REPORT
South Flank Surface Water
Environmental Impact Assessment

Prepared for BHP Billiton Iron Ore
29 August 2016
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REVISION SCHEDULE

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EXECUTIVE SUMMARY

MWH was engaged by BHP Billiton Iron Ore Pty Ltd (BHP BILLITON IRON ORE) to assess surface water-related environmental impacts associated with the development of the South Flank deposits (Highway, Grand Central, and Vista Oriental). Impacts of the proposed development on surface water runoff were evaluated for the 2-year, 5-year, 10-year, 20-year, 50-year, 100-year, 1,000-year, and 10,000-year average recurrence interval (ARI) events within the Mining Area C Additional Impact Assessment Area as defined in BHP Billiton Iron Ore’s General Arrangement Rev B (A780/06 Figure 3, 25 May 2016).

Impacts were assessed based on a comparison of flood extents, flood depths, peak flow rates, and flow volumes between the existing, developed, and post-closure conditions. This assessment is limited to the Additional Development Envelope and includes 12 overburden storage areas (OSAs), 2 ROM pads, 2 topsoil areas, and the South Flank mining pits. The locations of all OSAs, pit outlines, and other features delineated in this assessment are indicative only. Changes to the developed condition made subsequent to May 2016 are not included in this assessment. Surface water impacts related to pits, OSAs, and infrastructure associated with the Current Approved Development Envelope are included in this assessment as part of the cumulative impact assessment.

Existing conditions are taken from a 2016 2-metre by 2-metre grid resolution digital elevation model (DEM) provided by BHP BILLITON IRON ORE. Developed conditions were evaluated by incorporating the additional landforms and mining pits into the terrain surface and quantifying the effect on surface water runoff under each ARI event. Haul roads, processing plants, and other proposed mining infrastructure features within the Additional Impact Assessment Area are assessed qualitatively, with general recommendations presented for mitigation measures that minimise surface water impacts.

The Additional Development Envelope is generally located along catchment divides, with four primary local catchments and drainage directions (see Figure ES-1). The north western (NW) and south western (SW) local catchment areas drain westwards across the Great Northern Highway into Lake Robinson within the internally draining Coondewanna catchment. The north eastern (NE) local catchment area drains to Weeli Wolli Creek, and the south eastern (SE) local catchment area drains to Pebble Mouse Creek, a tributary of Weeli Wolli Creek. No external catchment areas drain toward the site, with the exception of Pebble Mouse Creek, which has a catchment area of 166 km² upstream of the Additional Development Area and runs along the downstream extent of the SE catchment.

Table ES-1 summarises the impacted areas. The total area of impact within the Additional Impact Assessment Area, including OSAs, ROM pads, topsoil areas, pits, and their contributing catchment areas, is approximately 18,580 ha. The impacted areas in this report include OSA 14, which is located in the northern portion of Mining Area C; OSA 14 is not included in the hydrologic and hydraulic modelling but is presented in terms of the total area of impact within the Coondewanna catchment.

Although one OSA encroaches on the Pebble Mouse Creek floodplain, no flow is lost to mining pits and the main channel flow path is essentially unaltered. The tabulated areas of impact thus do not include the Pebble Mouse Creek catchment area.

RORB models were developed to provide runoff hydrographs for Pebble Mouse Creek and for an internal catchment used as validation against hydraulic modelling results. A 2-dimensional TUFLOW model (WBM 2016) was developed using a direct rainfall (or rain-on-grid) approach to apply excess rainfall at each grid element using the same rainfall depths, temporal patterns, and infiltration rates as the RORB model.

Flow and stage hydrographs were extracted along index sections placed at the downstream extent of each of the four primary catchment areas. This assessment assumes that pits are not backfilled to surface and that runoff draining toward mining pits is diverted entirely into each pit. Landforms are assumed to be internally draining, with diversions around the landforms following the alignment of the proposed toe.
Figure ES-1: South Flank and regional catchments

Table ES-1: Summary of impacted areas

<table>
<thead>
<tr>
<th>Local Catchment ID</th>
<th>Additional pit area (ha)</th>
<th>Catchment draining to pit area (ha)</th>
<th>Additional landform area (ha)</th>
<th>Catchment draining to landforms (ha)</th>
<th>Total impacted area (ha)</th>
<th>Percent of regional catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td>NW</td>
<td>310</td>
<td>400</td>
<td>1020</td>
<td>140</td>
<td>1870</td>
<td>2.2% of Coondewanna</td>
</tr>
<tr>
<td>SW</td>
<td>410</td>
<td>550</td>
<td>450</td>
<td>800</td>
<td>2210</td>
<td>2.6% of Coondewanna</td>
</tr>
<tr>
<td>Total West</td>
<td>720</td>
<td>950</td>
<td>1470</td>
<td>940</td>
<td>4080</td>
<td>4.7% of Coondewanna</td>
</tr>
<tr>
<td>NE</td>
<td>130</td>
<td>450</td>
<td>820</td>
<td>6450</td>
<td>7850</td>
<td>1.9% of Weeli Wolli</td>
</tr>
<tr>
<td>SE</td>
<td>1430</td>
<td>1560</td>
<td>1710</td>
<td>1950</td>
<td>6650</td>
<td>1.6% of Weeli Wolli</td>
</tr>
<tr>
<td>Total East</td>
<td>1560</td>
<td>2010</td>
<td>2530</td>
<td>8400</td>
<td>14500</td>
<td>3.5% of Weeli Wolli</td>
</tr>
<tr>
<td>Total</td>
<td>2280</td>
<td>2960</td>
<td>4000</td>
<td>9340</td>
<td>18580</td>
<td></td>
</tr>
</tbody>
</table>
The most significant potential loss of catchment area draining to downstream receptors would be related to the capture of Pebble Mouse Creek by a mining pit. The edge of the closest South Flank pit is approximately 100 metres from the 10,000-year ARI floodplain extent at its closest point. The zone of geotechnical instability and required abandonment bund location may extend into the floodplain; however, the hydraulic modelling results show that the proposed pit edge is located above all assessed flood levels, so for the purpose of this study, creek capture is dismissed.

The pits and landforms that comprise the Additional Impact Assessment Area are primarily located near catchment divides without major watercourses. Most of the modelled pit inflow enters the pits through a series of overland flow paths. The pit outlines intersect several concentrated flow paths with contributing catchment areas of up to 400 ha. These flow paths are currently modelled as pit inflow locations; however, interception and diversion of these flows would likely be considered as part of further mine planning efforts and would reduce the overall impacts.

The total cumulative area of mine-affected areas and diverted catchments for South Flank, North Flank, Baby Hope, and Hope Downs 1 is approximately 6.9% of the Coondewanna catchment, 7.2% of the Weeli Wolli Creek catchment, and approximately 2% of the Fortescue Marsh catchment.

In summary, the proposed project will alter local flow paths and runoff volumes for small, ephemeral creeks within the Additional Development Envelope. Impacts will be minimised through BHP BILLITON IRON ORE’s standard surface water management measures. The risk of hydrocarbon or chemical spillage can be mitigated through standard best practices for pollution control.
BHP Billiton Iron Ore
South Flank Surface Water EIA

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1 Introduction

1.1 Background and objectives

BHP Billiton Iron Ore Pty Ltd (BHP BILLITON IRON ORE) are investigating the option of developing South Flank, located south of Mining Area C (MAC) and approximately 100 km northwest of Newman. MAC is one of four mining hubs in BHP BILLITON IRON ORE’s Western Australian Iron Ore (WAIO) business. The South Flank project is proposing to develop a mixture of brownfield and green field facilities with an annual production capacity of approximately 80 Mtpa. This will increase annual production to approximately 150 Mtpa from the MAC hub. This increase will substitute the ore generation of the Yandi mining hub whilst providing no increase to the total BHP Billiton’s annual production. MAC mining activities will be extended to the South Flank project area, approximately 8 kilometres south of existing processing facilities, within Mining Lease ML281SA. The South Flank development comprises three deposits: Highway, Grand Central, and Vista Oriental. Incremental mining activity will be supported with construction of new processing facilities as follows (Figure 1-1):

- Primary Crushing (PC) facilities located south of existing infrastructure;
- Run of Mine (ROM) pad’s at Vista Oriental (eastern) or Grand Central (western) project area’s;
- Overland conveyors;
- Coarse Ore Stockpile (COS);
- Ore Handling Plant (OHP) within existing MAC lease area;
- Upgrade to the existing stockyards and outflow facilities;
- Duplication of the existing rail loop and addition of a second Train Loadout (TLO);
- Advanced mine de-watering to support mining at South Flank;
- Expansion of Mulla Mulla Accommodation Village capacity to approximately 1500 beds;
- Installation of supporting non-processes infrastructure (e.g. power lines, access roads) to support new mining area: and
- Expansion of existing non-processing infrastructure (NPI) and industrial facilities to support production.

As part of these investigations, a surface water Environmental Impact Assessment (EIA) is required to assess the potential change in hydrological characteristics as a result of the proposed mine development. MWH was engaged by BHP BILLITON IRON ORE to assess surface water-related environmental impacts associated with the development of the Highway, Grand Central, and Vista Oriental deposits (Figure 1-2) for the 2-year, 5-year, 10-year, 20-year, 50-year, 100-year, 1,000-year, and 10,000-year average recurrence interval (ARI) events. The study area is limited to the Mining Area C Additional Impact Assessment Area as defined in BHP Billiton Iron Ore’s General Arrangement Rev B (A780/06 Figure 3, 25 May 2016). This report describes the approach taken for the hydrological and hydraulic modelling, including the selection of adopted parameters. Results are presented for selected scenarios along with recommendations for mitigation measures.
Figure 1-1: Indicative General Arrangement for Mining Area C (BHP Billiton Iron Ore 2016)

Figure 1-2: South Flank deposits
The intended purpose of the modelling developed for this study is to predict hydrological and hydraulic impacts related to the presence of the LOM pits and OSAs and to develop surface water management measures, aid in mine planning efforts, and optimise the configuration of mine-related infrastructure during construction, operation, and closure conditions.

This assessment is limited to the Additional Development Envelope and includes 12 overburden storage areas (OSAs), 2 ROM pads, 2 topsoil areas, and the South Flank mining pits. The locations of all OSAs, pit outlines, and other features delineated in this assessment are indicative only. Changes to the developed condition made subsequent to May 2016 are not included in this assessment. Surface water impacts related to pits, OSAs, and infrastructure associated with the Current Approved Development Envelope are included in this assessment as part of the cumulative impact assessment.

This report is prepared in accordance with the request for proposal issued by BHP BILLITON IRON ORE on 18 April 2016, the scope of work and proposal dated 22 April 2016, Purchase Order 4504493211 dated 19 May 2016, and as discussed and noted in ongoing project meetings.

1.2 Methodology and data sources

Impacts were assessed based on a comparison of flood extents and flood depths between the existing and developed condition for the Additional Development Envelope. Existing conditions are taken from a 2016 2-metre by 2-metre grid resolution digital elevation model (DEM) provided by BHP BILLITON IRON ORE. Developed conditions were evaluated by incorporating the additional overburden storage areas (OSAs) and mining pits into the terrain surface and quantifying the effect on surface water runoff under each ARI event.

Haul roads, processing plants, and other proposed mining infrastructure features within the Additional Impact Assessment Area are assessed qualitatively, with general recommendations presented for mitigation measures to minimise surface water impacts. Indicative diversion drain alignments and sediment pond locations are provided based on the May 2016 General Arrangement.

The modelling in this report is based on background data provided by BHP BILLITON IRON ORE. A desktop review was conducted to extract relevant information from the provided reports, computational models, and geospatial data. The following data sources were used in this study:

- Mining Area C Environmental Management Plan Surface Water Assessment ("RPD CPH 20150714 MAC EMP Rev6 010c.pdf")
- Baby Hope Hydrology and Hydraulic Assessment ("Appendix 6_Baby Hope Hydro Report.pdf")
- Mining Area C Creek Discharge Report (MWH 2015)
- 2016 aerial photography ("AerialImagery.tif")
- 2-metre Digital Elevation Model ("DEM_2m.tif")
- Landform and Pit Configuration ("20160525_SF_SPS_Ftprint_Draft")
• Hope Downs Disturbance Area (“HopeDowns.shp”)

The following software applications were used in the development and presentation of hydrological and hydraulic models in this assessment:

• RORB Model Version 6.18
• TUFLOW Build 2016-01-AC-iDP-w64
• WaterRide Version 7.00 2014-12-05
• ArcGIS Spatial Analyst and 3D Analyst V10.2
• QGIS and Crayfish

The existing condition modelling is based on the 2016 DEM, and the closure condition is based on the life of mine plan OSA configuration provided in shape file format. All geospatial data are projected to GDA 1994 MGA Zone 50 in the accompanying Geographic Information System (GIS) electronic files. No other information was used in the development of this report. Should relevant, additional information become available, the results and recommendations presented in this report may need to be revisited.

For consistency in this report, “Mining Area C” includes both the Current Approved Development Envelope (North Flank) as well as the Additional Development Envelope (South Flank). Table 1-1 lists the terminology for descriptions of proposed features used throughout this report.

Table 1-1: Mining Area C terminology

<table>
<thead>
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<th>Description</th>
<th>Proposed Terminology</th>
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<tr>
<td>Proposed Mining Area C Development Envelope</td>
<td>Proposed Mining Area C Development Envelope</td>
</tr>
<tr>
<td>Ministerial Statement 491 (Northern Flank)</td>
<td>Current Approved Development Envelope</td>
</tr>
<tr>
<td>Indicative Additional Pits, Indicative OSA and Indicative infrastructure Area, Indicative South Flank Overall arrangement and Topsoil</td>
<td>Additional Impact Assessment Area</td>
</tr>
<tr>
<td>Indicative Infrastructure, Existing Infrastructure, indicative OSA area, Indicative Pit Area (i.e. old MAC rev 6)</td>
<td>Current Approved Impact Assessment Area</td>
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<tr>
<td>Area between approved and proposed mining Area C development Area (aka South Flank area)</td>
<td>Additional Development Envelope</td>
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2 Hydrology

This chapter describes the approach for estimating rainfall and runoff over the Additional Development Envelope.

2.1 Hydrological setting

As shown in Figure 2-1, the Additional Development Envelope is generally located along catchment divides, with the north western (NW) and south western (SW) local catchment areas draining westwards across the Great Northern Highway into Lake Robinson within the internally draining Coondewanna catchment. OSA 14, which is located in the northern portion of Mining Area C, likewise drains to Lake Robinson. The north eastern (NE) local catchment area drains to Weeli Wolli Creek, and the south eastern (SE) local catchment area drains to Pebble Mouse Creek, a tributary of Weeli Wolli Creek. Additional details on the hydrology of the Current Development Envelope are addressed in the Mining Area C Environmental Management Plan (RPS 2015).

Figure 2-1: South Flank and regional catchments

No external catchment areas drain toward the site, with the exception of Pebble Mouse Creek, which has a catchment area of 166 km² upstream of the Additional Development Area and runs along OSA 36 at the downstream extent of the south eastern catchment.
The total area of impact within the Additional Impact Assessment Area, including OSAs, ROM pads, topsoil areas, pits, and their contributing catchment areas, is 18,580 ha. Following is a summary of the impacted areas:

Table 2-1: Impacted areas

<table>
<thead>
<tr>
<th>Additional pit area (ha)</th>
<th>Catchment draining to pit area (ha)</th>
<th>Additional landform area (ha)</th>
<th>Catchment draining to landforms (ha)</th>
<th>Total impacted area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,280</td>
<td>2,960</td>
<td>4,000</td>
<td>9,340</td>
<td>18,580</td>
</tr>
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</table>

The catchment areas summarised above include OSA 14, which is located in the northern portion of Mining Area C. OSA 14 is not included in the hydrologic and hydraulic modelling. Groundwater and surface water runoff in the vicinity of OSA 14 are covered in the Mining Area C Creek Discharge Report (MWH 2015) and in the Mining Area C Environmental Management Plan Surface Water Assessment (RPS 2015).

The development envelope crosses into the Pebble Mouse Creek floodplain but the primary flow path is not impacted by the assessment area; as such, the Pebble Mouse Creek catchment area is excluded from the areas of impact tabulated in this report. No flow is lost to mining pits and the main channel flow path is unaltered.

Due to the shorter flow paths and concentration times, peak flows from minor tributaries that drain across the South Flank site tend to reach their peak prior to the arrival of the peak flow from Pebble Mouse Creek. Figure 3-1 shows the coverage area for LiDAR mapping and aerial photography along with the index sections at the downstream hydraulic modelling extent. The longest flow path across the South Flank area extends over a length of approximately 6 km and has an average longitudinal slope of approximately 0.8%. The upper catchment divide is at an elevation of approximately 1,200 mAH and the downstream outflow is at an elevation of approximately 700 mAH.

2.2 Rainfall

Rainfall depths were taken from the 1987 Bureau of Meteorology Intensity-Frequency-Duration data. The 1987 IFD curves result in higher flood estimates than the 2013 curves. As a conservative estimate for the design events commonly used for the design of drainage structures and flood protection measures, the 1987 curves are applied in this assessment.

Design rainfall for the 1,000-year and 10,000-year ARI events were derived by interpolating between the 50- and 100-year ARI values and the probable maximum precipitation (PMP). The interpolation procedure is described in Australian Rainfall and Runoff (ARR, Pilgrim et al, 1987). The method involves calculating the 2,000-year and 50,000-year ARI estimates based on a shape factor approach. A frequency curve is then plotted using a log-normal scale through the derived rainfall totals (i.e. 50-yr, 100-yr, 2,000-yr, 5,000-yr ARI and the PMP) and the 1,000-year and 10,000-year ARI rainfall is read off the curve.
The Generalised Short Duration Method (GSDM) was used to estimate PMP values for use in the interpolation. Figure 2-2 illustrates the rainfall extrapolation curve for the South Flank internal catchment.

![Southflank PMP rainfall depths - Internal Catchment](image)

**Figure 2-2: South Flank internal catchment rainfall extrapolation**

Temporal patterns were taken from ARR for the 2-year through 100-year ARI events. Temporal patterns for the 1,000-year and 10,000-year ARI events are taken from the Generalised Short Duration Method (GSDM) based on critical durations being less than 6 hours (Figure 2-4).

Infiltration data (initial and continuing loss rates) were taken from ARR for the 2-year through 100-year ARI events. Loss rates for the 1,000 and 10,000-year ARI events were extrapolated between the 100-year ARI rates and the assumed minimal probable maximum precipitation loss (0.1mm). Critical durations (the rainfall duration resulting in the highest peak discharge rate) range from 3 to 24 hours and vary with catchment size and the ARI of each event.
Figure 2-3: Catchment delineations for South Flank

Table 2-2: Adopted loss rates

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<th>ARI</th>
<th>Initial Loss (mm/hr)</th>
<th>Continuing Loss (mm/hr)</th>
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<td>2-year</td>
<td>22</td>
<td>5</td>
</tr>
<tr>
<td>5-year</td>
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<td>5</td>
</tr>
<tr>
<td>10-year</td>
<td>52</td>
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<td>10,000-year</td>
<td>1</td>
<td>0.4</td>
</tr>
</tbody>
</table>
Figure 2-4: Temporal patterns for RORB and TUFLow models
2.3 Runoff

A stage recorder is located along Pebble Mouse Creek; however, the gauge has only been in operation since 2015 and no significant flood levels have been recorded since its installation. The nearest Department of Water (DoW) flow gauges are located along Marillana Creek (Flat Rocks) and Weeli Wolli Creek (Tarina).

RORB models were developed to provide runoff hydrographs for Pebble Mouse Creek and for an internal subcatchment within the south eastern catchment selected for validation of results (Validation Catchment). The purpose of the Validation Catchment was to generate hydrographs for comparison between the hydrologic and hydraulic models. The index location for the Validation Catchment is shown on Figure A-2 in Appendix A.

Rainfall depths and RORB peaks flows for critical durations are summarised for Pebble Mouse Creek and for the Validation Catchment in Table 2-3.

A 2-dimensional TUFLOW model (WBM 2016) was developed using direct rainfall (or rain-on-grid) to apply excess rainfall at each grid element using the same rainfall depths, temporal patterns, and infiltration rates as the RORB model. Outflow hydrographs were extracted at the downstream extent of the Validation Catchment. Computational grid sizes, roughness coefficients, and other modelling parameters were adjusted within reasonable ranges to generate results that match the RORB model most closely. A comparison of the resulting hydrographs is shown in Appendix E.

Table 2-3: Peak rainfall and discharge rates

<table>
<thead>
<tr>
<th>ARI</th>
<th>Internal validation catchment</th>
<th>Pebble Mouse Creek catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Critical duration (hr)</td>
<td>Rainfall depth (mm)</td>
</tr>
<tr>
<td>2-year</td>
<td>9</td>
<td>44</td>
</tr>
<tr>
<td>5-year</td>
<td>12</td>
<td>78</td>
</tr>
<tr>
<td>10-year</td>
<td>12</td>
<td>101</td>
</tr>
<tr>
<td>20-year</td>
<td>12</td>
<td>129</td>
</tr>
<tr>
<td>50-year</td>
<td>24</td>
<td>213</td>
</tr>
<tr>
<td>100-year</td>
<td>24</td>
<td>257</td>
</tr>
<tr>
<td>1,000-year</td>
<td>2</td>
<td>200</td>
</tr>
<tr>
<td>10,000-year</td>
<td>2</td>
<td>290</td>
</tr>
</tbody>
</table>
Figure 2-5: Peak discharge rates for South Flank catchments

Figure 2-6: Runoff hydrographs for Pebble Mouse Creek
3 Hydraulic model development

This chapter describes the process of selecting the modelling approach and the input parameters used in the hydraulic model.

3.1 Model setup

As described in the previous chapter, a 2-dimensional TUFLOW model (WBM 2016) was developed using direct rainfall (or rain-on-grid) to apply excess rainfall at each grid using the same rainfall depths, temporal patterns, and infiltration rates as the RORB model.

Mining pits were entered into the model with extremely high infiltration rates in order to simulate pit inflow. No levees, abandonment bunds, or diversion channels were included along the edge of the mining pits, so predicted inflow volumes reflect conservative maximum conditions. No erosional assessments or slope stability analyses were included in the modelling; inflow rates thus assume that pit walls and OSA slopes remain intact throughout the simulated flood event.

OSAs, ROM pads, and topsoil areas were incorporated into the model by raising the ground level around the perimeter of each landform. The modelled landforms thus receive rainfall and pond water internally. The overall volume of contained runoff is represented in the model; however, the distribution of the flow and the indicative flow paths do not reflect design conditions as the underlying terrain was not modified in the model. In practice, the top of each landform may be constructed to contain runoff internally; however, the external slopes would contribute some runoff to the surrounding catchment areas. When pit and OSA designs are further developed, the hydraulic modelling can be refined to account for the drainage design of perimeter bunds, toe drains, slope drains, and other surface water management features. No haul roads, processing plants, or other proposed infrastructure features are included in the modelling exercise.

Figure 3-1 shows the extents of the available LiDAR-based DEM and aerial photography along with the index sections applied at the downstream extent of the TUFLOW model covering the catchment areas within the Additional Development Envelope.
3.2 Inflow and outflow

Inflow was introduced into the model as direct rainfall according to the methodology outlined in Chapter 2. A time-varying flow hydrograph (QT) boundary condition was used in TUFLOW to represent inflow from Pebble Mouse Creek. Outflows are applied along the entire outside perimeter of the model using a height-flow (HQ) rating curve developed with a 0.3% normal depth slope. TUFLOW model runs are carried out to between 8 hours and 15 hours to allow peak flows to pass the downstream outflow boundary. Ongoing data collection efforts may provide the opportunity for future calibration efforts to introduce revised flows that match gauged results.

3.3 Validation

Outflow hydrographs were extracted at the downstream extent of the internal Validation Catchment. Computational grid sizes, roughness coefficients, and other modelling parameters were then adjusted within reasonable ranges to generate results that match the RORB model most closely. The values summarised in Table 3-1 resulted in a peak discharge rate for the 100-year ARI TUFLOW run within 5% of the 100-year peak flow predicted by the RORB model. Discrepancies between the models vary by ARI and are most significant for the lowest flows. For the 2-year ARI discharge for example, very little runoff is generated in the TUFLOW rain-on-grid model. Rather than changing coefficients between individual models, all ARIs use the same set of coefficients; discharge rates for events on the order of the 2-year ARI have a high degree of variability and the results should be treated as indicative only.

3.3.1 Loss rates

Soil infiltration loss rates were taken directly from the RORB model and were not varied as part of the validation exercise. As calibration data become available with future modelling efforts, the introduction
and adjustment of loss rates accounting for infiltration, evaporation, and evapotranspiration may be warranted.

3.3.2 Computational grid size

The DEM was provided at a 2-m by 2-m grid resolution. Various computational grid sizes were run as a sensitivity analysis in order to optimise run times against model performance. The final runs use a computational grid size of 20 metres. As flood mitigation designs are developed with further detail, the use of localised regions of the model at a 2-m grid resolution or the finest available grid resolution may be warranted.

3.3.3 Time step and duration

The TUFLOW manual (WBM 2016) recommends a computational time step in seconds equal to half the grid size in metres. Some instabilities arose with the application of the 10-second time step that corresponds to the 20-metre computational grid size. A sensitivity analysis was run using various time steps, and a final time step of 2 seconds was used in all model runs. For 1-dimensional elements, a time step of half the 2-D time step is recommended. Culvert routines in the model thus use a 1-second time step.

3.3.4 Manning’s roughness coefficient

Aerial and ground photographs of the South Flank area show some variation in substrate material size and vegetation cover along the defined channels. Based on a comparison of the photographs to published values (USACE 2016), in the absence of calibration data a depth-varying roughness coefficient was uniformly applied across the catchment areas. The direct rainfall model includes sheet flow areas as well as channelised reaches. The depth-varying roughness coefficient accounts for the large difference in roughness effects between channelised and shallow flow conditions (where flow depths are on the order of the roughness element heights). Depths of 5 cm or less use a roughness coefficient of 0.08 while depths of 2 metres or greater use a roughness coefficient of 0.04. Roughness coefficients are interpolated for intermediate depths. For localised model runs using a finer grid resolution, a further breakdown of roughness values between roadway surfaces, drains, and vegetated floodplain areas may be warranted. More detailed adjustment of roughness coefficients may be possible as future calibration data become available.

3.3.5 Wet-dry coefficients

The wet-dry coefficient applies a threshold that inhibits the movement of water from one grid cell to the next. The TUFLOW default wet-dry coefficient of 2 mm was replaced with the minimum value of 0.2 mm as recommended for direct rainfall models. The wet-dry coefficient was applied uniformly in the modelling for each of the ARI events. With the availability of future calibration data, the wet-dry coefficient associated with individual events may be customised to better reflect the physical characteristics of the existing terrain relative to the flow condition.
3.4 Culverts

As shown in Appendix A, 12 existing culverts were incorporated into the TUFLOW model as 1D model elements. The culvert lengths and diameters were estimated using measurements from the aerial photography where available. Culverts assume a downward longitudinal slope of 1% in accordance with WAIO standards (SPEC-000-C-00126). Should more detailed as-built information be provided, the model parameters may be refined. Flows that overtop the roadway are assumed to breach the embankment at the culvert locations, and the terrain was lowered in these locations to allow flow through.

3.5 Summary of model input parameters and runs

Table 3-1 summarises the TUFLOW model input parameters adopted for the final set of model runs. For variables not shown in the table, the final model runs utilise recommended default coefficients for direct rainfall models.
Table 3-2 presents the eighteen model runs used for comparison of existing and future conditions results. All model runs use the double-precision engine to improve performance in terms of mass balance. As shown in Appendix A, four index cross section locations were selected for consistent comparison of hydraulic results, including hydrographs, flow volumes, and water surface profiles.

Table 3-1: TUFLOW model input parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culverts</td>
<td>Based on 2016 Aerial observations</td>
</tr>
<tr>
<td>Computational grid size</td>
<td>20 m</td>
</tr>
<tr>
<td>Inflow type</td>
<td>Direct rainfall, with QT hydrograph for Pebble Mouse</td>
</tr>
<tr>
<td>Outflow type</td>
<td>Normal depth, $s=0.3%$</td>
</tr>
<tr>
<td>Wet-dry depth</td>
<td>0.002 m</td>
</tr>
<tr>
<td>2-dimensional time step</td>
<td>2 s</td>
</tr>
<tr>
<td>1-dimensional time step</td>
<td>1 s</td>
</tr>
<tr>
<td>Surface roughness</td>
<td>Depth-varying roughness coefficient 0.04 – 0.08</td>
</tr>
<tr>
<td>Losses (evaporation and infiltration)</td>
<td>ARR initial and continuing losses</td>
</tr>
<tr>
<td>Output interval</td>
<td>5 minutes</td>
</tr>
<tr>
<td>Duration</td>
<td>15 hours</td>
</tr>
</tbody>
</table>
### Table 3-2: TUFLOW model runs

<table>
<thead>
<tr>
<th>Scenario</th>
<th>ARI</th>
<th>LiDAR surface</th>
<th>Landforms</th>
<th>Pits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2-year</td>
<td>2016</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>5-year</td>
<td>2016</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>10-year</td>
<td>2016</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>4</td>
<td>20-year</td>
<td>2016</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>5</td>
<td>50-year</td>
<td>2016</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>6</td>
<td>100-year</td>
<td>2016</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>7</td>
<td>1,000-year</td>
<td>2016</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>10,000-year</td>
<td>2016</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>9</td>
<td>2-year</td>
<td>2016</td>
<td>All South Flank</td>
<td>All South Flank</td>
</tr>
<tr>
<td>10</td>
<td>5-year</td>
<td>2016</td>
<td>All South Flank</td>
<td>All South Flank</td>
</tr>
<tr>
<td>11</td>
<td>10-year</td>
<td>2016</td>
<td>All South Flank</td>
<td>All South Flank</td>
</tr>
<tr>
<td>12</td>
<td>20-year</td>
<td>2016</td>
<td>All South Flank</td>
<td>All South Flank</td>
</tr>
<tr>
<td>13</td>
<td>50-year</td>
<td>2016</td>
<td>All South Flank</td>
<td>All South Flank</td>
</tr>
<tr>
<td>14</td>
<td>100-year</td>
<td>2016</td>
<td>All South Flank</td>
<td>All South Flank</td>
</tr>
<tr>
<td>15</td>
<td>1,000-year</td>
<td>2016</td>
<td>All South Flank</td>
<td>All South Flank</td>
</tr>
<tr>
<td>16</td>
<td>10,000-year</td>
<td>2016</td>
<td>All South Flank</td>
<td>All South Flank</td>
</tr>
<tr>
<td>17</td>
<td>100-year</td>
<td>2016</td>
<td>None</td>
<td>R Pit</td>
</tr>
<tr>
<td>18</td>
<td>100-year</td>
<td>2016</td>
<td>All South Flank</td>
<td>All S.F. + R Pit</td>
</tr>
</tbody>
</table>
4 Impacts to hydrological processes

This chapter compares the existing and developed conditions hydraulic modelling results in order to assess the surface water impacts related to the Additional Development Envelope. The recommendations include standard surface water management measures to re-instate downstream flows where possible.

4.1 Impacted catchment areas

The relative disturbance area within both the local and regional catchments provides a conservative indication of the potential impacts that construction, operation, and closure of the proposed project may have on the adjacent surface water regimes. The most significant change in hydrological processes related to the Additional Development Envelope is the removal of catchment areas contributing to downstream receptors. The downstream receptors are Lake Robinson in the Coondewanna catchment to the west, and Weeli Wolli Creek – and ultimately the Fortescue Marsh – to the east. Figure 2-1 shows the local catchments relative to the broader Coondewanna, Pebble Mouse Creek and Weeli Wolli Creek catchments.

Impacted areas include areas draining to pits as well as areas that drain toward landforms. Figure 4-1 shows the catchment areas captured by mining pits or draining toward landforms. Impacted footprints are assumed to be the same for construction, operation, and closure. Table 4-1 summarises the impacted areas.

Figure 4-1: Catchments contributing to pits and landforms
Development of the proposed project has the potential to impact surface water resources by changing local surface water flow patterns and runoff volumes. Surface water-dependent vegetation and downstream receptors such as the Fortescue Marsh are particularly sensitive to changes in stormwater runoff. The Fortescue Marsh water balance is dominated by surface water contributions (MWH 2015); the major mechanism of groundwater recharge of the flows to the Marsh is dominated by the Fortescue River and Weeli Wolli Creek, contributing around 52% and 19% of mean annual inflows respectively.

The May 2016 General Arrangement indicates that the upper portions of small ephemeral creeks would be intercepted by the indicative footprints of proposed landforms and pits. As shown in Table 4-1, the potentially impacted areas within the eastern local subcatchments comprise approximately 3.5% of the total Weeli Wolli Creek catchment area at Fortescue Marsh (4150 km²). The potentially impacted areas within the western local subcatchment comprise approximately 5% of the Coondewanna catchment (860 km²). The tabulation includes areas draining to pits as well as areas that drain toward landforms. Runoff that is diverted around landforms will ultimately still reach the downstream receptors, with the primary impact being a change in the timing of the flow. Although flow volumes originating from these areas would essentially be unchanged, areas draining to potential diversions around landforms are included in the impact assessment because flow attenuation resulting from diversion may change downstream flood peak discharge rates, potentially affecting floodplain connectivity and surface water dependent vegetation in the floodplains.

The north western catchment areas summarised above include OSA 14, which is located to the north of Mining Area C and covers an area of approximately 510 ha. No major external catchments drain to the OSA 14 area, and standard practices for stormwater management and drainage design of landform runoff should be followed in the ongoing design of the OSA. OSA 14 is not included in the hydrologic and hydraulic modelling but forms part of the Additional Development Envelope and is thus included in the summary of impacted areas.

### Table 4-1: Summary of impacted areas

<table>
<thead>
<tr>
<th>Local Catchment ID</th>
<th>Additional pit area (ha)</th>
<th>Catchment draining to pit area (ha)</th>
<th>Additional landform area (ha)</th>
<th>Catchment draining to landforms (ha)</th>
<th>Total impacted area (ha)</th>
<th>Percent of regional catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td>NW</td>
<td>310</td>
<td>400</td>
<td>1020</td>
<td>140</td>
<td>1870</td>
<td>2.2% of Coondewanna</td>
</tr>
<tr>
<td>SW</td>
<td>410</td>
<td>550</td>
<td>450</td>
<td>800</td>
<td>2210</td>
<td>2.6% of Coondewanna</td>
</tr>
<tr>
<td>Total West</td>
<td>720</td>
<td>950</td>
<td>1470</td>
<td>940</td>
<td>4080</td>
<td>4.7% of Coondewanna</td>
</tr>
<tr>
<td>NE</td>
<td>130</td>
<td>450</td>
<td>820</td>
<td>6450</td>
<td>7850</td>
<td>1.9% of Weeli Wolli</td>
</tr>
<tr>
<td>SE</td>
<td>1430</td>
<td>1560</td>
<td>1710</td>
<td>1950</td>
<td>6650</td>
<td>1.6% of Weeli Wolli</td>
</tr>
<tr>
<td>Total East</td>
<td>1560</td>
<td>2010</td>
<td>2530</td>
<td>8400</td>
<td>14500</td>
<td>3.5% of Weeli Wolli</td>
</tr>
<tr>
<td>Total</td>
<td>2280</td>
<td>2960</td>
<td>4000</td>
<td>9340</td>
<td>18580</td>
<td></td>
</tr>
</tbody>
</table>

The north western catchment areas summarised above include OSA 14, which is located to the north of Mining Area C and covers an area of approximately 510 ha. No major external catchments drain to the OSA 14 area, and standard practices for stormwater management and drainage design of landform runoff should be followed in the ongoing design of the OSA. OSA 14 is not included in the hydrologic and hydraulic modelling but forms part of the Additional Development Envelope and is thus included in the summary of impacted areas.
Although OSA 36 encroaches on the Pebble Mouse Creek floodplain, no flows are removed from the creek, and the overall path of the creek does not change. Pebble Mouse Creek is thus not included in the contributing catchment areas tabulated above, and the hydraulic modelling includes only the portion of the Pebble Mouse Creek floodplain within the Additional Development Envelope.

4.2 Flood depths

Plan view figures showing the results of the hydraulic model runs are included in Appendix B. The figures in Appendix B include flood depth maps for the 2-year, 100-year, and 10,000-year ARI event and depth difference maps for all eight modelled scenarios. Peak flood depths were exported in raster grid format for eight existing conditions storms and eight development conditions storms. Depth values were then subtracted from each other to generate a set of eight difference maps in raster grid format. As shown in the difference mapping, the largest potential impact is ponded water that accumulates in low areas against the landforms with the potential formation of a breach, and a reduced water level downstream of pits that intercept upstream catchments.

R Pit is included in the Current Approved Development Envelope and has been excluded from this assessment. The difference maps in Appendix B are based on existing and developed conditions without R Pit in place. R Pit overlaps with landforms that comprise the Additional Development Envelope. Appendix C includes an additional comparison of flood depths with R Pit in place under both the existing and developed conditions for the 100-year ARI peak discharge. It is expected that R Pit will be in place before OSA 42 and OSA 43 to the north of the pit area constructed; this reduces the additional impact due to the construction of OSA 42 and OSA 43 as R Pit removes the majority of the upstream catchment area intercepted by these OSAs.

4.3 Hydrograph peaks and flow volume

Flow hydrographs were extracted along index sections placed at the downstream extent of each of the four local subcatchment areas. The hydrographs are shown in Appendix D. As shown in the hydrographs, both the peak flow rate and the time to peak flow are affected by the development. The total flow volume (as represented by the area under the hydrographs in Appendix D) is similarly affected. The changes in peak flow rate, time to peak, and flow volume are not considered to be significant on a regional scale.

4.4 Cumulative Impacts

The following existing and planned operations are included in the cumulative impacts assessment:

- Mining Area C North Flank (Current Development Envelope). Impacted areas, including contributing upstream catchments, are compiled along with their relative contribution to Weeli Wolli Creek and Lake Robinson from RPS (2014).
- Hope Downs 1. The impacted area is compiled from a shape files provided by BHP BILLITON IRON ORE (HopeDowns.shp)
- Baby Hope. Impacted areas, including contributing upstream catchments, are compiled from Rio Tinto Iron Ore’s public environmental approvals documents.

Table 4-2 summarises the cumulative impact areas and their relative contribution to the Coondewanna catchment and Weeli Wolli Creek. The impacted areas reflect a decrease in contributing catchment areas with a corresponding decrease in peak discharge rates and volumes. Reduced peak flows and volumes have the potential to reduce downstream floodplain connectivity and impact surface water dependent vegetation.

As shown in Table 4-2, the Additional Development Envelope includes impacts to approximately 3.5% of the total Weeli Wolli Creek catchment area and 5% of the total Coondewanna catchment area. The impacted area accounts for less than 1% of the total Fortescue Marsh catchment area. Cumulatively, the impacted area associated with South Flank, North Flank, Hope Downs 1, and Baby Downs accounts for approximately 6.9% of the Coondewanna catchment, 7.2% of the Weeli Wolli Creek catchment, and approximately 2% of the Fortescue Marsh catchment. Peak flow rates and volumes would be similarly affected. These total cumulative impacts reflect a conservative estimate of potentially impacted areas on a regional scale to key surrounding environmental receptors such as Fortescue Marsh and Lake Robinsons. In accordance with BHPBIO surface water management strategy, diversions and bunds will be used to minimise change in runoff volumes and peak flows associated with the impacted catchment areas.

### Table 4-2: Cumulative Impacts

<table>
<thead>
<tr>
<th>Receptor</th>
<th>Total Area (km²)</th>
<th>Development</th>
<th>Impacted Area (km²)</th>
<th>% of total area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coondewanna</td>
<td>860</td>
<td>North Flank</td>
<td>18.9</td>
<td>2.2</td>
</tr>
<tr>
<td>Coondewanna</td>
<td>860</td>
<td>South Flank</td>
<td>40.8</td>
<td>4.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>59.7</strong></td>
<td></td>
<td></td>
<td><strong>6.9</strong></td>
</tr>
<tr>
<td>Weeli Wolli Creek</td>
<td>4150</td>
<td>North Flank</td>
<td>111.4</td>
<td>2.7</td>
</tr>
<tr>
<td>Weeli Wolli Creek</td>
<td>4150</td>
<td>South Flank</td>
<td>145.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Weeli Wolli Creek</td>
<td>4150</td>
<td>Hope Downs 1</td>
<td>27.9</td>
<td>0.7</td>
</tr>
<tr>
<td>Weeli Wolli Creek</td>
<td>4150</td>
<td>Baby Downs</td>
<td>15.1</td>
<td>0.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>299.4</strong></td>
<td></td>
<td></td>
<td><strong>7.2</strong></td>
</tr>
</tbody>
</table>

#### 4.5 Diversions and bunds

The difference maps in Appendix B highlight areas where ponding occurs against OSAs, ROM pads, and top soil stockpile areas (positive changes) as well as areas where surface flows are reduced due to the presence of pits and OSAs (negative changes). A surface water management plan may allow for the diversion of natural flows around landforms and back into the nearest downstream drainage line, reducing
the impacted areas shown in Appendix B. Channel excavation can minimise the potential for ponding along diversion alignments with erosion control measures to prevent bank erosion, bed scour, or sedimentation. The diversion of flows into defined diversion channels has the potential to concentrate flood flows and increase flood velocities, thereby increasing the potential for scour; however, the removal of some catchment areas may reduce the peak discharges and the associated erosional risk. Failure of any proposed diversions under greater than design capacity events could pose some potential threat to the surrounding surface water regime, potentially requiring remedial measures under the operation and maintenance plan.

All landforms, pits, and other infrastructure associated with the Additional Development Envelope and shown on figures in this report are indicative only; diversion alignments, bund heights, longitudinal slopes, bottom widths, and side slopes of any required diversion channels will be refined as mine planning progresses.
5 Impacts to environmental quality

This chapter presents proposed measures to maintain groundwater and surface water quality during construction, operation, and closure of the proposed landforms and pits within the South Flank Additional Development Envelope. If not appropriately managed, development of the proposed project has the potential to impact groundwater and surface water quality through erosion, sedimentation, and contamination. The recommendations include standard groundwater and surface water quality management measures for mine site infrastructure.

5.1 Erosion and sedimentation

Specific areas with erosional risks include OSA 36, which encroaches on the Pebble Mouse Creek floodplain and will require armouring to prevent embankment erosion. Diversion of localised drainage paths around proposed pits or controlled inflow measures may be required where concentrated flow paths intercept pits and landforms.

During construction in particular, an increase in sediment runoff and scour may occur as a result of the additional ground disturbance and vegetation removal. Runoff resulting from direct rainfall on landforms is assumed to be contained onsite for the purpose of this study. Sediment-laden runoff from landform slopes will be collected in toe drains and diverted to downstream sediment ponds. Indicative sediment pond locations are shown at the downstream-most point along each landform in Figure A-4. Discharge that enters sediment ponds will not be discharged immediately into the downstream environment. Any excess water that passes through or around sediment ponds is assumed to have been attenuated sufficiently to avoid impacting the predicted peak flood extents.

The purpose of the sediment ponds is to capture and trap sediment-laden rainfall runoff to allow for the settling of sediments, before the runoff is allowed to enter the receiving environment, reducing the risk of sediment concentrations in excess of natural conditions. During operations, sediment ponds would be maintained. Following closure, however, sediment ponds would fill over time and eventually become ineffective, with the intention that exposed slopes would have been rehabilitated and vegetation established while the sediment ponds are still in use.

Residence time in the sediment ponds should be designed to allow for sands and coarse silts to be captured and to settle out, thereby minimising the potential for increased sediment runoff. Larger magnitude events will not be contained within sediment pond. In a naturally occurring scenario, sediment loads during large events are high, so the impact of releasing water from the sediment ponds during these events should be minimal on a regional scale.

A larger-than-design flow event could also flush out sediments from the sediment ponds, causing a localised concentration of silts into the downstream drainage line; however, pond designs should include overflow provisions to ensure the containment embankment remains stable during a large event. Sediment
flushing may be minimised by regular maintenance of the pond to remove and dispose of sediments into the body of the waste rock dump before large events occur. Even if full, provided the sediment pond embankments are sound, the water that passes through the pond is expected to have some settlement and associated improvement to discharge water quality due to residence time in the sediment pond, even in a larger-than-design event.

5.2 Chemicals and hydrocarbons

Construction and operation of the proposed project has the potential to contaminate surface water and/or groundwater with chemicals and hydrocarbons through a hazardous substance or hydrocarbon spill. The risk of potential spills can be significantly reduced with adherence to best practices as outlined in BHP BILLITON IREON ORE’s standard environmental, health and safety procedure for onsite work. ROM pads, workshops, explosive stores, and processing areas have the highest potential for chemical and hydrocarbon contamination within the Additional Development Area. Additional potential sources of contamination include the discharge of untreated sewage, sediment-laden water, acid mine drainage, and spillage from workshops, wash-down areas, transfer areas, haul roads, and access roads.

Increased sediment runoff into sediment ponds may lead to accumulation of contaminants within sediments over time. Regular inspection and clearing of the sediment ponds is required to minimise the risk that these contaminants may then be transported downstream along with sediments after flood events or periods of high rainfall. Infrastructure such as fuel storage and hazardous substance storage should have secondary containment to prevent potentially contaminated material from polluting the surrounding area.

The Additional Development Envelope is generally located on relatively high land above the floodplain of major creek systems. The height above the floodplain and the ephemeral nature of surface water runoff in local creek systems reduces the likelihood of contaminants reaching the downstream environment.

A monitoring program is recommended to test for hydrocarbons within surface water runoff samples. This assessment assumes that waste rock will be geochemically benign without acid rock drainage potential. Kinetic testing may be warranted to confirm the quality of any leachate generated from OSAs. If leachate is likely to have a significant impact then further containment management strategies may be required based on the type and scale of the likely impact. Any polluted runoff that is identified through monitoring programs should be treated prior to discharge into the downstream receiving environment.

In summary, standard practices for surface water management should prevent water quality impacts to downstream receptors.
6 Creek capture risk and closure options

The findings of this report assume that pits are not backfilled to surface but that any backfill remains below levels that would pass surface water through the pit with downstream discharge. The primary creek system within the Additional Development Envelope is Pebble Mouse Creek, with a catchment area of approximately 166 km² upstream of South Flank. Operational or post-closure creek capture of Pebble Mouse Creek would represent the most significant potential loss of catchment area draining to downstream receptors. Figure 6-1 shows the 10,000-year ARI Pebble Mouse Creek floodplain.

Figure 6-1: Plan view of Pebble Mouse Creek 10,000-year ARI floodplain

Figure 6-2: Cross section of Pebble Mouse Creek floodplain
At its closest point, the edge of the South Flank pit is approximately 100 metres away from the 10,000-year ARI floodplain extent of Pebble Mouse Creek. Figure 6-2 shows a cross section taken at this location. The zone of geotechnical instability and required abandonment bund location around the outside of the final pit void may extend into the floodplain; however, the proposed pit edge is located above all assessed flood levels through the 10,000-year ARI event. For the purpose of this study, creek capture is thus excluded.
7 Conclusions and recommendations

The hydrological and hydraulic assessment developed under this project provides indicative estimates of flood depths and other hydraulic parameters for existing and developed conditions within the Additional Development Envelope. The proposed landforms and pits are generally located on higher ground near catchment divides with relatively small catchment areas; therefore, the risk of significant pit inundation and creek capture is lessened, and the operations can be protected from flooding with relatively standard surface water management features.

Rainfall and runoff have been assessed over the Additional Impact Assessment Area, and design rainfall depths and runoff conditions have been derived for the 2-, 5-, 10-, 20-, 50-, 100-, 1,000-, and 10,000-year ARI events using ARR, BoM, RORB, and TUFLOW. Mitigation measures summarised in this report include measures to route flow around landforms, reduce flood risk on operations, and to minimise water quality and water quantity impacts to downstream receptors.

The results show that the presence of the proposed landforms and pits affect a substantial proportion of localised catchment areas along with the corresponding flow depths and volumes. On a regional scale, the total effect of the Additional Development Envelope comprises approximately 3.5% of the total Weeli Wolli Creek catchment area and 5% of the total Coondewanna catchment area. The impacted area accounts for less than 1% of the total Fortescue Marsh catchment area. Cumulatively, the impacted area associated with South Flank, North Flank, Hope Downs 1, and Baby Downs, accounts for approximately 6.9% of the Coondewanna catchment, 7.2% of the Weeli Wolli Creek catchment, and approximately 2% of the Fortescue Marsh catchment.

The impacted areas summarised in this report include all areas draining toward proposed pits and landforms. Peak flow reduction resulting from the presence of pits and landforms may potentially affect downstream floodplain connectivity and surface water dependent vegetation in floodplain areas. The pits and landforms are generally located near catchment divides, and the impacts to surface water flows are not considered to be significant on a regional scale.

Provided that standard mitigation measures are implemented, the risk of negatively impacting water quality appears to be low. The findings and recommendations in this report are based on a desktop study only. In order to proceed with additional planning and design, further consideration should be given to surface water management features developed in conjunction with detail design of the proposed landforms.

The results of this hydrological and hydraulic assessment highlight some specific areas where realignment of proposed features should be considered. In particular, OSA 43 blocks a significant catchment area that could be avoided with a relatively minor adjustment of the perimeter. Likewise, with relatively minor modifications, the toe of OSA 36 could be moved outside of the Pebble Mouse Creek floodplain; otherwise...
erosion along the toe may compromise the slope stability. Landform toe alignments should include a buffer zone of at least 20 metres from the floodplain unless bunding is constructed with suitable scour protection.

The validity of the results cannot be confirmed without gauge data relating rainfall to runoff within the local catchment; future calibration efforts may allow further model refinements that can increase confidence in the results. Calibration efforts may allow the introduction of additional surface water inflows or refinement of rainfall inputs to match gauged results. As additional gauge data become available from future flood events, wet-dry coefficients, loss values, roughness coefficients, and other parameters can be adjusted within reasonable ranges to provide model results that match observed conditions.

For more detailed future flood mitigation studies, it is recommended that the 2-metre by 2-metre grid DEM be applied in localised areas of interest to optimise diversion alignments, bund requirements, sediment pond configuration, and other surface water management features.

If more detailed or updated OSA, pit, and mine infrastructure designs become available, existing and proposed features such as railway embankments, culverts, haul roads, and other features can be added or refined in the model to produce more accurate results.

The accompanying electronic transmittal includes model input and output files in TUFLOW and WaterRide format, with peak depths and velocities provided in ASCII raster grid (*.asc) format.
8 References

Aquaterra (2005) - Area C Surface Water Management.

Aquaterra (2007) - Area C - F Deposit Surface Water Management.


BHP Billiton Iron Ore Pty Ltd (2012) - GWL Operating Strategy for Area C.

Department of Environment (1986). Environmental Protection Act.


Woodward-Clyde (1997) - Multiple Iron Ore Development Project Public Environmental Review.

Appendix A  Catchment maps
Figure A-1: South Flank and Pebble Mouse Creek catchments
Figure A-2: South Flank catchments and hydraulic model section locations
Figure A-3: Contributing catchment areas for South Flank landforms and pits
Figure A-4: South Flank landform and indicative sediment pond locations
Appendix B  Flood depth and difference mapping
Figure B-1: Existing condition depth map for 2-year ARI
Figure B-2: Developed condition depth map for 2-year ARI
Figure B-3: Existing condition depth map for 100-year ARI
Figure B-4: Developed condition depth map for 100-year ARI
Figure B-5: Existing condition depth map for 10,000-year ARI
Figure B-6: Developed condition depth map for 10,000-year ARI
Figure B-7: Developed condition depth map for 10,000-year ARI at Pebble Mouse Creek
Figure B-8: Existing and development conditions depth difference for 2-year ARI
Figure B-9: Existing and development conditions depth difference for 5-year ARI
Figure B-10: Existing and development conditions depth difference for 10-year ARI
Figure B-11: Existing and development conditions depth difference for 20-year ARI
Figure B-12: Existing and development conditions depth difference for 50-year ARI
Figure B-13: Existing and development conditions depth difference for 100-year ARI
Figure B-14: Existing and development conditions depth difference for 1,000-year ARI
Figure B-15: Existing and development conditions depth difference for 10,000-year ARI
Appendix C  
R Pit Comparison
Figure C-1: Existing and development conditions hydrographs with and without R Pit
Figure C-2: Existing vs development conditions depth difference for 100-year ARI without R Pit
Figure C-3: Existing vs development conditions depth difference for 100-year ARI with R Pit
Appendix D  Flow Hydrographs
Figure D-1: NW catchment hydrographs for 2-year through 10-year ARI

Figure D-2: NW catchment hydrographs for 20-year through 100-year ARI
Figure D-3: NW catchment hydrographs for 1,000-year through 10,000-year ARI

Figure D-4: NE catchment hydrographs for 2-year through 10-year ARI
Figure D-5: NE catchment hydrographs for 20-year through 100-year ARI

Figure D-6: NE catchment hydrographs for 1,000-year through 10,000-year ARI
Figure D-7: SW catchment hydrographs for 2-year through 10-year ARI

Figure D-8: SW catchment hydrographs for 20-year through 100-year ARI
Figure D-9: SW catchment hydrographs for 1,000-year through 10,000-year ARI

Figure D-10: SE catchment hydrographs for 2-year through 10-year ARI
**Figure D-11:** SE catchment hydrographs for 20-year through 100-year ARI

**Figure D-12:** SE catchment hydrographs for 1,000-year through 10,000-year ARI
Appendix E  Model validation
Figure E-1: Internal validation catchment outflow hydrographs for 20-metre grid