Water and Environment

OPR RAIL DEVELOPMENT: SURFACE WATER MANAGEMENT

Prepared for	Oakajee Port & Rail
Date of Issue	16 October 2009
Our Reference	1088/B1/002a

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	Date	Revision Description
Revision a	16/10/09	Draft for Review by Client

	Name	Position	Signature	Date
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1 INTRODUCTION

1.1 BACKGROUND

Oakajee Port and Rail (OPR) is currently developing the Oakajee Port and Rail Development, which consists of:

- A deepwater port facility at Oakajee (north of Geraldton), and land based port and iron ore handling infrastructure necessary to link the rail to the port.
- Development of approximately 523km of rail infrastructure extending from the Oakajee Port to the mining operations at Jack Hills, with a spur linking to the existing WestNet to Mingenew Rail, and another to Weld Range.

A Transport Options Study conducted in 2005 considered a number of potential rail routes. Following this study, several designs were put forward by OPR. Through elimination, based on environmental, heritage, economic, engineering and community factors, a single route was put to the WA government for consideration. Following a competitive tender process, OPR and the WA Government signed a State Development Agreement in March 2009 for the construction of the rail.

The proposed rail development will provide iron ore projects within the region access to the Oakajee Port for export, in turn providing benefits to the local area. OPR seeks to develop the project on a commercial basis, to promote open access to users of the port and rail infrastructure, and in particular to service mining operations in the Midwest, Gascoyne and Pilbara regions.

The location of these projects is shown in Figures 1.1, and 1.2.

1.2 OBJECTIVES AND SCOPE

This surface water assessment considers surface water impacts in relation to the main flow paths (rivers and creeks), as well as surface water protective measures required for the proposed development areas. The scope of work includes:

- Review published maps, air photos and proposed railway alignment plans;
- Review published reports and data on the surface water resources in the study area;
- Liaise with the OPR railway design engineers (as required);
- Characterisation and description of baseline drainage conditions (regional and local);
- Define surface water drainage patterns / characteristics along the railway;
- Preliminary assessment of the potential project development impacts on the natural drainage systems and sensitive vegetation communities;
- Strategies to minimise project impact on the natural drainage systems and vegetation;
- Prelim. assessment of the potential drainage systems impacts on proposed infrastructure;
- Site visit (14-17 September 2009);
- Liaison with Departments of Water, Environment and Conservation, and Agriculture and Food, and the Northern Agricultural Catchments Committee;
- Surface water management information for the proposed development areas (construction and operation);
- Completion of the surface water management report, suitable for inclusion as an Appendix to the project PER.

1.3 DEFINITIONS

- 100 year ARI flood - The flood having an average recurrence interval (ARI) of 100 years. It has a 1% chance of occurring or being exceeded in any one year, and at least a 50% chance of being experienced at least once in the average life span of a person. The 100 year ARI flood has been generally adopted in Australia and overseas as the basis for floodplain management planning.
- Floodplain - The portion of a river valley adjacent to the river channel which is covered with water when the river overflows its banks during floods. The term also applies to land adjacent to estuaries, which is subject to inundation during floods.

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PROJECTION:	MGA94 Z50
SCALE:	1:10,000,000

LEGEND

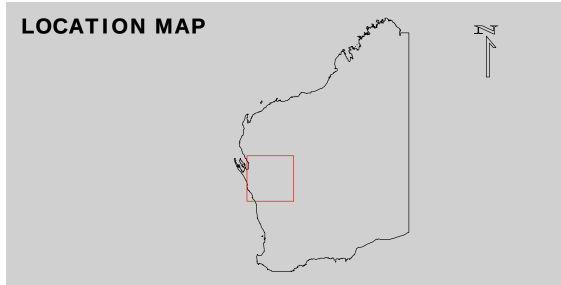
- ● Towns
- Roads
- Proposed Railway

FIGURE 1.1
GENERAL LOCATION PLAN

0 200 400 km

Location: F:\Jobs\1088\MapInfo\Figure1.1_Location Map.wor

LOCATION MAP



LEGEND

- ● WA Port Authority Port
- ★ Iron Ore Mine
- Major Roads
- Minor Roads
- Freight Railway
- River

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FIGURE 1.2
OPR RAIL ALIGNMENT

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Location: F:\Jobs\1088\MapInfo\Figure1.2_OPR_Rail_Alignment.wor

2 THE PROJECT

2.1 GENERAL

The rail route runs generally in a north easterly direction from Oakajee to Jack Hills. As the rail extends away from Oakajee, the land use changes from predominantly horticultural and orchard areas or hobby farms, to broad acre cropping, to cattle or sheep pastoral stations in the more arid areas.

OPR proposes to construct a multi-user rail facility to service the iron ore industry in the region. The trains will be up to 200 wagons and 2.2km in length, with one train movement about every 4 hours (ecologia Environment, draft).

The proposed route (OPR) extends from the western boundary of Reserve 16200 near the North West Coastal Highway (approximately 4.5 km from Oakajee), 523 km to the mining operations at Jack Hills including the rail loop, with a 21km spur to the WestNet system and a 31km spur to Weld Range.

The typical width of disturbance along the railway corridor would be 55-60m. Two large quarries are proposed to meet the requirements for the railway ballast supply.

Access would initially be a 20m wide haul road developed for rail construction activities. For operation and maintenance purposes a permanent rail maintenance access track of 10m width will be retained.

The rail chainage figure refers to the distance in km from the Oakajee Port reference point.

2.2 EARTHWORKS

The earthworks for the railway will require balancing cut to fill along the rail route (where practical), to minimise the creation of spoil or the need to import fill. However in largely flat terrain, this is not fully practical, and over 50% of the materials to be placed into railway embankments will be sourced from borrow areas.

Borrow areas are therefore required at regular intervals along and adjacent to the rail corridor, at a spacing not exceeding 4km. The number and size of borrow pits developed within each borrow area will vary, and will depend on the volume of borrow material required at each section of the railway formation.

Ballast will be sourced from quarries.

Concrete railway sleepers are expected to be manufactured at existing Western Australian sleeper plants and/or at a new sleeper factory to be established in Geraldton.

2.3 BRIDGES AND CULVERTS

The rail alignment will require a number of bridges and culverts across defined water courses. Including 'environmental' culverts, approximately 1.5-2 culverts per km of rail will be required (CEJV / BGE).

The current North West Coastal Highway will be realigned to the east, and a vehicular bridge constructed to direct traffic over the proposed railway.

3 ROUTE DESCRIPTION

3.1 GENERAL

Selected photographs along the route are shown in Appendix A. The overall rail route is shown in Appendix B1. The following 6 sheets in Appendix B demonstrate the relationship between the rail alignment and broad scale surface water features.

3.2 NW COASTAL HIGHWAY TO BINDOO HILL NATURE RES. (CH15 - CH90)

This section of the rail route is shown in Appendix B Sheet 1 of 6.

The rail route heads generally east from North West Coastal Highway (CH15), through undulating to hilly farmland and bushland and turns south in hilly terrain along the western side of the Moresby Range Nature Reserve (refer photo Appendix A1). The route then turns southeast across spurs in heavily undulating terrain through the Wokatherra Gap (CH21), where it follows the route of White Peaks Road.

The rail route continues in more gently undulating cleared farmland and swings south to cross the Chapman River at CH26.4 (proposed Bridge No 1).

The route then turns east again and runs up the Chapman River East valley. At CH35, the route crosses the river (proposed Bridge No 2). The route continues across undulating farmland, parallel to the south bank of the Chapman River East, and again crosses the river (CH46.6, proposed Bridge No 3).

The route continues east, crosses a large tributary to the Chapman River East, and then passes into the Greenough River catchment, in the generally gently undulating farmland to the Greenough River (CH80, proposed Bridge No 4).

The rail route then generally follows the north bank of the Greenough River, to a point 2km south of the Bindoo Hill Nature Reserve, where the spur line to the Westnet State rail system branches south toward the Geraldton to Mount Magnet Road, following Kockatea Creek (a tributary to the Greenough River) southward in generally flat to undulating cleared land. It links to the existing Westnet State rail system near the Tenindewa Road intersection with the Geraldton - Mount Magnet Road.

3.3 BINDOO HILL NATURE RES. TO CARNARVON MULLEWA RD (CH90 - 160KM)

This section of the rail route is shown in Appendix B Sheets 1/2 of 6.

The rail route passes through cleared farmland (refer photo Appendix A3), with cross drainage generally north towards the Greenough River, although distinct flow paths are generally not apparent. The rail route crosses the Greenough River again at CH111 (proposed Bridge No 5), just downstream of a junction with a major tributary.

The route continues along the Greenough River in flat to undulating cleared farmland, and some bushland. It passes just south of the Wandana Nature Reserve. Cross drainage in this area is generally southward toward the Greenough River, with a lack of distinct flow paths.

The last of the cleared farmland occurs at CH135, when the corridor passes into uncleared pastoral land. The alignment crosses proposed Bridge No 6 at Bangemall Creek at CH148, which flows south out of the DEC Estate. The alignment continues another 12km through flat mulga shrubland to the Carnarvon Mullewa Road (CH160).

3.4 CARNARVON MULLEWA TO BERINGARRA PINDAR RDS (CH160 - CH215)

This section of the rail route is shown in Appendix B Sheets 2/3 of 6. No bridge crossings are proposed in this section at this stage.

The rail route crosses the Carnarvon Mullewa Road about 3km north of the Greenough River floodway (refer photo Appendix A4), and then continues northeast to the north of Greenough River, in flat mulga country, passing through the southern end of the ‘Former Leasehold ex Woolgorong’ over about 8km.

At CH193, the route encounters the east west running vermin proof fence (refer photo Appendix A5).

The end of the section lies about 6km to the north of a flood sign erected by the Shire on the Beringarra Pindar Road (refer photo Appendix A6). The sign indicates historical large scale flooding in the area.

This section generally consists of flat wash plains with predominantly sheet flow.

3.5 BERINGARRA PINDAR RD TO YALGOO RD NORTH (CH215 - CH298)

This section of the rail route is shown in Appendix B Sheets 3/4 of 6. No bridge crossings are proposed in this section at this stage

From the Beringarra Pindar Road, the route continues north-east through flat mulga shrubland. The route enters the Sanford River catchment, and surface drainage direction changes, approaching the route from the south. The largest creeks are McNab Creek CH240, Kunbun Brook CH260 and Woolgarong Creek CH297. Again, this section generally consists of wash plains with predominantly sheet flow.

3.6 YALGOO RD NORTH TO BERINGARRA CUE RD (GAP) (CH298 - CH400)

This section of the rail route is shown in Appendix B Sheets 4/5 of 6.

From Yalgoo Road North in Meka Station, the rail route continues through uncleared flat mulga shrubland (refer photo Appendix A7). It enters the Sanford River catchment, where drainage is generally northward towards the river. The route is bridged at the Sanford River (CH308, proposed Bridge No 7), 5km east of Meka Station homestead.

After the proposed bridge, drainage impacts the route from the north. Ilkabiddy Creek (CH341, proposed Bridge No 8) has headwaters about 25km north of the proposed crossing.

For the last 17km of the section, the rail route leaves Sanford River catchment, and runs along the south side of the Weld Range. Run-off from the ridges is toward the south, and into Berring Creek, which generally runs south - east in parallel with the Beringarra Cue Road

3.7 THE GAP TO JACK HILLS (CH400 - 530KM)

This section of the rail route is shown in Appendix Sheets 5/6 of 6.

This section of rail travels generally north from The Gap (CH400) in Weld Range (through which the Beringarra Cue Road / Jack Hills haul road) also passes (refer photo Appendix A8). The terrain in The Gap is flat to undulating. On the north side of The Gap, the rail alignment crosses the eastern side of the lake, which has a large surrounding internal drainage catchment, and is reported to flood in large rain events.

On the north side of Weld Range, a proposed rail spur (CH410) extends 31km to Weld Range, running about 7km north of a steep ridge line.

The route to Jack Hills then heads north in flat terrain, running east of the Beringarra Cue Road. Drainage is west flowing across the route towards Pindarban / 12 Mile Creek. At CH520, the rail route passes through a ridge line and swings westward to finish at the Jack Hills rail loop (about 4km south of the Murchison River).

4 HYDROLOGY AND LAND USE

4.1 RAINFALL

4.1.1 GENERAL

With an area of over 472,000km^2, the Midwest region covers 20% of WA. The region extends along the west coast from Greenhead in the south, to beyond Kalbarri in the north, and more than 800 km east into the hinterland. The Midwest accommodates three broad climate types, ranging from the Mediterranean climate of the coastal belt, through to the semi-arid and desert climates found in the interior. Climatically, the coastal parts of the region represents a transitional zone between the well watered, forested, temperate regions of the south, and the relatively arid, harsh, semi tropical regions to the north.

The controlling climatic feature in summer is a subtropical belt of high pressure which directs hot dry easterly winds over the region. During winter, this belt moves northward, allowing cold fronts and associated low pressure systems to direct cool moist maritime winds over coastal areas of the region (BOM 2009).

4.1.2 MEDITERRANEAN CLIMATE

The Midwest coast experiences a typical Mediterranean climate, characterised by hot dry summers and mild wet winters. The higher and more reliable rainfall occurs nearer the coast, as proximity to both moisture sources and reliable rain-producing weather systems improves and supports more intensive farming pursuits, and higher population densities (BoM 2009).

Thus Geraldton on the coast has an annual rainfall of about 450mm (compared with, for example, Mullewa 85km inland, which has an annual rainfall of 337mm.

Coastal areas receive the bulk of their rain from cold fronts and associated low-pressure systems from the southwest during winter. A marked concentration of precipitation falls between the months of May and September. Historically, July is the wettest month.

4.1.3 SEMI-ARID CLIMATE

As distance increases northwards and eastward, the rainfall decreases inland to 200-300mm per annum, broad acre farming reverts to pastoralism and finally desert. This supports a smaller population base and subsequently fewer, more widely spaced settlements. The semi-arid climate is transitional between the coastal and arid desert climates.

From Mullewa (annual rainfall 337mm), the rainfall further to the east continues to decrease - Yalgoo 259mm, Mt Magnet 234mm, and Cue 231mm 350km from the coast. The railway route extends a maximum of about 360km from the coast.

Meekatharra and Wiluna, 450km and 620km from the coast, have annual rainfalls of 235mm/240mm respectively.

Rainfall also tends to be unreliable and erratic, and falls on few days as distance increases inland. Coupled with hot summers, this generates higher evaporation rates. Most of the rainfall falls through the first half of the year as a result of summer thunderstorms or tropical cyclones, but is highly variable. At times, these weather systems can also be destructive. These areas are under the dominance of the subtropical high pressure belt for most of the year, and lie far from potential moisture sources. The cold fronts, which bring rain to the coast in winter, are not strong enough to penetrate very far inland, resulting in dry winters.

4.2 TEMPERATURE

Temperature characteristics are heavily influenced by proximity to the ocean. On the coast, temperatures are moderated by the ocean, resulting in cooler summers and warmer winters than locations inland. This is reflected in the annual temperature range (the difference between the average temperature of the hottest and coldest months). Geraldton has an annual temperature range 11.3°, Mullewa 13.2°, Meekatharra 18.2° and Wiluna 18.3°.

Coastal areas tend to be the hottest in February (the average daily maximum temperature for Geraldton is 32.4°). January tends to be the hottest month for inland areas with Mullewa averaging 36.6° maximum daily temperature, and Wiluna 38.3°.

Coastal areas on average are coldest in August. Geraldton has an average minimum temperature of 9° (and an average maximum temperature of 20°). Wiluna experiences its coldest month in July, with an average minimum temperature of 5.8° (and an average maximum of 19.3°).

The diurnal temperature range (the difference between the daily maximum and minimum of locality) also tends to increase as distance inland increases again, reflecting the moderating influence of the ocean. The arid desert climate to the east is characterised by hot dry summers and mild dry winters.

4.3 EVAPORATION

Mean annual pan evaporation rate is about 2500mm at Geraldton and 3500m at Meekatharra. Daily summer evaporation figures over the region range from 11-16mm/d in January , to typical winter evaporation of 3mm/d in July.

There is a general surface water deficiency over most of the region for much of the year. For this reason, groundwater resources are particularly valuable, as the basis of most commercial and other activity within the region.

4.4 LAND USE AND VEGETATION

Land use in the Midwest region is largely dependent on the combination of climate and soil type, and can be divided into three zones: a cropped coastal strip, central rangelands, and the vacant Gibson desert in the northeast. Arid shrublands make up the vast majority of vegetation types encountered in this region (Midwest Development Commission).

The rail corridor traverses approximately 100km of freehold agricultural lands and 400km of uncleared, pastoral allocations.

Due to the lack of rainfall, the region exhibits absence of tall forests, and most vegetation is adapted for dry climates. Most woodland has has been cleared for agriculture in the freehold section, although remnants are found in nature reserves and some private property. The coastal strip has adequate rainfall for cereal crops and intensive pasture, and sheep, meat and wool production. This area has a well-developed infrastructure and contains most of the region's conservation areas. Native vegetation is highly fragmented and limited to remnant patches, predominantly on rocky uplands, riverine and coastal areas. Many patches are heavily grazed by sheep.

In the central range lands, annual rainfall is too low and unreliable for cropping. The main land use is pastoral, and the area consists largely of semi-arid acacia shrubland dominated by mulga and cotton bush. Although almost entirely uncleared, the pastoral leases traversed by the corridor vary significantly in vegetation condition due to heavy browsing pressures.

The far east of the region, has unreliable low rainfall, less than 200 mm per year, and consists of vacant crown land. Here the water sources and vegetation cover are too limited to sustain grazing.

Long stretches of the route cross broad flat plains, that may not have significant surface drainage channels, yet command a large catchment area. The landscape often appears almost flat, but there is usually a very gentle slope (e.g. 1 in 300) allowing water to flow slowly across the contour after rain. Vegetation on these soils is fairly scattered, but is sometimes denser, where vegetation is able to intercept run-off water from higher up the slope in ‘washes’ which carry more concentrated water flow.

The main soils are shallow loams, formed by slow weathering and deposition, normally stable and fairly shallow (typically 150 to 800mm thick), and overlays a red brown hardpan (coffee rock or Murchison cement), sometimes visible when exposed by erosion. Hardpan plains often adjoin stony hardpan plains with a surface covered with few stones and pebbles; or granitic shrubland on the higher side of the gentle slope, and sandier wanderrie country on the low side.

5 WATER RESOURCES

5.1 GENERAL

The water resources of the Midwest can be described in terms of surface and ground water features. Surface drainage features can be further divided into two broad groups: the external drainage provided by the catchment areas of rivers that flow into the ocean, and the internal drainage of water courses that drain into a number of salt lakes.

To the east of a line running generally north south between Meekatharra and Wiluna, lies the area of the internal drainage. Here, creeks and internal rivers drain surface water into numerous salt lakes.

External surface water drainage is provided by a number of intermittent rivers. The rail alignment crosses a number of episodic rivers and creeks including the Greenough, Sanford and Chapman Rivers.

Jack Hills is located in the upper reaches of the Murchison River, which is the second longest river in Western Australia. Other major rivers draining this area into the Murchison River include the Sandford and Roderick Rivers. The Greenough Basin to the south is characterised by the larger Chapman, Greenough and Irwin Rivers, together with other relatively small waterways that discharge directly to the ocean. Most major streams have brackish flows, although some small spring fed streams are fresh.

Streamflow is directly in response to rainfall and flows are ephemeral. Streamflow in the smaller creeks is typically of short duration, and ceases soon after the rainfall passes. In the larger rivers, which drain the larger catchments, runoff can persist for several weeks and possibly months, following major rainfall events, such as those resulting from tropical cyclones.

5.2 MURCHISON RIVER

The catchment area of the Murchison River (which occurs almost entirely within the Midwest region) covers an area of about 82,000km^2. Extending about 550km inland and beyond Meekatharra, this is the largest most significant river catchment in the region. The river runs 4km to the north of the proposed Jack Hills rail loop. The catchment is made up of an extensive drainage network. Large river gums exist along the river, although they are only present in the immediate vicinity of the main river channel, and do not generally extend into the flood plain.

From Jack Hills, the Murchison River flows west, then southwest, to its confluence with the Roderick and Sanford Rivers. The proposed rail alignment crosses the Sanford River tributary 160km south of Jack Hills. The river discharges into the ocean at Kalbarri, 110km north of Oakajee.

Rain generally only falls in the upper basin during summer cyclones, so for much of the year, the Murchison River does not flow, having dry sandy river beds with occasional permanent pools. The eastern reaches of the catchment contain large chains of salt lakes, which flow only intermittently. Water quality during floods is fresh, but turbid, while low flows are brackish and saline.

5.3 CHAPMAN RIVER

The Chapman River rises on the Victoria Plateau east of Northampton, and flows in a southerly direction. Near Geraldton, it descends to the coastal plain, turning to the west-northwest and discharging into the ocean at Bluff Point just north of Geraldton. It is about 80km long, and drains farmlands of the Waterloo Range and Chapman Valley, where rainfall is typically above 400mm per annum. Most of the Chapman River catchment consists of cleared agricultural land. The river generally does not flow in summer, but always flows in winter. From the mouth to about 1.5km upriver, the river is estuarine and always contains some water. The mouth itself is usually closed by a sandbar, but this opens at the onset of heavy flow, and closes after flow has receded. When the sandbar is open, sea water enters the estuary, mildly affecting its salinity.

5.4 GREENOUGH RIVER

The Greenough River is much longer than the Chapman River at about 250km in length. The rail alignment follows this river for a significant length. The headwaters are situated about 180km inland near Woojalong Hills, where average rainfall is less than 250mm and most of the natural vegetation remains. It runs in a south westerly direction through deep valleys for ~340km, passing through the Waterloo Ranges before descending to the coastal plain. The Greenough River runs through agricultural areas of the Victoria Plateau. A few kilometres from the ocean, it is obstructed by dunes, running along a dune swale parallel with the coast for about 35km before finally discharging into the ocean at Cape Burney, about 9km south of Geraldton. The lower reaches of the Greenough are estuarine. The river mouth is barred from the ocean by a sandbar that breaks only in periods of strong flow. Once open, it usually remains open for several months. The river is dry most of the time, but has a number of permanent pools, such as Bootenal Spring.

5.5 STREAMFLOW GAUGING STATIONS

Within the Greenough River catchment, the Department of Water (DoW) has gauging stations as follows:

- 701008 Pindarring Rocks (furthest upstream located on Carnarvon Mullewa Road);
- 701012 Mitthutharra;
- 701011 Eradu;
- 701002 Karlanew Peak (furthest downstream).

Within the Chapman River catchment, the relevant gauge is 701007 Utakarra.

The location of the gauging stations is shown in Appendix B Sheet 1. It is noted that the median creek and river flows are generally very small or zero - most of the time the creeks are not running.

6 RAINFALL INTENSITY FREQUENCY AND DURATION

6.1 AUSTRALIAN RAINFALL AND RUNOFF

In order to compute design flood flows for ungauged catchments, a rainfall intensity and frequency and duration (IFD) relationship is required for the project area. The document "Australian Rainfall and Runoff" (ARR, revised 1998) has been produced by the National Committee on Hydrology and Water Resources to provide information on design flood estimation and describes the procedures for determining IFD design rainfall information. The IFD determination requires nine basic parameters obtained from Volume 2 of Australian Rainfall and Runoff.

Separate IFD relationships were determined for Oakajee, a mid point such as the Sanford River Crossing and Jack Hills. Even though the annual rainfall decreases in an inland direction, the design rainfall intensity at each of the locations is approximately the same. For example, the 100 year ARI rain intensity for a 1hr duration, is 45-50mm/hr; and for a 6hr duration is 13-16mm/hr (generally slightly higher at Jack Hills). The largest rainfall intensities are associated with tropical cyclones.

Typically, about 15-20mm of rain is sufficient to cause difficulties in vehicular movement on un-made or low standard roads.

6.2 CYCLONE CLARE

Significant rain fell on the upper Greenough River catchment in the wake of disintegrating Tropical Cyclone Clare from 11-13 January 2006 (Australasian Hydrographer, May 2009). Falls of over 100mm occurred over large areas, with 24 hour falls (to 9am 12 January) of 175mm at Narloo and 129mm at Yuin station (through which the proposed rail alignment passes). At the time of the event, there were no Bureau of Meteorology (BoM) rain gauges in the outer part of the Greenough catchment, where the heaviest falls occurred.

The 24 hour falls are equivalent to 4.2-7.3mm/hr and commensurate with a 20-500 years ARI.

A flood sign erected on the Beringarra - Pindar Road by the Murchison Shire Council indicated that these same rainfalls fell over a 12 hour period (129mm at Yuin Station, 105mm at Tardie Station, 175mm at Narloo Station and 145mm at Parkers Mill, 1 km west of the sign). On this basis, the rainfall intensities were 9-15mm/hr, commensurate with a 100-1000+ year ARI.

The Yuin Station proprietor (pers. comm) indicated that 93mm fell at Yuin over 3.25 hours (9pm on 11 January to 12:15am), and ~125mm fell at Narloo north-east of the sign in this same time (i.e. an average 28.6-38mm/hr). These intensities would be commensurate with an ARI exceeding 1000+ years.

6.3 CYCLONE DOMINIC

Cyclone Dominic hit Onslow on 27 January 2009 and 238mm of rain fell in the 24 hours to 9am on 28 January (the highest daily total in 34 years). The system was downgraded to below tropical cyclone intensity on the afternoon of 27 January. The weakening system caused heavy rainfall and flooding in the northern part of the Murchison Shire with a rainfall of ~175mm (over 2 days) in the north eastern part of the Shire with associated extensive damage to the road network.

7 FLOOD ESTIMATION

7.1 FLOOD ESTIMATION

ARR provides information on design flood estimation. However, it is widely recognised that due to the relatively sparse and short stream gauging records in this area (upon which the estimation methods are based), the methods do not give reliable flood peak discharge estimates. Due to these shortcomings, estimation procedures should be supplemented by other information available, and consideration of previous hydrological work on rail lines in the Pilbara Region, in particular. ARR divides Western Australia into various regions for the purposes of flood estimation. The coastal third of the rail alignment lies in the "Wheatbelt Region", while the remainder to the east lies in the North-West Arid Interior (which includes the Gascoyne area).

Wheatbelt Region

ARR recommends the use of the Rational Method and Index Flood Method as most appropriate for the Wheatbelt Region. The Rational Method calculates the 10 year ARI flood discharge, which can then be factored for larger or smaller flood events by "frequency factors". The Index Flood Method calculates the 5 year ARI flood discharge which can similarly be factored. The accuracy of the flood estimates is low and the SEE (standard estimate of error) for the methods is high (the actual flow may reasonably be considered to lie within a range of 70-150% of the calculated estimate). Both methods (particularly the Rational Method) are considered to overestimate the flows.

The RORB runoff routing method is a general runoff and stream flow routing program used to calculate flood hydrographs from rainfall and other channel inputs, and is believed to be the most reliable method for flood discharge estimation, when using ARR parameters such as the Kc factor, and calibrated runoff coefficients for continuing rainfall losses. It is generally anticipated that flood discharge estimations produced from RORB would be most accurate, and recommended where the computational effort can be justified. The Index Flood Method is considered to provide a reasonable (but less accurate) estimate of the flood discharge.

The regional relationship provided in ARR (Book 5 Section 3.6.2) for the routing parameter Kc is the same for the Wheatbelt and Arid Interior (in the absence of data for the derivation of Kc) as well at the North West (Pilbara) and Kimberley regions. The design loss rates for Western Australia (Book 2 Section 3.5) are initial / continuing loss models for both the Wheatbelt, North West and Arid Interior methods.

Gascoyne / Arid Interior

The majority of the rail alignment lies in the Gascoyne (which lies north of Geraldton and includes Carnarvon and Meekatharra). ARR notes that there are very few data available in the Gascoyne region and firm recommendations can not be made. It notes that the magnitude of flood events in this region are considerably less than in the Pilbara. For the Arid Interior, ARR again noted that there are virtually no data available in this region and firm recommendations cannot be made. It recommends that the Rational Method for Wheatbelt catchments be adopted.

ARR suggests that runoff routing should be used when the computational effort is justified, and stated that RORB (or other types of runoff routing models) should give better flood estimates than the Rational and Index Flood Methods.

7.2 REVIEW OF CATCHMENT HYDROLOGY

7.2.1 GENERAL

For culverts designed for a 50 year ARI flood event, the probability of the flood event being equalled or exceeded (for an individual culvert / bridge) is 33% over 20 years and 45% over 30 years. With the many thousands of railway culverts in the Pilbara designed for a 50 year ARI flood, equally thousands should have been surcharged beyond their design capacity during the last 20 to 30 years. This does not appear to have occurred (Flavell, 1996) and generally indicates that design flood estimates based on ARR have been overly conservative.

Various flood estimation methods have been used to size railway culverts railways. For the Mt Newman to Port Hedland railway (GHD-Dwyer, 1981), the study defined three flood estimation procedures used for differing ranges of catchment sizes, as follows:

- 0 - 35km², Rational Method (ARR-1977)
- 35 - 250 km², Regional Flood Frequency Procedure (a derived correlation method)
- 250 km², Runoff Routing Method (RORB)

A study for the Marandoo to Homestead Creek Railway (1996) estimated catchment discharges for catchments less than 40km², using the 1977 Rational Method and RORB for other larger catchments.

In general, the 1977 Rational Method, used to size those culverts, has therefore provided satisfactory results, in that there have been few, if any, washouts of culverts sized using this method, but it follows that the lack of washouts is due to conservative (over) estimates of design floods.

Methods that have been previously considered for railway waterway crossing design include RORB, the Rational Method (ARR-1998), the Index Flood Method (IFM, ARR-1998) as described above; as well as the Index Flood Method (using the Q20 estimate as an estimate of the Q50 flow) and the Rational Method (ARR-1977).

7.2.2 ARR-1998 METHODS (RATIONAL METHOD AND INDEX FLOOD METHOD)

ARR recommends the use of the Rational Method and Index Flood Method for the Wheatbelt region (and by default for the arid interior). Both of these methods use parameters derived from streamflow data from the Wheatbelt region. However, this data has been collected for few catchments, and the data base typically has a short record and is poorly rated for large flows.

The Rational Method, due to its method of derivation is not recommended, as it is considered to greatly over-estimate peak flows for small to medium sized catchments. The Index Flood Method is generally considered the better of the two methods, although estimated flows are also considered over-estimated.

7.2.3 ARR-1977 METHOD (RATIONAL METHOD)

Prior to flood estimation procedures based on gauging data from the region (such as the 'probabilistic' Rational Method in ARR 1987), the Rational Method outlined in the 1977 edition of ARR has been used as the basis for flood estimate procedures on small catchments on numerous occasions to design waterway structures. This method is a 'deterministic' rational method, not based on gauging data or a statistical approach (as recommended in 1998 ARR), but on average values obtained for individual storm events and experience in regions other than Western Australia (Flavell, 1996).

Previous analysis indicated that the 1977 Rational Method gives similar 50 year ARI flood estimates to the Index Flood Method, but on flatter slopes, the ARR 1977 Rational Method tends to give lower design flood estimates (since the Index Flood Method does not include a slope parameter).

7.2.4 RORB

The RORB model requires a greater amount of detailed calculation, and has not generally been used for smaller catchments. In the Pilbara for example, the Index Flood Method and RORB generally provides similar discharge estimates (when using the ARR suggested initial / continuing loss rainfall coefficients), with the Rational Method estimates higher.

Based on previous work undertaken in the Pilbara (Dufty 1992, Flavell 1996), RORB using the "proportional loss" or "runoff coefficient" (RoC) approach for rainfall losses is preferred for that region. With the same ARR derived routing parameters (Kc and m set as constants for the model), and rainfall runoff loss parameters set as proportional losses (as derived by Main Roads WA), then RORB (RoC) gives lower peak discharge results than the Index Flood and Rational Methods.

These methods could usefully be applied in the Midwest, with some research.

7.2.5 CONCLUSION

The RORB runoff routing method is believed to be the most reliable of the methods considered for estimating catchment discharges, when using the runoff coefficient approach. Noting that, due to its time consuming complex nature, it is generally not warranted for use on smaller catchments, comparisons can be drawn between the results of simpler-to-apply methods when compared to the RORB - RoC method. Studies can be done to confirm or modify these findings for the Midwest.

7.3 SHEET FLOW

All flood discharge estimation procedures are based on the presence of a defined creek line. There has been very little research into sheet flooding in Australia or overseas and no small catchments subject to sheet flow are gauged in WA.

The (raised) railway embankment will cross flat terrain, and would require substantial culverting to reduce runoff shadowing, and pass sheet flows. However, the flood estimation procedures described above assume the presence of defined creek systems carrying the bulk of the runoff to the point of interest, as opposed to a sheet flow.

Sheet flooding results in lower flood peaks than predicted by the methods above. There is a lack of real data on which to base a method of flood estimation for flat catchment areas (refer Flavell, 1996). There will be a longer overland flow time or time of concentration for sheet flow, compared with flows in a catchment with a defined channel. Water which is temporarily stored, is the depth of water necessary for overland flow to occur (i.e. the volume of water in motion over the land) and is referred to as detention storage (relatively large compared with steeper catchments with a defined stream system) and reduces the flood peak.

Similarly, the process of infiltration has more time to affect rainfall excess, resulting in reduction of the volume of runoff and further reduction of the flood peaks and required culvert sizes.

In addition, available storage behind the rail embankment is potentially high in flat terrain, similarly reducing culvert waterway opening requirements.

In general, available flood estimation techniques will overestimate design sheet flow flood peaks.

8 SIGNIFICANT FLOOD EVENTS

The greatest rainfalls and flooding results from tropical cyclones.

In late January 2009, Cyclone Dominic caused widespread storms and flooding in the area. The weakening system caused heavy rainfall and flooding in the northern part of the Murchison Shire, with extensive damage to the road network. As a result the Beringarra-Cue Road and Yalgoo-Mt Magnet Road were closed to some traffic, including the Jack Hills heavy haul trucks. All airstrips in the area were closed and operations at Jack Hills temporarily suspended. The rainfall was less intense than that associated with Cyclone Clare and as such, flood impacts were less, although still extensive.

Cyclone Clare dumped significant rainfall on the upper Greenough River catchment from 11-13 January 2009 (Australasian Hydrographer, May 2006). Falls of over 100mm occurred over large areas, with higher falls recorded locally.

Two houses in Meekatharra were flooded with 150-200mm of water above floor level. Heavy rain in the headwaters of the Greenough River flooded various locations along the river, including Yuin Station (through which the proposed rail alignment passes). Yuin homestead was flooded with 100mm of water - this flood was 340mm higher than the previous highest water mark at Yuin, since records commenced over 100 years ago. The house was surrounded with water the next day from about 4am to 4pm.

The Greenough River flood warning network consisted of two gauging stations installed in the 1970s (Karlanew Peak and Pindarring Rocks) and two sites installed in 1998 (Eradu and Mittutharra). The tele-metered rain gauges were situated at Pindarring, Mittutharra and Karlanew, but were not situated in the areas where major falls occurred.

On the morning of Friday 13 January, the telemetry failed at Pindarring (the most distant of the Greenough gauging stations) due to flood damage (on the floodway on the Carnarvon Mullewa sealed road). The crossing was dry at 8am that morning, and peaked at about 130pm with 4.4m depth of water.

On Saturday 14 January, the Greenough River rose 3.3m between 320pm when dry to 355pm (95mm per minute) at the Tenindewa-Yuna crossing (fairly close to the Mittutharra gauging station). The final peak depth was 6.9m at 1015pm that night.

As a result of Cyclone Clare, Murchison Shire Council erected a number of flood signs throughout the shire to make people aware of the flood levels that occurred. A flood sign on the Beringarra - Pindar Road (located about 6km south of the proposed rail centreline, and 7km north of the Yuin homestead) indicates the flood level (debris in the trees) from the nearby 17 Mile Creek. The sign says:

> ***Record Flood Level***
>
> *11 January 2009*
>
> *Steady rain from ex-tropical cyclone Clare over a nine hour period ending with three hours of severe storms from 9pm to midnight caused extensive flooding over much of Yuin (Station). 32km of vermin barrier fence and 37km of internal and boundary fencing was flattened with 10km of this damaged beyond repair. Road damage was extensive.*
>
> *Rainfall recorded over the 12 hours*
>
> *Yuin 129mm Tardie 105mm Narloo 175mm*
>
> *Parkers Mill - 1 km west of here - 145mm*

At the location of the sign, the catchment commanded was a large flat area (typically 0.3-0.5% slopes) of about 120km^2. The flood depth of 1.5m indicated by the sign at that point (in what is basically a sheet flow area) is indicative of massive flooding.

As discussed above, the rainfall intensities from ex-tropical Cyclone Clare are estimated to have had an ARI in excess of 1000 years. As such, flooding of this magnitude is an extremely rare event. If the OPR railway had been installed prior to Cyclone Clare, then numerous culverts, bridges and sections of track, would have been washed out during this event.

9 WATER WAY STRUCTURES

9.1 GENERAL

The alignment will require the construction of a number of bridges over waterways, and multiple culverts along the alignment. Where it is necessary for the rail formation to cross water courses, the waterway structures will be constructed at defined channels and aligned perpendicular to the water flow to reduce the required bridge length and height and thus minimise impact to the water course. Proposed hydraulic criteria in the 50 year ARI event include:

- Maximum velocity at the structure outlet does not exceed 4m/sec;
- Maximum backwater effect 1.0m or 1.5m (as described above);
- Minimum freeboard of 500 mm to be deck soffit.

The existence of a waterway structure (bridge, culvert or floodway) can significantly restrict water flows and cause a backwater or afflux (water level increase) on the upstream side. The land area and distance upstream that is affected, depends on the size of the backwater, and the hydraulic gradient of the watercourse.

The acceptability of this increase is defined by the existence of upstream property or infrastructure. Upstream assets that cannot cope with increased flood levels will typically necessitate a higher capacity waterways structure, in order to minimise the backwater effects. On this basis, the proposed backwater limits are:

- 1.5m backwater within remote pastoral regions where backwater rises are expected to have minimal or no impact on local infrastructure and activities. This is consistent with the methodology typically used for railway bridge design in remote pastoral areas of the Pilbara; and
- 1.0m backwater within the Chapman and Chapman River East Valleys, where bridges are closer to infrastructure such as roads, tracks, houses, sheds and farms.

9.2 BRIDGES

Bridges will be required for well-defined streams with sand gravel alluvium beds, and large catchments (>200km^2 is considered a potential bridge site). The economic balance comparison between bridges and multi-culvert installations will be undertaken in future design phases.

Bridges are nominally proposed at CH26.4km Chapman River (approximate span 60m), CH35km Chapman River East (60m), CH46.6km Chapman River East 2 (80m), CH80.2km Greenough River 1 (100m), CH111.3km Greenough River 2 (80m), CH147.9km Bangemall Creek (40m), CH308km Sanford River (165m) and CH340.9km Ilkabiddy Creek (90m). The alignment will also require the construction of multiple culverts.

Spans will be 15m (in flatter terrain) or 20m spans (where the clearance height between the bridge soffit and the flood design water level exceeds the 500mm minimum) are proposed.

9.3 CULVERTS

Culverts will be provided at natural watercourses and drainage paths intercepted by the rail route. These are smaller streams with well-defined channels or shallow depressions, that may contain alluvium, but mostly would not. In addition, watercourses may comprise a large area of broad wash plains, subject to sheet flooding and with no defined channel. A combination of corrugated steel pipes and reinforced concrete box culverts will be used. Gabions, rip rap rock protection or reno mattresses will be used where required to mitigate the potential for erosion.

The drainage design will be such that the rail formation will not be over-topped during a 50year ARI flood event, with a minimum freeboard of 300mm to the top of the rail embankment. For individual culvert designs, it is proposed that 'major' culverts (defined as 50year ARI flow $>50m^3/s$) would be designed for the 50year ARI flow. 'Minor' culverts (50year ARI flow $<50m^3/s$) would be designed for the 20year ARI flow.

Individual culverts may be designed with a limit on the outlet velocity / headwater depth as follows:

- Max. headwater height to culvert barrel diameter ratio (Hw/D) 1.5 (to ensure inlet control);
- Max. outlet velocity 5m/s (to minimise the size of rock protection required).

In some locations, it may be economic / desirable to concentrate the flow from several waterways or long sheet flow areas, into one crossing by using longitudinal drains to reduce the number of crossings. However, this needs to be balanced with the placement of culverts to provide downstream flows for environmental purposes.

Good selection of the culvert alignment, grade and size will achieve good hydraulic performance, stability of the bed, and will minimise construction and maintenance costs. Sediment deposits tend to occur on the inside of stream bends, or where there is an abrupt change from the stream slope to a flatter grade in the culvert.

A culvert should ideally be laid on a straight alignment with the watercourse, either perpendicular or skewed to the embankment centreline. Sharp changes in channel alignment or construction of short radius bends in the channel are likely to erode the concave bank, and to deposit sediment on the opposite bank. A skewed culvert is generally more desirable than a severe change in channel alignment.

The culvert inlet and outlet levels should preferably remain at existing surface levels to avoid drop inlets and / or discharge drains to reach the natural surface.

One of the more significant tasks involved in the final railway design is the economic balance between limiting conditions such as culvert size, numbers of culverts and setting the railway embankment levels over many watercourse crossings - an optimal trade-off between culvert costs and earthworks costs. In flat terrain, the temporary storage behind embankments during flood events may be sufficient to reduce the size / number of culverts required, or otherwise provide a higher factor of safety against overtopping.

Diversion and cut-off drains will be provided to divert surface water away from railway cuttings and low embankments, to protect low rail embankments from overtopping, inundation and/or longitudinal scouring. It is proposed to treat diversion and cut off drains as minor drainage structures with 20year ARI design flows.

Levees will be constructed at key locations along the alignment to ensure that catchment flows are contained within the catchment boundary. This prevents spill-over of flood waters into adjoining catchments where culvert capacities could be exceeded thereby resulting in overtopping of the railway formation.

9.4 ENVIRONMENTAL FLOWS

Over and above the general need for the route to avoid or protect areas where priority flora are found, and avoid vegetation types of higher conservation significance, drainage measures include reducing any impacts on sensitive vegetation, as a result of upstream flooding or downstream flow reduction.

Where there are run-off dependant ecosystems downstream of hydraulic structures (bridges and culverts), consideration needs to be given to water distribution to ensure that water distribution shadows do not result. Tree deaths on roadsides have been identified as road shadow effect, and occur mainly in arid and semi-arid areas, with gentle slopes of less than 0.5%. Depending on construction / design, roads can impede the flow of surface water (sheet flow) along the slope, resulting in a runoff water reduction on the downstream side, thus potentially causing tree deaths. It is noted that borrow pits can similarly disrupt surface water.

Hence in flat terrain, the railway embankment may require environmental culverting (typically 600mm in diameter), to reduce shadowing, and pass sheet flows downstream. The spacing and size of culverts in conservation areas would be determined after a visual assessment of each of these areas.

The mulga tree has adapted to environments where the soil water regime almost always limits the growth. The mean rainfall for much of the habitat is ~200-250 mm/year and as low as 50–60mm/year. However, some possibility of water recharge in every season (i.e. both summer and winter rainfalls) are necessary as they are not particularly well suited to drought (Department of Agriculture WA, 1995). The species is absent from areas with a regular summer or winter drought.

Mulga trees are therefore susceptible to subtle changes in surface water distribution patterns and the disturbance to surface drainage flow by the rail embankment therefore has the potential to negatively impact downstream vegetation. In such places the proposed railway, if inappropriately constructed, could obstruct and significantly redirect surface water drainage, changing and adversely affecting the distribution of water to possible down slope mulga vegetation.

In the driest areas, direct precipitation figures may give a misleading impression of the water the trees receive, as mulga often receives sheet runoff water from surrounding areas. It is in these areas, that the densest stands of the trees occur and large areas of mulga are dependent on surface sheet flow.

The preliminary drainage design of the railway makes provision for ~650 environmental culverts. Subject to culvert cover constraints, it is nominally proposed to install environmental culverts between larger engineered culverts, so that the spacing between consecutive culverts does not exceed 400m. DEC will be consulted during the detailed design phase for the rail corridor to ensure any impacts on conservation vegetation areas are minimised.

9.5 CONTOUR BANKS

Contour banks are found in the Chapman Valley cropping areas (refer photo Appendix A2). Virtually all cropping land with a slope of 4% to 12% is likely to have a medium to high risk of water erosion. Contour banks are surveyed and constructed on slopes to:

- Intercept surface water flows and reduce the volume and speed of water flowing over the land, before it becomes large enough to start the erosion process;
- Collect and divert excess water to a safe disposal site or water storage areas. The best waterways are natural, stable drainage lines. In the absence of these, artificial waterways have to be established;
- Reduce soil loss;
- Protect land reclamation works such as the filling of old erosion gullies;
- Reduce water logging of flatter land;
- Moderate flood flows when used over a whole catchment.

Lower, gentler slopes generally do not need contour banks if steeper slopes above them are adequately protected. However, on very long gentle slopes, where large surface flows can accumulate, more widely spaced banks might be necessary.

The rail embankment will potentially interrupt existing contour banking and therefore effectively become part of the erosion management practices on that property. On the upstream side, surface water run-off will be directed longitudinally to a culvert and discharge to downstream. On the downstream side, discharge through culverts will concentrate flows, disrupting the effectiveness of the contour banking immediately downstream. Erosion mitigation and dispersion measures may be required at the outlet to the culvert.

9.6 ACCESS ROADS

Access roads will be constructed initially as a 20m wide haul road developed for rail construction activities. For operation and maintenance purposes, a permanent rail maintenance access track of 10m will be retained. Other access roads will be required to borrow pits.

The permanent access roads will be constructed with a camber to drain water off the road surface, and table drains constructed alongside to collect and drain this water away. These drains will be ‘turned out’ regularly, and discharged into the natural surrounds (i.e. close to source). No sediment traps will be provided at these discharge points due to the small catchment areas.

The access road alignment will need to cross a number of creeks and waterways along the rail route, and the road will generally pass down through the bed of the waterway with minimal alteration to the cross-sectional area of the creek, to minimise effects on the flow.

10 EROSION AND RUNOFF

10.1 GENERAL PRINCIPLES

The Midwest landscape is subject to heavy rainfall at times, and there is a risk of erosion and sedimentation on disturbed or degraded lands. Generally environmental approvals for projects that involve land disturbance require adherence to surface water protection principles. The general objectives with regards to surface water are to:

- Maintain the integrity, functions and environmental values of watercourses and sheet flow;
- Prevent or minimise impacts on the quality of surface water resulting from mining operations and contain any contaminated water on-site;
- Ensure that the quality of water returned to local and regional surface water resources will not result in significant deterioration of those resources.

Surface water management requires an integrated approach, starting with defining the discrete catchment/drainage areas. This allows appropriate engineering solutions and site-specific surface water controls to be developed, including diversion and dispersion mechanisms, and erosion and sedimentation controls. Sediment basins need to be considered for each disturbed catchment/drainage area, to prevent sediment (and other contaminants) from entering natural flow paths. Areas of major erosion hazard should be avoided where practicable, or specific management measures implemented to reduce the erosion risk.

Applicable guidelines and standards include:

- ANZECC/ARMCANZ Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCAZ, 2000);
- Water Quality Protection Guidelines (No. 1-11) (DoW & DoIR, 2000);
- State Water Quality Management Strategy (ANZECC and ARMCANZ, 2001).

10.2 SURFACE WATER MANAGEMENT

Potential surface water impacts as a result of the rail construction include:

- Interruption to existing surface water flow patterns;
- Reduction of surface water runoff volume & quality in the environment downstream /water reduction to downstream vegetation communities that may be dependent on upstream drainage;
- Discharge of chemicals, including hydrocarbons, etc;
- Pooling of water, growth of invasive vegetation in low-lying areas;
- Erosion from disturbed areas such as construction areas, stockpiles, laydown yards, borrow pits, access roads, other cleared areas, causing sedimentation in downstream areas;
- Bridges and culverts - causing alteration to the stream's natural flow pattern, erosion and bank destabilisation, reduction in hydraulic capacity of the stream, increased extent of flooding upstream (afflux), and removal of riparian and in-stream vegetation.

Surface water mitigation measures to be adopted include:

- Clearing, land disturbance and vehicle movements will be kept to a minimum to achieve the design function, and that necessary for safe working conditions. Existing tracks will be used where possible;
- Approvals will be obtained from the relevant government agencies prior to disturbance within any named watercourse (e.g. permit to interfere with bed and banks as required by the RIWI Act). Construction in river floodplains or other natural flow paths will be planned for the dry season, where practicable;
- Upstream surface water flows will be diverted around structures, with appropriate grades, into adjacent or downstream surface water courses;

- Sediment reduction control measures will be designed and implemented as required, within drainage lines downstream of active mine areas, and other disturbance areas. Bunds and drainage diversion works around the perimeter of infrastructure areas will separate "clean water" (i.e. runoff from undisturbed areas) from runoff from disturbed areas, to reduce the volume of water to be treated;
- All stormwater from the infrastructure sites will be collected by a drainage network, to ensure it does not cause undue erosion, and to guard against potential contamination of watercourses;
- On-site solid waste disposal will be minimised and properly managed. Controlled wastes, as defined by the Environmental Protection (Controlled Waste) Regulations, will be properly handled prior to removal from the site;
- Process and wash down water will be collected and re-used;
- Emergency response procedures will be used to manage events involving hazardous substances. Hazardous substances will be stored in properly bunded sites to minimise the potential for land, surface water or groundwater contamination.

10.3 SEDIMENT BASINS

Generally, sediment basins will be provided downgradient from disturbance areas only for concentrated sources of runoff. Basins along the rail route will not be provided as runoff from disturbed areas is discharged close to source off in sheet flow and off minimal catchments.

Where required, sediment basins are located at low points and constructed by forming earth bunds. The trap size is calculated to match the settling velocity of the target sediment size (generally medium sized silt particles). The outlet structure can consist of a spillway only ("normally full") or a 'control' outlet that allows continuous seepage from the basin ("normally-empty").

10.4 BORROW PITS

The environmental management procedures for borrow pits will include:

- Minimise imported fill requirements along the railway, balance cut and fill to the extent possible;
- Use previously disturbed land rather than clearing more land;
- Select locations in consultation with DEC (CALM), in areas where their presence would not impact on surface drainage patterns and considering the appearance of the area after it had been excavated and rehabilitated; behind physical terrain and / or vegetation, or otherwise in areas that would reduce its visual impact. Avoid where possible, trees and heavy stands of vegetation;
- Access borrow pits and quarries from a single track only;
- Disturb only the minimum area required by the project;
- Stockpile topsoil and vegetation for rehabilitation. This material will be pushed to the longitudinal sides of the borrow pit;
- Progressively rehabilitate borrow pits. Haul all excess topsoil and vegetation from under the railway embankment construction area to the borrow pits, and re-spread over / fill the borrow pits with all available excess material and make them as free draining or shallow as possible;
- Shape to match the original surface topography as closely as possible;
- Assess each borrow pit, whether to provide an exit drain to daylight or allow to remain non-free draining. The final depth of borrow pits and quarries to not be more than 2m, or as otherwise approved. Locations within 5km of urban residential areas (or isolated homesteads) to be rehabilitated either by filling or rendering them to be free draining;
- Ensure no dry season low flows are directed into borrow pits (only the rainfall that falls directly on the pit);
- Final batter angles will not exceed a 3 horizontal : 1 vertical ratio.

All earthworks will be designed to have minimal impact on current drainage channels with no additional pooling to that which already exists, wherever possible. In flat terrain (where fill cannot be provided from cuts, and which therefore require borrow pits), some borrow pits will be non-free draining, with the potential disadvantages of ponding and water logging of vegetation, mosquito breeding and the disruption to surface drainage.

Whilst free-draining borrow pits will be preferred, in flat terrain, a greater level of disturbance to the existing landscape is likely to be the outcome of pursuing this goal. Typically, the only reliable way to create a true free-draining pit in flat country is to excavate an exit drain. In flat terrain, where drainage in pits is likely to be the worst, this is likely to result in the requirement for a lengthy drainage channel, increasing land clearing requirements and interrupting surface water flow.

10.5 SURFACE WATER MONITORING

No surface water monitoring (water sampling is proposed). Most construction will be carried out in the dry. Any inflows in creeks will be small and will be diverted at the time of construction.

Performance indicators include compliance with water management requirements of licences issued under the RIWI Act and the Environmental Protection Act; and management of controlled waste (liquid waste, asbestos, clinical waste, tyres, etc).

If negative impacts attributable to the construction activities are detected, a report identifying contingency actions and timing will be implemented. Remediation strategies will be implemented as required (e.g. remedying the source of contaminant, on-site interception and recirculation of water, further erosion and sedimentation measures, etc)

Regular site inspections will check for evidence of potentially polluting activities (e.g. seepages, erosion, etc).

11 CONCLUSIONS AND RECOMMENDATIONS

Oakajee Port and Rail (OPR) is currently developing the Oakajee Port and Rail Development, which consists of a deepwater port facility at Oakajee (north of Geraldton) and development of approximately 523 km of rail infrastructure from Oakajee Port to the mining operations at Jack Hills, with a spur linking to the existing WestNet to Mingenew Rail and another to Weld Range.

The Midwest climate is Mediterranean near the coastal and semi-arid inland. The existing land use changes from predominantly horticultural and orchard areas or hobby farms near the coast, to broad acre cropping at CH135 with the remainder uncleared, pastoral runs.

The typical width of disturbance along the railway corridor would be 55-60m. Access would initially be a 20m wide haul road developed for construction activities with a 10m wide permanent rail maintenance access track retained.

The rail line will require a number of bridges and approximately 1.5-2 culverts per km of rail across defined water courses.

The drainage design will be such that the rail formation will not be over-topped during a 50year ARI flood event, with a minimum freeboard of 300mm to the top of the embankment. Significant flood events have occurred previously, as witnessed by the impacts of Cyclones Dominic and Clare.

Various design flood estimation methods are available for the design of waterway structures. These all based on the presence of a defined creek line, and will overestimate design floods in the large sheet flow areas crossed by the corridor.

Major culverts would be designed for the 50year ARI flow and Minor culverts for the 20year ARI flow. Gabions, rip rap rock protection or reno mattresses will be used where required to mitigate the potential for erosion.

Where there are run-off dependant ecosystems downstream of hydraulic structures (bridges and culverts), consideration needs to be given to water distribution to ensure that water distribution shadows do not result. The preliminary drainage design of the railway makes provision for ~650 environmental culverts.

The rail embankment will potentially interrupt existing contour banking in the Chapman Valley and this will need to be accommodated within the rail design.

The general objectives with regards to surface water management include the maintenance of the integrity, functions and environmental values of watercourses and sheet flow, and to maintain or improve the quality of surface water to ensure that existing and potential uses, including ecosystem maintenance are protected.

As such engineering designs will incorporate site-specific surface water controls as required, including diversion and dispersion mechanisms, and erosion and sedimentation controls. Areas of major surface water flow and/or quality change will be identified and avoided where practicable, or specific management measures implemented to minimise its risk.

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APPENDIX A PHOTOS

CH20km: Alignment runs along west side of Moresby Range in hilly-undulating terrain

CH45 (approx): contour bank erosion control measures in Chapman Valley

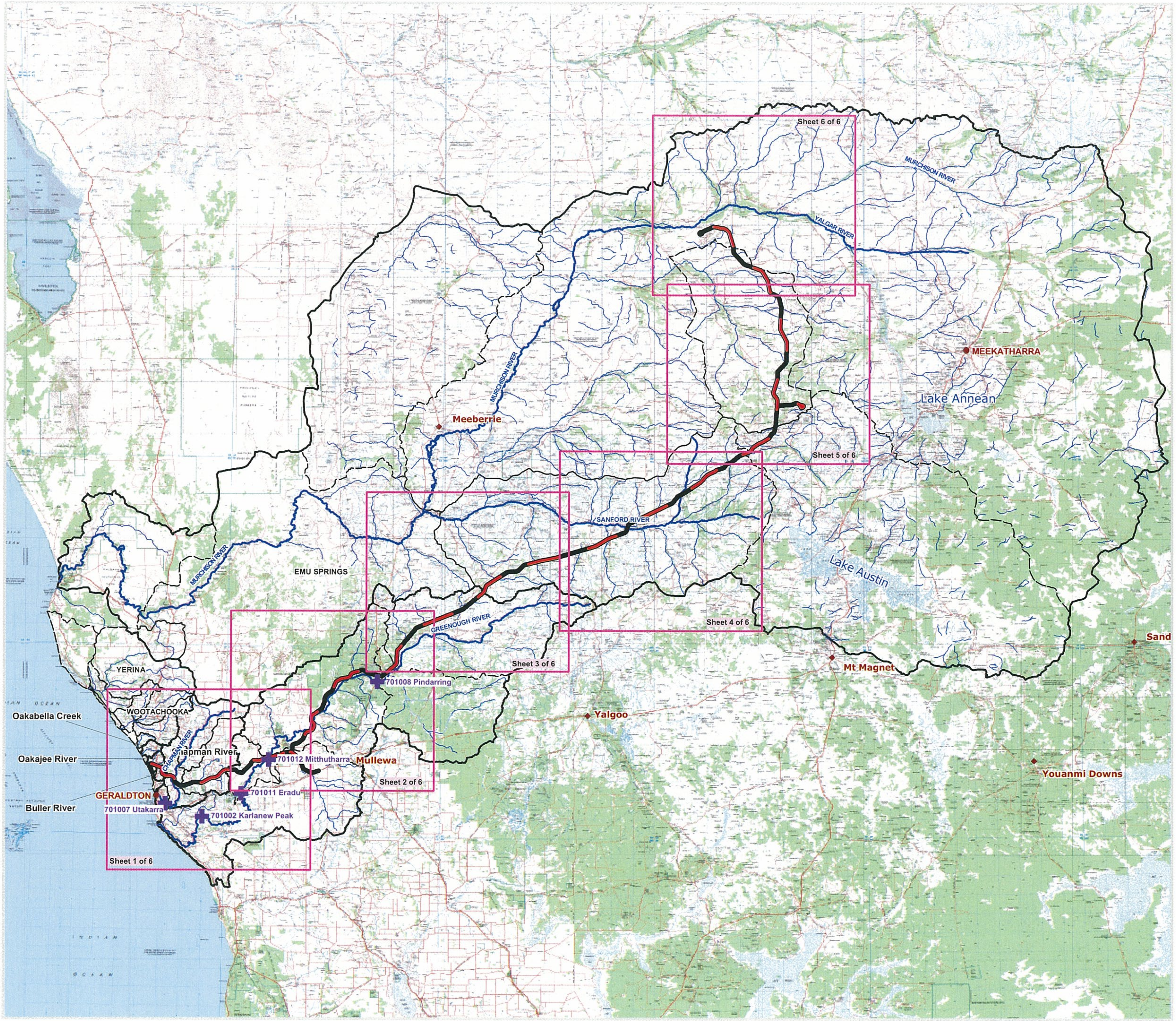
CH100km: Alignment through gently undulating broadacre farmland

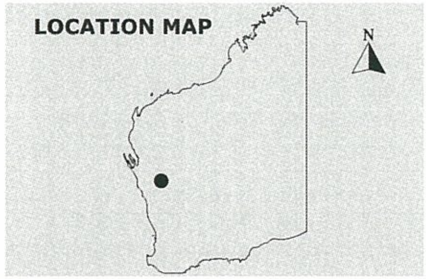
CH160km: Greenough River floodway on Carnarvon-Mullewa Road, about 3km south of the rail alignment

CH298km: Red loam and mulga on Yalgoo North Road

CH400km: Rail follows Jack Hills haul road (Berringarra Cue Road) north through the Weld Range

APPENDIX B SURFACE WATER MAPPING





LEGEND

701002 Karlanew Peak	RIVER MONITORING STATION
	PROPOSED RAIL ROUTE
	WATER COURSE
	CATCHMENT AREAS IMPACTING ON RAIL ALIGNMENT
	CATCHMENT BOUNDARY
	DRAINAGE DIRECTION
	SUB-CATCHMENT BOUNDARY

0 20 40 km

aquaterra

APPENDIX B

OPR SURFACE WATER MAPPING OVERVIEW

AUTHOR:	RW	REPORT NO:	...
DRAWN:	MS	REVISION:	...
DATE:	07/10/09	PROJECTION:	GDA94 Z50
JOB NO:	1088B	SCALE:	1:1,700,000

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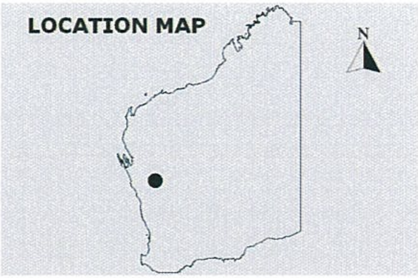

LEGEND

- 701002 Karlanew Peak — RIVER MONITORING STATION
- PROPOSED RAIL ROUTE
- WATER COURSE
- CATCHMENT AREAS IMPACTING ON RAIL ALIGNMENT
- CATCHMENT BOUNDARY
- DRAINAGE DIRECTION
- SUB-CATCHMENT BOUNDARY

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APPENDIX B

OPR SURFACE WATER MAPPING
SHEET 1 of 6

AUTHOR:	RW	REPORT NO:	002
DRAWN:	MS	REVISION:	a
DATE:	07/10/09	PROJECTION:	GDA94 Z50
JOB NO:	1088B	SCALE:	1:300,000

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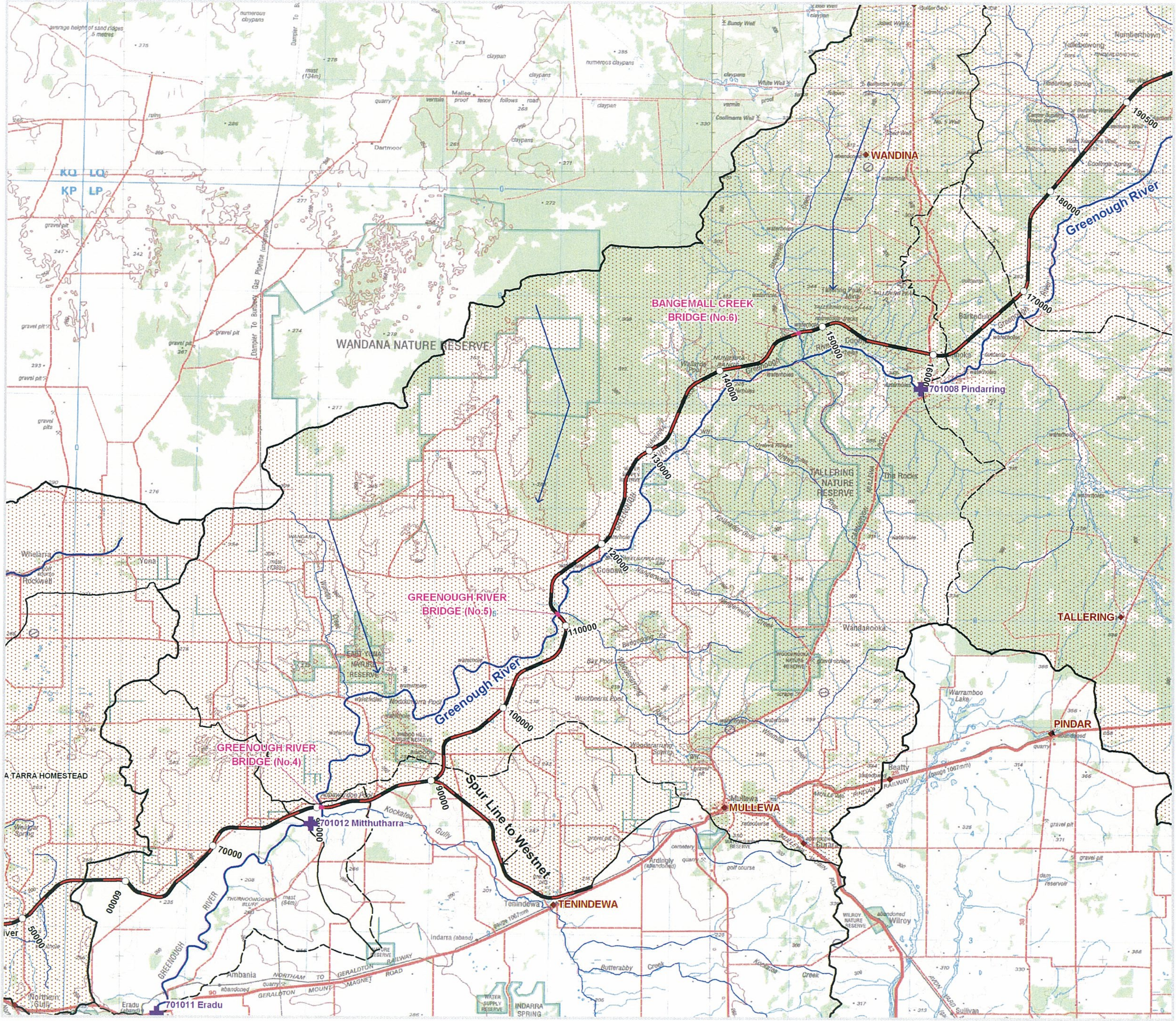

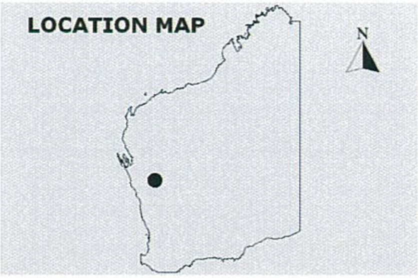

LEGEND

701002 Karlanew Peak	RIVER MONITORING STATION
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APPENDIX B

OPR SURFACE WATER MAPPING
SHEET 2 of 6

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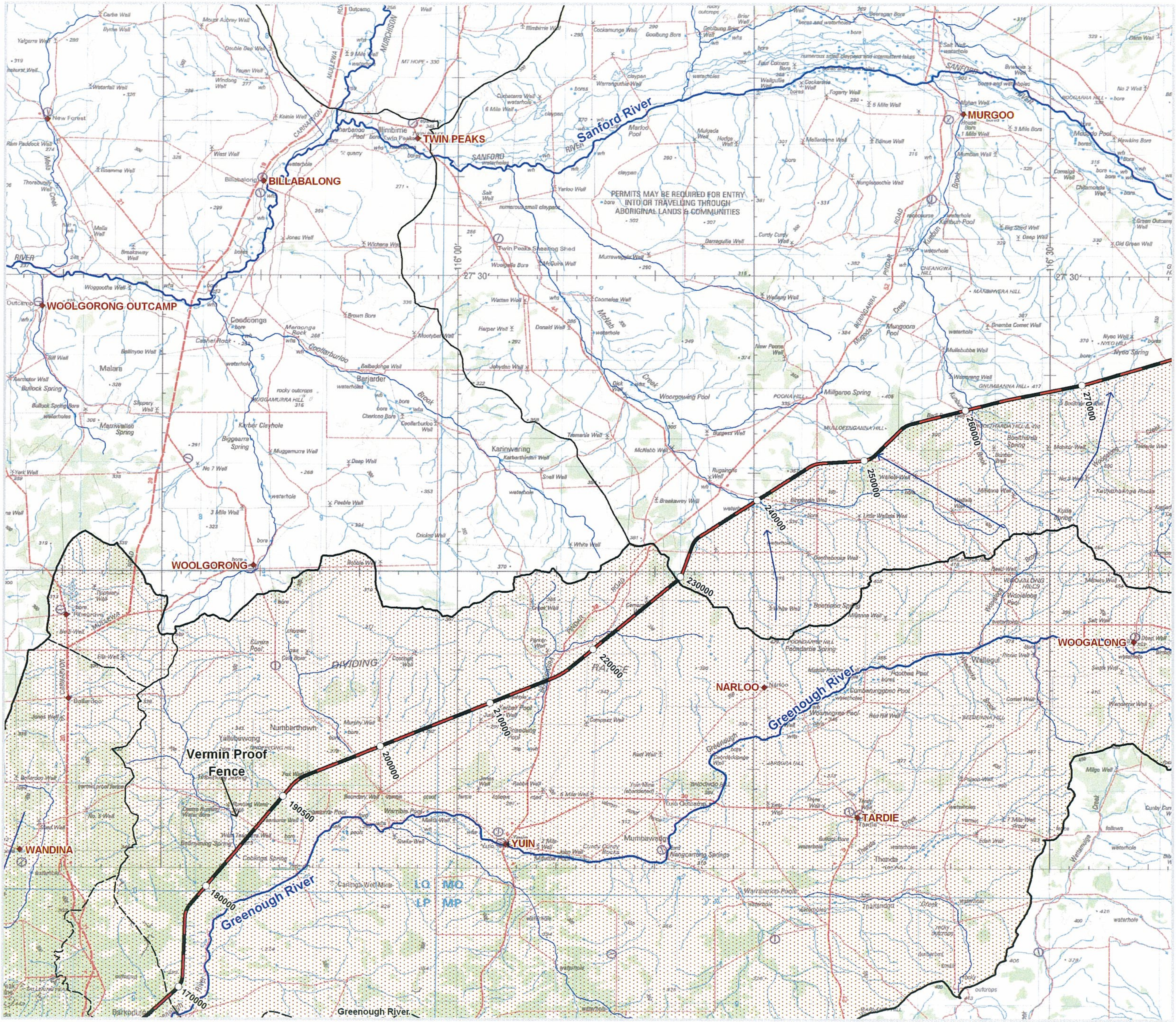

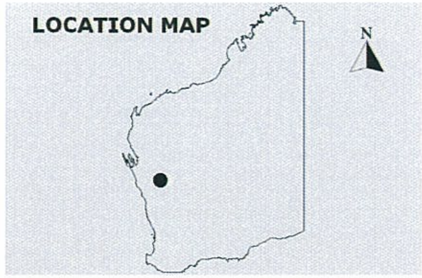

LEGEND

- PROPOSED RAIL ROUTE
- WATER COURSE
- CATCHMENT AREAS IMPACTING ON RAIL ALIGNMENT
- CATCHMENT BOUNDARY
- DRAINAGE DIRECTION
- SUB-CATCHMENT BOUNDARY

0 5 10 km

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APPENDIX B

OPR SURFACE WATER MAPPING
SHEET 3 of 6

AUTHOR:	RW	REPORT NO:	002
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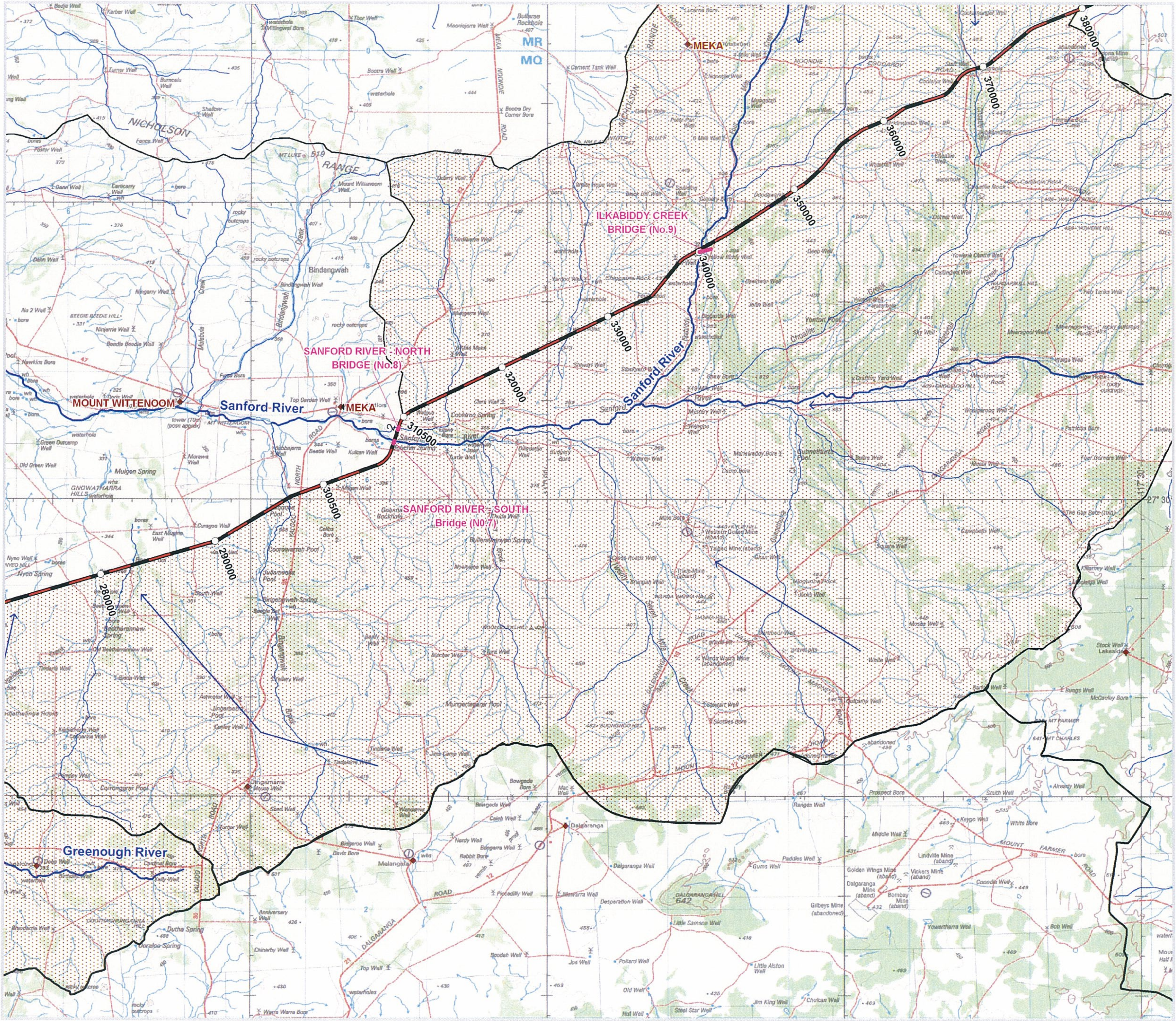

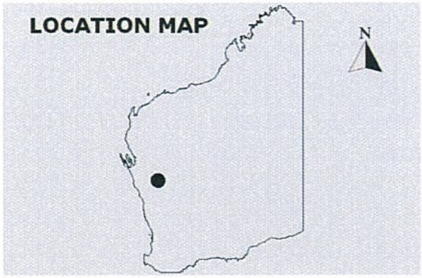

LEGEND

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APPENDIX B
OPR SURFACE WATER MAPPING
SHEET 4 of 6

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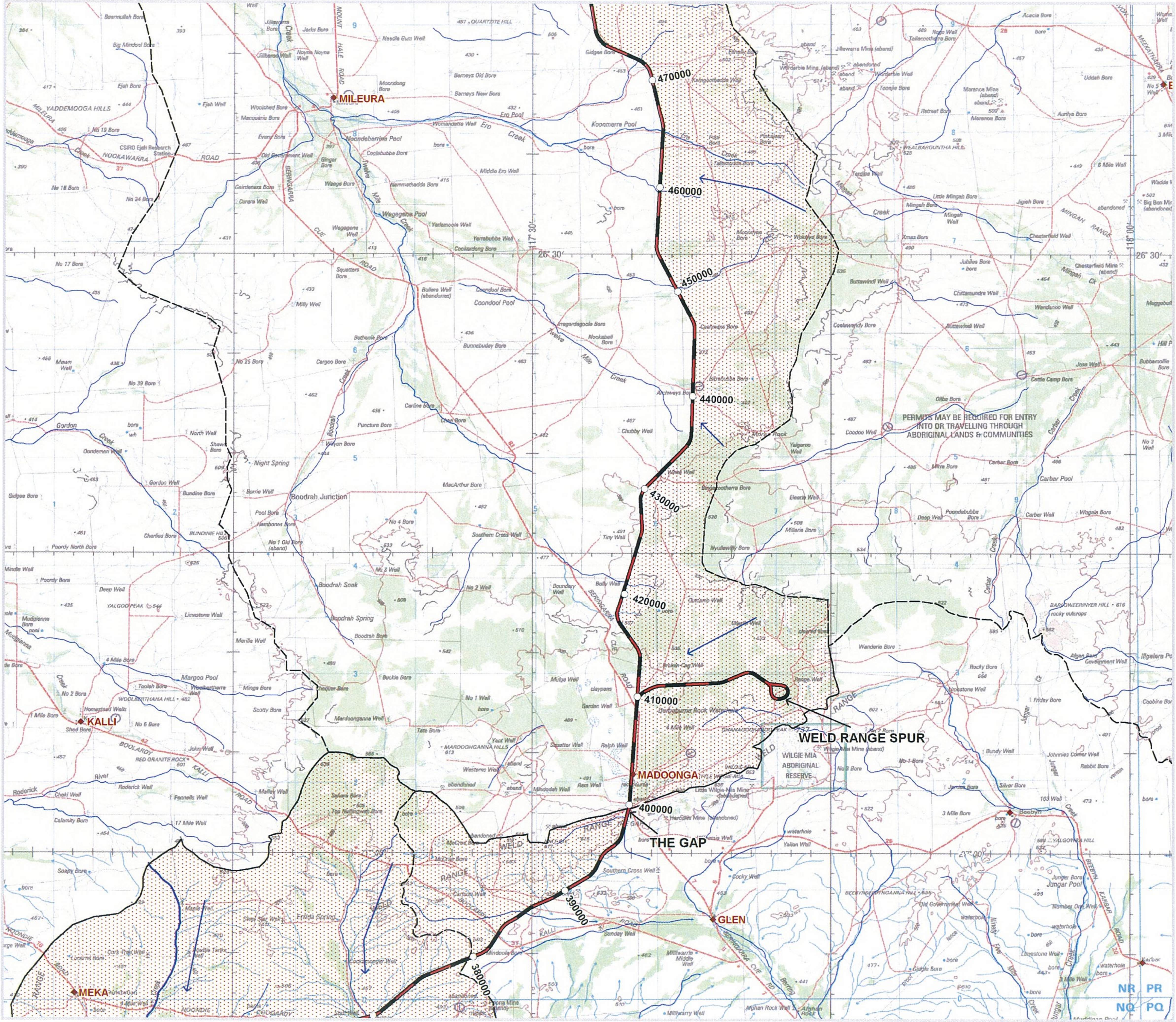

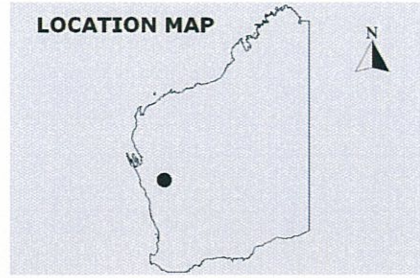

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APPENDIX B
OPR SURFACE WATER MAPPING
SHEET 5 of 6

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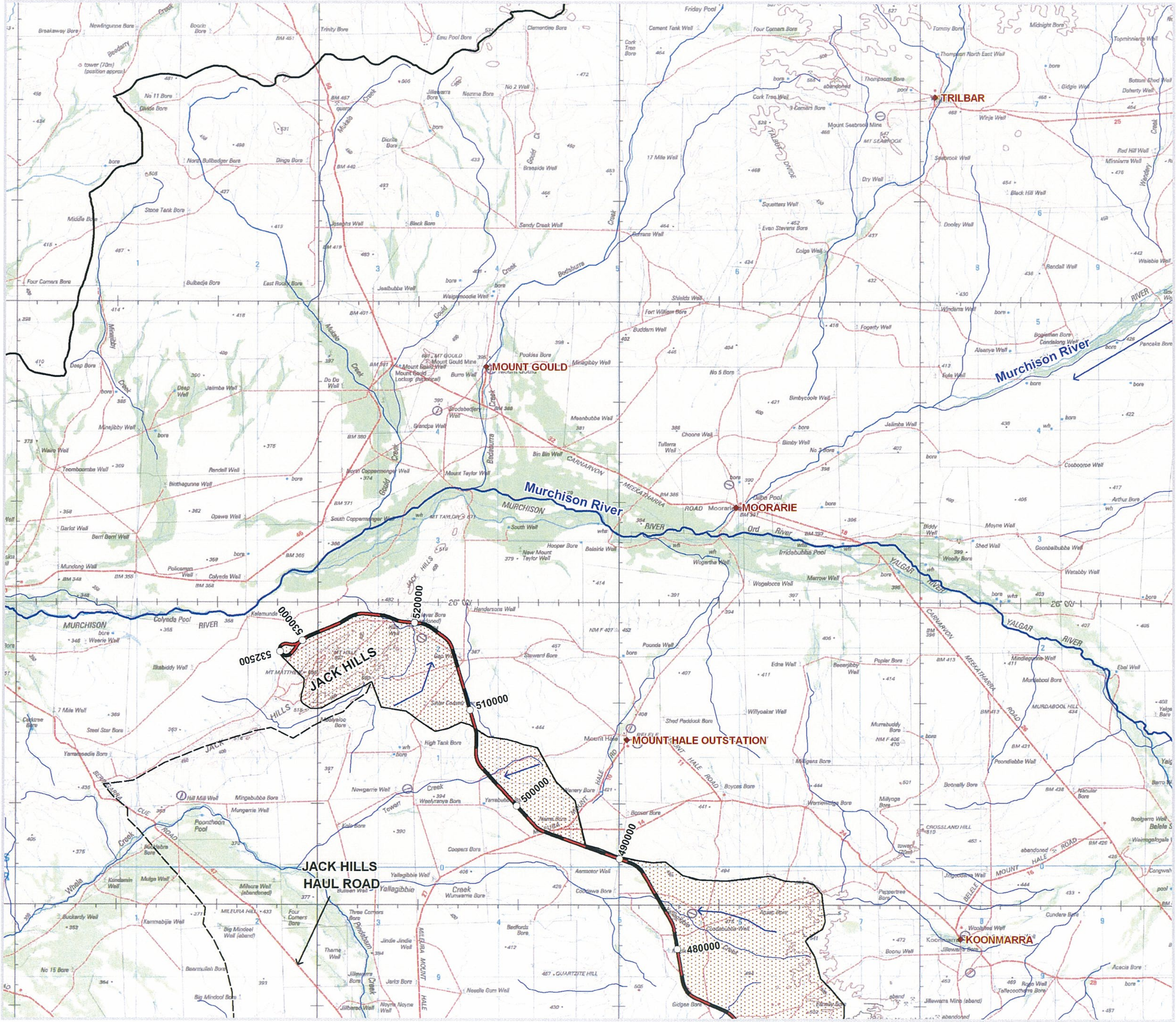

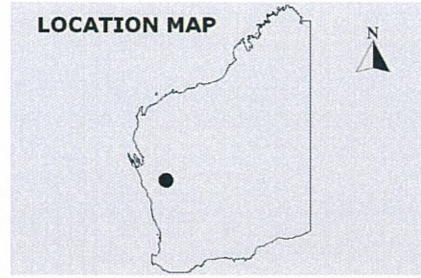

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APPENDIX B

OPR SURFACE WATER MAPPING
SHEET 6 of 6

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Water and Environment

1.0 BRIDGES

1.1 Catchment Hydrology and Stream Flow Estimation

Bridge consultant BG&E analysed the large catchments using the Australian Rainfall and Runoff (AR&R) Regional Rational and Index flood estimation methods to determine design flows up to the 50-year ARI. Detailed runoff-routing was not carried out during this preliminary design phase.

Calculated design flows for bridge crossings were based on the AR&R formulas for the Wheatbelt Region. Calculations were done using regional formulas applicable to both "loamy" and "loamy/lateritic" soils. For preliminary bridge sizing purposes, designers provisionally adopted the soil type formula that produced the larger flows for each catchment. Design flow estimation methodology will be further evaluated as part of the detailed waterways analysis in the next phase of design.

Bridge structures can significantly restrict water flows. The structure causes upstream water levels to rise higher than they would if the bridge was not there. This additional water level increase is called the bridge backwater effect.

For the preliminary bridge hydrology analysis the following backwater limits were used for preliminary bridge sizing:

- 1.5 metre backwater effect within remote pastoral regions of the rail corridor where backwater rises are expected to have minimal or no impact on local infrastructure and activities. This is consistent with the methodology typically used for railway bridge design in remote pastoral areas of the Pilbara; and
- 1.0 m backwater effect within the Chapman River Valley and the Chapman River East Valley where bridges are close to infrastructure such as roads, tracks, houses, sheds and farms.

In the next design phase more detailed flood studies will be carried out to determine whether the backwater criteria may be further relaxed at specific bridge locations.

1.2 Bridge Structures

Based on the 50-year ARI flows, BG&E identified 8 stream crossings that are likely to require bridge structures.

An hydraulic analysis was carried out for each potential bridge site. Natural ground sections at each crossing location were determined from the available digital survey and overlayed with the proposed railway line vertical design profile.

The hydraulic section was then analysed using the Main Roads Western Australia AFFLUX software program. AFFLUX is used to analyse bridge and culvert structures for natural (open) channel flow.

Preliminary assessment of bridge structure sizing was based on adoption of the following design criteria for the 50-year ARI design flood event:

- Maximum velocity at the structure outlet does not exceed 4 m/sec;
- Maximum backwater effect is 1.0 metre or 1.5 metres depending on bridge location; and
- Bridge structures will have a minimum freeboard of 500 mm to deck soffit.

Two types of precast, prestressed concrete bridge beams are notionally proposed for this project. The two designs have been recently used on heavy haulage rail bridges in the Pilbara region.

The drawings in Attachment 2.2 illustrate the types of bridge structures envisaged for this project.

One design is a relatively deep box-beam with a 20 m span suitable where the clearance height between the bridge soffit and the 50-year ARI flood water level (i.e the "freeboard") exceeds the 500 mm minimum. For these locations the bridge substructure elements are taller, and the longer span reduces the number of piers required, resulting in a more hydraulically efficient structure. This design is proposed for most of the bridges in the Chapman River Valley and the Greenough River Valley.

The second design is a relatively shallow trough beam with a 15 metre span suitable for shallow river crossings where the railway level is not much higher than the flood water level. In this case the freeboard is a governing criteria. This bridge design is proposed for most of the bridges in the pastoral areas.

All proposed bridge designs have superstructures based on simply-supported spans because these are generally the most suitable and cost-effective solution for rural and remote railway bridges.

All beams are constructed with square ends to simplify the rail transitions on and off the bridge and to avoid skew distortion of the run-on slabs. Skewed bridge beams are more costly and difficult to construct and have not been considered. Superstructure elements will be simply supported on steel pot bearings at the piers and abutments.

At some bridge sites spread footings are likely to be adequate based on visual assessment of the locations. Other bridge sites will likely require deep piling. These preliminary assessments should be reviewed after ground disturbing investigations are completed next calendar year.

Generally, bridge piers will be piles extending above the ground to a headstock. At some locations a pile cap with a single circular column will be required to meet waterways requirements.

The following summary table lists the location of the bridge structure and the design concept proposed for each bridge:

The following summary table lists the location of the bridge structure and the design concept proposed for each bridge:

River Crossing	**Rail Chainage**	**Minimum Structure** (total length)	**Probable Foundation Type**
Chapman River	26413	4 x 20 m spans = 80 m bridge deck	Spread footings
Chapman River East 1	35115	3 x 20 m spans = 60 m bridge deck	Spread footings / Piles
Chapman River East 2	46600	3 x 20 m = 60 m bridge deck	Spread footings / piles
Greenough River 1	80220	5 x 20 m = 100 m bridge deck	Spread footings
Greenough River 2	111250	4 x 20 m = 80 m bridge deck	Spread footings
Bangemall Creek	147900	2 x 20 m = 40 m bridge deck	Spread footings / Piles
Sanford River*	308000	11 x 15 m = 165 m bridge deck (total). *May consist of 2 separate shorter structures	Spread footings
Ilkabiddy Creek	340900	6 x 15 m = 90 m bridge deck	Spread footings / Piles

Attachment 2.2 contains additional information prepared by BG & E regarding bridge investigations.

1.3 Alternative Bridge Designs

Whilst BG&E notionally proposed concrete bridge decks and piers, there is agreement that steel bridges may also be a viable alternative. The choice of bridge type will ultimately depend on the relative cost of each option at the time of detailed design.

BG&E indicated that the cost of steel bridge structures was likely to be similar to that of concrete bridge structures in the current market. Hence, for the purposes of development of a pre-feasibility cost estimate, a unit rate based on recent costs of concrete railway bridges was adopted.

2.0 DRAINAGE DESIGN

2.5.1 General Design Philosophy

An extensive but preliminary drainage design was undertaken for the OPR rail alignment, from Oakajee Port to the Jack Hills mine. This analysis included:

- Catchment assessment including preliminary area measurement of all catchments. Catchments larger than 200km2 were considered potential bridge sites and were modelled as such;
- A detailed review of potential bridge sites by hydraulic/bridge engineers (BG&E);
- Review of the natural surface longitudinal section for the track alignment to confirm proposed culvert location and the need for drains; and
- Sections of formation that needed to be raised to provide drainage requirements.

2.5.2 Catchment Analysis

The drainage catchments and stream flow locations were defined from the digital terrain mapping (DTM) of local topography. The survey generated, at best, 2 metre contours for short sections towards the Oakajee Port and the Jack Hills mine. 5 metre contours were generated along the middle section of the railway route. Catchment boundaries were digitally defined using the available terrain contour data.

When more detailed survey information becomes available additional sub-catchments are likely to be identified and this may in turn increase the number of culvert locations.

2.5.3 Design Flows

The peak flows were based on the formulas for the loamy and lateritic soil catchments for the Wheatbelt Region as presented in the Australian Rainfall and Runoff (AR&R).
The rail corridor traversed across regions of varying rainfall patterns. To account for the rainfall variance, a number of different Intensity-Frequency-Duration (IFD) was used for peak flow calculations along the alignment.

Standard Calibre Engenium design criteria for design flows are 20-year and a 50-year Average Recurrence Interval (ARI) to determine if each site was classified as a major or minor culvert for hydraulic analysis. Peak flows were determined from the Regional Rational and Index Flood Methods and the maximum of the two methods was adopted as the design flow.

2.5.4 Culvert Design

Stream crossings where the 50-year ARI flow exceeded 50 m3/s and did not warrant provision of a bridge structure were designed as major culvert structures. The major culverts were designed so that:

- The rail formation is not over-topped during a 50-year ARI flood event.; They had a minimum freeboard of 300 mm to the top of the rail embankment at maximum design flow conditions;
- The maximum headwater height to culvert barrel diameter ratio is 1.5, to prevent the culvert from becoming outlet controlled; and
- The maximum outlet velocity is $5m^3/s$ to minimise the rock size and the extent of rock protection required.

For all stream crossings where the 50-year ARI flow is less than 50m3/s, the crossings were designed as minor culvert structures, and sized for the 20-year ARI flow. In all other respects, the design criteria adopted for minor culverts were identical to those adopted for major culverts. Major culverts are also designed for 1 in 20 years ARI flow and must not be over topped in a 50 year ARI flow event.

A preliminary culvert schedule is included in Attachment 1.10.

It is worth noting from the schedule that a large number of culverts have provisionally been identified as requiring 20 or more pipe barrels to handle the estimated design flows. Whilst equivalent hydraulic capacities could have been achieved using a smaller number of larger diameter pipes, the preliminary design specifically aimed to minimise railway earthworks volumes where possible. By nominating smaller culvert pipe diameters, designers were able to lower the vertical profile of the railway. More detailed economic evaluations will be undertaken in future design phases to ensure that the culvert design achieves optimal trade-off between culvert and earthworks costs.

2.5.5 Other Drainage Works

The preliminary design of the OPR 1 Rail Alignment included a variety of additional drainage works. These included environmental culverts, diversion drains, cut-off drains and levees.

Ideally, small culverts should be provided at all locations where the railway embankment intersects minor surface water drainage paths. Whilst such flows could in many cases be easily redirected to larger engineered culverts further along the rail alignment, provision of regular drainage relief points will ensure that the new railway will not adversely affect vegetation that is reliant on those surface water flows.

The preliminary drainage design of the OPR1 railway makes provision for 650 environmental culverts. Subject to culvert cover constraints, it is proposed to install environmental culverts between larger engineered culverts so that the spacing between two consecutive culverts does not exceed 400 metres. This will need to be confirmed during Bankable Feasibility Study. Environmental culverts are not essential for flood control, but serve an important environmental function.

Diversion and cut-off drains will be provided to divert surface water away from railway cuttings and low embankments. This helps ensure that vulnerable sections of low rail embankments are protected from overtopping, inundation and/or longitudinal scouring. During Value Engineering the diversion and cut off drains were treated as minor drainage structures and were therefore sized for the 20-year ARI design flows.

Levees will be constructed at key locations along the alignment to ensure that catchment flows are contained within the catchment boundary. This prevents spill-over of flood waters into adjoining catchments where culvert capacities could be exceeded thereby resulting in overtopping of the railway formation.