Dense drainage patterns.	Approx. 25 km WNW of the Project site	Rainfall station 61238 is located outside the catchment boundary approx. 30 km E of the gauging station.
5	33° 06' 20'' 151° 21' 08''	8	High ridges (~300m AHD), with steep drop to valleys (~100m AHD). Steep slopes ranging from 20% - 40%.	98% dense forest (incl. Olney State Forest)	Jilliby Creek (211004)	Water flows generally from N to S. Dense drainage patterns.	Approx. 30 km SW of the Project site	Rainfall station 61028 is located outside the catchment boundary approx. 10 km SE of the gauging station.
6	33° 00' 47'' 151° 28' 38''	55	The majority of the catchment is low-lying with gentle 3% slopes except for the ridge along the western edge of the catchment (~400 m AHD) with steep sloping dropping to the east.	40% dense forest (incl. Awaba State Forest in the north) 40% medium forest Rural residential areas	Jigadee Creek (211008)	Tributaries drain to centre of catchment, and enter Jilliby Creek which runs from N to S. Moderately dense drainage pattern.	Approx. 20 km S of the Project site	Rainfall station 61012 is located just outside the catchment area located approx. 2 km south of the gauging station.

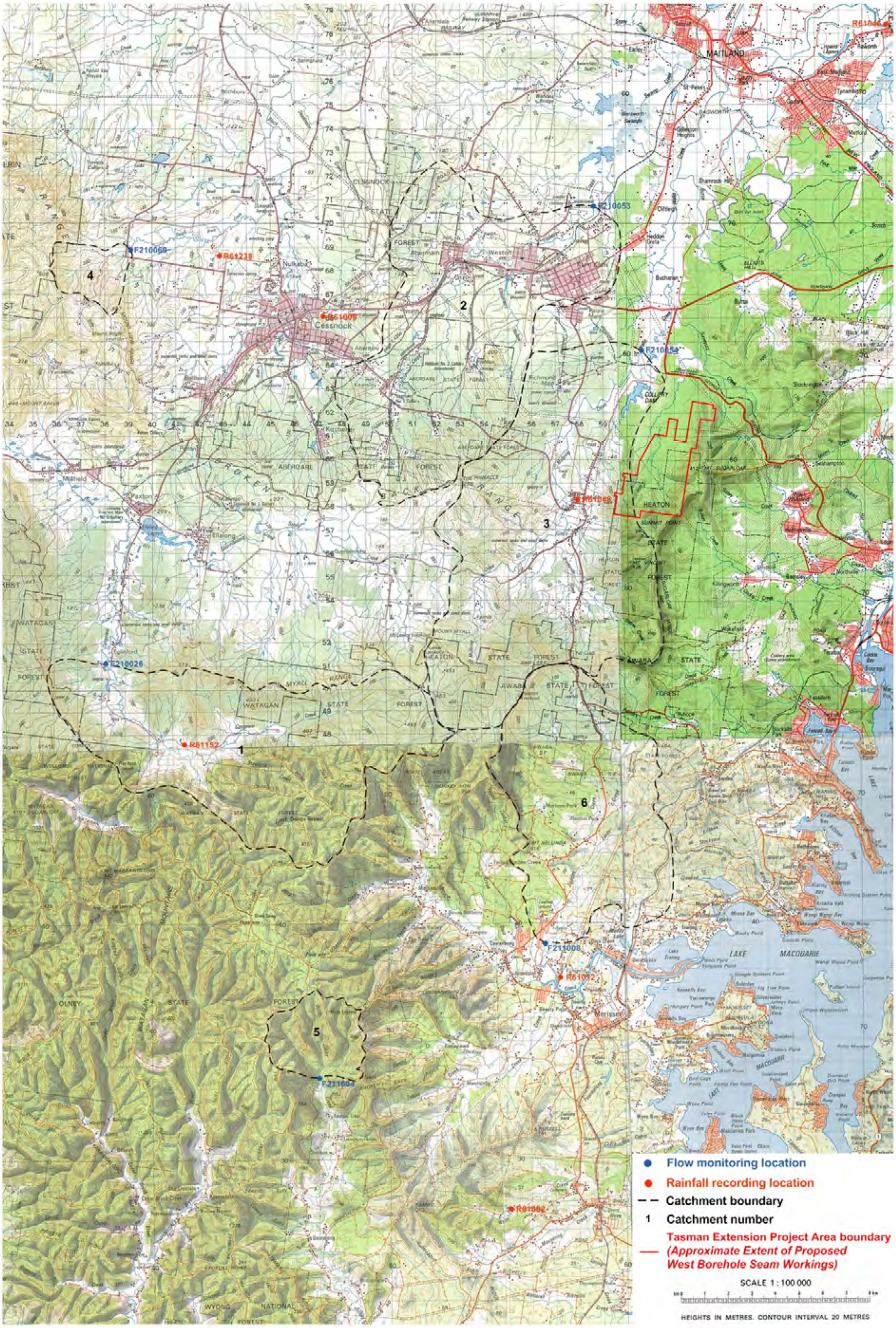


Figure 2:
Map Showing Location of Streamflow and Rainfall Stations

Table 3: Summary of Relevant Bureau of Meteorology Rainfall Stations

Station Name	Station No.	Latitude	Longitude	Station Opened	Station Closed
Rainfall Stations used for Modelling of Catchments 1 to 6					
Congewai (Greenock)	61152	32° 59' 58''	151° 17' 27''	1959	Open
Cooranbong (Avondale)	61012	33° 05' 07''	151° 27' 48''	1903	2011
Cessnock Post Office	61009	32° 49' 38''	151° 21' 58''	1903	1992
Pokolbin (Somerset)	61238	32° 48' 51''	151° 18' 09''	1962	Open
Wyee (Wyee Farms Road)	61082	33° 10' 45''	151° 26' 29''	1899	Open
Rainfall Stations used for Correlation and Project Area Modelling					
Morpeth Post Office	61046	32° 43' 31''	151° 37' 43''	1884	2010
Mulbring (Vincent Street)	61048	32° 54' 10''	151° 28' 55''	1932	2007

Where there were gaps in the record supplied by the Bureau of Meteorology due to missing data or aggregated measurements over a number of days, the data was in-filled consistent with the rainfall pattern at a neighbouring station. Missing rainfall data was in-filled with data from a neighbouring station adjusted to account for the ratio of cumulative rainfall of the stations over the period of common records. **Table 4** lists the rainfall stations used and corresponding stations used to in-fill missing or aggregated data. The table below shows the percentage of aggregated and missing data was minimal.

Table 4: Rainfall Stations Used to In-fill Aggregated or Missing Data

Rainfall Station	In-fill Rainfall Station	Aggregated Data (%)	Missing Data (%)
Cooranbong (Avondale) (61012)	Wyee (Wyee Farms Road) (61082)	1.9	0.0
Congewai (Greenock) (61152)	Cooranbong (Avondale) (61012)	0.2	0.2
Cessnock Post Office (61009)	Pokolbin (Somerset) (61238)	0.6	0.0
Cessnock Post Office (61009)	Pokolbin (Somerset) (61238)	2.5	0.2
Pokolbin (Somerset) (61238)	Cessnock Post Office (61009)	1.2	0.4
Wyee (Wyee Farms Road) (61082)	Cooranbong (Avondale) (61012)	1.1	0.0
Cooranbong (Avondale) (61012)	Wyee (Wyee Farms Road) (61082)	7.3	0.0

3.3 Rainfall Correlation and Relationship Analysis

Long term rainfall data was required to characterise the statistical distribution of flows and assess the flow regime within the Project area. The rainfall records at the existing Tasman Mine start in February 2006 and include a significant drought period. Accordingly it was necessary to analyse the correlation between other long term rainfall records in the area and that recorded at the Tasman Mine. The analysis was undertaken to assess similarities between the rainfall statistics at the Tasman Mine site and other long term rainfall stations.

The rainfall record from Mulbring (about 2 km west of the western boundary of Surveyors Creek) ceased in August 2007 and did not provide sufficient record for correlation against the records from Tasman Mine. Rainfall relationships between at the following stations were assessed:

- Tasman Mine and Morpeth Post Office for the period 6/11/2006 – 28/2/2011;
- Mulbring and Morpeth Post Office for the period 1/1/1933 – 31/8/2007.

Correlations between rainfall depth on days of equal probability of occurrence were also derived. The results of the analyses are set out in **Annexure 1A** (**Figure 15** and **Figure 16**). The correlations between rainfall depth on days of equal probability of occurrence shows some departure from a linear relationship, but still maintain high correlation coefficients.

In addition, the relationship between cumulative total daily rainfall at each station was plotted. Deviation from the trend between the cumulative rainfall patterns could indicate progressive interference with the measuring equipment, such as growth of a tree near the gauge. **Figure 17** and **Figure 18** in **Annexure 1A** show a constant relationship (close to 1:1) between the daily rainfall depth at Morpeth PO, the Tasman Mine site and Mulbring, respectively. The trend line for the Tasman Mine / Morpeth PO analysis indicates that Tasman Mine has 7% more rainfall than Morpeth PO. The trend line for the Mulbring / Morpeth PO analysis indicates that Mulbring has 11% more than Morpeth PO.

Although the period of co-incident rainfall data at Tasman Mine and Mulbring is not sufficient to establish a correlation relationship, the analysis undertaken indicates that Tasman Mine and Mulbring have very similar rainfall regimes, as would be expected given their proximity.

On the basis of the high degree of correlation shown in **Figure 15** and **Figure 16**, and the cumulative rainfall relationship illustrated in **Figure 17** and **Figure 18**, the rainfall record at Morpeth (complete years July 1885 – June 2010) has been adopted to represent the long term rainfall for the catchments in the vicinity of the existing Tasman Mine and the Project. A scaling factor of 1.07 to was applied to the Morpeth rainfall data to account for the slightly higher rainfall at Tasman Mine and Mulbring, which lie either side of the Surveyors Creek catchment. Although Morpeth is located approximately 20 km from the site of the Project, it provides one of the longest complete records available in the lower Hunter region and is located at a similar distance from the coast. Morpeth is, however, at a slightly lower elevation (about 10 m AHD) compared to the Surveyors Creek catchment (50-400 m AHD).

3.4 Evapotranspiration Data

Evapotranspiration data was sourced from the digital version of the *Climatic Atlas of Australia: Evapotranspiration* (Version 1.0, Bureau of Meteorology, 2002). The software was used to provide the monthly areal potential evapotranspiration values specific to each catchment, based on the latitude and longitude of the catchment centroid. Areal potential evapotranspiration is the evapotranspiration that would take place, if there was unlimited water supply from an area large enough such that the effects of any upwind boundary transitions are negligible, and local variations are integrated to an areal average (Chiew et al., 2002).

The daily evapotranspiration values were scaled to 0.85 for use in the calculation of the daily water balance (Refer **Section 4.1**). Applying a scale factor of 0.85 is an alternative to reducing the potential evapotranspiration rate as the surface stores dry out (Boughton, 2010).

3.5 AWBM Input Data

Coincident daily streamflow and rainfall data for each catchment to be modelled was required. Streamflow data is localised and cannot be determined from other sites, therefore only complete years (July – June) of data were used. It follows that flow data was the limiting factor and dictated the modelling periods. **Table 5** lists the flow and rainfall station and data periods used in the AWBM modelling while **Annexure 1D** contains a bar chart showing the periods of available rainfall and streamflow data.

The model was calibrated using the Leave-One-Out Cross Validation (LOOCV) procedure, a process which enables all available complete years of streamflow data to be utilised. This calibration procedure is described in **Section 4.1**.

As discussed in **Section 3.2**, monthly areal potential evapotranspiration values, sourced from the Bureau of Meteorology, were used to calculate daily potential evapotranspiration values for each month for the six catchments selected. The evapotranspiration values were incorporated into the model for the periods listed in **Table 5**.

Table 5: AWBM Input Data for Calibration Periods

Catchment No.	1	2	3	4	5	6
Flow Station	Congewai (210026)	Swamp (210053)	Wallis (210054)	Muggyrang (210069)	Jilliby (211004)	Jigadee (211008)
Rainfall Station	Cooranbong (Avondale) (61012) Congewai (Greenock) (61152)	Cessnock Post Office (61009)	Cessnock Post Office (61009)	Pokolbin (Somerset) (61238)	Wyee (Wyee Farms Road) (61082)	Cooranbong (Avondale) (61012)
Catchment Area (km^2)	83	83	95	5	8	55
Period (y)	27	11	8	20	6	16
Modelling Period (July to June)	1948 - 1959 1962 - 1964 1965 - 1979	1960 - 1971	1959 - 1964 1965 - 1966 1969 - 1970 1976 - 1977	1965 - 1969 1970 - 1971 1972 - 1973 1974 - 1982 1985 - 1991	1962 - 1963 1982 - 1987	1974 - 1976 1988 - 1991 1993 - 1994 1995 - 1996 1997 - 2006
Ave Rainfall (mm/y)	1,117	772	844	761	1,348	1,149
Ave Pot Evap (mm/y)	1,407	1,392	1,405	1,355	1,421	1,415
Ave Flow (mm/y)	397	78	215	79	205	315
% Runoff (Observed Mean Runoff / Mean Rainfall)	36%	10%	25%	10%	15%	27%

4 DAILY FLOW REGIME MODELLING OF COMPARABLE CATCHMENTS

Using streamflow and rainfall data for the modelling periods listed in **Table 5**, AWBM was utilised to generate a set of parameters describing the flow characteristics for six catchments within the lower Hunter Valley and Central Coast. The LOOCV procedure was applied to the model to guide the selection of the model parameters most representative of the actual flow regime. The modelling involved a three staged process:

1. For each catchment, calculate repeated derivations of the AWBM model parameters using the automatic calibration function of the AWBM, leaving out one year at a time.
2. Using the manual version of the AWBM, apply each set of parameters to a test sample (i.e. the year of data that was left out of the calibration) and calculate the Nash-Sutcliffe Coefficient of Efficiency for the test sample.
3. Using the full data set and manual version of the AWBM, select the model parameters using the calculated Nash-Sutcliffe Coefficient of Efficiency values and assessment of the flow duration curve as a guide.

Further description of this process is provided below.

4.1 Automatic Calibration (Leave One Year Out)

The AWBM has an automatic calibration component, AWBM2010, which generates parameters that describe the hydrological process when daily rainfall, monthly potential evapotranspiration and daily runoff are entered into the model.

All daily values were entered directly into the model except potential evapotranspiration, which was scaled by a factor of 0.85 (to account for the reduction of actual evapotranspiration as the soil dries out) for use in the calculation of the daily water balance.

The AWBM2010 model selects a warm up period at the start of the data record and then runs the calibration for the remaining record. Default values are adopted for the baseflow parameters and the surface runoff constant during the preliminary calibration of surface storage capacity. The average surface storage capacity is scaled up and down until the calculated runoff equals the actual runoff for the assessment period. Next the BFI, K_{base} and K_{surf} parameters are calibrated in that order, then a second time using a measure of difference between calculated and actual daily runoff hydrographs (Boughton, 2010).

Initially the model was set up and calibrated for the complete modelling period, using the full data set, and a set of parameters generated ($Ave_{(all\ years)}$, $BFI_{(all\ years)}$, $K_{base(all\ years)}$, $K_{surf(all\ years)}$). The LOOCV procedure was used to provide a validation process that utilises all available data. The model was calibrated N times, where N represents the number of years of data. For i = 1 to N, the data for $year_{(i)}$ was omitted from the calculations. The model was fitted to the remaining points, daily flow figures estimated and a set of model parameters derived ($Ave_{(i)}$, $BFI_{(i)}$, $K_{base(i)}$, $K_{surf(i)}$). The LOOCV procedure produced N estimates of the model parameters. Of the N parameter sets, the minimum and maximum parameter values ($Ave_{(min)}$, $BFI_{(min)}$, $K_{base(min)}$, $K_{surf(min)}$ and $Ave_{(max)}$, $BFI_{(max)}$, $K_{base(max)}$, $K_{surf(max)}$) are listed in **Table 7** to illustrate the range of results for each catchment. The N sets of parameters ($Ave_{(i)}$, $BFI_{(i)}$, $K_{base(i)}$, $K_{surf(i)}$ where i = 1 to N) provided an indication of the scatter in the parameter set.

As detailed in **Section 2**, the automatic calibration procedure uses a single parameter to represent a fixed pattern of surface storage capacities and partial areas represented by a single parameter (Ave). The model selects default values for A1, A2 and A3, 0.134, 0.433 and 0.433, respectively. Also, the values for C2, C2 and C3 are directly related (20*C1 = 2*C2 = C3), such that there is only one independent variable. Boughton (2010) reported that the average value of surface storage capacity was far more important to calibration than the individual set of capacities and partial areas. Accordingly, because the model parameters derived from the representative catchments were to be only used as a guide to parameters for the Project area, further disaggregation of A and C parameters was not attempted.

4.2 Manual Calibration (Test Sample)

AWBM has a spreadsheet version which was used to calculate the predicted runoff of the excluded year, $year_{(i)}$, using the parameter set generated when $year_{(i)}$ was omitted (i.e. $Ave_{(i)}$, $BFI_{(i)}$, $K_{base(i)}$, $K_{surf(i)}$). This method of model validation allows all data to be used. This is highly beneficial, particularly for sites where there is limited availability of data.

As adopted by Boughton (2006), the Nash-Sutcliffe Coefficient of Efficiency (E) was used as a measure of model performance. Boughton (2006) notes that E is based on monthly runoff and is the most common measure for comparing modelled and recorded monthly runoff. It is a normalised statistic used to determine the relative magnitude of the residual variance compared to the measured data variance to indicate the predictive accuracy of the model (Nash & Sutcliffe, 1970, Moriasi et al., 2007). The value measures how closely the modelled results fit the 1:1 line, and is given by:

$$E = 1 - \frac{\sum_{t=1}^{T}(Q_o^t - Q_m^t)^2}{\sum_{t=1}^{T}(Q_o^t - \overline{Q_o})^2}$$

where: T = final time-step period t = individual time-step period

Q_o = Observed data Q_m = Modelled data $\overline{Q_o}$ = Av of observed data

The efficiency value can range from –∞ to 1, where 1 indicates a perfect match of modelled data to observed data (Nash & Sutcliffe, 1970, Moriasi et al., 2007).

Table 6 lists the results for the test sample with the highest Nash-Sutcliffe Coefficient of Efficiency, when modelled using the parameters generated using all the other years. In addition to the E value, the table contains R^2, actual and calculated runoff, which also provide some indication of model accuracy.

Table 6: LOOCV Results for Year of Highest Coefficient of Efficiency

Catchment No. >	1	2	3	4	5	6
Flow Station	Congewai (210026)	Swamp (210053)	Wallis (210054)	Muggyrang (210069)	Jilliby (211004)	Jigadee (211008)
Annual Rainfall (mm/y)	1,175	1,060	803	1,192	1,884	1,707
Annual Evap (mm/y)	1,405	1,391	1,408	1,355	1,421	1,414
Annual Flow (mm/y)	404	250	200	318	499	800
Period (July to June)	76 - 77	62 - 63	63 - 64	88 - 89	62 - 63	89 - 90
Average Capacity (mm)	60.5	142.2	37.7	159.3	458.0	133.0
BFI	0.180	0.210	0.250	0.010	0.240	0.160
K_{base}	0.933	0.993	0.923	0.806	0.962	0.813
K_{surf}	0.520	0.350	0.410	0.280	0.490	0.440
E (monthly totals)	0.9519	0.6974	0.8512	0.9436	0.5143	0.9555
R^2 (monthly totals)	0.9706	0.8680	0.8941	0.9445	0.5726	0.9767
Actual Runoff (mm)	404	250	200	318	499	800
Calculated Runoff (mm)	496	215	263	327	483	859

For each catchment, the LOOCV highest E parameter set (i.e. $Ave_{(max\ E)}$, $BFI_{(max\ E)}$, $K_{base(max\ E)}$, $K_{surf(max\ E)}$), as presented in **Table 6**, were then modelled using the manual version of AWBM and the complete data set (i.e. modelling periods listed in **Table 5**).

4.3 Manual Calibration (Full Data Set)

Manual AWBMs were set up for each catchment containing the complete data set (i.e. N years of data). Estimated daily runoff and corresponding Nash-Sutcliffe Coefficient of Efficiency values, flow duration curves, cumulative runoff curves and scatter plots were calculated for the following parameter sets:

- $Ave_{(all\ years)}$, $BFI_{(all\ years)}$, $K_{base(all\ years)}$, $K_{surf(all\ years)}$
- $Ave_{(min)}$, $BFI_{(min)}$, $K_{base(min)}$, $K_{surf(min)}$
- $Ave_{(max)}$, $BFI_{(max)}$, $K_{base(max)}$, $K_{surf(max)}$
- $Ave_{(max\ E)}$, $BFI_{(max\ E)}$, $K_{base(max\ E)}$, $K_{surf(max\ E)}$

Table 7 contains these parameter sets and the statistical analysis which was used as a basis for adopting a parameter set for each catchment that best describe its flow characteristics. The Nash-Sutcliffe Coefficient of Efficiency, based on monthly totals, provided a guide to the model performance. The model parameters were manually adjusted to improve the fit of the flow duration curves and cumulative runoff curves. **Figure 3** shows an example of how the manual adjustment process was used to improve the fit between the actual and calculated daily flow duration curves. It should be noted that these adjustments only altered the shape of the flow duration curves, but did not change the total volume of runoff.

Table 7 lists the parameters adopted through this adjustment process. The majority of the parameters adopted are within the range generated by the automatic calibration process. For parameters outside the range, **Table 7** illustrates this has resulted in negligible impacts on the Nash-Sutcliffe Coefficient of Efficiency and generally a more accurate depth of calculated runoff. It is evident that the Coefficient of Efficiency has low sensitivity to the full range of parameters generated by the LOOCV procedure.

Annexure 1B contains the flow duration curves and cumulative runoff curves plots for the catchments modelled with the adopted parameters, as listed in **Table 7**. **Annexure 1B** also contains scatter plots of the calculated versus actual monthly runoff.

The Jilliby Creek record appears anomalous because, for the calibration period, it has the highest rainfall of all stations but a very low proportion of runoff (15%) (see **Table 5**). Published data for rainfall and average runoff from Ourimbah Creek (27%), and Wyong River (21%) (Boughton, 2010), which are located in the same general area as Jilliby Creek, provides further evidence for the Jilliby record being anomalous. In addition, **Table 6** shows that Jilliby Creek had the lowest Coefficient of Efficiency of all the catchments for the best test sample year. This indicates that, compared to the other catchments, the Jilliby Creek model is relatively poor. In the process of identifying suitable parameters for the catchments in the Tasman Extension Project area, less weight has been given to the model parameters derived for Jilliby Creek.

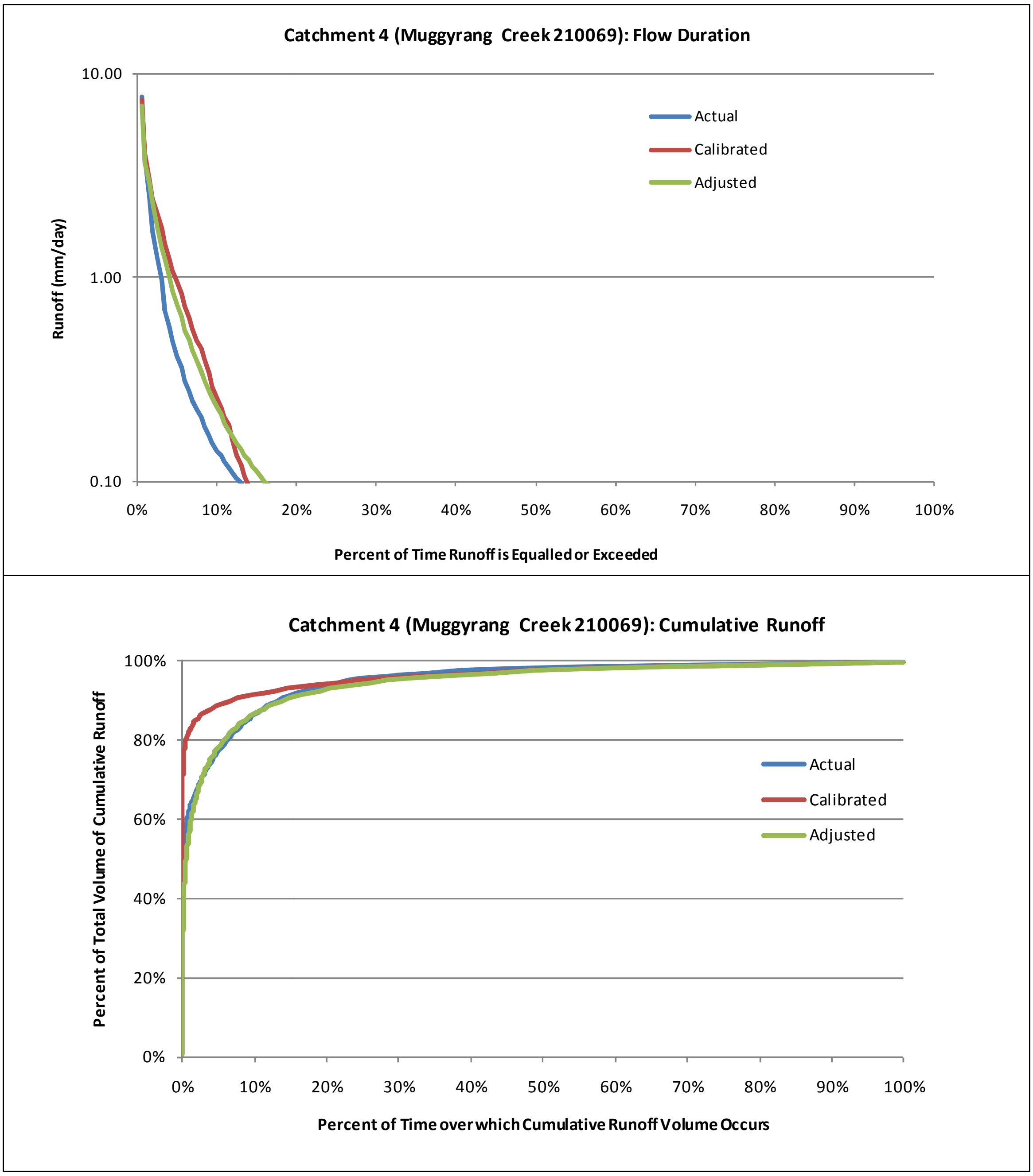


Figure 3:
Modelling Results for Catchment 1 (Congewai Creek 210026)

Table 7: AWBM Results

Input Parameters and Analysis	**Full Record**	**Min**	**Max**	**LOOCV (highest E)**	**Adopted**	**Full Record**	**Min**	**Max**	**LOOCV (highest E)**	**Adopted**
	Catchment 1 (Congewai Ck 210026)					**Catchment 2 (Swamp Ck 210053)**				
Average Capacity (mm)	61.8	57.2	72.7	60.5	61.8	132.7	121.5	148.2	142.2	137.0
BFI	0.210	0.160	0.210	0.180	0.210	0.200	0.200	0.210	0.210	0.180
K_{base}	0.923	0.923	0.943	0.933	0.950	0.973	0.973	0.993	0.993	0.992
K_{surf}	0.520	0.510	0.530	0.520	0.520	0.340	0.000	0.380	0.350	0.280
E (monthly data)	0.773	0.773	0.771	0.773	0.770	0.728	0.737	0.654	0.693	0.696
R^2 (monthly data)	0.775	0.774	0.777	0.775	0.774	0.785	0.770	0.775	0.786	0.783
Actual Runoff (mm)	396.5	396.5	396.5	396.5	396.5	77.6	77.6	77.6	77.6	77.6
Calculated Runoff (mm)	397.2	408.1	375.8	400.2	397.2	80.0	86.5	72.8	75.1	77.6
	Catchment 3 (Wallis Ck 210054)					**Catchment 4 (Muggyrang Ck 210069)**				
Average Capacity (mm)	38.9	34.8	44.5	37.7	38.0	157.5	152.6	169.6	159.3	159.3
BFI	0.240	0.210	0.310	0.250	0.250	0.010	0.010	0.010	0.010	0.250
K_{base}	0.923	0.893	0.943	0.923	0.943	0.806	0.806	0.806	0.806	0.890
K_{surf}	0.450	0.370	0.450	0.410	0.450	0.470	0.280	0.470	0.280	0.050
E (monthly data)	0.773	0.753	0.785	0.772	0.775	0.735	0.732	0.731	0.733	0.734
R^2 (monthly data)	0.773	0.758	0.790	0.773	0.775	0.736	0.733	0.737	0.735	0.740
Actual Runoff (mm)	214.7	214.7	214.7	214.7	214.7	79.1	79.1	79.1	79.1	79.1
Calculated Runoff (mm)	212.0	225.2	196.7	215.6	214.5	80.4	82.7	75.8	79.6	79.6
	Catchment 5 (Jilliby Ck 211004)					**Catchment 6 (Jigadee Ck 211008)**				
Average Capacity (mm)	744.9	458.0	977.4	458.0	550.0	134.7	123.6	167.3	133.0	135.3
BFI	0.360	0.240	0.540	0.240	0.280	0.160	0.160	0.210	0.160	0.160
K_{base}	0.887	0.869	0.962	0.962	0.965	0.813	0.806	0.813	0.813	0.930
K_{surf}	0.620	0.490	0.680	0.490	0.600	0.440	0.440	0.490	0.440	0.350
E (monthly data)	0.319	0.423	0.277	0.431	0.402	0.318	0.793	0.793	0.796	0.803
R^2 (monthly data)	0.371	0.563	0.316	0.531	0.461	0.446	0.809	0.798	0.808	0.809
Actual Runoff (mm)	204.9	204.9	204.9	204.9	204.9	314.8	314.8	314.8	314.8	314.8
Calculated Runoff (mm)	175.7	229.8	149.1	229.8	208.0	100.2	328.1	287.6	318.1	315.8

5 PROJECT AREA DAILY FLOW REGIME MODELLING

Model parameters for the Project area were derived based on the modelling results provided in **Section 4** together with published model parameters for the region (Refer **Annexure 1C** for adopted modelled parameters and published parameters). The parameters were applied to long term historical climate data to estimate the daily flow regime at various locations in Surveyors Creek. The modelled runoff for representative catchments within the Project area provide a best estimate of the "existing" conditions and form "baseline" conditions for use in the assessment of subsidence risk management zones and the subsequent assessment of residual impacts on flow and water resources. The process used to model the runoff in the Project area is described below.

5.1 Catchment Areas

For the purposes of characterising the flow regime typical of the various creek systems within the Surveyors Creek catchment, seven representative sub-catchments have been identified as listed in **Table 8** below. **Figure 4** shows six catchments in the area of the proposed West Borehole Seam Workings. The seventh catchment drains in a northerly direction from Mount Sugarloaf and runs immediately adjacent to the mine pit-top area before draining under George Booth Drive. The modelling locations have been selected based on location of headwaters creeks and valley fill creeks, pools, knick points, groundwater dependent endangered ecological communities (EECs) and subsidence control zones, as depicted in **Figure 4**.

Table 8: Details of Representative Catchments

Designation	Area (km^2)	Conditions
S2B	1.67	Headwaters creek – at the transition from "Headwater" to "Valley fill, Fine grained, Incised" creek style.
S2C	1.40	Headwaters creek – near pool that marks the transition from "Headwater" to "Valley fill, Fine grained, Incised" creek style.
S2D	1.08	Headwaters creek – at the transition from "Headwater" to "Valley fill, Fine grained, Incised" creek style.
S2(3)	5.32	Surveyors Creek "Tributary 2" at the downstream end of an area designated as containing Groundwater-Dependent Ecosystems
S2(2)	8.48	Surveyors Creek "Tributary 2" just downstream of the boundary of area to be undermined
S2(1)	13.26	Surveyors Creek "Tributary 2" at the junction of "Tributary S2G"
S1B	1.47	"Tributary S1B" just upstream of George Booth Drive where any impact from the pit-top facilities is likely to occur. No underground mining in the West Borehole Seam.

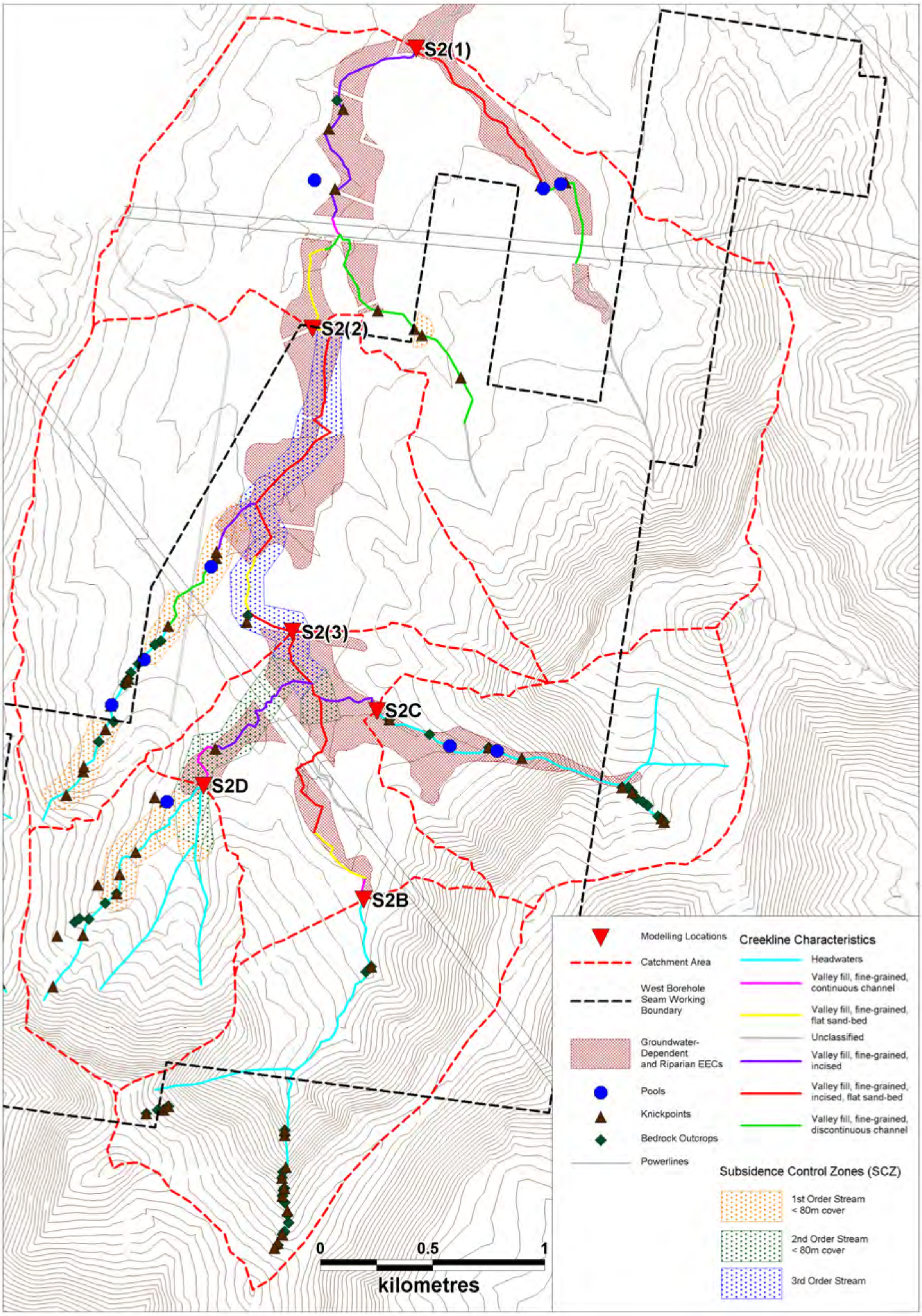


Figure 4:
Surveyors Creek Tributary Catchments Selected for Flow Regime Analysis

5.2 AWBM Parameter Selection

For the purposes of assessing the daily flow regime in Surveyors Creek, two AWBM catchment scenario models were set up:

1. A model with parameters selected from the calibration analysis and published data to represent the runoff characteristics of the steep forested catchments in terms of overall percentage runoff and relatively short period of baseflow following rainfall. (Denoted '**headwater creeks**' in the following discussion.)
2. A model with parameters selected from the calibration analysis and published data to represent the runoff characteristics of catchments that include the steep forested headwaters and also include lower gradient sections with incised alluvial channels in which more persistent baseflow would be expected. (Denoted '**valley fill creeks**' in the following discussion.)

Parameters representing headwater creeks were used to generate flows for catchments S2B, S2C, S2D and S1B, while parameters representing valley fill creeks were used to generate flows for catchments S2(3), S2(2) and S2(1). **Table 10** lists the parameters adopted for the two catchment scenarios.

The parameters produced by the model calibration process described in **Section 4** formed the starting point to derive the parameter sets for the two catchment scenarios. The modelling results were considered in conjunction with published model parameters for the region (Boughton, 2010) (see **Annexure 1C** for adopted modelled parameters and published parameters). Two other factors were taken into account in selecting appropriate AWBM model parameters:

- the general relationship between average annual rainfall and annual runoff; and
- the likely flow recession characteristics of the relatively steep catchments.

Figure 5 shows the relationship between average annual rainfall and average annual runoff in the Hunter Valley and Central coast derived from the recorded data used for model calibration, together with published data (Boughton, 2010). **Annexure 1C** contains the rainfall and runoff data used in **Figure 5**.

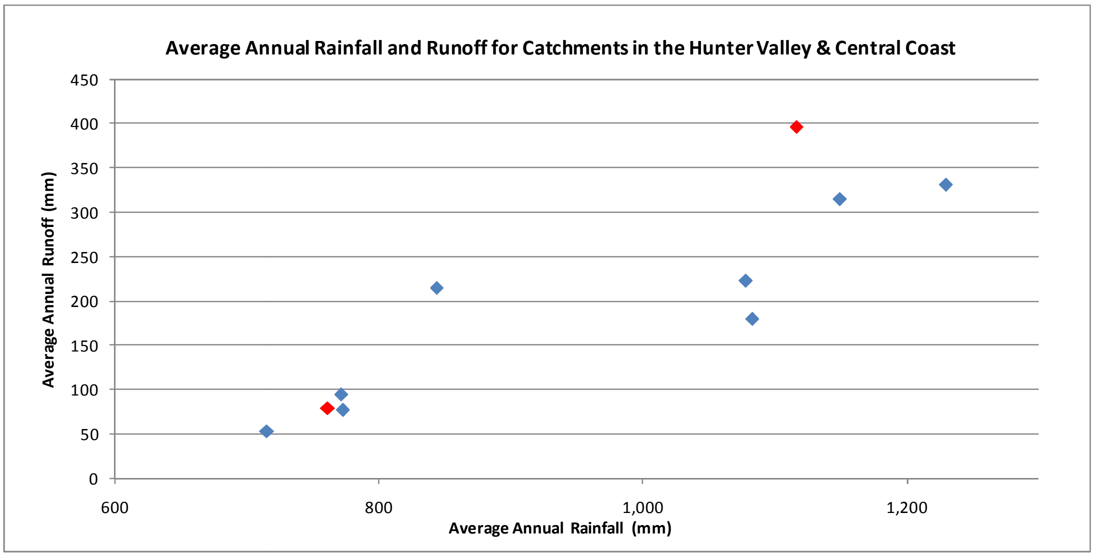


Figure 5:
Runoff Characteristics of Catchments in Hunter Valley and Central Coast

The blue data points shown in the figure indicate larger catchments with a significant proportion of flatter slopes, while the red data points indicate steep forested catchments.

As discussed in **Section 3.3**, the long term rainfall data for Morpeth (1885 – 2010) was adjusted by a factor of 1.07 to account for the rainfall at the site and used to generate runoff for the Project area. The average annual rainfall for the Project area is 993 mm.

On the basis of published data showing a non-linear relationship between average annual rainfall and average annual runoff (Gan et al, 1990; Boughton 2010) a non-linear relationship was adopted to fit the data in **Figure 5**. On this basis, average annual runoff of 170 mm can be expected in the lowland creeks (blue data points on indicated **Figure 5**). Assuming a similar trend between the steep forested catchments of Muggyrang and Congewai Creeks (red data points on indicated **Figure 5**), an average annual runoff in the order of 220 mm can be expected in the steep forested areas of Surveyors Creek. In his peer review of this *Surface Water Assessment*, Professor T McMahon suggested that the data in **Figure 5** could infer higher average annual runoff than the values adopted. However, on the basis that lower average annual runoff would accentuate any assessed impact as a result of changes in baseflow due to lowering of groundwater levels, average annual runoff of 170 mm for lowland creeks and 220 mm for steep forested catchments were adopted for assessment purposes. (It should also be noted that the recommended monitoring program for the Project includes flow monitoring on at least one of the potentially affected creeks in order to derive actual catchment runoff parameters.)

An AWBM model was created for the Project area using parameters with high Nash-Sutcliffe Coefficient of Efficiency derived from the calibration process (**Section 4**). Successive runs of the model were made using different values of average capacity to generate the relationship between runoff and average capacity shown in **Figure 6** below. Based on runoff depths of 220 mm and 170 mm, average capacity parameters of 120 mm and 180 mm were selected for the headwater creeks and valley fill creeks, respectively.

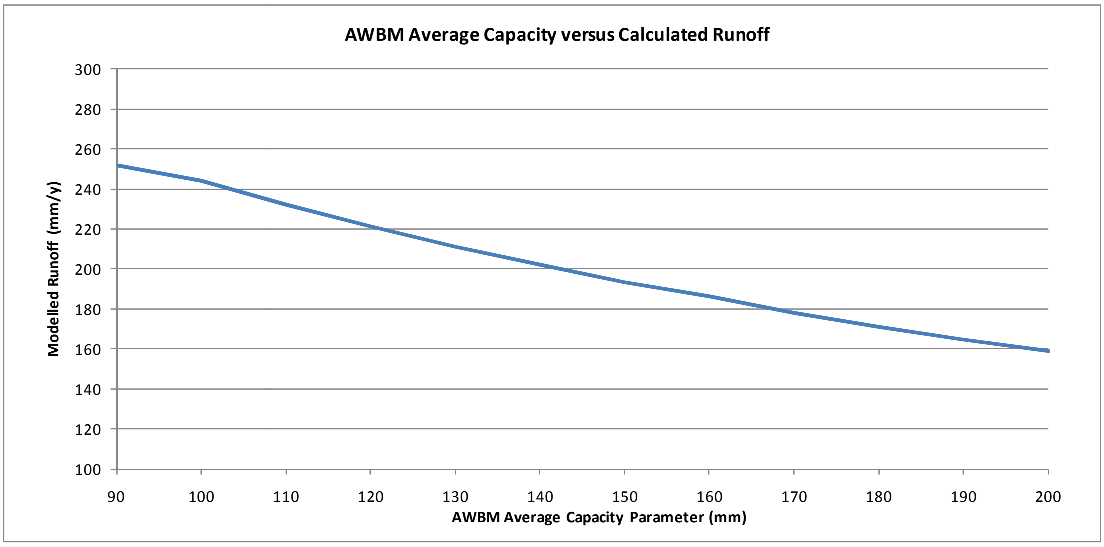


Figure 6:
AWBM Average Capacity Versus Calculated Runoff

As a guide to the likely duration of significant runoff, the rainfall data for Morpeth was analysed to derive the average number of days per year that rainfall exceeds 2, 5, 10, 20 or 30 mm.

Table 9 shows that rainfall exceeding 10 mm on a single day occurs on only 28 days per year (8% of the time). It is recognised, however, that this analysis does not take account of those occasions on which more than 10 mm may fall on two or more consecutive days without any one day exceeding 10 mm, which may also lead to runoff.

Table 9: Average Days per Year that Rainfall Exceeds the Stated Depth at Morpeth

	Rainfall Depth Exceeded (mm)				
	2	**5**	**10**	**20**	**30**
Days	66	46	28	13	7
% of Time	18%	13%	8%	4%	2%

The parameters that describe the relationship between baseflow and surface flow (BFI, K_{base} and K_{surf}) were adjusted to achieve flow durations that produce the majority of runoff on about 10% of days.

In determining the appropriate recession characteristics the baseflow parameters and surface runoff coefficient results have been considered with particular note taken of characteristics from Muggyrang Creek for headwater creeks.

Table 10 below provides the AWBM parameters adopted for the Project area.

Table 10: AWBM Parameters Adopted for Tasman Extension Project Area

	Ave	**BFI**	K_{base}	K_{surf}
Steep forested catchments	120	0.230	0.890	0.050
Lowland creeks with forested headwaters	180	0.210	0.950	0.520

5.3 Tasman Extension Area Flow Regime

Daily flow models were created for each of the representative Project area catchments based on the adopted historical climate record and the parameters listed in **Table 10**. **Table 11** provides a statistical summary of the modelled runoff for the representative catchments for the 125 years of climate data with the following climate statistics:

- Average annual rainfall 993 mm/year;
- Average annual areal potential evapotranspiration 1,412 mm/year.

The results indicate that the modelling for the Project area is consistent with the trend displayed in **Figure 5**, i.e. average annual runoff in the order of 170 to 220 mm per year.

Daily and annual flow duration curves were created for the modelled runoff for each representative catchment to illustrate the flow patterns (see **Figure 7** to **Figure 13**). Each figure includes daily flow duration curves corresponding to the full climate record and for various years representing minimum, 10^{th} percentile, median, 90^{th} percentile and maximum modelled flow years. The annual volume of runoff corresponding to each of these years is listed in **Table 11**.

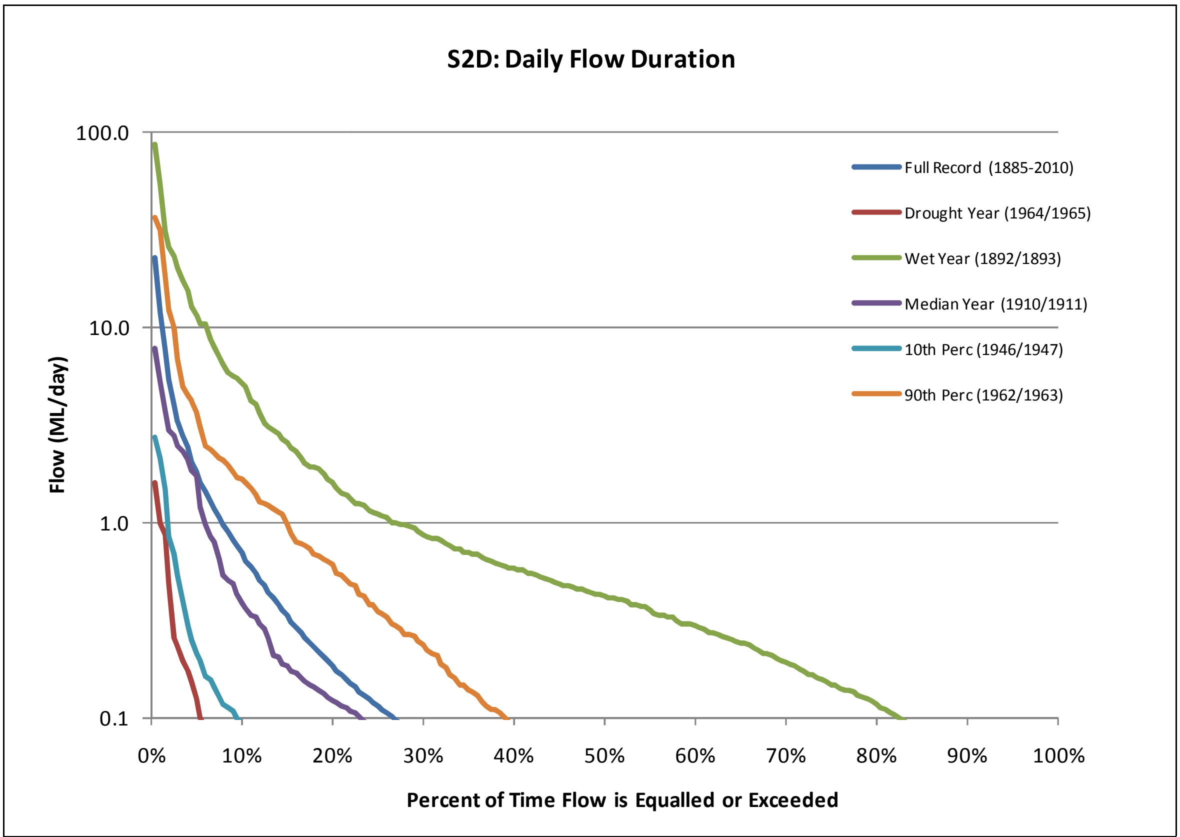
Table 11: Summary Statistics for Modelled Runoff from Representative Catchments

Catchment Designation (Catchment Type)	S2D (Headwater Creeks)	S2C (Headwater Creeks)	S1B (Headwater Creeks)	S2B (Headwater Creeks)	S2(3) (Valley Fill Creeks)	S2(2) (Valley Fill Creeks)	S2(1) (Valley Fill Creeks)
Area (km^2)	1.08	1.40	1.47	1.67	5.32	8.48	13.26
Ave Runoff (mm/y)	221	221	221	221	172	172	172
Ave Runoff (ML/y)	239	309	325	369	912	1454	2274
Runoff as % of Rainfall	22%	22%	22%	22%	17%	17%	17%
Minimum (ML/y)	18	23	24	27	78	124	194
10^{th} Percentile (ML/y)	56	73	77	87	194	309	483
Median (ML/y)	167	217	227	258	558	890	1,392
90^{th} Percentile (ML/y)	481	624	655	744	1,983	3,161	4,942
Maximum (ML/y)	1,395	1,809	1,899	2,158	6,754	10,766	16,834

It can be seen that the daily flow duration curve for the complete record is a smoother line than the others reflecting the fact that there are significantly more data points, i.e. 125 years of daily runoff values, whereas the other lines represent flow duration over a single year and therefore contain fewer data points which lead to greater variation around the overall trend.

The flow duration curves illustrate the wide variability in surface runoff that can be expected from year to year depending on the rainfall. This high variability indicates that it would be difficult to detect any subtle changes in runoff that might occur as a result of subsidence effects on the catchment.

It should also be noted that the modelled runoff from catchments within the Project area are based on parameters derived from catchments with similar characteristics, not from the potentially affected catchments themselves. The flow characteristics presented in this report are, therefore, only illustrative of the volume and distribution of runoff that can be expected. In order to improve the potential for modelling to be used to detect any changes in catchment runoff, a gauging station should be established on a representative catchment within the Project area. This gauging station should be established in an area that would be mined near the middle of the life of the mine (say 2020) in order to provide representative data for model calibration before mining occurs and post-mining data that can be used to compare runoff with pre-mining conditions.



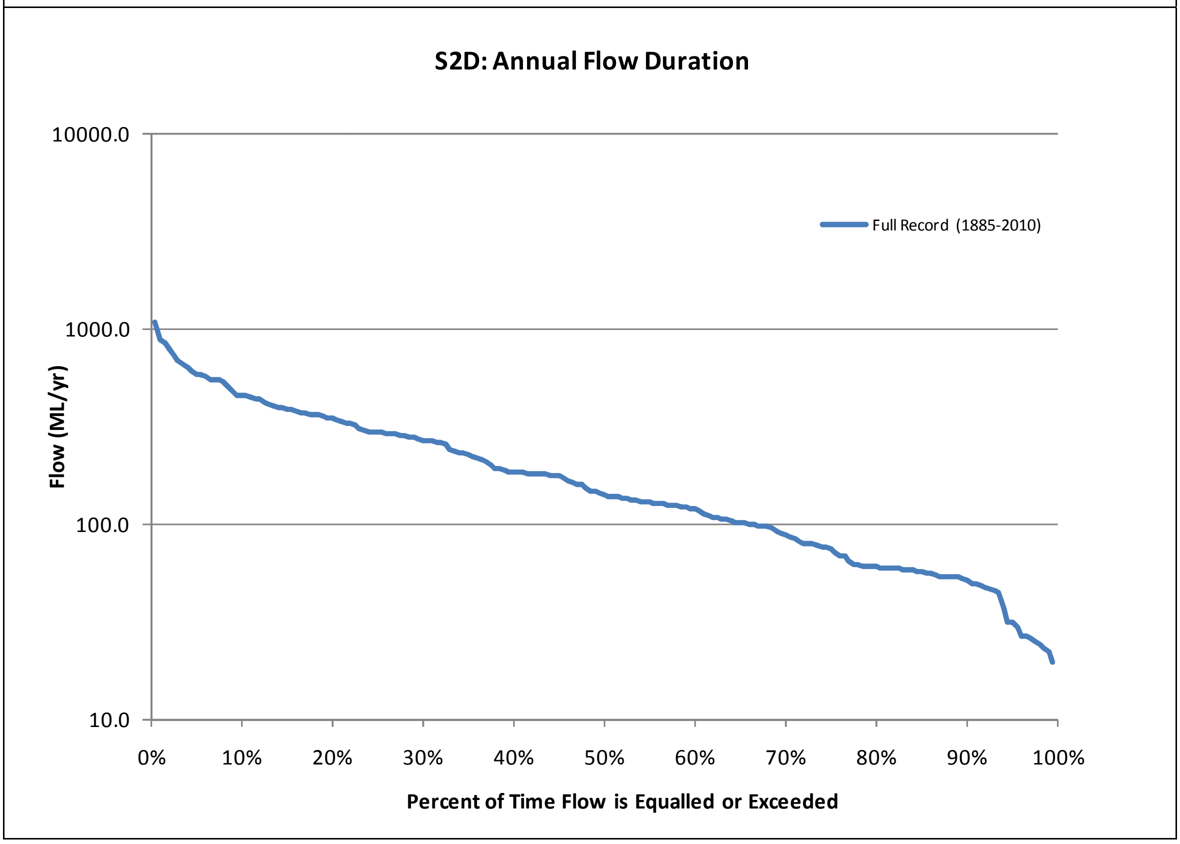
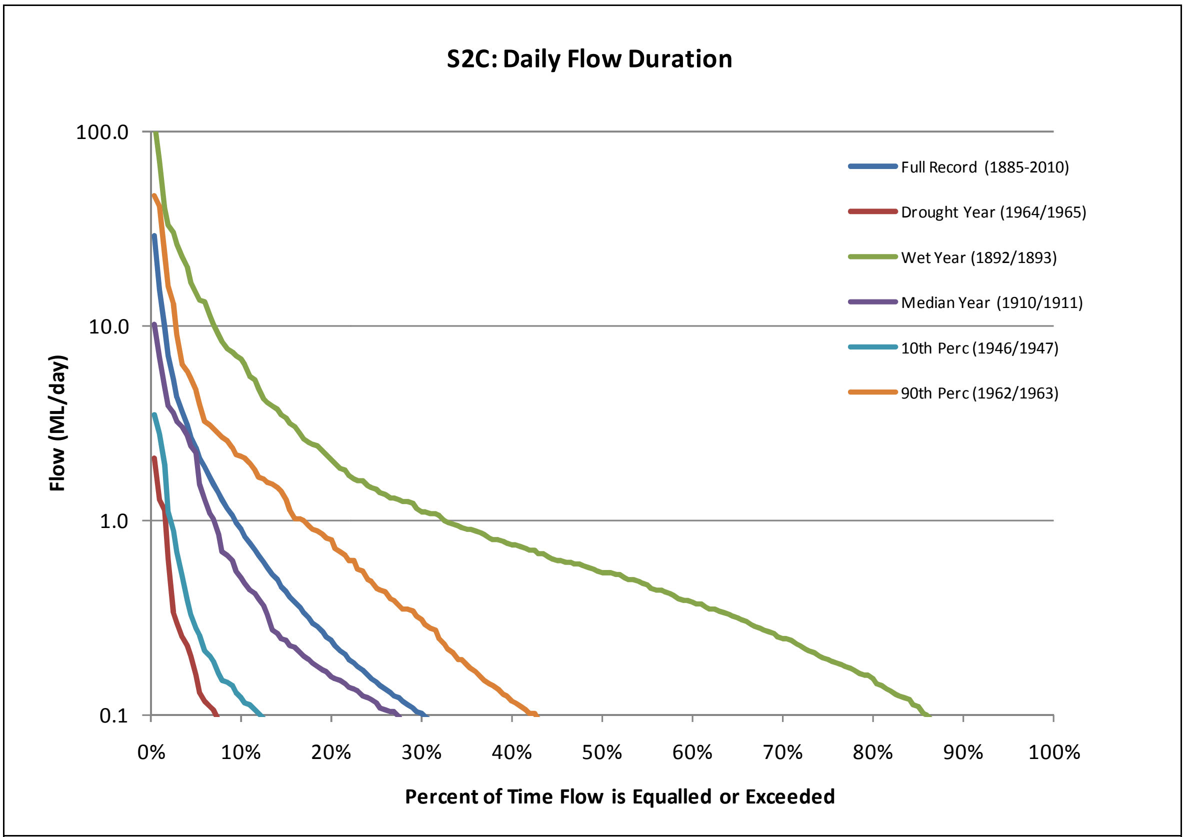


Figure 7:
Flow Duration Curves for Representative Catchment - S2D



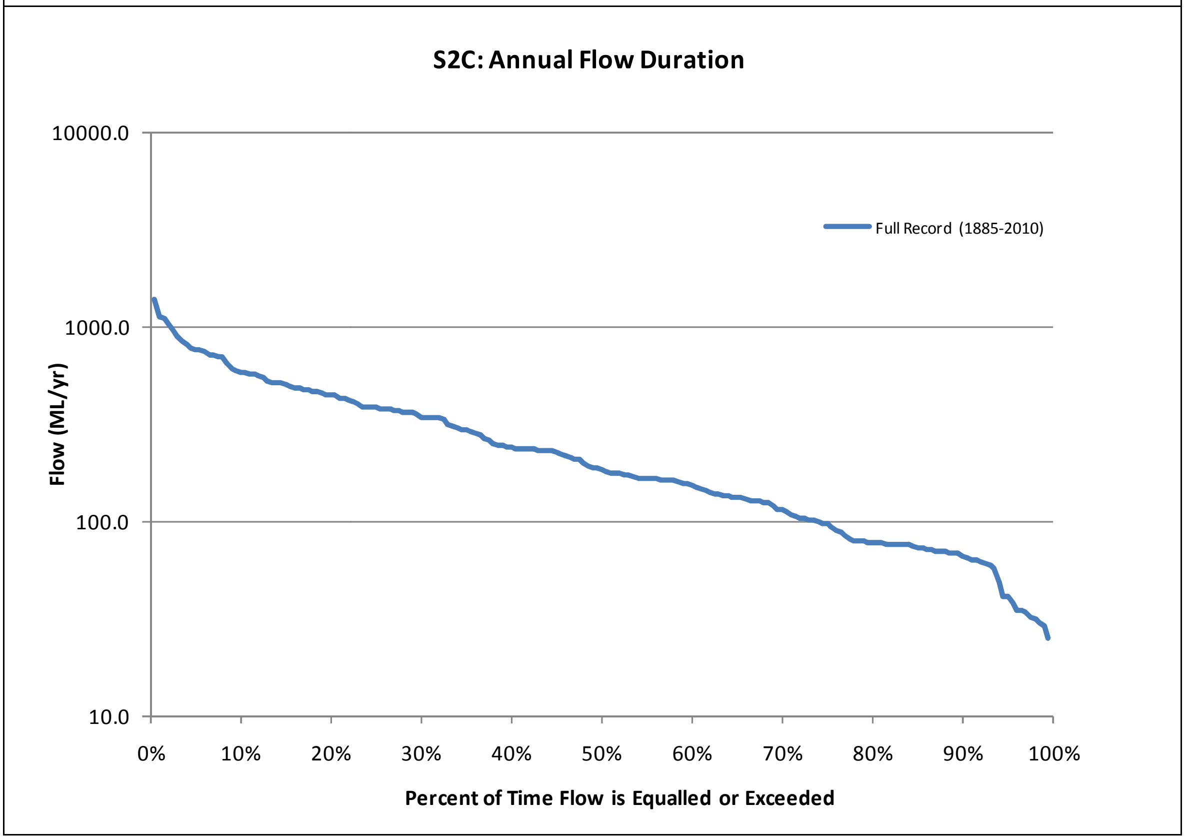
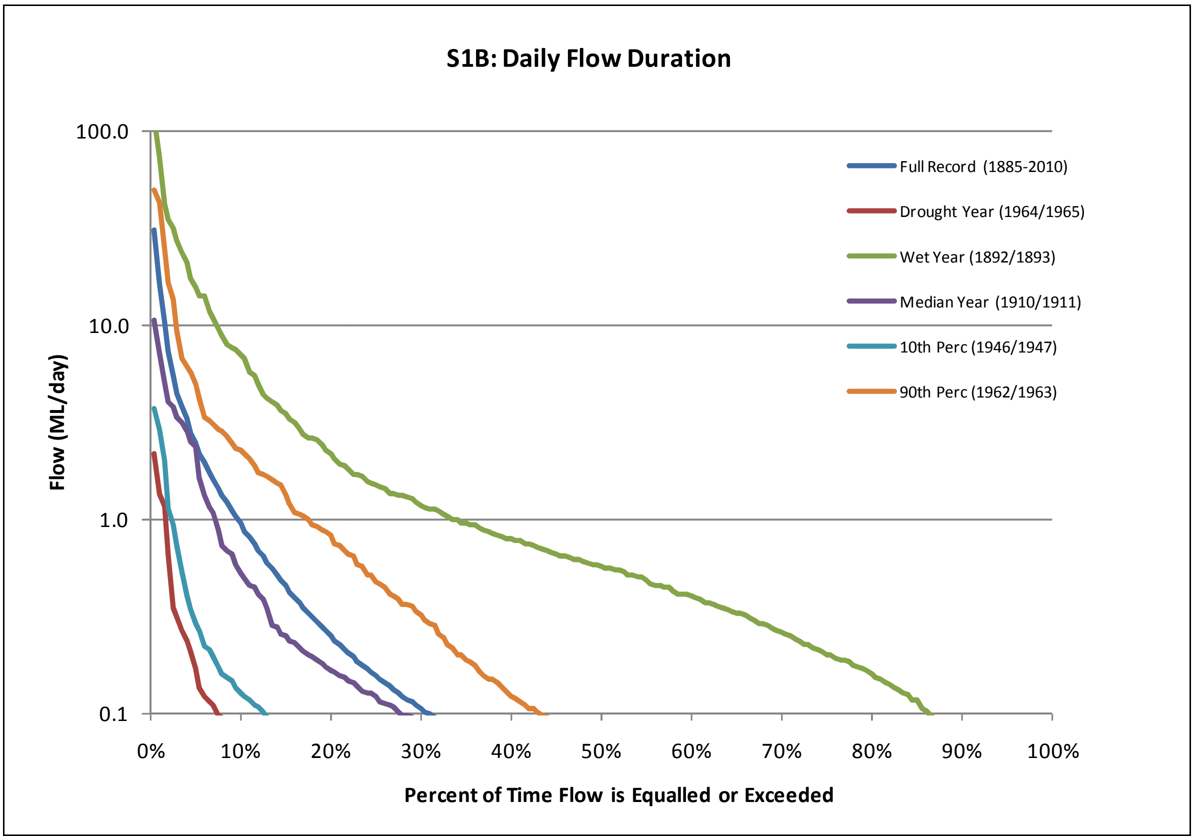


Figure 8:
Flow Duration Curves for Representative Catchment - S2C



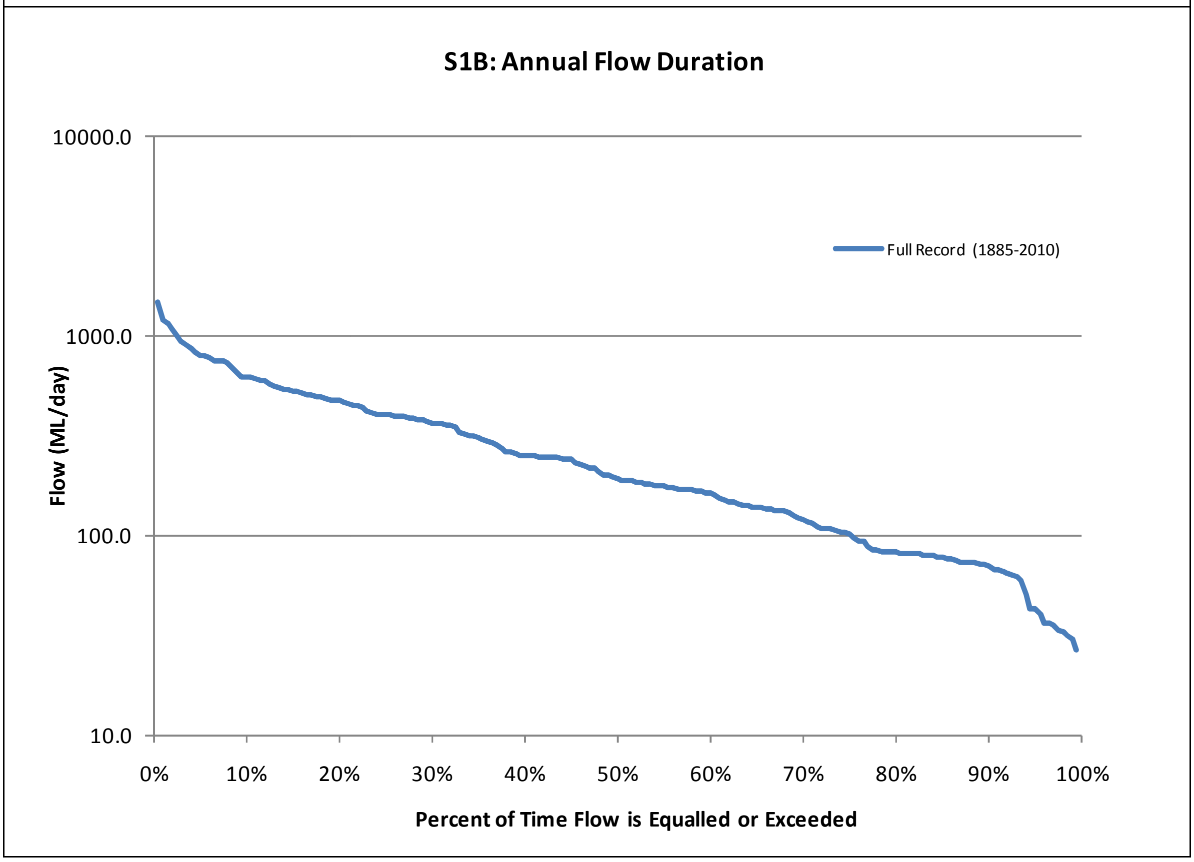
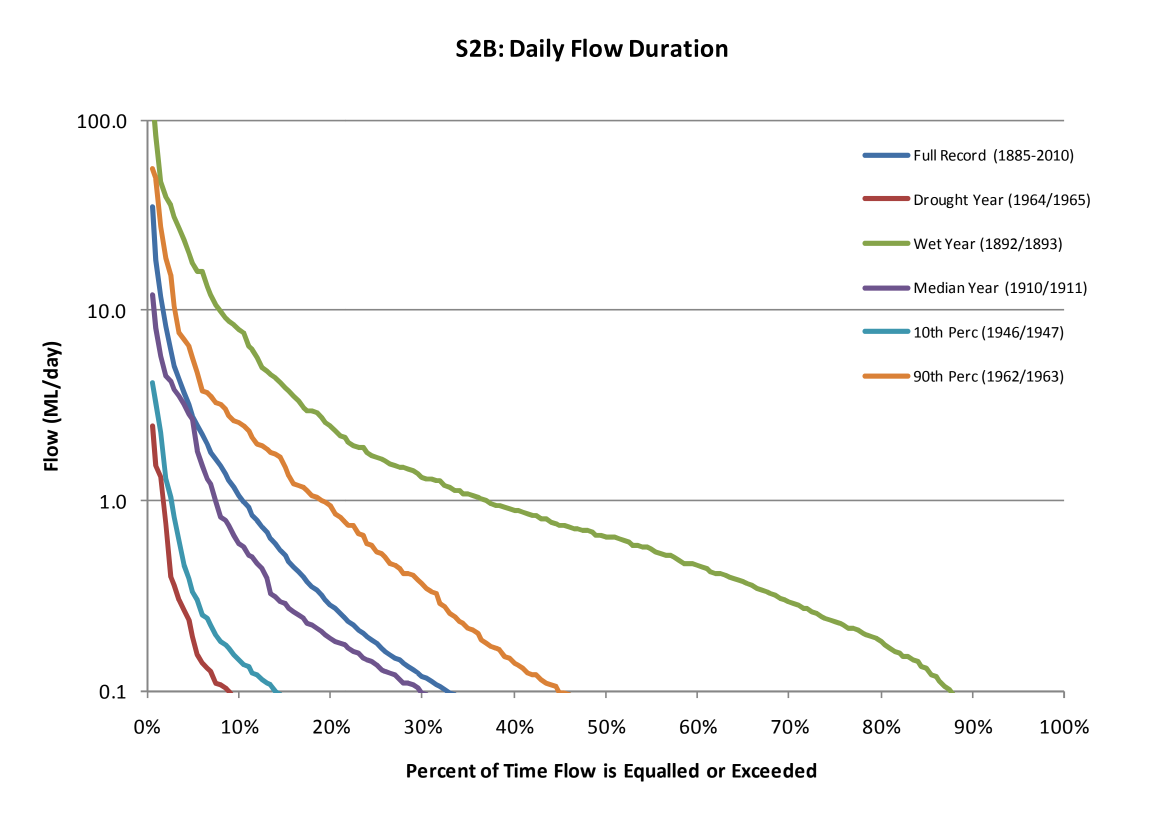


Figure 9:
Flow Duration Curves for Representative Catchment – S1B



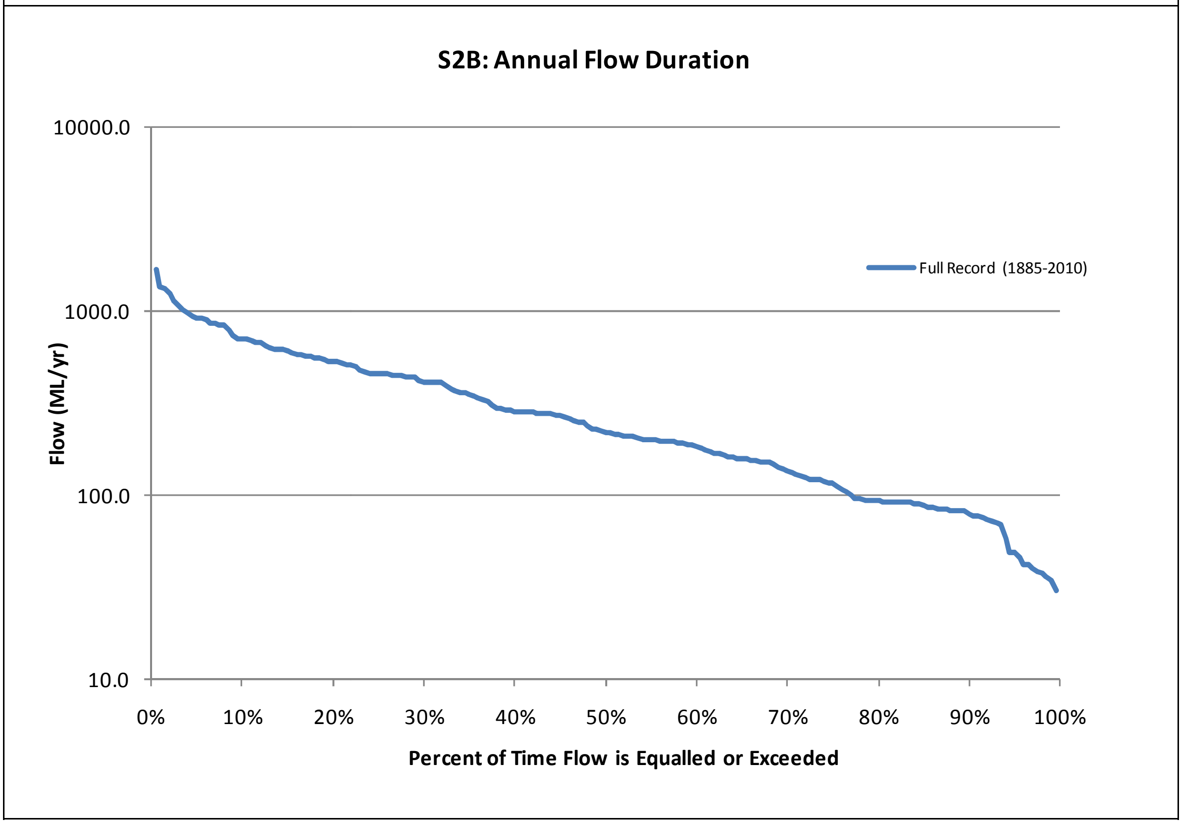
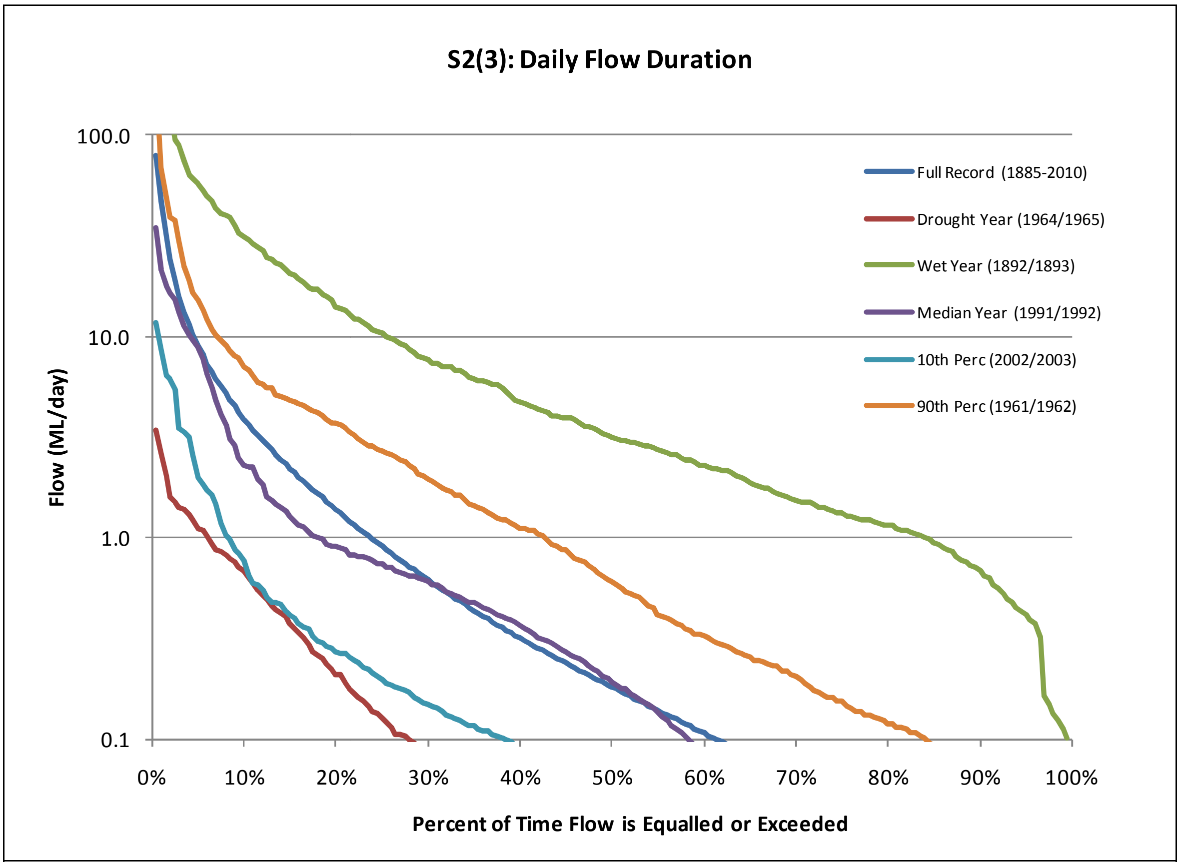


Figure 10:
Flow Duration Curves for Representative Catchment – S2B



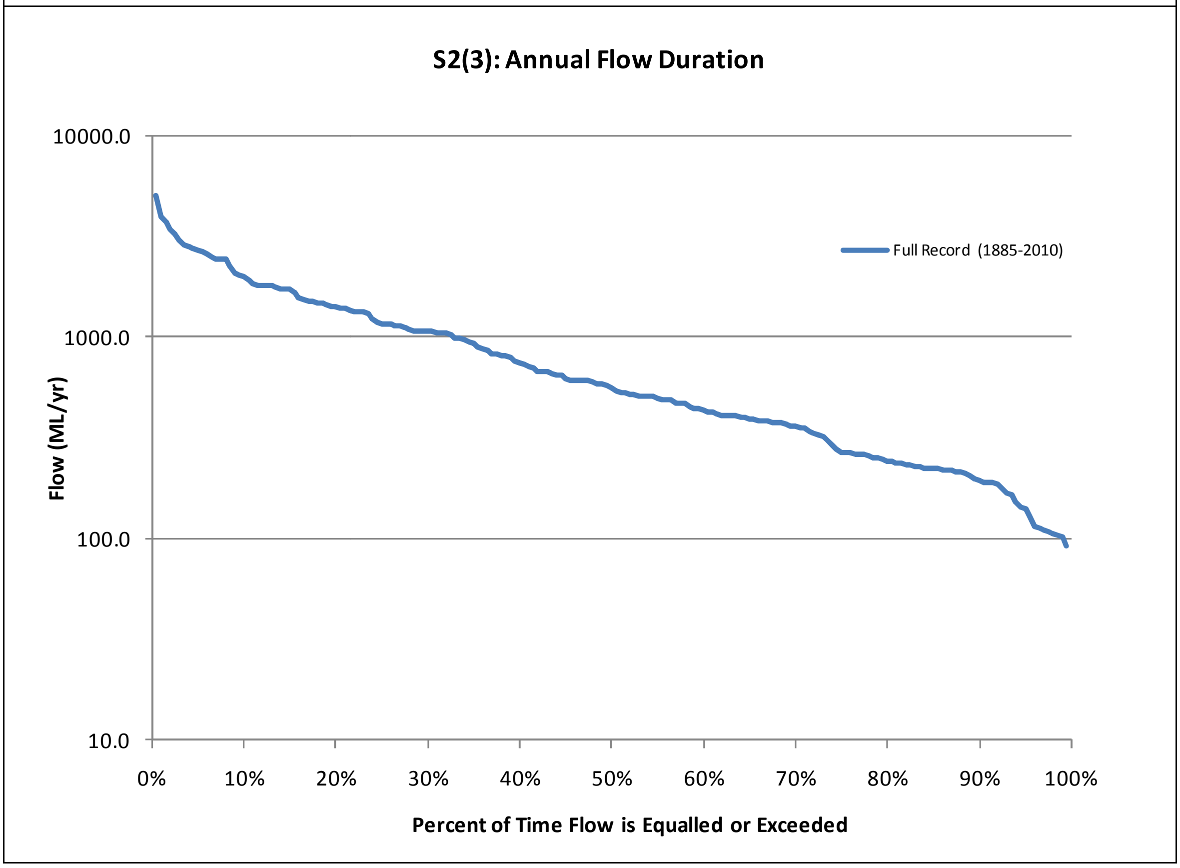
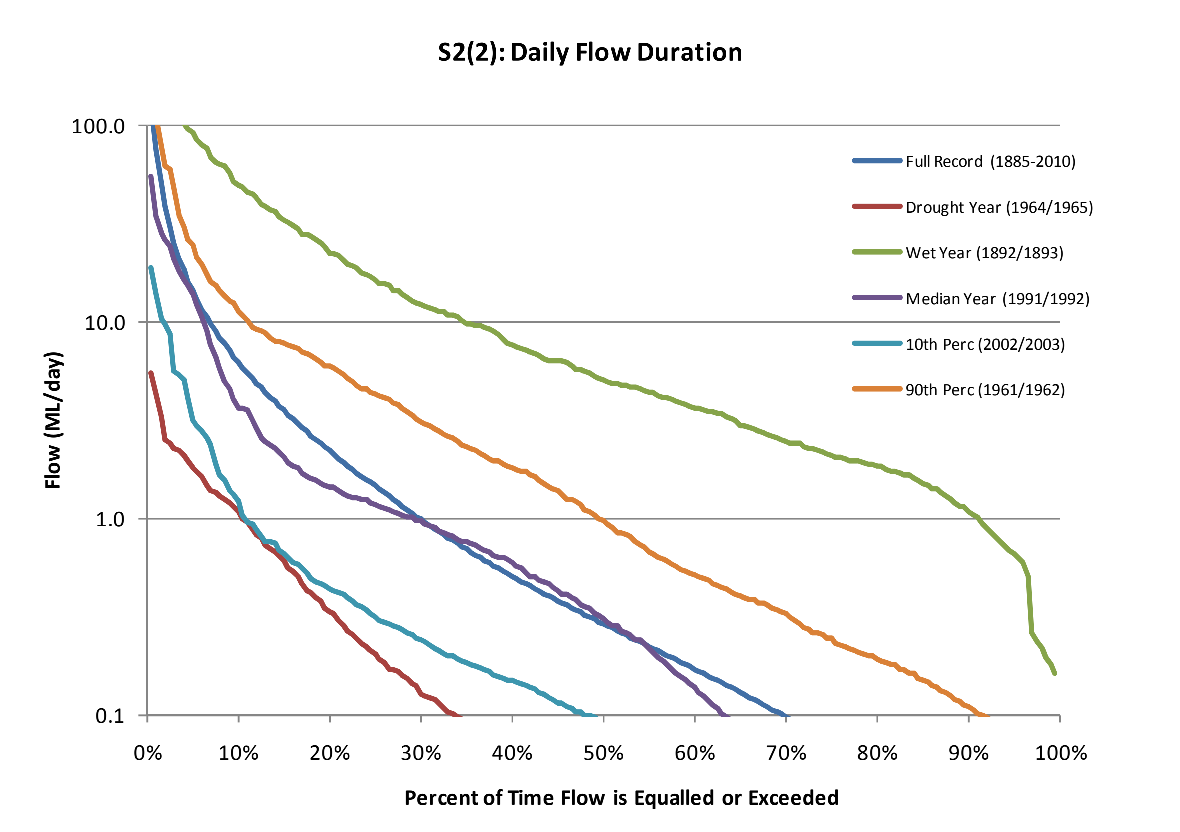


Figure 11:
Flow Duration Curves for Representative Catchment – S2(3)



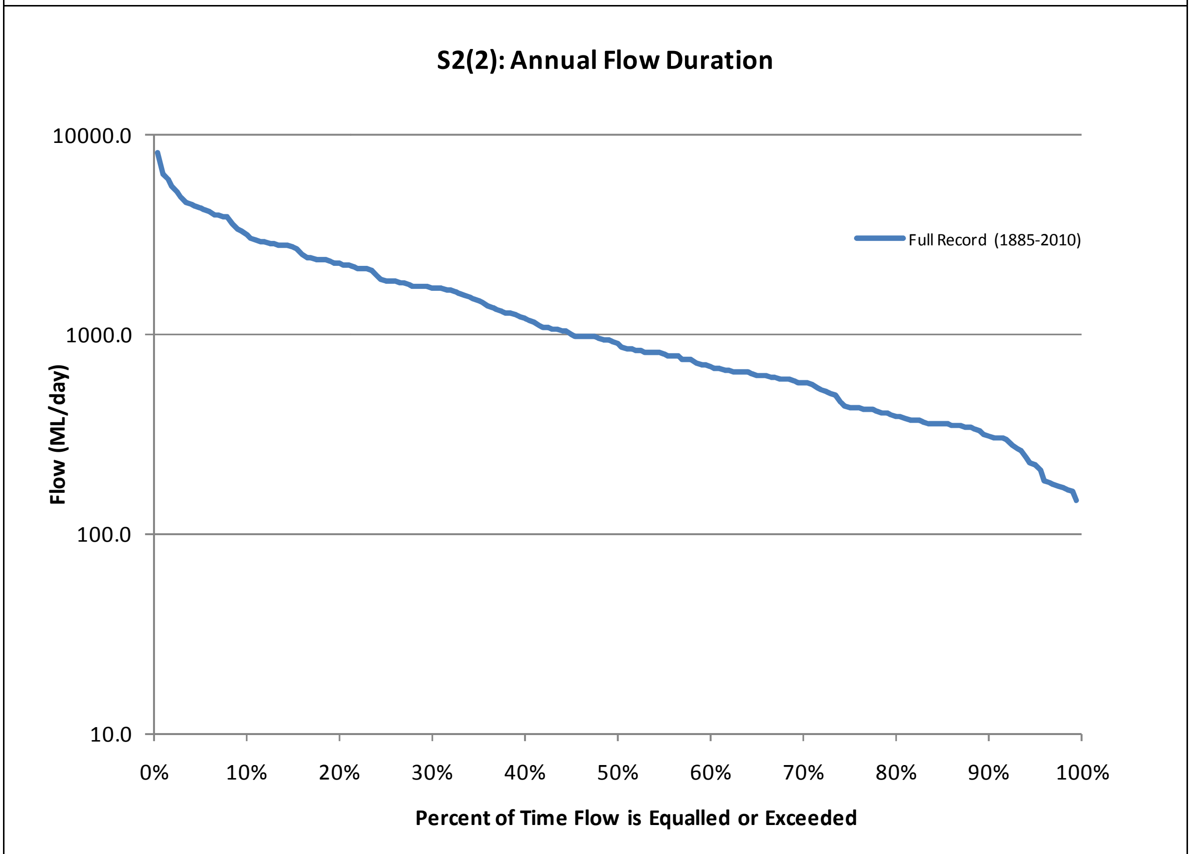
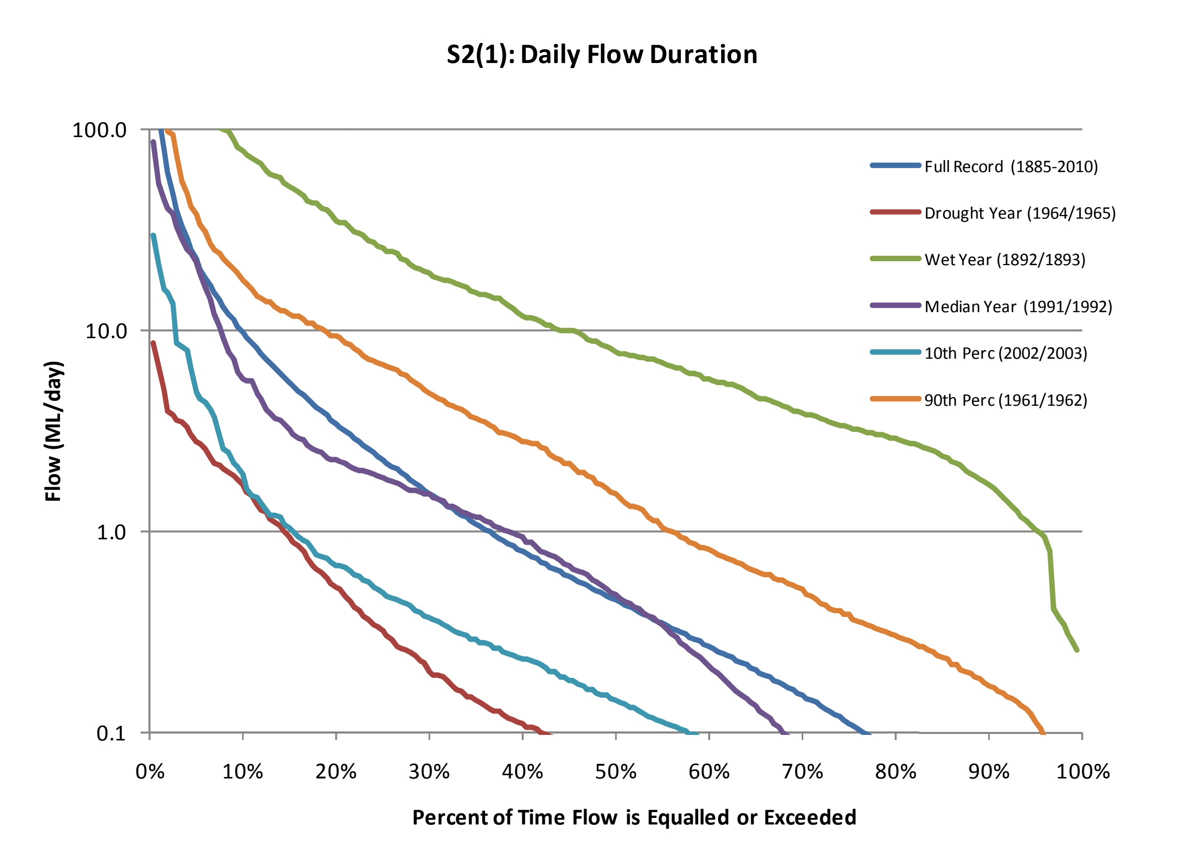


Figure 12:
Flow Duration Curves for Representative Catchment – S2(2)



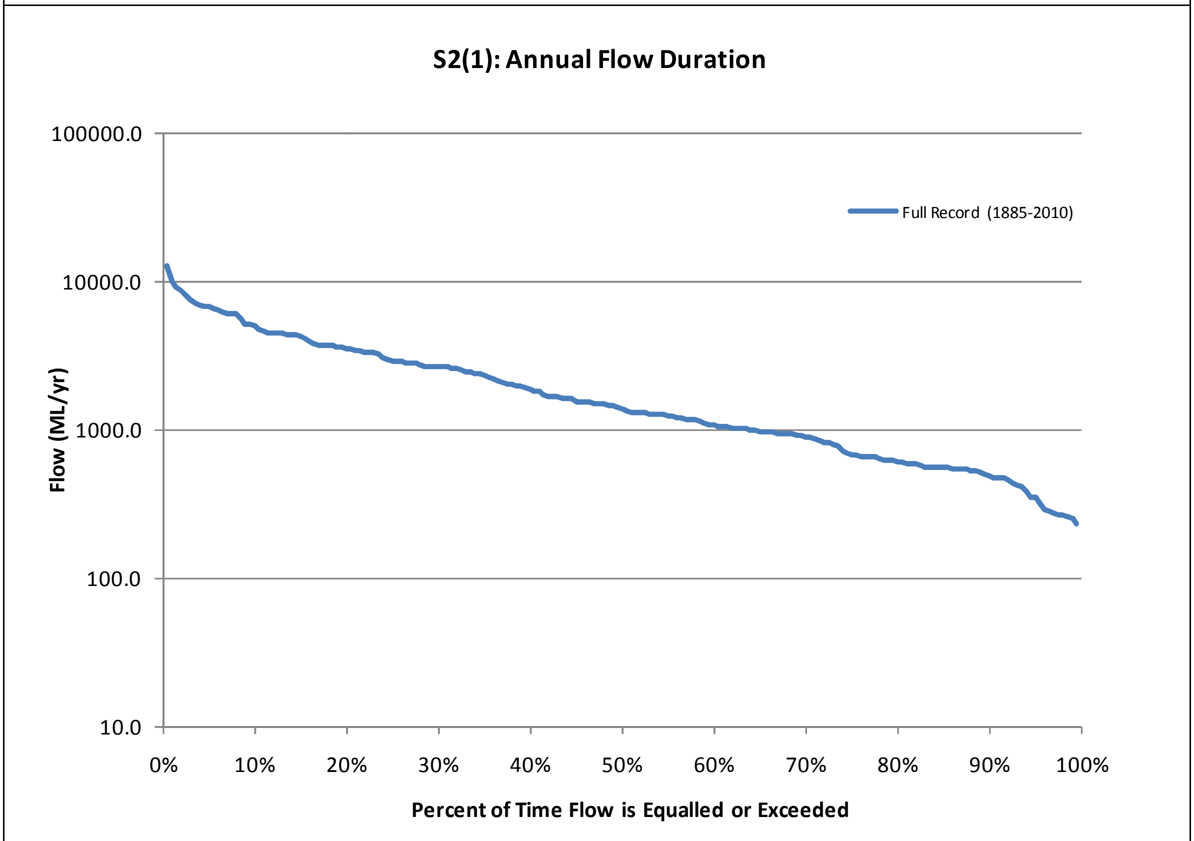


Figure 13:
Flow Duration Curves for Representative Catchment – S2(1)

5.4 Impacts of Mining

This section provides an assessment of the potential impacts of mining in the catchment area on the flow regime of the tributaries of Surveyors Creek that drain from the area that would be undermined. Four potential causes of change in the flow regime as a result of the Project are considered:

- Subsidence effects leading to cracking which could provide a pathway for loss of water from the catchment or creek channels; or provide alternative subsurface flow paths which bypass a section of creek;
- Subsidence effects leading to changes in the depth and surface area of water held in pools which could lead to a change in seepage and evaporation;
- Changes in groundwater levels leading to a change in the interactions between the groundwater system and the creeks;
- Reduction in the contributing catchment area as a result of the proposed stormwater retention for pollution control purposes at the pit-top area.

Potential Subsidence Effects on the Catchment and Creeks

Subsidence can potentially impact upon the flow regime in a number of ways, many of which, such as connective cracking to the mine workings, have been mitigated or eliminated by the proposed mine plan, particularly the establishment of Subsidence Control Zones (SCZs) that are designed to minimise the impacts of subsidence on cliff lines, steep slopes, groundwater dependent EECs and creeks:

- Shallow surface cracking on the land surface is considered possible, but would be minimised by subsidence controls that limit subsidence near cliffs to a maximum of 150 mm and to a maximum of 300 mm on steep slopes (>32.5%). The subsidence control zone for cliffs and steep slopes covers almost all of the slopes to be undermined above 100 m AHD in the upper catchment of Surveyors Creek Tributary 2. In these areas where there is minimal soil depth available to naturally fill any cracks, cracking is considered unlikely. Where surface cracking occurs on shallower slopes soil wash is likely to fill the majority of cracks.
- The *Subsidence Assessment* concludes that, even where surface cracking does occur, it would be relatively shallow and may lead to the creation of alternative sub-surface flow paths, but is unlikely to lead to drainage from the surface flow regime to the deep groundwater system.
- The implementation of SCZs would minimise subsidence along the creeks, particularly second and third order streams. The *Subsidence Assessment* concludes that surface cracks are not expected to develop where the proposed SCZs are left in place, and that it is 'very unlikely' that surface cracks would develop above first workings pillars (where subsidence magnitudes of <20 mm are expected) and 'unlikely' above partial pillar extraction panels (where subsidence magnitudes <300 mm may occur). As a result, no measurable loss of baseflow due to cracking is expected.

There may be some minor changes to the location, depth and volume of pools as described in **Section 5.3** of the *Surface Water Assessment*, but these are very unlikely to be significant in the context of catchment hydrology.

Due to the implementation of SCZs beneath the majority of second order and all third order streams, it is expected that there would be:

- minimal surface cracking;

- only a small number of areas where scouring potential would increase; and
- only a small number of pool areas that may have their shape and volume impacted by subsidence changes.

These changes are described in more detail in **Section 5 of the Surface Water Assessment**, but are not anticipated to lead to significant changes to baseflow.

Management strategies and monitoring of the ground surface along these watercourses would ensure that any low-scale impacts are identified, managed, minimised and rectified in a timely manner.

Changes in Groundwater / Creek Interactions

The *Groundwater Assessment* (RPS Aquaterra, 2012 which forms Appendix B of the EIS) indicates that under current conditions groundwater levels underlying the ridge between Mount Sugarloaf and Summit Point are at sufficient elevation to provide minor inflow to the creek system. Elsewhere, the water table is significantly lower than the creeks and minor losses of baseflow are estimated to occur.

Figure 14 below has been derived from outputs from the groundwater model and shows the predicted change in baseflow as a percentage of average annual runoff (from **Table 11**) for the representative catchments that would be affected by mining.

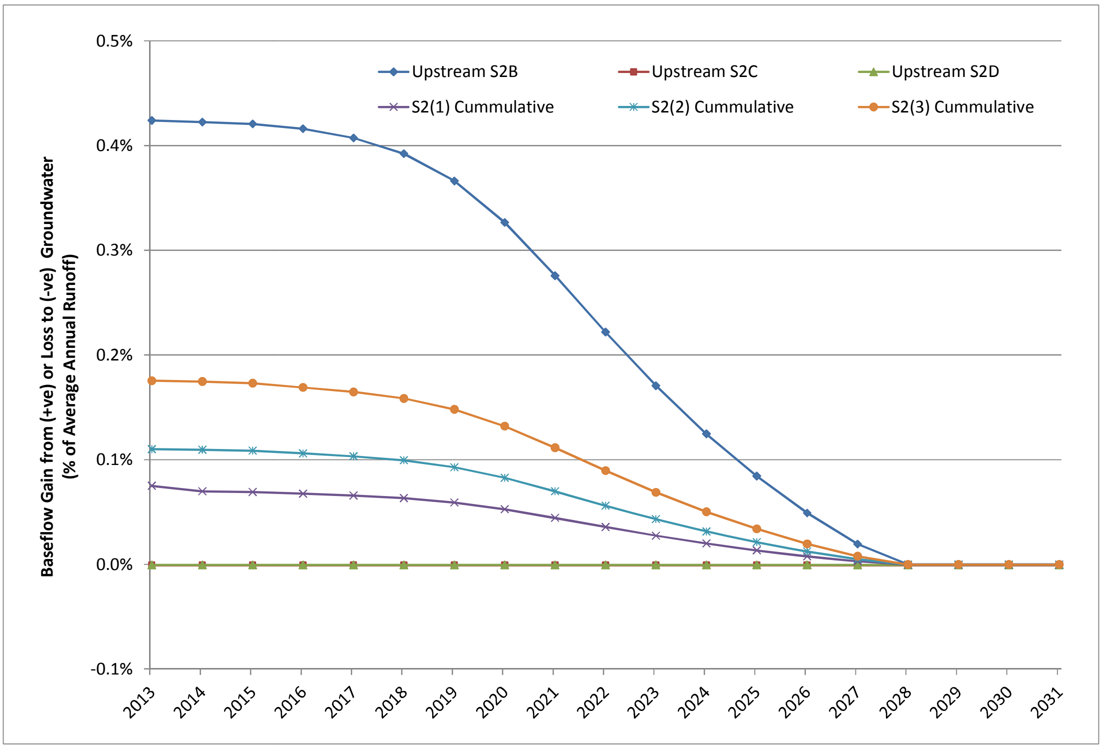


Figure 14:
Predicted Baseflow Losses/Gains in Surveyors Creek

The predicted changes in baseflow as a proportion of average annual runoff (see **Figure 14**) indicate that the main change would occur in the headwater creek above S2B where the existing groundwater inflow (about 0.42% of the average annual runoff) is predicted to reduce over the life of the mine to zero by about 2027. The other two headwater creeks (S2C and S2D) have bed levels above the existing water table and therefore have very minor losses to the groundwater system (0.001% of average annual runoff) which is not predicted to change as a result of mining. On the main tributary of Surveyors Creek where it leaves the area of mining (Site S2(1) on **Figure 4**) groundwater contribution is predicted to change from a net gain of about 0.07% of average annual flow at present (due to inflow above S2B) to zero by the end of mining. Even in a 1 in 10 dry year, by the end of mining the loss of groundwater baseflow from the catchment above S2B (1.6 ML/year) would only constitute about 0.3% of the flow at Site S2(1).

These predicted changes in baseflow attributable to changes in groundwater levels are negligible and would have no measurable effect on the flow regime in Surveyors Creek.

Reduction in Contributing Catchment Area

Stormwater runoff from the ‘dirty’ sections of the pit-top area (total 5.7 ha) would be captured and re-used or disposed of into historic old mine workings directly beneath the site. Other sections of the pit-top site would continue to drain off-site in a similar manner to the existing situation.

The effect of the loss of 5.7 ha of contributing catchment to tributary S1B would be to reduce the average annual runoff by about 12 ML/year (or 4% or the runoff from that sub-catchment). (Note that the increase in predicted runoff from the ‘dirty’ sections of the pit-top area compared to natural conditions [average 36 ML/year] is due to the replacement of the existing natural bushland with largely impervious surfaces.)

The reduction in runoff as a result of retention of all runoff from ‘dirty’ areas of the site would be partially offset by the sealing of the car park area (1.16 ha). Runoff from the car park would be directed into a bio-retention swale before being discharged into the road side drain on the southern side of George Booth Drive – which drains to tributary S1B. The runoff modelling indicates that the average annual runoff from the car-park would be about 8 ML/year.

The water balance modelling indicates that there would be an average net ‘retention’ of runoff of 4 ML/year.

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Annexure 1A: Long Term Rainfall Analysis

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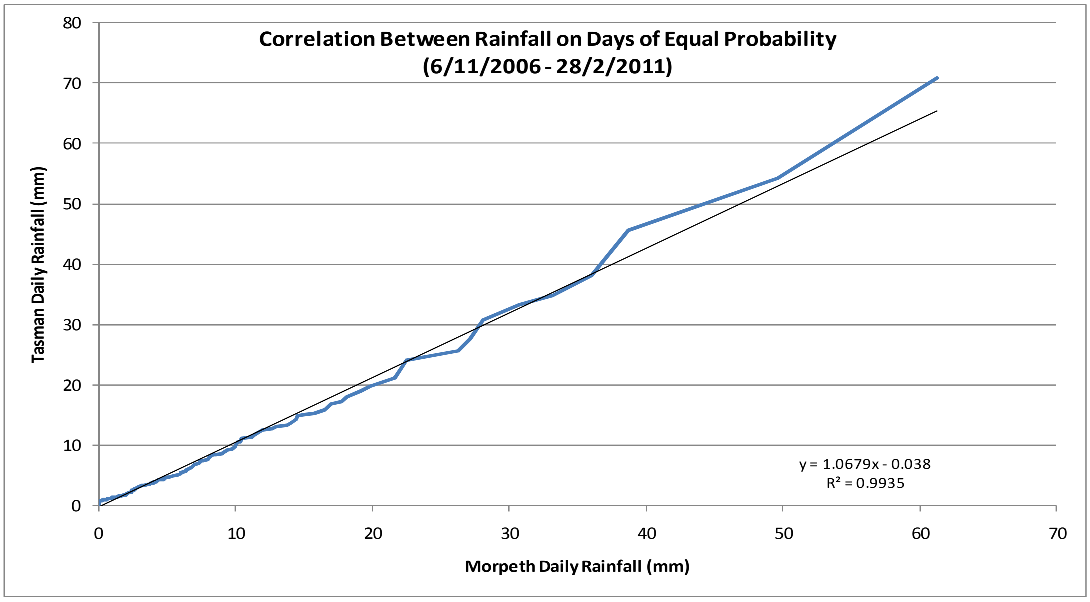

Figure 15:
Correlation Between Rainfall Depth on Days of Equal Probability at Tasman Mine and Morpeth

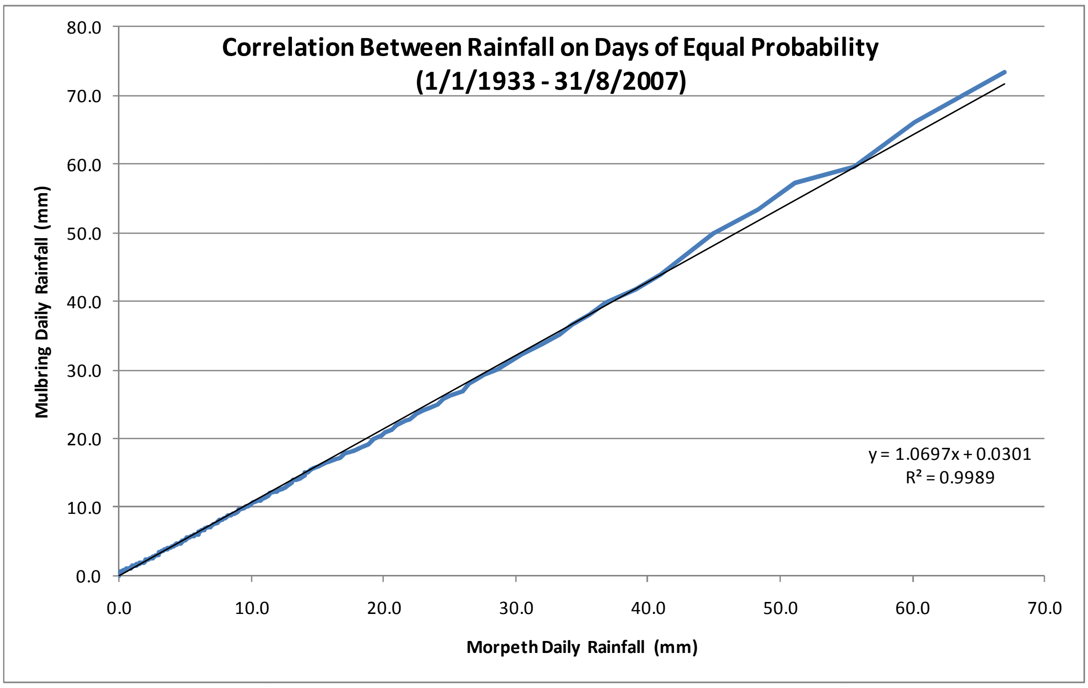

Figure 16:
Correlation Between Rainfall Depth on Days of Equal Probability at Morpeth and Mulbring

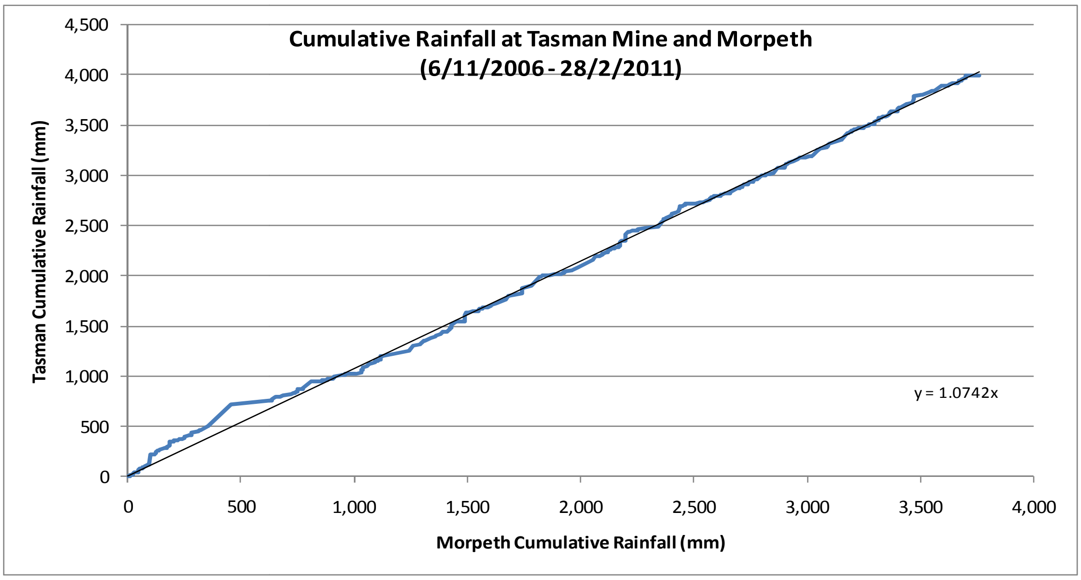

Figure 17:
Cumulative Daily Rainfall Relationship: Tasman Mine and Morpeth

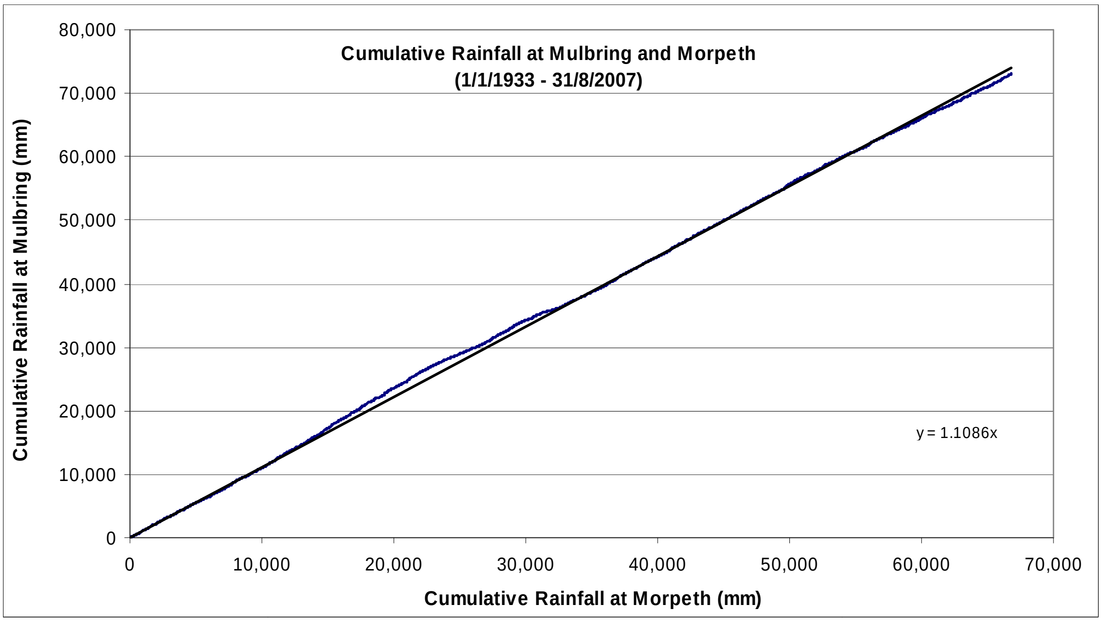

Figure 18:
Cumulative Daily Rainfall Relationship: Mulbring and Morpeth

Annexure 1B: Modelling Results for Comparable Catchments

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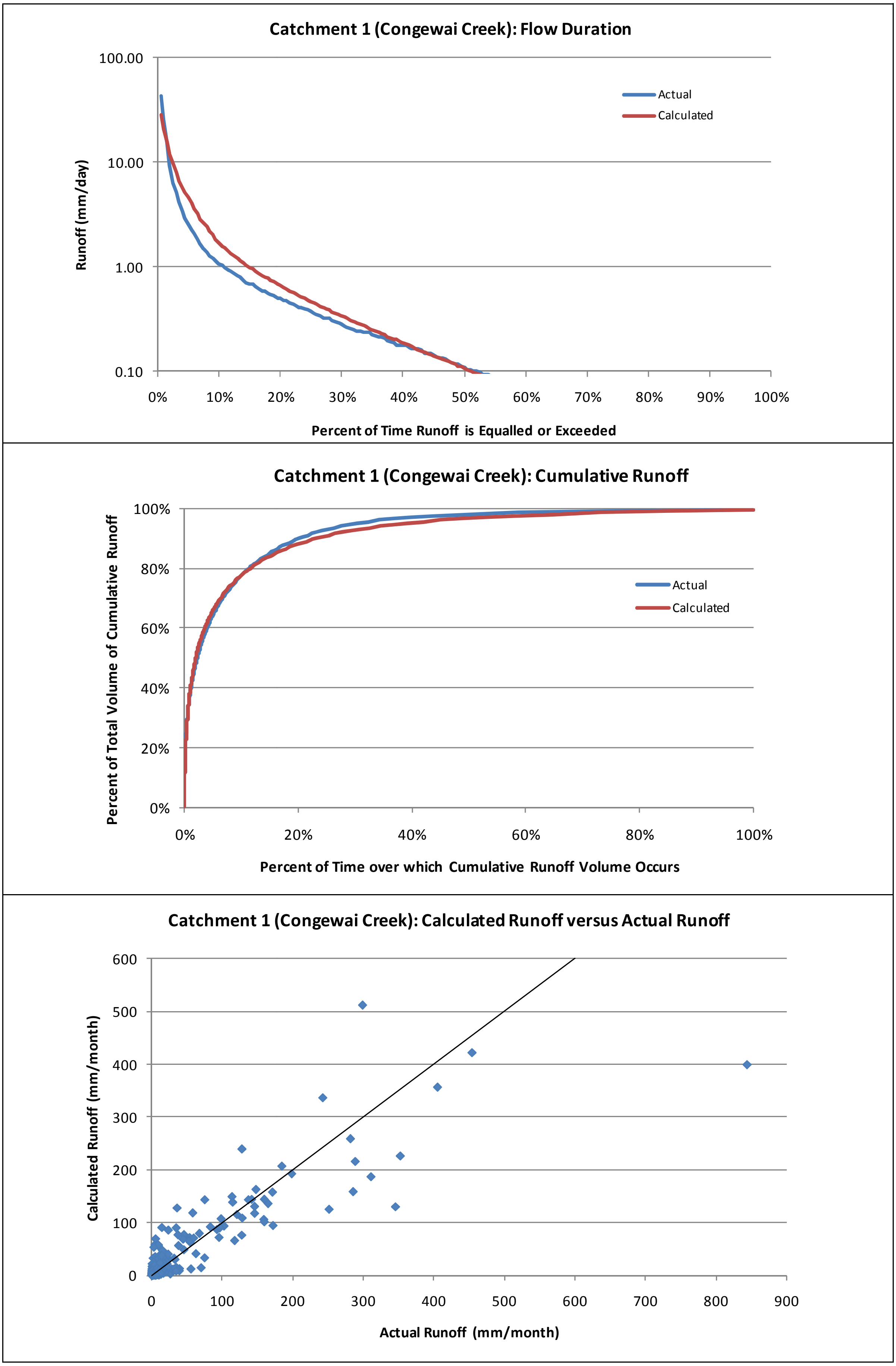
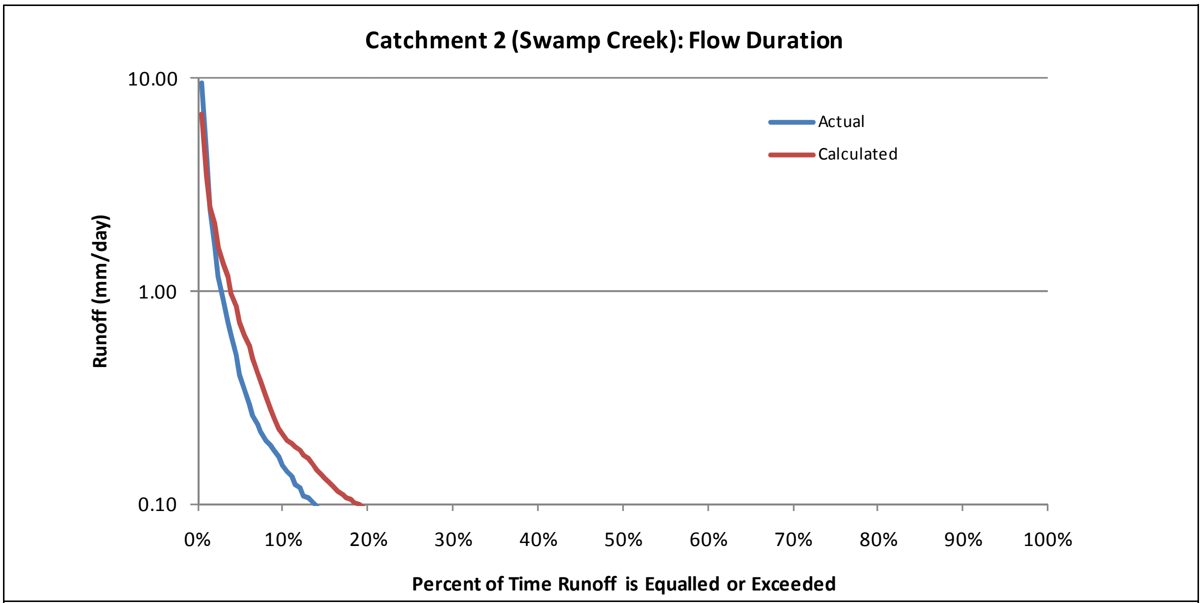
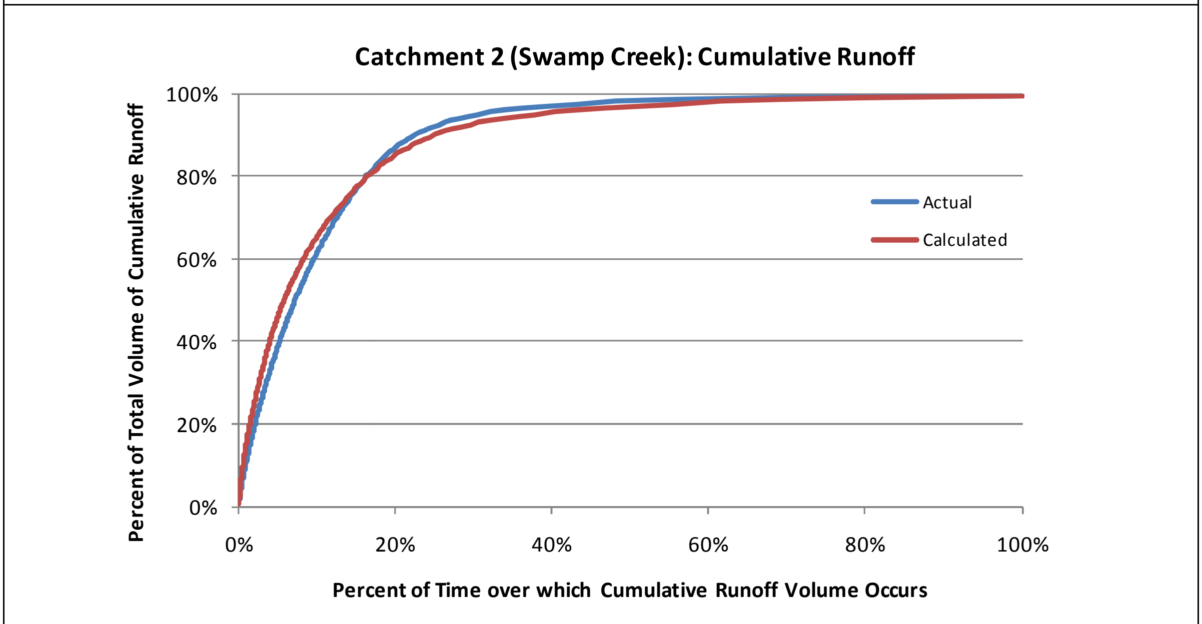


Figure 19: Modelling Results for Catchment 1 (Congewai Creek 210026)





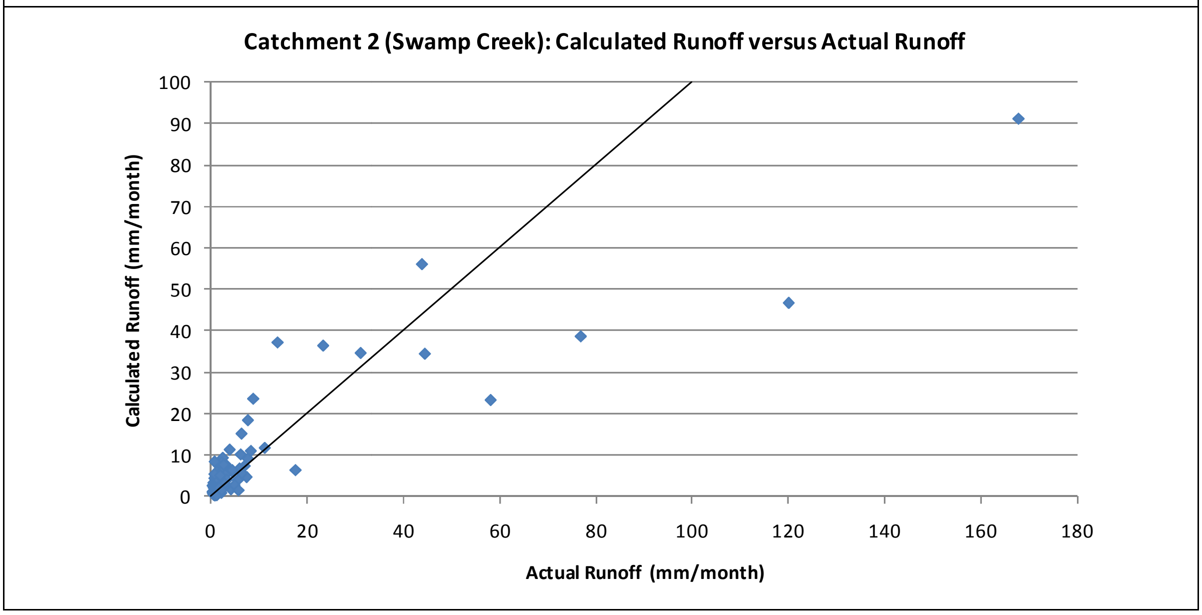


Figure 20: Modelling Results for Catchment 2 (Swamp Creek 210053)

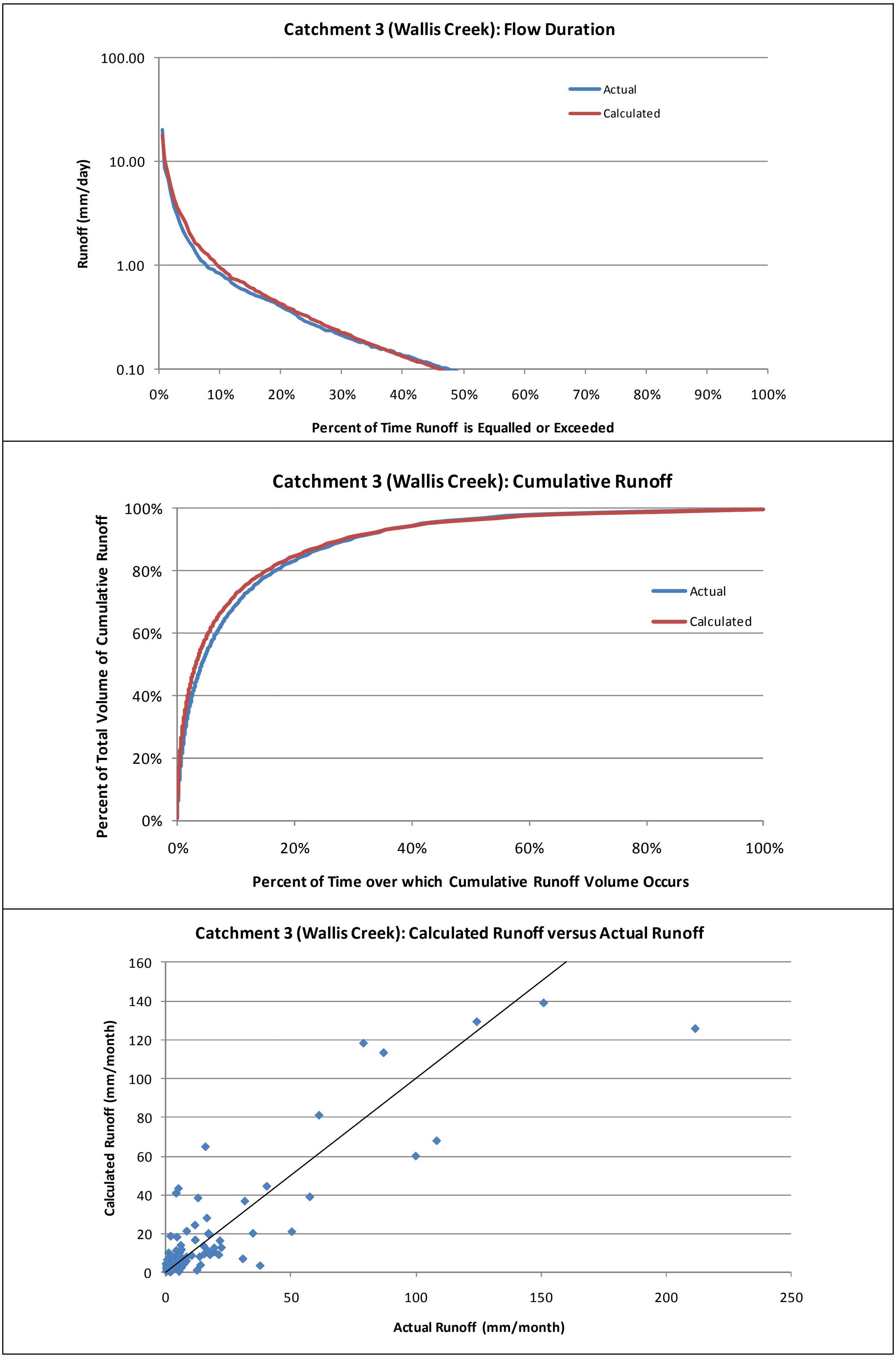
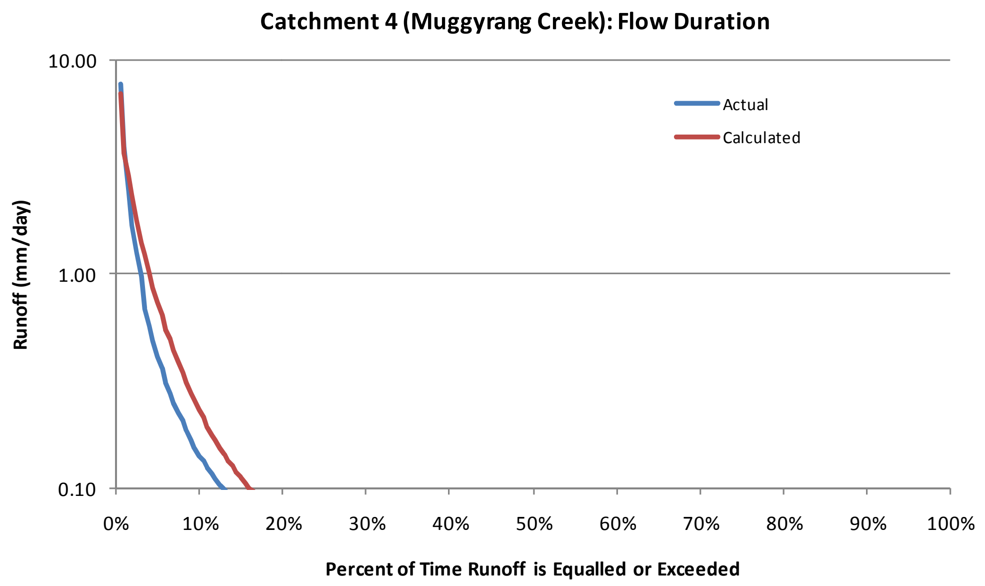
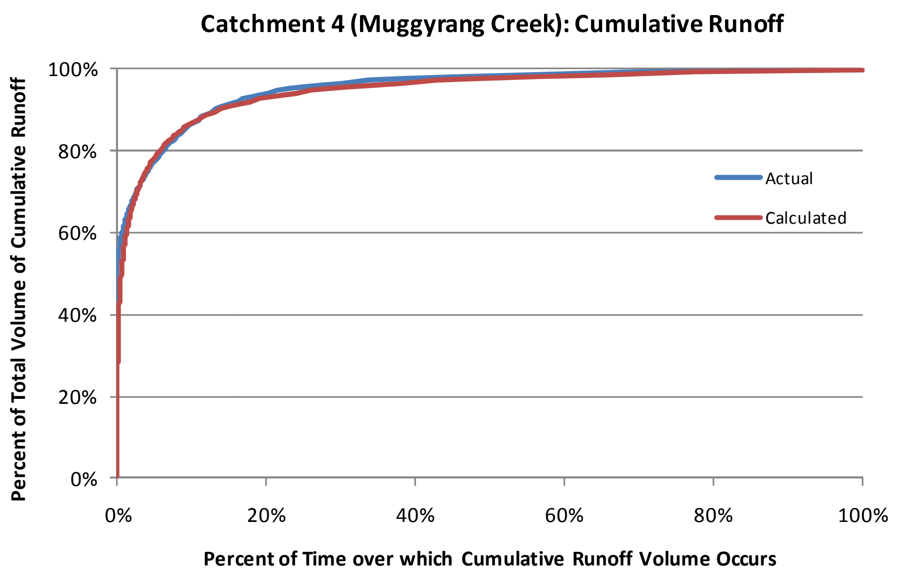


Figure 21: Modelling Results for Catchment 3 (Wallis Creek 210054)





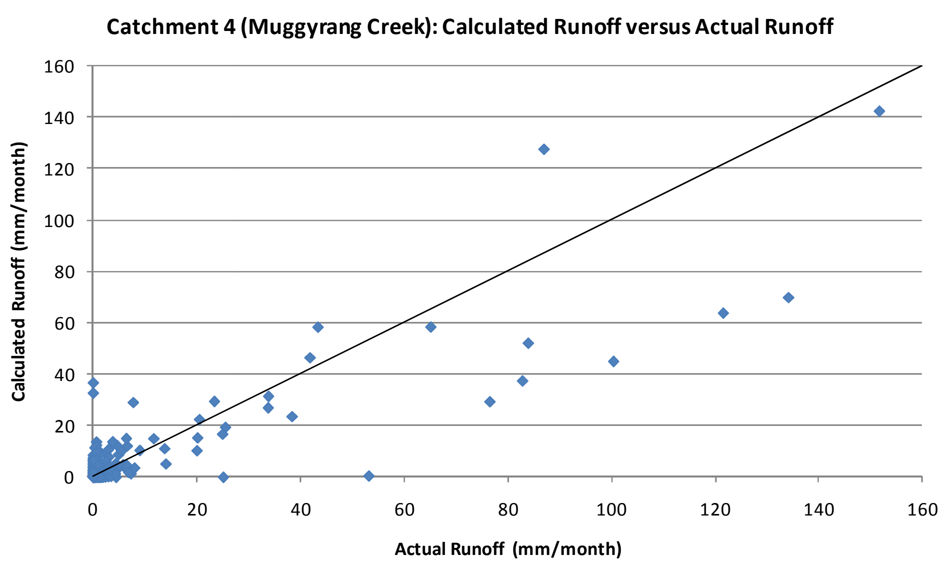
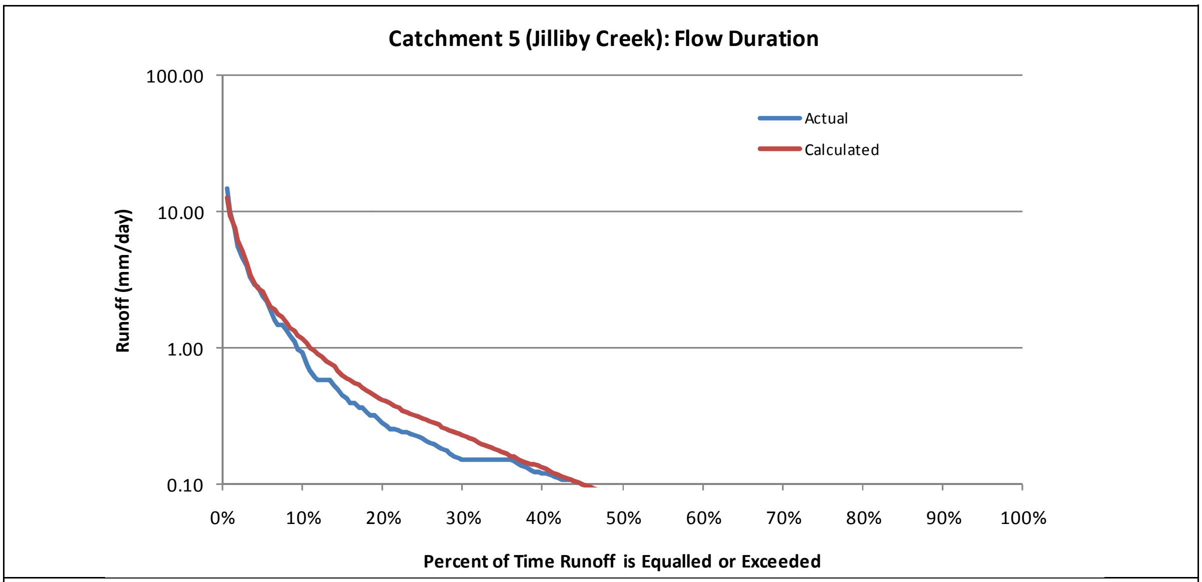
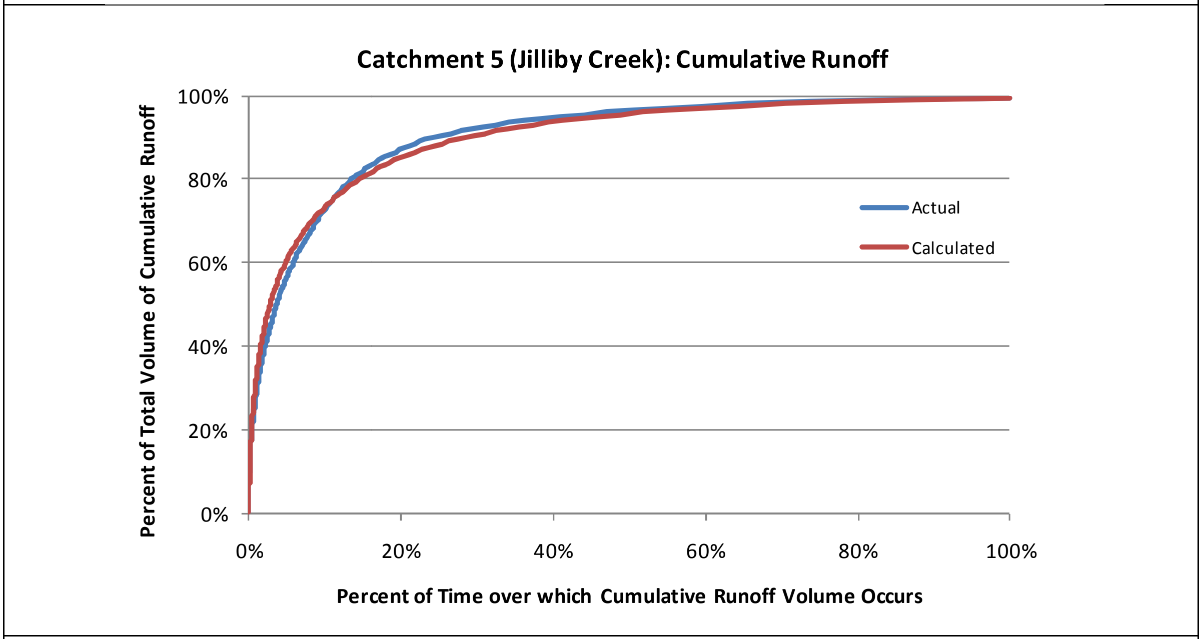


Figure 22: Modelling Results for Catchment 4 (Muggyrang Creek 210069)





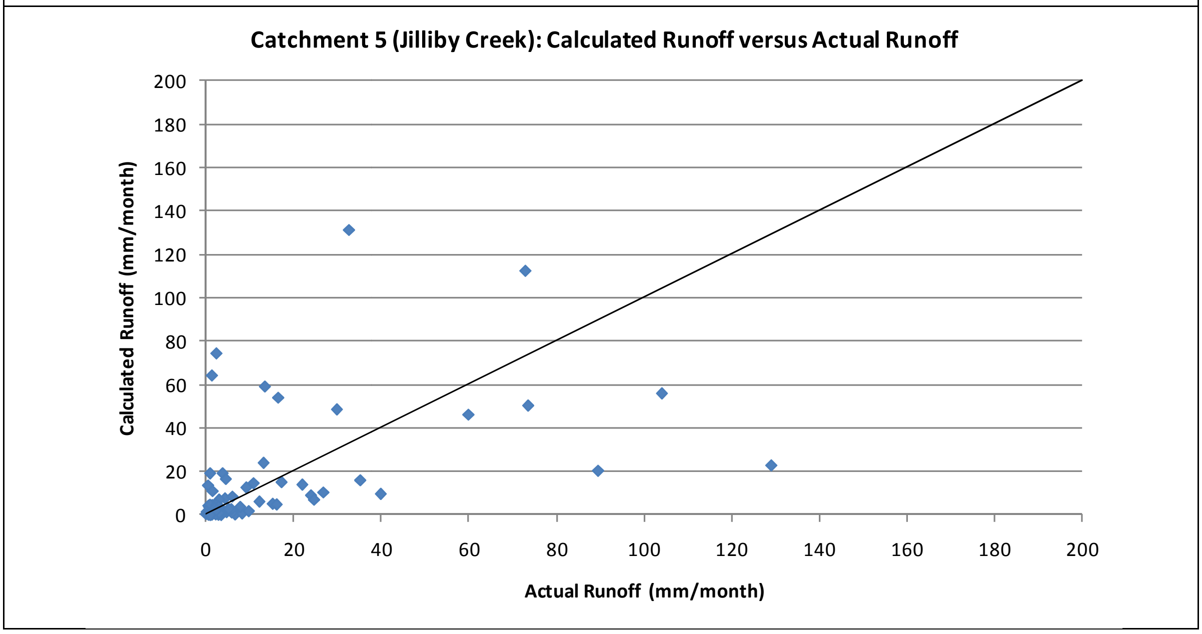


Figure 23: Modelling Results for Catchment 5 (Jilliby Creek 211004)

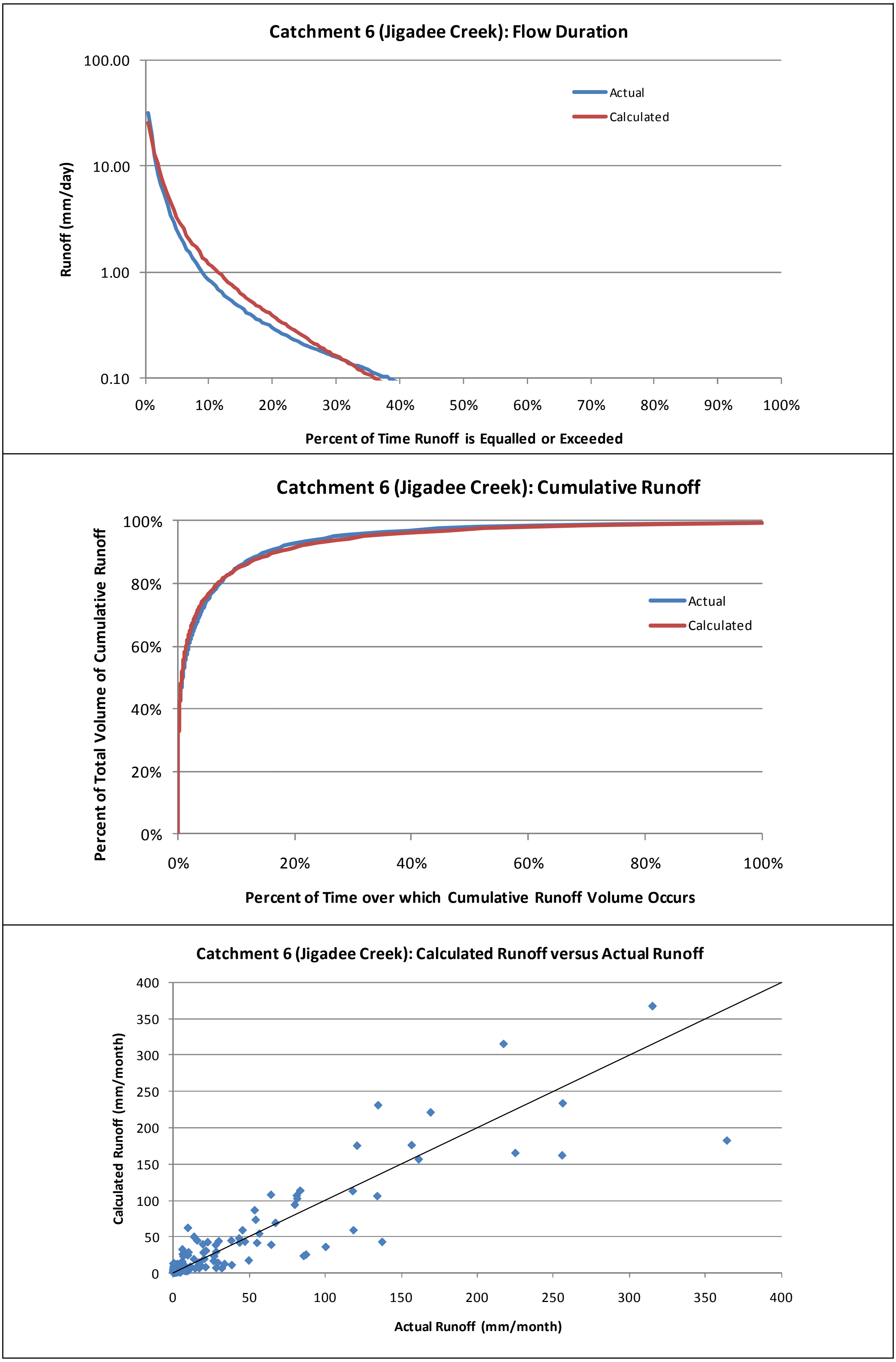


Figure 24: Modelling Results for Catchment 6 (Jigadee Creek 211008)

Annexure 1C: Adopted Modelled and Published AWBM Parameters and Annual Rainfall and Runoff

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Adopted Modelled AWBM Parameters and Published AWBM Parameters

Source	Tasman Extension Project						E&P Project	Boughton (2010)		
Creek	Congewai Creek	Swamp Creek	Wallis Creek	Muggyrang Creek	Jilliby Creek	Jigadee Creek	Kingdon Ponds	Ourimbah Creek	Wyong R @ Yarramalong	Foy Brook
Station No	210026	210053	210054	210069	211004	211008	210093	211013	211014	211042
Area (km^2)	83	83	95	5	8	55	177	83	181	170
Cal Start	1948	1960	1959	1965	1962	1974	1973			
Cal End	1979	1971	1977	1991	1987	2006	1988			
Years	27	11	8	20	6	16	16			
NB: Only years with complete data used between Period Start and Period End date										
C1 =	4.6	10.3	2.9	11.9	41.3	10.1	12	*9.4*	*9.8*	*9.1*
C2 =	47.1	104.4	29.0	121.4	419.1	103.1	122	*95*	*99*	*92*
C3 =	94.2	208.8	57.9	242.8	838.2	206.2	245	*191*	*198*	*184*
A1 =	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134
A2 =	0.433	0.433	0.433	0.433	0.433	0.433	0.433	0.433	0.433	0.433
A3 =	0.433	0.433	0.433	0.433	0.433	0.433	0.433	0.433	0.433	0.433
BFI =	0.210	0.180	0.250	0.250	0.280	0.160	0.22	0.25	0.33	0.25
K_{base} =	0.950	0.992	0.943	0.890	0.965	0.930	0.991	0.981	0.993	0.978
K_{surf} =	0.520	0.280	0.450	0.050	0.600	0.350	0.48			
Rf =	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Ef =	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Ave Cap *(ref)*	61.8	137.0	38.0	159.3	550.0	135.3	161	*125*	*130*	*121*
Rainfall (mm/y)	1,117	772	844	761	1,348	1,149	715	1,230	1,078	771
Runoff (mm/y)	397	78	215	79	205	315	53	331	223	95
Evap (mm/y)	1,407	1,392	1,405	1,355	1,421	1,415		1,343	1,346	1,337
Runoff%	36%	10%	25%	10%	15%	27%	7.4%	27%	21%	12%

(Data in italics assumed or calculated from published data)

Rainfall and Runoff for Modelled Catchments and Published Catchments

Creek	No.	Area (km^2)	Rainfall (mm/y)	Runoff (mm/y)	Source
Congewai Creek	210026	83	1,117	397	Tasman Calibration
Swamp Creek	210053	83	772	78	Tasman Calibration
Wallis Creek	210054	95	844	215	Tasman Calibration
Muggyrang Creek	210069	5	761	79	Tasman Calibration
Kingdon Ponds	210093	177	715	53	E&P Project
Jigadee Creek	211008	55	1,149	315	Tasman Calibration
Ourimbah Creek	211013	83	1,230	331	Boughton (2010)
Wyong R @ Yarram'lng	211014	181	1,078	223	Boughton (2010)
Foy Brook	211042	170	771	95	Boughton (2010)
Mangrove Creek	212039	104	1,083	180	E&P Project

Annexure 1D: Available Data Periods

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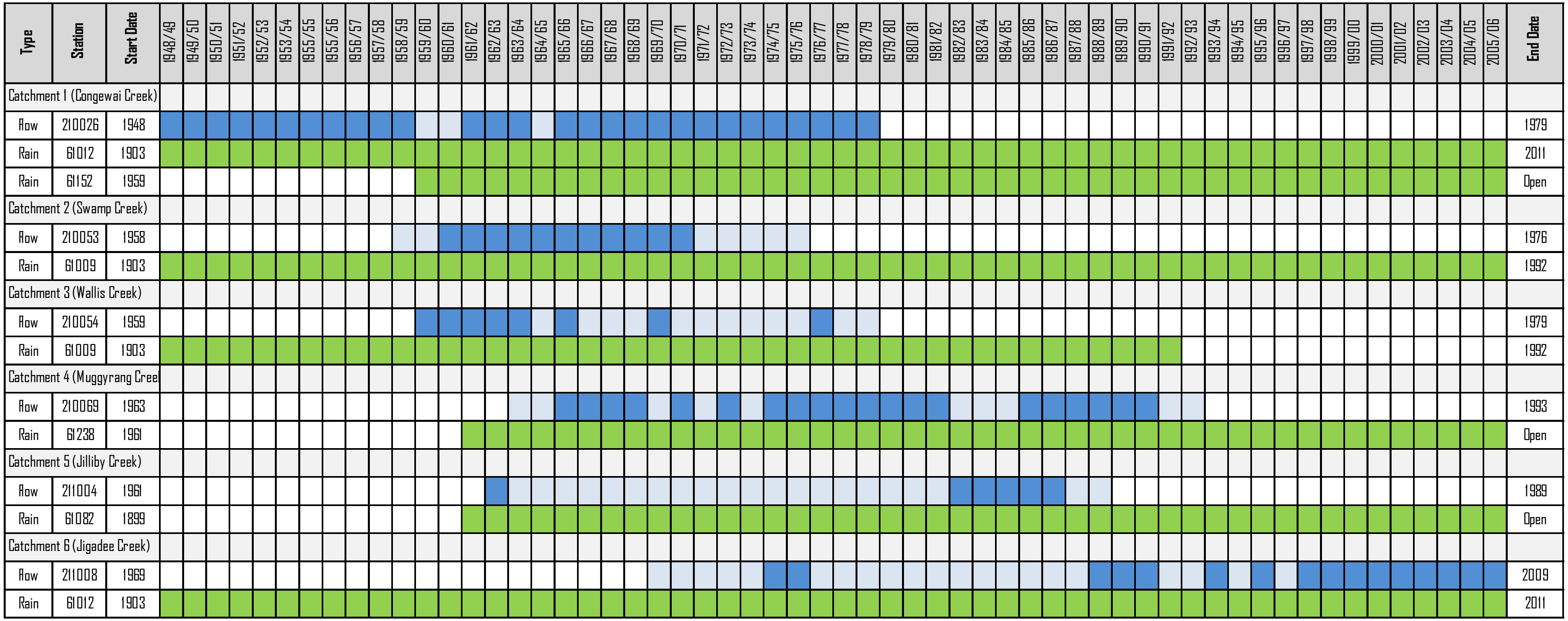
Bar Chart of Available Data and Selected Period



Legend

- Incomplete year of flow data
- Complete year of flow data
- Year of rainfall data (Refer to Table 4 for % completeness)

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Appendix 2: Surface Water Quality Data

Donaldson Coal Pty Ltd

Surface Water Assessment for the Tasman Extension Project Area

Appendix 2: Surface Water Quality Data

April 2012

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Table of Contents

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1 INTRODUCTION

This appendix provides a compendium and analysis of water quality data collected from various creeks and other water bodies in the vicinity of the existing Tasman Mine and the proposed Tasman Extension Project.

A total of twelve (12) monitoring sites have been monitored by Donaldson Coal to gather water quality data from around the existing Tasman Mine and Tasman Mine Extension areas since 2007. These monitoring sites are predominantly located along Blue Gum Creek and Surveyors Creek.

A limited amount of additional water quality data has also been obtained from:

- Two monitoring sites on Wallis Creek (into which Surveyors Creek flows). This data was monitored by the predecessors of New South Wales Office of Water (NOW) and includes generally intermittent and ad-hoc sampling dating from 1972 to 2006, and
- Five sites that have been monitored at monthly intervals since July 2010 in connection with the construction of the Hunter Expressway for Roads and Maritime Services (RMS) of NSW (formerly RTA). This dataset includes sites on Blue Gum Creek, Surveyors Creek and Wallis Creek.

1.1 Monitoring Locations

Figure 1 is a map that shows the locations of water quality monitoring sites in the immediate vicinity of the existing Tasman Mine and the proposed Tasman Extension project. **Figure 2** covers a larger area than **Figure 1** showing monitoring sites further downstream as well as those shown on **Figure 1**. On both figures the monitoring sites have been labelled according to the following colour code:

- **Black** – Donaldson Coal monitoring sites,
- **Blue** – NOW monitoring sites, and
- **Red** – RMS monitoring sites.

1.1.1 Donaldson Coal Monitoring Sites

As shown in **black** on **Figure 1** and **Figure 2**, the locations of the Donaldson Coal monitoring sites are primarily at the headwaters along:

- Blue Gum Creek and its tributaries (generally flowing in a north-easterly direction); and
- Tributaries of Surveyors Creek (located north and west of the existing Tasman Mine, generally flowing in a northerly direction).

The naming of the Blue Gum Creek and Surveyors Creek tributaries follows that set out in Figure 4 of the *Surface Water Assessment* main report (from the *Fluvial Geomorphology Assessment* [Fluvial Systems, 2011]).

Table 1 lists the relevant monitoring sites that have been monitored by Donaldson Coal and provides a brief description of the upstream catchment characteristics.

Table 1: Donaldson Coal Monitoring Sites

	Site	Location	Catchment Characteristics
Surveyors Creek	Site 2	Surveyors Creek, near intersection of George Booth Drive and John Renshaw Drive	- Predominantly cleared rural land upstream for about 3 km upstream to Site 4
	Site 3	Surveyors Creek, Tributary S2E at headwaters	- Steep forested headwaters catchment. - Minimal or no human influence.
	Site 4	Surveyors Creek, Tributary S2 at George Booth Drive	- Mixture of steep headwaters and lower slope valley fill. - Possible influence form rural residential areas along Sheppard's Drive.
	Site 5	Surveyors Creek, Tributary S1C at George Booth Drive	- Mixture of steep headwaters and flatter-slopes on valley fill material. - Minimal human influence.
	Site 6	Surveyors Creek, Tributary S1B at George Booth Drive	- Mixture of steep headwaters and flatter-slopes on valley fill material. - Minimal human influence. - Drains the area proposed for Tasman Extension pit-top facilities.
Blue Gum Creek and Tasman Mine	BG1	Blue Gum Creek, downstream of George Booth Drive	- Predominantly steep headwaters. - Influence from Tasman Mine pit-top and runoff from George Booth Drive. - Slightly downstream of George Booth Drive.
	BG2/3	Blue Gum Creek headwaters upstream of Tasman Mine	- Steep forested headwaters. - Minimal or no human influence. - Generally, BG3 - slightly upstream of BG2 - only used when BG2 is dry.
	Site 7	Blue Gum Creek headwaters upstream of Tasman Mine	- Steep headwaters. - Forested catchment. - Minimal or no human influence.
	Site 8	Blue Gum Creek tributary, upstream of George Booth Drive	- Predominantly steep headwaters. - Crossed by Tasman Mine entrance road. - Slightly upstream of George Booth Drive on Tributary 4.
	Site 9	Blue Gum Creek, at Stockrington Road	- Predominantly steep headwaters. - Potential influence from Tasman Mine, George Booth Drive and Daracon Quarry.
	Site 10	Blue Gum Creek, at Dog Hole Road	- Predominantly steep headwaters. - Some rural residential

1.1.2 RMS Monitoring Sites

Water quality has been monitored at least monthly at all locations immediately upstream and downstream of where the Hunter Expressway (currently under construction) crosses significant creeks. In order to avoid any influence from construction, only sites located immediately upstream of any Hunter Expressway crossings have been considered for analysis in this report. These sites are shown in **red** on **Figure 1** and **Figure 2**, and are designated by the following RMS names:

- BGC(U) Blue Gum Creek, Upstream,
- SC1(U) Surveyors Creek 1, Upstream (located on Tributary S1),
- SC2(U) Surveyors Creek 2, Upstream (located on Tributary S1),
- SC3(U) Surveyors Creek 3, Upstream, and
- WC(U) Wallis Creek, Upstream.

1.1.3 NOW Monitoring Sites

Water quality data has been obtained from NOW for two historic monitoring sites located on Wallis Creek. The locations of these sites are included in **blue** on **Figure 1** and **Figure 2**. These monitoring sites are both located along Wallis Creek and are designated as follows:

- WC-RV (NOW Station No. 210054) located on Wallis Creek at Richmond Vale about 2.8 km west of the north-west corner of the area which is proposed to be mined for the Tasman Extension Project. The monitoring site is located about 1 km upstream of the junction with a small un-named tributary which conveys overflow from the 'Colliery Dam' (see **Figure 2**).
- WC-LP (NOW Station No. 21010197) located on Wallis Creek at Louth Park near to the New England Highway (approximately 15 km downstream of site WC-RV – not shown on **Figure 2)**.

1.2 Water Quality Monitoring Parameters

1.2.1 Basic Parameters

The following 'basic parameters' have been monitored at each of the Donaldson Coal monitoring sites (see **Table 1**) on a monthly basis since June 2007, except for occasions when there was no water at a site or no access to the site:

- Electrical conductivity (EC), (µS/cm) - both the 'field' and 'laboratory' (used as a measure of salinity);
- pH - both the 'field' and 'laboratory';
- Total Suspended Solids (TSS), (mg/L);
- Total Dissolved Solids (TDS), (mg/L); and
- Turbidity, (NTU - Nephelometric Turbidity Units).

1.2.2 Dissolved Oxygen

No monitoring of dissolved oxygen was conducted at any Donaldson Coal monitoring sites, nor at any NOW monitoring sites. Limited data was available at RMS monitoring sites.

1.2.3 Metals

Monitoring of metals has only been conducted at Donaldson Coal monitoring sites BG1/2/3 and Site 9. These metals include aluminium, cadmium, chromium, copper, iron, lead, magnesium, manganese and zinc.

1.2.4 Others

In addition to these parameters, water samples were analysed from Donaldson Coal monitoring sites for a suite of anions, cations and other characteristics on a monthly basis for sites in the immediate vicinity of the Tasman Mine (i.e. BG1/2/3) and quarterly at other monitoring sites.

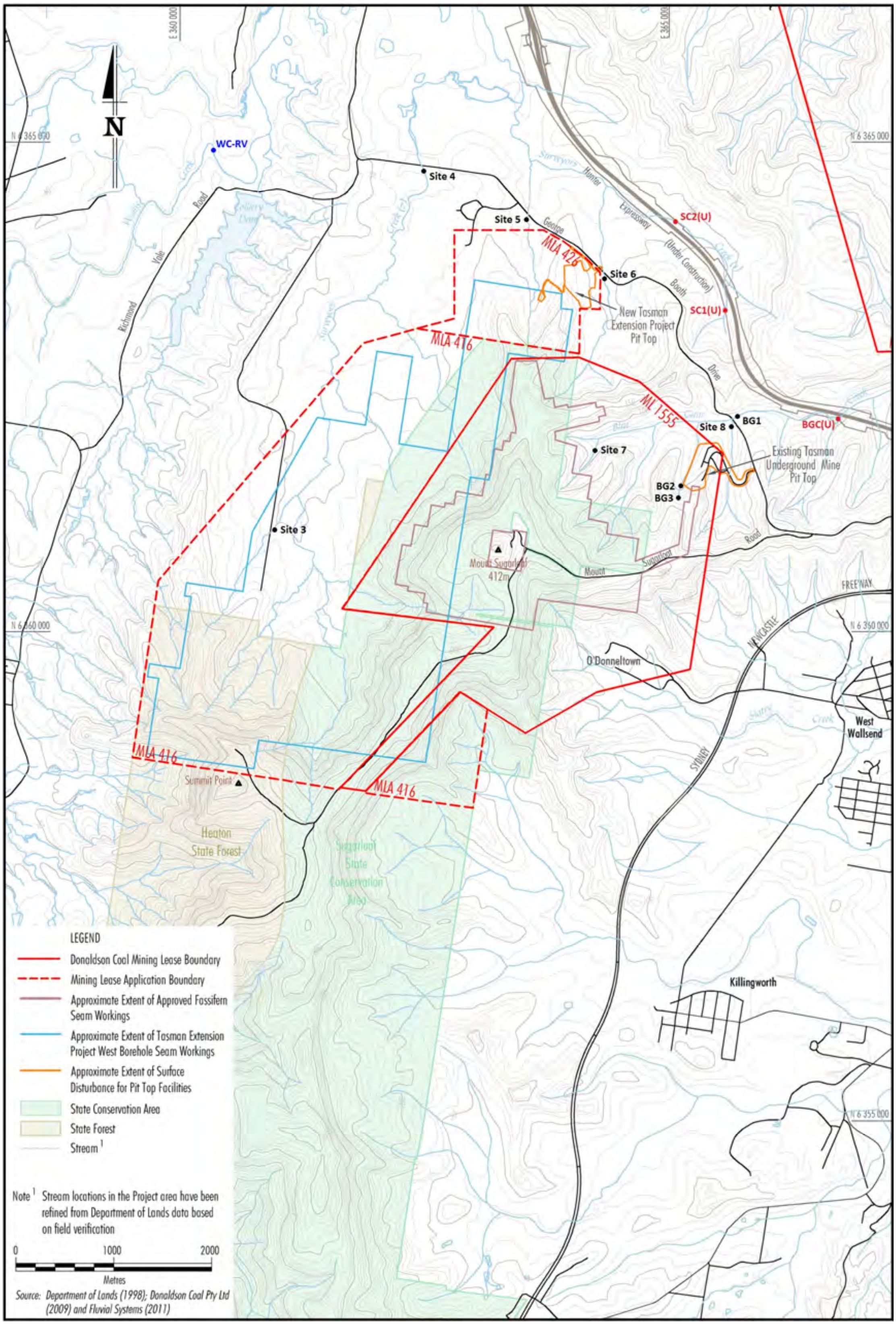

Figure 1: Tasman Mine Site, Tasman Extension Project Area and Surrounding Monitoring Sites

Figure 2: Broad Scale Plan Showing the Tasman Mine Site (Lower Centre) and Surrounding Monitoring Sites

1.3 Data Availability

1.3.1 Basic Parameters

Table 2 provides the number of available 'basic parameter' data entries from each of the twelve Donaldson Coal monitoring site datasets (November 2006 to December 2011).

Table 2: Basic Parameter Data Availability
(November 2006 - December 2011)

Monitoring Site	**EC** (field)	**pH** (field)	TSS	TDS	Turbidity
BG1	52	52	36	52	36
BG2	14	15	15	15	14
BG3	12	12	12	12	12
Site 2	43	43	44	44	43
Site 3	50	50	51	51	50
Site 4	42	42	42	43	42
Site 5	19	19	20	20	20
Site 6	34	34	35	35	35
Site 7	32	32	33	33	32
Site 8	45	45	46	46	45
Site 9	34	34	35	35	34
Site 10	47	47	48	48	47

1.3.2 Dissolved Oxygen

Table 3 provides the number of available dissolved oxygen data entries from each of the five (5) RMS monitoring site datasets (July 2010 to July 2011).

Table 3: Dissolved Oxygen Data Availability

Monitoring Site	Number of data
BGC(U)	16
SC1(U)	5
SC2(U)	8
SC3(U)	13
WC(U)	17

1.3.3 Metals

Table 4 provides the number of available metal data entries from each of the Donaldson Coal monitoring site datasets (November 2006 to December 2011).

Table 4: Metal Data Availability

Monitoring Site	Al (mg/L)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Mg (mg/L)	Mn (mg/L)	Zn (mg/L)
BG1	14	14	14	14	15	14	3	14	14
BG2	4	4	4	4	4	4	1	4	12
BG3	4	4	4	4	4	4	0	4	3
Site 2	No data								
Site 3	No data								
Site 4	No data								
Site 5	No data								
Site 6	No data								
Site 7	No data								
Site 8	No data								
Site 9	0	0	0	0	0	0	0	0	4
Site 10	No data								

Al = Aluminium   Cd = Cadmium   Cr = Chromium   Cu = Copper   Fe = Iron

Pb = Lead   Mg = Magnesium   Mn = Manganese   Zn = Zinc

2 DATA ANALYSIS

2.1 Donaldson Coal Monitoring Sites - Statistics

2.1.1 Basic Parameters

Table 5 summarises the key statistics for the 'basic parameters' measured at each of the twelve (12) Donaldson Coal monitoring sites (listed in the same order as in **Table 1**). Further details are contained in **Table 9** to **Table 20** in **Annexure 2A**. Annual statistics for EC (field), pH (field) and TSS are also shown graphically in **Figure 3** to **Figure 8**, with sites grouped in a similar order to the listing in **Table 1**, namely:

- Surveyors Creek: Sites 2 – 6;
- Blue Gum Creek and its tributaries: BG1 – 3 and Sites 7 - 10.

In these figures, the coloured bars represent one standard deviation above and below the mean (the mean being represented at the point where coloured bars join) while the black 'arms' represent the maximum and minimum. The numbers provided in the x-axis in parentheses indicate the number of measurements recorded for each data series.

2.1.2 Metals

Table 6 summarises the key statistics for metals at each of the twelve (12) Donaldson Coal monitoring sites and compares them against the default ANZECC trigger values for the 95th percentile level of protection.

2.2 RMS Monitoring Sites - Statistics

Monitoring at RMS sites appears to have only been undertaken at locations where construction work was being conducted or scheduled to commence shortly. Accordingly, there are differences in the numbers of records at different sites with the earliest record being July 2010.

Key statistical values for the available 'basic parameters' measured at the various RMS monitoring sites are summarised in **Table 8** while further details are provided in **Table 21** to **Table 25** in **Annexure 2A**

2.2.1 Dissolved Oxygen

Table 7 summarises the key statistics for dissolved oxygen measured at each of the five RMS monitoring sites and compares them against the default ANZECC trigger range for Southeast Australian lowland rivers.

Table 5: Statistical Summary for Basic Water Quality Parameters – Donaldson Coal Monitoring Sites

Site Name		**Site 3**	**Site 7**	**BG3**	**BG2**	**Site 5**	**Site 6**	**Site 8**	**Site 4**	**Site 2**	**BG1**	**Site 9**	**Site 10**	**ANZECC**
Creek Designation[1]		SC	BGC	BGC	BGC	SC	SC	BGC	SC	SC	BGC	BGC	BGC	**Default 'trigger values'** (range)
Catchment Characteristics		Steep forested headwaters	Steep forested headwaters	Steep forested headwaters	Steep forested headwaters	Moderately-sloped headwaters	Moderately-sloped headwaters	Moderately-sloped headwaters	Mixed-steepness	Downstream of headwaters	Moderately-sloped headwaters	Slightly downstream of headwaters	Downstream of headwaters	
Potential for human influence		Minimal human influence							Rural and rural residential		George Booth Drive & Tasman Underground Mine			
EC (field) (µS/cm)	*# Samples*	*50*	*32*	*12*	*14*	*19*	*34*	*45*	*42*	*43*	*52*	*34*	*47*	**125 – 2,200**
	Mean	333	803	698	583	234	365	744	728	590	708	872	1,130	
	20th %ile	216	632	544	161	159	282	606	402	354	510	526	751	
	50th %ile	337	750	705	370	205	369	770	653	530	750	835	1,160	
	80th %ile	415	976	872	1,022	256	411	941	1,018	766	918	1,126	1,410	
pH (field)	*# Samples*	*50*	*32*	*12*	*15*	*19*	*34*	*45*	*42*	*43*	*52*	*34*	*47*	**6.5 – 8.0**
	Mean	6.6	7.2	6.9	7.0	7.0	7.4	7.2	6.8	7.1	7.1	7.4	7.3	
	20th %ile	5.9	6.9	7.0	5.8	6.6	6.9	7.0	6.4	6.7	6.8	7.2	7.1	
	50th %ile	6.3	7.2	7.3	7.0	6.9	7.5	7.3	6.7	6.9	7.1	7.5	7.2	
	80th %ile	7.3	7.6	7.5	8.1	7.4	7.9	7.4	7.2	7.3	7.4	7.7	7.4	
Turbidity (NTU)	*# Samples*	*50*	*32*	*12*	*14*	*20*	*35*	*45*	*42*	*43*	*36*	*34*	*47*	**6 – 50**
	Mean	85	68	114	166	142	139	43	60	124	136	76	62	
	20th %ile	34	13	15	12	46	25	9	16	43	16	14	8	
	50th %ile	69	21	25	32	92	49	19	36	70	34	31	22	
	80th %ile	99	61	35	148	128	105	40	84	203	88	89	54	
TSS (mg/L)	*# Samples*	*51*	*33*	*12*	*15*	*20*	*35*	*46*	*42*	*44*	*36*	*35*	*48*	**N/A**
	Mean	22	14	17	12	31	31	12	21	68	35	20	25	
	20th %ile	5	2	7	4	14	6	3	6	26	2	4	4	
	50th %ile	11	7	12	8	21	16	7	12	38	8	8	8	
	80th %ile	34	24	20	21	34	38	18	23	104	25	31	23	
TDS (mg/L)	*# Samples*	*51*	*33*	*12*	*15*	*20*	*35*	*46*	*43*	*44*	*52*	*35*	*48*	**N/A**
	Mean	288	489	414	339	253	289	447	454	368	427	538	685	
	20th %ile	230	366	335	137	173	228	361	275	263	354	392	533	
	50th %ile	275	460	402	232	234	285	467	448	375	432	514	683	
	80th %ile	324	613	500	594	317	354	544	583	450	518	640	809	

Note 1: Creek Designation> BGC = Blue Gum Creek SC = Surveyors Creek WC = Wallis Creek

Table 6: Statistical Summary for Metals

Monitoring Site		Al (mg/L)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Mg (mg/L)	Mn (mg/L)	Zn (mg/L)
BG1	*# Samples*	*14*	*14*	*14*	*14*	*15*	*14*	*3*	*14*	*14*
	Minimum	0.06	0.00005	0.001	0.001	0.54	0.0004	3	0.026	0.006
	Average	0.62	0.00016	0.001	0.003	1.55	0.0013	9	0.104	0.058
	Maximum	1.95	0.00130	0.002	0.008	3.00	0.0030	12	0.280	0.490
BG2	*# Samples*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*
	Minimum	0.25	0.00005	0.001	0.001	0.41	0.0009	3	0.021	0.005
	Average	1.71	0.00010	0.002	0.002	1.16	0.0021	3	0.066	0.105
	Maximum	4.00	0.00017	0.003	0.004	2.70	0.0041	3	0.160	0.470
BG3	*# Samples*	*4*	*4*	*4*	*4*	*4*	*4*	*0*	*4*	*3*
	Minimum	0.07	0.00005	0.001	0.001	1.40	0.0003	-	0.098	0.007
	Average	1.33	0.00009	0.002	0.002	2.85	0.0027	-	0.510	0.010
	Maximum	4.70	0.00021	0.003	0.005	5.80	0.0060	-	1.300	0.017
Site 9	*# Samples*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*4*
	Minimum	-	-	-	-	-	-	-	-	0.095
	Average	-	-	-	-	-	-	-	-	0.644
	Maximum	-	-	-	-	-	-	-	-	1.300
ANZECC 95^{th} %iles		0.055	0.00002	0.001	0.0014		0.0034	1.9		0.008

Table 7: Statistical Summary for Dissolved Oxygen

Monitoring Site	Dissolved Oxygen (% saturated)		
	Minimum	**Average**	**Maximum**
BGC(U)	12	76	130
SC1(U)	56	85	115
SC2(U)	27	58	101
SC3(U)	21	70	96
WC(U)	59	85	118
ANZECC	**85 - 110**		

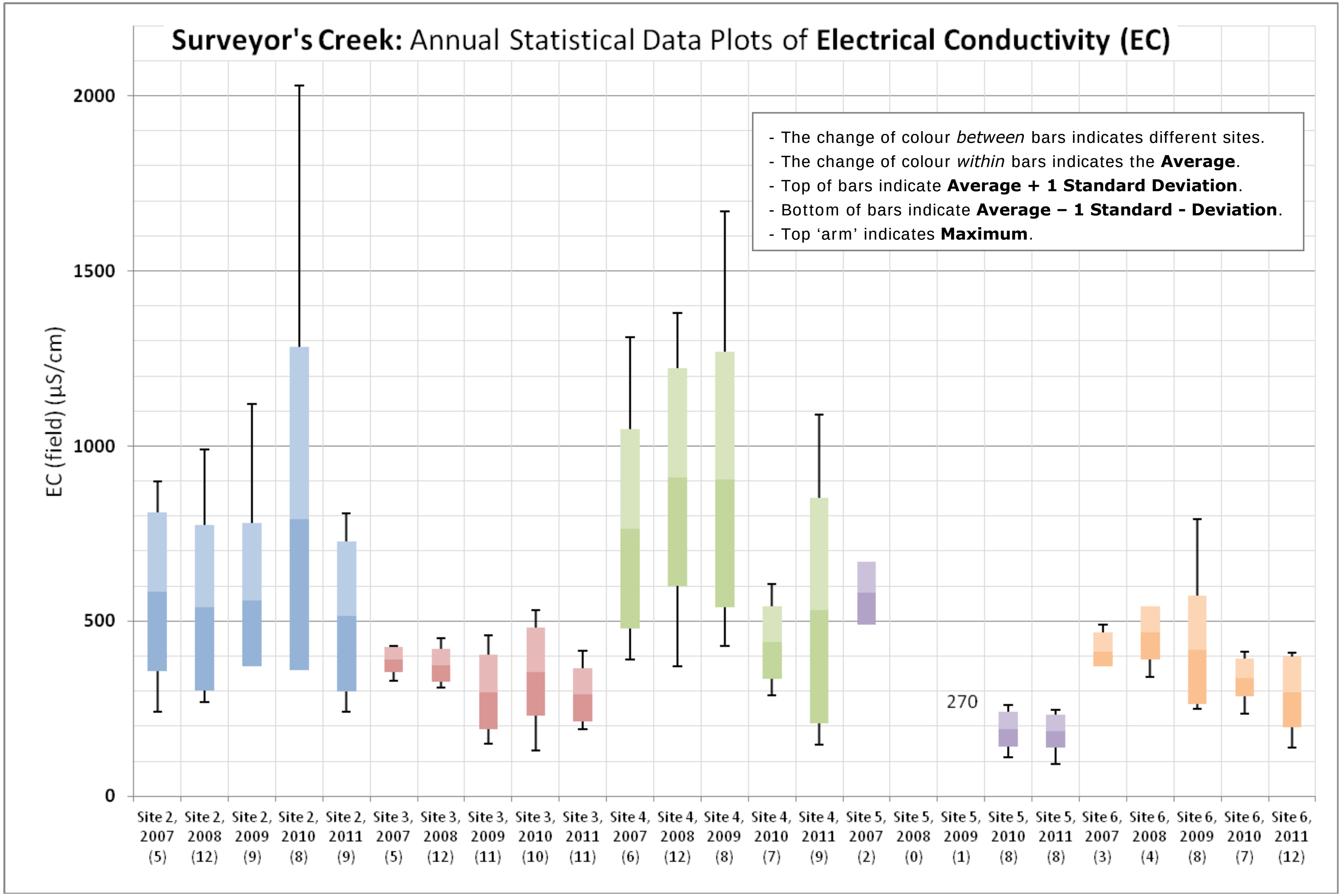

Figure 3: Annual Statistics for EC at Sites on Surveyors Creek

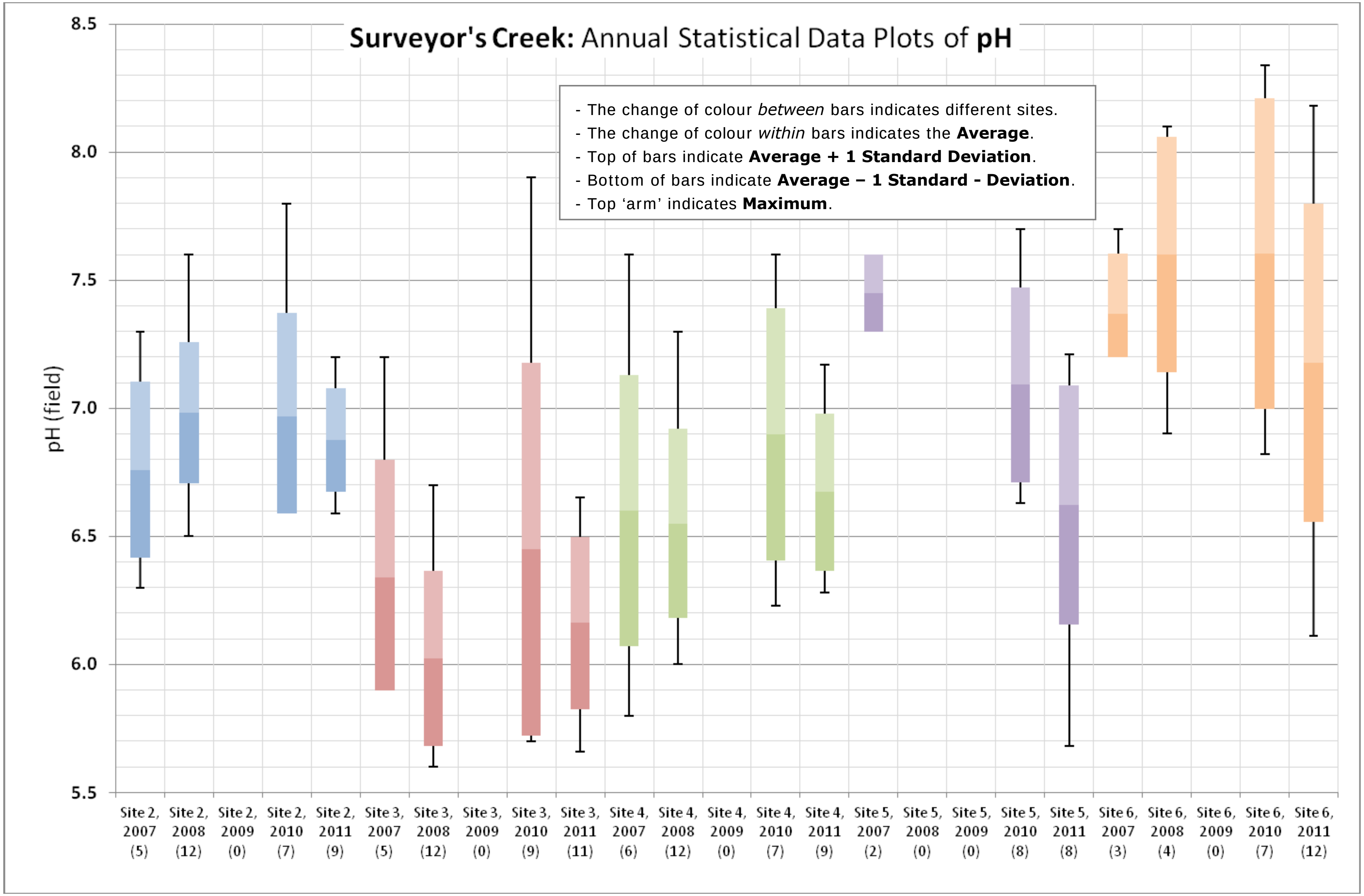

Figure 4: Annual Statistics for pH at Sites on Surveyors Creek

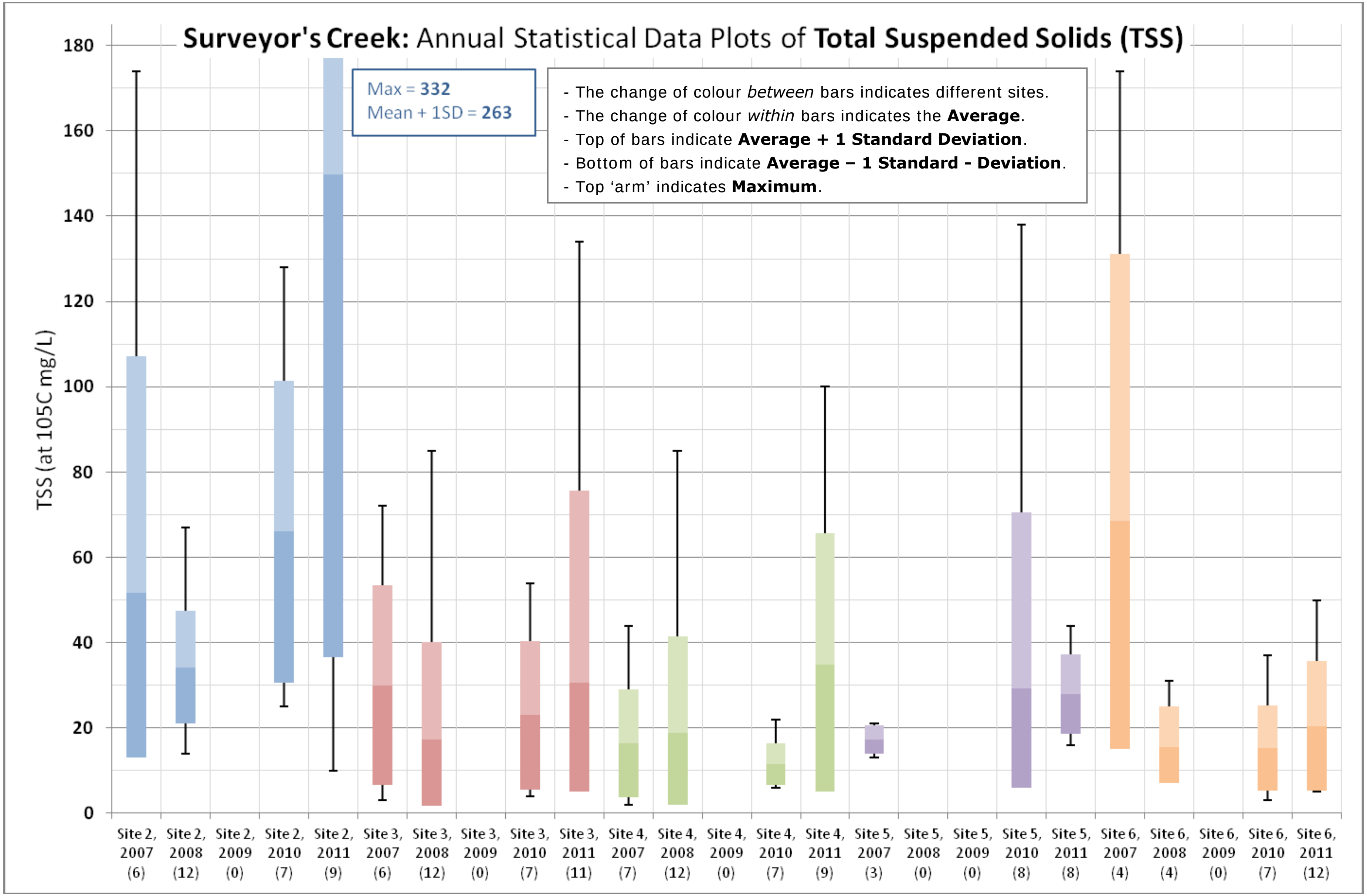

Figure 5: Annual Statistics for TSS at Sites on Surveyors Creek

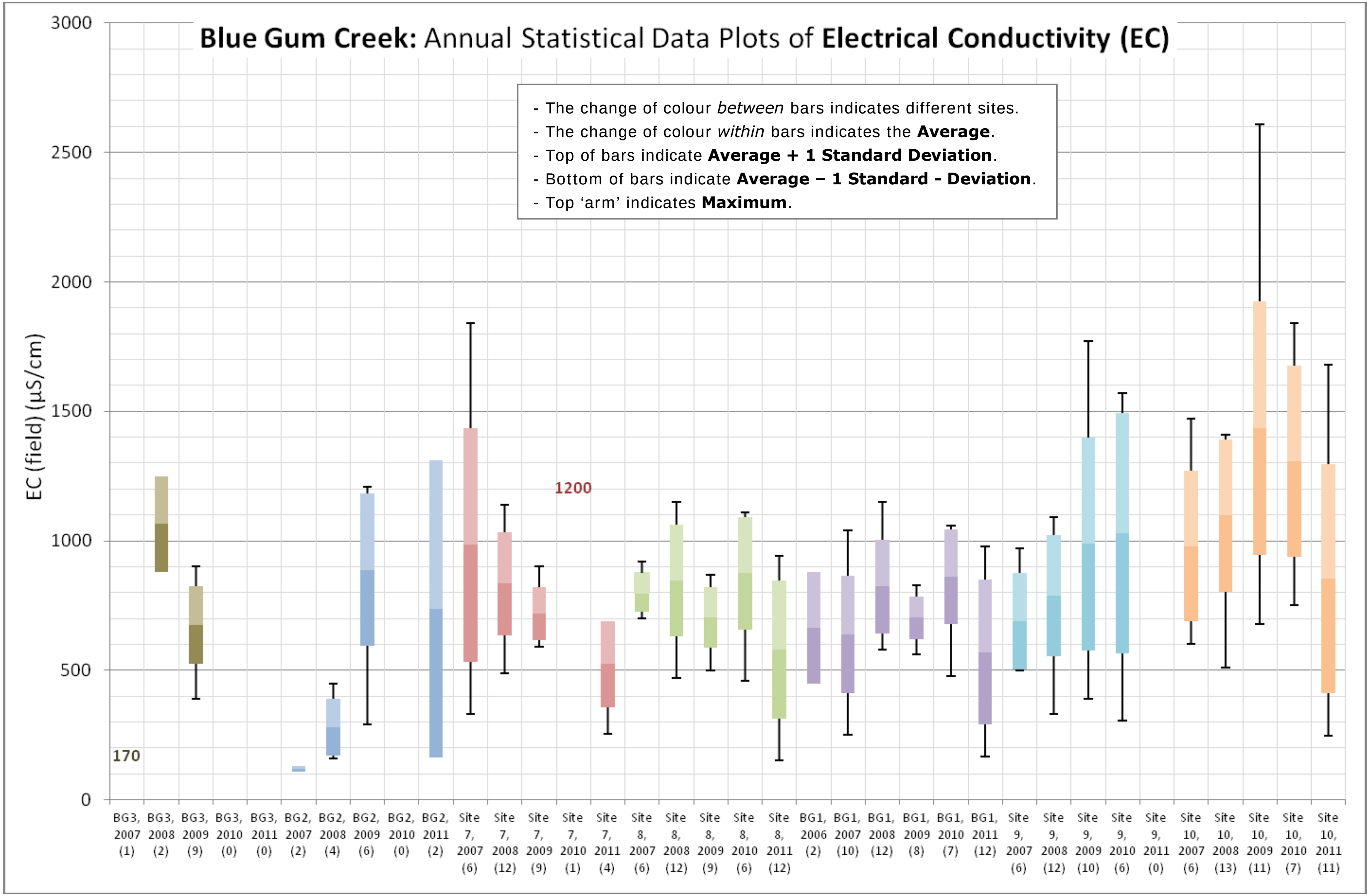

Figure 6: Annual Statistics for EC at Sites on Blue Gum Creek

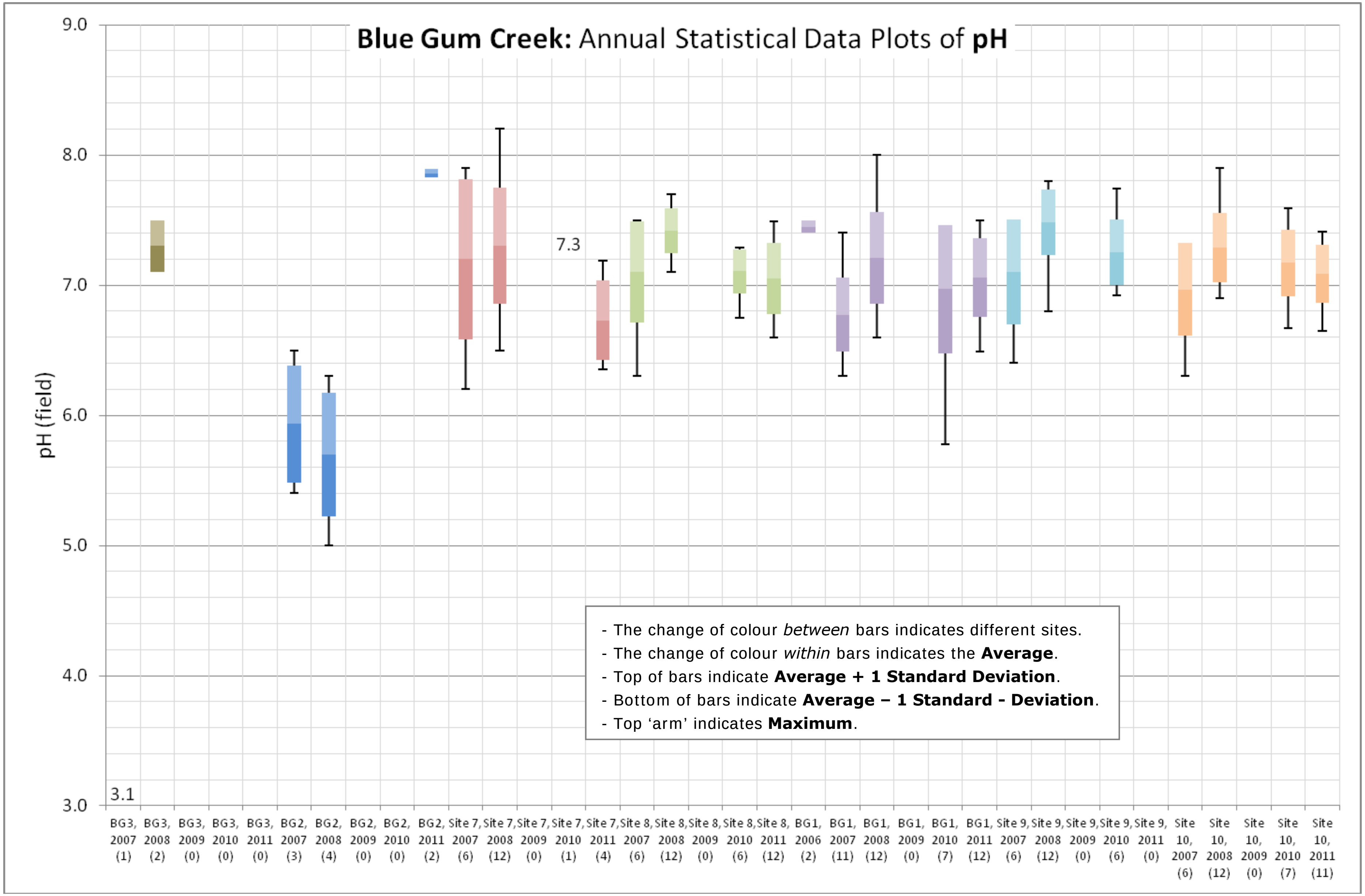

Figure 7: Annual Statistics for pH at Sites on Blue Gum Creek

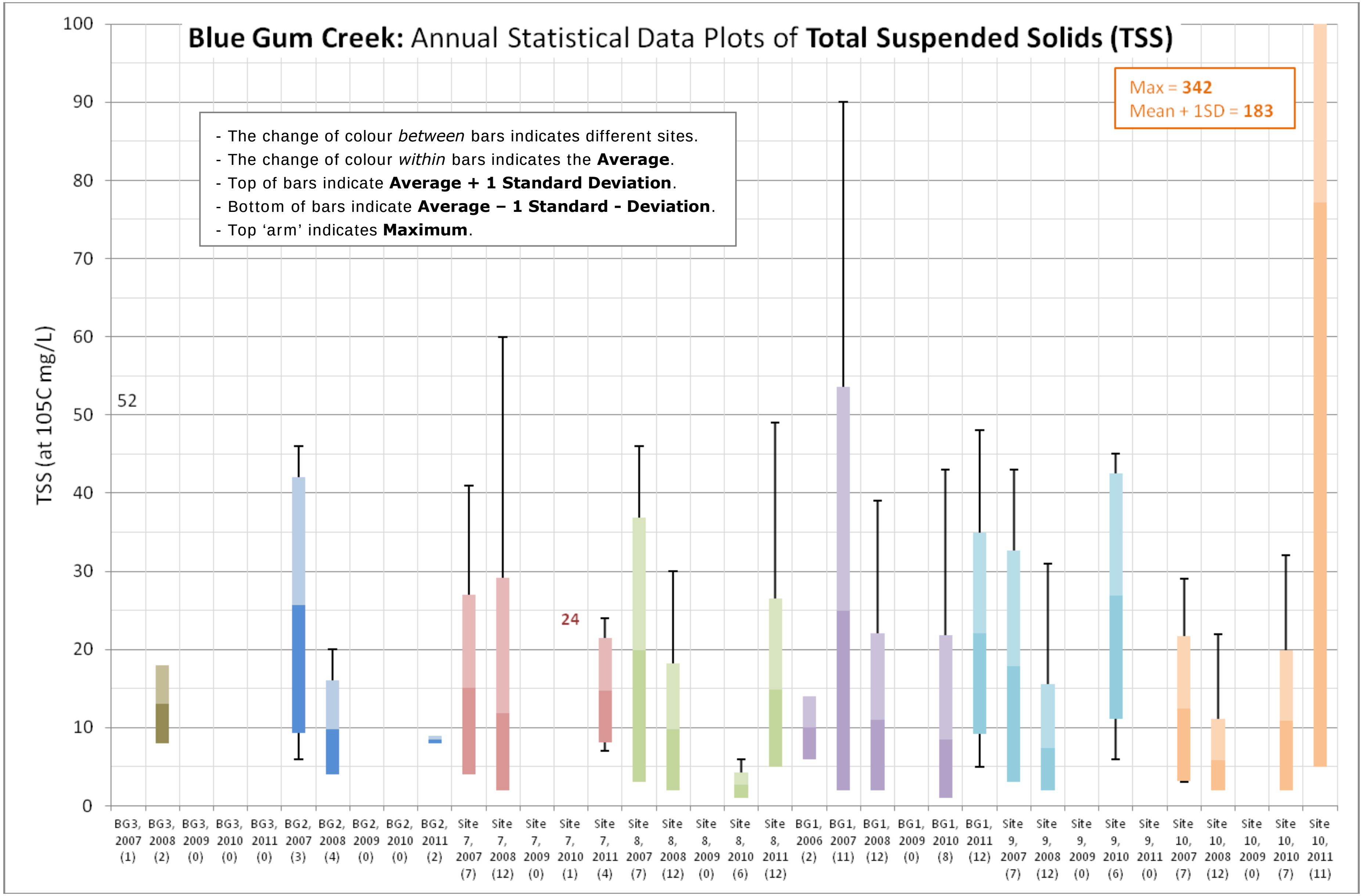

Figure 8: Annual Statistics for TSS at Sites on Blue Gum Creek

2.3 NOW Monitoring Sites - Statistics

Data measurements from the two NOW monitoring sites were fairly limited and the only 'basic parameters' measured at NOW monitoring sites were EC, pH and turbidity.

The most recent records for WC-RV are dated September 1978 (with only 8 data entries for pH and 9 data entries for turbidity measured since recording began on January 1972).

Data records from WC-LP are more recent with some data on a monthly basis from August 1998 to May 2006.

Key statistical values for the available 'basic parameters' measured at WC-RV and WC-LP are summarised in **Table 8** while further details are provided in **Table 26** and **Table 27** in **Annexure 2A**.

Table 8: Statistical Summary for Basic Water Quality Parameters – RMS and NOW Sites

Site Name		SC1(U)	SC2(U)	BGC(U)	SC3(U)	WC-RV	WC(U)	WC-LP	ANZECC
Creek Designation		SC	SC	BG	SC	WC	WC	WC	
Catchment Characteristics		Moderately-sloped headwaters	Moderately-sloped headwaters	Moderately-sloped headwaters	Downstream of headwaters	Large catchment with steep headwaters and low slope valley	Large catchment with steep headwaters and low slope valley	Large catchment with steep headwaters and low slope valley	**Default 'trigger values'** (range)
Potential for human influence		George Booth Drive			Rural and urban (Mulbring)				
				Tasman Underground Mine					
EC (field) (µS/cm)	*# Samples*	*9*	*14*	*21*	*13*	*39*	*19*	*48*	**125 – 2,200**
	Mean	385	770	454	1,046	857	991	915	
	20th %ile	142	309	310	278	646	482	695	
	50th %ile	166	660	499	585	899	661	895	
	80th %ile	650	892	561	716	1,068	769	1,156	
pH (field)	*# Samples*	*9*	*14*	*22*	*13*	*8*	*19*	*40*	**6.5 – 8.0**
	Mean	5.6	6.7	7.1	7.0	7.5	7.2	7.5	
	20th %ile	5.1	6.1	6.8	6.7	7.2	6.9	7.3	
	50th %ile	5.6	6.9	7.0	7.1	7.6	7.3	7.6	
	80th %ile	6.1	7.3	7.5	7.4	7.7	7.7	7.7	
Turbidity (NTU)	*# Samples*	*9*	*14*	*22*	*13*	*9*	*19*	*48*	**6 – 50**
	Mean	257	220	310	270	5	28	63	
	20th %ile	147	10	83	57	2	14	39	
	50th %ile	156	163	177	260	2	23	63	
	80th %ile	319	281	589	472	5	41	91	
TSS (mg/L)	*# Samples*	*4*	*5*	*5*	*0*	*0*	*0*	*0*	**N/A**
	Mean	61	8	29	-	-	-	-	
	20th %ile	26	1	21	-	-	-	-	
	50th %ile	38	3	26	-	-	-	-	
	80th %ile	87	10	43	-	-	-	-	

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Annexure 2A: Water Quality Statistics

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Donaldson Coal Monitoring Sites

Table 9 to **Table 20** provide statistical values calculated from measurements taken from each Donaldson Coal monitoring site.

Table 9: Water quality statistics at BG1

Statistic	**EC** (field) (µS/cm)	**EC** (lab) (µS/cm)	**pH** (field)	**pH** (lab)	**Turbidity** (NTU)	**TSS** (mg/L)	**TDS** (mg/L)
Mean	708	714	7.1	7.0	136	35	427
Standard Deviation	238	211	0.4	0.4	315	141	122
Minimum	165	230	5.8	6.1	6	1	119
10th Percentile	410	461	6.6	6.6	13	2	278
20th Percentile	510	558	6.8	6.7	16	2	354
50th Percentile	750	716	7.1	6.9	34	8	432
80th Percentile	918	842	7.4	7.1	88	25	518
90th Percentile	990	972	7.5	7.5	191	44	590
Maximum	1,150	1,180	8.0	8.0	1,575	1,032	670

Table 10: Water quality statistics at BG2

Statistic	**EC** (field) (µS/cm)	**EC** (lab) (µS/cm)	**pH** (field)	**pH** (lab)	**Turbidity** (NTU)	**TSS** (mg/L)	**TDS** (mg/L)
Mean	583	522	7.0	6.6	166	12	339
Standard Deviation	450	391	1.2	1.4	377	12	240
Minimum	110	115	5.0	5.0	5	2	75
10th Percentile	139	158	5.5	5.3	8	2	93
20th Percentile	161	190	5.8	5.3	12	4	137
50th Percentile	370	280	7.0	5.7	32	8	232
80th Percentile	1,022	944	8.1	8.3	148	21	594
90th Percentile	1,177	984	8.3	8.3	323	25	669
Maximum	1,310	1,200	8.4	8.3	1,425	46	714

Table 11: Water quality statistics at BG3

Statistic	**EC** (field) (µS/cm)	**EC** (lab) (µS/cm)	**pH** (field)	**pH** (lab)	**Turbidity** (NTU)	**TSS** (mg/L)	**TDS** (mg/L)
Mean	698	727	6.9	6.9	114	17	414
Standard Deviation	274	265	1.2	1.1	299	16	148
Minimum	170	190	3.1	3.9	7	2	115
10th Percentile	404	527	6.6	6.5	11	4	329
20th Percentile	544	598	7.0	6.6	15	7	335
50th Percentile	705	705	7.3	7.2	25	12	402
80th Percentile	872	893	7.5	7.6	35	20	500
90th Percentile	898	919	7.6	7.8	86	46	520
Maximum	1,250	1,290	7.7	7.8	1,060	52	745

Table 12: Water quality statistics at Site 7

Statistic	**EC** (field) (µS/cm)	**EC** (lab) (µS/cm)	**pH** (field)	**pH** (lab)	**Turbidity** (NTU)	**TSS** (mg/L)	**TDS** (mg/L)
Mean	803	830	7.2	6.9	68	14	489
Standard Deviation	292	264	0.5	0.4	139	14	177
Minimum	255	345	6.2	6.1	3	2	173
10th Percentile	530	604	6.6	6.4	10	2	334
20th Percentile	632	634	6.9	6.6	13	2	366
50th Percentile	750	778	7.2	6.9	21	7	460
80th Percentile	976	948	7.6	7.2	61	24	613
90th Percentile	1,129	1,109	7.8	7.4	150	31	689
Maximum	1,840	1,750	8.2	7.8	710	60	1,046

Table 13: Water quality statistics at Site 8

Statistic	**EC** (field) (µS/cm)	**EC** (lab) (µS/cm)	**pH** (field)	**pH** (lab)	**Turbidity** (NTU)	**TSS** (mg/L)	**TDS** (mg/L)
Mean	744	795	7.2	7.1	43	12	447
Standard Deviation	235	189	0.3	0.2	112	13	125
Minimum	151	485	6.3	6.6	4	1	108
10th Percentile	465	562	6.8	6.9	6	2	327
20th Percentile	606	613	7.0	6.9	9	3	361
50th Percentile	770	805	7.3	7.0	19	7	467
80th Percentile	941	908	7.4	7.3	40	18	544
90th Percentile	1,001	1,044	7.5	7.3	63	27	589
Maximum	1,150	1,180	7.7	7.6	760	49	665

Table 14: Water quality statistics at Site 9

Statistic	**EC** (field) (µS/cm)	**EC** (lab) (µS/cm)	**pH** (field)	**pH** (lab)	**Turbidity** (NTU)	**TSS** (mg/L)	**TDS** (mg/L)
Mean	872	855	7.4	7.2	76	20	538
Standard Deviation	366	358	0.4	0.2	147	32	183
Minimum	307	350	6.4	6.8	4	2	220
10th Percentile	503	504	6.9	6.9	8	2	356
20th Percentile	526	541	7.2	7.0	14	4	392
50th Percentile	835	850	7.5	7.2	31	8	514
80th Percentile	1,126	1,074	7.7	7.3	89	31	640
90th Percentile	1,377	1,202	7.8	7.4	121	42	768
Maximum	1,770	1,790	8.4	7.6	835	186	1,100

Table 15: Water quality statistics at Site 10

Statistic	**EC** (field) (µS/cm)	**EC** (lab) (µS/cm)	**pH** (field)	**pH** (lab)	**Turbidity** (NTU)	**TSS** (mg/L)	**TDS** (mg/L)
Mean	1,130	1,206	7.3	7.1	62	25	685
Standard Deviation	455	373	0.4	0.2	115	59	200
Minimum	248	600	6.3	6.7	2	2	242
10th Percentile	556	715	6.8	6.8	5	3	441
20th Percentile	751	880	7.1	6.9	8	4	533
50th Percentile	1,160	1,220	7.2	7.2	22	8	683
80th Percentile	1,410	1,430	7.4	7.3	54	23	809
90th Percentile	1,688	1,710	7.6	7.4	144	31	969
Maximum	2,610	2,120	8.5	7.5	545	342	1,200

Table 16: Water quality statistics at Site 2

Statistic	**EC** (field) (µS/cm)	**EC** (lab) (µS/cm)	**pH** (field)	**pH** (lab)	**Turbidity** (NTU)	**TSS** (mg/L)	**TDS** (mg/L)
Mean	590	539	7.1	6.8	124	68	368
Standard Deviation	314	235	0.4	0.3	145	74	122
Minimum	240	240	6.3	6.2	13	2	160
10th Percentile	290	317	6.6	6.5	32	19	230
20th Percentile	354	345	6.7	6.5	43	26	263
50th Percentile	530	483	6.9	6.8	70	38	375
80th Percentile	766	725	7.3	7.2	203	104	450
90th Percentile	833	852	7.8	7.3	316	161	507
Maximum	2,030	1,140	8.5	7.3	795	332	715

Table 17: Water quality statistics at Site 3

Statistic	**EC** (field) (µS/cm)	**EC** (lab) (µS/cm)	**pH** (field)	**pH** (lab)	**Turbidity** (NTU)	**TSS** (mg/L)	**TDS** (mg/L)
Mean	333	341	6.6	6.4	85	22	288
Standard Deviation	99	102	0.9	0.6	84	28	102
Minimum	130	120	5.6	5.6	5	2	100
10th Percentile	189	190	5.7	5.8	24	4	200
20th Percentile	216	279	5.9	6.0	34	5	230
50th Percentile	337	340	6.3	6.2	69	11	275
80th Percentile	415	450	7.3	6.8	99	34	324
90th Percentile	450	470	7.9	7.4	147	42	376
Maximum	530	480	9.8	7.9	465	134	692

Table 18: Water quality statistics at Site 4

Statistic	**EC** (field) (µS/cm)	**EC** (lab) (µS/cm)	**pH** (field)	**pH** (lab)	**Turbidity** (NTU)	**TSS** (mg/L)	**TDS** (mg/L)
Mean	728	829	6.8	6.3	60	21	454
Standard Deviation	360	332	0.5	0.3	87	25	191
Minimum	146	390	5.8	5.5	6	2	160
10th Percentile	352	420	6.3	6.0	11	4	242
20th Percentile	402	540	6.4	6.2	16	6	275
50th Percentile	653	785	6.7	6.3	36	12	448
80th Percentile	1,018	1,154	7.2	6.5	84	23	583
90th Percentile	1,298	1,280	7.4	6.7	118	44	711
Maximum	1,670	1,610	8.0	7.3	550	100	890

Table 19: Water quality statistics at Site 5

Statistic	**EC** (field) (µS/cm)	**EC** (lab) (µS/cm)	**pH** (field)	**pH** (lab)	**Turbidity** (NTU)	**TSS** (mg/L)	**TDS** (mg/L)
Mean	234	349	7.0	6.9	142	31	253
Standard Deviation	135	232	0.7	0.5	167	34	101
Minimum	91	110	5.7	6.0	31	6	135
10th Percentile	129	170	6.4	6.4	41	11	140
20th Percentile	159	230	6.6	6.7	46	14	173
50th Percentile	205	252	6.9	7.1	92	21	234
80th Percentile	256	510	7.4	7.2	128	34	317
90th Percentile	314	625	7.6	7.3	438	51	342
Maximum	670	740	8.9	7.3	565	138	508

Table 20: Water quality statistics at Site 6

Statistic	**EC** (field) (µS/cm)	**EC** (lab) (µS/cm)	**pH** (field)	**pH** (lab)	**Turbidity** (NTU)	**TSS** (mg/L)	**TDS** (mg/L)
Mean	365	417	7.4	7.2	139	31	289
Standard Deviation	123	138	0.6	0.6	271	55	81
Minimum	140	190	6.1	5.8	6	3	130
10th Percentile	214	294	6.8	6.7	17	5	205
20th Percentile	282	346	6.9	6.9	25	6	228
50th Percentile	369	400	7.5	7.2	49	16	285
80th Percentile	411	498	7.9	7.8	105	38	354
90th Percentile	490	522	8.2	7.9	338	48	375
Maximum	790	810	8.3	8.2	1,375	296	470

RMS monitoring sites

Table 21 to **Table 25** provide statistical values calculated from measurements taken from each of the five RMS monitoring sites.

Table 21: Water quality statistics at BGC(U)

BGC(U)	**EC** (µS/cm)	**pH**	**Turbidity** (NTU)	**TSS** (mg/L)
Mean	454	7.1	310	29
Standard Deviation	157	0.4	281	14
Minimum	225	6.3	56	11
10th Percentile	244	6.6	62	16
20th Percentile	310	6.8	83	21
50th Percentile	499	7.0	177	26
80th Percentile	561	7.5	589	43
90th Percentile	654	7.7	800	43
Maximum	758	8.1	800	43

Table 22: Water quality statistics at SC1(U)

SC1(U)	**EC** (µS/cm)	**pH**	**Turbidity** (NTU)	**TSS** (mg/L)
Mean	385	5.6	257	61
Standard Deviation	340	0.9	222	57
Minimum	116	4.0	80	24
10th Percentile	134	4.9	131	25
20th Percentile	142	5.1	147	26
50th Percentile	166	5.6	156	38
80th Percentile	650	6.1	319	87
90th Percentile	773	6.5	464	116
Maximum	1,075	7.1	800	146

Table 23: Water quality statistics at SC2(U)

SC2(U)	**EC** (µS/cm)	**pH**	**Turbidity** (NTU)	**TSS** (mg/L)
Mean	770	6.7	220	8
Standard Deviation	699	0.8	266	12
Minimum	144	5.1	3	1
10th Percentile	194	5.6	10	1
20th Percentile	309	6.1	10	1
50th Percentile	660	6.9	163	3
80th Percentile	892	7.3	281	10
90th Percentile	1,155	7.5	647	19
Maximum	2,951	7.7	800	28

Table 24: Water quality statistics at SC3(U)

SC3(U)	EC (µS/cm)	pH	Turbidity (NTU)	TSS (mg/L)
Mean	1,046	7.0	270	N/A
Standard Deviation	1,874	0.4	251	
Minimum	5	6.1	26	
10th Percentile	222	6.6	54	
20th Percentile	278	6.7	57	
50th Percentile	585	7.1	260	
80th Percentile	716	7.4	472	
90th Percentile	1,395	7.4	608	
Maximum	7,155	7.6	800	

Table 25: Water quality statistics at WC(U)

WC(U)	EC (µS/cm)	pH	Turbidity (NTU)	TSS
Mean	991	7.2	28	N/A
Standard Deviation	1,706	0.6	21	
Minimum	194	5.8	3	
10th Percentile	327	6.4	10	
20th Percentile	482	6.9	14	
50th Percentile	661	7.3	23	
80th Percentile	769	7.7	41	
90th Percentile	805	7.8	47	
Maximum	8,000	7.9	95	

NOW Monitoring Sites

Table 26 and **Table 27** provide statistical values calculated from measurements taken from the two NOW monitoring sites (namely WC-RV and WC-LP).

Table 26: Water quality statistics at WC-RV

WC-RV	**EC** (µS/cm)	**pH**	**Turbidity** (NTU)
Mean	857	7.5	5
Standard Deviation	239	0.4	7
Minimum	300	7.0	1
10th Percentile	535	7.0	1
20th Percentile	646	7.2	2
50th Percentile	899	7.6	2
80th Percentile	1,068	7.7	5
90th Percentile	1,095	7.9	11
Maximum	1,260	8.0	23

Table 27: Water quality statistics at WC-LP

WC-LP	**EC** (µS/cm)	**pH**	**Turbidity** (NTU)
Mean	915	7.5	63
Standard Deviation	274	0.3	31
Minimum	384	6.7	7
10th Percentile	585	7.2	23
20th Percentile	695	7.3	39
50th Percentile	895	7.6	63
80th Percentile	1,156	7.7	91
90th Percentile	1,320	7.8	97
Maximum	1,470	8.1	170

Appendix 3: Pit-top Water Management & Water Balance Analysis

Donaldson Coal Pty Ltd

Surface Water Assessment for the Tasman Extension Project Area

Appendix 3: Pit-Top Water Management & Water Balance Analysis

May 2012

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1 INTRODUCTION

This appendix documents the water management systems proposed for the Tasman Extension pit-top area and the analyses undertaken to determine the water balance of the Tasman Extension Project. These analyses have been undertaken to demonstrate the ability of the water management system to provide adequate supplies of water for operational purposes and control any discharge so as to minimise the potential for off-site impacts.

The two main sources of water considered in this water balance assessment are the groundwater inflow to the workings (derived from the *Groundwater Assessment* – Appendix B of the Environmental Impact Statement [EIS]) and surface runoff from the pit top area.

The pit-top for the Tasman Extension is located vertically above historic old mine workings in the West Borehole Seam. By reference to plans of the old workings and knowledge of the existing groundwater level, Donaldson Coal has established that there is at least 7,000 ML of void space in the old workings. It is proposed to use the void space to receive any excess water from the Tasman Extension Project, effectively making the site a 'zero discharge' site to the surface environment. As the majority of the water to be discharged to the old workings will be groundwater derived from elsewhere in the same seam, the water will effectively be recycled back to the same groundwater system.

Runoff from sub-catchments in the pit-top area (as shown on **Figure 1**) will be segregated according to their pollution potential as illustrated in the system diagram in **Figure 2**:

- Groundwater inflow to the mine will be pumped to a 5 ML turkeys-nest Mine Water Dam ('I' on **Figures 1 and 2**) located adjacent to the offices and amenities area. This water will be treated (removal of sediment and oil), disinfected and stored in a tank for re-use in the underground operations. Once fully operational, it is estimated that the underground operations will require an average of 90 kL/day. Any excess water pumped from the mine to the Mine Water Dam will overflow to a bore which will drain to the old workings immediately beneath the site.
- Surface runoff from the 'dirty' areas of the site (coal stockpile and loading area, mine portal and the workshop area - sub-catchments 'B', 'C', 'D' and 'E' on **Figure 1**) will be directed to the Surface Runoff Storage Dam located immediately to east of the coal stockpile area. This water will be re-used for dust suppression within the pit-top area and for the wheel wash facility. Any excess will be directed into the bore which will drain to the old workings immediately beneath the site.
- The car park and immediate surrounds of the offices and amenities (sub-catchment 'A' on **Figure 1**) will drain off-site via an oil/sediment trap and a bio-retention swale which will discharge into the roadside drainage system on the southern side of George Booth Drive.
- The equipment storage area to the south of the workshop area (sub-catchment 'F' on **Figure 1**) will be reserved for inert hardware required for mine operations such as pipes, mesh and conveyor belts. Runoff from this area will drain in a southerly direction around the portal via a grassed swale and will discharge into the tributary of Surveyors Creek that drains past the eastern side of the site.
- Roof runoff from all buildings will be collected and re-used for toilet flushing and other non-potable purposes.
- Potable water will be brought onto the site by tanker and stored in supply tanks.
- Sewage will be treated in a package treatment plant and the treated effluent sprayed onto open ground within the electricity transmission easement in the south-west corner of sub-catchment 'F' on **Figure 1**.

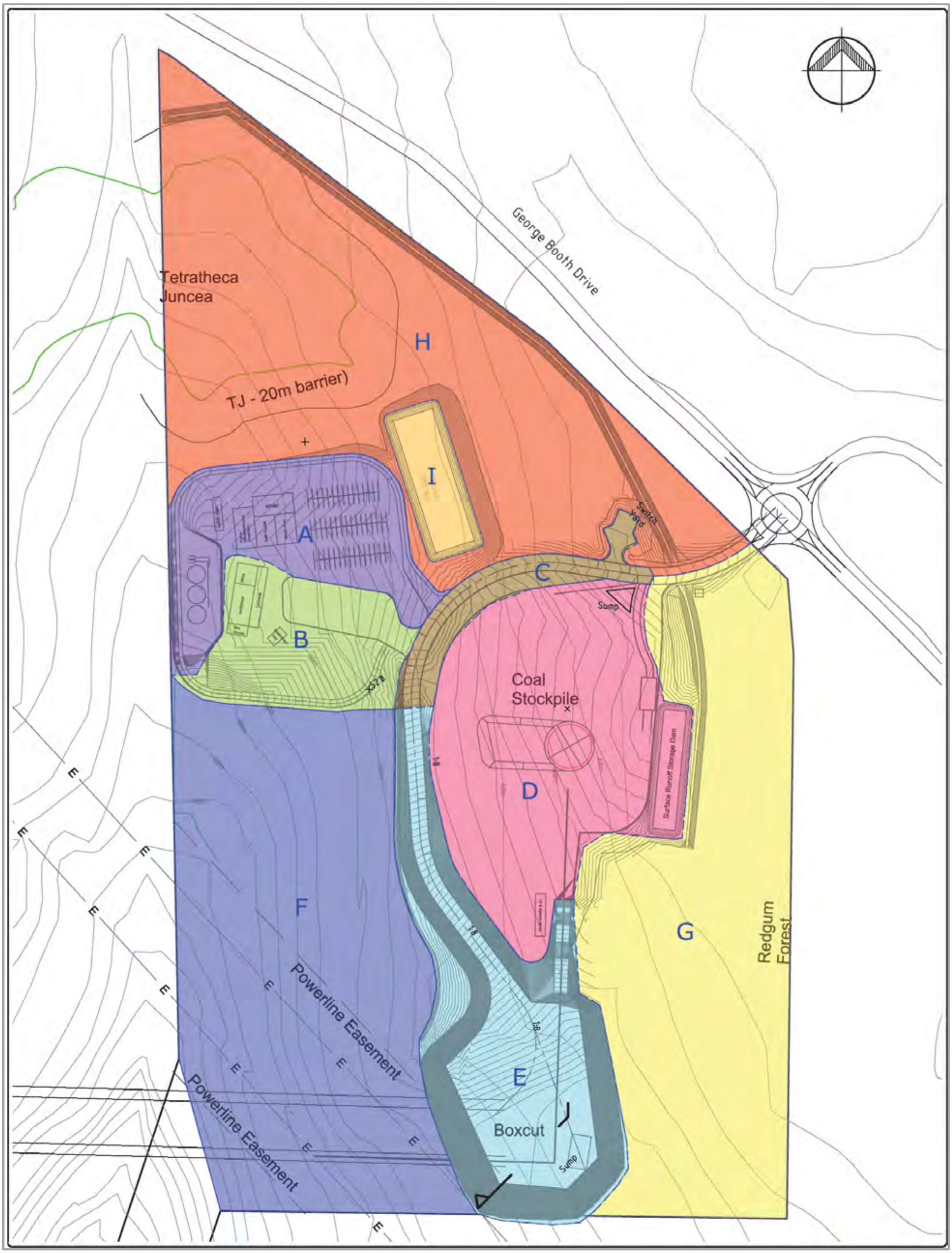

Figure 1:
Tasman Extension Pit-top Layout
(Source: Ardill Payne & Partners – Drawing 7247/Fig1/A)

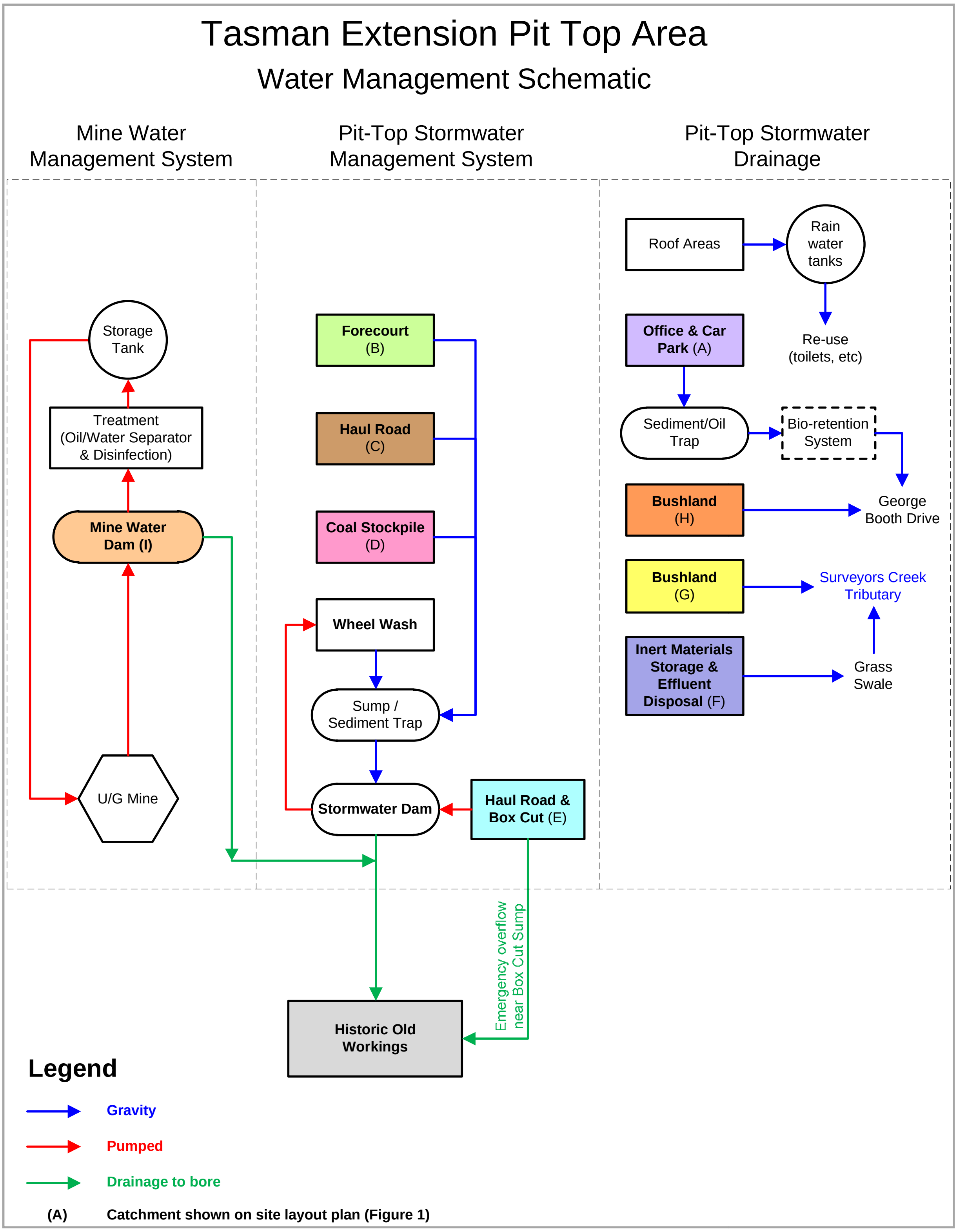

Figure 2:
Tasman Extension Project Water Management System Schematic

2 WATER SUPPLY AND EFFLUENT DISPOSAL

2.1 Underground Operations

At full production, the Tasman Extension will use four continuous miners, the same as the existing Tasman Mine.

In the existing Tasman Mine treated water is pumped underground for dust suppression and cooling purposes. Records of the volume of water required to support the operation between January 2009 and September 2010 indicate that the supply requirements are variable (see **Table 1**). The average water requirement over this period was 79 kL/day. For planning purposes water requirements for the Tasman Extension Project have been conservatively assumed to be 90 kL/day for four continuous miners.

Table 1: Water Delivery for Underground Operations at the Tasman Mine

Percentage of Time Water Delivery Exceeded	Water Delivered (kL/day)
90%	27
80%	54
50%	84
20%	104
10%	114

In order to accommodate the variability of water required for underground operations, a 200 kL storage tank will be provided for water that has been treated to a suitable standard. A balancing storage of 5 ML capacity will receive water pumped from the mine workings. Excess will be directed to the head-works for the bore discharge which will drain to the old workings (see **Section 1**).

During the start-up phase of the Project, it is anticipated that water requirements will progressively increase in line with the construction sequence set out in **Table 2**.

Table 2: Construction Activities and Estimated Water Requirements

Activity	Timing	Machinery	Water Requirements (kL/day)
Construction of drift	Approx 6 months Starting early 2014	Two road headers	45
Development works	Ongoing Starting late 2014	Two continuous miners	45
Development and secondary extraction	Ongoing Starting early 2016	Four continuous miners	90

The following arrangements are proposed for water supply for the activities identified in **Table 2**:

- One of the first elements to be constructed in association with the pit-top facilities will be the Surface Runoff Storage Dam which will initially act as a sediment control dam while earthworks are being undertaken. This is expected to be constructed 3-6 months in advance of the construction of the drift. Any water in excess of that required for surface earthworks will be available to meet the water requirements for construction of the drift after treatment to reduce sediment concentration and provide disinfection.
- In the event of there being insufficient water from surface runoff for the construction of the drift, potable water will be imported by tanker truck (up to two loads per day).
- Once development work commences in the coal seam, it is anticipated that groundwater inflow will commence. After treatment, this water will be used to meet the ongoing requirements for the development works.
- Any supplementary water supply for initial development work will be provided by excess surface runoff or potable supply by tanker truck.
- Once full secondary extraction commences in early 2016, it is anticipated that sufficient groundwater inflow will occur to exceed the requirements for underground operations.

2.2 Dust Suppression and Wheel Wash

Water requirements for dust suppression at the existing Tasman Mine site are estimated to be about 50 kL/day on a hot dry day, with an average of about 35 kL/day when the site is operating. This water is used for dust suppression on the truck access road to the coal loading area, around the workshop area and on the access road to the portal as well as top-up water for the wheel wash. No additional water is required for the coal stockpile because the coal is saturated when discharged.

The footprint of the pit-top facilities for the Tasman Extension is significantly smaller than the footprint of the existing Tasman Mine pit-top facilities. Accordingly, the water requirement is estimated to be about 30 kL/day (about 11 ML/year). This water will be drawn from the Surface Runoff Storage Dam.

Water for the wheel wash facility will also be drawn from the Surface Runoff Storage Dam. Based on experience of a similar facility at the Tasman Mine, 3.5 kL/day (1.3 ML/year) has been allowed for water loss from the wheel wash.

2.3 Potable Supply

Potable supply will be provided by tanker truck and stored in an on-site 200 kL tank. During 2011, the average usage of potable water at the Tasman Mine (which has a similar workforce to that proposed for the Tasman Extension Project) was approximately 15 kL/day. This water usage included water for toilet flushing.

At the Tasman Extension site water for toilet flushing will be sourced from rainwater. Accordingly, the potable water usage at the Tasman Extension site is expected to be less than 15 kL/day.

2.4 Effluent Treatment and Disposal

The wastewater treatment and effluent disposal system at the Tasman Mine was upgraded in 2011 following a review by Larry Cook & Associates (2011) and now comprises:

- An aerated wastewater treatment system including a final aeration stage to produce secondary quality effluent;
- Disposal of treated effluent by spray irrigation onto an area of about 6,000 m^2.

This system is licensed by the Environment Protection Agency under the overall Environmental Protection Licence for the mine.

The Tasman Extension Project will utilise a similar treatment and disposal system to that currently operating at the Tasman Mine. Effluent will be disposed of by spray irrigation onto the open grassed area located under the power-line easement (comprising the south west section of sub-catchment 'F' on **Figure 1**.) The available land area within the site located within the easement is approximately 2 ha (20,000 m^2) which provides sufficient area for effluent disposal (about 6,000 m^2) together with the necessary buffer distances including being more than 100 m from a drainage line.

3 GROUNDWATER INFLOW AND DISCHARGE

All groundwater inflow to the mine, together with any surplus water pumped into the mine for operational purposes, will be pumped to the Mine Water Dam (5 ML capacity) within the pit-top area.

The groundwater inflow to the mine workings has been assessed in the *Groundwater Assessment* (Appendix B of the EIS). The predicted annual inflows to the mine are shown in **Figure 3**. Note that the flows depicted in **Figure 3** represent the average rate over a calendar year. The actual volume pumped out of the mine on a particular day can be expected to fluctuate according to localised geological conditions and operational conditions. For example, if mining operations cease for some time (e.g. over a holiday period) subsequent pumping rates over several days may be significantly higher than the long term average.

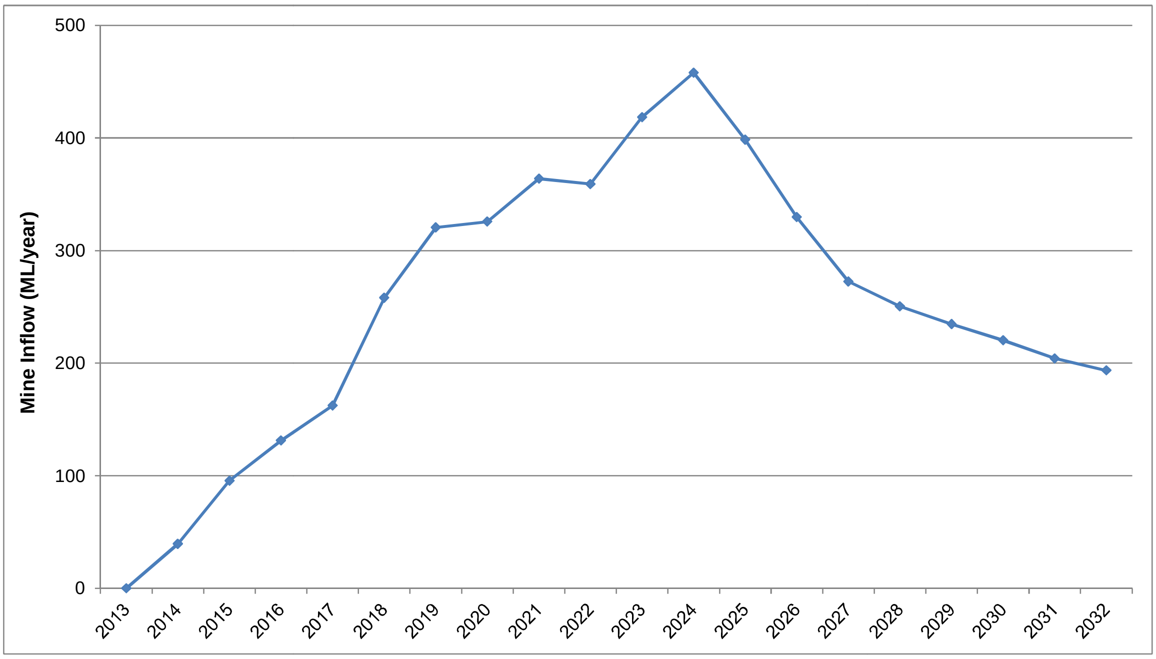

Figure 3:
Predicted Groundwater Inflows
(Source: Tasman Extension - Groundwater Assessment)

Water from the Mine Water Dam will be treated to remove sediment and oil before being disinfected and placed in a 200 kL storage tank from where it will be pumped back to the underground workings.

Overflow from the Mine Water Dam will be directed back into historic old workings in the West Borehole Seam that underlie the pit-top area. As noted in **Section 1**, the historic old workings in the West Borehole Seam have an estimated void space of at least 7,000 ML. One or more bores will be constructed from the pit-top area to connect to the old underground workings and allow discharge of excess mine water and stormwater runoff.

4 SURFACE RUNOFF AND DISCHARGE

As described in **Section 1,** the surface runoff systems for the pit-top area water will treat runoff from different areas appropriately, in line with the stormwater pollution potential of each area:

- The northern border of the site (sub-catchment 'H' on **Figure 1**) will remain undisturbed. This area will be allowed to continue to drain naturally to the table drain on the southern side of George Booth Drive.
- The equipment storage area to the south of the workshop area (sub-catchment 'F' on **Figure 1**) will be reserved for inert hardware required for mine operations such as pipes, mesh and conveyor belts. This area is not expected to be a source of any pollutants except occasional minor ground disturbance. Runoff from this area will be drained in a southerly direction around the portal via a grassed swale and will discharge into the tributary of Surveyors Creek that drains past the eastern side of the site.
- The car park and immediate surrounds of the offices and amenities (sub-catchment 'A' on **Figure 1**) will drain via an oil/sediment trap and a bio-retention swale into the roadside drainage system on the southern side of George Booth Drive.
- Surface runoff from the 'dirty' areas of the site (coal stockpile and loading area, mine portal and the workshop area - sub-catchments 'B', 'C' and 'D' on **Figure 1**) will be directed to a sump in the northern corner of the coal stockpile area from where, together with pumped runoff from sub-catchment E, it will overflow to the Surface Water Dam located immediately to east of the coal stockpile area. The sump will be designed to capture coarse sediment and allow easy access for removal of sediment by a front-end loader. The outlet of the sump will be equipped with a baffle to retain any oil within the sump. Water retained in the Surface Runoff Storage Dam will be re-used for dust suppression within the pit-top area and for the wheel wash. Any excess will be directed into the bore which will drain to the old historic workings immediately beneath the site.

The characteristics of the various sub-catchments described above and depicted on **Figure 1** are summarised in **Table 3**.

Table 3: Characteristics and Areas of Sub-catchments in the Pit-top Area

	Catchment	Area (ha)	Surface Treatm't	Runoff Destinat'n
A	Office, Mess and Car-parking areas (including water storage tanks)	1.16	Asphalt	Offsite
B	Workshop / Fuel storage / Wash-bay	0.87	Hardstand	Surface Runoff Storage Dam
C	Access Road	0.38	Asphalt	Surface Runoff Storage Dam
D	Coal Stockpile and Loading Area (including Surface Runoff Storage Dam)	2.35	Hardstand	Surface Runoff Storage Dam
E	Box Cut	2.06	Gravel Road	Surface Runoff Storage Dam
F	Inert Materials Storage Area / Effluent Disposal	4.16	Natural	Offsite
G	Bushland - Downstream of Box Cut	3.67	Natural	Offsite
H	Bushland - North Site	4.62	Natural	Offsite
I	Mine Water Dam (5ML)	0.31	Dam	Bore to old workings

4.1 Surface Runoff Storage Dam

The Surface Runoff Storage Dam located on the eastern side of the coal stockpile area will receive all runoff from sub-catchments 'B', 'C', 'D' and 'E' on **Figure 1**, a total of 5.53 ha. The dam will be designed to have two zones:

- A lower storage zone (nominal capacity 4 ML) which will be used to provide water for dust suppression and wheel wash purposes. The sizing of this zone has been undertaken using the water balance model (see **Section 5**) and has taken account of the variability of rainfall-runoff and requirements for dust suppression whilst seeking to maximise the proportion of water supplied from runoff. **Table 4** summarises the effect of increasing capacity of the lower storage zone on the proportion of water for dust suppression that could be provided from stormwater runoff. The table shows that, for each incremental increase in the capacity of the storage zone, there is a decrease in the additional water supplied. On this basis, a capacity of 4 ML was selected as being appropriate for this site.
- An upper surcharge zone (2 ML) which has been sized to be sufficient to retain excess runoff from a 20 year average recurrence interval storm without discharge to the natural environment.

Table 4: Effect of Storage Zone Capacity on Percentage of Water Supplied from Stormwater Runoff

	Storage Zone Capacity (ML)					
	1.5	**2**	**2.5**	**3**	**4**	**5**
Supplied from Dam (ML/year)	10.0	10.8	11.3	11.7	12.2	12.6
Make-up from Mine (ML/year)	3.4	2.7	2.1	1.7	1.2	0.8
Percentage Supply from Stormwater	75%	80%	84%	87%	92%	94%

A spillway culvert (nominal 600 mm diameter with invert at the top of the lower storage zone) will direct water retained in the surcharge zone into a discharge structure connected to the bore which drains to the old historic workings beneath the site. This structure will comprise a concrete header tank (nominal 1.8 m diameter x 2.4 m deep) with a funnel shaped base leading into a 225 mm diameter bore.

5 MANAGEMENT OF STORMWATER RUNOFF AND MINE WATER

As shown in **Figure 2**, there will be three main water management systems that will operate largely independently:

- A **pit-top stormwater management system** which will collect stormwater runoff from the 'dirty' areas of the site. This water will be re-used for dust suppression and the wheel wash and any excess will be discharged into historic old workings in the West Borehole seam.
- A **mine water management system** that takes water pumped out of the mine workings. A proportion of this water will be treated and returned to the workings for dust suppression and processing. Any excess water will be discharged into historic old workings in the West Borehole seam.
- Discharge of **relatively clean runoff** from remaining bushland areas and the car park.
  - Stormwater runoff from the car park will be treated by means of a sediment/oil trap and a bio-retention swale before draining off-site to the roadside drainage in George Booth Drive.
  - Runoff from the inert materials storage area will be drained via a grass swale to the tributary of Surveyors Creek adjacent to the site
  - All other areas in this category will drain off-site in the same manner as they do currently.

The water balance associated with the first two of these systems is described in **Section 5.1** and **Section 5.2** respectively.

5.1 Pit-top Stormwater Balance

5.1.1 Overview

The water balance associated with the stormwater management system for the 'dirty' runoff areas of the pit-top area (sub-catchments 'B', 'C', 'D' and 'E' on **Figure 1**) has been analysed using a daily water balance model with 125 years of climate data. The model accounts for:

- Different runoff characteristics of hardstand areas and the coal stockpile area;
- Storage of runoff in the Surface Runoff Storage Dam;
- Evaporation from water surfaces, the coal stockpile and hardstand area (as determined from the climate data - see below);
- An allowance for seepage loss from the Surface Runoff Storage Dam (0.5 mm/day);
- Extraction of water for dust suppression and for top-up of the wheel wash;
- Discharge of excess water via a culvert connected to a sump from which water is drained to the old historic workings via a bore;
- Overflow to the creek in the event that the volume of runoff is sufficient to exceed the surcharge capacity of the Surface Runoff Storage Dam. (Although this is anticipated to only occur in storms in excess of 20 years average recurrence interval, this mode of overflow is allowed for in the model.)

5.1.2 Climate Data

The runoff component of the water balance analysis has utilised the same rainfall and potential evapotranspiration dataset as that used for assessment of the runoff characteristics of the catchments overlying the extraction area (see **Appendix 1** of the *Surface Water Assessment*). This comprises a 125 year daily rainfall record based on correlation established between the rainfall records at Tasman Mine, Mulbring and Morpeth. For runoff modelling purposes monthly averages of potential evapotranspiration derived from the digital version of the *Climatic Atlas of Australia: Evapotranspiration* (Version 1.0, Bureau of Meteorology, 2002) have been used.

Because water requirements for dust suppression are largely a function of temperature and wind speed on a particular day, these requirements have been estimated from daily pan evaporation, which is much more variable than monthly averages of potential evapotranspiration. The daily pan evaporation record from Cessnock has been used for this purpose. For those years of the rainfall record that do not have coincident pan evaporation records, a synthetic record was created by reference to the annual rainfall. For a year without pan evaporation data the record was inserted for the year with the rainfall record closest to that of the missing year.

5.1.3 Runoff Estimation

Runoff was estimated using the Australian Water Balance Model (AWBM) which is described in further detail in **Appendix 1** of the *Surface Water Assessment*. The adopted model parameters for hardstand areas and the coal stockpile are listed in **Table 5**.

Table 5: Adopted AWBM Parameters for Pit-top Runoff Estimation

Parameter	Hardstand and Sealed Areas	Coal Stockpile Area
C1	2.0	5.0
C2	0.0	10.0
C3	0.0	0.0
A1	1.0	0.5
A2	0.0	0.5
A3	0.0	0.0
Kbase	0.96	0.96
Ksurf	0.1	0.1

5.1.4 Water Uses and Supplementary Supply

Water uses have been based on the following:

- ***Dust Suppression***: as a function of evaporation deficit (based on the work of Thompson and Visser, 2002);
- ***Wheel Wash***: average of 3.5 kL/day based on observed requirements at the existing Tasman Mine.

As noted in **Section 3** the average daily volume of groundwater inflow to the underground workings will exceed the volume required for operational purposes. The water balance model assumes that any shortfall in water in the Surface Runoff Storage Dam would be met from excess water from underground.

5.1.5 Stormwater Balance

The water balance model of the stormwater management and recycling system has been run for the full 125 years of climate data from which statistics for the long term annual average water balance have been extracted along with data for years that represent median, 1:10 dry and 1:10 wet years.

Because the rainfall patterns are different in years with comparable total rainfall, the performance of the stormwater management system is illustrated in each case by three examples: the year corresponding to the runoff statistic (median, 1:10 dry and 1:10 wet) and the closest year on either side of that year, when ranked in order of annual runoff. In each case the data for a particular year has been extracted from the full 125 years of model record and therefore realistically accounts for variation in water storage in the Surface Runoff Storage Dam at the beginning of a particular year (rather than assuming a set storage value at the start of a year).

Sizing of the Storage Zone Capacity

The full 125 years of daily climate record was used to assess the trade-off between the capacity of the storage zone in the Surface Runoff Storage Dam and the proportion of water requirements that could be met from stormwater runoff. The results of that analysis are set out in **Table 4**.

Long Term Average Performance

Key long term annual average statistics from the water balance model of the stormwater management and recycling system are set out in **Table 6**. Note that these data are <u>averages</u> whereas the data for representative years presented below are for representative median, 1:10 dry and 1:10 wet runoff years.

Table 6: Average Annual Statistics from the Stormwater Balance Model

Average Annual Statistic	Value
Base Data	
Rainfall	993 mm/year
Open Water Evaporation	1,125 mm/year
Water demand (dust suppression and wheel wash)	13.4 ML/year
Inputs	
Runoff	36.2 ML/year
Rainfall onto surface of Surface Runoff Storage Dam	1.2 ML/year
Total	***37.5 ML/year***[1]
Water Uses and Losses	
Water supply for dust suppression and wheel wash	12.3 ML/year
Evaporation loss from Surface Runoff Storage Dam	1.3 ML/year
Seepage loss from Surface Runoff Storage Dam	0.2 ML/year
Discharge to underground	23.9 ML/year
Total	***37.5 ML/year***[1]
System Performance	
Percentage supply from runoff	92%
Discharge to underground	36.7 days/year

Note 1: Apparent discrepancy in totals due to rounding

The data in **Table 6** indicates that, because of the impervious nature of the sub-catchments draining to the Surface Runoff Storage Dam, the site can be expected to generate significantly more runoff than can be used for dust suppression and the wheel wash. The model results also show that the proposed discharge to the bore and the associated surcharge capacity of the dam are adequate to minimise the risk of discharge to surface waters, in that the modelling indicates only one instance of overflow in 126 years of record.

The results also indicate that the modelled long term average annual water requirement for dust suppression and the wheel wash was 13.4 ML/year which slightly more than the estimates set out in **Section 2.2** (12.3 ML/year) indicating that the model is slightly conservative in the assessment of water demand.

Median Runoff Years

The model analysis indicates that 1895 was the median year with 1909 and 1999 being closest either side in terms of runoff. Summary statistics for these years are presented in **Table 7** while the water level variation in the Surface Runoff Storage Dam for these years is shown in **Figure 4**.

Table 7: Stormwater Management System Statistics: Median Years

Calendar Year	Rainfall (mm)	Runoff (ML)	Supply Shortfall (ML)	Storage Empty Days	Discharge to Bore (ML)	Discharge to Bore Days	Overflow to Creek (ML)	Overflow to Creek Days
1909	1,013	34.8	1.8	24	16.6	18	0.0	0
1895	1,036	35.0	0.0	0	21.5	53	0.0	0
1999	1,035	35.2	0.0	0	21.8	25	0.0	0

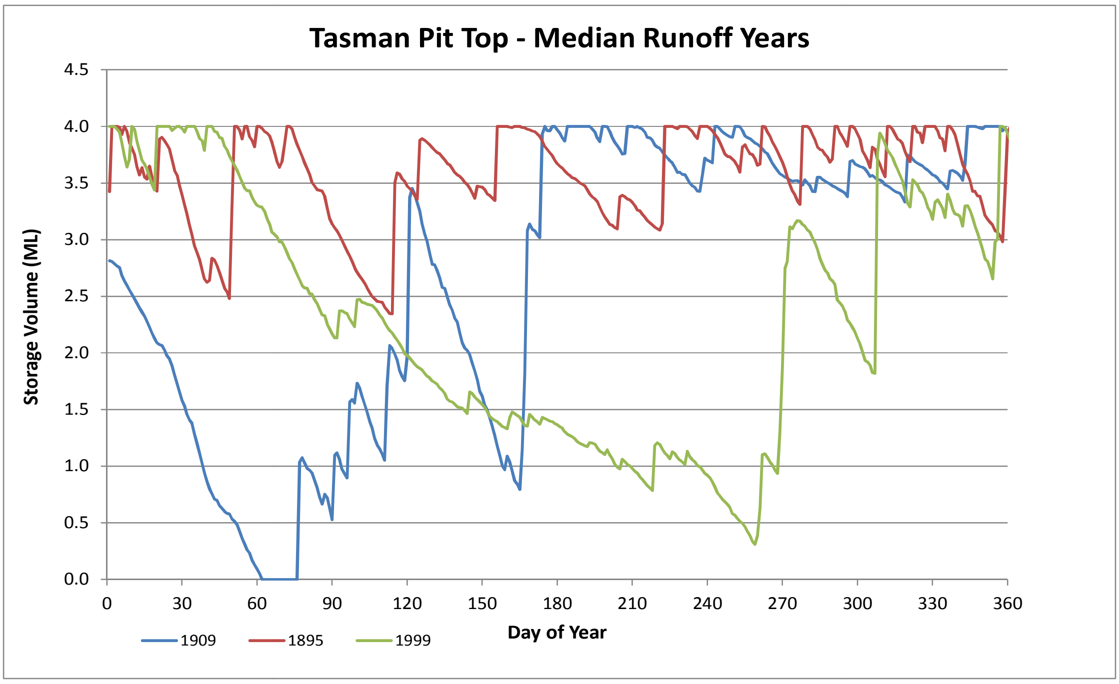

Figure 4:
Variation in Surface Runoff Storage Dam Volume for Representative Median Years

The data in **Table 7** and **Figure 4** illustrate the significant differences that can occur from year to year, depending on the timing of the rainfall and the volume held in storage at the beginning of the year.

The data shows that, although the long term average indicates that 92% of the required water could be supplied from runoff, in practice in a median year there is a good chance that the system would be capable of supplying all the required water for dust suppression and the wheel wash. (In two out of three years shown in **Table 7** and **Figure 4** the Surface Runoff Storage Dam never empties).

1:10 Dry Years

The model analysis indicates that 1901 was a 1:10 dry year with 1888 and 1907 being closest either side in terms of runoff. Summary statistics for these years are presented in **Table 8** while the water level variation in the Surface Runoff Storage Dam for these years is shown in **Figure 5**.

Table 8: Stormwater Management System Statistics: 1:10 Dry Years

Calendar Year	Rainfall (mm)	Runoff (ML)	Supply Shortfall (ML)	Storage Empty Days	Discharge to Bore (ML)	Discharge to Bore Days	Overflow to Creek (ML)	Overflow to Creek Days
1888	615	20.3	3.5	39	9.3	12	0.0	0
1901	708	21.0	0.0	0	4.5	6	0.0	0
1907	700	21.1	0.0	0	6.9	19	0.0	0

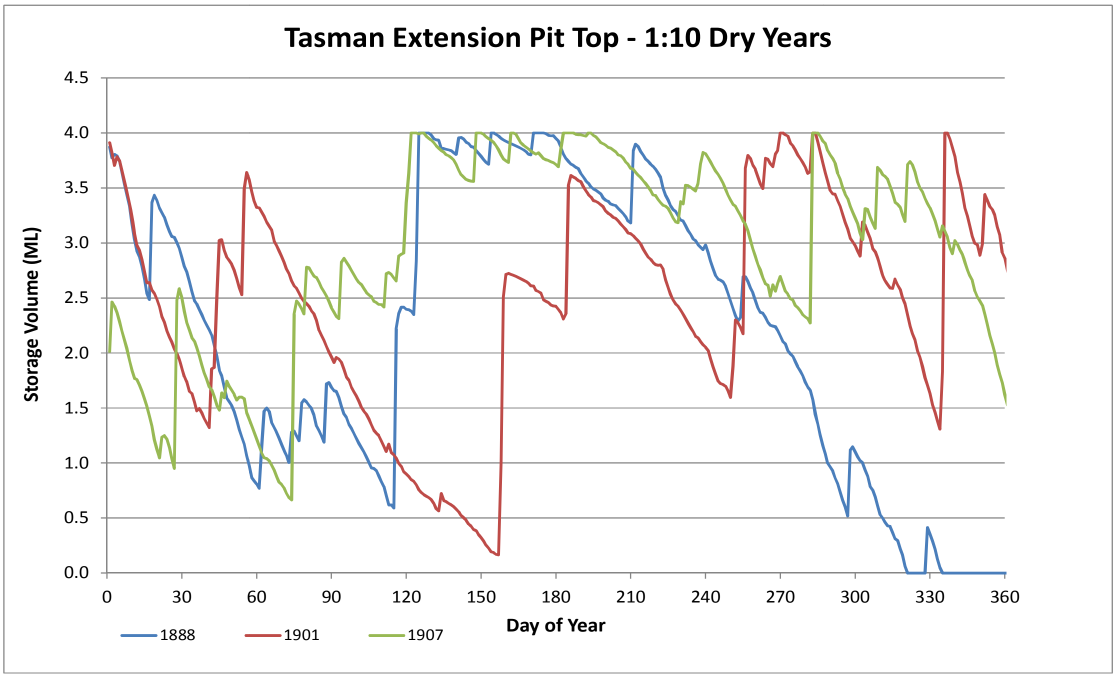

Figure 5:
Variation in Surface Runoff Storage Dam Volume for Representative 1:10 Dry Years

The main point of note in relation to 1:10 dry years represented by the data in **Table 8** and **Figure 5** is that in two out of three years, the full water demand could be met from the dam. In one year out of three dry years, the Surface Runoff Storage Dam could be expected to be empty for about a month.

1:10 Wet Years

The model analysis indicates that 1927 was the 1:10 wet year with 1931 and 1891 being closest either side in terms of runoff. Summary statistics for these years are presented in **Table 9** while the water level variation in the Surface Runoff Storage Dam for these years is shown in **Figure 6**.

Table 9: Stormwater Management System Statistics: 1:10 Wet Years

Calendar Year	Rainfall (mm)	Runoff (ML)	Supply Shortfall (ML)	Storage Empty Days	Discharge to Bore (ML)	Discharge to Bore Days	Overflow to Creek (ML)	Overflow to Creek Days
1931	1,291	53.1	0.0	0	36.3	68	0.0	0
1927	1,227	53.5	0.0	0	37.9	32	0.0	0
1891	1,418	54.5	0.0	0	41.7	79	0.0	0

In all representative examples of a 1:10 wet year, the Surface Runoff Storage Dam would provide all the water required for dust suppression and the wheel wash, although the dam might get drawn down to about 20% of its capacity at some stage. It should also be noted that in such years there are no occasions on which overflow would occur to the adjoining creek.

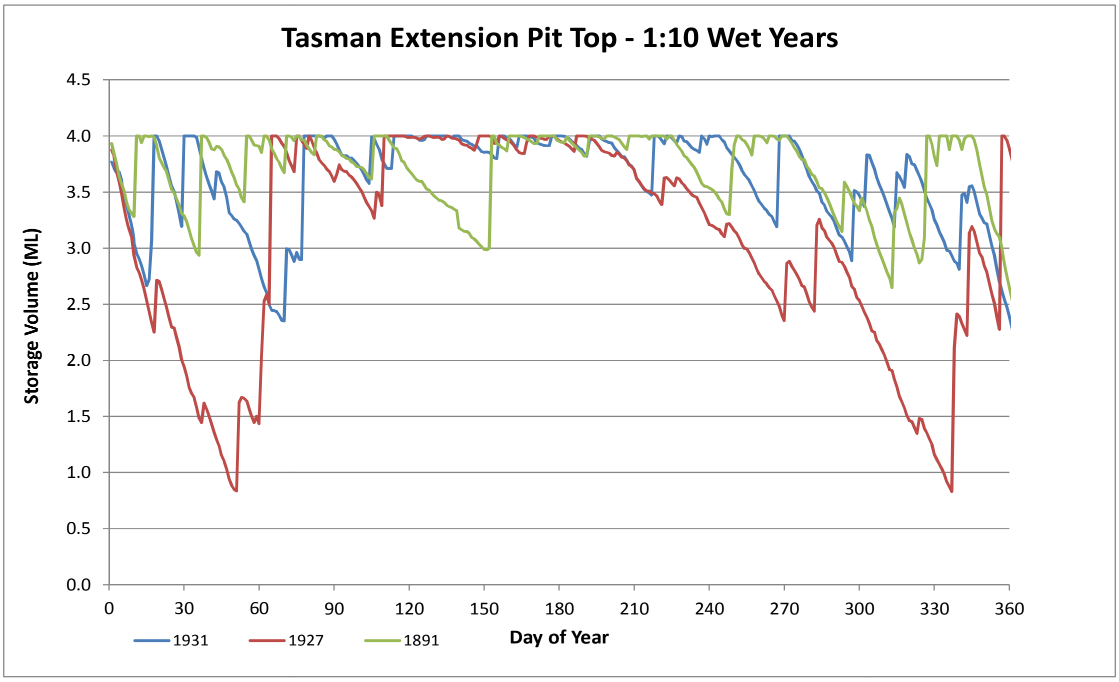

Figure 6:
Variation in Surface Runoff Storage Dam Volume for Representative 1:10 Wet Years

5.2 Underground Mine Water

Predicted groundwater inflows to the mine workings are shown in **Figure 3**. The predicted inflow rises rapidly once development starts in the coal seams from zero 2013 to 39 ML/year in 2014. Long term average inflow over the 17 years of mining is predicted to be about 0.7 ML/day. It can be seen that the predicted inflow significantly exceeds the required water for underground operations (90 kL/day = 0.09 ML/day – see **Section 2.1**).

Table 10 summarises the volumes of water that will need to be stored in the old historic workings over the life of the mine assuming that all excess water from the underground workings and from the 'dirty' areas of the surface facilities will be stored in the old workings.

Table 10: Components of Groundwater Balance Over the Mine Life

Source	Volume (ML)
Groundwater inflow to workings	5,035
Excess stormwater	415
Total	**5,450**

Note that, while a total of about 450 ML of water will be re-cycled for operational purposes, this will either be lost through evaporation (reflected in an increase in relative humidity of the exhaust air) or pumped out of the mine with the groundwater inflow. For purposes of **Table 10** it has been conservatively assumed that all water for operational purposes is recycled. The estimated volume in **Table 10** therefore represents a conservative (upper limit) to the estimated volume of excess water generated by mine operations that would need to be stored in the old historic workings in order to achieve zero discharge from the mine to the surface environment. It can be seen that the upper limit of the estimated excess water (about 5,500 ML) is significantly less than the estimated storage volume available in the historic workings (7,000 ML).

6 REFERENCES

Larry Cook & Associates, *Wastewater Management Plan - Tasman Mine: George Booth Drive, via Seahampton*, prepared for Donaldson Coal (February 2011).

Thompson and Visser (2002), "*Benchmarking and management of fugitive dust emissions from surface mine haul roads",* Trans. Inst. Min. Metal. V110, SA, A28 –A34.

Bureau of Meteorology (2002), *Climatic Atlas of Australia: Evapotranspiration* – gridded data DVD (IDCJMS02.200302)

Appendix 4: Director General's & Agency Requirements

Donaldson Coal Pty Ltd

Surface Water Assessment for the Tasman Extension Project Area

Appendix 4: Director-General's & Agency Requirements

May 2012

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1 INTRODUCTION

This appendix documents the relevant surface water requirements from the Director General's Requirements (DGRs) and Agency requirements. A cross reference to the location within the Surface Water Assessment where the requirement is addressed is also provided.

2 DIRECTOR-GENERAL'S REQUIREMENTS

The DGRs for the environmental assessment of the Project under Section 78A (8A) of the *Environmental Planning and Assessment Act 1979* State Significant Development were provided in a letter from the Department of Planning & Infrastructure (DP&I) on 14 December 2011. **Table 1** provides a summary of the DGRs relating to surface water. **Table 1** also indicates where the specific issues have been addressed within the Surface Water Assessment.

Table 1: DGRs Related to Surface Water

	Requirement	Reference
General Requirements	The EIS must include a: ▪ detailed description of the development including environmental protection;	▪ Section 5 Subsidence ▪ Section 6 Flow Regime ▪ Section 7 Water Quality ▪ Section 8 Water Management
	▪ risk assessment of the potential environmental impacts of the development, identifying the key issues for further assessment;	▪ EIS Section 4
	▪ detailed assessment of the key issues specified below, and any other significant issues identified in this risk assessment, which includes: - a description of the existing environment, using sufficient baseline data;	▪ Section 4 Catchment characteristics ▪ Section 6 and Appendix 1 - Flow Regime ▪ Section 7 and Appendix 2 - Surface Water Quality
	- an assessment of the potential impacts of all stages of the development, including any cumulative impacts, taking into consideration relevant guidelines, policies, plans and statutes; and	▪ Section 5- Subsidence ▪ Section 10 - Surface Water Impacts
	- a description of the measures that would be implemented to avoid, minimise and if necessary, offset the potential impacts of the development, including proposals for adaptive management and/or contingency plans to manage any significant risks to the environment; and	▪ Section 5 - Subsidence ▪ Section 8 – Water Management ▪ Section 9 – Site Water Balance
Key Issues: Subsidence	The EIS must include a detailed quantitative and qualitative assessment of the potential conventional and non-conventional subsidence impacts of the development that includes:	
	▪ the identification of the natural and built features (both surface and sub-surface) within the area that could be affected by subsidence, and an assessment of the respective values of these features using any relevant statutory or policy documents;	▪ EIS Appendix A ▪ Section 5 – Subsidence
	▪ a detailed assessment of the potential environmental consequences of these effects and impacts on both the natural and built environment, paying particular attention to those features that are considered to have significant economic, social, cultural or environmental values; and	▪ EIS Appendix A ▪ Section 5- Subsidence ▪ Section 6 - Flow Characteristics ▪ Section 7 - Water Quality ▪ Section 8 – Water Management
	▪ a detailed description of the measures that would be implemented to avoid, minimise, remediate and/or offset subsidence impacts and environmental consequences (including adaptive management and proposed performance measures);	▪ EIS Appendix A ▪ Section 5 – Subsidence

	Requirement	Reference
Key Issues: **Water Resources**	The EIS must include: ▪ a detailed assessment of potential impacts on the quality and quantity of existing surface water resources, including:	▪ Section 10.4 – Water Quality
	- impacts on affected licensed water users and basic landholder rights; and	▪ Section 10.5 – Water Sharing Plan
	- impacts on riparian, ecological, geo-morphological and hydrological values of watercourses, including environmental flows;	▪ Section 10.5 – Water Sharing Plan
	▪ 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;	▪ Section 9 – Water Balance
	▪ identification of any licensing requirements or other approvals under *the Water Act 1912* and/or *Water Management Act 2000;*	▪ Section 3.1.1 ▪ Section 12.2 – Licensing and Approvals
	▪ 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);	▪ Section 3.2.5 ▪ Section 9 – Site Water Balance
	▪ 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;	▪ Section 10.5 – Water Sharing Plan
	▪ a detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface water impacts;	▪ Section 8 – Water Management ▪ Section 9 – Water Balance ▪ Section 11 – Mitigation and Management Measures

3 AGENCY REQUIREMENTS

Agency requirements relating to surface water identified as part of the DGRs are summarised in **Table 2** below. **Table 2** also indicates where the specific issues have been addressed within this document.

Table 2: Authority Requirements Relating to Surface Water

Requirements		Reference
Office of Environment and Heritage		
Licensing Requirements	Newcastle Coal Company Pty Ltd holds EPL 12483 for Tasman Coal Mine. The EIA should address the requirements of Section 45 of the POEO Act by determining the extent of any impacts, and provide sufficient information to enable OEH to determine if any variation of the current EPL would be required.	▪ Section 11 – Mitigation and Management Measures
	Should project approval be granted, the proponent may need to make a separate application to OEH for a variation of the EPL.	▪ Section 11 – Mitigation and Management Measures
Flooding & Coastal Erosion	The EIA should include an assessment of the following referring to the relevant guidelines (in Attachment 2 of the OEH's submission):	Flooding only a localised issue adjacent to pit-top area. Not addressed in the Surface Water Assessment (addressed in EIS Attachment 3)
	1. Whether the proposal is consistent with any floodplain risk management plans.	▪ N/A
	2. Whether the proposal is compatible with the flood hazard of the land.	▪ N/A
	3. Whether the proposal will significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties.	▪ N/A
	4. Whether the proposal will significantly adversely affect the environment or cause avoidable erosion, siltation, destruction or riparian vegetation or a reduction in the stability of river banks or watercourses.	▪ N/A
	5. Whether the proposal incorporates appropriate measures to manage risk to life from flood.	▪ N/A
	6. Whether the proposal is likely to result in unsustainable social and economic costs to the community as a consequence of flooding.	▪ N/A
Water: Describe Proposal	1. Describe the proposal including position of any intakes and discharges, volumes, water quality and frequency of all water discharges.	▪ Section 8 – Water Management, ▪ Section 9 – Water Balance
	2. Demonstrate that all practical options to avoid discharge have been implemented and environmental impact minimised where discharge is necessary.	▪ Section 8 – Water Management ▪ Section 9 – Water Balance
	3. Where relevant include a water balance for the development including water requirements (quantity, quality and source(s)) and proposed storm and wastewater disposal, including type, volumes, proposed treatment and management methods and re-use options.	▪ Section 8 – Water Management ▪ Section 9 – Water Balance
Water: Background Conditions	4. Describe existing surface water quality. An assessment needs to be undertaken for any water resource likely to be affected by the proposal.	▪ Section 7 – Water Quality ▪ Appendix 2 – Surface Water Quality Data
	Proponents are generally only expected to source available data and information. However, proponents of relatively large and/or high risk developments may be required to collect some ambient water quality / river flow data to enable a suitable level of impact assessment. Issues to include in the description of	▪ Section 6 and Appendix 1 - Flow Regime ▪ Section 7 and Appendix 2 - Surface Water Quality

Requirements		**Reference**
	the receiving waters could also include, for example:	
	▪ water chemistry	▪ N/A
	▪ a description of receiving water processes, circulation and mixing characteristics and hydrodynamic regimes	▪ N/A
	▪ lake or estuary flushing characteristics	▪ N/A
	▪ sensitive ecosystems or species conservation values	▪ EIS Appendix E
	▪ specific human uses (e.g. fishing, proximity to recreation areas)	▪ N/A
	▪ a description of any impacts from existing industry or activities on water quality	▪ Section 7 – Water Quality
	▪ a description of the condition of the local catchment e.g. erosion, soils, vegetation cover, etc.	▪ Section 4 – Catchment Characteristics
	▪ an outline of baseline groundwater information, including, for example, depth to watertable, flow direction and gradient, groundwater quality, reliance on groundwater by surrounding users and by the environment	▪ EIS Appendix B
	▪ historic river flow data	▪ Section 6 – Flow Characteristics
	▪ State the Water Quality Objectives for the receiving waters relevant to the proposal.	▪ Section 3.2 – Policies and Plans ▪ Section 7.4 - ANZECC Default Trigger Values
	▪ State the indicators and associated trigger values or criteria for the identified environmental values. This information should be sourced from the *ANZECC (2000) Guidelines for Fresh and Marine Water Quality.*	▪ Section 7.4 - ANZECC Default Trigger Values
	▪ State any locally specific objectives, criteria or targets which have been endorsed by the NSW Government.	▪ Section 3.3 - Technical and Policy Guidelines
Water: Impact Assessment	Describe the nature and degree of impact that any proposed discharges will have on the receiving environment.	▪ No discharges expected ▪ Section 10 – Surface Water Impacts
	Depending on the nature, scale and/or risk of the proposal, this could include specific requirements to consider impacts on:	
	▪ water circulation, current patterns, water chemistry and other appropriate characteristics such as clarity, temperature, nutrient and toxicants;	▪ N/A
	▪ changes to hydrology (including drainage patterns, surface yield, flow regimes, and groundwater);	▪ Section 6 – Flow Characteristics ▪ Section 10 – Surface Water Impacts
	▪ disturbance of acid sulfate soils and potential acid sulfate soils;	▪ Section 4.3 – Soil Landscapes
	▪ stream bank stability and impacts on macro invertebrates.	▪ EIS Appendix D ▪ EIS Appendix E ▪ Section 5 – Subsidence Impacts and Management
	Depending on the nature, scale and/or risk of the proposal, modelling, monitoring, or both, may need to be undertaken to assess the potential impact of discharges on the receiving environment. If modelling is required to assess the potential impact of any discharge(s), this could include, for example:	▪ No discharge to the environment, so no modelling required.
	▪ a range of scenarios that encompass any variations in discharge quality and quantity as well as the relevant range of environmental conditions of the receiving waters. The scenarios could describe a set of worst-case conditions and typical conditions to ensure that both acute and chronic impacts are assessed	▪ N/A
	▪ assumptions used in the modelling, including identification and discussion of the limitations and assumptions to ensure full consideration of all factors, including uncertainty in predictions.	▪ N/A
	▪ The internal OEH document *Applying Goals for Ambient Water Quality Guidance for Operations Officers: - Mixing Zones* provides guidance on modelling considerations and principles for discharges to receiving waters.	▪ N/A (NB document could not be sourced from hyperlink provided)
	5. Assess impacts against the relevant ambient water quality outcomes. Demonstrate how the proposal will be designed and operated to:	▪ Section 10.4 – Water Quality

Requirements		Reference
	▪ protect the Water Quality Objectives for receiving waters where they are currently being achieved; and	▪ Section 10.4 – Water Quality
	▪ contribute towards achievement of the Water Quality Objectives over time where they are not currently being achieved.	▪ Section 10.4 – Water Quality
	6. Where a discharge is proposed that includes a mixing zone, the proposal should demonstrate how wastewater discharged to waterways will ensure the ANZECC (2000) water quality criteria for relevant chemical and non-chemical parameters are met at the edge of the initial mixing zone of the discharge, and that any impacts in the initial mixing zone are demonstrated to be reversible.	▪ N/A – no discharge proposed
	7. Assess impacts on groundwater and groundwater dependent ecosystems.	▪ EIS Appendix B ▪ EIS Appendix E
	8. Describe how stormwater will be managed both during and after construction.	▪ Section 8 – Water Management ▪ Section 9 – Water Balance
Water: Monitoring	9. Describe how predicted impacts will be monitored and assessed over time.	▪ Section 12.1 – Monitoring
	For relatively large and/or high risk developments proponents should develop a water quality and aquatic ecosystem monitoring program to monitor the responses for each component or process that affects the Water Quality Objectives that includes, for example:	▪ Section 12.1 – Monitoring
	▪ adequate data for evaluating compliance with water quality standards and/or Water Quality Objectives	▪ Section 12.1 – Monitoring
	▪ measurement of pollutants identified or expected to be present in any discharge	▪ Section 12.1 – Monitoring
	Water quality monitoring should be undertaken in accordance with the Approved Methods for the *Sampling and Analysis of Water Pollutant in NSW* (2004).	▪ Section 12.1 – Monitoring
NSW Office of Water		
Relevant Legislation	The proposal will require an access licence under the *Water Management Act 2000* (WMA) for any incidental take of surface water from the Surveyors Creek catchment, under legislation administered by the NSW Office of Water. Any proposal to access water from this source must be through purchase of existing entitlements and be subject to the rules of transfer outlined in the Water Sharing Plan for the *Hunter Unregulated and Alluvial Water Sources 2009* (WSPHUAWS).	▪ Section 12.2 – Licensing
Relevant Policies	The proposal must address the relevant NSW State Government natural resource management policies including:	▪ Section 3.2 – Policies and Plans
	- NSW State Rivers and Estuaries Policy	▪ Section 3.2 – Policies and Plans
	- NSW Wetlands Management Policy	▪ N/A
	- NSW Flood Prone Land Policy	▪ N/A
Statutory Requirements	The proposal must address the relevant rules of the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009* (WSPHUAWS) where applicable.	▪ Section 3.2.5 - Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009
Relevant Guidelines	The NSW Office of Water has adopted the *Rehabilitation Manual for Australian Streams* (Land and Water Resources Research and Development Corporation, 2000) ISBN 1876830166 as best practice management in the area of stream rehabilitation.	▪ N/A
Key Issues:	In order for the NSW Office to complete and assessment under relevant legislation, it is essential that the following issues are included in the EIS:	
Surface Water Impacts	▪ details of the existing surface water users (both licensed and stock and domestic users) within the area of the proposal and any potential impacts on these users, including the environment (environmental flows);	▪ Section 4.6 – Existing Water users ▪ Section 10.5 – Water Sharing Plan

Requirements		**Reference**
	▪ details of potential impacts on surface water features as a result of mine subsidence, including the potential for loss of surface water to the groundwater system and the potential for reversal of surface flows, for individual longwall panels and cumulative risk over the mine life;	▪ Section 5 – Subsidence Impacts and Management
	▪ details of potential impacts on both the physical and ecological in-stream habitat, for individual longwall panels and cumulative risk over the mine life;	▪ EIS Appendix A ▪ EIS Appendix E
	▪ a fluvial geomorphic assessment which specifically details the risk of initiation of bed and bank erosion, change in channel slope of plan form, for individual longwall panels and cumulative risk over the mine life;	▪ EIS Appendix E ▪ Section 5 – Subsidence Impacts and Management
	▪ details of the potential for methane to affect water quality, habitat, GDE, macrophytes and macro-invertebrates;	▪ Section 10.4 – Water Quality ▪ EIS Appendix E
	▪ details of a proposed subsidence monitoring program for impact on surface water features, with trigger levels for response actions and remedial measures.	▪ EIS Appendix A ▪ Section 5 – Subsidence Impacts and Management ▪ Section 11.1 – Subsidence Impacts on Creeks
Water Balance	A site specific water balance, covering both surface and groundwater, must be provided, which includes:	▪ Section 8 – Water Management ▪ Section 9 – Water Balance ▪ Appendix 3 – Pit-top Water Management & Water Balance Analysis
	▪ sources of water supply;	▪ Section 8 – Water Management
	▪ location and design specification for all clean water diversions;	▪ Section 8 – Water Management
	▪ details of internal drainage of the contaminated water circuit;	▪ Section 8 – Water Management
	▪ details in regard to any mine water storage proposed for the development	▪ Section 8 – Water Management
	▪ discussion of proposed monitoring programs and reporting procedures;	▪ Section S12 – Monitoring, Licensing and Reporting Procedures
	▪ description of the integrated water management system, including an assessment of the water management system under a range of conditions (including 10%, 50% and 90% wet years and severe storm events).	▪ Section 8 – Water Management ▪ Section 9 – Water Balance ▪ Appendix 3 – Pit-top Water Management & Water Balance Analysis
Lake Macquarie City Council		
Creeks and Watercourses	A report outlining any known or suspected impacts on watercourses from the existing operations of Tasman Mine.	▪ Not addressed in Surface Water Assessment
	Council is aware that Tasman Mine operations have been considered a possible source of hydrological changes in Slatey Creek. In April 2011, Resources & Energy NSW and NSW Office of Water completed an investigation into loss of water flows and degradation in water quality. The recommendations of this investigation were for Tasman Mine to:	▪ EIS Section 4
	▪ Carry out an analysis of rainfall trends	
	▪ Collect and periodically test soil samples	
	▪ Collect and compare water samples in the stream with samples from the Fassifern seam	
	▪ Conduct thorough site inspection and regular observation of the stream	
	▪ Monitor Panel 1 and 2 groundwater levels	
	▪ Assess community water usage of Slatey Creek	
	Tasman Mine agreed to undertake these actions and to provide a report within 3 months. It is requested that the DGR's include this and any other investigations / reported incidences of impacts on all affected watercourses from existing operations. Further, how the proposed mining extension will incorporate measures to prevent future similar impacts.	

Requirements		Reference
Surface Water Assessment	Assessment of existing surface water resources (intermittent and ephemeral) including:	
	▪ Existing creek conditions including surface gradient, substrate composition, flow rates and flow velocities	▪ EIS Appendix D ▪ Appendix 1 – Flow Regime
	▪ Depth of the coal seam in relation to the creek bed surfaces	▪ EIS Appendix A ▪ EIS Appendix B
	▪ Water quality indicators (salinity, turbidity, dissolved oxygen, pH)	▪ Section 7 – Water Quality ▪ Appendix 2 – Surface Water Quality Data
	Assessment of the impacts of the proposed mining on the affected creek beds including:	
	▪ Potential to result in cracking of the creek beds	▪ EIS Appendix A ▪ Section 5 – Subsidence Impacts and Management
	▪ Potential to create or alter riffle and pool sequences	▪ EIS Appendix A ▪ Section 5 – Subsidence Impacts and Management
	▪ Potential to change the flooding regime including depth, flood risk, direction of flows and speed	▪ N/A
	▪ Potential for interaction between surface water and groundwater	▪ EIS Appendix B ▪ Section 5 – Subsidence Impacts and Management
	Assessment of the impacts of the proposed mining on water quality that includes:	
	▪ Consideration of dissolved oxygen, salinity, heavy metals and electrical conductivity given that alterations in these indicators have previously been associated with subsidence in creek lines.	▪ Section 10.4 – Water Quality
	▪ Increased rates of erosion and associated turbidity impacts	▪ Sections 5.3 and 5.4 – Impacts of Subsidence on Watercourse Bed Slope and Knick Points
	Assessment of the environmental impacts of waste water discharge	▪ Section 8.5 – Effluent Treatment and Disposal
Stormwater	A stormwater management plan and strategy addressing stormwater detention, stormwater quality and disposal of mine waters.	▪ Section 8 – Water Management ▪ Section 9 – Water Balance
Cessnock City Council		
	It is advised that Council would anticipate that the EIS would contain:-	
	▪ a detailed description of the proposed development (including rehabilitation of the site and how this rehabilitation will be integrated with the rehabilitation for the existing development);	▪ Section 6.6 – Impact of Mining on Flow ▪ Section 8 – Water Management ▪ Section 10.4 – Water Quality ▪ Rehabilitation of existing development addressed in EIS Section 5
	▪ include a general environmental risk assessment of the proposal;	▪ EIS Appendix O
	▪ consider the impacts of the proposal together with the whole Tasman Project and justify why it should be approved;	▪ Section 10 - Surface Water Impacts (Surface water aspects only)
	In terms of the environmental assessment of the project it is anticipated that the potential impacts of the project (including any potential cumulative impacts that may arise from the combined operation of the project with Donaldson, the existing Tasman development and Abel and Bloomfield mines) will be identified and the measures which would be implemented to mitigate, manage and monitor these impacts would be described.	▪ Section 10.6 – Cumulative Impacts
Soil & Water	Include a detailed water balance and refer to the *Guidelines for Fresh and Marine Water Quality* (ANZECC); *Managing Urban Stormwater: Soils & Construction* (Landcom) and *NSW State Rivers & Estuaries Policy*.	▪ Section 3.3 – Technical and Policy Guidelines ▪ Section 8 – Water Management