

WATERMARK

COAL PROJECT

ENVIRONMENTAL IMPACT STATEMENT

February 2013

X

Geomorphological Impact
Assessment





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Watermark Coal Project Geomorphological Impact Assessment

September 2012

Revision 0

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

Executive Summary

Introduction

Shenhua Watermark Coal Pty. Ltd. is seeking State Significant Development Consent under Division 4.1 of Part 4 of the *Environmental Planning & Assessment Act 1979* (EP&A Act) for the Shenhua Watermark Coal Project.

The Director General of the NSW Department of Planning and Infrastructure (DP&I) issued the Director-General's Environmental Assessment Requirements (DGRs) for the EIS on 19 April 2012. This assessment has been prepared in consideration of the DGRs input from the NSW Office of Water (NOW). Specifically, NOW requested the EIS include:

"A geomorphic assessment of Native Dog Gully (Dog Trap) and Watermark Gully and associated tributaries within the mining area, including details of stream order (using the Strahler system), river style and energy regimes both in channel and on any adjacent floodplains".

This assessment has been prepared to satisfy the above requirement.

Existing Environment

Most waterways within the Study Area are first and second order streamlines. The exceptions are:

- ▶ The very downstream reach of Native Dog Gully is 3rd Order.
- ▶ The Mooki River which is at least 4th Order.

A total of four different stream types were identified during the desktop and field assessment of the waterways within the study area as follows:

- ▶ Undefined Drainage Lines.
- ▶ Low Sinuosity, Fine Grained systems.
- ▶ Channelised Fill Systems.
- ▶ Valley Fill Systems.

These stream types are low to moderate energy systems reflective of the relatively gentle gradients and intermittent flow regimes of the waterways. As a result, the waterways transport sediment in suspended load only and are generally stable.

Due to the relatively disturbed nature of the Study Area as a result of past agricultural practices, most of the streamlines assessed are in moderate to poor geomorphic condition.

Impacts

The potential impacts on the geomorphology of waterways in the Study Area as a result of the Project include:

- ▶ Changes to catchment areas resulting in altered hydrologic regimes and potential impacts on sediment transport and scour processes.
- ▶ Encroachment of the Western Mining Area into a section of Watermark Gully resulting in flow concentration, flow impedance and the potential for stream scour.
- ▶ Construction of the proposed pump station on the Mooki River resulting in localised changes to flow behaviour with the potential for bank erosion.
- ▶ Construction and/or upgrade of temporary and/or permanent waterway vehicular crossings.

Recommendations

This assessment has determined that the significance of these potential impacts will be negligible to low with implementation of the following recommendations:

- ▶ At the proposed pump station location on the Mooki River, appropriate bank protection measures should be implemented to address the existing erosion and to protect the pump station into the future.
- ▶ An appropriately designed channel diversion should be provided for the section of Watermark Gully subject to encroachment by the Western Mining Area.
- ▶ The potential for initiating bed and bank instabilities at waterway crossings can be minimised through adoption of the following recommendations:
 - Wherever possible, waterways should be crossed on a straight portion of the waterway to avoid the risk of erosion. Where this is not possible bank stability works may be implemented.
 - Avoid impeding flows through selection of an appropriate crossing type. Causeway crossings inset so that they are flush with the channel profile present the best means for crossing small waterways. For culverted crossings, the hydraulic capacity of the culvert should be equivalent to the channel capacity of the waterway, or at least equal to the hydraulic capacity of the waterway below the level of the road surface.
 - Avoid concentrating or redirecting flow on the outlet of crossings. Where this is not possible, appropriate scour protection measures will need to be provided.
 - Avoid the need for access of heavy machinery to the bed of the waterways as works should be undertaken from the top of the banks where possible.
 - Avoid disturbance of surrounding banks by machinery or other construction works.
 - Vegetation clearance should be avoided where possible to protect soils from erosion. If clearance cannot be avoided, the area of vegetation cleared at any one time should be minimised.
 - Stabilise disturbed areas and reinstate vegetation as quickly as practicable after construction.

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- A Catchment Area and Flow Regime Changes along Watermark Gully (WRM Water and Environment, 2012)

1. Introduction

1.1 Project Overview

In October 2008, Shenhua Watermark Coal Pty Limited (Shenhua Watermark) was granted Exploration Licence (EL) 7223. Shenhua Watermark is a subsidiary of the Shenhua Corporation.

The Watermark Coal Project (the Project) is located within EL 7223, approximately 25 km south-south-east of the township of Gunnedah and to the immediate west of the village of Breeza, within the Gunnedah Local Government Area (LGA). The Project is approximately 282 km by rail from the export Port of Newcastle. Figure 1-1 illustrates the regional locality of the Project in relation to the nearest town centres of Breeza and Gunnedah.

Shenhua Watermark is seeking State Significant Development Consent under Division 4.1 of Part 4 of the *Environmental Planning & Assessment Act 1979* (EP&A Act) for the Project. The Project Application Boundary (Project Boundary) is shown on Figure 1-2.

The Project generally comprises:

- ▶ The construction and operation of an open cut mining operation extracting up to 10 Million tonnes per annum (Mtpa) of Run of Mine (ROM) coal for a 30 year period;
- ▶ An open cut mining fleet of excavators and shovels, supported by haul trucks, dozers, graders, drill rigs and water carts.
- ▶ The construction and operation of a Coal Handling Process Plant (CHPP) with a throughput of 10 Mtpa ROM coal.
- ▶ The co-disposal of tailings and coarse reject within Overburden Emplacement Areas (OEA).
- ▶ The construction and operation of a rail spur, rail loop, Kamilaroi Highway rail overpass, associated load out facility and connection to the Werris Creek - Moree Railway Line.
- ▶ The construction and operation of a Mine Access Road.
- ▶ The construction and operation of administration, workshop and related facilities.
- ▶ The construction and operation of ground and surface water management and reticulation infrastructure including pipelines, pumping stations and associated infrastructure for access to water from the groundwater aquifers, the Mooki River and private dams to the north-east of the Project Boundary.
- ▶ The installation of communications and electricity reticulation infrastructure.
- ▶ A workforce of up to approximately 600 full-time equivalent employees during construction and up to 600 full-time equivalent employees during the operation of the Project.

The conceptual layout of the Project is shown in Figure 1-2.

1.2 Purpose of this Study

GHD Pty Ltd was commissioned by Hansen Bailey Pty Ltd (Hansen Bailey), on behalf of Shenhua Watermark, to undertake a Geomorphology Impact Assessment for the Project. This investigation forms part of an Environmental Impact Statement (EIS) being prepared by Hansen Bailey to support Shenhua Watermark's application for State Significant Development Consent under Division 4.1 of Part 4 of the EP&A Act for the Project.

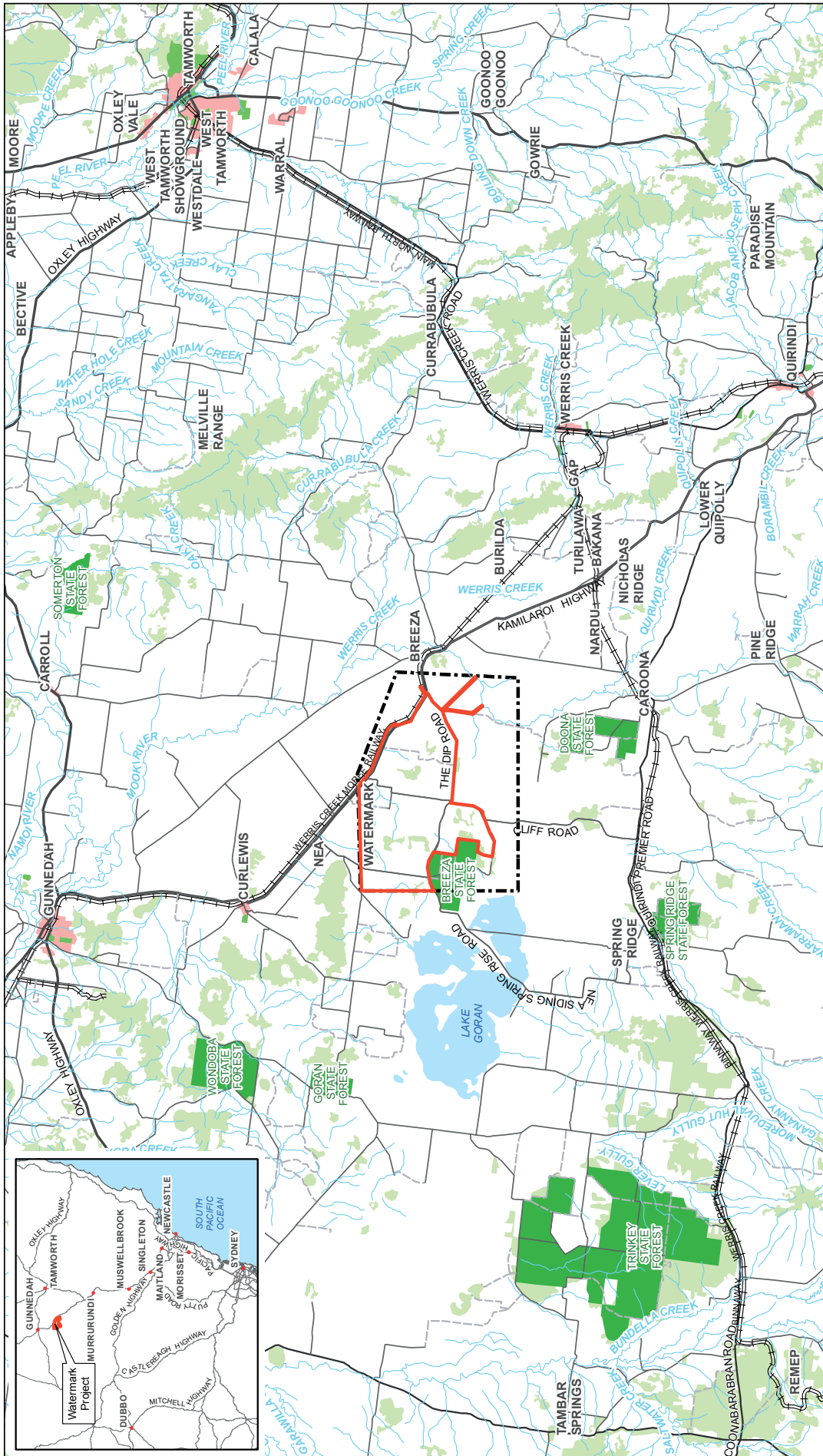
The Director General of the NSW Department of Planning and Infrastructure (DP&I) issued the Director-General's Environmental Assessment Requirements (DGRs) for the EIS on 19 April 2012. This assessment has been prepared in consideration of the DGRs input from the NSW Office of Water (NOW). Specifically, NOW requested the EIS include:

"A geomorphic assessment of Native Dog Gully (Dog Trap) and Watermark Gully and associated tributaries within the mining area, including details of stream order (using the Strahler system), river style and energy regimes both in channel and on any adjacent floodplains".

This assessment has been prepared to satisfy the above requirement.

1.3 Study Area

Figure 1-1 displays the location of the Study Area (EL 7223) and the location of Watermark Gully, Native Dog Gully and the Mooki River (and associated tributaries). This assessment investigated the three above mentioned waterways and other major tributaries where access was available.



Job Number 22-16163
Revision A
Date 11 Sept 2012

Hansen Bailey
Shenhua Watermark Coal Pty Limited



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- LEGEND**
- Watercourse
 - Railway
 - Dual Carriageway
 - Principal Road
 - Secondary Road
 - Minor Road
 - Track
 - Watercourse Area
 - Built Up Area
 - State Forest
 - Recreation Area
 - Forest Or Shrub
 - Project Boundary
 - EL 7223

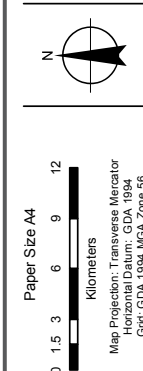
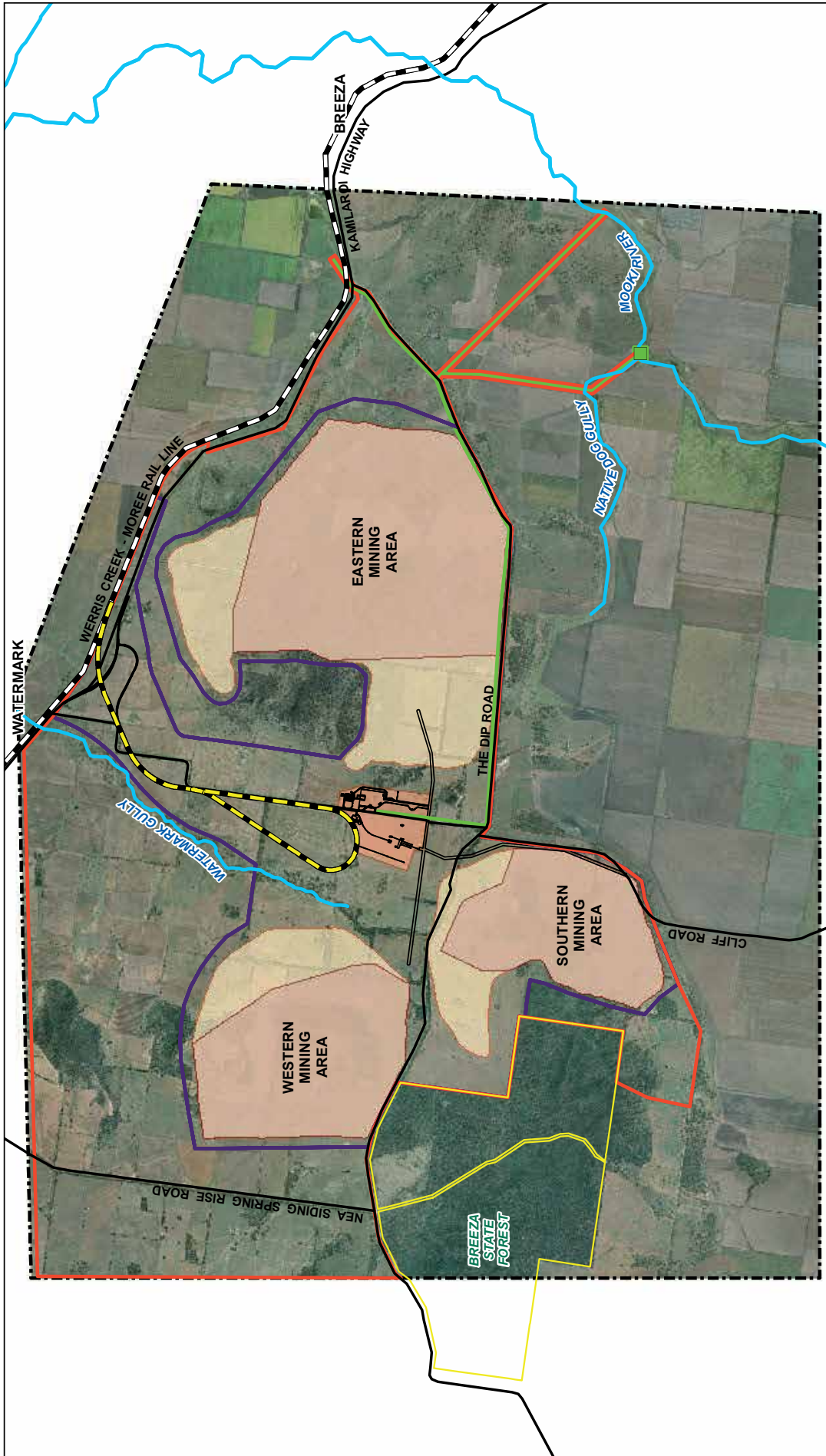


Figure 1-1

Regional Locality

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Data source: Hansen Bailey Project Bay 2012, Geoscience Australia: 250K Topographic Data Series 3, 2006. Created by Glampert



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LEGEND
Waterways
Roads
Rail
Proposed Rail Loop
Proposed Pump Station

Project Boundary
Disturbance Boundary
(Indicative)
Proposed Pipe Line Options
Proposed Pump Station

LEGEND
Mine Infrastructure Area
Open Cut Mining Areas
Overburden Emplacement Areas
Breeza State Forest

Paper Size A4
0 375 750 1,500 2,250 3,000
Metres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

Figure 1-2
Conceptual Project Layout

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Data source: Hansen Bailey, Aerial, Topography and Mining Data - 2011. Created by Giampert

2. Methodology

This assessment involved the following tasks:

- ▶ Desktop assessment of available information.
- ▶ Site Investigation.
- ▶ Interpretation of outputs from hydrologic and hydraulic studies undertaken by WRM Water and Environment (2012).

2.1 Desktop Assessment

A desktop assessment of existing information (GIS data and aerial imagery) was undertaken to identify and preliminarily map GIS the waterway types (river style), geomorphic condition and stream order of the Study Area. The assessment was focussed on Watermark Gully, Native Dog Gully and parts of the Mooki River and associated tributaries within the Study Area.

Stream ordering followed the Strahler stream classification system where waterways are given an 'order' according to the number of additional tributaries associated with each waterway (Strahler, 1952). Figure 2-1 indicates the Strahler stream ordering process for a generic catchment. Numbering begins at the top of a catchment with headwater ('new') flow paths being assigned the number one. Where two flow paths of order one join, the section downstream of the junction is referred to as a second order stream. Where two second order streams join, the waterway downstream of the junction is referred to as a third order stream, and so on.

Where a lower order stream (e.g. first order) joins a higher order stream (e.g. third order), the area downstream of the junction will retain the higher stream order.

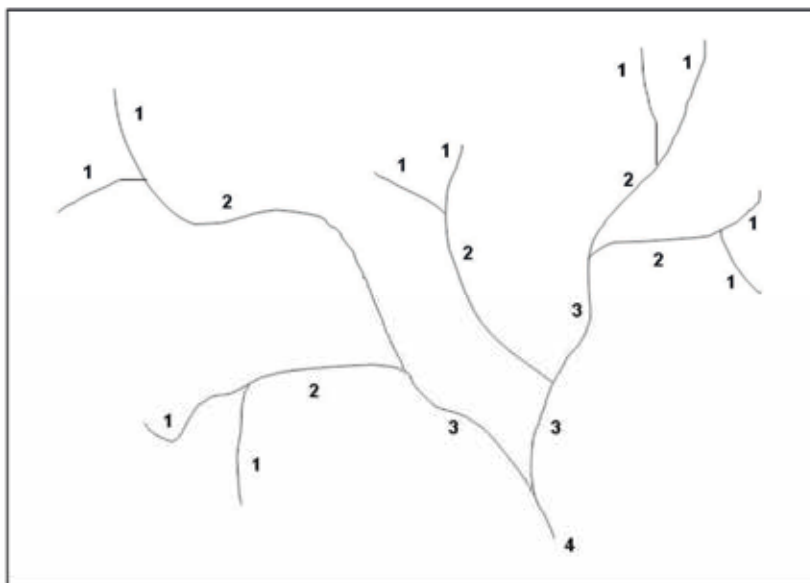


Figure 2-1 Stream Order for a Generic Catchment using Strahler (1952) Method

The assessment of stream physical form and function is broadly based on the methods and principles of the River Styles® framework (Brierley and Fryirs, 2005). This is the primary framework used in NSW for the geomorphic assessment of waterways.

Determination of stream types is largely based on the following parameters:

- Degree of valley confinement and bedrock influences.
- Presence and continuity of a channel.
- Channel planform (number of channels, sinuosity).
- Channel and floodplain geomorphic features.
- Nature of channel and floodplain sediments.

The assessment of geomorphic condition was based on Outhet and Cook (2004) who describe a rapid method of condition assessment that frames geomorphic condition in the context of natural and human induced variability. The characteristics of each condition category are described in Table 2-1. These categories provide an indication of the degree of alteration a reach has experienced from its expected natural form.

Table 2-1 Geomorphic Condition Category Descriptions

Indicative condition	Characteristics
Good	Geomorphic structure is largely unchanged from the pre-disturbance state such that only minor cases of localised instability occur. Relatively intact and effective vegetation coverage dominated by native species, giving resistance to natural disturbance and accelerated erosion. There is minimal alteration to catchment controls such as sediment supply and the hydrological regime allowing fast recovery from natural disturbance. There is also a high potential for ecological diversity.
Moderate	Geomorphic structure is moderately altered such that a reduced diversity of river features exist and floodplain connectivity is somewhat limited. Localised degradation of river character and behaviour, typically marked by modified patterns of geomorphic units. Patchy effective vegetation coverage allowing some localised accelerated erosion. The river has not fully adjusted to prevailing conditions and is experiencing ongoing changes.

Indicative condition	Characteristics
Poor	Considerable geomorphic alteration to the functioning and structure of the system when compared with the pre-disturbance condition. Type, extent and rate of processes are radically altered. Floodplain connectivity may be significantly altered. Abnormal or accelerated geomorphic instability (reaches are prone to accelerated and/or inappropriate patterns or rates of planform change and/or bank and bed erosion). Excessively high volumes of sediment inputs which blanket the bed, reducing flow diversity. Absent or geomorphologically ineffective coverage by vegetation (allowing most locations to have accelerated rates of erosion).

2.2 Site Investigation

A site investigation was undertaken on the 14th and 15th of March 2012 to identify the current physical characteristics of the waterways of Native Dog Gully and Watermark Gully and associated tributaries. Additionally, the investigation assessed the current stability of the banks of the Mooki River at the proposed pump station site shown on Figure 1-2. Information recorded during the field investigation included:

- ▶ Geomorphic type and condition of waterways.
- ▶ Nature, location and extent of existing waterway instabilities.
- ▶ Nature and location of waterway controls (e.g. bedrock, logs).
- ▶ Nature of channel and bedload materials.

General site data was recorded using a hand held GPS with other measurements being undertaken including valley widths and channel widths and depths during the site investigation.

3. Baseline Conditions

3.1 Stream Order

The results of applying the Strahler stream order methodology to the topographic waterways within the Study Area is displayed in Figure 3-1. This indicates that most waterways within the Study Area are first and second order streamlines. The exceptions are:

- ▶ The very downstream reach of Native Dog Gully is 3rd Order.
- ▶ The Mooki River, which is at least 4th Order.

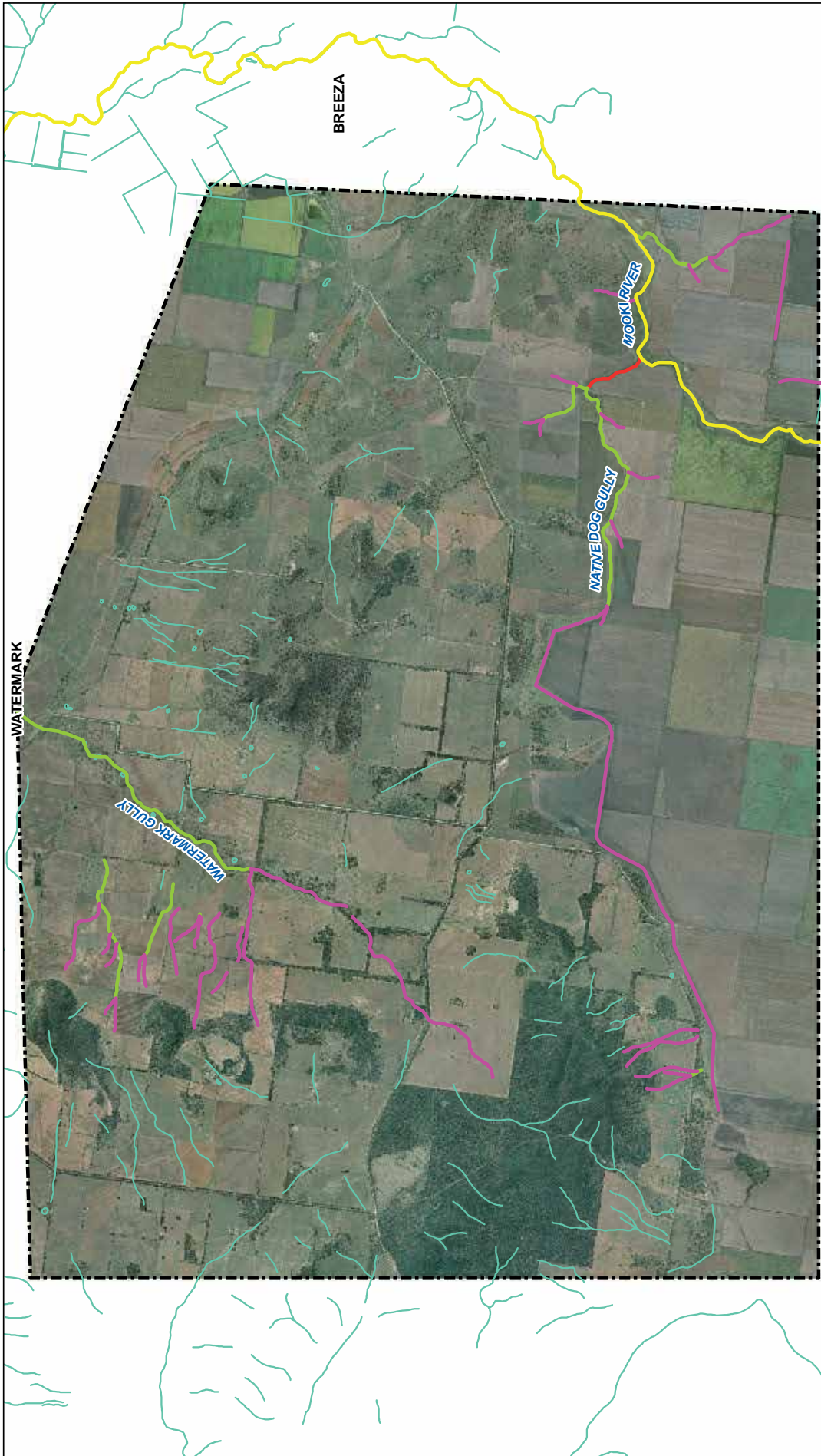
It should be noted that the topographic mapping of waterways does not always depict waterways where they become discontinuous systems (i.e. unchannelised). As a result, the topographic mapping does not always indicate that tributaries connect to main waterways. Hence, stream orders as displayed in Figure 3-1 for Native Dog Gully and the downstream section of Watermark Gully could be considered to be one or two orders greater if the unconnected streamlines as mapped were accounted for as connected systems.

3.2 Waterway Types

A total of four different stream types were identified during the desktop and field assessment of the waterways within the Study Area as follows:

- ▶ Undefined Drainage Lines.
- ▶ Low Sinuosity, Fine Grained Systems.
- ▶ Channelised Fill Systems.
- ▶ Valley Fill Systems.

The distribution of stream types within the Study Area is displayed in Figure 3-2 and their characteristics are described below.



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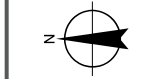


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EL 7223

Stream Order
2nd Order
3rd Order
4th Order and Higher

Stream Order
Predominantly 1st Order
1st Order



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Metres

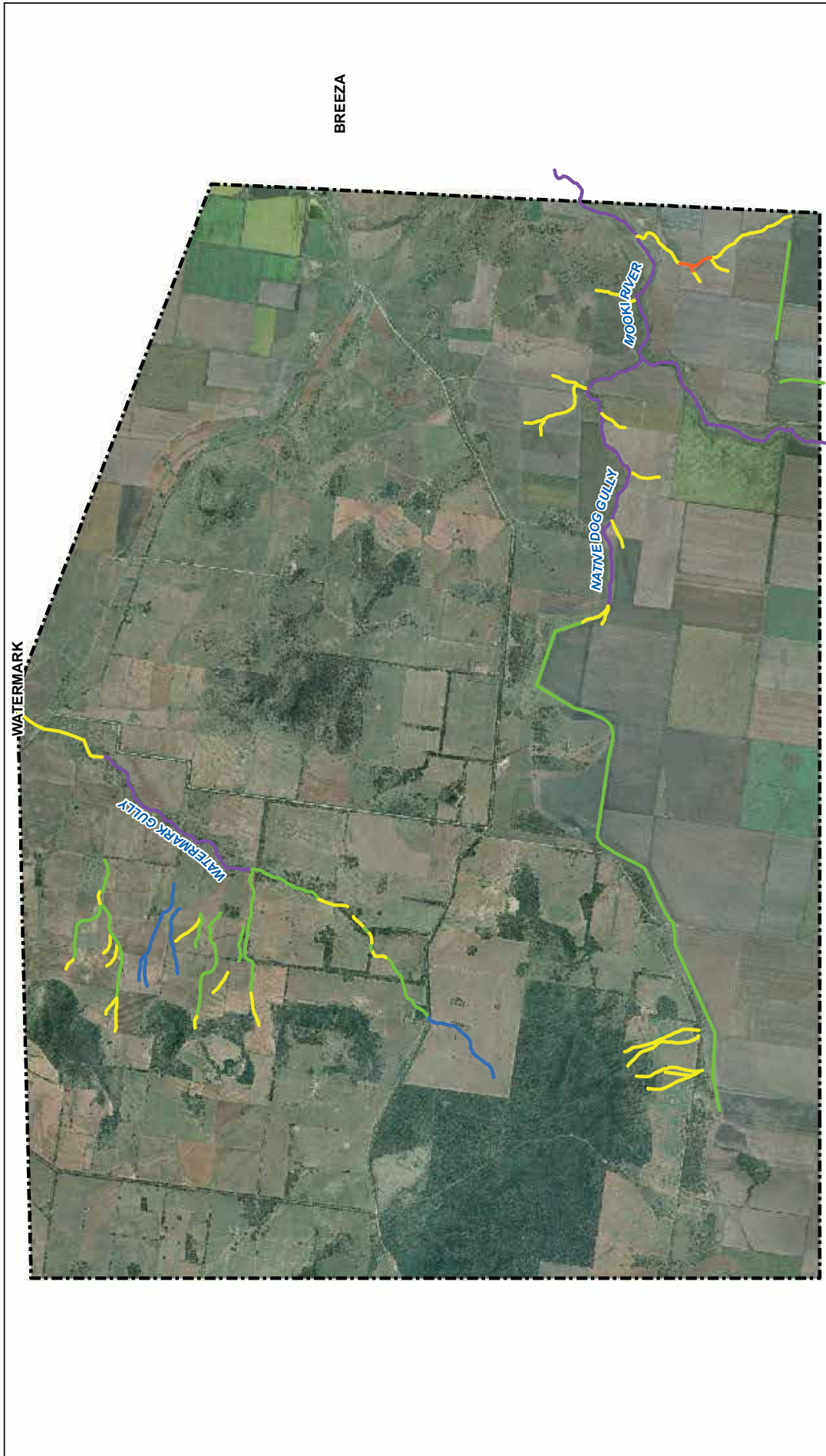
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Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

Figure 3-1

Stream Order

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G:\2216163\GIS\Maps\Deliverables\2216163_002_StreamOrder_A.mxd
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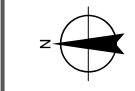
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LEGEND
Riverstyle
Channelised Fill
Low Sinuosity Fine Grained
Reservoir
Undefined Drainage
Valley Fill



Paper Size A4
0 375 750 1,500 2,250 3,000
Metres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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River Styles

Figure 3-2

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Data source: Hansen Bailey; Aerial / Mining Data - 2011, LPMA; DTDB - 2007. Created by Glampert

Undefined Drainage Line

Undefined Drainage Lines exist on a range of gradients that usually consist of a very slight depression in which it is assumed water will flow via sheet flow when available. That is, these systems do not exhibit a defined channel and floodplains are non-existent. Within the Study Area, these systems have often been altered through agricultural activities and contouring.

An Undefined Drainage Line was identified at the upstream 1st order extent of Watermark Gully (Figure 3-3). Several other Undefined Drainage Lines were identified to the west of Watermark Gully. These are unnamed waterways and are not mapped as connecting to Watermark Gully. However it is assumed that these would drain into Watermark Gully during high rainfall events. These drainage lines also exist through agricultural areas and are affected by artificial contour banks. They are geomorphologically stable with no visible signs of erosion or instability.



Figure 3-3 Upstream View of an Undefined Drainage Line Section of Watermark Gully

Low Sinuosity Fine Grained Systems

This waterway type exhibits a low sinuosity channel with wide, continuous floodplains and relatively stable, cohesive banks due to the fine-grained material. The channel generally holds water in isolated pools between flows. The channel itself is of low gradient and low energy such that sediment transported is predominantly limited to fine grained silts and clays in suspension. The low capacity channel allows overbank flows to be readily dissipated across the floodplain surfaces, activating flood channels and depositing fine grained sediments on the floodplain

The Low sinuosity, fine grained systems identified in the Study Area include the Mooki River and the lower reaches of Watermark Gully (Figure 3-4) and Native Dog Gully.



Figure 3-4 Downstream View of a Low Sinuosity Fine Grained Section of Watermark Gully

Channelised Fill Systems

Channelised Fill is, in relative terms, a laterally stable channel of low sinuosity incised within flat and featureless floodplains. Headcuts, which are usually the cause of the channeling, can progress upstream as a result of disturbances and unprotected banks will erode during times of higher flow. Most channels have incised to a point where all flows are contained within the channel such that the former fill surfaces are rarely inundated.

The channelised fill systems identified on the Study Area are located in the upper to middle reaches of Watermark Gully including some associated unnamed tributaries (Figure 3-5) and the upper extent of Native Dog Gully.



Figure 3-5 Upstream View of a Channelised Fill Section of an Unnamed Western Tributary of Watermark Gully

Valley Fill Systems

These systems are characterised by a relatively flat, featureless valley floor surface that lacks a continuous, well-defined channel. Substrates comprised of alluvial fine silts and muds vertically deposited out of suspension as flow velocity and competence is lost. Material eroded from the catchment is not transported through the reach resulting in the long-term deposition and storage of sediment. Hence, these stream types act as long term sediment accumulation zones. Degradation of these systems generally occurs through incisional processes such that a continuous channel forms within the valley floor sediments. Once incised, recovery back to an intact valley system is limited.

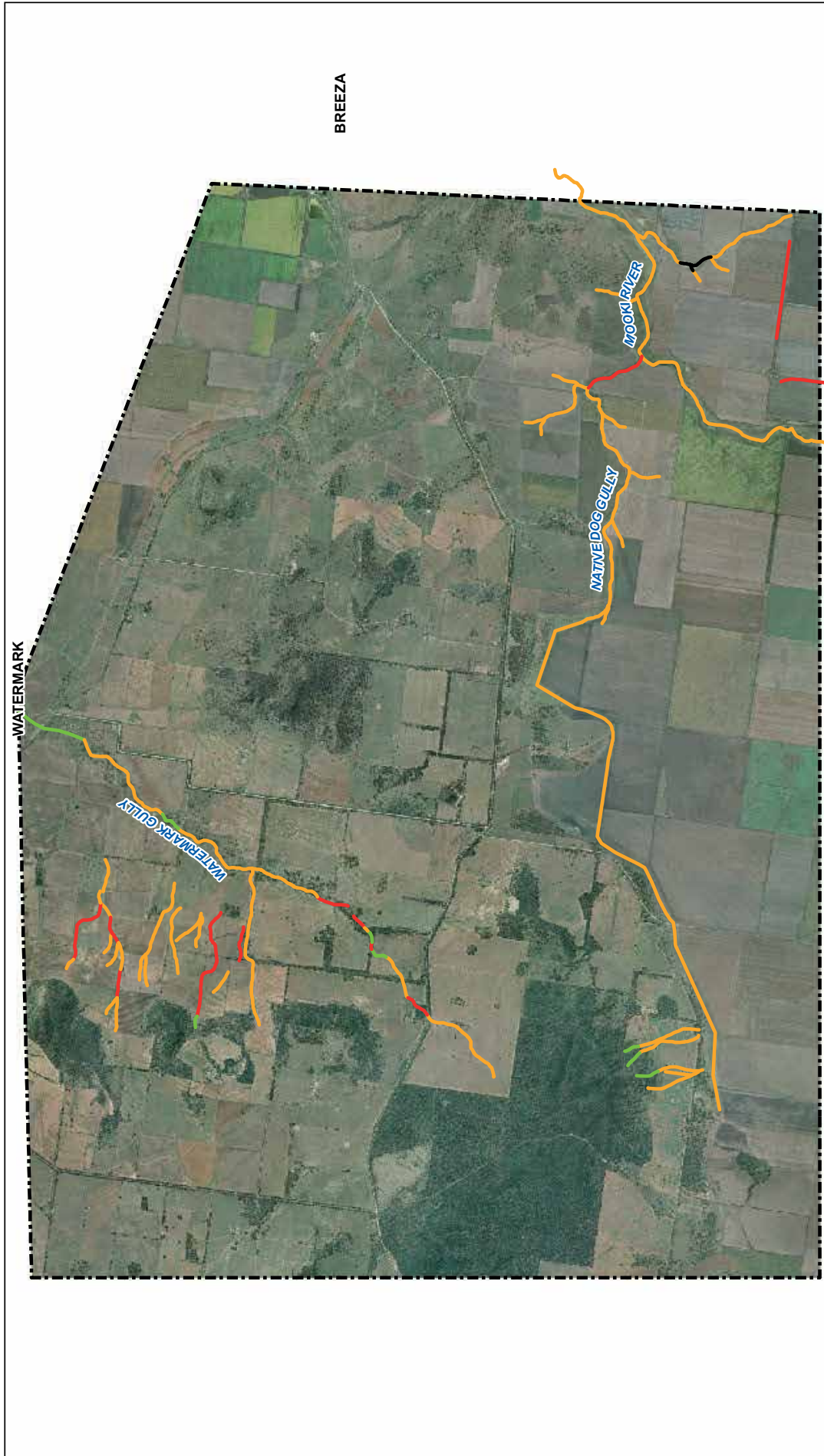
The valley fill systems identified in the Study Area are located in sections of Watermark Gully (Figure 3-6) including some associated unnamed tributaries and some small unnamed tributaries of Native Dog Gully and the Mooki River.



Figure 3-6 Downstream View of a Valley Fill Section of Watermark Gully

3.3 Geomorphic Condition

The geomorphic condition of the assessed streamlines in the Study Area is displayed in Figure 3-7. Due to the relatively disturbed nature of the Study Area as a result of past agricultural practices, most of the streamlines assessed are in moderate to poor geomorphic condition.



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Figure 3-7

Geomorphological Condition

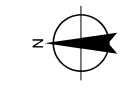
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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56



LEGEND
Condition
Good (green line)
Moderate (orange line)
Poor (red line)
None (black line)

EL 7223

Watermark Gully displays numerous earthen dams and small constructed levees along its length. Headcuts (Figure 3-8) and evidence of past incision and/or artificial channelling were also observed in some reaches. As a result, this waterway is largely considered to be in moderate geomorphic condition. The poor condition reaches generally exhibit active headcutting, ongoing localised bank erosion and degraded riparian vegetation conditions. The downstream extent of Watermark Gully is in good geomorphic condition with no identified instabilities or erosion and the limited presence of agricultural modifications such as dams and levees.



Figure 3-8 Upstream View of a Headcut on Watermark Gully

Tributaries of Watermark Gully and other minor drainage lines within the Study Area have largely been disturbed through the creation of contour banks and the impact of past agricultural practices. These waterways are generally considered to be in moderate condition, with a few reaches considered poor being subject to ongoing active gully processes.

The Mooki River through the Study Area has been classed as a moderate condition. Bank erosion is prevalent on the outside bank of bends and riparian vegetation associations are degraded.

The upstream assessed extent of Native Dog Gully consists of an excavated channel constrained by levee banks to reduce water logging of the surrounding alluvial soils. However, the channel is largely stable and this reach is therefore considered to be in moderate geomorphic condition.

The downstream extent of Native Dog Gully exhibits locations of ongoing bank failure through undercutting and slumping (Figure 3-9). There are also several small weirs constructed of loose rock along this length and riparian vegetation associations are largely limited to pasture grasses. As a result, this reach is considered to be in poor geomorphic condition.



Figure 3-9 Evidence of Bank Failure is Common Along the Lower Reach of Native Dog Gully

4. Impact Assessment

Based on a review of the proposed layout and description of the Project, the potential impacts on the geomorphology of waterways as a result of the Project include:

- ▶ Changes to catchment areas resulting in altered hydrologic regimes and potential impacts on sediment transport and scour processes.
- ▶ Encroachment of the Western Mining Area into a section of Watermark Gully resulting in flow concentration, flow impedance and the potential for stream scour.
- ▶ Construction of the proposed pump station on the Mooki River (shown in Figure 1-2), resulting in localised changes to flow behaviour with the potential for bank erosion.
- ▶ Construction and/or upgrade of temporary and/or permanent waterway vehicular crossings.

These potential impacts and their significance are discussed in the following sections.

4.1 Catchment Area Changes

The Project will alter catchment areas draining to the main creeks in the Study Area. However, following cessation of mining activities, catchment areas will be largely reinstated as rehabilitation of open cut mining areas and OEAs progress.

Over the life of the Project, there will be a temporary loss of catchment draining to Native Dog Gully and the Mooki River. These losses are minimal compared to the overall catchment areas of these systems. Hence, the impact on geomorphic processes along these systems will be negligible.

For Watermark Gully, the catchment area reduces with mining of the Western and Southern Mining Areas. However, following rehabilitation of the mining areas, the catchment area of Watermark Gully will be larger than the existing area due to the diversion of flow from the western edge of the Western Mining Area into Watermark Gully.

WRM Water and Environment (2012) have modelled the potential change in flow regimes as flow duration curves at three locations along Watermark Gully for existing conditions, Year 30 of the proposed mining operations and for post mine conditions. The reporting locations and results are displayed in Appendix A. The results indicate the following:

- ▶ Significant flow events (greater than 1,000 ML/day) are exceeded for less than 2% of the time, indicative of the intermittent flow regime of Watermark Gully.
- ▶ Under Year 30 proposed mining conditions, the flow duration curves indicate that the frequency of flow events reduces by up to approximately 0.4% at 'Reporting Locations 2 and 3'. There is minimal change to the flow at 'Report Location 1'.
- ▶ For post mine conditions, the frequency that flows are exceeded increases at all locations due to the larger catchment area. This is most pronounced at 'Reporting Location 1' where flow exceedances increase by up to approximately 0.25% from existing.

The potential geomorphic response to these flow regime changes could involve changes in the capacity of the waterway to transport sediment and maintain geomorphic features such as pools. Watermark Gully does not actively transport bedload sediment and its existing form is heavily modified as a result of the presence of on-line dams and past incision. Further, the Year 30 conditions flow regime reduction will be temporary, with the flow regime being restored or increased under post mine conditions. Hence, the impact of the reduction in catchment areas on geomorphic processes along Watermark Gully is considered low.

4.2 Encroachment of Western Mining Area into Watermark Gully

Under the proposed mine layout, the Western Mining Area along the eastern extent of its southern boundary encroaches into a 200 to 300 metre section of Watermark Gully. Hydraulic modelling undertaken by WRM Water and Environment (2012) indicates that this encroachment results in an increase in flow levels upstream and through the encroached section. This may result in increased potential for sediment deposition upstream.

On exiting the encroached section, the modelling indicates an increase in the gradient of flow surface profiles and flow velocities. This may result in erosion of the waterway at this point. Further, the encroachment may impede low flows from passing downstream entirely. Hence, it is likely that diversion of this section of Watermark Gully will be required so that flows are not impeded nor concentrated such that flow energies exceed erosion thresholds.

This section of Watermark Gully is a channelised fill in moderate condition. As a result, it displays a grassed channel with minimal instream form (Figure 4-1) and exhibits past modifications including flow diversion bunds and an instream dam. Construction of a diversion channel for this section of Watermark Gully therefore is not considered to be inappropriate due to the relatively noncomplex and modified form and functioning of the existing waterway. With construction of a diversion, the impact of encroachment of the Western Mining Area on geomorphic functioning is considered low.



Figure 4-1 Downstream View of the Section of Watermark Gully that may Require Diversion as Result of Encroachment of the Western Mining Area

4.3 Mooki River Pump Station

The proposed pump station on the Mooki River (shown in Figure 1-2) is located on the outside bank of a bend and exhibits active erosion (Figure 4-2). The bank is approximately six metres high and composed of alluvial silt materials. Without appropriate bank stabilisation measures, construction of the pump station may exacerbate the existing erosion issues at this location, as well as place the pump station at risk from channel erosion. In terms of exacerbating the existing erosion, the level of impact would be localised to the site without any significant change in stream form and functioning. However, given the risk to the proposed infrastructure from erosion, bank stabilisation measures will be required. With such mitigation, the impact of the pump station on channel stability and geomorphic processes is considered negligible.



Figure 4-2 Downstream View of the Actively Eroding Bank of the Mooki River at the Location of the Proposed Pump Station

4.4 Vehicular Crossings

The Project may require the construction of temporary or permanent waterway vehicular crossings for new roads and/or the upgrade of existing waterway vehicular crossings. Construction of waterway road crossings could cause or exacerbate bed and bank instabilities locally. The potential for initiating bed and bank instabilities can be minimised through adoption of the following recommendations in the design and construction of waterway crossings:

- ▶ Wherever possible, waterways should be crossed on a straight portion of the waterway to avoid the risk of erosion. Where this is not possible bank stability works may be implemented.
- ▶ Avoid impeding flows through selection of an appropriate crossing type. Causeway crossings inset so that they are flush with the channel profile present the best means for crossing small waterways. For culverted crossings, the hydraulic capacity of the culvert should be equivalent to the channel capacity of the waterway, or at least equal to the hydraulic capacity of the waterway below the level of the road surface.
- ▶ Avoid concentrating or redirecting flow on the outlet of crossings. Where this is not possible, appropriate scour protection measures will need to be provided.
- ▶ Avoid the need for access of heavy machinery to the bed of the waterways as works should be undertaken from the top of the banks where possible.
- ▶ Avoid disturbance of surrounding banks by machinery or other construction works.

- ▶ Vegetation clearance should be avoided where possible to protect soils from erosion. If clearance cannot be avoided, the area of vegetation cleared at any one time should be minimised.
- ▶ Stabilise disturbed areas and reinstate vegetation as quickly as practicable after construction.

With implementation of the above recommendations, the impact of vehicular crossings on the geomorphology of waterways is considered low.

5. Summary and Recommendations

5.1 Existing Environment

Most waterways within the Study Area are first and second order streamlines. The exceptions are:

- The very downstream reach of Native Dog Gully is 3rd Order.
- The Mooki River which is at least 4th Order.

A total of four different stream types were identified during the desktop and field assessment of the waterways within the study area as follows:

- Undefined Drainage Lines.
- Low Sinuosity, Fine Grained systems.
- Channelised Fill Systems.
- Valley Fill Systems.

These stream types are low to moderate energy systems reflective of the relatively gentle gradients and intermittent flow regimes of the waterways. As a result, the waterways transport sediment in suspended load only and are generally stable.

Due to the relatively disturbed nature of the Study Area as a result of past agricultural practices, most of the streamlines assessed are in moderate to poor geomorphic condition.

5.2 Impacts and Recommendations

The potential impacts on the geomorphology of waterways in the Study Area as a result of the Project include:

- Changes to catchment areas resulting in altered hydrologic regimes and potential impacts on sediment transport and scour processes.
- Encroachment of the Western Mining Area into a section of Watermark Gully resulting in flow concentration, flow impedance and the potential for stream scour.
- Construction of the proposed pump station on the Mooki River (shown on Figure 1-2) resulting in localised changes to flow behaviour with the potential for bank erosion.
- Construction and/or upgrade of temporary and/or permanent waterway vehicular crossings.

This assessment has determined that the significance of these potential impacts will be negligible to low with implementation of the following recommendations:

- At the proposed pump station location on the Mooki River, appropriate bank protection measures should be implemented to address the existing erosion and to protect the pump station into the future.
- An appropriately designed channel diversion should be provided for the section of Watermark Gully subject to encroachment by the Western Mining Area.

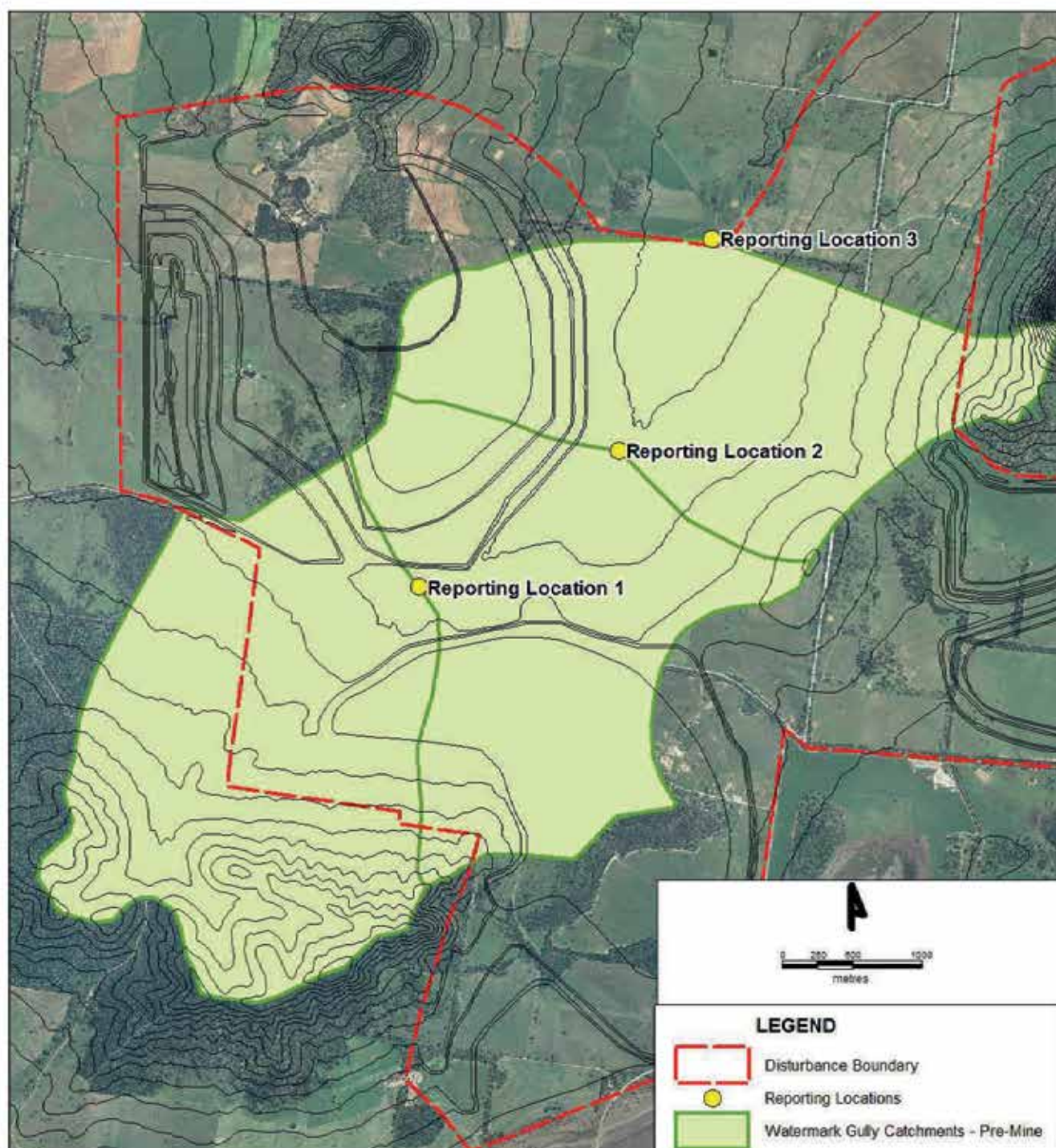
- ▶ The potential for initiating bed and bank instabilities at waterway crossings can be minimised through adoption of the following recommendations:
 - Wherever possible, waterways should be crossed on a straight portion of the waterway to avoid the risk of erosion. Where this is not possible bank stability works may be implemented.
 - Avoid impeding flows through selection of an appropriate crossing type. Causeway crossings inset so that they are flush with the channel profile present the best means for crossing small waterways. For culverted crossings, the hydraulic capacity of the culvert should be equivalent to the channel capacity of the waterway, or at least equal to the hydraulic capacity of the waterway below the level of the road surface.
 - Avoid concentrating or redirecting flow on the outlet of crossings. Where this is not possible, appropriate scour protection measures will need to be provided.
 - Avoid the need for access of heavy machinery to the bed of the waterways as works should be undertaken from the top of the banks where possible.
 - Avoid disturbance of surrounding banks by machinery or other construction works.
 - Vegetation clearance should be avoided where possible to protect soils from erosion. If clearance cannot be avoided, the area of vegetation cleared at any one time should be minimised.
 - Stabilise disturbed areas and reinstate vegetation as quickly as practicable after construction.

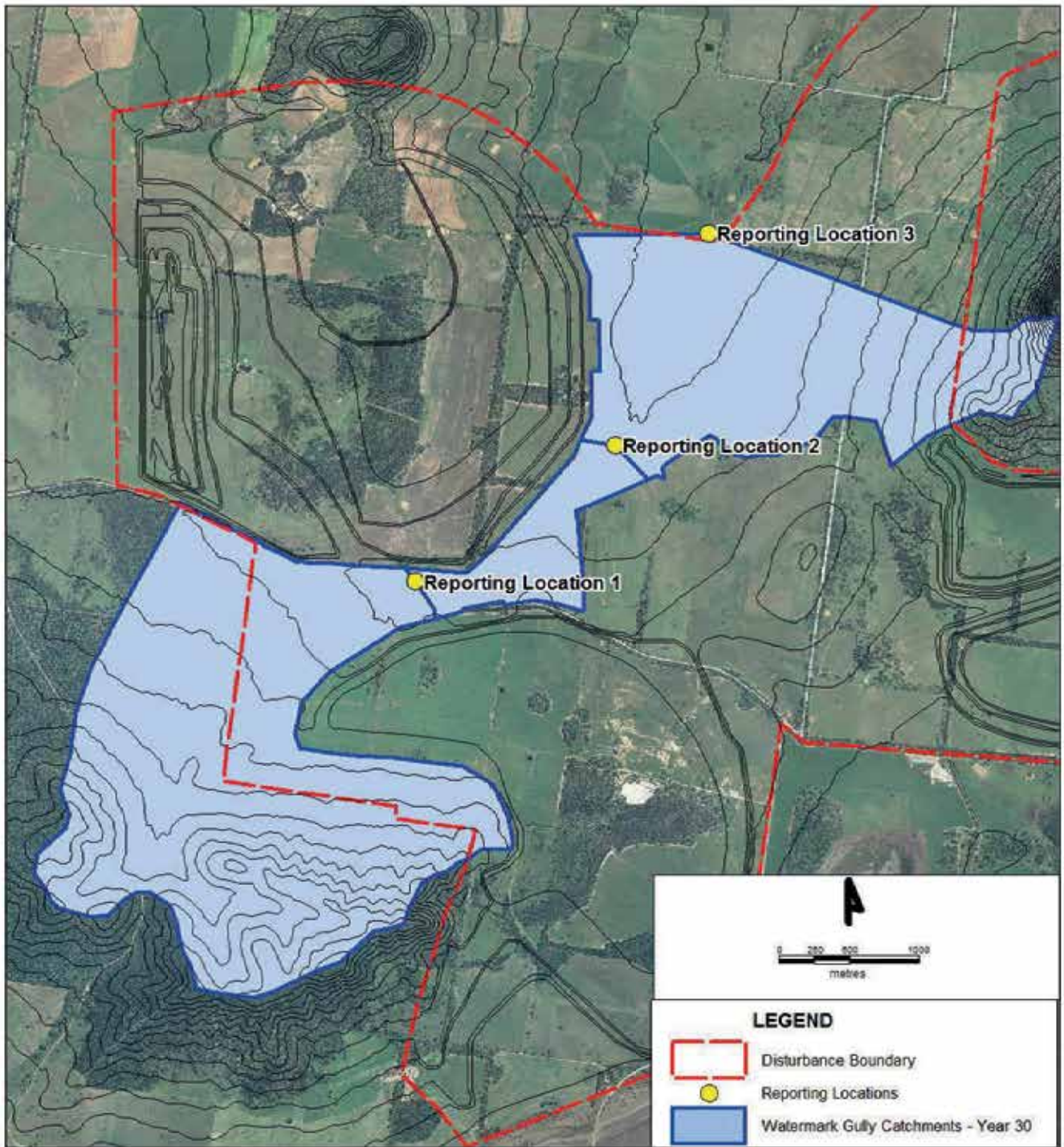
6. References

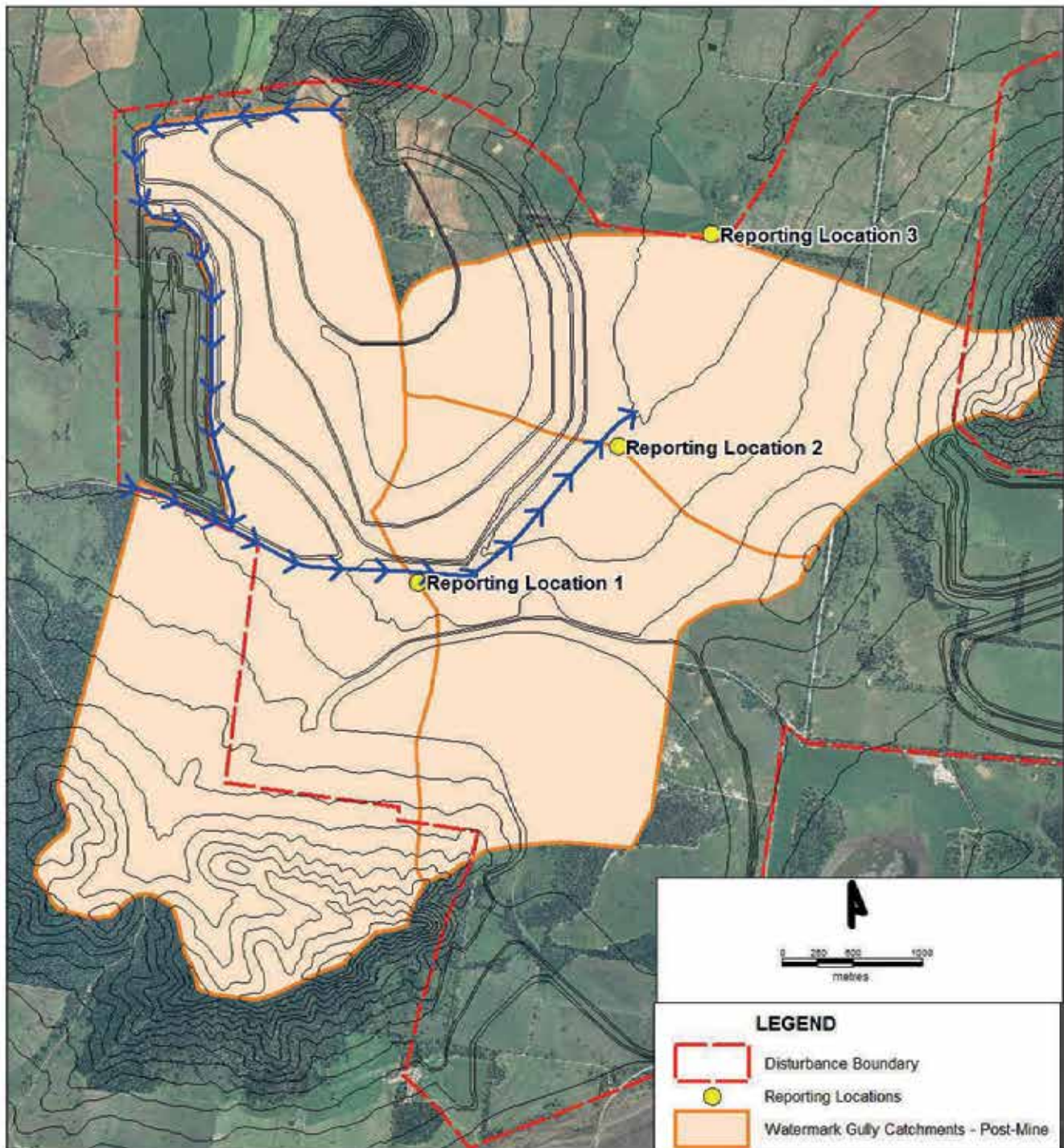
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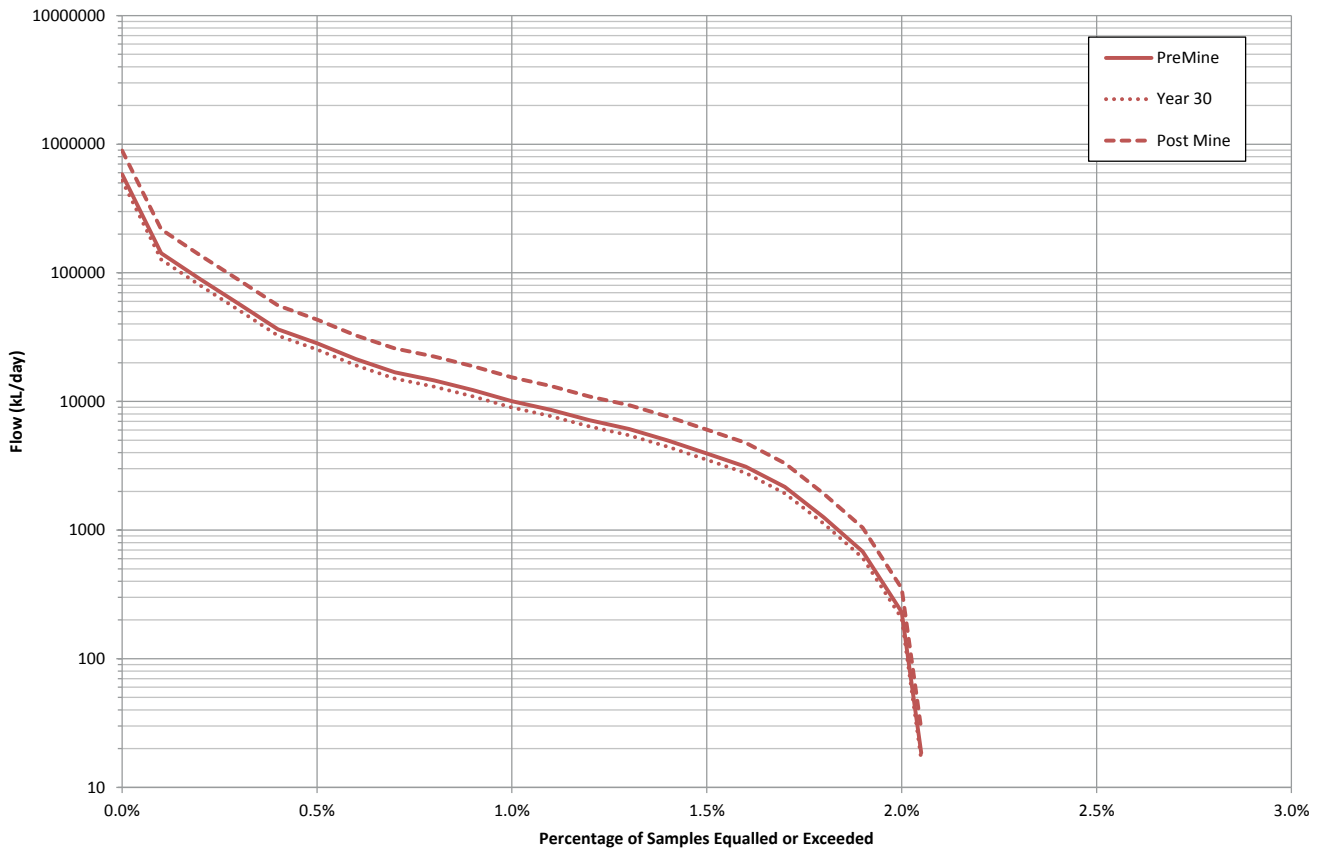
Appendix A

Catchment Area and Flow Regime Changes along Watermark Gully (WRM Water and Environment, 2012)

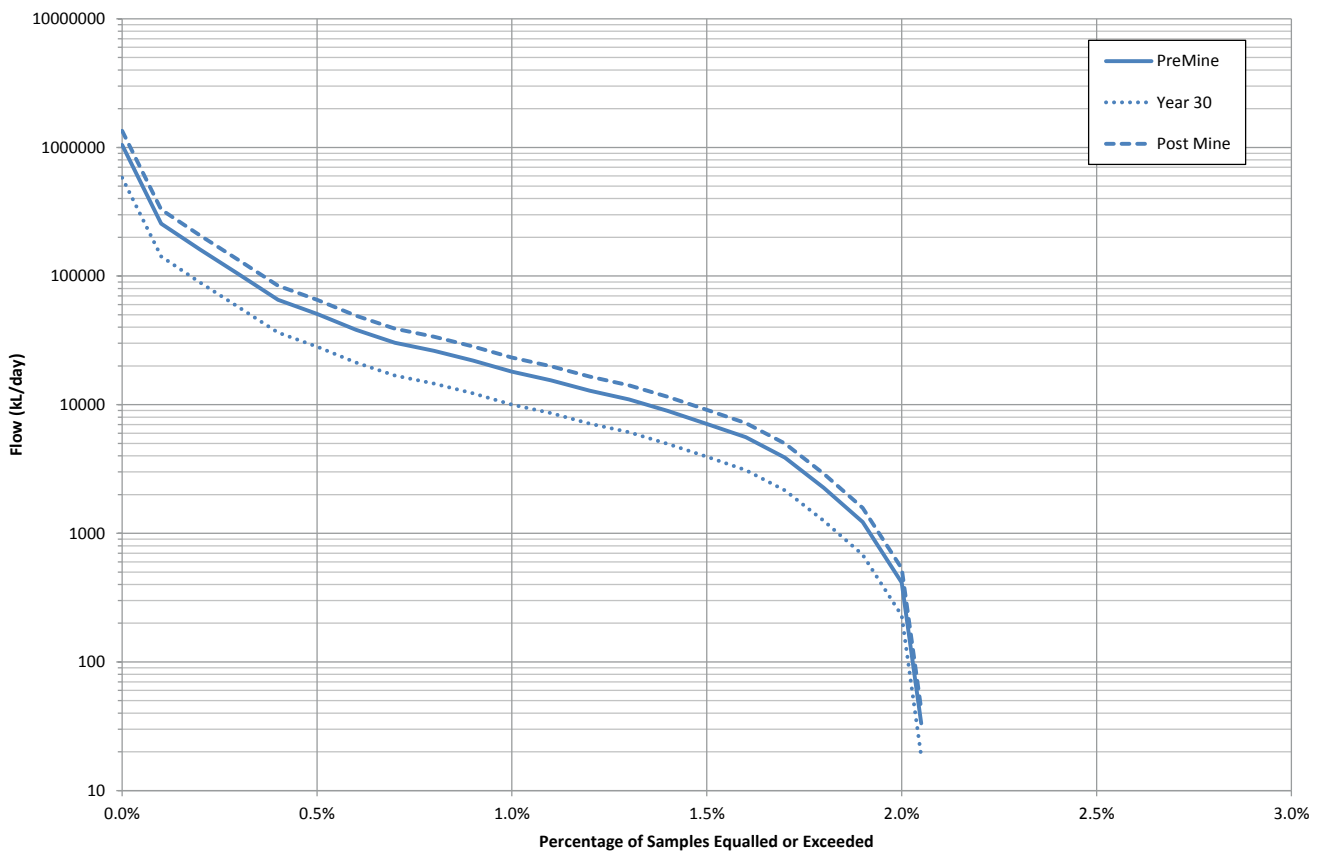




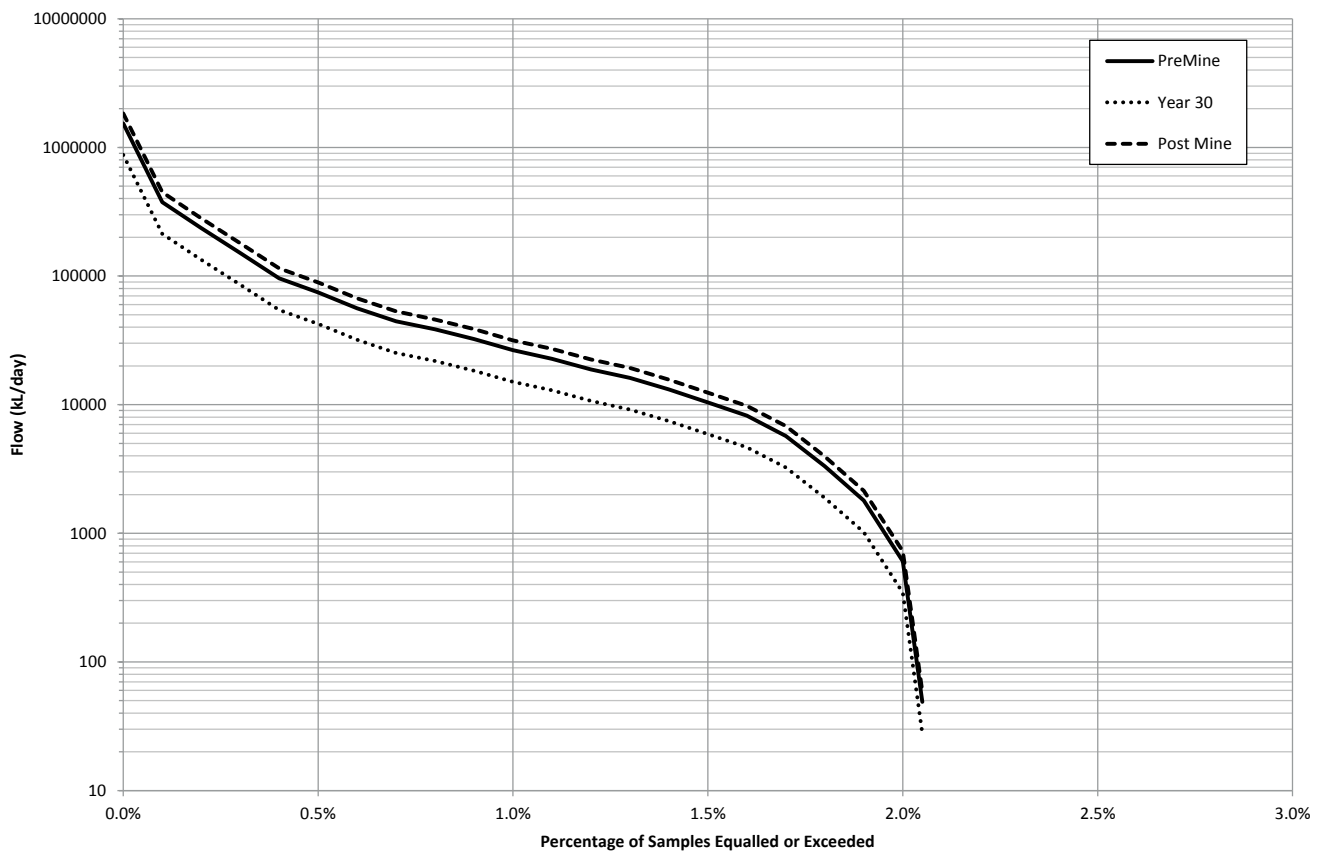




Flow Frequency – Reporting Location #1



Flow Frequency – Reporting Location #2



Flow Frequency - Reporting Location #3

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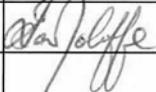
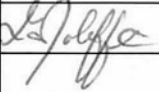
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		Name	Signature	Name	Signature	Date
0	G Lampert	I Joliffe		I Joliffe		12/09/2012