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KARARA IRON ORE PROJECT

SURFACE WATER BASELINE AND IMPACT ASSESSMENT

JUNE 2008

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In line with our Quality System, this document has been prepared by Nicholas Keenan, Sheena Cheng, Maria Heine, Tom Kerr.
It has been reviewed by Gary Clark.

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1. INTRODUCTION

The purpose of this document is to revise and update the Karara Magnetite Project Surface Water Impact Assessment undertaken by Coffey Mining in 2007.

Since the original surface water impact assessment was carried out in April 2007, the project description has changed significantly, warranting a full revision of the surface water impact assessment report.

1.1 PROJECT DESCRIPTION

Karara Mining Limited (KML) is proposing to develop the Karara Iron Ore Project. The Karara Iron Ore Project is located in the Mid-West region of WA, approximately 225 km southeast of Geraldton. Figure 1.1 shows the general location of the Karara minesite.

The project consists of an open cut pit, processing plant, dry-stacked tailings storage facility, waste rock dump and associated infrastructure.

KML propose to develop a large pit along the Karara Ridge line with a possible extension of the pit along the lower sections of the ridge at its western extent. Figure 1.2 provides details of the layout of the minesite infrastructure and catchments.

This report only relates to the development of the Karara Iron Ore Project and associated infrastructure which will be constructed independently of the Mungada Iron Ore Project.

Key changes to the project description since the Karara Magnetite Project PER was submitted to the EPA include:

- Removal of one of the proposed waste rock dumps (east of Karara pit) and refinement of the remaining waste rock dump (northwest of Karara pit).
- Inclusion of dry-stacking tailings storage facility (TSF) and water retention pond, instead of conventional, paddock style TSF.
- Removal of hematite crushing and screening facilities from near Mungada Ridge to the processing plant area.
- Repositioning of the airstrip to its present location southeast of the Accommodation village.
- Realignment of roads and pipelines within the minesite.

1.2 STUDY OBJECTIVES

The objectives of this study are to:

- Undertake a review of the baseline assessment of surface water hydrology for the Karara Magnetite Project.
- Identify and characterise the existing surface water hydrology and morphology within the project area.

- Determine the potential impacts of the project on surface water hydrology.
- Determine the potential impacts of the project on surface water quality; including potential surface water contamination by hydrocarbons, other hazardous substances and sediment.
- Recommend appropriate management measures to avoid or reduce these potential impacts.
- Determine the residual, unavoidable impacts, assuming that all recommended management measures are adopted.
- Recommend appropriate ongoing monitoring.

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Figure 1.1: Minesite Location

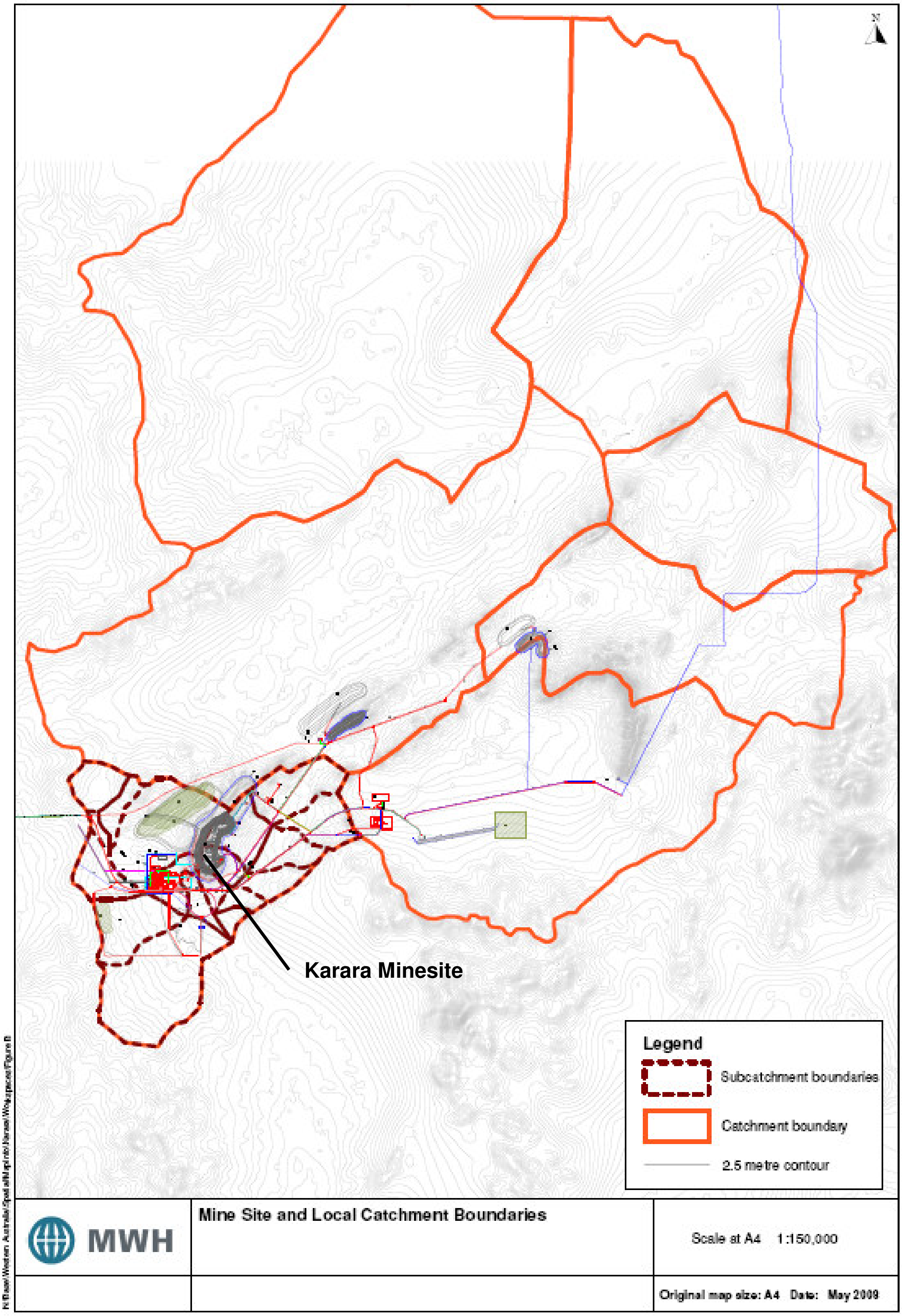


Figure 1.2: Mine Sites and Local Catchment Boundaries

2. EXISTING CATCHMENT CHARACTERISTICS

2.1 LOCATION

The Karara Iron Ore Project area sits within the Yarra Yarra Catchment Basin in the Mid-West Region of Western Australia. The nearest towns are Morawa, which is located 70 km to the west of the minesite area and Perenjori, which is located southwest of the minesite area. There are few well-developed creek systems in the area although one of the largest salt lakes within the Basin, Mongers Lake, extends from approximately 45 km east to 30 km south of the minesite.

The Yarra Yarra Catchment Basin has an area of 41,880 km^2. The Basin is lacking a defined river system but it is characterised by a continuous range of hills surrounding a series of inter-connecting salt lakes. These lakes are linked together and gravitate from the Yalgoo and Kalannie regions in the north towards the Yarra Yarra Lakes near Carnamah in the south. Rivers/creeks that drain across the Basin include Wattamulga Creek and Pindathuna Creek in the northwest and Salt River that drains from Wolla Wolla to Burra Lake in the south.

2.2 TOPOGRAPHY

Landform of the minesite varies from claypans and flat/gently sloping terrain broken by steep ridges, which are generally associated with magnetite mineralisation. The predominant topographic features of the area are the steep sided ridges which dominate the skyline and are formed by the remains of remnant outcrops of Banded Iron Formation (BIF). The proposed Karara mine pit is located along Karara Ridge, which rises to RL440 mAHD from a general level of RL340 mAHD in the broad valley. Blue Hills North pit sits on the adjacent Blue Hill Ridge, which rises up to RL410 mAHD and Terapod pit is located on the northern edge of Mungada Ridge, where elevation approaches RL420 mAHD.

Three types of slope forms can be identified within the minesite area: (1) Vertical to 30 degree slopes associated with the ridge areas, these are formed by hard rock outcrops comprising predominantly outcropping rocks of BIF; (2) Intermediate slopes generally less than 20 degrees at the base of the ridge areas and (3) Gentle to undulating slopes in low lying or valley areas. Incised ephemeral drainages are apparent in the first two slope domains while less defined drainage paths are present in the third slope form suggesting sheet flow may be more common over these surfaces.

A large partially vegetated claypan is present to the north of ridge areas. It is a low point in this area and based on contour information the claypan base is at least 5 m below the surrounding countryside. The contour information indicates the outflow point is located just west of Karara Ridge (between this ridge and the Blue Hill Ridge). This outflow point is approximately 5 m above the claypan base suggesting the claypan has the potential to accumulate large volumes of water after high rainfall events. No infrastructure is currently planned for construction over the claypan and any construction in the area should be avoided.

2.3 GEOLOGY

The geology at the site comprises a shallow soil horizon over fresh rock on the ridges with a thicker soil profile on the surrounding flat areas where no rock outcrops were observed. The BIF ridges are associated with the Windaning Formation and comprise jaspilite banded ironstone formations and chert units interlayered with felsic volcanics (including tuffs and basalts) and volcanoclastics.

2.4 VEGETATION

The vegetation on the hills and surrounding slopes is characterised by tall open sheoaks, Mulga (*Acacia aneura*) low woodlands with a mosaic of eucalyptus woodlands and acacia thickets. No Environment Protection and Biodiversity Act (EPBC Act) listed plant species or Threatened Ecological Communities were listed in the mine area.

2.5 GEOMORPHOLOGY AND DRAINAGE

Surface water hydrology is influenced to a large extent by topography and geomorphology at the site. Four hydrological patterns can be identified as such:

- Flow in incised drainage paths,
- Meandering flow in gently sloped areas,
- Sheet flow, over flatters areas, and
- Claypan accumulation.

Light rainfall events over extended periods in the area will produce small volumes of runoff generally of low velocity that have a minor sediment load. Heavier intense rainfall events usually produce higher velocity flows resulting in the transport of sediment.

The incised drainage paths along the ridge areas indicate high flows will be apparent after heavy rainfall events where erosion will occur due to high velocity flows. A variety or a mix of sediment load would occur ranging from cobble fragments to clay size particles with the larger sediment particles only travelling a short distance. Meandering flow occurs at the base of the ridges where the flow changes from defined drainage paths to a less intense flow regime that spreads out over the sloped area. The sediment load changes to where only the finer fraction is being transported and coarser sediments are deposited forming an alluvial fan due to the decrease in flow velocity. The flat areas spreading out from the ridges provided evidence of sheet flow with less defined drainage paths. The low profile drainage paths would cope with low flows but under high rainfall events some sheet flow would be apparent. In these areas finer materials would settle out as flow velocities decrease after a rainfall event.

A significant feature of the drainage within the project area is that all the catchments upstream of the Karara pit and processing plant are internally draining. Figure 2.1 shows the boundaries of these internally draining catchments, clay pan areas and flow paths.

The hydrological assessment (described in Section 5) indicates that when sufficient runoff occurs, there will be temporary water accumulation in the clay pan areas. When runoff is sufficient to fill the clay pan areas, floodwater will spill south west towards the Karara Ridge across a low divide and then to the south west past Karara Ridge in a restricted valley profile before turning due south in a broad valley towards Mongers Lake, located approximately 30 km to the south. It appears that a storm approaching the probable maximum flood would be required to cause these basins to spill south into the Karara minesite catchment. Further work is required to verify the ARI of the event that will cause this to occur but as is discussed in Section 5 of this report this event is certainly greater than the 100 year ARI, 72 hour storm.

The geomorphology of the major drainage system comprises broad drainage valleys having no extensive incised drainage paths. Areas of preferred flow are evident in some areas where stands of eucalyptus are present towards the southern end of Karara Ridge.

2.6 LAND USE

Land use in the Yarra Yarra Catchment Basin is dominated by cattle grazing on pastoral leases with some cereal production and vacant crown land. The arable area in the Basin is approximately 100,000 ha or about 4.2% of the State’s farming land.

Several mineral and mining leases exist with the Basin. Mineral exploration activities are mainly for magnetite, haematite and possibly gold deposits.

Some areas within the Basin are designated nature reserves. These include Bowgada Nature Reserve, located approximately 40 km west of the minesite adjacent to Weelhamby Lake, and Yarra Yarra Nature Reserve at Three Springs.

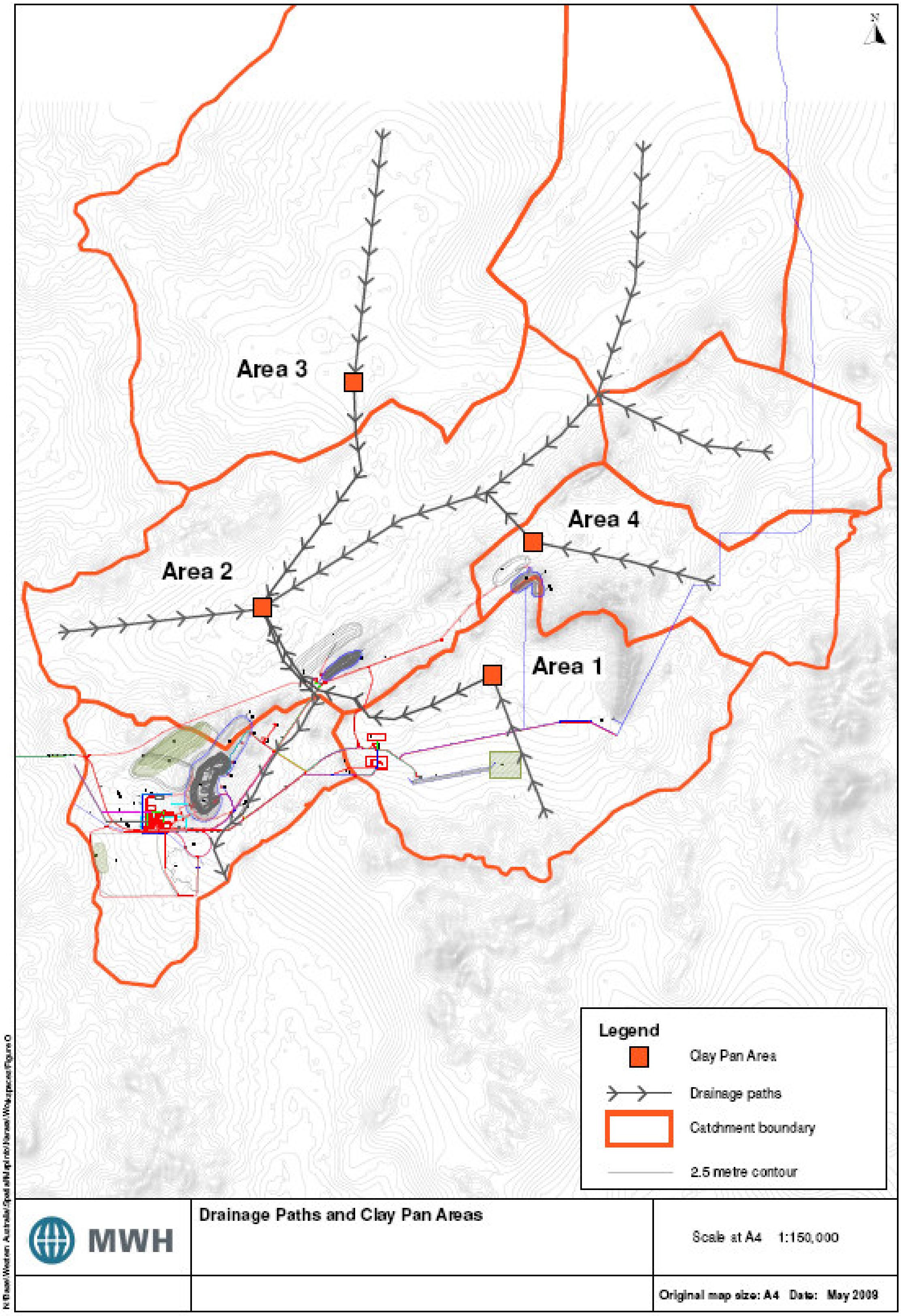


Figure 2.1: Catchments and Drainage Paths

3. REGIONAL CLIMATE

Yarra Yarra Catchment Basin is subject to an arid climate with hot summers and cold winters. Temperature variations in the region can be large, with the average daily maximum temperatures rising to 37 degrees in summer and dropping to a minimum of 6 degrees in winter.

Continuous meteorological data are available from Morawa Station (Bureau of Meteorological Station No. 008093) from 1925 to 2005. The station is located approximately 85 km west of the minesite area. Daily data are also available from Karara Station (Bureau of Meteorological Station No. 010195) between 1991 and 2006. The station is in close proximity to the project area; approximately 9 km south west of the minesite. A summary of temperature averages at Morawa Station is provided in Table 3.1

Table 3.1: Summary of Morawa Station temperature statistics (1925 – 2005)

Mean Daily Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Max (^{0}C)	36.7	36.2	33.1	28.2	22.9	19.3	18.2	19.5	23.0	26.7	31.0	34.5	27.4
Min (^{0}C)	19.1	19.5	17.5	13.8	9.9	7.6	6.2	6.4	7.8	10.3	13.8	16.7	12.4

Pan evaporation is almost an order of magnitude greater than average rainfall, and exceeds average rainfall in every month of the year. Rainfall will generally be less and evaporation greater at Karara than at Morawa, as Bureau of Meteorology maps of climatic averages show that rainfall decreases to the east and evaporation increases to the north-east.

3.1 RAINFALL

Average annual rainfall in the region varies from 300 – 400 mm. Rain is to be expected in the winter months, mainly from May to August, with June being the wettest month of the year. Most of the winter rain results from the passage of cold fronts. These fronts may associate with cloud bands from the northwest, which may enhance the totals. Table 3.2 below lists information on operating rainfall gauging stations in the Yarra Yarra Catchment Basin. Figure 3.1 shows the locations of these gauges. The variation in mean monthly rainfall for Morawa and Karara rainfall stations are shown in Figure 3.2 and Figure 3.3, respectively. Mean annual rainfall for the Karara station is 313mm and 327mm for the Morawa gauge.

3.1.1 CYCLONES

Cyclonic activities are uncommon in the region. Tropical cyclones originated from the northwest coast of WA generally weaken to rain bearing depressions as they move inland. One notable cyclone that affected the mainland Mid-West Region was Cyclone Herbie in 1988. Herbie was developed to the northwest of Cocos Island on 18 May. It crossed the Australian coast at Shark Bay on 20 May and continued its southeastward track through inland parts of WA and weakened. Herbie underwent a change in structure as it accelerated into the mid-latitudes, which caused the regions of dense cloud and heavy rainfall to displace over areas south of the track. Morawa meteorological station, located 85 km west of the minesite area, recorded rainfall totals over 100 mm. The track of Cyclone Herbie in May 1988 is illustrated in Figure 3.4.

Table 3.2: Operating rainfall gauging stations in the Yarra Yarra Catchment Basin

Station No.	Operating Agency	Station Name	Date Opened	Obs Interval
007000	BOM (AUS)	Barnong	29/04/1902	Daily
007006	BOM (AUS)	Boogardie	01/01/1910	Daily
008013	BOM (AUS)	Bowgada	28/02/1904	Daily
007010	BOM (AUS)	Bunnawarra	01/01/1912	Daily
008018	BOM (AUS)	Buntine East	29/06/1929	Daily
010018	BOM (AUS)	Burakin	30/03/1926	Daily
007011	BOM (AUS)	Burnerbinmah	29/04/1902	Daily
008157	BOM (AUS)	Canna	29/09/1915	Daily
008025	BOM (AUS)	Carnamah	30/05/1887	Daily
008025	BOM (AUS)	Carnamah	30/05/1887	Synop
007157	BOM (AUS)	Dalgaranga	01/01/1913	Daily
007024	BOM (AUS)	Edah	01/01/1937	Daily
008047	BOM (AUS)	Fairfield	30/10/1919	Daily
008233	BOM (AUS)	Five Gums	01/01/1945	Daily
007027	BOM (AUS)	Gabyon	01/01/1888	Daily
008016	BOM (AUS)	Glenferrie	30/08/1913	Daily
010026	BOM (AUS)	Goodlands	30/08/1951	Daily
010070	BOM (AUS)	Kalannie	30/07/1928	Daily
010195	BOM (AUS)	Karara	29/04/1991	Daily
007037	BOM (AUS)	Kirkalocka	30/07/1910	Daily
008078	BOM (AUS)	Mallee Vale	01/01/1935	Daily
007129	BOM (AUS)	Melangata	29/04/1910	Daily
008081	BOM (AUS)	Mellenbye	30/08/1903	Daily
508042	DOW (WA)	Morawa Pluvio / Evap Pan	30/07/2004	Continuous
007057	BOM (AUS)	Mount Magnet	30/10/1894	Daily
007057	BOM (AUS)	Mount Magnet	30/10/1894	Synop
007063	BOM (AUS)	Muralgarra	30/05/1904	Daily
007135	BOM (AUS)	Murrum Stn	29/06/1900	Daily
007065	BOM (AUS)	Nalbarra	01/01/1906	Daily
007068	BOM (AUS)	Ninghan Stn	30/05/1905	Daily
008231	BOM (AUS)	Oaklands	29/04/1967	Daily
007168	BOM (AUS)	Oudabunna	29/11/1921	Daily
008106	BOM (AUS)	Perangery	30/07/1910	Daily
008107	BOM (AUS)	Perenjori	01/01/1918	Daily
007071	BOM (AUS)	Pindathuna	30/07/1905	Daily
008021	BOM (AUS)	Sunnydale	30/10/1956	Daily
010306	BOM (AUS)	Tascosa	30/03/1994	Daily
008121	BOM (AUS)	Three Springs	01/01/1907	Daily
007081	BOM (AUS)	Thundelarra	30/08/1906	Daily
008264	BOM (AUS)	Wanarra	30/05/1973	Daily
007146	BOM (AUS)	Wogarno	01/01/1911	Daily
007090	BOM (AUS)	Wydgee	30/07/1904	Daily
010141	BOM (AUS)	Xantippe	01/01/1925	Daily
007091	BOM (AUS)	Yalgoo	29/09/1896	Daily
007091	BOM (AUS)	Yalgoo	29/09/1896	Synop
007095	BOM (AUS)	Yoweragabbie	27/02/1898	Daily

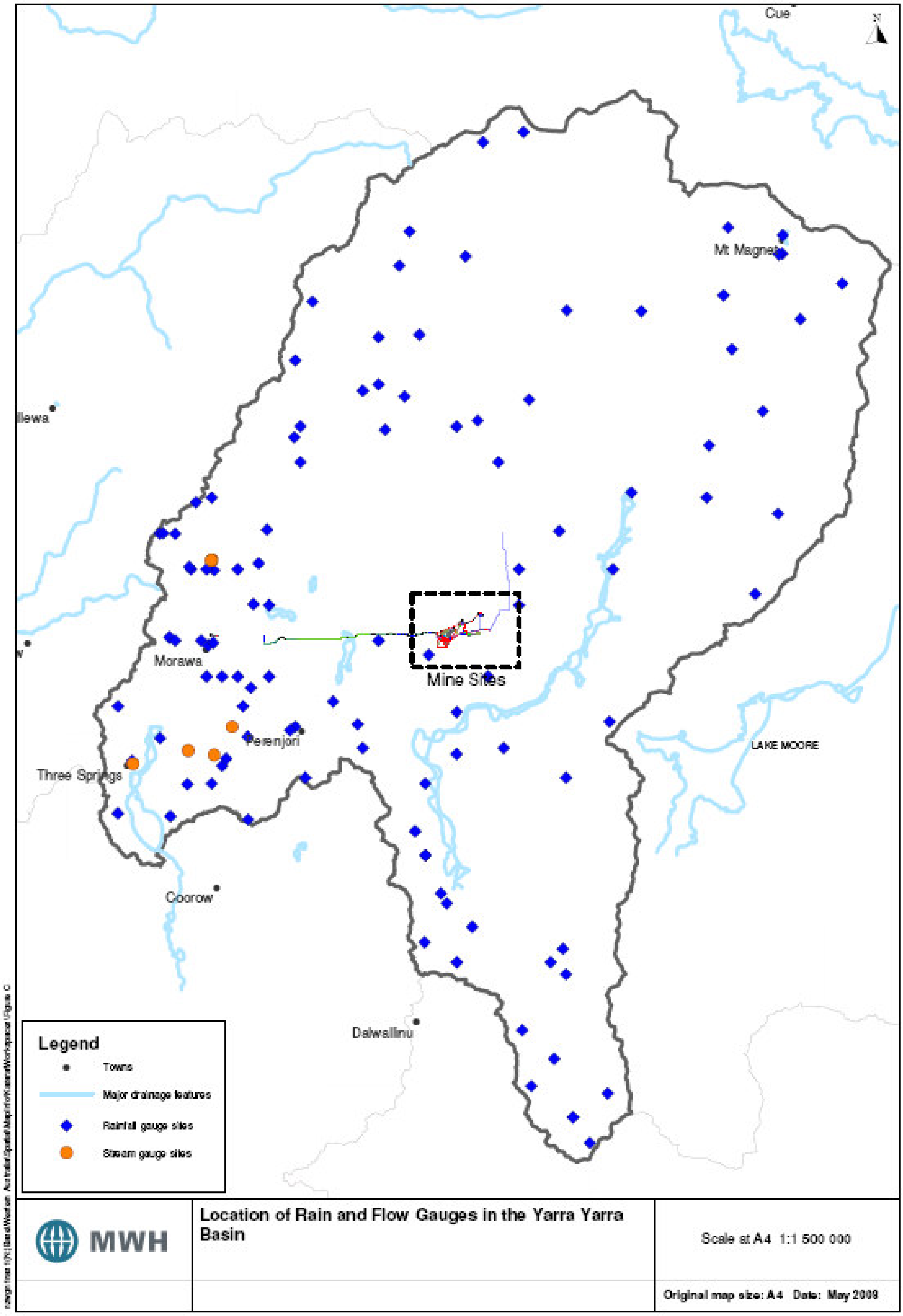


Figure 3.1: Location of Rain and Flow Gauges in the Yarra Yarra Basin

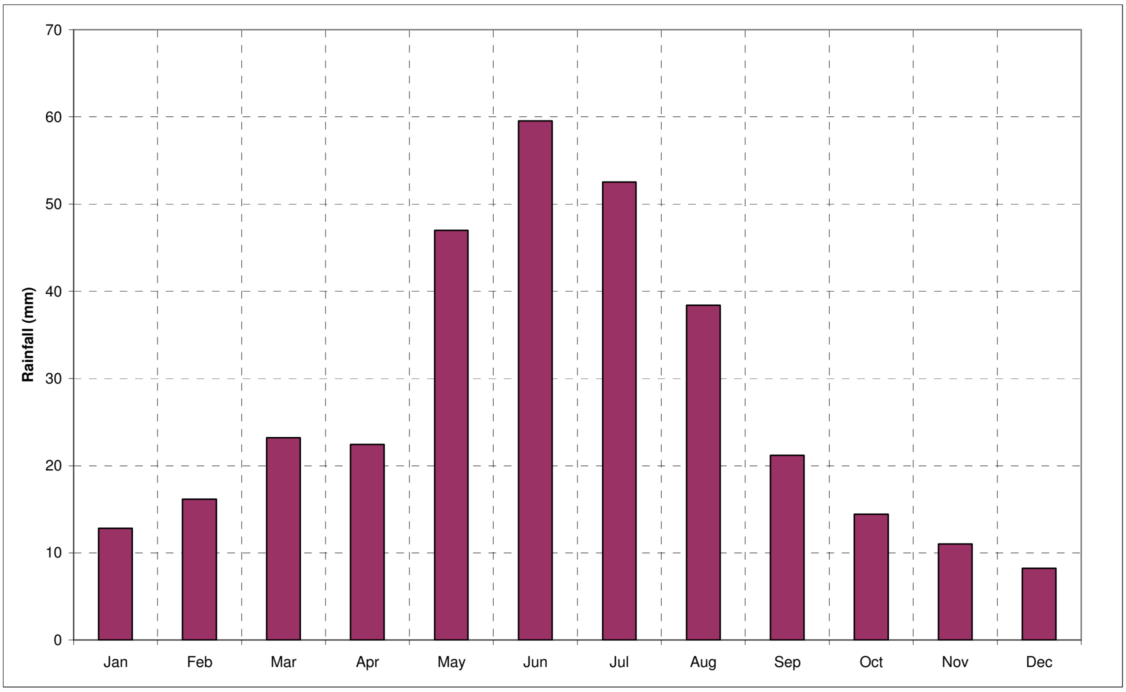


Figure 3.2: Average monthly rainfall (1925 – 2005), Morawa Station (008093)

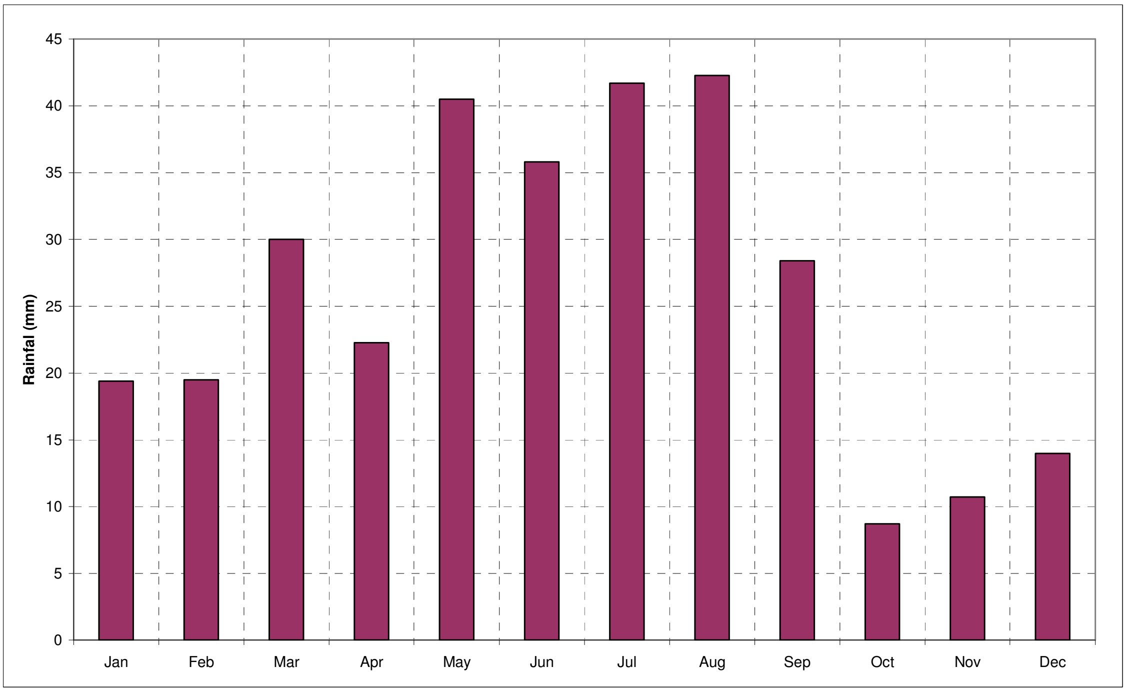


Figure 3.3: Average monthly rainfall (1991 – 2006), Karara Station (010195)

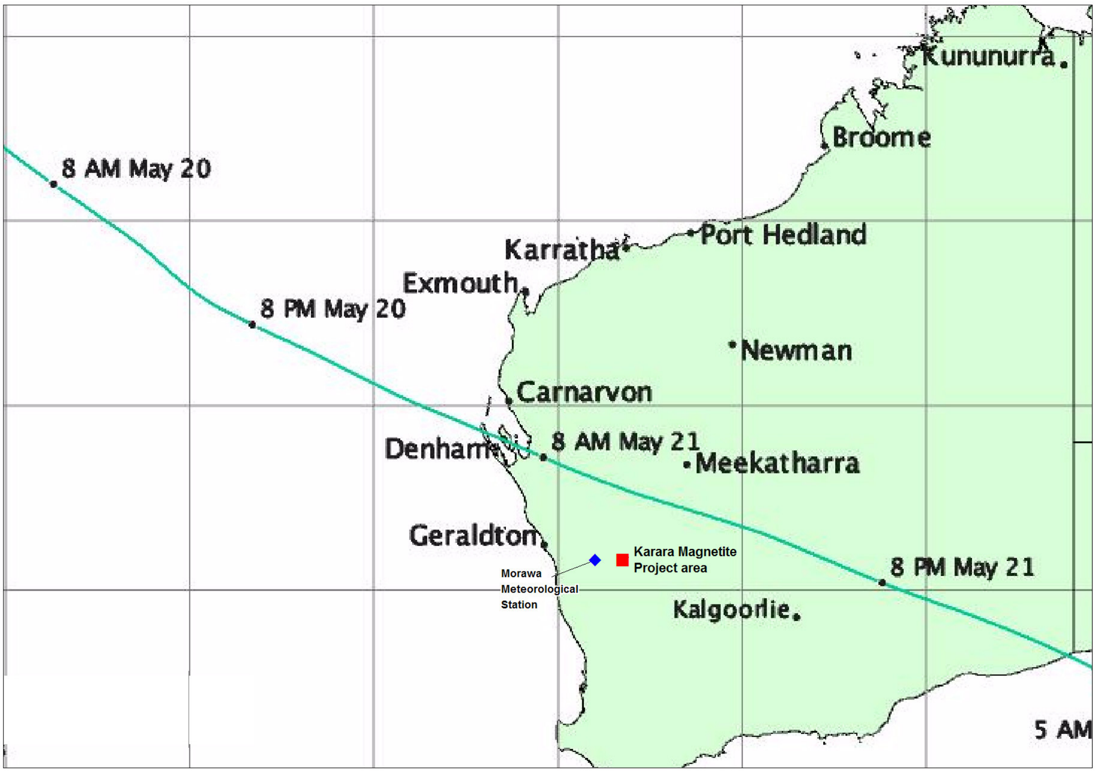


Figure 3.4: Track of Cyclone Herbie

3.2 STREAM FLOW

There are currently no operating stream flow gauging stations within the Yarra Yarra Catchment Basin. Previous operating flow gauges are located around Three Springs, approximately 100 km southwest of the Project area. Table 3.3 lists information on stream flow gauging stations in the Yarra Yarra Catchment Basin.

Moolanooka gauging station is located approximately 87 km southwest of the Project area and it is the closest gauging station in proximity to the minesite within the Basin. It was in operation in March 1971 and ceased in June 1999. Total annual discharges recorded at the gauging station, in conjunction with the total annual rainfall recorded at Moolanooka rainfall station are illustrated in Figure 3.5. The annual stream flow volumes in the region are minimal, with flow typically only in response to large rainfall events. The largest annual flow, 25180 ML, was recorded in 1999, despite 200 days of missing record.

Table 3.3: Stream flow gauging stations in the Yarra Yarra Catchment Basin

Station No.	Operating Agency	Station Name	River Name	Date Opened	Date Closed
618605	BOM (WA)	Morawa	Morawa	1/08/2004	14/10/2007
618601	DOW (WA)	Weirs Farm	Three Springs	27/04/1971	8/06/1998
618603	DOW (WA)	Moolanooka	Three Springs	30/03/1971	13/06/1999
618602	DOW (WA)	Minjin	Three Springs	30/03/1971	13/06/1999

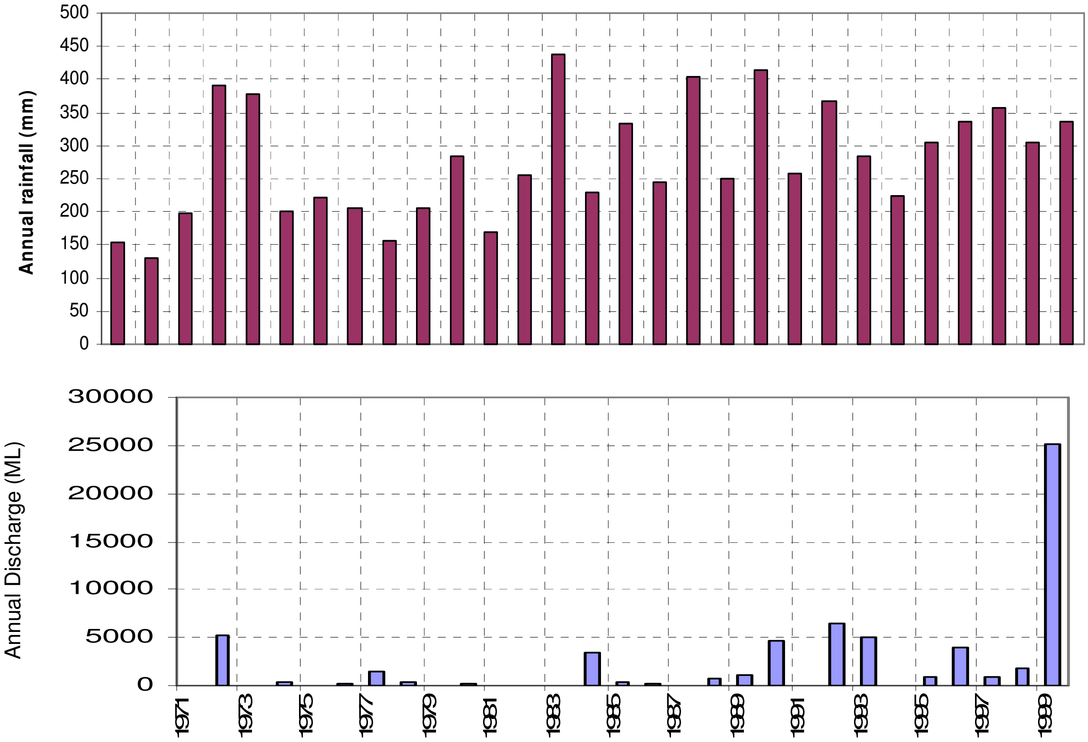


Figure 3.5: Annual rainfall and stream flow, Three Springs – Moolanooka (508004)

4. SUMMARY OF INFORMATION RECEIVED

4.1 GIS DATA

Extensive GIS data were obtained from the Department of Water and Geoscience Australia. Coverage of the Yarra Yarra Basin and adjacent catchments included information such as regional elevation, cartography, infrastructure, utilities and hydrography.

Also obtained from the Department of Water were:

- A Water Resources Information Catalogue including GIS layers of the location of all rainfall, flow, water level and water quality stations throughout the State.
- A Geographic Data Atlas providing detailed GIS data on catchment and sub-catchment boundaries and drainage alignments.

GIS data relating to mine infrastructure, detailed surface drainage channels and topographic contours, and aerial photographs were provided by Coffey Natural Systems, with additional contour information supplied by CAD Resources.

All GIS data were transferred to Mapinfo to determine catchment boundaries, to develop catchment rainfall runoff models of the proposed mine areas, design mine drainage managment, and to assist in the assessment of the existing hydrology of the surrounding area.

4.2 HYDROLOGICAL DATA

Hydrological metadata for rain and flow gauges within the region were obtained from the Bureau of Meteorology and Department of Water. Further details are provided in Section 3.

4.3 HYDROLOGY REPORTS

Karara Magnetite Surface Water Impact Assessment – Coffey Mining 2007.

5. HYDROLOGY

Estimates of peak flood flows and volumes have been derived for key locations around the minesite, haul road and infrastructure. As there are no flow records available for any of the watercourses that drain across the minesite a 'design event approach' has been adopted and rainfall-runoff models developed to generate flood hydrographs for these catchments.

The models have also been used to model flood runoff into detention storage areas.

This section describes the formulation of design rainfall events and use of a rainfall-runoff routing model to convert the design rainfall event into the corresponding design streamflow event. The design rainfall event is specified by rainfall duration, average rainfall intensity of a particular ARI and rainfall temporal pattern.

The design rainfall totals and intensities were determined using the techniques recommended in Australian Rainfall and Runoff, (2003) (ARR). Rainfall-runoff modelling was carried out using Hydstra Time Studio modelling software to establish peak flow estimates. The resulting peak flows were compared to those calculated using regional and rational methods. The rainfall-runoff model was then used to access the extent of flooding adjacent to mine infrastructure and downstream of the project.

5.1 DESIGN RAINFALL

In the absence of a long-term rainfall record at the mine site, design rainfall totals and intensities were determined using the techniques recommended in ARR.

A design rainfall intensity chart was issued by the Hydrometeorological Advisory Service of the Bureau of Meteorology (BOM) for the location 29.150 S, 116.825 E at Karara (issued 28 February 2008).

5.1.1 DESIGN RAINFALL TOTALS

The design rainfall intensities (mm/hour) and depths (mm) for a range of events and durations for Karara are tabulated in Table 5.1 and Table 5.2 respectively. The design rainfall depths are also depicted in Figure 5.1.

Table 5.1: Karara Design Rainfall Intensities (mm/hr)

Duration (hours)	10 Year	20 Year	30 Year	50 Year	100 Year
1	25.5	30.9	34.0	38.7	45.2
2	15.9	19.3	21.5	24.2	28.2
3	12.0	14.5	16.0	18.2	21.3
6	7.4	9.0	10.0	11.2	13.2
10	5.2	6.3	7.0	7.9	9.3
12	4.6	5.6	6.2	7.0	8.2
18	3.5	4.2	4.7	5.3	6.3
24	2.8	3.5	3.8	4.4	5.2
48	1.7	2.1	2.4	2.7	3.2
72	1.2	1.5	1.7	2.0	2.4

Table 5.2: Karara Design Rainfall Totals (mm)

Duration (hours)	10 Year	20 Year	30 Year	50 Year	100 Year
1	26	31	34	39	45
2	32	39	43	48	56
3	36	44	48	55	64
6	44	54	60	67	79
10	52	63	70	79	93
12	55	67	74	84	99
18	62	76	84	96	113
24	68	83	92	105	124
48	82	102	114	130	155
72	89	111	124	143	170

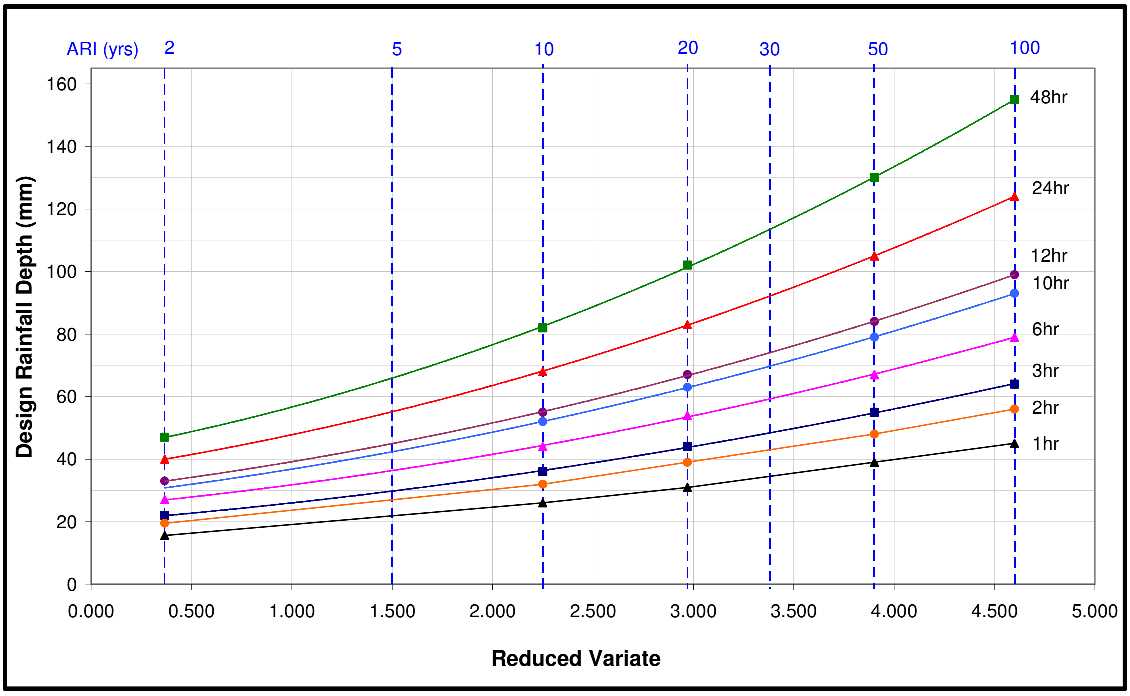


Figure 5.1: Karara Depth-Duration-Frequency Curves

5.1.2 TEMPORAL DISTRIBUTION

Rainfall intensity varies throughout a storm in accordance with the temporal pattern of the storm.

Temporal patterns for the design rainfall totals were determined in accordance with the methods described in ARR (ARR Vol 2, Book II, Section 2). Different temporal patterns are recommended for a number of rainfall durations, with methodology suggested to determine patterns for intermediate durations. Patterns also vary in relation to the design frequency (ARI), with different patterns for events of recurrence interval less than or equal to 30-years and greater than 30-years.

The temporal rainfall patterns as prescribed by ARR for the region have been derived by analysing recorded rainfall events and therefore contain typical variations in intensity. The temporal rainfall pattern is vital to the estimation of a flood with the same frequency as the design rainfall.

The temporal patterns for the 12-hour duration rainfall event for 5, 20 and 100-year ARI are shown in Figure 5.2.

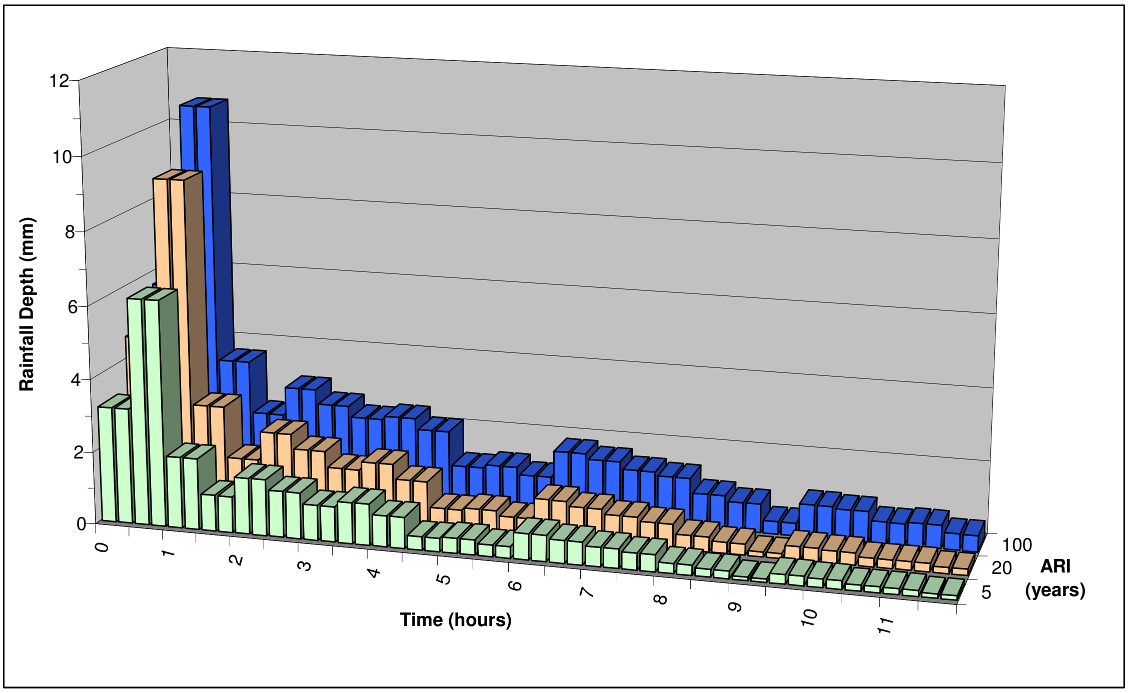


Figure 5.2: Karara Rainfall Temporal Pattern – 5, 20 & 100-Year ARI, 12 Hour Duration

The appropriate temporal patterns were assigned to design rainfall totals and the resulting data used as an input to the rainfall-runoff modelling process (Section 5.2)

5.1.3 CRITICAL DURATION

The critical duration of a rainfall event is that which produces the highest peak flow. This duration will vary based on the size, layout and geology of the catchment. Therefore, a number of rainfall events with varying durations were derived to input to the rainfall-runoff models. The range of event durations covered was one hour to 72 hours.

5.2 FLOOD FLOWS

The estimation of flood flows for the Karara study catchments has been carried out using three methods:

- Rainfall-runoff modelling using the design rainfall
- Regional Flood Frequency Method
- Rational Method

Methodology and results for each of the methods are detailed below.

5.2.1 RAINFALL RUNOFF MODELLING

An initial loss-continuing loss rainfall-runoff model was developed in order to determine design event peak flows and hydrograph shapes at a number of key locations. The model was constructed using Hydstra/Hydrol Modelling software (Hydstra Pty Ltd, 2005). Hydstra Modelling is a commonly used hydrological modelling package that accommodates RORB model parameters that are recommended by ARR for Australia.

The rainfall-runoff modelling process was divided into two parts. The first part being to model the four storage basin areas to the north and north-east of the Karara site and determine whether the design flood events would be contained within the basins, or if they would fill the basins and pass downstream and through the Karara mine site.

The second part of the modelling was to model flood flows from the catchment areas immediately above and surrounding the Karara mine site area. Depending on the outcome of the first part of the modelling exercise this would either be a straight rainfall-runoff model of the immediate catchment areas or would incorporate runoff from the large basin areas upstream if they overflowed during the design rainfall events. The layout of the rainfall-runoff models for both parts is given in Figure 4-3.

The rainfall-runoff modelling process requires estimation of the initial losses and continuing losses as well as channel lag and non-linearity parameters. Values for the initial loss and continuing losses expected in the catchments were determined from ARR for the Wheatbelt Region of Western Australia. The initial loss values vary with rainfall ARI, and differ sightly between the larger catchment areas of the storage basins and the smaller catchment areas around the Karara mine site. The adopted values are shown in Table 5.3.

Table 5.3: Rainfall-Runoff Model Parameters

Parameter	Storage Basins	Karara Mine Site	ARR Reference
Initial Loss (mm)	39 (100yr) 39 (50yr) 38 (30yr) 37 (20yr) 42 (10yr) 30 (5yr)	41 (100yr) 41 (50yr) 40 (30yr) 39 (20yr) 44 (10yr) 41 (5yr)	Extrapolated from values in Table 3.3 (Wheatbelt), ARR Vol.1, Book II, Section 3.
Continuing Loss (mm/hr)	3	3	From Table 3.3 (Wheatbelt), ARR Vol.1, Book II, Section 3.
Channel Lag Parameter (α)	0.67	0.67	Based on RORB parameters calculated using Equation (3.29), ARR Vol.1, Book V, Section 3.
Non-linearity Parameter (n)	0.8	0.8	From 3.4.4 part 1 (d) ii, ARR Vol.1, Book V, Section 3.

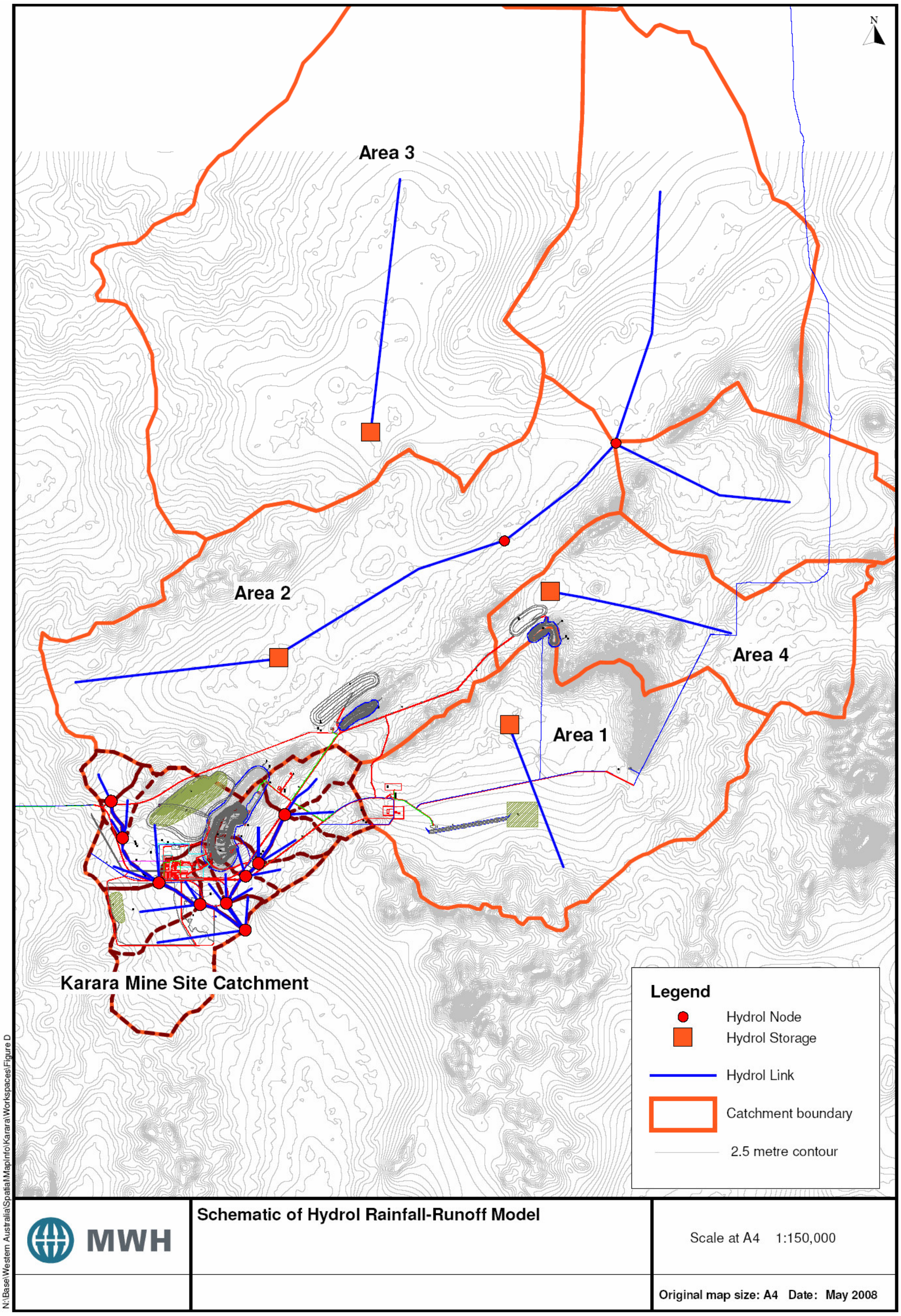


Figure 5.3: Schematic of Rainfall-Runoff Model

5.2.1.1 STORAGE BASIN MODELLING

Figure 5.4 shows the catchments draining to the four basin areas identified to the north and north-east of the Karara site. The catchments areas are 70 km^2, 230 km^2, 174 km^2 and 43 km^2 for Areas 1, 2, 3 and 4 respectively.

Area 2 consists of a vegetated claypan to the north of Karara Ridge. Based on contour information (1 m interval) the base of the claypan is 10.5 m below the outflow point (Table 5.4). A large storage volume of almost 178 million m^3 is available in Area 2 before any outflow would occur.

The drainage paths indicate that Areas 1, 3 and 4 will all drain into Area 2 if sufficient runoff occurs to exceed their storage capacity (as detailed in Table 5.4). If the storage capacity of Area 2 is reached the overflow will drain through a point between Karara Ridge and Blue Hills Ridge, before turning south-west and joining the flow path past the Karara pit.

Table 5.4 details the lowest level, the spill/outflow level, and the storage volume available in each of the four basin areas.

Table 5.4: Karara Basin Storage Areas

		RL (m)	Volume (m^3)
Area 1	Lowest Levels	340.5	0
	Spill Point	347.0	11,060,885
Area 2	Lowest Levels	332.5	0
	Spill Point	343.0	177,948,650
Area 3	Lowest Levels	342.5	0
	Spill Point	347.5	4,994,058
Area 4	Lowest Levels	356.5	0
	Spill Point	362.0	8,886,775

The four basin areas have been modelled as storage nodes within the rainfall-runoff model. No storage losses (such as evaporation or leakage) have been accounted for and therefore the derived peak water levels and volumes are considered conservative.

No mechanism for outflow was set in the initial storage modelling. This enabled a peak water level to be obtained for each basin area. If the peak water levels were found to exceed the spill levels (Table 5.4) then the model would be adjusted to incorporate spill channels as per the topography and appropriate outflow equations.

No channel routing mechanisms were included in the storage models. The initial scope of modelling the storage areas was to simply determine the amount of runoff for each catchment and the volume/level of storage reached in each basin. Channel routing is not required for this.

Model runs for design events from 5-year to 100-year ARI were completed. Rainfall event durations ranging from one hour to 72 hours were used as the input.

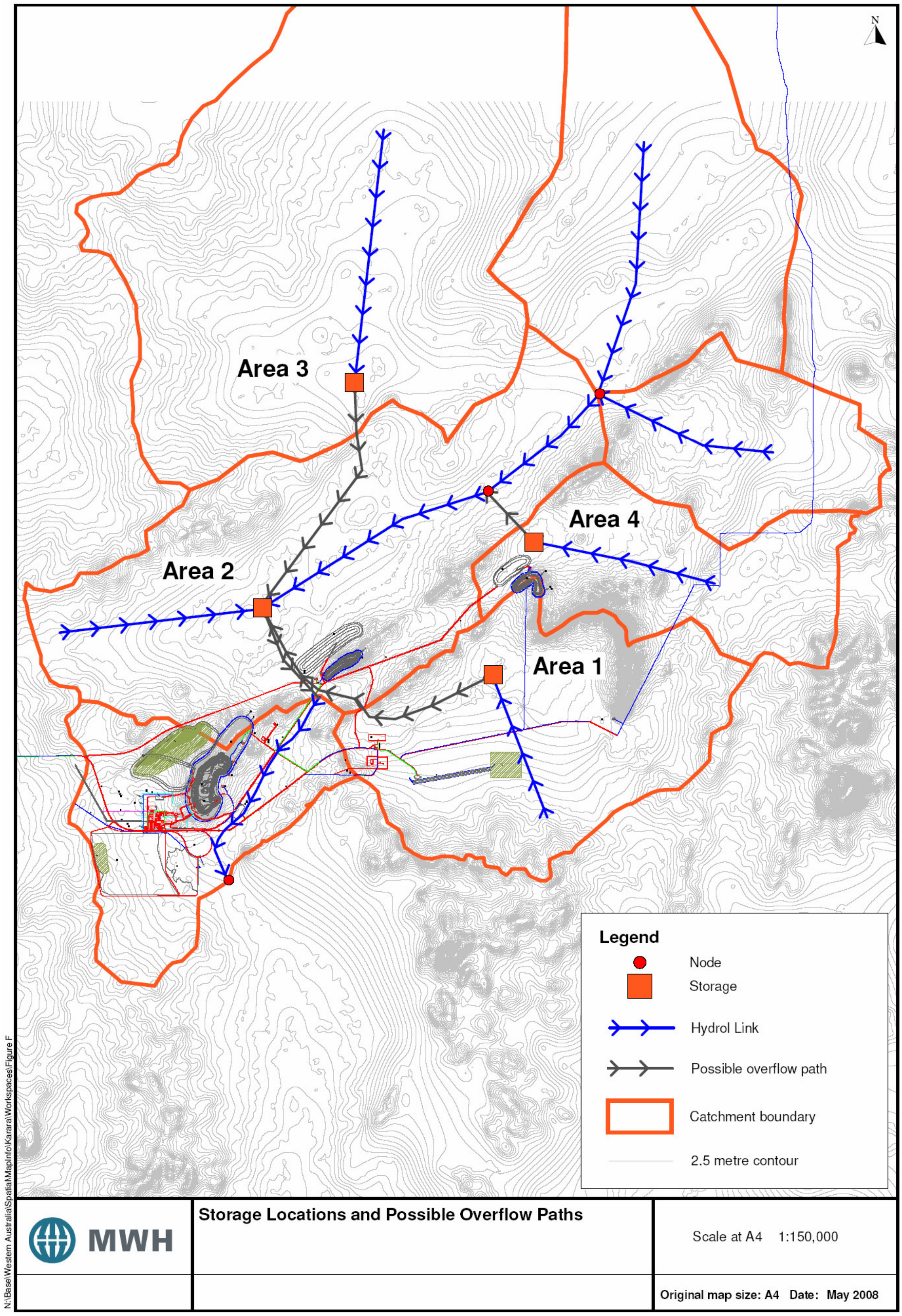


Figure 5.4: Storage Locations and Possible Overflow Paths

The model results show that no event causes any of the four basin areas to be inundated in excess of their respective spill levels. Table 5.5 details the peak water levels reached for the longer duration events (12 to 72 hours). The maximum water level reached at the critical duration for each ARI is highlighted by bold blue text for each storage area.

The critical duration events ranged between 18 and 24 hours for the 5 to 100-year ARI design events.

Table 5.5: Basin Peak Modelled Water Levels (RL m)

	Duration (hours)	**ARI (years)**				
		5	**10**	**20**	**50**	**100**
Area 1 *(Spill at 347 m RL)*	**12**	*NF*	341.98	343.22	343.82	344.31
	18	*NF*	**342.37**	343.28	**343.89**	344.37
	24	**341.82**	342.36	**343.32**	343.85	**344.39**
	48	*NF*	*NF*	343.16	343.44	344.22
	72	*NF*	341.87	343.06	343.30	344.02
Area 2 *(Spill at 343 m RL)*	**12**	*NF*	332.79	333.85	334.32	334.85
	18	**332.67**	333.01	333.87	334.32	334.92
	24	332.54	**333.08**	**333.91**	**334.33**	**334.94**
	48	*NF*	332.54	333.81	334.04	334.77
	72	*NF*	332.75	333.61	333.90	334.53
Area 3 *(Spill at 347.5 m RL)*	**12**	*NF*	342.70	345.84	346.73	347.44
	18	342.62	344.54	345.86	346.73	347.49
	24	**342.64**	**344.72**	**345.93**	**346.75**	**347.51**
	48	*NF*	*NF*	345.67	346.16	347.35
	72	*NF*	342.99	345.49	345.92	347.06
Area 4 *(Spill at 362 m RL)*	**12**	*NF*	356.53	357.42	357.89	358.33
	18	356.52	**356.85**	357.43	357.89	358.39
	24	**356.52**	356.84	**357.47**	**357.90**	**358.41**
	48	*NF*	*NF*	357.33	357.59	358.25
	72	*NF*	356.52	355.75	357.46	358.05

NF = No Flow

Note that for a number of the 5-year and 10-year events no runoff was produced due to the modelled initial and continuing losses (derived from ARR) exceeding the design rainfall intensity.

The peak water levels reached in each storage area occurred with the 24 hour duration 100-year ARI event. The spatial extents of these peak storages are shown in Figure 5.5. The modelled peak water level for Area 3 exactly matched the spill level of 347.5 m RL. Peak levels for Area 1, Area 2 and Area 4 were 2.6 m, 8.1 m and 3.6 m below their respective spill levels.

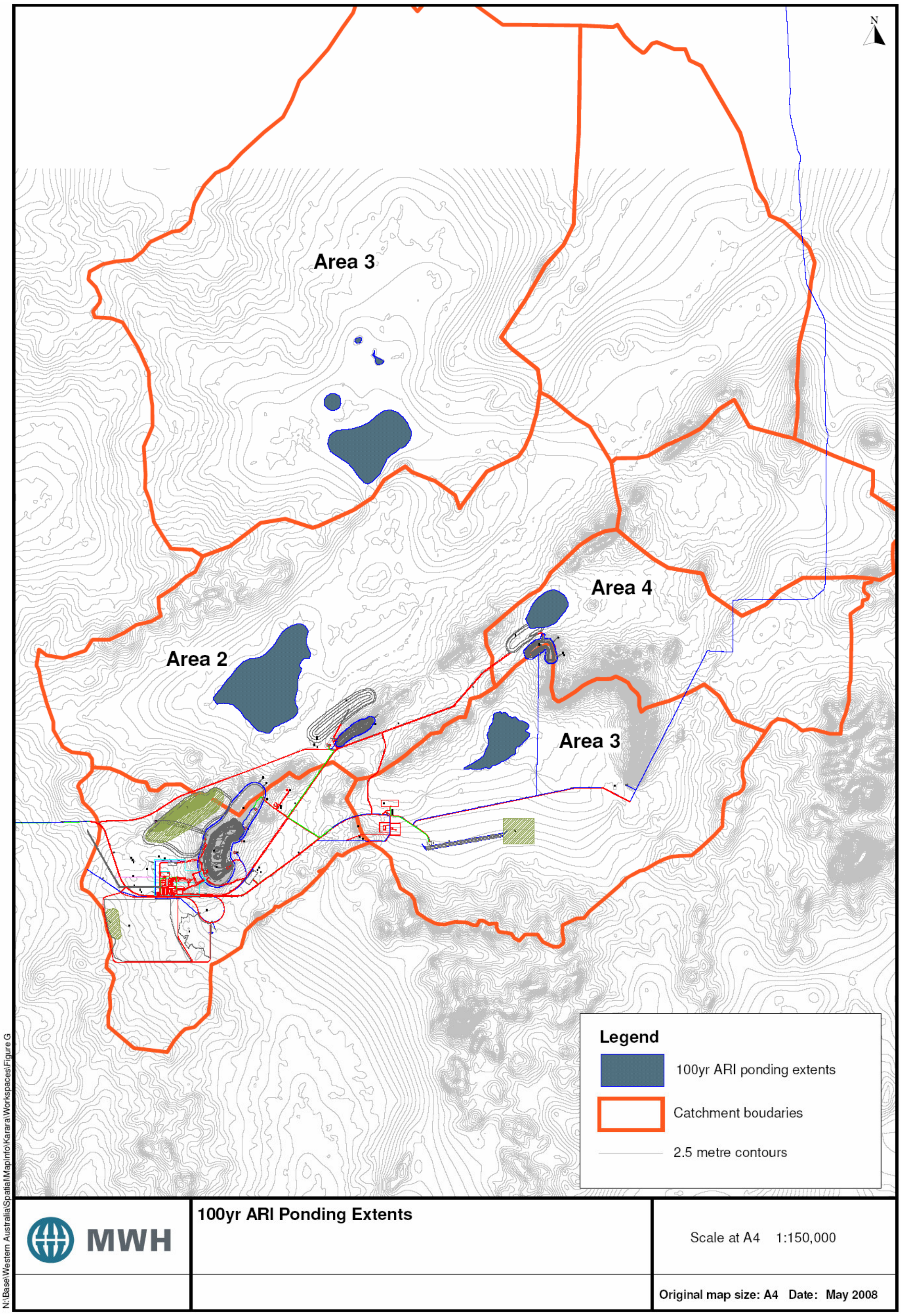


Figure 5.5: 100yr ARI Ponding Extents

As previously detailed, storage losses such as evaporation and leakage have not been accounted for in the modelling of the storage basin areas. As such the peak level attained for Area 3 can be considered to be slightly conservative and the actual level reached may be lower than this.

Even if stored flood runoff from Area 3 did overtop and spill it would subsequently drain into Area 2 (Figure 5.4) which has the largest capacity of available storage. For example, in the 100-year ARI 24-hour duration event there is still 8 m (170.5 million m^3) of storage available in Area 2.

The storage modelling of the four basin areas concludes that, for the design rainfall events, no runoff from the large upper catchment areas will flow beyond Area 2 and therefore will not impact on flood flows past/at the Karara mine site. All runoff up to the 100-year ARI event will be held in storage to eventually evaporate or seep through the subsurface.

5.2.1.2 KARARA MINE SITE MODELLING

A rainfall-runoff model was constructed for the area surrounding the Karara mine site (below the four storage basin areas) to determine design peak flood flows and hydrograph shapes at nine key nodes on the main drainage channels, as shown in Figure 5.6. The flood hydrograph outputs generated by the rainfall-runoff modelling are used in the subsequent 1D hydraulic modelling of flow channels and flood paths to determine impacts on mine infrastructure.

The total catchment area around the Karara mine site of 44.7 km^2 was divided into 17 sub-catchments (areas ranging between 0.4 and 9.6 km^2). Figure 5.6 details the rainfall-runoff configuration, catchment areas and the output nodes (2 to 6 and A to D) for flood flows and hydrographs.

The initial and continuing losses were set in the Karara mine site model as detailed in Table 5.3. Non-linear channel routing was used to route the runoff down the drainage paths to the catchment outlet.

Model runs for design events from 5-year to 100-year ARI were completed. Rainfall event durations ranging from one hour to 72 hours were used as the input. The critical duration events (Section 5.1.3) for each output node was determined through the modelling process and ranged from 6 hours for the 100-year ARI to 24 hours for the 5-year ARI.

Table 5.6 details the peak design flood flows at each output node for the given critical duration.

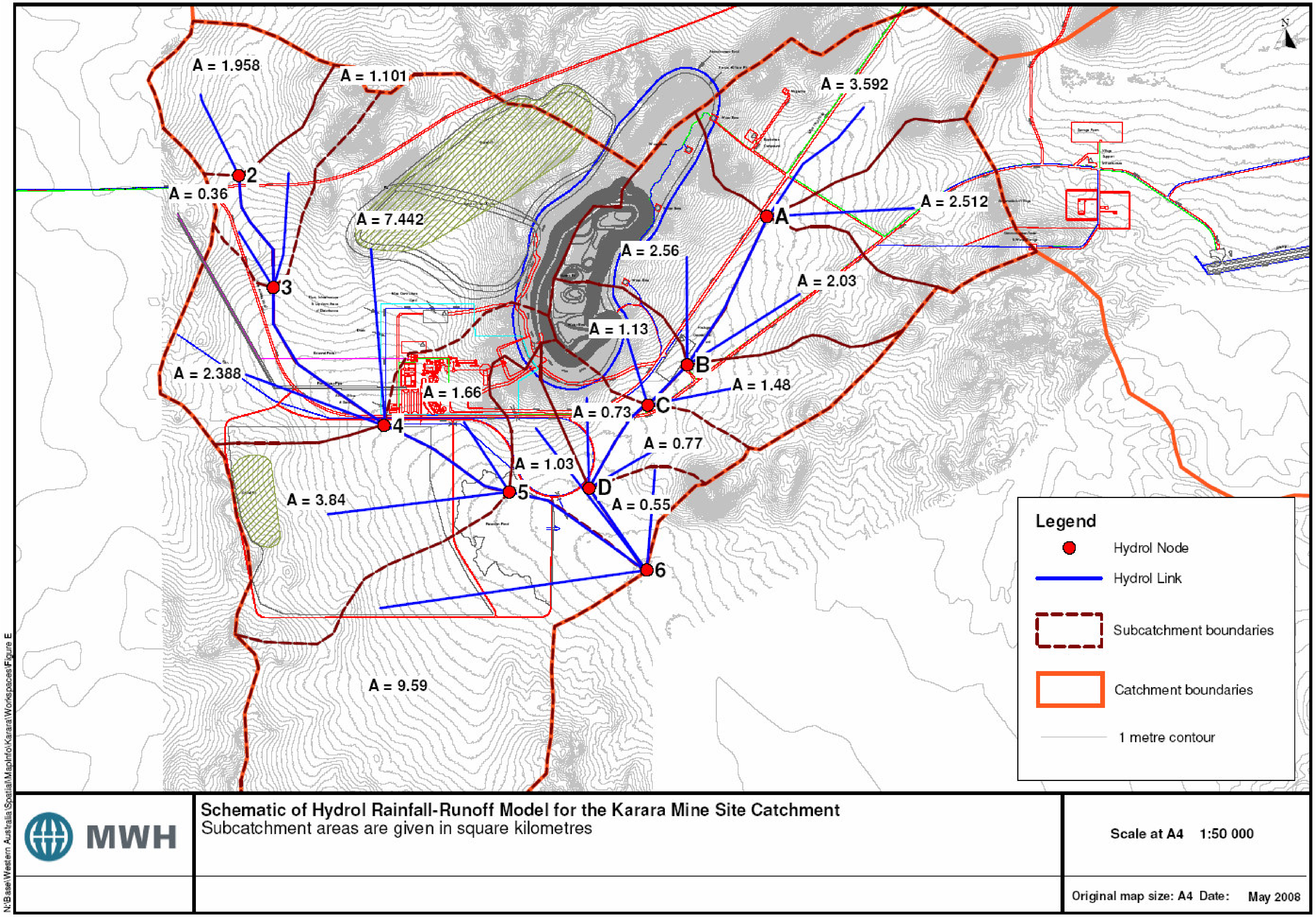


Figure 5.6: Schematic of Hydrol Rainfall-Runoff Model - Karara Mine Catchments

Table 5.6: Karara Mine Site Modelled Peak Flows (m^3/s)

Output Node	ARI (years)					
	5	10	20	30	50	100
2	0.02	0.4	1.5	2.2	2.9	6.1
3	0.01	0.4	2.3	3.2	4.0	7.4
4	0.05	1.4	7.9	11.0	13.9	24.3
5	0.04	1.6	9.9	14.4	18.4	31.2
A	0.04	0.9	4.4	5.7	7.2	14.6
B	0.04	1.1	6.5	9.1	11.5	20.0
C	0.04	1.4	8.0	11.2	14.1	24.6
D	0.03	1.3	8.1	11.8	15.0	26.0
6	0.07	3.0	20.8	31.7	41.1	72.5
Critical Duration (hrs)	*24*	*18*	*12*	*12*	*6*	*6*

The estimated peak flood for a 100-year ARI event is 72.5 m^3/s at Node 6.

The 100-year design hydrographs (6 hour critical duration) for the Karara mine site catchments are plotted in Figure 5.7. The peak flow at the model outlet (Node 6) is reached after 4 hours.

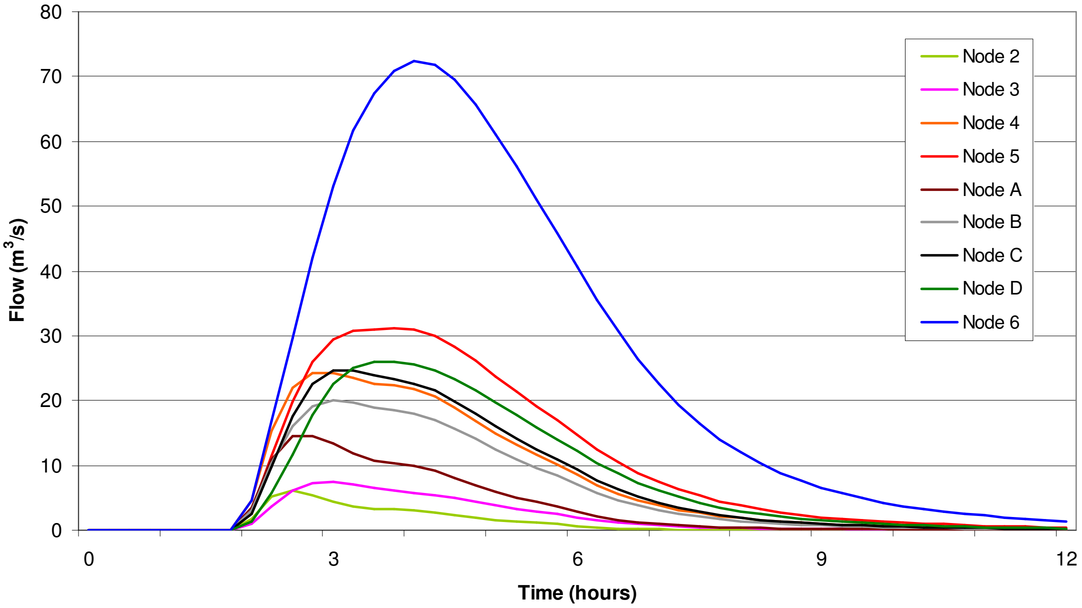


Figure 5.7: Karara Mine Catchment Design Flood Hydrographs (m^3/s)

5.2.2 RAINFALL RUNOFF MODEL LIMITATIONS

Certain assumptions have been made in the rainfall-runoff modelling process that can introduce uncertainties.

Australian Rainfall and Runoff (2003) places the Karara mine site and catchment areas in the Wheatbelt Region of Western Australia. Accordingly, rainfall temporal patterns and model parameters (such as initial loss, continuing loss and non-linear storage) have been adopted from the recommended ARR methodologies for the Wheatbelt region.

The modelling of the basin storage areas takes no account of storage losses such as evaporation, evapotranspiration or seepage.

All storage level/volume relationships for the storage basin areas have been determined from the contour information provided. This is in the form of 1 m contours for some of the site and 2.5 m contours for the remainder.

The design rainfall totals are uniformly distributed (spatially lumped) across the entire catchment area. In reality such constant rainfall over such a large area is unlikely to occur.

The main limitation of the rainfall-runoff modelling used in this study is the lack of recorded data to enable the models to be calibrated. There is no recorded flow data available. The model outputs have been compared to two other flood estimation methods (rational method and regional method) to ensure the results are not significantly different.

Using Australian Rainfall and Runoff (2003) recommended model parameters, rainfall temporal distribution patterns and comparison to the other flood estimation methods provides confidence in the modelled design flood outputs.

5.2.3 REGIONAL METHOD PEAK FLOW ESTIMATES

Peak flows have also been estimated using the Index Flood (Regional) Method applicable to the Wheatbelt Region of Western Australia (ARR Vol 1, Book IV, Section 1.4.7).

The parameters used in the Regional methodology for each of the catchments are:

- Catchment area (km^2)
- Average annual rainfall of 334 mm (as recorded at Morawa, Station 008093)
- Frequency factor (Qy/Q_5):

ARI (years)	2	5	10	20	50	100
	0.48	1.00	1.84	3.23	6.10	12.00

The resulting Regional Method estimated peak flows for the Karara mine site nodes for the 2-year to 100-year ARI are detailed in Table 5.7.

Table 5.7: Karara Mine Site Regional (Index) Method Peak Flows (m^3/s)

Output Node	ARI (years)					
	5	10	20	30	50	100
2	0.42	0.9	1.6	2.8	5.4	10.6
3	0.56	1.2	2.2	3.8	7.2	14.1
4	1.14	2.4	4.4	7.7	14.5	28.5
5	1.37	2.8	5.2	9.2	17.4	34.2
A	0.76	1.6	2.9	5.1	9.7	19.1
B	1.02	2.1	3.9	6.9	13.0	25.5
C	1.14	2.4	4.4	7.7	14.5	28.6
D	1.21	2.5	4.6	8.1	15.4	30.2
6	2.15	4.5	8.2	14.5	27.3	53.7

5.2.4 RATIONAL METHOD PEAK FLOW ESTIMATES

Peak flows have also been estimated using the Rational Method applicable to the Wheatbelt Region of Western Australia. The method is described in ARR (ARR Vol 1, Book IV, Section 1.4.7).

The parameters used in the Rational methodology for each of the catchments are:

- Catchment area (km^2)
- Mainstream channel length (catchment outlet to the most remote point of the catchment boundary, km)
- Time of concentration (calculated using catchment area in ARR equation 1.23 (ARR Vol 1, Book IV, Section 1.4.7)
- Rainfall intensity for ARI events (with the duration equal to the time of concentration)
- Runoff coefficient (calculated from mainstream length using ARR equation 1.24 (ARR Vol 1, Book IV, Section 1.4.7)
- Frequency factor (Cy/C_{10}):

ARI (years)	2	5	10	20	50	100
	0.41	0.65	1.00	1.54	2.20	2.47

Results of the Rational Method estimated peak flows for the Karara mine site nodes for the 2-year to 100-year ARI are detailed in Table 5.8.

Table 5.8: Karara Mine Site Rational Method Peak Flows (m^3/s)

Output Node	ARI (years)					
	5	10	20	30	50	100
2	0.6	1.3	2.4	4.4	7.9	10.4
3	0.8	1.8	3.3	6.1	10.9	14.2
4	2.5	5.5	10.1	18.9	33.8	44.3
5	3.2	7.0	12.8	23.8	42.6	55.9
A	1.4	3.0	5.6	10.4	18.5	24.3
B	2.4	5.3	9.7	18.1	32.5	42.6
C	2.8	6.2	11.3	21.1	37.7	49.5
D	2.8	6.2	11.4	21.2	37.9	49.7
6	5.4	11.8	21.6	40.4	72.3	94.8

5.2.5 SUMMARY OF FLOOD FLOWS

Table 5.9 compares the design flood estimates at various nodes for the 10 to 100-year ARI events.

Table 5.9: Karara Flood Estimates Comparison (m3/s)

ARI (years)	Node	Rainfall Runoff	Regional	Rational
100-Year ARI	**3**	7	14	14
	5	31	34	56
	A	15	19	24
	C	25	29	49
	6	73	54	95
50-Year ARI	**3**	4	7	11
	5	18	17	43
	A	7	10	19
	C	14	15	38
	6	41	27	72
20-Year ARI	**3**	3	4	6
	5	14	9	24
	A	6	5	10
	C	11	8	21
	6	32	14	40
10-Year ARI	**3**	2	2	3
	5	10	5	13
	A	4	3	6
	C	8	4	11
	6	21	8	22

The peak runoff results from the regional method and rainfall-runoff model are similar over all ARI for all catchment nodes except Node 6, where the regional method under-estimates the rainfall-runoff value. The rational method results are significantly higher than the estimates produced using the other two methods.

The regional method and the rational method are not considered as accurate as rainfall-runoff modelling as they do not take into account any site specific routing through the catchment. Estimates from these two methods are useful as a check on the magnitude of peaks produced by the rainfall-runoff model. The similarity of estimates between the rainfall-runoff modelling and the regional method gives confidence in the results produced by the model.

5.2.6 ADOPTED DESIGN FLOWS

It is recommended that the flood flow estimates derived by rainfall-runoff modelling of the Karara catchments (Section 5.2.1.2) be adopted as the design flood flows and used as input to hydraulic modelling.

5.3 HYDRAULIC MODEL

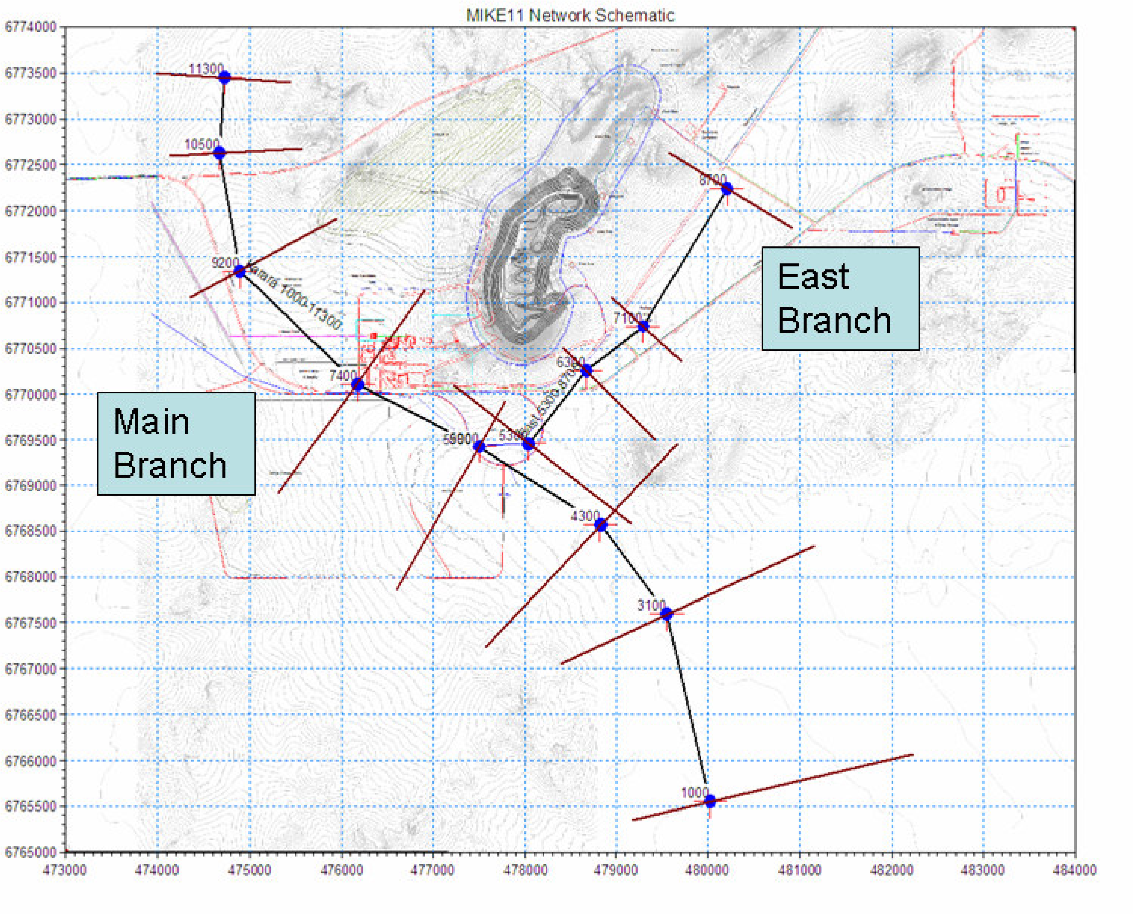
The hydraulic model used was Danish Hydraulics Institute (DHI) MIKE11 software which is internationally recognised as an appropriate model for simplified river and floodplain analysis applications. The model simulates one dimensional flow by calculating mass and energy balances at each time step over the simulation period. The Karara floodplain hydraulic model used runoff hydrograph inflow data from the rainfall – runoff model.

The hydraulic model was developed using cross sections cut from the minesite digital terrain model with an assumed surface roughness at each cross section.

Cross sections were derived from 1m and 2.5m contour information around the western end of the Karara minesite. Two branches were modelled with the Main Branch lying to the west of the proposed Karara pit and the East Branch lying to the east of the pit. 12 cross-sections were modelled, 8 on the Main Branch with a length of 10km and 4 on the East Branch with a length of 3.5km. The average spacing of the cross sections was 1100m over the total channel length of 13.5 km. The model is considered coarse because of the relatively long distances between cross-sections but appropriate for the terrain which is relatively homogeneous over the model area. The average gradient of the Main Branch was 1 in 200, and 1 in 300 for the East Branch

Figure 5.8 shows the model schematic layout and the locations of the cross-sections used in the MIKE11 model.

Figure 5.8: MIKE 11 Hydraulic Model - Scheme Layout



Hydrographs were input to the model at cross sections 11300, 10500, 9200, 7400, 5900 and 4300 on the Main Branch, and 8700, 7100, 6300 and 5300 on the East Branch. Runoff hydrographs were also input at Main Branch cross sections 3100 and 1000 based on the catchment area contributing to the cross sections and scaling rainfall –runoff results for the western side catchment that drains to Node 6.

The downstream boundary condition was modelled as a constant water level with depth of 1.0 metre at a position 3 kilometres downstream of the Karara tenement boundary. It was assumed that this point was far enough downstream to have no significant effect on water levels within the area of interest. This assumption was considered reasonable given the lack of contour detail at this position south of the tenement where 1m contours were not available.

5.4 CALIBRATION

As described in Section 5 there are no known recorded flows or levels within the minesite area. Consequently flows predicted by the hydraulic floodplain model are un-calibrated. It is therefore recommended that during the detailed design stage of the project further survey of this area be carried out and detailed hydraulic modelling undertaken to confirm the performance and impact of the proposed drainage design.

The 100 year ARI runoff event and the corresponding maximum water level determined from the hydraulic model indicate that flood levels during this event do not represent an unreasonable hazard. The proposed surface water mitigation measures which are based on the model results (described below) incorporate a freeboard that covers the effects of modelling uncertainties. In the case of the Karara minesite, the following factors provide further confidence in the results of the floodplain model.

- A rainfall runoff model was developed specifically for the Karara catchment with a number of scenarios run to determine dynamically the critical storm duration for each return period event.

- The ground surface was determined using a 1m interval contour model for the most part with the exception of the southern region beyond the mine tenement boundary.

- A surface roughness (Mannings n) of 0.050 is probably conservative for the flood events given that the modelled depth of flood flow was not high and would not generally intersect with tree branches. During the site visit in March 2008 it was observed that the terrain was comfortably able to be traversed on foot underneath a uniform canopy. The canopy was 3 to 5 metres above the ground with minimal undergrowth to cause impedance to flood flows.

5.5 FLOOD EXTENT MAPPING

Indicative flood extent maps have been constructed from the results produced by the MIKE-11 hydraulic floodplain model. The 10, 20, 50 and 100-year design events were run through the hydraulic model in order to generate maximum flood levels at a number of cross-sections. The maximum flood levels at each of the cross-sections were input into a GIS layer. To generate flood levels at intermediate locations the grid analysis software Vertical Mapper was used to construct a 3D water surface based on linear interpolation between the cross-section locations. A 3D ground surface was generated in the same way using 1m contours for the Karara minesite area. A 3D grid of maximum water depth across the area was then created by subtracting the ground surface from the water surface. The point at which the water depth reached 0m was then used to define the maximum extent of flooding for each event. Flood extent maps are shown in Figure 5.9 and

.

Figure 5.9 shows that the water surface for the 100 year ARI runoff event in the existing scenario is widespread over the shallow valley floor with an average width ranging between 200m and 400m through the proposed tailings facility and up to 1km wide south of the proposed railway loop. Peak flows, peak depths and locations are shown in Table 5.10, Table 5.11 and Table 5.12.

The proposed development scenario assumes that a 15m long, multi barrelled, culvert (4 barrels each of 1200mm diameter) is installed under the railway embankment and that a floodway or second culvert is installed in the adjacent access road, throttling the peak runoff flows and causing the upstream flood extent to be deeper and more widespread across the shallow valley. This extra flood extent is shown over the footprint of the office and security building. However, flooding can be prevented by placing the building floor level 1.2m (minimum) above the existing ground surface.

shows the water surface for the 5, 10, 20, 50 and 100 year ARI runoff events in the proposed development scenario to provide a comparison of the effects of the various design runoff events.

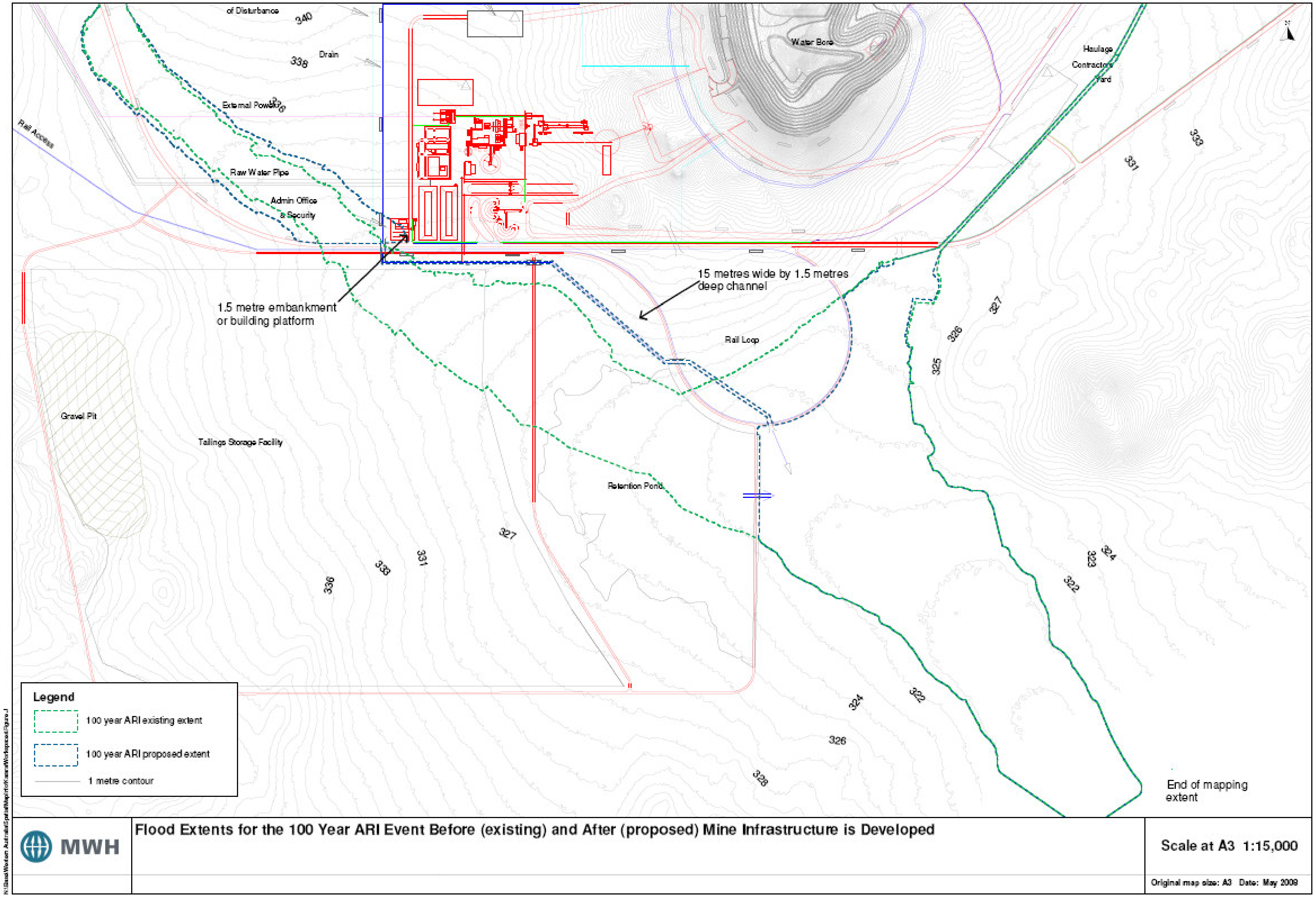


Figure 5.9: Hydraulic Model Flood Extents

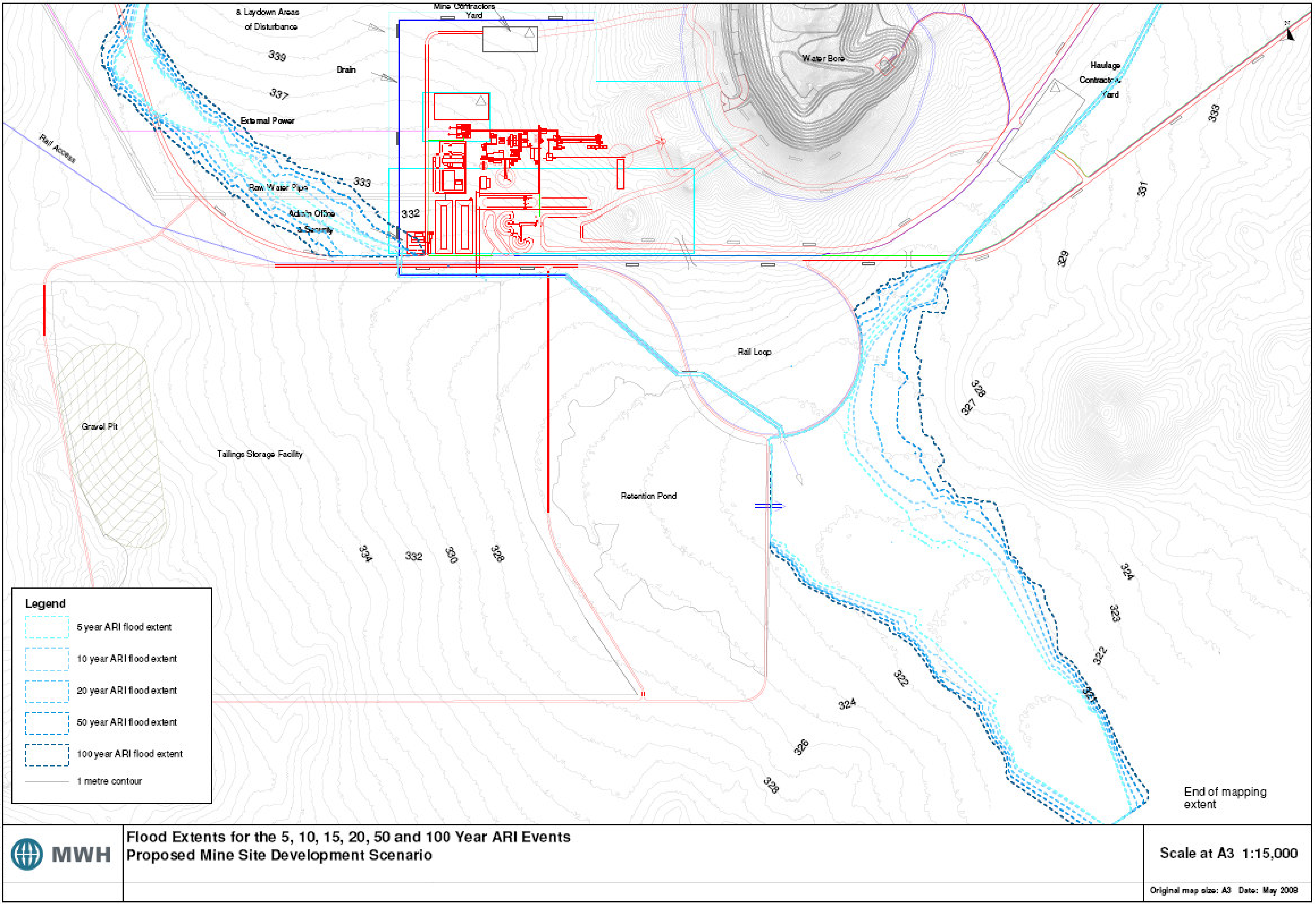


Figure 5.10: Hydraulic Model Flood Extents

Downstream of the railway embankment culverts, peak culvert flows can be contained within a cut channel with a trapezoidal cross section of 6m base, 1.5m average depth and 1 vertical to 3 horizontal channel side slopes. This gives a 15m wide channel at the top and includes approximately 0.8m freeboard allowance. The minimum channel gradient from the available contour data is approximately 1 in 450 where it runs parallel to the railway but downstream of this the channel gradient increases towards the rail loop embankment and the two sets of culverts. The culverts have been conservatively sized with 4 barrels of 1200mm diameter at this stage of design, but are subject to refinement during the detailed design phase.

Downstream of the rail loop culvert, the runoff flows may be directed towards the natural valley floor and away from the minesite. Ponding depths are not high, and the retention pond can be protected with a 2m high earth embankment.

The 100 year ARI runoff flows can be managed through the proposed development infrastructure due to the benefits of a large storage volume available upstream of the railway embankment culvert. The peak runoff from the natural topography can be reduced to the peak discharge available through the railway culvert dependent on the water depth at the upstream end of the culvert. With the large natural storage volume available, the 100 year ARI runoff volume only rises to a depth of 0.7m in front of the 1.2m diameter culverts upstream of the railway embankment. A freeboard of 0.8 to 1.0 metres should be applied to all top water level results to allow for model approximations.

Runoff within the East Branch is assumed to be managed over access roads and other roads with culverts sized to 10 year ARI capacity and floodways sized to pass the 100 year ARI flood flow.

Table 5.10: Hydraulic Model Flows – Existing Scenarios

	Peak Discharge m^3/s				
MIKE11 Cross Section Location	100 year ARI Event	50 year ARI Event	20 year ARI Event	10 year ARI Event	5 year ARI Event
Main Branch 10900	0	0	0	0	0
Main Branch 9850	4.0	1.8	1.5	0.4	0.0
Main Branch 8300	5.7	2.6	2.2	0.6	0.0
Main Branch 6650	21.5	10.7	6.5	1.9	0.0
Main Branch 5490	28.7	15.3	8.1	2.3	0.0
Main Branch 4690	56.1	29.9	14.0	2.2	0.1
Main Branch 3700	63.2	32.9	15.7	1.7	0.1
Main Branch 2050	58.8	29.8	15.0	1.4	0.1
East Branch 7900	14.7	7.3	3.9	1.0	0.0
East Branch 6700	24.0	13.1	6.7	1.3	0.1
East Branch 5800	26.1	14.7	6.8	0.9	0.1
East Branch 5250	28.2	15.6	6.8	1.0	0.1

Note: MIKE11 displays discharges midway between cross sections.

For the proposed development cases, a series of 4 x 1200mm diameter culverts were placed into the model where the channel is to pass beneath railway embankments and/or haul roads. This provides a number of other cross sections and outputs along the channel alignment.

Table 5.11: Hydraulic Model Flows –Proposed Development Scenarios

	Peak Discharge m^3/s				
MIKE11 Cross Section Location	100 year ARI Event	50 year ARI Event	20 year ARI Event	10 year ARI Event	5 year ARI Event
Main Branch 10900	0.0	0.0	0.0	0.0	0.0
Main Branch 9850	3.7	1.9	1.1	0.4	0.0
Main Branch 8300	6.0	3.5	2.5	0.6	0.0
Main Branch 7375	2.4	1.0	0.4	0.0	0.0
Main Branch 7040	2.4	1.0	0.4	0.0	0.0
Main Branch 6710	2.4	1.0	0.4	0.0	0.0
Main Branch 6362	2.4	1.0	0.4	0.0	0.0
Main Branch 5985	2.4	1.0	0.4	0.0	0.0
Main Branch 5925	2.4	1.0	0.4	0.0	0.0
Main Branch 5720	11.4	6.3	3.7	0.7	0.0
Main Branch 5495	11.2	6.3	3.7	0.7	0.0
Main Branch 5270	11.6	6.4	3.8	0.7	0.0
Main Branch 4690	35.6	18.4	6.3	0.7	0.4
Main Branch 3700	41.2	19.2	8.3	0.9	0.3
Main Branch 2050	35.4	20.7	6.3	1.1	5.5
East Branch 7900	14.3	7.5	4.0	1.1	0.0
East Branch 6700	21.4	12.3	6.1	1.1	0.1
East Branch 5800	26.8	15.8	7.0	0.7	0.1
East Branch 5150	28.9	16.3	5.5	0.7	0.1

Note: MIKE11 displays discharges midway between cross sections.

Table 5.12 below indicates the flood depths modelled in MIKE11 for the proposed development scenario. A freeboard of 0.8 to 1.0 metres should be applied to all design works based on these top water level results to allow for model approximations.

Table 5.12: Hydraulic Model Depths –Proposed Development Scenarios

	Peak Depths m					
MIKE11 Cross Section Location	Bed Level (m RL)	100 year ARI Event (m)	50 year ARI Event (m)	20 year ARI Event (m)	10 year ARI Event (m)	5 year ARI Event (m)
Main Branch 11300	356.2	0.0	0.0	0.0	0.0	0.0
Main Branch 10500	351.0	0.2	0.1	0.0	0.0	0.0
Main Branch 9200	338.6	0.1	0.1	0.0	0.0	0.0
Main Branch 7400	330.3	0.7	0.5	0.3	0.1	0.0
Main Branch 7350	328.8	0.5	0.3	0.2	0.0	0.0
Main Branch 6730	327.4	0.6	0.4	0.2	0.0	0.0
Main Branch 6690	327.3	0.4	0.2	0.1	0.0	0.0
Main Branch 6035	323.3	0.9	0.4	0.2	0.0	0.0
Main Branch 5950	322.8	1.4	0.9	0.6	0.0	0.0
Main Branch 5900	322.5	1.7	1.2	0.9	0.3	0.0
Main Branch 5540	322.1	1.8	1.1	0.9	0.4	0.1
Main Branch 5460	322.0	1.2	0.9	0.7	0.3	0.0
Main Branch 5080	321.6	0.4	0.3	0.2	0.1	0.0
Main Branch 5080	321.6	0.4	0.3	0.2	0.1	0.0
Main Branch 4300	320.8	0.6	0.4	0.3	0.2	0.0
Main Branch 3100	319.9	0.7	0.5	0.4	0.1	0.3
Main Branch 1000	319.2	1.3	1.1	0.8	0.8	1.0
East Branch 8700	335.4	0.3	0.2	0.1	0.0	0.0
East Branch 7100	328.8	0.4	0.4	0.3	0.2	0.0
East Branch 6300	325.8	0.5	0.4	0.3	0.2	0.0
East Branch 5300	322.3	0.3	0.2	0.2	0.0	0.0
East Branch 5000	321.6	0.4	0.3	0.2	0.1	0.1

5.6 CONCLUDING COMMENTS - HYDRAULICS

The existing topography to the west and east of the Karara minesite and its infrastructure is gently sloped towards the south east with a shallow valley floor cross section. In the existing development scenario (pre-minesite) the 100 year ARI runoff event would have a wide but shallow flood extent across the valley floors to the west and east of the minesite. In the proposed development scenario (as an operational minesite) the large natural storage available from the flat and shallow topography will be used upstream of the railway access embankment and culvert to throttle peak runoff flows to a manageable level through the proposed tailings facility and rail loop area.

A 15m wide trapezoidal channel could be cut downstream of the railway embankment with a depth of 1.5m to manage the 100 year ARI peak runoff of approximately 11 m^3/s. This value is made up the capacity of the railway embankment culverts (4 barrels of 1200mm diameter) and input from local catchments draining into the channel.

A 2m high (minimum) earth embankment surrounding the retention pond will provide adequate protection during a 100 year ARI event (including 1m freeboard).

Sizing of culverts and channel sections have been intentionally conservative at this stage of the design process. When more accurate information on the drainage channels through the Karara minesite is available, channel gradients and culvert invert levels will be determined and the dimensions of drainage elements can be refined.

6. POTENTIAL SURFACE WATER IMPACTS

6.1 POTENTIAL SURFACE WATER IMPACTS

The following aspects of the proposed mining activities have the potential to impact on surface water flow (hydrology) and water quality.

6.1.1 MODIFICATION OR INTERRUPTION OF EXITING NATURAL DRAINAGE CHANNELS AND OR FLOWS

The proposed Karara pit is located at the western end of a low ridge rising approximately 100m above the surrounding plain. The pit is planned to be 700m wide and 1,900m long and will occupy an area of 1.36km^2. The 40 year pit boundary will be 800m wide, 3,400m long and have an area of 2.7km^2. The proposed mine may interrupt or modify existing drainage channel patterns and flows from the range. This may create an area of reduced runoff downstream of the pit boundary.

Mine infrastructure including access roads, pipelines, bunds, waste-rock dumps and diversion channels also have the potential to create areas of reduced runoff volume downstream of these structures and to disrupt channel-flow and sheet-flow patterns. Interruption of sheet-flow may impact on mulga communities. Figure 8.1 shows potential locations of surface water drainage shadow.

Infrastructure upstream of channel constrictions such as road crossings, culverts, waste rock dumps may be inundated. Areas upstream of any new channel constriction may be adversely affected by inundation and extended periods of inundation. Vegetation communities in these areas may be unable to regenerate after long periods of inundation and flooding.

6.1.2 POTENTIAL INCREASED SEDIMENT RUNOFF AND SCOUR

An increase in sediment runoff is likely to occur as a result of ground disturbance from the mining operation, especially associated with waste rock, stockpile and open pit areas. Ground disturbance activities are likely to disturb existing groundcover increasing the risk and severity of erosion during rainfall events.

Activities within the mine pit are likely to agitate sediment at the base, increasing the level of suspended solids and turbidity in the water. As a result, surface water pumped from the floor of the pit may have high concentrations of sediment. The Karara magnetite project is understood to be capable of accommodating and utilising water from the base of pits in its process, and will not need to release pit water directly into the environment.

6.1.3 POTENTIAL CONTAMINANT DISCHARGE:

Mining activities have the potential to contaminate surface water including: through discharge of untreated sewage; sediment-laden water; and hydrocarbon contaminated water from workshops, wash-down areas, hazardous substance storage areas, ore processing plant and haul, access and rail road.

Increased sediment runoff into clay-pan areas may lead to accumulation of contaminants over time. There is a risk that these contaminants may then be transported downstream after flood events or periods of high rainfall.

6.1.4 DISCHARGE OF PIT SUMP WATER

Water from groundwater dewatering bores will be used in the processing of magnetite ore. On an annual basis evaporation exceeds rainfall by over five times so the accumulated sump water resulting from less severe rainfall events will evaporate from the pit floor. During a 10 year 72 hour rainfall event a total volume of 74,800 m^3 of sump water would collect in the pit (1.36 km^2 area) and 150,700 m^3 when the pit reaches its maximum (40 year) area of 2.74 km^2.

Assuming a pumping capacity of 0.4m^3/s (1440 m^3/hr) it would take 2.2 days to pump 74,800 m^3 and 4.4 days to pump out 150,700 m^3.

If excess pit sump water needs to be discharged to the environment it will be completed within a few days of the rainfall event and at a relatively low velocity. It is therefore unlikely to have a significant long term impact on existing drainage channels or fauna and flora.

6.2 PROPOSED MEASURES TO MANAGE IMPACTS

Management measures should be developed in liaison with operational personnel and should comply with and include relevant internal standards, procedures and guidelines. In order to management and mitigate the potential impacts described above, the following management measures are recommended:

- Locating all facilities away from seasonal waterholes, pools, and surface flow channels
- Installing culverts (not less than 600mm in diameter) in roads crossing drainage lines to ensure downstream vegetation is not affected by surface flow diversion or obstruction.
- Checking culverts for erosion control and energy dissipation requirements both up and downstream
- Directing clean surface water flow around the site using diversion embankments and channels
- Installing sediment traps or basins to manage the impact of increased flow velocities from hard stand areas and to limit erosion potential and to filter and settle out solids that are mobilised in the surface water runoff flows
- Adequately containing fuels and oils in line with AS 1940 The Storage and Handling of Flammable and Combustible Liquids and meeting design criteria for storage facilities
- Maintaining hydrocarbon spill kits at refuelling areas
- Collecting and treating potentially polluted wastes at their source (booms and matts)
- Managing safe transport and storage of hazardous materials
- Effective sewage management

- Designing waste dumps to incorporate water management features to minimise the potential for sediment-laden surface water run-off.

- Releasing pit sump water via a settling pond to remove silts and sediment, or to incorporate pit water into the magnetite process wherever possible

- Developing a surface water management plan for the site. (See Appendix A for a summary of the recommended contents of the plan).

- Monitoring in accordance with any license conditions.

6.2.1 MODIFICATION OF EXISTING NATURAL DRAINAGE CHANNELS

Modification of the existing channels can reduce the volume and distribution of runoff to some areas and increase flows and the period of ponding in other areas.

The mining area is located relatively high up within the catchment. This means that catchment slopes are moderately steep, drainage channels are generally well defined and the catchment areas contributing to open pits, waste rock dumps and other mining infrastructure are small. Hence, the proposed operation does not require the diversion of significant volumes of surface water away from existing watercourses and so impacts on ecosystems dependant on sheet flow are considered to be minimal.

Earth bunds will be constructed around pit perimeters consisting of diversion channels and low bunds to prevent runoff from entering mine pits. Where possible (and in adherence to relevant standards and guidelines), these structures may also act as safety (containment) bunds. These structures have the potential to divert water away from existing natural channels. However, as the pit is along the centre of the ridge, the volume of diverted stormwater is low. Modelling and existing studies indicate that under average conditions, diverted water will be directed back into the original waterway within a short distance of the open pit.

The waste rock dump is located to the north of the pit and is subject to minimal runoff from the relatively small upstream catchment. The perimeter of the waste rock dump will be protected by diversion channels and earth bunds to prevent upstream runoff entering the dump area. The diverted water will be directed back into the original waterway within a short distance of the downstream waste rock dump area. The entry point of diversion channel into the original waterway should be sited to minimise the risk of scouring and avoid increasing flow velocity.

Proposed access roads and the railroad traverse the catchments draining the low ranges. The design standard recommended for access roads is the 100 year ARI rainfall event for floodways and 10 years for culverts. Accordingly, drainage beneath and over the road has been designed to minimise obstruction or modification of surface water flows during a flood event. Where flows are impounded upstream of the access road, culverts will enable flow to re-enter the original watercourse downstream of the road.

The alignment of the access road crosses some relatively flat sections of the flood plain. In these areas the construction of the road may impede sheet flow and potentially create runoff shadows adjacent to the downstream side of the road. This potential effect is somewhat reduced during more severe events when large areas of the flood plain become inundated (including access roads).

The effects of runoff shadows can be mitigated by installation of relief culverts and floodways to retain the natural hydrologic regime. Flood water is distributed along the downstream side of the flow restriction to reflect the pre- road or airstrip regime.

Where airstrip foundations and access roads have potential to impede runoff, culverts and overflow floodways should be positioned to maintain the existing drainage system. Regular “spreader” culverts could be installed as part of the structure to spread flows across into the downstream “shadow” area.

Where floodwaters are impounded, outlet structures should be sized to ensure that the period of inundation will not cause adverse effects on vegetation. At no point are flood waters impeded from passing through the minesite by more than 24 hours in all cases up to the 100 year ARI runoff event.

Local effects on mulga communities immediately downstream of the mine can be managed by redirecting diverted surface water back to the general area that this water would have flowed across naturally. Options for re-distributing diverted water to enhance sheet water flow characteristics should be considered.

6.2.2 POTENTIAL INCREASED SEDIMENT RUNOFF

Increased sediment runoff may result where ground disturbance has occurred as a result of the proposed mining operation.

The proposed open pit mining and waste rock dump areas are all located in the upper reaches of their respective catchments with very small basin areas. The small catchment areas produce relatively low runoff volumes, and consequently the volume of transported sediment from areas of disturbed ground is also likely to be low.

In areas prone to elevated sediment and/or contaminant runoff such as infrastructure and processing hard stand areas, downstream of waste rock dumps and stockpile areas and water pumped from the pit floor, sediment detention ponds should be designed and used to capture and treat stormwater before flow is directed back into existing drainage channels.

Runoff from within the waste rock dumps has the potential to carry high levels of sediment, therefore runoff from these areas should be directed toward a sediment detention structure downstream of each waste rock dump area. The Karara waste rock dump is expected to have more than two sedimentation ponds to cope with its size, and the terrain in which the dump is positioned.

The existing predominant land use in the catchment is mineral exploration. The effect of increased sediment runoff as a result of the proposed minesite activities is therefore considered to be insignificant.

In accordance with the management measures described above, water should be directed away from open pits, stockpile and waste rock areas through the construction of bunds and diversion channels. Stormwater runoff from these areas should be diverted to settling ponds to reduce the velocity of flow, allowing large particles to fall out of suspension. This will assist in reducing sediment concentrations, associated contaminant concentrations (and possibly turbidity) prior to discharge.

The waste rock dump will be contained within a perimeter bund and internal runoff will be passed through one of a number of sedimentation ponds to remove at least 90% of the suspended sediment volume over 90% of the time. During a flood greater than the capacity of the sedimentation pond volume, sediment may pass through the detention ponds with lower rates of settlement. However, the percentage of runoff water and sediment from the disturbed ground within the mine operation will be a small percentage of the runoff from upstream and the adjacent natural catchment areas and so is not expected to have a significant impact on the overall catchment downstream of the minesite. The natural background suspended sediment load in the receiving waters will be high due to such a rainfall event, and overflows from a sedimentation pond would be diluted and dissipated quickly.

Increased flow velocities at the outlet of culverts and diversion channels may cause localised scouring and consequently, increased sediment load, but in the Karara minesite location, flow velocities are low due to the shallow gradients and wide floodplain.

6.2.3 POTENTIAL CONTAMINANT DISCHARGE

The processing plant, stockpile areas, workshop, administration buildings and fuel storage are sited near a major drainage channel to the west of the Karara pit. Accordingly, the area needs to be located at an appropriately high elevation to avoid the risk of flood inundation from the adjacent flood plain. In addition to being located above the design flood level, infrastructure such as fuel storage and hazardous substance storage should have secondary containment to prevent potentially contaminated material from polluting the surrounding area.

Runoff from these areas should to be directed to a number of concrete grit and oil interceptors for the workshop, fuel storage and wash down areas. These are designed to screen out gross pollutants and litter before draining into a sedimentation pond.

There is potential for leachate to be generated from acid forming material in the waste rock dumps. Any acid material should be contained in cells within the waste rock dumps to minimise the risk of leaching of contaminants. Where there is a risk of inundation of the waste rock dump these cells should be sited within the dump at sufficient elevation to avoid the cell becoming saturated.

The assessment of passive and active strategies for the stability of waste rock dumps and minimisation of leachate generation and treatment are to be undertaken as part of a specialist geotechnical study. In the context of this report, the risk of contamination from acidic leachate from waste rock dumps can be minimised by appropriate passive strategies including slope stabilisation and capping procedures with hard wearing inert materials. Active maintenance of the capping integrity and monitoring of leachate in the sedimentation ponds during mine development and waste rock dump construction are also highly recommended. If leachate pH monitoring proves to be lower than acceptable, pH neutralisation treatment by lime dosing or similar procedure can be undertaken in purpose-built holding ponds.

6.2.4 DISCHARGE OF PIT SUMP WATER

Following periods of extreme rainfall excess pit sump water may need to be discharged. To mitigate the impacts of the discharge the water will be piped to a detention pond to allow settling out of sediment before being piped to an existing natural drainage channel. The drainage channel at the discharge point will be protected from erosion with standard energy dissipating structures such as a concrete apron or/and rip rap boulders. Discharges should be monitored to ensure compliance with discharge quality criteria. Alternatively, it is understood that the magnetite process can make use of pit water and if so then this should be the higher priority method of disposal.

6.3 SUMMARY OF POTENTIAL IMPACTS AND MITIGATION

Potential impacts on surface water are:

- Increased sediment runoff from disturbed ground and stockpiled materials associated with the mining operation.
- Modification and interruption of existing natural drainage channels resulting from the construction of the access and haul roads and development of mine pits and infrastructure.
- Discharge of excess water from mine dewatering possibly resulting in scouring and erosion
- Potential for contaminants to be discharged into the environment from workshop/wash-down/Hazardous substance storage areas.

The individual mining areas are located relatively high up within each catchment. As a result, the catchment slopes are moderately steep, drainage channels are generally well defined and the catchment areas contributing to open pits, waste rock dumps and other mining infrastructure are small. Therefore, volumes of stormwater and sediment within the minesites will be relatively small and impacts on ecosystems dependant on sheet flow are considered to be minimal.

During a flood greater than the capacity of sedimentation ponds, sediment will pass through the detention ponds with lower levels of settlement treatment but this effect will be diluted in a large event.

The proposed access and rail road traverses large catchments to the north of the minesite. The design standard adopted for road drainage (culverts and overflow floodways in combination) is the 100 year ARI storm flow. Culverts are specified in existing drainage lines and sized to pass the 10 year ARI runoff events. Accordingly, drainage beneath the road will not impede flood flows up to the culvert capacity. For larger runoff events that exceed the culvert capacity, flows across the road floodway will in most cases discharge back into their original watercourses within a short distance downstream of the road.

The alignment of the access road crosses some relatively flat sections of the river plain. In these areas the construction of the road may create runoff shadows adjacent to the downstream side of the road. This potential effect is somewhat reduced during more severe events when large areas of the flood plain become inundated.

At times during the mining operation, an excessive volume of water may be produced after extreme rainfall. In this situation, the excess water will be discharged into an existing natural drainage channel following the flood event, or added into the magnetite process for re-use.

In areas prone to elevated sediment and/or contaminant runoff such as downstream of waste rock dumps and the stockpile, sediment detention ponds should be constructed to capture and treat surface water before being discharged into existing drainage channels.

Runoff from workshops and wash down areas will be directed toward oil and sediment interceptors and then into sedimentation ponds, prior to being discharged into the natural environment.

6.4 APPLICABLE LEGISLATION

Two approvals have been identified and considered as part of the surface water hydrological assessment. They are:

- ***Permits to Obstruct or Interfere with Beds and Banks issued under Section 17 of the Rights in Water and Irrigation Act. 1914***. This Section specifies that where a drainage channel is crossed by a road or any mine structure a permit to obstruct or interfere with the beds and banks of the channel may be required. Rainfall-runoff and hydraulic models will cover locations where such permits are required. The results of the model simulations will assist in assessing the effects of modifications to the drainage channels.

  *According to DoW there is no legal definition for a drainage channel but in the Mid-West Region it is generally defined as the distinct riparian zone identified by changes in vegetation, topography etc.

- ***A part V licence under the Environmental Protection Regulations (1987) to discharge mine water.*** If flows produced from dewatering of the proposed open cut mines are in excess of that required for dust suppression and on-site processing, a means of disposing of the surplus water will be required. In this case a permit to discharge water to the environment may be required and the likely effects on existing downstream flora and fauna caused by the mine water discharge will need to be assessed. It is unlikely that excess dewatering water will be discharged to the environment.

Due to the ephemeral nature of surface water flows in the region there is no intention at this stage to take surface water and so a ***Licence to take water issued under Section 5C of the Rights in Water and Irrigation Act*** is not required.

7. SURFACE WATER MANAGEMENT

7.1 INTRODUCTION

The control of stormwater runoff is required around pit workings, waste rock dumps, the mine operations centre and processing plant, the proposed airstrip and road infrastructure. Management around these areas is aimed at avoiding excessive scour erosion and nuisance ponding and the control and treatment of sediment leadened stormwater.

The following principles have been adopted for surface water management at the Karara Iron Ore project:

:

- To direct clean water from undisturbed catchment areas around or through the active mine operations by means of drainage channels and earth bunds, and culverts if necessary. To isolate minesite infrastructure from surface water flows with bunds and channels.
- To isolate the waste rock dump and tailings areas by bunding and diverting internal flows to a sedimentation pond prior to runoff draining into the receiving environment. During pit excavation and construction of the associated waste rock dump, sedimentation ponds will require maintenance from time to time to maintain their performance and storage volume during the wetter parts of the year. Materials removed from the ponds by pumping (or by excavator if the pond runoff volume has evaporated) are to be deposited within the waste rock dump and backfilled in a secure location.
- To design culverts and overflow areas for access and haul roads to pass extreme flows across or under road surfaces back into existing natural drainage channels.
- To isolate intensive machine operation areas and stockpile areas with bunding and capture internal runoff with grit and oil interceptors prior to release into sedimentation ponds. The interceptors will require a maintenance schedule to maintain performance and the materials removed from the interceptors are to be disposed of according to mine protocols for environmentally sensitive materials.
- To maximise waste rock dump slope stability and specify an exterior surfacing such as granite in a granular mix to inhibit erosion and sediment migration to the downstream environment. The capping layer is to create a near impermeable surface that sheds rainfall down the slope rather than allowing infiltration, and to inhibit air from entering the interior and oxidising sulphide material and lowering pH (causing acidic conditions).

7.2 DESIGN STANDARDS ADOPTED AND RISK CONSIDERATIONS

The design life of Karara magnetite is understood to be approximately 40 years. This has influenced the design standards recommended for drainage and surface water management components. The likelihood of an event exceeding design criteria for different mine elements over the operational lifetime is listed below and indicates the risk of an exceedence event. Each element is discussed in terms of the effects of design exceedence on the mine operation and the wider environment.

For example: for an *n*=10 year design life for the entire project, the probability (*p*) of encountering a *Tr*=100 year ARI rainfall event is given by

$$p = 1 - \left[\frac{(T_r - 1)}{T_r} \right]^n = 1 - \left[\frac{(100 - 1)}{100} \right]^{10} = 0.095$$

In this example, there is a 9.5% chance that a 100 year ARI event (or greater) flood will occur over the 10 year life of the operation. For Karara, *n*=40 years design life and the probability (*p*) of encountering a *Tr*=100 year ARI rainfall event is 0.33 or 33%.

Table 7.1 summarises the design standards recommended, along with the estimated risk of exceedence.

Table 7.1: Design Standard & Probability of Exceedence

DESIGN ELEMENT	ENGINEERING ASSESSMENT		
	DESIGN LIFE	DESIGN STANDARD	RISK OF DESIGN EXCEEDENCE
Local Diversion Channels And Culverts Around Pit Site And Waste Rock Dump Including Haul Roads	Assume 40 Years	20 Year Ari Capacity	*Tr = 20, N=40, P= 0.87 (87%)*
Sedimentation Ponds	Assume 40 Years	20 Year Ari Capacity	*Tr = 20, N=40, P= 0.87 (87%)*
Access Road Culverts	Assume 40 Years Mine Operation Life	10 Year Ari Capacity	*Tr = 10, N=40, P= 0.98 (98%)*
Access Road Floodways, Railway Culverts	40 Years Mine Operation Life	100 Year Ari Capacity	*Tr = 100, N=40, P= 0.33 (35%)*

For localised channels, culverts and sedimentation ponds around pit areas, a 20 year ARI capacity is proposed to limit the risk of runoff from the waste rock dump spilling from the sedimentation pond into the natural environment. The increase in size and cost of earthworks compared to a 5 year ARI design capacity was considered worthwhile compared to the reduction in risk of design exceedence during the mine life. Even with a 20 year design capacity in the sedimentation pond and channels the chance of an exceedence event over the forty years of mine life is likely but the effects of event larger than a 20 year ARI capacity will be masked by the natural flood flows and sediment mobilisation.

Access road culverts and floodways should be designed to function together to pass the 100 year ARI flood event across the road structure without significant erosion damage. The continuous use of the access road is considered vital to the productivity of the mine operation during the minesite life and so the design standard for managing surface water is high. The design standard of the railway culverts is to account for the lack of overland flow options across the railway embankment. The railway embankment is assumed to be in excess of 2 metres above the natural ground level and is likely to be higher. The larger sizes of culvert also reduce the risk of blockage over many dry years, and make maintenance safer and easier over the long term.

7.3 KARARA MINESITE COMPONENTS

The Karara minesite has the following major components.

- The open pit including a large working void to be expanded over time, and associated haul roads
- Waste rock dump and containment bunds
- Ore processing plant and infrastructure including the slurry pipeline
- Railway and access road serving the nearby haematite minesite operation
- Karara magnetite tailings storage facility and runoff containment pond area.
- Airstrip and access roads

These features are shown on Figure 8.1 and the impacts of this infrastructure is briefly described below.

7.3.1 KARARA OPEN PITS

The development of the pit void below the crest of the ridge will collect rainwater into the pit sumps where it will be managed by pumping out as part of the mine operation. The pit will permanently reduce the amount of runoff from the natural crest of the Karara ridge and the slopes of the ridge just below the rim of the pit will experience less overland flow during rainfall events. Some localised diversions will occur at haul roads between the pit and the rest of the minesite which will reduce overland flow from parts of the downstream catchments and concentrate flows at road culverts or low points.

7.3.2 WASTE ROCK DUMP

The Karara waste rock dump is to be encircled with a low level containment embankment to control runoff originating from the dump and direct it to sedimentation ponds prior to release into natural drainage channels. The containment embankments also direct surface water runoff originating from natural areas around the waste rock dump footprint. Each sedimentation pond discharge is a concentration of a large surface area at an outlet point, and the deflection of natural surface water around the waste rock dump will concentrate flows from upper areas. The water quality of the sedimentation pond discharge is expected to be similar to the water quality of the natural runoff during heavy rainfall events. Between rainfall events pond water volumes will reduce rapidly due to evaporation.

7.3.3 PROCESSING PLANT AND INFRASTRUCTURE

The built up areas of the plant and infrastructure area will cause rainfall surface water to shed more rapidly from the hard stand areas and run into the associated cut channel drains. The area will have a higher sediment and contaminant loading from moving equipment and accumulated dust which will tend to be mobilised during a "first flush" following rainfall events especially following extended dry periods. This sediment and contaminant load can be intercepted with site drainage leading to sediment traps and grease removal traps.

7.3.4 RAILWAY AND ACCESS ROADS

Railways and roads will divert smaller surface water flows through side drains parallel with the rail or road and then concentrate flows to a point discharge through a culvert. Larger events involving surface water in volumes greater than the culvert capacities will be passed across roads at floodways where road levels are designed to be lower than adjacent pavement.

Railroad embankments will cause floodwaters to back-up upstream of culverts until the culverts can drain flooded areas. As discussed in Section 5.3 railway culverts adjacent to the processing plant and TSF can be sized for the 100 year ARI event, resulting in minor upstream ponding.

7.3.5 TAILINGS STORAGE FACILITY AND RETENTION POND

Surface water originating from the proposed tailings facility is proposed to be directed into the retention pond where it will evaporate. The TSF and retention pond are designed to contain the 100 year ARI rainfall event without discharge from the structure.

7.3.6 AIRSTRIP AND ROADS

The proposed airstrip and access and haul roads will be built proud of the existing terrain. The construction of linear infrastructure across gently sloping ground may create a barrier to sheetflow as described in Section 6. The potential for drainage shadow areas to be created downstream of roads can be reduced by the regular placement of spreader culverts (pipes) into the road structure to more regularly pass sheetflow across these structures. Some further dispersion measures may be undertaken if the terrain is suitable such as the installation of spreader ditches on the downstream side of the structure.

The airstrip will be in the order of 0.3m above the surrounding ground surface. Diversion drains will be constructed around its perimeter to receive runoff from the landing surface and direct upstream runoff away from the structure. Discharge from the downstream diversion channel should be designed to minimise drainage shadow areas.

7.4 SURFACE WATER MANAGEMENT – KARARA MINESITE

Surface water management around the waste rock dump is shown below in Figure 7.1. The entire waste rock dump footprint is shown but will be developed in stages over the course of the mine life. The waste rock dump should be surrounded by a 1.5m high earth bund with an internal channel draining runoff to the sedimentation ponds at the low points at both ends of the dump area. When further design information is available, the number and location of sedimentation ponds can be confirmed. The construction of the sedimentation ponds will require assessment of surface water catchment area at each new stage of development to ensure runoff is contained and directed into a sedimentation pond for treatment before entering the natural environment.

The design volume of sedimentation ponds should be in the order of a 20 year ARI runoff volume for a 24 hour rainfall event. An extra 50% volume should be provided as “dead storage” below the decanting level where finer materials have extra time to settle out. The ponds would aim to settle out a minimum of 90% of suspended solids for at least 90% of the time. The final sizing of the ponds will depend on the catchment areas served by the ponds and the sediment distribution defined for the waste rock material. Detailed design of the ponds will be required at a later stage.

Overflow weirs from the sedimentation ponds should be designed to pass the 100 year ARI peak runoff discharge to allow extreme events to pass through the pond without damage. Some maintenance of bunds and ponds would be expected following an extreme event.

During extreme rainfall events flows may be released into the environment over the spillway without receiving adequate settlement detention time. In this case the receiving environment is likely to be carrying significant natural sediment loads which will minimise the effect of sediment laden runoff from the waste rock dump/sedimentation pond.

Maintenance of sedimentation ponds and removal of residues would be carried out prior to the wetter part of the year to minimise the amount of concentrated sediment in the ponds at any one time.

When Karara pit is closed, the waste rock dump should be protected with an armoured exterior of granite or inert material to protect against rainfall infiltration in the long term. Sedimentation ponds will be decommissioned.

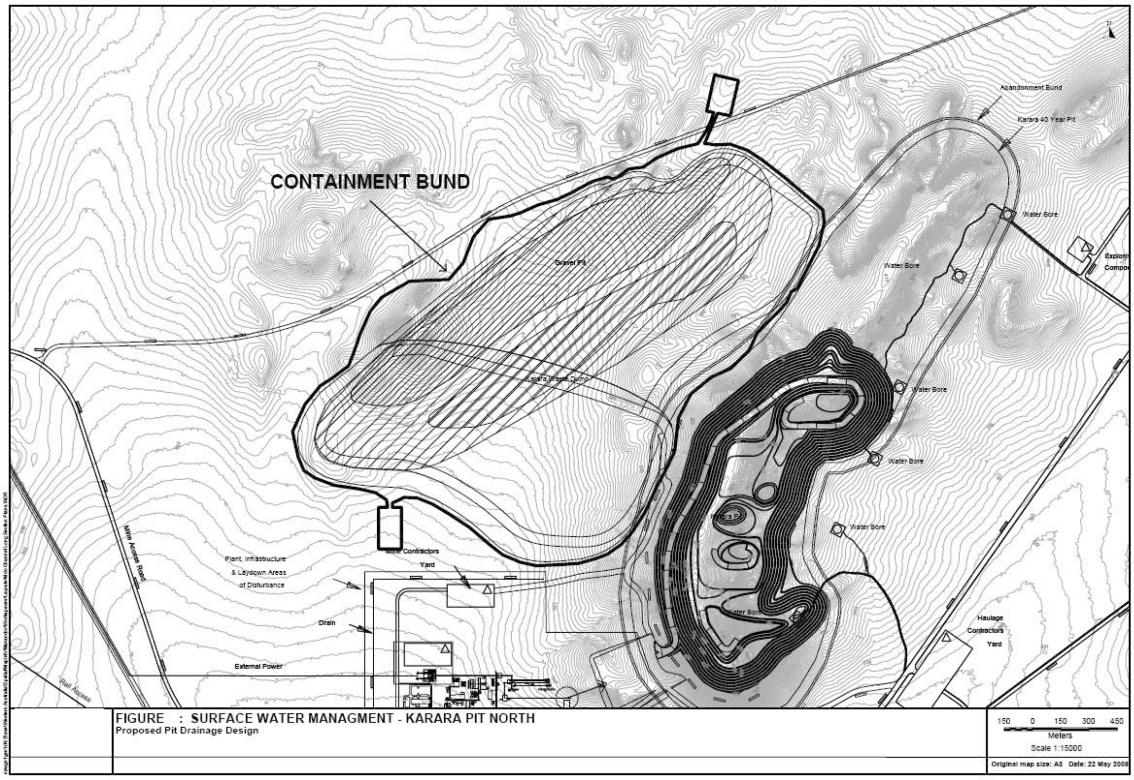


Figure 7.1: Surface Water Management Scheme – Waste Rock Dump

Surface water management around the processing plant and mine operations centre is shown below. The infrastructure platforms are assumed to be relatively level and compacted to support the mining structures' foundation loads and vehicle movements, and the surface will have a high runoff coefficient. The "first flush" of runoff will contain the highest concentrations of contaminants, debris and oils attached to surface sediments. Grit and oil interceptor units are required to remove the majority of debris and oils (including diesel and lubricants). The interceptors around the Mine Operation Centre would require regular inspection and maintenance to ensure adequate performance.

The failure of a culvert or floodway in an event greater than a 100 year ARI event would mean the transportation of road fill materials downstream. The concentration of flows through a breach would result in high velocities and possibly scour along the existing downstream drainage channel. At the Karara minesite, the design flows, even in a 100 year ARI event, are not large. Deposition of scour material where flows disperse in flatter regions would occur but can be expected to be minor as the entire drainage system is flat with low velocities. Effects on the mining operation as a result of flows exceeding the culvert and floodway capacities during an event greater than a 100 year ARI are only significant if the integrity of the road structure fails, which is unlikely given the relatively low velocities modelled.

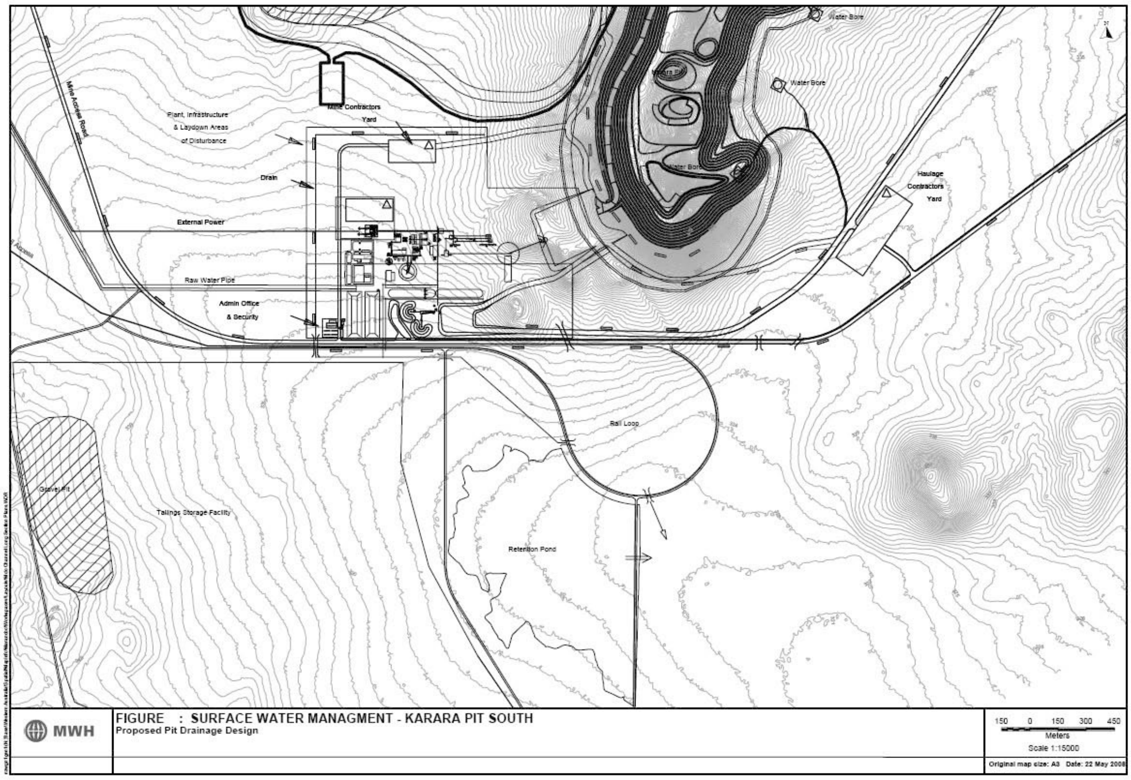
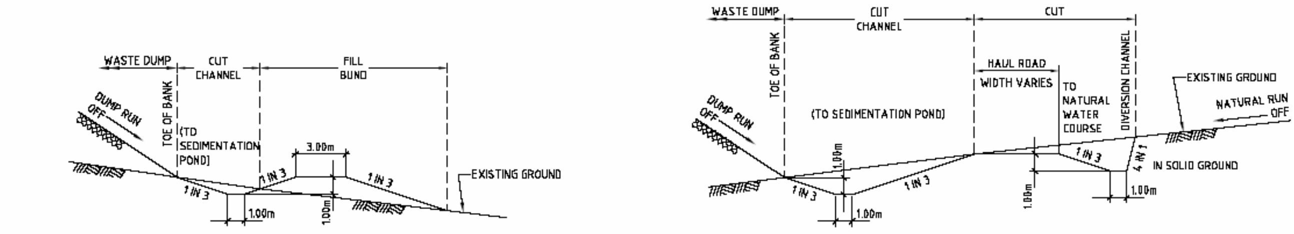


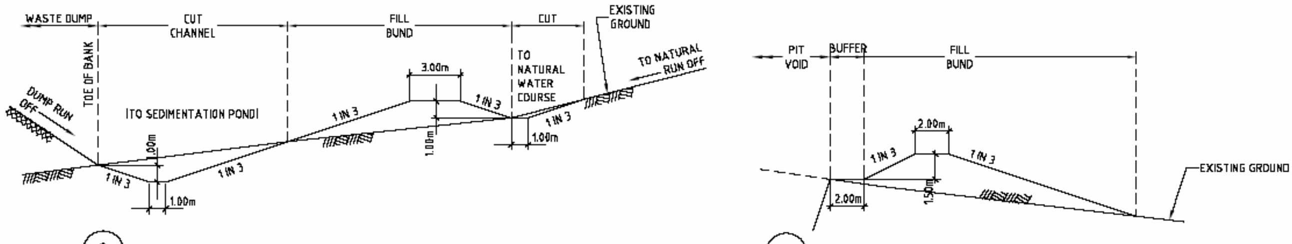
Figure 7.2: Surface Water Management Scheme – Processing Plant and Retention Pond

The following figure illustrates the types of surface water drainage channels envisaged around the waste rock dump at Karara minesite.



① AT TOE OF DUMP ON FALLING GROUND

③ AT TOE OF DUMP ON RISING GROUND WITH ROAD ON BUND



② AT TOE OF DUMP ON RISING GROUND

④ AT TOP OF PIT ON FALLING GROUND (SAFETY BUND)

NOTES:

1. CHANNELS ARE ASSUMED TO BE MAINTAINED DURING THE WORKING LIFE OF THE PIT, AND DEBRIS REMOVED FROM BASE.
2. BUNDS ARE TO BE CONSTRUCTED OF WEATHERED SITE MATERIALS, COMPACTED IN 200mm (APPROXIMATE) LAYERS, WITH ADDED WATER DURING COMPACTION.
3. DETAILS ARE GENERAL, AND MAY VERY FROM THE PLANS ACCORDING TO SITE-SPECIFIC REQUIREMENTS.

Figure 7.3: Surface Water Management Scheme – Containment Bunding around the Waste Rock Dump

8. RESIDUAL SURFACE WATER IMPACTS

8.1 SUMMARY OF IMPACTED AREAS

Figure 8.1 shows the potential areas of surface water drainage shadows caused by linear infrastructure impeding sheetflow. Sections 6 and 7 describe methods for mitigating the impacts of reduced flows in these areas but some residual impact is possible.

Figure 8.1 also shows areas where there is potential for natural surface water flows to be increased. These are principally where runoff from disturbed ground is diverted or pumped to settling ponds. During runoff events the capacity of the settling pond (nominally 20 years ARI) may be exceeded. This will result in the discharge of relatively greater volumes of water and sediment at the discharge point than would be the case prior to commencement of the mining operation.

8.2 SIGNIFICANCE OF RESIDUAL IMPACTS

The residual impact caused by surface water drainage shadow areas and by intermittent excess discharge from sediment settling ponds is not considered significant providing that the measures described in Sections 6 and 7 are implemented and ongoing monitoring of the potential impacts is carried out. If significant impacts are detected as a result of monitoring, corrective action should be taken.

8.3 MONITORING

Long-term monitoring options are described below to test the effectiveness of the adopted management measures and provide an early warning system of any adverse impact. To achieve this objective the following the following should be carried out:

- Determine if the rate of sediment transported within the minesite is increasing during the period of operation
- Determine if contaminants from the operation are being discharged into the catchment

A measurement of the mass of sediment deposited within the clay pans and downstream of the processing plant and an estimate of the total runoff during a specific period will provide a concentration of sediment transported in mg/m^3. The information will also provide a record of total sediment load. If this measurement is made before mining commences or within catchments with minimal exploration activity a comparison can be made between the existing situation and the mining phase of the operation.

To determine the mass of sediment deposited within a given period of time various methods should be assessed. Static sediment traps could be installed within the clay pans and downstream of the processing area so that sediment deposition depths can be monitored. Alternatively water and sediment could be sampled during the event either manually or using an auto-sampler and estimates of sediment and flow used to determine total sediment transported.

Sediment samples would be taken and analysed for concentration of likely contaminants. Concentrations should be monitored before and after the commencement of mining to assess any significant impacts.

An assessment of total runoff could be made following an event by measuring the average depth and area of accumulated water within the clay pan areas. Runoff downstream of the processing plant could be measured using a water level recording instrumentation within the defined channel. Alternatives for flood water level measurement include:

- Simple peak water level indicators installed along the axis of the channel.
- Level sensors such as pressure transducers installed above or below the channel bed
- Downward pointing ultrasonic or radar sensors

The water level recordings would need to be converted to discharge measurements using either measured calibration data or a slope area calculation or hydraulic model.

A continuous record of rainfall should be maintained at site. This would consist of a tipping bucket type gauge with a data-logger to enable the assessment of rainfall intensity.

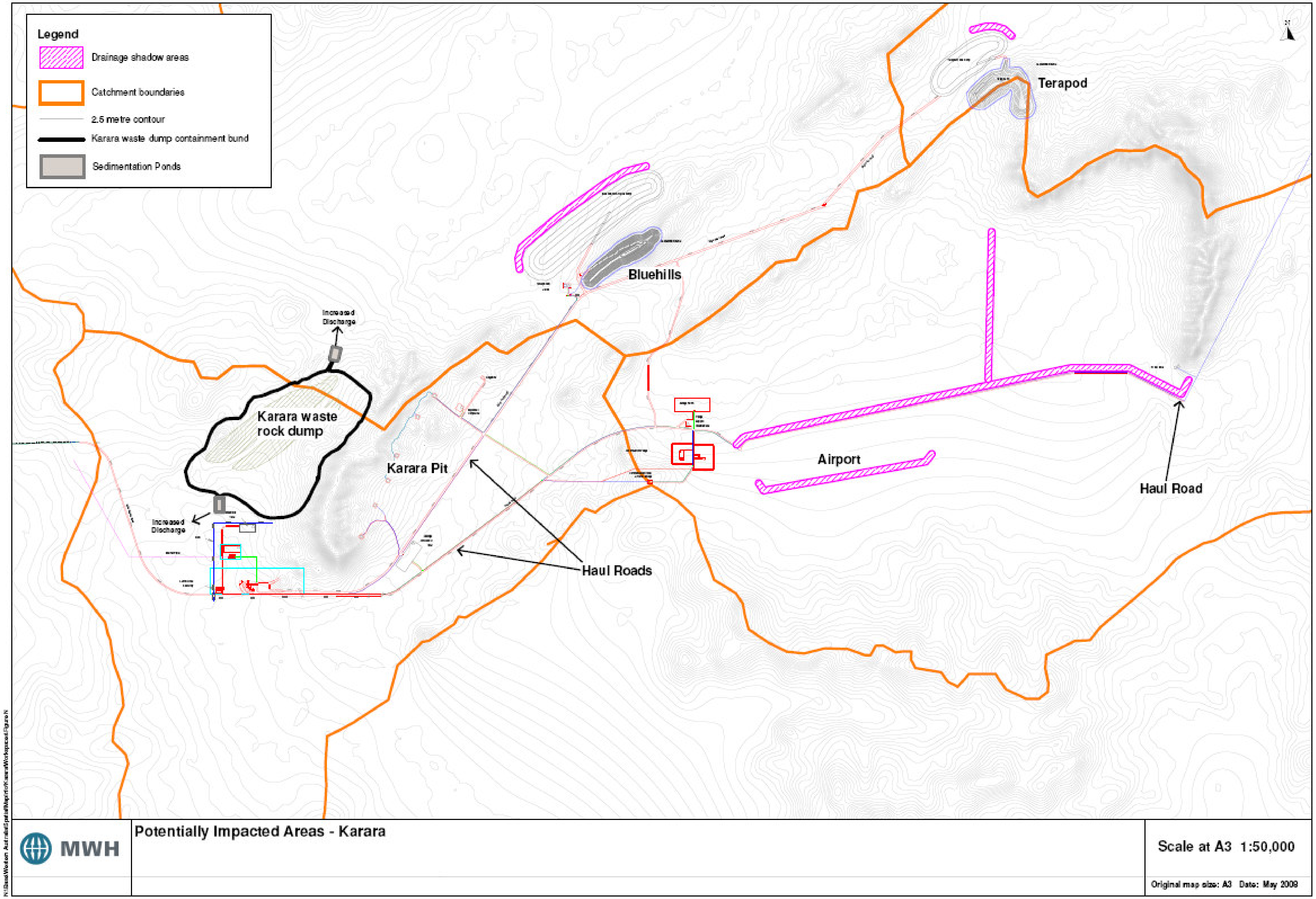


Figure 8.1: Potentially Impacted Areas

9. SUMMARY AND CONCLUSIONS

The main objectives of the investigation are to describe the existing surface water hydrology of the proposed minesite, assess the likely impacts of the operation and present options for mitigating those potential impacts.

Hydrological rainfall-runoff models were developed to determine runoff within the minesite catchments and the extent of water accumulation within internally draining clay pan areas to the north of the Karara mine site. Results of the assessment show that during a 100 year ARI event the maximum water level in storage area 2, directly north of the Karara minesite catchments, will reach 335m RL. This leaves 8m freeboard or about 170 million m^3 of storage available before this area would spill in to the Karara minesite catchments.

A hydraulic model of the drainage channel across which the railway and tailings storage facility will be constructed was developed. Results show that during a 100 year ARI event flows from the catchment will reach a maximum of 7.3 m^3/s. The proposed infrastructure designed to convey this flood from above the railway embankment to downstream of the TSF is considered adequate and will not cause excessive ponding or velocities.

A significant feature of the drainage within the project area is that all the catchments upstream of the Karara pit and processing plant are internally draining. The hydrological assessment indicates that when sufficient runoff occurs, there will be temporary water accumulation in the clay pan areas. When runoff is sufficient to fill the clay pan areas, floodwater will spill south west towards the Karara Ridge across a low divide and then to the south west past Karara Ridge in a restricted valley profile before turning due south in a broad valley towards Mongers Lake, located approximately 30 km to the south. It appears that a storm approaching the probable maximum flood would be required to cause these basins to spill south into the Karara minesite catchment.

Potential surface water related environmental impacts resulting from the mining operation include:

- Increased sediment runoff from disturbed ground and stockpiled materials associated with the mining operation.
- Modification and interruption of existing natural drainage channels resulting from the construction of the access and haul roads and development of mine pits and infrastructure.
- Discharge of excess water from mine dewatering.
- Release of contaminants.

The waste rock dump footprint stretches across a natural land saddle requiring at least two sedimentation ponds on the low points of the containment bund perimeter. The sizes of the sedimentation ponds are to be designed in accordance with the development of the waste rock dump site and when the sediment particle size distribution is determined for the waste rock material.

The processing plant and operations centre areas are a source of contaminants including hydrocarbons and debris from machinery and vehicles. Much of the contaminant load can be intercepted and treated during the “first flush” of a rainfall event through the use of sediment and grease traps installed in the hardstand drainage system.

Potential interruption of sheetflow may occur on gently sloping terrain, downstream of linear infrastructure such as access roads and the proposed airstrip. The installation of regular spreader culverts are proposed across such barriers. Further dispersion measures such as specially designed ditches on the down-slope side of the barrier could also be utilised to further reduce the potential for drainage shadows to be created.

10. RECOMMENDATIONS

It is recommended that rainfall, flow and sediment monitoring instrumentation be installed to collect information on runoff, rainfall, sediment load and contaminant concentrations at specific locations. The measurements should be carried out before and during mining operations and the results be used to test the validity of model output and provide an indication of any impacts of the mining operation. The results could also be used to calibrate the rainfall and hydraulic models developed during this investigation.

A Probable Maximum Flood assessment should be carried out to assess the effect of an extreme flood event on the stability of waste rock dumps. The assessment would also determine the ARI of the event that would cause accumulated water from the clay pan catchments to spill into the Karara minesite catchments and into Mongers Lake.

11. REFERENCES

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