FORTESCUE METALS GROUP PTY LTD

PILBARA IRON ORE AND INFRASTRUCTURE PROJECT

STAGE B
MINES AND EAST-WEST RAILWAY
SURFACE HYDROLOGY

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EXECUTIVE SUMMARY

Fortescue Metals Group Ltd (FMG) is undertaking Feasibility Studies and Public Environmental Reviews (PERs) for the proposed Pilbara Iron Ore Project. Aquaterra Consulting Pty Ltd (Aquaterra) has been engaged by FMG to examine the natural surface water drainage patterns associated with the proposed mining areas and Stage B railway corridor and assist FMG to develop appropriate design criteria and management strategies to minimise potential environmental impacts.

Potential Surface Water Impacts of Mine Development and Proposed Management Measures

The four mine sites being developed by FMG, namely Mt Nicholas, Mt Lewin, Christmas Creek and Mindy Mindy, are located in the Upper Fortescue River Catchment. The initial three of these mine sites are located on the southern flanks of the Chichester Plateau, north and east from the Fortescue Marshes, whereas the fourth site is located south from the marshes on the northern flank of the Hamersley Ranges. The Fortescue Marshes is an extensive intermittent wetland that receives runoff from the Upper Fortescue River Catchment and all four mine development areas are located above any potential flood storage level in the marshes.

The proposed FMG mine developments could potentially alter the existing surface water flow patterns in the development areas including flooding characteristics; scour and siltation of the drainage channels; inundation of upstream areas and water starvation to downstream areas. The main surface water impact from the proposed mine developments will be interruption to the existing surface water flow patterns and a potential reduction of surface water runoff volume and quality in the downstream environment. In particular, grove/intergrove mulga communities, which are partially dependent on sheetflow runoff, may potentially be impacted. These communities are spread through the general project area with their main concentrations on the lower flanks of the Chichester and Hamersley Ranges adjacent to the Fortescue Marshes.

Aquaterra recommends that FMG commits to implementing the following surface water management strategies to reduce the potential for environmental impact:

Open Pit Areas

- Construct surface water bunding around the pit perimeters to prevent external surface water from entering the pit areas.
- Divert upstream surface water flows around the pit development areas and directed into adjacent defined surface water pathways or to join existing flow pathways located downstream.
- Where diversion options are not practical, external surface water runoff allowed to enter the pit area to be primarily used for process purposes.
- In sheetflow areas and in critical flow zones, diverted flows to be discharged over riprap pads to encourage flows to slow and disperse.
- Where a sheetflow zone containing a grove/intergrove mulga community is located immediately downslope from an open pit area and external surface water runoff is collected in the pit, then after a major rainfall event some of the collected in-pit water to be used to irrigate this sheetflow zone. However, irrigation not to be applied to grove/intergrove areas that are proposed to be disturbed by future mining activities.
- All in-pit water to be treated through a sediment pond prior to external discharge.
- Progressive backfill and rehabilitate the open pits upon completion of mining.

Waste Dumps

- Construct surface water bunding around the waste facility perimeters to prevent external surface water from entering the waste facility areas.
- Divert upstream surface water flows around the waste facility areas and directed into adjacent defined surface water pathways or to join existing flow pathways located downstream.
- Drainage from within the waste facility areas to be directed through a sediment basin prior to external discharge. For long term closure conditions, where appropriate, external discharges will also be directed over a riprap pad to slow and redistribute runoff.

Process Plant and Stockpile Areas

- Locate and design the process plant sites to minimise impact arising from interruptions to sheetflow.
- Bund the process plant and stockpile areas, as appropriate, to prevent external surface water entry.
- Collect internal drainage from the process plant and stockpile areas for reuse in the process water circuit.

Potential Surface Water Impacts of Stage B Railway Corridor and Proposed Management Measures

The FMG East-West railway is proposed to be constructed along the north side of the Fortescue Marshes (a minimum of 4km north from the Marsh boundary) linking the Mt Nicholas mine site to the FMG Stage A railway corridor. This east-west route is around 160km in length and links into the Christmas Creek and Mt Lewin mine development areas. Located predominantly on the lower slopes of the Chichester Plateau, the railway corridor typically crosses perpendicular to the surface water flow directions. Numerous small creeks cross the corridor.

The railway construction comprising predominantly fill earthworks could potentially interrupt the surface water drainage features that naturally cross through the rail corridor. For the east-west route, these natural drainage features include creeks, floodplains and sheetflow areas. No major river systems cross the railway, with the largest flowpath being Kulkinbah Creek draining a catchment area of around 770 km^2 above the railway corridor. Inappropriate management of these features could potentially alter existing natural drainage patterns including flooding characteristics; scour, erosion and siltation of the drainage channels; inundation of upstream areas and water starvation to downstream areas. In particular, grove/intergrove mulga communities, which are partially dependent on sheetflow runoff, may potentially be impacted.

Culverts will be installed under the east-west railway at all drainage crossings and in the sheetflow areas. These culverts will be designed with erosion protection works, as appropriate, to neutralise the potential for adverse water flow impacts. Installation of the railway embankment will not prevent surface water runoff from the upslope catchments draining to the Fortescue Marshes.

Windrows formed by grading of the railway access road are a potential source for sediments in surface water runoff. To reduce the potential for mobilising access road sediments through the sheetflow areas, FMG will typically install the railway access road on the downslope side of the railway formation thus preventing sheetflow from impacting on the windrows and reducing the potential for sediment to block culverts.

Aquaterra recommends that FMG commits to implementing the following surface water management strategies to reduce the potential for environmental impact:

Defined Flow Channels

- Install culverts at all defined drainage crossings and with capacity to safely pass the 20 year Average Recurrence Interval (ARI) flood.
- Design culverts with limiting upstream water levels to control flow velocities and with riprap or similar scour protection blankets on the inlets and outlets.
- Install culverts with small interceptor embankments, where appropriate, to prevent long drainage pathways developing adjacent and parallel to the railway formation.

Sheetflow Areas and Dependent Vegetation

- Install small diameter culverts at regular intervals through sheetflow areas, with provision for larger sized culverts where higher discharges are predicted.
- Where sheetflow dependent grove/intergrove mulga areas are located immediate downstream from the railway, culvert locations shall be based on ground and vegetation conditions.
- Install the railway access road on the downslope side of the railway formation.
- Downstream from the culverts, install a shallow dip in the railway access road using cement stabilised road base material and do not place graded windrow material in this flow zone.
- Downstream from the culverts and railway access road, install riprap pads to slow and disperse culvert runoff to the downstream environment.
- Where sheetflow dependent grove/intergrove mulga areas are located immediately downstream from the railway, install a spreader ditch sheetflow redistribution system to disperse culvert runoff to the downstream environment.
- Monitor the operation of the sheetflow spreader ditch system and conduct maintenance as required.

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SECTION 1 - INTRODUCTION

1.1 BACKGROUND

Fortescue Metals Group Ltd (FMG) is undertaking Feasibility Studies and Public Environmental Reviews (PERs) for the proposed Pilbara Iron Ore Project. The overall Project comprises:

- four mining areas and a number of potential satellite ore bodies;
- two railway lines;
- processing plants, stockpiles and associated mine infrastructure; and
- ship loading facilities at Port Hedland.

Three of the mining areas, Mt Nicholas, Mt Lewin and Christmas Creek, are located in the eastern Chichester Ranges. These deposits comprise mineralised Mara Mamba Formation, which outcrop northeast and east of the Fortescue River valley. The fourth area, located within the Mindy Mindy Creek valley approximately 25 km east of Hope Downs, comprises enriched Channel Iron Deposits (CID).

The two proposed railway lines connect the Mindy Mindy and Chichester Range mining areas to the Port Hedland loading facility, and comprise a north-south railway and east-west railway respectively. The loading facility at Port Hedland includes a rail loop, stockyard area, conveyor and berthing facilities.

The project development has been divided into two stages. Stage A includes the north-south railway line and port facility, and Stage B the east-west railway line and mining areas.

Aquaterra Consulting Pty Ltd (Aquaterra) has been engaged by FMG to examine the natural surface water drainage patterns associated with the proposed mining areas and Stage B railway corridor and assist FMG to develop appropriate design criteria and management strategies to minimise potential environmental impacts.

This report presents the results of the surface hydrology study for the proposed Stage B development. A separate report was prepared for the Stage A development (Aquaterra 2004).

1.2 STUDY OBJECTIVES

The objectives of the study are to examine the natural surface water drainage patterns associated with the proposed mining areas and Stage B railway corridor and assist FMG to develop appropriate design criteria and management strategies to minimise potential environmental impacts. This study:

- identifies watercourses and types of surface water flow including sheetflow;
- investigates topography, catchment areas and surface water runoff patterns;
- assesses the potential impacts on surface water flows, drainage patterns, sediment transport, vegetation (particularly mulga communities) and the Fortescue Marshes as a result of development activities; and
- provides advice to the engineering team with regards to location and design of drainage structures.

SECTION 2 - METHODOLOGY

2.1 GENERAL

The approach to the surface hydrology study comprised:

Mines

- Review proposed mine development plans.
- Liaise with the Mulga impact and Flora / Vegetation consultants and Department of Conservation and Land Management (CALM).
- Review existing information on regional drainage, the Fortescue Marshes and vegetation associations.
- Provide advice on potential impacts related alterations of surface water drainage patterns due to the proposed Project.
- Provide advice on design criteria, surface water management and erosion/sediment control.
- Liaise with the FMG designers to mitigate surface water impacts.

Stage B Rail Corridor

- Review published maps, air photos and proposed railway alignment plans.
- Liaise with the Railway Design consultant on adopted hydrology design methodology and issues.
- Define surface water drainage patterns and characteristics.
- Review existing maps and reports on regional drainage, the Fortescue Marshes and vegetation associations.
- Liaise with the Mulga impact and Flora / Vegetation consultants, and CALM;
- Provide advice on potential impacts related alterations of surface water drainage patterns due to the proposed railway alignment.
- Provide advice for flood protection, surface water management, environmental flows and erosion control.
- Liaise with FMG designers on methods to mitigate surface water impacts.

2.2 DATA REVIEW

Mapping data sources used for the study included:

- Orthophoto plans of the railway corridor
- Detailed contour plans of the railway corridor
- Mapping of the mulga communities along the railway corridor
- 1:75,000 plans of the mining areas
- 1:50,000 topography plans covering the rail corridor
- WRC plan titled “Surface Hydrology of the Pilbara Region”

In addition, we have drawn on Aquaterra’s expertise and previous experience on surface hydrology in the Pilbara Region and the reports and papers referenced in Section 5.

We also had discussions with and sourced available literature from the Mulga Research Centre at Curtin University and the Ecosystem System Research Group at the University of Western Australia regarding:

- Mulga plant water relationships
- Sheetflow management
- Mulga communities at the base of the Chichester Ranges.

2.3 PREVIOUS EXPERIENCE

Aquaterra has specific expertise in the investigation, environmental assessment, design and implementation of surface water flood control and diversion works for the mining industry. Projects undertaken by Aquaterra have largely related to the diversion of floodwaters around mine pits, minerals processing facilities and transport infrastructure in the Pilbara and Goldfields.

Relevant previous surface hydrology projects undertaken by our study team in the Pilbara Region include:

- Sherlock Bay NOI: Flood study and impact assessment for mine and process plant development in the Sherlock River floodplain (2004).
- Austeel-Mineralogy Project, Pilbara: Flood study and impact assessment for mine and process plant development in the Lower Fortescue River floodplain (2003).
- Robe River Bungaroo Creek Deposit: Flood study and layout designs for pit development in a major floodplain (2003).
- BHPBIO Area C, Pilbara: Hydrological and environmental assessment of flows at Weeli Wolli Springs (2003).
- HI Marandoo-Homestead Junction-Yandicoogina Railway: Hydrological investigations and designs for bridges, culverts and drainage structures (1993-1996).
- Water and Rivers Commission (WRC): Pilbara Region Water Resources Review and Development Plan 1996. Vol. I of II. Water Resource Allocation and Planning Series. Report No. WRAP 4 1996, Western Australia (co-author).

2.4 FIELD INSPECTION

A field visit to inspect the proposed mine development areas and railway route was undertaken by Aquaterra on the 30-31 March 2004. The full length of the Stage B rail corridor and mining areas were view from the air using a low flying aircraft. A second visit to view grove/intergrove mulga communities was undertaken by Aquaterra on the 20-21 September 2004, together with CALM personnel.

2.5 ASSESSMENT OF IMPACTS

Plans and mapping for the proposed mining areas area and Stage B railway route were examined in detail and proposed locations were viewed during the field visit. Based on this review and Aquaterra's expertise and experience with surface water projects in the Pilbara Region, the potential impacts arising from the project development were identified and assessed.

SECTION 3 - EXISTING ENVIRONMENT

3.1 REGIONAL SURFACE HYDROLOGY

The proposed FMG mining areas and Stage B railway corridor are located in the vicinity of the Fortescue Marshes in the Upper Fortescue River Catchment as shown in Figure 1. This area is in the physiographic unit known as the Fortescue Valley and occupies a trough between the Chichester and Hamersley Plateaux (Beard, 1975). In common with other areas in the Pilbara Region, the Fortescue Valley is subjected to localised thunderstorm and cyclonic rainfall events. Typically these events occur during the period December to April and can produce very large runoff events. The period May to November typically has relatively low rainfall and significant runoff events during this time are not common.

The Goodiadarrie Hills, located on the valley floor around 60km east from the town of Wittenoom, effectively cuts the Fortescue River into two separate river systems. West from the Goodiadarrie Hills, the Lower Fortescue River Catchment drains to the coast, whereas east from the hills the Fortescue Marshes receives drainage from the Upper Fortescue River Catchment. The alluvial outwash fan from the Weeli Wolli Creek system abutting the Goodiadarrie Hills is believed to be partially responsible for this obstruction to the Fortescue River and forming the Fortescue Marshes.

The Fortescue Marshes is an extensive intermittent wetland occupying an area around 100km long by typically 10km wide located on the floor of the Fortescue Valley. The marshes have an elevation around 400m above sea level. To the north, the Chichester Plateau rises to over 500m above sea level, whereas to the south the Hamersley Range rises to over 1000m above sea level. Following significant rainfall events, runoff from the approx 31,000 km^2 Upper Fortescue River Catchment drains to the marshes. For the smaller runoff events, isolated pools form on the marshes opposite the main drainage inlets, whereas for the larger events the whole marsh area could flood.

On the southern and northern flanks of the Fortescue Valley, numerous creeks discharge to the marshes. Runoff from rainfall on the valley sides initially drains down gradient as overland flow before concentrating in a defined flow channel. In this process surface detention, vegetation, seepage and other mechanisms absorb water from the runoff stream. In steep areas, the runoff processes are rather rapid with relatively low losses and defined drainage channels are typically in close proximity. In the lower slope areas, the runoff processes are rather slow with relatively higher losses and a greater distance between defined drainage channels.

Where defined drainage channels from the steeper slopes enter the lower slope areas, the channels typically have a reduced discharge capacity and in many instances become less well defined and braided or may even completely disperse in flat areas. In these reducing slope channels, runoff tends to over spill the main channel flow zones and spread over a wider front. In some of the lower slope areas, vegetation communities (scrub and mulga woodlands) have developed which are dependent on seepage water provided by the overland flow process. In these areas, the overland flow process has been termed sheetflow. Conversely, the Fortescue River, Weeli Wolli Creek and other main channels entering the marshes typically support eucalypt woodlands in their banks and floodplains.

Published topographical mapping indicates that bed levels in the Fortescue Marshes predominantly lie between 400m and 405m above sea level and that a flood storage level in the Marshes would need to be around 415m above sea level to overspill westwards past the Goodiadarrie Hills. No published flood level data are available for the marshes. Enquires with BHPBIO indicate that flood levels have never overtopped their railway crossing over the marshes, although large floods in the early 1970's are reported to have caused inundation up to the existing railway track level (pers. comm. Geoff Liddell, BHPBIO).

At the eastern end of the marshes, an indication of flood levels can be obtained from the Roy Hill streamflow gauging station data (S708008) established on the Upper Fortescue River. This gauging station, used to monitor streamflows entering the marshes, was located just downstream from the Roy Hill Homestead and was operating from September 1973 to September 1986. At the gauging station, the main flow channel bed level was around 405.5m above sea level and during the 13 years of record, the maximum recorded streamflow level was 408.75m above sea level (Feb. 1980). The corresponding peak flood storage level in the downstream marshes would have been less than this gauge level.

Surface water runoff to the marshes is of low salinity and turbidity, though the runoff turbidity typically increases significantly during peak periods of flooding (WRC, 2000). Following a significant flood event that flooded the whole marsh area, the ponded water could be over 4m depth in the lower elevation marsh areas. Water stored on the marshes slowly dissipates through the processes of seepage and evaporation. During the evaporation process, the water salinity levels increase and as the ponded areas recede, traces of surface salt can be seen. During the seepage process, as the ponds evaporate, increasingly more saline water is believed to seep into the valley floor alluvial deposits.

3.2 SURFACE HYDROLOGY (MINE AREAS)

FMG propose to develop four mine sites, namely Mt Nicholas, Mt Lewin, Christmas Creek and Mindy Mindy, the general locations for which are shown in Figure 1. The initial three of these mine sites are located on the southern flanks of the Chichester Plateau, north from the Fortescue Marshes and are serviced by the Stage B railway corridor. The fourth site (Mindy Mindy), located south from the marshes on the northern flank of the Hamersley Ranges, is serviced by the Stage A railway corridor. Published topographical mapping indicates that no springs or pools are located in the mining areas.

The Fortescue Marshes, an extensive intermittent wetland, receives runoff from the Upper Fortescue River Catchment, as previously described (Section 3.1). The marshes have an elevation around 400m above sea level, whereas to the north, the Chichester Plateau rises to over 500m above sea level, and to the south, the Hamersley Range rises to over 1000m above sea level. The proposed mine developments have pit perimeter levels at Mt Lewin and Christmas Creek of around 430m to 500m above sea level and at Mt Nicholas and Mindy Mindy of around 500m above sea level. Hence all the pit development areas are located well above any potential flood storage level in the marshes.

The proposed Mt Nicholas mine pit is located parallel to a north-south ridge and natural drainage is generally to the west. Several small creeks pass through the proposed pit area which have relatively steep gradients (typically 10 to 20m per kilometre) adjacent to the main ridge and have upslope local catchment lengths varying up to around 4km. Away from the main ridge, natural drainage gradients are relatively flat. The mine development area also includes stockpiles, facilities and access/haul roads.

The proposed Mt Lewin mine development is located along the southern flank of the east-west running Chichester Plateau adjacent to Kondy Creek and comprises several pits and associated stockpiles, facilities and access/haul roads. Kondy Creek with a catchment area around 270 km^2 above the proposed mine development area drains into the Fortescue River, which in turn drains to the Fortescue Marshes. During peak flood events, Kondy Creek would carry a significant discharge and flow over a relatively wide shallow floodplain. One of the Mt Lewin pits is partially located in the western floodplain of Kondy Creek, whereas the other pits are away from the floodplain. Numerous small creeks pass through the proposed pit development areas. These creeks have relatively steep slopes in the higher rocky ridge areas and relatively flat slopes away from the ridge.

The proposed Christmas Creek mine development comprises several various sized pits located along the southern flank of the east-west running Chichester Plateau. These pits are predominantly located on the western side of Christmas Creek, which has a catchment area around 225 km^2 above the proposed mine development area. During peak flood events, Christmas Creek would carry a significant discharge and over the lower slopes of the plateau, creek flows would spread over the relatively wide shallow floodplain. One of the proposed pits abuts the western floodplain of Christmas Creek, whereas the other pits are away from the floodplain. In common with the other proposed pit areas, numerous small creeks discharge southwards through the proposed pit development area. These creeks have relatively steep slopes in the higher rocky ridge areas and relatively flat slopes away from the ridge. The mine development area also includes a plant site, workshop, stockpiles, facilities and access/haul roads.

The proposed Mindy Mindy pit development is located south from the Fortescue Marshes on the northern flank of the Hamersley Ranges. The proposed pit follows a NW-SE trending valley located between the Weeli Wolli Creek and Mindy Mindy Creek systems. The pit valley has a total catchment of 24 km^2 and drains towards Weeli Wolli Creek at an average slope of 5m per kilometre. Numerous small creeks drain into the pit valley from the surrounding ridges. The mine development area also includes stockpiles, facilities and access/haul roads.

3.3 SURFACE HYDROLOGY (RAILWAY CORRIDOR)

The FMG proposed Stage B railway corridor runs along the north side of the Fortescue Marshes linking the Mt Nicholas mine site to the FMG Stage A Mindy Mindy to Port Hedland railway corridor (Figure 1). Along this route, the Stage B railway corridor connects with the Mt Lewin and Christmas Creek mine sites. Located predominantly on the lower slopes of the Chichester Plateau, the railway corridor typically crosses perpendicular to the surface water flow directions. The closest distance from the railway corridor centreline and the boundary to the marshes is 4km. Numerous small creeks intersect the corridor with the larger catchments being those for Christmas, Kulkinbah and Kondy Creeks. Published topographical mapping indicates that no springs or pools are located along this railway corridor.

The characteristics of the main creeks passing through the proposed Stage B railway corridor are presented in Table 1. These creeks range from the Goman with a catchment area upstream of the railway corridor of about 30 km^2 to the Kulkinbah with an upstream area of about 770km^2. Within the railway corridor zone, these main creeks cross a predominantly alluvial plain with gently sloping channel beds, ranging from around

1 to 4m per kilometre. Goman Creek is the only watercourse with a well defined drainage channel through the railway corridor compared with the other main creeks which have braided channels with wide floodplains.

Table 1
Characteristics of the Main Creek Crossings of the Stage B Railway Corridor

Creek	Catchment Area (km^2) (1)	Average Slope (m per kilometre) (2)	Flowpath Characteristics (3)
Goman	30	4	Defined channel around 50m wide
Sandy	80	3	Braided channels, wide floodplain
Christmas	250	2	Braided channels, wide floodplain
Kulbee	70	4	Braided channels, wide floodplain
Kulkinbah	770	1	Braided channels, wide floodplain
Kondy	280	2	Braided channels, wide floodplain

Notes
(1) Area upstream of railway corridor
(2) Channel slope through railway corridor
(3) Characteristics through railway corridor zone

Starting from the Stage A railway corridor near the crest of the Chichester Plateau, at around 500m above sea level, the proposed Stage B railway corridor initially proceeds in a southeast direction towards the marshes. This corridor route has been selected to gradually descend over a distance of 20 to 25km to the lower slopes of the plateau. Once on the lower slopes, the railway corridor is typically located between the 420m to 430m above sea level contours until the Kondy Creek floodplain after which the route slowly ascends to around 460m above sea level near the Mt Nicholas mine site. The railway corridor is located well above any potential flood storage level in the marshes.

On the lower slopes of the plateau, numerous small creeks cross the railway corridor. These southerly draining small creeks typically have slopes between 5 to 10m per kilometre through the corridor area. For the larger Christmas, Kulkinbah and Kondy Creeks, the floodplain drainage slopes through the railway corridor are flatter at around 1 to 2m per kilometre. These flatter slopes arise because of the more extensive alluvial fans developed from the larger capacity creek systems. East of the Kondy Creek floodplain, surface water runoff drains in a general westerly direction parallel to the railway corridor. This corridor section up to Mt Nicholas is relatively flat, with a natural gradient of around 2m per kilometre, but without defined drainage flowpaths crossing the corridor. Conversely, in the higher elevation western portion of the railway corridor, rocky ground conditions occur and drainage slopes are significantly steeper with many steep gullies crossing the corridor.

Together with the numerous small creeks, the railway corridor crosses extensive areas of sheetflow along the lower slopes of the plateau. Catchments to these sheetflow areas are difficult to define, as they comprise a combination of the directly upgradient overland flow areas plus over spill from nearby main creek flow zones. Scrub and mulga woodland communities have developed in large sections of the lower slope areas, which are reported to be partially dependent on seepage water provided by the sheetflow process. Of particular note are the extensive grove-intergrove mulga communities located west of Sandy Creek (Figure 1).

SECTION 4 - POTENTIAL IMPACTS AND MANAGEMENT

4.1 MINE AREAS SURFACE HYDROLOGY IMPACTS AND MANAGEMENT MEASURES

The four mine sites being developed by FMG, namely Mt Nicholas, Mt Lewin, Christmas Creek and Mindy Mindy, are located in the Upper Fortescue River Catchment, as shown in Figure 1. The initial three of these mine sites are located on the southern flanks of the Chichester Plateau, north and east from the Fortescue Marshes, whereas the fourth site is located south from the marshes on the northern flank of the Hamersley Ranges. The Fortescue Marshes is an extensive intermittent wetland that receives runoff from the Upper Fortescue River Catchment and all four mine development areas are located above any potential flood storage level in the marshes, as previously described (Section 3.2).

The main surface water impact from the proposed mine developments will be interruption to the existing surface water flow patterns and a potential reduction of surface water runoff volume and quality in the downstream environment. In particular, grove/intergrove mulga communities, which are partially dependent on sheetflow runoff, may potentially be impacted. These communities are spread through the general project area with their main concentrations on the lower flanks of the Chichester and Hamersley Ranges adjacent to the Fortescue Marshes.

Grove/intergrove mulga communities are reported to be dependent on both direct rainfall and sheetflow for providing soil moisture and nutrients for stability and productivity (Anderson and Hodgkinson, 1997). To determine the extent that grove/intergrove mulga communities are dependent on sheetflow and their potential to be impacted by interruption to sheetflow runoff, assistance was sought from both the Mulga Research Centre at the Department of Environmental Biology at the Curtin University of Technology and the Ecosystem Research Group at the School of Plant Biology at the University of Western Australia. These research establishments have undertaken extensive investigations themselves and are aware of other Australian research into various aspects of the mulga communities. Based on discussions, numerous factors affect the ecology of the grove/intergrove mulga communities, but no quantitative data is available as to the upstream catchment area required to sustain the communities.

4.1.1 Open Pit Areas

The proposed open pit mining areas are located on the lower flanks of the Chichester and Hamersley Ranges and their development will interrupt existing surface water flow patterns. With the proposed pit locations, the upstream pit perimeters will typically be located in defined creek flow zones whereas their downstream perimeters will typically be located in sheetflow zones. Some of these sheetflow zones contain grove/intergrove mulga communities.

Surface water protection bunding will be constructed around the pit perimeters, comprising a combination of bunding and diversion channels, to prevent external surface water from entering the pit area. However, as pits will be excavated in stages, then this surface water protection bunding may also be developed in stages. Where feasible, upstream surface water flows will be diverted around the pit development areas and directed into adjacent defined surface water pathways. Where adjacent defined surface water flow pathways are not present, diverted water will be directed around the pit areas to join existing flow pathways located downstream. Where sheetflow zones are located immediately downstream from the pit area, diverted surface water will be discharged over a riprap (rockfill) pad to encourage the flows to slow and disperse. The conceptual layout for diversion of runoff around the open pit areas is shown in Figure 2.

Where due to topography, diversion of upstream surface water runoff around the pit perimeter is not feasible, the external runoff water will be ponded against external bunds and removed by pumping or allowed to dissipate by evaporation and seepage. Alternatively, the upstream surface water runoff will be allowed to discharge into the pit area (within engineering safety constraints). In-pit sumps and pumps will be designed to manage any external surface water entering the pit, together with in-pit stormwater volumes. To save on water abstractions from the water supply bores, it is proposed that the in-pit water will be primarily used as process water. However, prior to pumping from the pit, the in-pit water will be treated via sediment ponds.

Where a sheetflow zone containing a grove/intergrove mulga community is located immediately downslope from an open pit area and external surface water runoff is collected in the pit, it is proposed that some of the collected in-pit water will be used to irrigate this sheetflow zone. However, as sheetflow only occurs following a major rainfall event, then this irrigation system will only be used following such an event. The proposed irrigation system, as conceptually shown in Figure 2, will comprise a separate mobile pump feeding water to a movable spreader pipework system. Irrigation will not be applied to grove/intergrove areas that are approved to be cleared by future mining activities.

During the mining process, it is proposed that the pit areas will be progressively backfilled to an extent dependent on the backfill material available. Upon completion of mining, if sufficient material is available, the pits will be backfilled such that a whole pit area can drain to the downstream environment. This would be achieved by backfilling the pit to a level above the lowest elevation on the pit perimeter and then ensuring that the finished pit surface is continuously draining to this area. The backfilled pit surface will be finished with a layer of fine grained material and topsoil prior to rehabilitation such that surface water runoff from the backfilled pit area will drain to the downstream environment. Some portions of the pits may be preferentially backfilled during the mining process, to enable upstream (external) surface water runoff to pass through the pit area, rather than be diverted around the pit footprint (within engineering safety constraints).

The potential impact of runoff water volume loss to the Fortescue Marshes, due to the proposed pit developments, is assessed as being insignificant. This can be illustrated by a comparison of the area collectively intercepted by the pit developments and not contributing runoff to the marshes and the surface water catchment area to the marshes of approx 31,000 km^2. During the mining phase, assuming that a quarter of the pits could possibly be open at any one time (a conservative estimate, as FMG will minimise its open area), the open pit areas may total around 40 km^2. This open area, which significantly reduces after closure and backfill of the pits, is only 0.1% of the total marsh catchment area. Such a small and temporary catchment area reduction does not represent a significant catchment loss to the marshes in the context of natural seasonal variability of catchment yield to the marshes.

As described above, runoff water external to the pit areas will typically be diverted around the pits to adjacent defined surface water pathways or directed around the pit areas to join existing flow pathways located downstream. As appropriate, riprap pads will be provided in key areas along the edges of the diversion bunding to slow and redistribute runoff. During a runoff event, the Pilbara creek systems discharge water with naturally high turbidity and sediment loads (WRC, 2000). In proximity to the pits, diverted flows may potentially increase their naturally high sediment and turbidity loadings, however these potentially elevated levels will dissipate with distance from the pit area. The closest mine pits to the Fortescue Marshes are those at Christmas Creek with a separation distance of 6.5km. The potential impact on runoff water quality draining to the marshes from the external diversion works at Christmas Creek and other sites, in particular sediment loadings and turbidity, is assessed as being insignificant due to the large distances between the pit development areas and the Marsh.

Sediment ponds will treat surface water collected in the pits prior to any irrigation discharges to the downstream environment. With this treatment, the potential impact to runoff water quality in the downstream environment is also assessed as being insignificant.

Where a sheetflow zone containing a grove/intergrove mulga community is located immediately downstream from a pit development area, there is potential for the zone to be impacted. Such zones are located in the proposed Christmas Creek and Mt Lewin mining areas. During the mining phase, the potential impact arising from sheetflow interruption will be managed by a combination of diverted external surface water runoff being discharged over a riprap pad to encourage the flows to slow and disperse, and by in-pit collected surface water runoff being irrigated over the downstream zone. Upon completion of mining, the rehabilitated backfilled pit area would drain to the natural downstream environment. With these management works, impacts to a grove/intergrove mulga community located immediately downstream from a pit development area would be minimised.

4.1.2 Waste Areas

During the initial mining phases, waste areas will be established to contain waste materials from the mining and process activities. However, as mining progresses and open pit space becomes available, most waste materials will be deposited in the pits. Generally, these initial waste areas will be established in the higher elevation areas upstream from the open pits. In these higher elevation areas, drainage is characterised by defined creek flowpaths, therefore the proposed waste area locations will avoid the lower elevation sheetflow zones. Additionally, as the immediate downstream area contains an open pit, the waste areas have a reduced potential to impact the downstream environment.

In a similar manner as used for the open pit areas, surface water protection bunding will typically be constructed around the waste area perimeters (in a similar fashion as shown in Figure 2). These protection works, comprising a combination of earth bunds and diversion channels, will prevent external surface water from entering the sediment prone waste areas. Upstream surface water flows will be diverted around the waste areas, where feasible and directed into defined surface water pathways either adjacent or downstream from the waste areas. Where appropriate, riprap pads will be provided in key areas along the edges of the diversion bunding to slow and redistribute runoff.

Where due to topography diversion of upstream surface water runoff around the bund perimeter is not feasible, external runoff water will pond against the waste area and be dissipated by evaporation and seepage. In these locations, the waste areas will likely form part of the surface water protection works for the downstream pit.

Within the waste areas, surface water runoff will be drained from the waste area top surface and batters to the downslope sides and then directed through sediment basins, to reduce sediment loadings and turbidity, prior to discharging to the downstream environment. Depending on the waste materials, the waste area top surface may be dished in the centre, so to be internally draining thus reducing runoff and the potential for erosion down the waste area faces. If constructed in this manner, the collected runoff water on the top surface will dissipate by evaporation and seepage.

With construction and operation of the waste areas utilising these proposed surface water management measures, the impact to the downstream environment due to a potential reduction of surface water runoff volume and quality is assessed as being insignificant. That is, the reduction in surface water runoff volume will be minimal as most external surface water will be redirected around waste dumps and redistributed downstream, and internal runoff collected and discharged downstream. Any reduction in surface flow volume will be minimal when compared with the overall catchment runoff. Increases in the surface water sediment load will also be minimal, due to management through sediment basin interceptors. For long-term closure conditions, riprap pads will be provided, as appropriate, at the exit from the waste areas to slow and redistribute runoff.

4.1.3 Process Plant and Stockpile Areas

Plant sites will likely be developed at both Christmas Creek and Mt Lewin, to process the mined ore. These plant sites will be located in the general sheetflow zone downslope from the open pit areas and upslope from the railway. Site selection will be undertaken to minimise impact arising from sheetflow interruptions to the downstream environment. The plant sites will be bunded as appropriate to prevent external surface water runoff entering the infrastructure area and to retain internal drainage. The internal drainage will be collected and reused in the process water circuit. It is assessed that the process plants will have an insignificant impact on the surface water runoff volumes, due to the relatively small area utilised for the process plant as compared to the total catchment to the marshes. Similarly it is assessed that the process plants will have no impact on the surface water quality in the downstream environment, due to external surface waters being diverted around the sites and internal drainage water being retained.

Ore stockpiles will be established at the process plants and at the train loading facilities in the rail corridor. These stockpiles will typically occupy relatively small areas and will be bunded to contain internal drainage and protect from any external surface water runoff. Water collected from within the bunded areas will be returned to the process water circuit. As with the process plants, it is assessed that the stockpiles will have an insignificant impact on the surface water runoff volumes and have no impact on the surface water runoff quality in the downstream environment, due to the perimeter bunding and retaining of the internal drainage waters.

4.1.4 Recommended Mine Areas Surface Water Management

The proposed FMG mine developments could potentially alter the existing surface water flow patterns in the development areas including flooding characteristics; scour and siltation of the drainage channels; inundation of upstream areas and water starvation to downstream areas. In particular, the grove intergrove mulga communities, which are partially dependent on sheetflow runoff, may potentially be impacted. The mine developments could also result in a potential reduction of surface water runoff volume and quality in the downstream environment. Aquaterra recommends that FMG commits to implementing the following surface water management strategies to reduce the potential for environmental impact:

1. Construct surface water bunding around the pit perimeters to prevent external surface water from entering the pit areas.
2. Divert upstream surface water flows around the pit development areas and directed into adjacent defined surface water pathways or to join existing flow pathways located downstream.
3. Where diversion options are not practical, external surface water runoff allowed to enter the pit area to be primarily used for process purposes.
4. In sheetflow areas and in critical flow zones, diverted flows to be discharged over riprap pads to encourage flows to slow and disperse.
5. Where a sheetflow zone containing a grove/intergrove mulga community is located immediately downslope from an open pit area and external surface water runoff is collected in the pit, then after a major rainfall event some of the collected in-pit water to be used to irrigate this sheetflow zone. However, irrigation not to be applied to grove/intergrove areas that are proposed to be disturbed by future mining activities.
6. All in-pit water to be treated through a sediment pond prior to external discharge.
7. Progressive backfill and rehabilitate the open pits upon completion of mining.
8. Construct surface water bunding around the waste facility perimeters to prevent external surface water from entering the waste facility areas.
9. Divert upstream surface water flows around the waste facility areas and directed into adjacent defined surface water pathways or to join existing flow pathways located downstream.
10. Drainage from within the waste facility areas to be directed through a sediment basin prior to external discharge. For long term closure conditions, where appropriate, external discharges to also be directed over a riprap pad to slow and redistribute runoff.
11. Locate and design the process plant sites to minimise impact arising from interruptions to sheetflow.
12. Bund the process plant and stockpile areas, as appropriate, to prevent external surface water entry.
13. Collect internal drainage from the process plant and stockpile areas for reuse in the process water circuit.

4.2 RAIL CORRIDOR SURFACE HYDROLOGY IMPACTS AND MANAGEMENT

The FMG East-West railway is proposed to be constructed along the north side of the Fortescue Marshes linking the Mt Nicholas mine site to the FMG Stage A railway corridor, as shown in Figure 1. This east-west route is around 160km in length and links into the Christmas Creek and Mt Lewin mine development areas. Located predominantly on the lower slopes of the Chichester Plateau, the railway corridor typically crosses perpendicular to the surface water flow directions. Numerous small creeks cross the corridor and a description of the existing surface water environment has been given in Section 3.3.

The railway construction comprising predominantly fill earthworks could potentially interrupt the surface water drainage features that naturally cross through the rail corridor. For the east-west route, these natural drainage features include creeks, floodplains and sheetflow areas. No major river systems cross the railway, with the largest flowpath being Kulkinbah Creek draining a catchment area of around 770 km^2 above the railway corridor. Inappropriate management of these features could potentially alter existing natural drainage patterns including flooding characteristics; scour, erosion and siltation of the drainage channels; inundation of upstream areas and water starvation to downstream areas.

Culverts will be installed under the east-west railway at all drainage crossings and in the sheetflow areas. These culverts will be designed with erosion protection works, as appropriate, to neutralise the potential for adverse water flow impacts. Installation of the railway embankment will not prevent surface water runoff from the upslope catchments draining to the Fortescue Marshes, due the culverts being provided

4.2.1 Defined Flow Channels

The railway formation crosses numerous defined flow channels where culverts will be designed and installed to safely pass the 20 year ARI (Average Recurrence Interval) flood event. Although these culverts will partially constrict flood flows, they will not prevent runoff draining to the downstream environment. During a flood event, upstream culvert water levels at the culverts become elevated and pressurise the flow through the culverts generating a higher velocity discharge stream. Downstream from the culverts, the discharging water slows and reverts to natural flow conditions and water levels are not affected. In proximity to the culverts, localised higher flow velocities occur with the potential for scouring and appropriate erosion protection works are required. Methods to manage these potentially adverse factors to acceptable levels include limiting the upstream water levels, the provision of riprap or similar scour protection blankets and at some locations the provision of additional support earthworks.

Where the railway formation is located such that topography would cause intercepted drainage pathways to flow along the upstream side of the formation for long distances, there is potential that large and erosive drainage discharges could develop. In these areas, culverts will be installed under the railway formation at regular intervals together with small interceptor embankments to direct runoff into the culverts.

4.2.2 Sheetflow Areas and Dependent Vegetation

Along the flanks of the Chichester Ranges, the FMG east-west rail corridor passes through sheetflow areas where extensive sections contain sheetflow dependent grove/intergrove mulga vegetation. It is generally reported by CALM and others that in grove/intergrove mulga community areas the runoff shadowing effect caused by a linear structure, such as a road or railway, has a detrimental effect on the mulga communities. These linear structures cause an interruption to sheetflow through the area and a subsequent reduction in the potential for soil moisture replenishment in the mulga grove areas. Most of these anecdotal observations in the Pilbara describe extensive areas of dead mulgas, some of which are located downslope from road and railway alignments. Observations also report extensive areas of healthy grove/intergrove mulgas located downslope from roads and railways.

The Ecosystem Research Group from the University of Western Australia has an on-going study investigating the impacts of linear structures on grove/intergrove mulga communities in the Pilbara (pers. comm. Dr Pauline Grierson). Although these investigations are yet to be completed, they have as yet not been able to fully quantify or even determine qualitatively the catchments required for mulga species. The studies at UWA have so far focused on detailed field surveys of mulga health, recruitment and carbon patterns across extensive rail lines in the Pilbara and they can not yet identify either clear patterns in mulga health or adverse effects directly resulting from infrastructure shadowing. Because of the often contradictory survey results, remote sensing and GIS are now being used to quantify both spatial extent of areas where mulga is showing signs of stress and to identify patterns of decline in association with rail lines, slope position and culvert placement.

Through these sheetflow areas, where the railway formation effectively runs along the contour (ie: perpendicular to the drainage flowpaths) the formation will block the sheetflow pathways causing water to collect along the upstream side. With inappropriate management, areas with sheetflow dependent downstream vegetation could potentially be impacted by the blocking action from the railway formation. In these areas, drainage culverts need to be installed under the railway formation at regular intervals together with works to redistribute the sheetflow on the downstream side of the culverts.

Where the railway passes through the sheetflow areas, FMG will install small diameter culverts under the railway formation at regular intervals. In these sheetflow areas, discharge, sediment and debris loadings are predicted to be relatively low and culverts with a minimum 300mm diameter will be used to redistribute the sheetflow. Where higher discharges are predicted, larger sized culverts will be installed to suit. To reduce the potential for impact through the more sensitive grove/intergrove mulga areas, ground and vegetation conditions along the railway route will be visually assessed to determine the required locations and spacings for the culverts. In these more sensitive areas, the culvert spacings would likely be at around 100m centres.

The access road adjacent to the railway needs to be considered in conjunction with the railway formation for the potential to block the sheetflow pathways and to introduce sediments into the surface water runoff. To maintain the access road, regular grading will be required which typically results in the formation of a loose earth windrow along the road verges. If the access road is located such that sheetflow collects against these windrows, this loose material will tend to be mobilised by the flows and redistributed downstream. Additionally, diverted water may pond over poorly graded sections in the road.

To reduce the potential for mobilising access road sediments through the sheetflow areas, FMG will typically install the railway access road on the downslope side of the railway formation thus preventing sheetflow from impacting on the windrows and reducing the potential for sediment to block culverts. Where culverts through the railway formation discharge across the access road, a shallow dip will be formed in the road and cement stabilised road base material (or similar) locally used for the road construction. This stabilised material will protect the road base from erosion and prevent it from becoming soft. Maintenance grading of the access road will be conducted such that windrows will not be formed in the culvert outlet flow zones.

On the downstream side of the railway sheetflow culverts and access road, FMG will install works to redistribute the runoff. Where grove/intergrove mulga communities are not located in the immediate area downstream from the railway, discharges from the culverts will be directed against a riprap pad where the flows will slow and disperse to the downstream environment. Where grove/intergrove mulga communities are located in the immediate area downstream from the railway, a spreader ditch redistribution system will be constructed. This spreader ditch system will be based on the gap spreader bank design as developed for soil conservation earthworks (Soil Conservation Service of NSW, 1985)

For the spreader ditch system, as conceptually shown in Figure 3, a small ditch will be carefully constructed along the contour, using survey control, with a level outflow sill to uniformly distribute runoff to the downstream environment. Discharges to the spreader ditch from a 300mm diameter sheetflow culvert, would be relatively small (peak around 60 L/s) due to the culvert's limited flow capacity. Hence flow velocities through the spreader ditch system would be relatively low and non-erosive. Prior to entering the spreader ditch, runoff from the culvert will be discharged to a silt trap that then overflows to the spreader ditch. A small riprap pad will be installed directly in-line with the spreader ditch inlet, to restrict any potential for flows to breakout of the ditch before lateral redistribution. The final design layout for the spreader ditch will be based on field trials, prior to construction. In service, operation of the spreader ditch system will be monitored and modifications made as considered appropriate. The system will also be adequately maintained to ensure its effectiveness over time.

4.2.3 Recommended Railway Corridor Surface Water Management

Construction of the FMG railway could potentially alter the existing natural drainage patterns along the route including flooding characteristics; scour, erosion and siltation of the drainage channels; inundation of upstream areas and water starvation to downstream areas. In particular, grove/intergrove mulga communities, which are partially dependent on sheetflow runoff, may potentially be impacted. Aquaterra recommends that FMG commits to implementing the following surface water management strategies to reduce the potential for environmental impact:

1. Install culverts at all defined drainage crossings and with capacity to safely pass the 20 year Average Recurrence Interval (ARI) flood.
2. Design culverts with limiting upstream water levels to control flow velocities and with riprap or similar scour protection blankets on the inlets and outlets.
3. Install culverts with small interceptor embankments, where appropriate, to prevent long drainage pathways developing adjacent and parallel to the railway formation.
4. Install small diameter culverts at regular intervals through sheetflow areas, with provision for larger sized culverts where higher discharges are predicted.
5. Where sheetflow dependent grove/intergrove mulga areas are located immediate downstream from the railway, sheetflow culvert locations shall be based on ground and vegetation conditions.
6. In sheetflow areas, install the railway access road on the downslope side of the railway formation.
7. Downstream from the sheetflow culverts, install a shallow dip in the railway access road using cement stabilised road base material and do not place graded windrow material in this flow zone.
8. Downstream from the sheetflow culverts and railway access road, install riprap pads to slow and disperse culvert runoff to the downstream environment.
9. Where sheetflow dependent grove/intergrove mulga areas are located immediately downstream from the railway, install a spreader ditch sheetflow redistribution system to disperse culvert runoff to the downstream environment.
10. Monitor the operation of the sheetflow spreader ditch system and conduct maintenance as required.

SECTION 5 - REFERENCES

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FIGURES

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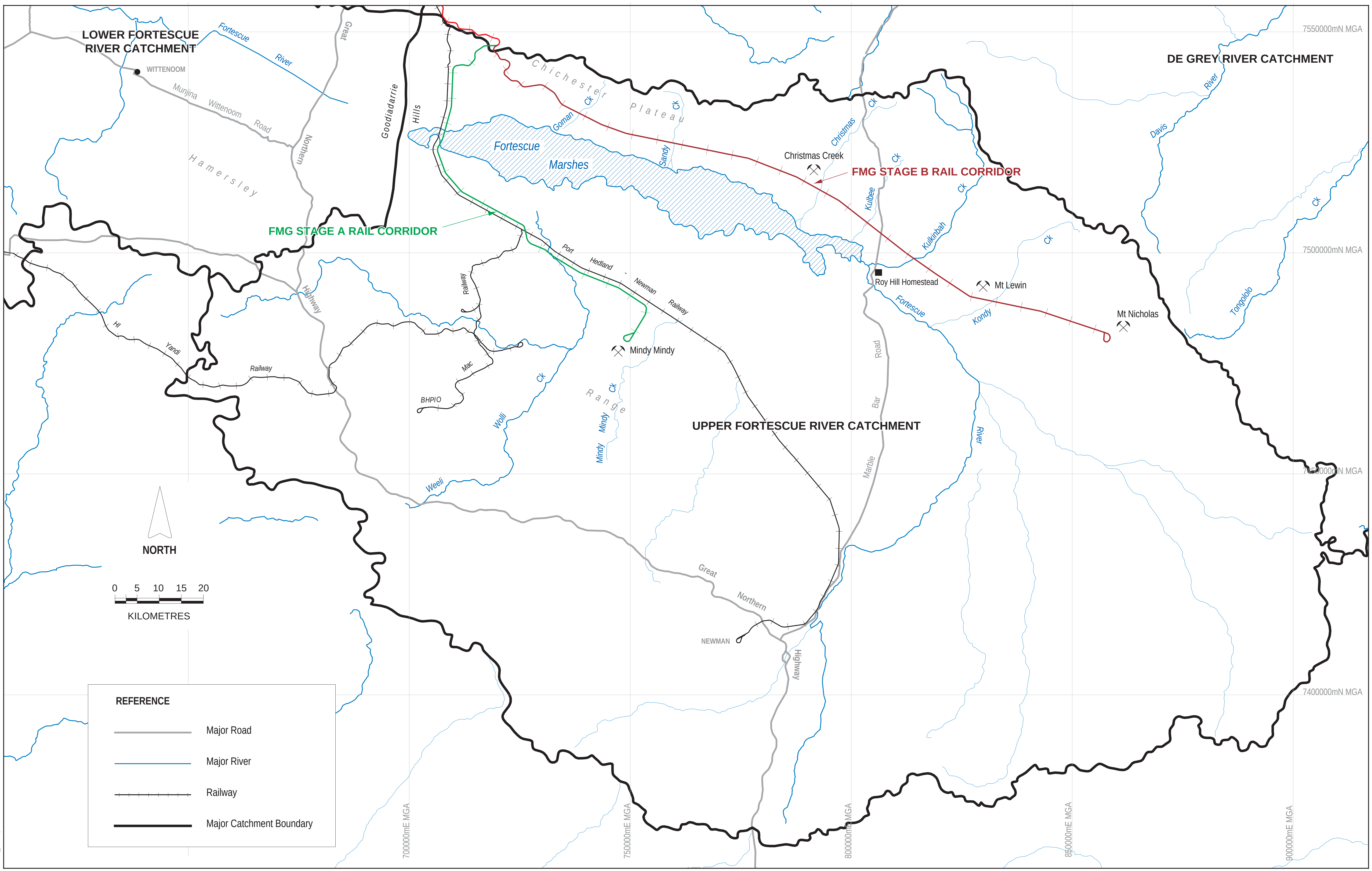

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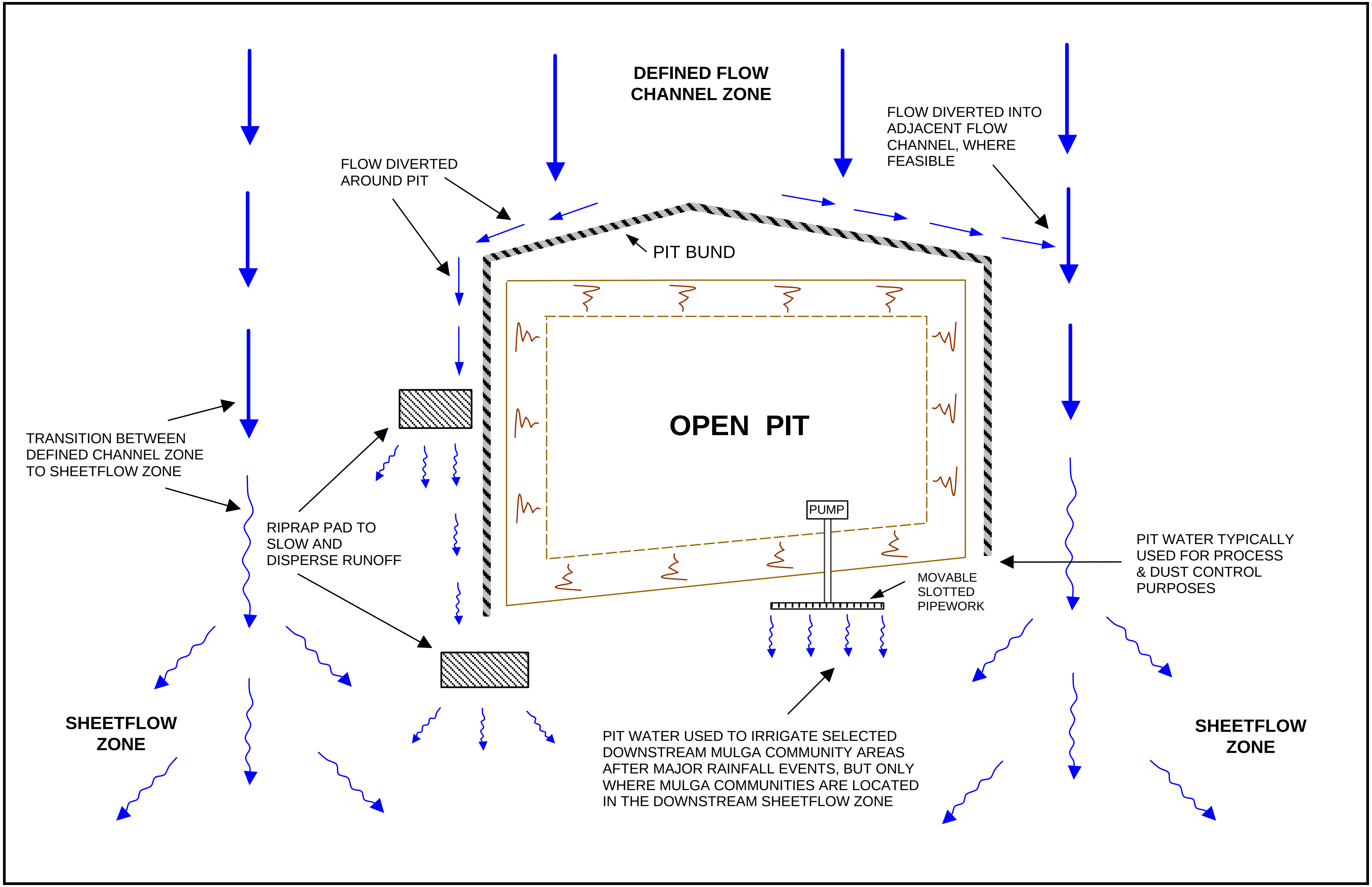
FIGURE 1

FORTESCUE METALS GROUP

MINES AND EAST-WEST RAILWAY

UPPER FORTESCUE RIVER CATCHMENT



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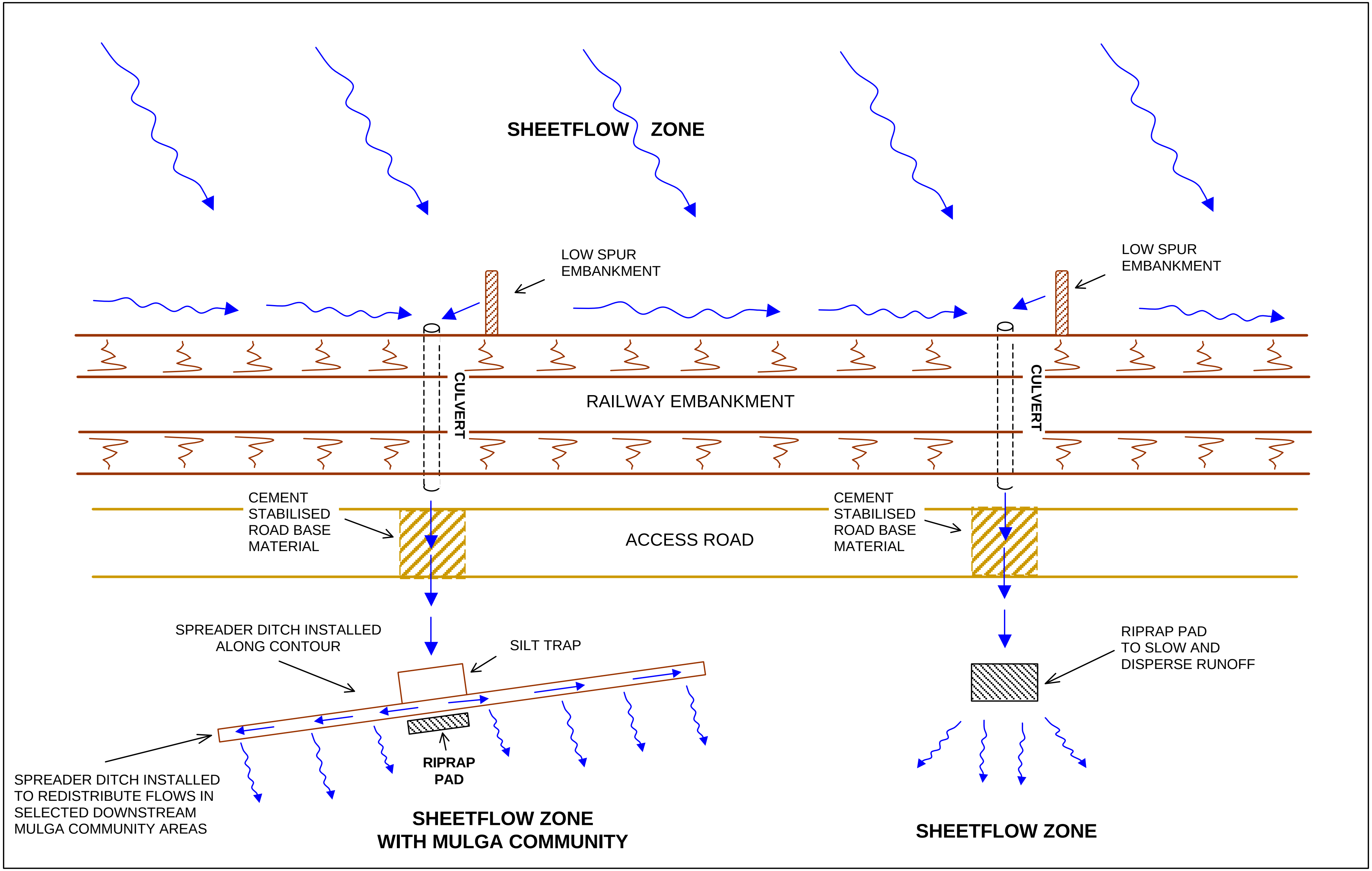
OPEN PIT AREA
SHEETFLOW REDISTRIBUTION

FIGURE 2



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RAILWAY CORRIDOR SHEETFLOW REDISTRIBUTION

FIGURE 3