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Project Execution Plan for Major Civil Works
McArthur River Mine Open Cut Project
Xstrata

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Approvals		Name	Position	Signed	Date
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Revisions

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Distribution

Name	Date	Revision	Name	Date	Revision
P Thompson			G Prince		
I Gordon			Project Manager		
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1. Introduction

1.1 Overview

The McArthur River Mine open cut Project will result in a change in mining method, from an underground to an open cut mine. Open cut mining will necessitate the following major civil works:

- Realignment of McArthur River and Barney Creek around the proposed open cut.
- Construction of a flood protection bund around the open cut.
- Construction of an overburden emplacement facility.
- Construction of a haul road to the overburden emplacement facility.
- Construction of various drainage and hydraulic structures.
- Raising the existing tailings dam.
- Construction of mining facilities.

Construction of the civil works will be undertaken over a two-year period during 2006 and 2007, with the majority of activities taking place during the dry seasons.

1.2 Purpose

This project execution plan outlines the objectives, processes and strategies that will be employed by the parties managing the project to execute the works and also establishes a framework to ensure that the project expectations and key performance indicators are met.

The plan ensures that a consistent approach is adopted by all parties managing the project and is intended to be a mandatory control document for all aspects of the project.

This document is applicable only to the construction activities of the project, and does not include mining or construction activities external to the mine site.

1.3 Related Documents

The project execution plan is one of a number of documents that define the project and describe how the project will be delivered. These defining documents are supported by specific management plans (eg safety management plan), policies and procedures.

This project is defined by the following documents:

- Scope of work
- Approved budget
- Approved schedule
- Project execution plan

Reference documentation also includes:

- Draft Environmental Impact Statement – August 2005.
- Supplement to the Draft Environmental Impact Statement – December 2005.
- Public Environmental Report – June 2006
- Design Basis Report (Appendix A)
- Technical Specification and Drawings for Civil Works (Appendix B).

2. Scope of Work

2.1 Detailed Scope

The project scope of the work includes, but is not limited to, the major activities listed in Section 1.1. The major civil works will involve the following:

- Construction of approximately 5.5 km of realigned open channel for diversion of the McArthur River around the open cut.
- Construction of approximately 3.1 km of realigned open channel for diversion of Barney Creek and Surprise Creek around the open cut.
- Construction of approximately 7.3 km of flood protection bund around the open cut comprising a zoned fill embankment.
- Site preparation for the initial stage of the overburden emplacement facility of approximately 50 hectares.
- Construction of a haul road approximately 1.2 km in length between the open cut and the overburden emplacement facility.
- Construction of a high level bridge across the Barney Creek diversion channel for the haul road crossing.
- Construction of various hydraulic structures such as scour control devices and rock lining.
- Miscellaneous works including:
  - temporary stream crossings
  - temporary bunding
  - fencing
  - protection of the gas pipeline

The proposed civil works are shown on the layout plan drawing BEE508-C-DWG-002.

2.2 Exclusions

The following items are not part of this scope of work:

- Relocation of mine services.
- Mine hardstand area.
- Mine workshop.
- Additional accommodation.
- Revegetation of diversion and flood protection bund batters.
- Flattening of flood protection bund batters to 1 in 4.
- Raising the tailings dam.

3. Objectives

3.1 Primary Requirement

The McArthur River mine cannot utilise open cut mining methods without protection from flooding of the McArthur River and surrounding streams. Implementation of the activities comprising the major civil works addressed by this document is essential for the continuation of open cut mining

3.2 Goals and Expectations

The key drivers and desired outcomes for the project are:

- Occupational Health and Safety – zero harm and no incidents
- Environment and Community – zero harm and no incidents
- Implementation deliverables – meet or exceed project requirements for scope, cost, time and quality
- Existing mining operations – no delays

3.3 Key Performance Indicators

The following threshold performance criteria (KPI's) are expected outcomes for the successful delivery of the project:

- Occupational health and safety
  - Disabling injuries - Nil
  - Medical treated injuries - Nil
  - Serious or reportable incidents - TRIFR <20
  - 100% of all incidents to be reported (and recorded) with 80% of all incidents reported by the Project Team.

- Environmental and community
  - MRM licence breaches - Nil
  - Community complaints - Nil
  - 100% of all incidents to be reported (and recorded) with 80% of all incidents reported by the Project Team.

- Implementation and deliverables
  - Scope - no unauthorised deviations
  - Cost - completion within approved budget
  - Time - completion within approved schedule
  - Quality - meet requirements of technical specifications

- Existing mining operations
  - Delays - Nil

3.4 Qualifications

Delivery of the project in accordance with the performance criteria (KPI's) is dependant on the following:

- Project approval to proceed given in accordance with the agreed programme
- Finalisation of contractual arrangements in accordance with the agreed programme
- Provision of 'Approved for Construction' drawings and documentation to the contractor in accordance with the agreed programme
- No significant delays due to inclement weather or latent conditions on the site

4. Project Constraints

4.1 Intent

This section of the project execution plan is intended to identify and address those issues or conditions that are beyond what are usually considered to be normal project constraints, such as cost and time. These issues or conditions can originate from a variety of sources, ie internal, external, climatic, physical, and cultural. This document will categorise the issues into the following areas as follows.

4.2 Statutory and Community

Key issues will be derived from NT Government consent conditions.

4.3 Project and Site Specific

The key issues are:

- The wet/dry season cycle that imposes access, safety and workability constraints on progress of the work.
- The requirement to source materials for the flood protection bund from the river and creek diversion excavations.
- Competition for resources (both labour and equipment) between construction and mining.
- Ability to source and retain suitable and adequate resources (both labour and equipment).
- Availability of adequate survey data to complete detail design and determine final quantities in order to meet the programme.

These issues are crucial constraints and will be pivotal elements of the contractor's resource plan and work schedule.

These issues are addressed further in the staging section, 6.2 of this document.

5. Organisation and Responsibilities

5.1 Overview

Management of the project will be implemented through an integrated project team comprising personnel from three organisations as follows:

- Owner — Xstrata / MRM
- Contractor — J J McDonald and Sons (JMS)
- Project Manager — Xstrata / MRM

It is considered that project team members from the contractor and project manager will be full-time whilst the owner's representative(s) may be full-time or part-time.

In order to achieve successful project completion, other specialist personnel or organisations may supplement the project team on an as-required basis.

The project team will be located in a dedicated project office at the mine site.

5.2 Project Organisation Structure

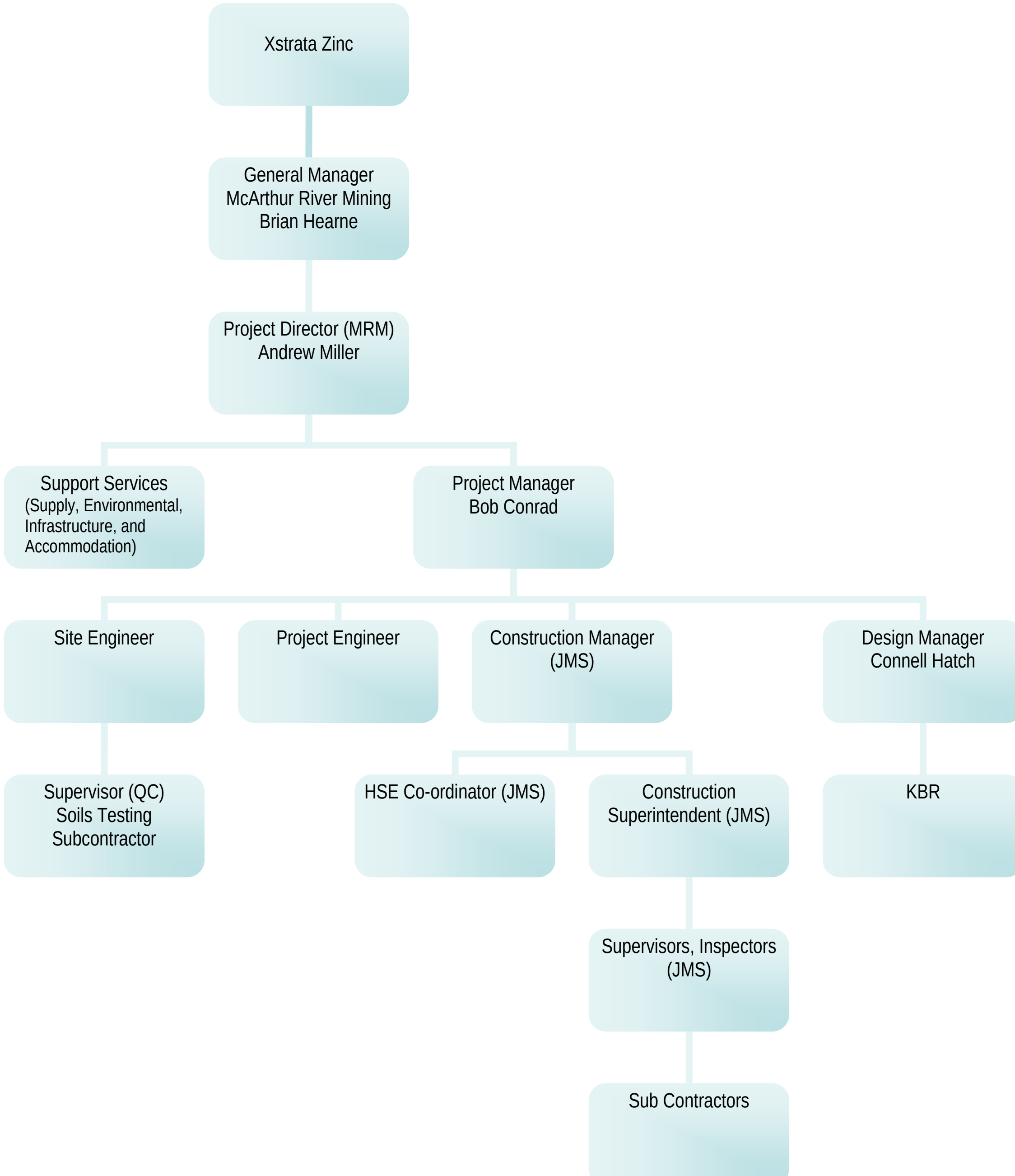


Figure 1 - Project organisation structure

5.3 Roles and Responsibilities

The following section is a summary description of the key project team members' roles and responsibilities.

5.3.1 Owners Team

- Project Director (Open Cut Manager)
  - Champions the project
  - Provides senior management support and guidance to the project team
  - Audits and reviews project delivery
  - Reports progress and significant issues to Xstrata senior management
  - Principal point of contact and prime responsibility for managing major project interfaces with mining operations
  - Ensures agreed mine support services are provided to the project as required
  - Audits and reviews project safety and environmental performance for compliance

5.3.2 Contractor's Team

- Construction Manager
  - Champions the project
  - Manages the implementation phase of the project, including resourcing, detailed scheduling, methodology, work packaging and sub-contracting
  - Ensures relevant management plans are prepared and implemented
  - Co-ordinates, in collaboration with the Open Cut Manager, major project interfaces with mining operations
  - Oversees and reviews progress of the work on a daily basis
  - Manages and reviews safety and environmental performance on a daily basis
  - Reports on progress, all aspects of project delivery (including time and cost), project issues, and incidents to the Project Manager
  - Manages contractual issues in collusion with the Project Manager
  - Manage industrial relations on the project site

- Construction Superintendent
  - Implements and oversees the works on a daily basis
  - Prepares and monitors detailed resource plans and schedules
  - Requisitions, allocates and maintains resources
  - Determines, in collusion with the Construction Manager, work packaging and methodology
  - Implements and audits all safety, environmental and quality requirements for the work
  - Manages sub-contractors
  - Liaises with mining operations personnel on a daily basis to identify and coordinate site interface issues
  - Ensures all quantities for completed work are verified and recorded
  - Reports on all aspects of site progress, site issues and incidents to the Construction Manager
  - Manages daily site industrial relations

5.3.3 Project Management Team

- Project Manager
  - Champions the project
  - Overall responsibility for delivery of the project and agreed project outcomes
  - Provides leadership and direction to the project team
  - Manages all aspects of the project in accordance with agreed delivery criteria, policies, management plans and constraints
  - Performs a pivotal role in determining in collaboration with senior members of the project team, the overall direction and delivery strategy for the project

- Assumes the role of Owner's Agent (Superintendent) for administering contracts
- Establishes and manages the project control system for the project
- Audits and reviews all aspects of project performance
- Conducts regular project progress and review meetings with the project team
- Delegates duties and monitors performance of the project team
- Manages, in collaboration with the Design Manger, engineering and technical requirements during the implementation phase
- Reports on all aspects of project delivery, project issues and incidents to senior management

- Project Engineer
  - Provides day to day support to the Project Manager principally for project control, reporting, contract administration, invoicing and payment
  - Application and maintenance of the project control system for all aspects of project delivery
  - Collect and record project data and information to enable accurate cost and time reporting and forecasting
  - Participates in audit and review of project delivery
  - Coordination of project consultants and external service providers

5.4 Authority Levels

To ensure appropriate control, authority is to be established for various project functions. The authority levels that apply to the project are given in the following Table 1 – Table of Authority.

A fundamental aspect of authority for the project will be that all significant commitments relating to scope, cost and time require owner approval.

Table 1 – Table of Authority

Description	Project Director	Project Manager
Commitments and expenditure		
• < $5,000	✓	✓
• < $100,000	✓	✓
• > $100,000	✓	
Variations		
• < $5,000	✓	✓
• < $50,000	✓	✓
• > $50,000	✓	
Purchase Order/ Contract Enquiry		
• < $10,000	N/A	✓
• > $10,000	N/A	✓
Change of Scope	✓	✓
Change to Schedule	✓	✓

A responsibility matrix for the various key or significant administration and process functions associated with the project (eg approval of management plans, authorisation of travel/accommodation) will be prepared by the project manager.

6. Programme

6.1 Primary Requirement

Open cut mining of the test pit commenced during the 2005 dry season. To ensure continuation of mining it is proposed to commence construction of the main flood protection bund and stream realignments during the 2006 dry season and complete construction during the 2007 dry season.

The construction work will be staged to achieve the following goals:

- Ensure efficient use of excavated materials from the diversion channels and test pit as a source of construction material for the bund.
- Optimise haulage distances and construction equipment usage.
- Ensure flood flows during the 2006 / 2007 wet season can be passed through the partially completed works without erosion damage and channels are free draining.

6.2 Staging

Construction that is proposed during the 2006 dry season is shown on the staging plan, drawing BEE508-C-DWG-005 (Appendix B). The work period for resource and scheduling purposes will generally be 01 April to 30 November (dry season) in each of the project years 2006/2007.

During the 2006 dry season, it is proposed that the following construction will be carried out:

- McArthur River diversion channel, full depth excavation between chainages 5400 and 1800, including scour protection.
- Barney Creek diversion channel – full depth excavation for full length including all erosion protection works and tributary treatment works.
- Main flood protection bund – full height construction between changes 0 and 1800, 3200 and 6100, and between 6800 and 7400 including scour protection.
- Temporary flood protection bund around the test pit – construction of the southern extension and northern extension to connect with the main bund (chainage 1800 approximately) to provide flood protection to the expanded trial pit during the 2006/2007 wet season.
- Haul road to overburden emplacement facility – construction of bulk earthworks over main flood bund.

As a minimum requirement it will be necessary to construct the Barney Creek diversion channel and tributary treatment works, the test pit levee extension and the flood protection bund between changes 0 and 1800 during the 2006 dry season.

During the 2006/2007 wet season, the following work is proposed:

- Construct the first stage of the overburden emplacement facility in readiness to receive the first PAF and NAF material in 2007.
- Construct the mine hardstand area.

During the 2007 dry season, the balance of the construction works will be carried out as follows:

- McArthur River diversion channel – full depth excavation over remaining length including erosion protection and tributary treatment works.
- Main flood protection bund – full height construction over remaining length.
- High level bridge over Barney Creek diversion.

6.3 Key Dates

The following dates are considered critical to the successful execution of the works:

- 10 June 2006 - Commence camp mobilisation.
- 19 June 2006 - Commence equipment mobilisation.
- 14 August 2006 - Anticipated project approval.
- 21 August 2006 - Commence construction

6.4 Project Schedule

The project schedule has been developed in conjunction with the contractor and is based on the approved scope of work, the staging requirements, and known constraints and site conditions at the time of preparation.

7. Project Execution

7.1 Strategy

The overriding requirement is to take maximum advantage of the dry seasons in order to complete the construction works in accordance with the agreed programme. The works will be staged as described in Section 6.2 to address the restrictions imposed by the wet seasons and to ensure that work is executed efficiently and effectively. This will include ensuring that work completed during the dry season is protected from flood damage during the wet season.

Other key aspects of the execution strategy are:

- Establish and maintain a dedicated, project-specific resource base.
- An integrated project team as described in Sections 5 and 8.
- A contract delivery approach which capitalises on existing commercial arrangements and relationships.
- An overriding commitment to the health, safety, environment and community objectives for the project.
- Existing site knowledge and past learning's to be incorporated into relevant areas of project methodology and implementation.

7.2 Methodology

The key elements of the work methodology are:

- Use materials from the river diversion excavations (cut to fill) and trial pit efficiently in the flood protection bund.
- Optimise haul distances and equipment usage.
- Identify suitable materials that will meet the required technical specifications.
- Select of suitable equipment and placement techniques that will meet the technical requirements and operate effectively in the site conditions.
- Avoid or minimise the double handling of materials.
- Implement a quality control system that optimises inspection and testing and effectively eliminates or minimises rework.
- Provide clear work instructions and effective site management in order to achieve required productivity.
- Set appropriate performance targets and parameters to meet the programme requirements, such as equipment productivity, equipment availability/utilisation, and labour productivity.

Detailed work plans or method statements will be prepared by the contractor and will be reviewed and approved by the project manager and the construction manager prior to implementation.

The work plans will be reviewed on a regular basis, and updated or amended to reflect prevailing requirements and conditions.

7.3 Resources

A detailed resource plan will be developed and maintained by the contractor. The resource plan will be based on the project schedule and the detailed work method plans. A key requirement of the resource plan is that it is to be project specific, and completely independent of other site based activities.

In order to meet the construction programme for the works, both day and night shift will need to be operated.

A key item for consideration in resource planning is the demand and availability of water for construction purposes, and in particular whether the existing bore system can meet the required construction demand. Estimated maximum demand is approximately 2 megalitres per day.

The project scope and estimate do not include any additional water extraction or reticulation facilities, therefore consideration should be given to developing a water contingency plan to address any potential shortcomings in the existing bore supply.

7.4 Management Plans

Detailed management plans are required for the construction works. These plans detail how various aspects of the works are implemented, managed and controlled. They are working documents and relate directly to execution of the work.

They include, but are not limited to, the following:

- Work method plan/statement
- Resource plan
- Equipment management plan
- Quality management plan
- Traffic management plan
- Safety management plan
- Environmental management plan
- Subcontractors management plan
- Site management plan

All management plans will be prepared by the contractor, and will be reviewed and approved by the project manager and the construction manager prior to implementation. The plans will be reviewed on a regular basis and updated or amended to reflect prevailing requirements and conditions. Some of these management plans are described further, elsewhere in this document.

7.5 Interfaces

Project interfaces are most likely to arise with existing open cut mining operations, such as extensions to the flood protection bund around the trial pit.

The project team will identify significant interfaces, incorporate them into relevant management plans and coordinate them with mining operations.

7.6 Subcontracting

The use of approved subcontractors will be a necessary part of project execution strategy. During project planning, the contractor, in collaboration with the project manager will identify those activities that need to be subcontracted. The nominated activities will then need to be identified in the relevant management plans so that due consideration can be given to issues such as resources, training/induction, accommodation, etc.

The contractor will prepare a subcontracting management plan.

7.7 Review and Monitoring

The project execution strategy and methodology may need to change during the course of the project, to adapt to prevailing conditions and requirements. Regular ongoing review of implementation methodology based on the parameters in Section 7.2 will be crucial to successful completion of the work.

The principal mechanism for review and monitoring project execution will be regular project meetings involving all affected team members.

8. Contractor Engagement

8.1 Strategy

The approach to service delivery for this project will be a negotiated arrangement that capitalises on the existing commercial arrangement and relationship with a site established service provider (the contractor).

The contractor will be part of an alliance type project team tasked with successful delivery of the project.

Key criteria for the project team to function effectively are:

- Commitment to the project goals and MRM performance requirements.
- Open and clear communication between all team members
- Transparency in commercial and contractual issues relevant to the project having regard to the risk sharing arrangements in place.

8.2 Contract

The commercial arrangement for engagement of the services of the contractor for execution of the work will be between McArthur River Mining Pty Ltd (the Principal) and J J McDonald and Sons (the contractor).

The form of contract for the project works will be Schedule of Rates.

The contract will apply exclusively to the project works as described in Section 2.1 of this document. The tenure of the contract will be based on the project programme.

8.3 Priority

A prerequisite for successful completion of the project is the establishment and commitment of a dedicated independently resourced project team.

This is a key priority for the project, and the contractor will make this the basis of the resource and mobilisation plans.

8.4 Alignment

The contractor has prime responsibility for the implementation phase of the project within the context of the project's management procedures and responsibilities. It is therefore essential that the contractor, the project manager and the owner have aligned objectives relevant to the project.

Effective alignment of objectives and responsibilities for all aspects of the project, from pre-mobilisation through to de-mobilisation and close-out, must be an integral part of all project activities.

In the context of this project, the contractor alignment process that usually forms part of the pre-qualification and tender processes will be assumed to be in place.

8.5 Project Role

For this project the contractor will perform the role of construction manager with prime responsibility for the project implementation and reporting to the project manager.

9. Project Control

9.1 General

This section describes the processes that will be used to manage key elements of project delivery. The key elements addressed in this section are crucial to the successful completion of the project.

9.2 Work Breakdown Structure (WBS)

The project scope will be broken down into logical components that align with both physical units and work packages. This work structure will form the basis for the project budget and the project schedule.

The work breakdown structure is as follows:

- Season 1 Barney Creek
- Season 1 McArthur River
- Season 1 Main Levee
- Season 1 Test Pit Bunds
- Season 1 Overburden Emplacement Facility
- Season 1 Other Works
- Season 1 Contractor's Overheads

- Season 2 Barney Creek
- Season 2 McArthur River
- Season 2 Main Levee
- Season 2 Test Pit Bunds
- Season 2 Overburden Emplacement Facility
- Season 2 Other Works
- Season 2 Contractor's Overheads

9.3 Cost

The approved budget is the baseline document for control of cost on the project.

Cost control will be focused on and implemented at work package level.

Measurement and control of cost performance will be based primarily on four elements:

- Commitment
- Expenditure
- Earned value
- Forecast final cost

Each work package will be monitored with reference to the approved budget and S-curves will be generated to review performance. The status of each work package will be reviewed and updated on a regular basis. Progress of each work package will be combined to provide an overall picture of project cost performance. Work package status information will be used to generate a monthly update of the approved budget.

Work packages that are forecast to exceed their budget allocation will be referred immediately to the project manager for review. Approval by the project manager is required before any further cost commitments are made.

Significant budget under-runs also require identification to ensure accurate cost forecasting.

9.4 Time

The approved schedule is the baseline document for control of time on the project.

The schedule is based primarily on the work package level of the scope of work.

For control purposes, the schedule will contain the following key elements:

- Work package
- Work flow logic
- Start and finish dates
- Dependencies
- Critical path(s)

The schedule will integrate all phases of the project into a single-network document and will include major resource requirements.

An appropriate software package, such as Microsoft Project, will be used to establish and manage the schedule. The status of each work package will be reviewed and updated on a regular basis. Progress of each work package will be combined to provide an overall picture of project time performance.

Work package status information will be used to generate a monthly update of the approved schedule.

9.5 Change Management

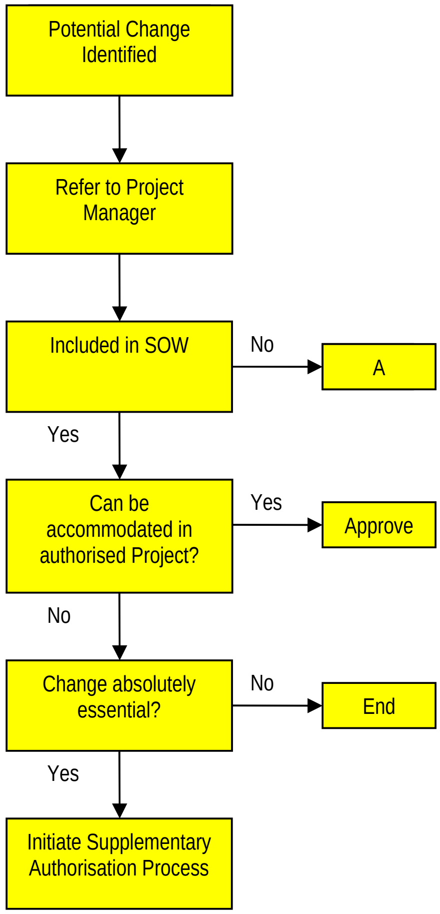
Generally the difficulty and cost of changes to the project works increases through the life-cycle of the project. In order to respond to this the project team will focus on early issue identification and timely implementation of approved change.

The project team will aim to influence the factors that create change to ensure that changes are relevant and beneficial. The change management process aims to:

- Maintain the integrity of the project performance baselines
- Coordinate change consistently across all aspects of the project

The change process is primarily focussed on controlling scope, cost and time changes, however the process can also be used to control changes to other aspects of the project.

The basic change management process is described in the following flowchart (Figure 2).



Responsibility	Description
Xstrata/MRM Contractor Project Team	
Initiator	The initiator of the potential change refers it to the Project Manager
Project Manager	The Project Manager will assess whether the change is included or implied in the SOW
Project Manager	
Project Manager Project Director	The need for the change will be discussed and agreed between all those nominated
Project Manager	

Figure 2 – Change process for out-of-scope items

Approval of change requests will be in accordance with authority levels specified in Section 5.4. Changes that are not clearly identified within an authority level will be reviewed by the project manager to determine the appropriate authority level for approval. Once a change has been approved, all impacts identified in the assessment process must be managed. Changes to the project baselines will be incorporated in relevant documents and communicated to all relevant project team members.

All approved changes will be recorded in a project change register.

9.6 Risk Management

The risk management process involves identifying, analysing and responding to project risk. Generally, it aims to maximise the effect of positive issues and minimise the effect of negative issues.

The risk management process will focus on the following key areas:

- Commercial risk (cost and time)
- Safety risk
- Environmental risk

Business risk will not be managed by the project team, this will primarily be the responsibility of the project director.

A risk register has been developed as part of a risk assessment process undertaken during the planning phase of the project. The risk register ranks all identified risks according to the magnitude of their potential to impact on the project. Some of the key risks identified in the register have been incorporated or addressed in this execution plan. Regular risk assessment sessions will be held during the course of the project to ensure that the register is updated and to monitor the mitigation and control measures applicable to the risks.

9.7 Document Control

Project documentation will be managed primarily at two levels by the project team, as follows:

- Individual or organisation
- Project

The project manager will establish and maintain a project document management system that has the following key features:

- Each work package or function has a file.
- Each file is identified by the package or function number.
- Each file contains records and documents required by project procedures and correspondence.
- Hard copy files must be backed up by secure electronic files.
- Individual files may be used during implementation provided the project files contain a copy of all relevant documentation.
- Controlled documents are clearly identified.
- All documentation is retained for the life of the project.
- Documentation of ongoing interest to the owner is identified and retained.

The project manager will establish and maintain a document register. The register will be used to manage controlled documents produced by the project team. A controlled document is one requiring approval for implementation and revision.

9.8 Reporting

The primary purpose of project reporting is to provide the stakeholders with a clear understanding of the progress being achieved and actions being undertaken to achieve the project outcomes.

Project reporting will be conducted at two levels, namely:

- Within the project team
  - The nature and frequency of this will be determined by the project manager.
- To the owner
  - A formal written report will be produced monthly with informal reporting as required.

Reporting will focus on the following key areas:

- Physical progress
- Cost status
- Programme status
- Safety and Environment
- Highlights and issues

Other project aspects and statistics may also be included. The format of the formal monthly report will be determined by the project director and the project manager.

9.9 Contingency Management

Due to the risks associated with delivery of the project, contingency amounts have been allocated to the cost and time elements of the project. The contingency amounts will need to be controlled so that a realistic assessment of project performance can be made.

At the beginning of the project, the purpose and level of contingency will be determined by the project director and the project manager.

The project manager will determine whether a change or delay is to be funded or accommodated from contingency or a variation is to be sought. This will apply equally to both cost and schedule contingency allocations.

9.10 Procurement

The procurement process controls the placing of purchase orders and the awarding of contracts for the project.

Given the critical nature of the programme, processing of orders and contracts will be crucial to meeting the project schedule.

The McArthur River Mining supply system will be used for processing and expediting all major purchase orders and contracts. Purchase order and contract documentation will therefore be based on MRM standard documents and processes.

The project procurement requirements will need to take into account any special features or requirements of the MRM system so that there are no negative impacts on the project schedule. All purchase order requests and contract enquiries will need to be approved by the project manager. All enquiry packages must contain approved commercial conditions and technical specifications. It is essential that all procurement documentation is aligned with the project scope of work, budget, schedule and other relevant project requirements. All orders must be in an approved written form. Each order must be authorised in accordance with the authority levels specified in Section 5.4 of this document.

10. Site Management

10.1 General

Site management entails the general administration and control of the implementation phase on the construction site and this will be primarily the responsibility of the construction manager.

Given the integrated nature of the project team, some of the site management functions may coincide with project management functions. The project manager and the construction manager will determine the allocation of functions and responsibilities to effectively manage the site and avoid duplication of functions and resources.

10.2 Site Management Plan

Generally the project site work will consist of the following broad functions:

- Administration
- Coordination and supervision of work activities
- Inspection and auditing of work
- Resource management
- Safety management
- Environmental management

A site management plan will be prepared by the construction manager to address the above site functions.

The plan will include, but not necessarily be limited to, the following detailed functions:

- Administration
  - General correspondence
  - Site communications
  - Access control
  - Security
  - Filing
  - Site meetings
  - Asset control
  - Receipt of drawings and documentation
  - Site purchase orders and minor contracts
  - Site consumables
  - Material control
  - Request for information register

- Coordination and supervision
  - Work methodology
  - Work scheduling
  - Progress monitoring and reporting
  - Industrial relations
  - Interfaces with operations
  - Constructability reviews

- Inspection and auditing
  - Inspection and test plans
  - Inspection reports
  - Non-conformance reports

- Resource management
  - Resource planning and allocation
  - Equipment maintenance and servicing
  - Equipment register
  - Inspections

- Safety management
  - Work permits
  - Operating procedures
  - Training
  - Operator competency
  - Inductions
  - Auditing
  - Incident investigation and reporting

- Environmental management
  - Operating procedures
  - Permits
  - Auditing
  - Incident investigation and reporting

The site management plan will be reviewed on a regular basis by the project manager and the construction manger, and updated as required.

11. Project Budget

The budget estimate has been developed in conjunction with the contractor and is based on the approved scope of work, and known constraints and site conditions at the time of preparation.

The level of contingency applied to the estimate aligns with the assumed level of project risk.

The project budget will be a controlled document.

12. Safety

12.1 Policy

MRM has adopted the following Occupational Health and Safety (OHS) policy that outlines their commitment to safety:

OCCUPATIONAL HEALTH AND SAFETY POLICY

McArthur River Mining is committed to the principle that occupational injury and illness is preventable. It is the right of each employee, contractor and visitor who comes to site, leaves site free of injury or work related illness.

- *Our priority is safe production in a work environment where our people feel all risks have been adequately controlled.*
- *We will identify, assess and reduce all major risks wherever practicable through a recognised risk assessment process.*
- *We shall demonstrate strong leadership and commitment to health and safety where we will meet or exceed all legal requirements to achieve a safe, productive and healthy work environment.*
- *We will use the MIM Safe strategy to achieve industry best safety standards. This effort will be directed to reducing incidents and especially injuries.*
- *We will commit the necessary resources for the development of Safety Management Plans, incorporating contribution and commitment from al stakeholders.*
- *We are committed to continuous improvement through the auditing of our health and safety health systems.*
- *We will provide education and training to our employees, contractors and visitors to ensure they have the skills to ensure an incident free workplace.*
- *We shall ensure two way communications with our employees, contractors, regulators and external stakeholders on health and safety matters.*

Accountabilities

- *The General Manager is accountable for the implementation of this policy including the provision of adequate resources and skills to achieve the stated objectives.*
- *Managers, Superintendents and Supervisors are accountable for the implementation of safety strategies, maintaining safety and hazard management plans, investigation of incidents and the promotion of safety improvements in areas of their control.*
- *Every individual is accountable to work in a manner that is healthy and safe for themselves, their workmates, persons influenced by their work and the environment in which they work.*
- *Every person at McArthur River Mining has a responsibility to identify hazards, rectify them where possible or report them for remedial action.*

12.2 Safety Management System

The safety management system (SMS) in place at the McArthur River mine is presently based largely on the SiteSafe system.

The SiteSafe system is a risk-based system, the main elements of which are:

- Safety risk management procedure
- Hazard reduction
- Job safety analysis and standard operating procedures
- Risk register

MRM is currently in the process of establishing a Health, Safety, Environment and Community (HSEC) Management System structure, based on the 17 Xstrata HSEC standards presented in Appendix C. The procedures within the current SMS will be amended and updated, as appropriate, for inclusion within the new HSEC Management System.

It is MRM's intention to develop the SMS in the form of an integrated HSEC Management System which will be compatible with the requirements of AS/NZS 4801:2001 Occupational Health and Safety Management System. System development is scheduled for certification in 2006.

The HSEC Management system will be subject to internal auditing by site-independent Xstrata auditors and external audits by an AS/NZS 4801:2001 Certification Body.

The construction phase of the open cut project will be incorporated into the integrated HSEC Management System.

12.3 Jurisdiction

Statutory jurisdiction for the project will be under the Northern Territory Mining Management Act 2001 and relevant regulations.

Part 3 of the Act specifically deals with safety, health and environment.

Other legislation that may be applicable to the project is:

- Dangerous Goods Act 1981
- Work Health Act 2005
- Work Health Regulation 2004
- Work Health (OHS) Regulation 2003

12.4 Management Plan

A project-specific safety management plan will be developed for the project by the contractor in collaboration with the project manager and the MRM HSEC coordinator. The management plan will define the issues and processes for control of safety on the site and may utilise existing MRM procedures where appropriate.

The management plan will include the following:

- Responsibilities
- Goals and targets
- Hazard identification and control
- Training and inductions
- Safe systems of work
- Communication
- Incident investigation and reporting
- Emergency response

The safety management plan is a controlled document and will be reviewed on a regular basis and updated as required.

13. Environment

13.1 Policy

MRM have developed the following Environment Policy that outlines their commitment to environmental protection.

ENVIRONMENT POLICY

McArthur River Mining's Environmental Policy is to maintain a high standard of environmental protection. In maintaining this standard, MRM will take appropriate precautions to minimise any potentially adverse impacts of its activities on the environment, the community and its employees.

MRM operates with the belief that strong environmental management is essential to a sustainable business specifically:

- *Conducting operations using the Xstrata HSEC Policy and Management Standards, and in compliance with relevant laws, regulations and standards;*
- *Ensuring all employees and contractors as necessary to meet our environmental requirements;*
- *Assessing the potential environmental effects of our activities and integrating environmental considerations into all aspects of our planning, operational decisions and processes;*
- *Communicating with our employees, the community, regulators and other stakeholders in relation to environmental issues;*
- *Ensuring the efficient use of resources and the minimisation of waste generation and disposal;*
- *Progressively rehabilitating areas no longer required for efficient operation using the most practical methods;*
- *Maintaining an effective, integrated environmental management system;*
- *Ensure continual improvement in environmental performance incorporating advances in environmental, community and technology;*
- *Taking appropriate actions to correct any deficiencies identified.*

McArthur River Mining acknowledges its environmental responsibilities and ranks them equally with its other business objectives. Environmental management plans are an integral part of the overall planning and management process, and will be reviewed continuously.

13.2 Environment Management System

MRM has established an environment management system to assist with the overall environmental management of the site. It is intended to fully develop the EMS by the end of 2005 in the form of an integrated HSEC Management System based on the 17 Xstrata HSEC management standards listed in Appendix C.

The HSEC Management System will be fully compatible with the requirements of ISO 14001.

Environmental management of the open cut project will be fully integrated with the site's existing environmental objectives and systems.

13.3 Jurisdiction

The principal statutory jurisdiction for the project will be the Northern Territory Environmental Assessment Act 1982.

Other legislation that may be applicable to the project is:

- Territory Parks and Wildlife Conservation Act (2001)
- Heritage Conservation Act (1991)
- Aboriginal and Torres Strait Islander Heritage Protection Act (1984)
- Aboriginal Land Rights (Northern Territory) Act (1976)
- Waste Management and Pollution Control Act (1999)
- Weeds Management Act (2001)
- Water Act (1992)
- Soil Conservation and Land Utilisation Act (1980)
- Northern Territory Aboriginal Sacred Sites Act (1989)

13.4 Management Plan

A project specific environmental management plan will be developed for the project by the contractor in collaboration with the project manager and MRM HSEC coordinator.

The management plan will define the issues and processes for environment protection on the site and may utilise existing MRM procedures where appropriate.

The management plan will include the following:

- Responsibilities
- Targets and licence conditions
- Training and inductions
- Communication
- Procedures and mitigation strategies
- Emergency response
- Incident investigation and reporting

The plan will also address the following specific aspects of the work:

- Waste management
- Vegetation management
- Surface water
- Noise
- Air quality
- Hazardous goods
- Mosquitos

The environmental management plan is a controlled document and will be reviewed on a regular basis and updated as required.

14. Quality

14.1 General

A planned and systematic approach to quality management will be adopted for the project that will focus on delivering project outcomes that are fit for purpose and meet or exceed project requirements.

14.2 Quality Assurance

The quality system used on the project will comply with the requirements of AS/NZ ISO 9001:2000. A quality management plan will be developed for the project by the project manager in collaboration with the construction manger.

The plan will define the requirements and processes for quality management on the project and will be the principal mechanism for ensuring compliance and consistency of completed work on the project.

The management plan will include the following:

- Responsibilities
- Best practice
- Continuous improvement
- Procedures
- Standards and codes
- Audit and review
- Corrective actions
- Communication

The quality management plan is a controlled document and will be reviewed on a regular basis and updated as required.

14.3 Quality Control

All construction work will be controlled through a site based quality control plan. The key elements of the plan will be:

- Conformance to the scope of work
- Compliance with specifications
- Inspection and testing

The quality control plan will be developed by the construction manager in collaboration with the project manager.

The plan is a controlled document and will be reviewed as required.

15. Project Completion

15.1 Practical Completion

Practical completion will be reached when the project works are completed in accordance with the scope and performance criteria and are functionally ready.

Achievement of practical completion will be determined and agreed by the project manager, the mining manager and the construction manager. Relevant details of practical completion will be recorded on a certificate of practical completion.

15.2 Handover

Following practical completion, the works will be handed over to the owner for operational purposes. A handover certificate will be prepared and signed by the project manager for acceptance and sign-off by the owner.

Any outstanding items of work and an agreed timeframe for their completion will form part of the handover certificate. When all outstanding work is complete the handover certificate will be updated accordingly.

Staged handover of completed portions of the work will be determined and agreed by the project manger and the mining manger.

15.3 Close out

Project close out occurs when all work has been completed and handed over to the owner. A project review will be carried out by the project director and senior members of the project team, following the handover.

The review will identify positive project outcomes and areas for improvement.

Key learning's from the review will be captured for incorporation into future work. Feedback on project outcomes and performance will be communicated to individual project team members as appropriate.

A project close out report will be prepared by the project manager. The report will include all relevant project outcomes and the results of the project review.

All relevant project documentation and records will be archived and/or handed over to the owner.

Appendix A

Design Basis Report
BEE508-Z-REP-001

MCARTHUR RIVER MINE

Design Basis Report

Prepared for:

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22 June 2006

BEE508-Z-REP-001 Rev C

Revision History

Revision	Date	Comment	Signatures		
			Originated by	Checked by	Authorised by
A	10/11/05	Draft	REV	GJD	REV
B	20/12/05	Appendices added, IG comments added	REV	GJD	REV
0	15/2/06	Final issue	REV	GJD	REV
C	22/6/06	Connell Hatch and URS comments added	REV	GJD	REV

CONTENTS

1 Background

The McArthur River Mining Joint Venture (MRM) is proposing a change in mining method for the existing McArthur River zinc/lead/silver mining and processing operation, which is located approximately 45 km south-west of Borroloola and 740 km south-east of Darwin in the Gulf Region of the Northern Territory.

The current operations were established in 1995, and consist of an underground mine and processing plant which converts the mined ore into bulk concentrate. The concentrate is trucked from the mine to the port of Bing Bong, where it is loaded into ships for export to refineries around the world to be made into zinc and lead metal and alloys.

The McArthur River Mine Open Cut Project will result in

- extend life of mine by 25 years
- change in mining method
- increase production 1.6–1.8 Mt/a

All operations will take place within the existing mining leases.

Open cut mining will involve the following:

- Realignment of the McArthur River, and Barney Creek around the proposed open cut.
- Construction of a flood protection bund around the open cut and associated infrastructure facilities, to prevent floodwaters inundating these operational areas.
- Excavation of the alluvial cover materials that overlie the ore. The material will be used for construction purposes, encapsulation of other waste rock or rehabilitation.
- Excavation of overburden above and in between the ore body. The waste rock will be placed in overburden emplacement facilities.
- Excavation of ore from the open cut. The ore will be hauled to the run-of-mine (ROM), where it will be fed into the existing ore processing plant.
- Rehabilitation of the disturbed areas in accordance with statutory requirements and agreed post-mine land uses.

1.1 SCOPE OF CIVIL DESIGN

The civil works covered by this Design Basis Report include;

- Realignment of the McArthur River around the eastern side the proposed open cut.
- Realignment of Barney Creek around the northern side of the proposed open cut.
- Construction of a flood protection levee around the proposed open cut.
- Foundation preparation and construction runoff water management structures for the Overburden Emplacement Facility (OEF).
- Construction of a haul road from the proposed open cut to the OEF including a crossing of the proposed Barney Creek realignment.

Apart from rock armouring, the placement of large woody debris, the excavation of pools in the base of the channels, the construction of riffles in the bed of the channels and spreading topsoil, all other rehabilitation works associated with the realigned sections of the river and creek channels and the flood protection levee will be covered by a separate Rehabilitation Plan.

1.2 ASSOCIATED DOCUMENTS

This design criteria is to be used in conjunction with the following reports:

- McArthur River Mine Open Cut Project, Draft Environmental Impact Statement prepared by URS, August 2005.
- McArthur River Mine Open Cut Project, Supplement to Draft Environmental Impact Statement prepared by URS, October 2005 (URS);
- Hydraulic Design and Flooding Investigation report BEW428-W-REP-001 prepared by KBR, June 2005 (Appendix A).
- Report on Geotechnical Investigation, Detailed Feasibility Study, McArthur River Expansion Project, McArthur River, Northern Territory. Report No. 04632206-005 prepared by Golder Associates, December 2004.
- Addendum Report to Report 04632206-009 Geotechnical Investigation, Detailed Feasibility Study, McArthur River Expansion Project, McArthur River, Northern Territory prepared by Golder Associates, June 2006 (Appendix B).

2 Design criteria

2.1 STATEMENT OF APPLICABLE REGULATIONS

A draft Environmental Impact Statement (EIS) has been prepared in accordance with the requirement of the *Northern Territory Environmental Assessment Act 1982*, and the Environmental Assessment Administration Procedures under which the Act is implemented.

A referral under the Commonwealth Government's Environmental Protection and Biodiversity Conservations Act has been submitted. The proposed development constitutes a controlled action under the following section of the Act:

- Sections 18 and 18A (listed threatened species and communities)
- Sections 20 and 20A (listed migratory species).

There are a number of registered and recorded sites of cultural significance in the vicinity of the project area. The Aboriginal Area Protection Authority (AAPA) have issued authority certificates for all the open cut project areas in accordance with Sections 22 of the *Northern Territory Aboriginal Sound Sites Act 1989*.

The AAPA certificates include requirements for protection nesting sites during project construction.

The airfield is controlled by the *Civil Aviation Act 1988* and the applicable document is Civil Aviation Safety Regulation Part 139, Manual of Standards—Part 139—Aerodromes.

2.2 STATEMENT OF THE CLIENTS REQUIREMENT AND STANDARDS

2.2.1 MRM policies and standards

Xstrata's business principles ensure that all of Xstrata's operations are committed to the highest standards of health, safety and environmental performance, community consultation and to the principles of sustainable development.

MRM environmental policy is to maintain a high standard of environmental protection. MRM will take appropriate precautions to minimise any potential adverse impact of its activity on the environment, the community and its employees.

MRM is a signatory to the Australian Mineral Industry Code for Environmental Management.

The Safety Management System (SMS) in place at the McArthur River Mine is based on the site safe system. MRM is in the process of establishing a Health, Safety, Environment and Community (HSEC) management system structure. The construction phase will be incorporated into the integrated HSEC management system.

The risk management process used by MRM is consistent with Australian Standards AS/NZS 4360:1999 Risk Management.

MRM has an Environmental Management System (EMS) that applies to the site. The EMS is being upgraded to conform with the new HSEC and ISO 14001 (International Environmental Management Standard).

2.2.2 MRM requirements (construction)

The construction for the open cut mine will be undertaken over a two-year period (2006 and 2007), with the majority of activities taking place during the dry season.

Flood protection bund

The open cut mine is located within the floodplains of the McArthur River, thus a flood protection bund will be constructed around the pit and infrastructure to protect the working area from inundation in flood events. The bund is to be designed for a 500 ARI flood event.

Air strip

The existing airstrip is a single sealed runway 1500 m in length and will continue to be used for the open cut project. The airstrip is unrated as per AIP Australia—Enroute Supplement Australia (ERSA). Intro 7-24 and FAC M-1 and RDS M-1 for McArthur River Mine.

The ERSA-FACM-1 refers to limits on runways for aircraft with maximum take off weight (MTOW) above 5700 kg. The specified clearance envelopes are defined in the publication: Civil Aviation Safety Regulations—Part 139 and Manual of Safety—Part 139.

Overburden emplacement facility

The overburden has been divided into the following categories:

- *PAF:* Potentially acid forming, this material has the potential in the presence of air and water to generate acid water, soluble metals and salts that could impact on the environment (11% of total overburden).
- *NAF:* Non-acid forming, this material is chemically stable with low potential for generation of environmentally significant product.
- *AC:* Acid consuming, this material has the capacity to neutralise runoff and seepage from PAF material.

In the Overburden Emplacement Facility (OEF), the PAF will be encapsulated with clay wells and layers of NAF/AC waste in the western zones of the OEF, to ensure that there are no acidic seepage generated by the facility. NAF overburden only will be used to construct the eastern zone of the OEF.

NAF material will also be deposited in selected sections of the flood protection bund, to provide shorter hauls and overburden placement capability times of flooding outside the flood protection bund.

McArthur River and Barney Creek realignment

The design of the realigned channels has been developed to mimic the general geometry of the existing McArthur River low-flow channel and the Barney Creek channel. The size and slopes of the new channels have been designed with the objective of minimising the potential for erosion of the channels and the reaches immediately upstream and downstream of the diversion.

2.3 LIST OF PRINCIPAL DESIGN CODES

AS 1000	The international system of units (SI) and its application
AS1170.4 - 1993	Minimum Design loads on structures—Part 4—Earthquake loads.
AS 2041	Buried corrugated metal structures
AS 3600	Concrete structures
AS/ISO 9001	Quality system—model for quality assurance in design development, productions, installation and servicing.
AS 3798	Guidelines on earthworks for commercial and residential developments.
Civil Aviation Act, 1998	Manual of Standards (MOS)—Part 139 Aerodromes
ANCOLD, 1998	Guidelines for Design of Dams For Earthquake (Australian National Committee on Large Dams)

2.4 PERFORMANCE REQUIREMENTS

2.4.1 Flood protection bund

The alignment of the proposed flood protection bund has been selected to provide maximum opportunity for the future development of the McArthur River deposit as well as taking greatest advantage of the natural topography to minimise earthworks. In addition the alignment has been selected to maximise separation between the proposed creek and river realignments and bund, maintain regulatory separation (CASA) between the bund crest and the flight path for the McArthur River airstrip and avoid features of cultural heritage significance.

A geotechnical study of the flood protection bund footprint and proposed construction materials that will be sourced from the McArthur River and Barney Creek realignments was undertaken by independent specialist geotechnical consultants Golder Associates in accordance with Australian Standard AS1726-1993 (Geotechnical site Investigations). The geotechnical investigations included drillholes, test pits, seismic refraction surveys, hydrogeological drilling and tests, and laboratory testing. The investigations provided information on the strength of the foundation soils and construction materials to assess the stability of the bund as well as the permeability of the materials to assess the watertightness of the bund.

The proposed flood protection bund will be a zoned fill embankment designed in accordance with ANCOLD (Australian National Committee on Large Dams) guidelines for water retaining embankment dams. The inner two thirds of the embankment will be comprised of clayey earthfill to provide an impervious barrier to water ingress and the outer third of the embankment will be rockfill to provide resistance to erosion. Clay material will be sourced from watercourse rechannelling, however supplementary supplies of clay (if required) are available from excavation for the open pit and between the bund and final pit limit. The outer third of the bund wall will be constructed of durable non-acid forming rockfill to provide protection against erosion and scouring of floodwaters; and this material will be sourced from either the McArthur River realignment or the open pit.

Material from the McArthur River and Barney Creek diversions will be used to construct the "initial flood protection bund" which will be designed as a water retaining structure to ANCOLD standards and constructed by a civil construction contractor. Non acid forming (NAF) materials from the open pit mine will be used to flatten the batters of the "initial construction" to 1 vertical to 4 horizontal as part of the mining operation. The flatter batters of the "final arrangement" will increase the long-term stability of the embankment and will allow immediate and progressive rehabilitation to proceed.

Key design criteria for the flood protection bund include:

- Long term protection against the average 500-year ARI flood event with appropriate allowance for wind generated wave setup and runup.
- Clear crest width of 12 m for the final arrangement to allow the crest to be used as a one way haul road.
- The stability of the flood protection levee will meet the minimum factors of safety (FoS) detailed in Table 2.1.

Table 2.1 Minimum Factors of Safety for flood protection bund stability

Loading Condition	Minimum FoS
End of Construction – Initial Construction	1.30
Inner (downstream) face of Initial Construction under design flood event (500 year ARI).	1.30
Inner (downstream) face of Final Arrangement under design flood event (500 year ARI).	1.50
Outer (upstream) face of Initial Construction under receding 500 year ARI design flood event (Rapid Drawdown Condition)	1.25
Inner (downstream) face of Initial Construction under and earthquake loading.	1.10

- Key trench to minimise seepage beneath the bund. The key trench will have a base width of 5m and a minimum depth of 1m to and will intersect a minimum of 0.5m into low permeability
- Crest cross fall – 3% away from pit.
- Crest wearing surface for final arrangement to comprise 1m deep select rockfill.
- An emergency spillway to allow the flood protection bund to be breached in a controlled manner should flooding in excess of the 500 year ARI event (with freeboard allowance) be exceeded. The emergency spillway will limit damage to a small area where the potential for environmental damage will be minimised.
- Service penetrations through the bund are to incorporate seepage control provision.
- Rock armouring on external batters where flood scour velocities exceed 2.0m/sec or where the outer face is not constructed with rockfill.A 2.0m thick upstream clay blanket (beneath the rockfill section of the levee) in the vicinity of the McArthur River to allow construction of a slurry wall cut-off at a later date (if required).
- Access ramps to crest for haul roads.
- Safety bunds on both sides of levee crest.
- Construction tolerances.
  - Plan location ±1000 mm.
  - External batters line ±600 mm (horizontal)
  - Internal batters line ±300 mm (horizontal)
  - Zone boundaries ±1000 mm (horizontal)
  - Crest level 0 mm to +200 mm (vertical)

Geotechnical analysis of the flood protection bund has been undertaken by Golder Associates and is contained in an Addendum Report to Geotechnical Investigation Report 04632206-009 (Appendix B).

2.4.2 Diversions

The diversion channels will be designed to mimic the general geometry of the existing McArthur River low-flow channel and the Barney Creek channel, while ensuring that the new channels will have acceptable hydraulic performances in terms of river stability and maintaining fish passage.

Details relating to the hydrology of the McArthur River area and hydraulic modelling of the channel realignments is provided in Appendix A.

McArthur River

The design parameters for McArthur River channel are:

- A simple or compound trapezoidal channel section with a flat base.
- Channel flow capacity sufficient to convey a 5 year ARI event similar to the existing McArthur River bankfull flow capacity as defined in the EIS.
- Bed width in the range of 15–28 m to replicate the original channel bed width as defined in the EIS.

- Channel banks with a slope of 1(V) in 2(H) to replicate the original channel bank slopes.here the channel depth in soil is in excess of 9 m, a compound trapezoidal shape will be adopted with a terrace level 9m above bed level.
- For flows up to 100 m^3/s, flow velocities in the McArthur River Channel should not to exceed flow velocities reported in draft EIS to allow adequate fish passage.
- Streampower (evaluated using the 1995 Annandale Method) should not exceed the erodibility of bed and bank materials defined in the PER.
- Minimise excavation.
- Mannings 'n' values to be consistent with those defined in the PER. Rock excavation tolerances of 0 to –600 mm (perpendicular to face) and soil excavation tolerance of (0 to –200mm (perpendicular to face) adopted to achieve surface roughness and design 'n' values.
- Upstream and downstream beds levels of the new channels are to match the bed levels at the junctions of the existing streams.
- Transitions between channel types are to occur over 100 m.
- Upstream and downstream transitions between new channel and original channel to include timber groynes for bank protection.
- McArthur River Channel profile details are provided in Table 2.2.

Table 2.2 Proposed McArthur River channel realignment

Design chainage (m)[1]	Bed slope	Channel bed width (m)	Channel side slopes (V:H)	Foundation conditions and general features
0 to 600	1:2500	28	1:2	Sandstone and alluvial soils bed. Bank intercept silty clay and clayey sand.
600 to 950	1:2500	28	1:2	Bed and banks intercept alluvial soils with layers of silty clay, clayey sand and gravely clayey sand.
950 to 1500	1:2500	27	1:2	Bed and lower banks (up to 5 m above bed) in shale, mudstone and breccia, upper banks intercept sand, gravely sand and silty clays. 6 m wide terraces 9 m above the channel bed, with bank slope above terraces at 1 in 3.
1500 to 1750	1:2500	25	1:2	Bed and majority of bank height (up to 10 m above bed) predominantly in breccia with zones of shale and mudstone. 6 m wide terraces 9 m above the channel bed, with bank slope above terraces at 1 in 3
1750 to 2550	1:714	25 to 23	1:2	As Above. Bull Creek intercepted at chainage 2400 m
2550 to 3350	1:714	25	1:1	Bed and majority of bank height predominantly in breccia. Upper level banks intercept silty clays and sandy silty clay.

				4m wide terrace at interface with soil and rock. Upper level bank slope at 1:3.
3350 to 3850	1:714	20	1:1	As Above Tributary creek intersected at chainage 3600 m.
3850 to 4000	1:714	15	1:2	Bed banks in sandy clay and silty clay. Zones of clayey sandy gravel.
4000 to 4200	1:2500	15	1:2	Bed banks in sandy clay and silty clay. Zones of clayey sandy gravel.
4200 to 4900	1:2500	15	1:2	Bed and 5–10 m of lower bank in Dolomite. Upper banks in silty clay.
4900 to 5260	1:2500	15	1:2	Bed and banks in clay and clayey sand.
5260 to 5490	1:2370	15	1:2	Bed and banks in clay and clayey sand. Downstream junction with McArthur River at chainage 5490 m.

Barney Creek

Design parameters for Barney Creek diversion are:

- Hydraulic performance of the Barney Creek diversion is to be determined without separate tailwater effects resulting from McArthur River flows.
- A simple trapezoidal channel section with a flat base except where the channel depth in soil is in excess of 9 m, in which case a compound trapezoidal shape will be adopted with a terrace level 9m above bed level.
- Bed width 15m.
- Channel banks with a slope of 1(V) in 2(H) to replicate the original channel bank slopes.
- Low flow velocities and streampower in diversion channel should not to exceed low flow velocities in existing Barney Creek to allow adequate fish passage.
- Pools and riffles (with 1 vertical to 20 horizontal downstream faces) to be provided in bedrock similar to existing Barney Creek.
- Rock armouring of bed and banks to be provided where streampower (evaluated using the 1995 Annandale Method) exceeds the erodibility of the bed and bank materials.
- Minimise excavation.
- Upstream and downstream bed levels of the new channels are to match the bed levels at the junctions of the existing streams.

- Barney Creek Channel profile details are provided in Table 2.3

Table 2.3 Proposed Barney Creek channel realignment

Design chainage (m)	Bed slope	Channel bed width (m)	Channel side slopes (V:H)	Foundation conditions and general features
0 to 1080	1:100 (average)	15	1V:2H	Bed and lower banks in rock. Bed comprised of nine (9), 1.2m high riffles at 120m spacing.
1080 to 1700	1:3,600	15	1V:2H	Bed and lower banks in rock. 6 m wide terraces 9 m above the channel bed, with bank slope above terraces at 1 in 3.
1700 to 3080	1:3,600	15	1V:2H	Bed and banks in silty clay and sandy clay. Ch 1700 to 2350 6 m wide terraces 9 m above the channel bed, with bank slope above terraces at 1 in 3.

Tributary Streams

A number of tributary streams of varying sizes will intersect both the proposed diversions of the McArthur River and Barney Creek. In most cases the bed level of the streams will be above the bed level of the main diversion channel and the energy of the streams will need to be effectively dissipated to control erosion.. In the case of smaller streams this will be able to be achieved by rock lined chutes down the channel batters, however in the case of the larger streams either rock lined chutes or stepped cascades may be appropriate hydraulic control structures.

Parameters for the design of hydraulic control structures on tributary streams include:

- Rock lined chutes to be designed using the Co-operative Research Centre (CRC) for Catchment Hydrology program Chute (Version 10.0).
- Diversion tailwater levels calculated using HECRAS for the case where the channel flow is three times that of the tributary stream.
- Rock sizing to be based on the Critical Shear Stress Method and the chute batter angle.
- Mannings ‘n’ determined using the Strickler Equation.
- Chute and cascade lining to accommodate flows up to Q_{100} (for a range of realistic tailwater levels) without major damage.
- Cascade structures to be designed in accordance with “Hydraulic Design of Stepped Cascades, Channels, Weirs and Spillways (H. Chanson, 1994)

Scour Protection

Dumped rock to be used for scour protection shall be hard, dense and durable and shall comply with the requirements of Table 2.4.

Dumped rock scour protection shall be underlain by geofabric. The geofabric shall be a non-woven needle punched continuous filament polyester or polypropylene (ultra-violet light stabilised) having a minimum mass of 270 gm/m^2 and an Austroads G Rating in excess of 3500. The geofabric will be stored an installed in accordance with manufacturers' recommendations.

Table 2.4 Scour protection typical gradings

Item	D_{450}	D_{600}
Maximum Particle Size	700 mm	900 mm
No more than 60 % passing	450 mm	600 mm
No more than 10 % passing	200 mm	250 mm
Crushing Strength	Greater than 25 Mpa	
Length	Greater than 2.5 x width	
Shape	Angular – no diffused cleavage planes	
Layer thickness	Greater than 2 x D_{50}	

Rock Armouring

Rock armouring is required on excavation batters in residual soil and alluvium to provide an environment where seeds can germinate and riparian vegetation can become established. The rock armouring will comprise slightly weathered to fresh, reasonably well graded "run of excavation rock" with a maximum block size of 600mm and no more than 60% passing 250 mm. Rock armouring shall be designed in accordance with the average Strickler Method.

Except where soils have been identified to be dispersive (Emerson Class = 1), the rock armouring is to be spread on excavation batters without underlying geofabric.

Non-dispersive topsoil containing locally occurring grass and riparian vegetation seeds shall be spread over the rock armouring to assist in revegetation. Sluicing with water cannons may be undertaken to assist the topsoil in penetrating the rock.

Rock Fracturing

Where blasting is required to loosen weathered and fresh rock in diversion channels prior to excavation, the blasting shall extend 2m beyond the lines of the excavation when measured normal to the face of the excavation. The purpose of the blasting is to assist in the establishment of vegetation by fracturing the rock mass and allowing soil and moisture to penetrate the crevices.

Timber Groynes

Timber groynes shall be placed in the vicinity of stream, river or channel junctions, as to minimise the likelihood of bank erosion by trapping debris and sediment.

The timber groynes shall comprise hardwood piles with a minimum diameter of 300mm. The piles shall be driven approximately 3m into alluvial materials and shall protrude approximately 1m above the surface of the channel.

Fish Resting Areas

Fish resting pools shall be incorporated as deeper sections along the bed of the new channel, as off-stream pools at the junctions with tributaries and side gullies and/or pools and riffles. Fish resting areas shall be provided in the new channels generally in accordance with the following requirements.

- *In rock areas:* Pools shall be located in areas of weaker rock at least 30 m long and at random spacings but at least two pools per 250 m along the length of the channel. The pools will be at least 0.5 m deep and extend at least 60% of the channel width.
- *In soil areas:* Pools shall be at least 30 m long and at random spacings but at least two pools per 120 m along the length of the channel. The pools will be up to 1.5 m deep and extend at least 50–60% of the channel width.
- *Behind riffles*. Riffles with a downstream face of 20H : 1V and an upstream face of 4H : 1V will be formed by dumped rock with a nominal size of 450 mm. The depth of the pool formed by the riffle shall be approximately 1.5m and the spacing between riffles in alluvium shall be approximately 300m.

Large Woody Debris

- Large woody debris (LWD) is to be placed in bed of channel to assist in rehabilitation, to provide habitat, encourage sediment trapping and meandering. LWD should comprise dead trees with Diameter Breast Height (DBH) 300mm minimum preferably > 450mm. Preference is for LWD with intact root ball & up to 8m of the trunk, with a few main branches but not too much of the entire tree canopy.

  LWD should be located at irregular spacing, placement, and alignment to resemble a random distribution. In channel sections with a sand/clay bed ,the maximum spacing of LWD should be ~100m with spaced as low as 30m. In rock bed sections the maximum spacing of LWD should be 200m.LWD to be placed irregularly on alternating sides of the river bed, with randomness. Near tributary junctions, LWD should be placed on the bank opposite to the side where the tributary joins. About 20 to 40% of LWD should be in groups of 2 or 3 logs placed to resemble a log jam. 'Log-jams' should be placed closer to the banks and should not obstruct more than 50% of channel bed.

  Shallow loose sand (around 200mm to 400mm depth) should be placed on upstream and downstream side of logs to resemble sand bar. At least two thirds of LWD should be anchored. Anchoring may be achieved by partial (>25%) burying of the log and rootball, chaining to a timber pile driven into a sand or clay bed or chaining to a grouted steel bar in rock beds.

  Approximately 60 to 80% of LWD should be aligned angled from the bank (about 30 to 60 deg) in downstream direction. The remainder should be perpendicular to bank and some pointing upstream.

2.4.3 Overburden emplacement facility

The OEF design is required to meet the following objectives:

- physical stability
- chemical stability
- height consistent with local surrounds
- minimal dirty water catchment.

The OEF design will incorporate the following multiple lines of defence to manage the key environmental risks:

- *Base preparation:* The base of the OEF will be prepared, compacted and graded to ensure that any seepage through the OEF flows out through the toe to drainage collection facilities.
- *Construction:* The OEF will comprise an eastern and western zone. The western zone will contain PAF materials in clay encapsulated cells surrounded by NAF/AC materials. The eastern zone will contain NAF/AC materials only.
- *Surface water management and seepage control:* Surface water and seepage from the OEF will be contained within collection ponds. In the western zone, the pond will contain seepage and runoff that may have contacted PAF materials, and this pond is referred to as the PAF pond. In the eastern zone, the pond will contain essentially clean runoff that may contain sediment, and this pond is referred to as the sediment pond.
- *Final rehabilitation:* The outer batters of the OEF will be designed to provide a final landform that is chemically and physically stable in the long term and limits erosion. Final rehabilitation of the OEF will include placing a surface cover on the crest of the OEF and on the immediate benches across the outer slopes.

Design of the OEF will be in accordance the Draft EIS and EIS Supplement. Preliminary designs will be prepared for the whole facility, while detailed designs will be prepared for the initial stages of the development.

All surface and seepage flow from the Western Zone of the OEF will report to the PAF pond, which will be designed to a 1 in 100 annual exceedance probability of spilling. The size of the PAF pond to achieve this overflow risk criteria shall be determined from Mine Water Balance studies reported by Water Solutions (2005). The spillway crest will be developed to above the 1 in 100 flood level (RL 40 m). Design of the pumps to transfer water from the PAF pond to the water management dam at the tailings pond will be by others.

The key design parameters for the PAF ponds are:

- impervious clay zone in the bund—target permeability for this layer is 10^{-8} m/s
- base to be scarified to a depth of 150 mm and compacted to a low permeability base, with a target permeability for this layer is 10^{-8} m/s
- erosion protection to outside bund wall to resist flood scour
- emergency spillway to discharge excess water in extreme rainfall conditions.

All surface and seepage flow from the eastern zone will report to the sediment pond, which will be designed to contain up to 50 mm of average erosion depth from the contributing catchment. The sediment ponds will be designed to remove the majority of the sediment before discharge to Barney Creek. Key features of the sediment ponds are:

- homogeneous clay embankments with a target permeability of 10^{-6} m/s
- outer bud walls to be capped with topsoil and vegetated with grass to reduce the risk of erosion
- overflow spillway will be able to discharge runoff water (up to 1in 100 ARI event)
- access ramp for periodic removal of sediment
- there will be three ponds developed for the various stages of the OEF.

2.4.4 Haul roads

Unless specified to the contrary haul roads and ramps will be designed to be wide enough to enable the safe two-way passage of the largest trucks, with an allowance for drains and safety bunds. Industry practice recommends a road with of three times the width of the largest truck using the road, with an allowance of 5.5–9 m for a safety windrow and berm and 1.5 m for drains.

The design vehicle will initially be Cat 785C (220t) dump trucks with possibly Cat 793 (330t) trucks being used during the latter part of the mine development. Haul road pavements will be designed for Cat 785C vehicles, however should Cat793 vehicles be used, formation widening and pavement strengthening will be required.

Haul road design parameters are:

- Design vehicle—Cat785C haul truck
- Formation width—36 m
- Cross-fall—2.5% each way
- Maximum grade—10%
- Design life—20 years
- Vehicle repetitions—300/day
- Design sub-grade support value —Natural ground CBR=3 / engineered fill CBR=5.
- Haul road geometry and drainage in accordance with US Bureau of Mines Circular 8758 “Design of Surface Mine Haulage Roads by Kaufman and Ault.
- Safety bunds – half wheel height of largest vehicle.

2.4.5 Barney Creek haul road crossing

It is proposed that the OEF haul road crossing of the Barney Creek Channel will be a single lane prestressed concrete bridge with appropriate traffic control devices to ensure safe operation. The bridge deck, located at approximately RL33.3 will have a high flood immunity and will not impede fish passage.

The bridge will be designed to accommodate Cat793 trucks, however should Cat 793 trucks be used in the future then a dupplicate bridge will beconstructed to allow for two –way traffic.

2.4.6 Temporary river crossings

Temporary crossings of the McArthur River will be required to enable construction equipment access during the dry season. Nested Armco (steel) pipes will be provided in the centre of the channel to permit dry season low-flow conditions and the occasional minor storm event. The pipes and fill associated with the temporary river crossing will be removed prior to the commencement of the wet season (during construction) and on completion of the construction works.

2.4.7 Bore fields

The mine site has established a number of bore fields to supply process water. These sites are connected to the Barney Hill facility by overhead power and on the ground pipe work. The protection bund and diversion channels will impact on the services.

A service corridor is to be identified for the relocations of these services.

2.4.8 Gas pipeline

The gas feed pipeline to the McArthur River power station runs along the northern side of the airfield and crosses the southern abutment of the flood protection levee.. This pipe location is to be identified and special seepage provisions detailed where the bund crosses.

2.4.9 Airfield

The existing airfield is located to the south-west of the mine. The flood protection bund will be located below the flight path. Access to the bund crest in the vicinity of the flight path will be restricted both during construction and operation.

2.5 OCCUPATIONAL HEALTH AND SAFETY REQUIREMENTS

MRM are developing the current SMS into an integrated HSEC management system, which will be compatible with the requirement of AS/NZS 4801:2001 Occupational Health and Safety Management System. The HESC is scheduled for certification in 2006. The construction operation will be incorporated in to the integrated HSEC management system.

2.6 ENVIRONMENTAL REQUIREMENTS

Topsoil management, erosion and sediment control during construction, rehabilitation requirements for the realigned channel sections and the flood protection levee and monitoring of rehabilitation will be contained in a site specific Environmental Management Plan.

3 Referenced documents

McArthur River Mine Open Cut Project, draft Environmental Impact Statement, August 2005.

McArthur River Mine Open Cut Project, EIS Supplement October 2005.

Hydraulic Design and Flooding Investigation, Report BEW428-W-REP-001 prepared by KBR, June 2005

Report on Geotechnical Investigation, Detailed Feasibility Study, McArthur River Expansion Project, McArthur River, Northern Territory. Report No. 04632206-005 prepared by Golder Associates, December 2004.

Addendum Report to Report 04632206-009 Geotechnical Investigation, Detailed Feasibility Study, McArthur River Expansion Project, McArthur River, Northern Territory prepared by Golder Associates, June 2006.

Appendix A

HYDRAULIC DESIGNS AND FLOODING INVESTIGATION

MCARTHUR RIVER MINE

Hydraulic Design Report

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29 June 2006

BEW508-W-REP-002 Rev0

Revision History

Revision	Date	Comment	Signatures		
			Originated by	Checked by	Authorised by
Draft	27/4/06	Draft Issue			
0	29/06/06	Final Issue			

1 Introduction

Kellogg Brown & Root Pty Ltd (KBR) was commissioned by Xstrata to undertake hydrologic and hydraulic assessment associated with the proposed development of the McArthur River Open Cut Mine.

The purpose of this document is to provide a summary of the hydrologic and hydraulic analyses undertaken during the design phase of the project.

2 Project Scope

2.1 SCOPE OF INVESTIGATIONS

The mine proposal includes the flowing elements which require hydraulic design:

- The flood protection bund around the mine
- The diversions channels on the McArthur River and Barney Creek.

The scope of the investigations in this report covers the following:

- Review and revision of the previous hydraulic analysis undertaken for preliminary design
- Estimation of flood levels adjacent to the flood protection bund around the mine
- Design of the crest level of the flood protection bund taking account freeboard allowance
- Consideration of the management of the potential impacts from overtopping of the flood protection bund.

The hydraulic design of the diversion channels was undertaken by URS based on the flood hydrology information supplied KBR. A full description if the hydraulic design of the channels is provided in the PER.

2.2 SOURCES OF DATA

The data utilised in the hydraulic investigations as part of the detailed design are largely from the previous studies undertaken by KBR.

The current design layout of the proposed mining operation as used in the hydraulic modelling is shown on drawing number BEE508-C-DWG-002.

The digital terrain model (DTM) used for the 2D hydraulic modelling is the same as used in the previous KBR investigations.

3 Hydrology Analysis

3.1 INTRODUCTION

For detailed design it is appropriate to review and re-assess the hydrology analysis undertaken previously for the preliminary design.

Design of the diversion channels requires consideration of both the major event long-duration flooding which would generate the largest flows in the McArthur River as well as the shorter duration flooding which is more significant for Barney Creek.

3.2 McARTHUR RIVER FLOOD HYDROLOGY

In the previous investigations (KBR 2005a), design flood peak discharges for the 2-year, 5-year, 50-year, 100-year and 500-year ARI events were estimated using flood frequency procedures, as described in Australian Rainfall and Runoff (1987). The analysis was based on 32 complete years of record at the DIPE gauging station on the McArthur River spanning the period 1969 to 2003. The annual series of flood peak discharges and the flood frequency results for the DIPE station on the McArthur River at the MIM Pump Site is shown plotted in Figure 3.1.

On review it was considered that extrapolation of the flood frequency analysis to estimate peak flows for the 500 year ARI event required additional verification to ensure a greater degree of accuracy.

A runoff-routing model (RORB) was therefore developed for the McArthur River catchment to estimate flows in the main river as well as the coincident flooding in the tributary creeks. The model was calibrated to the peak discharge estimates from the flood frequency analysis for the 20, 50 and 100 year ARI event. Note that the alternative method of calibration, that is matching historic runoff events, was not considered due to lack sufficient detailed rainfall data across the McArthur River catchment.

Design rainfall was obtained using the procedures in Australian Rainfall and Runoff (1987). The rainfall for the 500-year ARI event was estimated using the procedures outlined in Book VI of Australian Rainfall and Runoff (2001).

The model was simulated for all storm events to derive estimates of the coincident flows from the six other tributary catchments. The resulting estimated peak discharges are given in Tables 3.1 and 3.2.

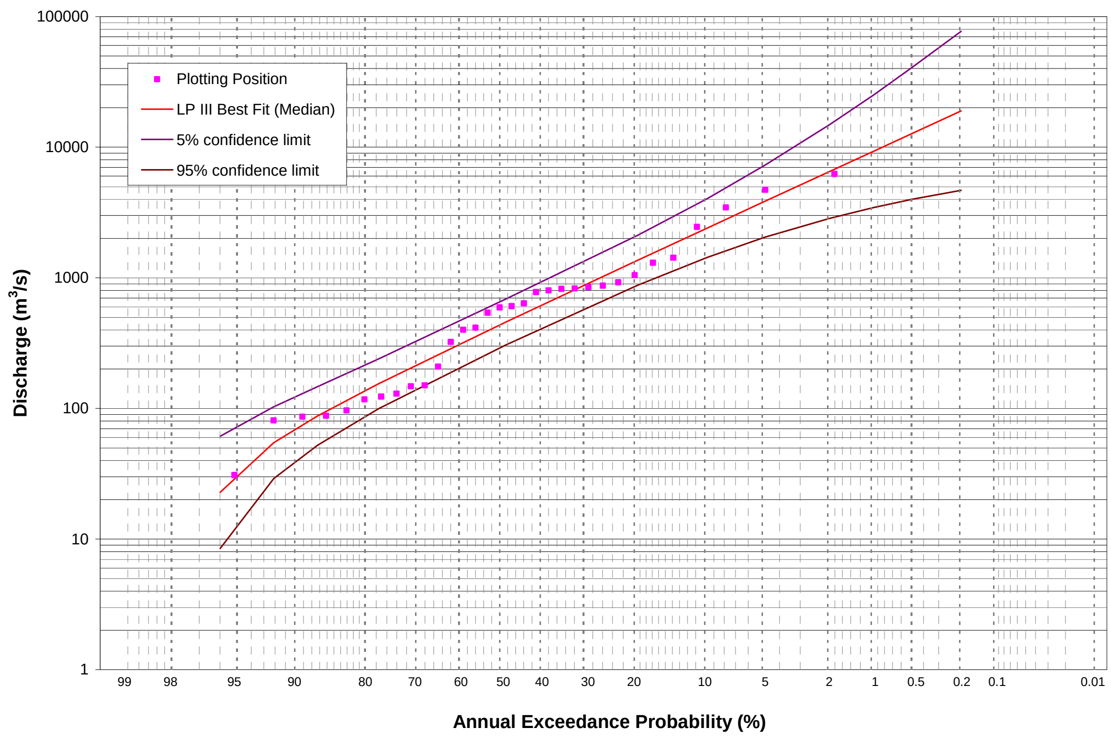

Figure 3-1
FLOOD FREQUENCY ANALYSIS, McARTHUR RIVER AT MIM PUMP STATION

Table 3.1 Adopted design flood peak discharges (2-20Y ARI)

Stream	Catchment area (km^2)	Design peak discharge (m^3/s) 2-year ARI	5-year ARI	10-year ARI	20-year ARI
Buffalo Creek	168	39	89	110	176
Barney Creek	390	49	128	181	313
McArthur River at MIM Pump	10,400	459	1,360	2,074	3,800
Bull Creek	74	14	33	41	65
Glyde River	2,500	137	397	594	1,072
Emu Creek	56	21	46	54	86
Surprise Creek	101	34	76	93	148
McArthur R Downstream of Glyde R confluence	13,689	605	1,795	2,755	5,075

Table 3.2 Adopted design flood peak discharges (50-500Y ARI)

Stream	Catchment area (km^2)	Design peak discharge (m^3/s)		
		50-year ARI	100-year ARI	500-year ARI
Buffalo Creek	168	248	321	587
Barney Creek	390	467	644	1256
McArthur River at MIM Pump	10,400	6530	9290	17450
Bull Creek	74	92	119	217
Glyde River	2,500	1,848	2,588	4,708
Emu Creek	56	118	150	272
Surprise Creek	101	207	265	483
McArthur R Downstream of Glyde R confluence	13,689	8,750	12,705	23,230

3.3 BARNEY CREEK FLOOD HYDROLOGY

The catchment upstream of the Barney Creek diversion channel is $659km^2$ and includes contributions from upper Barney Creek ($390km^2$), Buffalo Creek ($168km^2$) and Surprise Creek ($101km^2$). Surprise Creek joins the proposed diversion channel 600m down from the upstream end. The calculation of the peak design discharges for the Barney Creek diversion channel is based upon discharges from each of these catchments during the critical storm duration for the combined Barney, Buffalo and Surprise Creek catchments.

3.3.1 Peak Discharges

Due to the lack of available historic stream gauging data, the peak discharge for each respective ARI event for the Barney Creek diversion channel was determined using the relationships developed by KBR for the Alice Springs to Darwin Railway project (Weeks, 2005). These relationships are based upon a regional flood frequency analysis and are as indicated below, where “A” represents the area of the catchment.

- $Q_5 = 5.55A^{0.740}$
- $Q_{10} =7.82A^{0.737}$
- $Q_{20} = 10.2A^{0.737}$
- $Q_{50} = 18.5A^{0.667}$

The resulting peak discharges for the Barney Creek catchment downstream of the Surprise Creek confluence are indicated in Table 3.2. It should be noted that the 2-yr and 100-yr ARI peak discharges were estimated using rational method calculations assuming a runoff coefficient (C) of 0.52 and 0.75 respectively.

Table 3.3 Barney Creek – Peak Discharges (m^3/s)

Catchment area (km^2)	Design ARI (years)					
	2	5	10	20	50	100
659	450	680	930	1220	1400	1650

The flood hydrographs for the 2-dimensional modelling were developed using a RAFTS (runoff routing) model of the Barney Creek catchment.

It is noted that the estimates of peak discharge in Barney Creek are (if anything) likely to be high. This is because, as discussed in Section 5 of the PER, the creek passes through many swamps and billabongs in the region upstream of the mine area, with the largest swamp covering more than 6 km^2. It is likely these features would have a significant delaying or attenuation effect on peak discharge in Barney Creek. This influence is not considered in the hydrologic assessment hence the estimate of peak discharge is likely to be conservatively high.

In addition as indicated in Section 5 of the PER there is high flow connection between the Surprise Creek catchment and Emu Creek. In the vicinity of Bald Hills to the north east of the mine there is a shallow drainage line which feeds south and east into a chain of billabongs that in turn drain east into Emu Creek. During a major flood in 2001 water from this area flowed across the Carpentaria Highway damaging several hundred metres of the road. It is likely that floodwaters from Surprise Creek may have contributed to flow into this area. This suggests Surprise Creek may loose some water during higher magnitude flood events resulting in less than predicted flows in Barney Creek downstream.

4 McArthur River Hydraulic Model

4.1 INTRODUCTION

The hydraulics of the McArthur River and the impacts of the proposed development were investigated using a two-dimensional hydraulic model of the river and floodplain. The hydraulic model developed previously was updated to include the latest mine layout and diversion channel arrangement and to increase the resolution of the model. A full description of the development and calibration of the model is contained in the report "McArthur River Open Cut Mine - Hydraulic Design and Flooding Investigations" BEW428-W-REP-001 Rev A, 21 January 2005.

The 2-dimensional hydraulic model developed using Delft-FLS is based on a grid of points spaced every 21 m which is suitable for broad scale assessments under large flood conditions.

The model was run for a range of flood events using the inflow hydrographs developed from the RORB model analysis as described above in Section 3. The downstream rating curve relationship for the model was reassessed taking into account the additional hydraulic modelling of the river undertaken by URS using HEC-RAS.

4.2 EXISTING CONDITIONS

In order to assess the flooding impact of the proposed mining operation, the 2-dimensional model was initially used to simulate flooding for the existing topography case. This allowed evaluation of flow patterns, flood levels and velocities for the 10, 20, 50, 100, and 500 year ARI events.

The maximum flood levels from the 2-dimensional modelling are plotted in Figures 4.1 to 4.5. The existing condition peak flood levels at key locations are given in Table 4.1.

The peak velocities flow velocities for the 10, 20, 50, 100, and 500 year ARI events are plotted in Figures 4.6 to 4.10.

Table 4-1 McArthur River Existing Case - 2D Modelling Results, Peak Flood Levels

Location	Peak Flood Level (mAHD)				
	10y ARI	20y ARI	50y ARI	100y ARI	500y ARI
A - D/s Glyde R confluence	31.67	33.97	37.12	39.59	42.50
B - D/s McArthur R diversion	32.01	34.29	37.33	39.75	42.60
C - On McArthur R d/s of mine levee	32.49	34.68	37.53	39.85	42.69
D - Bull Ck at Diversion	32.55	34.41	37.49	39.90	42.72
E - U/s of McArthur R diversion	32.95	35.13	37.80	39.98	42.76
F - U/s Barney Ck diversion	32.78	34.89	37.63	39.90	42.72
G – Barney Ck opp staff facilities	35.64	36.50	37.73	39.98	42.79
H – Barney Ck at Carpentaria Hwy	37.21	37.98	38.85	40.13	42.87
I – Surprise Ck at Carpentaria Hwy	37.84	38.71	39.80	40.66	42.72

4.3 DEVELOPED CONDITIONS

The 2-dimensional model was then modified to include all the features of the proposed design, including the mine flood protection bund, the diversion channels and the over burden emplacement facility.

The developed case model was then run for the 10, 20, 50, 100, and 500 year ARI events. Flood levels at various locations are shown in Table 4.2. The flood levels for the developed case are shown in Figures 4.7 to 4.10 and the peak velocities are shown in Figures 4.11 to 4.15.

The increase in flood level (or afflux) for the 100 year ARI flood event is shown in Figure 4.21. The results show the lateral extent of the increase in flood level due to the mine proposal.

Table 4.2 McArthur River Developed Case - 2D Modelling Results, Peak Flood Levels

Location	Peak Flood Level (mAHD)				
	10y ARI	20y ARI	50y ARI	100y ARI	500y ARI
A - D/s Glyde R confluence	31.65	33.88	37.06	39.59	42.61
B - D/s McArthur R diversion	32.00	34.21	37.31	39.79	42.71
C - On McArthur R d/s of mine levee	32.06	34.30	37.39	39.86	42.78
D - Bull Ck at Diversion	33.42	35.68	38.42	40.39	43.07
E - U/s of McArthur R diversion	34.85	37.77	39.39	40.89	43.34
F - U/s Barney Ck diversion	35.72	37.51	38.52	40.32	43.14
G – Barney Ck opp staff facilities	36.26	37.82	38.83	40.48	43.27
H – Barney Ck at Carpentaria Hwy	37.30	38.41	39.34	40.63	43.37
I – Surprise Ck at Carpentaria Hwy	37.87	38.92	40.06	40.86	43.11

5 Flood protection levee

5.1 DESIGN OF CREST ELEVATION

The principal design criterion is that the levee is required to provide full flood immunity up to the 500 year ARI event.

The design crest level for the levee is the 500 year ARI flood level plus an allowance for freeboard. Freeboard is required to ensure the integrity of the levee wall at the design flood level. It allows for wind and wave effects and also some contingency against small settlement in the embankment.

Required levee crest levels were calculated for a range of flood and wind speed ARI events and are summarised in Table 5.1. Flood level and wind speed are assumed to be independent of each other, that is, the joint probability of, for example, the ARI 500 year flood and an ARI 2 year wind is an overall ARI 1,000 years. In the case of the McArthur River flood protection bund, the design freeboard allowance for the final arrangement (4:1 batters) was assessed using the US Bureau of Reclamation (1992) recommendations.

Table 5.1 Levee Crest Elevation considerations

ARI (years)	Flood level[1] (mAHD)	Design freeboard allowance (m)		Embankment Settlement Allowance[4] (m)	Minimum Levee Crest Level[5] (mAHD)
		Wind Speed[2] ARI (years)	Required freeboard[3] (m)		
20	37.77	50	1.6	0.4	39.8
100	40.89	10	1.6	0.4	42.9
500	43.34	2	1.6	0.4	45.3

Notes:

1. Refer Table 4.2
2. Design wind speeds are based on Australian Standard AS1170.2.
3. Freeboard includes allowance for wind set-up and run-up in accordance with ACER Technical Memorandum No.2 Freeboard Criteria and Guidelines for Computing Freeboard Allowances for Storage Dams US Bureau of Reclamation Revised 1992
4. Allowance for foundation consolidation and embankment settlement.
5. Minimum crest level is at the upstream face of the final arrangement rounded up to nearest 0.1m. For the initial arrangement, subtract 1.1m, for the downstream final arrangement minimum crest level; subtract 0.6m

Based on the calculations presented in Table 5.1, an upstream crest level of RL44.2m AHD is recommended for the initial arrangement and RL 45.3m AHD for the final arrangement, with downstream crest levels of RL43.6 m AHD and RL44.7m AHD respectively.

5.2 YEAR 1 PARTLY CONSTRUCTED SCENARIO

It is planned that the mine development will be constructed over two dry seasons. This creates the need to investigate the impact of flooding on the partially completed mine development works. Of concern is the flood level adjacent to the temporary mine works and stability of the works with regard to erosion due to floodwaters.

The 2-dimensional hydraulic model was modified to include elements of the current mine layout that will be constructed during the first stage of construction. The key component to be analysed by the hydraulic modelling is the partially constructed flood protection levee. During the first stage of construction the levee would be constructed from chainages 0 to 1800m, 3200 to 6000m, and 6800 to 7314m.

This results in clear openings of approximately 800m and 1400m at the upstream and downstream ends respectively. It should be noted that the extent of the levee given corresponds to the toe of the levee. It has been assumed that from this toe there will be a 1v:20h batter longitudinally to the levee crest.

The adopted 2-dimensional model layout is shown in Figure 5.1.

This model was simulated using the McArthur River event inflows for the 10, 20, 50, and 100 year ARI events. The modelled flood levels at selected locations are shown in Table 5.2. Plots of flood level are shown in Figures 5.1 to 5.4.

Table 5.2 Peak flood levels - Year 1 Scenario

Location	Peak flood level (m AHD)			
	10-year ARI	20-year ARI	50-year ARI	100-year ARI
On McArthur River Downstream of mine levee	32.49	34.71	37.56	39.85
Upstream of Test Pit Levee	32.86	35.08	37.80	39.94
Upstream of McArthur River diversion	32.97	35.21	37.90	40.00

Peak velocities for the 10, 20, 50 and 100 year ARI events are shown in Figures 5.5 to 5.8. The maximum velocity adjacent to either the test pit levee or the partially completed southern section of the mine protection levee does not exceed 1.0m/s for the events simulated. At most locations adjacent to the work the velocity is less than 0.5m/s. It is considered that these velocities are relatively mild and are not likely to cause scour.

5.3 LEVEE BREACH ANALYSIS

An analysis was undertaken to investigate the effect of a breach in the flood protection levee for an event larger than the 500 year ARI design event. The objective was to determine the feasibility of controlling any possible breach of the embankment and thus confine the washed out section embankment to a limited extent.

A hypothetical breach was modelled by lowering a section of the embankment by 0.5m in a straight section of the flood protection bund on the southern side of Barney Hill. The intention is that because this area is away from the main flow path, any failure of this part of the embankment would not cause significant material to be washed into the McArthur River.

The breach simulation was carried out using the 2-dimensional model with the addition of dam-break nodes at the location of the simulated breach. The 2-dimensional model included an approximation of the mine pit which was estimated to have a volume (below natural surface level) of $86.9 \times 10^6 m^3$. The resulting total volume below the levee crest is approximately $155 \times 10^6 m^3$.

In order to investigate the effects of the breach, a number of parameters were estimated based on appropriate dam-break literature including Wahl (1998) and Froehlich (1995). The dam-break width was taken as 200m, and the time of failure as 2hrs for the centre 100m of the breach and 8hrs for the outer sections of the breach. A summary of the dam-breach is given in the table below

Table 5.3 Breach Timing

Time (hrs)	Depth (m) (Centre Nodes)	Depth (m) (Outer Nodes)	Total Depth (m)	Waterway Area (m^2)
0.0	0.0	0.0	0.0	0
2.0	8.0	2.0	20.0	1000
4.0	8.7	4.0	25.3	1270
6.0	9.3	6.0	30.7	1530
8.0	10.0	8.0	36.0	1800
10.0	10.0	8.0	36.0	1800

The breach was initialised after a limited amount of overtopping of the lowered section of the levee. The resulting flow through the breach reached a peak of approximately $6,000 m^3/s$ and filled the volume inside the flood protection levee (including pit) in approximately eight hours.

It was concluded that, in concept, it would be possible to instigate a levee breach at a controlled portion of the embankment. Overtopping of this section would rapidly fill the mine void and bunded area within the embankment in such a way that no overtopping would take place elsewhere before the void had filled. In other words there would be no drop in water level across the embankment causing scour (other than at the "control" location). In this way it is concluded that with appropriate engineering of the breach area, it will be possible to limit the damage caused by overtopping and thus prevent significant fill material from the embankment entering the McArthur River waterway.

6 References

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KBR 2005b “McArthur River Mine Test Pit - Hydraulic Assessment of Bund Wall” Report BEW428-W-REP-002 Rev A, 26 April 2005.

Wahl, Tony L., 1998, “Prediction of Embankment Dam Breach Parameters: A Literature Review and Needs Assessment” USBR, Water Resources Research Laboratory, Denver, Colorado.

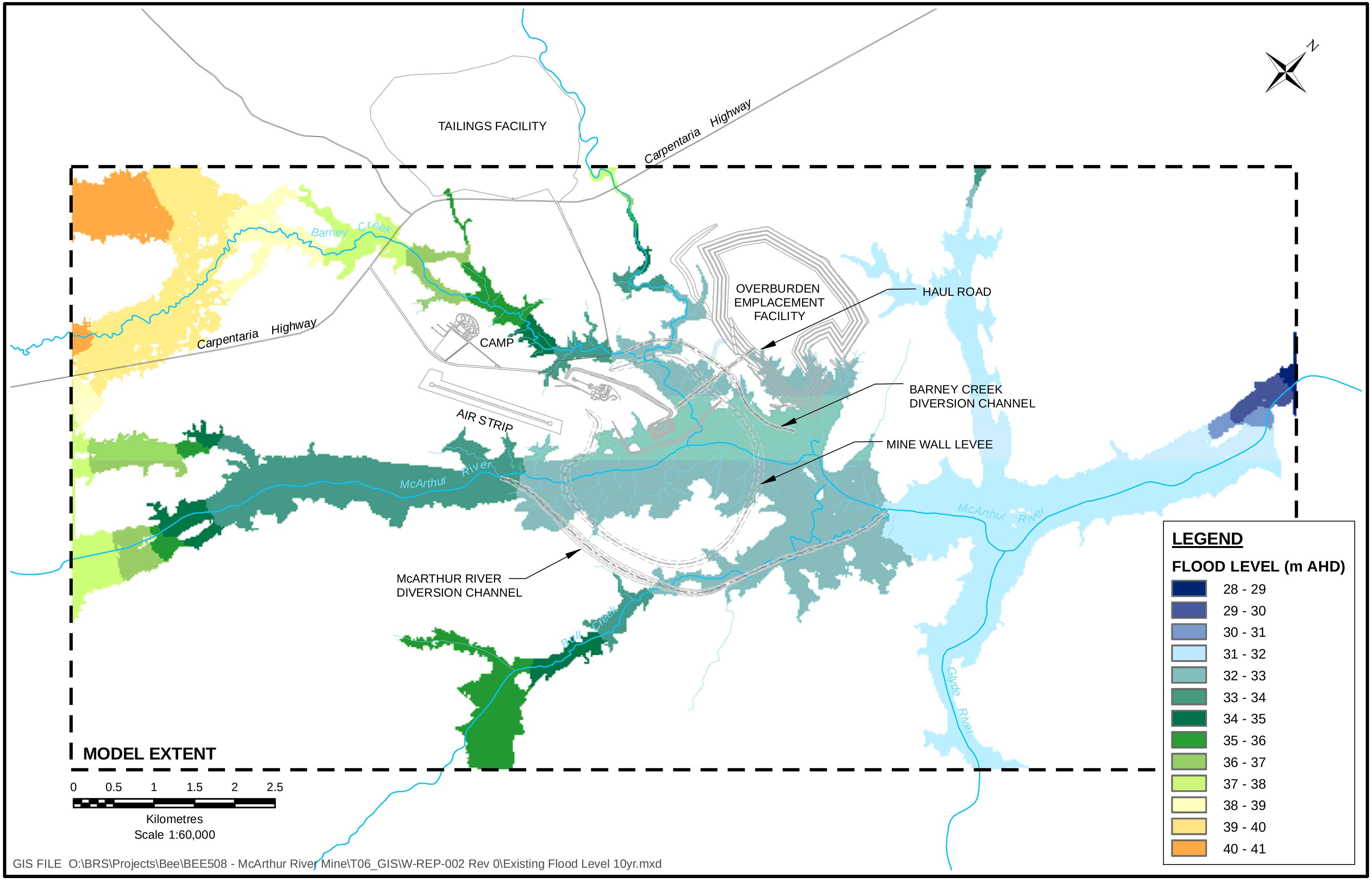

Figure 4.1
McARTHUR RIVER 10 YEAR ARI EVENT
EXISTING CONDITIONS - PEAK WATER LEVEL

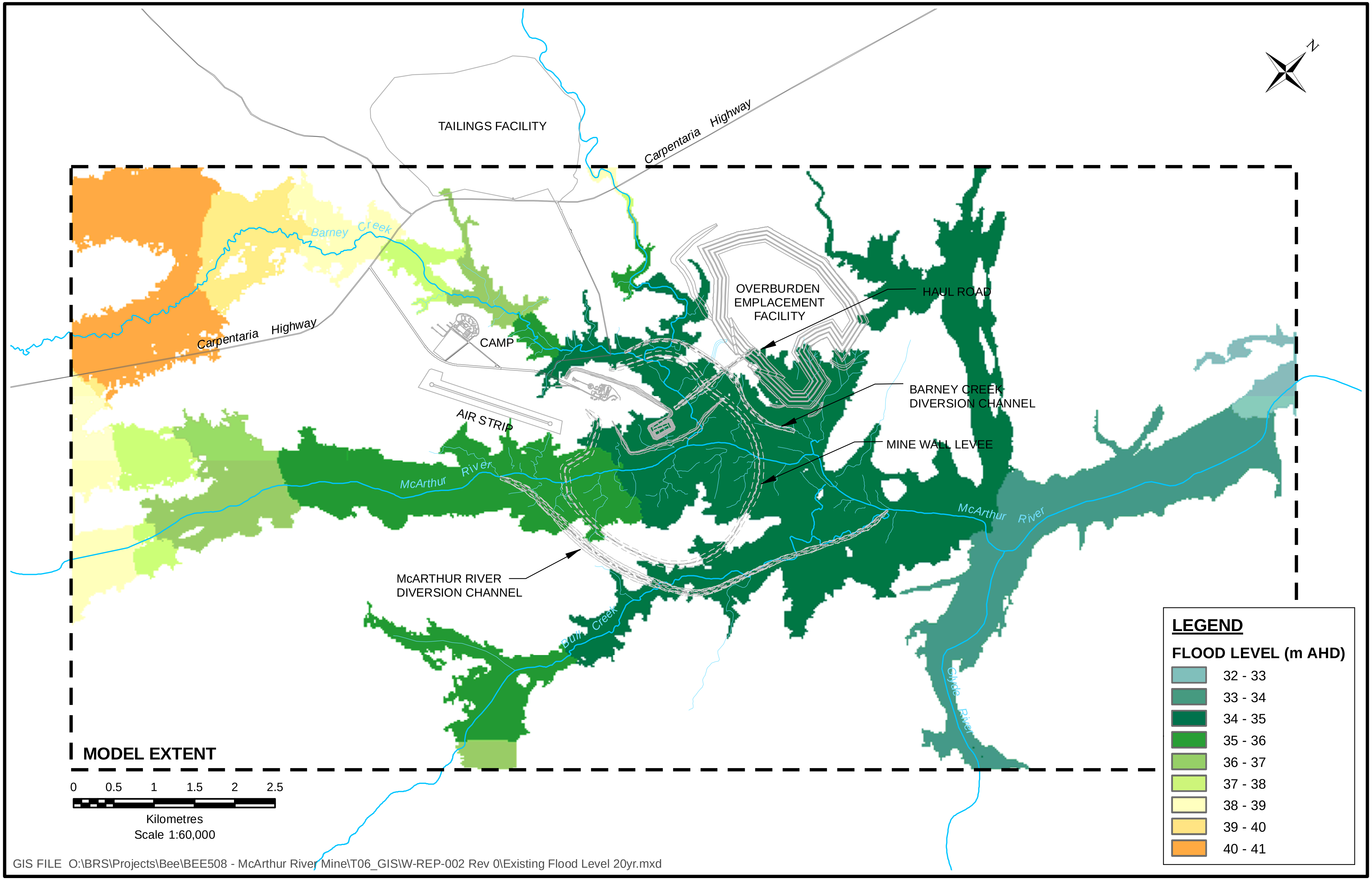

Figure 4.2
McARTHUR RIVER 20 YEAR ARI EVENT
EXISTING CONDITIONS - PEAK WATER LEVEL

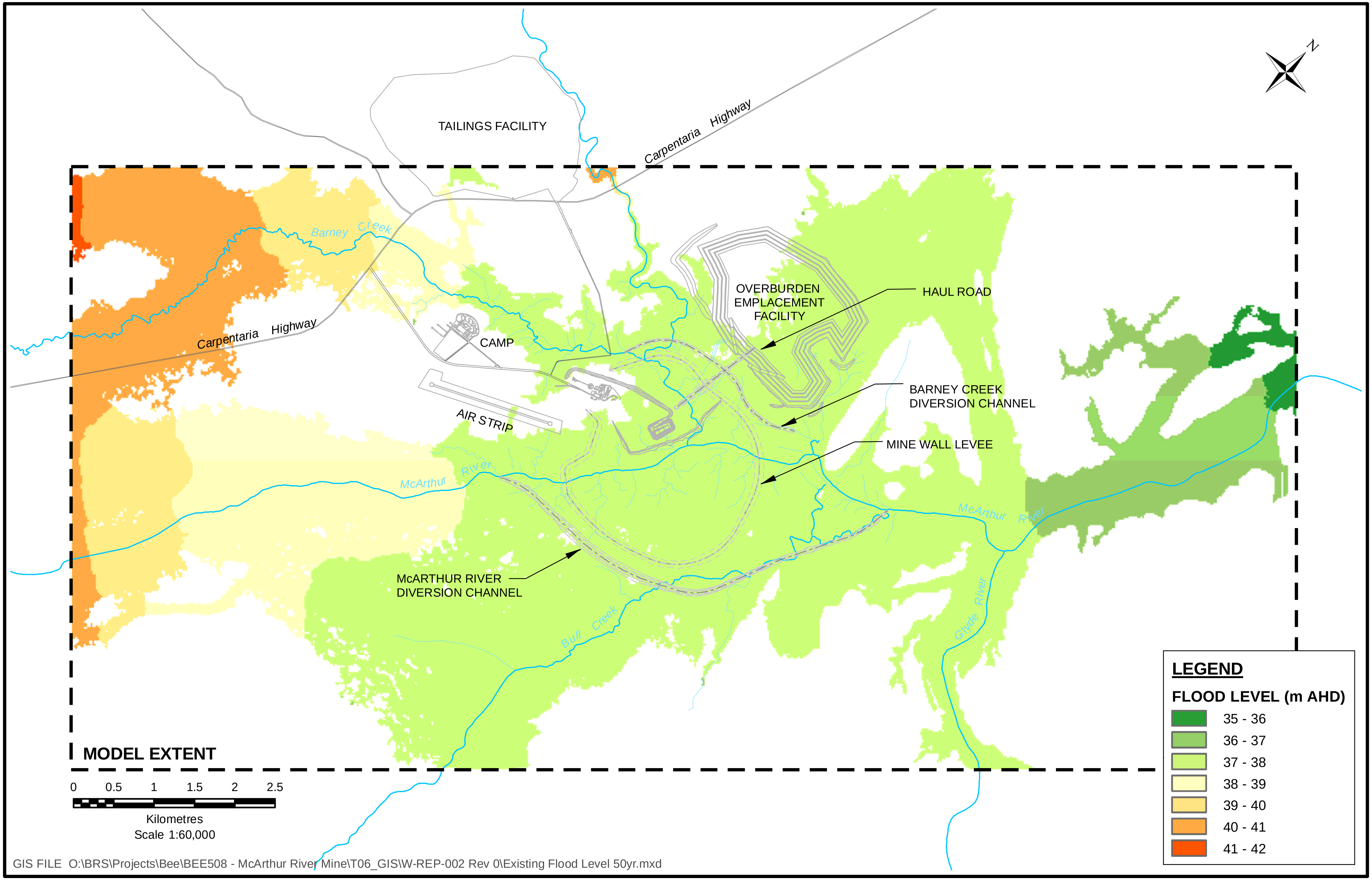

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Figure 4.3
McARTHUR RIVER 50 YEAR ARI EVENT
EXISTING CONDITIONS - PEAK WATER LEVEL

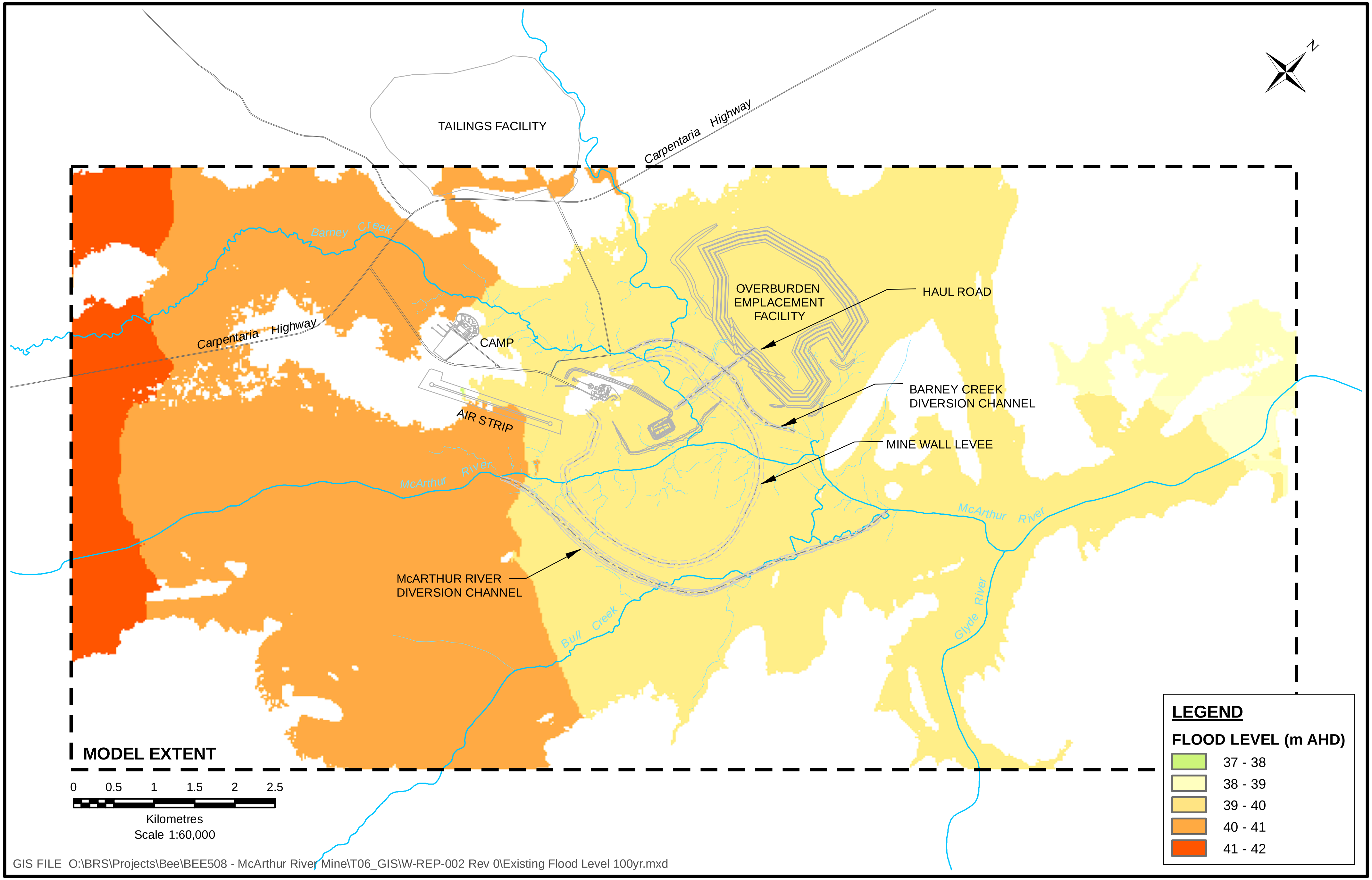

Figure 4.4
McARTHUR RIVER 100 YEAR ARI EVENT EXISTING CONDITIONS - PEAK WATER LEVEL

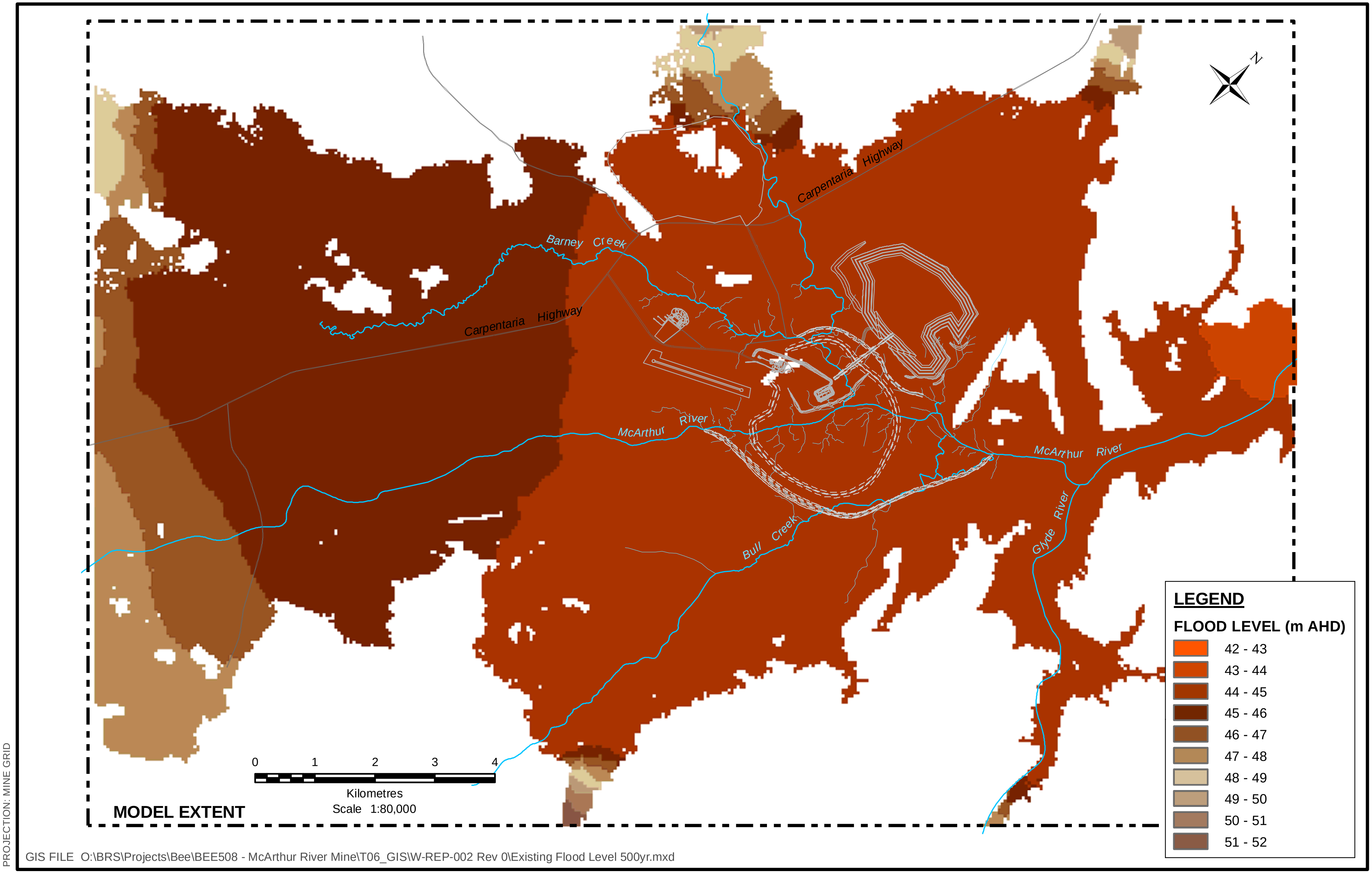

Figure 4.5
McARTHUR RIVER 500 YEAR ARI EVENT
EXISTING CONDITIONS - PEAK FLOOD LEVEL

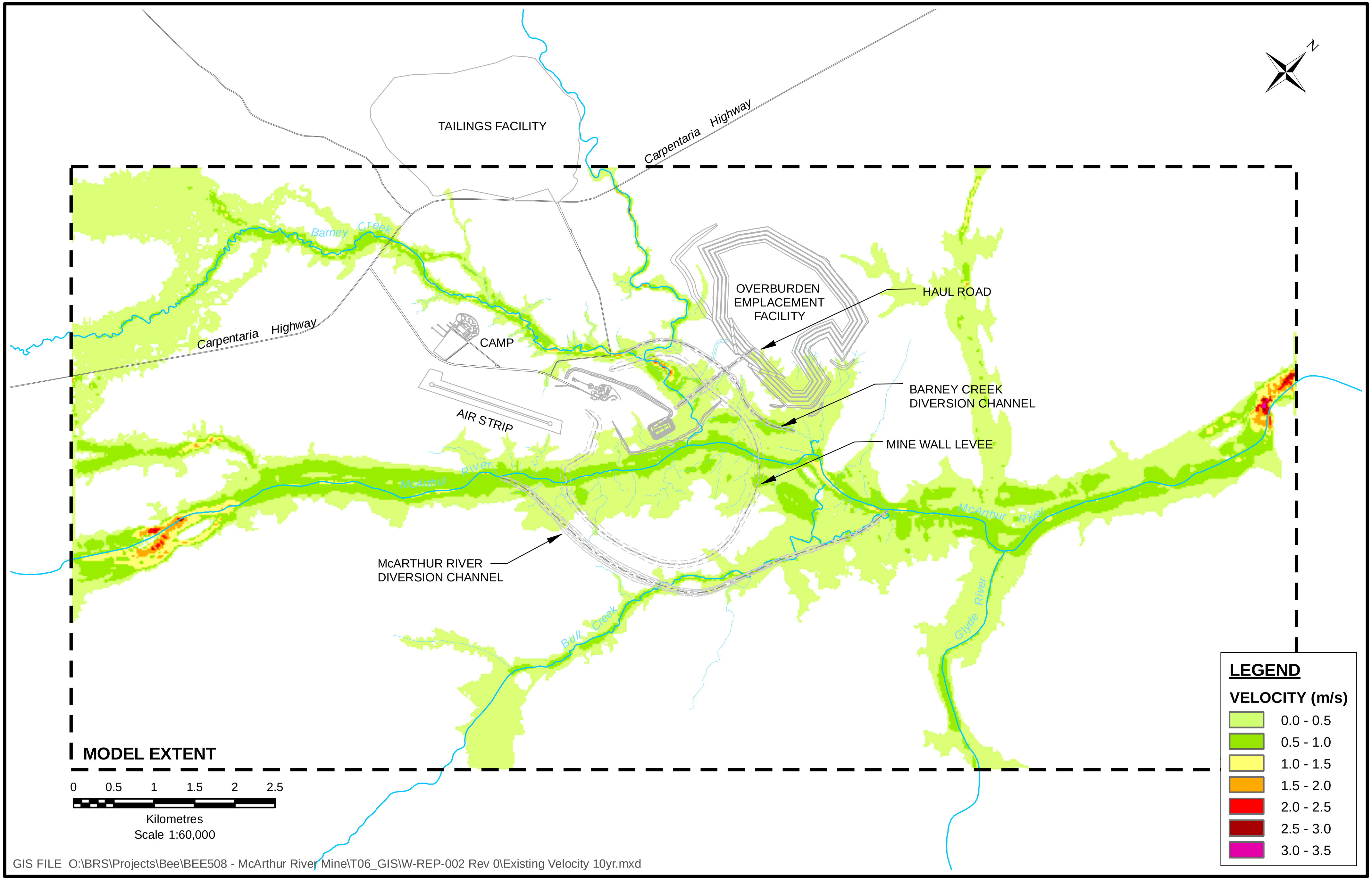

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Figure 4.6
McARTHUR RIVER 10 YEAR ARI EVENT
EXISTING CONDITIONS - MAXIMUM VELOCITY

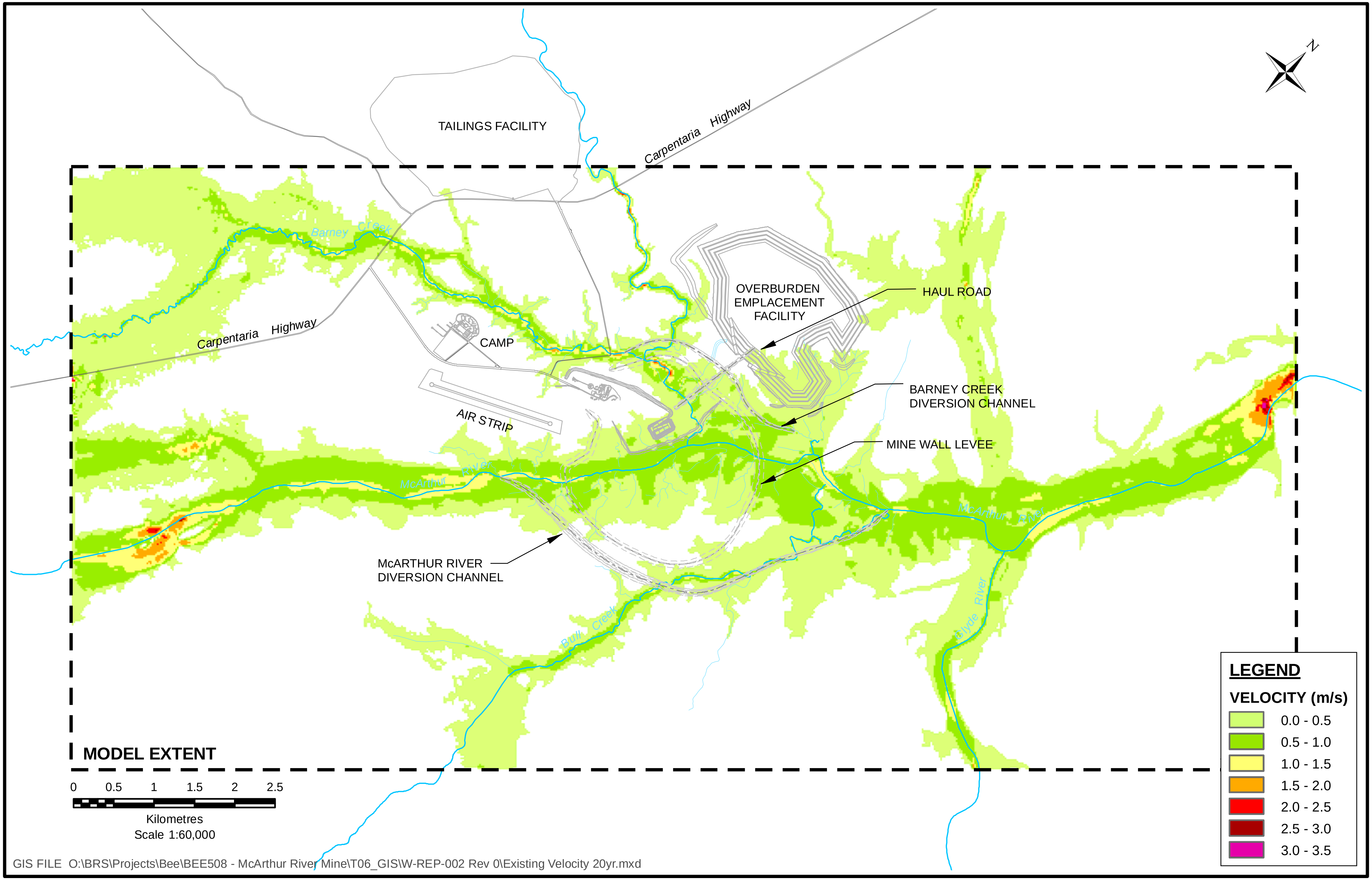

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Figure 4.7
McARTHUR RIVER 20 YEAR ARI EVENT
EXISTING CONDITIONS - MAXIMUM VELOCITY

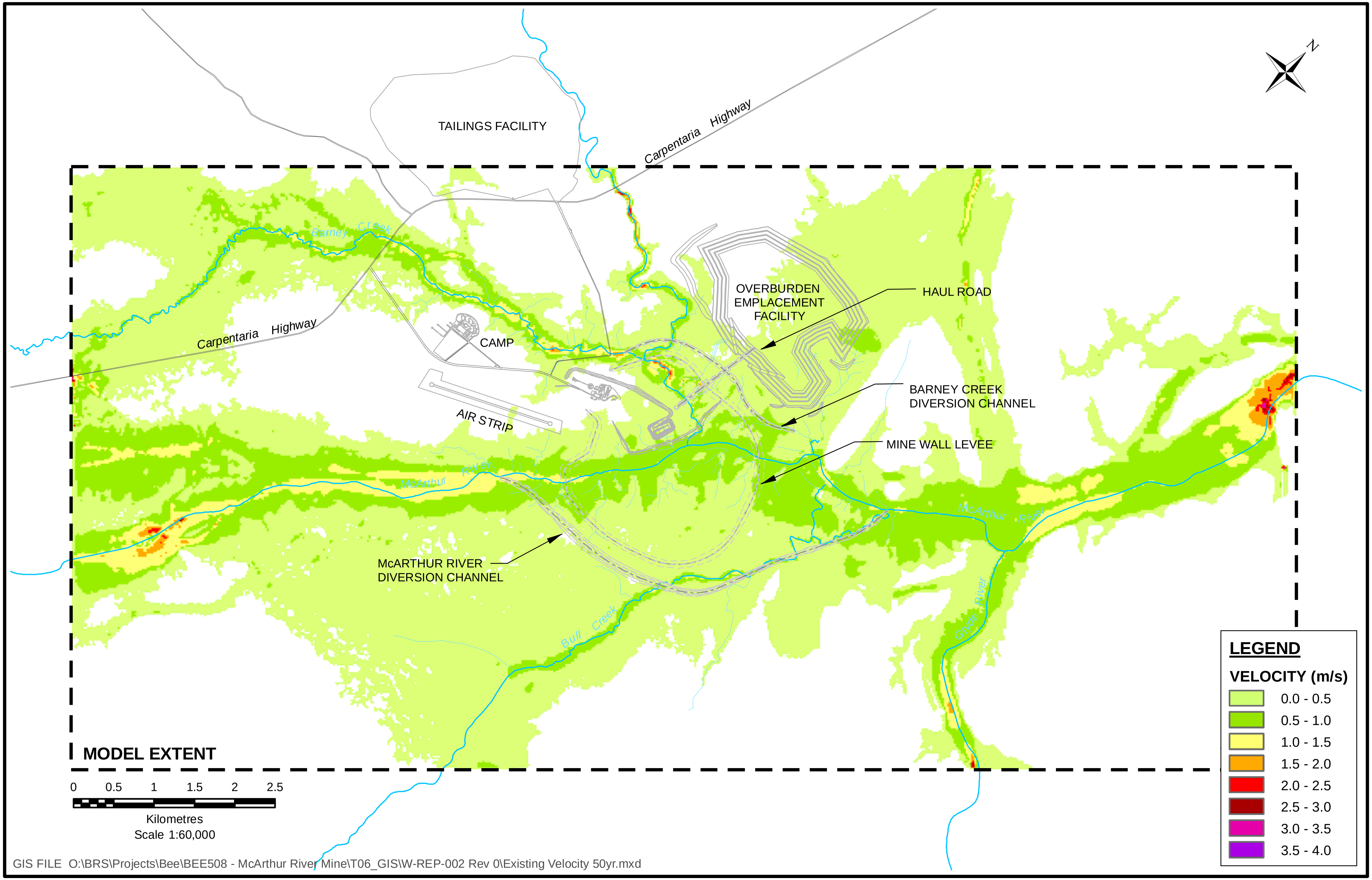

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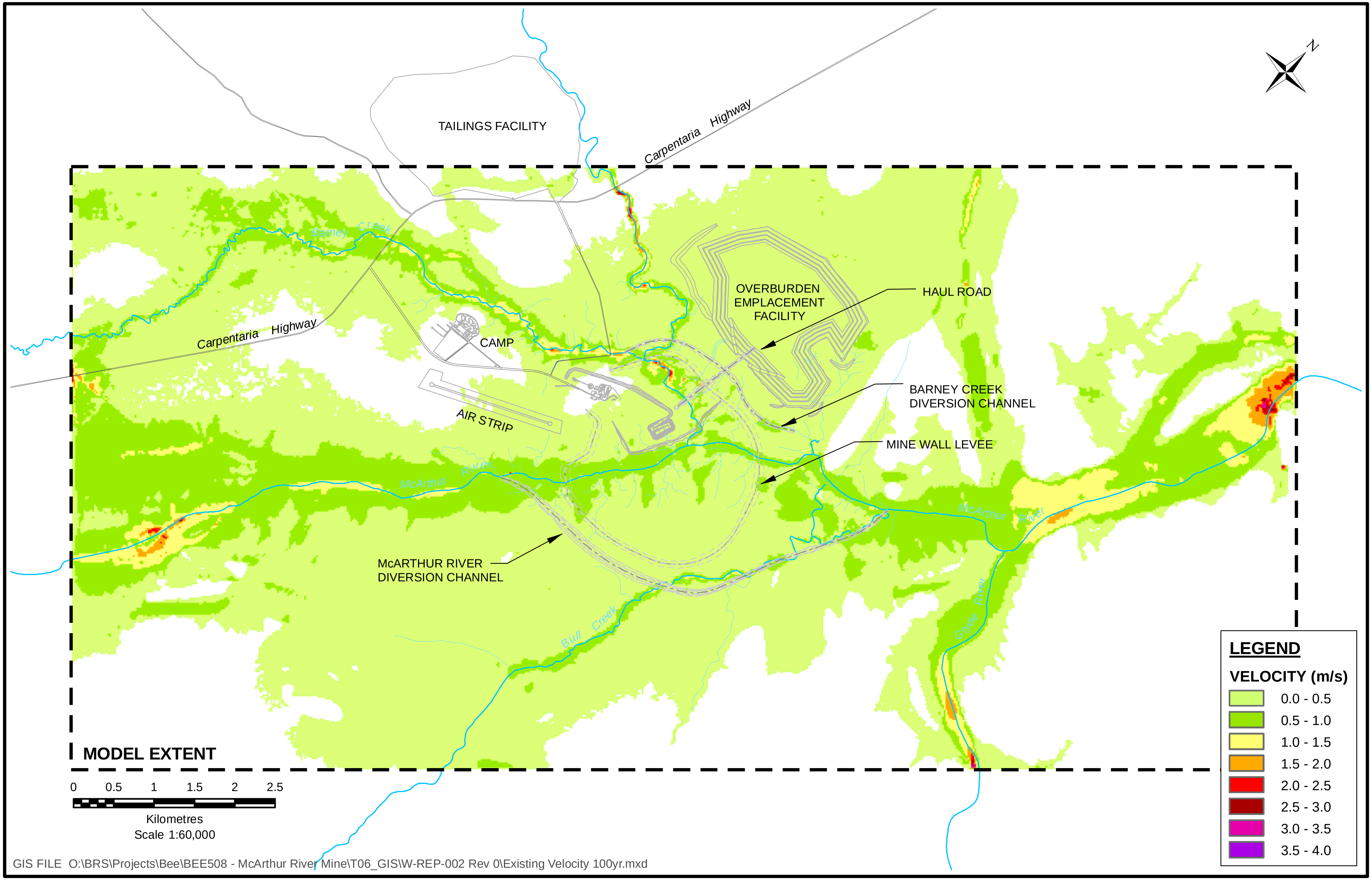
Figure 4.8
McARTHUR RIVER 50 YEAR ARI EVENT
EXISTING CONDITIONS - MAXIMUM VELOCITY



PROJECTION: MINE GRID

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Figure 4.9
McARTHUR RIVER 100 YEAR ARI EVENT
EXISTING CONDITIONS - MAXIMUM VELOCITY

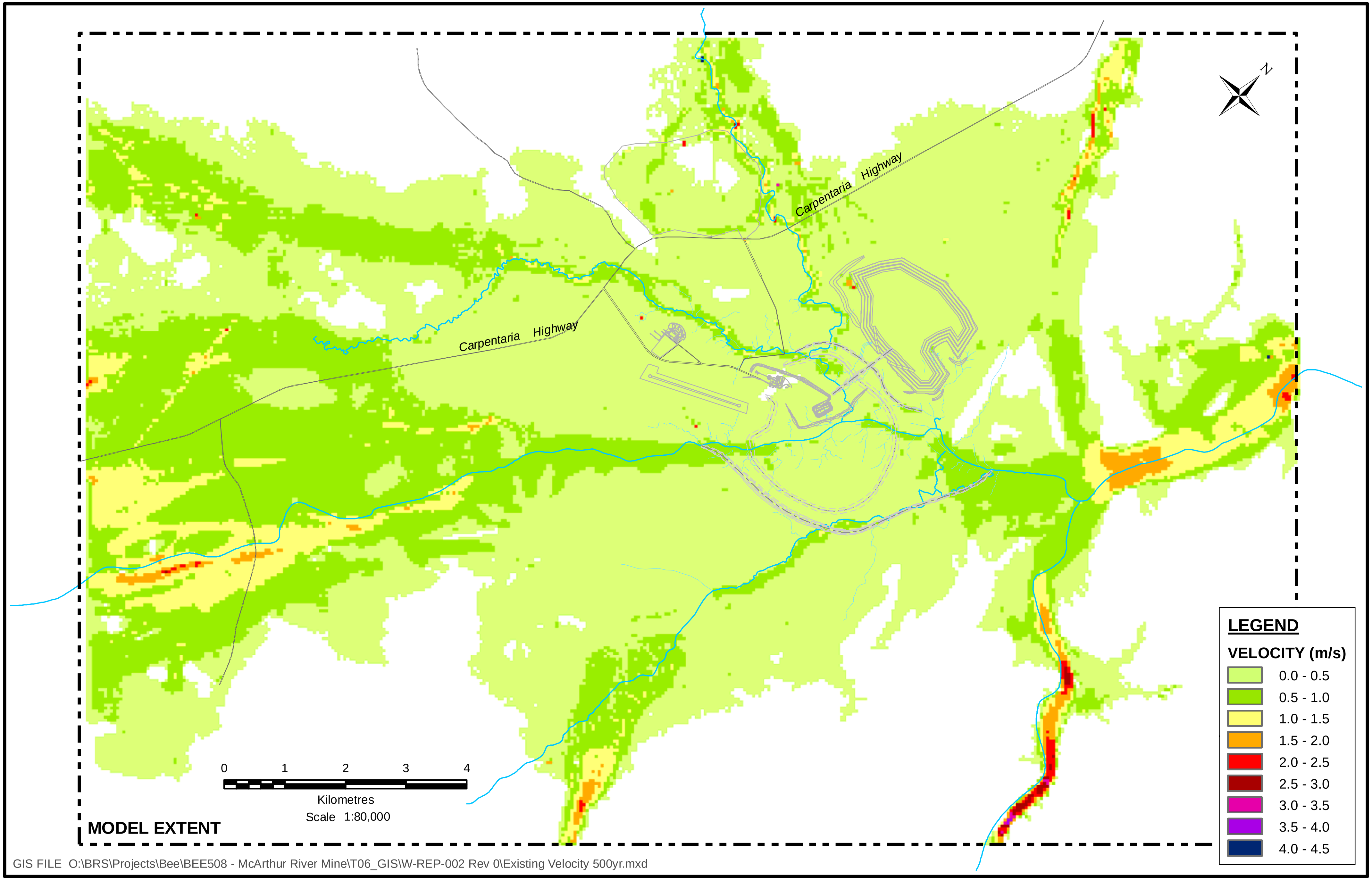

Figure 4.10
McARTHUR RIVER 500 YEAR ARI EVENT
EXISTING CONDITIONS - MAXIMUM VELOCITY

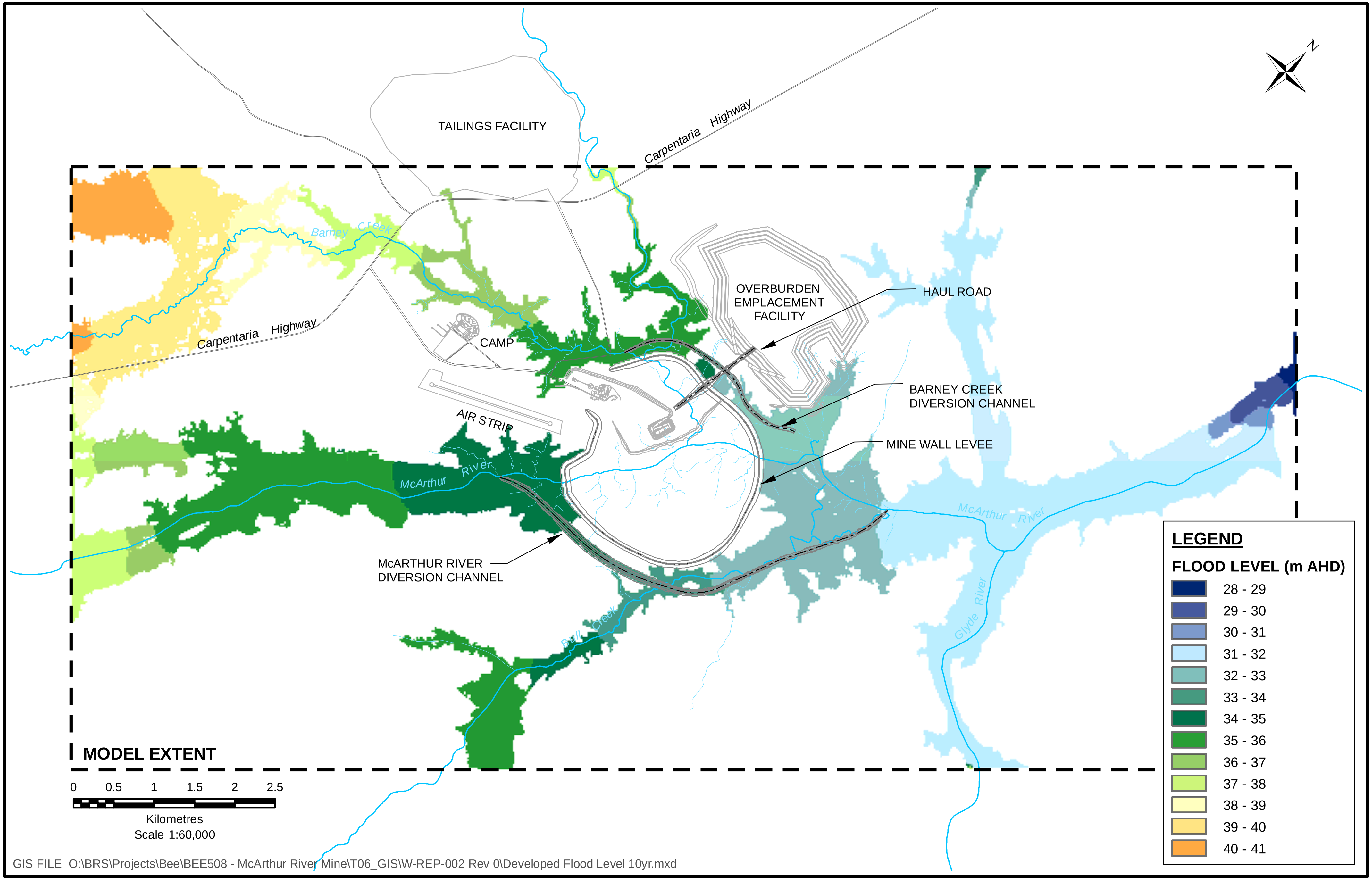

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Figure 4.11
McARTHUR RIVER 10 YEAR ARI EVENT
DEVELOPED CONDITIONS - PEAK FLOOD LEVEL