Our Ref: CB-EN-0179

Office of the Environmental Protection Authority
File:
8 APR 2014
A: For Information
fa: For Discussion
Officer: For Action
Dir.AC
Dir. Bus Ops
Dir. SPPD
Dir. Strat Sup
Response please:

Fortescue
The New Force in Iron Ore

Dr Paul Vogel
Chairman
Environmental Protection Authority
Locked Bag 33
Cloisters Square
PERTH WA 6850

7 April 2014

Dear Dr Vogel

REFERRAL – INCREASE IN GROUNDWATER ABSTRACTION AND INJECTION AT THE CLOUDBREAK MINE

Under Section 38 of the *Environmental Protection Act 1986* (EP Act), Fortescue Metals Group Limited (Fortescue) wishes to refer a proposal for the increase in groundwater abstraction and injection at the Cloudbreak mine. Please find enclosed the completed EPA Referral Form - Proponent (Attachment 1) and *Increase in Groundwater Abstraction and Injection – Supporting Environmental Document* CB-AS-EN-0047 (Attachment 2).

The Cloudbreak mine is an existing mine approved under the EP Act pursuant to Ministerial Statement 899. This proposal is limited to the increase in groundwater abstraction and injection volumes only. All other mining activities including those activities related to groundwater abstraction and injection will be undertaken in accordance with the limits of the existing approval.

If you have any queries regarding this matter please do not hesitate to contact Fiona Rowland on 92301534.

Yours sincerely
FORTESCUE METALS GROUP

ISAK BUITENDAG
Director, Health, Safety, Environment and Security

Enc.
Attachment 1 EPA Referral Form - Proponent
Attachment 2 *Increase in Groundwater Abstraction and Injection – Supporting Environmental Document* (CB-AS-EN-0047)
Attachment 3 CD of Referral Form and Supporting Document

Fortescue Metals Group Limited ABN 57 002 594 872 ACN 002 594 872
ADDRESS Level 2, 87 Adelaide Terrace, East Perth, Western Australia 6004
POSTAL ADDRESS PO Box 6915, East Perth, Western Australia 6892
TEL +61 8 6218 8888 FAX +61 8 6218 8880 EMAIL fmgl@fmgl.com.au

GOVERNMENT OF WESTERN AUSTRALIA

Environmental Protection Authority

EPA REFERRAL FORM PROPONENT

Referral of a Proposal by the Proponent to the Environmental Protection Authority under Section 38(1) of the *Environmental Protection Act 1986*.

PURPOSE OF THIS FORM

Section 38(1) of the *Environmental Protection Act 1986* (EP Act) provides that where a development proposal is likely to have a significant effect on the environment, a proponent may refer the proposal to the Environmental Protection Authority (EPA) for a decision on whether or not it requires assessment under the EP Act. This form sets out the information requirements for the referral of a proposal by a proponent.

Proponents are encouraged to familiarise themselves with the EPA's *General Guide on Referral of Proposals* [see Environmental Impact Assessment/Referral of Proposals and Schemes] before completing this form.

A referral under section 38(1) of the EP Act by a proponent to the EPA must be made on this form. A request to the EPA for a declaration under section 39B (derived proposal) must be made on this form. This form will be treated as a referral provided all information required by Part A has been included and all information requested by Part B has been provided to the extent that it is pertinent to the proposal being referred. Referral documents are to be submitted in two formats – hard copy and electronic copy. The electronic copy of the referral will be provided for public comment for a period of 7 days, prior to the EPA making its decision on whether or not to assess the proposal.

CHECKLIST

Before you submit this form, please check that you have:

	Yes	No
Completed all the questions in Part A (essential).		
Completed all applicable questions in Part B.		
Included Attachment 1 – location maps.		
Included Attachment 2 – additional document(s) the proponent wishes to provide (if applicable).		
Included Attachment 3 – confidential information (if applicable).		
Enclosed an electronic copy of all referral information, including spatial data and contextual mapping but excluding confidential information.		

Following a review of the information presented in this form, please consider the following question (a response is optional).

Do you consider the proposal requires formal environmental impact assessment? ☒ Yes ☐ No ☐ Not sure
If yes, what level of assessment? ☒ Assessment on Proponent Information ☐ Public Environmental Review

PROPONENT DECLARATION (to be completed by the proponent)

I, Sean McGunnigle, declare that I am authorised on behalf of Fortescue Metals Group (being the person responsible for the proposal) to submit this form and further declare that the information contained in this form is true and not misleading.

Signature	Name (print): Sean McGunnigle
Position: Manager, Environmental Approvals	Company: Fortescue Metals Group Ltd
Date 7 April 2014	

PART A - PROPONENT AND PROPOSAL INFORMATION

(All fields of Part A must be completed for this document to be treated as a referral)

1 PROPONENT AND PROPOSAL INFORMATION

1.1 Proponent

Name	Fortescue Metals Group Limited (Fortescue)
Joint Venture parties (if applicable)	n.a.
Australian Company Number (if applicable)	002 594 872
Postal Address (where the proponent is a corporation or an association of persons, whether incorporated or not, the postal address is that of the principal place of business or of the principal office in the State)	PO Box 6915 East Perth WA 6892
Key proponent contact for the proposal: • name • address • phone • email	Sean McGunnigle Level 2, 87 Adelaide Tce, East Perth WA 6004 Ph: 6218 8415 Email : smcgunnigle@fmgl.com.au
Consultant for the proposal (if applicable): • name • address • phone • email	n.a.

1.2 Proposal

Title	Increase in Injection and Abstraction Limits at Cloudbreak Mine
Description	As a result of an increased understanding of the hydrogeology at Cloudbreak mine, and subsequent refining of the groundwater model; and the opportunity to blend ore at the mine, Fortescue proposes to increase the volume of groundwater abstraction and injection limits at Cloudbreak to 150 gigalitres per annum (GL/a).
Extent (area) of proposed ground disturbance.	n.a.
Timeframe in which the activity or development is proposed to occur (including start and finish dates where applicable).	Increased abstraction and injection would commence immediately upon approval and continue for the life of the mine.
Details of any staging of the proposal.	n.a.
Is the proposal a strategic proposal?	No
Is the proponent requesting a declaration that the proposal is a derived proposal? If so, provide the following information on the strategic assessment within which the referred proposal was identified: • title of the strategic assessment; and • Ministerial Statement number.	No
Please indicate whether, and in what way, the proposal is related to other proposals in the region.	The Proposal relates to the increase in groundwater abstraction and injection at the existing Cloudbreak mine. Cloudbreak was

	originally referred under Part IV of the *Environmental Protection Act 1986* (EP Act) in 2005. Approval for the mine was granted pursuant to Ministerial Statement (MS) 721. In 2010 the Cloudbreak Expansion Project was referred under Part IV of the EP Act. The Cloudbreak Life of Mine Public Environmental Review (LOM PER) document was submitted to the WA EPA to support the assessment. Subsequently, the Cloudbreak Expansion Project was approved pursuant to MS 899. Fortescue also operates the Christmas Creek mine which is located immediately to the east of Cloudbreak in the Chichester Range. The two mines, collectively termed the Chichester Hub, are linked by haul and light vehicle access roads as well as a 37 km railway line. Fortescue has obtained approval (20 December 2013) under the EP Act for the increase in the annual volume of groundwater injection, to integrate groundwater management between Cloudbreak and Christmas Creek mine sites; and to amend the groundwater monitoring locations presented in MS 899. This approval has been granted via the submission of the following documents to the EPA: • *Request to Amend Ministerial Statement 899 under Section 45C of the Environmental Protection Act 1986* (Section 45C) • *Request to Amend Conditions 7-1 and 7-2 of Ministerial Statement 899 under Section 46 of the Environmental Protection Act 1986* (Section 46).
Does the proponent own the land on which the proposal is to be established? If not, what other arrangements have been established to access the land?	Fortescue does not own the land but holds mining leases, general purposes leases and miscellaneous leases on Mulga Downs and Hillside pastoral stations.
What is the current land use on the property, and the extent (area in hectares) of the property?	The current land use is pastoral grazing and mining at the existing Fortescue Cloudbreak mine. The Fortescue mining leases cover approximately 28,000 ha.

1.3 Location

Name of the Shire in which the proposal is located.	Shire of East Pilbara, Shire of Ashburton
For urban areas: • street address; • lot number; • suburb; and • nearest road intersection.	n.a.
For remote localities: • nearest town; and • distance and direction from that town to the proposal site.	The Cloudbreak mine site is located in the Pilbara region of Western Australia approximately 120 km north of Newman
Electronic copy of spatial data - GIS or CAD, geo-referenced and conforming to the following parameters: • GIS: polygons representing all activities and named; • CAD: simple closed polygons representing all activities and named; • datum: GDA94; • projection: Geographic (latitude/longitude) or Map Grid of Australia (MGA); • format: Arcview shapefile, Arcinfo coverages, Microstation or AutoCAD.	Not required. Pdf of application attached.

1.4 Confidential Information

Does the proponent wish to request the EPA to allow any part of the referral information to be treated as confidential?	No
If yes, is confidential information attached as a separate document in hard copy?	n.a.

1.5 Government Approvals

Is rezoning of any land required before the proposal can be implemented? If yes, please provide details.		No	
Is approval required from any Commonwealth or State Government agency or Local Authority for any part of the proposal? If yes, please complete the table below.		Yes	
Agency/Authority	Approval required	Application lodged Yes / No	Agency/Local Authority contact(s) for proposal
Department of Water (DoW)	5C licence amendment to take water	No.	Kevin Hopkinson
Department of Environmental Regulation	Part V EP Act Licence amendment L8199/2007/2	No	Teresa Wilkie

PART B - ENVIRONMENTAL IMPACTS AND PROPOSED MANAGEMENT

2. ENVIRONMENTAL IMPACTS

Describe the impacts of the proposal on the following elements of the environment, by answering the questions contained in Sections 2.1-2.11:

2.1 flora and vegetation;

2.2 fauna;

2.3 rivers, creeks, wetlands and estuaries;

2.4 significant areas and/ or land features;

2.5 coastal zone areas;

2.6 marine areas and biota;

2.7 water supply and drainage catchments;

2.8 pollution;

2.9 greenhouse gas emissions;

2.10 contamination; and

2.11 social surroundings.

These features should be shown on the site plan, where appropriate.

For all information, please indicate:

(a) the source of the information; and

(b) the currency of the information.

2.1 Flora and Vegetation

2.1.1 Do you propose to clear any native flora and vegetation as a part of this proposal?

[A proposal to clear native vegetation may require a clearing permit under Part V of the EP Act (Environmental Protection (Clearing of Native Vegetation) Regulations 2004)]. Please contact the Department of Environment and Conservation (DEC) for more information.

(please tick) ✔ Yes **If yes**, complete the rest of this section.

☐ No **If no**, go to the next section

There is no direct clearing of vegetation beyond that approved in MS 899.

Indirect impacts are expected as a result of groundwater drawdown and mounding impacts to the health of vegetation that is either groundwater dependent, vegetation impacted by groundwater drawdown or intolerant to waterlogging.

No impacts to threatened flora species or DRF are predicted.

2.1.2 How much vegetation are you proposing to clear (in hectares)?

The proposal to increase groundwater abstraction and injection to 150 GL/a will result in an increase in 922 ha of Mulga and a reduction in 4 ha of samphire when compared with the disturbance areas currently approved for the Cloudbreak mine (LOM PER), pursuant to MS 899. The increase in Mulga disturbance corresponds to a 5% increase in total (direct and indirect) predicted impacts. The areas of disturbance are presented in the table below.

Vegetation Type	Mulga (ha)	Samphire (ha)	Coolibah / Redgum (ha)
Predicted area of direct impact – LOM PER	10 500	4	473
Predicted area of in-direct impact – LOM PER	380	13	0
Total Predicted Impact (LOM PER)	10 880	17	473
Predicted area of direct impact – this proposal	0	0	0
Change in area of indirect impact – this proposal compared to LOM PER	+ 542	-4	0
Change in area of total impact – this proposal compared to LOM PER	+ 542	0	0
Revised total impact Cloudbreak Mine	11 422	13	473
Percent change in impact (this Proposal vs LOM PER)	5.0 %	-24 %	0 %

It is not expected that these predicted disturbances will have any significant impact on the representation, diversity, viability and ecological function of these vegetation types at the species, population and community levels.

Impacts to vegetation (when combined with existing approval) will not compromise any vegetation association by taking it below the "threshold level" of 30% of its pre-clearing extent (EPA, 2000[1]).

2.1.3 Have you submitted an application to clear native vegetation to the DEC (unless you are exempt from such a requirement)?

☐ Yes ✔ No **If yes**, on what date and to which office was the application submitted of the DEC?

2.1.4 Are you aware of any recent flora surveys carried out over the area to be disturbed by this proposal?

✔ Yes ☐ No **If yes**, please attach a copy of any related survey reports and provide the date and name of persons / companies involved in the survey(s).

If no, please do not arrange to have any biological surveys conducted prior to consulting with the DEC.

The flora and vegetation surveys are presented in the *Cloudbreak Life of Mine Public Environmental Review* (Fortescue, April 2011).

2.1.5 Has a search of DEC records for known occurrences of rare or priority flora or threatened ecological communities been conducted for the site?

✔ Yes ☐ No If you are proposing to clear native vegetation for any part of your proposal, a search of DEC records of known occurrences of rare or priority flora and threatened ecological communities will be required. Please contact DEC for more information.

[1] EPA (2000). *Environmental Protection of Native Vegetation in Western Australia Position Statement No. 2.* Environmental Protection Authority, Perth.

2.1.6 Are there any known occurrences of rare or priority flora or threatened ecological communities on the site?

☐ Yes ☐ No **If yes**, please indicate which species or communities are involved and provide copies of any correspondence with DEC regarding these matters.

Threatened Ecological Communities

No vegetation communities in the Proposal area are representative of any Threatened Ecological Community (TEC) under the Commonwealth EPBC Act or by the DEC (2013).

Priority Ecological Communities

None of the identified vegetation communities within the Proposal area represent any Priority Ecological Communities (PEC) listed by the DEC (2013).

The proposal is located near the Fortescue Marsh which has recently been classified as a Priority 1 PEC DEC (2009). The Fortescue Marsh PEC is characterised by the presence of endemic and new to science *Eremophila* and *Tecticornia* species occurring on the fringe of the Fortescue Marsh (ENV 2011).

Flora of Conservation Significance

No Threatened species pursuant to the EPBC Act have been identified within the Proposal area.

No plant taxa gazetted as Declared Rate Fauna (DRF) pursuant to the WC Act have been identified within the Cloudbreak area (Biota 2004, Mattiske 2005a, 2007, ENV 2011).

Seven priority flora have been recorded within the Cloudbreak area (Biota 2004, Mattiske 2005a, 2007, ENV 2011). An additional 11 species listed as Priority Flora have not been recorded within the Proposal area, but may occur in the vicinity of the Proposal area.

2.1.7 If located within the Perth Metropolitan Region, is the proposed development within or adjacent to a listed Bush Forever Site? (You will need to contact the Bush Forever Office, at the Department for Planning and Infrastructure)

☐ Yes ✔ No **If yes**, please indicate which Bush Forever Site is affected (site number and name of site where appropriate).

2.1.8 What is the condition of the vegetation at the site?

The Proposal area includes the existing approved mine footprint which currently comprises cleared areas that have been developed for the mine pits and associated mine infrastructure. Several existing roads and pipelines associated with the mine also intersect vegetation in the area.

The condition of the vegetation in the Proposal area ranges from Good to Excellent in condition as per Trudgen (1991) condition scale with the majority of the vegetation in the fringe of the Samphire Flats, Creek and Drainage line and Ranges, Hills and Hill slope vegetation type categorised as Excellent with the remaining type categories as Good as a result of grazing pressures (ENV 2011).

2.2 Fauna

2.2.1 Do you expect that any fauna or fauna habitat will be impacted by the proposal?

(please tick) ✔ Yes **If yes**, complete the rest of this section.

☐ No **If no**, go to the next section.

2.2.2 Describe the nature and extent of the expected impact.

Potential impacts to fauna as a result of the Proposal include:

- Impacts from the loss of habitat (either direct or indirect loss)
- Fauna entrapment
- Fauna death or mortality via interaction with site vehicles.

The proposal to increase groundwater abstraction and injection to 150 GL/a will result in an increase in 922 ha of Mulga and other Acacia woodland habitat and a reduction in the other habitat types when compared with the disturbance areas currently approved for the Cloudbreak mine (LOM PER), pursuant to MS 899. The revised disturbance areas predicted as a result of this proposal are presented in the table below.

Vegetation Type	Low halophytic shrubland (samphire)	Hummock grassland (spinifex)	Mulga and other Acacia woodland	Spinifex covered hills and ranges	Creeklines with shrubland and/or eucalypt open woodland	Rocky escarpments
Predicted area of direct impact – LOM PER	1	2	5,695	985	683	0
Predicted area of in-direct impact – LOM PER	763	5.5	744	4.4	115.5	0
Total Predicted Impact (LOM PER)	764	7.5	6439	989.4	798.5	0
Predicted area of direct impact – this proposal	0	0	0	0	0	0
Change in area of indirect impact – this proposal compared to LOM PER	5.5	2.5	922*	0	4	0
Change in area of total impact – this proposal compared to LOM PER	-757.5	-3	178	-4.4	-111.5	0
Revised total impact Cloudbreak Mine	6.5	4.5	6617	985	687	0
Percent change in impact (this Proposal vs LOM PER)	-99%	-40%	2.8%	-0.4%	-14%	0.0

* Note: 17 ha of the 922 ha of indirect impact in Mulga and other Acacia Woodland habitat are outside and to the west of the Project Area.

The predicted areas of direct and indirect impact are located in the Mulga and other Acacia Woodland habitat (6617 ha) followed by the Spinifex Covered Hills and Ranges (985 ha).

Loss of Habitat – Clearing

No additional direct impact (clearing) beyond that approved in MS 899 is proposed. No additional impacts to fauna as a result of vegetation clearing are expected as a result of the Proposal.

Loss of Habitat – Indirect

A total of 98.7% of all expected indirect impact is within the Mulga and other Acacia Woodland habitat (922 ha).

While there is predicted to be some degradation in the health Mulga and other Acacia Woodland habitat, the impact is expected to be minimal and localised. An additional 178 ha of Mulga and other Acacia Woodland habitat may potentially be affected as a result of the increase in abstraction and injection quantities. This represents a 22% increase in the indirect impact to Mulga and other Acacia Woodland habitat approved in MS 899 and EPBC 2010/5696 but only a 2.8% increase in total (direct and indirect) disturbance for Mulga and other Acacia Woodland habitat.

The percent of expected indirect impact to Low Halophytic Shrubland (samphire) habitat and Creeklines with Shrubland and/or Eucalypt Open Woodland habitat are significantly lower than presented in the LOM PER.

Habitat fragmentation

Clearing of vegetation has the potential to result in fragmentation of habitats and lead to the inability of individuals to move between areas of habitat, as well as increase predation events as individuals move across cleared areas. Clearing within the mine footprint has the potential to create a barrier for some species that typically move north-south through this area to access the food, water and habitat resources of the Fortescue Marsh.

A 2.8% increase in the disturbance of Mulga and Acacia Woodland habitat is considered a minimal increase and any additional fragmentation of habitat will be minimised through progressive rehabilitation.

The percent of expected indirect impact to Low Halophytic Shrubland (samphire) habitat and Creeklines with Shrubland and/or Eucalypt Open Woodland habitat are significantly lower than presented in the LOM PER, as such the impacts to habitat fragmentation are significantly lower than originally proposed.

There is not expected to be any significant increase in impacts to Fortescue Marsh, yintas or creek lines as a result of the Proposal.

Given the lack of predicted impacts and the large regional representation of the key vegetation types, there is not predicted to be any significant impact to terrestrial fauna as a result of indirect impacts to fauna habitat as a result of the Proposal.

Fauna Entrapment

The ponds associated with the dewatering and injection infrastructure may attract fauna in times of drought. This could result in fauna becoming trapped and/or drowning within the ponds. There is also potential of fauna entrapment and/or drowning in the trenches associated with pipeline installation.

There is not expected to be a significant increase in the number or size of ponds associated with dewatering or the length of trenching required as part of the Proposal. Potential entrapment of fauna can be managed via established procedures. There is not expected to be any significant impact to fauna as a result of entrapment.

Vehicle Movements during Construction and Operations

The Proposal is not expected to lead to any increase in the number, type or timing of vehicle movements and as such, is not expected to result in any additional risk of fauna injury or mortality due to vehicle movements.

2.2.3 Are you aware of any recent fauna surveys carried out over the area to be disturbed by this proposal?

✔ Yes ☐ No **If yes**, please attach a copy of any related survey reports and provide the date and name of persons / companies involved in the survey(s).

If no, please do not arrange to have any biological surveys conducted prior to consulting with the DEC.

The fauna surveys are presented in the *Cloudbreak Life of Mine Public Environmental Review* (Fortescue, April 2011).

2.2.4 Has a search of DEC records for known occurrences of Specially Protected (threatened) fauna been conducted for the site?

✔ Yes ☐ No (please tick)

2.2.5 Are there any known occurrences of Specially Protected (threatened) fauna on the site?

✔ Yes ☐ No **If yes**, please indicate which species or communities are involved and provide copies of any correspondence with DEC regarding these matters.

Please also refer to Table 9 of the supporting information document for this referral.

Threatened Species

Six fauna species that are listed under Schedule 1 under the *Wildlife Conservation Act 1950* (WC Act) may potentially be present in the Proposal area:

- Night Parrot (*Pezoporus occidentalis*)
- Northern Quoll (*Dasyurus hallucatus*)
- Greater Bilby (*Macrotis lagotis*)
- Orange Leaf-nosed Bat (*Rhinonicteris aurantius*)
- Pilbara Olive Python (*Liasis olivaceus barroni*)

Other Listed Fauna

Other fauna listed under the WC Act that may potentially be present include:

- Seven Schedule 3 species
- One Schedule 4 species
- Two Priority 1 species
- One Priority 2 species
- One Priority 3 species
- Eight Priority 4 species.

Night Parrot (Schedule 1)

The only confirmed sighting of Night Parrot was at Minga Well (Mulga habitat) although the habitat of the Night Parrot is thought to, but not confirmed to consist of Triodia grasslands in stony or sandy environments and of Samphire and chenopod shrublands on floodplains and clay pans, and on the margins of salt lakes, creeks or other sources of water (SEWPAC 2010b). No additional areas of disturbance within the Triodia grasslands have been identified as a result of the proposal and as such no impacts to this species are expected.

Northern Quoll (Schedule 1)

The rocky habitat preferred by the Northern Quoll will not be affected by the Proposal and as such no impacts to this species are expected.

Greater Bilby (Schedule 1)

The spinifex dominated vegetation types preferred by the Greater Bilby will not be affected by the Proposal and as such no impacts to this species are expected.

Pilbara Leaf-nosed Bat (Schedule 1)

The species roosts in caves with high humidity and temperature. No roosting habitat will be affected by the Proposal and as such no impact to this species is expected to occur as a result of the Proposal.

Pilbara Olive Python (Schedule 1)

The rocky habitat preferred by the Pilbara Olive Python will not be affected by the Proposal and as such no impacts to this species are expected.

Migratory Birds and other Specially Protected Fauna (Schedule 3 and 4)

A variety of migratory birds may utilise the Proposal area (refer to the Supporting Information Document for this referral), particularly the Fortescue Marsh and creek lines.

Changes to the water table level as a result of the Proposal have the potential to effect vegetation in the vicinity of Fortescue Marsh with subsequent potential indirect impact to migratory birds). However as impacts to these vegetation types are expected to be minimal and they are well represented in the region, no significant impacts to migratory birds are expected as a result of the Proposal.

Priority Species

The Supporting Information Document for this referral details the priority species that may occur within the Proposal area. As no significant impacts are expected to occur to fauna habitat or important vegetation communities, no significant impacts to any Priority species is expected to occur as a result of the Proposal.

2.3 Rivers, Creeks, Wetlands and Estuaries

2.3.1 Will the development occur within 200 metres of a river, creek, wetland or estuary?

(please tick) ✔ Yes **If yes**, complete the rest of this section.

☐ No **If no**, go to the next section.

2.3.2 Will the development result in the clearing of vegetation within the 200 metre zone?

☐ Yes ✔ No **If yes**, please describe the extent of the expected impact.

2.3.3 Will the development result in the filling or excavation of a river, creek, wetland or estuary?

☐ Yes ✔ No **If yes**, please describe the extent of the expected impact.

2.3.4 Will the development result in the impoundment of a river, creek, wetland or estuary?

☐ Yes ✔ No **If yes**, please describe the extent of the expected impact.

2.3.5 Will the development result in draining to a river, creek, wetland or estuary?

✔ Yes ☐ No **If yes**, please describe the extent of the expected impact.

Surface water discharge of dewatered groundwater may occur as a contingency if injection infrastructure fails. This may result in alterations to surface flows through courses and into Fortescue Marsh and yintas. If uncontrolled, this process could lead to the creation of new flow paths and erosion.

The *Dewatering Discharge Contingency Procedure* (Fortescue 2009) was presented in the Cloudbreak LOM PER and therefore approved under MS 899. In line with the Dewatering Discharge Contingency Procedure discharge of water will only occur at designated creek line discharge points.

Contingency surface water discharge was approved in the Cloudbreak LOM PER which concluded impacts could be managed by limiting discharge to up to 35 ML/day of fresh or brackish water for periods of up to 21 days under limited circumstance.

No change to these discharge limits is proposed in the Proposal and therefore there is not expected to be any significant impact above that presented in the Cloudbreak LOM PER.

2.3.6 Are you aware if the proposal will impact on a river, creek, wetland or estuary (or its buffer) within one of the following categories? (please tick)

Conservation Category Wetland	✔ Yes	☐ No	☐ Unsure
Environmental Protection (South West Agricultural Zone Wetlands) Policy 1998	☐ Yes	✔ No	☐ Unsure
Perth's Bush Forever site	☐ Yes	✔ No	☐ Unsure
Environmental Protection (Swan & Canning Rivers) Policy 1998	☐ Yes	✔ No	☐ Unsure
The management area as defined in s4(1) of the *Swan River Trust Act 1988*	☐ Yes	✔ No	☐ Unsure
Which is subject to an international agreement, because of the importance of the wetland for waterbirds and waterbird habitats (e.g. Ramsar, JAMBA, CAMBA)	☐ Yes	✔ No	☐ Unsure

The Fortescue Marsh has been identified as a 'Nationally Important Wetland' and is listed as an 'indicative place' on the Register of the National Estate due to its importance as a habitat for migratory birds.

Previous studies and the protected matter search undertaken on 14 October 2013 identified no wetlands listed under the Ramsar Convention located in the vicinity of the Proposal area.

Fortescue Marsh is the key area of conservation significance in the vicinity of the Proposal and supports a number of significant flora and fauna species. The Marsh has been classified as a Priority 1 PEC.

MS 899 specifies conditions with respect to acceptable drawdown and mounding (maximum 1 m) on the fringes of Fortescue Marsh. Fortescue monitors compliance with this condition via a series of monitoring bores located on the fringe of the Marsh.

The numerical modelling has shown that maximum drawdown and mounding at monitoring bores may be up to 1.8m, with consideration for climatic and parameter sensitivity. Although a 1.8 m change is predicted by modelling, the adaptive groundwater management scheme including the redistribution of water will ensure that groundwater levels within and at the fringe of the Marsh do not change by more than 1 m, as required by the existing condition 7 of MS 899.

As such, it is expected that the Proposal will comply with the conditions specified in MS 899 and that no additional impacts to Fortescue Marsh will occur as a result of drawdown or mounding associated with the Proposal.

As can be seen from Figure 4 to Figure 14 of the supporting information document there is not predicted to be any impacts to vegetation with Fortescue Marsh as a result of the Proposal.

2.4 Significant Areas and/ or Land Features

2.4.1 Is the proposed development located within or adjacent to an existing or proposed National Park or Nature Reserve?

☐ Yes ✔ No **If yes**, please provide details.

2.4.2 Are you aware of any Environmentally Sensitive Areas (as declared by the Minister under section 51B of the EP Act) that will be impacted by the proposed development?

☐ Yes ✔ No **If yes**, please provide details.

2.4.3 Are you aware of any significant natural land features (e.g. caves, ranges etc) that will be impacted by the proposed development?

☐ Yes ✔ No **If yes**, please provide details.

2.5 Coastal Zone Areas (Coastal Dunes and Beaches)

2.5.1 Will the development occur within 300metres of a coastal area?

(please tick) ☐ Yes **If yes**, complete the rest of this section.

✔ No **If no**, go to the next section.

2.5.2 What is the expected setback of the development from the high tide level and from the primary dune?

2.5.3 Will the development impact on coastal areas with significant landforms including beach ridge plain, cuspate headland, coastal dunes or karst?

☐ Yes ☐ No **If yes**, please describe the extent of the expected impact.

2.5.4 Is the development likely to impact on mangroves?

☐ Yes ☐ No **If yes**, please describe the extent of the expected impact.

2.6 Marine Areas and Biota

2.6.1 Is the development likely to impact on an area of sensitive benthic communities, such as seagrasses, coral reefs or mangroves?

☐ Yes ✔ No **If yes**, please describe the extent of the expected impact.

2.6.2 Is the development likely to impact on marine conservation reserves or areas recommended for reservation (as described in *A Representative Marine Reserve System for Western Australia*, CALM, 1994)?

☐ Yes ✔ No **If yes**, please describe the extent of the expected impact.

2.6.3 Is the development likely to impact on marine areas used extensively for recreation or for commercial fishing activities?

☐ Yes ✔ No **If yes**, please describe the extent of the expected impact, and provide any written advice from relevant agencies (e.g. Fisheries WA).

2.7 Water Supply and Drainage Catchments

2.7.1 Are you in a proclaimed or proposed groundwater or surface water protection area?

(You may need to contact the Department of Water (DoW) for more information on the requirements for your location, including the requirement for licences for water abstraction. Also, refer to the DoW website)

✔ Yes ☐ No **If yes**, please describe what category of area.

The project lies within the Proclaimed Pilbara Groundwater Area.

2.7.2 Are you in an existing or proposed Underground Water Supply and Pollution Control area?

(You may need to contact the DoW for more information on the requirements for your location, including the requirement for licences for water abstraction. Also, refer to the DoW website)

☐ Yes ✔ No **If yes**, please describe what category of area.

2.7.3 Are you in a Public Drinking Water Supply Area (PDWSA)?

(You may need to contact the DoW for more information or refer to the DoW website. A proposal to clear vegetation within a PDWSA requires approval from DoW.)

☐ Yes ✔ No **If yes**, please describe what category of area.

2.7.4 Is there sufficient water available for the proposal?

(Please consult with the DoW as to whether approvals are required to source water as you propose. Where necessary, please provide a letter of intent from the DoW)

✔ Yes ☐ No (please tick)

2.7.5 Will the proposal require drainage of the land?

✔ Yes ☐ No **If yes**, how is the site to be drained and will the drainage be connected to an existing Local Authority or Water Corporation drainage system? Please provide details.

The Proposal involves increasing the amount of mine dewatering and subsequent reinjection of both brackish and saline water. The Proposal does not connect with any Local Authority or Water Corporation drainage system.

Dewatering water of different salinities (brackish and saline) are currently kept separate and reinjected separately into appropriate receiving aquifers. Brackish water is currently re-injected at locations lateral to

the active mining areas, into the same aquifer system, namely the Marra Mamba Formation. The focal point(s) of brackish water injection will shift throughout the mine life due to the lateral progression of mine pits such that some earlier mining areas will become reinjection areas (Figure 2 of Supporting Information Document).

Excess saline groundwater will be re-injected into the Oakover Formation, at locations between the resource footprint and the Fortescue Marsh. The focal point for saline injection will mirror the location of mining to some extent as part of the strategy to mitigate potential drawdowns near Fortescue Marsh.

2.7.6 Is there a water requirement for the construction and/ or operation of this proposal?

(please tick) ☐ Yes **If yes**, complete the rest of this section.

✔ No **If no**, go to the next section.

Approximately 11 GL/a of abstracted water is reused for purposes such as ore processing and dust suppression, all additional water is returned to the environment through injection. There is currently no opportunity to reuse any of the additional abstracted groundwater that will result from this Proposal.

2.7.7 What is the water requirement for the construction and operation of this proposal, in kilolitres per year?

2.7.8 What is the proposed source of water for the proposal? (e.g. dam, bore, surface water etc.)

2.8 Pollution

2.8.1 Is there likely to be any discharge of pollutants from this development, such as noise, vibration, gaseous emissions, dust, liquid effluent, solid waste or other pollutants?

(please tick) ☐ Yes **If yes**, complete the rest of this section.

✔ No **If no**, go to the next section.

2.8.2 Is the proposal a prescribed premise, under the Environmental Protection Regulations 1987?

(Refer to the EPA's *General Guide for Referral of Proposals to the EPA under section 38(1) of the EP Act 1986* for more information)

☐ Yes ✔ No **If yes**, please describe what category of prescribed premise.

Various components of the Cloudbreak mine are prescribed premises. This proposal will not affect any prescribed premises or change the status of any premises in relation to the EP Act.

2.8.3 Will the proposal result in gaseous emissions to air?

☐ Yes ✔ No **If yes**, please briefly describe.

2.8.4 Have you done any modelling or analysis to demonstrate that air quality standards will be met, including consideration of cumulative impacts from other emission sources?

☐ Yes ✔ No **If yes**, please briefly describe.

2.8.5 Will the proposal result in liquid effluent discharge?

☐ Yes ✔ No **If yes**, please briefly describe the nature, concentrations and receiving environment.

2.8.6 If there is likely to be discharges to a watercourse or marine environment, has any analysis been done to demonstrate that the State Water Quality Management Strategy or other appropriate standards will be able to be met?

✔ Yes ☐ No **If yes**, please describe.

The Dewatering Discharge Contingency Procedure (Fortescue 2009) was presented in the Cloudbreak LOM PER and therefore approved under MS 899. In line with the Dewatering Discharge Contingency Procedure discharge of water will only occur at designated creek line discharge points.

Contingency surface water discharge was approved in the Cloudbreak LOM PER which concluded impacts could be managed by limiting discharge to up to 35 ML/day of fresh or brackish water for periods of up to 21 days under limited circumstance No change to this regime is proposed and as such no additional impact to surface water quality is expected.

2.8.7 Will the proposal produce or result in solid wastes?

☐ Yes ✔ No **If yes**, please briefly describe the nature, concentrations and disposal location/ method.

2.8.8 Will the proposal result in significant off-site noise emissions?

☐ Yes ✔ No **If yes**, please briefly describe.

2.8.9 Will the development be subject to the Environmental Protection (Noise) Regulations 1997?

☐ Yes ✔ No **If yes**, has any analysis been carried out to demonstrate that the proposal will comply with the Regulations?

Please attach the analysis.

2.8.10 Does the proposal have the potential to generate off-site, air quality impacts, dust, odour or another pollutant that may affect the amenity of residents and other "sensitive premises" such as schools and hospitals (proposals in this category may include intensive agriculture, aquaculture, marinas, mines and quarries etc.)?

☐ Yes ✔ No **If yes**, please describe and provide the distance to residences and other "sensitive premises".

2.8.11 If the proposal has a residential component or involves “sensitive premises”, is it located near a land use that may discharge a pollutant?

☐ Yes ✔ No ☐ Not Applicable

If yes, please describe and provide the distance to the potential pollution source

2.9 Greenhouse Gas Emissions

2.9.1 Is this proposal likely to result in substantial greenhouse gas emissions (greater than 100 000 tonnes per annum of carbon dioxide equivalent emissions)?

☐ Yes ✔ No **If yes**, please provide an estimate of the annual gross emissions in absolute and in carbon dioxide equivalent figures.

2.9.2 Further, if yes, please describe proposed measures to minimise emissions, and any sink enhancement actions proposed to offset emissions.

2.10 Contamination

2.10.1 Has the property on which the proposal is to be located been used in the past for activities which may have caused soil or groundwater contamination?

☐ Yes ✔ No ☐ Unsure **If yes**, please describe.

2.10.2 Has any assessment been done for soil or groundwater contamination on the site?

☐ Yes ✔ No **If yes**, please describe.

2.10.3 Has the site been registered as a contaminated site under the *Contaminated Sites Act 2003*? (on finalisation of the CS Regulations and proclamation of the CS Act)

☐ Yes ✔ No **If yes**, please describe.

2.11 Social Surroundings

2.11.1 Is the proposal on a property which contains or is near a site of Aboriginal ethnographic or archaeological significance that may be disturbed?

✔ Yes ☐ No ☐ Unsure **If yes**, please describe.

Approximately 1573 heritage sites are located within the Chichester Project area (Cloudbreak and Christmas Creek), including 567 salvaged sites. These sites comprise artefact, manmade structures, mythological, repository, ceremonial, grinding patch, midden, skeletal material / burial, engraving, historical, scarred tree

and quarry sites. Artefact scatters account for over 80% of the identified sites within the Chichester Project area.

The Fortescue Marsh has some semi-permanent water pools or “yintas” along the northern shoreline which have been identified as having cultural significance. Two yintas have part of their catchments within the Proposal area being Yinta 1 which receives flow from Gorman Creek and Yinta 2 (Figure 15 of the Supporting Information Document).

Impacts to heritage are expected to be minimal and with the scope of the approvals granted in MS 899.

Impacts will be limited to impacts on Aboriginal heritage sites to the extent permitted under the *Aboriginal Heritage Act 1972* Section 19 – Consent to Disturb.

2.11.2 Is the proposal on a property which contains or is near a site of high public interest (e.g. a major recreation area or natural scenic feature)?

☐ Yes ✔ No **If yes**, please describe.

2.11.3 Will the proposal result in or require substantial transport of goods, which may affect the amenity of the local area?

☐ Yes ✔ No **If yes**, please describe.

3. PROPOSED MANAGEMENT

3.1 Principles of Environmental Protection

3.1.1 Have you considered how your project gives attention to the following Principles, as set out in section 4A of the EP Act? (For information on the Principles of Environmental Protection, please see EPA Position Statement No. 7, available on the EPA website)

1. The precautionary principle.	✔ Yes	☐ No
2. The principle of intergenerational equity.	✔ Yes	☐ No
3. The principle of the conservation of biological diversity and ecological integrity.	✔ Yes	☐ No
4. Principles relating to improved valuation, pricing and incentive mechanisms.	✔ Yes	☐ No
5. The principle of waste minimisation.	✔ Yes	☐ No

Please refer to Table 5 of the Supporting Information Document for further details of how the Principles of Environmental Protection have been addressed.

3.1.2 Is the proposal consistent with the EPA's Environmental Protection Bulletins/Position Statements and Environmental Assessment Guidelines/Guidance Statements (available on the EPA website)?

✔ Yes ☐ No

3.2 Consultation

3.2.1 Has public consultation taken place (such as with other government agencies, community groups or neighbours), or is it intended that consultation shall take place?

✔ Yes ☐ No **If yes**, please list those consulted and attach comments or summarise response on a separate sheet.

Date	Stakeholder	Purpose	Outcome	Fortescues Response
28 October 2013	Office of Environmental Protection Authority	To provide an overview of the Proposal and proposed assessment approach under the EP Act.	- EPA requests that Guidance Statement 9 be used to identify key environmental factors and that the impact assessment focuses on these factors. - EPA requests that some discussion is provided with respect to non-key factors and the reasons why these factors will not be impacted on by the Proposal.	Fortescue has incorporated each recommendation into the referral documentation.

Date	Stakeholder	Purpose	Outcome	Fortescues Response
			- EPA provided suggestions with respect to the preferred format of the supporting information document and cited suitable examples that could be followed.	
21 November 2013	Department of the Environment	To provide an overview of the Proposal and assess requirement for a formal referral under the EPBC Act.	- DoE noted that the scope of the existing controlled action refers to the predicted impacts to MNES and not the volume of abstracted and injected groundwater. - DoE noted that if the predicted impacts to MNES remain in the scope of the existing controlled action, no referral of the Proposal would be required.	Fortescue has assessed the potential impacts of the Proposal and has concluded that there are no changes to the predicted impacts to MNES from the impact already approved in the existing controlled action. As such Fortescue is not referring the Proposal to the DoE.
15 November 2013	Department of Water	To provide an overview of the Proposal.	DoW informed Fortescue that the tri-annual report remains under review.	No response required.

Assessment

Increase in Groundwater Abstraction and Injection – Supporting Environmental Document

Cloudbreak

Rev 0: April 2014
CB-AS-EN-0047

FMG
Fortescue
The New Force in Iron Ore

Disclaimer:
This document is protected by copyright, no part of this document may be reproduced or adapted without the consent of the originator/company owner, all rights are reserved. This document is "uncontrolled when printed", refer to electronic copy for up to date version.

	Increase in Groundwater Abstraction and Injection – Supporting Environmental Document		**CB-AS-EN-0047**
Revision Number	**REV 0**		**4/04/2014**
Status	**IFU - ISSUED FOR USE**		
Author	Arne De Vos	Signature	2/12/2013
Checked	Fiona Rowland	Signature	1/04/2014
Approved	Sean McGunnigle	Signature	4/04/2014
Confidentiality	**FORTESCUE STAFF & CONTRACTORS**	**Publish on Extranet**	☐ Yes ☒ No

This document was prepared on behalf of Fortescue Metals Group Limited by:			**Sinclair Knight Merz**
Approved by Fortescue:	Fiona Rowland	Signature	2/12/2013

EXECUTIVE SUMMARY

Overview

The Proponent, Fortescue Metals Group Ltd (Fortescue) is currently developing the Pilbara Iron Ore and Infrastructure Project (the Project), which involves a series of iron ore mines in the Pilbara region of Western Australia, and rail and port infrastructure for export of iron ore through Port Hedland. Cloudbreak, which forms a component of the Project, is located in the Pilbara region of Western Australia approximately 120 km north of Newman. The mine site is located approximately 2.5 km from the Fortescue Marsh at the closest point.

As a result of an increased understanding of the hydrogeology at Cloudbreak and subsequent refining of the groundwater model; and the opportunity to blend ore at the mine, Fortescue proposes to increase the volume of groundwater abstraction and injection limits at Cloudbreak to 150 gigalitres per annum (GL/a) (hereafter referred to as 'the Proposal').

This document is a supporting information document and has been prepared as part of the referral of the Proposal under the Western Australian *Environmental Protection Act 1986* (EP Act). In addition this document provides supporting information to notify the Department of the Environment (DoE) that the action and predicted impacts are considered a controlled action and within the scope of EPBC 2010/5696 and to confirm no further approval requirements under the Commonwealth *Environment Protection and Biodiversity Conservation* Act 1999.

The purpose of the document is to present an environmental impact assessment of the Proposal.

Western Australian *Environmental Protection* Act 1986 (EP Act)

Section 38 of the EP Act allows for significant proposals (i.e. proposals that may have a significant effect on the environment) to be referred to the Western Australian Environmental Protection Authority (EPA). The information provided as part of the referral should be sufficient for the EPA to decide whether the proposal should be assessed, and the level of assessment that should be applied (EPA, 2012). Fortescue anticipates that this Proposal meets the above criteria and that the Proposal can be assessed at the level of "Assessment on Proponent Information Category A" (API).

Commonwealth *Environment Protection and Biodiversity Conservation* Act 1999 (EPBC Act)

Under the EPBC Act, any action which is likely to have a significant impact on Matters of National Environmental Significance (MNES) is required to be referred to the DoE for assessment as to whether the action constitutes a "controlled action". Where an action forms part of the action which has already been approved (as is the case with this action) then a referral to the DoE is not required. The action and predicted impacts are considered a controlled

action within the scope of EPBC 2010/5696 and as such Fortescue is not proposing to refer this action to the DoE. In accordance with Condition 7 of controlled action EPBC 2010/5696, which states "…*the person taking the action must advise the Minister of the quantity of de-watering and reinjection in operation and not increase dewatering or reinjection activities above the amount unless the Minister has given the person taking the action written approval*…" Fortescue is seeking Ministerial approval for the increase in groundwater abstraction and injection.

Identification of Key Environmental Factors

The identification of Key Environmental Factors for this Proposal has been undertaken in accordance with Environmental Assessment Guideline 9 and on the basis of the extensive studies, surveys and environmental assessments undertaken to date in reference to Cloudbreak.

The following have been identified as Key Environmental Factors for this Proposal:

- Hydrogeological Processes – Groundwater
- Flora and Vegetation
- Terrestrial Fauna
- Conservation and Natural Heritage Areas

Other relevant environmental factors that may be affected by the proposal, but where the environmental objectives will clearly be met, include heritage, inland water environmental quality, surface water, subterranean fauna, landforms and terrestrial environmental quality.

Assessment of Impacts

The environmental impact assessment of the potential impacts to key environmental factors concluded:

Hydrogeological Processes – Groundwater

- While some increase in the scale of groundwater drawdown and mounding will occur as a result of the Proposal, it is not expected that this will result in any significant impacts to existing or potential users or to ecosystem maintenance.
- Numerical modelling (Fortescue 2013a) has shown that maximum drawdown and mounding at monitoring bores may be up to 1.8 m, with consideration for climatic and parameter sensitivity. Although a 1.8 m change is predicted by modelling, the adaptive groundwater management scheme, including the redistribution of water, will ensure that groundwater levels within and at the fringe of the Marsh do not change by more than 1 m, as required by the existing condition 7 of Ministerial Statement (MS) 899.

- It is expected that the EPA Management Objective for Hydrogeological Processes – Groundwater will be achieved.

Flora and Vegetation

- A lower impact to Samphire vegetation is expected when compared to the conservative estimates presented in the Cloudbreak Life of Mine Public Environmental Review (LOM PER).
- A higher impact to water logging intolerant vegetation (Mulga) is expected as a result of the Proposal (increase of 522 ha or 5% when compared to LOM PER). Given the large representation of Mulga in the region, this small increase in indirect impacts is not expected to significantly impact the representation, diversity, viability and ecological function of the Mulga in the region.
- No vegetation communities are expected to be impacted to an extent where they are reduced to below 30% of their pre-clearing extent.
- No impacts to DRF are predicted.
- It is expected that the EPA Management Objective for Vegetation and Flora will be achieved.

Terrestrial Fauna

- No additional direct impact (clearing) beyond that approved in MS 899 and EPBC 2010/5696 is proposed.
- The predicted areas of direct and indirect impact are located in the Mulga and other Acacia Woodland habitat (6617 ha) followed by the Spinifex Covered Hills and Ranges (985 ha).
- A total of 98.7% of all expected indirect impact is within the Mulga and other Acacia Woodland habitat (922 ha).
- While it is predicted there may be some degradation in the health of the Mulga and other Acacia Woodland habitat, the impact is expected to be minimal and localised. An additional 178 ha of Mulga and other Acacia Woodland habitat may potentially be affected as a result of the increase in abstraction and injection quantities. This represents a 22% increase in the indirect impact to Mulga and other Acacia Woodland habitat approved in MS 899 and EPBC 2010/5696 but only a 2.8% increase in total (direct and indirect) disturbance for Mulga and other Acacia Woodland habitat.
- The percent of expected indirect impact to Low Halophytic Shrubland (samphire) habitat and Creeklines with Shrubland and/or Eucalypt Open Woodland habitat are significantly lower than presented in the LOM PER.
- It is expected that the EPA Management Objective for Terrestrial Fauna will be achieved.

Conservation and Natural Heritage Areas

- No additional impacts to Fortescue Marsh are expected to occur as a result of the Proposal.
- It is expected that the EPA's Objective for Conservation and Natural Heritage area will be achieved.

Matters of National Environmental Significance

- Based on the predicted impacts to threatened fauna species and the relevant significance criteria it is considered that it is unlikely that the proposed action will have a significant impact on a critically endangered or endangered ecological community.
- Six species listed in the EPBC Act may be present in the Proposal area including Night Parrot, Northern Quoll, Greater Bilby, Orange Leaf-nosed Bat, Pilbara Olive Python and the Crest-tailed Mulgara.
- There are no changes to the predicted impacts to MNES which have already been approved in the existing controlled action (EPBC 2010/5696).

TABLE OF CONTENTS

EXECUTIVE SUMMARY 3

1. INTRODUCTION 10
   - 1.1 Overview 10
   - 1.2 Existing Relevant Approvals 10
   - 1.3 Purpose and Scope of this Document 11

2. PROPOSAL OVERVIEW 12
   - 2.1 Key Proposal Characteristics 12
   - 2.2 The Proponent 13
   - 2.3 Related Proposals 13
   - 2.4 Overview of Relevant Activities 14

3. ENVIRONMENTAL ASSESSMENT AND MANAGEMENT APPROACH 16
   - 3.1 Western Australian *Environmental Protection Act* 1986 16
   - 3.2 Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 16
   - 3.3 Principles of Environmental Protection 17
   - 3.4 Principle of Environmental Impact Assessment 19

4. STAKEHOLDER CONSULTATION 21

5. SUPPORTING STUDIES 22

6. ENVIRONMENTAL IMPACT ASSESSMENT AND MANAGEMENT 23
   - 6.1 Identification of Key and Relevant Factors 23
   - 6.2 Identification of Environmental Management Objectives 23
   - 6.3 Impact Assessment 23

7. MATTERS OF NATIONAL ENVIRONMENTAL SIGNIFICANCE 35
   - 7.1 Legislative Background 35
   - 7.2 Impact Assessment – Matters of National Environmental Significance 35

List of Tables

Table 1: Key Characteristics of Approved Development and Proposed Changes 12
Table 2: Water Abstraction and Injection Limits 13
Table 3: Department of Water Management Hierarchy and Application at Cloudbreak 14
Table 4: Proposal Comparison with API Category A Criteria 16
Table 5: Principles of Environmental Protection 17
Table 6: Principles of Environmental Impact Assessment 19
Table 7: Summary of Stakeholder Consultation undertaken for this Proposal to Date 21
Table 8: Summary of Supporting Studies 22
Table 9: Impact Assessment - Key Environmental Factors 24
Table 10: Impact Assessment - Relevant Environmental Factors 32
Table 11: Impact Assessment – Matters of National Environmental Significance .. 37

LIST OF FIGURES

Figure 1: Location of Cloudbreak .....
Figure 2: Indicative Injection Areas .....
Figure 3: Conceptual Hydrogeological Model .....
Figure 4: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts – 2014 .....
Figure 5: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts – 2015 .....
Figure 6: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts – 2016 .....
Figure 7: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts – 2017 .....
Figure 8: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts – 2018 .....
Figure 9: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts – 2019 .....
Figure 10: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts – 2020 .....
Figure 11: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts - 2021 .....
Figure 12: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts – 2022 .....
Figure 13: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts - 2023 .....
Figure 14: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts - 2024 .....
Figure 15: Surface Water Features .....
Figure 16: Vegetation Mapping .....
Figure 17: Indirect Impacts to Fauna Habitat.....

LIST OF APPENDICES

Appendix 1: Hydrogeological Assessment
Appendix 2: Cloudbreak Groundwater Operating Strategy
Appendix 3: Vegetation Types in the Cloudbreak Area
Appendix 4: Priority Flora Recorded in the Proposal Area
Appendix 5: Summary of Potential Presence of Conservation Significant Species

1. INTRODUCTION

1.1 Overview

The Proponent, Fortescue Metals Group Ltd (Fortescue) is currently developing the Pilbara Iron Ore and Infrastructure Project (the Project), which involves a series of iron ore mines in the Pilbara region of Western Australia, and rail and port infrastructure for export of iron ore through Port Hedland.

Cloudbreak, which forms a component of the Project, is located in the Pilbara region of Western Australia approximately 120 km north of Newman. The site is within the Mulga Downs and Hillside pastoral leases. The mine site is located approximately 2.5 km from the Fortescue Marsh at the closest point (Figure 1).

Cloudbreak commenced production in 2008 and includes mining of open pits, ore processing, access roads, an accommodation village, airport and the transport of a maximum of 50 Million tonnes per annum (Mtpa) of iron ore to Port Hedland for shipment.

As a result of an increased understanding of the hydrogeology at Cloudbreak and subsequent refining of the groundwater model; and the opportunity to blend ore at the mine, Fortescue proposes to increase the volume of groundwater abstraction and injection limits at Cloudbreak to 150 gigalitres per annum (GL/a) (hereafter referred to as 'the Proposal').

1.2 Existing Relevant Approvals

Cloudbreak was originally referred under Part IV of the Western Australian *Environmental Protection* Act 1986 (EP Act) and the Commonwealth *Environment Protection and Biodiversity Conservation* Act 1999 (EPBC Act) in 2005. Approval for the mine was granted pursuant to Ministerial Statement (MS) 721 and EPBC 2005/2205.

Subsequent to this approval, additional project components such as a power station and tailings facility have been referred to the Western Australian (WA) Environmental Protection Authority (EPA) and also approved under Part V of the EP Act.

More recently the Cloudbreak Expansion Project was referred under the EPBC Act and Part IV of the EP Act and assessed via the Federal Government/WA Government Bilateral Agreement. The *Cloudbreak Life of Mine Public Environmental Review* (LOM PER) document was submitted to the Department of Sustainability, Environment, Water, Population and Communities (DSEWPC) (now Department of the Environment (DoE)) and the WA EPA to support the assessment. Subsequently, the Cloudbreak Expansion Project was approved pursuant to EPBC 2010/5696 and MS 899.

Fortescue has obtained approval (20 December 2013) under the Section 45C of the EP Act for the increase in the annual volume of groundwater injection, to integrate groundwater

management between Cloudbreak and Christmas Creek mine sites; and to amend the groundwater monitoring locations presented in MS 899. This approval has been granted via the submission of the document *Request to Amend Ministerial Statement 899 under Section 45C of the Environmental Protection Act 1986* (Section 45C) to the EPA. Fortescue has also obtained approvals (18 March 2014) under Section 46 of the EP Act for the change in the groundwater monitoring locations presented in MS 899. This approval has been granted via the submission of the document *Request to Amend Conditions 7-1 and 7-2 of Ministerial Statement 899 under Section 46 of the Environmental Protection Act 1986*.

Fortescue has also notified DSEWPC (now DoE) of the above changes by submitting *Notification of Proposed Changes to the Cloudbreak Water Management Controlled Action EPBC 2010/5696) (refer to letter CB-EN-0146.04 dated 27 September 2013)*. Given that these changes were within the scope of that which was referred and approved under EPBC 2010/5696, no further approval was required.

1.3 Purpose and Scope of this Document

This document is a supporting information document and has been prepared as part of the referral of the Proposal under the WA EP Act. In addition this document provides supporting information to notify the DoE that the action and predicted impacts are considered a controlled action and within the scope of EPBC 2010/5696.

The purpose of the document is to present an environmental impact assessment of the Proposal.

The scope of Proposal is limited to the increase in abstraction and injection limits as described in Section 2. Any related activities such the potential clearing of land for infrastructure development will be undertaken in accordance and within the limits of existing project approvals.

The scope of the environmental impact assessment presented in this document includes cumulative impacts including potential impacts from the existing Cloudbreak water management scheme and the nearby Christmas Creek water management scheme.

2. PROPOSAL OVERVIEW

2.1 Key Proposal Characteristics

Fortescue proposes to increase the volume of groundwater abstraction and injection at Cloudbreak to 150 GL/a. This is a result of increased understanding of the hydrogeology and subsequent refining of the groundwater model. No other changes to the existing approved project are proposed. There are no changes to the requirement to comply with the 1 m mounding and drawdown limits at the Fortescue Marsh monitoring bores as required by Condition 7-1 of MS 899.

All associated infrastructure required for the implementation of the Proposal are within the scope of the existing approvals and no additional clearing outside of the current approved footprint is required. No access to any new aquifers for injection is required.

The key characteristics of the existing mine and the proposed changes are outlined in Table 1.

Table 1: Key Characteristics of Approved Development and Proposed Changes

Relevant Characteristic	Current Approved (MS 899 and EPBC 2010/5696)	Proposed Changes (cumulative with current approved project)
Main Activities	Iron ore strip mining, dewatering and injection, pit backfilling, ore processing, transport of ore to rail loading facility, ore loading to rail, mine rehabilitation and closure.	No change
Resource	700 Million Ton (MT) Marra Mamba iron ore deposit.	No change
Ore Production	Up to 50 Mtpa wet production down-rail from the Cloudbreak Ore Processing Facility (OPF) consisting of either: • 100% from Cloudbreak Run of Mine (ROM) ore feed • Up to 10 Mtpa from Christmas Creek ROM ore feed.	No change
Overburden	Approximately 3150 MT.	No change
Tailings	In-pit disposal of up to 70 Million m^3.	No change
Life of Mine	Approximately 17 years (from commencement in 2008).	No change
Area disturbed	Up to 18 100 ha	No change
Pit depth	Up to 90 m	No change
Dewatering Requirements	Mine dewatering up to 100 GL/yr. Injection of all water that is not used for ore processing or dust suppression (up to 95 GL/yr.)	**Mine dewatering up to 150 GL/yr.** **Injection of excess water up to 150 GL/yr.**
Power	40 MW diesel fuelled power station.	No change
Greenhouse gas emissions	Approximately 18kg CO_2-e per tonne of ore mined (based on an average production rate of 35 Mtpa).	No change

The abstraction, injection, mounding and drawdown limits for Cloudbreak based on the various approvals are presented in Table 2.

Table 2: Water Abstraction and Injection Limits

Approval	Date	Abstraction Limit (GL/a)	Injection Limit (GL/a)
MS 721	24 April 2006	25 GL/a	n/a
MS 899	5 June 2012	100 GL/a	85 GL/a
Section 45c	20 December 2013	100 GL/a	95 GL/a
This referral		**150 GL/a**	**150 GL/a**

2.2 The Proponent

The proponent for the Proposal is Fortescue Metals Group Limited. The contact person for the Proposal is:

Sean McGunnigle

Fortescue Metals Group Limited

Level 2, 87 Adelaide Tce, East Perth WA 6004

PO Box 6915, East Perth WA 6892

Ph: 6218 8415

Email : smcgunnigle@fmgl.com.au

Web: http://www.fmgl.com.au

2.3 Related Proposals

Fortescue operates the Christmas Creek mine which is located immediately to the east of Cloudbreak in the Chichester Range. The two mines, collectively termed the Chichester Hub, are linked by heavy and light vehicle access roads as well as a 37 km railway line.

The Section 45C application recently approved on the 20 December 2013 by the EPA relates to integrating groundwater management between Cloudbreak and Christmas Creek mine sites.

The expansion of the adjacent Christmas Creek mine was referred under the EP Act on the 31 October 2013 and under the EPBC Act on the 13 November 2013. This proposed expansion includes the increase in the volume of abstraction and injection of groundwater at the Christmas Creek mine.

Potential cumulative impacts presented by the Christmas Creek mine (including expansion) are accounted for in the groundwater modelling undertaken for this Proposal and have been considered within this document.

2.4 Overview of Relevant Activities

As this Proposal relates solely to the increase of groundwater abstraction and injection quantities, a full description of the Cloudbreak mining operations is not included within this document. A description of the activities relevant to this Proposal is provided below and a detailed description of the mining operations can be found in the Cloudbreak LOM PER.

Groundwater at Cloudbreak lies within the alluvium and mineralised Marra Mamba Formation (MMF), the ore body. Dewatering is therefore required to lower groundwater levels below the base of each pit to enable access to the ore.

The ore body is dewatered ahead of the advancing mine faces using bores, with some sump dewatering in the pit required due to seepage and rainfall. Revised groundwater modelling (based on a greater understanding of the local hydrogeology) indicates that up to 150 GL/a may be required to be abstracted in a wet rainfall scenario (Fortescue, 2013a) (Appendix 1).

Fortescue manages abstracted groundwater in line with the Department of Water (DoW) hierarchy of water management methods (DoW, 2009). The hierarchy of management methods and their application at Cloudbreak is presented in Table 3.

Table 3: Department of Water Management Hierarchy and Application at Cloudbreak

Management Measure (in order of preference)	Application at Cloudbreak
Efficient on-site use – used for fit for purpose activities (such as processing or dust suppression).	Approximately 11 GL/a of abstracted water is reused for purposes such as ore processing and dust suppression, all additional water is returned to the environment through injection. There is currently no opportunity to reuse any of the additional abstracted groundwater that will result from this Proposal.
Transferred to meet other demand, including other proponents in the area and public water supply.	Fortescue will continue to investigate the feasibility of transferring excess water to meet other demands, however no such opportunities have been identified to date.
Injection back in to the aquifer at designated sites.	An aquifer injection scheme has operated a Cloudbreak since 2008. It is proposed that all additional excess water resulting from this Proposal will be reinjected via this aquifer injection scheme.
Controlled release to the environment where the abstracted groundwater release is allowed to flow (through a pipe or overland) into a designated water course or wetland.	Controlled release is only considered as a method of discharge in the event that adequate injection capacity is not available due to system failure or maintenance requirements. If required, controlled release is undertaking in accordance with the *Dewatering Discharge Contingency Procedure* (Fortescue 2009) which outlines discharge quantity and quality and duration limits, discharge points and water quality monitoring requirements.

Excess water that cannot be reused on site is reinjected into three available injection areas via a series of bores (Figure 2). A strategic approach to injection is adopted to allow injection into aquifers of similar water quality characteristics. Brackish and saline waters are abstracted and injected to conserve brackish water for future reuse by the mine. Brackish water is considered to have salinity less than 6000 mg/L.

Excess brackish water, from Cloudbreak operations, is currently injected into the Hillside West Injection Area which is located west of the active mining area. The location of brackish water injection will change throughout the life of the mine as the mine pits move and some earlier

mining areas become injection areas. Indicative injection bore locations over the life of the mine are shown in Figure 2.

Excess saline groundwater is injected into the Oakover Formation, at locations between the mining area and the Fortescue Marsh. This location is part of the strategy to reduce the potential impacts from drawdown from mine dewatering near the Fortescue Marsh.

The approach of separating the groundwater based on salinity levels and location of the injection bores is intended to:

- Minimise the drawdown footprint
- Conserve the brackish water resource for future reuse
- Minimise impacts to Fortescue Marsh, mulga communities and groundwater dependent vegetation and Samphire vegetation.

No change to the surplus water injection method or locations is proposed as part of this Proposal.

Supporting infrastructure relating to groundwater management includes:

- Settlement, transfer and storage ponds
- Pipes used for transporting water to the injection zones
- Storage and processing facilities for use in dust suppression and other uses.

The pipeline corridors are configured in a network that allows water to be transferred around the site according to volume and quality. Any potential changes to the supporting infrastructure will be within the limits of current approvals and are excluded from this Proposal.

3. ENVIRONMENTAL ASSESSMENT AND MANAGEMENT APPROACH

3.1 Western Australian *Environmental Protection Act* 1986

Section 38 of the WA EP Act allows for significant proposals (i.e. proposals that may have a significant effect on the environment) to be referred to the WA EPA. The information provided as part of the referral should be sufficient for the WA EPA to decide whether the proposal should be assessed, and the level of assessment that should be applied (EPA, 2012).

Fortescue anticipates that this Proposal meets the above criteria and that the Proposal can be assessed at the level of "Assessment on Proponent Information Category A" (API). The criteria used to determine that an API Category A level of assessment can be applied are presented in Table 4 (EPA, 2012).

Table 4: Proposal Comparison with API Category A Criteria

API Category A Criteria	Proposal Comparison with Criteria
The proposal raises a limited number of key environmental factors that can be readily managed and for which there is an established condition-setting framework.	The environmental impact assessment identified five key environmental factors (refer to Section 6.1). These key environmental factors have previously been identified in the original Cloudbreak environmental impact assessment and the Cloudbreak LOM PER. Existing measures to manage impacts on these factors are in place as part of the operating mine. The identified key environmental factors are typical of numerous existing iron ore mines in the Pilbara and as such there is an established approach to the setting of conditions.
The proposal is consistent with established environmental policies, guidelines and standards	The Proposal is consistent with established environmental policies, guidelines and standards as detailed in Section 3.
The proponent can demonstrate that it has conducted appropriate and effective stakeholder consultation, in particular with Decision Making Authorities (DMAs).	Extensive consultation with stakeholders including DMAs has been undertaken in reference to the Cloudbreak mine. Consultation undertaken specific to this Proposal is detailed in Section 4.
There is limited or local concern only about the likely effect of the proposal, if implemented, on the environment.	No major concerns have been raised by stakeholders in relation to the Proposal.

3.2 Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999

The Commonwealth EPBC Act provides for the protection of nationally and internationally important flora, fauna, ecological communities and heritage places (collectively referred to as Matters of National Environmental Significance (MNES)). Under the Act, any action which is likely to have a significant impact on MNES is required to be referred to the DoE for assessment as to whether the action constitutes a "controlled action". If the action is deemed a "controlled action" implementation will consequently be subject to an approval from the Federal Minister for the Environment.

Where an action forms part of the controlled action which has already been approved (as is the case with this action) then a referral to the DoE is not required. The action and predicted impacts are considered a controlled action and within the scope of EPBC 2010/5696 and as such Fortescue is not proposing to refer this action to the DoE.

In accordance with Condition 7 of controlled action EPBC 2010/5696, which states "…*the person taking the action must advise the Minister of the quantity of de-watering and reinjection in operation and not increase dewatering or reinjection activities above the amount unless the Minister has given the person taking the action written approval*…" Fortescue is seeking Ministerial approval for the increase in groundwater abstraction and injection.

Potential impacts to MNES are addressed in Section 7 of this report.

3.3 Principles of Environmental Protection

Part 1, Section 4A of the WA EP Act sets out five principles by which protection of the environment is to be achieved in Western Australia. These principles and the manner in which Fortescue has sought to apply them in the design and planned implementation of the Proposal are outlined in Table 5.

Table 5: Principles of Environmental Protection

Principle	Consideration given in Proposal	Corresponding Section
1. Precautionary Principle Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, decisions should be guided by: • careful evaluation to avoid, where practicable, serious or irreversible damage to the environment; and • an assessment of the risk-weighted consequences of various options.	Fortescue recognises the importance of minimising environmental impacts as it is vital in ensuring its longevity, success, growth and positioning in the domestic and global markets. Fortescue aims to gain a level of achievement beyond its legal obligations. This will be achieved by successful management of potential risks. Fortescue maintains an environmental management system (EMS) that addresses all of its activities with a potential to affect the environment. The key elements of the EMS include assessing environmental risk arising from environmental aspects with the intention of identifying issues early in the process to enable planning for avoidance and/or mitigation. Part of this process includes undertaking detailed site investigations of the biological and physical environments. Where these investigations identify significant conservation issues, management measures are incorporated into the project design to avoid, where practicable, and/or minimise any potential impacts. As a result, this Proposal has been designed to minimise potential impacts to the key environmental values of the local flora, vegetation, fauna and Fortescue Marsh.	Section 6
2. Intergenerational Equity The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future	Fortescue's decision making processes incorporate sustainability principles and the implementation of new and better technologies where feasible. Fortescue aims to inspire an ethic and attitude that strives for continuous improvement and ongoing learning. Fortescue encourages employees to engage in positive	Addressed in existing management procedures.

Principle	Consideration given in Proposal	Corresponding Section
generations.	attitudes and behaviour concerning respect for the environment. It recognises sustainability cannot be achieved without the contribution and action of the entire team.	
3 Conservation of biological diversity and ecological integrity Conservation of biological diversity and ecological integrity should be a fundamental consideration.	Conservation of biological diversity and ecological integrity is fundamental to the Fortescue's approach to environmental management and is a major environmental consideration for the Proposal. Biological investigations have been undertaken by Fortescue early in the Cloudbreak planning process to identify values of environmental conservation significance required to be protected from disturbance. This Proposal has been designed to minimise potential impacts to the key environmental values of the surrounding flora and vegetation and the Fortescue Marsh. Fortescue has previously committed to rehabilitating disturbed environments upon decommissioning, as well as ongoing rehabilitation of vegetation around Cloudbreak. The aim of all rehabilitation is to establish sustainable endemic vegetation units consistent with reconstructed landforms and surrounding vegetation. Fortescue is also undertaking monitoring of groundwater and surface water in the area to determine impacts, as well as funding ongoing studies into the Fortescue Marsh.	Section 6
4. Improved valuation, pricing and incentives mechanisms Environmental factors should be included in the valuation of assets and services. The polluter pays principle – those who generate pollution and waste should bear the cost of containment, avoidance or abatement. The users of goods and services should pay prices based on the full life cycle costs of providing goods and services, including the use of natural resources and assets and the ultimate disposal of any wastes. Environmental goals, having been established, should be pursued in the most cost effective way, by establishing incentives structures, including market mechanisms, which enable those best placed to maximise benefits and/or minimise costs to develop their own solutions and responses to environmental problems.	Fortescue acknowledges the need for improved valuation, pricing and incentive mechanisms and endeavours to pursue these principles when and wherever possible. For example: • environmental factors have played a major role in determining infrastructure locations • Fortescue has put in place procedures that will ensure that pollution-type impacts are minimised as far as practicable • the cost of rehabilitation and closure requirements has been incorporated into the costs of the product from the commencement of operation.	Not addressed in this document (addressed under existing management measures as a requirement of MS 707 and MS 899).
5. Waste minimisation All reasonable and practicable measures should be taken to minimise the generation of waste and its discharge into the environment.	Fortescue's approach to waste management is to, in order of priority: • avoid and reduce at source • reuse and recycle • treat and/or dispose.	Waste minimisation is addressed in existing management plans and is not

Principle	Consideration given in Proposal	Corresponding Section
	Fortescue operates an appropriately licensed landfill for the disposal of general domestic solid wastes. Fortescue has a comprehensive recycling program on-site which includes the recycling of aluminium cans, scrap steel, plastic, batteries, light globes, fluorescent tubes, polyethylene pipe, office paper and cardboard.	specifically addressed in this document.

3.4 Principle of Environmental Impact Assessment

The Environmental Impact Assessment Administrative Procedures 2012 describe the Principles of EIA for Proponents (EPA, 2012). The principles and how they are addressed within this document are presented in Table 6.

Table 6: Principles of Environmental Impact Assessment

Principle		How addressed in Proposal
1	Consult with all stakeholders, including the EPA, DMAs, other relevant government agencies and the local community as early as possible in the planning of their proposal, during the environmental review and assessment of their proposal, and where necessary during the life of the project.	Section 4 details the stakeholder consultation undertaken in relation to the Proposal. Fortescue will continue to consult with relevant stakeholders and DMAs throughout the assessment process and throughout the life of Cloudbreak.
2	Ensure the public is provided with sufficient information relevant to the EIA of a proposal to be able to make informed comment, prior to the EPA completing the assessment report.	Sections 2 and 6 provide comprehensive information with respect to the Proposal, existing environmental and predicted impacts that may occur as a result of the Proposal implementation.
3	Use best practicable measures and genuine evaluation of options or alternatives in locating, planning and designing their proposal to mitigate detrimental environmental impacts and to facilitate positive environmental outcomes and a continuous improvement approach to environmental management.	Best practicable measures (such as injection and integration of groundwater management between the Cloudbreak and Christmas Creek mines) have been implemented throughout the development of Cloudbreak. The implementation of these measures will continue throughout implementation of the Proposal. These measures are applied to mitigate potential impacts – for example, it is predicted that the Proposal can be implemented within the groundwater drawdown and mounding conditions currently imposed under the approvals, leading to no predicted additional impacts to Fortescue Marsh – a positive environmental outcome. The management measures that will be implemented are described in Section 6.
4	Identify the environmental factors likely to be impacted and the aspects likely to cause impacts in the early stages of planning for their proposal. The onus is on the proponent through the EIA process to demonstrate that the unavoidable impacts will meet the EPA objectives for environmental factors and therefore their proposal is environmentally acceptable.	The key environmental factors and the key aspects of the proposal that may impact these factors were identified during an internal scoping phase and discussed with the EPA on 28 October 2013. Table 9 details how the EPA Management Objectives for the key environmental factors will be achieved.
5	Consider the following, during project planning and discussions with the EPA, regarding the form, content and timing of their environmental review: (a) the activities, investigations (and consequent authorisations) required to undertake the environmental review (b) the efficacy of the investigations to produce	A significant number of surveys and studies have been undertaken in and around the Proposal area in support of the Cloudbreak and Christmas Creek mines. These surveys and studies have been undertaken over a number of years and have been scoped to provide an adequate dataset to enable the effective and comprehensive environmental assessment of

Principle		How addressed in Proposal
	sound scientific baseline data about the receiving environment (c) the documentation and reporting of investigations (d) the likely timeframes in which to complete the environmental review and use best endeavours to meet assessment timelines.	Cloudbreak and its expansions; as well as the environmental management of the mines operations. The scope and contents of the environmental assessment of the Proposal was discussed with the EPA on 28 October 2013. The results of these discussions have been incorporated into the EP Act referral form and this supporting document. Timeframes for the preparation and submission of the referral were also discussed with the EPA. Fortescue will use best endeavours to meet these target timeframes.
6	Identify in their environmental review, subject to the EPA's guidance: (a) best practicable measures to avoid, where possible, and otherwise minimise, rectify, reduce, monitor and manage impacts on the environment (b) responsible corporate environmental policies, strategies and management practices, which demonstrate how the proposal can be implemented to meet the EPA's environmental objectives for environmental factors.	Best practicable measures to avoid and mitigate potential environmental impacts from the Proposal are presented in Section 6. Fortescue is committed to the responsible environmental management of the Cloudbreak operations through the implementation of environmental policies, strategies and management practices. Of particular relevance to this Proposal is the *Cloudbreak Groundwater Operating Strategy – Water Management* (Fortescue, 2013b). The groundwater operating strategy will be updated as required in the event of changes to the management approach (continual improvement) or changes to the approved abstraction and/or injection limits.

4. STAKEHOLDER CONSULTATION

Stakeholder consultation for the Proposal has been undertaken as part of an extensive ongoing stakeholder engagement program undertaken for Fortescue's expansion projects. This program started in October 2009 with the objectives of:

- disclosing the Proposal to all interested parties with sufficient detail such that they are able to provide feedback at the project development stage
- establishing relationships with key stakeholders that enable ongoing dialogue throughout implementation and regulation of the Proposal.

Details of the stakeholder engagement undertaken for the Cloudbreak expansion project can be found in the Cloudbreak Life of Mine PER (FMG 2011).

Stakeholder engagement undertaken in reference to this Proposal and how stakeholder comments have been addressed are detailed in Table 7.

Table 7: Summary of Stakeholder Consultation undertaken for this Proposal to Date

Date	Stakeholder	Purpose	Outcome	Fortescue's Response
28 October 2013	Office of Environmental Protection Authority	To provide an overview of the Proposal and proposed assessment approach under the EP Act.	- EPA requests that Guidance Statement 9 be used to identify key environmental factors and that the impact assessment focuses on these factors. - EPA requests that some discussion is provided with respect to non-key factors and the reasons why these factors will not be impacted on by the Proposal. - EPA provided suggestions with respect to the preferred format of the supporting information document and cited suitable examples that could be followed.	Fortescue has incorporated each recommendation into the referral documentation.
21 November 2013	Department of the Environment	To provide an overview of the Proposal and assess requirement for a formal referral under the EPBC Act.	- DoE noted that the scope of the existing controlled action refers to the predicted impacts to MNES and not the volume of abstracted and injected groundwater. - DoE noted that if the predicted impacts to MNES remain in the scope of the existing controlled action, no referral of the Proposal would be required.	Fortescue has assessed the potential impacts of the Proposal and has concluded that there are no changes to the predicted impacts to MNES from the impact already approved in the existing controlled action.
15 November 2013	Department of Water	To provide an overview of the Proposal.	DoW informed Fortescue that the tri-annual report remains under review.	No response required.
6 November 2013	WWF	To provide an overview of the Proposal.	WWF will not be commenting on the Proposal.	No response required.

5. SUPPORTING STUDIES

Numerous supporting surveys and studies have been undertaken in support of the environmental assessment and management of Cloudbreak. A summary of the studies relevant to this Proposal are provided in Table 8. All surveys were conducted in accordance with methodology and approaches of EPA Position Statement No.3 (EPA 2002) and EPA Guidance Statement No. 51 (EPA 2004).

Table 8: Summary of Supporting Studies

Report Author and Year	Survey / Study Details
ATA 2006a and 2006b	Level 1 fauna assessment of a trial mine pit site, airstrip, camp and access road.
Bamford 2005a	Level 2 Terrestrial Vertebrate Fauna Survey of Proposal Area (excluding some injection areas).
Bamford 2005b, 2006, 2007a, 2007b, 2009, 2010a and 2011	Annual Night Parrot Surveys.
Bamford 2010b	Level 1 and Level 2 terrestrial fauna survey for the proposed duplication of sections of the Fortescue railway including areas within the Proposal area.
Bennelongia 2011	Desktop subterranean fauna assessment of the Cloudbreak site.
Biota 2004	Mapping of vegetation communities in the Cloudbreak area.
Biota 2005	Level 2 Terrestrial Vertebrate Fauna Survey and Habitat Mapping of the Fortescue Stage B rails corridor and proposed mines at Cloudbreak, Christmas Creek, Mindy Mindy, Mt Lewin and My Nicholas.
Ecologia 2010a	Desktop terrestrial fauna study.
Ecologia 2010b	Desktop short-range endemic (SRE) invertebrate assessment.
Ecologia 2011a	One Phase Level 2 Vertebrate Fauna Assessment of the Cloudbreak tenements and part of the Fortescue Marsh.
Ecologia 2011b	Baseline SRE invertebrate fauna survey of the proposal area.
ENV 2011	Assessment of flora and vegetation in the Cloudbreak area including consolidation of previous surveys along with additional fieldwork to verify and expand existing mapping.
Fortescue 2013a	Hydrogeological assessment of the proposed increase in groundwater abstraction and injection volumes. This study utilises the conceptual hydrogeological model that has been developed based on field investigations undertaken since 2005, including an extensive drilling and testing program and assessment of hydrological properties conducted during 2008/2009. This assessment takes into account groundwater abstraction and injection associated with the Christmas Creek mine including its proposed expansion.
Mattiske 2005a	Mapping of vegetation communities in the Cloudbreak area.
Mattiske 2005b	Review of the condition of vegetation within Cloudbreak using the Trudgen (1991) vegetation condition scale.
Mattiske 2007	Mapping of vegetation communities near the Fortescue Marsh.

6. ENVIRONMENTAL IMPACT ASSESSMENT AND MANAGEMENT

6.1 Identification of Key and Relevant Factors

In preparing this referral document, Fortescue has applied the Environmental Assessment Guideline 9 (EAG9). EAG9 provides guidance for the application of a significance framework in the environmental impact assessment process. This approach allows the environmental assessment's focus to be on Key Environmental Factors which are those factors where the EPA's environmental management objectives may be met, but where there is a (current) lack of confidence, signifying the need for more information or conditions relating to implementation (EPA 2013a).

The identification of Key Environmental Factors for this Proposal has been undertaken on the basis of the extensive studies, surveys and environmental assessments undertaken to date in reference to Cloudbreak.

The following have been identified as Key Environmental Factors for this Proposal:

- Hydrogeological Processes – Groundwater
- Flora and Vegetation
- Terrestrial Fauna
- Conservation and Natural Heritage Areas.

Other relevant environmental factors that may be affected by the proposal, but where the environmental objectives will clearly be met are presented in Table 10. Objectives include heritage, inland water environmental quality, surface water, subterranean fauna, landforms and terrestrial environmental quality.

6.2 Identification of Environmental Management Objectives

Environmental Assessment Guideline 8 (EAG8) outlines the EPA's Environmental Management Objectives for each environmental factor. The Proponent of any Proposal is then required to demonstrate that these environmental management objectives can be met for each key and relevant factor. If these objectives are likely to be met, then it may be considered that the Proposal is not expected to have a significant impact on the environment (EPA 2013b).

6.3 Impact Assessment

An assessment of the potential impacts on the key and relevant environmental factors is presented in Table 9 and Table 10. Fortescue expects that with the implementation of the proposed management measures, the EPA environmental management objectives will be met for each environmental factor.

Table 9: Impact Assessment - Key Environmental Factors

Environmental Factor	EPA Management Objective (EPA 2013b)	Existing Environment	Impact Assessment	Management and Mitigation	Predicted Environmental Outcome
Hydrogeological Processes – Groundwater	To maintain the hydrological regimes of groundwater and surface water so that existing and potential uses, including ecosystem maintenance, are protected.	**Geology** The local geology is dominated by the Fortescue Group and the lower part of the Hamersley Group, the Marra Mamba Formation (MMF). The mineralisation of the Chichester Range is confined to the Nammuldi Member, the lowermost unit of the MMF, overlying the black shales of the Jeerinah Formation at the top of the Fortescue Group. Beneath the Fortescue Valley the MMF is conformably overlain by the Wittenoom Formation of the Hamersley Group. The MMF (and Wittenoom Formation where present beneath the Fortescue Valley) is unconformably overlain by younger Tertiary to Quaternary deposits. The Oakover Formation comprises a sequence of lacustrine carbonate, silcrete and mudstone rocks that have been deposited in the palaeodrainage of the Fortescue Valley. The Fortescue Valley is covered by a thick (up to 50 m) blanket of Tertiary colluvial scree slopes (close to the range) and flood plain alluvial sediments. **Conceptual Hydrogeological Model** Characterisation of the hydrogeology of Cloudbreak has been based on field investigations undertaken since 2005, including an extensive drilling and testing program and assessment of hydrological properties conducted during 2008/09. The field investigations resulted in development of a conceptual hydrogeological model of the Cloudbreak area intended to represent the understanding of the natural groundwater regime and to enable the potential effects of the Cloudbreak mine on that regime to be assessed (Fortescue 2010). More recent investigations and observations during the mining process have led to a greater understanding of the natural groundwater regime and subsequently a refinement of the hydrogeological model. Figure 3 shows the conceptual hydrogeology of the Cloudbreak Area. **Groundwater Recharge** Primary mechanisms for groundwater recharge are: - Infiltration recharge from direct rainfall and local stream flow on MMF outcrop and Tertiary detritals/alluvium - Infiltration recharge associated with ponding on the Fortescue Marsh - Inflow from aquifers within the Fortescue Group located to the north of the project area. Direct rainfall recharge to the Tertiary detritals/alluvium and MMF aquifers is considered to be low in the Cloudbreak area, reflecting the low rainfall and high evaporation of the region. Recharge is enhanced in creeks and areas of stream flow. Areas of outcrop and subcrop with drainage incisions can have direct connection between surface	**Potential Impacts** An increase in the abstraction and injection rates may potentially impact groundwater hydrological processes in the following ways: - Result in the lowering of the water table at locations (drawdown) and subsequent impacts to environmental factors such as groundwater dependent vegetation and Samphire vegetation. - Result in the raising of the water table at locations (mounding) and subsequent impact to environmental factors such vegetation that are intolerant to groundwater inundation. - Reduce the duration of surface water on the Fortescue Marsh and the presence of yintas. - Result in loss of water supply to station supply bores in the vicinity of Cloudbreak. **Model Predictions** A hydrogeological model has been used to predict groundwater levels should the Proposal be implemented. Predicted changes to groundwater depth (drawdown and mounding) for each year of the Proposal are shown in Figure 4 to Figure 14. The predicted levels account for the existing approved Project, recently approved changes as part of Fortescue's Section 45 C application under MS 899; and cumulative impacts from the Christmas Creek mine (including proposed expansion). The modelling report is provided in Appendix 1. **Impact Assessment** *Drawdown and Mounding* Abstraction and injection will result in localised changes in groundwater levels as shown in Figure 4 to Figure 14. Extreme changes of up to 50 m will occur within the mine site. Smaller changes (1-5 m) will extend over larger areas. The numerical modelling (Fortescue 2013a) has shown that maximum drawdown and mounding at monitoring bores may be up to 1.8 m, with consideration for climatic and parameter sensitivity. Although a 1.8 m change is predicted by modelling, the adaptive groundwater management scheme including the redistribution of water will ensure that groundwater levels within and at the fringe of the Marsh do not change by more than 1 m, as required by the existing condition 7 of MS 899. Therefore, while the extent of the changes (both in magnitude and spatially) will increase from that presented in the LOM PER, it is expected that drawdown and mounding at the groundwater monitoring sites can be managed within the limits approved in MS 899. *Surface Water at Fortescue Marsh and Yintas* Due to high evaporation rates in the Pilbara region, evaporation is the key process in removing surface water from Fortescue Marsh and yintas. The Fortescue Marsh is adapted to a highly variable rainfall regime in terms of magnitude and frequency and is not inundated on an annual basis. Given the natural variability of the system and the localised short term effect of drawdown on the edge of the marsh, no significant effect on the surface water regime at Fortescue Marsh or yintas is expected as a result of drawdown or mounding associated with the Proposal. *Station Bores* Five station bores are present within the Proposal area and may be affected by drawdown (depending on the rainfall scenario). As part of the existing Cloudbreak operations, Fortescue manages these potential impacts in consultation with station managers. Fortescue will continue this process and considers that any potential impacts on station bores are manageable.	**Department of Water Requirements** Fortescue manages abstracted groundwater in line with the Department of Water (DoW) hierarchy of water management methods as described in Table 3. Dewatering of groundwater is subject to a licence issued by the DoW under the RIWI Act that specifies the annual dewatering volume and includes conditions for monitoring. An application to amend the existing license will be submitted to the DoW separate to this referral. As part of the licensing process, an Operating Strategy detailing the monitoring and adaptive management of the dewatering program is required by DoW. **Cloudbreak Groundwater Operating Strategy** Fortescue will continue to manage groundwater in accordance to the established *Cloudbreak Groundwater Operating Strategy* (Appendix 2). This operating strategy has been prepared and implemented in accordance with Fortescue's current water licenses. Upon approval of an increase in abstraction and injection to 150 GL/a, this operating strategy will be updated to reflect the revised volumes. This groundwater operating strategy outlines the groundwater management scheme with the objective of: - Managing excess groundwater - Minimising potential environmental impacts - Conserving groundwater resources. The key component of the scheme is the disposal of abstracted water via injection into nearby aquifers in accordance with the *Operational Policy 1.01 Managed Aquifer Recharge in Western Australia* (DoW, 2011). Key management measures currently being implemented with respect to the management of groundwater quantities at Cloudbreak include: - Progressive dewatering only in active mining areas to minimise groundwater abstraction - Monitor groundwater levels during mining activities and post closure - Apply groundwater level trigger criteria and implement an appropriate management response should trigger levels be exceeded. The primary management response is the	Fortescue has successfully managed groundwater abstraction and injection at Cloudbreak to date. All groundwater related conditions specified in MS 899 have been met. While there are minor increases in groundwater drawdown and mounding as a result of the Proposal, the impacts are of a similar magnitude as the currently approved impacts. With the adaptive management strategy and existing controls the Proposal is not expected to result in any significant impacts to existing or potential users or to ecosystem maintenance. It is considered that the Proposal can be implemented with the same condition on drawdown and mounding as contained in MS 899 Condition 7; and that in doing so the EPA Management Objective for Hydrological Processes – Groundwater will be achieved.

Environmental Factor	EPA Management Objective (EPA 2013b)	Existing Environment	Impact Assessment	Management and Mitigation	Predicted Environmental Outcome
		water and underlying permeable lithologies. **Groundwater Discharge** Based on the evolution of groundwater within the upper Fortescue Valley the groundwater system beneath the Fortescue Marsh is considered a closed system with limited outflow to the west beneath the Goodardarie Hills. Discharge is therefore interpreted to only occur through evaporation and evapotranspiration processes beneath and fringing the Marsh. Discharge would be greatest when water levels are high, following recharge events and lowest after a prolonged dry period when the extinction zone for evaporation or evapotranspiration (from the water table) is reached. **Recent Groundwater Trends** Monitoring bore data, for all hydrostratigraphic units, display a general groundwater level recession between 2006 and 2010, related to below-average rainfall. The recession between 2006 and 2007 was approximately 1 m and approximately 0.5 to 1 m from 2007 to early 2010, within the Tertiary detrital/alluvium. The recession trend was punctuated by a rainfall event in early 2009 and subsequent groundwater recharge. Since 2010, a number of large rainfall events resulted in variable Tertiary detrital/alluvium water levels across Cloudbreak. Since 2010, Tertiary detrital/alluvium groundwater levels adjacent to the Fortescue Marsh have shown annually fluctuations of up to 2m. Predicted natural groundwater depths for each year of the Proposal are shown in Figure 4 to Figure 14.		modification of the water injection regime. The groundwater operating strategy details the monitoring program, trigger level system and the responses that are initiated when trigger level are exceeded. This includes a monthly 'near marsh' water level assessment to monitor potential changes to groundwater near Fortescue Marsh. No change to the existing monitoring program, trigger levels or management responses is proposed in this Proposal. **Cloudbreak and Christmas Creek Integration** In addition, the proposed integration of groundwater management between the Cloudbreak and Christmas Creek mines offers significant opportunities to address optimisation of water management at the Chichester operations to meet both operational and environmental objectives via operational planning and review. Note that this integration is the subject of a separate submission as detailed in Section 2.3, although it has been taken into account in the cumulative impact assessment under this Proposal.	
Flora and Vegetation	To maintain representation, diversity, viability and ecological function at the species, population and community level.	**Vegetation Mapping** Cloudbreak is located within the Fortescue Botanical District of the Eremaean Botanical Province (Beard 1975). The vegetation of this province is typically open, and frequently dominated by Spinifex, Wattles and occasionally Eucalypts. Vegetation in the Proposal area comprises a mosaic of low woodland with Mulga in valleys and hummock grasslands, low open tree steppe and Snappy Gum (*Eucalyptus luecophloia*) over Limestone Spinifex (*Triodia wiseana),* and Kanji (*Acacia pyrifolia*) over Soft Spinifex (*Triodia pungens*) and Limestone Spinifex grasslands. Mapping of the vegetation communities in and around Cloudbreak has been completed by Biota (2004), Mattiske (2005a, 2007) and ENV (2011). Thirty-five vegetation communities have been mapped in the Cloudbreak, Christmas Creek and surrounding areas. Of these, 21 have been identified in the Cloudbreak area. Appendix 3 details the vegetation communities within the Cloudbreak area. Figure 16 shows the vegetation mapping of the Cloudbreak area. **Vegetation Condition** The Proposal area includes the existing approved mine footprint which currently comprises cleared areas that have been developed for the mine pits and associated	**Potential Impacts** Potential impacts to vegetation and flora as a result of the Proposal include: - Impacts to the health of vegetation that is either groundwater dependent, vegetation impacted by groundwater drawdown or intolerant to waterlogging.. - Impacts to vegetation via the change in surface water flows - Impacts to vegetation health as a result of the change in groundwater quality. Note that no direct clearing of vegetation beyond that approved in MS 899 is proposed. No changes to the mine's operation that are likely to increase the potential for the introduction of introduced species are proposed. **Impact Assessment - Groundwater Drawdown and Mounding** Changes to groundwater levels may affect the health of vegetation that is either groundwater dependent, vegetation impacted by groundwater drawdown or intolerant to waterlogging. The groundwater modelling results presented above (Hydrogeological Processes – Groundwater) have been interpreted to identify areas where vegetation health may be impacted by drawdown or mounding. Three trigger levels for impact of mounding/drawdown to vegetation have been applied in this Proposal: *Drawdown Trigger Level* Any area outside of the approved mine footprint where: • Coolibah/Redgum vegetation exists,	Fortescue approach to the management of indirect impacts to vegetation as a result of abstraction and injection is based on responding to information provided through the implementation of a monitoring program and response plan. If monitoring indicates that unexpected and significant impacts are likely, Fortescue, in consultation with the regulatory agencies, will implement an appropriate contingency action. The *Vegetation Health Monitoring and Management Plan* prepared under conditions 6-2 and 6-3 of MS 899 details the procedures that are used to assess impacts to vegetation health and condition from changes in groundwater levels (from either drawdown or mounding) outside of the mine envelope. **Ground Disturbance Permit** A procedure of internal review and approval of all proposed vegetation clearing and ground disturbance activities is required prior to the commencement of works (a Ground Disturbance Permit). Under the permitting process areas of vegetation which may comprise high value may require ground-	An increased understanding of the local hydrogeology as well as potential impacts to important vegetation as a result of drawdown and mounding has been applied to this assessment. The assessment indicates that a lower impact to Coolibah / Redgum and Samphire vegetation is expected when compared to the conservative estimates presented in the LOM PER. The assessment indicated that a slightly higher impact to water

Environmental Factor	EPA Management Objective (EPA 2013b)	Existing Environment	Impact Assessment	Management and Mitigation	Predicted Environmental Outcome
		mine infrastructure. Several existing roads and pipelines associated with the mine also intersect vegetation in the area. The condition of the vegetation in the Proposal area ranges from Good to Excellent in condition as per Trudgen (1991) condition scale with the majority of the vegetation in the fringe of the Samphire Flats, Creek and Drainage line and Ranges, Hills and Hill slope vegetation type categorised as Excellent with the remaining type categories as Good as a result of grazing pressures (ENV 2011). **Threatened Ecological Communities** No vegetation communities in the Proposal area are representative of any Threatened Ecological Community (TEC) under the Commonwealth EPBC Act or by the DEC (2013). **Priority Ecological Communities** None of the identified vegetation communities within the Proposal area represent any Priority Ecological Communities (PEC) listed by the DEC (2013). The proposal is located near the Fortescue Marsh which has recently been classified as a Priority 1 PEC DEC (2009). The Fortescue Marsh PEC is characterised by the presence of endemic and new to science *Eremophila* and *Tecticornia* species occurring on the fringe of the Fortescue Marsh (ENV 2011). The Samphire (Tecticornia species.) vegetation communities 12, 13, 22, 25 and 26 (refer to Appendix 3) that are recorded within the Fortescue Marsh are part of the PEC and are also significant due to the presence of varying endemic and new to science species including Eremophila spongiocarpa (Priority 1). **Nationally Important Wetlands** The Fortescue Marsh is listed as a 'Nationally Important Wetland' in the Directory of Important Wetlands in Australia (Environment Australia 2001). **Surface Water Dependent Mulga** Mulga (Acacia aneura) is abundant in the low open woodlands and shrublands on Flats and Broad Plains within the Proposal area. Vegetation communities containing Mulga are a dominant vegetation type of semi-arid and arid Australia and occupy almost 20% of the Australian continent (Johnson and Burrows 1994). Despite this, the Mulga within the Proposal area is considered significant by the DEC as it: - is the northern extent of Mulga in Western Australia - is highly morphologically variable - appears to play an important role in water and nutrient capture and is important to ecosystem function - supports a range of Priority flora such as *Phyllanthus aridus, Eremophila youngii* subsp. *lepidota, Goodenia nuda*	• the natural groundwater is less than 5 m below the surface, and: • where drawdown of greater than 2 metres is expected to occur. These triggers are used to identify areas where the health of groundwater dependent vegetation (Coolibah/Redgum) may be affected by the Proposal. Any area outside of the approved mine footprint where: • Samphire exists, • groundwater is less than 5 m below the surface, and • drawdown of greater than 3 metres is expected to occur. These triggers are used to identify areas of potential impact to Samphire from the Proposal. *Mounding Trigger Level* Any area outside of the approved mine footprint where: • Mulga exists, and • groundwater levels are predicted to rise to within 2 m of the surface where not previously the case. This criterion is used as an impact trigger for water potentially entering the root zone of Mulga, which has a shallow root system and is sensitive to waterlogging. *Trigger Levels - Comparison with LOM PER* The Cloudbreak LOM PER presented a conservative approach to assessing the potential impacts on vegetation from drawdown. This reflected the application of the precautionary principle which was appropriate due to the lack of understanding of the potential effect drawdown may have on the vegetation types present in the area. The trigger levels presented above have been refined from those used in the LOM PER based on increased understanding of the aquifer, hydrological processes and how vegetation (particularly Samphire) is effected by groundwater drawdown. Simulations as part of a recent study entitled *Modelling Analysis of the Impact of Mine Dewatering on Soil Water Availability to the Samphire Vegetation on the Fringe of Fortescue Marsh* (Fortescue 2013c) showed that the root water uptake under repeated 3-year dry weather spells is little affected by up to 3 m groundwater drawdowns, and soil water content remains above the Samphire permanent wilting point at all times even under conditions of prolonged drought and with a 3 m groundwater drawdown. The overall findings of the study concluded that groundwater drawdown of up to 3 m would not introduce any significant adverse impacts on the Samphire communities near Fortescue Marsh (Fortescue 2013c). As such a 3 m drawdown has been applied as the trigger level for impacts to Samphire for this Proposal. Two trigger levels for drawdown have been applied to this Proposal to separate potential impacts to Samphire from potential impact to Coolibah / Redgum. While the study discussed above focusses on Samphire, a similar principle can be applied to Coolibah / Redgum. A 2 m drawdown trigger level (in areas where groundwater is less than 5 m from the surface) has been applied as this represents the natural variation of groundwater levels experienced by this vegetation type at Cloudbreak. *Predicted Impacts* Figure 4 to Figure 14 show the predicted impact to vegetation health (Coolibah / Red Gum, Samphire and Mulga) for each year of the Proposal in average climatic conditions. <u>Samphire</u> – The Cloudbreak LOM PER predicted that a total of 767 ha of Samphire may be affected by drawdown at some stage during the life of the mine, with a total of 13 ha being affected by drawdown for two or more consecutive years. It is considered that Samphire is resistant to short term drawdown impacts (less than two consecutive years). A total of 4 ha would be removed via direct clearing. Based on the revised trigger levels and updated hydrogeological model (see above), no indirect impacts to Samphire are expected as a result of drawdown. No additional clearing will occur as a result of the Proposal.	truthing surveys to assess its value.	logging intolerant vegetation (Mulga) is expected as a result of the Proposal. Given the large representation of Mulga in the region, this small (5%) increase in total impacts is not expected to significantly impact the representation, diversity, viability and ecological function of the Mulga in the region. No vegetation communities are expected to be impacted to an extent where they are reduced to below 30% of their pre-clearing extent. No impacts to DRF are predicted. As such it is expected that the EPA Management Objective for Vegetation and Flora will be achieved.

Environmental Factor	EPA Management Objective (EPA 2013b)	Existing Environment	Impact Assessment	Management and Mitigation	Predicted Environmental Outcome

- is highly susceptible to disturbance from fire, grazing and the development of infrastructure.

Mulga is considered to be generally shallow-rooted (likely less than 2 m depth) and to utilise water from shallow surface soils (Ecoscape 2009). Currently it is generally accepted that groved Mulga communities have a strong reliance on sheet flow to replenish soil water in the groves (ENV 2011).

Groundwater-Dependent Vegetation

Open woodlands of *Eucalyptus camaldulensis* (River Red Gum) and *Eucalyptus victrix* (Coolibah) occur on the creek lines that occur in the Proposal area. River Red Gum and Coolibah are considered to have a partial dependence on groundwater (partially phreatophytic) to meet their physiological moisture requirements through the use of deep, aggressive root systems (Fisher et al 2004).

Both River Red Gum and Coolibah grow in areas subject to highly varying groundwater levels, which may vary by more than 10 m due to rainfall conditions (Ecoscape 2009).

Flora

A total of 230 taxa from 47 families and 159 genera have been previously recorded during surveys of the Cloudbreak area (Biota 2004, Mattiske 2005a and 2007, ENV 2011). The plant families most frequently recorded from the surveys were *Fabaceae* (82 taxa), *Poaceae* (68 taxa) and *Malvaceae* (42 taxa). The most frequently recorded genera were *Acacia* (44 taxa), *Ptilotus* (14 taxa) and *Senna* and *Sida* (13 taxa).

Flora of Conservation Significance

No Threatened species pursuant to the EPBC Act have been identified within the Proposal area.

No plant taxa gazetted as Declared Rate Fauna (DRF) pursuant to the WC Act have been identified within the Cloudbreak area (Biota 2004, Mattiske 2005a, 2007, ENV 2011).

Seven priority flora have been recorded within the Cloudbreak area (Biota 2004, Mattiske 2005a, 2007, ENV 2011). An additional 11 species listed as Priority Flora have not been recorded within the Proposal area, but may occur in the vicinity of the Proposal area. This list is based on the DEC database search (DEC 2010) and recent survey results from the adjoining survey area of Christmas Creek and Fortescue Marsh. Appendix 4 details the priority flora and their conservation significance.

Introduced Species

Four introduced species were recorded by Mattiske (2007); **Aerva jananica*, **Cenchrus ciliaris*, **Chloris barbata* and **Malvastrum americanum*, none of which is listed as a Declared Plant.

Coolibah/Redgum - The Cloudbreak LOM PER predicted that no indirect impacts to Coolibah / Redgum would occur while 473 ha would be directly cleared. This Proposal is not expected to result in any indirect impacts to Coolibah / Red gum and does not require any additional clearing.

Mulga - The Cloudbreak LOM PER predicted that a total of 380 ha of Mulga would be affected by mounding at some stage during the life of the mine. A further 10 500 ha would be directly cleared. This Proposal is predicted to increase the area of Mulga that would be affected by mounding at some stage during the life of the mine to 922 ha. No additional clearing will be required. This corresponds to a 5% increase in total (direct and indirect) predicted impacts to Mulga as a result of the Proposal.

Vegetation Type	Mulga (ha)	Samphire (ha)	Coolibah / Redgum (ha)
Predicted area of direct impact – LOM PER	10 500	4	473
Predicted area of in-direct impact – LOM PER	380	13	0
Total Predicted Impact (LOM PER)	10 880	17	473
Predicted area of direct impact – this proposal	0	0	0
Change in area of indirect impact – this proposal compared to LOM PER	+ 542	-4	0
Change in area of total impact – this proposal compared to LOM PER	+ 542	0	0
Revised total impact Cloudbreak Mine	11 422	13	473
Percent change in impact (this Proposal vs LOM PER)	5.0 %	-24 %	0 %

It is not expected that these predicted disturbances will have any significant impact on the representation, diversity, viability and ecological function of these vegetation types at the species, population and community levels.

Impacts to vegetation (when combined with existing approval) will not compromise any vegetation association by taking it below the “threshold level” of 30% of its pre-clearing extent.

No impacts to threatened flora species or DRF are predicted.

Impact Assessment – Other Factors

Alternations to Surface Water Flow

Alterations to surface water flows are addressed above. There is not expected to be any significant change to surface water flows and as such no impact to flora or vegetation is predicted as a result of the Proposal.

Change to Water Quality

Potential changes to ground and surface water quality are address in Table 10. There is not expected to be any impact on vegetation and flora from change in water quality as a result of the proposal.

<table>
<tr>
<th>Environmental Factor</th>
<th>EPA Management Objective (EPA 2013b)</th>
<th>Existing Environment</th>
<th>Impact Assessment</th>
<th>Management and Mitigation</th>
<th>Predicted Environmental Outcome</th>
</tr>
<tr>
<td>Terrestrial Fauna</td>
<td>To maintain representation, diversity, viability and ecological function at the species, population and assemblage level.</td>
<td>
Ecologia (2010a) undertook a desktop review to consolidate all existing fauna surveys and studies undertaken within the Proposal area. The following description of the fauna habitat and fauna species present in the Proposal area is adapted from Ecologia (2010a) unless otherwise stated.

Fauna Habitat

Six broad habitat types exist in the Proposal area:
- Low halophytic shrubland
- Hummock grassland on fringe of Fortescue Marsh
- Low Mulga, Snakewood and Acacia woodland
- Spinifex covered hills and ranges
- Creek lines and wells with Acacia shrubland and/or Eucalypt woodland
- Rocky escarpments.

The halophytic shrubland occurs within the boundary of the Fortescue Marsh, with areas of hummock grassland on the edge of the marsh, moving into low Mulga woodland on alluvial flats, followed by the Spinifex covered hills and ranges. Creek and drainage lines supporting either Acacia shrubland or eucalypt woodland, run north-south into the Fortescue Marsh.

Minga Well is a permanent water source and is likely to be important to local animals, especially during the dry season and times of drought. A total of eight species of conservation significance have been observed at Minga Well, including the Night Parrot which was observed drinking at Minga Well during a period of drought (Bamford 2006). Minga Well is over 2.5 km from the closest mine pit and over 3km from the Fortescue Marsh. It is not expected to be impacted on by the Proposal. It should be noted that extensive annual surveys for Night Parrot have not resulted in any further sightings of Night Parrot in the Proposal area.

The presence of the Night Parrot at Minga Well has been assessed in the Cloudbreak LOM PER and approved under MS 899 and EPBC2010/5696.

Terrestrial Fauna

Counts of the number of fauna species that may be present at the site and the numbers that have been recorded are presented below.

<table>
<tr><th>Fauna Group</th><th>No. Species that may potentially occur in Proposal Area.</th><th>No. of Species recorded in Proposal Area</th></tr>
<tr><td>Mammal (native)</td><td>33</td><td>21</td></tr>
<tr><td>Mammal (introduced)</td><td>9</td><td>8</td></tr>
<tr><td>Avifauna</td><td>165</td><td>138</td></tr>
<tr><td>Herpetofauna</td><td>100</td><td>35</td></tr>
<tr><td>Total</td><td>307</td><td>202</td></tr>
</table>
</td>
<td>
Potential Impacts

Potential impacts to fauna as a result of the Proposal include:
- Impacts from the loss of habitat (either direct or indirect loss)
- Fauna entrapment
- Fauna death or mortality via interaction with site vehicles.

Impact Assessment

The revised impacts to fauna habitat types are presented in the table below.

<table>
<tr><th>Vegetation Type</th><th>Low halophytic shrubland (samphire)</th><th>Hummock grassland (spinifex)</th><th>Mulga and other Acacia woodland</th><th>Spinifex covered hills and ranges</th><th>Creeklines with shrubland and/or eucalypt open woodland</th><th>Rocky escarpments</th></tr>
<tr><td>Predicted area of direct impact – LOM PER</td><td>1</td><td>2</td><td>5,695</td><td>985</td><td>683</td><td>0</td></tr>
<tr><td>Predicted area of in-direct impact – LOM PER</td><td>763</td><td>5.5</td><td>744</td><td>4.4</td><td>115.5</td><td>0</td></tr>
<tr><td>Total Predicted Impact (LOM PER)</td><td>764</td><td>7.5</td><td>6439</td><td>989.4</td><td>798.5</td><td>0</td></tr>
<tr><td>Predicted area of direct impact – this proposal</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Change in area of indirect impact – this proposal compared to LOM PER</td><td>5.5</td><td>2.5</td><td>922*</td><td>0</td><td>4</td><td>0</td></tr>
<tr><td>Change in area of total impact – this proposal compared to LOM PER</td><td>-757.5</td><td>-3</td><td>178</td><td>-4.4</td><td>-111.5</td><td>0</td></tr>
<tr><td>Revised total impact Cloudbreak Mine</td><td>6.5</td><td>4.5</td><td>6617</td><td>985</td><td>687</td><td>0</td></tr>
<tr><td>Percent change in impact (this Proposal vs LOM PER)</td><td>-99%</td><td>-40%</td><td>2.8%</td><td>-0.4%</td><td>-14%</td><td>0.0</td></tr>
</table>
</td>
<td>
Refer to Vegetation and Flora section of this table for management of drawdown and mounding impacts.

Refer to Vegetation and Flora section of this table for management of ground disturbances.

The following species specific management plans will continue to be implemented at Cloudbreak:
- Night Parrot (Pezoporus occidentalis) Management Plan
- Bilby (Macrotis lagotis) Management Plan
</td>
<td>
Night Parrot (Schedule 1)

The habitat of the Night Parrot consists of Triodia grasslands in stony or sandy environments and of Samphire and chenopod shrublands on floodplains and clay pans, and on the margins of salt lakes, creeks or other sources of water (SEWPAC 2010b). No additional areas of disturbance within the Triodia grasslands have been identified as a result of the proposal and as such no impacts to this species are expected.

Northern Quoll (Schedule 1)

The rocky habitat preferred by the Northern Quoll will not be affected by the Proposal and as such no impacts to this species are expected.

Greater Bilby (Schedule 1)

The spinifex dominated vegetation types preferred by the Greater Bilby will not be affected by the Proposal and as such no impacts to this species are expected.

Pilbara Leaf-nosed Bat (Schedule 1)

The species roosts in caves with high humidity and temperature. No
</td>
</tr>
</table>

Environmental Factor	EPA Management Objective (EPA 2013b)	Existing Environment	Impact Assessment	Management and Mitigation	Predicted Environmental Outcome
		The highest number of mammal species and individuals occur where dense *Triodia* hummocks are present as these hummocks offer excellent habitat for small mammals. The most common mammal trapped during the Bamford (2005a) survey was the Desert Mouse (*Pseudomys desertor)*. A relatively large number of Little Red Kalutas (*Dasykaluta rosamondae*) and Pilbara Ningaui (*Ningaui timealeyi*) were captured during the Ecologia (2011a) survey while Red Kangaroos (*Macropus rufus*) are present in low densities throughout the site. Two micro-bat species were captured in mist-nets, seven species of bat were identified through recordings of echolocation calls and a single bat species was observed during spotlighting activities during the Bamford (2005a) survey. Bird abundances are generally low, most likely reflecting the dry conditions experienced during the main survey periods (Bamford 2005a, Ecologia 2011a). Bird life was notably concentrated around sources of permanent water such as Minga, Qwirriawirrie and Moojarri Wells. These sources of permanent water harboured significant numbers of Cockatiels, Crested Pigeons, Common Bronzewings and Bourke's Parrots. Creek-line habitats also tended to provide attractive habitat for a range of bird species (Bamford 2005a). Ecologia (2011a) recorded 47 species of Herpetofauna in the survey area. Several families of reptiles were recorded consisting of Plate-shelled Tortoise (*Cheluidae)*, dragon lizards (*Agamidae*), geckoes (*Gekkonidae*), legless lizards (*Pygopodidae*), skink lizards (*Scincidae*), goanna or monitor lizards (*Varanidae*), elapid snakes (*Elapidae*), blind snakes (*Typhlopidae)* and pythons (*Boidae*). The Bamford surveys recorded four amphibian species within the survey area, with most belonging to the *Hylidae* (tree frogs) family. **Introduced Species** Previous surveys of the Cloudbreak area recorded seven introduced species, including house mouse (*Mus musculus),* feral cat (*Felis catus*), dog/dingo (*Canis lupus*), European rabbit (*Oryctolagus cuniculus*), donkey (*Equus asinus*), horse (*Equus coballus*), cow (*Bos Taurus*) and camel (Camelus dromedaries) (camel). **Fauna of Conservation Significance** A summary of the potential presence of conservation significant species is provided in Appendix 5.	* Note: 17 ha of the 922 ha of indirect impact in Mulga and other Acacia Woodland habitat are outside and to the west of the Project Area. The predicted areas of direct and indirect impact are located in the Mulga and other Acacia Woodland habitat (6617 ha) followed by the Spinifex Covered Hills and Ranges (985 ha). *Loss of Habitat – Clearing* No additional direct impact (clearing) beyond that approved in MS 899 and EPBC 2010/5696 is proposed. All clearing will be undertaken under existing approvals and in line with existing operational procedures. No additional impacts to fauna as a result of vegetation clearing are expected as a result of the Proposal. *Loss of Habitat – Indirect* A total of 98.7% of all expected indirect impact is within the Mulga and other Acacia Woodland habitat (922 ha). While there is predicted to be some degradation in the health Mulga and other Acacia Woodland habitat, the impact is expected to be minimal and localised. An additional 178 ha of Mulga and other Acacia Woodland habitat may potentially be affected as a result of the increase in abstraction and injection quantities. This represents a 22% increase in the indirect impact to Mulga and other Acacia Woodland habitat approved in MS 899 and EPBC 2010/5696 but only a 2.8% increase in total (direct and indirect) disturbance for Mulga and other Acacia Woodland habitat. The percent of expected indirect impact to Low Halophytic Shrubland (samphire) habitat and Creeklines with Shrubland and/or Eucalypt Open Woodland habitat are significantly lower than presented in the LOM PER. Figure 17 shows the predicted indirect impacts to the fauna habitat types. *Habitat fragmentation* Clearing of vegetation has the potential to result in fragmentation of habitats and lead to the inability of individuals to move between areas of habitat, as well as increase predation events as individuals move across cleared areas. Clearing within the mine footprint has the potential to create a barrier for some species that typically move north-south through this area to access the food, water and habitat resources of the Fortescue Marsh. A 2.8% increase in the disturbance of Mulga and Acacia Woodland habitat is considered a minimal increase and any additional fragmentation of habitat will be minimised through progressive rehabilitation. The percent of expected indirect impact to Low Halophytic Shrubland (samphire) habitat and Creeklines with Shrubland and/or Eucalypt Open Woodland habitat are significantly lower than presented in the LOM PER, as such the impacts to habitat fragmentation are significantly lower than originally proposed. There is not expected to be any significant increase in impacts to Fortescue Marsh, yintas or creek lines as a result of the Proposal. Given the lack of predicted impacts and the large regional representation of the key vegetation types, there is not predicted to be any significant impact to terrestrial fauna as a result of indirect impacts to fauna habitat as a result of the Proposal. *Fauna Entrapment* The ponds associated with the dewatering and injection infrastructure may attract fauna in times of drought. This could result in fauna becoming trapped and/or drowning within the ponds. There is also potential of fauna entrapment and/or drowning in the trenches associated with pipeline		roosting habitat will be affected by the Proposal and as such no impact to this species is expected to occur as a result of the Proposal. *Pilbara Olive Python (Schedule 1)* The rocky habitat preferred by the Pilbara Olive Python will not be affected by the Proposal and as such no impacts to this species are expected. *Migratory Birds and other Specially Protected Fauna (Schedule 3 and 4)* A variety of migratory birds may utilise the Proposal area (Appendix 4), particularly the Fortescue Marsh and creek lines. Changes to the water table level as a result of the Proposal have the potential to effect vegetation in the vicinity of Fortescue Marsh with subsequent potential indirect impact to migratory birds. However as impacts to these vegetation types are expected to be minimal and they are well represented in the region, no significant impacts to migratory birds are expected as a result of the

Environmental Factor	EPA Management Objective (EPA 2013b)	Existing Environment	Impact Assessment	Management and Mitigation	Predicted Environmental Outcome
		Threatened Species Six fauna species that are listed under Schedule 1[1] under the *Wildlife Conservation* Act 1950 (WC Act) may potentially be present in the Proposal area: - Night Parrot (*Pezoporus occidentalis*) - Northern Quoll (*Dasyurus hallucatus*) - Greater Bilby (*Macrotis lagotis*) - Orange Leaf-nosed Bat (*Rhinonicteris aurantius*) - Pilbara Olive Python (*Liasis olivaceus barroni*) *Other Listed Fauna* Other fauna listed under the WC Act that may potentially be present include: - Seven Schedule 3[2] species - One Schedule 4[3] species - Two Priority 1[4] species - One Priority 2[5] species - One Priority 3[6] species - Eight Priority 4[7] species. **Matters of National Environmental Significance** Twelve fauna species listed as MNES under the EPBC Act may potentially be present in the Proposal area. Of these two are considered endangered (Night Parrot (*Pezoporus occidentalis*) and Northern Quoll (*Dasyurus hallucatus*). Four species are listed as vulnerable and six are listed as migratory species. A full list of EPBC listed fauna that may be present at the site is included in Appendix 5.	installation. There is not expected to be a significant increase in the number or size of ponds associated with dewatering or the length of trenching required as part of the Proposal. Potential entrapment of fauna can be managed via established procedures. There is not expected to be any significant impact to fauna as a result of entrapment. *Vehicle Movements during Construction and Operations* The Proposal is not expected to lead to any increase in the number, type or timing of vehicle movements and as such, is not expected to result in any additional risk of fauna injury or mortality due to vehicle movements. **Priority Species** Appendix 4 details the priority species that may occur within the Proposal area. As no significant impacts are expected to occur to fauna habitat or important vegetation communities, no significant impacts to any Priority species is expected to occur as a result of the Proposal. **Matters of National Environmental Significance** Potential impacts to MNES are addressed in Section 7.		Proposal. As such, it is expected that the EPA Management Objective for terrestrial fauna will be achieved.
Conservation and Natural Heritage Areas	To protect the environmental values of areas identified as having significant environmental attributes. To maintain the integrity, functions and environmental values (of the Fortescue Marsh).	The Fortescue Marsh has been identified as a 'Nationally Important Wetland' and is listed as an 'indicative place' on the Register of the National Estate due to its importance as a habitat for migratory birds. Previous studies and the protected matter search undertaken on 14 October 2013 identified no wetlands listed under the RAMSAR Convention located in the vicinity of the Proposal area. Fortescue Marsh is the key area of conservation significance in the vicinity of the Proposal and supports a number of significant flora and fauna species. The Fortescue Marsh has been classified as a Priority 1 PEC. The Department of Parks and Wildlife (DPW) is proposing that portions of the Mulga Downs, Hillside, Marillana and Roy Hill stations associated with the Fortescue Marsh be excluded from the renewal of pastoral leases in 2015 and	**Potential Impacts** Potential impacts to conservation and natural heritage areas as a result of the Proposal include: - Impacts to Fortescue Marsh via mounding or drawdown as a result of groundwater abstraction and injection. - Impacts to Fortescue Marsh as a result of contingency surface releases of abstracted groundwater - Impact to Fortescue Marsh as a result of changes in ground or surface water quality. **Impact Assessment** *Drawdown and Mounding Impacts on Fortescue Marsh* MS 899 specifies conditions with respect to acceptable drawdown and mounding (maximum 1 m) on the fringes of Fortescue Marsh. Fortescue monitors compliance with this condition via a series of monitoring bores located on the fringe of the Marsh. The numerical modelling has shown that maximum drawdown and mounding at monitoring bores may be up to 1.8m (Figure 4 to Figure 14) , with consideration for climatic and parameter sensitivity. However, the existing water management scheme and optimisation of injection is believed to be sufficiently robust such the current conditions within MS 899 (1 m variation) are achievable under	Refer to the Hydrological Processes - Groundwater section of this table for management of drawdown and mounding impacts. Refer to Vegetation and Flora section of this table for management of ground disturbances. **Fortescue Marsh Management Plan** The *Fortescue Marsh Hydrology and Vegetation Monitoring and Management Plan* is required to meet Condition 7 of EPBC 2010/5696. This plan outlines existing information available on the Fortescue Marshes and aims to identify assess and minimise potential environmental impacts of the life of mine operations on the Fortescue Marsh.	No additional impacts to Fortescue Marsh are expected to occur as a result of the Proposal. As such it is expected that the EPA's Objective for Conservation and Natural Heritage area will be achieved.

[1] Species that are rare or likely to become extinct.
[2] Birds protected under international agreements
[3] Other specially protected fauna
[4] Taxa with few, poorly known populations on threatened lands
[5] Taxa with few, poorly known populations, some of which occur on conservation lands
[6] Taxa with several, poorly known populations, some of which occur on conservation lands
[7] Taxa in need of monitoring

Environmental Factor	EPA Management Objective (EPA 2013b)	Existing Environment	Impact Assessment	Management and Mitigation	Predicted Environmental Outcome
		be added to the conservation estate (or managed by conservation agreement).	the increased abstraction scenario. As such, it is expected that the Proposal will comply with the conditions specified in MS 899 and that no additional impacts to Fortescue Marsh will occur as a result of drawdown or mounding associated with the Proposal. As can be seen from Figure 4 to Figure 14, it is not predicted to be any significant impacts to vegetation with Fortescue Marsh as a result of the Proposal. *Surface Water Releases* As detailed above (Hydrological Processes – Groundwater), there is not proposed to be any change to the contingency surface water release regime that is currently in place for Cloudbreak. As such there is not expected to be any additional impacts to Fortescue Marsh as a result of contingency surface release of water. *Groundwater and Surface Water Quality* As detailed in Table 10 (Inland Waters Environmental Quality) there is not expected to be any significant change to ground or surface water quality as a result of the Proposal.		

Table 10: Impact Assessment - Relevant Environmental Factors

Environmental Factor	EPA Management Objective (EPA 2013b)	Existing Environment	Impact Assessment	Management and Mitigation	Predicted Environmental Outcome
Heritage	To ensure that historical and cultural associations are not adversely affected.	The Proposal area is located within two areas subject to native title claims (Nyiyaparli and Palyku claimant groups). Approximately 1573 heritage sites are located within the Chichester Project area (Cloudbreak and Christmas Creek), including 567 salvaged sites. These sites comprise artefact, manmade structures, mythological, repository, ceremonial, grinding patch, midden, skeletal material / burial, engraving, historical, scarred tree and quarry sites. Artefact scatters account for over 80% of the identified sites within the Chichester Project area. The Fortescue Marsh has some semi-permanent water pools or "yintas" along the northern shoreline which have been identified as having cultural significance. Two yintas have part of their catchments within the Proposal area being Yinta 1 which receives flow from Gorman Creek and Yinta 2 (Figure 15).	**Potential Impacts** Potential impacts to heritage include: - Physical disturbance of heritage sites - Impacts to heritage sites as a result of alteration to surface water flow. **Impact Assessment** *Physical Disturbance* Physical disturbance of the land surface during the construction of groundwater management infrastructure was considered in the Cloudbreak LOM PER which concluded that with the proposed management and mitigation measures; impacts would be limited to the extent permitted under the *Aboriginal Heritage* Act 1972 Section 19 – consent to disturb. No additional ground disturbance beyond that approved in MS 899 is proposed. *Alteration of Surface Water Flow* Surface water discharge of dewatered groundwater may occur as a contingency if injection infrastructure fails. This may result in alterations to surface flows, which has potential to result in erosion of Aboriginal heritage sites and impacts to yinta. Contingency surface water discharge was considered in the Cloudbreak LOM PER which concluded impacts would be limited to the extent permitted under the *Aboriginal Heritage Act 1972* Section 19 – consent to disturb. The Proposal will not increase the frequency or volume of these contingency releases. Therefore there is not expected to be any significant impact above that presented in the Cloudbreak LOM PER.	**Cultural Heritage Management** The existing Cultural Heritage Management Plan (CHMP) will continue to be implemented. This plan provides for Aboriginal monitors to oversee construction activities within the relevant native title claims. The existing Aboriginal sites register will continue to be used to provide description, location and condition of heritage sites within Cloudbreak. **Management of Surface Water Release** Disposal of water via surface will only occur during emergencies and when maintenance is required. All surface discharges will be undertaken in accordance with the *Dewatering Discharge Contingency Procedure* (Fortescue 2009).	Impacts to heritage are expected to be minimal and with the scope of the approval granted in MS 899. Impacts will be limited to impacts on Aboriginal heritage sites to the extent permitted under the *Aboriginal Heritage Act 1972* Section 19 – Consent to Disturb. It is expected that the EPA Environmental Management Objective will be achieved.
Inland Waters Environmental Quality	To maintain the quality of groundwater and surface water, sediment and biota so that the environmental values, both ecological and social, are protected.	**Groundwater Quality** Cloudbreak groundwater chemistry data shows groundwater in the resource area is generally brackish and becomes increasingly saline towards the Fortescue Marsh and with depth (Fortescue 2013). Groundwater in the Cloudbreak region ranges from marginally brackish (>500 mg/L Total Dissolved Solids [TDS]) in recharge areas to hypersaline in areas closer to the Fortescue Marsh and in fractured rock zones below the Marra Mamba Formation (>100 000 mg/L TDS) (Fortescue 2010a). **Surface Water Quality** Surface water runoff to the Fortescue Marsh is typically of low salinity and high turbidity. However during flooding events, salts deposited from previous drying events are redissolved; and the water entering the marsh becomes moderately saline (Fortescue 2009).	**Potential Impacts** Potential impacts to Inland Waters Environmental Quality include: - Changes to groundwater salinity due to abstraction and injection of groundwater - Impacts to surface water quality through contingency surface release - Acidification of Potential Acid Sulphate Soil due to drawdown in marsh areas. - Potential oxidisation of Potential Acid Sulphate Soils potentially resulting in acid mine drainage. **Impact Assessment** *Changes to Groundwater Salinity due to abstraction and injection of groundwater* Abstraction of groundwater result in depletion of the brackish water resource and migration of saline water from aquifers beneath the Fortescue Marsh and deeper aquifer zones beneath the pits to the dewatering area. Impacts to groundwater salinity due to saline injection are expected to be minimal as the receiving aquifer is saline and confined. Impacts to groundwater salinity due to brackish injection are expected to be minimal; the injected water is abstracted from the same aquifer and has similar water quality.	Potential impacts to inland waters environmental quality will be managed via: - *Cloudbreak Groundwater Operating Strategy* - *Dewatering Discharge Contingency Procedure* - *Acid and/or Metalliferous Drainage Plan* required by Condition 12-3 of MS 899. Further details on these plans are included in Table 9.	It is expected that the EPA's Management Objective for Inland Waters Environmental Quality will be achieved.

Environmental Factor	EPA Management Objective (EPA 2013b)	Existing Environment	Impact Assessment	Management and Mitigation	Predicted Environmental Outcome
			Surface Water Quality Contingency surface water discharge was considered in the Cloudbreak LOM PER which concluded impacts could be managed by limiting discharge to up to 35 ML/day of fresh or brackish water for periods of up to 21 days under limited circumstance (Fortescue 2009). No change to this regime is proposed and as such no additional impact to surface water quality is expected. *Acidification in Marsh Areas* Acidification of any potential Acid Sulphate Soils (ASS) may occur in marsh areas if drawdown occurs during dry climate periods. The potential for acidification will be prevented through the manipulation of the injection regime to maintain water levels. No significant impact to water quality is expected to occur through this process. *Acid Mine Drainage* Acid mine drainage is not expected to occur as dewatering will not target the Roy Hill Shale member below the ore body and generally the dewatering cone of depression will not extend into the Roy Hill Shale.		
Hydrological Process – Surface Water	To maintain the hydrological regimes of groundwater and surface water so that existing and potential uses, including ecosystem maintenance, are protected.	Figure 15 shows the surface water features of the Proposal area. **Surface Water Flow** Surface water flow in and around Cloudbreak takes several different forms depending on the characteristics (e.g. slope) of the area. The two most important forms with respect to the local environment are channel flow and sheet flow. Rainfall from the Chichester Range flows through the Proposal area in a southerly direction towards the Fortescue Marsh. Runoff tends to form overland flow paths without defined water courses. Water courses and sheet flow areas frequently support scrub and Mulga woodlands, particularly in the low lying areas. **Fortescue Marsh** The Fortescue Marsh forms an extensive intermittent wetland (located on the floor of the Fortescue Valley) occupying an area around 100 km long by typically 10 km wide. The Fortescue Marsh has an elevation of around 400 m AHD. To the north, the Chichester Plateau rises to over 500 m AHD, whereas to the south the Hamersley Range rises to over 1,000 m AHD. Following significant rainfall events, runoff from the upper Fortescue River catchment (approximately 31,000 km^2) drains to the Fortescue Marsh. For the smaller runoff events, isolated pools form on the Marshes at the main drainage inlets, whereas for the larger events the whole marsh area may flood. On the southern and northern flanks of the Fortescue Valley, numerous creeks discharge to the Fortescue Marsh. Rainfall runoff from the valley sides initially drains down gradient as overland flow before concentrating in defined flow channels. In this process, surface detention, vegetation, infiltration and other mechanisms absorb water from the runoff stream. In steep areas, the runoff processes are rapid with relatively low losses, and defined drainage channels are typically in close proximity. In the lower slope areas, the runoff processes are slow with relatively higher losses and greater distances between defined drainage channels.	**Potential Impacts** Potential impacts to surface water hydrological processes as a result of the Proposal include: - Changes to flow regimes including ponding or sheetflow shadowing through the physical presence of infrastructure - Alterations to surface flows through water courses and into Fortescue Marsh and yintas from the contingency surface release of abstracted groundwater - Surface water expressing due to mounding. **Impact Assessment** *Physical Presence of Infrastructure* The physical presence of infrastructure such as pipelines may cause disruptions to channel and sheet flow surface water regimes through the diversion, ponding or capture of surface flows. No additional infrastructure beyond that presented in the Cloudbreak LOM PER (and approved under MS 899) is proposed in this Proposal. All pipelines associated with groundwater abstraction and injection are either buried; or raised at channel crossings and at regular intervals in sheet flow areas. As such, no significant impacts to surface water flows are expected to occur as a result of this Proposal. *Surface Water Discharge – Water Quantity* Surface water discharge of dewatered groundwater may occur as a contingency if injection infrastructure fails. This may result in alterations to surface flows through courses and into Fortescue Marsh and yintas. If uncontrolled, this process could lead to the creation of new flow paths and erosion. Contingency surface water discharge was considered in the Cloudbreak LOM PER which concluded impacts could be managed by limiting discharge to up to 35 ML/day of fresh or brackish water for periods of up to 21 days under limited circumstance (Fortescue 2009). No change to these discharge limits is proposed in the Proposal and therefore there is not expected to be any significant impact above that presented in the Cloudbreak LOM PER.	**Dewatering Discharge Contingency Procedure** If required, controlled surface release of abstracted groundwater will be undertaking in accordance with the *Dewatering Discharge Contingency Procedure* (Fortescue 2009) which outlines discharge quantity and quality as well as duration limits, discharge points and water quality monitoring requirements. In line with the *Dewatering Discharge Contingency Procedure* discharge of water will only occur at designated creek line discharge points. This procedure includes provisions for limiting discharge to up to 35 ML/day of fresh or brackish water for periods of up to 21 days under limited circumstance. No change to this regime is proposed in this Proposal. The *Dewatering Discharge Contingency Procedure* (Fortescue 2009) was presented in the Cloudbreak LOM PER and therefore approved under MS 899.	With the application of the *Dewatering Discharge Contingency Procedure* (including discharge limits), it is not expected that any direct or indirect impacts will occur as a result of change to surface water regimes as a result of the Proposal. As such it is expected that the EPA's management objective for hydrological processes – surface water will be achieved.

Environmental Factor	EPA Management Objective (EPA 2013b)	Existing Environment	Impact Assessment	Management and Mitigation	Predicted Environmental Outcome
		Yinta The Fortescue Marsh and some semi-permanent water pools or "yintas" along the northern shoreline have been identified as having cultural significance. The yintas are located at low points in the marsh topography and are thought to be associated with seasonal surface water flows. Each of the yintas is associated with large catchments draining the Chichester Ranges. There are two yintas that have part of their catchments within the Proposal area, Yinta 1, which receives flow from Gorman Creek, and Yinta 2 (Figure 15).	*Surface Water Expression* If the quantity of water being injected into an aquifer is greater than the capacity of the aquifer, the ground will become water logged and new surface waters may be created. By comparing predicted natural groundwater levels and predicted mounding caused by injection potential ground water expression can be identified. As can be seen in Figure 4 to Figure 14, no surface water expression is expected as a result of the Proposal.		
Subterranean Fauna	To maintain representation, diversity, viability and ecological function at the species, population and assemblage level.	**Stygofauna** Stygofauna are any fauna that live in groundwater systems or aquifers. Results from sampling indicate a moderately rich stygofauna community of 21 species belonging to eight higher order taxonomic groups occurring in the Proposal area. Only two species appear to be restricted to the vicinity of the Proposal area; the *copepods Parapseudoleptomesochra sp. and Goniocyclops sp*. (Bennelongia 2011). **Troglofauna** There has been no sampling of troglofauna in the vicinity of the Proposal area. However, two species, the isopods Philosciidae sp. and Troglarmadillo sp., have been collected just south the maximum mine disturbance area as by-catch during stygofauna sampling. The occurrence of troglofauna elsewhere in the Chichester Range, the collection of some troglofauna around the Proposal area while stygofauna sampling, and the presence of prospective lithologies at Cloudbreak Mine suggest that a modest troglofauna community is likely to be present within the Proposal area (Bennelongia 2011).	**Potential Impacts** Potential impacts to subterranean fauna include: - Impact resulting from drawdown of the water table - Impacts resulting from the injection of saline water. **Impact Assessment** *Drawdown and Mounding* Stygofauna may be affected by groundwater abstraction and groundwater injection. If drawdown occurs through the full thickness of the aquifer, any stygofauna species restricted to the drawdown area will be affected. No stygofauna species is restricted to an area where the Proposal is likely to cause significant impact through groundwater drawdown. *Abstraction and Injection of Groundwater* As discussed above (inland waters environmental quality) there is not expected to be any significant impact to groundwater salinity in shallow water table aquifers fringing the Fortescue Marsh as a result of the Proposal.	Potential impacts to subterranean fauna will be managed via the *Cloudbreak Groundwater Operating Strategy*. Further details on this plan are included in Table 9.	It is expected that the EPA's Management Objective for Subterranean Fauna will be achieved.
Landforms	To maintain the variety, integrity, ecological functions and environmental values of landforms and soils.	Please refer to the Cloudbreak LOM PER for details on the existing landforms and soils in the Project area. This Proposal is highly unlikely to have any adverse effect on landforms or soils in the area and as such, this factor is not considered further in the document.			
Terrestrial Environmental Quality	To maintain the quality of land and soils so that the environment values, both ecological and social, are protected.	Please refer to the Cloudbreak LOM PER for details the quality of land and soils in the Project area. This Proposal is highly unlikely to have any adverse effect on the quality of land or soils in the area and as such, this factor is not considered further in the document.			

7. MATTERS OF NATIONAL ENVIRONMENTAL SIGNIFICANCE

7.1 Legislative Background

Matters of National Environmental Significant (MNES), including nationally and internationally important flora, fauna, ecological communities and heritage places are afforded protection under the Commonwealth EPBC Act. Under this Act, any action which is likely to have a significant impact on a MNES is required to be referred to the DoE for assessment as to whether the action constitutes a "controlled action". If the action is deemed a "controlled action" implementation will consequently be subject to an approval from the Federal Minister for the Environment.

Where an action forms part of the controlled action that has already been approved (as is the case with this action) then a referral to the DoE is not required. The action and predicted impacts are considered a controlled action within the scope of EPBC 2010/5696.

MNES include:

- Listed threatened species and ecological communities
- Listed migratory species
- RAMSAR Wetlands on International Importance
- The Commonwealth marine environment
- World heritage properties
- National heritage places
- Nuclear actions
- Great Barrier Reef Marine Park
- A water resource, in relation to coal seam gas development and large coal mining development.

7.2 Impact Assessment – Matters of National Environmental Significance

An assessment of the predicted impacts on MNES is presented in Table 11. This assessment is made against the significance criteria as outlined in the *Significant Impact Guidelines 1.1 – Matters of National Environmental Significance* (DoE, 2013).

The summary of MNES presented in Table 11 is based on previous and ongoing flora and fauna surveys (refer to Section 5), previous database and literature searches undertaken as part of the various environmental impact assessments undertaken for the Cloudbreak and Christmas Creek mines; and an updated Protected Matters Search undertaken on 14 October 2013.

A desktop study undertaken by Ecologia (2010a) summarises all the survey data and information available within the vicinity of Fortescue's projects in the Chichester area. This includes the results of numerous Level 1 and Level 2 surveys within 50km of Cloudbreak. Unless indicated otherwise, the descriptions of the likelihood of species occurring are adapted from Ecologia (2010a).

Where an action forms part of the action that has already been (as is the case with this action) then a referral to the DoE is not required. Based on the impact assessment presented in Table 11, it is considered unlikely that the action will result in any significant impacts to MNES or result in any changes to the level of impact to MNES approved in the existing controlled action (EPBC 2010/5696). Therefore, it is considered that the action and predicted impacts are considered a controlled action within the scope of EPBC 2010/5696 and as such Fortescue is not proposing to refer this action to the DoE.

In accordance with Condition 7 of controlled action EPBC 2010/5696, which states "…*the person taking the action must advise the Minister of the quantity of de-watering and reinjection in operation and not increase dewatering or reinjection activities above the amount unless the Minister has given the person taking the action written approval*…" Fortescue is seeking Ministerial approval for the increase in groundwater abstraction and injection.

Table 11: Impact Assessment – Matters of National Environmental Significance

Matter of National Environmental Significance	Significance Criteria	Existing Environment	Impact Assessment	Management and Mitigation	Significance of Impact
Listed Threatened Species and Ecological Communities	An action is likely to have a significant impact on a critically endangered or endangered ecological community if there is a real chance or possibility that it will: - reduce the extent of an ecological community - fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines - adversely affect habitat critical to the survival of an ecological community - modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns - cause a substantial change in the species composition of an occurrence of an ecological community, including causing a decline or loss of functionally important species, for example through regular burning or flora or fauna harvesting - cause a substantial reduction in the quality or integrity of an occurrence of an ecological community, including, but not limited to: o assisting invasive species, that are harmful to the listed ecological community, to become established o causing regular mobilisation of fertilisers, herbicides or other chemicals or pollutants into the ecological community which kill or inhibit the growth of species in the ecological community o interfere with the recovery of an ecological community.	No endangered ecological communities are present in or adjacent to the Proposal area. Six threatened fauna species listed under the EPBC Act may be present in the Proposal area: **Night Parrot *(Pezoporus occidentalis)*** – Endangered Recorded from Minga Well (>2.5 km from nearest mine pit) and possible, but not previously recorded in the Samphire and Spinifex country of the Fortescue Marsh. Extensive surveys undertaken since the initial recording of the Night Parrot in 2005 have failed to identify any further Night Parrots in the Proposal area. **Northern Quoll (Dasyurus hallucatus)** – Endangered Previously recorded near the Proposal area in 1980. There is only a limited area of rocky breakaways that may provide a small amount of suitable habitat. **Greater Bilby (*Macrotis lagotis*)** – Vulnerable Records of active burrows within the Proposal area (Bamford 2005a). Areas of suitable habitat present along the Fortescue Marsh and in Mulga Woodland. **Orange Leaf-nosed Bat (*Rhinonicteris aurantius*)** – Vulnerable Recorded at Thieves Well. No suitable roosting habitat but may forage within the Proposal area. **Pilbara Olive Python (*Liasis olivaceus barroni*)** – Vulnerable May be present within the rocky areas in the north of the Proposal area. **Crest-tailed Mulgara (*Dasycerus cristicauda*)** - Vulnerable May occur within the Proposal Area. Potential burrows observed but no evidence of individuals. Small amount of suitable habitat (spinifex) in Proposal area.	**Potential Impacts** Potential impacts to threatened fauna form the action include: - Impacts from the loss of habitat (either direct or indirect loss) - Fauna entrapment - Fauna death or mortality via interaction with site vehicles. **Impact Assessment** *Loss of Habitat – Clearing* All clearing will be undertaken under existing approvals and in line with existing operational procedures. No additional impacts to threatened fauna as a result of vegetation clearing are expected as a result of the action. *Loss of Habitat – Indirect* The predicted areas of direct and indirect impact are located in the Mulga and other Acacia Woodland habitat (6617 ha) followed by the Spinifex Covered Hills and Ranges (985 ha). A total of 98.7% of all expected indirect impact is within the Mulga and other Acacia Woodland habitat (922 ha). While there is predicted to be some degradation in the health Mulga and other Acacia Woodland habitat, the impact is expected to be minimal and localised. An additional 178 ha of Mulga and other Acacia Woodland habitat may potentially be affected as a result of the increase in abstraction and injection quantities. This represents a 22% increase in the indirect impact to Mulga and other Acacia Woodland habitat approved in MS 899 and EPBC 2010/5696 but only a 2.8% increase in total (direct and indirect) disturbance for Mulga and other Acacia Woodland habitat. The percent of expected indirect impact to Low Halophytic Shrubland (samphire) habitat and Creeklines with Shrubland and/or Eucalypt Open Woodland habitat are significantly lower than presented in the LOM PER. There is not expected to be any significant increase in impacts to Fortescue Marsh, yintas or creeklines as a result of the action. Given the lack of predicted impacts and the large regional representation of the key vegetation types, there is not predicted to be any significant impact to threatened fauna as a result of indirect impacts to fauna habitat as a result of the action. *Fauna Entrapment* The ponds associated with the dewatering and injection infrastructure may attract fauna in times of drought. This could result in fauna becoming trapped and/or drowning within the ponds. There is also potential of fauna entrapment and/or drowning in the trenches associated with pipeline installation. There is not expected to be a significant increase in the number or size of ponds associated with dewatering or the length of trenching required as part of the action. Potential entrapment of fauna can be managed via established procedures. There is not expected to be any significant impact to fauna as a result of entrapment. *Vehicle Movements during Construction and Operations* The action is not expected to lead to any increase in the number, type or timing of vehicle movements and as such, is not expected to result in any additional risk of fauna injury or mortality due to vehicle	Fortescue approach to the management of indirect impacts to vegetation as a result of abstraction and injection is based on responding to information provided through the implementation of a monitoring program and response plan. If monitoring indicates that unexpected and significant impacts are likely, Fortescue, in consultation with the regulatory agencies, will implement an appropriate contingency action. The *Fortescue Marsh Hydrology and Vegetation Monitoring and Management Plan* is required to meet Condition 7 of EPBC 2010/5696. This plan outlines monitoring and management requirements for the Fortescue Marsh with the aim to protect suitable habitat for MNES. **Ground Disturbance Permit** A procedure of internal review and approval of all proposed vegetation clearing and ground disturbance activities is required prior to the commencement of works (a Ground Disturbance Permit). Under the permitting process areas of vegetation which may comprise high value may require ground-truthing surveys to assess its value. **Species Specific Management Plans** The following species specific management plans will continue to be implemented at Cloudbreak: - Night Parrot (*Pezoporus occidentalis)* Management Plan - Bilby (*Macrotis lagotis*) Management Plan	Based on the predicted impacts to threatened fauna species and the relevant significance criteria it is considered that it is unlikely that the proposed action will have a significant impact on a critically endangered or endangered ecological community.

Matter of National Environmental Significance	Significance Criteria	Existing Environment	Impact Assessment	Management and Mitigation	Significance of Impact
			movements. **Impact Assessment – Threatened Species** *Night Parrot – Endangered* The only confirmed sighting of Night Parrot was at Minga Well (Mulga habitat) although the habitat of the Night Parrot is thought to, but not confirmed to consist of *Triodia* grasslands in stony or sandy environments and of Samphire and chenopod shrublands on floodplains and clay pans, and on the margins of salt lakes, creeks or other sources of water (DSEWPC 2010a). It should also be noted that extensive Night Parrot surveys undertaken annually have failed to identify any Night Parrots in the Proposal area since mining commenced. The habitat of the Night Parrot consists of Triodia grasslands in stony or sandy environments and of Samphire and chenopod shrublands on floodplains and clay pans, and on the margins of salt lakes, creeks or other sources of water (SEWPAC 2010b). The proposal expects that 757.5 ha of Low halophytic shrubland (samphire) and 3 ha of Hummock Grassland (spinifex) which was originally expected to be impacted by the EPBC 2010/5696 approval (LOM PER), will now no longer be impacted. The only habitat with an expected increase in indirect impacts is Mulga and other Acacia Woodland habitat. Due to the lack of recent confirmed Nigh Parrot sightings, the nomadic nature and the large home ranges of the Night Parrot; and the extensive areas of similar habitat surrounding the Proposal area, no impacts to the Night Parrot are expected to occur as a result of this action. *Northern Quoll - Endangered* The rocky habitat preferred by the Northern Quoll will not be affected by the action and as such no impacts to this species are expected. *Greater Bilby - Vulnerable* The spinifex dominated vegetation types preferred by the Greater Bilby will not be affected by the action and as such no impacts to this species are expected. *Orange Leaf-nosed Bat – Vulnerable* No roosting habitat will be affected by the action and as such no impact to this species is expected to occur as a result of the action. *Pilbara Olive Python – Vulnerable* The rocky habitat preferred by the Pilbara Olive Python will not be affected by the action and as such no impacts to this species are expected. *Crest-tailed Mulgara - Vulnerable* The spinifex dominated vegetation types preferred by the Crest-tailed Mulgara will not be affected by the action and as such no impacts to this species are expected. Refer to Table 9, Terrestrial Fauna for impact areas.		
Listed Migratory Species	An action is likely to have a significant impact on a migratory species if there is a real chance or possibility that it will: - substantially modify (including by fragmenting, altering fire	Eight Listed Migratory Species may potentially be present in the area: **Fork-tailed Swift (*Apus pacificus*)** Will occasionally overfly Proposal area, but will not utilise it directly.	Please refer to the assessment of potential impacts from loss of habitat, fauna entrapment and vehicle movements above. There are no additional potential impacts to migratory species than presented for threatened species above. Migratory species primarily utilise terrestrial wetlands (such as Fortescue Marsh) or water course / creek and drainage lines. There is	Please refer to management and mitigation described for threatened fauna species above.	Based on the predicted impacts and the relevant significance criteria it is considered that it is unlikely that the proposed action will

Matter of National Environmental Significance	Significance Criteria	Existing Environment	Impact Assessment	Management and Mitigation	Significance of Impact
	regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species - result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species, or - seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	**White-bellied Sea-eagle (*Haliaeetus leucogaster*)** Recorded at Fortescue Marsh. Uncommon in area, although suitable habitat present along the marsh where water present. Unlikely to be suitable habitat within the Proposal area. **Rainbow bee-eater (*Merops ornatus*)** Recorded within Proposal area. Suitable habitat for hunting and breeding. **Great Egret (*Ardea alba*)** Suitable hunting habitat when surface water present in Fortescue Marsh and some potential habitat along creek lines within Proposal area. **Cattle Egret (*Ardea ibis*)** Occasionally occur in terrestrial wetlands. Has not been recorded in the Proposal area. **Wood Sandpiper (*Tringa glareola*)** Recorded at Fortescue Marsh. Suitable habitat present in marsh especially after rain. Some potential habitat along creek lines within the Proposal area. **Common Greenshank (*Tringa nebularia*)** Recorded at Fortescue Marsh. Suitable habitat present in marsh especially after rain. Some potential habitat along creek lines within the Proposal area. **Red-necked Stint (*Calidris ruficollis*)** Few records, but suitable habitat present in marsh especially after rain. Some potential habitat along creek lines within the Proposal area.	not expected to be any significant impacts to these features or important vegetation that may subsequently impacts on migratory species.		have a significant impact on a migratory species.
RAMSAR Wetlands of International Importance	Previous studies and the protected matter search undertaken on 14 October 2013 identified no wetlands listed under the RAMSAR Convention located in the vicinity of the Proposal area. While Fortescue Marsh has been identified as national important wetland and a potential future Ramsar wetland, there is currently no formal nomination at this stage (DEC 2009). As such this MNES is not considered further in this report.				
The Commonwealth marine environment	The proposed action is not in the vicinity of the Commonwealth Marine Environment and as such this MNES is not considered further in this report.				
World heritage properties	Previous studies and the protected matter search undertaken on 14 October 2013 identified no World Heritage properties in the vicinity of the Proposal area. As such this MNES is not considered further in this report				
National heritage places	Previous studies and the protected matter search undertaken on 14 October 2013 identified no National Heritage Places in the vicinity of the Proposal area. As such this MNES is not considered further in this report.				
Nuclear actions	The proposed action is not a Nuclear Action and as such this MNES is not considered further in this report.				
Great Barrier Reef Marine Park	The proposed action is not in the vicinity of the Great Barrier Reef Marine park and as such this MNES is not considered further in this report.				
A water resource, in relation to coal seam gas development and large coal mining	The proposed action is not in relation to a coal seam gas development or large coal mining development and as such this MNES is not considered further in this report.				

Matter of National Environmental Significance	Significance Criteria	Existing Environment	Impact Assessment	Management and Mitigation	Significance of Impact
development					

REFERENCES

ATA Environmental (ATA) 2006a, Fauna Assessment Extension to the Cloud Break Mining Pit, August 2006.

ATA Environmental (ATA) 2006b, Fauna Assessment Cloudbreak Airstrip, Camp and Access Road, September 2006.

Bamford Consulting Ecologists (Bamford) 2005a, Fauna survey of proposed Iron Ore Mine, Cloud Break, Prepared for Fortescue Metals Group Ltd, June 2005.

Bamford Consulting Ecologists (Bamford) 2005b, Survey for the Night Parrot Pezoporus occidentalis in the Cloud Break Project Area, May 2005, Fortescue Metals Group, Prepared for Fortescue Metals Group, Perth.

Bamford Consulting Ecologists (Bamford) 2006, Survey for the Night Parrot Pezoporus occidentalis in the Cloud Break Project Area, March 2006, Fortescue Metals Group, Prepared for Fortescue Metals Group, June 2006.

Bamford Consulting Ecologists (Bamford) 2007a, Night Parrot survey November-December 2006 at FMG's Cloudbreak site, Prepared for Fortescue Metals Group, Perth.

Bamford Consulting Ecologists (Bamford) 2007b, Survey of the Night Parrot Pezoporus occidentalis in the Cloud Break Project Area, November 2007, Fortescue Metals Group. Prepared for Fortescue Metals Group, Perth.

Bamford Consulting Ecologists (Bamford) 2009, Report on September 2008 search for the Night Parrot, A Fortescue Metals Group Project, Prepared for Fortescue Metals Group, January 2009.

Bamford Consulting Ecologists (Bamford) 2010a, Report on September 2009 search for the Night Parrot, A Fortescue Metals Group Project, Prepared for Fortescue Metals Group, July 2010.

Bamford Consulting Ecologists (Bamford) 2010b, Fortescue Metals Group Targeted Fauna Assessment of the Railway Duplication, Prepared for Fortescue Metals Group, Perth.

Bamford Consulting Ecologists (Bamford) 2011, Report on 2010 search for the Night Parrot, A Fortescue Metals Group Project, Prepared for Fortescue Metals Group, January 2011.

Beard J.S. 1975, Pilbara Explanatory Notes and Map Sheet 5, 1:1,000,000 series. Vegetation Survey of Western Australia, University of Western Australia Press, Nedlands, Western Australia.

Bennelongia Environmental Consultants (Bennelongia) 2011, Cloudbreak Project Expansion Subterranean Fauna Assessment, Prepared for Fortescue Metals Group by Benneloniga Pty Ltd, March 2011.

Biota Environmental Sciences (Biota) 2004, Fortescue Metals Group Stage B Rail Corridor, Christmas Creek, Mt Lewin, Mt Nicholas and Mindy Mindy Mine Areas: Vegetation and Flora Survey, Prepared for Fortescue Metals Group Ltd, December 2004.

Biota Environmental Sciences (Biota) 2005, Fauna habitats and fauna assemblages of proposed the FMG Stage B rail corridor and Mindy Mindy, Christmas Creek, Mt Lewin and Mt Nicholas mine areas, Prepared for Fortescue Metals Group, Perth, January 2005.

Department of Environment and Conservation (DEC) 2009, Resource Condition Report for Significant Western Australian Wetland: Fortescue Marsh, Department of Environment and Conservation. Perth, Australia.

Department of Environment and Conservation (DEC) 2010, Threatened and Priority Ecological Community Database Search, Department of Environment and Conservation, Perth, Western Australia.

Department of Environment and Conservation (DEC) 2013, Threatened and Priority Ecological Community Database Search, Department of Environment and Conservation, Perth, Western Australia.

Department of Sustainability, Environment, Water, Population and Communities (SEWPAC) 2010A, Directory of Important Wetlands in Australia - Information sheet Fortescue Marshes – WA066 [Online], Available from: <http://www.environment.gov.au/cgi-bin/wetlands/report.pl> [13 October 2010].

Department of Sustainability, Environment, Water, Population and Communities (SEWPAC) 2010A, *Pezoporus occidentalis* – Night Parrot [Online], Available from: www.environment.gov.au/cig-bin/sprat /public/publicspecies.pl?taxon_id=59350 [22 June 2010]

Department of Water (DoW) 2009, Pilbara water in mining guidelines: Looking after our water needs, Water Resource Allocation Planning Series. Perth, Western Australia: Government of Western Australia.

Department of Water (DoW), 2011, Operational Policy 1.01 – Managed aquifer recharge in Western Australia, 2011, DoW, Perth, Western Australia.

Ecologia 2010a, Cloudbreak Terrestrial Vertebrate Fauna Desktop Assessment, Prepared for Fortescue Metals Group, September 2010.

Ecologia 2010b, Cloudbreak Short-Range Endemic Desktop Assessment, Prepared for Fortescue Metals Group, October 2010.

Ecologia 2011a, Cloudbreak Level 2 Terrestrial Vertebrate Fauna Assessment, Prepared for Fortescue Metals Group, February 2011.

Ecologia 2011b, Cloudbreak Short-Range Endemic Invertebrate Survey, Prepared for Fortescue Metals Group, February 2011.

Ecoscape 2009, Flora and Vegetation Impact Assessment for Dewatering at Fortescue Cloudbreak Mine, Unpublished report prepared for Fortescue Metals Group, June 2009.

ENV Australia (ENV) 2011, Cloudbreak Flora and Vegetation Assessment, Prepared for Fortescue Metals Group Ltd, February 2011.

Environment Australia 2001, A Directory of Important Wetlands in Australia, Third Edition, Environment Australia, Canberra, Australian Capital Territory.

Environmental Protection Authority (EPA) 2002, Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection, EPA, Perth, Western Australia.

Environmental Protection Authority (EPA) 2004, Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia, Guidance Statement No 51, EPA, Perth, Western Australia.

Environmental Protection Authority (EPA) 2010, Marandoo Mine Phase 2, Hamersley Iron Pty Ltd, Report and Recommendations of the Environmental Protection Authority, Report 1355, EPA, Perth, Western Australia, April 2010.

Environmental Protection Authority (EPA) 2012, Environmental Impact Assessment Administrative Procedures 2012, EPA, Perth, Western Australia.

Environmental Protection Authority (EPA) 2013a, Environmental Assessment Guideline for Application of a significance framework in the environmental impact assessment process – focussing on Key Environmental Factors, 2013, EPA, Perth, Western Australia.

Environmental Protection Authority (EPA) 2013b, Environmental Assessment Guideline for Environmental factors and objectives, 2013, EPA, Perth, Western Australia.

Fisher A., Hunt L., James C., Landsberg J., Phelps D., Smyth, A. and Watson, I. 2004, 'Review of Total Grazing Pressure Management and Issues in Biodiversity Conservation in Rangelands' in A resource to aid NRM planning, Desert Knowledge CRC Project Report No. 3 (August 2004);

Desert Knowledge CRC and Tropical Savannas Management CRC, Alice Springs.

Fortescue Metals Group (Fortescue) 2009, Dewatering Discharge Contingency Procedure, Unpublished Report, Ref. 45-PL-EN-0009, August 2009.

Fortescue Metals Group (Fortescue) 2010, Hydrogeological Assessment for Cloudbreak Water Management Scheme, Document No. CB-RP-HY-0019, Perth, Western Australia.

Fortescue Metals Group (Fortescue) 2011, Cloudbreak Life of Mine Public Environmental Review, April 2011.

Fortescue Metals Group (Fortescue) 2013a, Hydrogeological Assessment for the Cloudbreak Water Management Scheme. November 2013 Ref. CB-RP_HY-0019

Fortescue Metals Group (Fortescue) 2013b, Cloudbreak Groundwater Operating Strategy – Water Management, Unpublished Report, Ref. CB-PH-HY-0009, June 2013.

Fortescue Metals Group (Fortescue) 2013c , Modelling Analysis of the Impact of Mine Dewatering on Soil Water Availability to the Samphire Vegetation on the Fringe of Fortescue Marsh, unpublished report prepared for Fortescue Metals Group, Perth, Western Australia 2103.

Johnson R. and Burrows W. 1994, 'Acacia open forests, woodlands and shrublands' pp. 257-290 in Groves, RH (Ed), Australian Vegetation 2nd ed. Cambridge University Press, Cambridge.

Mattiske Consulting Pty Ltd (Mattiske) 2005a, Flora and Vegetation on the Cloudbreak and White Knight Leases, Prepared for Fortescue Metals Group Ltd, June 2005.

Mattiske Consulting Pty Ltd (Mattiske) 2005b, Review of Vegetation Condition on the Cloudbreak Lease Area, Prepared for Fortescue Metals Group Ltd, June 2005.

Mattiske Consulting Pty Ltd (Mattiske) 2007, Flora and vegetation near Fortescue Marshes, unpublished report for Fortescue Metals Group, June 2007.

Trudgen M.E. 1991, 'Vegetation Condition Scale' in National Trust (WA) 1993, Urban Bushland Policy. National Trust of Australia (WA), Wildflower Society of Western Australia (Inc.) and the Tree Society (Inc.), Perth, Western Australia.

Worley Parsons 2011, Cloudbreak Life of Mine Expansion Surface Water Investigation and Impact Assessment, Unpublished Report for Fortescue Metals Group, March 2011, Perth, Western Australia.

Figure 1: Location of Cloudbreak

This page has been left blank intentionally

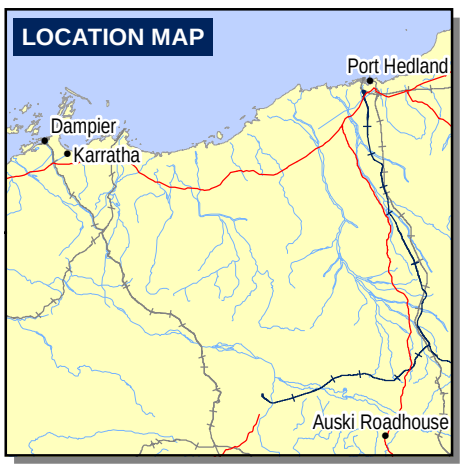
600,000 675,000 750,000 825,000

7,725,000 7,650,000 7,575,000 7,500,000 7,425,000

Port Hedland
Mount Goldsworthy
Marble Bar
Nullagine
Cloudbreak Mine
Christmas Creek Mine
Auski Roadhouse
KARIJINI NATIONAL PARK
Tom Price
KARIJINI NATIONAL PARK
Paraburdoo
Newman

600,000 675,000 750,000 825,000

LOCATION MAP



- Towns
- FMG Mines
- Rail
- Drainage
- Reserves
- Fortescue Marsh

Data Source(s):
Marsh Data sourced from Enviro Australia (2001)
Directory of important Wetlands in Australia

N

0 10 20 30 40
Kilometers

Figure 1
Location of Cloudbreak

Requested By: Fiona Rowland
Drawn By: C Whyte
Revised By: admoore
Approved By:
Scale: 1:1,100,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_EN_0279.001

Date: 29/11/2013
Size: A3P
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 2: Indicative Injection Areas

This page has been left blank intentionally

720,000 730,000 740,000 750,000 760,000 770,000

7,540,000

7,530,000

7,520,000

- Existing Injection Bores
- Proposed Brackish Re-injection Bores
- Proposed Saline Re-Injection Bores
- Proposed Pipelines
- Approved Freshwater Pipelines
- Existing pipelines outside of Part IV approval (approved through POW & Part V)
- Existing Infrastructure
- Settlement & Treatment Ponds
- Maximum Mine Disturbance (MS899 - CB Mine Area)
- Previous Proposal Area (MS899 - CB Project Area)
- Injection Areas

N

0 1 2 3 4 5

Kilometres

Requested By: Fiona Rowland
Drawn By: C Whyte
Revised By: admoore
Approved By:
Scale: 1:140,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_EN_0279.002

Date: 29/11/2013
Size: A3L
Revision: 0
Confidentiality: 1

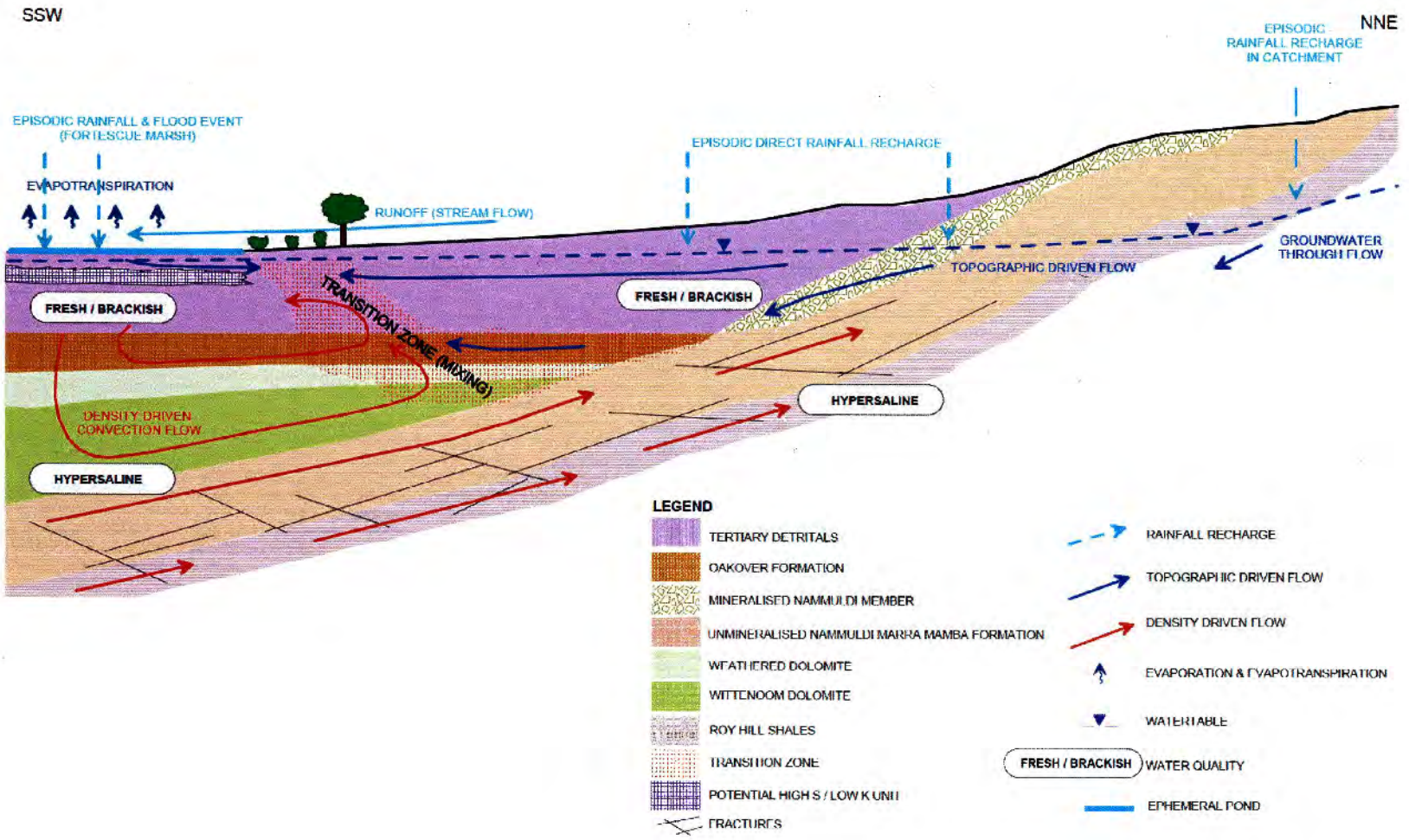
FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Figure 2
Indicative Injection Areas and Infrastructure

Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 3: Conceptual Hydrogeological Model

This page has been left blank intentionally



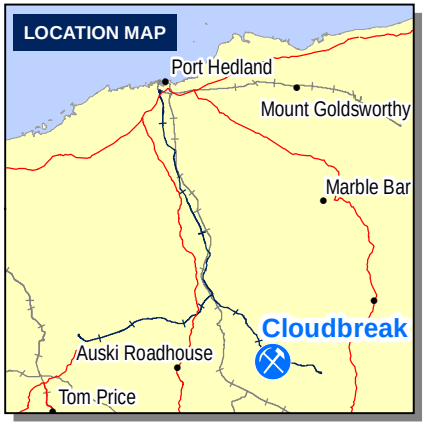


FIGURE 3
Conceptual Hydrogeology Of
The Cloudbreak Area

Requested By: A. De Vos
Drawn By: PM
Revised By: admoore
Approved By:
Scale: N/A
Coordinate System: N/A
Document Name: CB_MP_EN_0279.003

Date: 29/11/2013
Size: A4L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

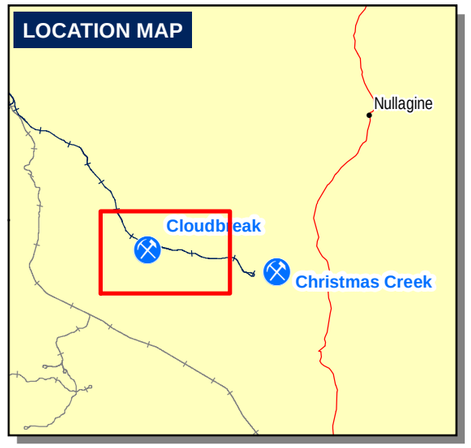
Figure 4: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts – 2014

This page has been left blank intentionally

720,000
735,000
750,000
765,000
7,545,000
7,530,000
7,515,000

CBFMM01
CBFMM02
CBFMM04
CBFMM05
CBFMM06
CBFMM07
CBFMM08

LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga - Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2014

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.001_r0_2014

Date: 29/11/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

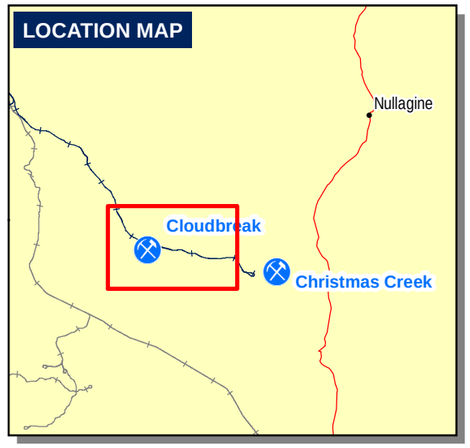
Figure 5: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts – 2015

This page has been left blank intentionally

720,000
735,000
750,000
765,000
7,545,000
7,530,000
7,515,000

CBFMM01
CBFMM02
CBFMM04
CBFMM05
CBFMM06
CBFMM07
CBFMM08

LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga – Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2015

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.002_r0_2015

Date: 29/11/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 6: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts – 2016

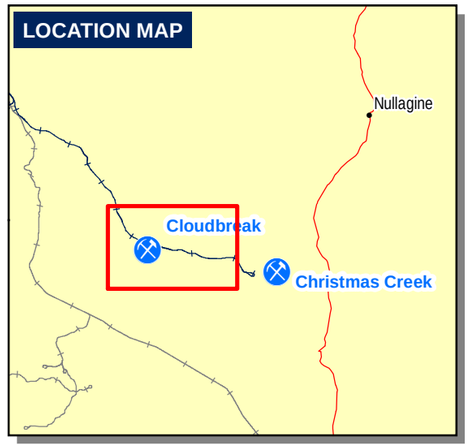
This page has been left blank intentionally

720,000 735,000 750,000 765,000

7,545,000 7,530,000 7,515,000

CBFMM01 CBFMM02 CBFMM04 CBFMM06 CBFMM05 CBFMM07 CBFMM08

LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining.
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga – Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2016

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.003_r0_2016

Date: 29/11/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

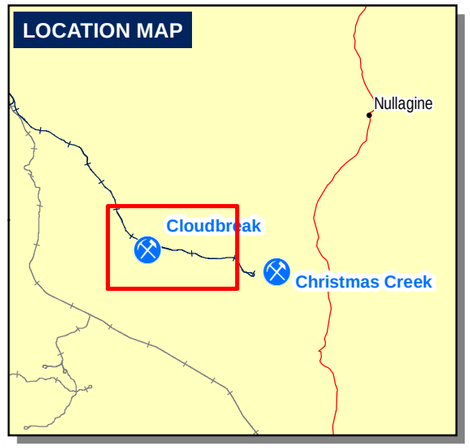
Figure 7: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts – 2017

This page has been left blank intentionally

720,000
735,000
750,000
765,000
7,545,000
7,530,000
7,515,000

CBFMM01
CBFMM02
CBFMM04
CBFMM05
CBFMM06
CBFMM07
CBFMM08

LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining.
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga – Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2017

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.004_r0_2017

Date: 29/11/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 8: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts – 2018

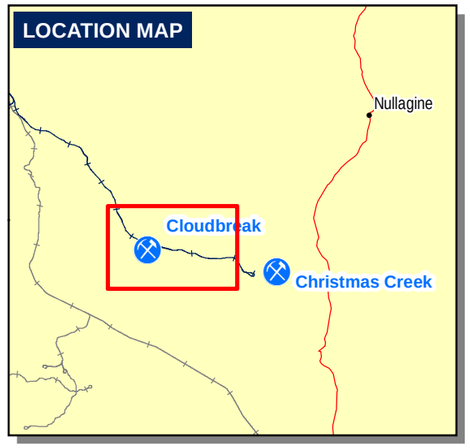
This page has been left blank intentionally

720,000 735,000 750,000 765,000

7,545,000 7,530,000 7,515,000

CBFMM01 CBFMM02 CBFMM04 CBFMM05 CBFMM06 CBFMM07 CBFMM08

LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga - Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2018

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.005_r0_2018

Date: 29/11/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 9: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts – 2019

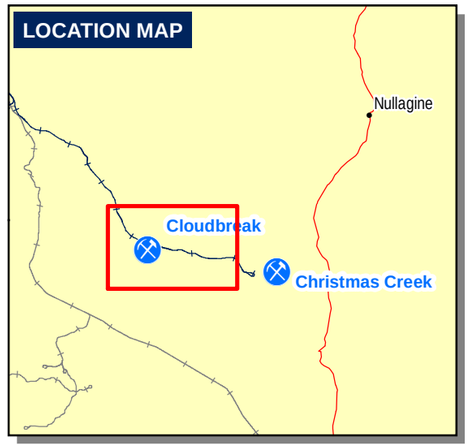
This page has been left blank intentionally

720,000 735,000 750,000 765,000

7,545,000 7,530,000 7,515,000

CBFMM01 CBFMM02 CBFMM04 CBFMM06 CBFMM05 CBFMM07 CBFMM08

LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining.
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga – Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2019

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.006_r0_2019

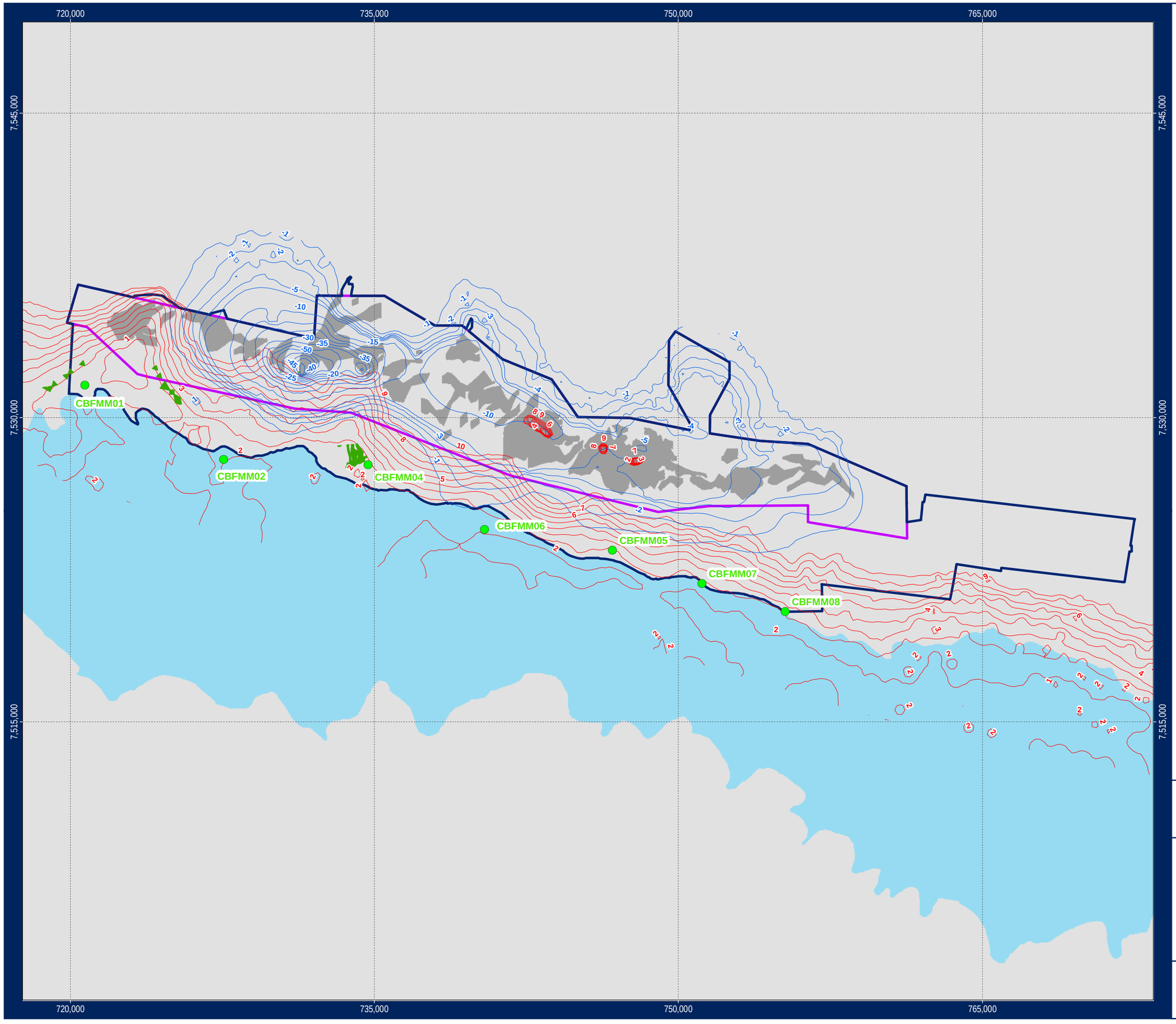
Date: 3/12/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

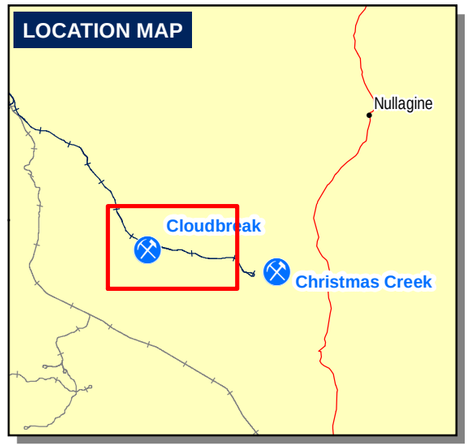
Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 10: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts – 2020

This page has been left blank intentionally



LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining.
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga – Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2020

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.007_r0_2020

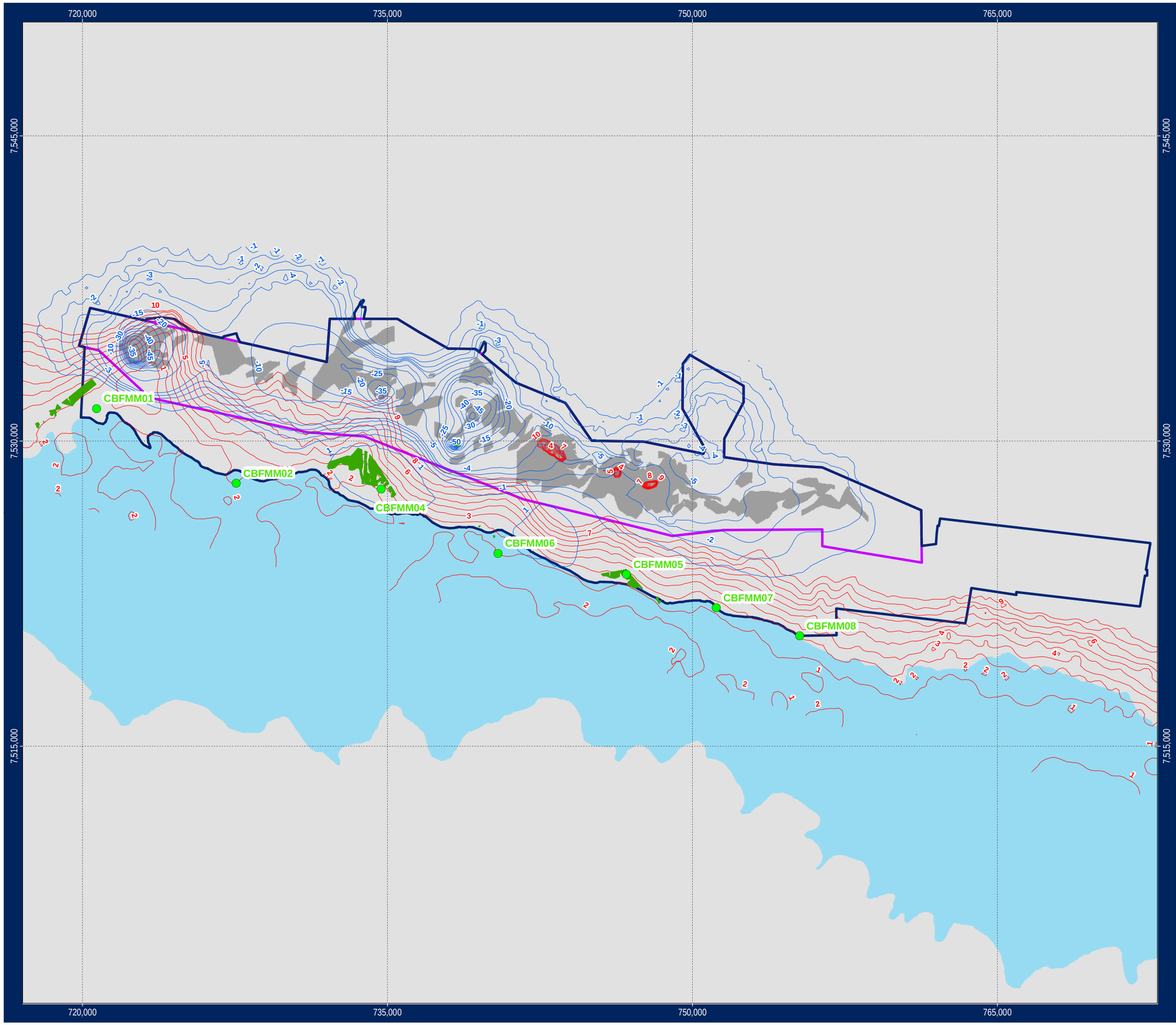
Date: 3/12/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

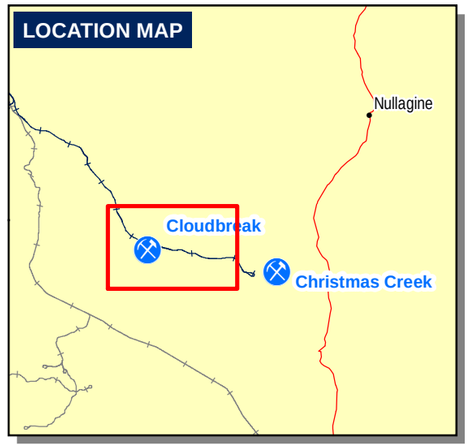
Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 11: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts - 2021

This page has been left blank intentionally



LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining.
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga – Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2021

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.008_r0_2021

Date: 3/12/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 12: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts – 2022

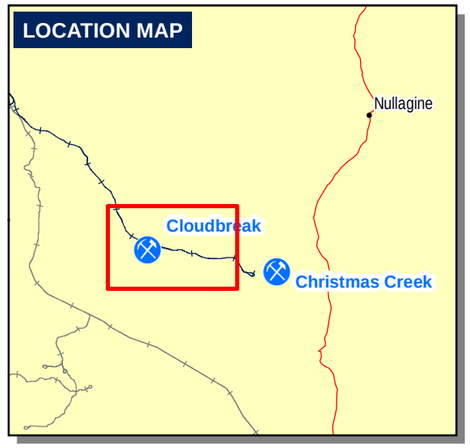
This page has been left blank intentionally

720,000 735,000 750,000 765,000

7,545,000 7,530,000 7,515,000

CBFMM01 CBFMM02 CBFMM04 CBFMM06 CBFMM05 CBFMM07 CBFMM08

LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining.
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga – Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2022

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.009_r0_2022

Date: 3/12/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

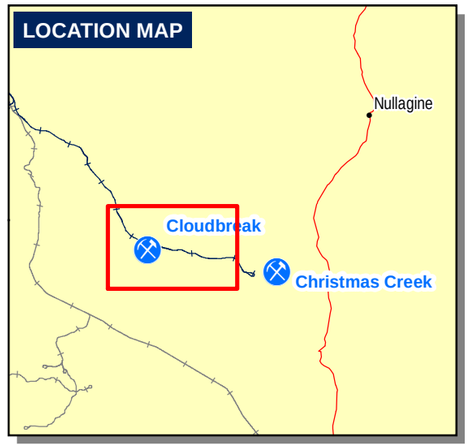
Figure 13: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts - 2023

This page has been left blank intentionally

720,000
735,000
750,000
765,000
7,545,000
7,530,000
7,515,000

CBFMM01
CBFMM02
CBFMM04
CBFMM06
CBFMM05
CBFMM07
CBFMM08

LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining.
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Samphire – Drawdown greater than 3m in areas where the natural groundwater was 0-5 mbgl.
- Impacts to Mulga – Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2023

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.010_r0_2023

Date: 14/02/2014
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

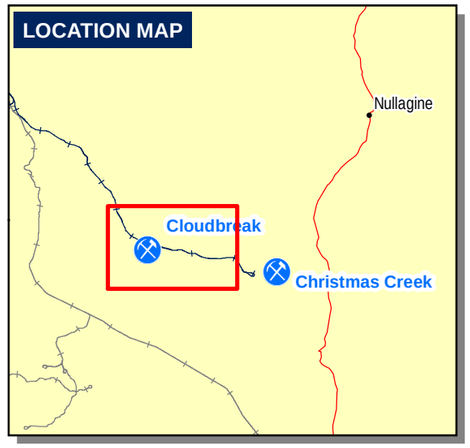
Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 14: Predicted Natural Groundwater Levels, Mounding and Drawdown Levels and Vegetation Health Impacts - 2024

This page has been left blank intentionally

720,000
735,000
750,000
765,000
7,545,000
7,530,000
7,515,000
CBFMM01
CBFMM02
CBFMM04
CBFMM06
CBFMM05
CBFMM07
CBFMM08

LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining.
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga – Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2024

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.011_r0_2024

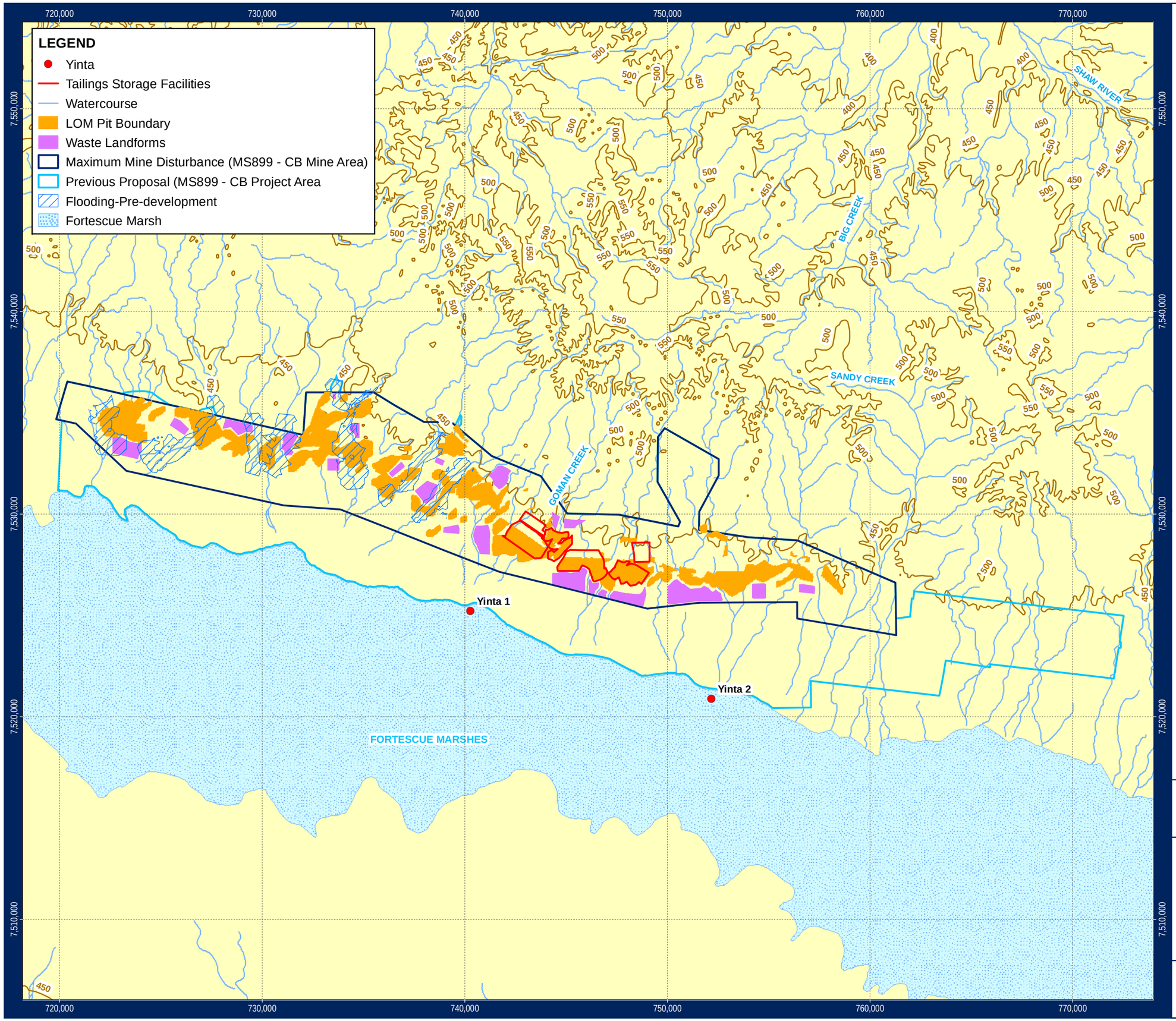
Date: 4/12/2013
Size: A3L
Revision: 0
Confidentiality: 1

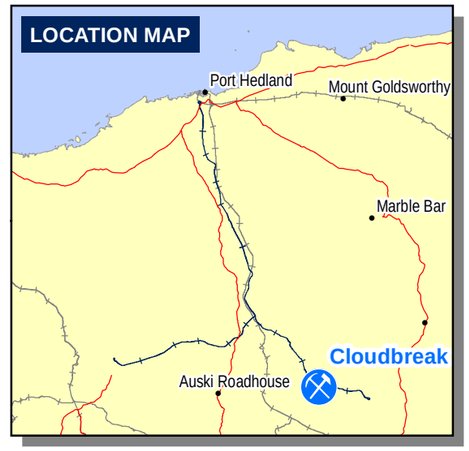
FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 15: Surface Water Features

This page has been left blank intentionally





N

0 2 4 6 8 10
Kilometres

Figure 15
Surface Water Features

Requested By: F Rowland
Drawn By: R Maconachie
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_EN_0279.004

Date: 29/11/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 16: Vegetation Mapping

This page has been left blank intentionally

720,000 730,000 740,000 750,000 760,000 770,000

7,560,000 7,550,000 7,540,000 7,530,000 7,520,000 7,510,000

LEGEND

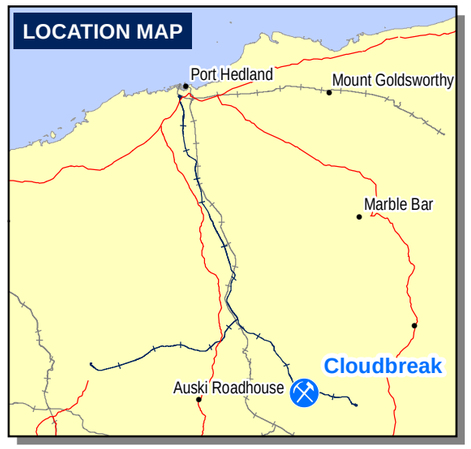
- Maximum Mine Disturbance (MS899 - CB Mine Area)
- Previous Proposal Area (MS899 - CB Project Area)
- Previous Approved Footprint (MS721 - CB Mine Area)
- Indicative Pipelines Outside of Maximimum Mine Disturbance
- Existing Pipelines
- Existing Ponds
- Fortescue Marsh

Vegetation Communities

- Creek lines and drainage lines – Coolibah/River Red Gum dominated
- Creek lines and drainage lines – Mulga dominated
- Creek lines and Drainage lines – other Acacia dominated
- Flats and broad plains containing Mulga
- Flats and broad plains without Mulga
- Fringes of Samphire Flats containing Samphire
- Fringes of Samphire Flats without Samphire
- Infrastructure
- Ranges, hills and hillslopes

FORTESCUE MARSH

LOCATION MAP



N

0 2 4 6 8 10

Kilometres

FIGURE 16
Broad Vegetation Mapping

Requested By: A. De Vos
Drawn By: PM
Revised By: admoore
Approved By:
Scale: 1:200,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_EN_0279.005

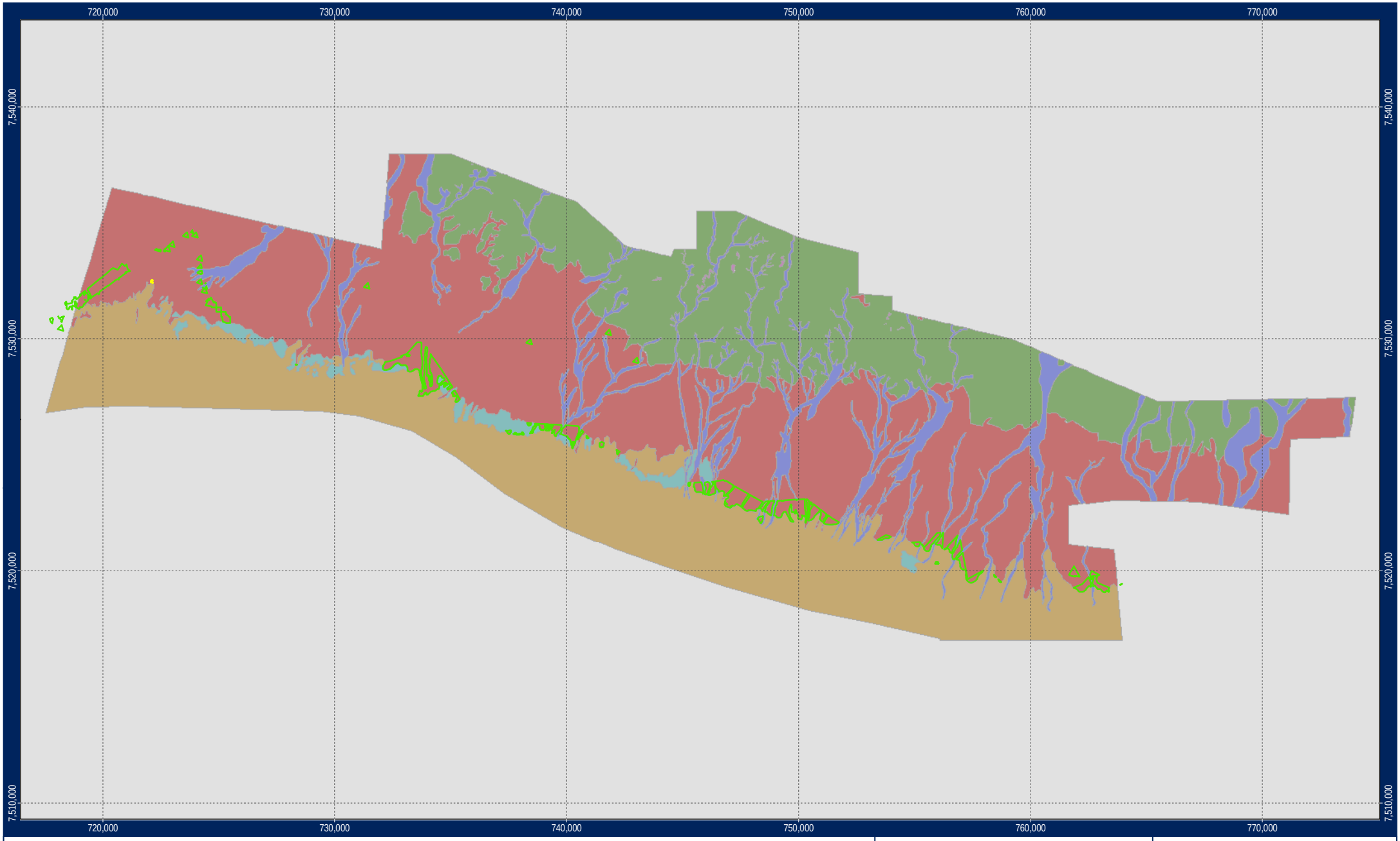
Date: 29/11/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 17: Indirect Impacts to Fauna Habitat

This page has been left blank intentionally



Impacts to Samphire
Impacts to Mulga

Fauna Mapping

- Drainage Line/River/Creek (Minor / Major)
- Hills/Ranges/Plateaux
- Hummock grassland
- Rocky Escarpments (Ridges/Mesa/Cliffs/Outcrops/Breakaways)
- Samphire/Marsh
- Woodland (Open/Closed)

N

0 2 4 6
Kilometres

Requested By: Fiona Rowland
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:210,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_EN_0283.001_r0

Date: 13/02/2014
Size: A4L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Indirect Impacts to Fauna Habitat

Fortescue Metals Group Ltd
The New Force in Iron Ore

Appendix 1: Hydrogeological Assessment

This page has been left blank intentionally

Report

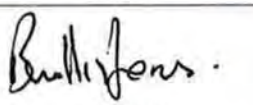
Hydrogeological Assessment for Cloudbreak Water Management Scheme

Technical Services

December 2013
CB-RP-HY-0019

Fortescue
The New Force in Iron Ore

Disclaimer:
This document is protected by copyright, no part of this document may be reproduced or adapted without the consent of the originator/company owner, all rights are reserved. This document is "uncontrolled when printed", refer to electronic copy for up to date version.

	Hydrogeological assessment for the Cloudbreak Water Management Scheme		**CB-RP-HY-0019**
Revision Number	**2**		**20/12/2013**
Status	**IFU - ISSUED FOR USE**		
Author	Fuli Wang, Paul Ricketts	Signature	25/10/2013
Checked	Paul Ricketts	Signature	16/12/2013
Approved	Bobak Willis Jones	 Signature	20/12/2013
Confidentiality	**PUBLIC USE (ACCESS TO ALL)**	**Publish on Extranet**	☐ Yes ☒ No
Review Date	**22/11/2013**		

Revision History *(to be completed for each version retained by Document Control)*

Author	Checker	Approver	Rev No.	Status	Issued Date
Bobak Willis-Jones	**Jed Youngs**	**Doug Brown**	1.2	**IFU**	5/11/2010
Fuli Wang	**Paul Ricketts**	**Bobak Willis Jones**	2	**IFU**	20/12/2013

EXECUTIVE SUMMARY

Fortescue Metals Group's (Fortescue's) Cloudbreak iron ore mine (Cloudbreak) is within the Pilbara region of Western Australia. Cloudbreak is located approximately 30 kilometres west of Fortescue's Christmas Creek mine, 80 kilometres south west of Nullagine and approximately 120 kilometres north of Newman (Figure 1). The Cloudbreak iron ore mine has been operating since 2008, and is currently approved to ship iron ore, via a rail link, from Port Hedland (Figure 1 and Figure 2).

About 90% of iron ore at Cloudbreak is below the watertable, and mine dewatering is undertaken to minimise water ingress into mining pits. Below watertable mining commenced in July 2008, current mine dewatering and associated water management activities are approved under Ministerial Statement 899 (MS899) granted in 2012[1], controlled action EPBC 2005/2205 granted in July 2006 and EPBC 2010/5696 granted in November 2012. Key characteristics of the project stated in MS899, controlled actions EPCB 2005/2205 and EPBC 2010/5696 and the recently approved applications under section 45C and 46 of the *Environmental Protection Act 1986* limit groundwater abstraction to 100 GL/a and injection to 95 GL/a.

Knowledge developed during operations has improved the understanding of the hydrogeological conditions. On this basis the Life of Mine (LOM) plan (FMG, 2010d) has been reassessed, identifying dewatering and injection requirements up to 150 GL/a. The level of groundwater impact, in the shallow alluvial aquifer, at the fringe or within the Fortescue Marsh is within the range predicted in the previous assessment (FMG, 2010d).

Dewatering will be achieved through advance dewatering methods and operational dewatering methods. Dewatering may significantly exceed mine water use requirements, and any surplus (the difference between abstraction water and mine water use) may be transferred to Christmas Creek if required or will be returned to compatible aquifers through injection to preserve water resources and to minimise environmental impacts (groundwater level drawdown/mounding). This process of groundwater abstraction and injection is referred to as the Cloudbreak water management strategy.

The hydrological setting of the project area is characterised by three broad hydrological regimes; a topographic driven flow regime; a density driven flow regime; and the Fortescue Marsh regime which cycles between a recharge and discharge feature in accordance with flooding and drying cycles. Detailed understanding of these flow regimes and the interaction between the flow regimes has been developed based on nearly 10 years of investigations and operations in the region.

Empirical evidence, in particular the demonstrated ability of *T. indica subsp. bidens* to tolerate drought and other stressors, and numerical simulation of soil water dynamics and plant water

[1] MS899 supersedes the conditions of Statement 721 which was published on 24th April 2006, changed on September 2005, 12th July 2010 and 10th June 2011.

uptake by samphire vegetation on the fringe of the Fortescue Marsh (HYDRUS) suggest that the ecological water requirements of the fringing samphire communities are wholly or predominantly met by surface inputs (Equinox Environmental, 2012).

A density-driven flow and transport numerical groundwater model was developed and calibrated in the FEFLOW modelling platform for the purpose of conceptual design of the dewatering and injection system and predicting groundwater level conditions. The results of the numerical modelling, including sensitivity and uncertainty analysis has shown;

- The average annual dewatering volume is predicted to be up to 110 GL/a over the LoM period.
- The peak annual dewatering volume is predicted to be up to 168 GL/a (realistic requirement likely to be up to 150 GL/a).
- Maximum watertable drawdown along the Fortescue Marsh fringe[1] is predicted to be up to 1.7 m.
- Maximum watertable mounding along the Fortescue Marsh fringe is predicted to be up to 1.8 m.
- Injection of surplus water into suitable aquifers minimises the long term impacts of drawdown at the watertable.
- With the cessation of dewatering, groundwater level drawdown in the mining area decreases from over 50 m at the end of mining (2024) to about 5 m, after ten years (2034), and to about 3 m after 20 years (2044).

An eco-hydrological study (Equinox Environmental, 2012) has provided confidence that prolonged dry conditions and drawdown, of up to 3 m, will not significantly affect samphire survival and health. Other potential groundwater system impacts associated with the Cloudbreak Project water management strategy, such as disruption to the surface flow regime, watertable mounding (due to injection) and water quality changes, are also not predicted to be significant.

Modelling results suggest that the Cloudbreak water management scheme can operate independently. However, the adaptive management strategy of Cloudbreak would be strongly enhanced (enable greater flexibility to distribute injection) by adopting an integrated water management approach with Christmas Creek.

[1] Watertable measurements and predictions at the fringe of the Fortescue Marsh relate to monitoring locations CBFMM01_s to CBFMM08_s (excluding CBFMM03_s)

TABLE OF CONTENTS

EXECUTIVE SUMMARY 3

1. INTRODUCTION 11
   - 1.1 Scope of works 11
   - 1.2 Previous studies at Cloudbreak 12
   - 1.3 Previous studies at adjacent sites 14

2. EXISTING ENVIRONMENT 16
   - 2.1 Location 16
   - 2.2 Topography 16
   - 2.3 Climate 16
   - 2.4 Hydrology 17
     - 2.4.1 Regional Hydrology 17
     - 2.4.2 Localised/Site Hydrology 19
     - 2.4.3 Fortescue Marsh surface water balance 20
     - 2.4.4 Cultural significance 21
   - 2.5 Geology 21
     - 2.5.1 Stratigraphy, structure and mineralisation 21
   - 2.6 Hydrogeology 23
     - 2.6.1 Hydrostratigraphy 23
     - 2.6.2 Hydraulic Properties 26
     - 2.6.3 Hydrostratigraphic connectivity 26
     - 2.6.4 Groundwater Levels and Flow 29
     - 2.6.5 Groundwater Quality 31
     - 2.6.6 Density Driven Flow 32
     - 2.6.7 Groundwater Recharge 33
     - 2.6.8 Groundwater Discharge 33
     - 2.6.9 Hydrogeological setting comparison 33
   - 2.7 Flora and Fauna 34
     - 2.7.1 Flora and Vegetation 34
     - 2.7.2 Fauna 37
     - 2.7.3 Fortescue Marsh 37

2.8 Aboriginal heritage 38
2.9 Pastoral bore use 38

3. CLOUDBREAK OPERATIONS 40
3.1 Groundwater management strategy 40
3.2 Operations management 41
3.3 Operations performance summary 42

4. CONCEPTUAL HYDROGEOLOGICAL MODEL 43
4.2 Density driven groundwater flow system of the Upper Fortescue Valley 43
4.3 The Fortescue Marsh and peripheral shallow groundwater system 44
4.3.1 Flood phase 44
4.3.2 Inter-flood phase 44
4.3.3 Prolonged dry phase 45

5. GROUNDWATER MODELLING ASSESSMENT 48
5.1 Modelling objectives and scope 48
5.2 Numerical model construction 48
5.2.1 Numerical model complexity 48
5.2.2 Model software selection and code settings 48
5.2.3 Numerical mesh and numerical layers design 49
5.2.4 Model parameters 50
5.2.5 Boundary conditions for groundwater flow 51
5.2.6 Recharge 52
5.2.7 Evapotranspiration 54
5.2.8 Solute transport and density couple flow modelling 55
5.3 Model calibration 57
5.3.1 Initial conditions 57
5.3.2 Transient calibration 57
5.3.3 Calibration Summary 60
5.4 Water management simulations 61
5.4.1 Mine plan and water management strategy 61
5.4.2 Setup of numerical simulations 61
5.4.3 Generation of synthetic rainfall sequences 62

5.5 Model limitations 64
5.5.1 Heterogeneity of hydraulic parameters 64
5.5.2 Duration of dataset 64
5.5.3 Limited resolution in salinity distribution 64

6. GROUNDWATER MODELLING RESULTS 65
6.1 Predicted Results - Base Scenario 65
6.1.1 Predicted natural groundwater regime 65
6.1.2 Predicted dewatering and injection volumes 65
6.1.3 Predicted groundwater drawdown/mounding distribution 66
6.1.4 Predicted water demand and supply strategies 67
6.2 Numerical Model Sensitivity and uncertainty analysis 68
6.2.1 Sensitivity analysis of dewatering volumes 68
6.2.2 Sensitivity analysis of drawdown/mounding 70
6.3 Water balance analysis 71
6.4 Cumulative impacts 72
6.4.1 Marillana project 72
6.4.2 Roy Hill project 72
6.4.3 Christmas Creek project 72
6.5 Simulation of post-mining groundwater level recovery 75

7. CONCLUSION 76
7.1 Key Changes from (FMG, 2010d) 76
7.2 Summary 77
7.3 Future work 80

List of Tables

Table 1: **Previous groundwater investigations at Cloudbreak** 12
Table 2: **Previous groundwater investigations at Christmas Creek and other sites** 14
Table 3: **Average monthly temperature, evaporation and rainfall** 17
Table 4: **Cloudbreak Generalised stratigraphy** 22
Table 5: **Summary of geological and hydro-stratigraphic framework** 25
Table 6: **Hydraulic assessment results by aquifer and borefield** 28
Table 7: **Hydrogeological setting comparison** 34
Table 8: **Vegetation communities occurring within Cloudbreak** 35
Table 9: **Pastoral groundwater bores** 39
Table 10: **Water management objectives and strategies** 40
Table 11: **Conceptual model summary** 45
Table 12: **Simplified analytical water balance** 47
Table 13: **Model layers** 50
Table 14: **Initial model hydraulic parameters** 51
Table 15: **Numerical model boundary conditions** 51
Table 16: **Numerical model recharge zones** 52
Table 17: **Fortescue Marsh evaporation algorithm** 55
Table 18: **Solute transport parameters** 56
Table 19: **Solute transport boundary conditions** 56
Table 20: **Calibrated model hydraulic parameters** 58
Table 21: **Model water balance in the calibration period** 59
Table 22: **Model generated monthly rainfall data used for groundwater model predictions** 63
Table 23: **Model results – Base scenario** 66
Table 24: **Co-ordinates of the five key near-marsh monitoring locations** 67
Table 25: **Model water balance in prediction period (2014 to 2024) for Base, Dry and Wet scenarios** 71
Table 26: **Model results (abstraction volumes) from sensitivity study** 73
Table 27: **Model results (drawdown change) from sensitivity study** 74
Table 28: **Model results (mounding change) from sensitivity study** 74
Table 29: **Key assessment changes from** (FMG, 2010d) 76

LIST OF FIGURES

Figure 1: Location Plan 85
Figure 2: Site setting 87
Figure 3: Conceptual Chichester cross section 89
Figure 4: Historical rainfall 91
Figure 5: Baseline groundwater levels – Tertiary Detrital 93
Figure 6: Baseline groundwater levels (fresh water equivalence) – Marra Mamba Formation 95
Figure 7: Fortescue Marsh ponding event 97
Figure 8: Cloudbreak Water Types 99
Figure 9: Baseline E.C. – Tertiary Detritals 101
Figure 10: Baseline E.C. – Marra Mamba Formation 103
Figure 11: Airborne EM conductivity – Marra Mamba Formation 105
Figure 12: Airborne EM conductivity – watertable minus five metres 107
Figure 13: Fortescue Marsh conceptual section 109
Figure 14: Model domain and boundary conditions 111
Figure 15: Model stratigraphic section 113
Figure 16: Model Recharge Zones 115
Figure 17: Steady state calibration results: Measured v's model predicted groundwater levels 117
Figure 18: Transient calibration results: Measured v's model predicted groundwater levels 119
Figure 19: Hydrographs at five key locations for the base simulation without mining 121
Figure 20: Hydrographs at five key locations for the dry simulation without mining 123
Figure 21: Hydrographs at five key locations for the wet simulation without mining 125
Figure 22: Distribution of drawdown/mounding due to mining for the base simulation - 2014 127
Figure 23: Distribution of drawdown/mounding due to mining for the base simulation - 2015 129
Figure 24: Distribution of drawdown/mounding due to mining for the base simulation - 2016 131
Figure 25: Distribution of drawdown/mounding due to mining for the base simulation - 2017 133
Figure 26: Distribution of drawdown/mounding due to mining for the base simulation - 2018 135
Figure 27: Distribution of drawdown/mounding due to mining for the base simulation - 2019 137
Figure 28: Distribution of drawdown/mounding due to mining for the base simulation - 2020 139
Figure 29: Distribution of drawdown/mounding due to mining for the base simulation - 2021 141
Figure 30: Distribution of drawdown/mounding due to mining for the base simulation - 2022 143
Figure 31: Distribution of drawdown/mounding due to mining for the base simulation - 2023 145

Figure 32: Distribution of drawdown/mounding due to mining for the base simulation - 2024 147
Figure 33: Groundwater level change at the seven key monitoring locations for the base simulation 149
Figure 34: Groundwater level change at the seven key monitoring locations for the dry simulation 151
Figure 35: Groundwater level change at the seven key monitoring locations for the wet simulation 153
Figure 36: Hydrograph at CBFMM01_s, under natural and mining conditions for the Base, Dry and Wet simulations 155
Figure 37: Hydrograph at CBFMM02_s, under natural and mining conditions for the Base, Dry and Wet simulations 157
Figure 38: Hydrograph at CBFMM04_s, under natural and mining conditions for the Base, Dry and Wet simulations 159
Figure 39: Hydrograph at CBFMM05_s, under natural and mining conditions for the Base, Dry and Wet simulations 161
Figure 40: Hydrograph at CBFMM06_s, under natural and mining conditions for the Base, Dry and Wet simulations 163
Figure 41: Hydrograph at CBFMM07_s, under natural and mining conditions for the Base, Dry and Wet simulations 165
Figure 42: Hydrograph at CBFMM08_s, under natural and mining conditions for the Base, Dry and Wet simulations 167
Figure 43: Cumulative impact on groundwater levels 169
Figure 44: Fortescue Marsh Water Balance 171

LIST OF APPENDICES

Appendix 1: Historical Landsat data
Appendix 2: Geological cross sections
Appendix 3: Numerical model hydraulic property zones and layer thicknesses
Appendix 4: Numerical model calibration - Measured hydrographs at monitoring bores compared to those predicted by the calibrated model
Appendix 5: Hydrographs at selected key locations from all sensitivity simulations
Appendix 6: Distribution of drawdown/mounding and depth to groundwater predicted under dry and wet climatic simulations
Appendix 7: Groundwater level recovery after mine closure
Appendix 8: Effect of hydraulic property of backfilling materials on model predictions

1. INTRODUCTION

Fortescue Metals Group's (Fortescue's) Cloudbreak iron ore mine (Cloudbreak) is within the Pilbara region of Western Australia. Cloudbreak is located approximately 30 kilometres west of Fortescue's Christmas Creek mine, 80 kilometres south west of Nullagine and approximately 120 kilometres north of Newman (Figure 1). The Cloudbreak iron ore mine has been operating since 2008, and is currently approved to ship iron ore, via a rail link, from Port Hedland (Figure 1 and Figure 2).

About 90% of iron ore at Cloudbreak is below the watertable, and mine dewatering is undertaken to minimise water ingress into mining pits. Below watertable mining commenced in July 2008, current mine dewatering and associated water management activities are approved under Ministerial Statement 899 (MS899) granted in 2012[2], controlled action EPBC 2005/2205 granted in July 2006 and EPBC 2010/5696 granted in November 2012. Key characteristics of the project stated in MS899, controlled actions EPBC 2005/2205 and EPBC 2010/5696 and the recently approved applications under Section 45C and 46 of the *Environmental Protection Act 1986* (EP Act) limit groundwater abstraction to 100 GL/a and injection to 95 GL/a. Knowledge developed during operations has improved the understanding of the hydrogeological conditions. On this basis the Life of Mine (LOM) plan (FMG, 2010d) has been reassessed, identifying dewatering and injection requirements up to 150 GL/a. The level of groundwater impact, in the shallow alluvial aquifer, at the fringe or within the Fortescue Marsh is within the range predicted in the previous assessment (FMG, 2010d).

1.1 Scope of works

This report presents the updated detailed hydrogeological assessment for the proposed LOM plan. Specifically this document includes a description of;

- Site specific hydrogeological data and the conceptual model for the groundwater and surface water hydrology.
- The development of a numerical model.
- The groundwater abstraction and injection management strategy.
- The results of dewatering and injection simulations, including volumes and water level changes.
- The method and results of sensitivity and uncertainty analysis.

Revision of concepts, parameters and other changes from the previous assessment (FMG, 2010d) are highlighted through this document.

[2] MS899 supersede the conditions of Statement 721 which was published on 24th April 2006, changed on September 2005, 12th July 2010 and 10th June 2011.

1.2 Previous studies at Cloudbreak

Hydrogeological assessments undertaken both pre and post commencement of dewatering and injection operations at Cloudbreak are outlined in Table 1. These assessments have been used, in conjunction with those from adjacent sites (Christmas Creek) and regional knowledge (Section 1.3), to inform the conceptual hydrogeological understanding for this assessment.

Table 1: Previous groundwater investigations at Cloudbreak

Project/Reference	Scope	Outcomes
Hydrogeology report (Aquaterra, 2005)	• 2 test production bores. • Groundwater model developed. • Dewatering assessment conducted.	• Conceptual model and numerical model utilising 'average' Pilbara hydraulic parameters. • Predicted dewatering requirements of up to 12 GL/a over life of mine.
Hydrogeology assessment (FMG, 2009)	• To support change to Ministerial Statement. • Increase dewatering to 25 GL/a and injection to 18 GL/a. Included. • Review of short term dewatering and injection requirements. • Hydrological Impact assessment.	• Updated conceptual hydrogeology and short term dewatering requirements. • Key updates include significant increase of hydraulic conductivity parameters and inclusion of density coupling in groundwater flow modelling.
Geochemical Assessment (FMG, 2007)	• Measurement of groundwater quality parameters and sampling of groundwater from proposed mine dewatering borefield. • Chemical analysis of groundwater samples. • Assessment of likely changes to the groundwater composition and mineral precipitation due to mixing of water types, using aqueous geochemical modelling software PHREEQC. • Documentation of methodologies, results, conclusions and recommendations.	• Information on the borefield and aquifer geochemistry. • Precipitation of secondary minerals in the injection bore and the receiving aquifer is unlikely to be significant: calcite and dolomite were already oversaturated in the receiving aquifer. Si is unchanged, Gypsum was and remains after mixing with the injected water, under-saturated in the aquifer. • The potential for bio-fouling to occur is low, due to the presence of iron-precipitating bacteria, oxygen and ferrous iron.
Geochemical Assessment (MWH, 2009)	• Predicted geochemical interactions for re-injection of saline abstraction water into the saline Oakover Formation and in surface storage facilities. • Assessment of the potential for mineral precipitation with the PHREEQC geochemical model using 3 different scenarios.	• The degrees of saturation with respect to potential mineral precipitates are approximately the same for both the abstraction and injection zone groundwater. • The most likely mineral precipitates for the South Transfer Pond are Ca-Mg carbonates, amorphous silica, and ferric oxyhydroxide according to geochemical modelling results. • Geochemical model calculations for three scenarios predict that mixing of abstraction water with injection zone water (except brackish water) generally reduces the potential for precipitation of most carbonate, sulphate, and silica minerals (except Mn and Fe oxyhydroxides) and therefore limits potential for geochemical fouling.
Saline Injection Trial (FMG, 2010b)	• Assessment of a 6-month saline injection trial. • Summary of the operations, groundwater levels, water	• Proof of concept has been achieved. • Environmental impact consistent with predictions. • Injection of saline water has not impacted the upper, brackish aquifers except in isolated sites

Project/Reference	Scope	Outcomes
	quality data, and vegetation monitoring. • Hydrogeological assessment of these data, hydrogeological characterisation of the saline injection area, numerical model assessment. • Commitments assessment. • Compliance assessment.	thought to relate to bore construction. • Telemetry system control being developed. • Hydrogeological characterisation of the saline injection area and validation of the model in this area were limited due to limited aquifer response. • Progress in the assessment of clogging potential of saline reinjection.
Cloudbreak Triennial Aquifer Review (FMG, 2010c)	• Three year summary of groundwater abstraction, injection and monitoring. • Hydrogeological assessment of data. • A compliance assessment against the regulatory commitments.	Presentation of monitoring data and assessment to verify the conceptual hydrogeological model for the Cloudbreak site.
Cloudbreak FY11 Dewatering and injection program (FMG, 2013b)	• Groundwater abstraction, injection and monitoring. • Hydrogeological assessment of data. • A compliance assessment against the regulatory commitments.	• 98 production bores and 51 injection bores were active during the reporting period. • 24.9 GL abstraction during reporting period. • 14.2 GL injection during the reporting period. • No Class 2 trigger exceedances (environmental significant) were recorded.
Saline Injection Trial – Stage 2 Close Out Report (FMG, 2012a)	• Updated report to cover full length of saline injection trial and early operation. • Summary of the operations, groundwater levels, water quality data, and vegetation monitoring. • Hydrogeological assessment of these data, hydrogeological characterisation of the saline injection area, numerical model assessment. • Commitments assessment. • Compliance assessment.	• Injection has been demonstrated to be a feasible strategy for managing excess water. • Groundwater monitoring indicated a limited hydrogeological response to injection. • Operations will cause minimal impact (drawdown/mounding) to groundwater levels in the shallow aquifer at the Fortescue Marsh, predicted to be within the maximum permissible impact of <1m as set out in the PER document (FMG, 2010d). • Injected saline water has not impacted the upper, brackish watertable aquifers. • The primary clogging mechanism for injection bore has been identified as physical clogging by introduced sediment and debris.
Cloudbreak FY12 Dewatering and injection program (FMG, 2013b)	• Groundwater abstraction, injection and monitoring. • Hydrogeological assessment of data. • A compliance assessment against the regulatory commitments.	• 159 production bores and 53 injection bores were active during the reporting period. • 31.7 GL abstraction during reporting period. • 20.3 GL injection during the reporting period. • No Class 2 trigger exceedances (environmental significant) were recorded.
Cloudbreak Triennial Aquifer Review (FMG, 2013b)	• Three year summary of groundwater abstraction, injection and monitoring. • Hydrogeological assessment of data. • A compliance assessment against the regulatory commitments.	Presentation of monitoring data and assessment to verify the conceptual hydrogeological model for the Cloudbreak site.
Aquifer reviews	• As part of licencing conditions for the Cloudbreak 5C licence. Frequency FMG have produced a series of monitoring summaries and aquifer reviews: • Annual during the mine-	Descriptions of volumetric data (abstraction, injection, mine water use), groundwater level data and groundwater quality data.

Project/Reference	Scope	Outcomes
	construction phase (the 2006 and 2007 licence periods); • Quarterly and annual since dewatering operations commenced in mid-2008.	
Cloudbreak FY13 Dewatering and injection program (FMG, 2013b)	• Groundwater abstraction, injection and monitoring. • Hydrogeological assessment of data. • A compliance assessment against the regulatory commitments.	• 151 production bores and 48 injection bores were active during the reporting period. • 59.4 GL abstraction during reporting period. • 45.7 GL injection during the reporting period. • No Class 2 trigger exceedances (environmental significant) were recorded.
University of Western Australia (UWA). Ongoing research and investigation into the Fortescue Marsh.	Research projects, investigation works and publications into the dynamics and processes within and adjacent to the Fortescue Marsh, (Skrypek G., 2013).	• Fortescue Marsh is currently recharged by occasional floodwater. • Salt in the Marsh is concentrated by evaporation of rainfall. • Brackish waters mainly reflect modern recharge. • Saline water reflects mixing between modern and old waters. • Deep saline groundwater beneath Fortescue Marsh developed under different climatic regime and accumulated over the last 40,000 to 700,000-years.

1.3 Previous studies at adjacent sites

The conceptual understanding of the Cloudbreak hydrogeological setting has also been supported by extensive hydrogeological work undertaken at Fortescue's adjacent mine site, Christmas Creek, and other relevant regional studies. Table 2 summarises the works that have contributed to the regional geological and hydrogeological understanding of Cloudbreak, and the hydrological functioning of the Fortescue Marsh.

Table 2: Previous groundwater investigations at Christmas Creek and other sites

Project/Reference	Scope	Outcomes
Hydrogeology report (Aquaterra, 2004)	• Drilling (four 150mm ND test production bores). • Pumping tests (24 to 48 hour duration). • Develop a numerical model (based on steady-state calibration and hydraulic properties from other Pilbara sites).	• Marra Mamba Formation (MMF) hydraulic conductivity of 0.5 m/day. • Saline gradient toward Fortescue Marsh identified. • Dewatering requirement 1.15 GL/a for 60 metre deep pits. • Remote water supply needed to meet 11.4 GL/a demand. • No impact on vegetation or Fortescue Marsh groundwater anticipated. • Salinity increase through up-coning or ingression not anticipated.
Hydrogeology assessment (FMG, 2009)	• Drilling (14 production bores, three multi-level monitoring bores). • Pump test assessments.	• Improved regional-scale and mine-scale stratigraphic data. • Mineralised MMF hydraulic conductivities in the order of 10 to 200 m/day, therefore greater dewatering rates. • The Oakover Formation's presence and aquifer properties identified. • Cloudbreak-style water management solutions proposed.

Project/Reference	Scope	Outcomes
Bore Completion report (FMG, 2010)	• Drilling (10 test production bores, 12 multi-level monitoring bores). • Test-pumping (up to seven days duration). • SkyTEM geophysical survey. • Geochemical aquifer characterisation. • Numerical model development.	• Mineralised MMF hydraulic conductivities up to 311 m/day. • Oakover Formation hydraulic conductivities of similar magnitude to Mineralised MMF. • Variable connection between the Oakover Formation and Mineralised MMF; connection between these two units appears to be stronger than that at Cloudbreak. • Saline interface further defined from SkyTEM data; discrete saline pathways identified. • Cloudbreak-style water management solutions proposed.
Hydrogeological assessment in support of Fortescue's Christmas Creek API submission (FMG, 2010a)	• FEFLOW modelling. • Ongoing drilling and testing data.	• Natural watertable fluctuation at the fringe of Fortescue Marsh predicted to be up to 3m following large rainfall events. • Abstraction up 50 GL/a required to deliver the mine plan presented. • Watertable change due to mining was predicted to be in the order of 1 m.
Christmas Creek FY11 Dewatering and injection program. (FMG, 2013a)	• Groundwater abstraction, injection and monitoring. • Hydrogeological assessment of data. • A compliance assessment against the regulatory commitments.	• 29 production bores and 4 injection bores were constructed during the reporting period. • 0.9 GL abstraction during reporting period. • No injection during the reporting period. • No Class 2 trigger exceedances (environmental significant) were recorded.
Hydrogeological assessment in support of Fortescue's API submission (FMG, 2013e)	• FEFLOW modelling. • Ongoing drilling and testing data. • Updated mine plan and project expansion.	• Natural watertable fluctuation at the fringe of Fortescue Marsh predicted to be up to 3m following large rainfall events. • Abstraction up 110 GL/a required to deliver the mine plan presented. • Watertable change due to mining was predicted to be in the order of 2.3 m.
Christmas Creek FY12 Dewatering and injection program. (FMG, 2013a)	• Groundwater abstraction, injection and monitoring. • Hydrogeological assessment of data. • A compliance assessment against the regulatory commitments.	• 65 production bores and 15 injection bores where constructed during the reporting period. • 10.2 GL abstraction during reporting period. • 1.3 GL injection during the reporting period. • No Class 2 trigger exceedances (environmental significant) were recorded.
Vegetation dependence on shallow groundwater study. (Equinox Environmental, 2012)	Investigation into the impact of drawdown upon groundwater dependent vegetation.	Groundwater drawdown up to 3m, for prolonged periods of time, does not adversely impact the ability for samphire vegetation to acquire water.
Christmas Creek April 2013 Quarterly groundwater monitoring summary (FMG, 2013a)	Christmas Creek groundwater monitoring review for quarter (Feb 2013 to April 2013)	• 64 production bores and 21 injection bores were operational during the reporting period. • 9.5 GL abstraction during reporting period. • 4.6 GL injection during the reporting period. • No Class 2 trigger exceedances (environmental significant) were recorded.
Christmas Creek FY13 Dewatering and injection program (FMG, 2013a)	• Groundwater abstraction, injection and monitoring. • Hydrogeological assessment of data. • A compliance assessment against the regulatory commitments.	• 73 production bores and 29 injection bores were constructed during the reporting period. • 34.4 GL abstraction during reporting period. • 17.4 GL injection during the reporting period. • No Class 2 trigger exceedances (environmental significant) were recorded.

2. EXISTING ENVIRONMENT

2.1 Location

The Cloudbreak project area is located in the eastern Chichester Range within an escarpment that gently slopes down to the Fortescue Marsh to the south (Figure 1). The Cloudbreak mine site is located approximately 30 kilometres west of Fortescue's Christmas Creek mine, 80 kilometres south west of Nullagine and approximately 120 kilometres north of Newman (Figure 1).

2.2 Topography

The regional topography is dominated by the Chichester Range (immediately to the north) and Hamersley Range to the south. These features are separated by the Fortescue Marsh, which forms the terminating point for the Upper Fortescue River catchment. The Upper Fortescue River flow northwards from Ethel Creek Station and then northwest past Roy Hill Station, before entering into Fortescue Marsh on its eastern margin.

The topography of Cloudbreak is gently sloping from north to south, with a relief ranging from 500 to 600 m AHD in the Chichester Ranges and 400 to 450 m AHD in the Fortescue Valley. The Chichester Range and the major drainage system of the Upper Fortescue catchment both trend west-northwest to east-southeast.

2.3 Climate

The climate of the Pilbara region is classed as subtropical to dry being, characterised by very low rainfall, high daytime temperatures in summer and low winter minima (Gentilli, 1972). The region is defined by two distinct seasons; a dry winter season and a wet summer season. Rainfall during summer is typically associated with tropical cyclones and local thunderstorms. Winter rains are infrequent, with typically one or two falls of 20 to 30 mm per year. The average annual rainfall is around 320mm per year. Annual pan evaporation is about 3500 mm (Bureau of Meteorology, 1977).

Monthly average temperature, rainfall and evaporation data for the region are presented in Table 3. Rainfall data recorded at Cloudbreak and for BoM site at Newman are presented in Figure 4.

Normal maximum temperature ranges are 35 to 40 degrees Celsius (^{o}C) in summer and 24 to 28 ^{o}C in winter. Most summer rainfall is from scattered thunderstorms and occasional tropical cyclones.

For the period 1907 to 2012, the mean annual rainfall recorded at Bonney Downs (Site 004006), Figure 1, was 310mm, compared to 406mm over the last 10 years (2002 to 2012). Five of the

last ten years have recorded annual rainfall in excess of 400 mm, with only two years recording less than 200mm.

Table 3: Average monthly temperature, evaporation and rainfall

Month	Mean temperature (C)[3]		Average rainfall (mm/month)		Cloudbreak rainfall (mm/month)[4]		Pan evaporation (mm/month)[5]
	Daily max	Daily min	Roy Hill[6]	Bonney Downs[7]	2011	2012	
Jan	39.5	25	45	57.2	95.7	409.1	390
Feb	37	23.9	58	77	178	13	310
Mar	35	21.5	45	40.7	44	42.5	290
Apr	31.7	17.3	22	19.6	29	1.4	205
May	27.3	11.6	19	18.1	17	0	138
Jun	23.1	6.8	18	14.2	17.5	0	100
Jul	23	5.9	11	14.9	22.9	0	110
Aug	25.8	7.5	6	7.7	0	0	165
Sep	30.5	11.8	2	3.4	0	0	230
Oct	35	17.2	5	4.9	0	9	315
Nov	37.4	20.6	8	10.5	55.2	82.75	380
Dec	38.9	23.6	24	37.4	13	0	405
Annual:	32	16.1	261	310	472.3	557.75	3038

2.4 Hydrology

2.4.1 Regional Hydrology

The Chichester operations are located in the vicinity of the Fortescue Marsh in the upper Fortescue River catchment. 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 between December to April and can produce very large runoff events. The period between July to November typically has relatively low rainfall, although significant runoff events during this time can occur.

The Goodiadarrie Hills, about 60 km east from the town of Wittenoom, effectively cut 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 Marsh receives drainage from the upper Fortescue River catchment. The alluvial outwash fan from the

[3] Bureau of Meteorology, Newman Station, 1971-2010
[4] Cloudbreak rainfall data, recorded on site by Fortescue
[5] Interpolated from Bureau of Meteorology 1961-1990 spatial evapotranspiration dataset
[6] Bureau of Meteorology, Roy Hill Station 0050523, 1961-1990
[7] Bureau of Meteorology, Bonney Downs Station 004006, 1907-2012

Weeli Wolli Creek system abutting the Goodiadarrie Hills is believed to be partially responsible for obstructing the Fortescue River and forming the Fortescue Marsh.

The Fortescue Marsh forms an extensive intermittent wetland (located on the floor of the Fortescue Valley) occupying an area around 100 km long by typically 10 km wide. The Fortescue Marsh is listed in the directory of Important Wetlands (Env, 2001) and is listed by the Department of Environment and Regulation (DER) as a Priority 1 Priority Ecological Community. The Fortescue Marsh has an elevation of around 400 m AHD. To the north, the Chichester Plateau rises to over 500 m AHD, whereas to the south the Hamersley Range rises to over 1,000 m AHD. Following significant rainfall events, runoff from the upper Fortescue River catchment (approximately 31,000 km^2) drains to the Fortescue Marsh. For the smaller runoff events, isolated pools form on the Marshes at the main drainage inlets, whereas for the larger events the whole marsh area may flood.

On the southern and northern flanks of the Fortescue Valley, numerous creeks discharge to the Fortescue Marsh. Rainfall runoff from the valley sides initially drains down gradient as overland flow before concentrating in defined flow channels. In this process, surface retention, vegetation, infiltration and other mechanisms absorb water from the runoff stream. In steep areas, the runoff processes are rapid with relatively low losses, and defined drainage channels are typically in close proximity. In the lower slope areas, the runoff processes are slow with relatively higher losses and greater distances 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 defined, braided, or may even completely disperse in flat areas. In these reducing slope channels, runoff tends to overspill 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. These are dependent on seepage water provided by the overland flow process. In these areas, the overland flow process has been termed sheet-flow. Conversely, the Fortescue River, Weeli Wolli Creek, and other main channels entering the Marshes typically support Eucalyptus woodlands on their banks and floodplains.

Surface water runoff to the Fortescue Marsh is of low salinity and turbidity, though the runoff turbidity significantly increases during peak periods of flooding. Following a significant event that floods the whole marsh area, the ponded water may be over 4 m deep in the lower elevation marsh areas. Water stored on the Fortescue Marsh 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.

2.4.2 Localised/Site Hydrology

Surface water flows at the Chichester Operations have previously been characterised as one of several modes, summarised as follows:

- Hillslope Runoff. Hillslope runoff zones are located in the portion of catchments where the majority of runoff is contained within small creeks, broad swales or gullies. Naturally, flows are generally convergent which concentrate flows, increases velocities, promotes scour and enhances channel formation. Catchment sizes are usually small but can be larger in cases where the terrain is flat and velocities are insufficient to maintain well defined channels
- Channel Flow. Channel Flow zones are located in the portion of catchments with large channels and adjacent floodplains. These zones are associated with large catchments that predominantly drain the steep areas of the Chichester Range rather than the low relief terrain closer to the Fortescue Marsh. Large convergent flows, high velocities and large, well defined channels are typical of these creeks. Smaller, more frequent flows are mostly confined to the channel while larger and less frequent flood flows break out onto the adjacent floodplain. These zones can be identified using topographic information and vegetation patterns in aerial photos. Channels are usually devoid of vegetation due to bed load movement during flood events. Vegetation on the adjacent floodplains is maintained either by periodic inundation or has rooting depths sufficient to access the superficial fresh aquifer replenished by more frequent smaller flows.
- Diverging Flow. Diverging flow zones are located in the portion of catchments where channel flow has become dispersed, leading to a loss of channel form. The transition from channel flow to diverging flow normally occurs on the low relief terrain after large rivers have discharged from the Chichester Ranges. The distance that the channel form is maintained is proportional to the slope of terrain and the size of the flows generated by a catchment (i.e. the greater the flow, the more well defined the channel is further downstream). Banded grove-intergrove vegetation patterns typical of sheet flow areas are not normally found downstream of areas where diverging flows intersect with sheet flow zones. Sheet flow zones form in ‘fan’ like terrain.
- Sheet flow. Sheet flow zones form in areas where overland flow moves down slope while maintaining a broad shallow front. This is the initial hillslope response to infiltration excess prior to channel initiation. Channel initiation is dependent on a threshold level of stream power, controlled in part by the extent of flow convergence and gradient. There are many examples in the study area where the terrain has been formed by remnant alluvial fans. These areas do not promote convergence of flows and are relatively flat, causing sheet flow zones to be maintained over large areas. The banded Mulga (Acacia aneura) formations common throughout the study area, are part of an ecological response to the sheet flow patterns.

Some areas, including those closer to the shore of the Marsh, may exhibit one or more of these characteristics.

The Cloudbreak mining footprint is typically located in the channel flow and diverging flow zone. None of the Cloudbreak operations are located within either the Hillslope runoff or Sheetlow Zones.

2.4.3 Fortescue Marsh surface water balance

In June 2012 Worley Parsons prepared the Fortescue Marsh Catchment Water Balance Study (Worley Parsons, 2012). As part of this study a water balance model was constructed to assess:

- Rainfall directly on the water surface of the Fortescue Marsh
- Runoff inflows to the Fortescue Marsh
- Evaporation losses from the water surface of the Fortescue Marsh.

A daily rainfall runoff model was established and used to estimated surface runoff into the Marsh. There are four stream flow gauging stations within Weeli Wolli Creek and one stream flow gauging station on the Fortescue River. A rainfall runoff model was established and calibrated for each of these catchments. These gauging stations are all located to the south of the Fortescue Marsh in hilly terrain. The calibrated model parameters were found to be similar for each of these gauging stations.

Median parameters from these gauged catchments were applied to the ungauged catchments draining the Chichester East Hamersley Ranges, which were considered to have similar terrain and hydrologic properties. These computed flows were input to the water balance model. The gauged flows for Weeli Wolli Creek (measured at Waterloo Bore) were also entered into the water balance model. (Note that Waterloo is located approximately 30 km south of the Marsh and Weeli Wolli Creek traverses an alluvial fan between Waterloo and the Marsh incurring significant transmission losses during low flows. However, during major inflow events it was considered that transmission losses would be minor.)

The gauging station on the Fortescue River is located at Newman, just upstream of Opthalmia Dam which was constructed in 1981. Opthalmia Dam has a storage capacity of 32 GL, and has only overflowed three times since construction. There is no stream flow gauge downstream of Opthamia Dam and so flows downstream of the dam were estimated by use of the Source Catchments model[8] (Worley Parsons, 2012). This model utilized observed stream flows at Newman and then simulated the storage behaviour of the dam to compute the spills which were then entered into the water balance model.

The water balance model was run for the period from 1/12/1984 to 30/04/2011 for the natural pre-development scenario with no mines at Cloudbreak, Christmas Creek or Roy Hill and with the remainder of the catchment in current conditions in place. Figure 44, shows the annual

[8] Source Catchments is a rainfall runoff modelling package developed by eWater CRC

volume of water entering the Fortescue Marsh for this scenario. Total annual flows into the Fortescue Marsh have been predicted to range between <50 GL/a to 1400 GL/a depending on climatic variation, (Worley Parsons, 2012)

2.4.4 Cultural significance

Semi-permanent water bodies along the shores of the Fortescue Marsh are culturally significant areas. These water bodies, known as Yintas (Goode, 2009), are located at low points in the surface topography of the marsh. Each Yinta is associated with local catchments that drain from the Chichester Range.

Aboriginal heritage surveys associated with the Chichester Range operations (Chichester Range operations refer to mining activities at both the Cloudbreak and Christmas Creek mine sites) have been undertaken since late 2003.

2.5 Geology

The main iron ores of the Hamersley Province are hosted with in the Archean to Palaeoproterozoic volcanic and sedimentary sequence of the Mount Bruce Supergroup (MBS). The MBS spans a time interval of over 400 million years (Ma), from greater than 2770 Ma to near 2350 Ma. The MBS rests unconformably on 3.50 to 2.80 billion year old (Ga) granitoids and greenstones that occupy the northern half of the Pilbara Craton. The MBS comprises late Archean metasediments and metavolcanics of the Fortescue Group, unconformably overlain by early Proterozoic metasediments of the Hamersley Group, which in turn are conformably overlain by siliclastics, carbonates and basalts of the Turee Creek Group.

This section describes the geology of the north eastern margin of the basin, which is directly relatable to the Cloudbreak mine.

2.5.1 Stratigraphy, structure and mineralisation

The local geology is dominated by the Fortescue Group and the lower part of the Hamersley Group, the Marra Mamba Formation (MMF). The mineralisation of the Chichester Range is confined to the Nammuldi Member, the lowermost unit of the MMF, overlying the black shales of the Jeerinah Formation at the top of the Fortescue Group. Beneath the Fortescue Valley the MMF is conformably overlain by the Wittenoom Formation of the Hamersley Group.

The MMF (and Wittenoom Formation where present beneath the Fortescue Valley) is unconformably overlain by younger Tertiary to Quaternary deposits. The Oakover Formation comprises a sequence of lacustrine carbonate, silcrete and mudstone rocks that have been deposited in the palaeodrainage of the Fortescue Valley. The Fortescue Valley is covered by a thick (up to 50 m) blanket of Tertiary colluvial scree slopes (close to the range) and flood plain alluvial sediments. A summary of the generalised stratigraphy is presented in Table 4.

Table 4: Cloudbreak Generalised stratigraphy

Age	Group/Formation/Member			Stratigraphy Code[9]	Stratigraphy Description	Geological Description
Cenozoic	Tertiary alluvium			Ta	Tertiary alluvium	Variable clast composition
	Tertiary detritals			Tdi	Tertiary detrital	Immature
				Tds		Semi-mature
				Tdm		Mature
	Tertiary Clay			Te	Tertiary clay	Layer forms semi aquitard above the Oakover Formation
	Oakover Formation			To	Oakover	Calcrete, silcrete and calcareous sediments
Unconformity						
Archean	Hamersley Group	Hardcap		Hc	Hardcap	Commonly vuggy hard 'ore' with moderate GGM or VGH)
		Wittenoom Formation		WD	Dolomite	Varies between fresh to fractured and/or weathered
		Marra Mamba Formation	Nammuldi Member	MuX	Ore Body	Bedded iron mineralisation, Goethitic & hematitic shales, chert and BIF. Ore body aquifer
	Fortescue Group	Jeerinah Formation	Roy Hill Shale	Jr	Roy Hill Shale	Commonly leached kaolonitic or black shale when fresh
				Fj	Jeerinah Formation	Dolomites, volcanics, sandstones, conglomerates

Regionally, the Chichester Range has gentle dips, usually less than 5°S, marking the onlap of the Hamersley Basin onto the Pilbara Craton. However, the gentle regional southerly dip of the Nammuldi Member at Cloudbreak has been offset by north-south to northeast-southwest trending faults. This is further overprinted by low amplitude (<20 m), long wavelength (200 to 800 m), north-south to northeast-southwest trending and south southwest plunging folds. This folding is interpreted to be the result of waning phases of deformation in the underlying Pilbara Craton (Hannon, 2005) and (Thorne, 2008).

Small amplitude folds developed at Christmas Creek, and elsewhere along the Chichester Range, have influenced both the development and preservation of mineralisation. The formation of high-grade ore is controlled by northeast-southwest trending faults and folds. Synclines appear to have focused supergene fluids resulting in their preferential mineralisation compared to adjacent anticlines. Subsequent erosion, controlled in part by the same structures, led to the broad stripping of anticlines and also the local removal of synclines along drainage channels.

[9] Stratigraphy codes defined in Table 4 represent Fortescue's interpretation and nomenclature.

The majority of mineralisation developed in the Chichester Range occurs as a sub-horizontal sheet of typical supergene martite-goethite and martite-ocherous goethite enrichment, overprinting hypogene microplaty hematite, which locally persists below the martite-goethite sheet. Hypogene enriched microplaty hematite mineralisation is structurally controlled, while supergene enriched mineralisation is very extensively developed as a sheet continuing for kilometres under recent cover. The majority of the mineralisation is typically a mixture of goethite, martite and hematite in varying amounts, similar to other Marra Mamba ores in the Hamersley Basin.

2.6 Hydrogeology

Groundwater dynamics in the Cloudbreak area are strongly controlled by stratigraphy, topography, mineralisation, structure and density (related to groundwater salinity). This section provides a description of the hydrogeology with consideration for hydraulic characteristics, groundwater recharge, throughflow, storage, discharge, quality and density. A conceptual hydrogeological cross section is provided in Figure 3

2.6.1 Hydrostratigraphy

The main hydrostratigraphic units and their characteristics are described below and are summarised in Table 5. A major finding after the submission of the previous PER report (FMG, 2010d) is the widespread existence of Tertiary clay, which overlies the Oakover Formation and functions as an aquitard between the Oakover Formation aquifer and the shallow aquifer.

Jeerinah Formation (Roy Hill Shale)

The Roy Hill Shale is generally considered to have low transmissivity; however permeability can be enhanced along the interface with the overlying Marra Mamba Formation (MMF) and predominantly north east to south west orientated fault zones. Additionally, a number of stratigraphic horizons within the Roy Hill Shale (located north of the MMF outcrop) have been found to have moderate permeability associated with bedded cherts which have undergone brittle deformation. Groundwater quality in the Roy Hill Shale, beneath the ore body, is generally saline to hypersaline.

Marra Mamba Formation

The distribution of permeability and storage in the MMF is influenced by lithological characteristics, faulting and secondary geochemical processes. In the upper part of the Nammuldi Member, supergene mineralisation processes have formed a broad sub-horizontal aquifer with high permeability and storage characteristics. Although this alteration has developed over a large lateral extent of the Chichester Ranges, later erosion (by drainage features) of the anticlines and in some places synclines has resulted in lateral discontinuity of the aquifer. The supergene zone diminishes to the south, which also results in lower permeability and storage.

The lower part of the Nammuldi Member is dominated by chert and has not undergone the same alteration to form an extensive aquifer. Zones of high permeability are associated with fracture zones, which based on regional structural interpretation, are dominantly developed in a north east to south west orientation. Permeability is expected to persist more extensively to the north and south along these features than the aquifer associated with the supergene mineralisation of the Nammuldi Member. Structural features that have been the focus of sub-vertical hypogene mineralisation can display higher permeability.

Groundwater quality is generally brackish in the upper part of the Nammuldi Member and becomes more saline within the lower part.

Wittenoom Formation

The Wittenoom Formation conformably overlies the MMF in the area of the Fortescue Valley. It comprises calcitic dolomite, with minor interbedded chert and shale and volcaniclastic sandstone. Lithological logging suggests that where fresh, it is crystalline, massive in nature, and has low intergranular permeability. Local permeable zones may be developed along fault zones.

Tertiary Calcrete and Silcrete (Oakover Formation)

The Oakover Formation is approximately 20 m thick and continuously developed beneath the Tertiary clay at about 50 metres below ground level (m bgl). The Oakover Formation onlaps with the MMF at its northern extent and extends beneath the Fortescue Marsh to the south, where it overlies the Wittenoom Formation.

Within the project area the Oakover Formation consists of calcretised and silicified carbonate formation, which typically has karstic characteristics that result in secondary permeability and enhanced storage properties. It is poorly developed or absent to the east, towards the Roy Hill deposit.

Regionally the Oakover Formation is described as a sequence of Tertiary lacustrine carbonate, silcrete and mudstone rocks deposited in the palaeodrainage of the Fortescue River Valley (Clout, 2011). Fortescue's definition for the Oakover Formation may only comprise a section of the larger formation identified within the Fortescue Valley.

Tertiary Clay

Beneath the mixed Tertiary detritals and alluvial sedimentary sequence within the Fortescue Valley, there is a clay layer. The homogeneous nature of the clay suggests deposition within a lacustrine environment. It is typically 10 to 20 metres thick and continuous across the Christmas Creek and Cloudbreak project areas. At its northern limit, the Tertiary clay overlies the MMF (Figure 18). The clay is considered an aquitard that results in confining conditions for the Oakover Formation.

Evidence of significant clay layers has been identified from drilling completed within and to the south of the Fortescue Marsh by Rio Tinto Iron Ore, UWA and others (Skrypek G., 2013).

Tertiary Detrital and Alluvium

Detrital and alluvial deposits cover the Tertiary clay, MMF and Fortescue Valley. Hydraulic characteristics are often variable due to the nature of deposition in alluvial fans and flood plains. Areas of low to moderate yield and storage are associated with chert and reworked MMF gravels that have been deposited proximal to source. More distal deposits comprise clayey (variable) magnetite pisolitic gravels that have lower permeability. Recent work, (Equinox Environmental, 2012), has shown the importance of varying conditions of the detritals and alluvium deposits in controlling near surface and groundwater processes, in particular, at the Marsh fringe.

- Tertiary alluvium– variable hydraulic conductivity and storativity as influenced by depositional heterogeneity, substrate geology and particle size distribution. Aquifers within the Tertiary depositional sequence are semi-confined to unconfined. Fortescue bore records show that the watertable at the fringe of the marsh fluctuate in the order of 2 to 3 m under natural conditions, and are responsive to significant rainfall events. However, the response of shallow watertable to rainfall rapidly diminish moving further north from the marsh boundary.

- Tertiary Detritals - thick unit of detrital and alluvial sediments with moderate permeability. Basal layers are of low permeability layer with significant clay lenses prominent in the deeper profile near the Fortescue Marsh. These overlie the Oakover Formation, and at their northern extent onlap the Marra Mamba Formation. These layers are believed to impede vertical water transfer between the surficial and deeper groundwater systems.

Table 5: Summary of geological and hydro-stratigraphic framework

Fortescue Stratigraphy Code	Stratigraphy Description[10]	Hydrogeological Characteristics
Ta	Tertiary alluvium	Detrital and alluvial sediments, ranging from proximal cobble to pebble, alluvial fans to distal silty and clayey flood plain deposits. Basal layers can have well-rounded hematite and magnetite pisoliths in clay matrix.
Tdi	Tertiary detrital	
Tds		
Tdm		
Te	Tertiary clay	Consolidated red-brown clay, highly plastic, cohesive. Forms aquitard overlying Oakover Formation
To	Oakover Formation	Zones of re-precipitated calcium carbonate and silica developed within Fortescue Valley. Can be karstic creating zones of high permeability. Confined aquifer conditions developed beneath Tertiary clay.
WD	Wittenoom Formation	Generally massive dolomite, localised permeability associated with fault zones. Upper zone generally weathered and clay-dominant. Conformably overlies the MMF, only present to the south of the mineralised MMF
Hc	Hardcap	Cherty shale and ferruginous chert, intrusive hypogene hematite deposits and post-depositional supergene geochemical alteration and iron

[10] Refer to Table 4

Fortescue Stratigraphy Code	Stratigraphy Description[10]	Hydrogeological Characteristics
		enrichment zones. Noticeably vuggy and porous, high porosity and permeability. Generally thin and discontinuous unit.
MuX	MMF	– Hematite zones; massive, friable, foliated, intrusion and precipitation of iron rich fluids along fault zones. Interpreted to have high porosity (micro-scale), but tends to have low to moderate permeability.
	Mineralised MMF	Goethite, martite and hematite zones; secondary alteration and mineralisation. Complex overprinting of primary deposits by secondary processes. Geochemical alteration (iron mineralogy transformations) resulting in iron enrichment zone, related to hydration and dehydration. Enhanced 'secondary' porosity and moderate to high permeability. Very high permeability zones generally only semi-continuous.
	MMF lower (non-mineralised)	Ferruginous bedded chert and iron formation, generally very low storage and low permeability with higher permeability associated with NE – SW fault zones
Jr	Royhill shale	Upper weathered zones can have moderate permeability. Lower, unweathered zones represent a thick unit with generally low permeability. Enhanced permeability zones associated with cross cutting fractures and cherty interbeds.

2.6.2 Hydraulic Properties

The results of hydraulic testing from previous field programs are summarised in Table 6. Table 6 provides summary data for borefields and hydrostratigraphic units. These data are derived from ongoing operations being referenced in (FMG, 2013), (FMG, 2013a), (FMG, 2013b), (FMG, 2013e) and (FMG, 2010d).

2.6.3 Hydrostratigraphic connectivity

Knowledge of connectivity between hydrostratigraphic units is of particular importance for this assessment. The significance and interpreted nature of the connectivity between the hydrostratigraphic units is described below:

Tertiary alluvium and Tertiary Detritals

The Tertiary alluvium and Tertiary Detritals contain a significant proportion of clay sediments deposited in overlapping lenses such that the vertical conductance between the watertable and groundwater occurrence in the deeper parts of the Tertiary detritals is low.

Tertiary Detrital (detrital) and Oakover Formation

The presence of the thick clay layer (Tertiary clay) between the Oakover Formation and the Tertiary detritals is observed[11] to limit fluxes between these aquifer systems. This is significant as the Oakover Formation will be subject to pressurisation and depressurisation at different stages during the LOM, and the low connectivity due to the presence of the clay layer will inhibit manifestation of pressure changes in overlying detrital and alluvial aquifer zones.

Tertiary Detrital (alluvium and detrital) and Mineralised MMF

Tertiary detritals/alluvium overlying the MMF are saturated and therefore require dewatering where the mine plan requires access to the ore body. They also represent a store of water in water supply areas. The Tertiary detritals/alluvium has low hydraulic conductivity, and is often separated from the underlying MMF by the presence of Tertiary clay, making it inefficient to abstract groundwater directly from the aquifer; as such, there is a reliance on leakage being induced by abstracting from the underlying MMF.

Dewatering operations, at both Cloudbreak and Christmas Creek, has shown that leakage from the Tertiary detritals and alluvium overlying the ore body occurs in response to lowering the piezometric head in the MMF.

Oakover Formation and Mineralised MMF

The connectivity between the mineralised MMF and Oakover Formation is an important factor in determining the flux of high salinity groundwater to the mine pits and abstraction borefields. The connectivity between these aquifers may be direct, in areas where the Oakover Formation overlies the mineralised MMF; or indirect via NE-SW orientated fracture zones through the Wittenoom Formation and unmineralised MMF. The connectivity, as assessed by investigations and piezometric response to dewatering, is variable with the possibility of indirect pathways being the more prevalent means of connection. Greater connection in some areas, are considered a factor contributing to increased dewatering rates in this assessment.

[11] Injection of saline water into the Oakover Formation has pressurised the Oakover aquifer. This has resulted in an increase in monitoring bore water level in the Oakover Formation. This rise in water level has not been observed in monitoring bores screened across the watertable within the Tertiary alluvium at coincidental locations.

Table 6: Hydraulic assessment results by aquifer and borefield

Aquifer	Area	B[12] (m)	K[13]		T[14]		S[15]		Number of bores tested	Test Duration Range (mins)	Source
			Range (m/d)	Average (m/d)	Range (m^2/d)	Average (m^2/d)	Range	Average			
Marra Mamba Formation[16]	Hillside West	2 to 50	2 to 1055	140	70 to 20000	3115	$6.2e^{-4}$ to $1.8e^{-1}$	4.53e-02	52	360 to 2880	(FMG, 2010d) (FMG, 2013a) (FMG, 2013b)
	Hillside East	12 to 48	2 to 214	37	33 to 8145	1101	$1.2e^{-4}$ to $5e^{-4}$	6.52e-2	22	90 to 2880	
	Cockatoo Pit	28 to 35	1 to 42	17	30 to 1400	560	$4.2e^{-5}$ to $7.8e^{-2}$	2.00E-02	3	1440	
	Cocos Pit	16 to 60	0.2 to 160	37	8 to 4600	1200	$2.7e^{-5}$ to $8.7e^{-2}$	6.70E-03	39	360 to 2160	
	Brampton	10 to 60	2 to 770	120	14 to 11500	3600	$2.4e^{-4}$ to $8.9e^{-2}$	8.66e-03	133	60 to 2880	
	Hook Pit	11 to 42	2 to 500	90	7 to 10000	3400	$1.48e^{-10}$ to $8e^{-2}$	6.1E-3	126	150 to 14400	
	Hayman Pit	8 to 50	4 to 220	10	7 to 7500	3500	$7.9e^{-7}$ to $6.3e^{-3}$	2.5e-03	40	360 to 2880	
	Hamilton	9 to 36	2 to 38	14	11 to 1100	520	$2.7e^{-4}$ to $2.0e^{-3}$	1.00E-03	33	720 to 2880	
	Gnarloo Pit (Long Pit)	9 to 36	2 to 500	130	30 to 10000	2760	$1.4e^{-4}$ to $4.2e^{-1}$	3.45E-2	84	180 to 2880	
Tertiary Detritals	Regional	5 to 20	0.2 to 8	4	1 to 210	130	-	-	3	1440	(Aquaterra, 2005) (FMG, 2010d)
Oakover Formation	Saline reinjection area	8 to 48	81 to 1333	380	2480 to 25000	6805	$1.7e^{-4}$ to $8.0e^{-2}$	2.11e-4	41	120 to 720	(FMG, 2010d) (FMG, 2013a) (FMG, 2013b)

[12] Aquifer thickness (m)
[13] Hydraulic Conductivity (m/day)
[14] Transmissivity (m^2/day)
[15] Aquifer stativity (dimensionless) (not assessed where no monitoring bore data are available)
[16] All includes both the mineralised and un-mineralised MMF. However, the bore may not screen the entire non-mineralised sequence.

Roy Hill Shale and MMF

The degree of hydraulic connection between the Roy Hill Shale and the MMF is important to understand with respect to geotechnical issues and the potential for up-welling of saline water. Observations from operations and investigations at Cloudbreak have shown that abstraction from the MMF does induce depressurisation of the Roy Hill Shale during the latter stages of the dewatering program. It is conceivable that decreasing the overlying pressure in the Roy Hill Shale by dewatering and mining may result in the opening of fine fractures and facilitate greater vertical leakage of water. The Roy Hill Shale has a typically low storage and contributing only a small volume of groundwater though upward leakage.

2.6.4 Groundwater Levels and Flow

Baseline[17] (2007) groundwater levels in the Tertiary detrital and the MMF[18] measured in hydraulic head[19] and freshwater equivalent head[20] , respectively, are shown in Figure 5 and Figure 6. Groundwater gradients are relatively shallow from the mining area to the Fortescue Marsh in both the Tertiary detrital and MMF. When measured piezometric head in the hypersaline Oakover Formation are converted to fresh water equivalent a pressure gradient can be observed in the opposing direction to the topographical driven gradient from the Chichester Ranges into the Fortescue Valley. Isotopic analysis (Skrypek G., 2013) has suggested the dominant process at the Marsh fringe is vertical with a low horizontal component of groundwater flow.

Seasonal fluctuations in water levels are observed to vary across the site and in different hydrostratigraphic units. Figure 7 shows ponding of water observed across the Fortescue Marsh, following a significant rainfall event in late February 2009[21], and the locations of reference monitoring bores from the Cloudbreak monitoring network and two University of Western Australia research sites[22]. Interpretation of this data and operational monitoring provides the following conclusions:

- Cloudbreak and Christmas Creek monitoring bore data, for all hydrostratigraphic units, display a general groundwater level recession between 2006 and 2010, related to below-average rainfall.

[17] Baseline data taken prior to dewatering activities commenced in 2008.
[18] The Oakover Formation and MMF are considered as a single unit for the purpose of generating contours shown in Figure 6.
[19] A combined measure of the elevation and the water pressure at a point in an aquifer which represents the total energy of the water
[20] Hydraulic head is dependent on density (salinity) of water. To compare one or more hydraulic heads they need to be standardised to a constant density. This is usually to their fresh water head, i.e. the hydraulic head if all water bodies had a salinity and hence density of fresh water.
[21] Interpreted from Landsat imagery (Appendix 1).
[22] Data is available for the Cloudbreak and UWA monitoring bores, shown on Figure 7, from 2006 onwards.

- Groundwater recession between 2006 and 2007 was approximately 1 m and approximately 0.5 to 1 m from 2007 to early 2010, within the Tertiary detrital/alluvium. The recession trend was punctuated by a rainfall event in early 2009 and subsequent groundwater recharge.
- Since 2010, a number of large rainfall events resulted in variable Tertiary detrital/alluvium water levels across Cloudbreak and Christmas Creek. Since 2010, Tertiary detrital/alluvium groundwater levels adjacent to the Fortescue Marsh have shown annually fluctuations of up to 2m.

Ponding on the Fortescue Marsh, related to high intensity rainfall, is directly related to Tertiary alluvium groundwater level responses observed within and at the fringe of the Fortescue Marsh. The control exerted, on groundwater levels, by ponding within the Marsh is reduced with distance from the Marsh. These trends are supported by the following observations:

- Significant rainfall and flooding of the Fortescue Marsh between January and March 2006 (380 mm rainfall recorded at Newman) resulted in the cessation of the long-term Tertiary detrital/alluvium groundwater level recession.
- Subsequent smaller rainfall events resulted in a groundwater level rise (130mm) between March and April 2007. Notably, Tertiary alluvium groundwater level increases were only observed in monitoring bores located adjacent to the Fortescue Marsh.
- Tertiary alluvium groundwater level increases in the order of 0.5 m, adjacent to the Fortescue Marsh, were observed in response to a rainfall event (105 mm in one day) in early 2009. This rainfall event caused significant ponding on the Fortescue Marsh[23] which is clearly visible from Landsat imagery and was recorded at two UWA research sites within the margin of the Fortescue Marsh (see Figure 7). The westernmost site (Site B) recorded ponding of approximately 0.5 m above ground level (406.8 m AHD)
- The easternmost site (Site A) recorded ponding of approximately 0.2 m above ground level (405.8).
- Tertiary alluvium groundwater level increases, at the fringe of the Marsh, were observed following Cyclone Heidi (Jan 2012) at both Cloudbreak and Christmas Creek. The increase observed varied spatially along the Marsh and was directly related to proximity and localised/regional ponding.
    - Cloudbreak bores, being located distal from the Marsh, showed a delayed and small increase in groundwater level (0.3 – 1 m). Most pronounced variations were observed closest to the Marsh and adjacent to areas of previous ponding (Historical Landsat data, Appendix 1).
    - Christmas Creek bores[24] showed a rapid increase in groundwater level (0.5-1.5 m) in the month following Cyclone Heidi. Water level fluctuation was most

[23] This ponding event was localised and appears to be related to discharge from discrete catchments in the Chichester Range.
[24] Monitoring bores CBFMM01_s – CBFMM08_s (excluding CBFMM03_s).

pronounced at CCFMM03, adjacent to a creek line, with a relatively subdued response to the east and west.

Further information regarding long-term groundwater trends is developed from the modelled groundwater levels under various climatic conditions (Section 5.6).

2.6.5 Groundwater Quality

Groundwater in the Cloudbreak region ranges from marginal/brackish (<1,500 milligrams per litre [mg/L] Total Dissolved Solids [TDS]) in shallow recharge areas to hypersaline at depth and close to the Fortescue Valley (>150,000 mg/L TDS). Hypersaline groundwater has evolved through evapo-concentration beneath the Fortescue Marsh, over prolonged periods of time and potentially under different climatic regimes over periods of up to 700,000 years (Skrypek G., 2013).

The distribution of brackish and saline water within the Cloudbreak area is shown schematically in Figure 3. Baseline salinity levels in the Tertiary detrital and the MMF are shown in Figure 9 and Figure 10. Baseline salinity in both the Tertiary detrital and MMF increases with proximity to Fortescue Marsh and are generally aligned with the alignment of the Marsh fringe. Salinity concentrations in Tertiary detrital and MMF vary between 25,000 us/cm (south of the active mining area) to 150,000 us/cm (at the Marsh fringe). Isotopic analysis (Skrypek G., 2013) of shallow groundwater beneath and adjacent to Fortescue Marsh shows the predominance of vertical recharge in their development with limited horizontal groundwater flow.

The composition of 135 groundwater samples have been plotted on a Piper diagram (Figure 8) for classification of water types). It illustrates two dominant water types and a definite mixing trend. The majority of waters plot in the high Na-Cl-SO_4 window with variability between end members, resulting in two predominant types:

- Na-Cl-SO_4
- Na-Cl

The Na-Cl and Na-Cl-SO_4 typically correlate with the higher salinity groundwater located proximal to the Fortescue Marsh or at greater depth. The influence of the density driven saline groundwater system is evident at distance from the Marsh with almost all groundwater signatures from the Tertiary sequence and upper MMF closer to the Chichester Ranges displaying elevated proportions of Cl-SO_4. At further distances from the Marsh into the Chichester Ranges catchment, the water type in the Roy Hill Shale member is noted as Ca-Mg-Na-K.

The spatial distribution of groundwater salinity was assessed via a SkyTEM[25] airborne electromagnetic survey. Data-inversion was carried out using the Laterally-Constrained Inversion (LCI) method. Field data was filtered and then modelled against a subsurface layer structure constrained laterally on a number of chosen model parameters (including layer conductivity and layer thickness). The 3D inversion data were provided as slices through specific hydrogeological surfaces, including 5 m below the watertable (Figure 12) and the top of the ore zone (Figure 11). This approach has assisted in mapping the position of the salt interface and developing the following concepts:

- The heterogeneity of the saltwater interface, in particular associations with structural lineaments and other preferential flow paths.
- Brackish water forms a lens in the MMF and Tertiary detritals/alluvium overlying saline groundwater near the Chichester Ranges.
- Salinity increases towards the Marsh in all hydrostratigraphic units, and
- Saline zones beneath the ore zone may be disconnected from principal flow mechanisms ('fossil' groundwater).

2.6.6 Density Driven Flow

Density gradients due to salinity difference are an important driving force of groundwater flow. Density contrast between saline groundwater beneath and adjacent to the Fortescue Marsh and fresher groundwater along the flanks of the Chichester Ranges has resulted in a saline transition zone. Stratigraphy, structure, hydraulic head and salinity concentration influence the extent and nature of the saline transition zone. The saline interface may, naturally, move seasonally owing to changes in hydraulic head conditions.

When comparing pressure conditions between fresh and saline aquifers, the piezometric head[19] measured in a saline aquifer must be converted to a fresh water equivalent head to account for the pressure exerted by the overlying column of saline water. The measured piezometric heads can be converted to equivalent freshwater head via the following density-conversion equation[26]:

$$equivalent\ head = measured\ head \times \frac{(0.0007723 \times S) + 997.31}{1000}$$

When measured piezometric head in the hypersaline Oakover Formation are converted to fresh water equivalent a pressure gradient can be observed in the opposing direction to the topographical driven gradient from the Chichester Ranges into the Fortescue Valley (Figure 3).

[25] SkyTEM is a helicopter-mounted, time domain electromagnetic (TDEM) system. The SkyTEM survey was conducted by Geoforce Pty Ltd over an eight-day field program in September 2009. The surveyed area extended from the Fortescue Marsh boundary to the Chichester Range, from Christmas Creek in the East to Cloudbreak in the West.

[26] Where S is salinity (mg/l) as adapted from (Bear, 1972)

2.6.7 Groundwater Recharge

Primary mechanisms for groundwater recharge are:

- Infiltration recharge from direct rainfall and local stream flow on MMF outcrop and Tertiary detritals/alluvium.
- Infiltration recharge, into Tertiary detritals, associated with ponding on the Fortescue Marsh.
- Inflow from aquifers within the Fortescue Group located to the north of the project area.

Direct rainfall recharge to the Tertiary detritals/alluvium and MMF aquifers is considered to be low in the Cloudbreak area, reflecting the low rainfall and high evaporation of the region (see Section 2.3).

Recharge is enhanced in creeks and areas of stream flow. Areas of outcrop and subcrop with drainage incisions can have direct connection between surface water and underlying permeable lithologies.

2.6.8 Groundwater Discharge

Based on the evolution of groundwater within the upper Fortescue Valley the groundwater system beneath the Fortescue Marsh is considered a closed system with limited outflow to the west beneath the Goodardarie Hills. Discharge is therefore interpreted to only occur through evaporation and evapotranspiration processes beneath and fringing the Marsh. Discharge would be greatest when water levels are high, following recharge events and lowest after a prolonged dry period when the extinction zone for evaporation or evapotranspiration (from the watertable) is reached.

2.6.9 Hydrogeological setting comparison

Table 7 provides a comparison of the hydrogeological setting at Cloudbreak with respect to that of the nearby Christmas Creek and Roy Hill projects in order to provide a regional context.

Table 7: Hydrogeological setting comparison

Aspect	Cloudbreak	Christmas Creek	Roy Hill (Hancock , 2009)
Drawdown Footprint			
Operational Dewatering strike length	~30 km	~30 km	~35 km
Distance from the Fortescue Marsh boundary	4 - 6 km	7 - 9 km	5 - 10 km
Ore Body Parameters			
Mineralised Marra Mamba Formation	30 to 100 m/day	30 to 100 m/day	7.5 m/day
Oakover Formation	50 to 300 m/day	200 m/day	Up to 5 m/day
Regional hydraulic connection	Discrete zones of connection between MMF and Oakover Fm.	Regional connection between MMF and Oakover Fm.	Oakover Fm. not present to the south of Roy Hill.
Numerical modelling			
Estimated annual abstraction rate	Up to 100[27] GL/a (dewatering)	Up to 110 GL/a (dewatering)	22 GL/a (dewatering)
Basis for assessment	Pumping tests and calibration against over 36 months of operational data	Pumping tests and calibration against over 18 months of operational data	10 pump tests of up to 4 days duration.
Modelling approach	FEFLOW density-coupled model; 11 model layers, BASD (moving mesh) saturated flow parameters	FEFLOW density-coupled model; 11 model layers, BASD (moving mesh) saturated flow parameters	MODFLOW Finite difference model; 6 model layers. Further details (e.g. density coupling) unknown
Water excess management approach	Reinjection to compatible aquifers (all excess water)	Reinjection to compatible aquifers (all excess water)	Evaporation pond(s); salt encapsulation.

2.7 Flora and Fauna

2.7.1 Flora and Vegetation

Eight broad vegetation formations have been described for the Project Area, comprising 21 vegetation communities ((ENV, 2011) and (Mattiske, 2005)) (Table 8).

No Threatened Ecological Communities are known to occur in the Project Area (ENV, 2011). The Fortescue Marsh Priority 1 Priority Ecological Community (PEC) is known to occur in the Project Area, though outside of the mine disturbance footprint (ENV, 2011). The Fortescue Marsh is characterised by its collection of endemic *Eremophila* and Samphire species as well as populations of Priority flora occurring on the fringe of the Fortescue Marsh. The Samphire (*Tecticornia* species) vegetation communities 12, 13, 22, 25 and 26 that are recorded within the Project Area are considered to be representative of the PEC (ENV, 2011).

[27] 100GL as defined within (FMG, 2010d). This assessment predicts abstraction up to 150GL.

Table 8: Vegetation communities occurring within Cloudbreak

Broad Vegetation Formation	Vegetation Community No.	Vegetation Community Description
Creek line and drainage lines – Coolibah and River Red Gum dominated	1	Open Woodland of *Eucalyptus victrix,* E. *camaldulensis* with pockets of *Acacia coriacea* subsp. *pendens* over *Grevillea wickhamii* subsp. *aprica*, *Petalostylis labicheoides* and *A. tumida* over *Triodia longiceps*, *Chrysopogon fallax, Themeda triandra* and *Aristida* species.
Creek line and drainage lines – Mulga dominated	2	Low Woodland to Low Open Forest of *Acacia aneura* var. *aneura*, *A. citrinoviridis*, *A. pruinocarpa* over *A. tetragonophylla* and *Psydrax latifolia* over *Chrysopogon fallax*, *Stemodia viscosa*, *Blumea tenella*, *Themeda triandra* and species of *Triodia* and *Aristida*.
Creek line and drainage lines – other *Acacia* dominated	8	Closed Scrub to Tall Shrubland of *Acacia pruinocarpa*, *A. tumida*, *A. ancistrocarpa*, *A. maitlandii*, *A. kempeana*, *A. tetragonophylla* with occasional *Eucalyptus gamophylla* and *Corymbia deserticola* over *Triodia epactia*, *Themeda triandra* and *Aristida* species.
	9	Closed Scrub to Shrubland of *Acacia ancistrocarpa*, *A. maitlandii*, *A. kempeana*, *A. monticola* with occasional *Eucalyptus gamophylla* and *Corymbia deserticola* over *Senna* species, *Triodia basedowii* and *Aristida* species.
Flats and broad plains containing Mulga	3	Low Woodland to Low Open Forest of *Acacia aneura* var. *aneura*, *A. pruinocarpa*, *A. tetragonophylla*, *A. tenuissima*, *Grevillea wickhamii* subsp. *aprica*, *Psydrax latifolia* over *Dodonaea petiolaris* and species of *Triodia* and *Aristida*.
	4	Low Open Woodland of *Acacia aneura* var. *aneura*, *A. pruinocarpa*, *A. xiphophylla*, *A. victoriae* over *A. tetragonophylla*, *Psydrax latifolia* and *Psydrax suaveolens* over *Ptilotus obovatus* and species of *Maireana* and *Sclerolaena*.
	10	Low Open Woodland of *Acacia xiphophylla*, *Acacia victoriae*, *Acacia aneura* var. *aneura* over *Acacia tetragonophylla*, *Ptilotus obovatus*, *Senna* species and species of *Maireana* and *Sclerolaena*.
Flats and broad plains without Mulga	15	Low Open Woodland of *Acacia victoriae*, *A. xiphophylla* over *Ptilotus obovatus*, *Senna* species and species of *Maireana* and *Sclerolaena.*
Ranges, hills and hillslopes	7	Hummock Grassland of *Triodia basedowii* with emergent patches of *Eucalyptus gamophylla*, *E. leucophloia*, *Corymbia deserticola* over *Acacia ancistrocarpa*, *A. sclerosperma* subsp. *sclerosperma*, *A. kempeana*, *A. arida*, *Grevillea berryana*, *G. wickhamii* subsp. *aprica*, *Calytrix carinata* over *Goodenia stobbsiana* and mixed Poaceae species.
	16	Hummock Grassland of *Triodia basedowii* with pockets of *Triodia epactia* and *T. lanigera* with emergent patches *of Eucalyptus leucophloia*, *Corymbia deserticola* over *Acacia ancistrocarpa*, *A. hilliana*, *A. acradenia*, *A. pyrifolia*, *Hakea lorea* subsp. *lorea* over *Goodenia stobbsiana* and mixed *Senna* species.
	17	Hummock Grassland of *Triodia basedowii* with areas of *T. epactia* and *T. lanigera* with emergent patches of *Eucalyptus leucophloia*, *Corymbia deserticola* over *Acacia ancistrocarpa*, *A. pyrifolia*, *Hakea lorea* subsp. *lorea* over *Goodenia stobbsiana* and mixed *Senna* and *Ptilotus* species.
	18	Hummock Grassland of *Triodia angusta* with emergent patches of *Eucalyptus leucophloia* over *Acacia ancistrocarpa*, *A. pyrifolia*, *Hakea lorea* subsp. *lorea* over *Goodenia stobbsiana* and mixed *Senna* and *Ptilotus* species.
Fringes of Samphire flats containing Samphire	12	Low Halophytic Shrubland of *Tecticornia auriculata* and *T. indica* subsp. *leiostachya* with associated *Maireana* species and *Atriplex flabelliformis* with *Muehlenbeckia florulenta* with patches of *Acacia victoriae* and *A. sclerosperma* subsp. *sclerosperma*.
	13	Low Halophytic Shrubland of *Tecticornia auriculata*, *T. indica* subsp.

Broad Vegetation Formation	Vegetation Community No.	Vegetation Community Description
		leiostachya, *T. halocnemoides* subsp. *tenuis* with patches *of Frankenia species*.
	22	Low Shrubland of *Tecticornia indica* subsp. *bidens* and *Nicotiana occidentalis* over grasses with occasional stands of *Sesbania cannabina* and *Cullen cinereum*.
	25	Low Shrubland of *Tecticornia auriculata*, *T. indica* subsp. *bidens* and *Frankenia ambita* over *Eragrostis dielsii*.
	26	Low Shrubland of *Muellerolimon salicorniaceum* and *Tecticornia indica* subsp. *bidens*.
Fringes of Samphire flats without Samphire	11	Hummock Grassland of *Triodia angusta* with patches of *Acacia victoriae*, *A. aneura* var. *aneura*, *A. xiphophylla over Atriplex codonocarpa*, *Eremophila cuneifolia* and mixed Chenopodiaceae species.
	14	Hummock Grassland of *Triodia angusta* with patches of *Acacia victoriae* over *Atriplex codonocarpa* and mixed Chenopodiaceae and Poaceae species.
	20	Scrub of *Acacia sericophylla* over *Muellerolimon salicorniaceum*, *Nicotiana occidentalis* and *Mimulus gracilis*.
	27	Low Shrubland of *Maireana carnosa*, *Atriplex codonocarpa* and *Sclerolaena cuneata* over *Eragrostis dielsii* and *Trianthema turgidifolia*.

No Declared Rare Flora/Threatened flora species are known to occur within the Project Area. However, eight Priority flora taxa have been recorded ((Biota, 2004); (Mattiske, 2005), (Mattiske, 2007); (ENV, 2011); (Astron, 2012) and (Astron, 2012a)) as follows:

- *Eremophila spongiocarpa* (Priority 1);
- *Nicotiana heterantha* (Priority 1);
- *Gymnanthera cunninghamii* (Priority 3);
- *Phyllanthus aridus* (Priority 3);
- *Rostellularia adscendens* var. *latifolia* (Priority 3);
- *Themeda* sp. Hamersley Station (M.E. Trudgen 11431) (Priority 3);
- *Eremophila youngii* subsp. *lepidota* (Priority 4); and
- *Goodenia nuda* (Priority 4).

The vegetation of the Project Area has previously been described to be in variable condition. Vegetation in best condition, rated as 'Excellent' is mostly in the broad vegetation formations of 'Fringe of Samphire flats', 'Creek and drainage lines' and 'Ranges, hills and hillslopes'. Vegetation categorised as being in Good condition, exhibiting the effects of grazing pressure and fire, and is mostly found in the broad vegetation formations of 'Broad flats and plains' (ENV, 2011).

2.7.2 Fauna

Six broad fauna habitats have been identified within the Project Area (Ecologia, 2010) and (Ecologia, 2011):

- Low halophytic shrubland;
- Hummock grassland on fringe of Fortescue Marsh;
- Low Mulga, Snakewood and other Acacia woodlands;
- Spinifex covered hills and ranges;
- Creek and wells with Acacia shrubland and/or Eucalypt woodland; and
- Rocky escarpments.

The potential fauna assemblage for the region comprises 34 native and nine introduced mammal species, 165 bird species, 100 reptile species and five amphibian species (Ecologia, 2011). A total of 14 native and three introduced mammal species, 63 bird, 47 reptile and one amphibian species have been previously recorded in the Project Area (Ecologia, 2011). Fifteen species of conservation significance have been recorded within the Project Area (either directly or through secondary evidence) (FMG, 2011).

A total of 685 invertebrate specimens have been recorded in the Project Area, of which one is confirmed, one is likely, and five are potential Short Range Endemic (SRE) species (FMG, 2011). These potential SREs include mygalomorph spiders, millipedes, scorpions and pseudoscorpions.

2.7.3 Fortescue Marsh

Work recently completed by Equinox Environmental (Equinox Environmental, 2012) provides a consolidated summary of knowledge gained from studies relating to ecohydrology of the Fortescue Marsh. (Equinox Environmental, 2012) also describes a conceptual ecohydrological model of the Fortescue Marsh fringe and discusses potential indirect impacts to the Fortescue Marsh and fringing areas, Figure 13.

Supported by empirical evidence from multiple studies, the Fortescue Marsh conceptual ecohydrological model indicates that the water balance dynamics of the marsh are principally controlled by surface water inflows from the greater marsh catchment, as dictated by episodic flooding events. The flood events replenish a shallow aquifer system in the Tertiary sediments beneath the marsh, which is gradually depleted by direct surface evaporation and evapotranspiration by the fringing vegetation communities. In periods of prolonged drought, the shallow watertable reaches a pseudo-steady state set by the evaporation extinction depth in the lowest parts of the marsh basin. The fringing vegetation is dominated by samphire communities

which exhibit zonal species distribution patterns influenced by soil water and salinity dynamics, depth to watertable and flooding frequency (Equinox Environmental, 2012).

A vertical 2-dimensional variably-saturated model (HYDRUS) was used to simulate soil water dynamics and plant water uptake by samphire vegetation on the fringe of the Fortescue Marsh (Equinox Environmental, 2012). In combination with empirical observations, in particular the demonstrated ability of *T. indica* subsp. *bidens* to tolerate drought and other stressors, the findings of the modelling study suggest that the ecological water requirements of the fringing samphire communities are wholly or predominantly met by surface inputs. The findings also provide confidence that drawdown, of up to 3 m, will not significantly affect samphire survival and health. Other potential groundwater system impacts associated with the Cloudbreak Project water management strategy, such as injection mounding and water quality changes, are also not predicted to be significant.

Mining and infrastructure development associated with the Cloudbreak Project will disturb the surface flow regime north of the Fortescue Marsh, within a zone of relatively stable channel systems occasionally separated by sheetflow areas. The divergent channel drainage network downstream from these areas will remain largely unaffected by mining disturbances. Assuming effective implementation of the Cloudbreak Life of Mine Surface Water Management Plan (FMG, 2013f), minimal disruption to the downstream flow regime at the marsh fringe is expected. Where changes to the flow regimes of individual drainage outlets occur, these are predicted to be modest and will not significantly affect the ecological water requirements of the Fortescue Marsh samphire communities.

2.8 Aboriginal heritage

There is a long history of Aboriginal habitation in the vicinity of Fortescue Marsh. A number of ethno-archaeological sites (mainly stone artefact scatters) have been identified in the course of exploration and mine development activities associated with the Chichester Operations. Aboriginal heritage surveys associated with the Cloudbreak mine commenced in late 2003.

2.9 Pastoral bore use

Cloudbreak is located on Hillside and Mulga Downs pastoral leases. These pastoral stations operate beef cattle production enterprises. Station infrastructure is minimal but includes multiple stock watering points derived from shallow bores. The details of operational pastoral bores in the vicinity of the project area is summarised in Table 9. Future water requirements in terms of volumes and draw points are not expected to increase as the current supply is based on the stock numbers that the area can sustainably support, however further water sources have been made available by Fortescue at Cloudbreak and ongoing provision of this infrastructure will be as agreed between relevant parties.

Additionally, two pastoral bores; Mulga Bore and Cooks Bore are no longer in use having been subject to rising salinity levels. It is understood that the salinity levels in these bores exceeded

acceptable limits between 12 to 18 years ago, which has anecdotally been attributed to the upstream development of Opthalmia Dam.

Table 9: Pastoral groundwater bores

Station Bore Name	Pastoral Station	Easting (GDA94, Zone 50)	Northing (GDA94, Zone 50)	Water Quality (TDS in mg/L)
Walla Bore	Mulga Downs	710,020E	7,534,549N	Unknown
Kardardarrie Bore	Mulga Downs	714,520E	7,534,070N	5,000 mg/L
Thieves Bore	Mulga Downs	722,537E	7,534,269N	2,500 mg/L
Moojari Bore	Mulga Downs	727,900E	7,531,200N	2,000 to 2,500 mg/L
Minga Well	Mulga Downs	733,719E	7,529,737N	1,100 to 1,700 mg/L
Outcamp Well	Hillside	760,711E	7,521,638N	Unknown
Mulinyury Bore	Hillside	756,803E	7,522,730N	Unknown

3. CLOUDBREAK OPERATIONS

3.1 Groundwater management strategy

The groundwater management approach developed for Cloudbreak has been successfully implemented since 2008 and has since been expanded to the Christmas Creek operation. The strategy has been developed to meet requirements of the mine and Fortescue Marsh Management objectives (EPA, 2013). Key components of the groundwater management approach include:

- Advance dewatering and operational dewatering methods for multiple water quality streams;
- Managed aquifer recharge of brackish and saline water, including recovery of brackish water;
- Mine to mine transfer of brackish water to meet inter-mine water demands; and
- Mine to mine transfer of saline water (adaptive management strategy).

The Groundwater management strategy has been enhanced with the connectivity of the Cloudbreak and Christmas Creek brackish systems, which enables maximum beneficial use of brackish water abstracted during dewatering. Fortescue has recently obtained approval for transfer of saline water between Cloudbreak and Christmas Creek which will enable redistribution of saline injection across 90km of Oakover aquifer strike, significantly enhancing the adaptive management approach to management of groundwater drawdown and or mounding impacts in the alluvial aquifer.

A summary of objectives and management strategies is presented in Table 10 and briefly described below.

Table 10: Water management objectives and strategies

Objectives	Strategies
Cloudbreak • Prevention of disruption to mining due to water. • Conservation of groundwater resource. • Completion of water management operations in a cost-effective manner.	• Inclusion of water management as a key parameter in the mine planning process. • Adoption of Managed Aquifer Recharge (MAR) as the principal excess water management method.
Fortescue Marsh Management Objectives • Minimisation of impacts associated with discharge of excess water to the environment. • Minimisation of Groundwater Dependent Ecosystem (GDE) impact due to operational groundwater level change. • Prevention of aquifer contamination. • Sustainable use of groundwater resource.	• Operation of separate water management conveyance systems for brackish and saline water. • Banking (storing) brackish groundwater for future recovery. • Targeted injection of excess water to reduce drawdown footprint. • Injection of saline groundwater into compatible saline quality aquifer(s). • Adoption of a flexible water conveyance system

Objectives	Strategies
• carbon-efficient construction and operation. • Minimisation of ground clearing requirement. • Minimisation of closure legacy.	that enables the redistribution of water as required to manage potential impacts. • Adoption of mine site surface water diversion strategies to minimise disruptions to volume of surface water flow from the Chichester Range to the Fortescue Marsh.
Social • Minimisation of impact to cultural values. • Minimisation of impact to other stakeholders.	• Continued pursuit of process-improvement strategies for water management. • Continued development and implementation of Fortescue's groundwater management framework.

3.2 Operations management

The following regulation applies to abstraction and injection operations:

- Groundwater abstraction is regulated under Section 5C of *the Rights in Water and Irrigation* (RIWI) *Act 1914* by the Department of Water (DoW). The applicable groundwater instrument is groundwater licenses GWL166200 and GWL 166354, which has an abstraction entitlement of 100 GL/a. Operational commitments applicable to the licence, including monitoring and reporting commitments are documented in the *Cloudbreak Groundwater Operating Strategy*. (FMG, 2013d)
- Groundwater injection is regulated under Part V of the EP Act, by the Department of Environmental Regulation (DER). The applicable licence instrument is L8199/2007/2. Operational commitments applicable to L8199/2007/2, including monitoring and reporting commitments are documented in the *Cloudbreak Water Management Scheme* (FMG, 2013c).

Reporting, to the DoW, is undertaken quarterly to demonstrate compliance with the operating strategy and to inform of groundwater impacts. The most recent quarterly monitoring summary covers the period from 1 February 2013 to 30 April 2013 (FMG, 2013). A triennial review summarising data up to July 2013 was submitted in September 2013 (FMG, 2013b).

Groundwater monitoring is undertaken by a dedicated Cloudbreak Monitoring and Compliance team. Groundwater levels, salinities and abstraction volumes are measured monthly (or at more frequent intervals).

A brief summary of performance against Fortescue Marsh management objectives and the Cloudbreak Operating strategy is outlined below.

3.3 Operations performance summary

To date, Fortescue has been compliant with all requirements of the Operating Strategy (FMG, 2013d) and Water Management Scheme (FMG, 2013c). No significant impacts have been recorded and adaptive management solutions have been implemented to ensure continuing success of operations (FMG, 2013b).

Mining below watertable has progressed in several mine pits spanning approximately 17km of the mineralised Marra Mamba Formation (MMF). Water quality permitting this groundwater is used for ore processing and dust suppression; excess brackish water has been transferred to Christmas Creek and or injected to the east and west of the below watertable mining area (but within the same aquifer) and saline groundwater has been injected to the Oakover Formation located to the south of the below watertable mining area (and north of the Fortescue Marsh). In the 2013 period, some brackish groundwater was abstracted from previous brackish injection areas to supplement brackish supply for the mine site.

A total of 24,928,000kL; 31,697,000 kL; and 59,388,000 kL were abstracted for the 2010, 2011 and 2012 licence periods respectively. Of the total abstraction, mine site water use and injection comprised 30% and 57% respectively for 2010; 24% and 64% respectively for 2011; and 10% and 77% for 2012.

Water level changes due to dewatering and injection activities have followed the expected trends, being summarised as;

- The piezometric level has been lowered in the MMF aquifer and overlying Tertiary detrital/alluvial aquifer in the below watertable mining (and dewatering) area.
- The piezometric level has risen and subsequently started to recede in the MMF aquifer and overlying Tertiary detrital/alluvial aquifer in the brackish injection area to the east and west of the below watertable mining area in response to periods of injection and abstraction.
- Piezometric levels have risen in the Oakover Formation in the saline injection area and to a lesser extent in the near marsh area.
- Piezometric levels in the shallow Tertiary alluvial aquifer (overlying the Oakover Formation) in the saline injection area and near marsh areas have displayed cyclical periods of rise and fall in response to climatic induced groundwater recharge events.

The salinity of groundwater abstracted from dewatering operations has increased in response to depletion of the brackish water resource in the dewatering area; salinity has remained relatively constant in the MMF in the brackish injection zones; and salinity has remained relatively stable in the Oakover Formation and overlying detrital and alluvial aquifer in the saline injection and near-marsh areas.

4. CONCEPTUAL HYDROGEOLOGICAL MODEL

Extensive hydrological data developed from site and regional investigations, and operations (Sections 1 & 3) have been synthesised to inform the conceptual hydrogeological model for Cloudbreak. The conceptual model forms the basis of the numerical modelling. The hydrogeological setting can be classified based on the dominant flow processes into three regimes:

- Topographic driven groundwater flow system of the Chichester Range.
- Density driven groundwater flow system of the Upper Fortescue Valley.
- Surface water driven Fortescue Marsh and peripheral shallow groundwater system.

Characteristics of each of these systems and the relationship between the flow systems are described below and in Figure 3. Elements of the conceptual model which are represented in the numerical modelling study are summarised in Table 11, including key revisions from the previous LOM assessment (FMG, 2010d).

4.1 Topographic driven groundwater flow system of the Chichester Range

Rainfall and stream flow on the upper and lower slopes of the Chichester Ranges infiltrate the soil and recharge the MMF directly or through Tertiary detritals/alluvium. The mineralised MMF is the main aquifer in this part of the flow system. The mineralised MMF is bounded below by the lower MMF and Jeerinah Formation and overlain by saturated Tertiary detritals/alluvium.

Groundwater flow is generally in a south to south westerly direction towards the Fortescue Marsh. The hydraulic gradient is very low due to the opposing density driven flow system, a small amount of discharge for limited periods is expected to occur by evapotranspiration at the Fortescue Marsh.

Seasonal groundwater trends are generally subdued due to the low infiltration rate, high storage of Tertiary detritals/alluvium and low rate of discharge from the system.

4.2 Density driven groundwater flow system of the Upper Fortescue Valley

The hypersaline environment of the Upper Fortescue Valley groundwater system creates a density driven flow system that directly opposes the topographic driven flow system. Evidence suggests that hypersaline conditions developed due to a constriction of the regional groundwater flow system at the Goodardarie Hills, as well as a long period of evapo-concentration of flood waters on the Fortescue Marsh.

The Oakover Formation is the main aquifer in this part of the flow system. The Oakover Formation is bounded below by the Wittenoom Formation and overlain by a homogeneous clay layer which in turn is overlain by saturated Tertiary detritals/alluvium.

The opposing density driven and topographic driven flow systems result in the formation of a dynamic saline interface, which extends over many kilometres between the Fortescue Marsh and the lower slopes of the Chichester Ranges, and is present throughout the flow system. Changing pressure conditions within each part of the system create a dynamic interface, the distribution of which reflects hydrostratigraphic connectivity and dispersion characteristics of the aquifer system.

Direct connectivity between the mineralised MMF and the Oakover Formation is variable and indirect connectivity is locally enhanced through north east to south west fault zones in underlying MMF and Wittenoom Formation.

4.3 The Fortescue Marsh and peripheral shallow groundwater system

The upper groundwater system of the Upper Fortescue Valley is associated with the Fortescue Marsh, which is the discharge point for the Upper Fortescue surface water catchment. The Upper Fortescue catchment covers an area of 30,000 km^2. Runoff following major rainfall events in the catchment result in significant flooding on the Fortescue Marsh.

The extreme variability of hydrological dynamics that occur between flood and prolonged dry periods can be described by three dynamic phases and are illustrated in Figure 13:

4.3.1 Flood phase

Following major rainfall events catchment runoff enters the Fortescue Marsh and forms a lake or series of lakes. Lake volumes in excess of 300 GL have been calculated. Under this condition, the surface water and shallow groundwater become connected as surface water infiltrates and raises the groundwater level to the surface. The capacity of the groundwater system beneath the Fortescue Marsh to receive water is generally low as the watertable is normally around 1 or 2 m below ground surface. The fresh surface water infiltrating the unsaturated zone is quickly salinized due to abundance of salts in the soil profile (Skrypek G., 2013). The elevated head associated with the lake creates a hydraulic gradient away from the Fortescue Marsh and groundwater flows into the adjacent alluvium.

Flooding within the Fortescue Marsh has been observed to have an influence on shallow groundwater (Tertiary detrital/alluvium) levels up to 2 km from the fringe of the Marsh.

4.3.2 Inter-flood phase

Between flooding events, referred to as the inter-flood period (Figure 13), rainfall and catchment runoff is generally low and evaporation exceeds the direct rainfall on the Fortescue Marsh. The lake is reduced over time through evaporation. At this stage, hydraulic gradients developed by the interplay of the topographic and density driven flow systems resumes, and evaporative discharge through and fringing the lake continues to lower the watertable.

4.3.3 Prolonged dry phase

Following an extended period of low rainfall, the Fortescue Marsh may reach the 'prolonged dry' condition (Figure 13). If the dry period progresses for a prolonged period the watertable level will fall below the evaporative extinction depth and discharge will diminish.

Table 11: Conceptual model summary

Element	Description	Key change from previous LOM assessment (FMG, 2010d)
Model Framework		
Domain	The model domain covers an area of approximately 2745 km^2.	Slightly smaller area
Hydrogeological units	See Section 2.6.1	No change
Hydraulic properties	See Section 2.6.2	No change to calibrated model properties.
Salinity	Groundwater salinity ranges between fresh (<500 mg/L) and hypersaline (up to 150,000 mg/L)	No change
Model boundaries	Northern boundary. Though the MMF is truncated where it outcrops in the Chichester Range, this does not represent the northern boundary of the hydrogeological system. Groundwater occurrence within the underlying Jeerinah Formation (Roy Hill Shale) is connected with the MMF. However, the connection (between MMF & Roy Hill Shale) is constrained to discrete fracture zones and thus groundwater flow across the northern boundary is believed to be negligible, i.e., the northern boundary can be approximated as a no-flow boundary. The southern boundary is located at such a large distance away from the Cloudbreak mine site that groundwater levels along the boundary would not be affected by mine dewatering or water injection.. The eastern boundary is beyond the eastern extent of the operation, and groundwater flow is considered to be parallel to this boundary. The western boundary is beyond the western extent of the operation, and groundwater flow is considered to be parallel to this boundary. The model base is at a selected level below the groundwater flow system. The model top is represented by groundwatertable or surface watertable over the Fortescue Marsh during the period of surface ponding.	No change
Groundwater Recharge		
Chichester Range recharge	Recharge due to infiltration of rainfall is estimated to range between 0.2 to 3% of rainfall (approximately 0.5 GL/a 6 GL/a).	No change
Fortescue Marsh	After a prolonged dry period in which water levels below the	No change

Element	Description	Key change from previous LOM assessment (FMG, 2010d)
recharge	Fortescue Marsh decline to 3 m below the surface, the occurrence of a significant ponding event (over 600 km^2) could recharge the groundwater system by approximately 30 GL of water. Groundwater recharge related to flooding can be predicted based on correlation between observed flooding and rainfall records.	
Groundwater Discharge		
Evaporation and evapotranspiration	Evaporation and evapotranspiration principally occur in the Fortescue Marsh area, where the depth to watertable is shallowest. Potential evapotranspiration rates in the region are as high as 3,000 mm/year. This rate is expected to exponentially decline as depth to watertable increases (to a maximum depth of 3 metres).	Zone of evaporation and evapotranspiration amended based on topography rather than simply the prescribed boundary of Fortescue Marsh
Groundwater Flow		
Hydraulic gradient and through flow (topographic-driven flow)	Groundwater flow through the Chichester Range aquifer system is considered to be equivalent to catchment recharge. Chichester Range groundwater through flow is low compared to the Fortescue Marsh's recharge and evapotranspiration fluxes, as it is constrained by the presence of dense water beneath the Fortescue Marsh. Topographic driven flow from the Chichester Ranges tends to flow through shallow stratigraphy towards the watertable beneath the Fortescue Marsh	No change
Salinity and density gradients (density-driven flow)	High salinity water has a higher density than fresh water, and resultant density gradients have an important influence on groundwater flow. The density value at 150,000 mg/L is 1.114kg/L.	No change
Anthropogenic		
Pastoral bores	Several pastoral bores are located in the project area. These bores pump shallow groundwater around watertable and groundwater drawdown due to these bores is usually small.	No change
Cloudbreak dewatering	Mining pits are located at areas with mineralised MMF.	No change
Cloudbreak injection	The injection of brackish groundwater will occur laterally into MMF; the injection of saline groundwater will be to the south of mine pits into the Oakover Formation aquifer.	No change
Christmas Creek operations	Christmas Creek mining operations are located to the east of Cloudbreak and some dewatering and injection activities at Christmas Creek may affect groundwater flow at the Cloudbreak site.	No change

4.4 Water Balance

A conceptual water balance for each of the Fortescue Marsh phases is presented in Table 12. The water balance is for illustrative purposes and represents broad average recharge conditions, whereas recharge (especially related to the Fortescue Marsh) is event based.

- On an annual basis recharge to the groundwater system beneath the upper and lower slopes of the Chichester Ranges is estimated to be approximately 0.5 GL/a based on average rainfall conditions, an estimated 3% of rainfall recharging the aquifer system and the aerial extent of the Christmas Creek domain.
- Under flooded conditions, the groundwater system is being recharged. The lake, or open water, formed on the Fortescue Marsh following significant rainfall (average lake volume of around 300 GL) results in around 30 GL of water entering the shallow groundwater system.
- Under interflood conditions, the groundwater system is still receiving around 0.5 GL of recharge from the Chichester Ranges; however, discharge (evaporative) through and fringing the Fortescue Marsh is dominant.
- Under the prolonged dry condition, the system is effectively static (not receiving recharge or discharging).

Table 12: Simplified analytical water balance

	Recharge (GL/a)	Discharge (GL/a)
Flooded Condition		
Chichester Ranges	6	0
Fortescue Marsh (groundwater system)	30	0
Net	**36**	
Interflood Condition		
Chichester Ranges	0.5	0
Fortescue Marsh (groundwater system)	0	30
Net	**29.5**	
Prolonged Dry Condition		
Chichester Ranges	0	6
Fortescue Marsh (groundwater system)	0	0
Net	**-6**	

5. GROUNDWATER MODELLING ASSESSMENT

5.1 Modelling objectives and scope

A computer based, numerical groundwater flow and transport model has been developed for the Cloudbreak project area for the purpose of predicting groundwater level conditions and conceptual design of the dewatering and injection system.

This section describes the following key components of this assessment:

- Construction of a numerical groundwater flow and transport model.
- Calibration.
- Simulation of dewatering and injection and prediction of water level change.
- Uncertainty analysis.
- Model limitations.
- Where relevant, updates to the model since the previous Cloudbreak LOM assessment (FMG, 2010d) are noted.

5.2 Numerical model construction

5.2.1 Numerical model complexity

Within the context of the Australian Groundwater Modelling Guidelines (SKM & NGRT, 2012), the numerical model is considered to be of moderate complexity as an Impact Assessment model. Within this approach, where understanding or data is lacking, it is possible to design the associated model aspects to be conservative with respect to their intended use.

5.2.2 Model software selection and code settings

To select suitable modelling software, several criteria were used:

- The software should have the function of simulating density driven flow and transport, since density-driven flow and salt transport is a major feature of the aquifer system.
- The model domain, which is very large (2745 km^2) to achieve the goal of assessing environmental impacts, has to be discretised efficiently with the total number of elements (largely determining computer running time) being at a reasonable level.
- The software should industry recognised and technically well supported.

FEFLOW software (version 6.0) was determined to rate highly against the criteria and was selected as the preferred modelling code.

The following solver and code settings were adopted:

- Default iterative non-symmetrical equation solver 'preconditioned Lanczos-type BICGSTAPB'.
- Default convergent form transport equations.
- Non-Fickian dispersion law.
- Extended Boussinesq approximation to density dependence.
- Neglect fluid viscosity effects on conductivity.
- The predictor-corrector, automatic, time-stepping system utilising the Forward Adams-Bashford/backward trapezoid rule.
- Default Euclidean L2 integral Root Mean Square (RMS) error norm with a convergence criteria of 0.0005.
- 'Full upwinding' techniques were applied to dampen oscillations.

5.2.3 Numerical mesh and numerical layers design

Model domain

The model domain (Figure 14) covers the Fortescue Marsh and the mining area as well as extending in all directions to locations where no flow boundary conditions are valid assumptions. The total model area is about 2745 km^2.

Model layer structure

The hydrostratigraphy represented in the model is listed in Table 13 and shown graphically in Figure 15. An additional numerical layer (Layer 1) is used in the model to represent open water in Fortescue Marsh. This layer has a porosity of 1 and a large conductivity of 8640 m/day to simulate surface water ponding that may occur after significant rainfall events.

Spatial discretisation

Each numerical layer within the FEFLOW model is discretised into triangles with variable element sizes throughout the model domain. The finite element mesh was refined in and around the proposed mining area (Figure 14) with elemental side length down to 50 m.

Discretisation parameters were selected on the basis of the ability of the mesh to represent the curvature in the watertable and corresponding groundwater heads at depth. The gradation in element size from small to large radiating out from the mining regions is considered appropriate. Figure 15 shows the distribution of hydrogeological units in a vertical cross section of the model.

Table 13: Model layers

Numerical Model Layer Number	Description
1	Fortescue Marsh Open Water
2	Tertiary Detrital
3	Tertiary Clay
4	Oakover Formation
5 and 6	Wittenoom Formation
7	Hardcap: Depleted Marra Mamba Formation (MMB)
8	Mineralised MMB: above the Economical Ore Base
9	Mineralised MMB: below the Economical Ore Base
10	Fractured MMB
11	Un-mineralised MMB
12	Jeerinah Formation (Roy Hill Shale)

5.2.4 Model parameters

The values and distribution of model hydraulic properties have been developed from field based aquifer testing (see Section 2.6.2) and model calibration (undertaken for borefield planning and design purposes) at both Cloudbreak and Christmas Creek. Initial hydraulic parameter values used in the model are presented in Table 14.

Model calibration undertaken as the operation has progressed has assisted in constraining parameters determined from aquifer tests, particularly vertical conductivity and specific yield parameters, which are inherently difficult to determine from relatively short duration tests.

Table 14: Initial model hydraulic parameters

Hydrostratigraphic unit	Hydraulic conductivity			Specific yield	Specific storage coefficient
	K_h (m/s)	K_h (m/day)	K_h/K_z		
Marsh water body	1.0×10^{-1}	8640.0	1	1.0	10^{-5}
Tertiary Detrital	2.48×10^{-5}	2.15	50	0.04	10^{-4}
Alluvial clay	1.16×10^{-7}	0.01	10	0.01	10^{-4}
Oakover Formation	2.31×10^{-3}	200.0	10	0.04	10^{-4}
Wittenoom Formation	1.16×10^{-5}	1.0	10	0.005	10^{-5}
Hardcap	1.16×10^{-6}	0.1	10	0.03	10^{-5}
Mineralised Marra Mamba Formation	6.94×10^{-4}	60.0	50	0.03	10^{-5}
Fractured Marra Mamba Formation	5.78×10^{-5}	5.0	10	0.03	10^{-5}
Un-mineralised Marra Mamba Formation	5.78×10^{-6}	0.5	50	0.01	10^{-5}
Roy Hill Shale	1.16×10^{-7}	0.01	10	0.001	10^{-5}

5.2.5 Boundary conditions for groundwater flow

All boundary conditions used in the current numerical model are the same as those used in the previous hydrogeological assessment (FMG, 2010d) Table 15.

Table 15: Numerical model boundary conditions

Boundary	Boundary Type	Description of hydrogeological representation
Western	No flow Boundary	For simplicity, the western and eastern boundaries are represented as no flow boundaries. • Under natural flow conditions, the assumption of a no flow boundary is considered appropriate as natural groundwater flow is roughly parallel to these boundaries. • Under mining conditions, no flow boundary conditions are also considered appropriate as they are located significant distances from active areas of mining (over 6 km to the western boundary
Eastern	No flow Boundary	

Boundary	Boundary Type	Description of hydrogeological representation
		and over 10 km from the eastern boundary). If any significant drawdown is predicted along these boundaries, it would represent the worst case scenario that might occur as long as no significant drawdown is caused by the neighbouring mining activity.
Northern	No flow boundary	The northern boundary is aligned with the surface water catchment divide within the Chichester Ranges. Groundwater flow is expected to closely follow topography and therefore the selected alignment represents a natural groundwater divide. Drawdown impacts are not expected to extrapolate to this boundary thereby not influencing the natural groundwater flow regime.
Southern	Constant head boundary	The southern model boundary is located to the South of the Fortescue Marsh and is at least 29 km away from mining pits and at least 27 km away from proposed injection wells. Boundary heads were assigned based on measured groundwater levels nearby the boundary.

5.2.6 Recharge

Recharge is the component of direct rainfall or surface water flowing across the land surface that infiltrates to the watertable. The model area was divided into seven recharge zones as described in Table 16 and presented in Figure 16.

Recharge zones are mostly the same as those in the previous PER model, except that the Marsh recharge zone was extended to include some lowland area to the Northwest of the Fortescue Marsh (see Figure 16).

Table 16: Numerical model recharge zones

Recharge zone	Name	Description
1	Southern TD recharge zone	The zone is covered with Tertiary Detritals and the land surface is flat or with a gentle slope. It receives moderate recharge.
2	Weeli-Wolly Creek zone	This is used to represent recharge from Weeli Wolly Creek. It is high recharge zone.
3	Fortescue Marsh recharge zone	This zone is the lowland area of the Fortescue valley. It receives direct rainfall recharge as well as surface runoff from the large catchment. Watertable rises to

Recharge zone	Name	Description
		above ground surface when flooding occurs. Note that most of the recharge in this zone stores above the ground surface (part of model domain) and leaves from the model through evaporation.
4	Southern Bedrock recharge zone	The zone is mostly covered with Roy Hill Shales. It receives little recharge due to the low permeability and the steep slope ground surface.
5	Northern TD recharge zone	The zone is covered with Tertiary Detritals and the land surface is flat or with a gentle slope. It receives moderate recharge.
6	Northern MMF recharge zone	The zone is mostly covered with mineralised MMF. It receives significant recharge from direct rainfall and surface runoff from upslope area.
7	Northern bedrock recharge zone	The zone is mostly covered with Roy Hill Shales or un-mineralised MMF. It receives little recharge due to the low permeability and the steep slope ground surface.

Recharge rate for catchment zones (all zones except the Marsh zone)

It was assumed that recharge occurs only when the monthly rainfall is 50 mm or over and the recharge rate is proportional to the monthly rainfall. The recharge coefficient was determined through model calibration.

Recharge rate for the Fortescue Marsh

The recharge over the Fortescue Marsh is calculated as:

Equation 1 $$Recharge = POW \times Repot$$

Equation 2 $$Repot = F \times Raflood - Epan$$

Equation 3 $$POW = \begin{cases} 0 & HMSE > 407 \\ \frac{(407 - HMSE)}{2} & 405 \leq HMSE \leq 407 \\ 1 & HMSE < 405 \end{cases}$$

Where,

- POW represents the potential of receiving recharge that is assumed to be inversely proportional to ground surface elevation, i.e., the lower the surface ground the larger the potential to receive water from surface runoff.

- Repot is the potential net recharge.
- F is the coefficient to be calibrated and is related to stream flow entering Fortescue Marsh from the greater catchment region in flooding events.
- Raflood is the moving average (over 3 months) of measured monthly rainfall events that are greater than 90mm/month.
- Epan is the average monthly rate of pan evaporation (mm/month).
- HMSE is the land surface elevation ().

From Equation 3, the following conclusions can be drawn.

- Low ground areas receive more recharge than high ground areas in the Fortescue Marsh.
- The actual recharge rate is equal to the potential net recharge rate in areas where the land surface elevation is less than 405 m AHD and decreases with increasing land surface elevation.
- In areas with ground surface elevations greater than 407 m AHD, the actual recharge equals zero.

The approach used for calculating catchment and Marsh water recharge are the same as used in the previous hydrogeological assessment (FMG, 2010d).

5.2.7 Evapotranspiration

Evaporation is the sum of evaporation and plant transpiration direct from the watertable or surface water feature. Evapotranspiration is not significant over the upper and lower slopes of the Chichester Ranges owing to the depth to the watertable and nature of plant assemblage's, which dominantly draw moisture from the soil profile. Evapotranspiration is the dominant process occurring within the Fortescue Marsh (Recharge Zone 3).

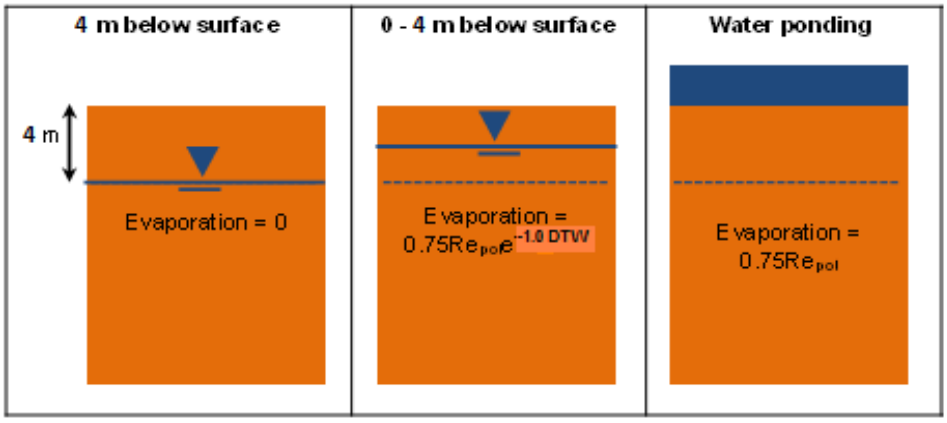
Evaporation is the discharge mechanism for open water occurring on the Fortescue Marsh and shallow groundwater beneath the Marsh. The application of evapotranspiration to the Fortescue Marsh is described below.

Fortescue Marsh evaportranspiration

In the model evaporation over Fortescue Marsh is calculated using the formulas outlined in Table 17. Under inter flood conditions, groundwater in the aquifer system flows towards the Fortescue Marsh area, where water flows out of the system through evapotranspiration. The rate of evapotranspiration is assumed to be proportional to the depth to groundwater. The rate of evapotranspiration declines exponentially with the increase in depth to groundwater. When the watertable reaches the extinction depth (assumed to be 3-4 m), the rate of groundwater evapotranspiration is assumed to be zero (prolonged dry period).

During flooding events, when the watertable is above the ground surface, the rate of evapotranspiration is assumed to be 75% of the potential evapotranspiration rate (about 3000 mm/year).

Table 17: Fortescue Marsh evaporation algorithm



5.2.8 Solute transport and density couple flow modelling

Solute transport processes

Solute transport occurs in two ways, advection and hydrodynamic dispersion (Bear, 1972).

- Advection is the process by which a volume of water is transported through porous media, carrying with its own concentration of solutes (dissolved mass).
- Hydrodynamic dispersion consists of diffusion and mechanical dispersion.
    - Diffusion is a process whereby spatial variations in concentration lead to movement of solutes, even when the water itself is motionless.
    - Mechanical dispersion is caused by spatial variations in velocity at various scales as a result of the tortuosity of porous media and heterogeneity of hydraulic conductivity.

Dissolved salts at low concentrations have little effect on flow processes. However, it has been shown that a concentration difference as small as several thousand mg/L may cause enough density effect that significantly affects groundwater flow, especially in situations where hydraulic gradients are small. In the Cloudbreak area, the hydraulic gradient is only 0.1 to 0.2% (head differences of 1 or 2 m over a horizontal distance of 10 km). In such circumstances, small density differences may cause density-driven groundwater flow. Given that the salinity gradient at Cloudbreak is large, density-driven flow may be a dominating process in some areas of the model domain.

Solute transport and density driven flow have been included in the numerical model, key solute transport parameters are listed in Table 18.

Table 18: Solute transport parameters

Parameter	Value
Reference concentration (C_o)	0 mg/L
Maximum concentration (C_s)	150,000 mg/L
Density ratio (α)	0.114 ($\alpha = (\rho_{max}-\rho_0)/\rho_0$, where ρ_0=1.0 and ρ_{max}=1.114 (the density of water at concentration of 150,000 mg/L)
Molecular diffusion coefficient	10^{-9} m^2/s
Longitudinal dispersivity (α_L)	200 m
Transverse dispersivity (α_T)	20 m
Effective Porosity	Sy (used to calculate pore velocity in the solute transport equation)

Boundary conditions for solute transport

For solving the transport equation, boundary conditions need to be specified (Table 19). Zero-solute fluxes were applied to all lateral boundaries since they are all no-flow boundaries. As the salt concentration of rain water is small compared to groundwater salinity, the top boundary with rainfall recharge was assumed to be zero solute flux boundary. Salt concentrations of groundwater underneath the Fortescue Marsh are very high, up to 150,000 mg/L, and are not likely to change significantly over the model simulation period. As a result, a constant concentration boundary condition (internal boundary condition) was applied to all nodes underneath the Fortescue Marsh.

Table 19: Solute transport boundary conditions

Boundary Condition	Rationale
Zero solute flux on all lateral boundaries	These boundaries are either no flow boundaries or constant head boundary with very low salt concentration (southern boundary)
Zero solute flux on top of the model	Rain water salinity is close to 0 mg/L
The concentration at nodes underlying the Fortescue Marsh is constant at 150,000 mg/L.	The hypersaline groundwater body has been formed over geological time periods (Skrypek G., 2013). Groundwater salinity is unlikely to change significantly over the simulation time period (20 years).

All boundary conditions for solute transport are the same as used in the previous hydrogeological assessment (FMG, 2010d).

5.3 Model calibration

5.3.1 Initial conditions

The initial head and salinity distributions were derived from a long-term (4500 year) simulation. This long term simulation modelled the evolution of an initially brackish aquifer system by applying a constant salinity boundary condition set at 150,000 mg/L at the Fortescue Marsh surface to represent evapo-concentration processes. The actual historical evolution of the current salinity distribution is currently hypothesised to be due to similar processes but may have taken place over 10,000 to 100,000's of years, with various inter-waning periods (Skrypek G., 2013). The process applied enables the derivation of a reasonable and stable spatial distribution of salinity to be used as the initial condition for the calibration model.

5.3.2 Transient calibration

Transient calibration was conducted by using monitoring bore records and Fortescue Marsh flooding records (interpreted from Landsat images) in the period from 1/01/1997 to 30/06/2013 (16.5 years). The period is divided into two stages, i.e., the pre-dewatering stage (from 1/01/1997 to 31/12/2007) and dewatering stage (from 1/01/2008 to 30/06/2013).

The evaluation criteria for the model included:

- Residuals between observed and simulated heads at monitoring bores.
- Correlation between simulated and measured hydrographs of head (representing groundwater hydraulic dynamics at selected monitoring bores).
- Consistency between modelled water balance and estimated water balance in the model conceptualisation stage.
- Correlation between simulated and observed salinity distribution in the model area.

Calibration results for the two stages are presented separately in the following sections.

Pre-dewatering calibration stage

By adjusting key model parameters and boundary conditions described, the best overall agreement between simulated and measured heads was achieved by using:

- Model parameter values shown in Table 20. Calibrated parameters are consistent with calculated parameters, Table 14. The only change was to include a high permeable zone within the Tertiary Detrital layer, Appendix 3. Conductivity in this zone has been increased by a factor of 20.
- The average annual Fortescue Marsh catchment runoff and evapotranspiration are 306.9 and 345.8 GL/a (see Table 21), respectively. The runoff of 306.9 GL/a equals 5% of effective rainfall over the whole Fortescue catchment (30,000 km^2).

- Average Fortescue catchment rainfall recharge rate is 1.4% of total rainfall, or 2.5% of the effective rainfall (sum of rainfall in all months with rainfall over 50 mm).

Table 20: Calibrated model hydraulic parameters

Hydro-stratigraphic unit	Hydraulic conductivity			Specific yield	Specific storage coefficient (1/m)
	K_h (m/s)	K_h (m/day)	K_h/K_z		
Marsh water body	1.0×10^{-1}	8640.0	1	1.0	10^{-5}
Tertiary Detrital	2.89×10^{-5}	2.15	20	0.04	10^{-4}
High permeable zone of Tertiary Detrital	5.78×10^{-5}	50	20	0.04	10^{-4}
Alluvial clay	1.16×10^{-8}	0.01	10	0.01	10^{-4}
Oakover Formation	23.1×10^{-4}	200	10	0.04	10^{-4}
Wittenoom Formation	0.35×10^{-4}	3	10	0.005	10^{-5}
Hardcap	1.16×10^{-6}	0.1	10	0.03	10^{-5}
Mineralised Marra Mamba Formation	6.94×10^{-4}	60	50	0.03	10^{-5}
Fractured Marra Mamba Formation	5.78×10^{-5}	5.0	100	0.03	10^{-5}
Un-mineralised Marra Mamba Formation	5.78×10^{-6}	0.5	50	0.01	10^{-5}
Roy Hill Shale	1.16×10^{-7}	0.01	10	0.001	10^{-5}

Simulated heads are compared with measured levels in Figure 17. The error between observed and simulated groundwater levels is in the range of -10.58 to 13.01 m. The average absolute error is 1.14 m, which is about 3.9% of the maximum difference (29.54 m) in observed groundwater levels. Typically, an error less than 10% is indicative of an acceptable calibration, since it means that the error is only a small part of natural groundwater level variations. The normalised Root Mean Squared error of the calibration is 5.8%, which is smaller than the value of 10% recommended by (SKM & NGRT, 2012).

Calibration of the model to the record of flooding for the Fortescue Marsh was undertaken for the period 1st January 1997 to 1st June 2011. The available rainfall data from Newman rainfall station was used as the primary time-varying model parameter for the Fortescue Marsh recharge formulation. The Fortescue Marsh runoff was adjusted to reproduce the observed Fortescue Marsh flood water levels.

The water balance of the calibrated model is shown in Table 21. Catchment rainfall recharge which refers to groundwater recharge is approximately 7.8 GL/a.

The water balance is dominated by surface water fluxes (340 GL/a) and evapotranspiration (341.7 GL/a) from the surface of the Fortescue Marsh. Water levels in the zone immediately beneath the marsh surface fluctuate by 1 to 4 m in response to cycles of flooding and evapotranspiration and the related groundwater storage change is small when compared to the surface water storage change. The small increase in groundwater storage change (6.1 GL/a) suggests that groundwater levels are slightly higher at the end than at the beginning of the model calibration period.

Table 21: Model water balance in the calibration period

Model Input		Model Output	Aquifer Storage Change (GL/a)
Catchment Recharge (GL/a)	Fortescue Marsh Recharge (GL/a)	ET[1] (GL/a)	
7.8	340	341.7	6.1

The pre-dewatering calibration results are similar to the transient calibration results presented in the previous hydrogeological assessment (FMG, 2010d).

Dewatering calibration stage

Recorded monthly pumping and injection rates were used as model inputs. Model parameters and recharge coefficients obtained from the pre-dewatering stage calibrations were used as initial parameters. In the dewatering stage calibration hydraulic parameters were adjusted to achieve reasonable fit with water levels, abstraction rates and injection rates. A scattergram for observed versus simulated water levels is presented in Figure 18. The results of the dewatering stage calibration are summarised as below:

- Simulated model abstraction was close to the actual abstraction (116.7 GL against 117.0 GL).
- The error between observed and simulated groundwater levels is in the range of -9.88 to 9.84 m. The average absolute error is 1.79 m.
- The ratio of the average absolute error to the maximum observed groundwater level difference (40.0 m) is 4.5%.
- The normalised Root Mean Squared error of the calibration is 5.9%, which is to that (5.8%) achieved in the pre-dewatering calibration.

As expected the average absolute error (1.79 m) is larger than that (1.14 m) achieved in the pre-dewatering calibration as groundwater levels are more dynamic under dewatering conditions. However, the ratio of the average absolute error to the maximum observed groundwater level difference is still significantly smaller than 10%, the commonly recommended guidance. All other calibration indicators are considered appropriate.

Hydrographs showing simulated and observed groundwater levels for both the pre dewatering and dewatering stage calibrations are presented in Appendix 4. The correlation between measured and simulated hydrographs at key locations is consistent, implying that the calibrated model has included the major processes and is representative of the groundwater system.

- The Fortescue Marsh zone is well calibrated to the magnitude, timing and absolute level of observed flooding events.
- The near marsh zone is well calibrated to the magnitude and timing of observed watertable change. Calibration to absolute levels could be improved with greater local refinement of the numerical model and density predictions, however the variation is generally less them one metre.
- The dewatering zone is generally well calibrated to the magnitude, timing and absolute level of observed water level changes in all horizons. Small scale structures and localised heterogeneity of the aquifer systems often result in individual poor calibration. Continual refinement of hydraulic parameters and understanding from operation will allow increased accuracy of calibration at a local scale.

During the dewatering stage calibrations, adjustments to some parameters were made:

- The specific yield of the mineralised MMF aquifer was increased from 0.03 to 0.04;
- Conductivity of the mineralised MMF aquifer was increased from 60 m/day to between 115 and 190 m/day in some pits area.
- Conductivity of the alluvial clay was reduced from 0.01 m/day to 0.001 m/day.

5.3.3 Calibration Summary

The updated groundwater model was calibrated against all available data at the end of June 2013. Calibration results are generally similar to those achieved in the calibration of the previous assessment (FMG, 2010d).

The MMF aquifer in the updated groundwater model is more continuous in the horizontal direction and deeper in some mining pits area compared to the 2010 assessment (FMG, 2010d). As a result the difference in abstraction volumes between model input (from measured data) and model result decreased from 11% in the 2010 assessment (FMG, 2010d) to 0.3% in this assessment. This demonstrates that the model structure provides a more accurate representation of reality.

In the dewatering stage calibrations it was found that the hydraulic conductivity of the ore body in some areas may be much higher than the average value calibrated in the pre dewatering calibration. Therefore, it is important to investigate the sensitivity of dewatering volumes to ore body conductivity when simulating mining operations.

5.4 Water management simulations

5.4.1 Mine plan and water management strategy

The basis for the model prediction is the Cloudbreak Life of Mine (LOM) Plan used within the 2010 assessment (FMG, 2010d). The plan defines a mining sequence which if mined accordingly will enable production of required tonnes of ore at suitable product grade over LOM.

The simulated abstraction and injection program is in line with the Water Management Strategy outlined in Section 4.1, as such, the following key elements are represented in the model:

- Dewatering of below watertable resource areas in accordance with the mine sequence outlined in the mine plan.
- Provision of brackish water for mine water use requirements.
- The remaining dewatered groundwater is mainly saline water and thus injected to the Oakover Formation aquifer located to the south of the mining area.

Dewatering and injection is simulated in the following manner:

Dewatering

- Dewatering is simulated by applying seepage nodes to the bottom of mine pits.
- Mining pits are assumed to be mined over a period of one year.
- Mine site water use (supplied from the dewatering operation) is assumed to be 10 GL/a in the LOM period from 2014 to 2024.

Injection

- Yearly injection volumes were calculated by subtracting mine water usage from predicted dewatering volumes.
- The reinjection of saline water was modelled by injection through conceptual bores.

5.4.2 Setup of numerical simulations

Non-dewatering scenario

A non-dewatering simulation is conducted in order to provide a baseline from which groundwater level changes due to operation can be estimated. This simulation is run for the whole LoM period but without any dewatering or injection. This simulation therefore provides a prediction of the natural fluctuation and dynamics of the hydrogeological system without mining. Figure 19, Figure 20 and Figure 21 show the fluctuation of the watertable at key monitoring locations adjacent to Fortescue Marsh for the base, dry and wet rainfall simulations respectively.

Dewatering and injection scenario

An initial dewatering only simulation (without injection) is conducted to provide an initial abstraction volume from which injection rates are estimated (abstraction less mine water use).

This injection volume is then applied in the second iteration of the scenario. Injection results in an increased in the abstraction rate due to recirculation of injected water to the abstraction point. The results of this simulation are used to revise the injection rate for the next simulation. This process is continued until abstraction is equivalent to the sum of mine water use and injection. Groundwater injection is adjusted spatially during this process to minimise water level impacts in areas sensitive to water level fall or rise.

The number and locations of injection bores in the model are conceptual only. In practice, bore locations and number of bores required will be determined by actual bore injection capacity.

Post-mining recovery

Following cessation of mining in 2024, the numerical model was run without further dewatering and injection to simulate the rebound of groundwater levels. Further information is provided in Section 6.5 and Appendix 7.

5.4.3 Generation of synthetic rainfall sequences

To enable consideration of climate variation on the water level predictions rainfall data from the Newman rainfall station dating back to 1971 were used to create three rainfall sequences representing average, wet and dry climate scenarios, respectively. Only 31 years in the period have complete rainfall records. These years were ranked based on the annual rainfall. The five years (1980, 1983, 2006, 2007 and 2008) with rainfall closest to the median annual rainfall in the 31 years were selected for generating an average rainfall sequence. A fourteen year time series was randomly generated using the five year data. The result is a sequence of 2008, 2006, 2008, 2007, 1983, 2008, 2008, 1983, 2007, 1983, 2007, 1983, 2007, and 1980). Using 100 mm/month as the threshold value for Marsh flooding, there are nine flooding events in the 14 years prediction period. The rainfall for each event is 122.8, 122.8, 124.6, 122.8, 122.8, 124.6, 124.6, 124.6 and 112.9 mm (Table 22).

A stochastic method from the Stochastic Climate Library (SCL) (http://www.toolkit.net.au/scl) was used to generate 1000 realisations of rainfall data for the 38 year Newman rainfall record. Stochastic climate data are random numbers that are modified so that they have the same statistical characteristics (in terms of mean, variance, skew, long-term persistency, and etcetera) as the historical data from which they are based. Each stochastic replicate (sequence) has different characteristics compared to the historical data, but the average of each characteristic from all the stochastic replicates is the same as the historical data.

The 1000 realisations were ranked from the driest realisation to the wettest realisation based on the total rainfall over the period. The realisation at 5% ranking was used to generate the dry

scenario. The driest continuous 14 years in the 5% ranking realisation was used for the dry scenario, which had five flood events (monthly rainfall >90 mm) in the prediction period (Table 21). The realisation at 95% ranking was used to generate the wet scenario. The wettest continuous 14 year period in this realisation was used for the wet scenario, which has 25 flood events (monthly rainfall > 100 mm) (Table 22).

Table 22: Model generated monthly rainfall data used for groundwater model predictions

Average Scenario			Dry Scenario			Wet Scenario		
Year	Month	Rainfall	Year	Month	Rainfall	Year	Month	Rainfall[28]
1	3	122.8	3	4	101.6	1	2	142.5
3	3	122.8	12	2	278.9	1	12	249.5
4	2	124.6				2	1	172.1
6	3	122.8				2	2	179.0
7	3	122.8				3	2	325.4
9	2	124.6				4	1	294.1
11	2	124.6				4	3	135.8
13	2	124.6				5	1	228.1
14	2	112.9				6	2	260.1
						8	2	338.2
						9	1	229.4
						9	3	106.0
						10	1	160.7
						10	2	123.8
						11	12	199.2
						12	1	164.6
						12	2	171.2
						13	2	286.7
						14	12	211.1
						17	3	121.6

[28] Only rainfall events >=100mm/month are shown

5.5 Model limitations

All numerical groundwater models are representations of the natural groundwater system. As a result of assumptions used in model conceptualisation and numerical model construction, groundwater models are subject to various limitations when applied to make predictions. The following limitations of the Cloudbreak model are noted.

5.5.1 Heterogeneity of hydraulic parameters

The hydraulic conductivity of the MMF and Oakover Formation aquifers is spatial-variability; as such their representation in the model as largely homogeneous aquifers is a simplification of hydrogeological complexity. Groundwater levels at some localised areas may be either over-predicted or under-predicted. Numerical scenarios employing a broad parameter range for key hydraulic units have been conducted to assess the regional water level impact of these uncertainties. Monitoring and in some cases incorporation of additional detail to models through operations will be employed to manage local scale responses.

5.5.2 Duration of dataset

The groundwater monitoring bore dataset used for Cloudbreak model calibrations covers the period from 2006 to 2012. This is sufficient for a robust characterisation of the aquifer system under natural conditions. The calibration of the model under the mine dewatering condition (calibration stage 2 period) was limited to the active mine pits area.

The fluctuation of Fortescue Marsh water levels were verified by using Landsat-derived data, and direct measurements from Cyclone Heidi. The model will need to be further calibrated against additional direct measured Marsh water levels, as such data becomes available.

5.5.3 Limited resolution in salinity distribution

Simulation of salinity distribution has been undertaken to provide a broad representation of the density-driven flow mechanism. Salinity was not modelled with sufficient spatial resolution to accurately predict salinity distribution in the vertical direction. Therefore, the salinity in the shallow aquifer may be over predicted owing to numerical dispersion in the vertical direction.

A 2-D numerical modelling investigation for the Chichester Range (FMG, 2010e) demonstrated that groundwater salinity in the shallow aquifer, at the fringe of the Marsh, is little affected by mine dewatering and saline water injection. Initial operational data confirms this finding and will be updated with continued observation and monitoring data.

6. GROUNDWATER MODELLING RESULTS

6.1 Predicted Results - Base Scenario

The base scenario has been simulated using average climatic conditions. An initial simulation without dewatering or injection was completed followed by simulation incorporating dewatering and injection, again with the average climate conditions. Comparison of the two simulations enables assessment of mining impacts. Results of this assessment are presented below.

6.1.1 Predicted natural groundwater regime

Hydrographs[29] at seven key locations along the Fortescue Marsh fringe are shown in Figure 19 to Figure 21. These figures show:

- Groundwater levels on the margin of the Fortescue Marsh only respond following rainfall events of 100 mm/month or more. This is directly related to flooding and ponding of water on the surface of Fortescue Marsh.
- Groundwater levels on the margin of the Fortescue Marsh may naturally vary between surface and 3.2 m bgl at various times and locations.
- The expected natural change in water level at locations on the fringe of the Fortescue Marsh for the LoM period will depend on the rainfall sequence. The groundwater level may recede by up to 3 m after a long dry period; whilst a major rainfall event may result in groundwater level rise of up to 3 m.

The rate of groundwater evapotranspiration decreases with depth to watertable. Evapotranspiration (of groundwater) is therefore greatest when water levels are closest to ground surface without ponding of water on the surface of Fortescue Marsh, i.e. immediately following flooding events. These simulated natural conditions are consistent with observed baseline data available.

6.1.2 Predicted dewatering and injection volumes

Model predicted dewatering and injection volumes for the base scenario are presented in Table 23. The predicted average annual dewatering volume (no injection) over the period of 2014 to 2024 is 74 GL/a, which increases to 94 GL/a as surplus water is injected back to the aquifer system. Injection, results in an increase of approximately 27% in average annual dewatering volumes and up to 44% in an individual year (2023) at peak recirculation (Table 23). Peak dewatering rate has been simulated at 136 GL/a, which occurs in 2019.

[29] Hydrographs presented in Figure 19 to Figure 21 do not include abstraction or injection and represent the predicted natural groundwater levels without mining.

Table 23: Model results – Base scenario

Year ending	Mine water use (GL/a)	Dewatering volume (GL/a)			Injection volume (GL/a)
		Without injection	With injection	Increase due to Recirculation	
June 2014	10	99	108	9%	98
June 2015	10	43	58	33%	49
June 2016	10	78	95	22%	81
June 2017	10	91	122	34%	111
June 2018	10	28	31	9%	21
June 2019	10	98	136	39%	128
June 2020	10	66	75	14%	63
June 2021	10	105	133	27%	120
June 2022	10	50	61	22%	53
June 2023	10	63	91	44%	82
June 2024	10	93	125	35%	114
Average Annual (GL/a)	**10**	**74**	**94**	**27%**	**84**
Total (GL)	**110**	**814**	**1035**		**920**

The average annual dewatering rate increased from 63.5 GL/a predicted by the previous assessment (FMG, 2010d) to 94 GL/a by the updated groundwater model of this assessment. Similarly, the peak dewatering rate increased from 91 GL/a to 136 GL/a. The substantial increase in dewatering rates is due mainly to two changes in the model;

1. The mineralised MMF aquifer being more continuous in the horizontal direction and deeper in some pits area,
2. Better connections between the mineralised MMF aquifer and the Oakover Formation aquifer. These changes were made based on recent drilling data and operational data.

6.1.3 Predicted groundwater drawdown/mounding distribution

For the base scenario, the predicted drawdown and mounding impact (difference between simulated water levels under natural conditions and water levels under dewatering and injection conditions) at the end of each mining year is presented in Figure 22 to Figure 32. These figures also include the depth to watertable contours (m bgl).

Time series of drawdown and mounding at seven key monitoring bore locations along the Fortescue Marsh fringe are plotted in Figure 33. The locations of the key monitoring bores are shown on Figure 22 and their coordinates presented in Table 24.

Table 24: Co-ordinates of the five key near-marsh monitoring locations

Site name	Location (MGA, Zone 50)	
	Easting	Northing
CBFMM01	720,703	7,531,612
CBFMM02_s	727,559	7,527,940
CBFMM04	734,697	7,527,655
CBFMM06_s	740,436	7,524,558
CBFMM05	746,758	7,523,454
CBFMM07	751,176	7,521,806
CBFMM08	755,273	7,520,434

The drawdown and mounding predictions illustrate the impact mining related dewatering and injection has on the watertable. Predicted drawdown and mounding shown in Figure 22 to Figure 32 indicate that:

- Watertable drawdown due to mine dewatering is restricted to the mining area. Small drawdown may extend towards the Fortescue Marsh.
- The maximum drawdown at the key monitoring locations (Table 24) is predicted to be about 0.9 m, occurred at CBFMM06_s in 2018.
- Watertable mounding is limited to small areas. The Oakover Formation is highly permeable and its storage capacity is much larger than the volume of injected water. The presence of the Tertiary clay also serves to mitigate pressure transmission to the watertable.
- The maximum watertable mounding at the key monitoring locations (Table 24) is 1.5 m, occurred at CBFMM05 in 2017.
- Saline water injection is an essential component for mitigating groundwater drawdown and impacts to the Fortescue Marsh. Modelling suggest that groundwater drawdown would be much larger without injection into the Oakover Formation.

The updated model predicts significantly larger abstraction volumes when compared to the previous assessment (FMG, 2010d). With the larger volumes the predicted maximum drawdown (0.9 m) and mounding (1.5) are slightly less (1 m maximum drawdown and 2 m maximum mounding) than predicted by the previous assessment (FMG, 2010d). This is due to the net abstraction from the system (difference between abstraction and injection volumes) being similar in both simulations and the presence of a lower permeability clay zone within the Tertiary detritals.

6.1.4 Predicted water demand and supply strategies

The assessment assumes mine water use (Table 25) will be met by the volume of brackish groundwater abstracted during mine dewatering. Based on an estimated brackish resource of 200 GL and remaining LOM water requirement of 110 GL this is plausible. However long term

water quality is difficult to predict since the quality (salinity) of pumped groundwater is determined by multiple factors, such as locations of active mining pits relevant to saline water body, depth of dewatering bores, and bore field operation schedules, etc. The following approach to mitigating brackish water shortfalls from dewatering operations is recommended:

- Reduce brackish water demand where possible (water saving options are currently being assessed).
- Transfer water between Cloudbreak and Christmas Creek to balance brackish water demand (such transfers are currently being undertaken).
- Abstract 'banked' brackish groundwater previously injected.
- Assess water transfer options such as other proximal mine sites.
- Assess other brackish water supply options such as reverse osmosis (RO) treatment of abstracted water and/or supply from a remote borefield.

6.2 Numerical Model Sensitivity and uncertainty analysis

Sensitivity analysis has been undertaken to examine the model response to extreme values of the primary impact-determining parameters (SKM & NGRT, 2012). Five key parameters were selected to undertake the sensitivity study:

- Rainfall sequence;
- Hydraulic conductivity of the Oakover Formation;
- Hydraulic conductivity of the ore body (mineralised Marra Mamba Formation);
- Specific yield of the ore body; and
- Specific storage coefficient of the Oakover Formation.

For each parameter, two simulations were conducted by varying the parameter value used in the base scenario to an upper value and a lower value, respectively. The upper and lower values of each parameter are listed in Table 26. These values were chosen based on field data from both Cloudbreak and Christmas Creek, representing the end member values that may be reasonably expected.

6.2.1 Sensitivity analysis of dewatering volumes

Predicted dewatering volumes for all sensitivity simulations are summarised and compared to the base scenario results in Table 26 and summarised below;

The highest uncertainty in average and peak annual dewatering rates is associated with the hydraulic conductivity of the ore body.

- The average annual dewatering volume increased by 16.6% in the simulation with the upper conductivity value, but decreased by 12.0% in the simulation with the lower conductivity value.
- The peak annual dewatering volume increased by 23.5% for the high conductivity simulation and decreased by 16.9% for the low conductivity simulation.

The second most sensitive parameter is the conductivity of the Oakover Formation.

- With an upper conductivity value, the average and the peak annual dewatering volumes increased by 13.7% and 25%, respectively.
- The average and peak annual dewatering volumes decreased by 14.8% and 24.3%, respectively, when the lower end value was used,

Predicted dewatering volumes are slightly sensitive to climate condition.

- Under the wet climate condition average and peak annual dewatering volumes increased by 1.7% and 4.4%, respectively.
- Changing from the average climate condition to the dry climate condition didn't result in any significant change in the average or the peak annual dewatering volume (less than 1.5%).

Dewatering volumes are not sensitive to specific yield of the ore body or the specific storage coefficient of the Oakover Formation. Both average and peak annual dewatering volumes changed by less than 2.2% when the upper or lower end values of these two parameters were used,

Comparing the sensitivity study results to those reported in the previous PER model assessment, it was found that:

- The sensitivity of dewatering volume to Oakover formation conductivity increased substantially due to the increased connections between the two major aquifers in the current model with dewatering volume increased. The increase in dewatering volume due to the use of the upper end value of Oakover conductivity is substantially higher for the current model (13.7%) than for the previous PER model (3%). Similarly, the decrease in dewatering volume due to the adoption of the lower end value of the conductivity is much larger for the current model (14.8%) than for the previous PER model (1.4%).
- The change in dewatering volume due to the use of the upper end value of the conductivity of the mineralised MMF aquifer increased significantly from 11% for the previous PER model to 16.6% for the current mode.
- The change in sensitivity associated with other model parameter values is not significant.

6.2.2 Sensitivity analysis of drawdown/mounding

Hydrographs at selected key locations for dry and wet scenarios are shown and compared to those for the base scenario in Figure 36 to Figure 42. Groundwater levels under both natural and mining conditions are significantly affected by climate with watertable increase of up to 2.5 m following large rainfall events.

Hydrographs at selected key locations for investigated in the sensitivity study are presented in Appendix 5 and discussed below.

Maximum drawdowns and deviations of maximum drawdown at each of key locations over the whole mining period are summarised for all sensitivity simulations and the Base scenario. Maximum mounding and deviations of maximum mounding, over the whole mining period at key locations for climatic sensitivity simulations are summarised and compared to those from the Base scenario in Table 28.

- The largest drawdown of all simulations occurred in the scenario with the wet climate condition at six out of seven key locations[30], and in the scenario with upper end value of the ore body conductivity at one key location (CBFMM04).
- The largest mounding (1.8 m) of all simulations occurred in the scenario with the wet climate condition at key location CBFMM04.
- The largest drawdown of all sensitivity simulations (1.68 m), which is 0.78 m larger than the maximum drawdown (0.9 m) in the base scenario, occurred at the key location CBFMM06_S in the simulation under the wet climate condition.
- Based on calculated maximum drawdown deviations (Table 26), groundwater drawdown is most sensitive to the climate data with the average deviation of the seven key locations being 0.47 m under the wet climate scenario.
- The sensitivity of groundwater drawdown to other model parameters is less significant (average deviation less than -0.15 m) and does not show significant variations among these parameters (average deviation in the range of 0.03 to -0.14).

In summary, groundwater drawdown/mounding are generally less sensitive to model parameters than dewatering volumes. This is similar to the results presented in the previous PER report (FMG, 2010d).

[30] Drawdown is the variation between natural and simulated water levels at a given point in time. Although maximum impacts would be expected in dry conditions, impacts from mining (drawdown) may be of a greater magnitude when there is a greater volume of water to impact, i.e. during the wet scenario. Absolute water levels are lower in the dry scenario (Figures 36 to Figure 42), even though drawdown has been calculated to be lower.

6.3 Water balance analysis

The water balance of the simulated Base, Dry and Wet scenarios is summarised in Table 25 as average annual volumes over the life of mine (LoM). The results highlight:

- Under natural conditions (no mine dewatering) recharge is dominated by the Fortescue Marsh runoff (94% to 98% of the total recharge). Catchment recharge is small (between 2% and 6% of the total recharge). Evaporation is the only model output.
- Under mine dewatering conditions, water injection becomes a significant part of total model recharge being 18%, 41% and 68% of the total model input, respectively for the Wet, Base and Dry scenarios. Both evaporation and mine dewatering are important model output. There is more evaporation than dewatering in the Base and Wet scenarios, but less evaporation than dewatering in the Dry scenario.
- The net mine water use (the difference between dewatering and injection volumes) is about 10 GL/a during the life of mine.
- Change in aquifer storage is small compared to total model input in the Base and Wet scenarios (1% to 6% of the total model input), but increased to 11% to 18% of the total model input in the Dry scenario due to that the total model input in the Dry scenario is much smaller than those in the Base and Wet scenarios. In all scenarios, the change in aquifer storage is less than 0.3% of the total aquifer storage.

Table 25: Model water balance in prediction period (2014 to 2024) for Base, Dry and Wet scenarios

Scenario	Water Management Option	Model inputs (GL/a)[31]			Model outputs (GL/a)		Change in storage (GL/a)
		Catchment Recharge	Fortescue Marsh Runoff	Water Injection	ET[32]	Mine Dewatering	
Base	No dewatering[33]	4.4	115.0	0.0	123.2	0.0	-3.8
	Dewatering[34]	4.4	115.0	83.6	119.1	94.1	-10.2
Dry	No dewatering	2.5	37.0	0.0	46.6	0.0	-7.1
	Dewatering	2.5	37.0	83.6	43.3	93.6	-13.8
Wet	No dewatering	9.6	389.0	0.0	375.1	0.0	23.5
	Dewatering	9.6	389.0	85.7	385.6	95.7	3.0

[31] Average annual volume (GL/a)
[32] Evapotranspiration
[33] Natural conditions (with no mine dewatering)
[34] Water management, as outlined in Section 5.4

6.4 Cumulative impacts

The predicted drawdown and mounding at the end of LOM are shown in Figure 33 to Figure 35. This has considered and included predicted drawdowns associated with the Christmas Creek Operations, and other publicly-available drawdown predictions of water level impacts in the region, as detailed in Figure 43 and summarised below:

- The Hancock Prospecting PER document (Hancock , 2009) for the proposed Roy Hill project. This lies to the east of the Christmas Creek project.
- The Brockman Resources PER (Aquaterra, 2010) document for the proposed Marillana project. This lies on the southern side of the Fortescue Marsh.

6.4.1 Marillana project

The Brockman Resources Project is located on the southern side of the Fortescue Marsh. The proposed water management for the project includes dewatering and injection. Dewatering results in a drawdown cone which is limited to the southern side of the Fortescue Marsh (Aquaterra, 2010). On this basis there is expected to be no overlap between the drawdown impacts associated with the Marillana Project and groundwater impacts associated with the Cloudbreak project.

6.4.2 Roy Hill project

The Roy Hill project, developed by Roy Hill Iron Ore Pty Ltd (RHIO), is located to the east of the Christmas Creek project, some 60 km from Cloudbreak. The project requires dewatering and therefore development of a drawdown cone results. There is no overlap between the drawdown impacts associated with the Roy Hill Project and groundwater impacts associated with the Cloudbreak project.

6.4.3 Christmas Creek project

The modelling results presented in Section 6.5.3 include proposed injection in the Hillside East injection area by the Christmas Creek operation. Fortescue have adopted an integrated Chichester Range approach to water management to support Fortescue Marsh management objectives.

Table 26: Model results (abstraction volumes) from sensitivity study

Sensitivity case	Hydraulic parameter				Average dewatering rate		Peak dewatering rate		Sensitivity ranking
	Oakover Formation		MMF						
	Kh (m/d)	Ss (1/m)	Kh (m/d)	Sy	GL/a	Change from base case	GL/a	Change from base Case	
Base Case	***200***	***1.00E-04***	***60***	***0.04***	**94.1**	**-**	**136**	**-**	
Wet	200	1.00E-04	60	0.04	95.7	1.7%	142	4.4%	3
Dry	200	1.00E-04	60	0.04	93.6	-0.5%	138	1.5%	
High Oakover K	*400*	1.00E-04	60	0.04	107.0	13.7%	170	25.0%	2
Low Oakover K	*100*	1.00E-04	60	0.04	80.2	-14.8%	103	-24.3%	
High Ore Body K	200	1.00E-04	*120*	0.04	109.7	16.6%	168	23.5%	1
Low Ore Body K	200	1.00E-04	*30*	0.04	82.8	-12.0%	113	-16.9%	
High Ore Body S_y	200	1.00E-04	60	*0.06*	94.2	0.1%	139	2.2%	4
Low Ore Body S_y	200	1.00E-04	60	*0.02*	93.1	-1.1%	137	0.7%	
High Oakover S_s	200	*5.00E-04*	60	0.04	93.5	-0.6%	138	1.5%	5
Low Oakover S_s	200	*2.00E-05*	60	0.04	93.6	-0.5%	137	0.7%	

Table 27: Model results (drawdown change) from sensitivity study

Sensitivity case	Hydraulic parameter				Maximum Drawdown at Key Locations (m)							Deviation of Maximum Drawdown from the Base Scenario (m)						
	Oakover Formation		MMF															
	Kh (m/d)	Ss (1/m)	Kh (m/d)	Sy	CBFM01	CBFMM02_S	CBFMM04	CBFMM06_S	CBFMM05	CBFMM07	CBFMM08	CBFMM01	CBFMM02_S	CBFMM04	CBFMM06_S	CBFMM05	CBFMM07	CBFMM08
Base Case	***200***	***1.00E-04***	***60***	***0.04***	0.08	0.37	0.76	0.90	0.73	0.54	0.14	-	-	-	-	-		
Wet	200	1.00E-04	60	0.04	**0.46**	**0.87**	1.26	**1.68**	**1.06**	**1.05**	**0.45**	0.38	0.50	0.50	0.78	0.33	0.51	0.31
Dry	200	1.00E-04	60	0.04	0.10	0.46	0.62	0.93	0.62	0.50	0.17	0.02	0.09	-0.14	0.03	-0.11	-0.04	0.03
High Oakover K	***400***	1.00E-04	60	0.04	0.30	0.39	1.48	0.69	0.00	0.24	0.00	0.22	0.02	0.72	-0.21	-0.73	-0.30	-0.14
Low Oakover K	***100***	1.00E-04	60	0.04	0.02	0.51	0.86	0.60	0.00	0.22	0.13	-0.06	0.14	0.10	-0.30	-0.73	-0.32	-0.01
High Ore Body K	200	1.00E-04	***120***	0.04	0.15	0.60	**1.52**	0.80	0.00	0.22	0.00	0.07	0.23	0.76	-0.10	-0.73	-0.32	-0.14
Low Ore Body K	200	1.00E-04	***30***	0.04	0.01	0.32	1.01	0.71	0.00	0.28	0.17	-0.07	-0.05	0.25	-0.19	-0.73	-0.26	0.03
High Ore Body S_y	200	1.00E-04	60	***0.06***	0.08	0.46	1.17	0.65	0.00	0.18	0.10	0.00	0.09	0.41	-0.25	-0.73	-0.36	-0.04
Low Ore Body S_y	200	1.00E-04	60	***0.02***	0.17	0.45	1.24	0.72	0.00	0.18	0.06	0.09	0.08	0.48	-0.18	-0.73	-0.36	-0.08
High Oakover S_s	200	***5.00E-04***	60	0.04	0.01	0.39	1.17	0.67	0.00	0.19	0.07	-0.07	0.02	0.41	-0.23	-0.73	-0.35	-0.07
Low Oakover S_s	200	***2.00E-05***	60	0.04	0.00	0.42	1.23	0.72	0.00	0.23	0.07	-0.08	0.05	0.47	-0.18	-0.73	-0.31	-0.07

Table 28: Model results (mounding change) from sensitivity study

Sensitivity case	Hydraulic parameter				Maximum Mounding at Key Locations (m)							Deviation of Maximum Mounding from the Base Scenario (m)						
	Oakover Formation		MMF															
	Kh (m/d)	Ss (1/m)	Kh (m/d)	Sy	CBFM01	CBFMM02_S	CBFMM04	CBFMM06_S	CBFMM05	CBFMM07	CBFMM08	CBFMM01	CBFMM02_S	CBFMM04	CBFMM06_S	CBFMM05	CBFMM07	CBFMM08
Base Case	***200***	***1.00E-04***	***60***	***0.04***	0.6	**0.3**	1.4	**1.5**	**1.1**	0.8	1.3	-	-	-	-	-		
Wet	200	1.00E-04	60	0.04	**0.8**	0.2	**1.8**	1.5	1	0.7	1.1	0.2	-0.1	0.4	0	-0.1	-0.1	-0.2
Dry	200	1.00E-04	60	0.04	0.7	0.3	1.6	1.5	1.1	**0.9**	**1.4**	0.1	0	0.2	0	0	0.1	0.1

6.5 Simulation of post-mining groundwater level recovery

Groundwater level recovery after mine closure was simulated over a range of time frames. In the mine area drawdown is predicted to recover from a maximum of around 50 m to around 6 m after 10 years and 3 m after 20 years.

The drawdown distribution for time increments following mine closure is shown in Appendix 7 and key changes are summarised below;

- One year after mining (2025) –Within the mining area drawdown has reduced significantly following 12 months on non-abstraction from over 50 m in 2024, Figure 32, to approximately 38 m in 2025. At the fringe of Fortescue Marsh there is little observed change between 2024 and 2025.
- Five years after mining (2029) – Drawdown within the mining area continues decreased significantly from 38 m in 2025 to 13 m in 2029. At the fringe of Fortescue Marsh drawdown has reduced slightly with only two of the key locations having drawdown over 1 m, but less than 1.5 m.
- Ten years after mining (2034) – Drawdown across all areas has reduced. Within the mining area drawdown is 6 m or less and at Fortescue Marsh is less than 1 m.
- Twenty years after mining (2044) – Drawdown has reduced further to less than 3 m within the area of mining, and to less than 0.5 m at monitoring locations at the fringe of Fortescue Marsh.
- Fifty years after mining (2074) – Drawdown across all areas is less than 2 m with very little impact at key monitoring locations at the fringe of Fortescue Marsh.

Following mining activities and the cessation of abstraction and dewatering the recovery of water levels will be highly dependent on rainfall.

7. CONCLUSION

7.1 Key changes from (FMG, 2010d)

Key changes from the conceptual model, interpretation and assessment for the previous PER assessment (FMG, 2010d) are summarised in Table 29.

Table 29: Key assessment changes from (FMG, 2010d)

Element/Concept	Change	Assessment Implication
Hydraulic Parameters	Three additional years of observation and testing data was used to refine the range of hydraulic parameters for each of the model layers.	No change to pre dewatering calibration hydraulic parameters used in the numerical model.
Mineralised MMF	The MMF aquifer in the updated groundwater model is more continuous in the horizontal direction and deeper in some mining area compared to the 2010 assessment (FMG, 2010d).	Increase in dewatering abstraction volumes. The difference in abstraction volumes between model input (from measured data) and model result decreased from 11% in the 2010 assessment (FMG, 2010d) to 0.3% in this assessment. This demonstrates that the model structure provides a more accurate representation of reality than previous assessment (FMG, 2010d).
Recharge	The Marsh recharge zone was extended to include some lowland area to the Northwest of the Fortescue Marsh (see Figure 16).	Area of inclusion subjected to flooding events and evapotranspiration effects up to 3 m bgl. Predicted watertable in this additional zone therefore reflects cyclic events of Fortescue Marsh rather than regional groundwater.
Operational Data & Model Calibration	The updated groundwater model was calibrated against all available data at the end of June 2013.	In the dewatering stage calibrations it was found that the hydraulic conductivity of the ore body in some areas may be much higher than the average value calibrated in the pre dewatering calibration. This may result in an increase in dewatering volumes.

7.2 Summary

Hydrogeological characteristics of the stratigraphy in the project area include:

- The project area is underlain by the Jeerinah Formation the upper-most formation of the Fortescue Group. The lithology is shale dominated creating low permeability conditions. Regional NE-SW fault systems and lithological variation can create zones of enhanced permeability.
- The Nammuldi Member of the Marra Mamba Formation (MMF) conformably overlies the Jeerinah Formation. This formation outcrops in the Chichester Ranges and dips gently southward beneath a blanket of recent cover. A broad blanket of supergene mineralisation (mineralised MMF) in the upper part of the Nammuldi Member has formed a laterally extensive and high permeability and storage aquifer along the strike of the Chichester Ranges. The aquifer is unsaturated to the north and the mineralisation and aquifer properties diminish to the south at around 4 to 8 km from the Fortescue Marsh. The lower part of the Nammuldi member is characteristically cherty and unaltered. Permeability is more constrained to sub vertical NE-SW trending fracture zones.
- The Wittenoom Formation overlays the MMF in areas south of where mineralisation occurs and is characteristically massive with low hydraulic conductivity. Regional NE-SW fault zones may have associated higher permeability.
- The mineralised MMF and Wittenoom Formation are unconformably overlain by a sequence of Tertiary detrital and alluvial sediments that thicken towards the south. The Tertiary sequence is characterised by; a lower calcrete and silcrete unit (Oakover Formation) with high permeability and storage; a clay aquitard (Tertiary clay), which overlays the Oakover Formation; and silts, sands and gravels (Tertiary Detritals) with generally low permeability. The shallow alluvial (watertable) layer is not a major aquifer due to its low permeability, but it is potentially environmentally important as it may be a source of water for vegetation in areas fringing the Fortescue Marsh.
- Groundwater salinity distribution in the mining area is brackish in the detrital aquifer and mineralised MMF; saline in the lower fracture dominated MMF; and becoming hypersaline in the Jeerinah Formation. Laterally towards the Fortescue Marsh, the saline interface occurs higher in the hydrostratigraphy with groundwater in portions of the alluvial, detrital and Oakover Formation being hypersaline near the Fortescue Marsh. The origins of saline water are associated with evapoconcentration and hydrological function within the closed basin.

The key regional groundwater and surface water hydrological regimes include:

- Topographic driven groundwater regime; in which rainfall and stream flow infiltration on the upper and lower slopes of the Chichester Ranges flows in a southward direction through the Tertiary Detritals, mineralised MMF and Oakover Formation.
- Density driven groundwater regime; in which high salinity groundwater beneath the Fortescue Valley results in a pressure gradient that directly opposes the topographic

driven regime. The interface of these two systems creates a saltwater interface that extends over many kilometres and is gradational throughout the flow system.

- The Fortescue Marsh regime; cycles periodically from a surface water dominated recharge system under flood conditions that recharges the shallow groundwater system, to a discharge regime where evapotranspiration is dominant.

A density-driven flow and transport numerical groundwater model was updated and calibrated in the FEFLOW modelling platform for the Cloudbreak project area. Calibration of steady state pre-mining conditions, short term aquifer tests and longer term operational conditions have validated the numerical model. The calibrated numerical model was used to predict groundwater dynamics in the LoM period by using various rainfall sequences (that is, Base [an average-probability rainfall sequence], Dry [5% probability extreme-dry rainfall sequence] and Wet [5% probability extreme-wet rainfall sequence] scenarios) that were generated based on historical rainfall records in the area.

Incorporating the baseline climatic conditions into a non-mining scenario, the model has simulated water levels in the alluvial aquifer adjacent to the Fortescue Marsh consistent with historical observed water level rise and fall in response to cycles of flooding evapotranspiration on the Marsh.

The proposed mine water management strategy for Cloudbreak is consistent with the strategy employed at Christmas Creek, and is designed to meet the mining requirements and Fortescue Marsh Management objectives. A cornerstone of the strategy is managed aquifer recharge.

Dewatering will be achieved through advance borefield abstraction and operational dewatering within pits as required. Dewatering may significantly exceed mine water use requirements, and any surplus (the difference between abstraction water and mine water use) will be returned to compatible aquifers through injection to preserve water resources and to minimise environmental impacts (groundwater level drawdown/mounding).

Excess brackish water will generally be injected into the along-strike mineralised Marra Mamba Formation aquifer for future use. Excess saline water will be injected into the naturally-saline Oakover Formation aquifer, south of mining areas, to reduce the dewatering drawdown footprint.

Groundwater dewatering volumes and drawdown/mounding predicted using the average rainfall updated calibrated model show that:

- The average annual dewatering volume is predicted to be 94 GL/a over the LoM period.
- The peak annual dewatering volume is predicted to be 136 GL/a (see statements below regarding dewatering-volume sensitivity).
- Groundwater drawdown along the Fortescue Marsh fringe is small (less than 1 m) over the LoM period.

- Groundwater mounding of the watertable along the Fortescue Marsh fringe is small (less than 1 m) over the majority of LoM period and 1.5 m for short periods of time at CBFMM04_s, CBFMM05_s and CBFMM08_s. It is believed this can be managed through optimisation of the Cloudbreak water management scheme.

The sensitivity of model predictions to climate conditions and key model parameters was investigated through numerical simulations. Results show that:

- Groundwater abstraction volumes are most sensitive to conductivities of ore body.
    - Average annual dewatering rates increasing by up to 16.6% (to about 110 GL/a, with ore body having the upper end value of conductivity).
    - Peak (as opposed to average) annual dewatering rates may increase by up to 23.5% (to about 168 GL/a).
- Groundwater drawdown at the watertable along the Fortescue Marsh fringe is moderately sensitive to climate conditions and conductivities of the ore body and the Oakover Formation.
    - Maximum watertable drawdown (as measured at the seven key near-marsh monitoring sites) may slightly increase from 0.9 m in the base scenario to about 1.68 m in the worst scenario with wet climate conditions.
    - Maximum watertable mounding (as measured at the seven key near-marsh monitoring sites) may slightly increase from 1.5 m in the base scenario to about 1.8 m in the worst scenario with wet climate conditions.
- The model is sensitive to the degree of connection between the Oakover Formation and MMF ore body aquifers. A high degree of connection is assumed for this modelling assessment; however, less connectivity will result in less drawdown and lower dewatering volumes.

To assess potential groundwater-quality impacts from the proposed water management scheme on the near-marsh environment, a 2-D numerical modelling assessment for the Chichester Range was undertaken (FMG, 2010e). This work concluded that the groundwater salinity of the shallow aquifer, adjacent to Fortescue Marsh, is little affected by mine dewatering and saline water injection.

Groundwater level recovery after mine closure was simulated over a range of time frames. In the mine area drawdown is predicted to recover from a maximum of around 50 m to around 6 m after 10 years and 3 m after 20 years.

Modelling results suggest that the Cloudbreak water management scheme can operate independently. However, opportunities to improve operational efficiencies and control of water levels near the Fortescue Marsh would be realised by adopting an integrated water management approach with Christmas Creek.

Inter-mine transfer has the opportunity to provide contingency options to mitigate potential shortfalls in the brackish water resource and near marsh watertable impacts. These contingencies are listed below in order of priority:

- Reduce brackish water demand where possible (water saving options are currently being assessed).
- Transfer water between Cloudbreak and Christmas Creek to balance brackish water demand (such transfers are currently being undertaken).
- Abstract 'banked' brackish groundwater previously injected.
- Assess water transfer options such as other proximal mine sites.
- Assess other brackish water supply options such as reverse osmosis (RO) treatment of abstracted water and/or supply from a remote borefield.

7.3 Future work

Ongoing hydrogeological assessment will assist in conceptual understanding and water management at Cloudbreak. Further investigations that could improve understanding and operational water management are outlined below.

- Ongoing hydrogeological investigations in areas of uncertainty to support ongoing development of the conceptual model particularly associated with Fortescue Marsh.
- Ongoing hydrogeological investigations of the Oakover Formation to confirm long term sustainable injection rates. Injection of saline water is an integral part of continued operations, contingency measures will be developed to reduce or limit injection of saline water and may include;
    - Ensure mine plans and hydrogeological assessments align with the long term capacity of the Oakover Formation.
    - Transfer of water between Cloudbreak and Christmas Creek to utilise the full strike length of Oakover Formation for injection.
    - Continued exploration of Oakover Formation to the west of Cloudbreak, south of areas of future mining.
    - Investigation and exploration of formations beneath the Oakover Formation which may be suitable for injection of surplus saline water.
    - Implement water saving measures within all areas of operation to determine if additional volumes of saline water can be utilised to reduce the demand on injection.
    - Consideration of a reverse osmosis (RO) plant which would utilise saline water and reduce demand on the Oakover Formation.

- Routine updating of the numerical model with findings of investigations and operational groundwater response to refine the model predictive capability.

.

REFERENCES

Aquaterra. (2004). *east Pilbara Iron Ore Project, Hydrogeology report for the Public Environmental Review.* Perth: Aquaterra.

Aquaterra. (2005). *Hydrogeological report for Cloudbreak Public Envioronmental Review, Unpublished report.* Perth: Aquaterra.

Aquaterra. (2010). *Marillana Project Groundwater Study & Management Plan, PER supporting docuemnt prepared for Brockman Resources, Ref. 832G/G7154f.* Aquaterra.

Astron. (2012). *Cloudbreak Life of Mine Conservation Significant Flora Survey Phase 1. .* Astron, Unpublished report prepared for the Fortescue Metals Group Pty Ltd. .

Astron. (2012a). *Cloudbreak Life of Mine Conservation Significant Flora Survey Phase 2. .* Astron, Unpublished report prepared for the Fortescue Metals Group Pty Ltd.

Bear, J. (1972). *Dyanimcs of fluids in porous media.* New York, Am.: El764psevier Publishing Co., .

Biota. (2004). *Fortescue Metals Group Stage B Rail Corridor, Christmas Creek, Mt Lewin, Mt Nicholas and Mindy Mindy Areas Vegetation and Flora Survey, Report pRepared for Fortescue Metals Group.* Perth: Biota Environmental Sciences Pty Ltd .

Bureau of Meteorology. (1977). *Climatic Atlas of Australia.* Canberra: Australian Government Publishing Service.

Clout, J. (2011). *The Royhill Project.* AisiMM 3, 52-65.

Ecologia. (2010). *Cloudbreak Terrestrial Vertebrate Fauna Desktop Assessment. .* Ecologia, Unpublished report prepared for Fortescue Metals Group.

Ecologia. (2011). *Cloudbreak Level 2 Terrestrial Vertebrate Fauna Assessment. .* Ecologia, Unpublished report prepared for Fortescue Metals Group.

Env. (2001). *A Directory of Importnat Wetlands in Australia, Third Edition.* Environment Australia, ISBN 0 642 54721 1.

ENV. (2011). *Cloudbreak Flora and Vegetation Assessment.* ENV Australia, Unpublished reoprt prepared for Fortescue Metals Group Lts.

EPA. (2013). *Environmental and water assessments relating to mining and mining-related activities in the Fortescue Marsh management area - Advice o fthe Environmental Protection Authority to the Minister for Environment under Section 16(e) of the EPA 1986.* Environmental Protection Authority, Report 1484.

Equinox Environmental. (2012). *Fortescue Marsh: Synthesis of Hydrological knowledge.* Perth: Equinox Environmental Pty Ltd.

Equinox Environmental Pty Ltd. (2012). *Fortescue Marsh, Synthesis of Hydrological Knowledge.* Perth: Equinox Environmental Pty Ltd.

FMG. (2007). *Pilbara Iron Ore and Infrastructure Projects< Draft, Re-injection Water Chemical Compatibility Study, 206-24-WR-RP-0001.* Perth: Fortescue Metals Group.

FMG. (2009). *Pilbara Iron Ore and Infrastructure Project, hydrogeolgoical Assessment.* Perth: Fortescue Metals Group.

FMG. (2009a). *Chichester Operations Surface Water Management Plan, 45-PL-EN-0015.* Perth: Fortescue Metals Group.

FMG. (2010). *Christmas Creek 2009 Bore Completion Report, Reference Code CC-RP-HY-0007.* Perth: Fortescue Metals Group.

FMG. (2010). *Hydrogeological Assessment for Cloudbreak Water Management Scheme.* Perth: Fortescue Metals Group.

FMG. (2010a). *Hydrogeological Assessment for the Christmas Creek Water Management Scheme, CC-RP-HY-0004.* Perth: Fortescue Metals Group.

FMG. (2010b). *Cloudbreak Saline Injection Trial Six Months Compliance Report, CB-RP-HY-0021.* Perth: Fortescue Metals Group.

FMG. (2010c). *Cloudbreak Operations triennial Aquifer Review: 1st August 2007 – 31 July 2010, CB-RP-HY-0023.* Perth: Fortescue Metals Group.

FMG. (2010d). *Hydrogeological Assessment for the Cloudbreak Water Management Scheme, CB-RP-HY-0019.* Perth: Fortescue Metals Group.

FMG. (2010e). *Modelling Two Dimensional Density Driven Flwo and transport under Mine Dewatering and Saline Water Injection Conditions.* Perth: Fortescue Metals Group.

FMG. (2011). *Cloudbreak Life of Mine - Public Environmental Review, April 2011. .* Perth: Fortescue Metals Group.

FMG. (2012). *Cloudbreak Saline Injection trial Stage 2 Close-out report, Water Management Department .* Perth: Fortescue Metals Group.

FMG. (2012). *Hydrogeological Assessment for the Christmas Creek Water Management Scheme Under Alternative Mining Sequence, CC-AS-WM-00001.* Perth: Fortescue Metals Group.

FMG. (2012a). *Cloudbreak Saline Injection trial Stage 2 Close-out report, Water Management Department, CB-RP-HY-0030.* Perth: Fortescue Metals Group.

FMG. (2012b). *Christmas Creek Groundwater Operating Strategy.* Perth: Fortescue Metals Group.

FMG. (2013). *Cloudbreak Groundwater Monitoring Summary (1 February 2013 to 31 April 2013).* Perth: Fortescue Metals Group.

FMG. (2013a). *Christmas Creek Triennial Groundwater Monitoring Review - August 2010 - July 2013, CC-RP-HY-0039.* Perth: Fortescue Metals Group.

FMG. (2013b). *Cloudbreak Triennial Groundwater Monitoring Review (August 2010 - July 2013), CB-RP-HY-0037.* Perth: Fortescue Metals Group.

FMG. (2013c). *Part V Licence (L8199/2007/2) Supporting Document, Cloudbreak Water Management Scheme.* Perth: Fortescue Metals Group.

FMG. (2013d). *Cloudbreak Groundwater Operating Strtaegy.* Perth: Fortescue Metals Group.

FMG. (2013e). *Hydrogeological Assessment of the Christmas Creek life of mine water management scheme.* Perth: Fortescue Metals Group.

FMG. (2013f). *Cloudbreak Life of Mine Surface Water Management Plan, CB-PL-EN-0023.* Perth: Fortescue Metals Group.

Gentilli, J. (1972). *Australian Climate Patterns.* Melbourne: Thomas Nelson - Austrlaian Government Publishing Service.

Goode, B. (2009). *Reort on the Ethnographic Aboriginal heritage Survey of the Christmas Creek Hydrological System, Western Australia, FMG Survey Request ETH_NYI_001, Prepared for Fortescue Metals Group ltd (FMG) and the Nyiyaparli Title Claimants.* Perth.

Hancock . (2009). *Roy Hill 1 Iton Ore Project Stage 1, Public Environmental Review Document.* Perth: Hancock Prospect Pty Ltd.

Hannon, E. K. (2005). *From Target Generation to Two Billion Tonnes in 18 Months - The re-invention fo the Chichester Range: in Iron Ore 2005 Conference, Perth WA, September 19-20, 2005.* Melbourne: The Australsian Institute of Mining and Metallurgy, pp 73-77.

Mattiske. (2005). *Flora and Vegetation on the Cloud Break and White Knight Leases.* Mattiske Consulting Pty Ltd , Unpublished report prepared for the Fortescue Metals Group Pty Ltd.

Mattiske. (2007). *Flora and Vegetation near Fortescue Marsh.* Mattiske Consulting Pty Ltd , Unpublished report prepared for the Fortescue Metals Group Pty Ltd.

MWH. (2009). *Technical Memorandum, Predicted geochemical interactions for re-injection of Fortescue abstraction water.* Perth: MWH.

SKM & NGRT. (2012). *Australian Groundwater Modelling Guidlines.* Waterlines Report Series No. 82, June 2012.

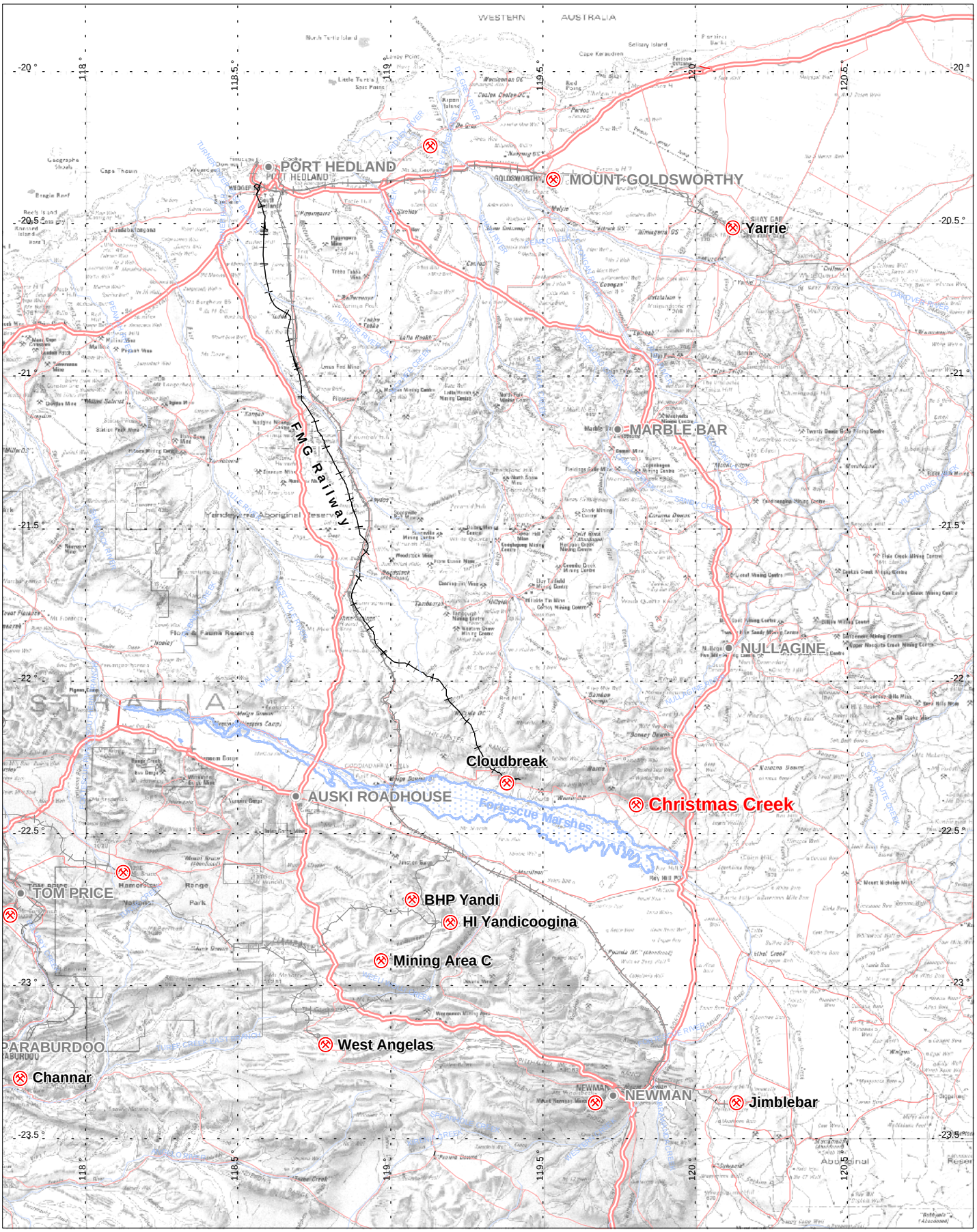
Skrypek G., D. S. (2013). *Geochemical and hydrological processes controlling groundwater salinity of a large inland wetland of north west Australia.* Chemical Geology 357 (2013) 164-177.

Thorne, W. H. (2008). *Banded Iron formation-related iron ore deposits of the Hamersley Province, Western Australia.* Perth: Economic Geology v.15.pp. 197-221.

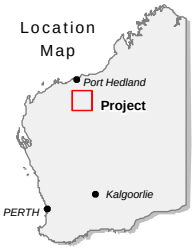
Worley Parsons. (2012). *The Fortescue Marsh Catachemnt Water Balance Study, 301012-01527-SS-REP-0003.* Worley Parsons.

Figure 1: Location Plan

This page has been left blank intentionally



Location Map



- Mine Sites
- Towns
- FMG Railway
- Other Railways
- Roads
- Major Creek/Drainage

N

0 25 50
kilometres

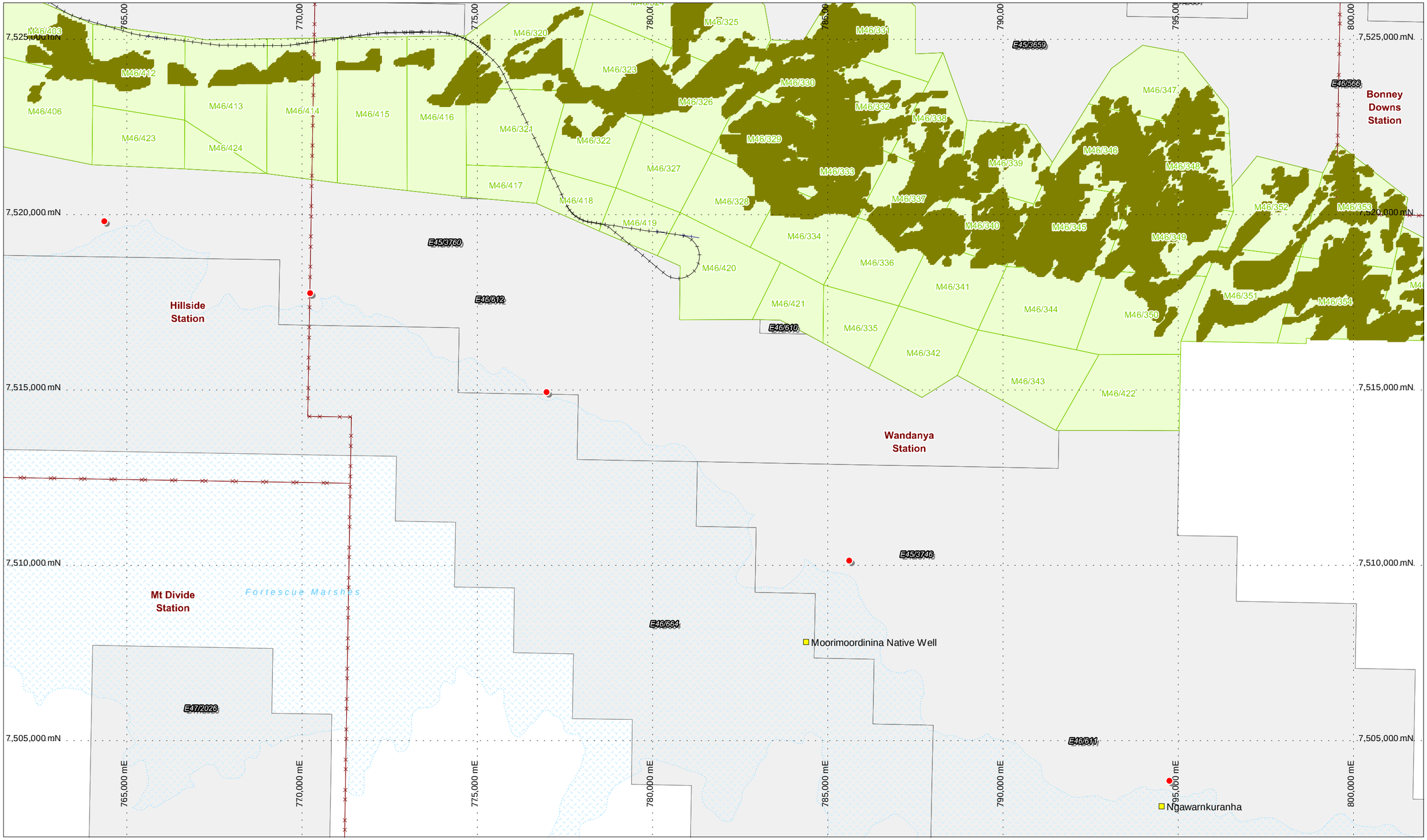
Fortescue Metals Group Ltd

Site Location

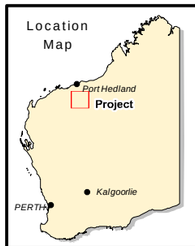
Author: IBdR	Date: 27/05/2010
Drawn By: SH	Revision: 5
Doc No: GE_MP_HY_0005_Fig1	Confidentiality: 1
Projection: Longitude / Latitude (WGS 84)	Scale: 1:1750000

Figure 2: Site setting

This page has been left blank intentionally



Location Map



Map Legend

- Existing Bore Sites
- Fortescue Marshes
- Environmentally Surveyed Area
- FMG Exploration Licence
- FMG Mining Lease
- Pastoral Lease
- Christmas Creek Special Rail Licence
- Resource outline
- Christmas Creek Rail Alignment
- Fortescue Marsh monitoring sites
- Yinta (Aboriginal Heritage Site)

N

0 1 2 4

KILOMETRES

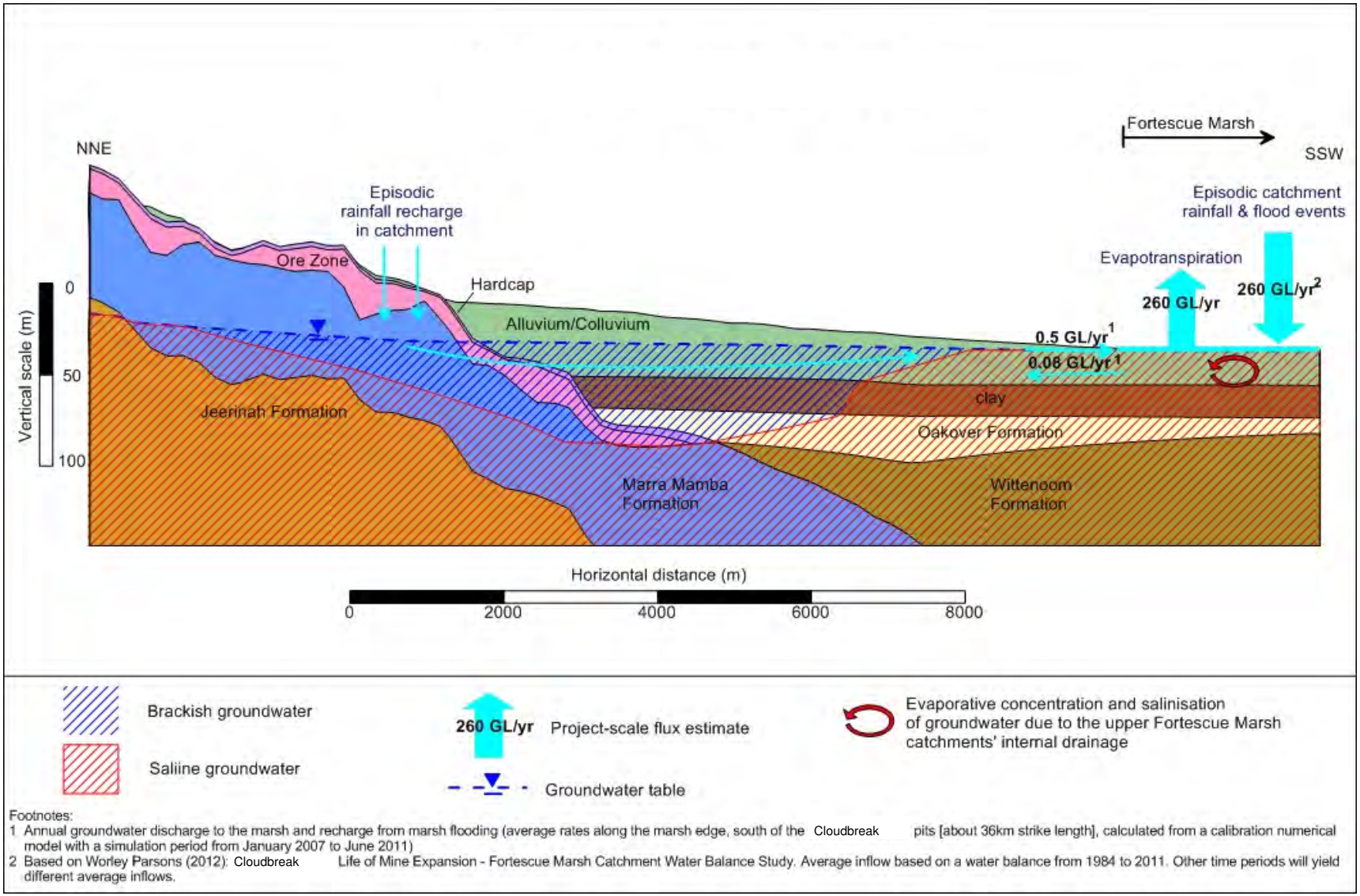
Fortescue Metals Group Ltd

Site Setting

Author: Ian Brandes De Roos	Date: 28/11/2011
Drawn By: S. Hendricksen/C. Whyte	Revision: 11
Doc No: CC_PE_EN_0002_r13	Confidentiality: 1
Projection: MGA Zone 50 (GDA 94)	Scale: 1:100000

Figure 3: Conceptual Chichester cross section

This page has been left blank intentionally



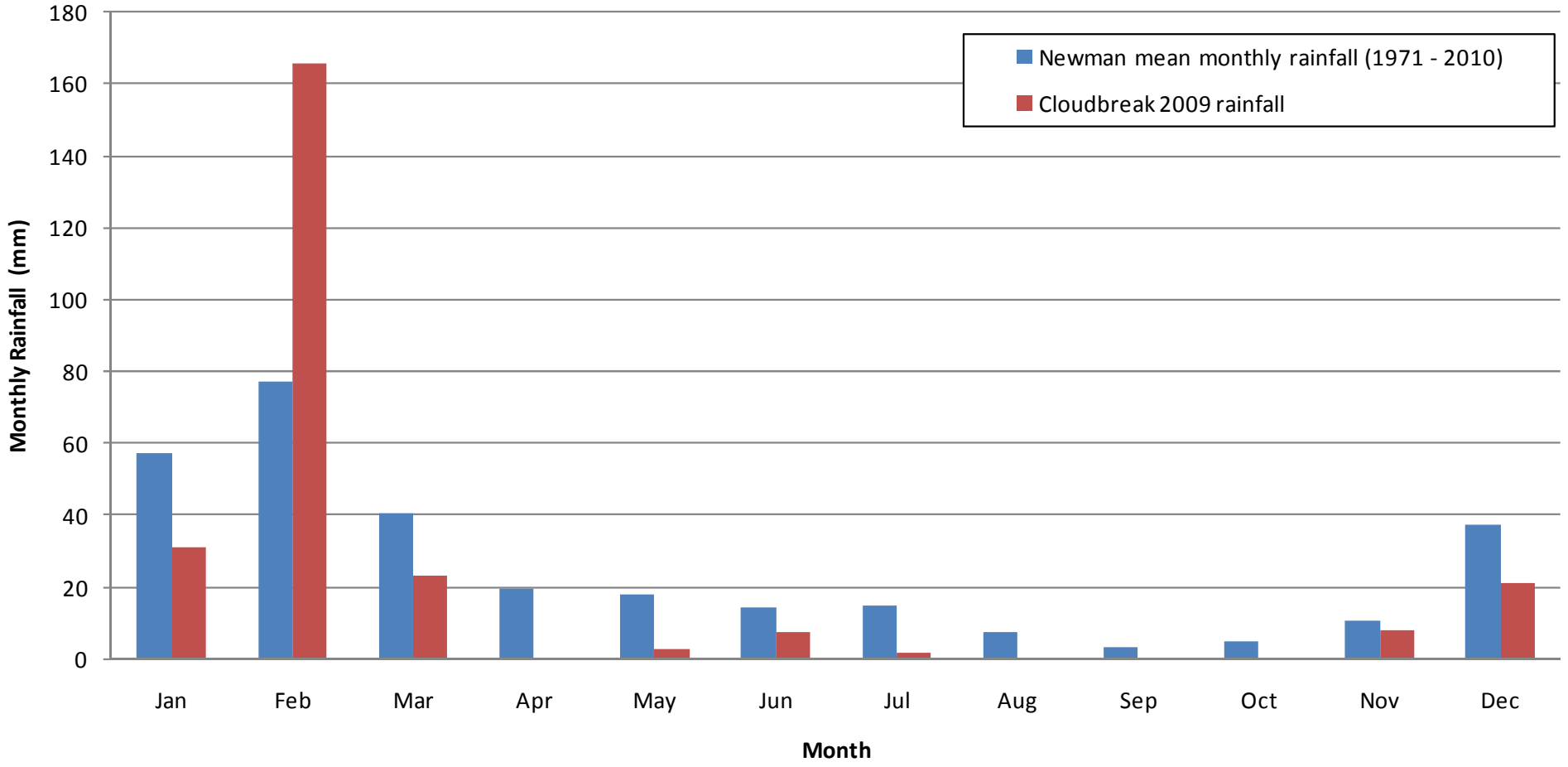
Footnotes:
1 Annual groundwater discharge to the marsh and recharge from marsh flooding (average rates along the marsh edge, south of the Cloudbreak pits [about 36km strike length], calculated from a calibration numerical model with a simulation period from January 2007 to June 2011)
2 Based on Worley Parsons (2012): Cloudbreak Life of Mine Expansion - Fortescue Marsh Catchment Water Balance Study. Average inflow based on a water balance from 1984 to 2011. Other time periods will yield different average inflows.

Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Cloudbreak Conceptual Cross Section**	**Figure 03**
		07/11/2013

Figure 4: Historical rainfall

This page has been left blank intentionally

Rainfall Data for Newman and Cloudbreak



Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Rainfall Data for Newman and Cloudbreak**	**Figure 04**
		07/11/2013

Figure 5: Baseline groundwater levels – Tertiary Detrital

This page has been left blank intentionally

Cloudbreak

Chichester CID

720,000 mE
730,000 mE
740,000 mE
750,000 mE
760,000 mE
770,000 mE

7,540,000 mN
7,530,000 mN
7,520,000 mN
7,510,000 mN

Location Map

Port Hedland
Project
Kalgoorlie
PERTH

Mine Sequence

Fortescue Marsh Boundary

Water Table Elevations (Late 2007)

Existing Roads/Tracks

Cloudbreak Monitoring Bores

N

0 1.25 2.5 5
kilometres

Fortescue Metals Group Ltd

Water Table Elevation (Late 2007)

Author: B. Willis-Jones	Date:9/9/2010
Drawn By: S.Hendricksen	Revision: 0
Dwg No: CB_MP_HY_0044	Confidentiality: 1
Projection: MGA Zone 50 (GDA 94	Scale: 1:140000

Figure 6: Baseline groundwater levels (fresh water equivalence) – Marra Mamba Formation

This page has been left blank intentionally

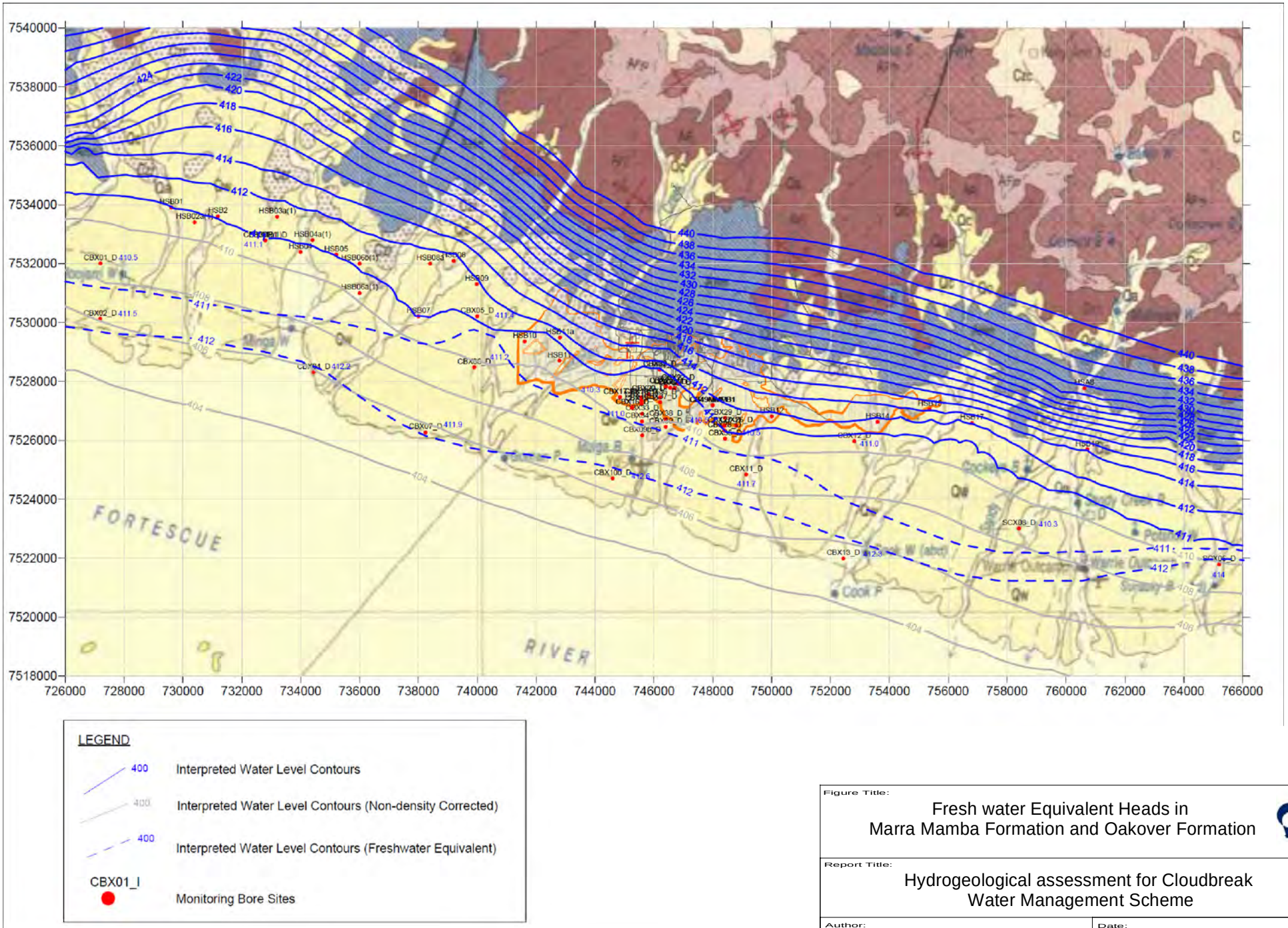


Figure Title: Fresh water Equivalent Heads in Marra Mamba Formation and Oakover Formation	
Report Title: Hydrogeological assessment for Cloudbreak Water Management Scheme	
Author:	Date:
Drawn By:	Revision:
Drawing Ref:	Report Ref:
Scale:	Figure No: 17

Figure 7: Fortescue Marsh ponding event

This page has been left blank intentionally

7,550,000 mN
7,540,000 mN
7,530,000 mN
7,520,000 mN
7,510,000 mN
710,000 mE
720,000 mE
730,000 mE
740,000 mE
750,000 mE
760,000 mE
770,000 mE
780,000 mE

CB30MB1_S
CBX02
CBX04_D
CBX05_D
CBX06_I
Cloudbreak
B1
A1
CBX07_D
CBX10a_WT
CBX13_I
SCX03_D
SCX06_D
CCF07A_D

Location Map
Port Hedland
Project
Kalgoorlie
PERTH

Fortescue Marsh Boundary
Mine Sequence
Marsh Ponding
250k Drainage
Existing Roads/Tracks
Reference Monitoring Bores
UWA Marsh Water Level Monitoring Sites

N
0 2 4 8
kilometres

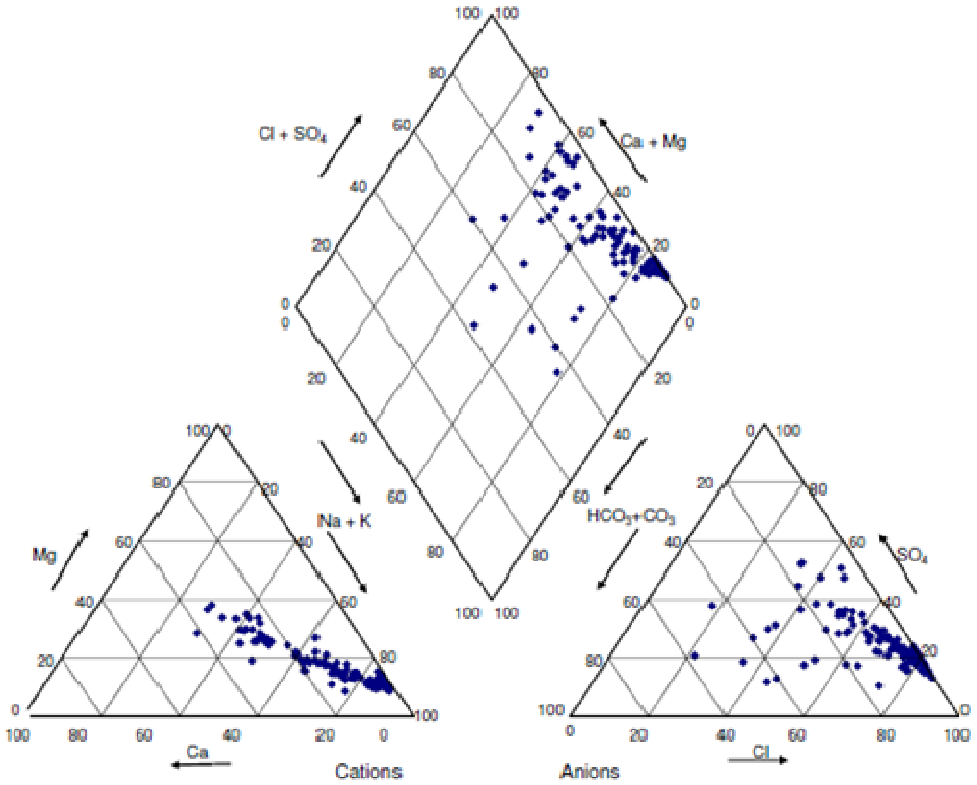
Fortescue Metals Group Ltd

February 2009 Marsh Ponding Event

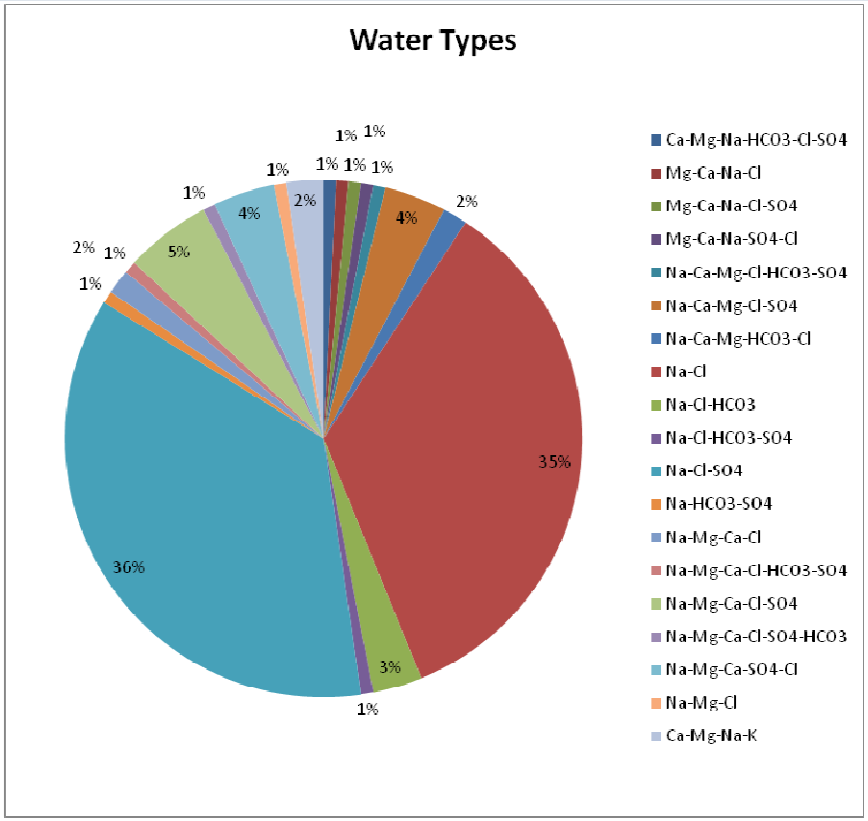
Author: B. Willis-Jones	Date:9/9/2010
Drawn By: S.Hendricksen	Revision: 0
Dwg No: CB_MP_HY_0044	Confidentiality: 1
Projection: MGA Zone 50 (GDA 94	Scale: 1:200000

Figure 8: Cloudbreak Water Types

This page has been left blank intentionally



Piper Plot of 135 Groundwater Samples Across the Cloudbreak-Christmas Creek Area. Jeerinah Fm samples shown in red.



Water Types Based on Chemical Composition and Position on Piper Plot. Dominant Water Types 1) Na-Cl-SO4 (36%), 2) Na-Cl (34%), 3) Na-Mg-Ca-Cl-SO4 (5%), 4) Na-Mg-Ca-SO4-Cl (4%)

Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Water Types**	**Figure 08**
		07/11/2013

Figure 9: Baseline E.C. – Tertiary Detritals

This page has been left blank intentionally

720,000 mE
730,000 mE
740,000 mE
750,000 mE
760,000 mE
770,000 mE
7,540,000 mN
7,530,000 mN
7,520,000 mN
7,510,000 mN
Cloudbreak
Chichester CID
2000
5000
10000
20000
30000
40000
50000

Location Map
Port Hedland
Project
Kalgoorlie
PERTH

Mine Sequence
Fortescue Marsh Boundary
Salinity Upper TD3
Existing Roads/Tracks
Cloudbreak Monitoring Bores
Sampling Points

N

0 1.25 2.5 5
kilometres

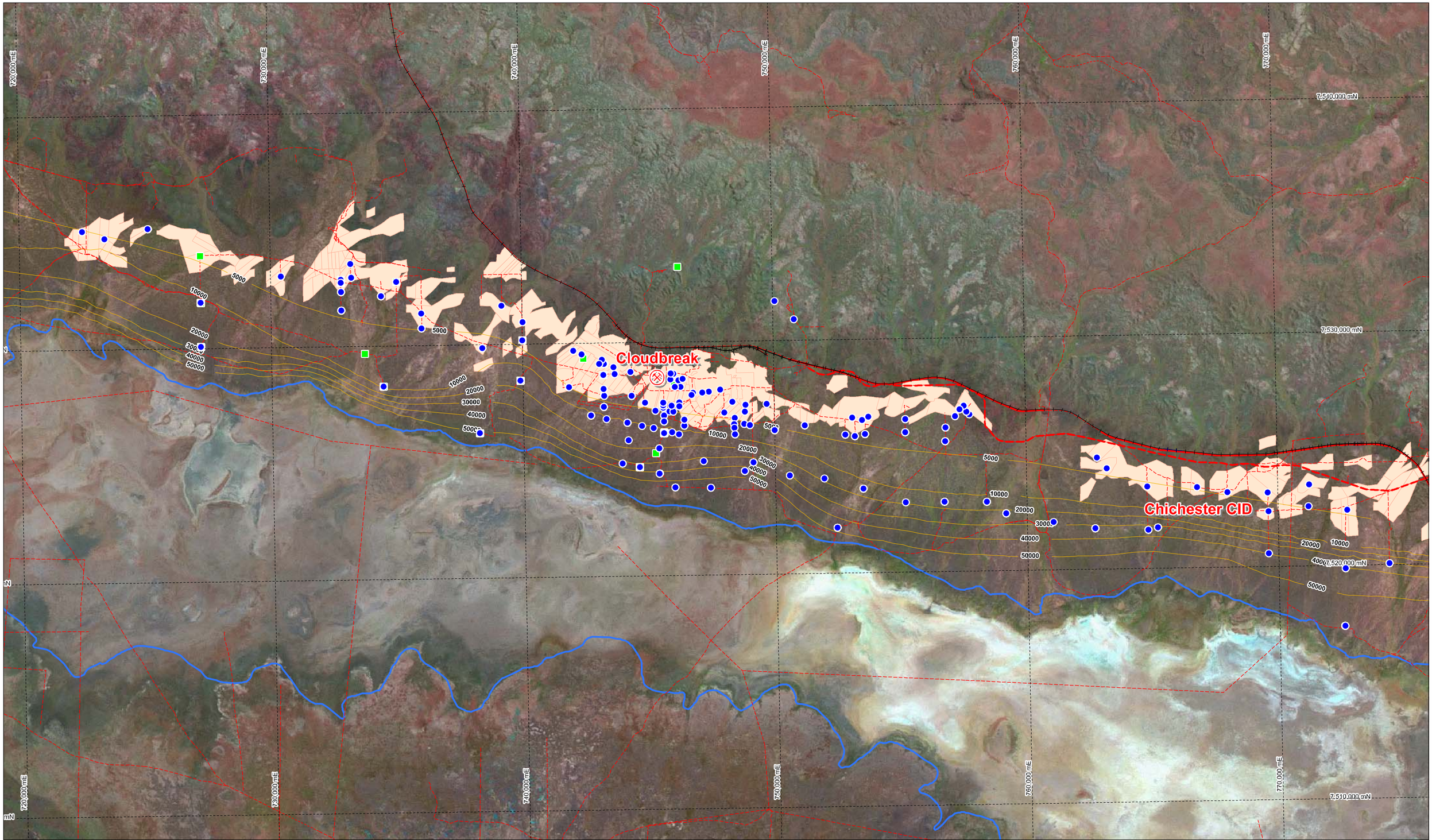
Fortescue Metals Group Ltd

Salinity Distribution in Upper Teriary Detritals (TD3) in mg/L

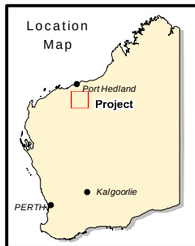
Author: B. Willis-Jones	Date:9/9/2010
Drawn By: S.Hendricksen	Revision: 0
Dwg No: CB_MP_HY_0044	Confidentiality: 1
Projection: MGA Zone 50 (GDA 94)	Scale: 1:140000

Figure 10: Baseline E.C. – Marra Mamba Formation

This page has been left blank intentionally



Location Map



Mine Sequence

Fortescue Marsh Boundary

TDS(mgl) Distribution in OF and UMMF

Existing Roads/Tracks

Cloudbreak Monitoring Bores

Sampling Points

N

0 1.25 2.5 5

kilometres

Fortescue Metals Group Ltd

Upper Marra Mamba & Oakover Formations

Author: B. Willis-Jones	Date:9/9/2010
Drawn By: S.Hendricksen	Revision: 0
Dwg No: CB_MP_HY_0044	Confidentiality: 1
Projection: MGA Zone 50 (GDA 94	Scale: 1:140000

Figure 11: Airborne EM conductivity – Marra Mamba Formation

This page has been left blank intentionally

720,000 mE
730,000 mE
740,000 mE
750,000 mE
760,000 mE
770,000 mE
7,540,000 mN
7,530,000 mN
7,520,000 mN
7,510,000 mN
Cloudbreak
Chichester CID
2000
5000
10000
20000
30000
40000
50000

Location Map
Port Hedland Project
Kalgoorlie
PERTH

Mine Sequence
Fortescue Marsh
Salinity Upper TD3
Existing Roads/Tracks
FMG Rail
Sampling Points
Cloudbreak Monitoring Bores

N
0 1.25 2.5 5
kilometres

Fortescue Metals Group Ltd

Airborne EM Conductivity
Water Table minus Five Metres

Author: B. Willis-Jones	Date:10/9/2010
Drawn By: S.Hendricksen	Revision: 0
Dwg No: CB_MP_HY_0044	Confidentiality: 1
Projection: MGA Zone 50 (GDA 94	Scale: 1:140000

Figure 12: Airborne EM conductivity – watertable minus five metres

This page has been left blank intentionally

720,000 mE
730,000 mE
740,000 mE
750,000 mE
760,000 mE
770,000 mE
7,540,000 mN
7,530,000 mN
7,520,000 mN
7,510,000 mN
Cloudbreak
Chichester CID
5000
10000
20000
30000
40000
50000

Location Map
Port Hedland
Project
Kalgoorlie
PERTH

Mine Sequence
Fortescue Marsh
TDS (mgl) Distribution in OF and UMMF
Existing Roads/Tracks
FMG Rail
Sampling Points
Cloudbreak Monitoring Bores

N
0 1.25 2.5 5
kilometres

Fortescue Metals Group Ltd

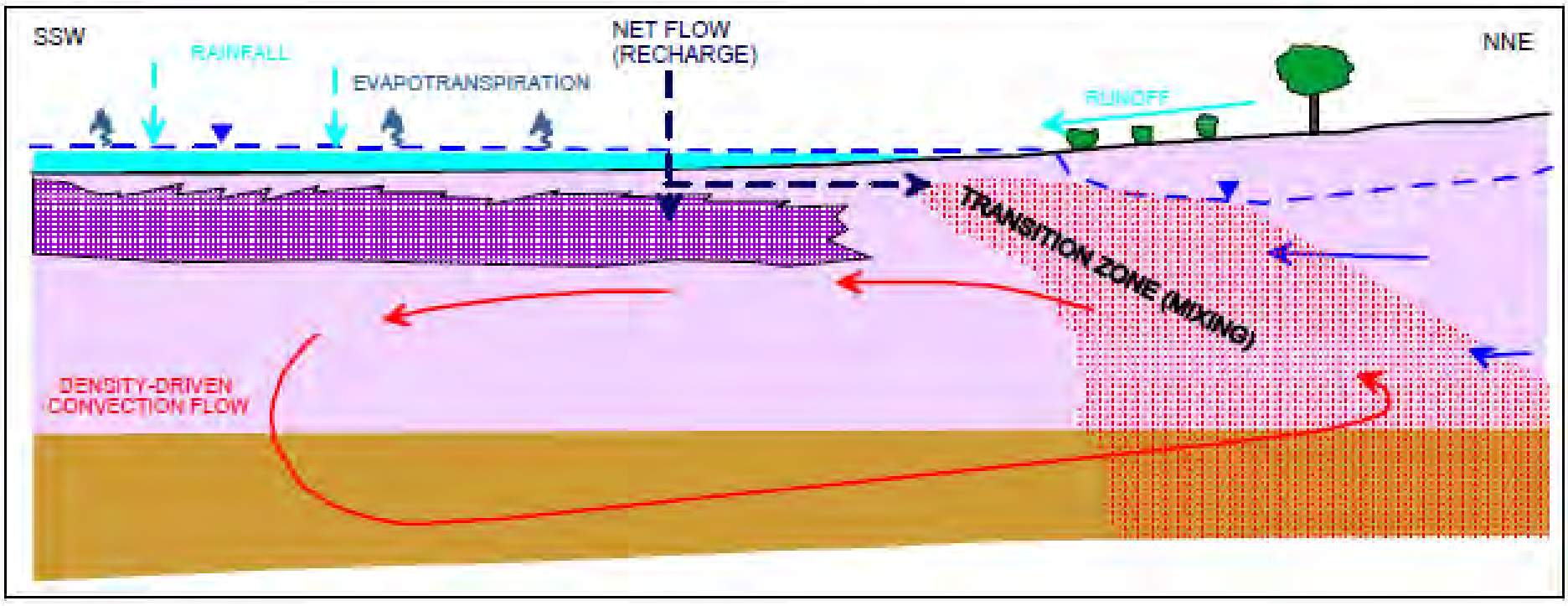
Airbourne EM Conductivity
Upper Marra Mamba &
Oakover Formation

Author: B. Willis-Jones	Date:10/9/2010
Drawn By: S.Hendricksen	Revision: 0
Dwg No: CB_MP_HY_0044	Confidentiality: 1
Projection: MGA Zone 50 (GDA 94	Scale: 1:140000

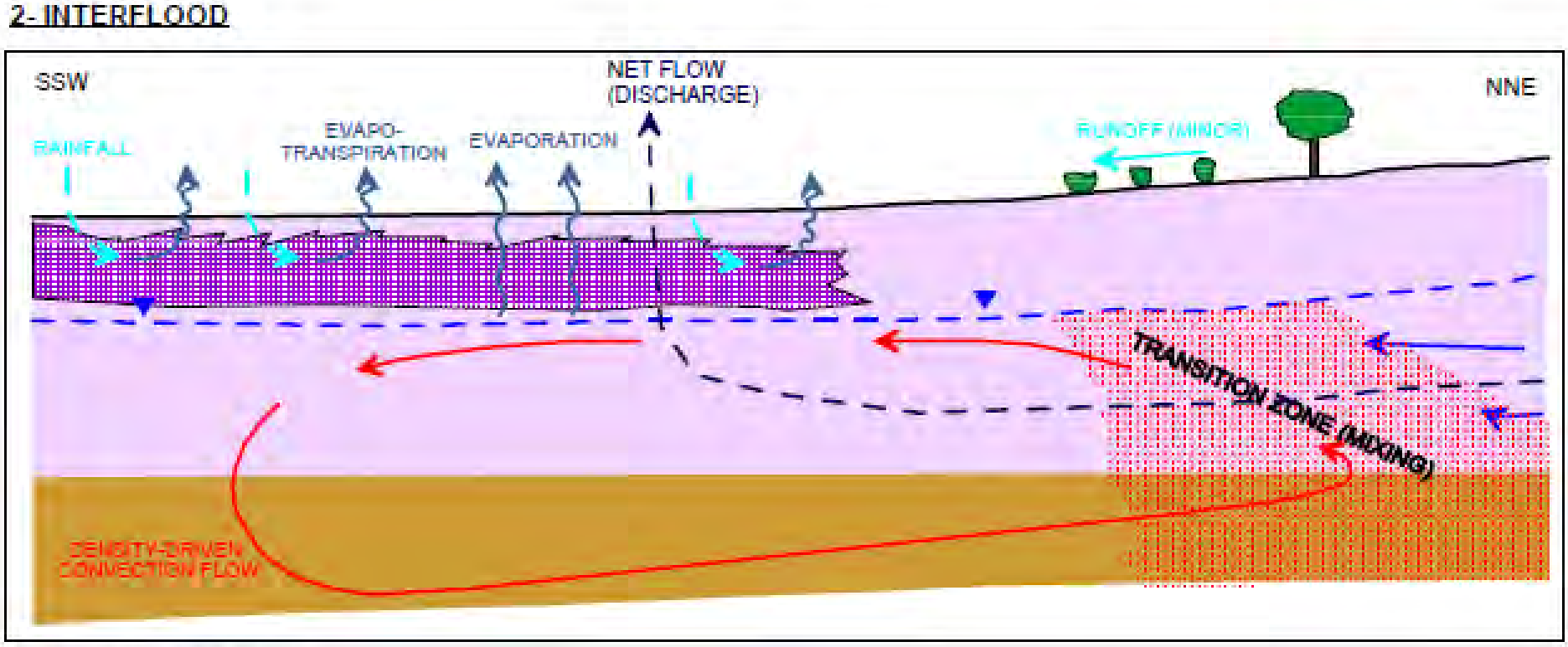
Figure 13: Fortescue Marsh conceptual section

This page has been left blank intentionally

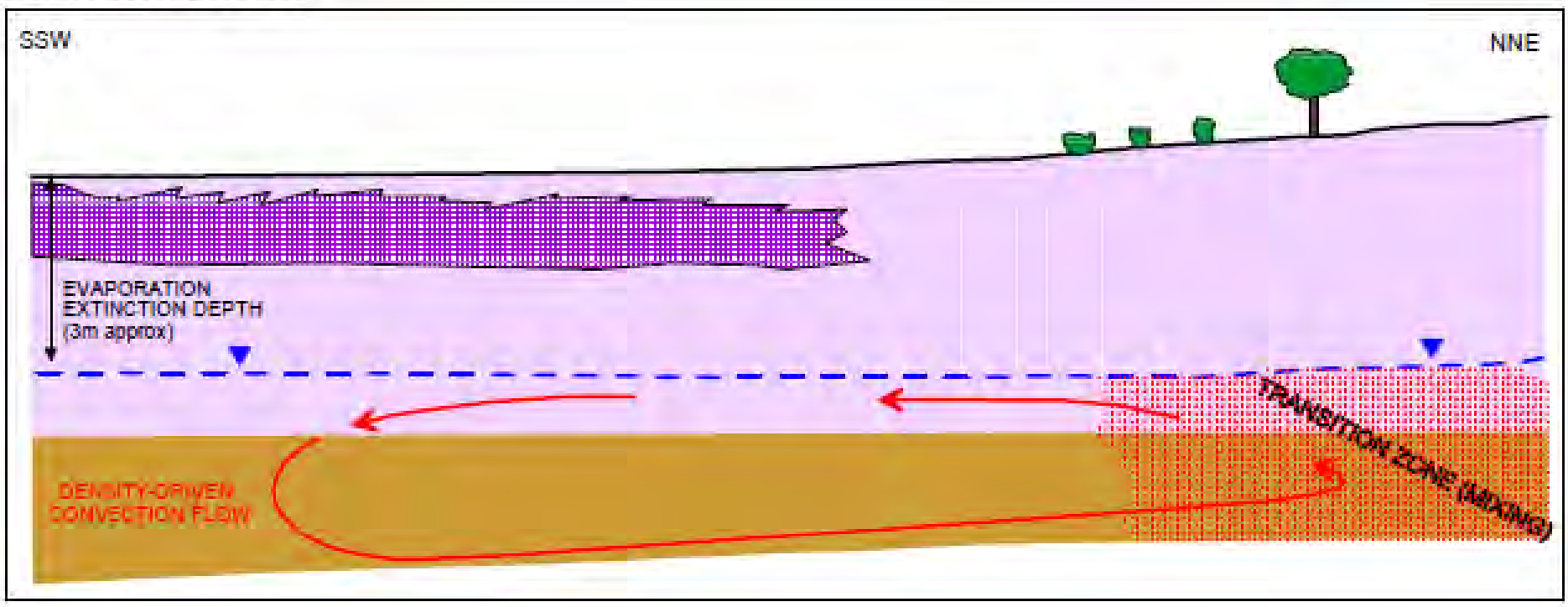
1- FLOOD



2- INTERFLOOD



3- PROLONGED DRY



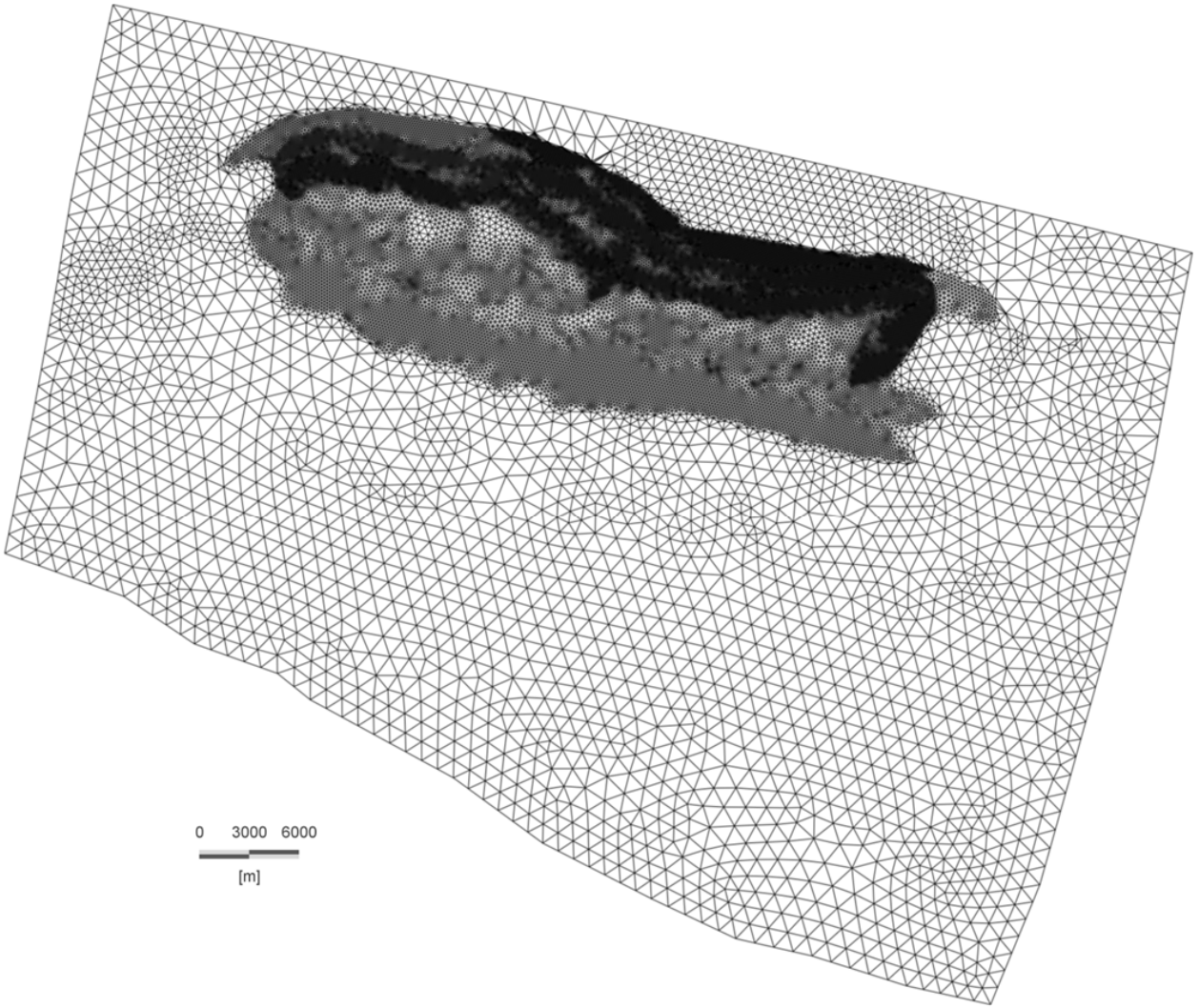
LEGEND

- TERTIARY DETRITALS
- OAKOVER FORMATION
- TRANSITION ZONE
- POTENTIAL HIGH S / LOW K UNIT
- EPHEMERAL POND
- RAINFALL RECHARGE
- TOPOGRAPHIC DRIVEN FLOW
- DENSITY DRIVEN (CONVECTION) FLOW
- EVAPORATION & EVAPOTRANSPIRATION
- WATERTABLE

Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Fortescue Marsh Conceptual Hydrogeology**	**Figure 13**
		29/08/2013

Figure 14: Model domain and boundary conditions

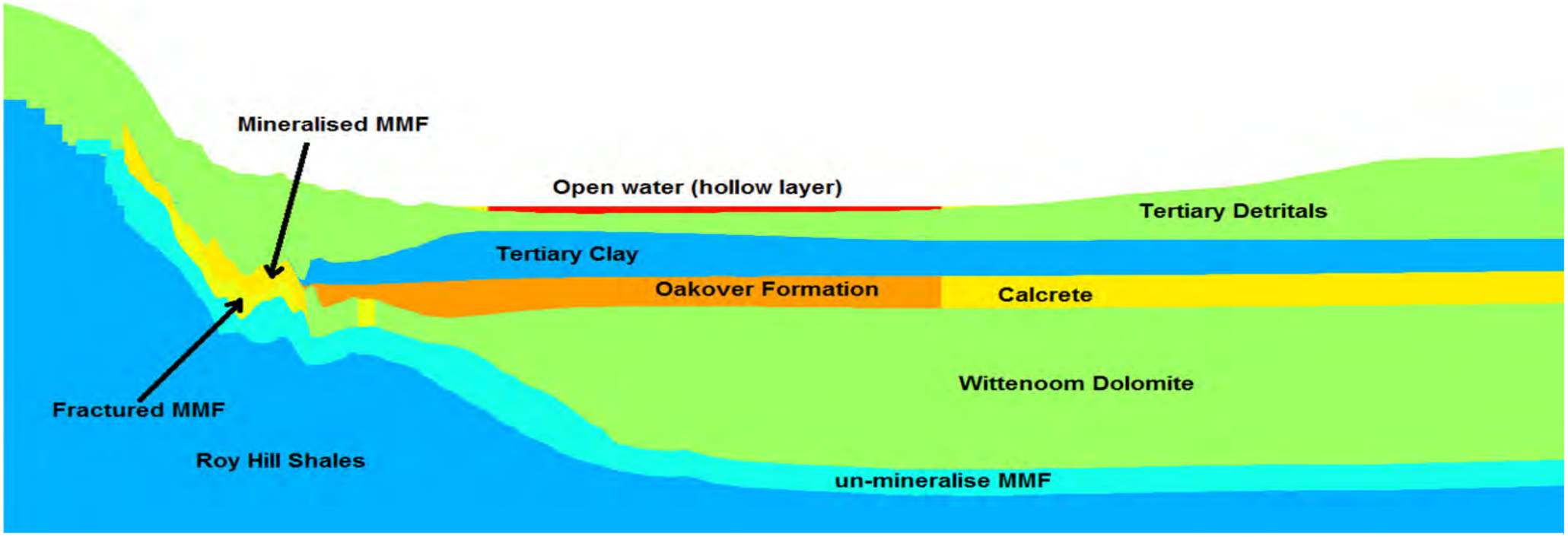
This page has been left blank intentionally

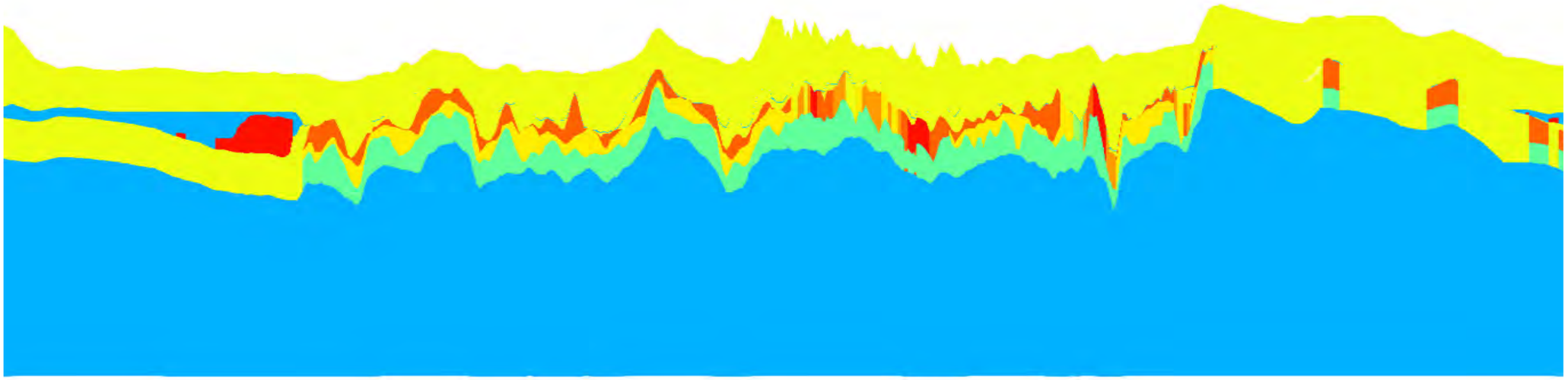


Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Numerical Model Domain and Mesh**	**Figure 14**
		12/11/2013

Figure 15: Model stratigraphic section

This page has been left blank intentionally



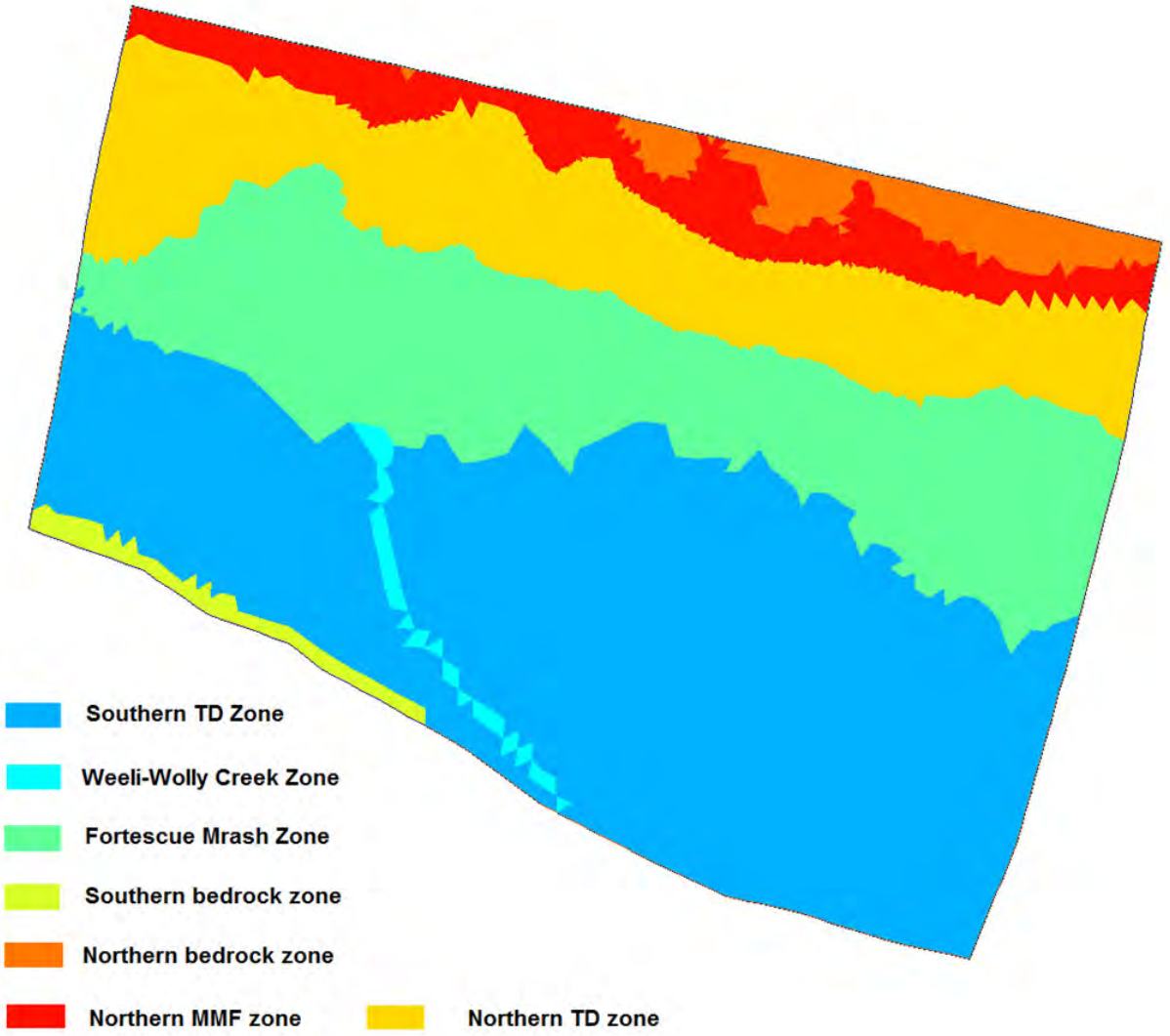


Tertiary Detritals
Mineralised MMF
Un-mineralised MMF
Tertiary Clay
Fractured MMF
Roy Hill Shales

Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Numerical Model Cross Section**	**Figure 15**
		12/11/2013

Figure 16: Model Recharge Zones

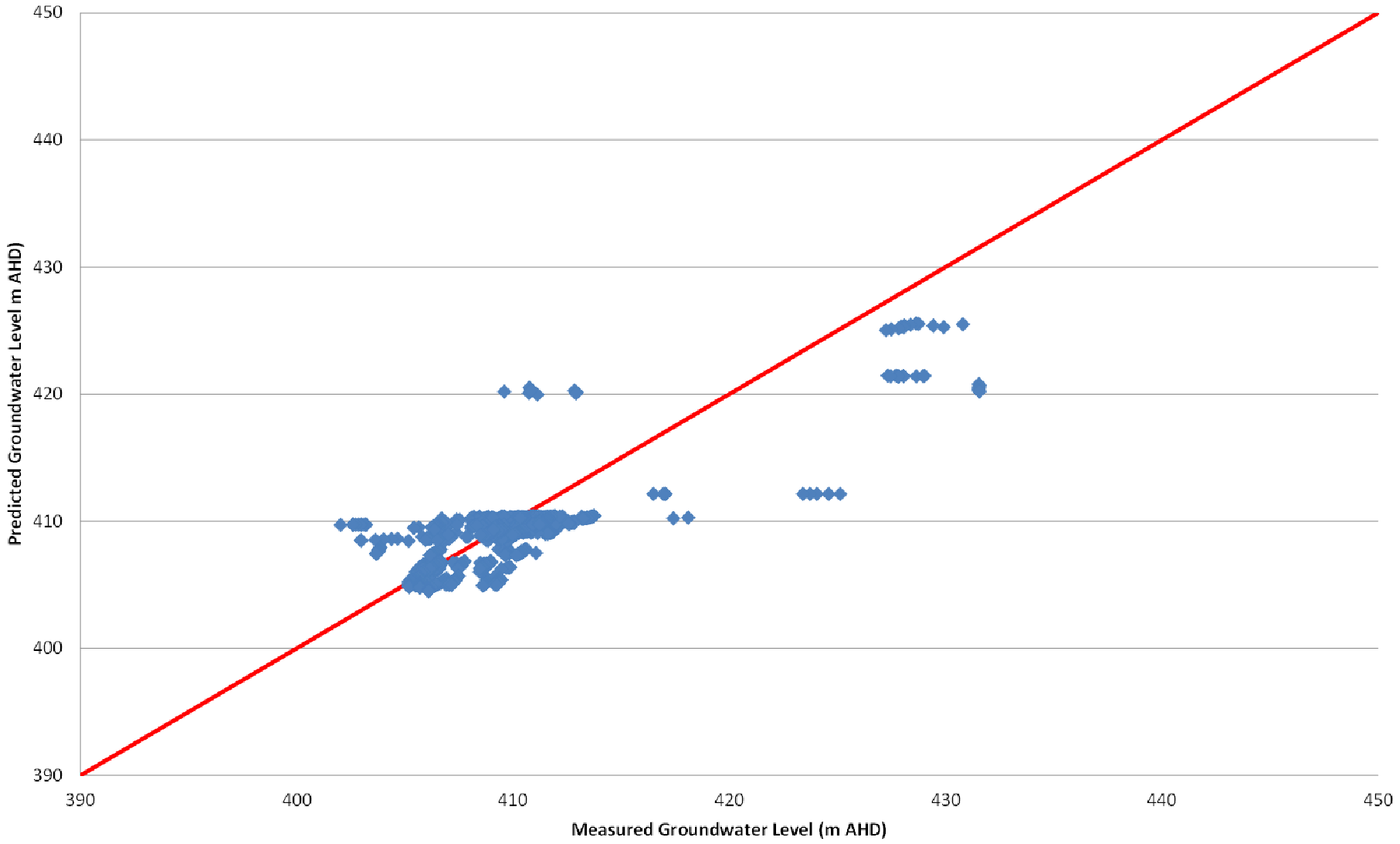
This page has been left blank intentionally



Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Numerical Model Recharge Zones**	**Figure 16**
		12/11/2013

Figure 17: Steady state calibration results: Measured v's model predicted groundwater levels

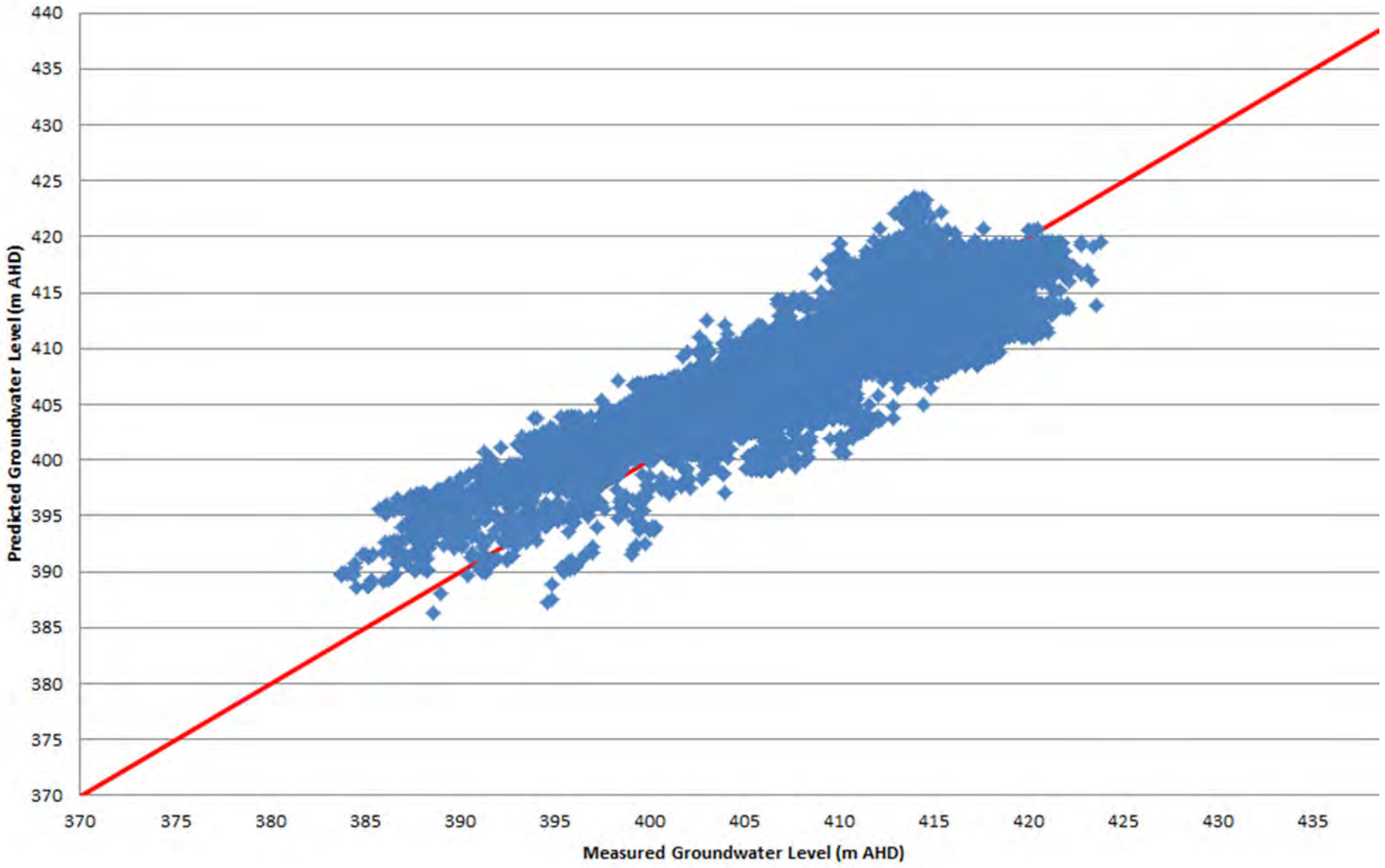
This page has been left blank intentionally



Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Pre-dewatering Calibration Stage**	**Figure 17**
		12/11/2013

Figure 18: Transient calibration results: Measured v's model predicted groundwater levels

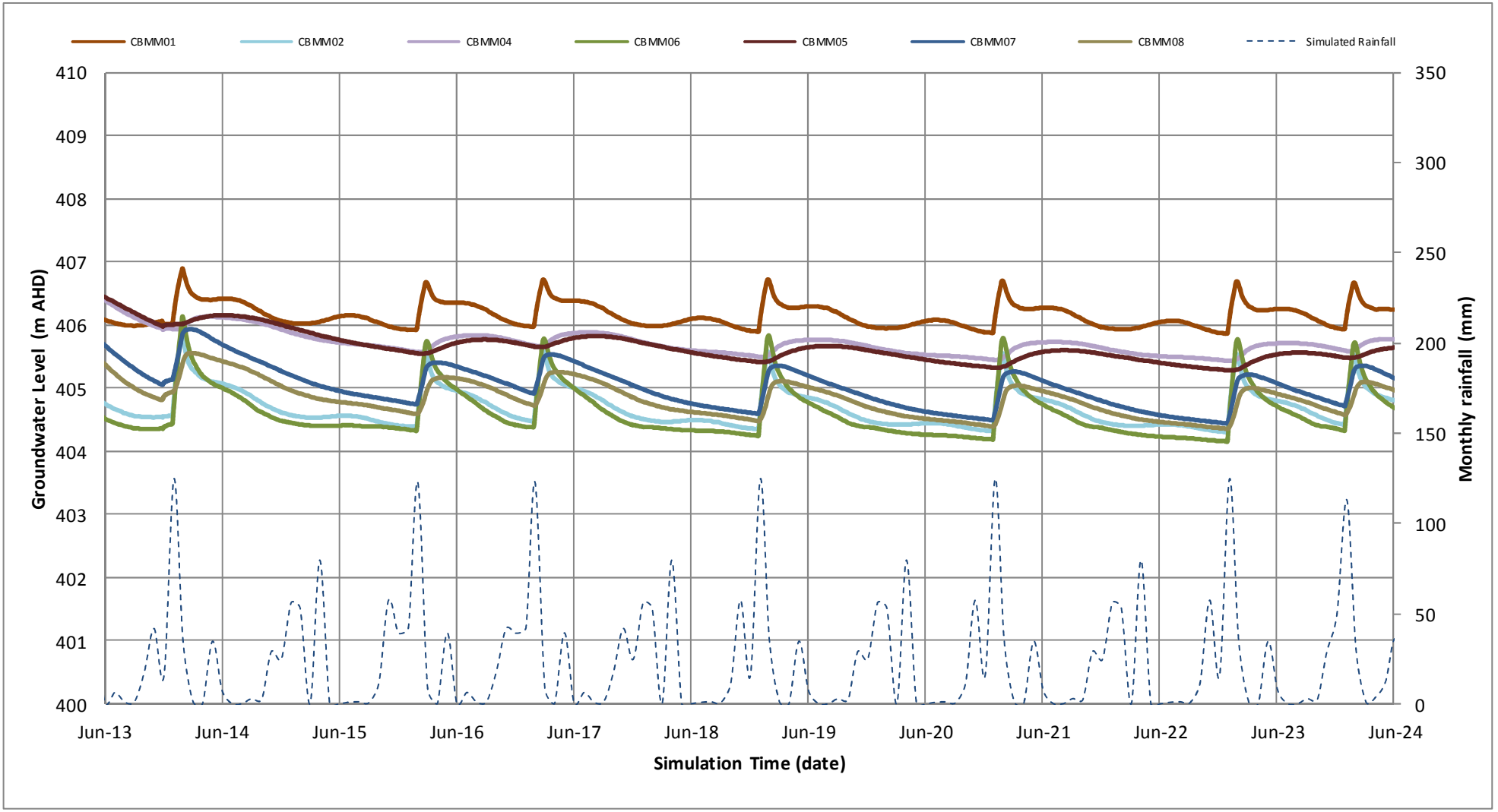
This page has been left blank intentionally



Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Dewatering Calibration Stage**	**Figure 18**
		12/11/2013

Figure 19: Hydrographs at five key locations for the base simulation without mining

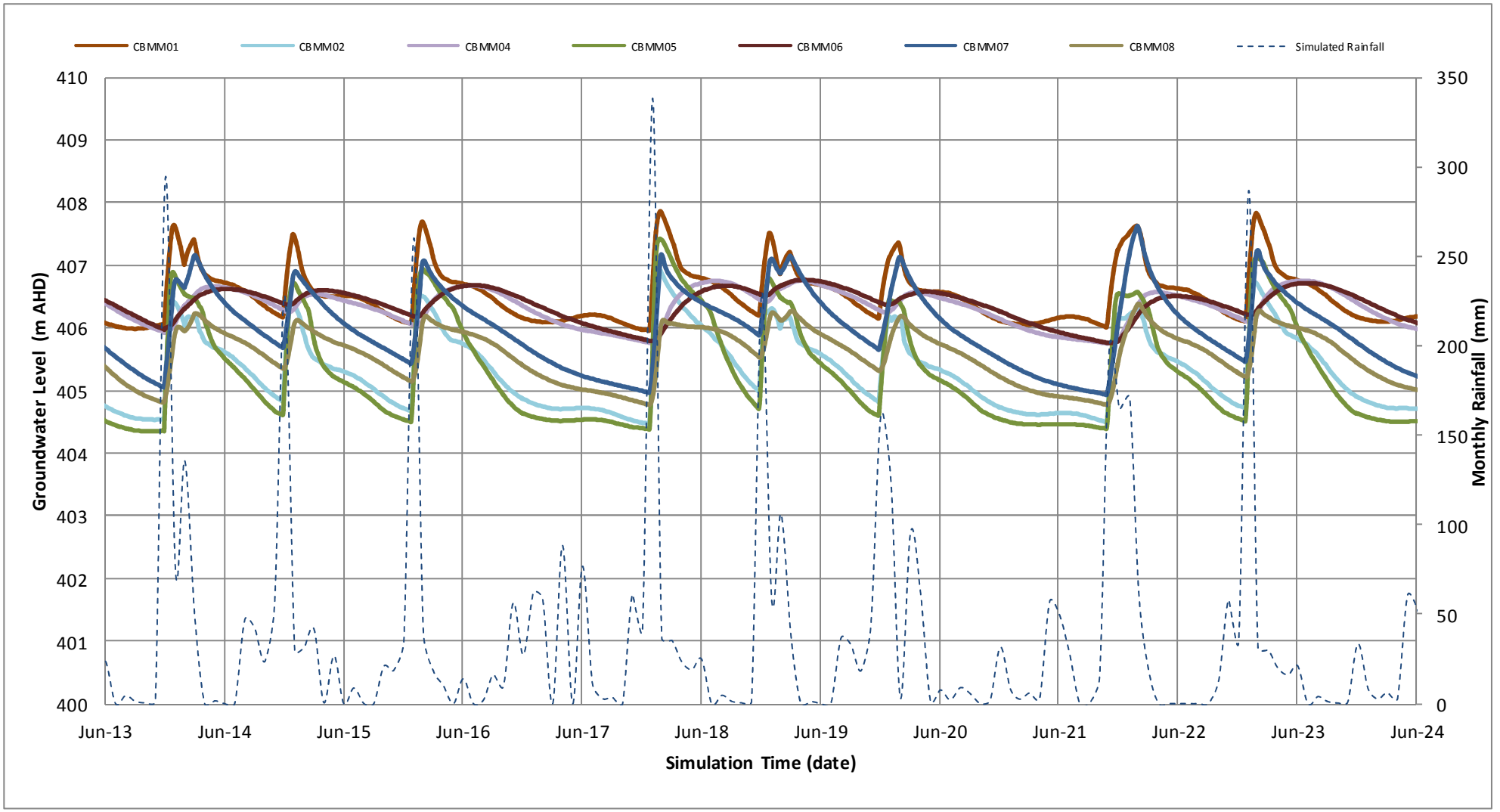
This page has been left blank intentionally



Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Hydrograph at key locations for the Base scenario without mine dewatering**	**Figure 19**
		07/11/2013

Figure 20: Hydrographs at five key locations for the dry simulation without mining

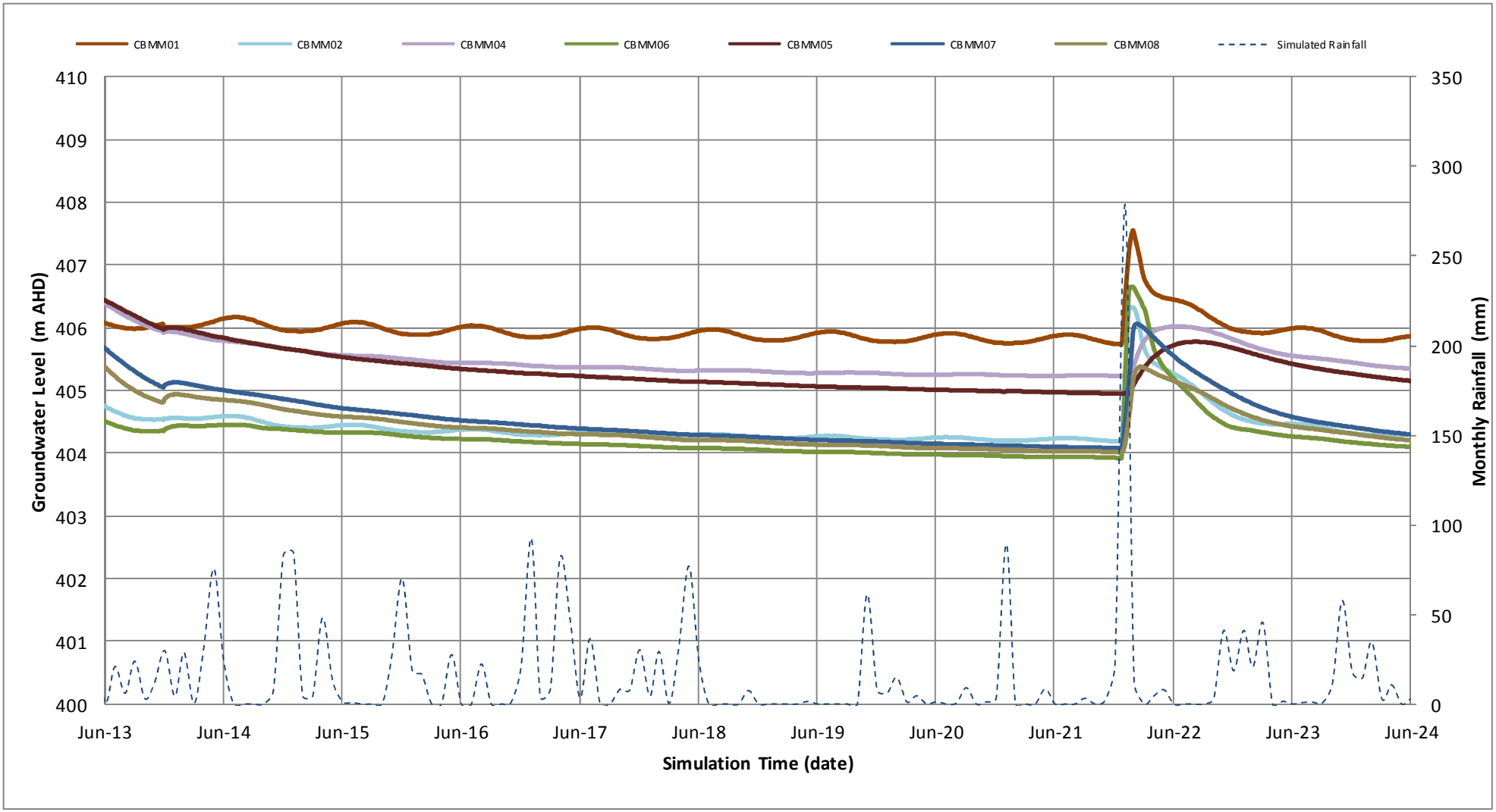
This page has been left blank intentionally



Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Hydrograph at key locations for the Wet scenario without mine dewatering**	**Figure 20**
		07/11/2013

Figure 21: Hydrographs at five key locations for the wet simulation without mining

This page has been left blank intentionally



Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Hydrograph at key locations for the Dry scenario without mine dewatering**	**Figure 21**
		07/11/2013

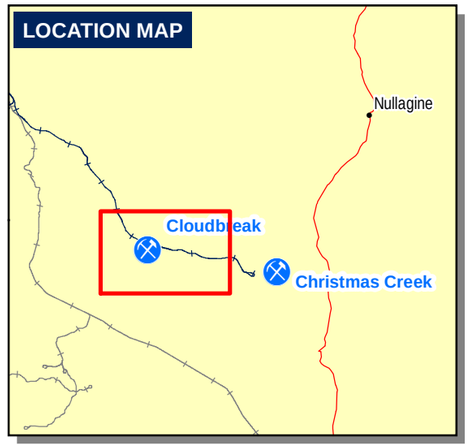
Figure 22: Distribution of drawdown/mounding due to mining for the base simulation - 2014

This page has been left blank intentionally

720,000
735,000
750,000
765,000
7,545,000
7,530,000
7,515,000

CBFMM01
CBFMM02
CBFMM04
CBFMM05
CBFMM06
CBFMM07
CBFMM08

LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga - Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2014

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.001_r0_2014

Date: 29/11/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

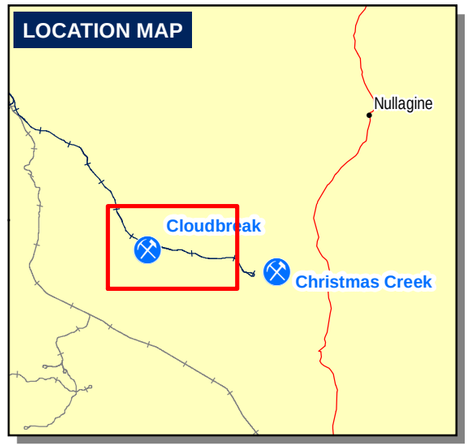
Figure 23: Distribution of drawdown/mounding due to mining for the base simulation - 2015

This page has been left blank intentionally

720,000
735,000
750,000
765,000
7,545,000
7,530,000
7,515,000

CBFMM01
CBFMM02
CBFMM04
CBFMM05
CBFMM06
CBFMM07
CBFMM08

LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga – Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2015

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.002_r0_2015

Date: 29/11/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 24: Distribution of drawdown/mounding due to mining for the base simulation - 2016

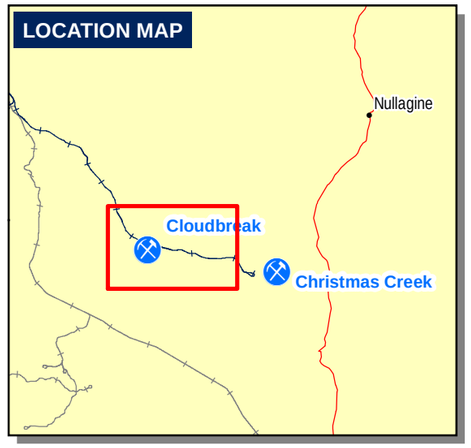
This page has been left blank intentionally

720,000 735,000 750,000 765,000

7,545,000 7,530,000 7,515,000

CBFMM01 CBFMM02 CBFMM04 CBFMM06 CBFMM05 CBFMM07 CBFMM08

LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining.
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga – Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2016

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.003_r0_2016

Date: 29/11/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

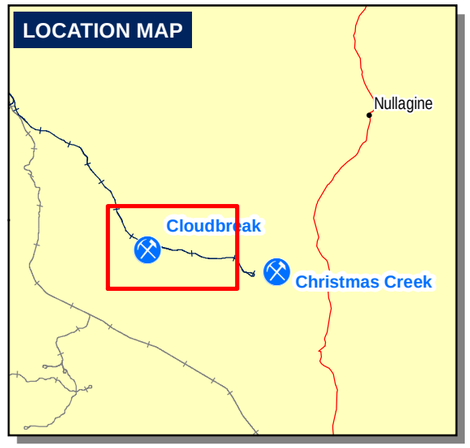
Figure 25: Distribution of drawdown/mounding due to mining for the base simulation - 2017

This page has been left blank intentionally

720,000
735,000
750,000
765,000
7,545,000
7,530,000
7,515,000

CBFMM01
CBFMM02
CBFMM04
CBFMM05
CBFMM06
CBFMM07
CBFMM08

LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining.
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga – Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2017

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.004_r0_2017

Date: 29/11/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 26: Distribution of drawdown/mounding due to mining for the base simulation - 2018

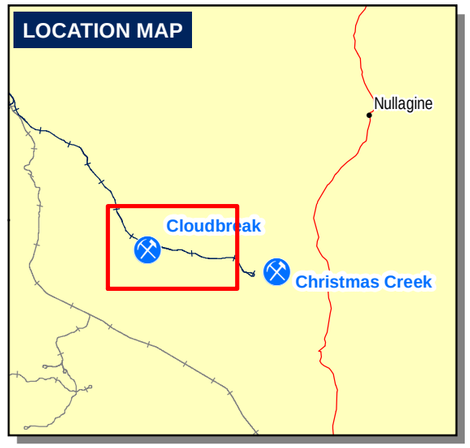
This page has been left blank intentionally

720,000 735,000 750,000 765,000

7,545,000 7,530,000 7,515,000

CBFMM01 CBFMM02 CBFMM04 CBFMM05 CBFMM06 CBFMM07 CBFMM08

LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga - Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2018

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.005_r0_2018

Date: 29/11/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 27: Distribution of drawdown/mounding due to mining for the base simulation - 2019

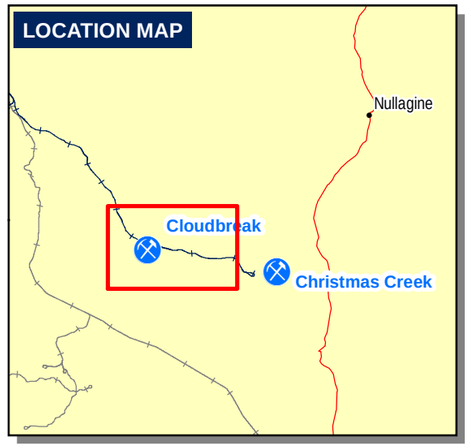
This page has been left blank intentionally

720,000 735,000 750,000 765,000

7,545,000 7,530,000 7,515,000

CBFMM01 CBFMM02 CBFMM04 CBFMM06 CBFMM05 CBFMM07 CBFMM08

LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining.
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga – Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2019

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.006_r0_2019

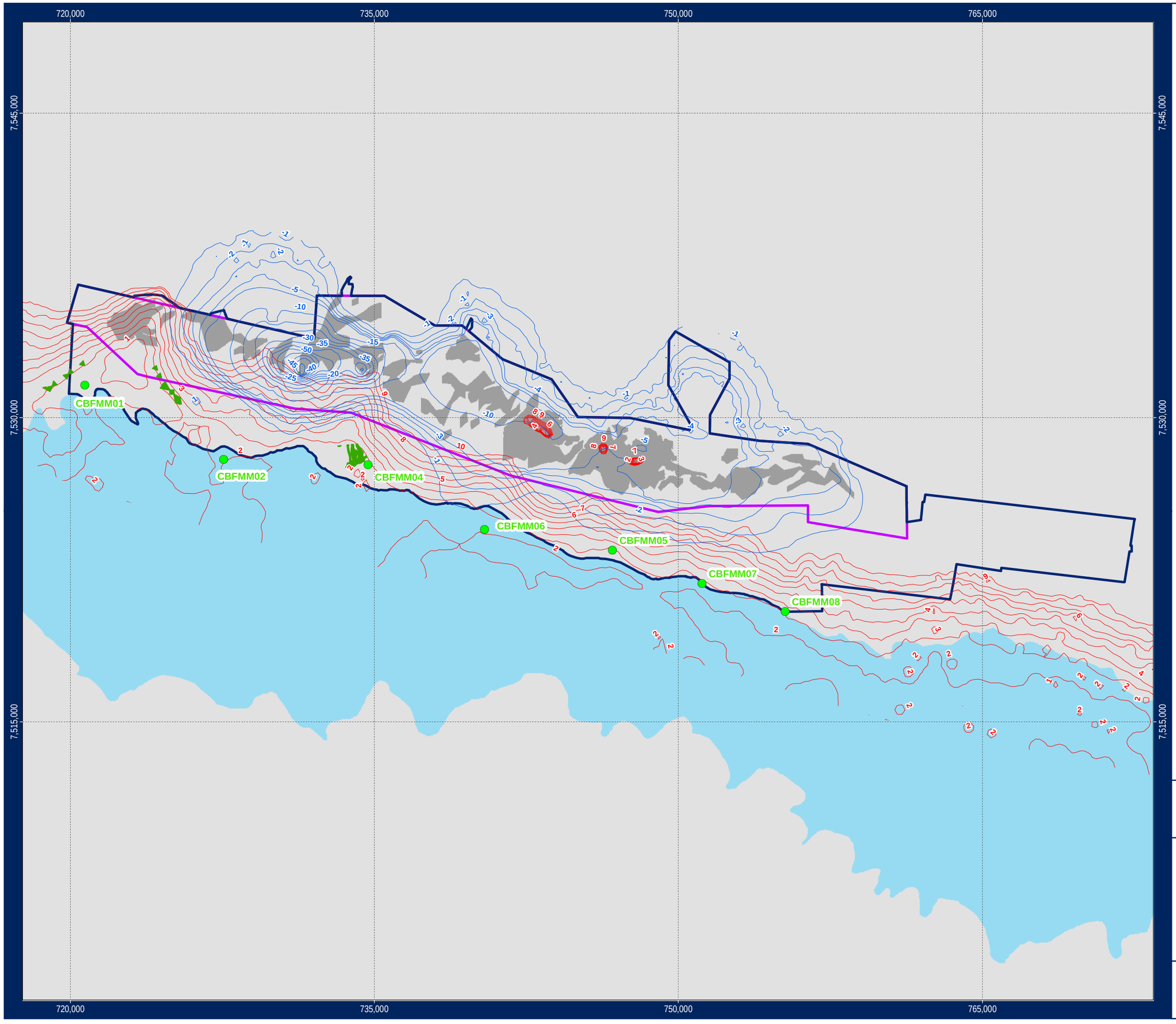
Date: 3/12/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

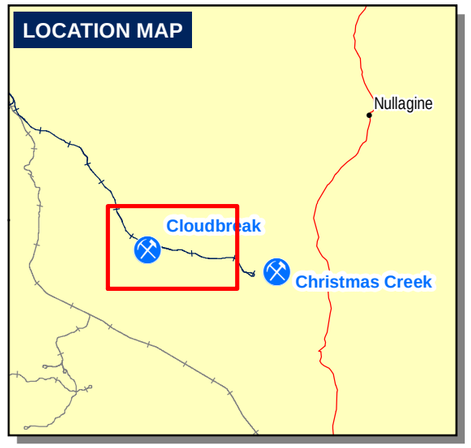
Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 28: Distribution of drawdown/mounding due to mining for the base simulation - 2020

This page has been left blank intentionally



LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining.
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga – Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2020

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.007_r0_2020

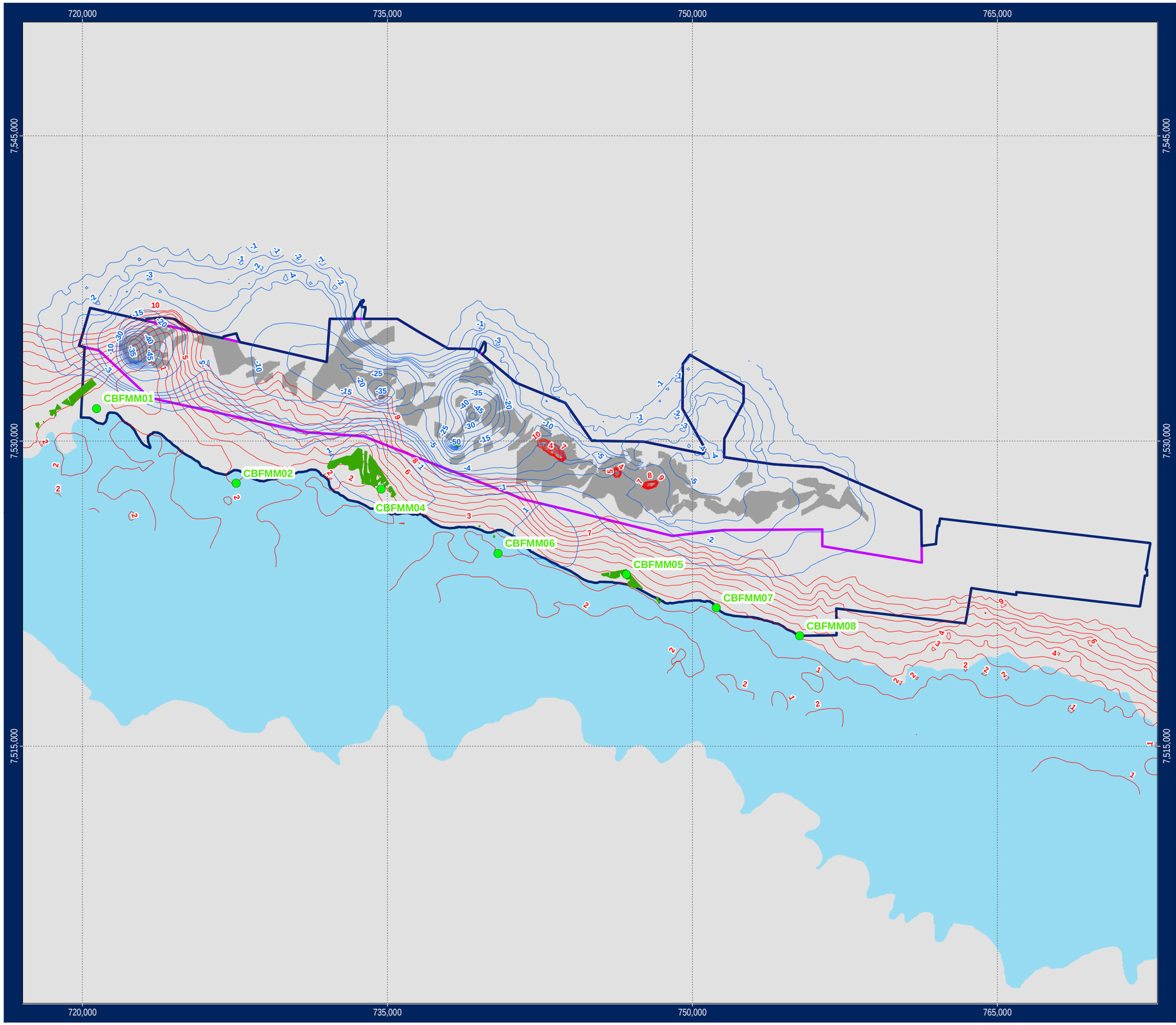
Date: 3/12/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

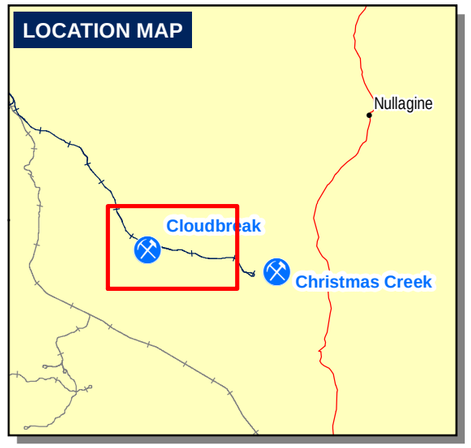
Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 29: Distribution of drawdown/mounding due to mining for the base simulation - 2021

This page has been left blank intentionally



LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining.
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga – Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2021

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.008_r0_2021

Date: 3/12/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 30: Distribution of drawdown/mounding due to mining for the base simulation - 2022

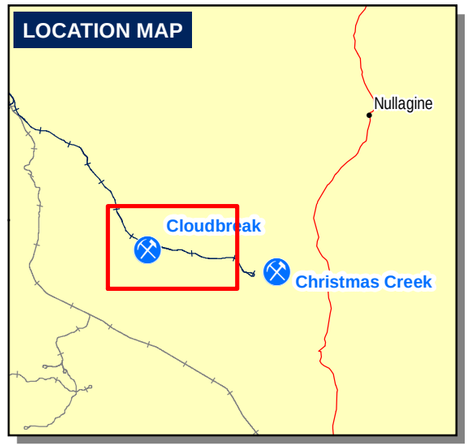
This page has been left blank intentionally

720,000 735,000 750,000 765,000

7,545,000 7,530,000 7,515,000

CBFMM01 CBFMM02 CBFMM04 CBFMM06 CBFMM05 CBFMM07 CBFMM08

LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining.
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga – Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2022

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.009_r0_2022

Date: 3/12/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 31: Distribution of drawdown/mounding due to mining for the base simulation - 2023

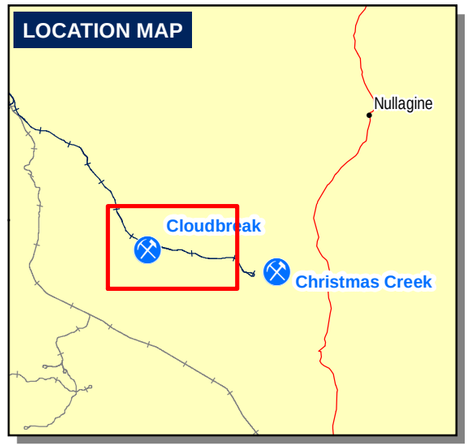
This page has been left blank intentionally

Figure 32: Distribution of drawdown/mounding due to mining for the base simulation - 2024

This page has been left blank intentionally

720,000
735,000
750,000
765,000
7,545,000
7,530,000
7,515,000
CBFMM01
CBFMM02
CBFMM04
CBFMM06
CBFMM05
CBFMM07
CBFMM08

LOCATION MAP



LEGEND

- MS 899 bores
- Change in watertable due to mining.
- Depth to watertable (Natural) baseline_mbgl
- CB Mine Area - MS899
- CB Project Area - MS899
- Mine Plan
- Fortescue Marsh boundary
- Impacts to Mulga – Mounding within 2m of the ground surface where the natural groundwater was below 2mbgl.

Data Source(s):
Marsh data sourced from Enviro Australia,(2001). Directory of Important Wetlands in Australia
Observation wells,mine plan data sourced from FMG (2013)

N

0 1 2 3 4 5
Kilometres

2024

Requested By: Paul Ricketts
Drawn By: A.Moore
Revised By: admoore
Approved By:
Scale: 1:180,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: CB_MP_HY_0073.011_r0_2024

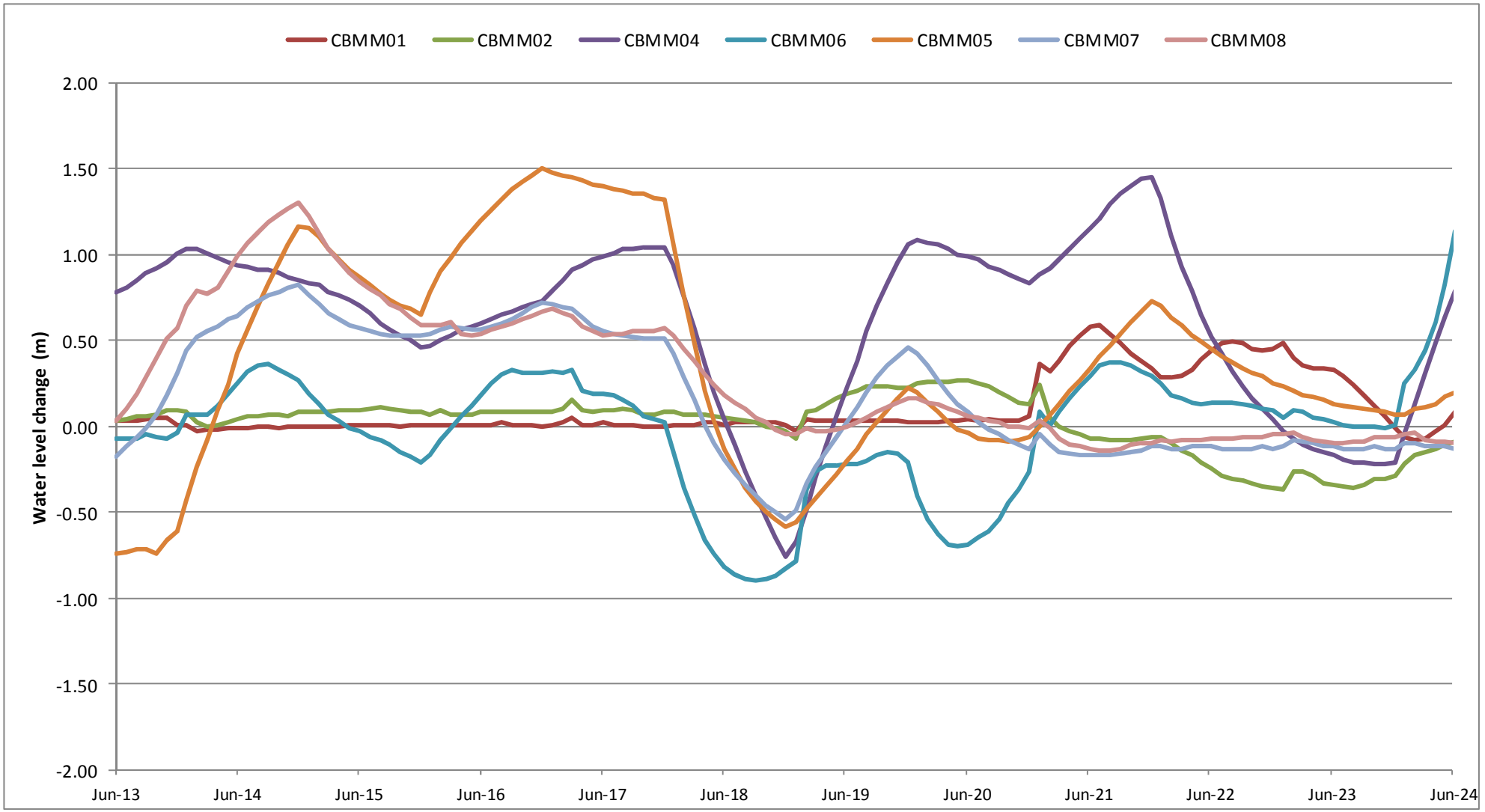
Date: 4/12/2013
Size: A3L
Revision: 0
Confidentiality: 1

FMG accepts no liability and gives no representation or warranty, express or implied, as to the information provided including its accuracy, completeness, merchantability or fitness for purpose.

Fortescue Metals Group Ltd
The New Force in Iron Ore

Figure 33: Groundwater level change at the seven key monitoring locations for the base simulation

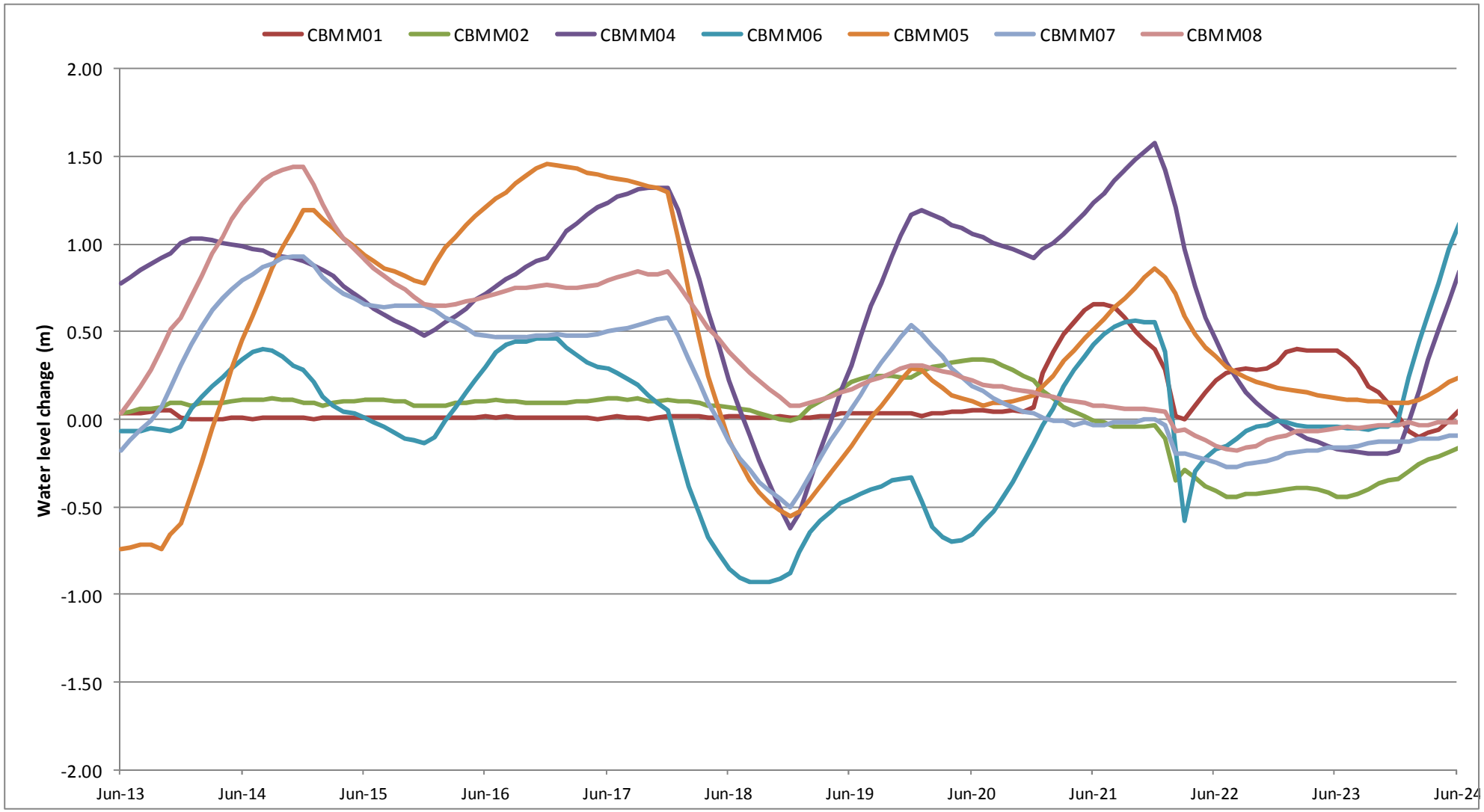
This page has been left blank intentionally



Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Groundwater level change (drawdown/mounding relative to natural conditions) at seven key locations—Base scenario**	**Figure 33**
		08/11/2013

Figure 34: Groundwater level change at the seven key monitoring locations for the dry simulation

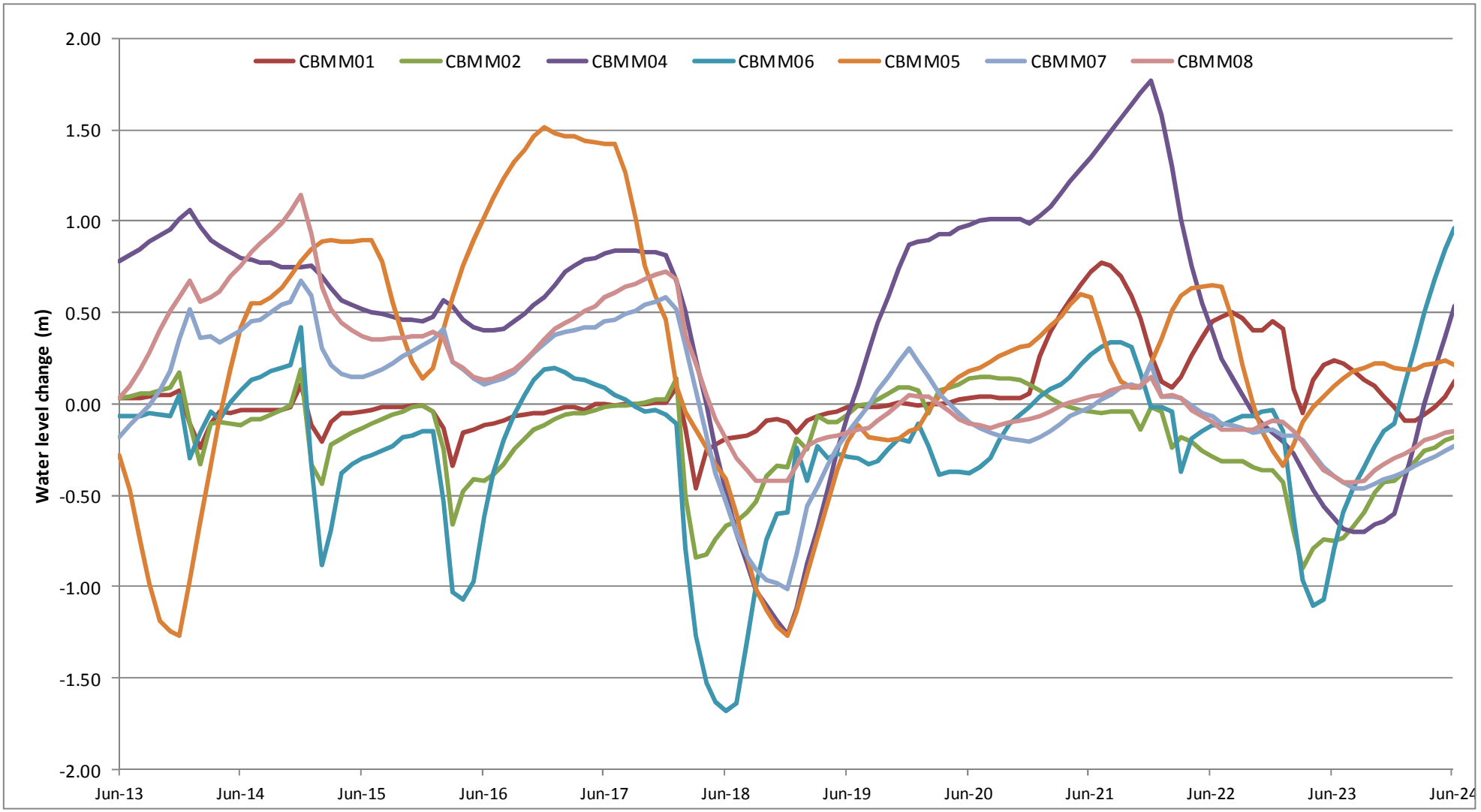
This page has been left blank intentionally



Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Groundwater level change (drawdown/mounding relative to natural conditions) at seven key locations—Dry scenario**	**Figure 34**
		08/11/2013

Figure 35: Groundwater level change at the seven key monitoring locations for the wet simulation

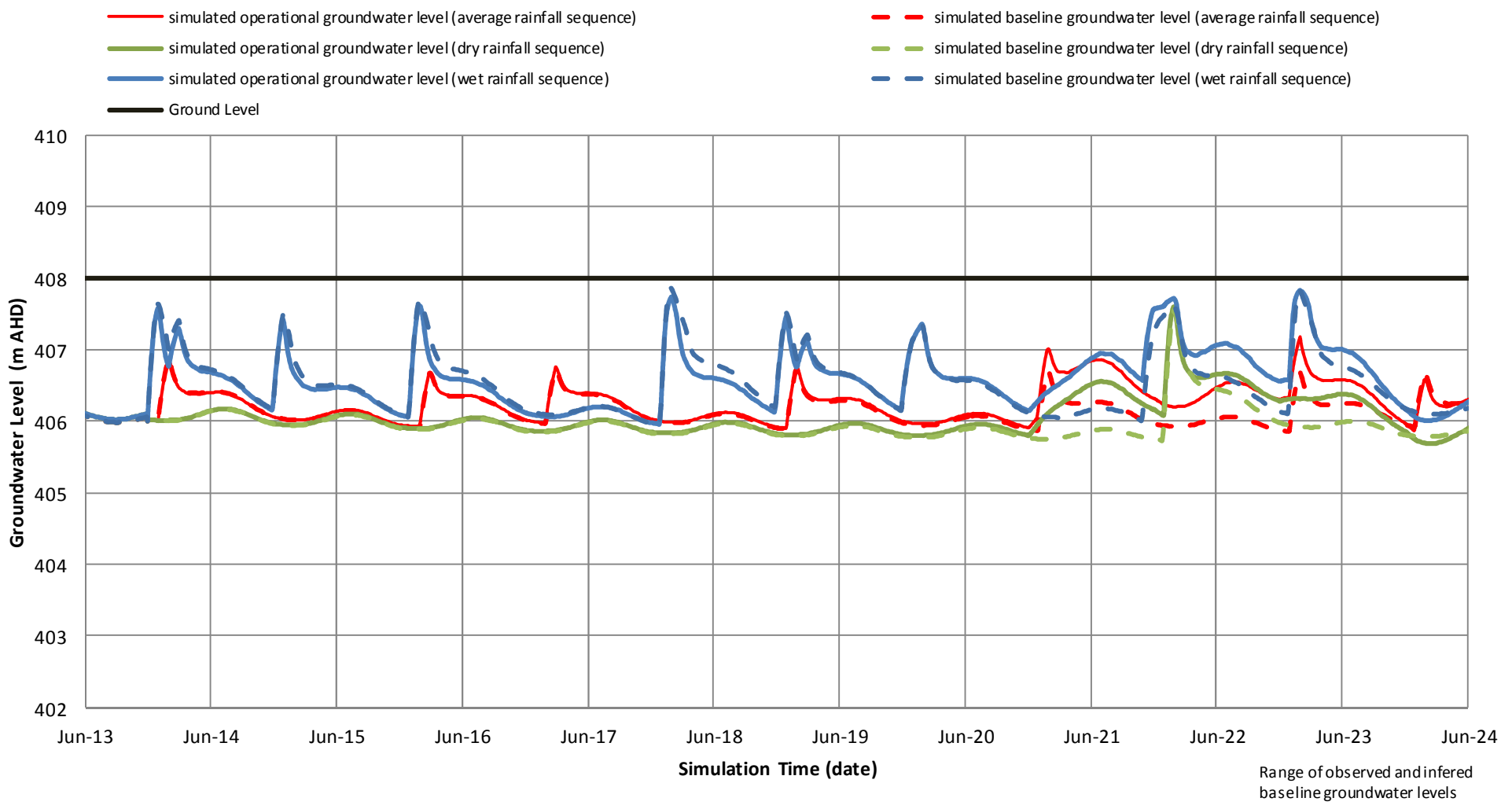
This page has been left blank intentionally



Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Groundwater level change (drawdown/mounding relative to natural conditions) at seven key locations—Wet scenario**	**Figure 35**
		08/11/2013

Figure 36: Hydrograph at CBFMM01_s, under natural and mining conditions for the Base, Dry and Wet simulations

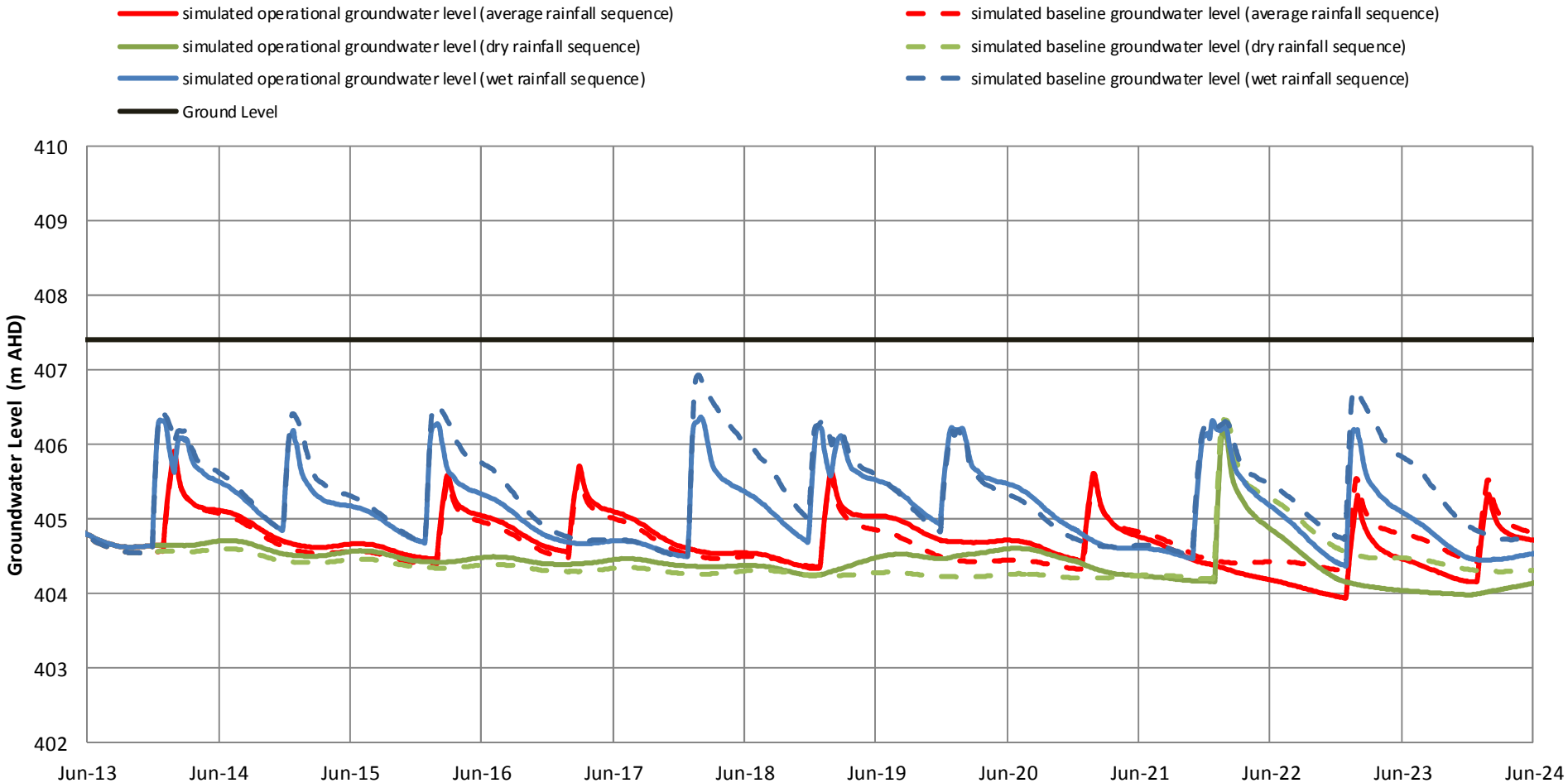
This page has been left blank intentionally



Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Hydrographs at CBFM01 under natural (dashed lines) and mining (solid lines) conditions for Base, Dry and Wet scenarios**	**Figure 36**
		11/11/2013

Figure 37: Hydrograph at CBFMM02_s, under natural and mining conditions for the Base, Dry and Wet simulations

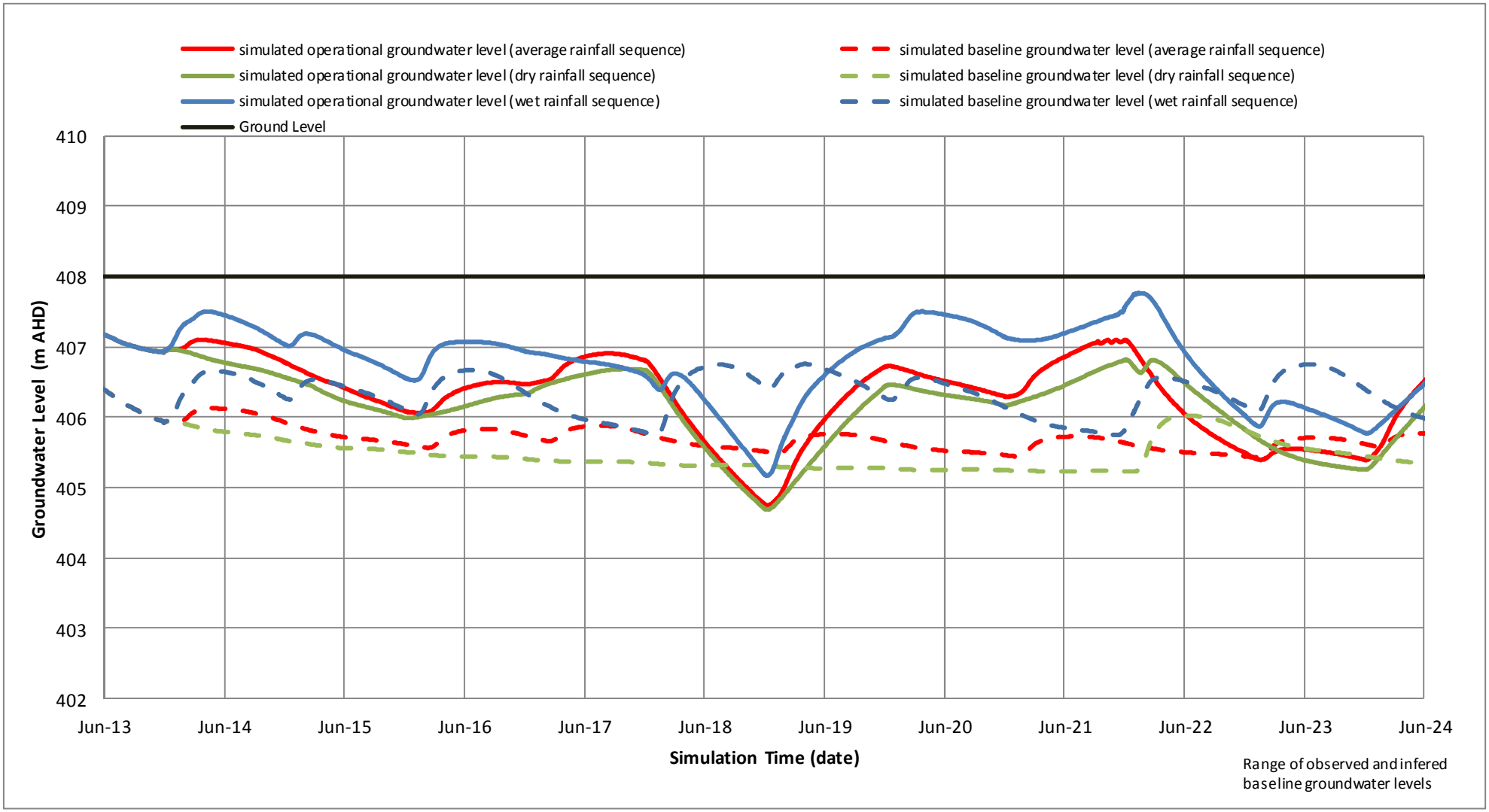
This page has been left blank intentionally



Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Hydrographs at CBFM02 under natural (dashed lines) and mining (solid lines) conditions for Base, Dry and Wet scenarios**	**Figure 37**
		11/11/2013

Figure 38: Hydrograph at CBFMM04_s, under natural and mining conditions for the Base, Dry and Wet simulations

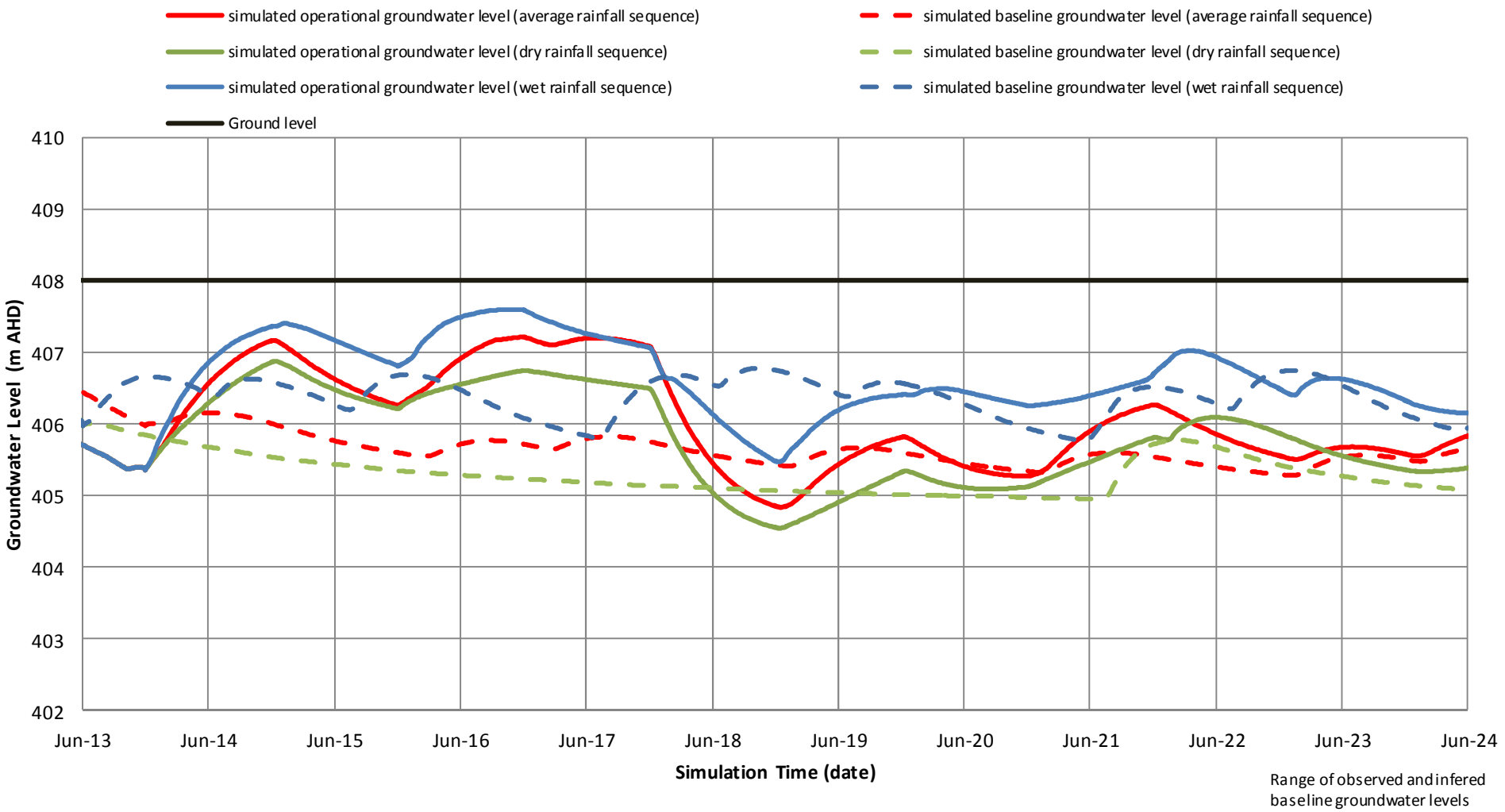
This page has been left blank intentionally



Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Hydrographs at CBFM04 under natural (dashed lines) and mining (solid lines) conditions for Base, Dry and Wet scenarios**	**Figure 38**
		11/11/2013

Figure 39: Hydrograph at CBFMM05_s, under natural and mining conditions for the Base, Dry and Wet simulations

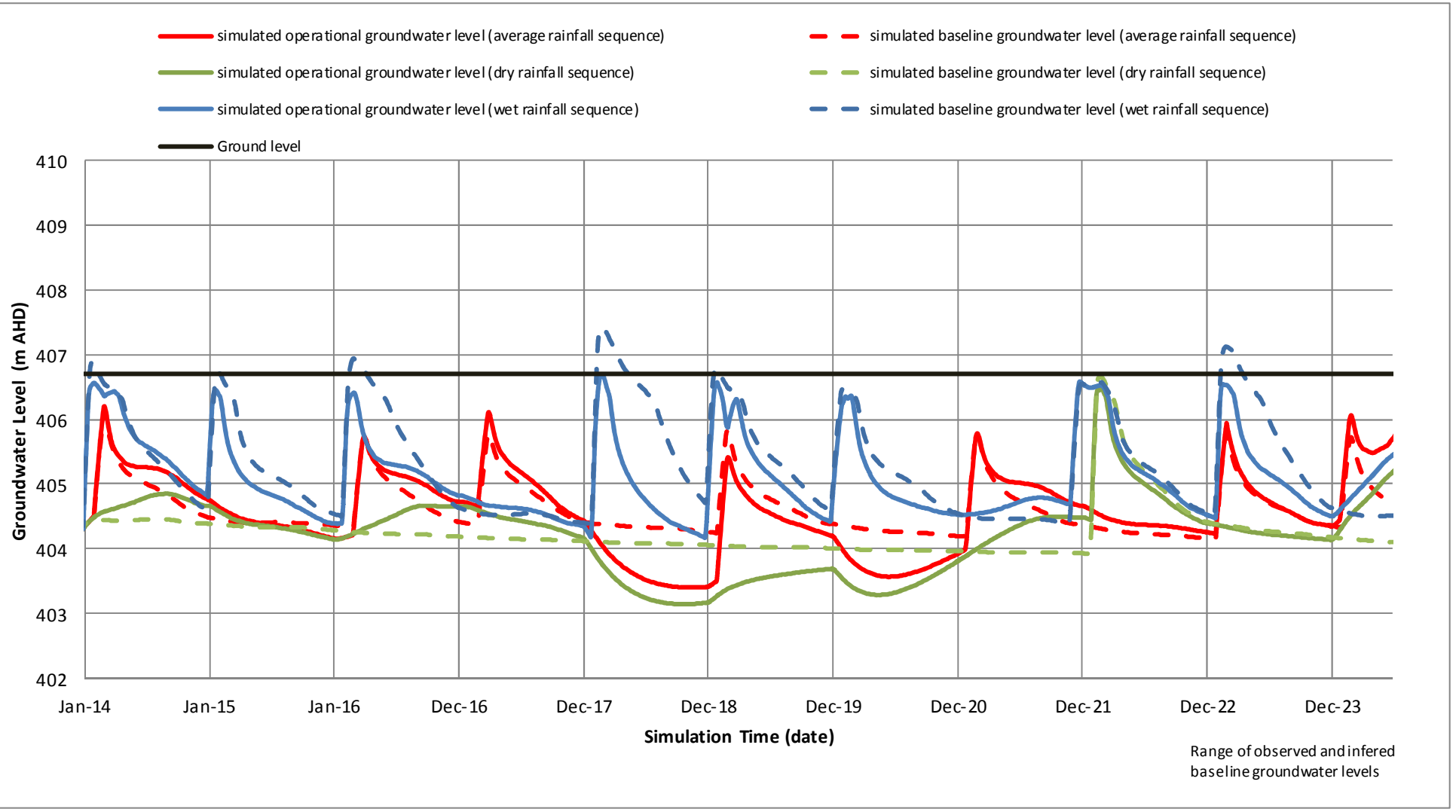
This page has been left blank intentionally



Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Hydrographs at CBFM05 under natural (dashed lines) and mining (solid lines) conditions for Base, Dry and Wet scenarios**	**Figure 39**
		11/11/2013

Figure 40: Hydrograph at CBFMM06_s, under natural and mining conditions for the Base, Dry and Wet simulations

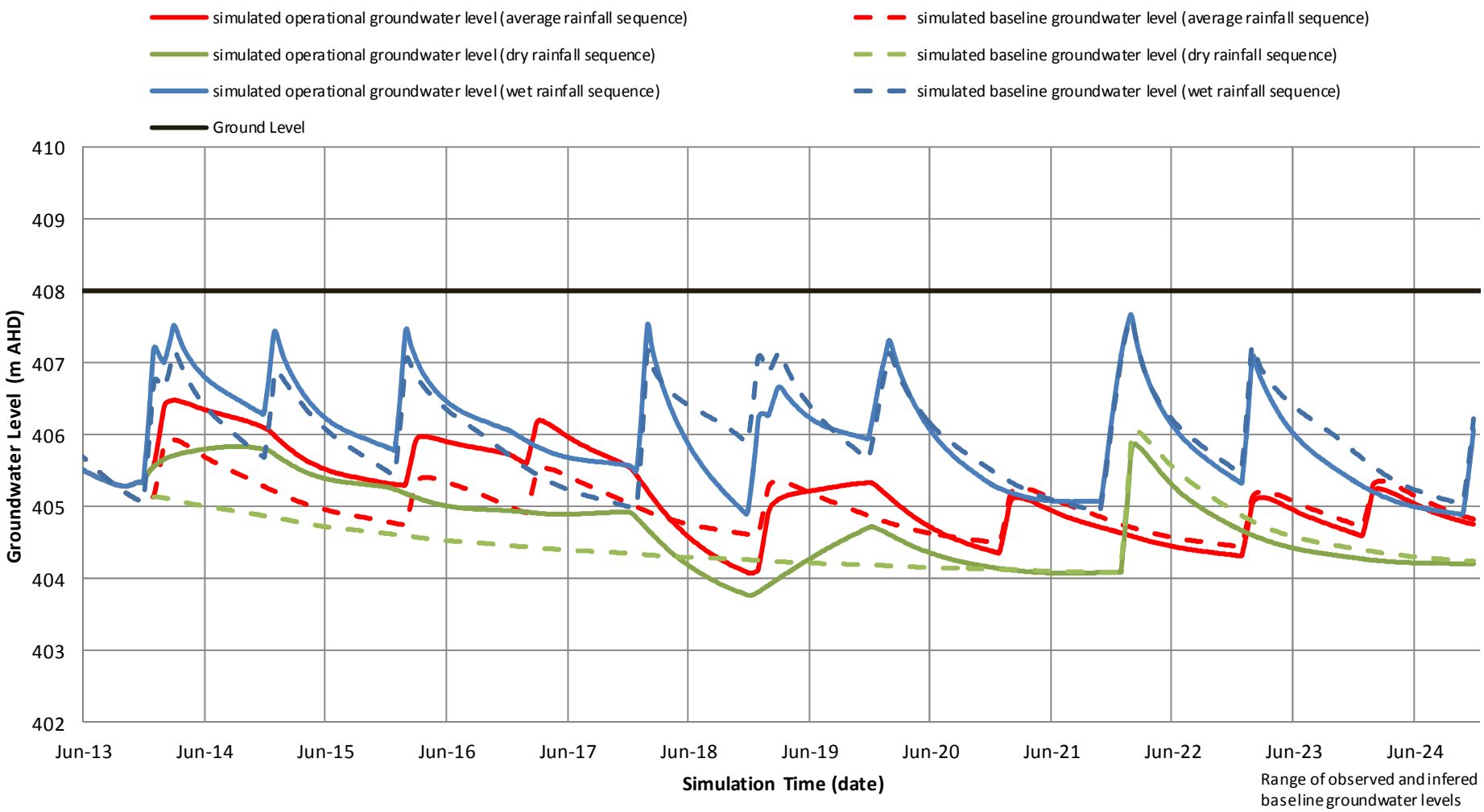
This page has been left blank intentionally



Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Hydrographs at CBFM06 under natural (dashed lines) and mining (solid lines) conditions for Base, Dry and Wet scenarios**	**Figure 40**
		11/11/2013

Figure 41: Hydrograph at CBFMM07_s, under natural and mining conditions for the Base, Dry and Wet simulations

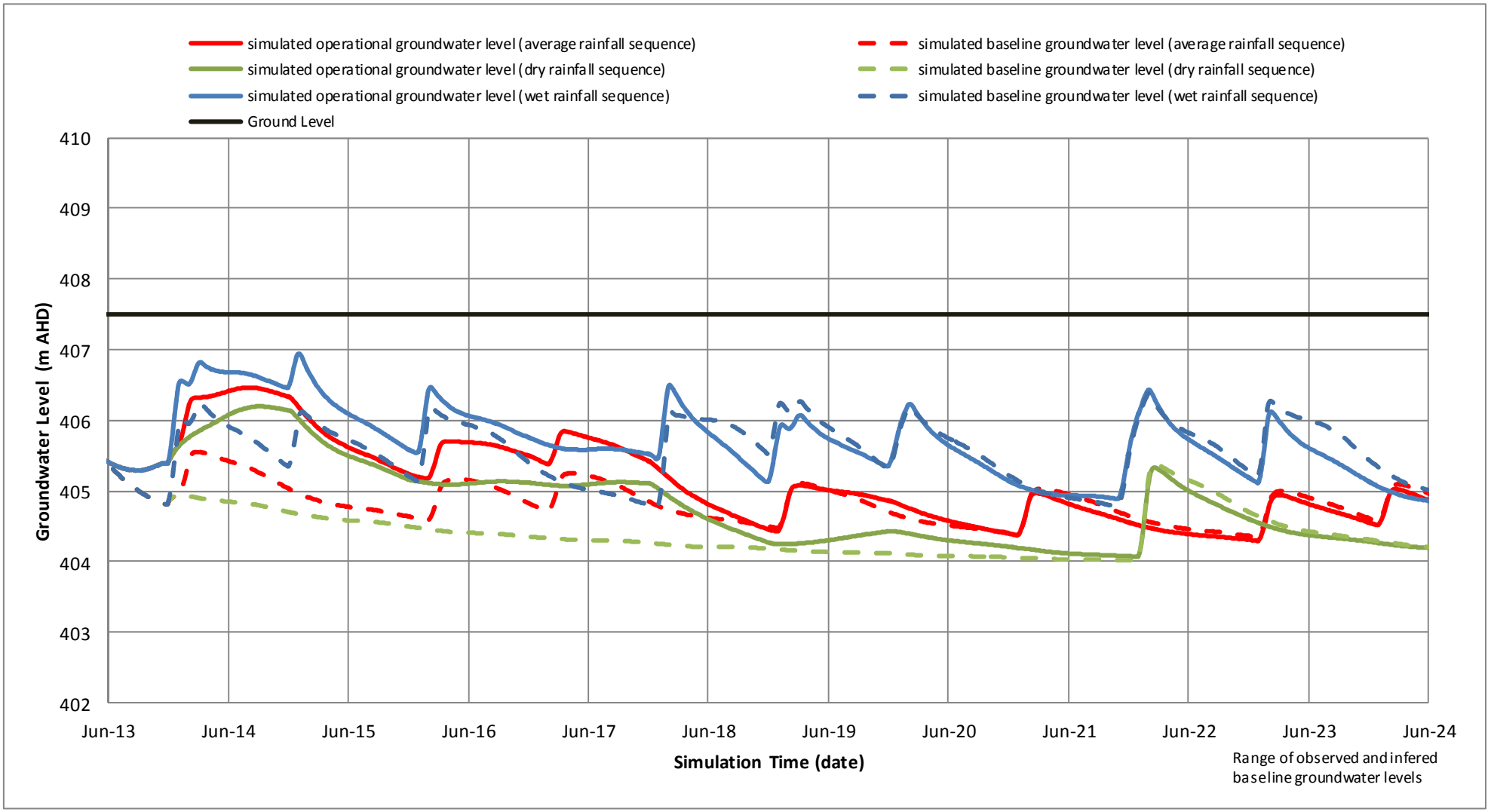
This page has been left blank intentionally



Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Hydrographs at CBFM07 under natural (dashed lines) and mining (solid lines) conditions for Base, Dry and Wet scenarios**	**Figure 41**
		11/11/2013

Figure 42: Hydrograph at CBFMM08_s, under natural and mining conditions for the Base, Dry and Wet simulations

This page has been left blank intentionally



Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Hydrographs at CBFM08 under natural (dashed lines) and mining (solid lines) conditions for Base, Dry and Wet scenarios**	**Figure 42**
		11/11/2013

Figure 43: Cumulative impact on groundwater levels

This page has been left blank intentionally

720,000 mE
740,000 mE
760,000 mE
780,000 mE
800,000 mE
820,000 mE
7,540,000 mN
7,520,000 mN
7,500,000 mN

Rail Camp CH230

FMG Cloudbreak Project

Cloudbreak Village

FMG Christmas Creek Project

CC Mine Camp

CC Temporary Camp

Hancock Roy Hill Project

Hancock Resources Camp

FORTESCUE MARSH

Brockman Resources Marillana Project

Location Map

Port Hedland Project

Kalgoorlie

PERTH

Hancock Tenements

Fortescue Marsh

Groundwater drawdown (metres) (-ve numbers) June 2015

Groundwater mounding (metres) (+ve numbers) June 2015

Source: Hancock contours from Roy Hill PER (Year 5),
Brockman contours from Brockman Resources Marillana Project PER (Year 20)

N

0 2.5 5 10
kilometres

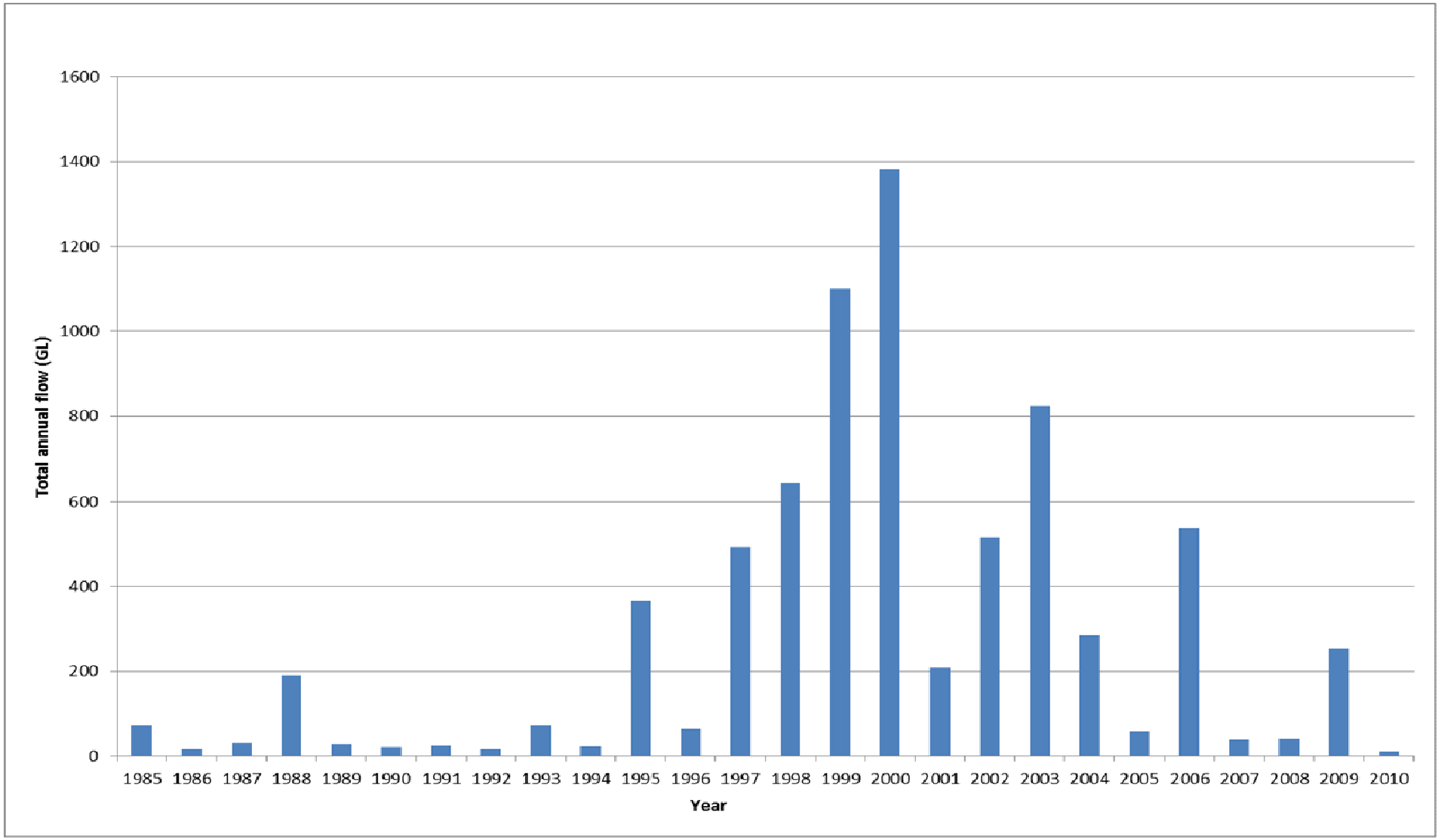
Fortescue Metals Group Ltd

Potential Cummalative Impacts Cloudbreak

Author: B.Willis-Jones	Date: 12/11/2010
Drawn By: PM	Revision: 1
Dwg No: CB_MP_HY_0044 Fig53	Confidentiality: 1
Projection: MGA Zone 50 (GDA 94)	Scale: 1:260000

Figure 44: Fortescue Marsh Water Balance

This page has been left blank intentionally

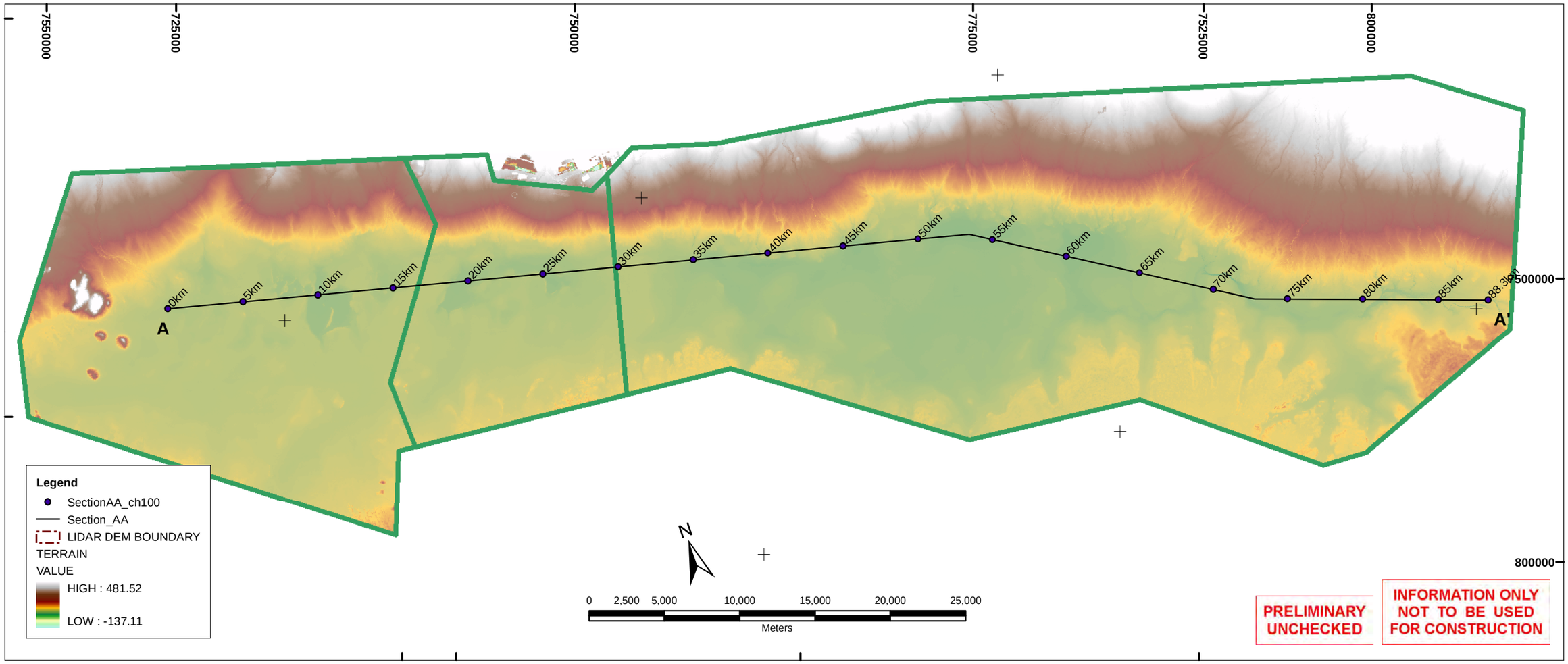


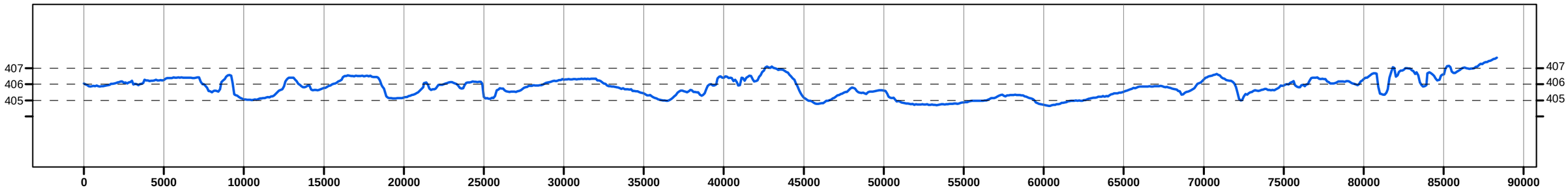
Fortescue Metals Group Ltd ACN: 002 594 872 87 Adelaide Terrace, East Perth Western Australia 6004	**Fortescue Marsh—Water Balance Model results (1985 to 2010)**	**Figure 44**
		13/11/2013

Appendix 1: Historical Landsat data

This page has been left blank intentionally

LANDSAT INTERPRETATION - Flooding area, volume and water level			
Date	**Area (km2)**	**Volume (GL)**	**Water Level (mAHD)**
Aug-99	322	159	405.9
Nov-99	156	35	405.39
Jun-00	853	794	406.98
Sep-00	807	673	406.83
Dec-00	460	299	406.26
Mar-01	591	396	406.45
Jun-01	347	186	405.98
Sep-01	265	101	405.7
Nov-01	60	10	405.15
Feb-02	764	587	406.72
Apr-02	482	318	406.3
Sep-02	216	63	405.54
Dec-02	20	3	404.95
Mar-03	726	526	406.64
Aug-03	326	163	405.91
Oct-03	169	40	405.42
Jan-04	2	0	404.69
Apr-04	276	113	405.74
Aug-04	145	32	405.37
May-05	0	0	-
Mar-06	259	96	405.68
Jun-06	262	98	405.69
Sep-06	188	48	405.47
Dec-06	105	20	405.27
Jul-07	3	0	404.72
Oct-07	0	0	-
Jun-09	218	65	405.55
Apr-10	0	0	-
Jul-10	0	0	-





WorleyParsons EcoNomics
resources & energy

LOCALITY MAP

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	ISSUED FOR INTERNAL REVIEW			06.10.10

NOTES

CLIENT: FMG

TITLE: FORTESCUE MARSH INUNDATION MAPPING SECTION PROFILE A-A'

WORLEYPARSONS PROJECT: 201012-00252

SCALE: 1:275,000 @ A3

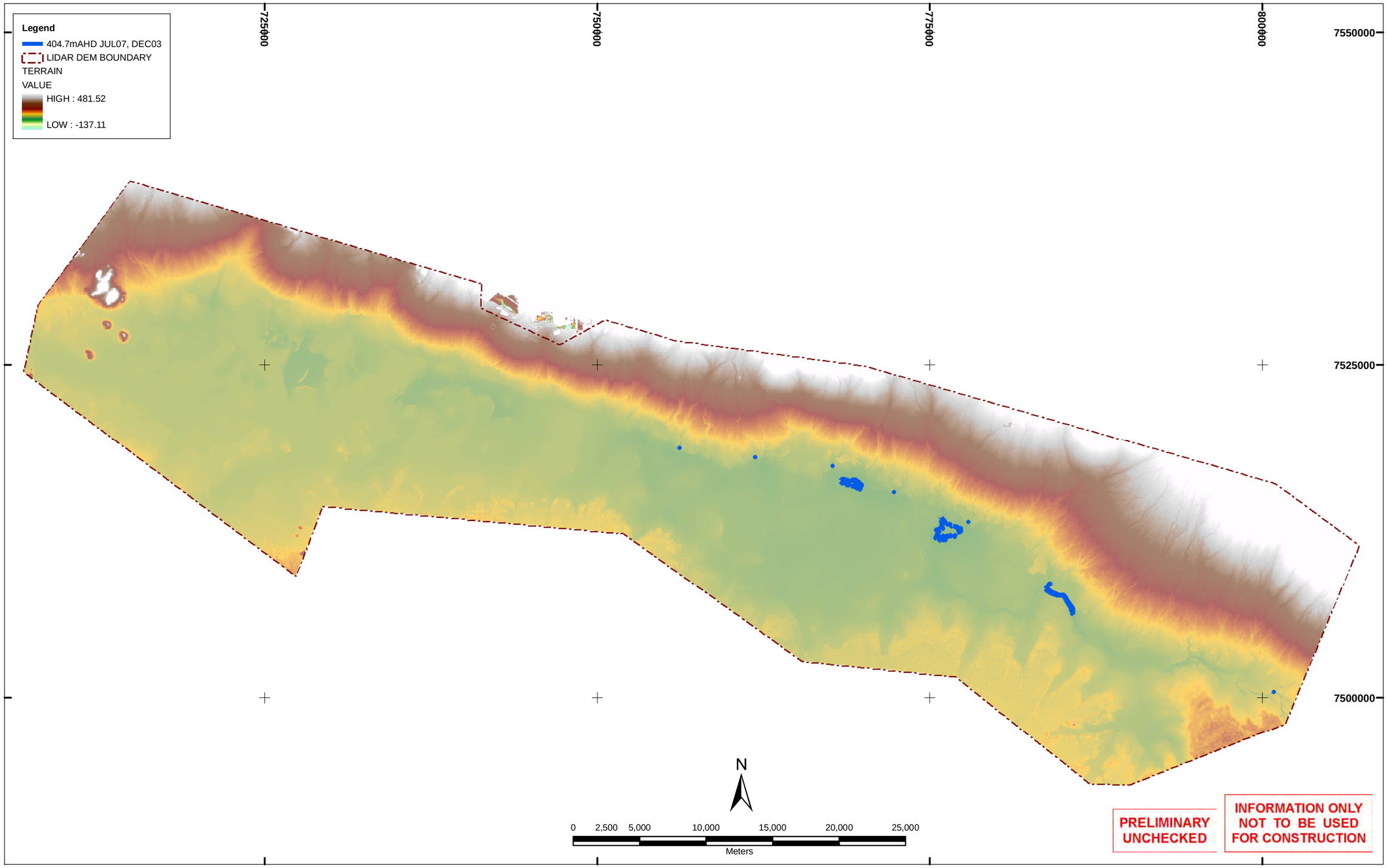
DATUM: GDA_1994_MGA_Zone_50

DRG NO: 201012-00252-GIS-DSK-003

REV: A

Produced by: daniel.hornby@worleyparsons.com - Geomatics W.A.

V:\201012-00252_FMG_FortescueMarsh\03Project\Workspace_SKT\201012-00252_GIS-DSK_002.mxd



WorleyParsons EcoNomics
resources & energy

LOCALITY MAP

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	ISSUED FOR INTERNAL REVIEW			06.10.10

NOTES

CLIENT: FMG

TITLE: FORTESCUE MARSH INUNDATION MAPPING 404.7mAHD JUL07, DEC03

WORLEYPARSONS PROJECT: 201012-00252

SCALE: 1:275,000 @ A3

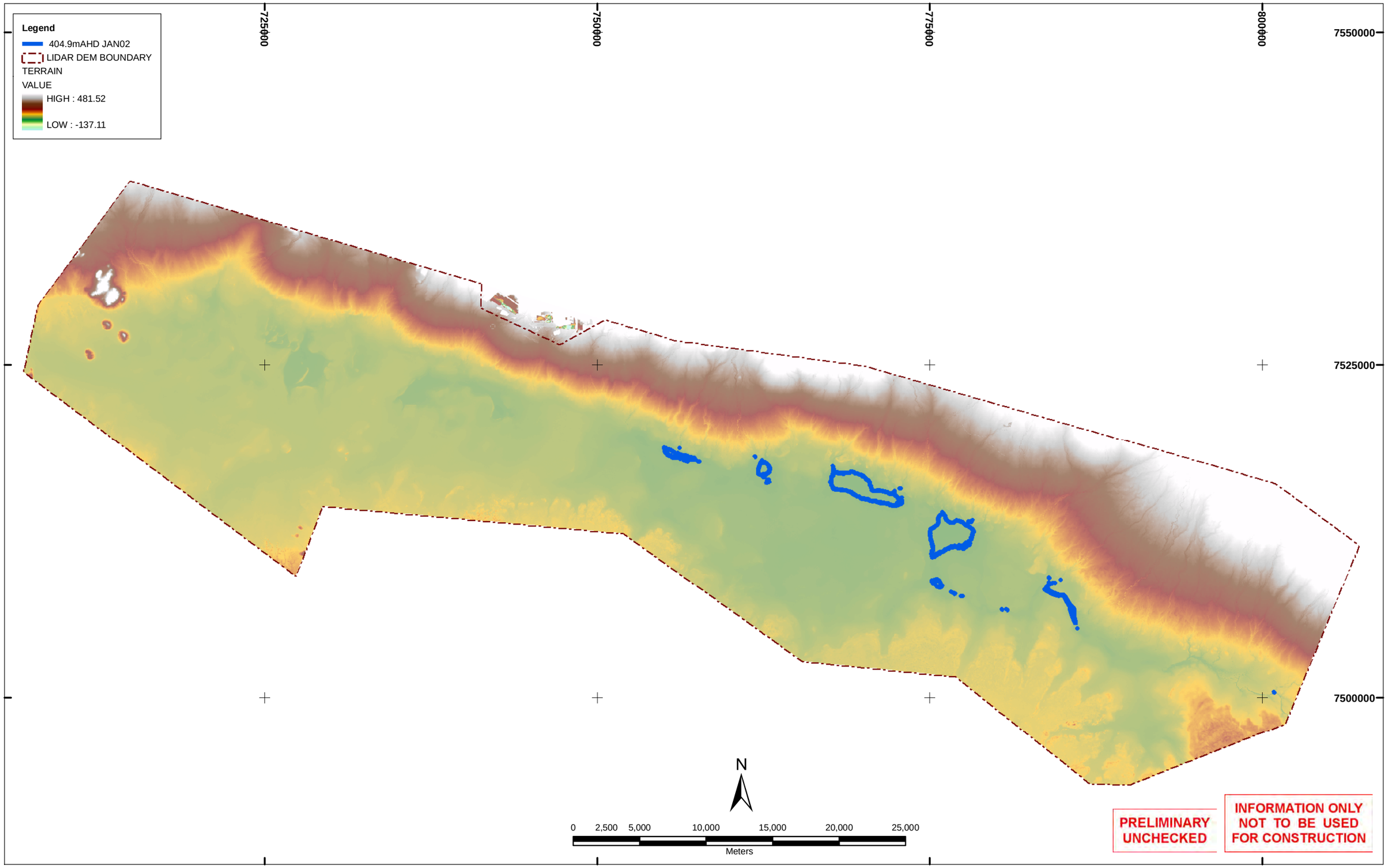
DATUM: GDA_1994_MGA_Zone_50

DRG NO: 201012-00252-GIS-DSK-002

REV: A

V:\201012-00252_FMG_FortescueMarsh\03Project\Workspace_SKT\201012-00252_GIS-DSK_002.mxd

Produced by: daniel.hornby@worleyparsons.com - Geomatics W.A.



WorleyParsons EcoNomics
resources & energy

WORLEYPARSONS PROJECT
201012-00252

SCALE 1:275,000 @ A3

DATUM GDA_1994_MGA_Zone_50

LOCALITY MAP

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	ISSUED FOR INTERNAL REVIEW			06.10.10

NOTES

CLIENT
FMG

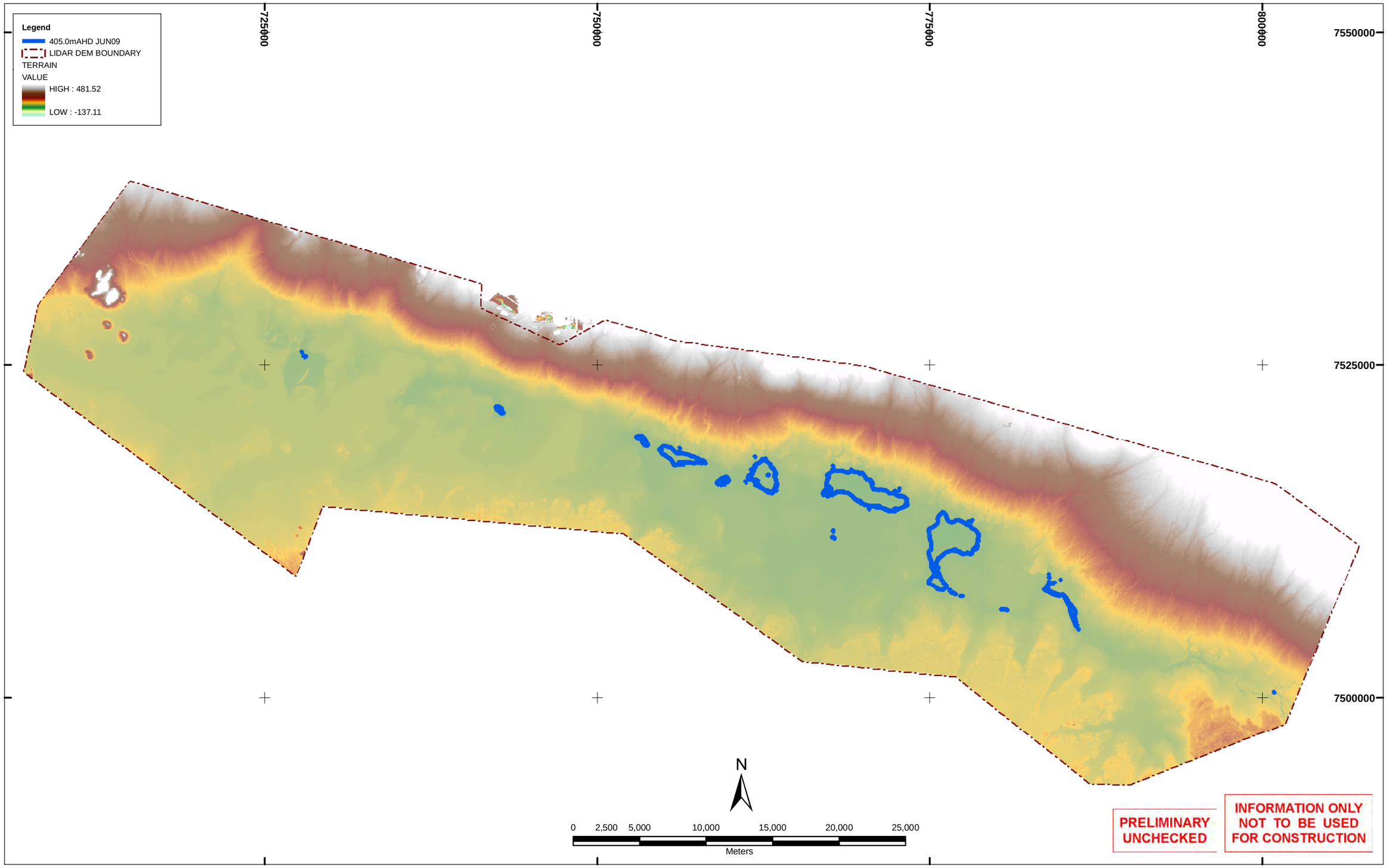
TITLE
FORTESCUE MARSH
INUNDATION MAPPING
404.9mAHD JAN02

DRG NO
201012-00252-GIS-DSK-002

REV
A

V:\201012-00252_FMG_FortescueMarsh\03Project\Workspace_SKT\201012-00252_GIS-DSK_002.mxd

Produced by: daniel.hornby@worleyparsons.com - Geomatics W.A.



WorleyParsons EcoNomics
resources & energy

LOCALITY MAP

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	ISSUED FOR INTERNAL REVIEW			06.10.10

NOTES

CLIENT: FMG

TITLE: FORTESCUE MARSH INUNDATION MAPPING 405.0mAHD JUN09

WORLEYPARSONS PROJECT: 201012-00252

SCALE: 1:275,000 @ A3

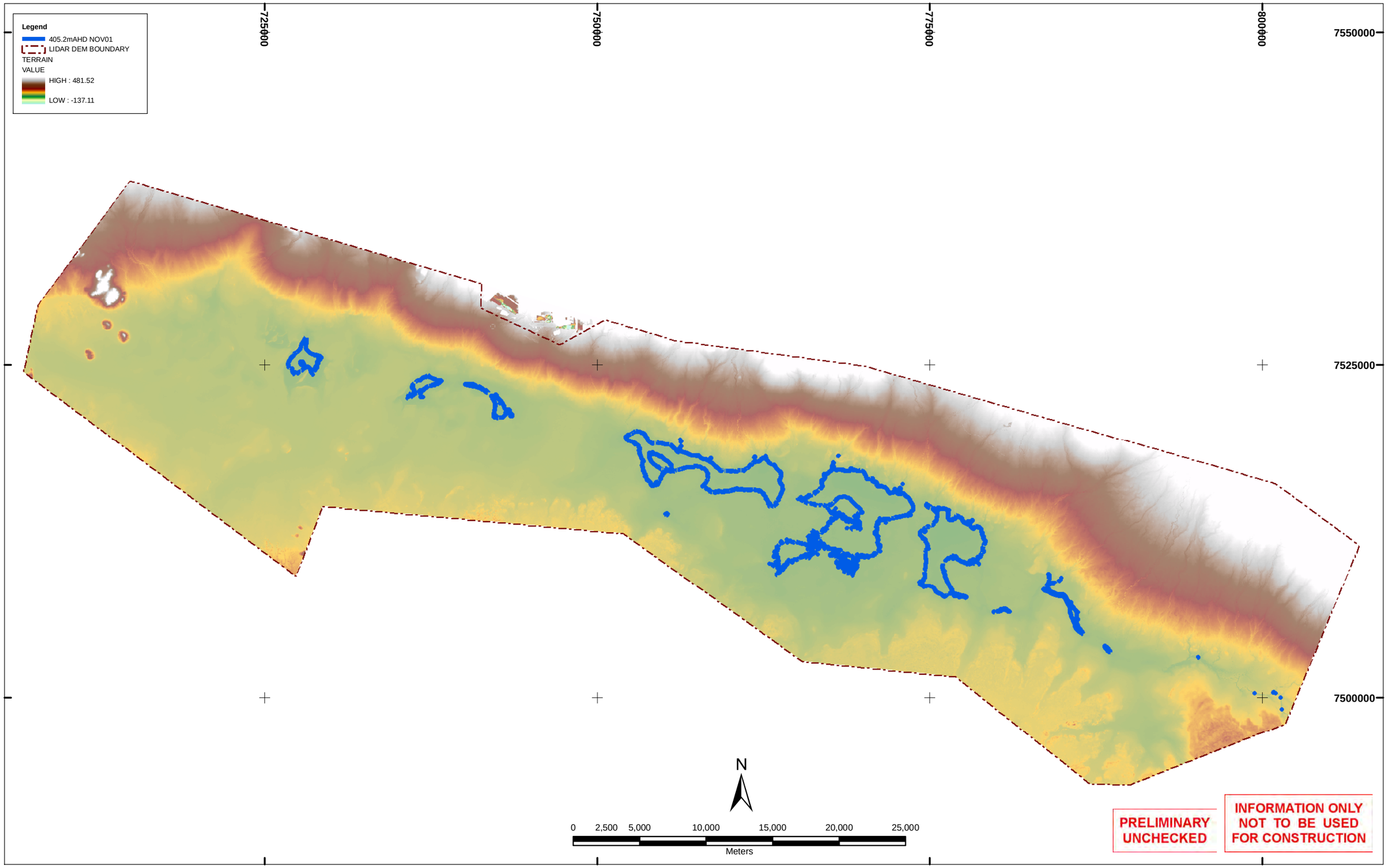
DATUM: GDA_1994_MGA_Zone_50

DRG NO: 201012-00252-GIS-DSK-002

REV: A

V:\201012-00252_FMG_FortescueMarsh\03Project\Workspace_SKT\201012-00252_GIS-DSK_002.mxd

Produced by: daniel.hornby@worleyparsons.com - Geomatics W.A.



WorleyParsons EcoNomics
resources & energy

LOCALITY MAP

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	ISSUED FOR INTERNAL REVIEW			06.10.10

NOTES

CLIENT: FMG

TITLE: FORTESCUE MARSH INUNDATION MAPPING 405.2mAHD NOV01

WORLEYPARSONS PROJECT: 201012-00252

SCALE: 1:275,000 @ A3

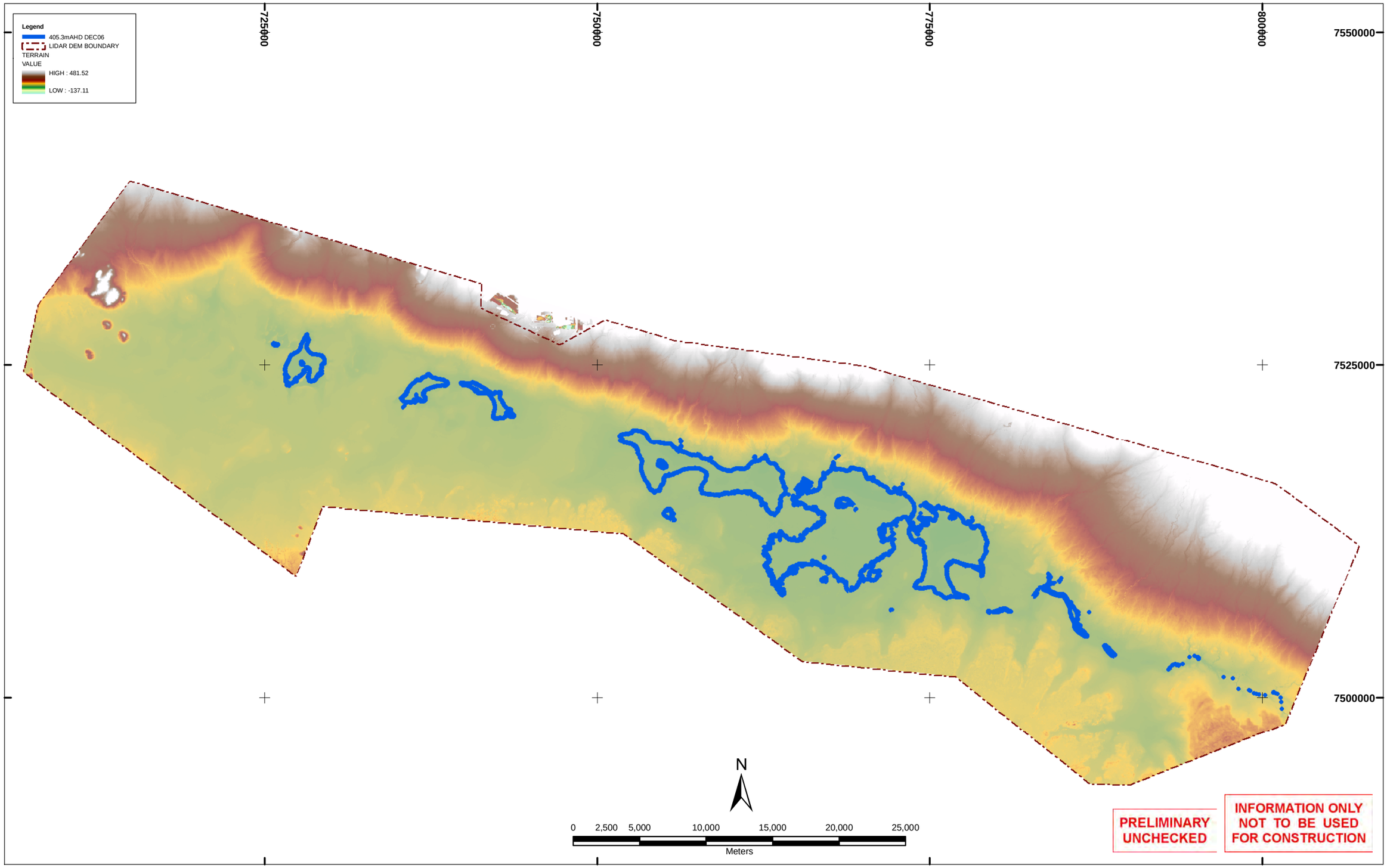
DATUM: GDA_1994_MGA_Zone_50

DRG NO: 201012-00252-GIS-DSK-002

REV: A

V:\201012-00252_FMG_FortescueMarsh\03Project\Workspace_SKT\201012-00252_GIS-DSK_002.mxd

Produced by: daniel.hornby@worleyparsons.com - Geomatics W.A.



WorleyParsons EcoNomics
resources & energy

LOCALITY MAP

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	ISSUED FOR INTERNAL REVIEW			06.10.10

NOTES

CLIENT: FMG

TITLE: FORTESCUE MARSH INUNDATION MAPPING 405.3mAHD DEC06

WORLEYPARSONS PROJECT: 201012-00252

SCALE: 1:275,000 @ A3

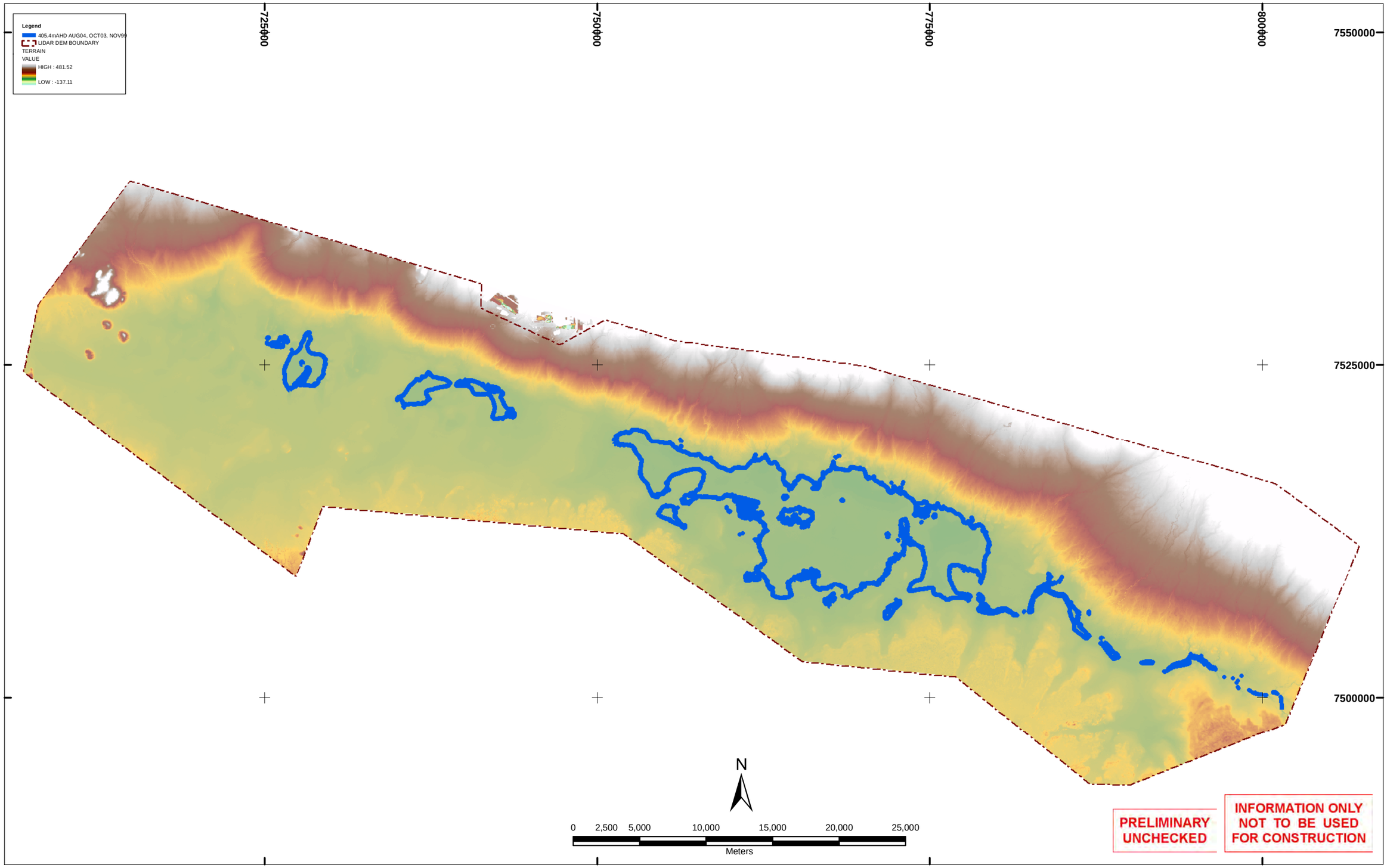
DATUM: GDA_1994_MGA_Zone_50

DRG NO: 201012-00252-GIS-DSK-002

REV: A

Produced by: daniel.hornby@worleyparsons.com - Geomatics W.A.

V:\201012-00252_FMG_FortescueMarsh\03Project\Workspace_SKT\201012-00252_GIS-DSK_002.mxd



WorleyParsons EcoNomics
resources & energy

WORLEYPARSONS PROJECT
201012-00252

SCALE 1:275,000 @ A3

DATUM GDA_1994_MGA_Zone_50

LOCALITY MAP

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	ISSUED FOR INTERNAL REVIEW			06.10.10

NOTES

CLIENT
FMG

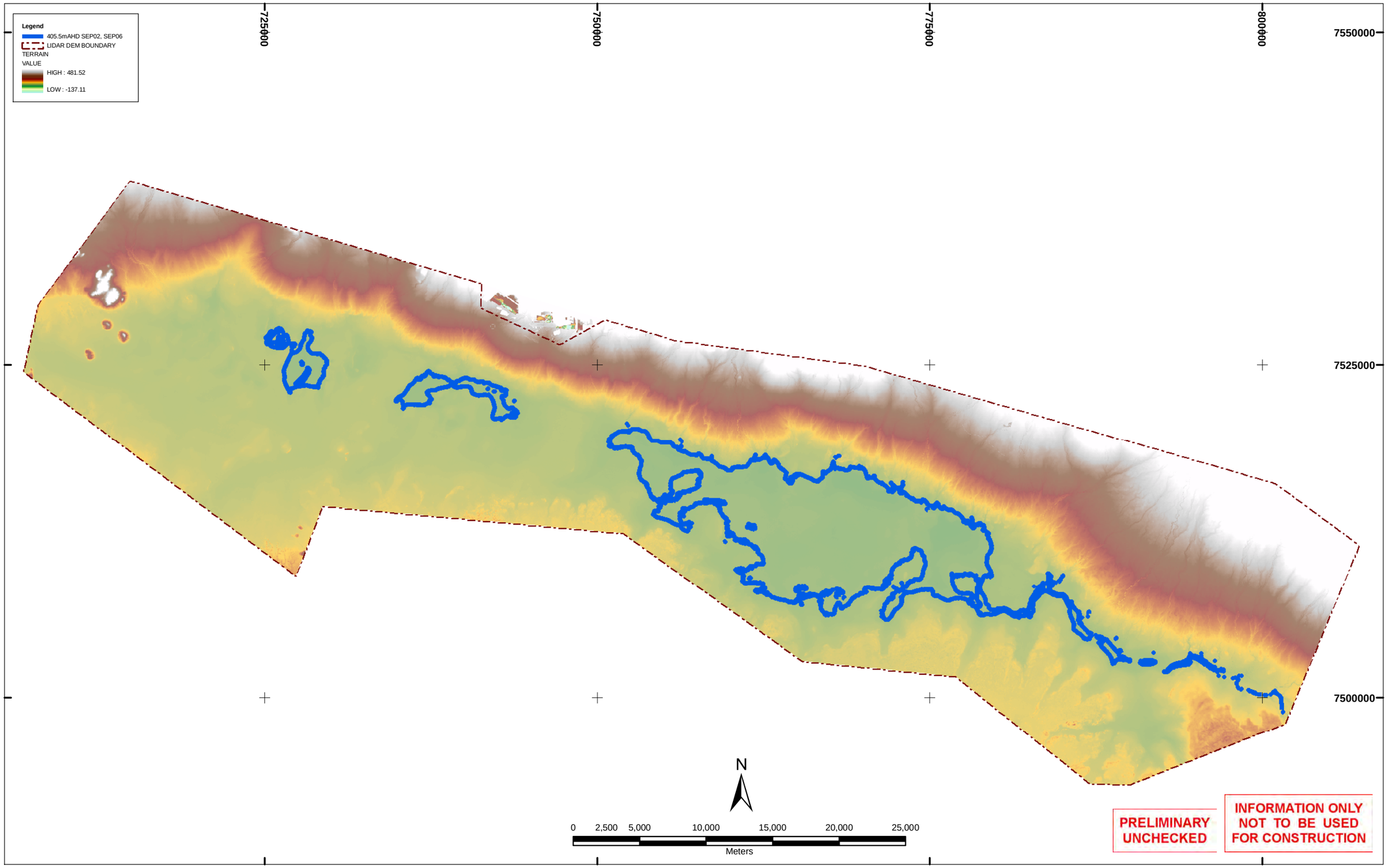
TITLE
FORTESCUE MARSH
INUNDATION MAPPING
405.4mAHD AUG04, OCT03, NOV99

DRG NO
201012-00252-GIS-DSK-002

REV
A

V:\201012-00252_FMG_FortescueMarsh\03Project\Workspace_SKT\201012-00252_GIS-DSK_002.mxd

Produced by: daniel.hornby@worleyparsons.com - Geomatics W.A.



WorleyParsons EcoNomics
resources & energy

LOCALITY MAP

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	ISSUED FOR INTERNAL REVIEW			06.10.10

NOTES

CLIENT: FMG

TITLE: FORTESCUE MARSH INUNDATION MAPPING 405.5mAHD SEP02, SEP06

WORLEYPARSONS PROJECT: 201012-00252

SCALE: 1:275,000 @ A3

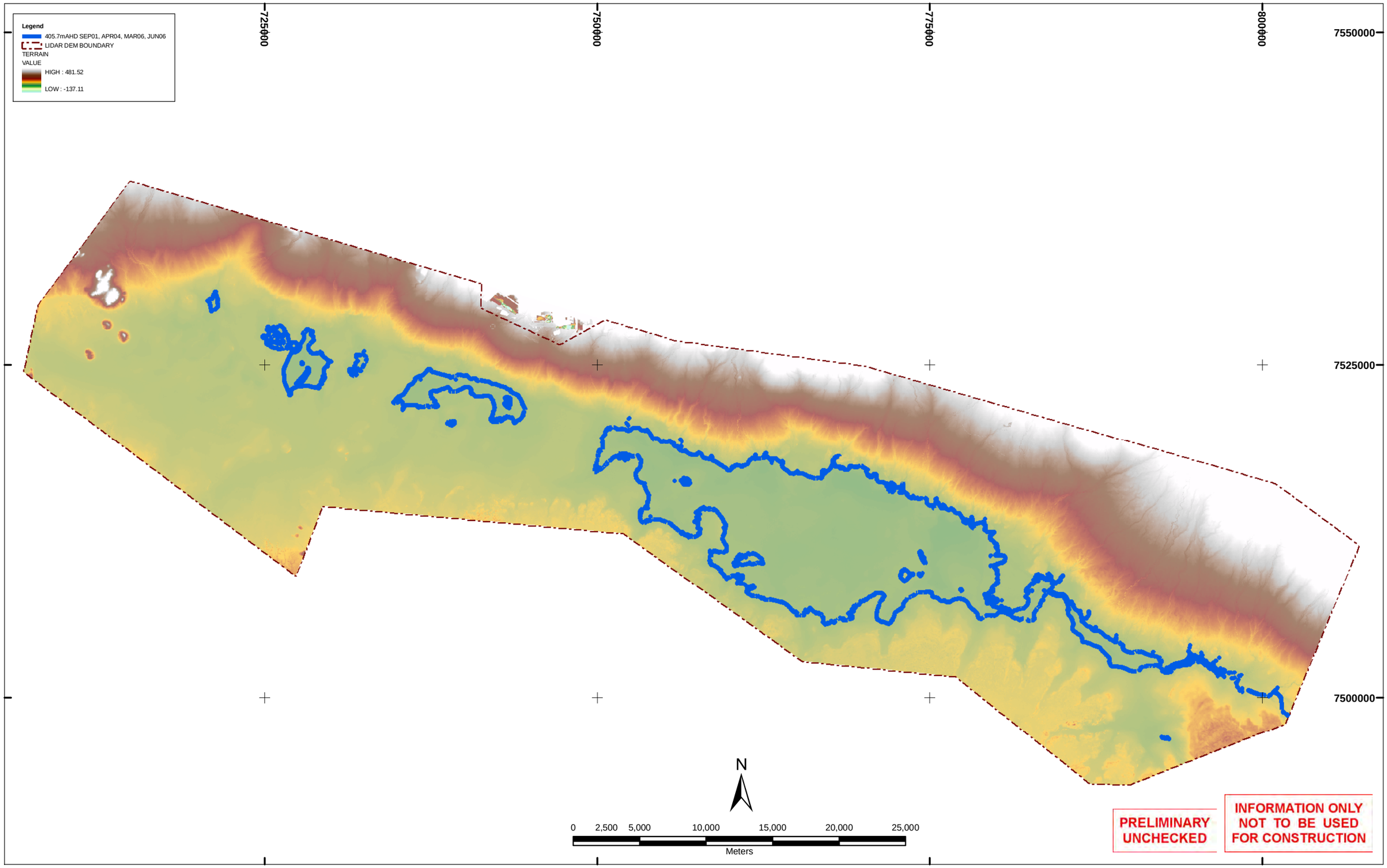
DATUM: GDA_1994_MGA_Zone_50

DRG NO: 201012-00252-GIS-DSK-002

REV: A

V:\201012-00252_FMG_FortescueMarsh\03Project\Workspace_SKT\201012-00252_GIS-DSK_002.mxd

Produced by: daniel.hornby@worleyparsons.com - Geomatics W.A.



WorleyParsons EcoNomics
resources & energy

LOCALITY MAP

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	ISSUED FOR INTERNAL REVIEW			06.10.10

NOTES

CLIENT: FMG

TITLE: FORTESCUE MARSH INUNDATION MAPPING 405.7mAHD SEP01, APR04, MAR06, JUN06

WORLEYPARSONS PROJECT: 201012-00252

SCALE: 1:275,000 @ A3

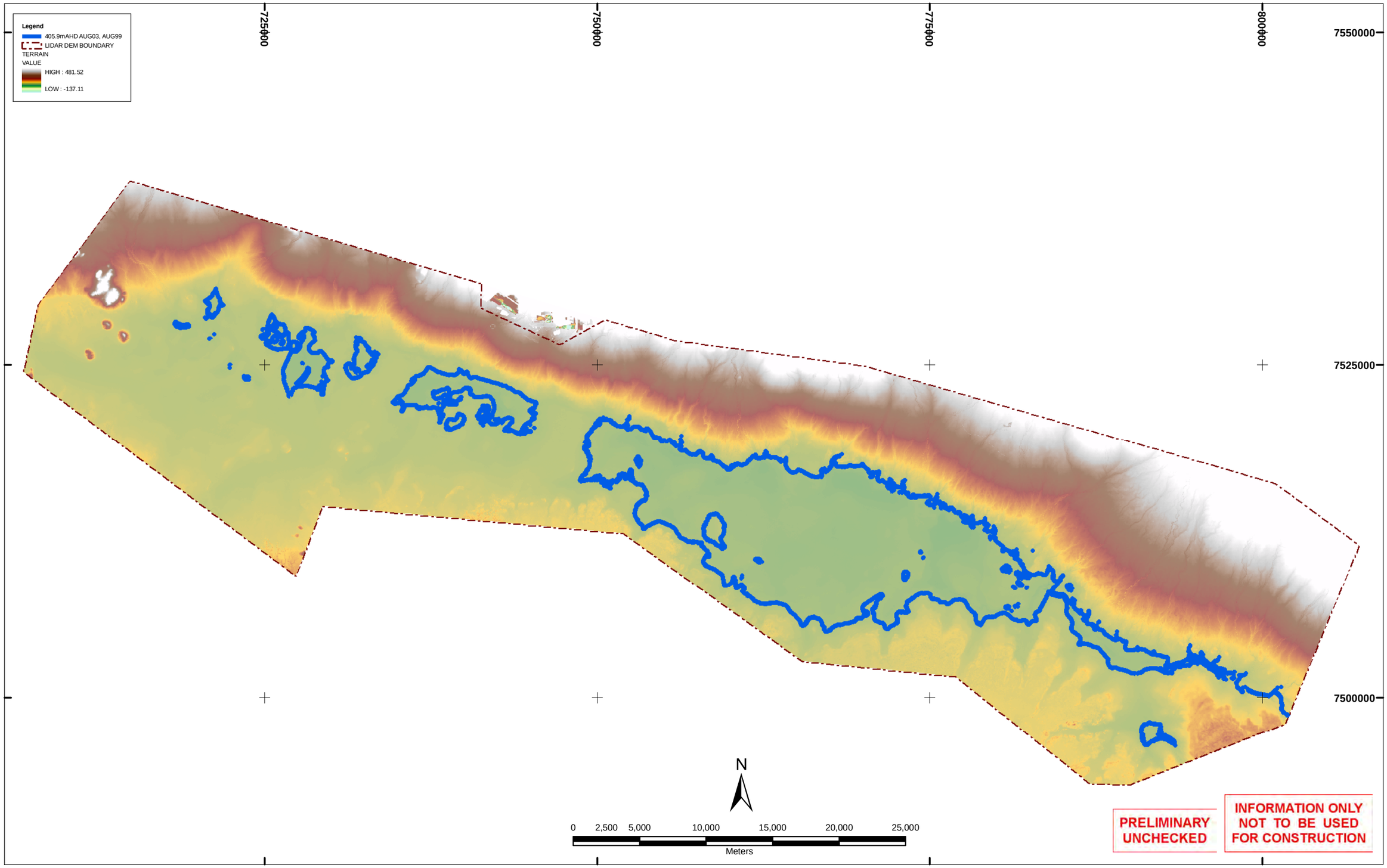
DATUM: GDA_1994_MGA_Zone_50

DRG NO: 201012-00252-GIS-DSK-002

REV: A

V:\201012-00252_FMG_FortescueMarsh\03Project\Workspace_SKT\201012-00252_GIS-DSK_002.mxd

Produced by: daniel.hornby@worleyparsons.com - Geomatics W.A.



WorleyParsons EcoNomics
resources & energy

WORLEYPARSONS PROJECT
201012-00252

SCALE 1:275,000 @ A3

DATUM GDA_1994_MGA_Zone_50

LOCALITY MAP

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	ISSUED FOR INTERNAL REVIEW			06.10.10

NOTES

CLIENT
FMG

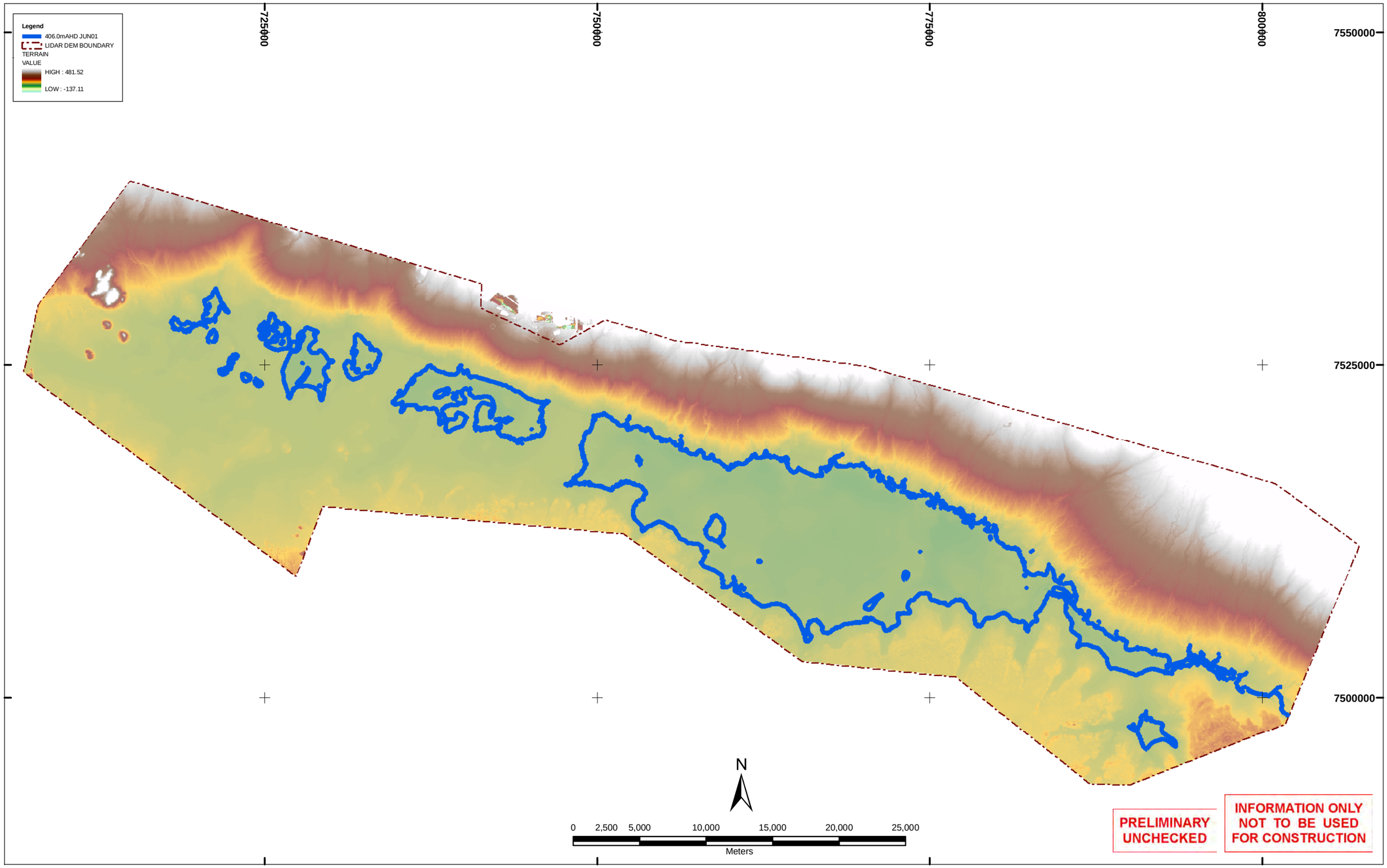
TITLE
FORTESCUE MARSH
INUNDATION MAPPING
405.9mAHD AUG03, AUG99

DRG NO
201012-00252-GIS-DSK-002

REV
A

V:\201012-00252_FMG_FortescueMarsh\03Project\Workspace_SKT\201012-00252_GIS-DSK_002.mxd

Produced by: daniel.hornby@worleyparsons.com - Geomatics W.A.



WorleyParsons EcoNomics
resources & energy

LOCALITY MAP

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	ISSUED FOR INTERNAL REVIEW			06.10.10

NOTES

CLIENT: FMG

TITLE: FORTESCUE MARSH INUNDATION MAPPING 406.0mAHD JUN01

WORLEYPARSONS PROJECT: 201012-00252

SCALE: 1:275,000 @ A3

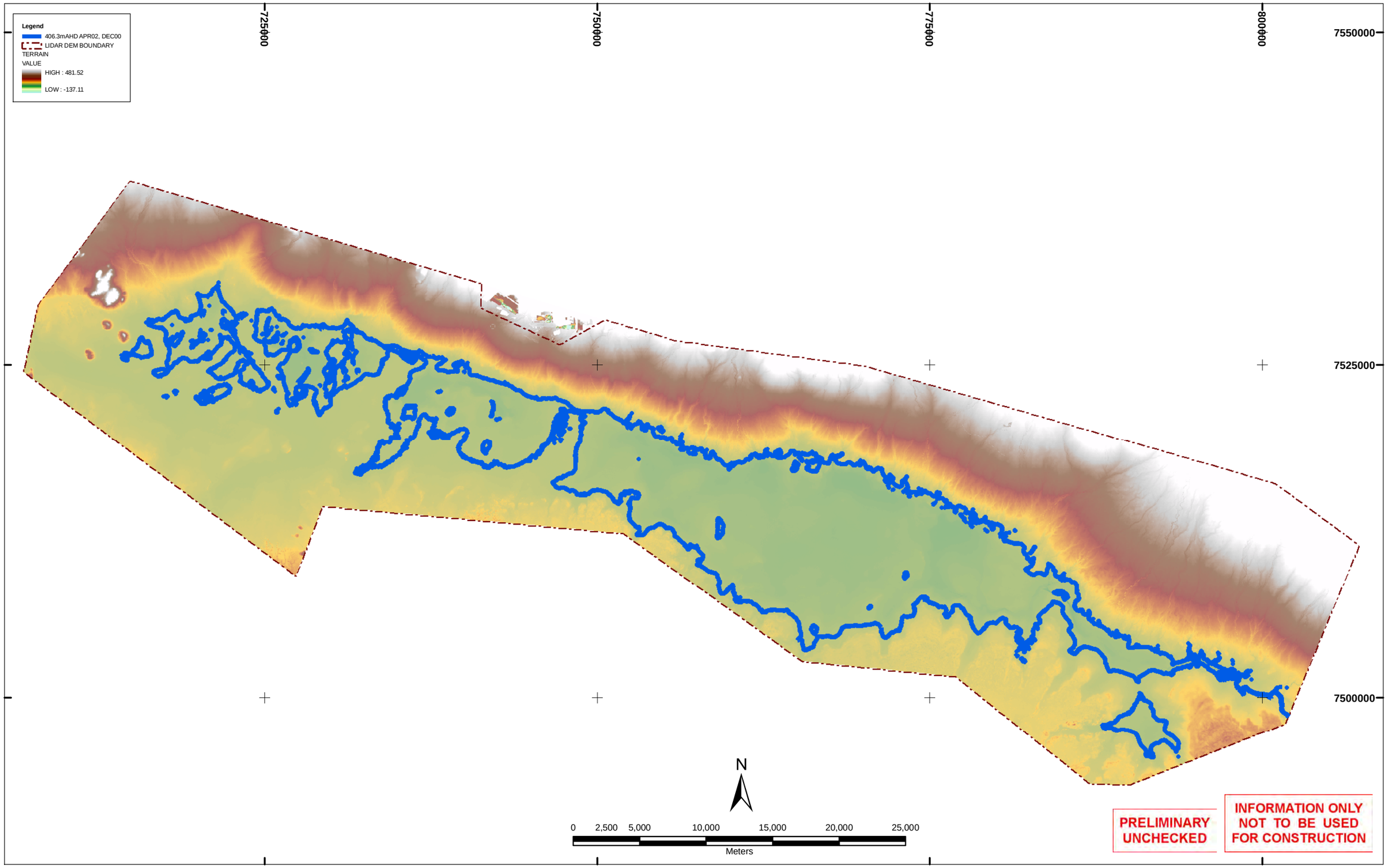
DATUM: GDA_1994_MGA_Zone_50

DRG NO: 201012-00252-GIS-DSK-002

REV: A

V:\201012-00252_FMG_FortescueMarsh\03Project\Workspace_SKT\201012-00252_GIS-DSK_002.mxd

Produced by: daniel.hornby@worleyparsons.com - Geomatics W.A.



WorleyParsons EcoNomics
resources & energy

LOCALITY MAP

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	ISSUED FOR INTERNAL REVIEW			06.10.10

NOTES

CLIENT: FMG

TITLE: FORTESCUE MARSH INUNDATION MAPPING 406.3mAHD APR02, DEC00

WORLEYPARSONS PROJECT: 201012-00252

SCALE: 1:275,000 @ A3

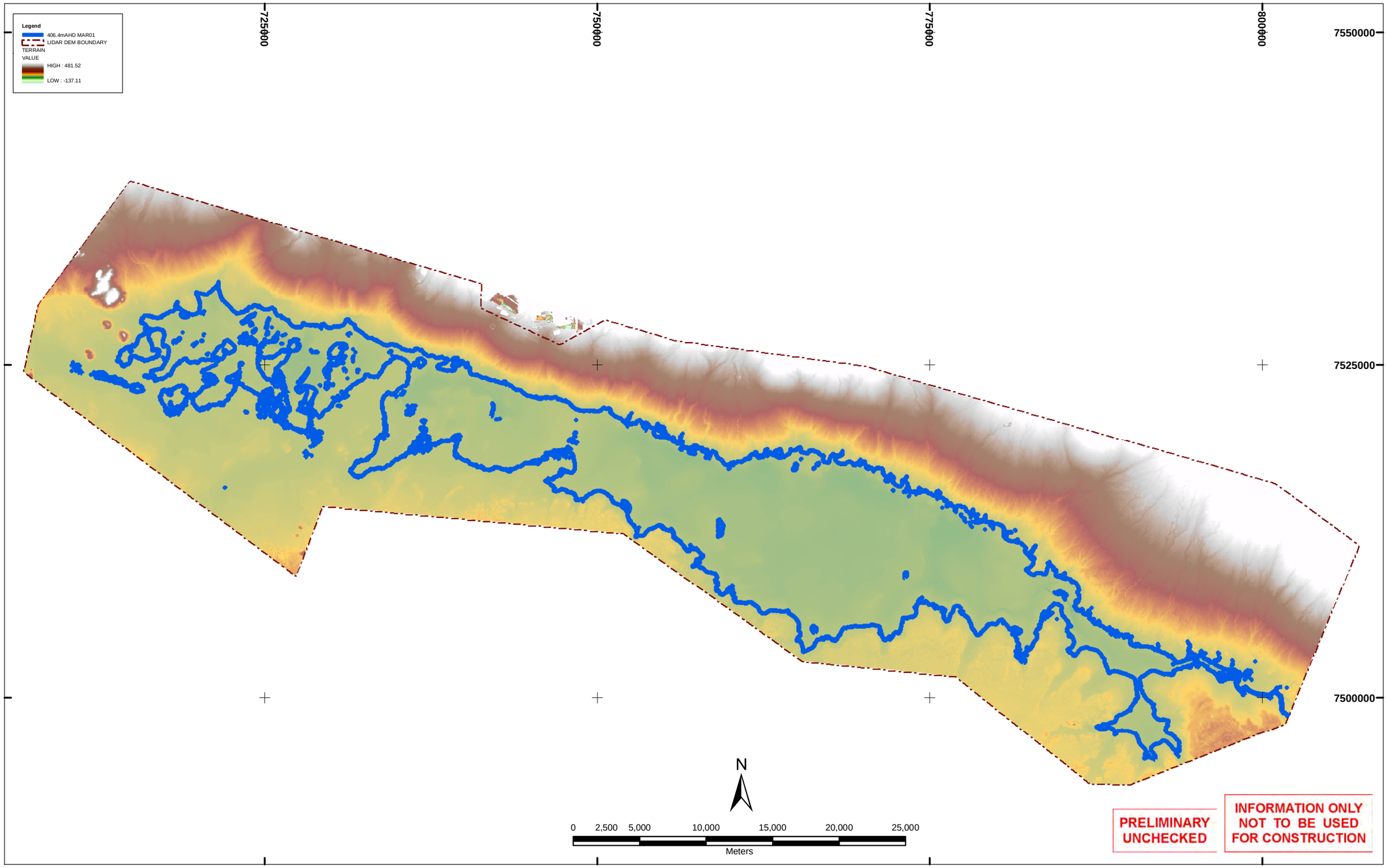
DATUM: GDA_1994_MGA_Zone_50

DRG NO: 201012-00252-GIS-DSK-002

REV: A

V:\201012-00252_FMG_FortescueMarsh\03Project\Workspace_SKT\201012-00252_GIS-DSK_002.mxd

Produced by: daniel.hornby@worleyparsons.com - Geomatics W.A.



WorleyParsons EcoNomics
resources & energy

WORLEYPARSONS PROJECT
201012-00252

SCALE 1:275,000 @ A3

DATUM GDA_1994_MGA_Zone_50

LOCALITY MAP

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	ISSUED FOR INTERNAL REVIEW			06.10.10

NOTES

CLIENT
FMG

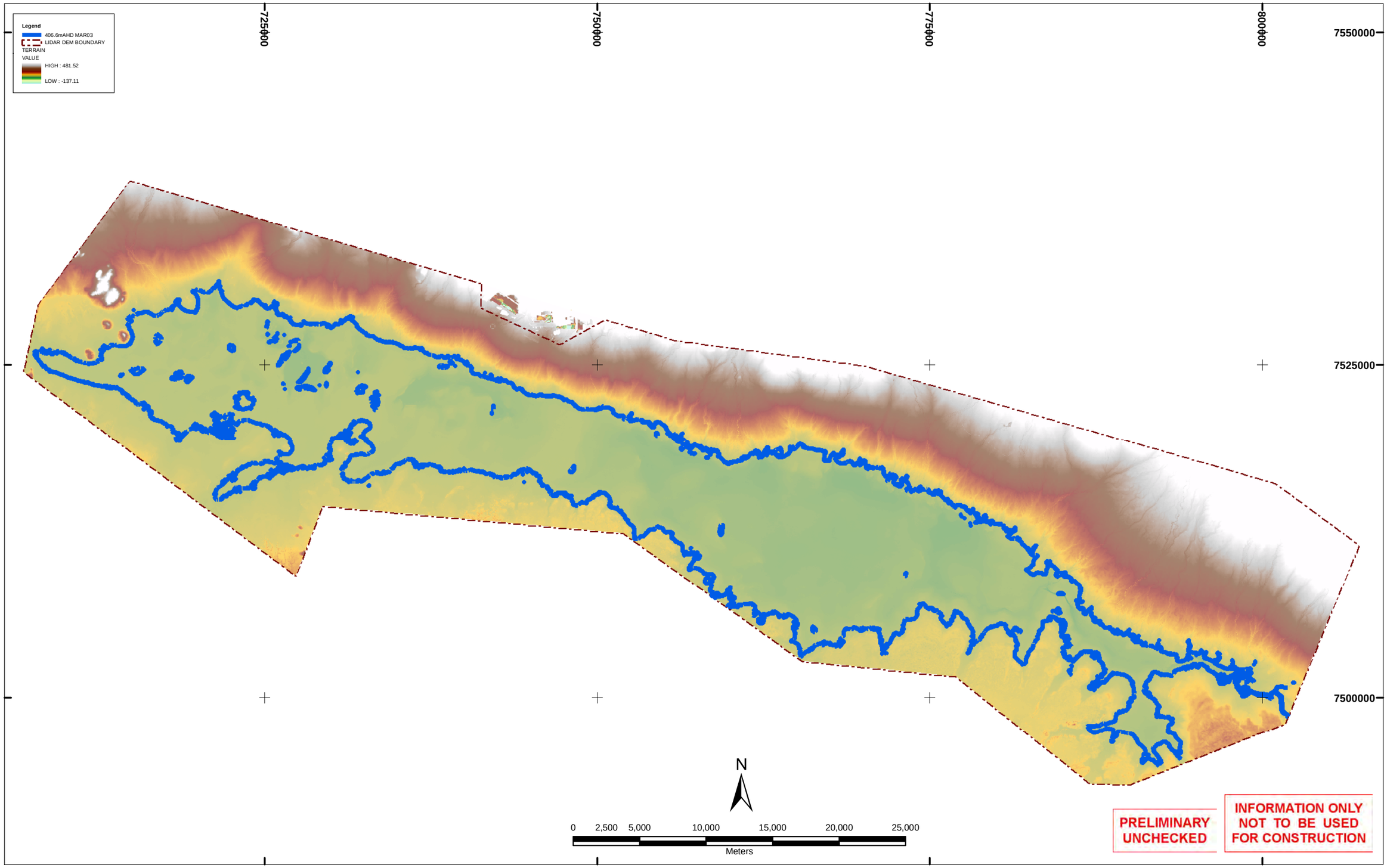
TITLE
FORTESCUE MARSH
INUNDATION MAPPING
406.4mAHD MAR01

DRG NO
201012-00252-GIS-DSK-002

REV
A

V:\201012-00252_FMG_FortescueMarsh\03Project\Workspace_SKT\201012-00252_GIS-DSK_002.mxd

Produced by: daniel.hornby@worleyparsons.com - Geomatics W.A.



WorleyParsons EcoNomics
resources & energy

WORLEYPARSONS PROJECT
201012-00252

SCALE 1:275,000 @ A3

DATUM GDA_1994_MGA_Zone_50

LOCALITY MAP

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	ISSUED FOR INTERNAL REVIEW			06.10.10

NOTES

CLIENT
FMG

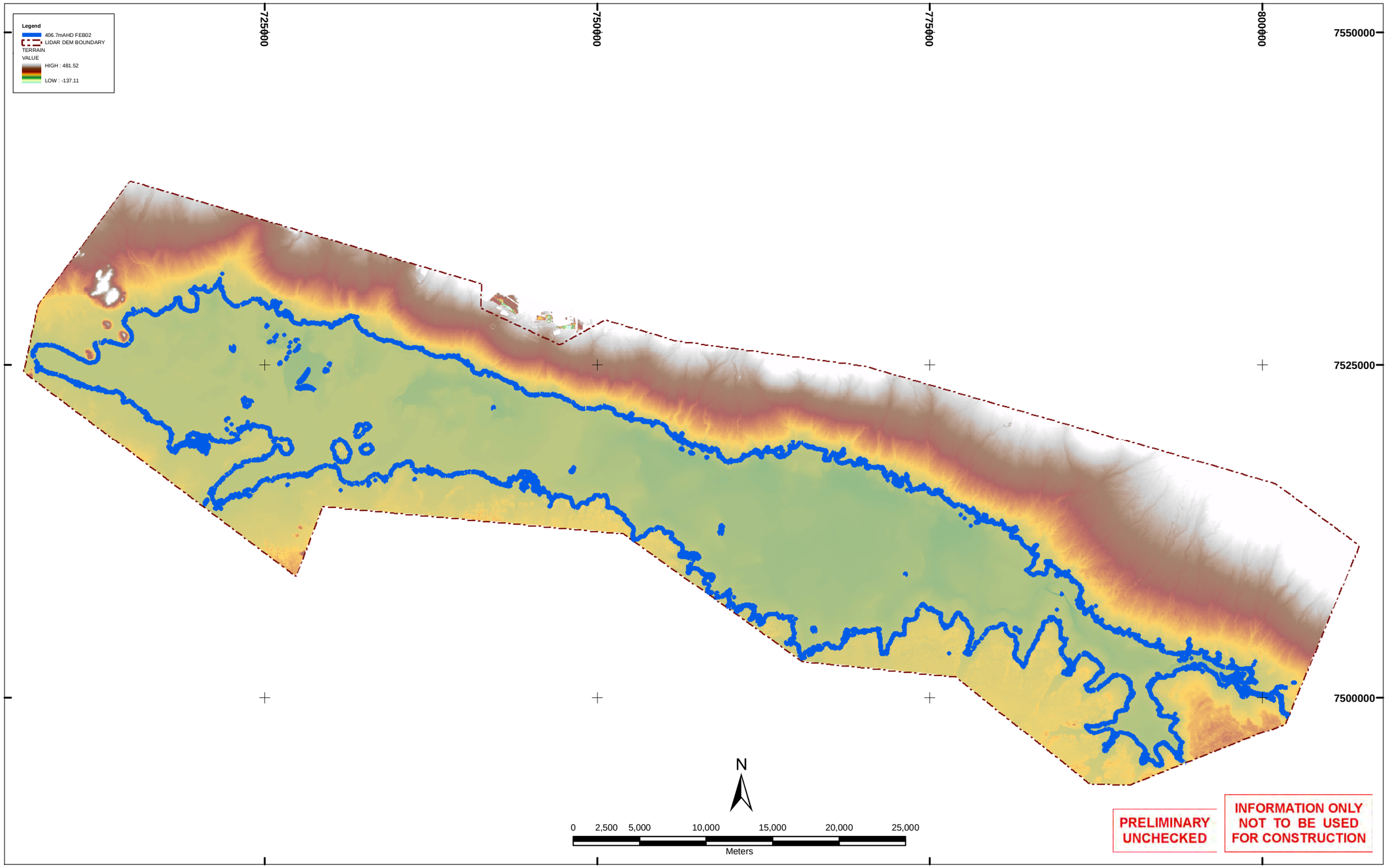
TITLE
FORTESCUE MARSH
INUNDATION MAPPING
406.6mAHD MAR03

DRG NO
201012-00252-GIS-DSK-002

REV
A

V:\201012-00252_FMG_FortescueMarsh\03Project\Workspace_SKT\201012-00252_GIS-DSK_002.mxd

Produced by: daniel.hornby@worleyparsons.com - Geomatics W.A.



WorleyParsons EcoNomics
resources & energy

LOCALITY MAP

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	ISSUED FOR INTERNAL REVIEW			06.10.10

NOTES

CLIENT: FMG

TITLE: FORTESCUE MARSH INUNDATION MAPPING 406.7mAHD FEB02

WORLEYPARSONS PROJECT: 201012-00252

SCALE: 1:275,000 @ A3

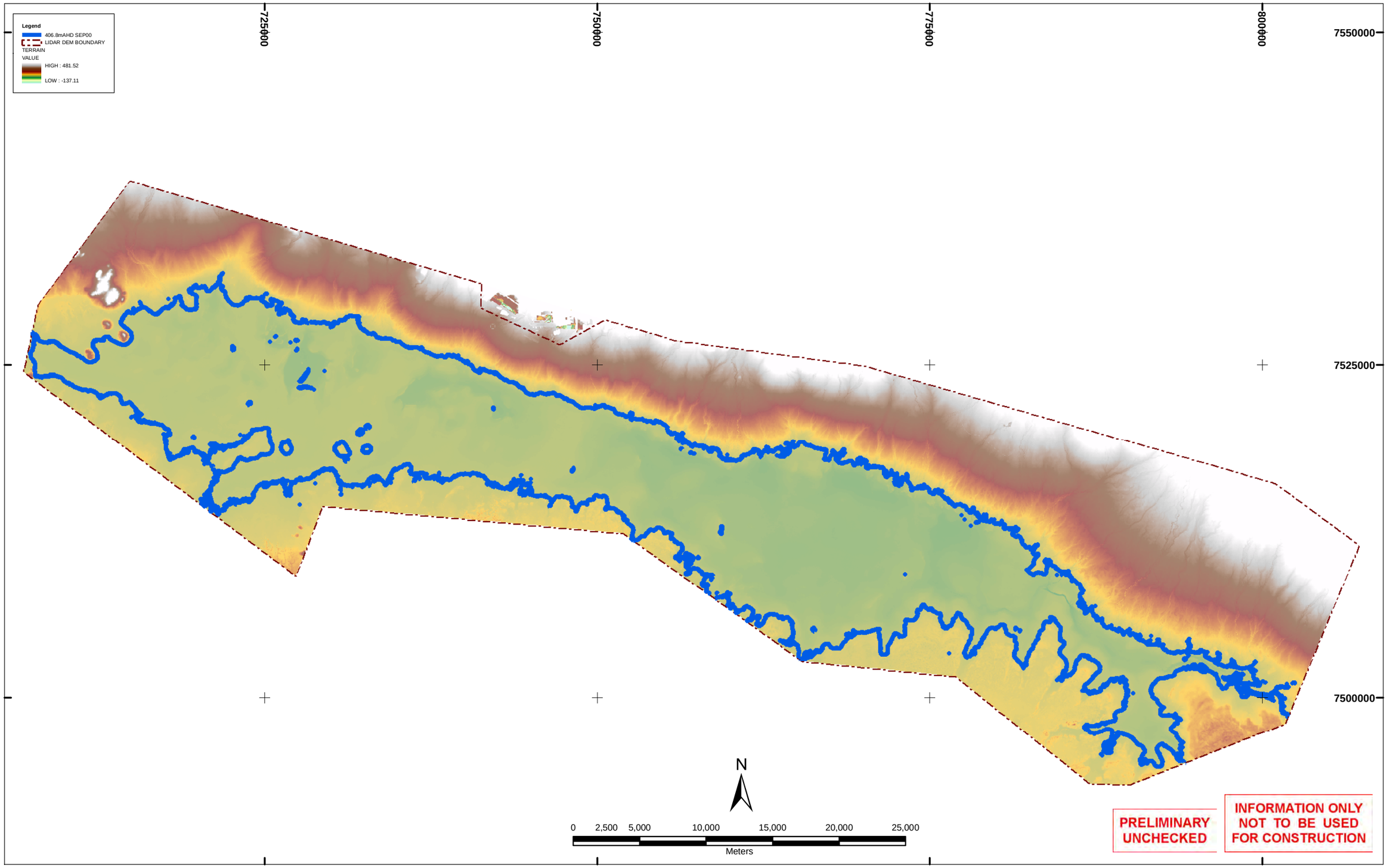
DATUM: GDA_1994_MGA_Zone_50

DRG NO: 201012-00252-GIS-DSK-002

REV: A

V:\201012-00252_FMG_FortescueMarsh\03Project\Workspace_SKT\201012-00252_GIS-DSK_002.mxd

Produced by: daniel.hornby@worleyparsons.com - Geomatics W.A.



WorleyParsons EcoNomics
resources & energy

LOCALITY MAP

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	ISSUED FOR INTERNAL REVIEW			06.10.10

NOTES

CLIENT: FMG

TITLE: FORTESCUE MARSH INUNDATION MAPPING 406.8mAHD SEP00

WORLEYPARSONS PROJECT: 201012-00252

SCALE: 1:275,000 @ A3

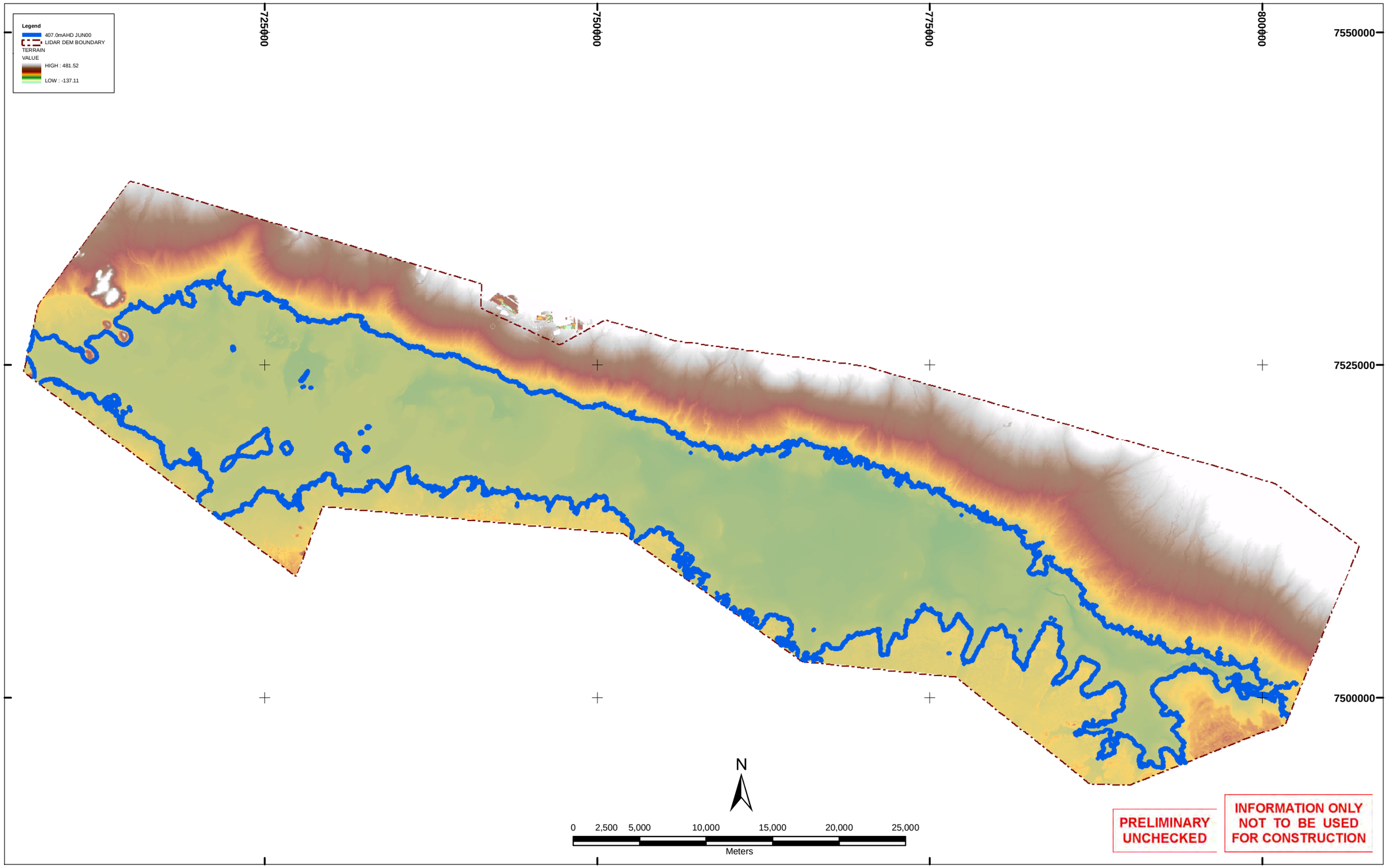
DATUM: GDA_1994_MGA_Zone_50

DRG NO: 201012-00252-GIS-DSK-002

REV: A

V:\201012-00252_FMG_FortescueMarsh\03Project\Workspace_SKT\201012-00252_GIS-DSK_002.mxd

Produced by: daniel.hornby@worleyparsons.com - Geomatics W.A.



WorleyParsons EcoNomics
resources & energy

LOCALITY MAP

REV	REVISION DESCRIPTION	DRN	CHK	DATE
A	ISSUED FOR INTERNAL REVIEW			06.10.10

NOTES

CLIENT: FMG

TITLE: FORTESCUE MARSH INUNDATION MAPPING 407.0mAHD JUN00

WORLEYPARSONS PROJECT: 201012-00252

SCALE: 1:275,000 @ A3

DATUM: GDA_1994_MGA_Zone_50

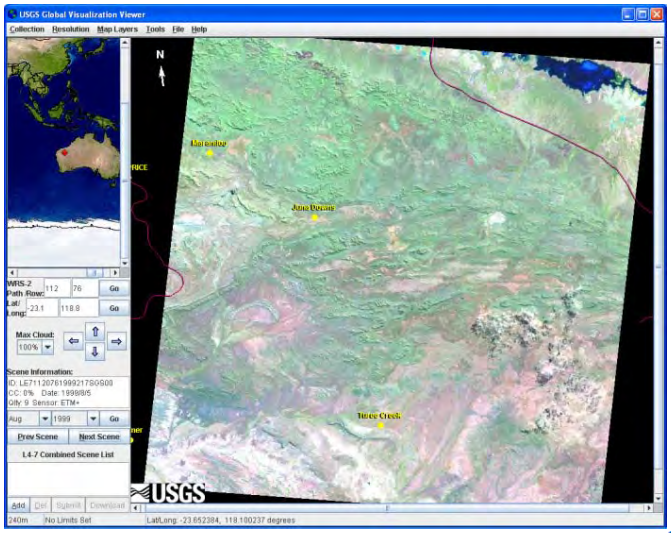
DRG NO: 201012-00252-GIS-DSK-002

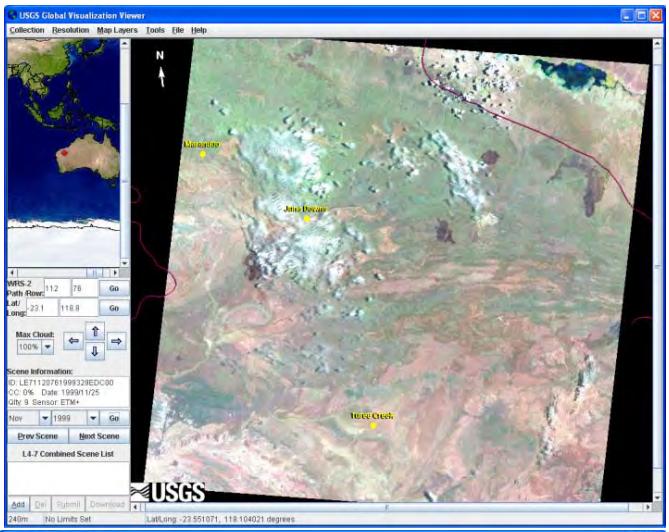
REV: A

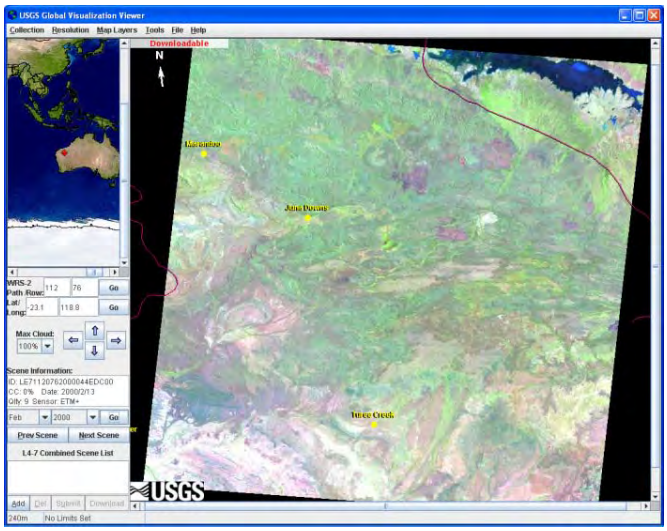
V:\201012-00252_FMG_FortescueMarsh\03Project\Workspace_SKT\201012-00252_GIS-DSK_002.mxd

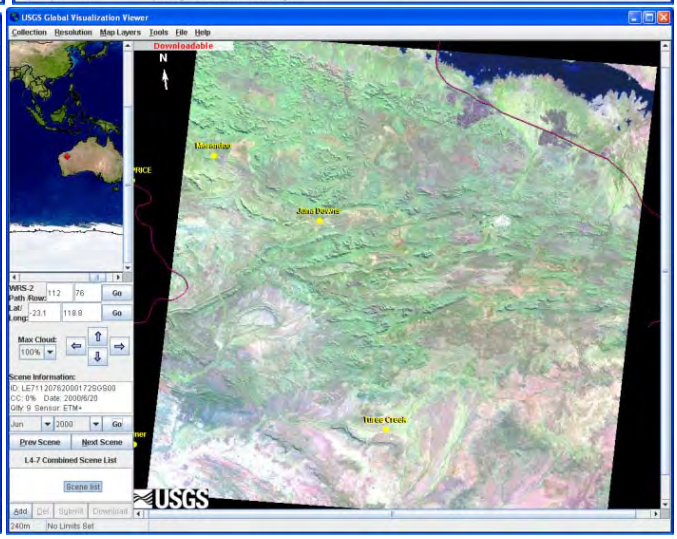
Produced by: daniel.hornby@worleyparsons.com - Geomatics W.A.

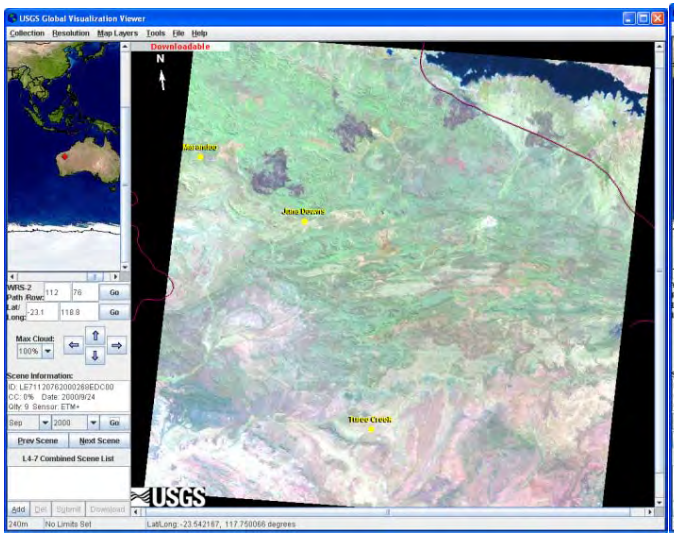
Aug 1999-Dec 2000

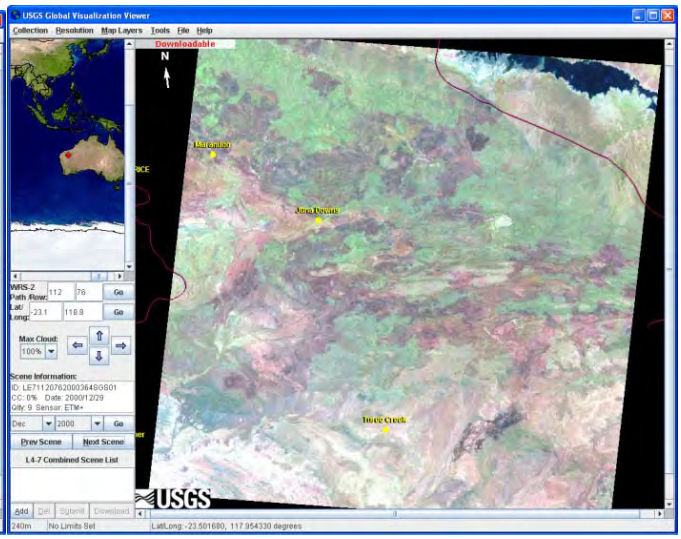




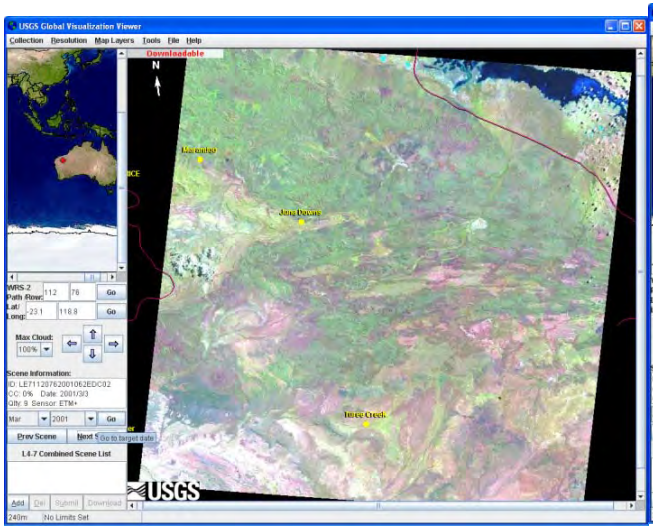


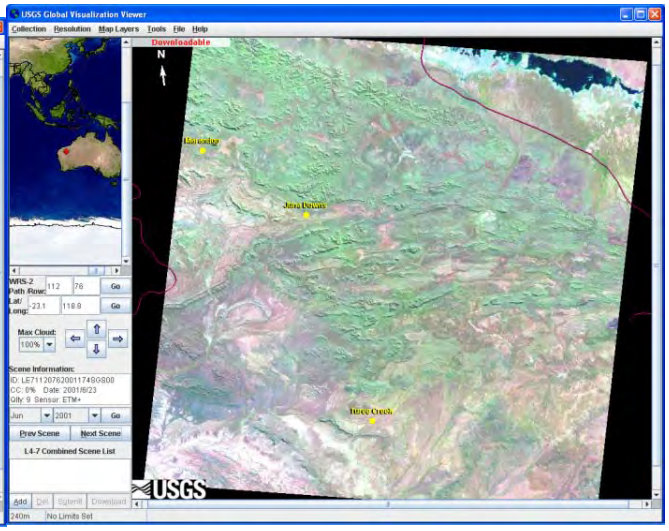


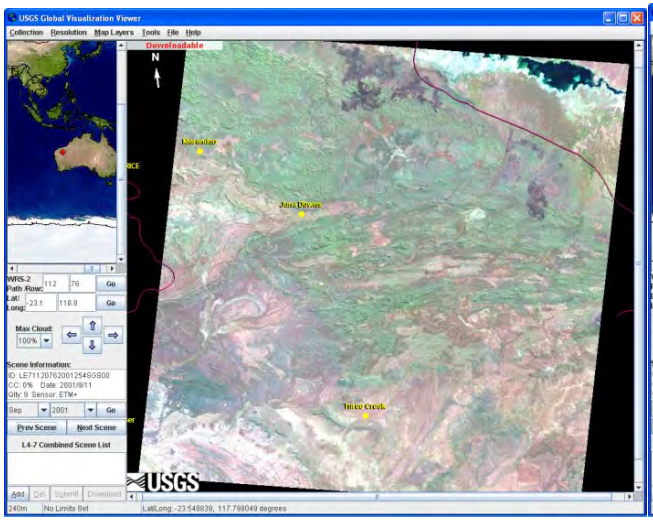


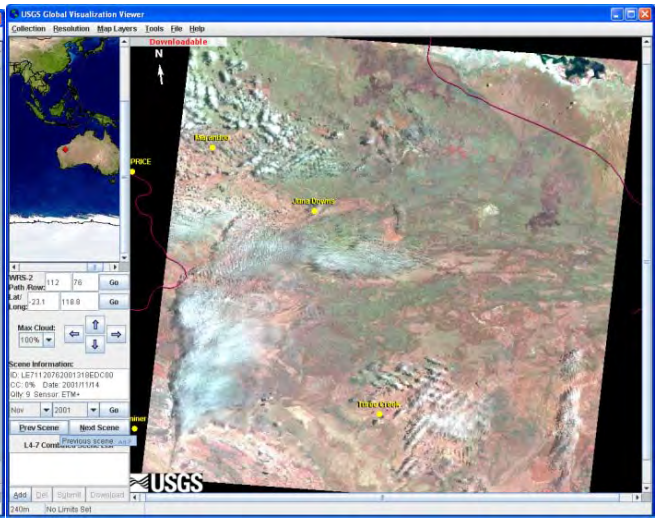


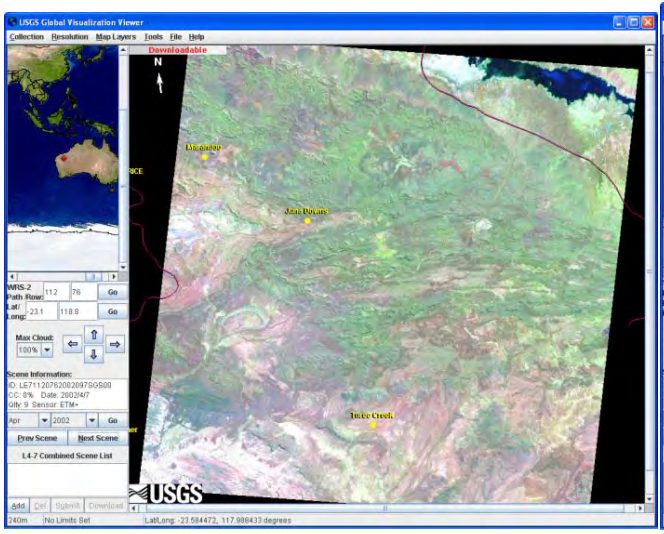
Mar 2001 – Sep 2002

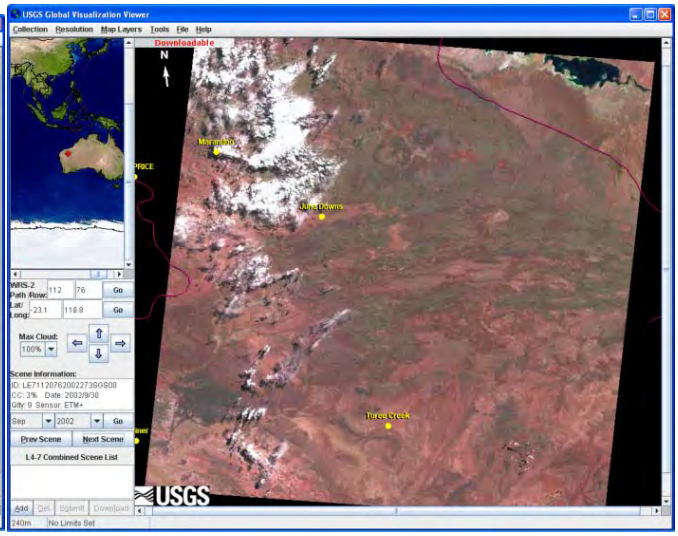




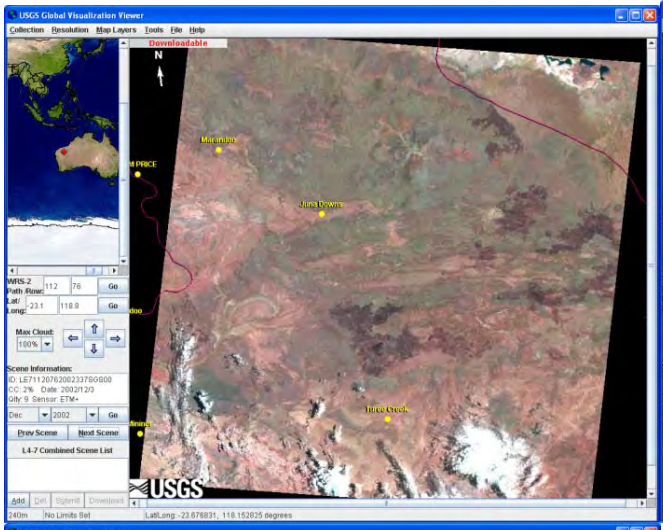


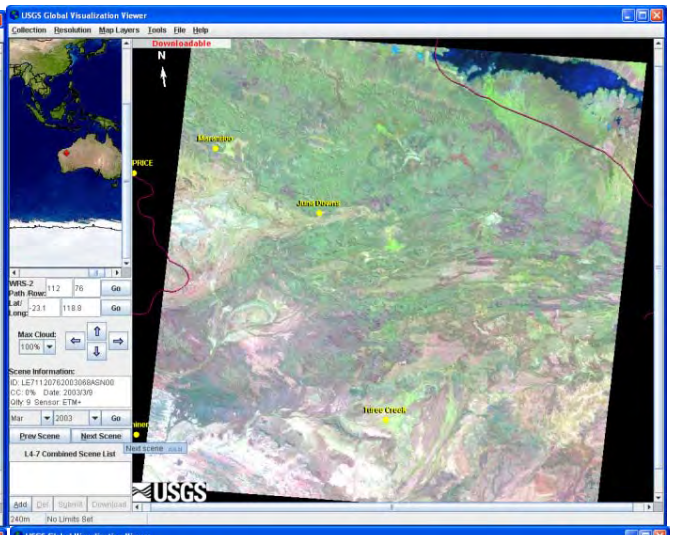


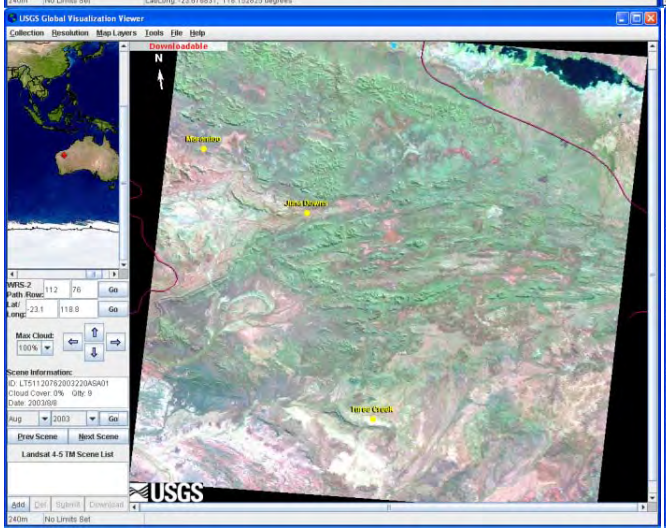


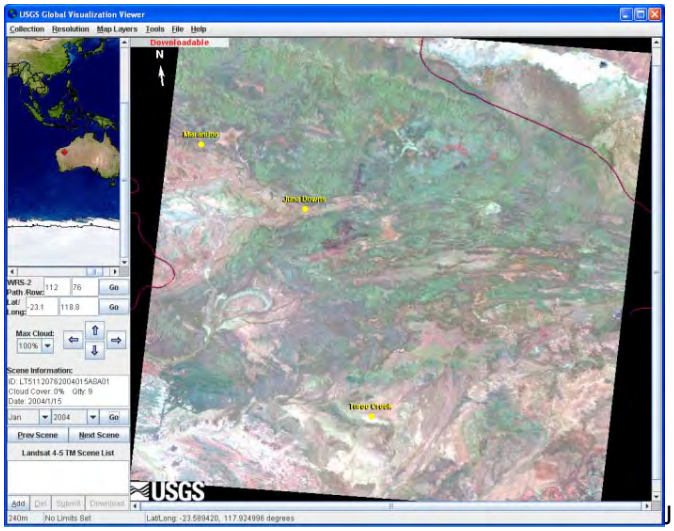


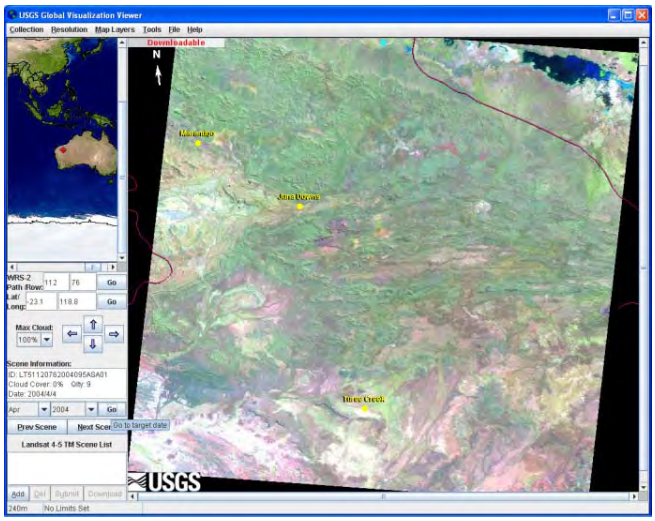
Dec 2002 – April 2004



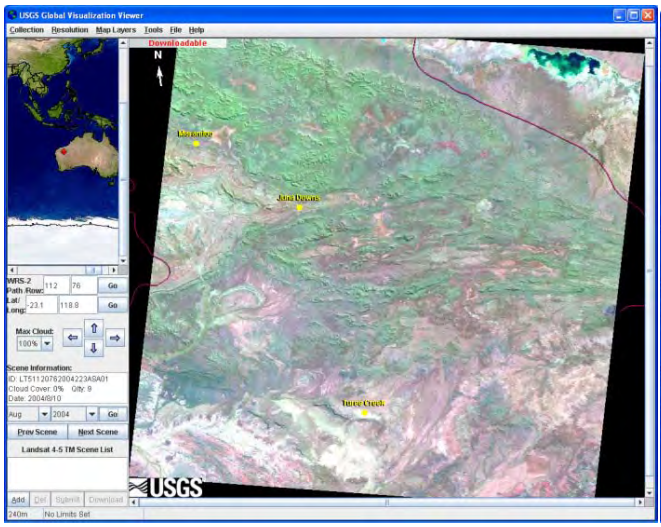


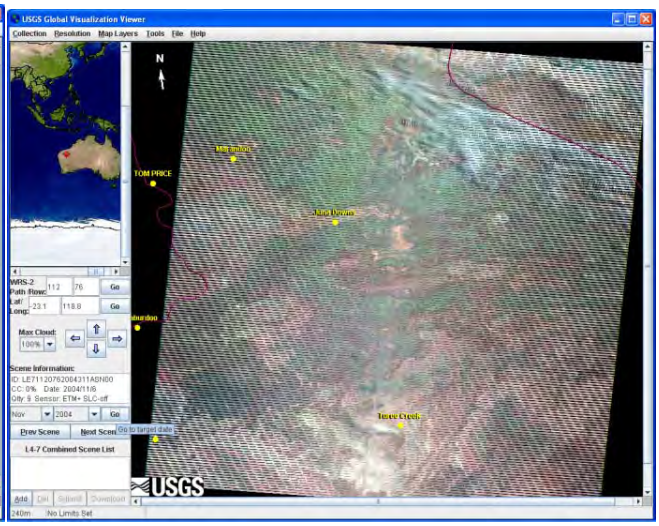


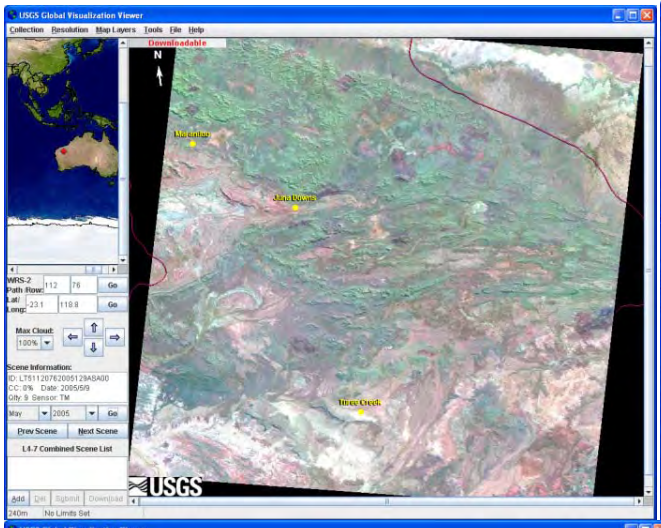


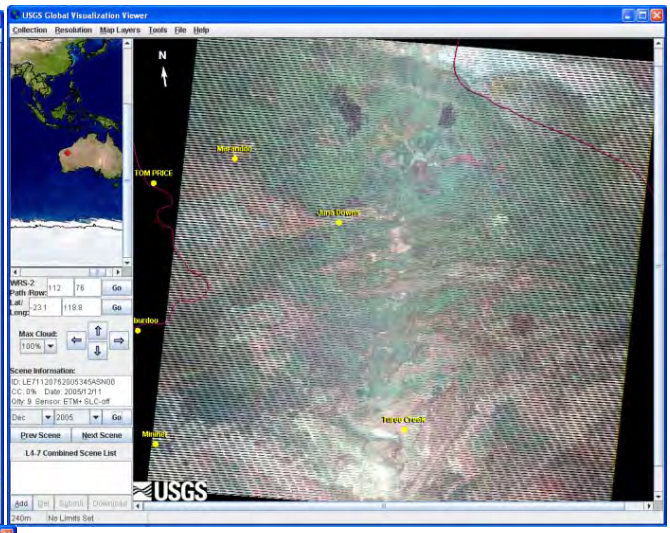


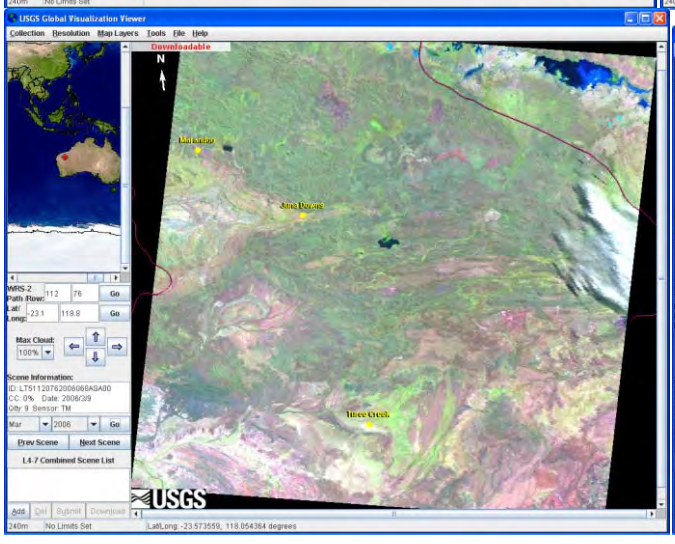
Aug 2004 – June 2006



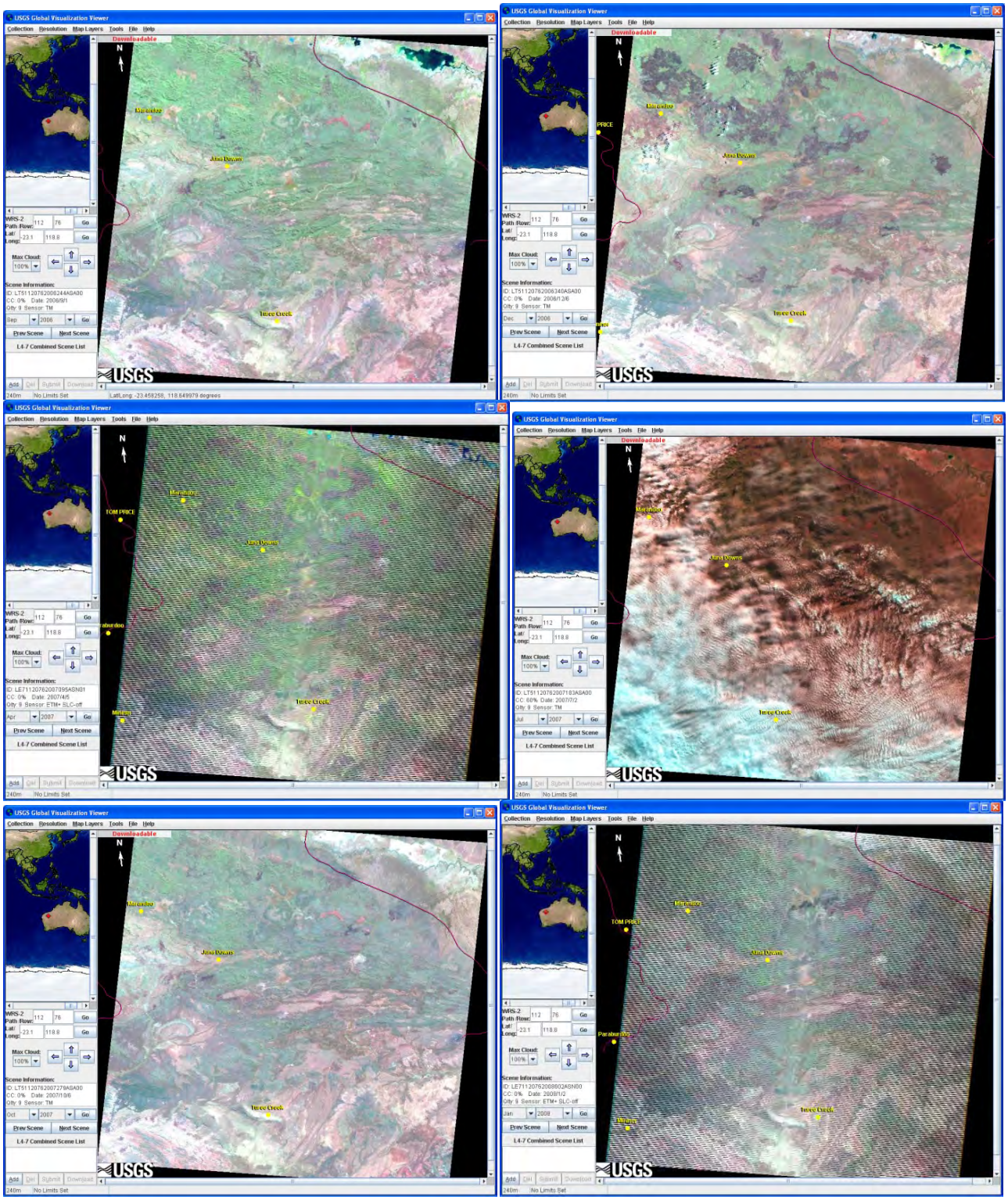




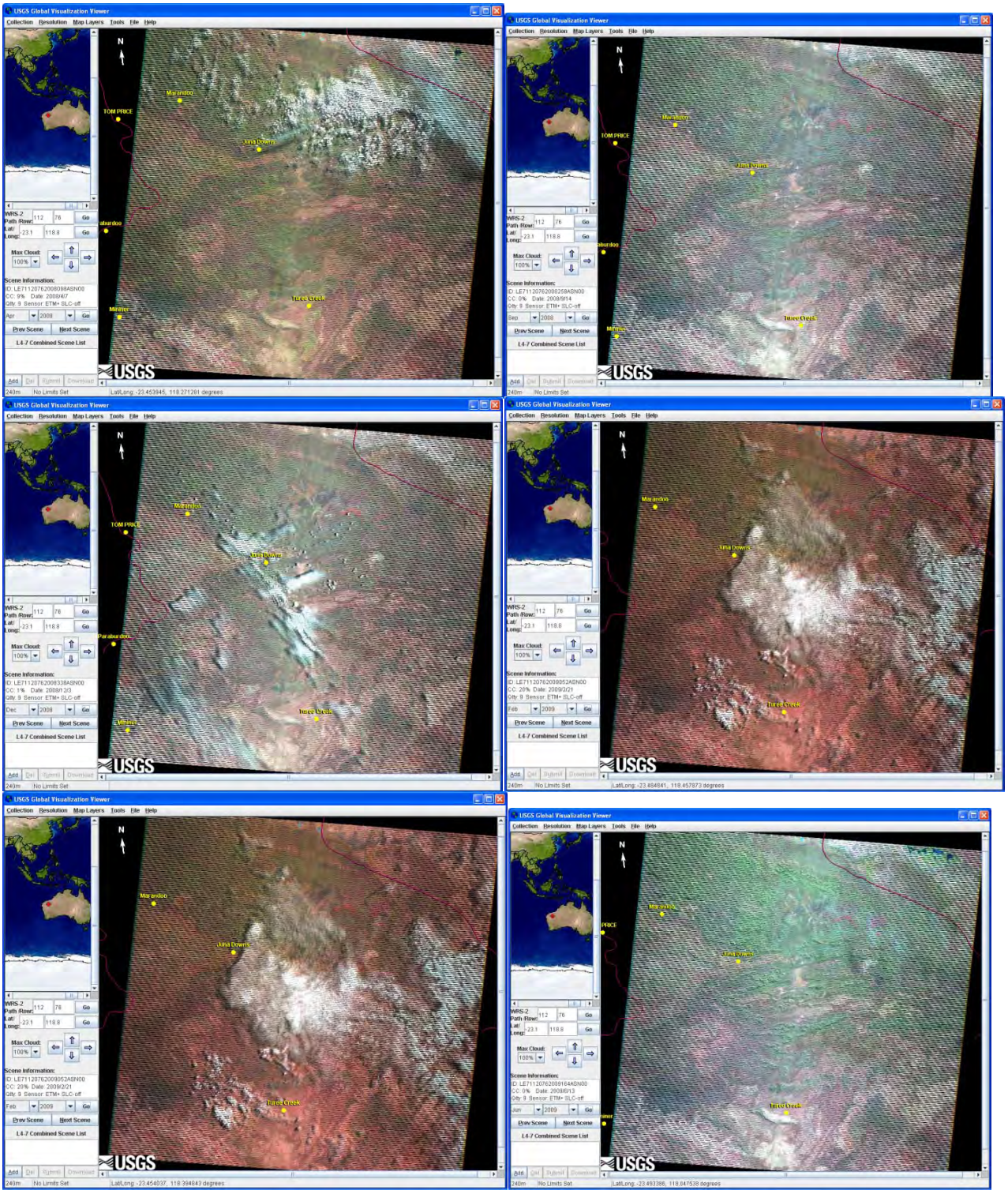




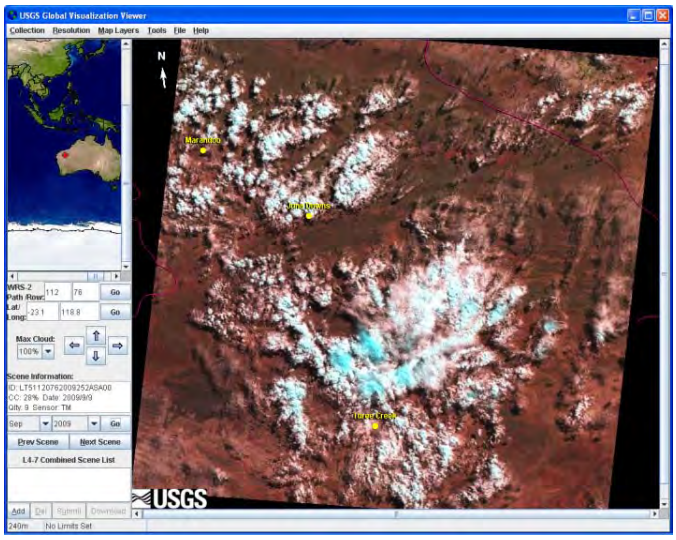
Sep 2006 – Jan 2008

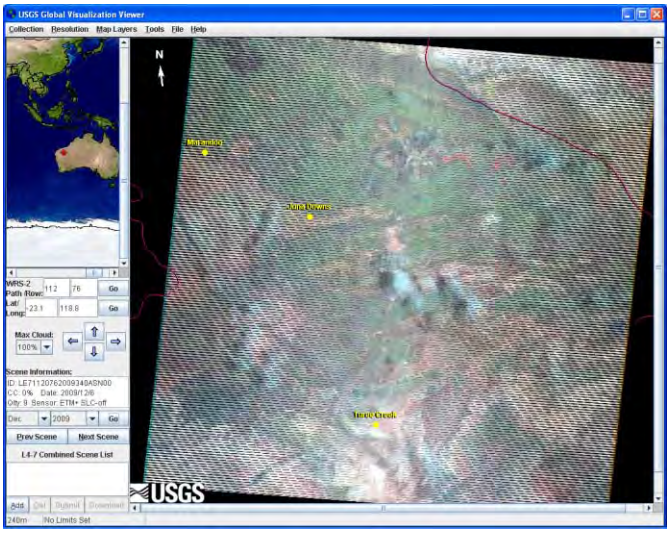


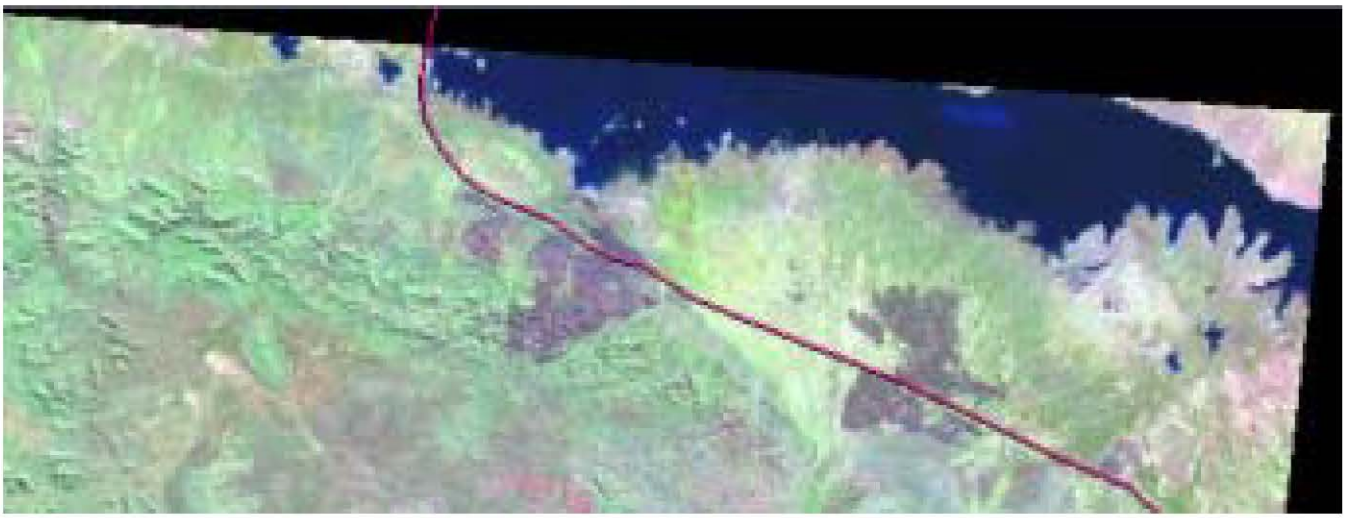
April 2008-June 2009



Sep 2009 – April 2010

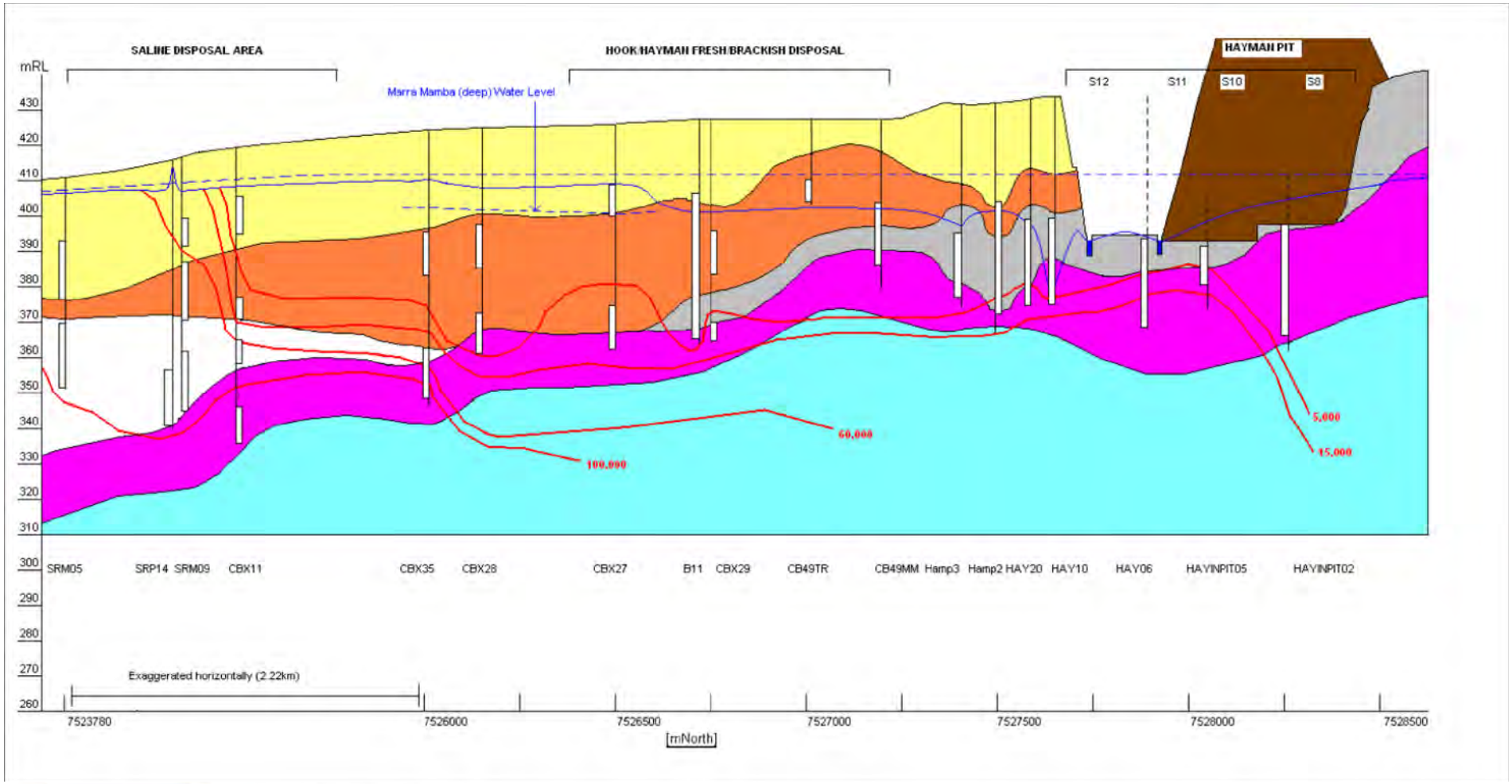






Appendix 2: Geological cross sections

This page has been left blank intentionally



Alluvium Ta (gravelly soils)

Tertiary Detritals Tds (including hardcap Hc)

Oakover Formation To (calcrete and silcrete/chalcedony)

Mineralised Marra Mamba MUm/MUh (including transition zone MUt)

Unmineralised Lower Marra Mamba MUb (Cherts/BIF)

Wittenoom Formation (Dolomites and Shales)

Roy Hill Shale Jr (Jeerinah Formation - leached white to fresh black carbonaceous shales)

Original Static Water Level

Equipotential electrical conductivity lines (uS/cm)

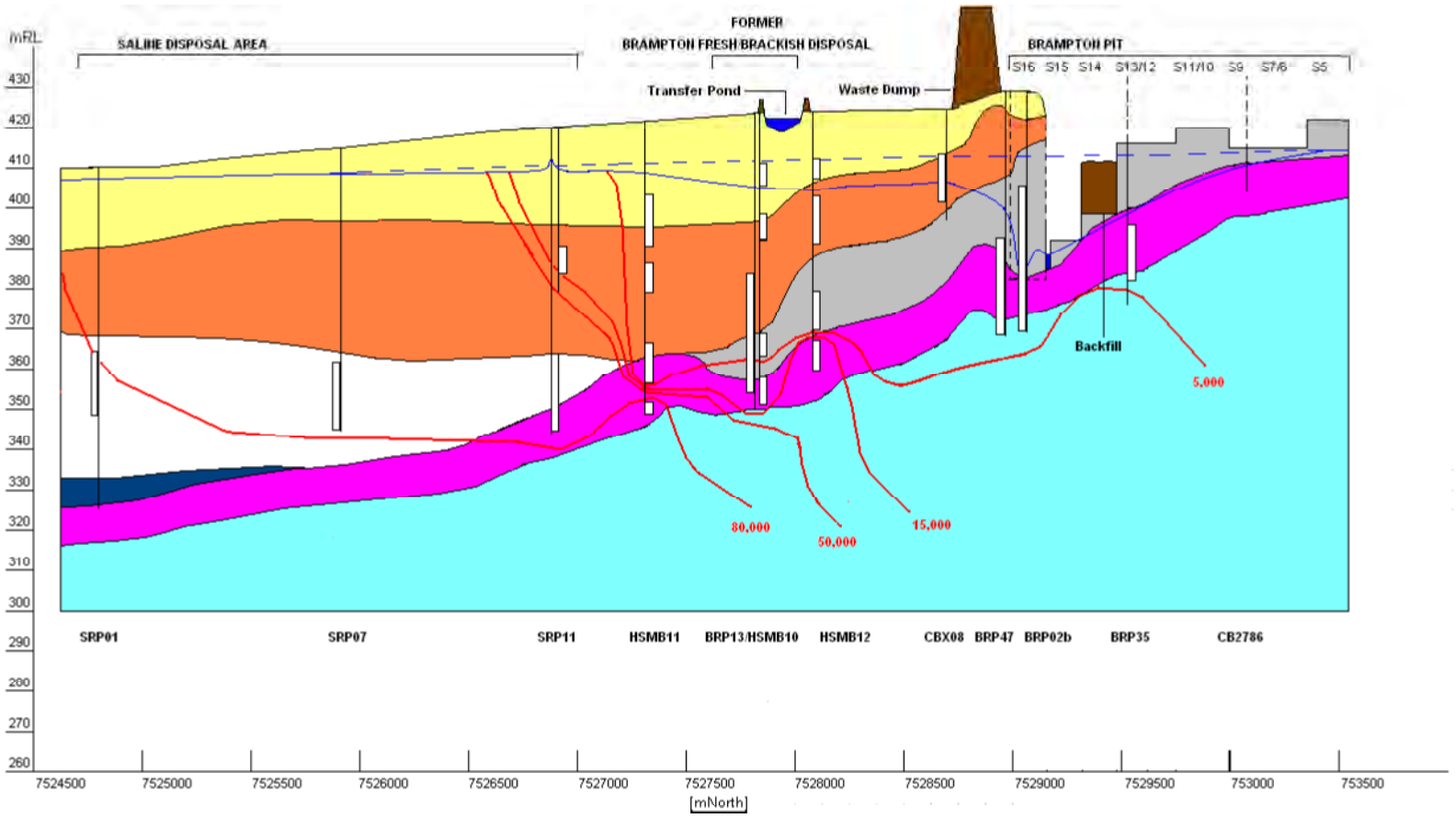
Water table level

Monitoring/Production bore location and screened interval

SECTION SCALES:

Vertical Scale (all sections):	1:1,250
Horizontal Scale (Hook & Brampton sections):	1:23,810
Horizontal Scale (Gnarloo and Hayman sections):	1:11,905

Figure Title:	hydrogeological cross sections showing salinity transition zone - Hayman Pit
Report Title:	Hydrogeological assessment for Cloudbreak Water Management Scheme
Author:	Date:
Drawn By:	Revision:
Drawing Ref:	Report Ref:
Scale:	Figure No: 11



CLOUDBREAK SECTIONS LEGEND

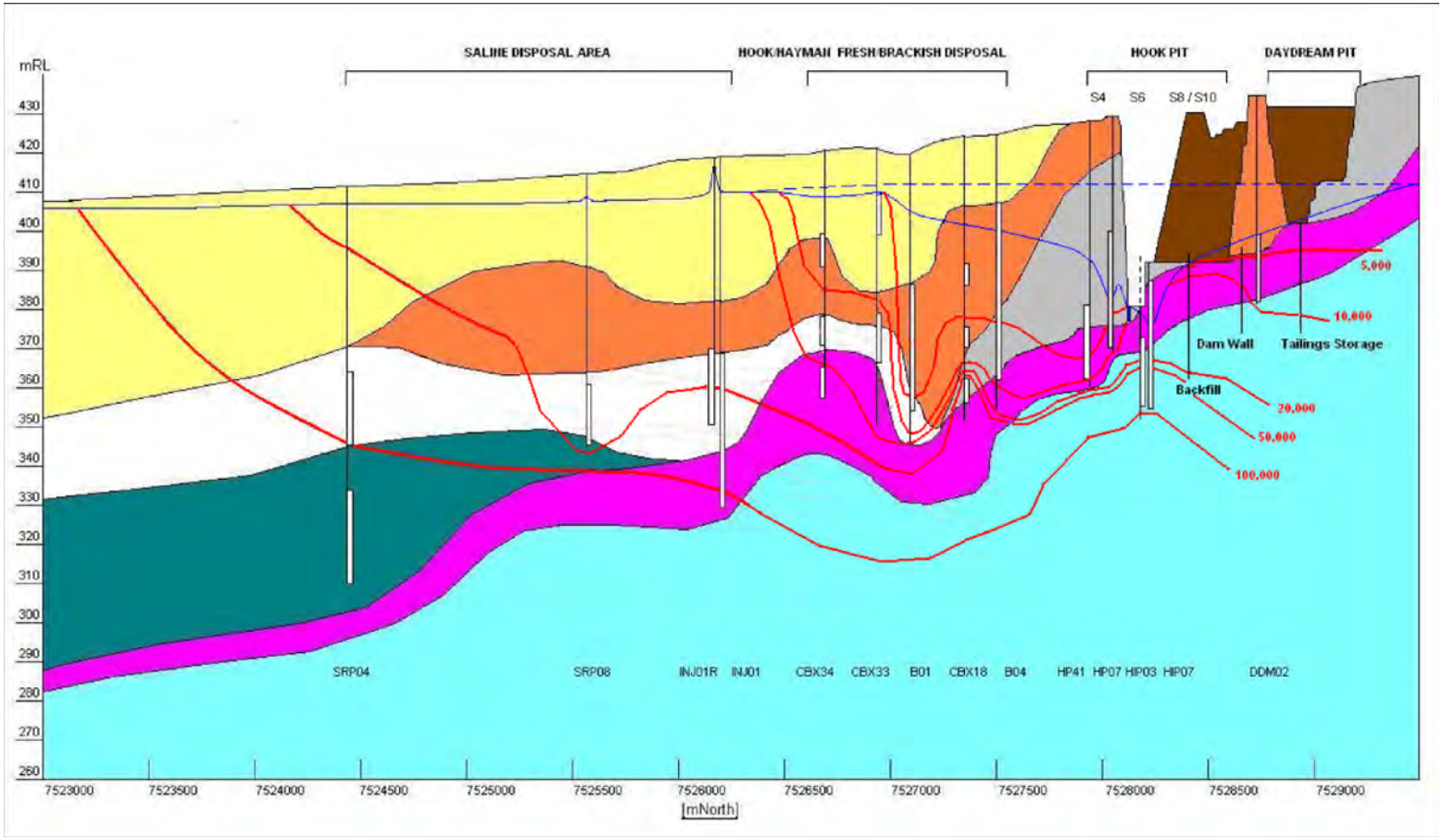
- Alluvium Ta (gravelly soils)
- Tertiary Detritals Tds (including hardcap Hc)
- Oakover Formation To (calcrete and silcrete/chalcedony)
- Mineralised Marra Mamba MUm/MUh (including transition zone MUt)
- Unmineralised Lower Marra Mamba MUb (Cherts/BIF)
- Wittenoom Formation (Dolomites and Shales)
- Roy Hill Shale Jr (Jeerinah Formation - leached white to fresh black carbonaceous shales)
- Original Static Water Level
- Equipotential electrical conductivity lines (uS/cm)
- Water table level
- Monitoring/Production bore location and screened interval

SECTION SCALES:
Vertical Scale (all sections): 1:1,250
Horizontal Scale (Hook & Brampton sections): 1:23,810
Horizontal Scale (Gnarloo and Hayman sections): 1:11,905

Figure Title:
hydrogeological cross sections showing salinity transition zone - Brampton Pit

Report Title:
Hydrogeological assessment for Cloudbreak Water Management Scheme

Author:	Date:
Drawn By:	Revision:
Drawing Ref:	Report Ref:
Scale:	Figure No:



CLOUDBREAK SECTIONS LEGEND

- Alluvium Ta (gravelly soils)
- Tertiary Detritals Tds (including hardcap Hc)
- Oakover Formation To (calcrete and silcrete/chalcedony)
- Mineralised Marra Mamba MUm/MUh (including transition zone MUt)
- Unmineralised Lower Marra Mamba MUb (Cherts/BIF)
- Wittenoom Formation (Dolomites and Shales)
- Roy Hill Shale Jr (Jeerinah Formation - leached white to fresh black carbonaceous shales)
- Original Static Water Level
- Equipotential electrical conductivity lines (uS/cm)
- Water table level
- Monitoring/Production bore location and screened interval

SECTION SCALES:
Vertical Scale (all sections): 1:1,250
Horizontal Scale (Hook & Brampton sections): 1:23,810
Horizontal Scale (Gnarloo and Hayman sections): 1:11,905

Figure Title: hydrogeological cross sections showing salinity transition zone - Hook Pit	
Report Title: Hydrogeological assessment for Cloudbreak Water Management Scheme	
Author:	Date:
Drawn By:	Revision:
Drawing Ref:	Report Ref:
Scale:	Figure No: 12

Appendix 3: Numerical model hydraulic property zones and layer thicknesses

This page has been left blank intentionally

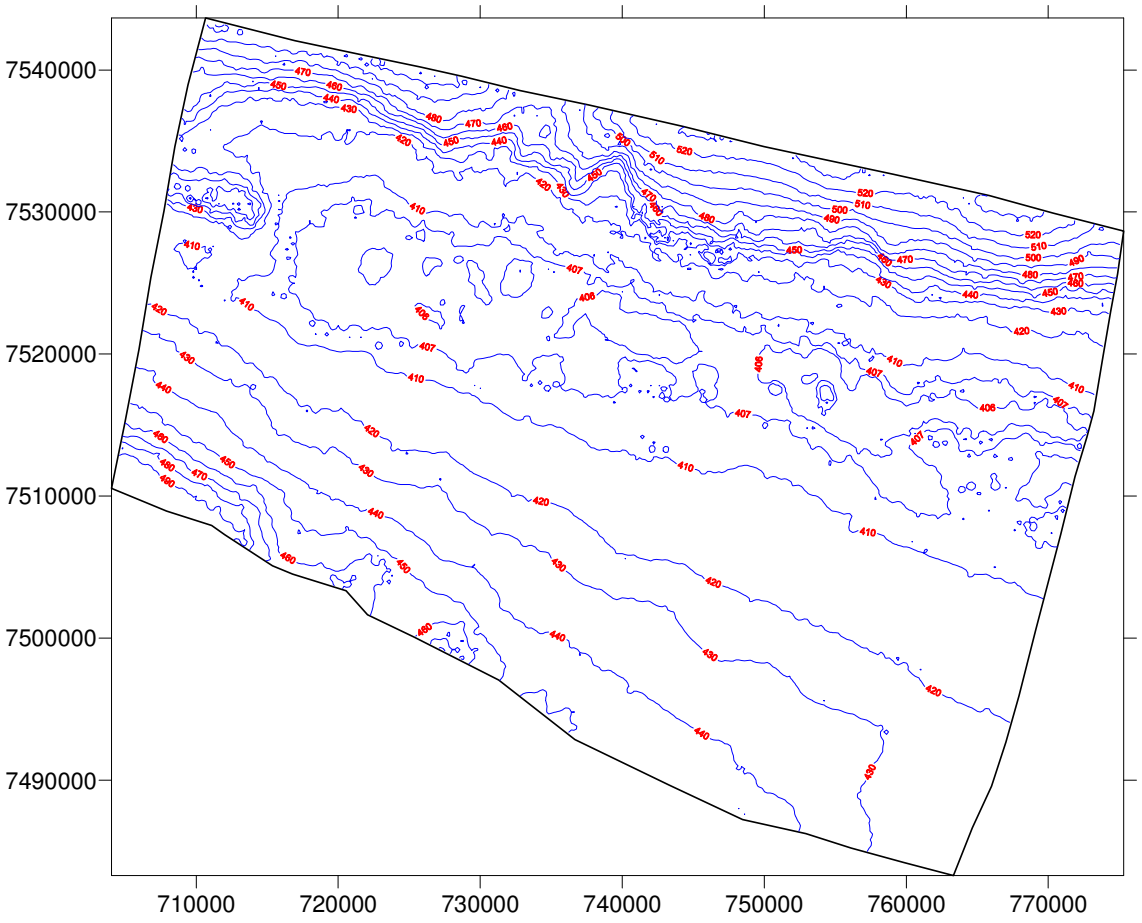


Figure 3.1: Elevation of ground surface.

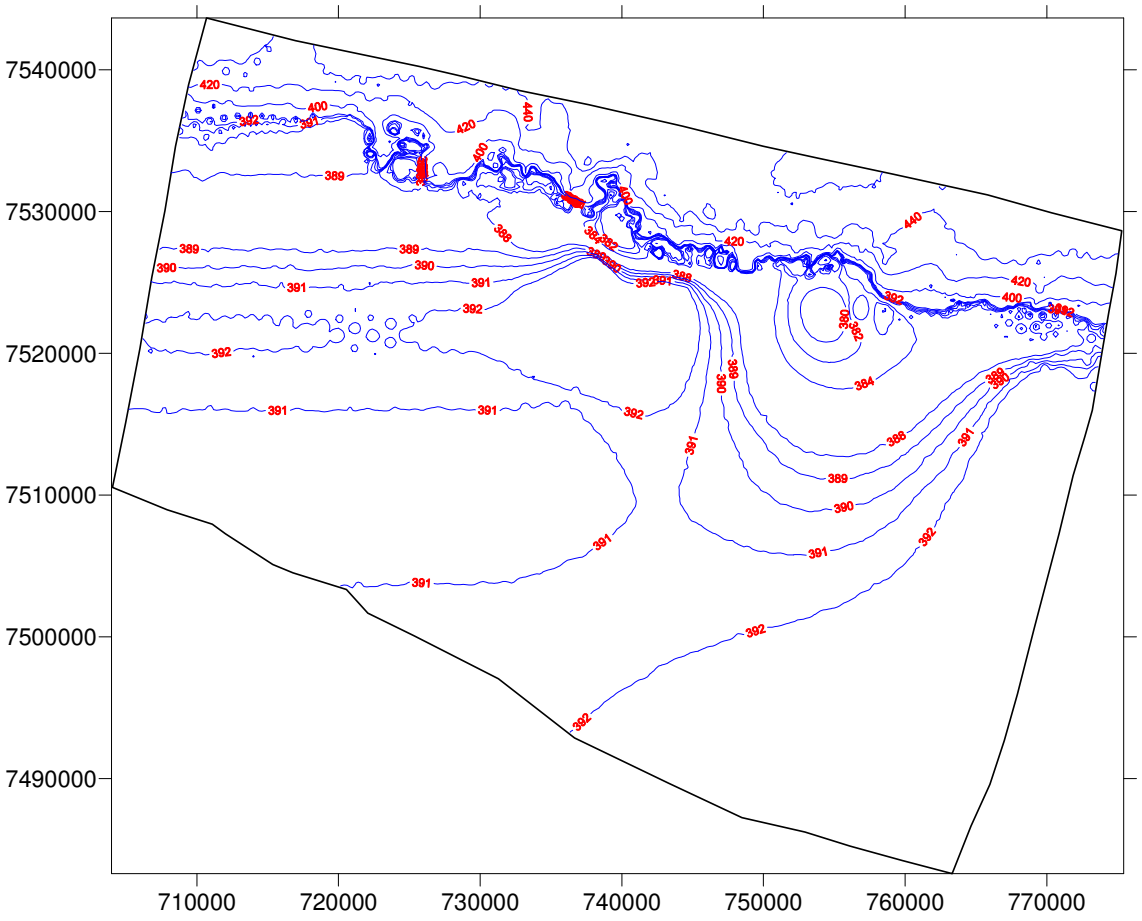


Figure 3.2: Elevation of slice 3 of the numerical model (base of Tertiary Detritals).

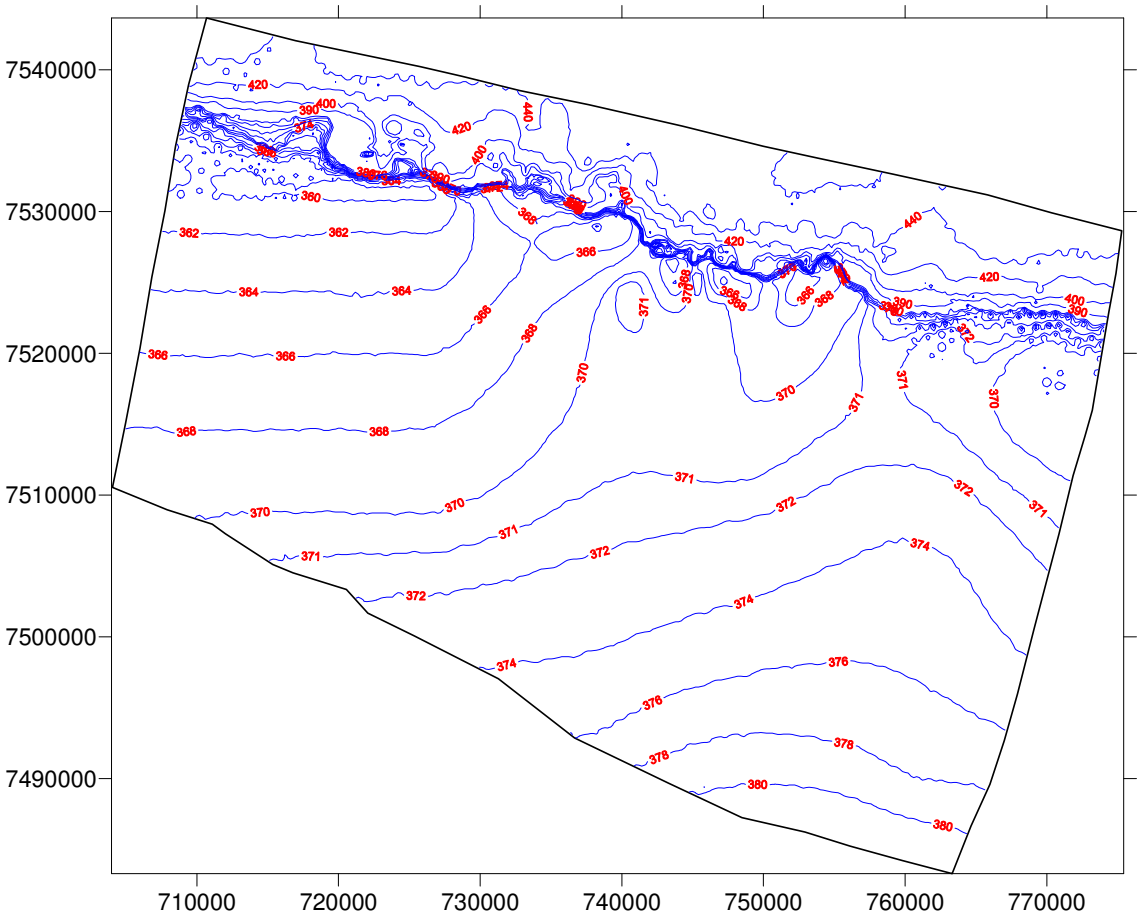


Figure 3.3: Elevation of slice 4 of the numerical model (base of Tertiary Clay).

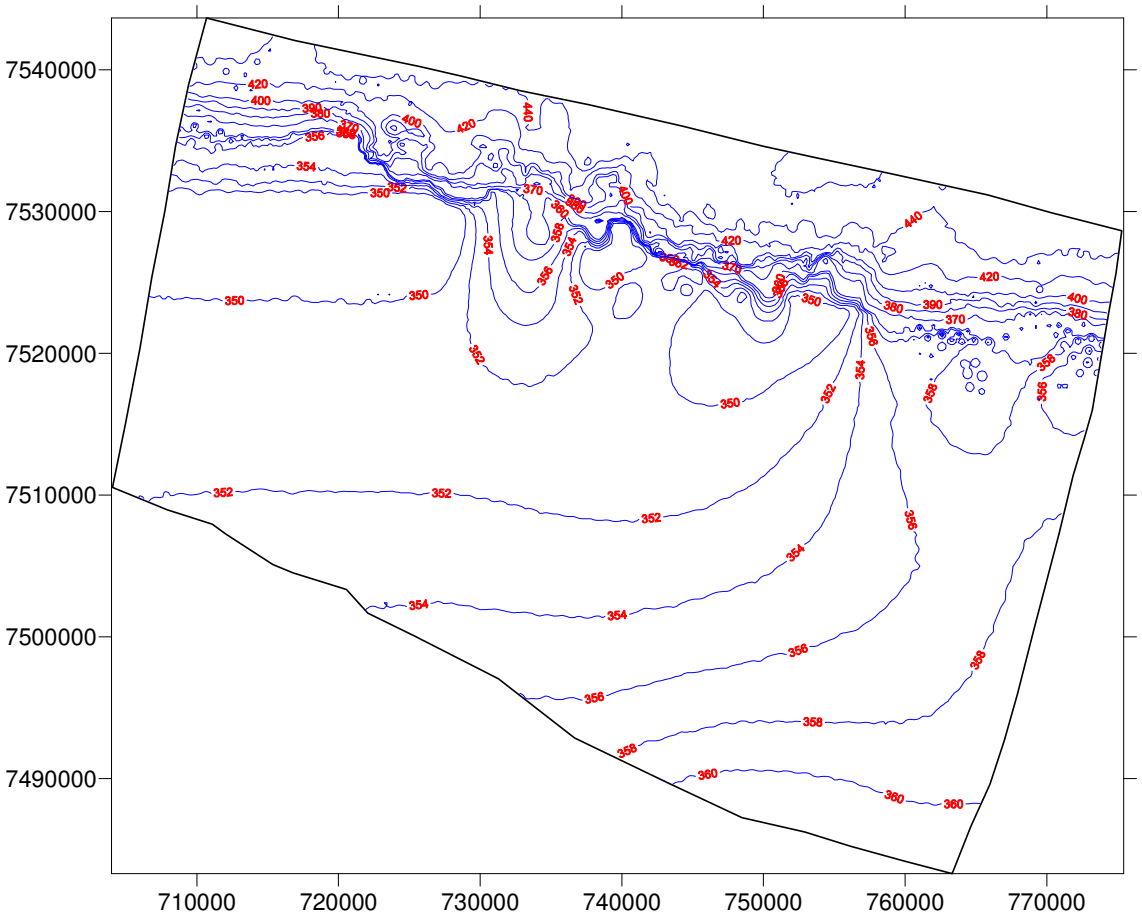


Figure 3.4: Elevation of slice 5 of the numerical model (base of Oakover formation).

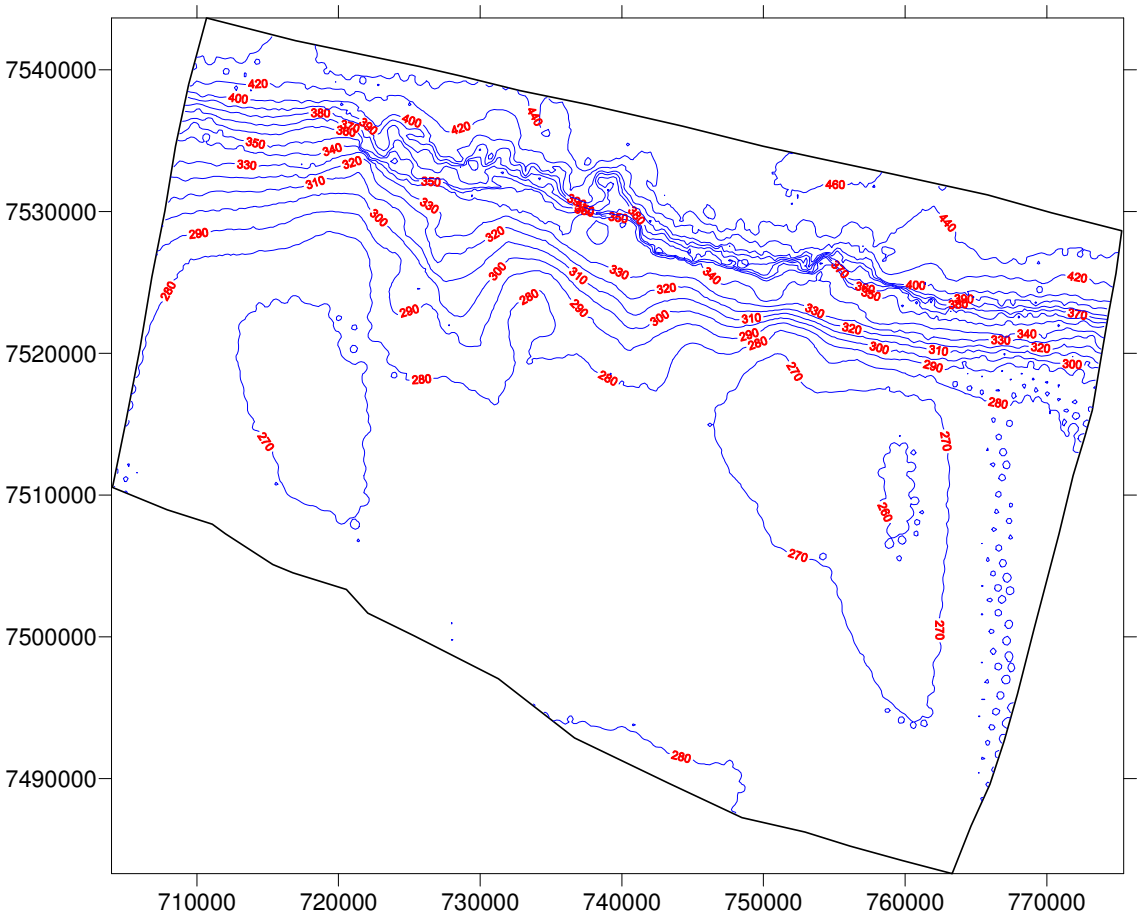


Figure 3.5: Elevation of slice 7 of the numerical model (base of Wittenoom Dolomite).

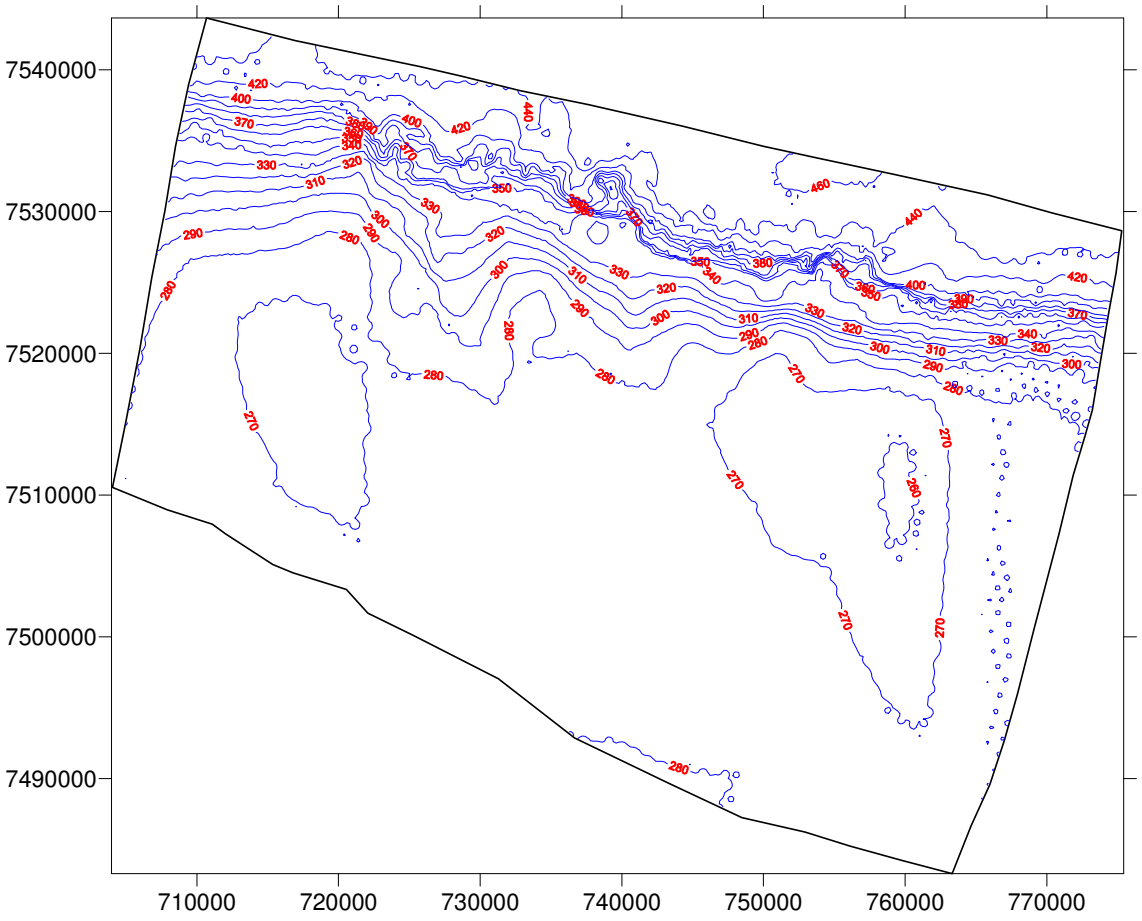


Figure 3.6: Elevation of slice 8 of the numerical model (base of Hardcap).

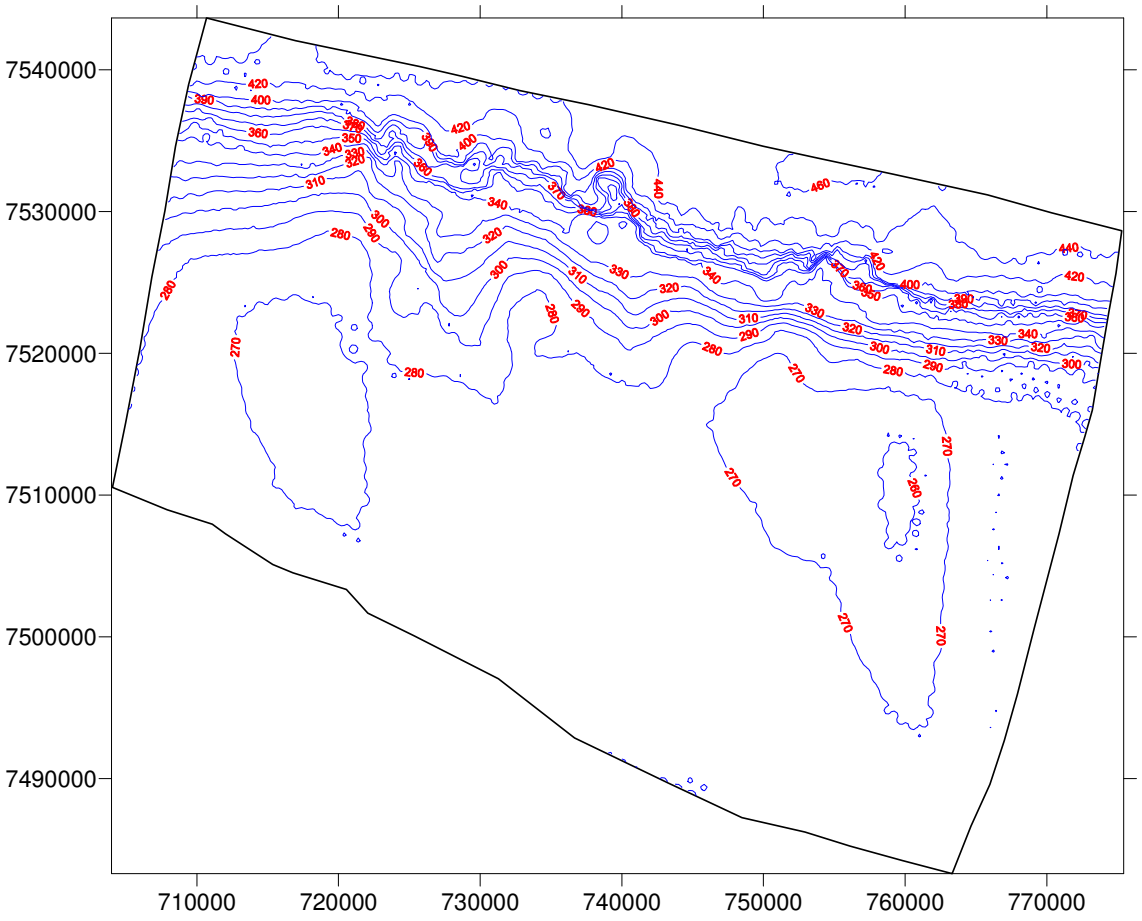


Figure 3.7: Elevation of slice 9 of the numerical model (base of Economic ore).

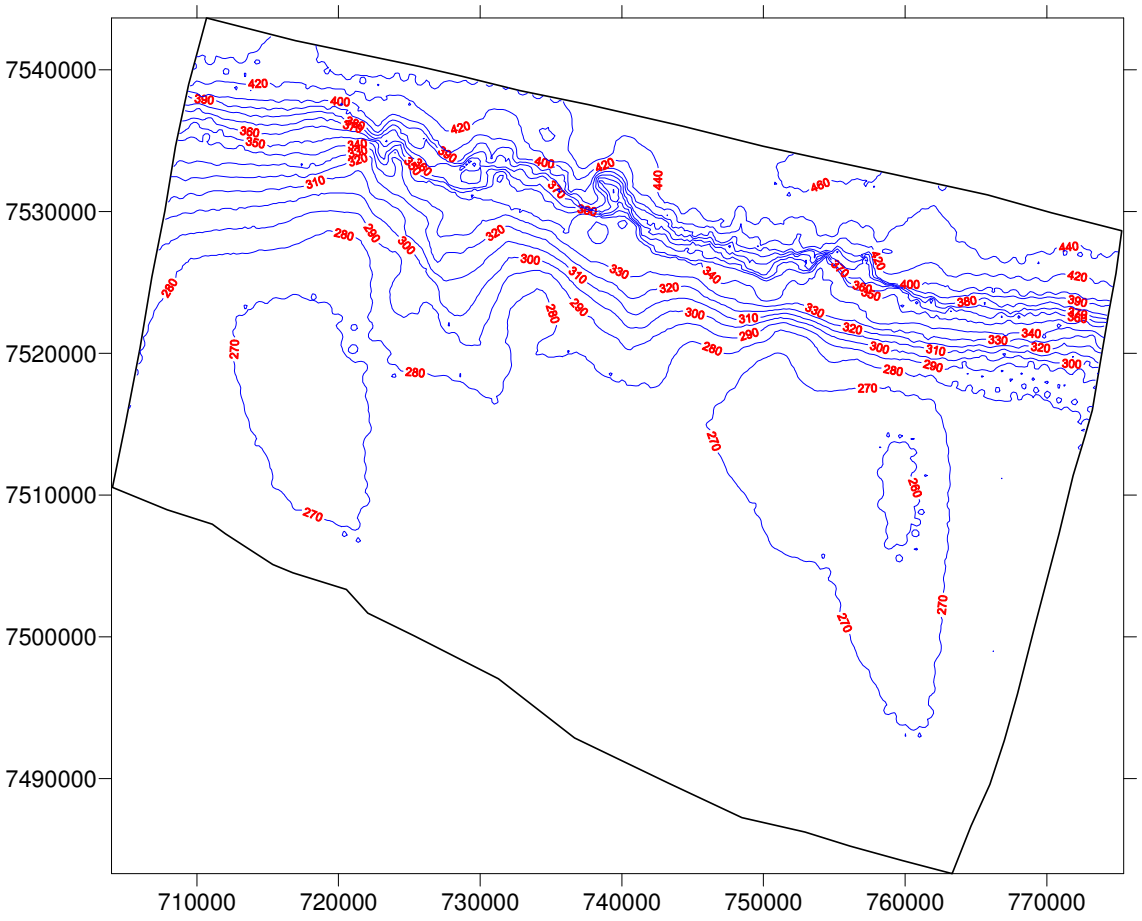


Figure 3.8: Elevation of slice 10 of the numerical model (base of mineralised MMF).

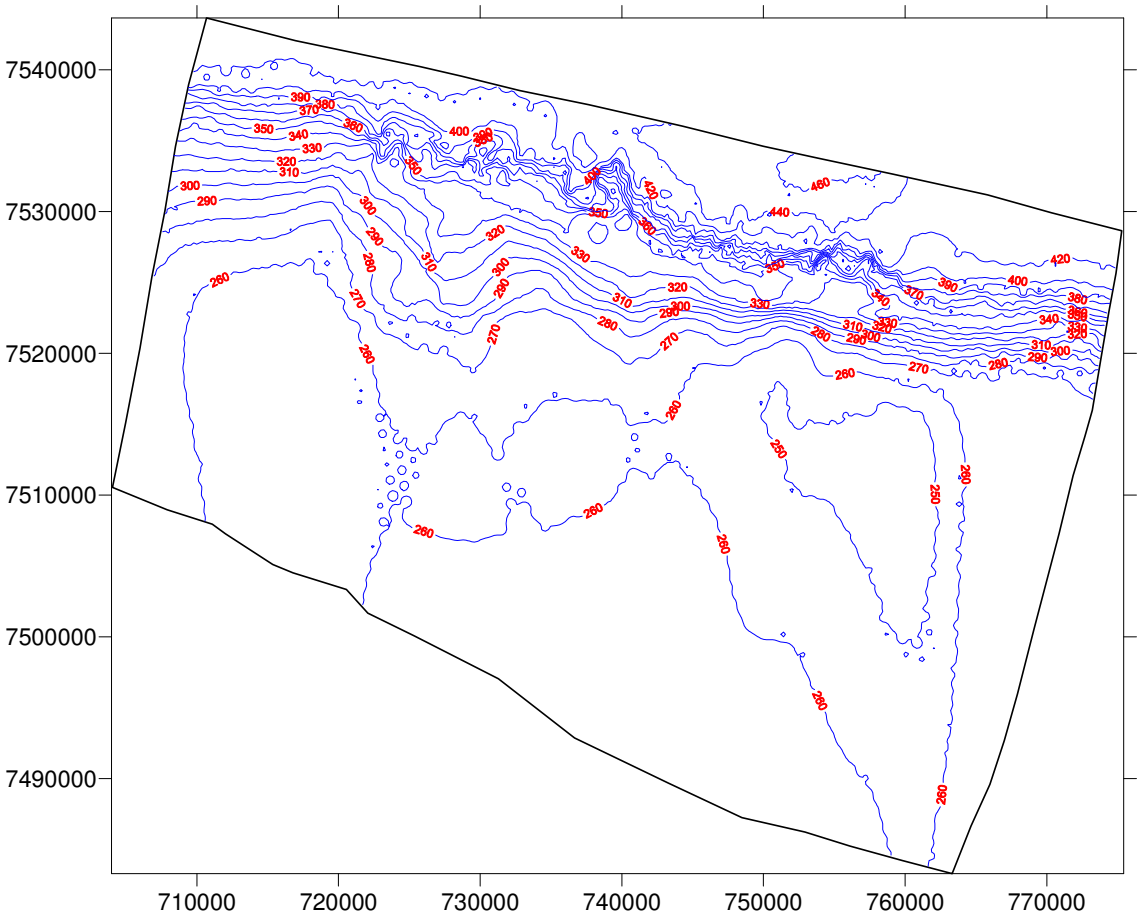


Figure 3.9: Elevation of slice 11 of the numerical model (base of fractured MMF).

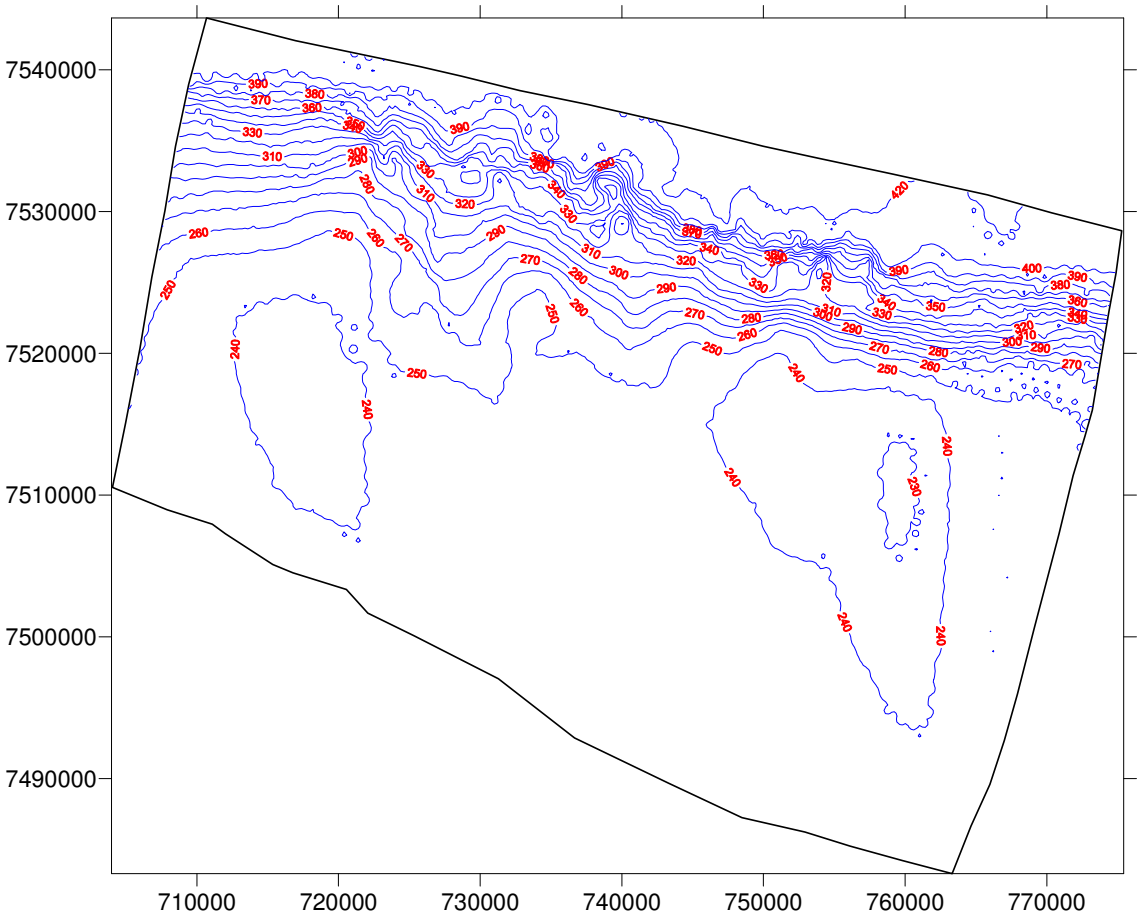


Figure 3.10: Elevation of slice 12 of the numerical model (base of un-mineralised MMF).

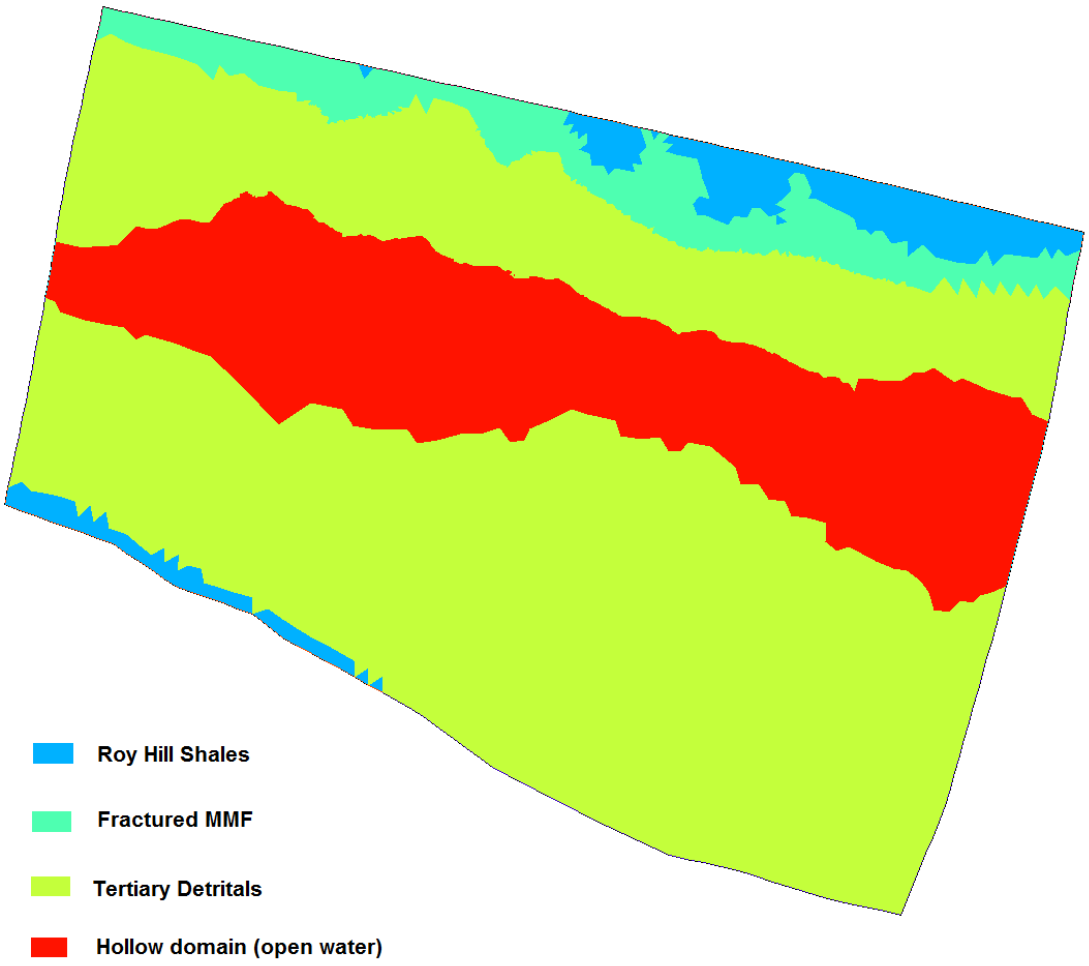


Figure 3.11: Hydraulic Property Distribution of Numerical Layer 1.

Figure 3.12: Hydraulic Property Distribution of Numerical Layer 2.

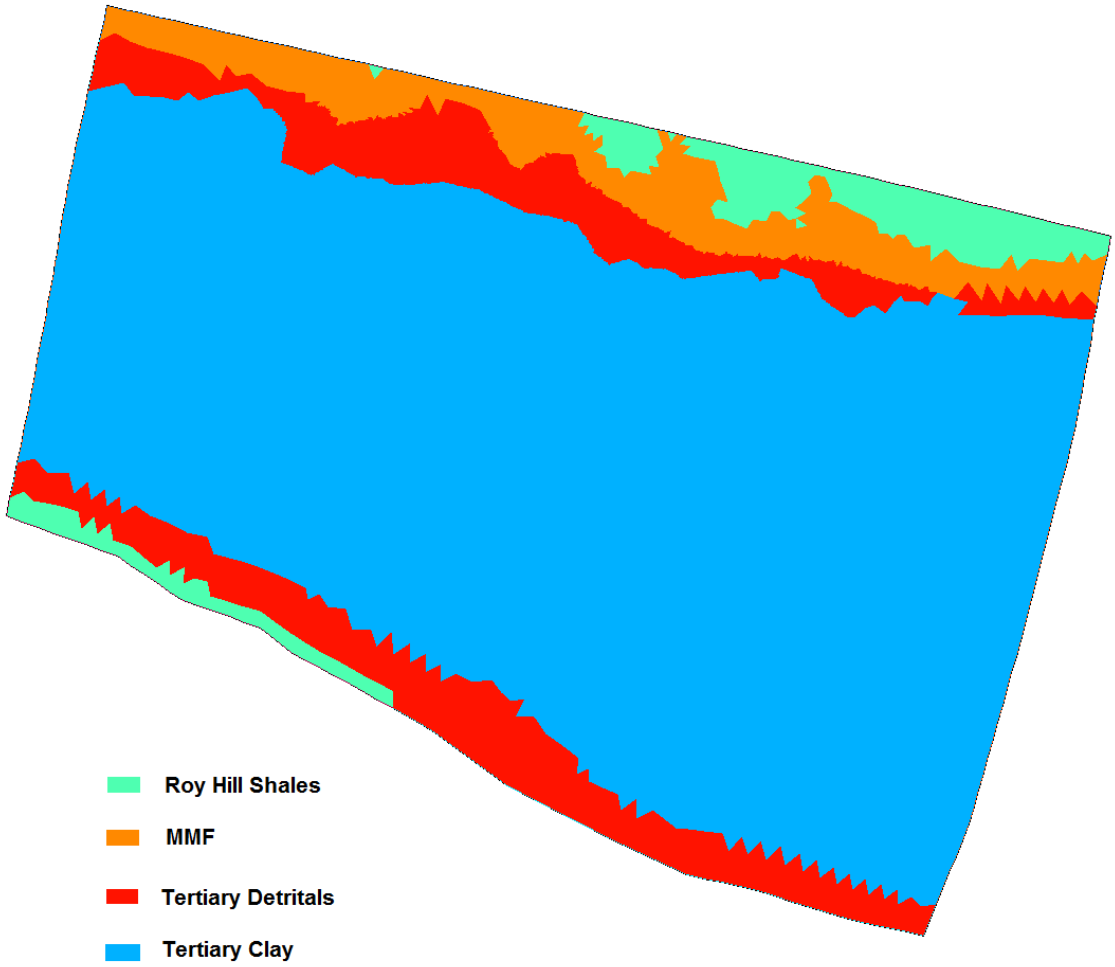


Figure 3.13: Hydraulic Property Distribution of Numerical Layer 3.

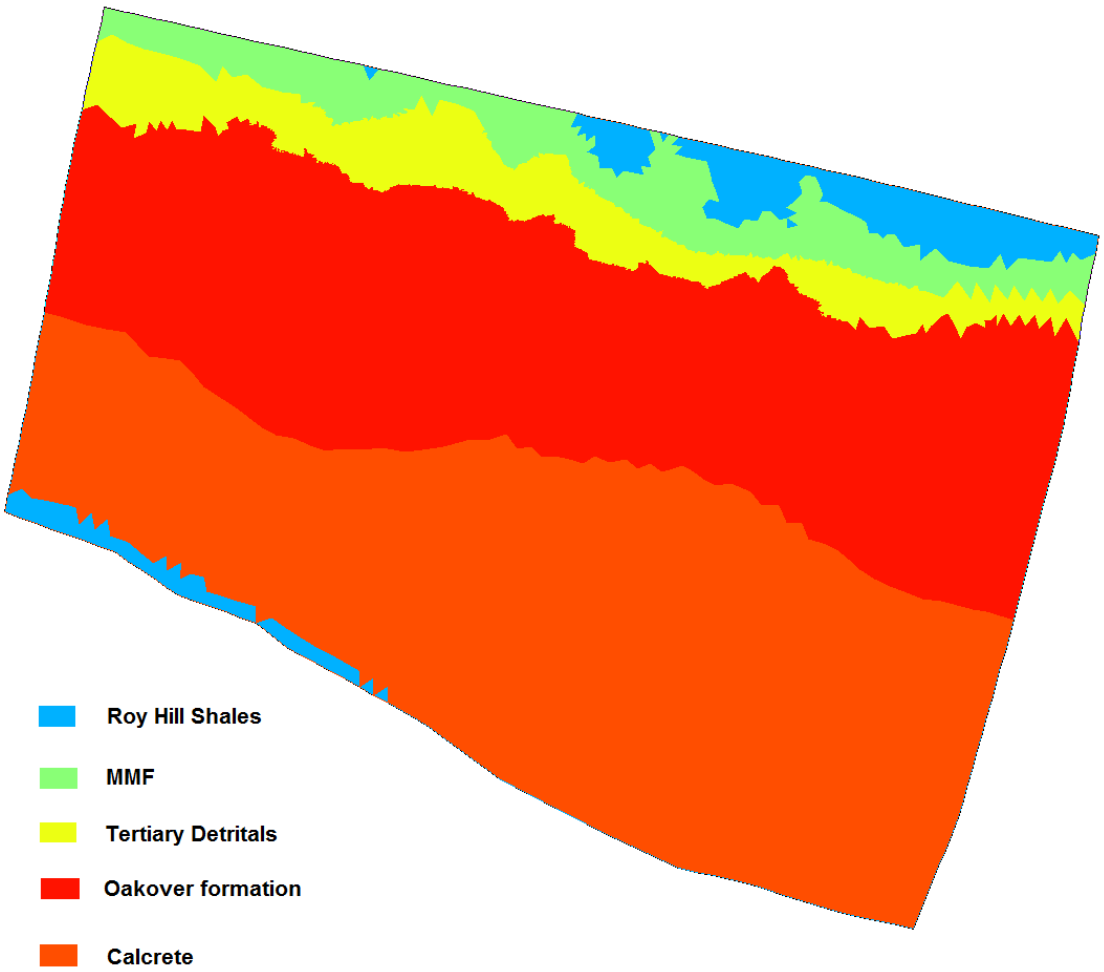


Figure 3.14: Hydraulic Property Distribution of Numerical Layer 4.

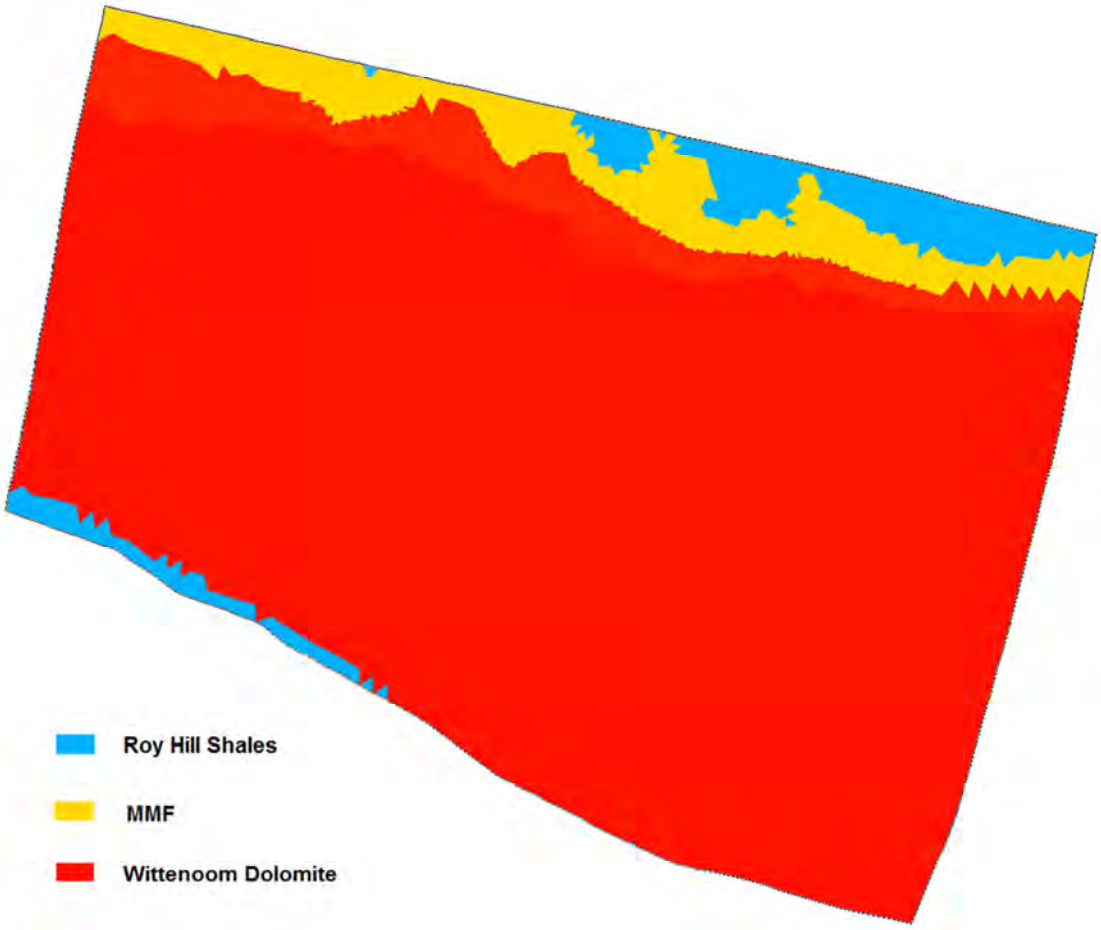


Figure 3.15: Hydraulic Property Distribution of Numerical Layers 5&6.

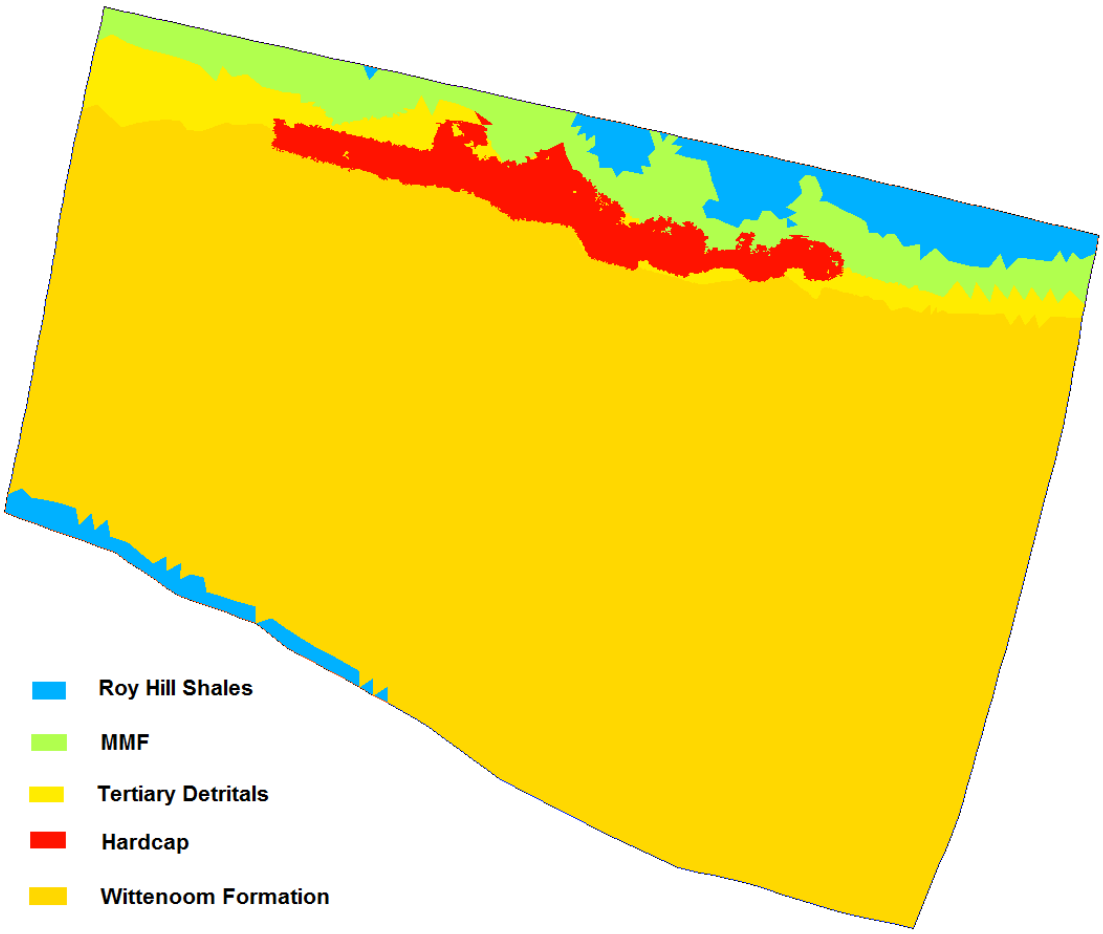


Figure 3.16: Hydraulic Property Distribution of Numerical Layer 7.

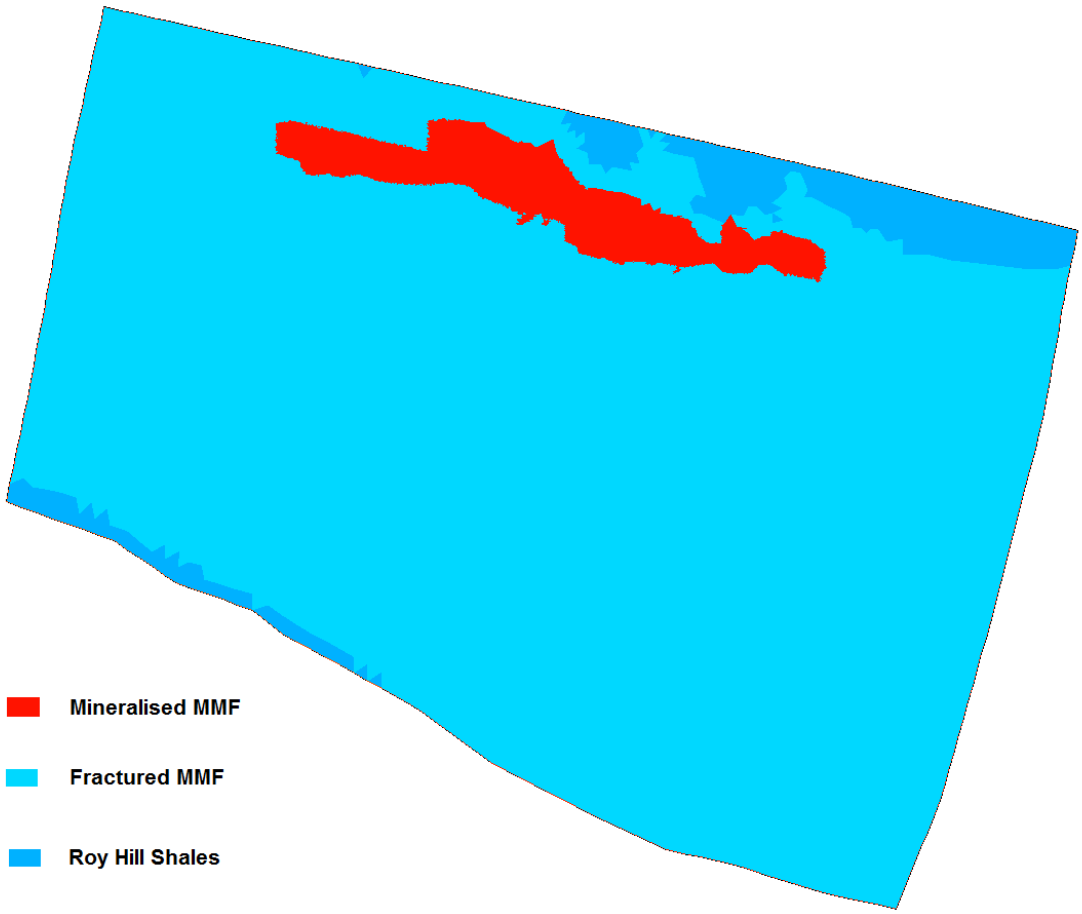


Figure 3.17: Hydraulic Property Distribution of Numerical Layers 8&9.

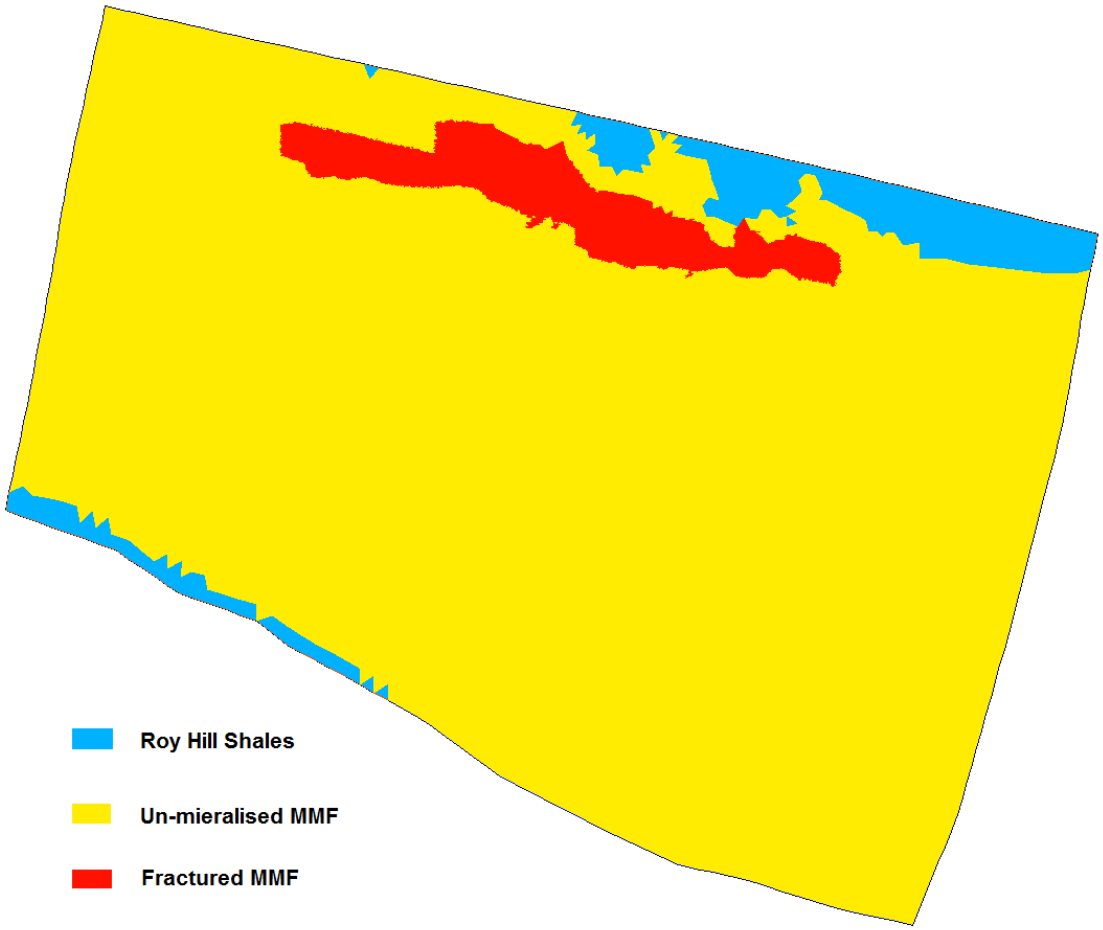
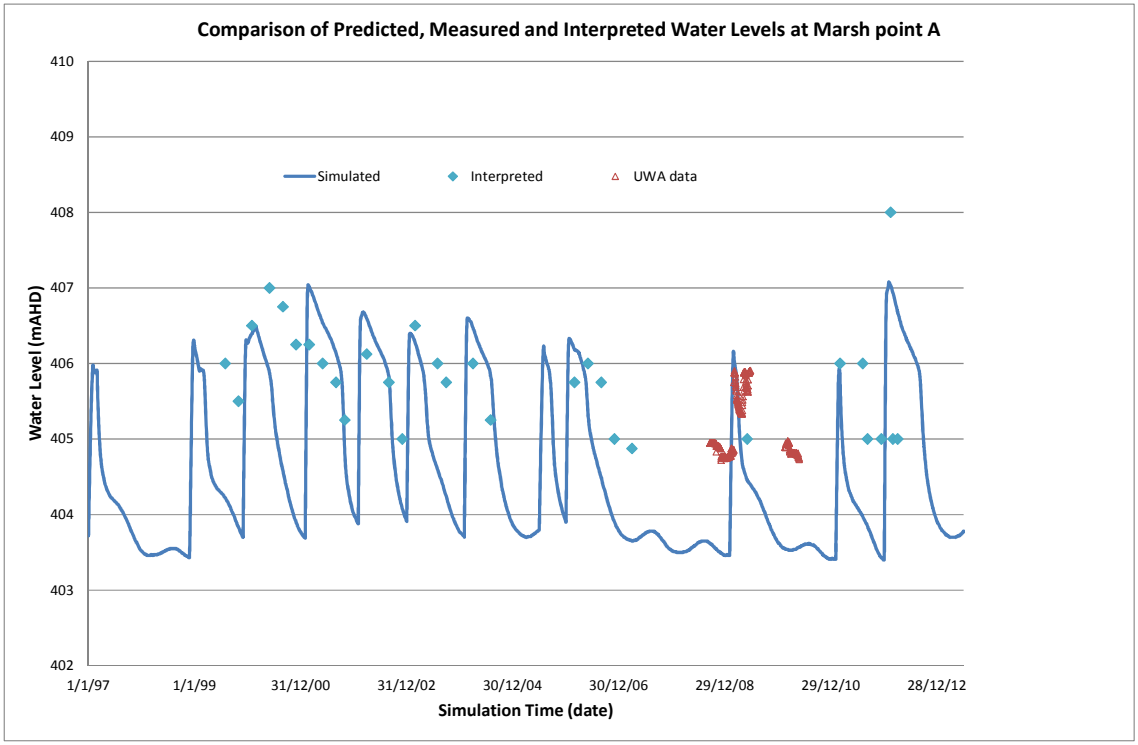


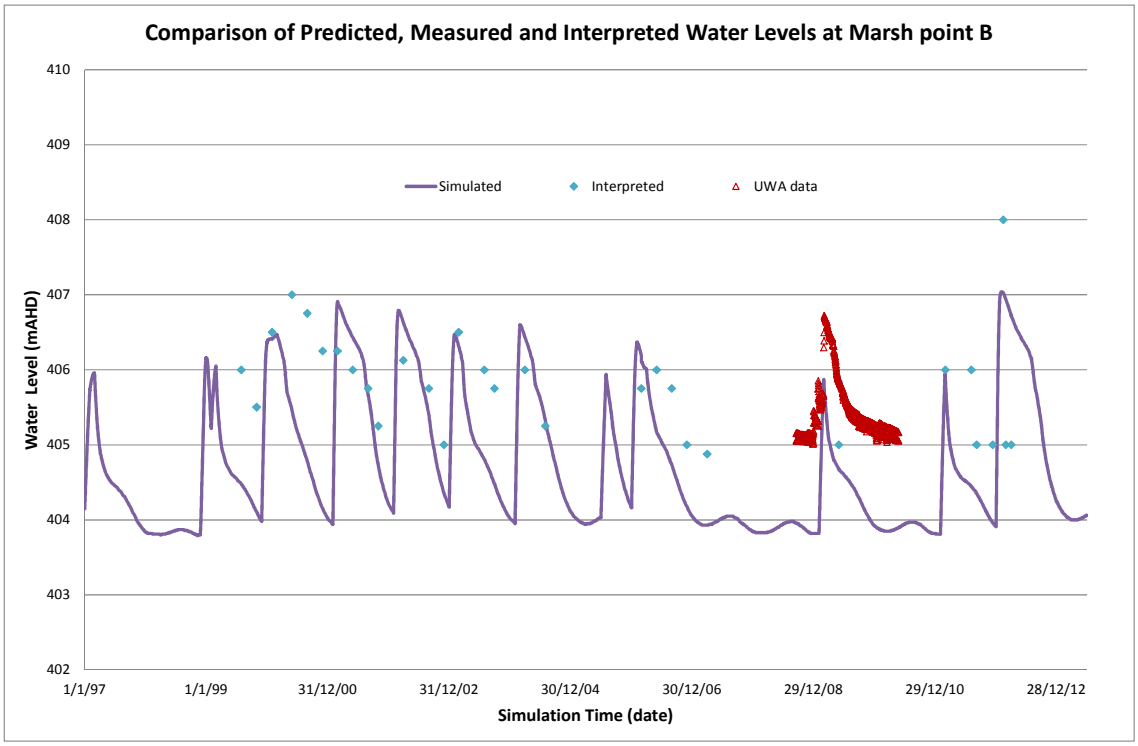
Figure 3.18: Hydraulic Property Distribution of Numerical Layer 10.

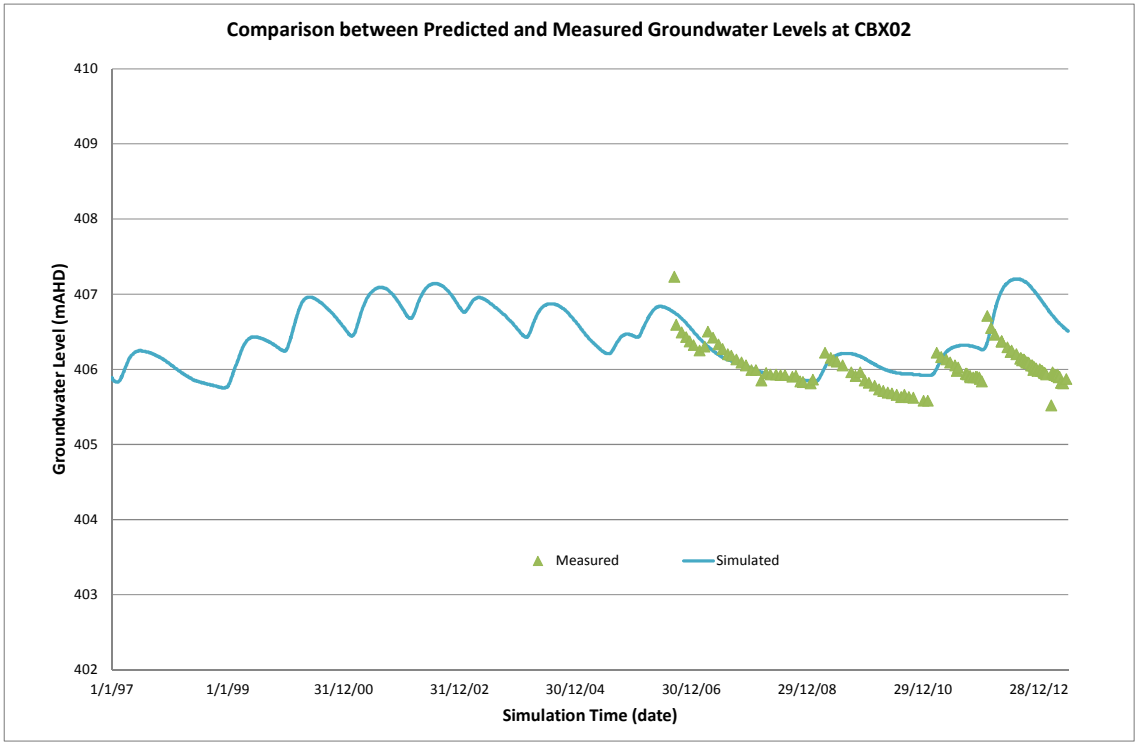
Figure 3.19: Hydraulic Property Distribution of Numerical Layer 11.

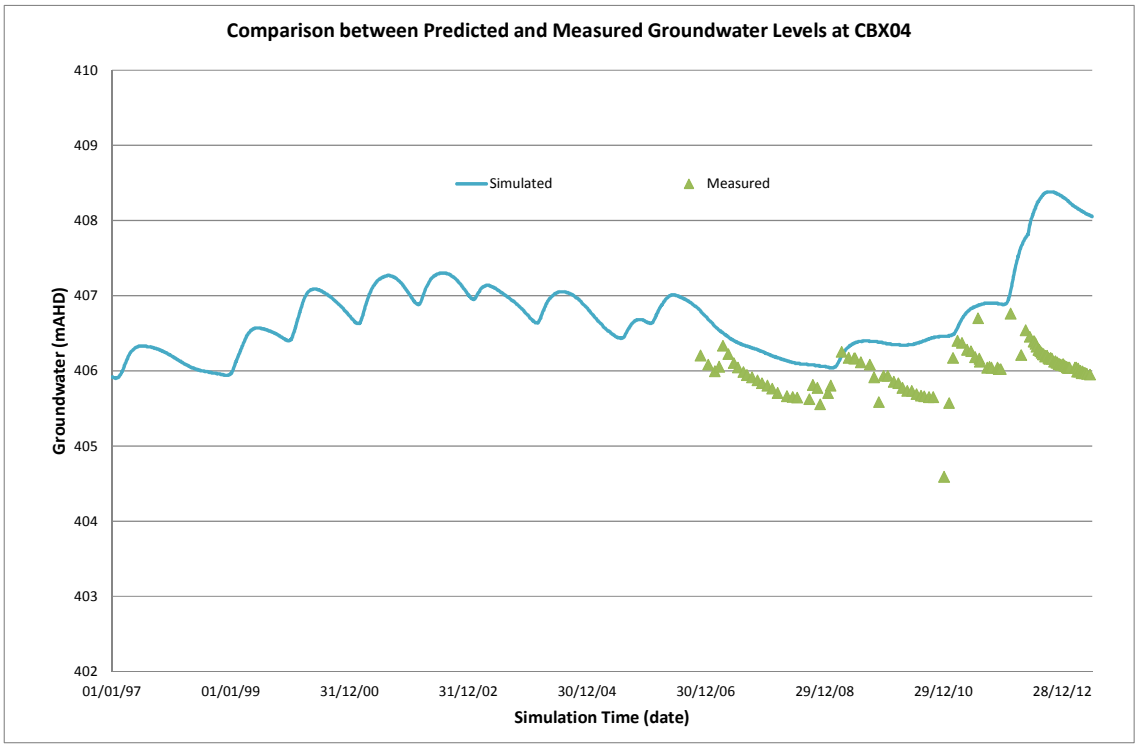
Appendix 4: Numerical model calibration - Measured hydrographs at monitoring bores compared to those predicted by the calibrated model

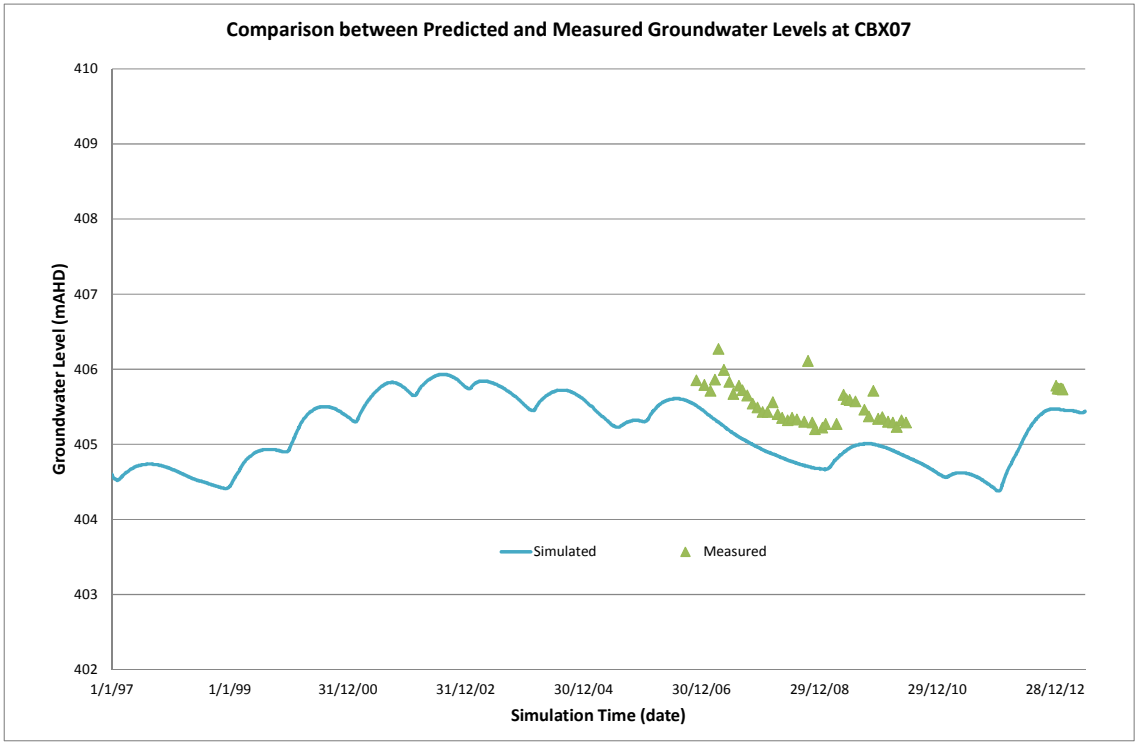
This page has been left blank intentionally

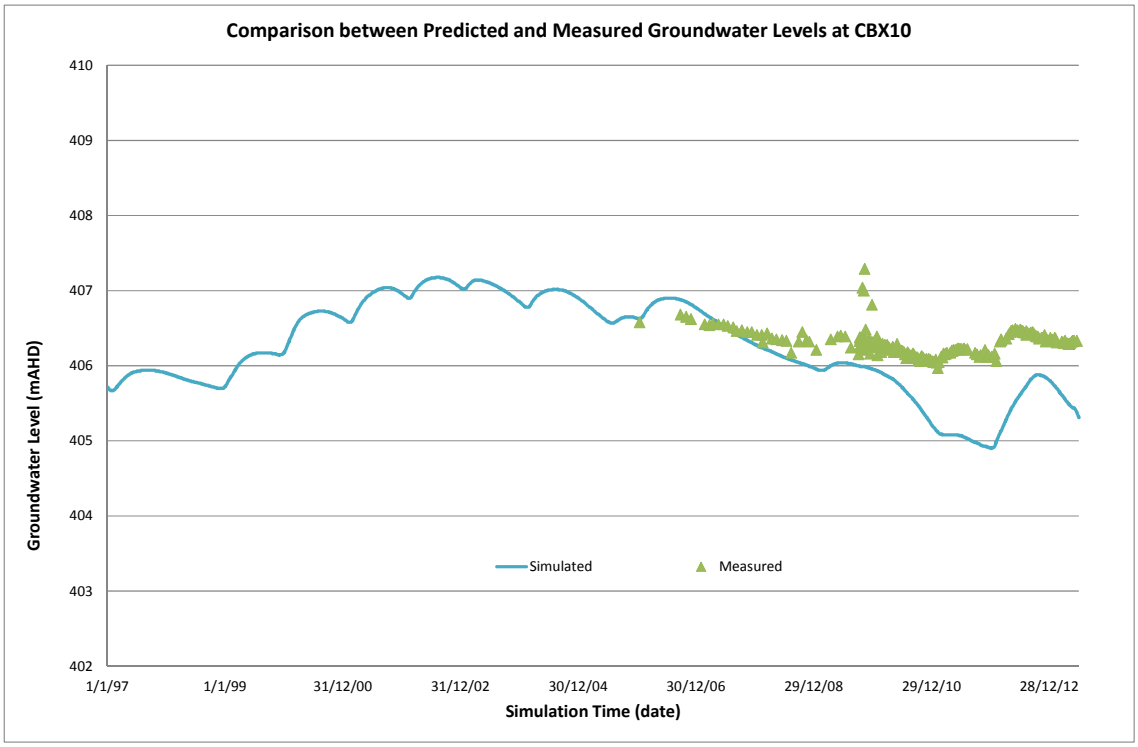

Comparison of Predicted, Measured and Interpreted Water Levels at Marsh point A
Simulated
Interpreted
UWA data
Water Level (mAHD)
410
409
408
407
406
405
404
403
402
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time (date)

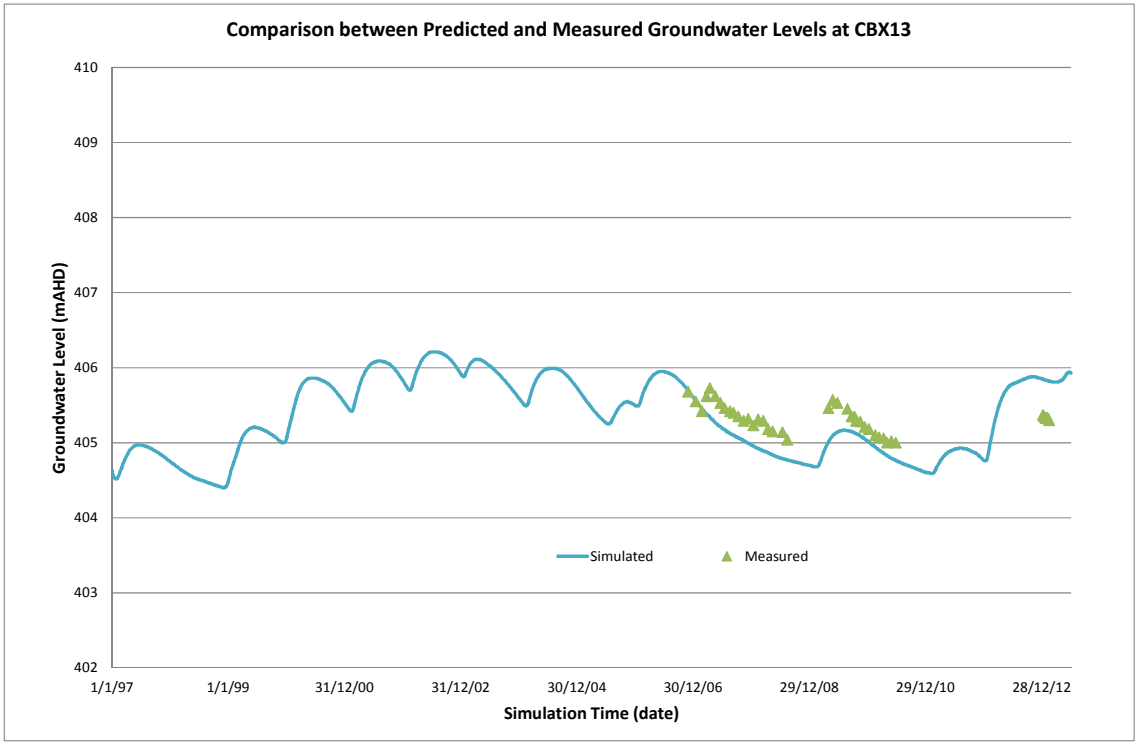

Comparison of Predicted, Measured and Interpreted Water Levels at Marsh point B
Simulated
Interpreted
UWA data
Water Level (mAHD)
410
409
408
407
406
405
404
403
402
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time (date)

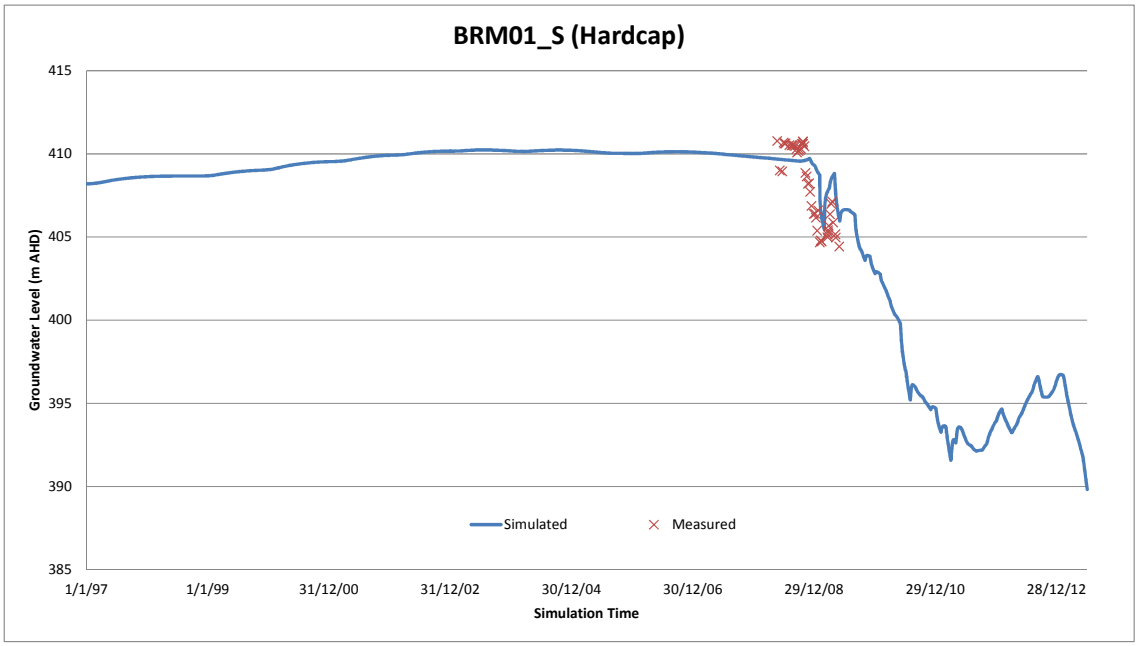

Comparison between Predicted and Measured Groundwater Levels at CBX02
Groundwater Level (mAHD)
410
409
408
407
406
405
404
403
402
Measured
Simulated
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time (date)

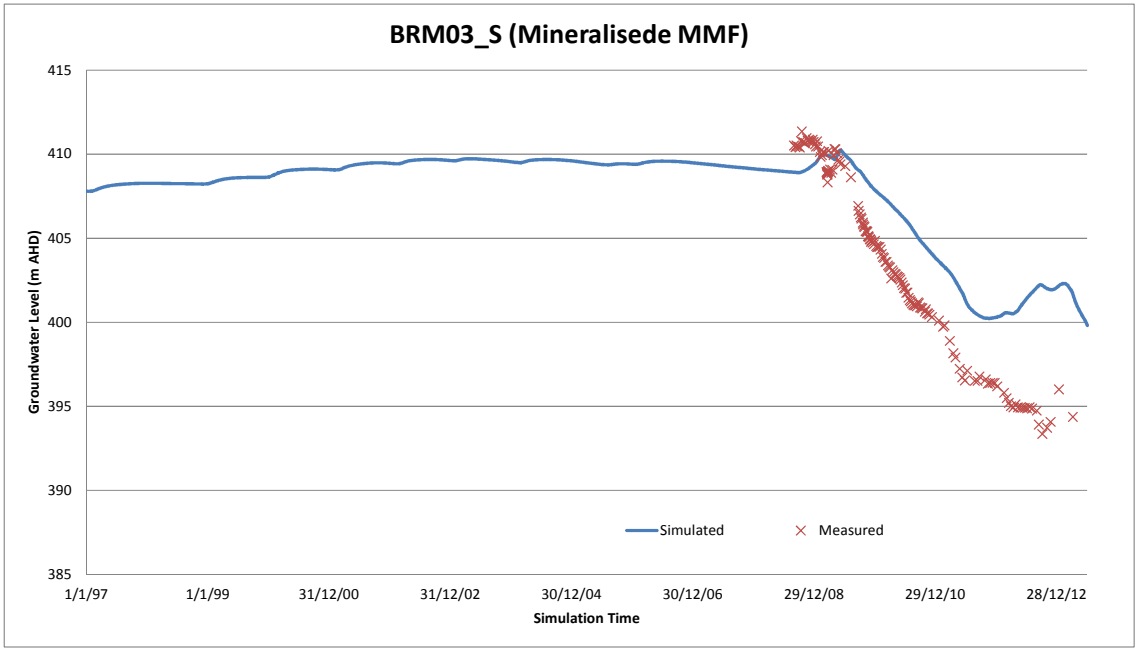

Comparison between Predicted and Measured Groundwater Levels at CBX04
Groundwater (mAHD)
410
409
408
407
406
405
404
403
402
Simulated
Measured
01/01/97
01/01/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time (date)

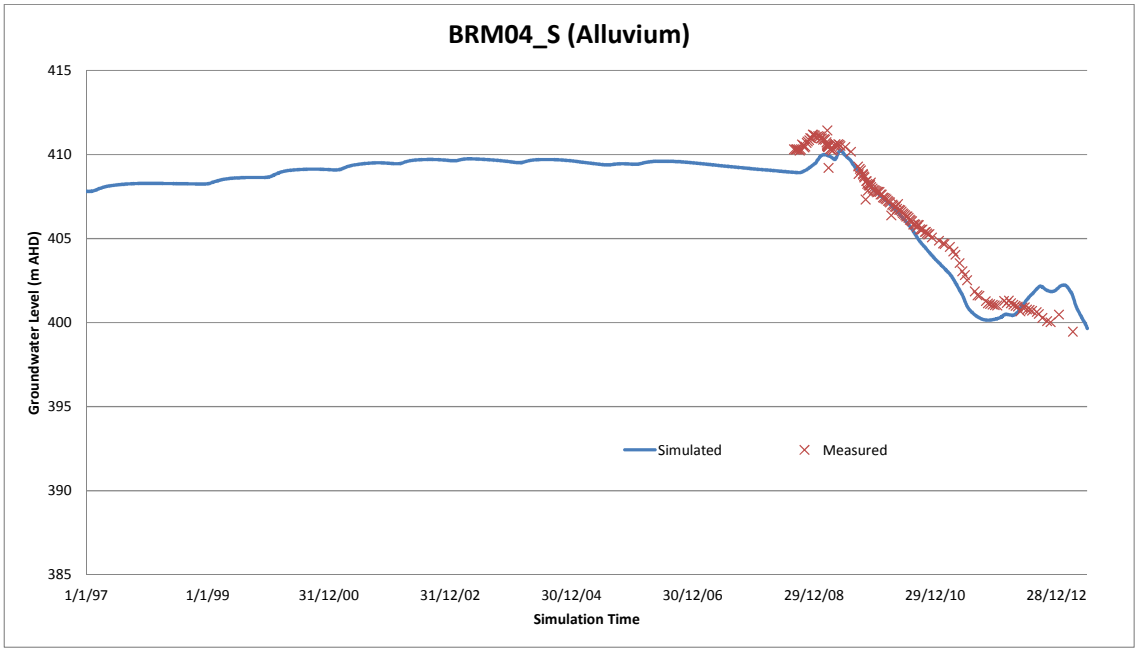

Comparison between Predicted and Measured Groundwater Levels at CBX07
Groundwater Level (mAHD)
410
409
408
407
406
405
404
403
402
Simulated
Measured
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time (date)

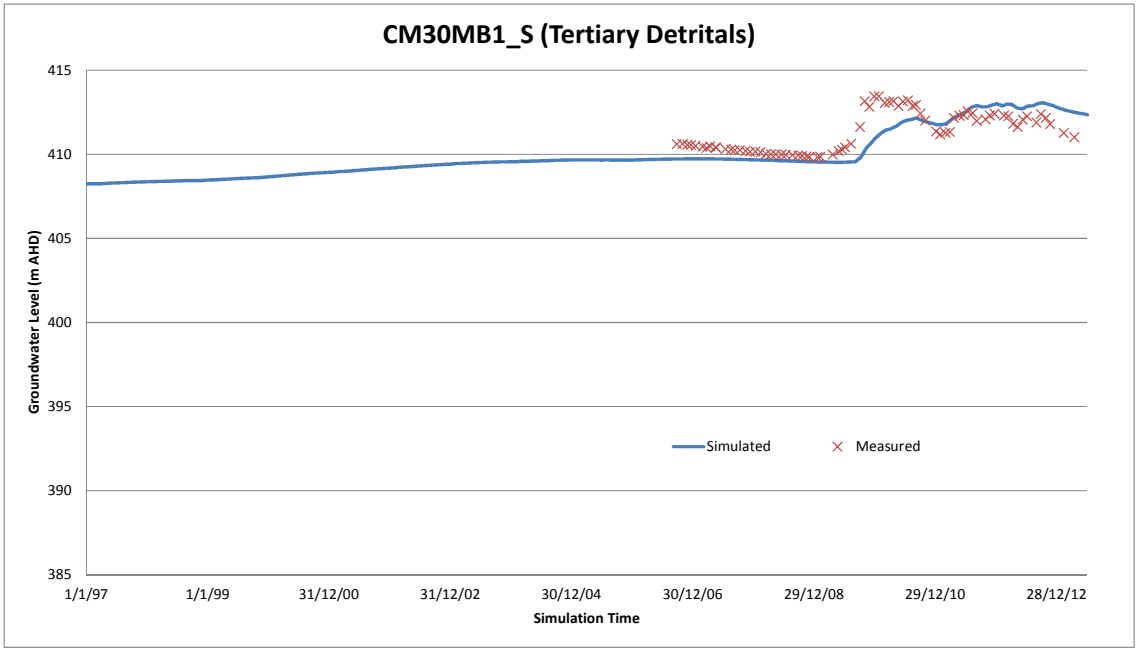

Comparison between Predicted and Measured Groundwater Levels at CBX10
Groundwater Level (mAHD)
410
409
408
407
406
405
404
403
402
Simulated
Measured
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time (date)

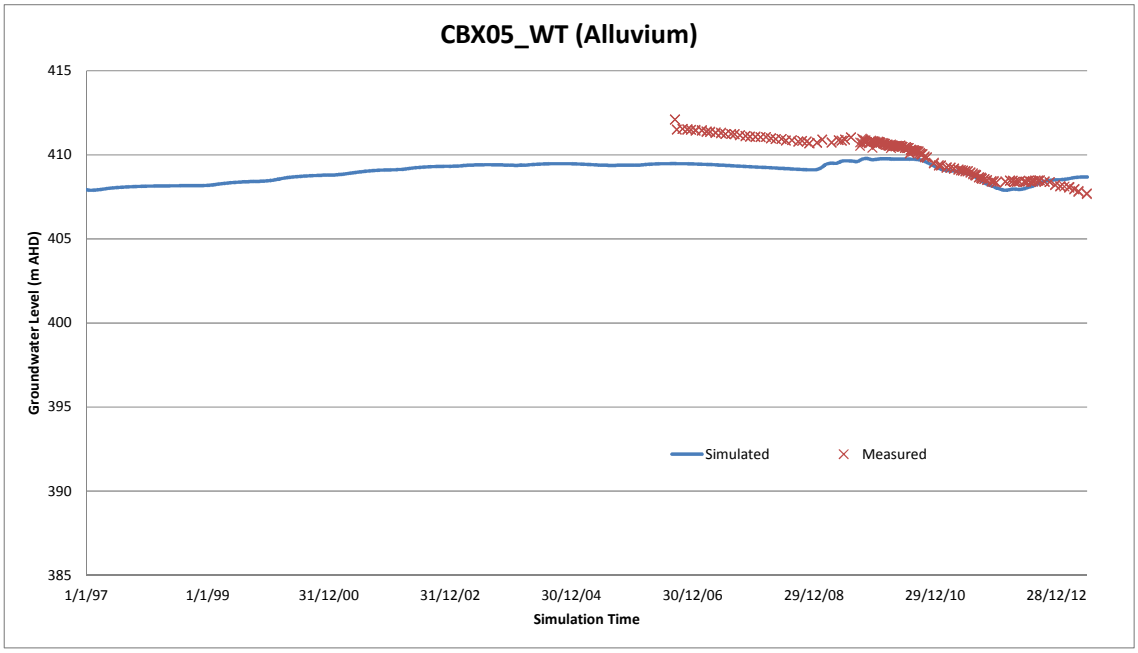

Comparison between Predicted and Measured Groundwater Levels at CBX13
Groundwater Level (mAHD)
410
409
408
407
406
405
404
403
402
Simulated
Measured
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time (date)

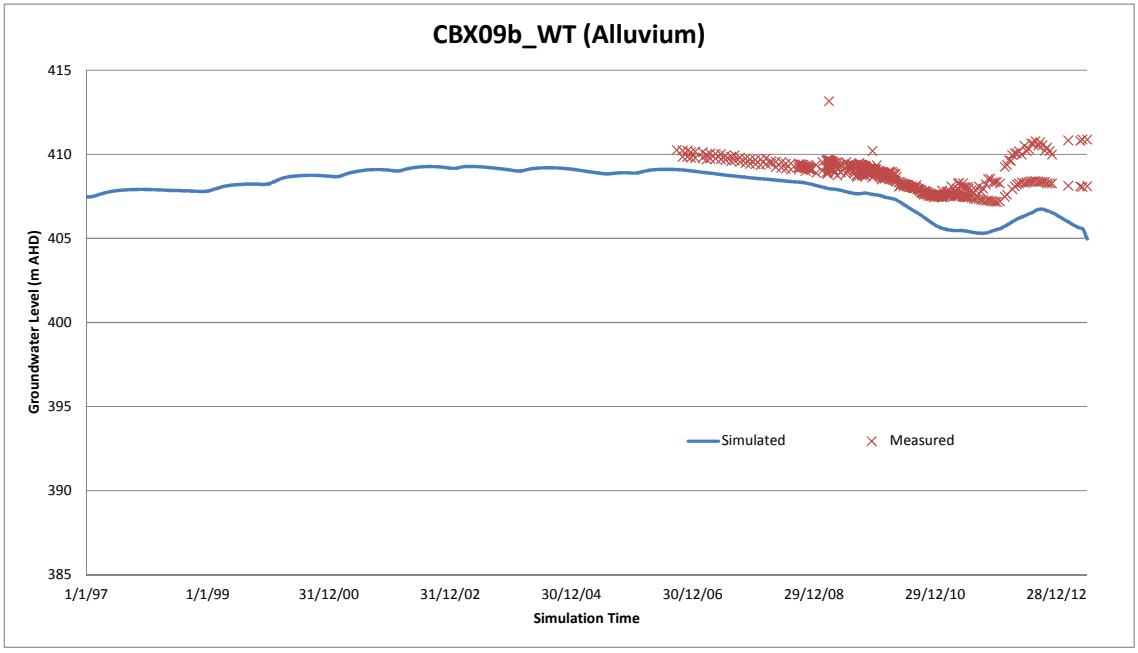

BRM01_S (Hardcap)
Groundwater Level (m AHD)
415
410
405
400
395
390
385
Simulated
Measured
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time

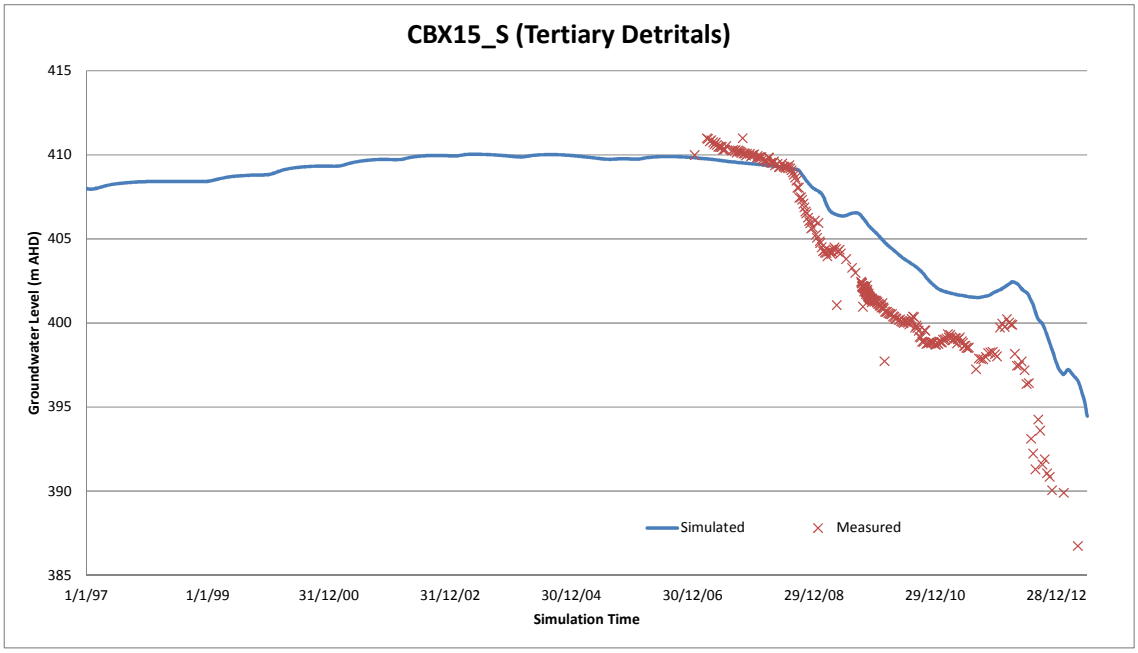

BRM03_S (Mineralisede MMF)
Groundwater Level (m AHD)
415
410
405
400
395
390
385
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time
Simulated
Measured

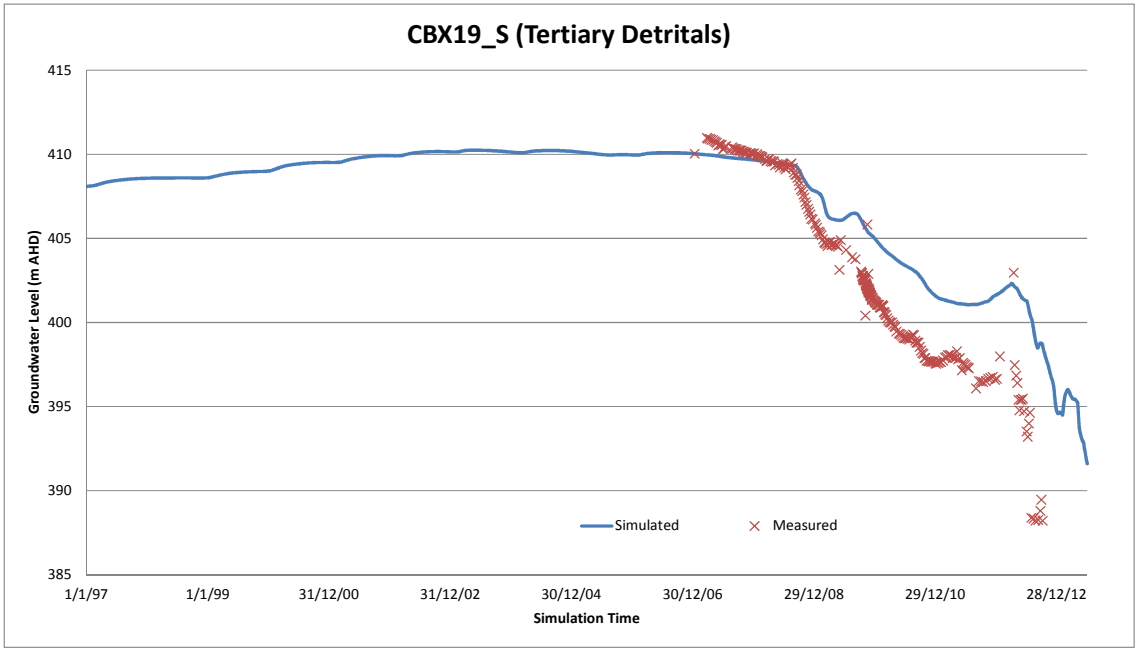

BRM04_S (Alluvium)
Groundwater Level (m AHD)
415
410
405
400
395
390
385
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time
Simulated
Measured

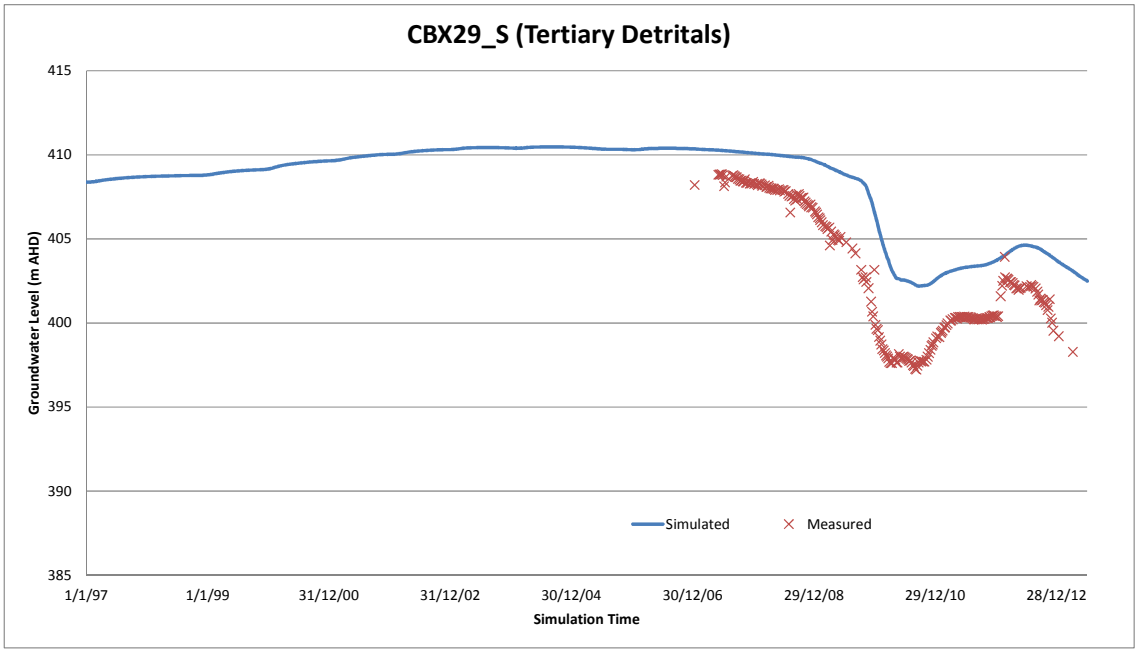

CM30MB1_S (Tertiary Detritals)
Groundwater Level (m AHD)
415
410
405
400
395
390
385
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time
Simulated
Measured

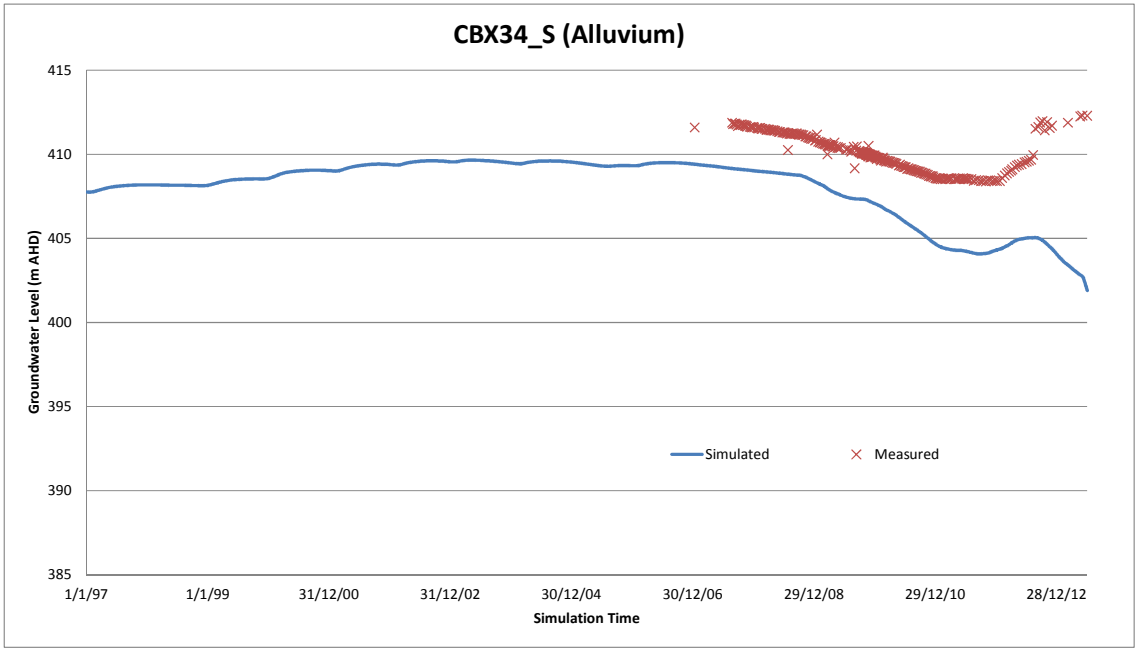

CBX05_WT (Alluvium)
Groundwater Level (m AHD)
415
410
405
400
395
390
385
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time
Simulated
Measured

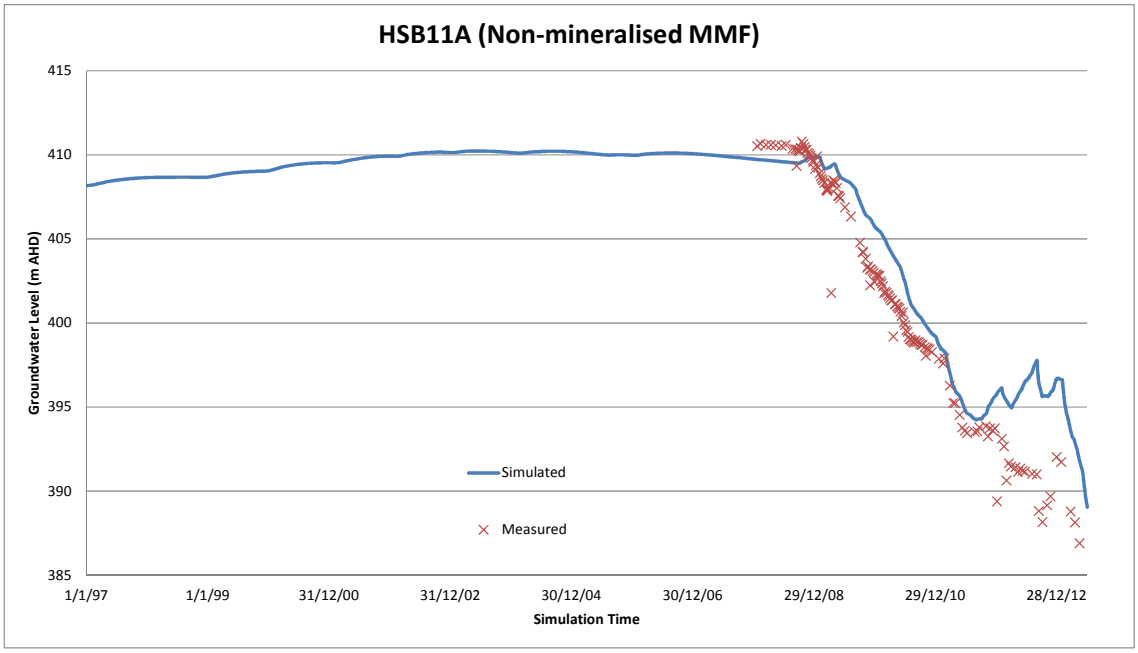

CBX09b_WT (Alluvium)
Groundwater Level (m AHD)
415
410
405
400
395
390
385
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time
Simulated
Measured

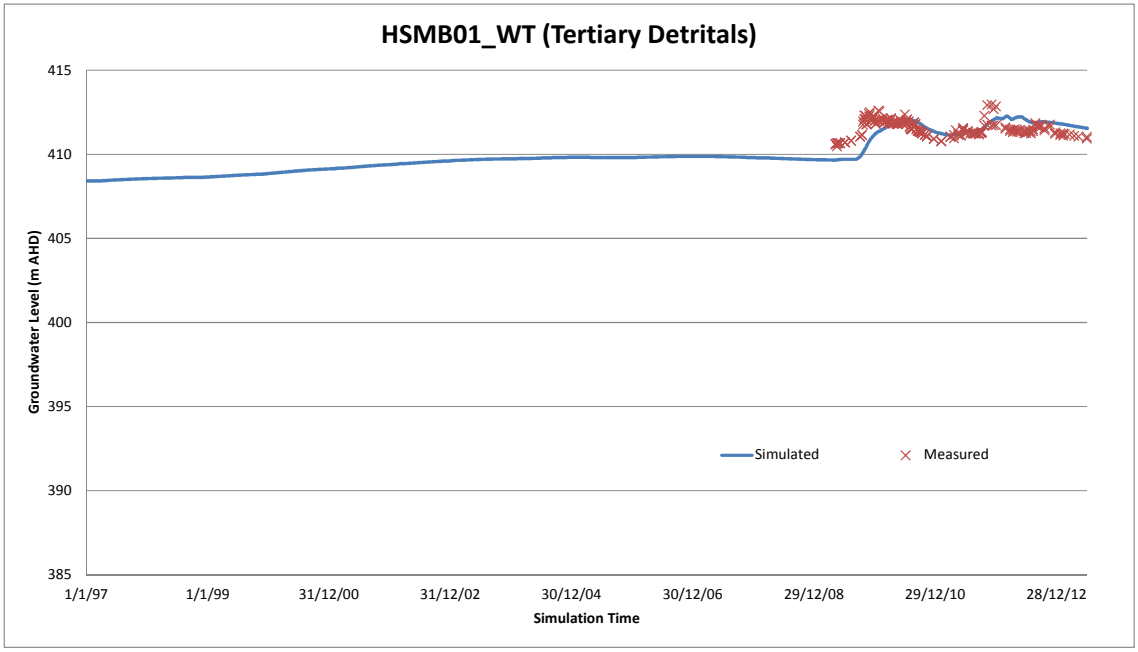

CBX15_S (Tertiary Detritals)
Groundwater Level (m AHD)
415
410
405
400
395
390
385
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time
Simulated
Measured

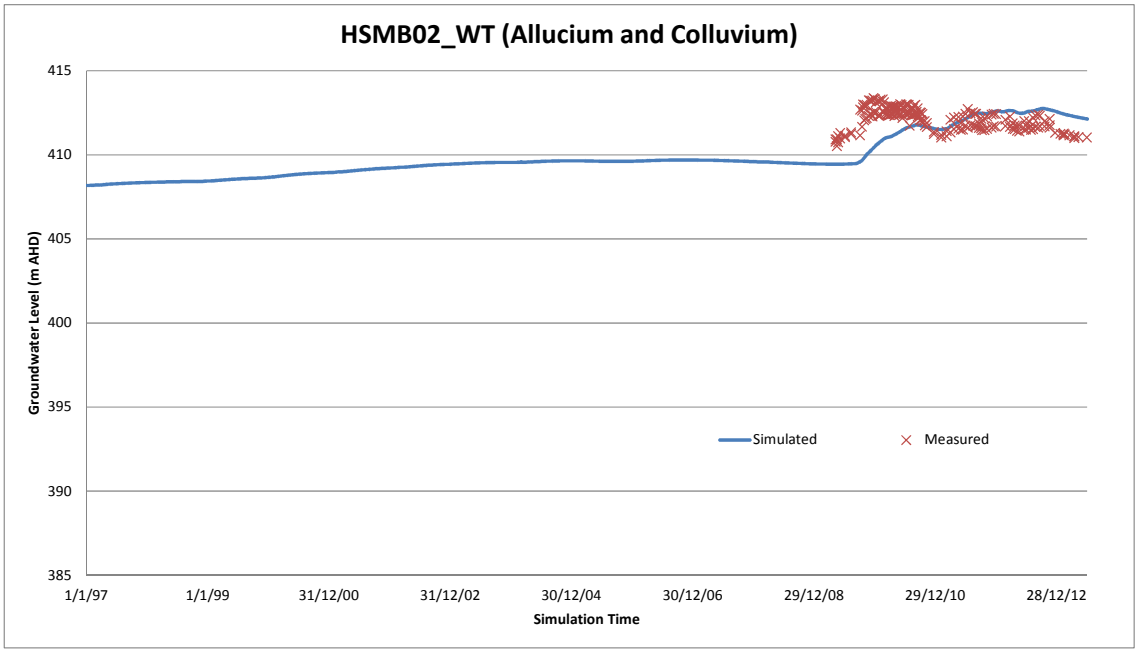

CBX19_S (Tertiary Detritals)
Groundwater Level (m AHD)
415
410
405
400
395
390
385
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time
Simulated
Measured

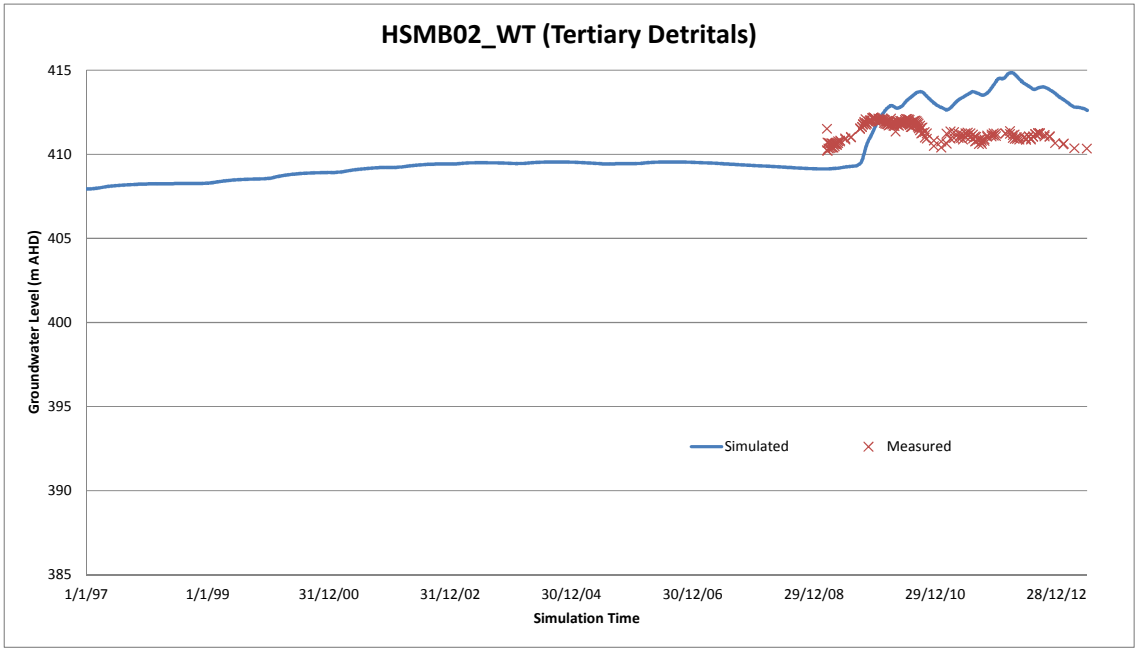

CBX29_S (Tertiary Detritals)
Groundwater Level (m AHD)
415
410
405
400
395
390
385
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time
Simulated
Measured

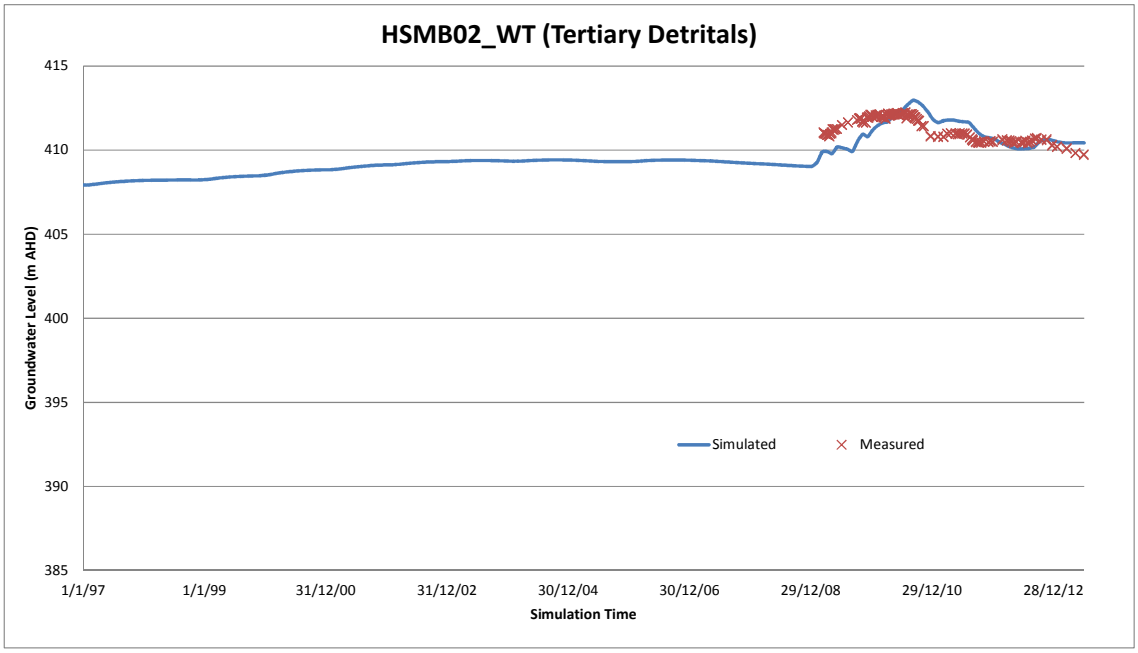

CBX34_S (Alluvium)
Groundwater Level (m AHD)
415
410
405
400
395
390
385
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time
Simulated
Measured

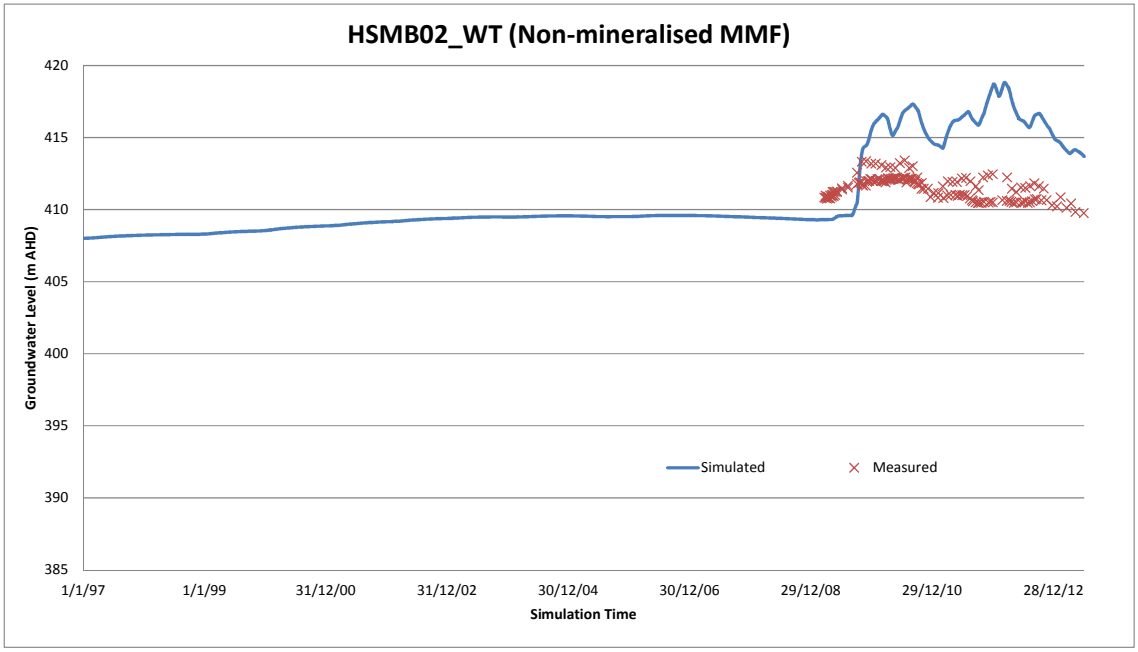

HSB11A (Non-mineralised MMF)
Groundwater Level (m AHD)
415
410
405
400
395
390
385
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time
Simulated
Measured

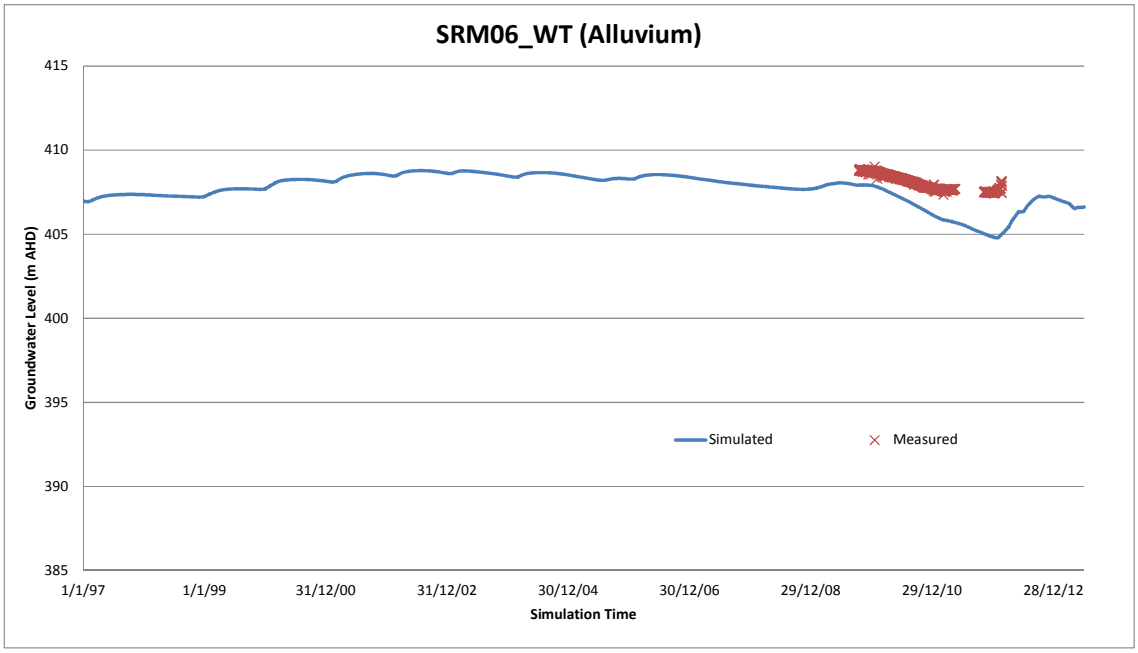

HSMB01_WT (Tertiary Detritals)
Groundwater Level (m AHD)
415
410
405
400
395
390
385
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time
Simulated
Measured

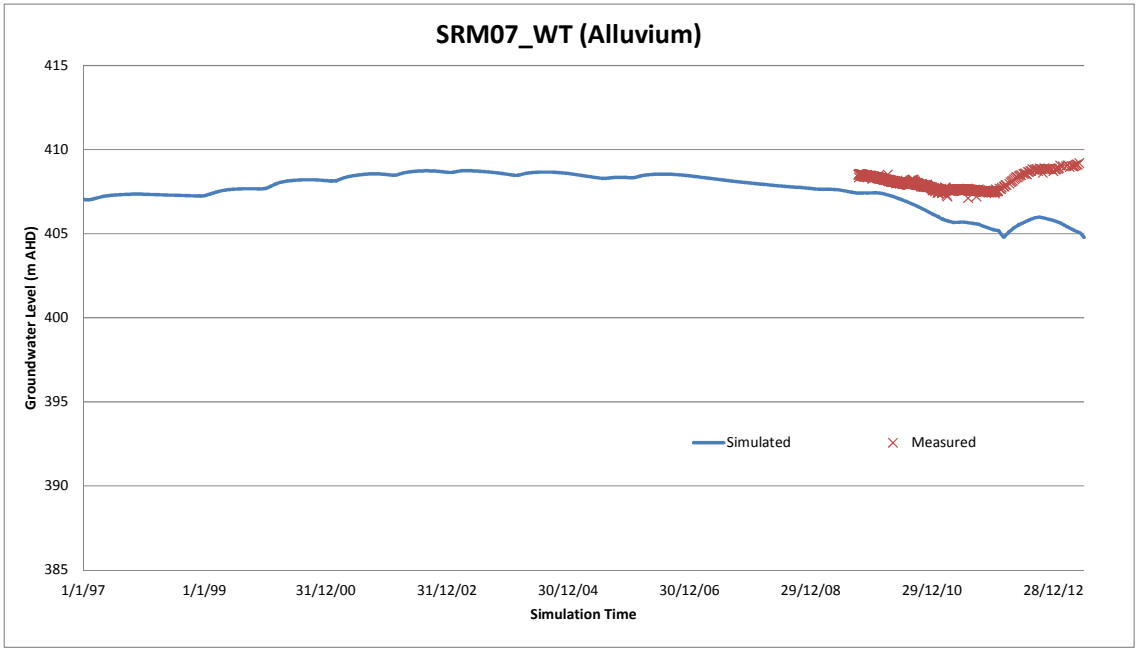

HSMB02_WT (Allucium and Colluvium)
Groundwater Level (m AHD)
415
410
405
400
395
390
385
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time
Simulated
Measured


HSMB02_WT (Tertiary Detritals)
Groundwater Level (m AHD)
415
410
405
400
395
390
385
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time
Simulated
Measured


HSMB02_WT (Tertiary Detritals)
Groundwater Level (m AHD)
415
410
405
400
395
390
385
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time
Simulated
Measured

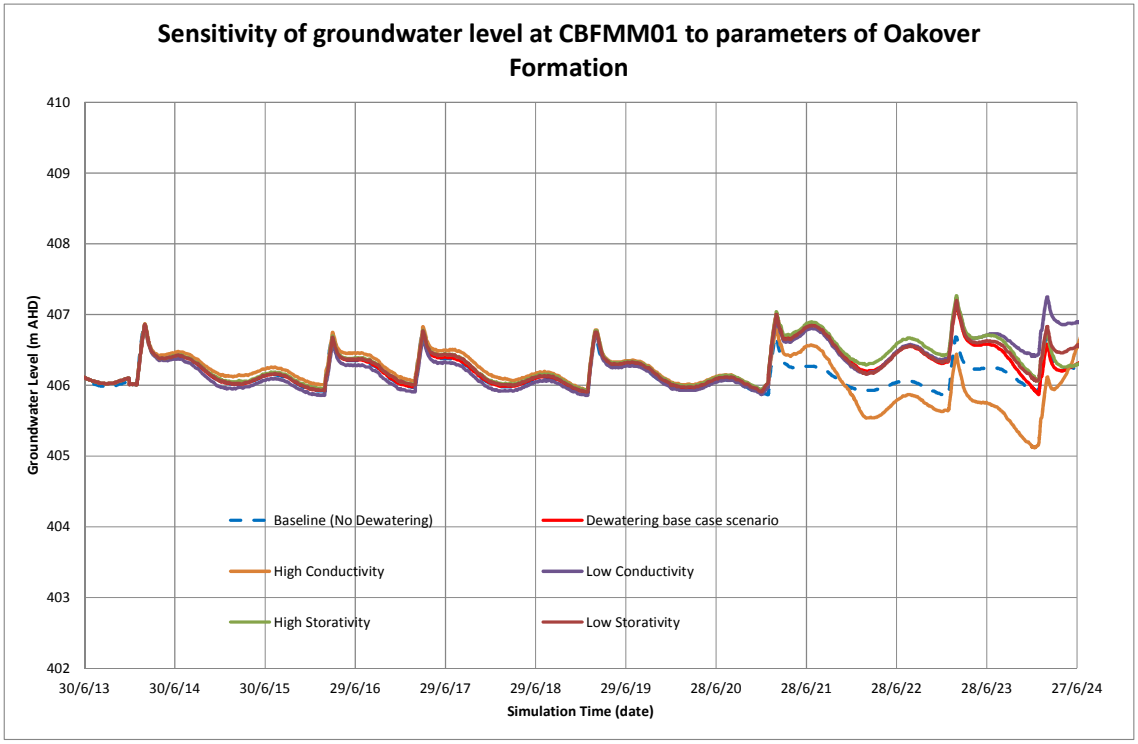

HSMB02_WT (Non-mineralised MMF)
Groundwater Level (m AHD)
420
415
410
405
400
395
390
385
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time
Simulated
Measured

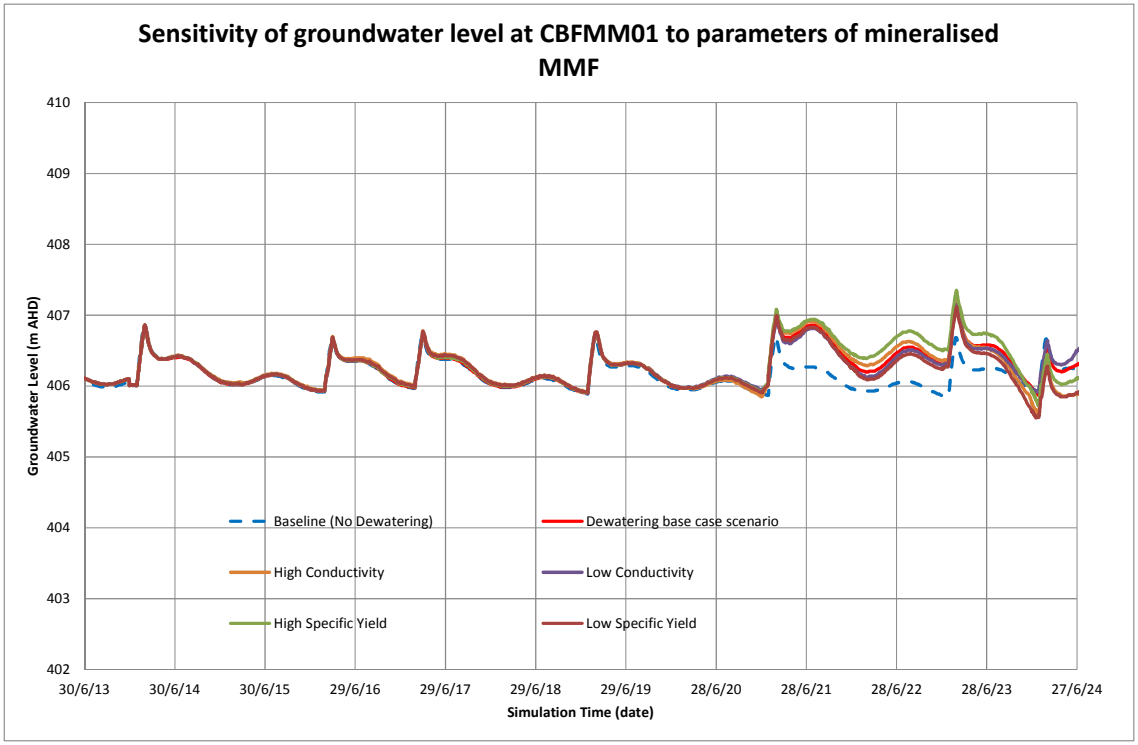

SRM06_WT (Alluvium)
Groundwater Level (m AHD)
415
410
405
400
395
390
385
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time
Simulated
Measured

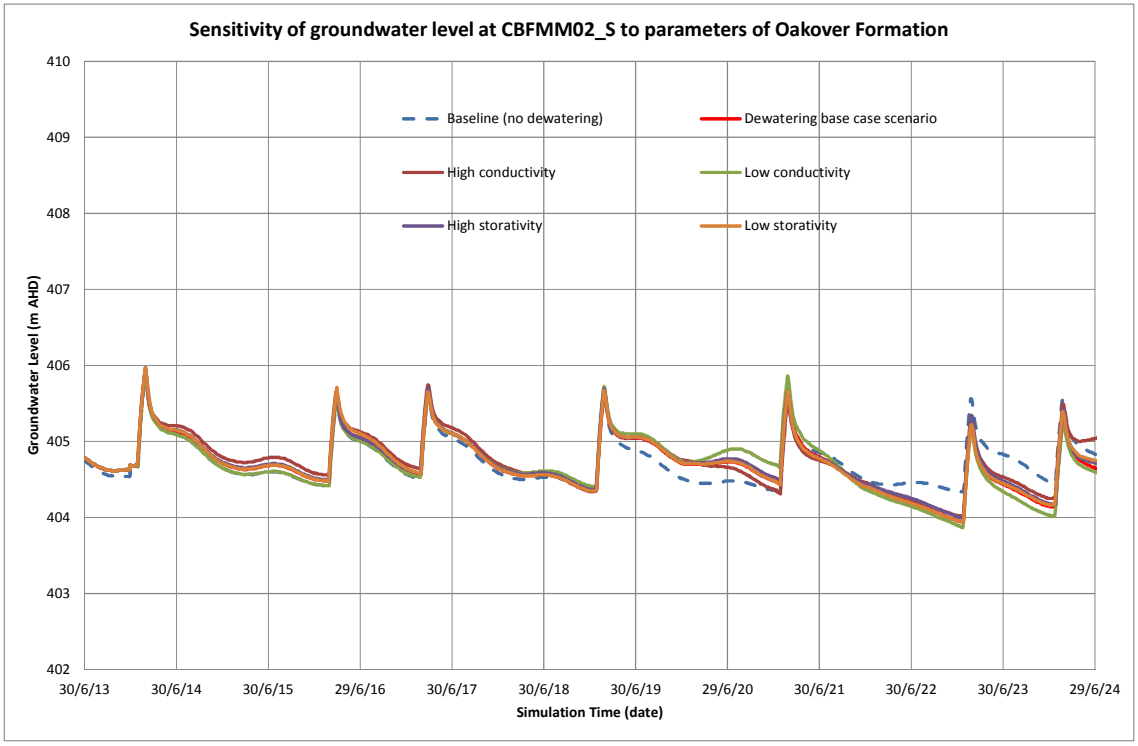

SRM07_WT (Alluvium)
415
410
405
400
395
390
385
Groundwater Level (m AHD)
1/1/97
1/1/99
31/12/00
31/12/02
30/12/04
30/12/06
29/12/08
29/12/10
28/12/12
Simulation Time
Simulated
Measured

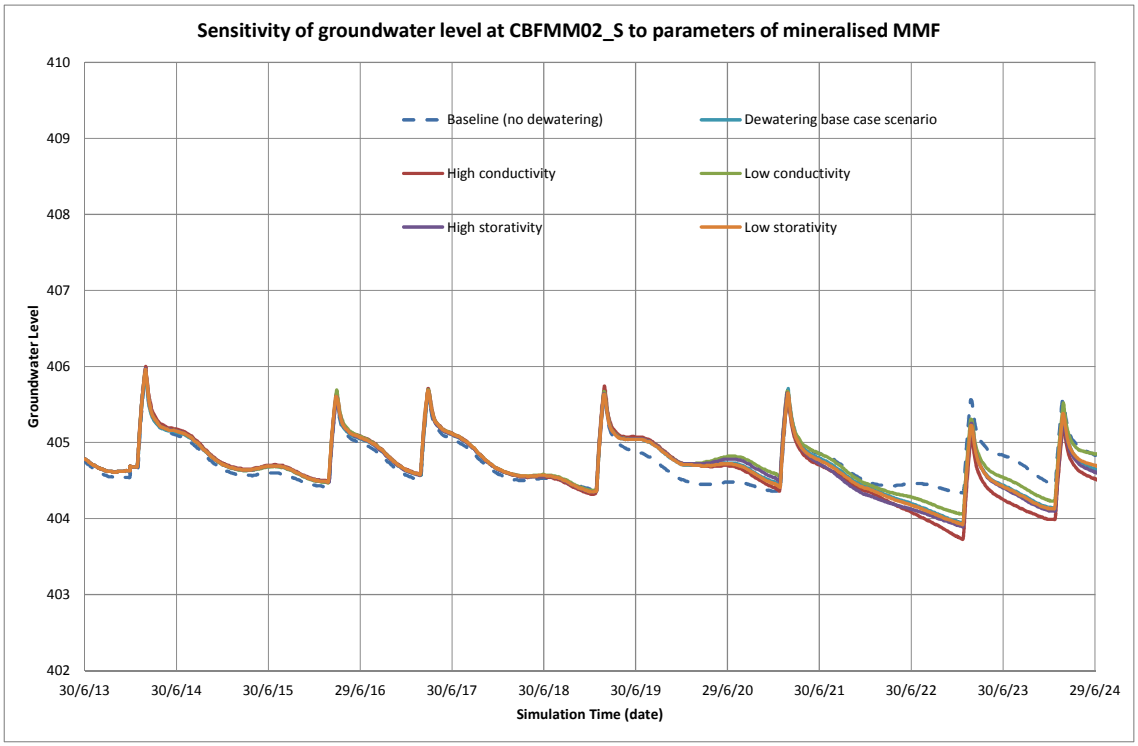
Appendix 5: Hydrographs at selected key locations from all sensitivity simulations

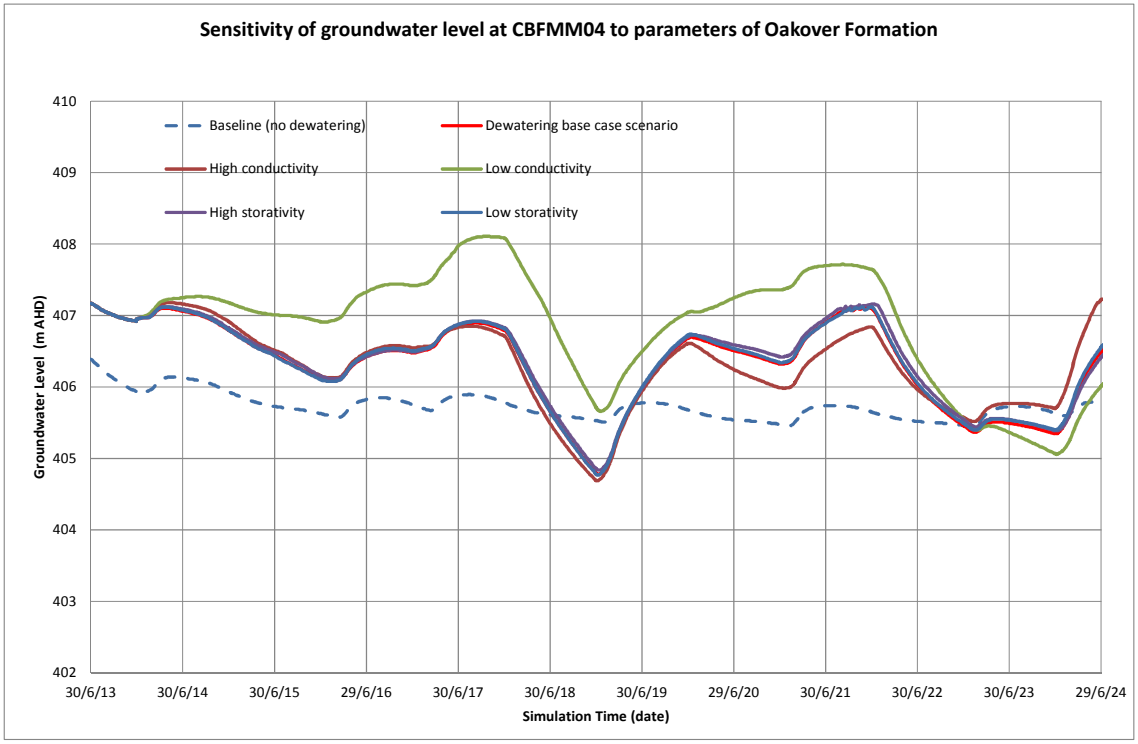
This page has been left blank intentionally

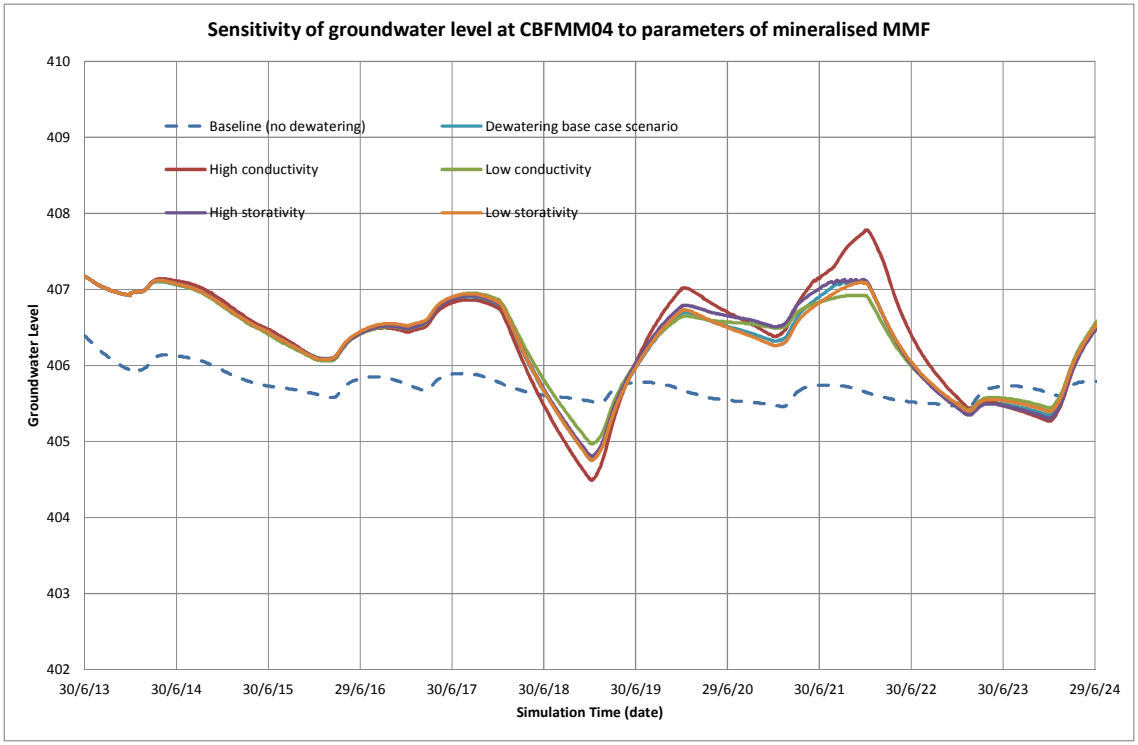

Sensitivity of groundwater level at CBFMM01 to parameters of Oakover Formation
Groundwater Level (m AHD)
410
409
408
407
406
405
404
403
402
30/6/13
30/6/14
30/6/15
29/6/16
29/6/17
29/6/18
29/6/19
28/6/20
28/6/21
28/6/22
28/6/23
27/6/24
Simulation Time (date)
Baseline (No Dewatering)
Dewatering base case scenario
High Conductivity
Low Conductivity
High Storativity
Low Storativity

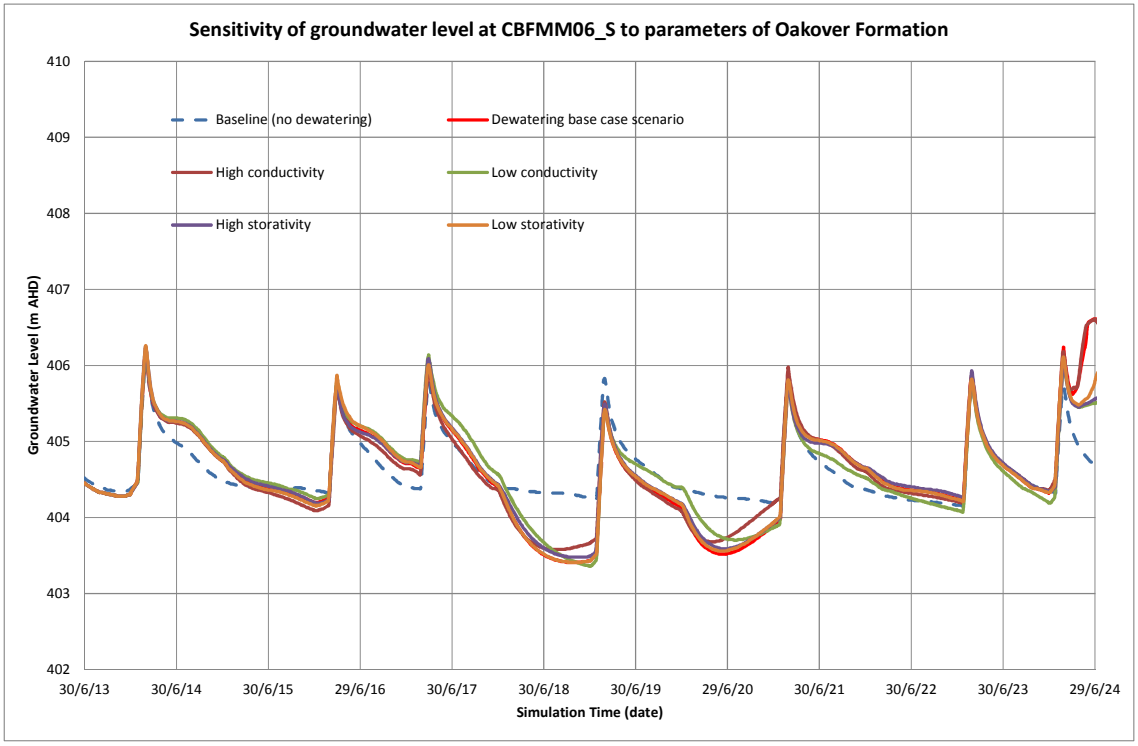

Sensitivity of groundwater level at CBFMM01 to parameters of mineralised MMF
Groundwater Level (m AHD)
410
409
408
407
406
405
404
403
402
30/6/13
30/6/14
30/6/15
29/6/16
29/6/17
29/6/18
29/6/19
28/6/20
28/6/21
28/6/22
28/6/23
27/6/24
Simulation Time (date)
Baseline (No Dewatering)
Dewatering base case scenario
High Conductivity
Low Conductivity
High Specific Yield
Low Specific Yield

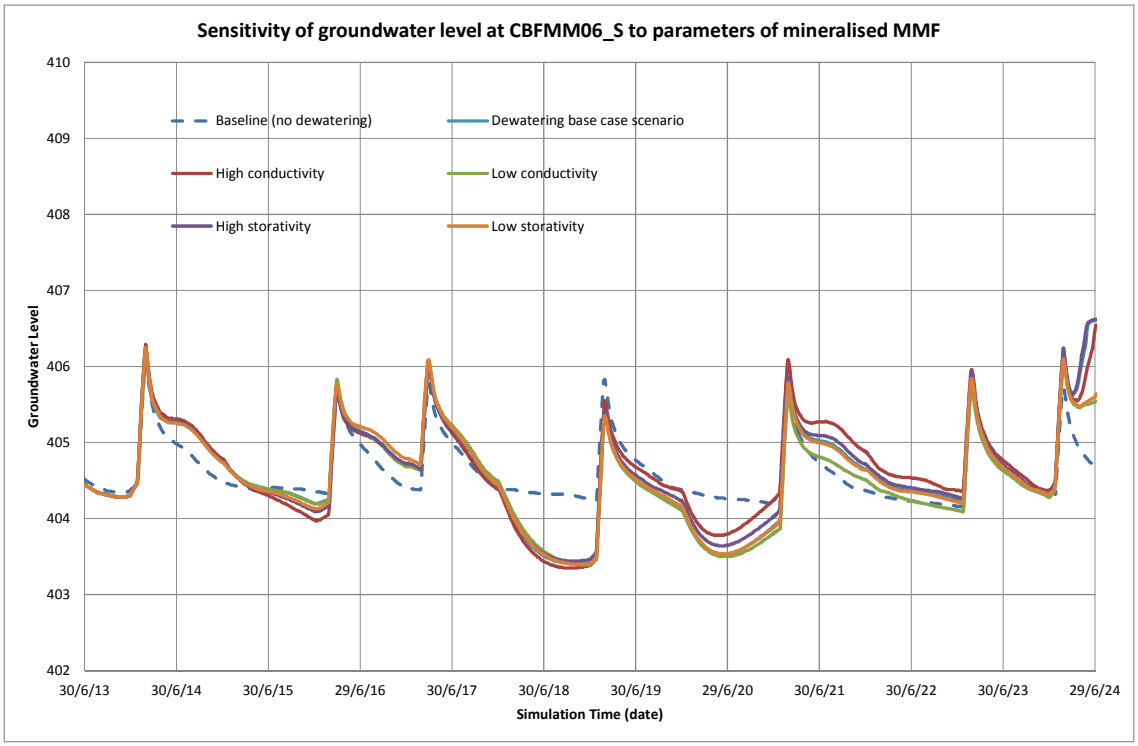

Sensitivity of groundwater level at CBFMM02_S to parameters of Oakover Formation
Baseline (no dewatering)
Dewatering base case scenario
High conductivity
Low conductivity
High storativity
Low storativity
Groundwater Level (m AHD)
410
409
408
407
406
405
404
403
402
30/6/13
30/6/14
30/6/15
29/6/16
30/6/17
30/6/18
30/6/19
29/6/20
30/6/21
30/6/22
30/6/23
29/6/24
Simulation Time (date)

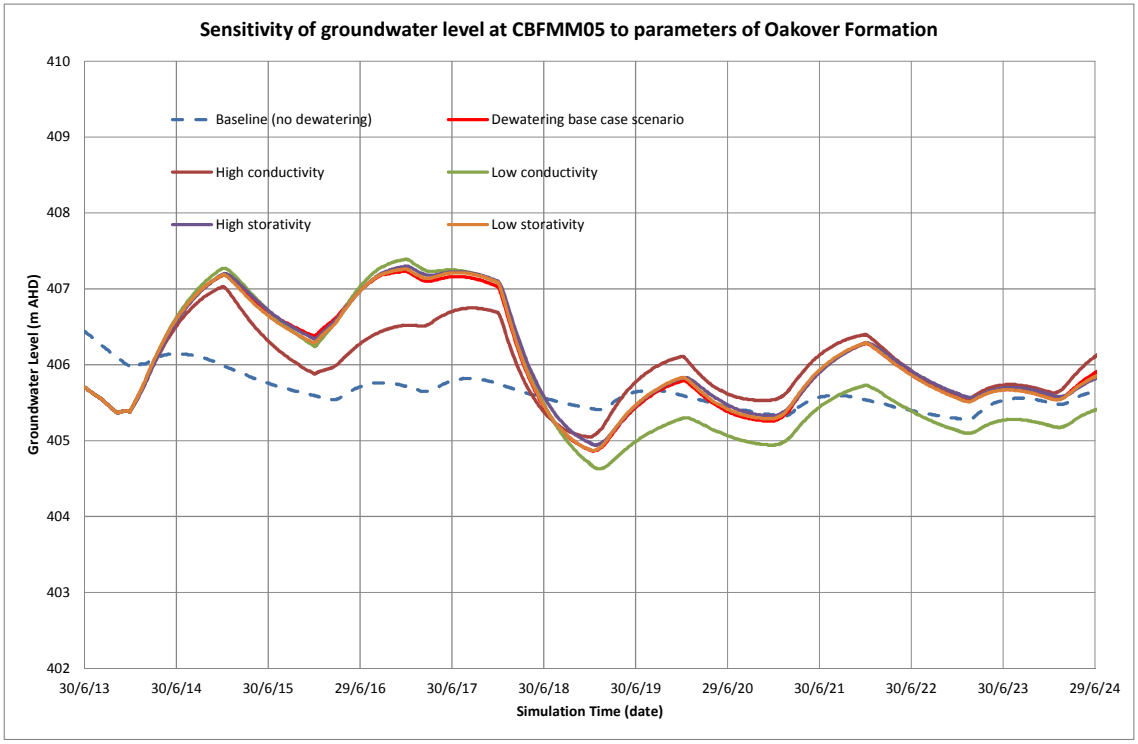

Sensitivity of groundwater level at CBFMM02_S to parameters of mineralised MMF
Baseline (no dewatering)
Dewatering base case scenario
High conductivity
Low conductivity
High storativity
Low storativity
Groundwater Level
410
409
408
407
406
405
404
403
402
30/6/13
30/6/14
30/6/15
29/6/16
30/6/17
30/6/18
30/6/19
29/6/20
30/6/21
30/6/22
30/6/23
29/6/24
Simulation Time (date)

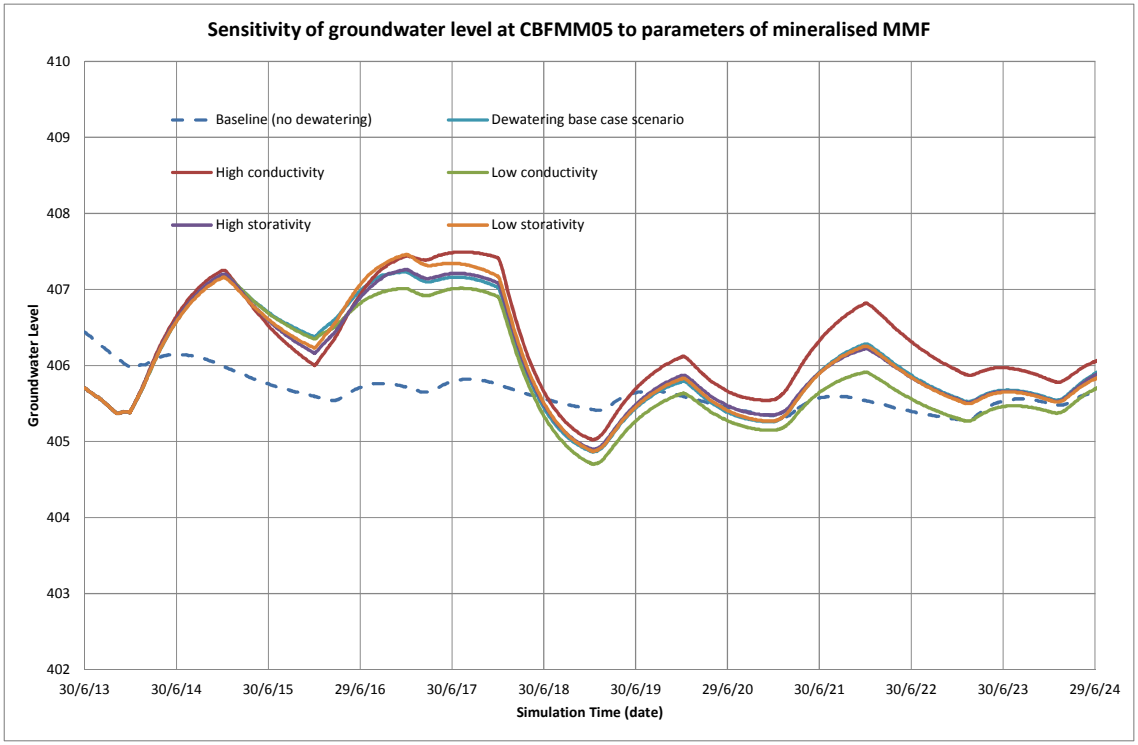

Sensitivity of groundwater level at CBFMM04 to parameters of Oakover Formation
Baseline (no dewatering)
Dewatering base case scenario
High conductivity
Low conductivity
High storativity
Low storativity
Groundwater Level (m AHD)
410
409
408
407
406
405
404
403
402
30/6/13
30/6/14
30/6/15
29/6/16
30/6/17
30/6/18
30/6/19
29/6/20
30/6/21
30/6/22
30/6/23
29/6/24
Simulation Time (date)

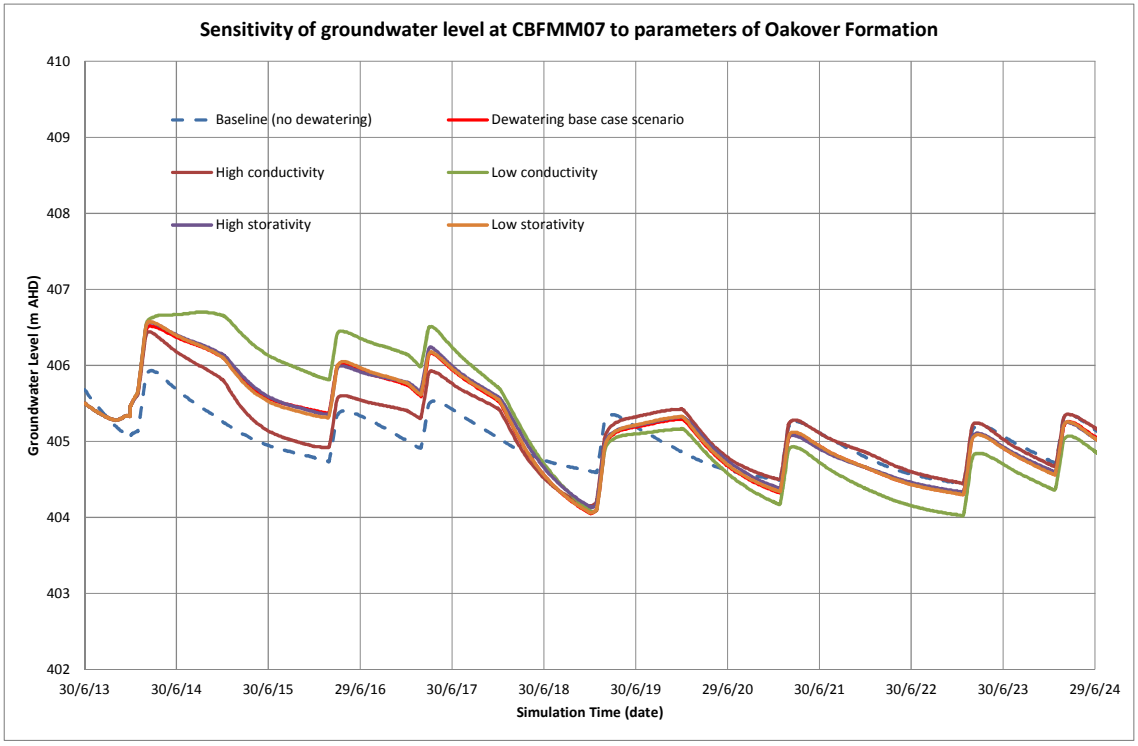

Sensitivity of groundwater level at CBFMM04 to parameters of mineralised MMF
Baseline (no dewatering)
Dewatering base case scenario
High conductivity
Low conductivity
High storativity
Low storativity
Groundwater Level
410
409
408
407
406
405
404
403
402
30/6/13
30/6/14
30/6/15
29/6/16
30/6/17
30/6/18
30/6/19
29/6/20
30/6/21
30/6/22
30/6/23
29/6/24
Simulation Time (date)

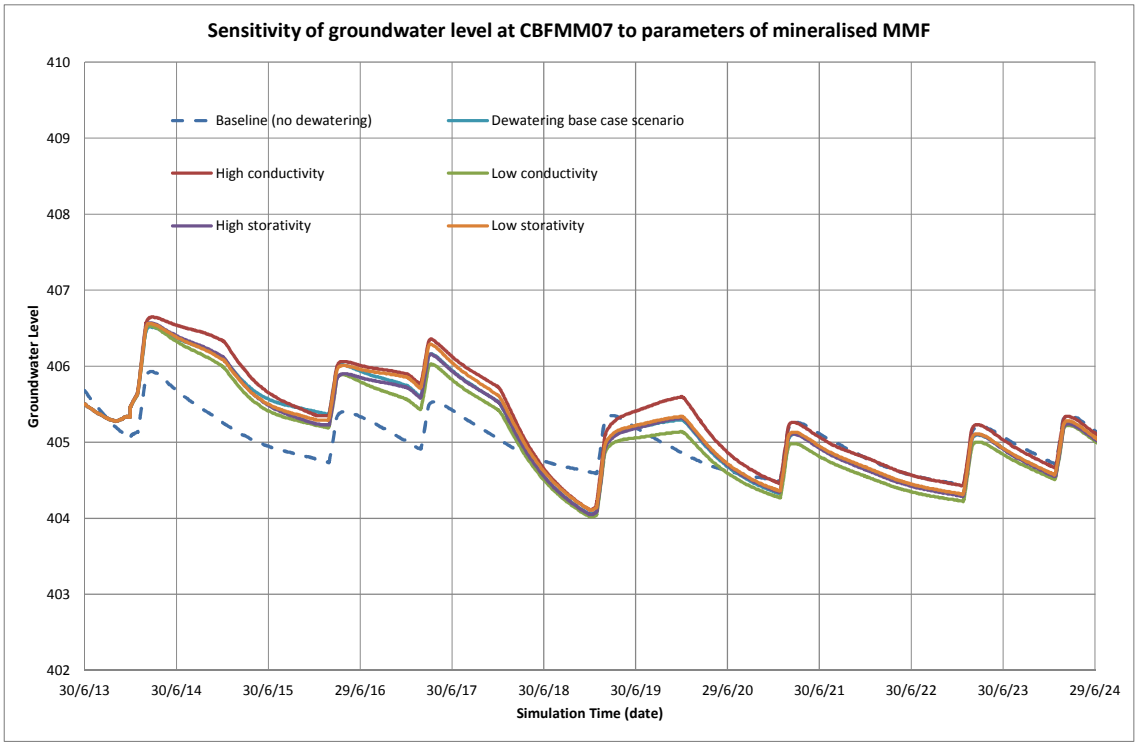

Sensitivity of groundwater level at CBFMM06_S to parameters of Oakover Formation
Baseline (no dewatering)
Dewatering base case scenario
High conductivity
Low conductivity
High storativity
Low storativity
Groundwater Level (m AHD)
410
409
408
407
406
405
404
403
402
30/6/13
30/6/14
30/6/15
29/6/16
30/6/17
30/6/18
30/6/19
29/6/20
30/6/21
30/6/22
30/6/23
29/6/24
Simulation Time (date)

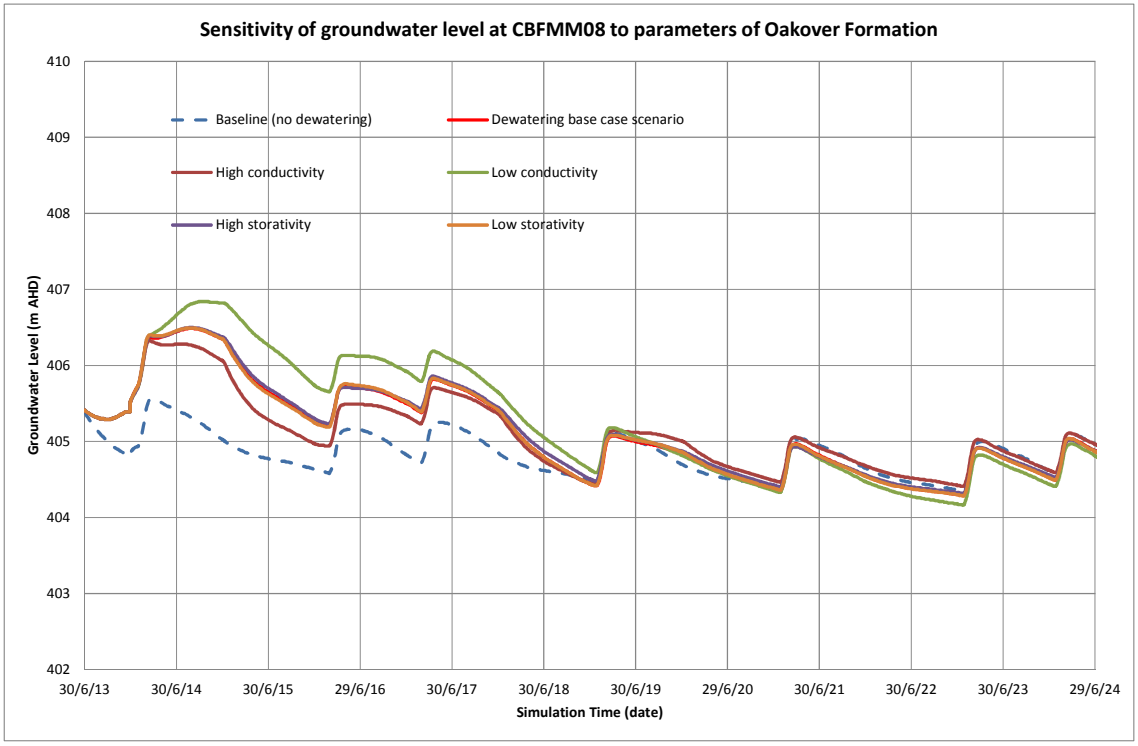

Sensitivity of groundwater level at CBFMM06_S to parameters of mineralised MMF
Baseline (no dewatering)
Dewatering base case scenario
High conductivity
Low conductivity
High storativity
Low storativity
Groundwater Level
410
409
408
407
406
405
404
403
402
30/6/13
30/6/14
30/6/15
29/6/16
30/6/17
30/6/18
30/6/19
29/6/20
30/6/21
30/6/22
30/6/23
29/6/24
Simulation Time (date)

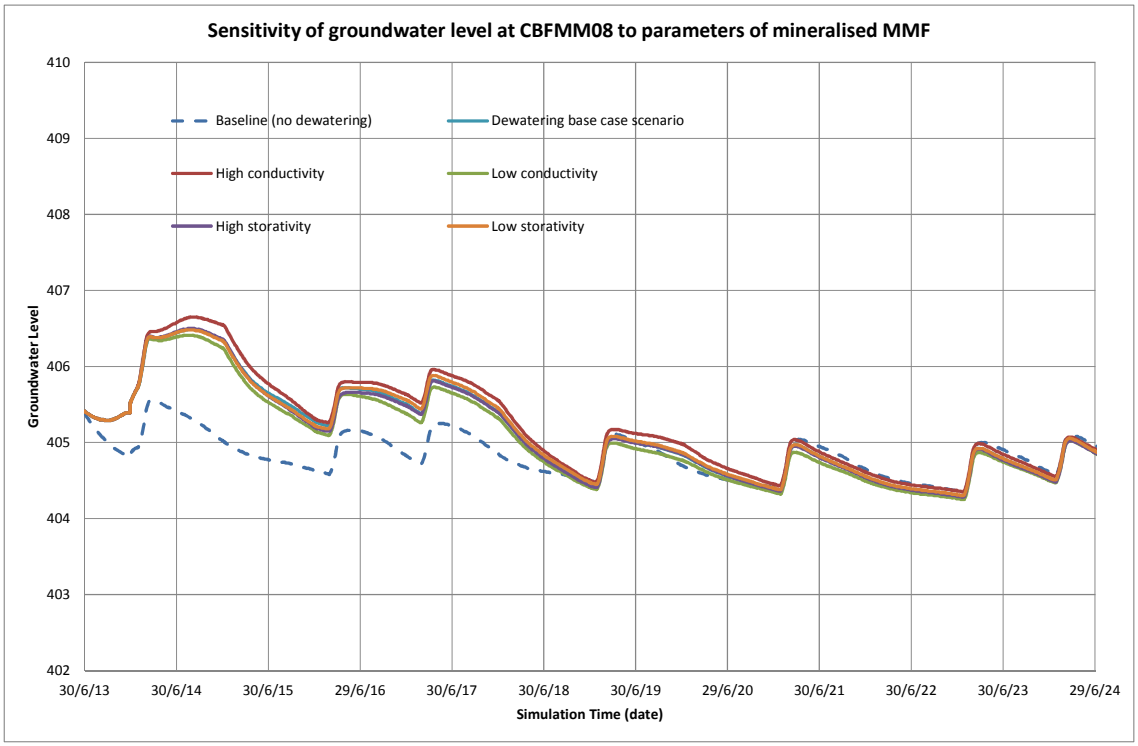

Sensitivity of groundwater level at CBFMM05 to parameters of Oakover Formation
Baseline (no dewatering)
Dewatering base case scenario
High conductivity
Low conductivity
High storativity
Low storativity
Groundwater Level (m AHD)
410
409
408
407
406
405
404
403
402
30/6/13
30/6/14
30/6/15
29/6/16
30/6/17
30/6/18
30/6/19
29/6/20
30/6/21
30/6/22
30/6/23
29/6/24
Simulation Time (date)


Sensitivity of groundwater level at CBFMM05 to parameters of mineralised MMF
Baseline (no dewatering)
Dewatering base case scenario
High conductivity
Low conductivity
High storativity
Low storativity
Groundwater Level
410
409
408
407
406
405
404
403
402
30/6/13
30/6/14
30/6/15
29/6/16
30/6/17
30/6/18
30/6/19
29/6/20
30/6/21
30/6/22
30/6/23
29/6/24
Simulation Time (date)


Sensitivity of groundwater level at CBFMM07 to parameters of Oakover Formation
Baseline (no dewatering)
Dewatering base case scenario
High conductivity
Low conductivity
High storativity
Low storativity
Groundwater Level (m AHD)
410
409
408
407
406
405
404
403
402
30/6/13
30/6/14
30/6/15
29/6/16
30/6/17
30/6/18
30/6/19
29/6/20
30/6/21
30/6/22
30/6/23
29/6/24
Simulation Time (date)

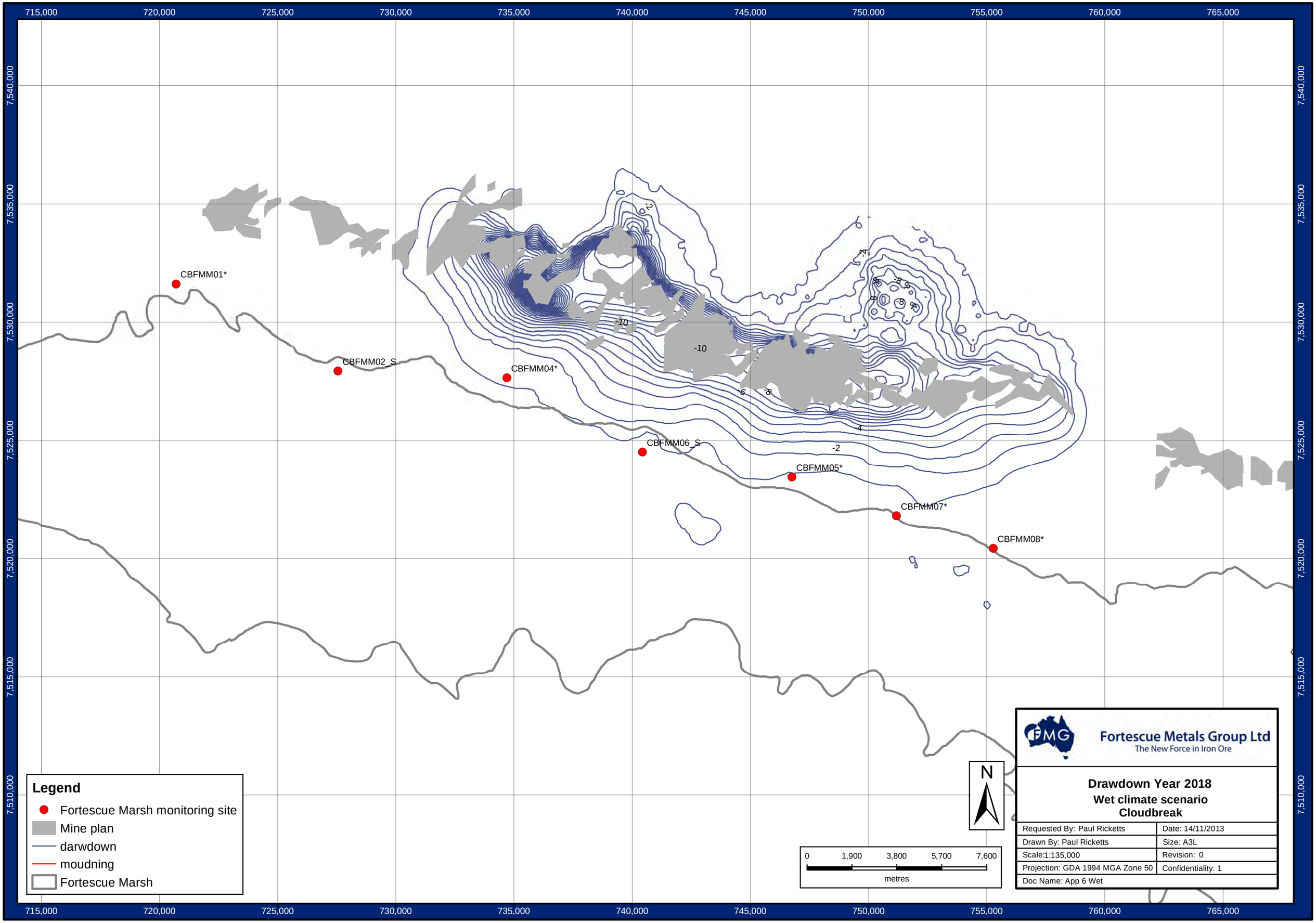

Sensitivity of groundwater level at CBFMM07 to parameters of mineralised MMF
Baseline (no dewatering)
Dewatering base case scenario
High conductivity
Low conductivity
High storativity
Low storativity
Groundwater Level
410
409
408
407
406
405
404
403
402
30/6/13
30/6/14
30/6/15
29/6/16
30/6/17
30/6/18
30/6/19
29/6/20
30/6/21
30/6/22
30/6/23
29/6/24
Simulation Time (date)


Sensitivity of groundwater level at CBFMM08 to parameters of Oakover Formation
Baseline (no dewatering)
Dewatering base case scenario
High conductivity
Low conductivity
High storativity
Low storativity
Groundwater Level (m AHD)
410
409
408
407
406
405
404
403
402
30/6/13
30/6/14
30/6/15
29/6/16
30/6/17
30/6/18
30/6/19
29/6/20
30/6/21
30/6/22
30/6/23
29/6/24
Simulation Time (date)


Sensitivity of groundwater level at CBFMM08 to parameters of mineralised MMF
Baseline (no dewatering)
Dewatering base case scenario
High conductivity
Low conductivity
High storativity
Low storativity
Groundwater Level
410
409
408
407
406
405
404
403
402
30/6/13
30/6/14
30/6/15
29/6/16
30/6/17
30/6/18
30/6/19
29/6/20
30/6/21
30/6/22
30/6/23
29/6/24
Simulation Time (date)

Appendix 6: Distribution of drawdown/mounding and depth to groundwater predicted under dry and wet climatic simulations

This page has been left blank intentionally


715,000
720,000
725,000
730,000
735,000
740,000
745,000
750,000
755,000
760,000
765,000
7,540,000
7,535,000
7,530,000
7,525,000
7,520,000
7,515,000
7,510,000
CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*
-2
-4
-6
-8
-10
Legend
Fortescue Marsh monitoring site
Mine plan
darwdown
moudning
Fortescue Marsh
N
0
1,900
3,800
5,700
7,600
metres
Fortescue Metals Group Ltd
The New Force in Iron Ore
Drawdown Year 2018
Wet climate scenario
Cloudbreak
Requested By: Paul Ricketts
Date: 14/11/2013
Drawn By: Paul Ricketts
Size: A3L
Scale:1:135,000
Revision: 0
Projection: GDA 1994 MGA Zone 50
Confidentiality: 1
Doc Name: App 6 Wet

715,000 720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000 765,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

CBFMM01*

CBFMM02_S

CBFMM04*

CBFMM06_S

CBFMM05*

CBFMM07*

CBFMM08*

-2 -4 -6 -8 -10

Legend

- Fortescue Marsh monitoring site
- Mine plan
- drawdown
- mounding
- Fortescue Marsh

N

0 1,900 3,800 5,700 7,600

metres

Fortescue Metals Group Ltd
The New Force in Iron Ore

Drawdown Year 2017
Wet climate scenario
Cloudbreak

Requested By: Paul Ricketts	Date: 14/11/2013
Drawn By: Paul Ricketts	Size: A3L
Scale:1:135,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: App 6 Wet	

715,000 720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000 765,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

CBFMM01*

CBFMM02_S

CBFMM04*

CBFMM06_S

CBFMM05*

CBFMM07*

CBFMM08*

Legend

- Fortescue Marsh monitoring site
- Mine plan
- drawdown
- mounding
- Fortescue Marsh

N

0 1,900 3,800 5,700 7,600

metres

Fortescue Metals Group Ltd
The New Force in Iron Ore

Drawdown Year 2016
Wet climate scenario
Cloudbreak

Requested By: Paul Ricketts	Date: 14/11/2013
Drawn By: Paul Ricketts	Size: A3L
Scale:1:135,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: App 6 Wet	

715,000 720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000 765,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

CBFMM01*

CBFMM02_S

CBFMM04*

CBFMM06_S

CBFMM05*

CBFMM07*

CBFMM08*

Legend

- Fortescue Marsh monitoring site
- Mine plan
- drawdown
- mounding
- Fortescue Marsh

N

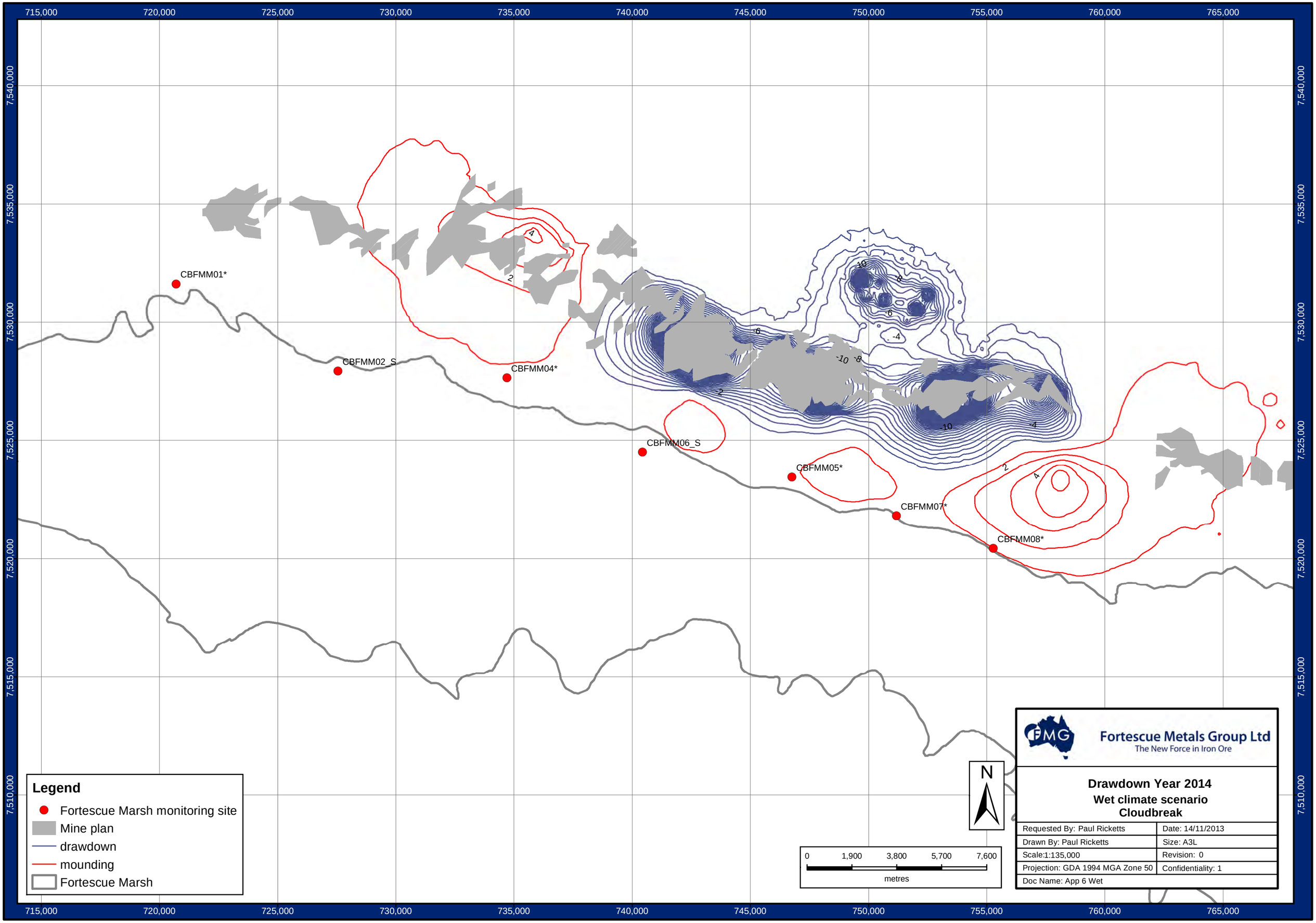
0 1,900 3,800 5,700 7,600

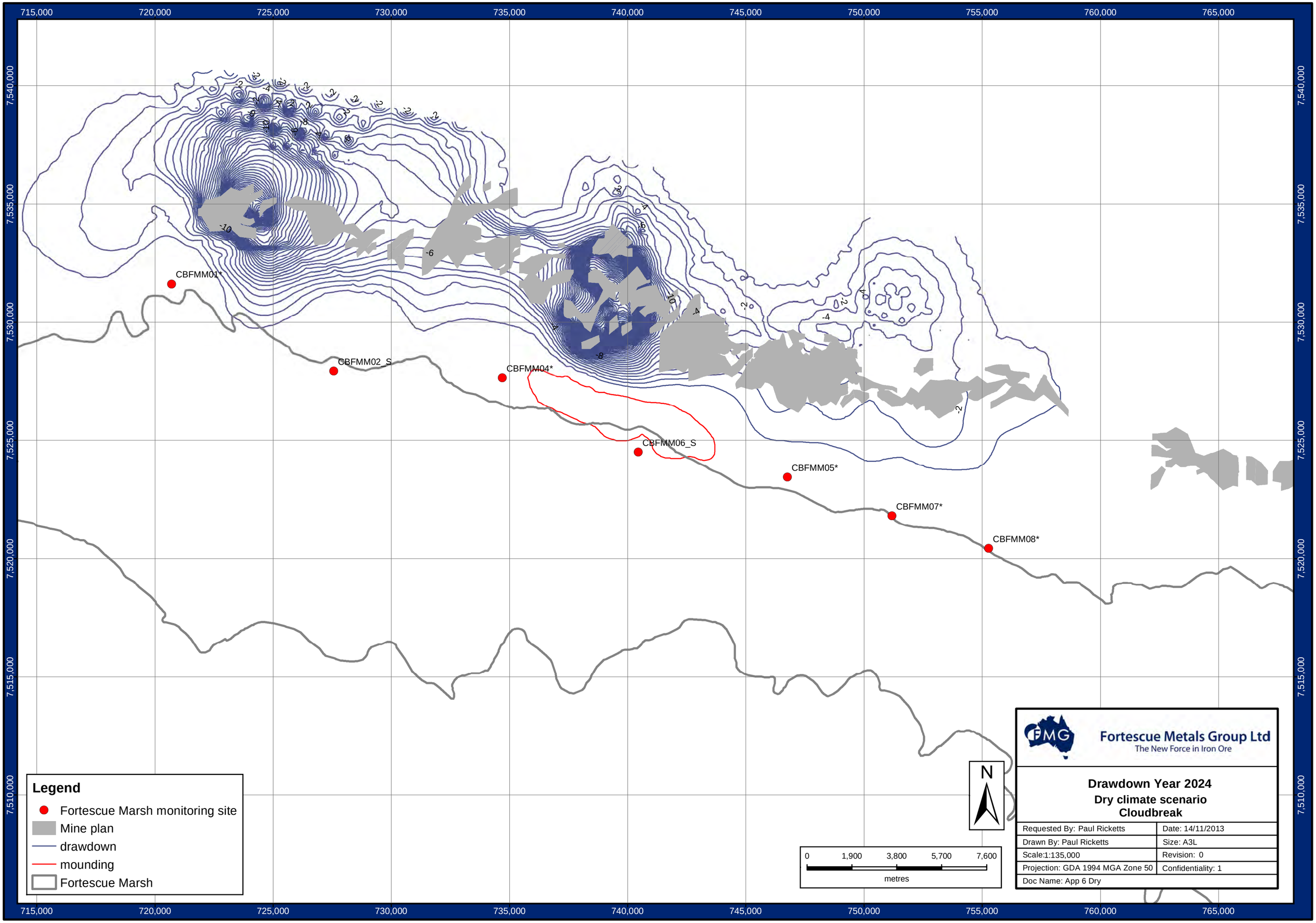
metres

Fortescue Metals Group Ltd
The New Force in Iron Ore

Drawdown Year 2015
Wet climate scenario
Cloudbreak

Requested By: Paul Ricketts	Date: 14/11/2013
Drawn By: Paul Ricketts	Size: A3L
Scale:1:135,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: App 6 Wet	


715,000
720,000
725,000
730,000
735,000
740,000
745,000
750,000
755,000
760,000
765,000
7,540,000
7,535,000
7,530,000
7,525,000
7,520,000
7,515,000
7,510,000
CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*
2
4
-2
-4
-6
-8
-10
Legend
Fortescue Marsh monitoring site
Mine plan
drawdown
mounding
Fortescue Marsh
N
0
1,900
3,800
5,700
7,600
metres
Fortescue Metals Group Ltd
The New Force in Iron Ore
Drawdown Year 2014
Wet climate scenario
Cloudbreak
Requested By: Paul Ricketts
Date: 14/11/2013
Drawn By: Paul Ricketts
Size: A3L
Scale:1:135,000
Revision: 0
Projection: GDA 1994 MGA Zone 50
Confidentiality: 1
Doc Name: App 6 Wet


715,000
720,000
725,000
730,000
735,000
740,000
745,000
750,000
755,000
760,000
765,000
7,540,000
7,535,000
7,530,000
7,525,000
7,520,000
7,515,000
7,510,000
CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*
Legend
Fortescue Marsh monitoring site
Mine plan
drawdown
mounding
Fortescue Marsh
N
0
1,900
3,800
5,700
7,600
metres
Fortescue Metals Group Ltd
The New Force in Iron Ore
Drawdown Year 2024
Dry climate scenario
Cloudbreak
Requested By: Paul Ricketts
Date: 14/11/2013
Drawn By: Paul Ricketts
Size: A3L
Scale:1:135,000
Revision: 0
Projection: GDA 1994 MGA Zone 50
Confidentiality: 1
Doc Name: App 6 Dry

715,000 720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000 765,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*

Legend

- Fortescue Marsh monitoring site
- Mine plan
- drawdown
- mounding
- Fortescue Marsh

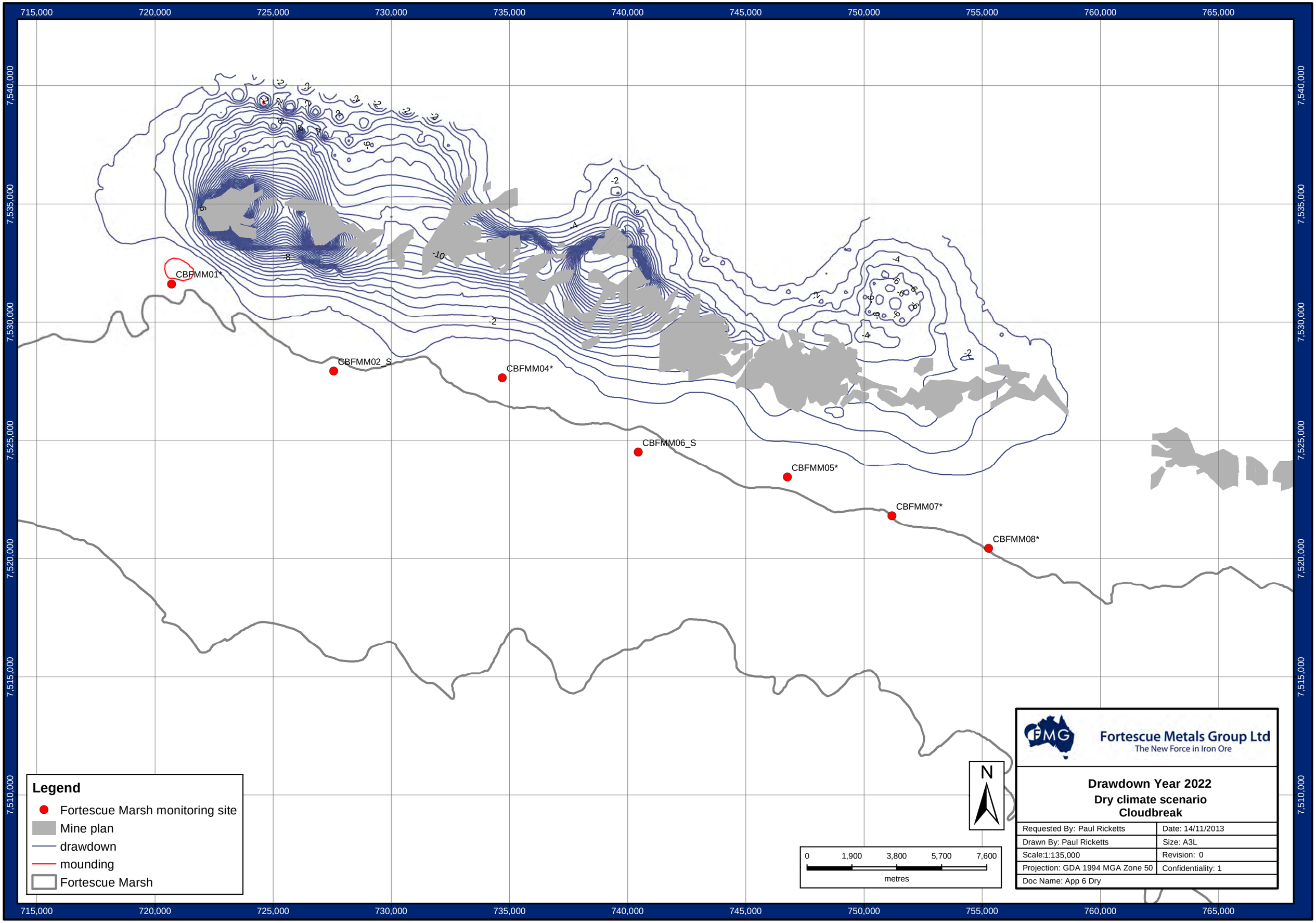
N

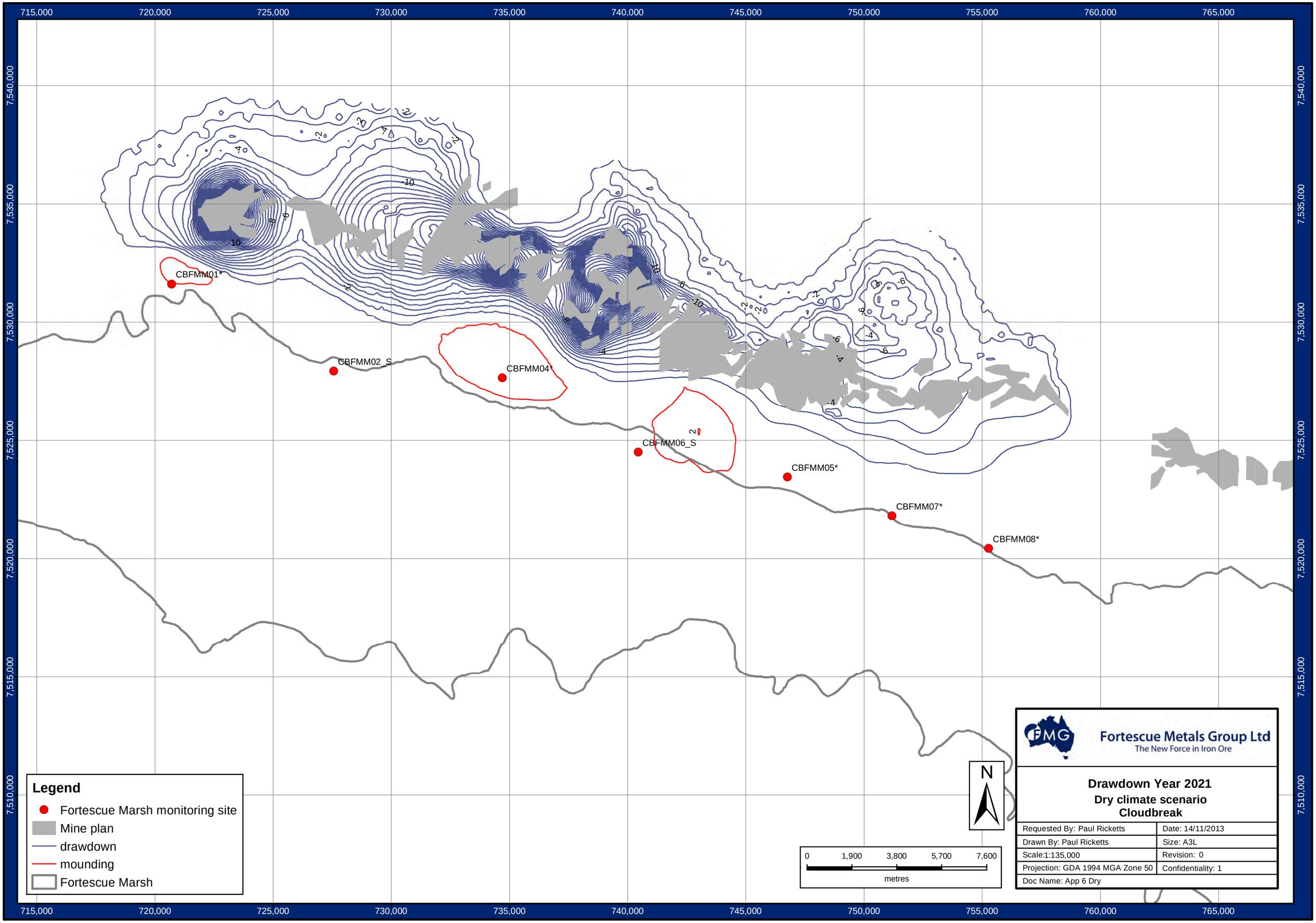
0 1,900 3,800 5,700 7,600
metres

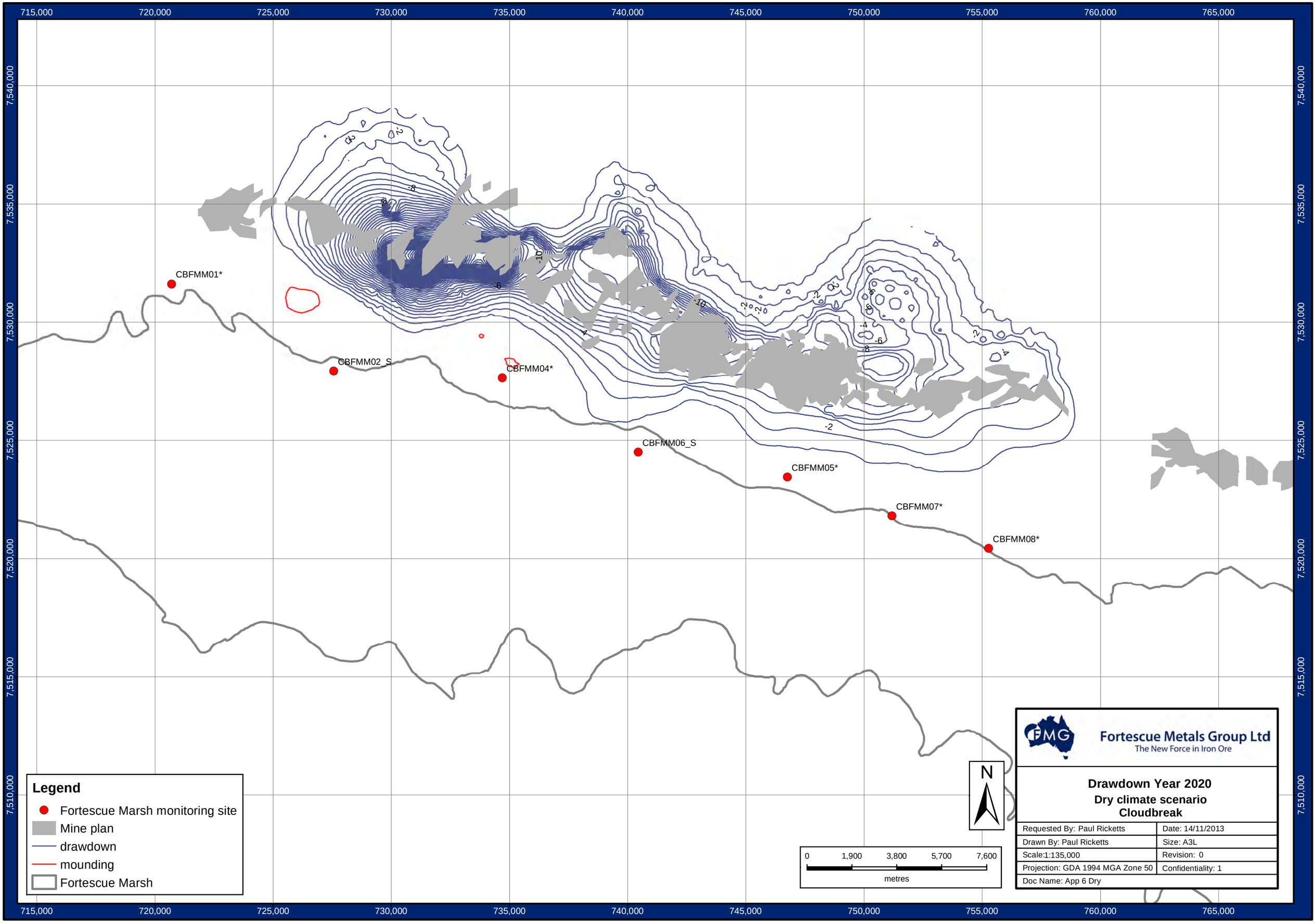
Fortescue Metals Group Ltd
The New Force in Iron Ore

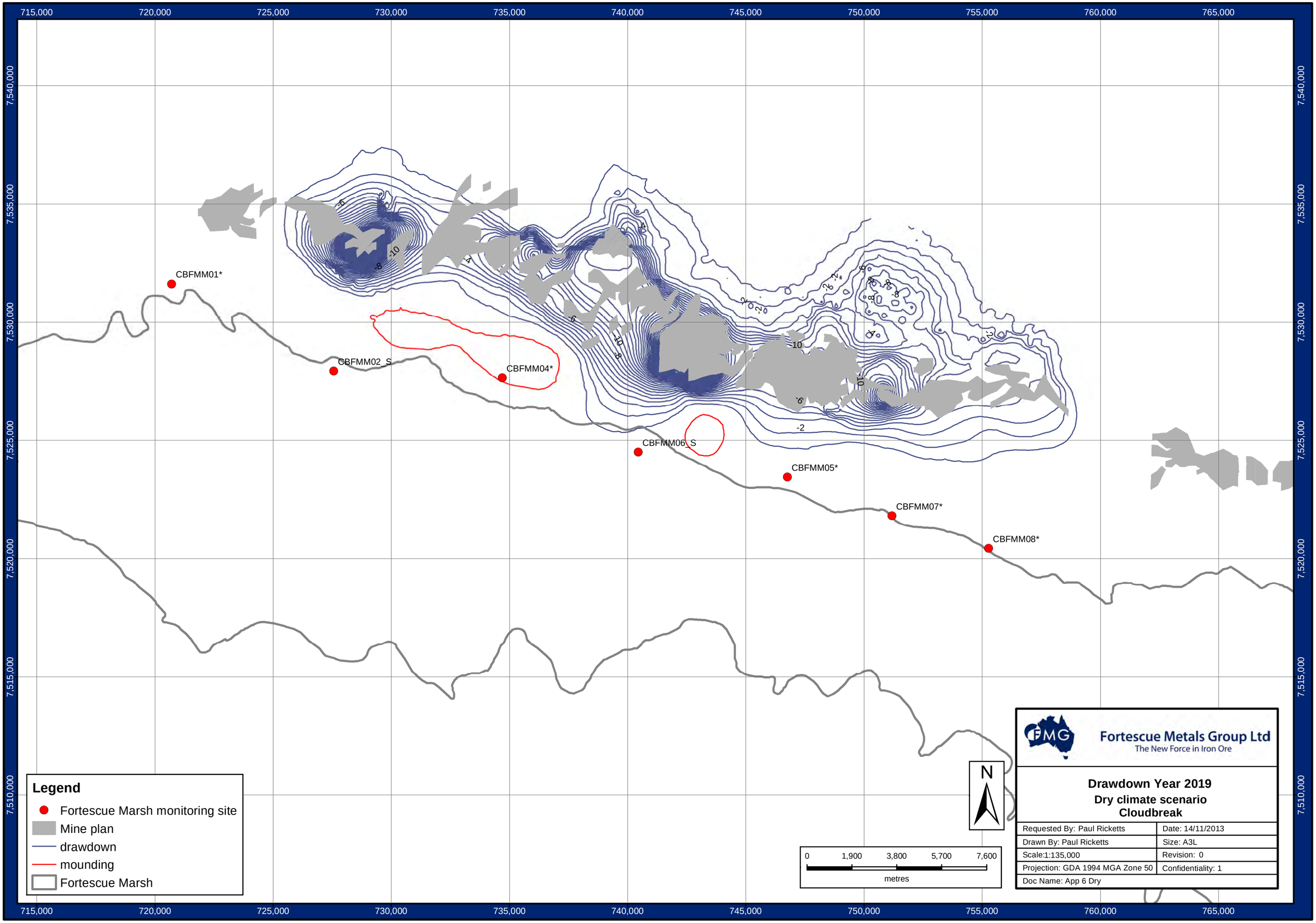
Drawdown Year 2023
Dry climate scenario
Cloudbreak

Requested By: Paul Ricketts	Date: 14/11/2013
Drawn By: Paul Ricketts	Size: A3L
Scale:1:135,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: App 6 Dry	


715,000
720,000
725,000
730,000
735,000
740,000
745,000
750,000
755,000
760,000
765,000
7,540,000
7,535,000
7,530,000
7,525,000
7,520,000
7,515,000
7,510,000
CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*
-2
-4
-6
-8
-10
Legend
Fortescue Marsh monitoring site
Mine plan
drawdown
mounding
Fortescue Marsh
N
0
1,900
3,800
5,700
7,600
metres
FMG
Fortescue Metals Group Ltd
The New Force in Iron Ore
Drawdown Year 2022
Dry climate scenario
Cloudbreak
Requested By: Paul Ricketts
Date: 14/11/2013
Drawn By: Paul Ricketts
Size: A3L
Scale:1:135,000
Revision: 0
Projection: GDA 1994 MGA Zone 50
Confidentiality: 1
Doc Name: App 6 Dry


715,000
720,000
725,000
730,000
735,000
740,000
745,000
750,000
755,000
760,000
765,000
7,540,000
7,535,000
7,530,000
7,525,000
7,520,000
7,515,000
7,510,000
CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*
Legend
Fortescue Marsh monitoring site
Mine plan
drawdown
mounding
Fortescue Marsh
N
0
1,900
3,800
5,700
7,600
metres
Fortescue Metals Group Ltd
The New Force in Iron Ore
Drawdown Year 2021
Dry climate scenario
Cloudbreak
Requested By: Paul Ricketts
Date: 14/11/2013
Drawn By: Paul Ricketts
Size: A3L
Scale:1:135,000
Revision: 0
Projection: GDA 1994 MGA Zone 50
Confidentiality: 1
Doc Name: App 6 Dry


715,000
720,000
725,000
730,000
735,000
740,000
745,000
750,000
755,000
760,000
765,000
7,540,000
7,535,000
7,530,000
7,525,000
7,520,000
7,515,000
7,510,000
CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*
-2
-4
-6
-8
-10
Legend
Fortescue Marsh monitoring site
Mine plan
drawdown
mounding
Fortescue Marsh
N
0
1,900
3,800
5,700
7,600
metres
Fortescue Metals Group Ltd
The New Force in Iron Ore
Drawdown Year 2020
Dry climate scenario
Cloudbreak
Requested By: Paul Ricketts
Date: 14/11/2013
Drawn By: Paul Ricketts
Size: A3L
Scale:1:135,000
Revision: 0
Projection: GDA 1994 MGA Zone 50
Confidentiality: 1
Doc Name: App 6 Dry


715,000
720,000
725,000
730,000
735,000
740,000
745,000
750,000
755,000
760,000
765,000
7,540,000
7,535,000
7,530,000
7,525,000
7,520,000
7,515,000
7,510,000
CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*
-10
-8
-6
-4
-2
Legend
Fortescue Marsh monitoring site
Mine plan
drawdown
mounding
Fortescue Marsh
N
0
1,900
3,800
5,700
7,600
metres
Fortescue Metals Group Ltd
The New Force in Iron Ore
Drawdown Year 2019
Dry climate scenario
Cloudbreak
Requested By: Paul Ricketts
Date: 14/11/2013
Drawn By: Paul Ricketts
Size: A3L
Scale:1:135,000
Revision: 0
Projection: GDA 1994 MGA Zone 50
Confidentiality: 1
Doc Name: App 6 Dry

715,000 720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000 765,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*

-2 -4 -6 -8 -10

Legend

- Fortescue Marsh monitoring site
- Mine plan
- drawdown
- mounding
- Fortescue Marsh

N

0 1,900 3,800 5,700 7,600
metres

Fortescue Metals Group Ltd
The New Force in Iron Ore

Drawdown Year 2018
Dry climate scenario
Cloudbreak

Requested By: Paul Ricketts	Date: 14/11/2013
Drawn By: Paul Ricketts	Size: A3L
Scale:1:135,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: App 6 Dry	

715,000 720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000 765,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

CBFMM01*

CBFMM02_S

CBFMM04*

CBFMM06_S

CBFMM05*

CBFMM07*

CBFMM08*

Legend

- Fortescue Marsh monitoring site
- Mine plan
- drawdown
- mounding
- Fortescue Marsh

N

0 1,900 3,800 5,700 7,600

metres

Fortescue Metals Group Ltd
The New Force in Iron Ore

Drawdown Year 2017
Dry climate scenario
Cloudbreak

Requested By: Paul Ricketts	Date: 14/11/2013
Drawn By: Paul Ricketts	Size: A3L
Scale:1:135,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: App 6 Dry	

715,000 720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000 765,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

CBFMM01*

CBFMM02_S

CBFMM04*

CBFMM06_S

CBFMM05*

CBFMM07*

CBFMM08*

2 -4 -10 -8 -6 -2

Legend

- Fortescue Marsh monitoring site
- Mine plan
- drawdown
- mounding
- Fortescue Marsh

N

0 1,900 3,800 5,700 7,600

metres

Fortescue Metals Group Ltd

The New Force in Iron Ore

Drawdown Year 2016

Dry climate scenario

Cloudbreak

Requested By: Paul Ricketts	Date: 14/11/2013
Drawn By: Paul Ricketts	Size: A3L
Scale:1:135,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: App 6 Dry	

715,000 720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000 765,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

CBFMM01*

CBFMM02_S

CBFMM04*

CBFMM06_S

CBFMM05*

CBFMM07*

CBFMM08*

2 -2 -4 -6 -8 -10

N

0 1,900 3,800 5,700 7,600

metres

Legend

- Fortescue Marsh monitoring site
- Mine plan
- drawdown
- mounding
- Fortescue Marsh

Fortescue Metals Group Ltd
The New Force in Iron Ore

Drawdown Year 2015
Dry climate scenario
Cloudbreak

Requested By: Paul Ricketts	Date: 14/11/2013
Drawn By: Paul Ricketts	Size: A3L
Scale:1:135,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: App 6 Dry	

715,000 720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000 765,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*

4 2 2 -6 -4 -10 -8 6 -8 -16 -4 -10 4 2

Legend

- Fortescue Marsh monitoring site
- Mine plan
- drawdown
- mounding
- Fortescue Marsh

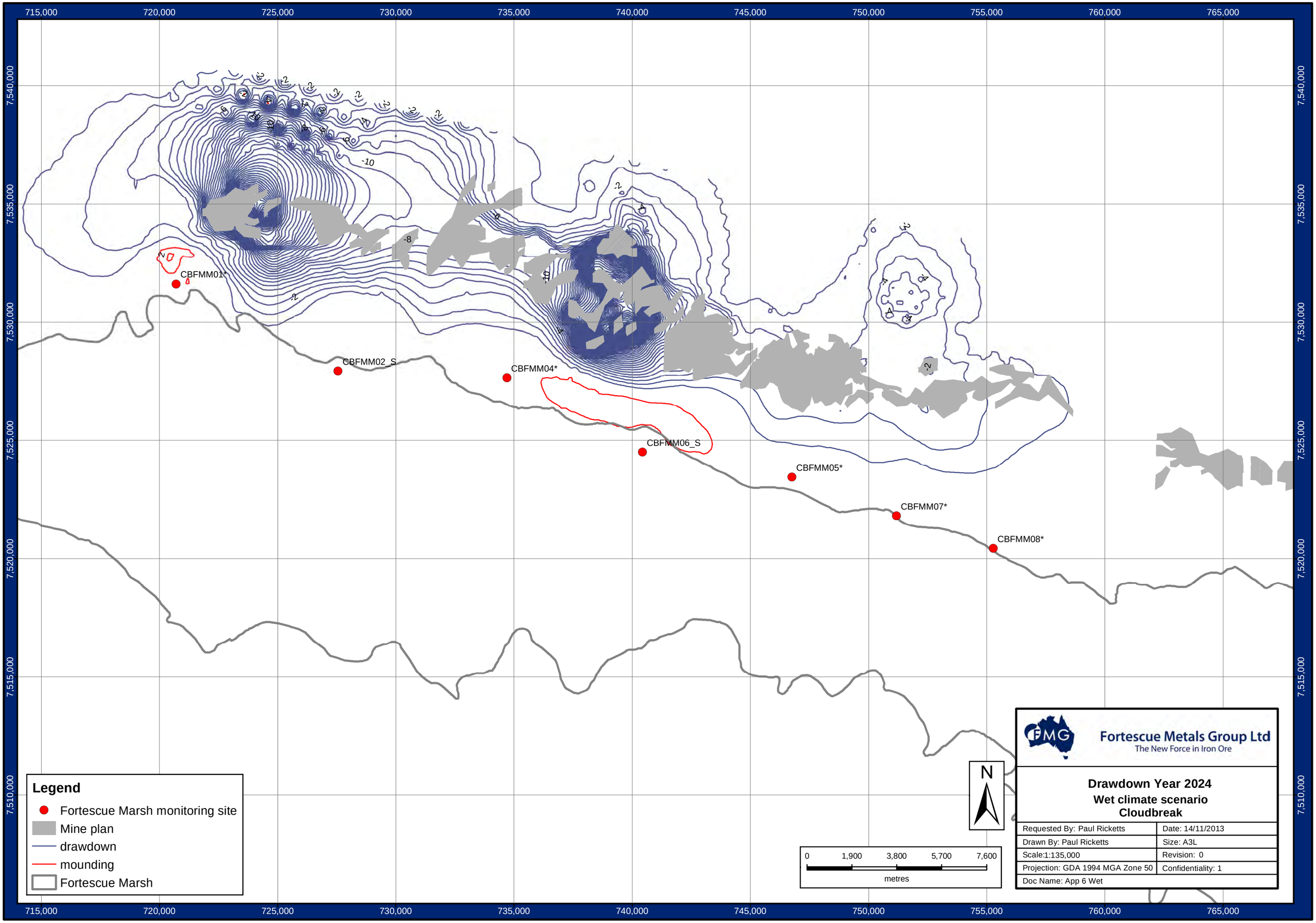
N

0 1,900 3,800 5,700 7,600
metres

Fortescue Metals Group Ltd
The New Force in Iron Ore

Drawdown Year 2014
Dry climate scenario
Cloudbreak

Requested By: Paul Ricketts	Date: 14/11/2013
Drawn By: Paul Ricketts	Size: A3L
Scale:1:135,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: App 6 Dry	


715,000
720,000
725,000
730,000
735,000
740,000
745,000
750,000
755,000
760,000
765,000
7,540,000
7,535,000
7,530,000
7,525,000
7,520,000
7,515,000
7,510,000
CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*
-2
-4
-6
-8
-10
Legend
Fortescue Marsh monitoring site
Mine plan
drawdown
mounding
Fortescue Marsh
N
0
1,900
3,800
5,700
7,600
metres
Fortescue Metals Group Ltd
The New Force in Iron Ore
Drawdown Year 2024
Wet climate scenario
Cloudbreak
Requested By: Paul Ricketts
Date: 14/11/2013
Drawn By: Paul Ricketts
Size: A3L
Scale:1:135,000
Revision: 0
Projection: GDA 1994 MGA Zone 50
Confidentiality: 1
Doc Name: App 6 Wet

715,000 720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000 765,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*

Legend

- Fortescue Marsh monitoring site
- Mine plan
- drawdown
- mounding
- Fortescue Marsh

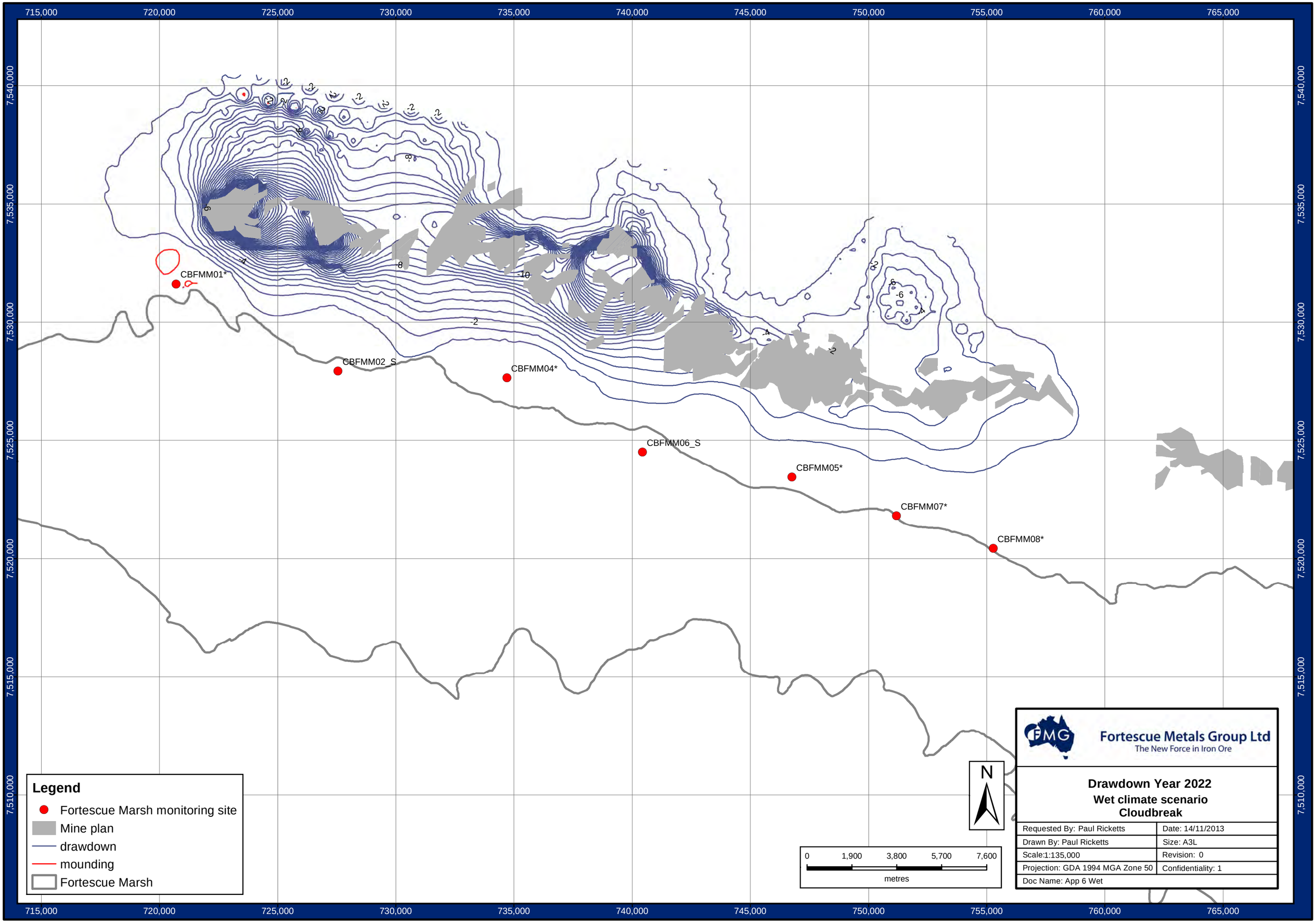
N

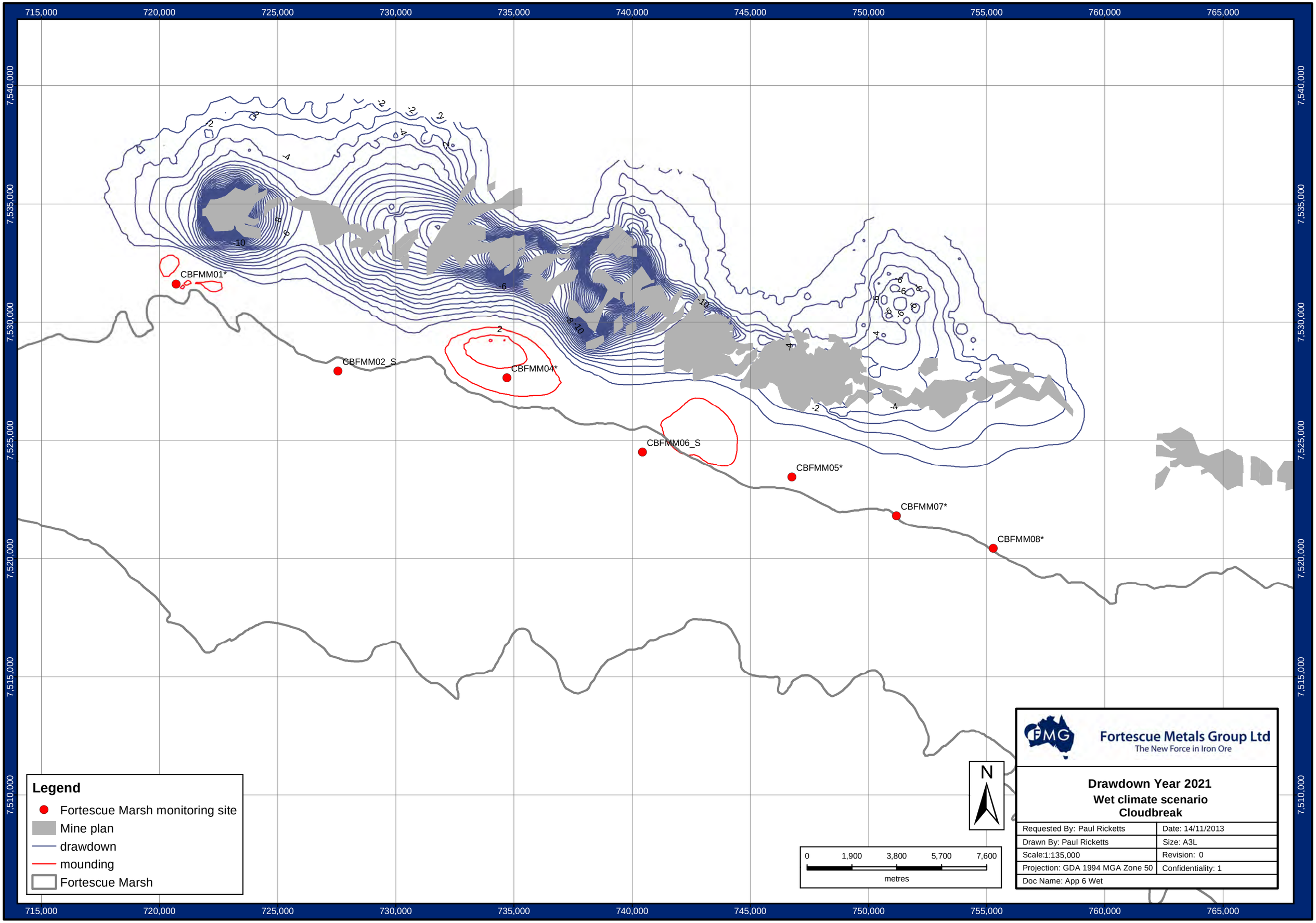
0 1,900 3,800 5,700 7,600
metres

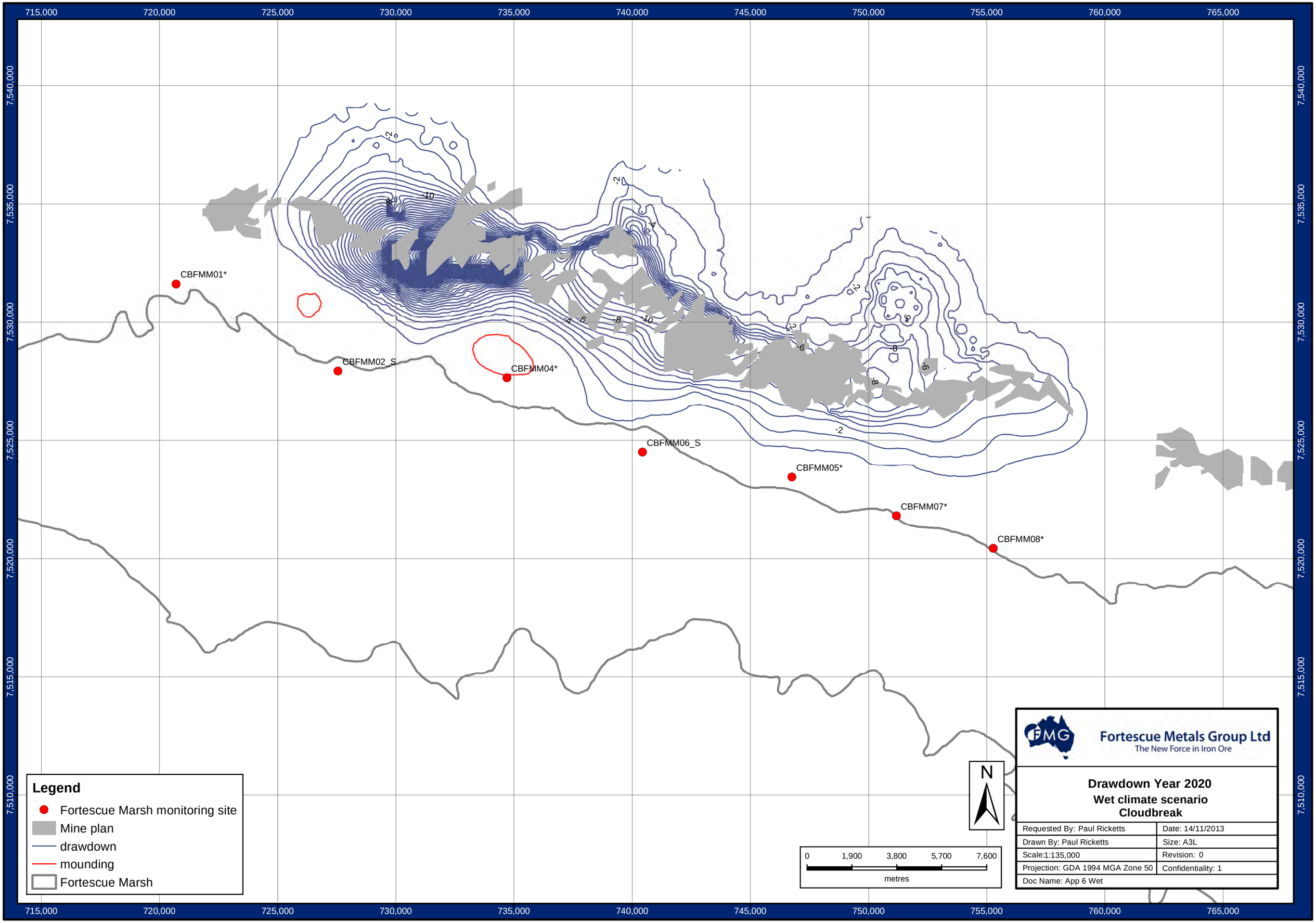
Fortescue Metals Group Ltd
The New Force in Iron Ore

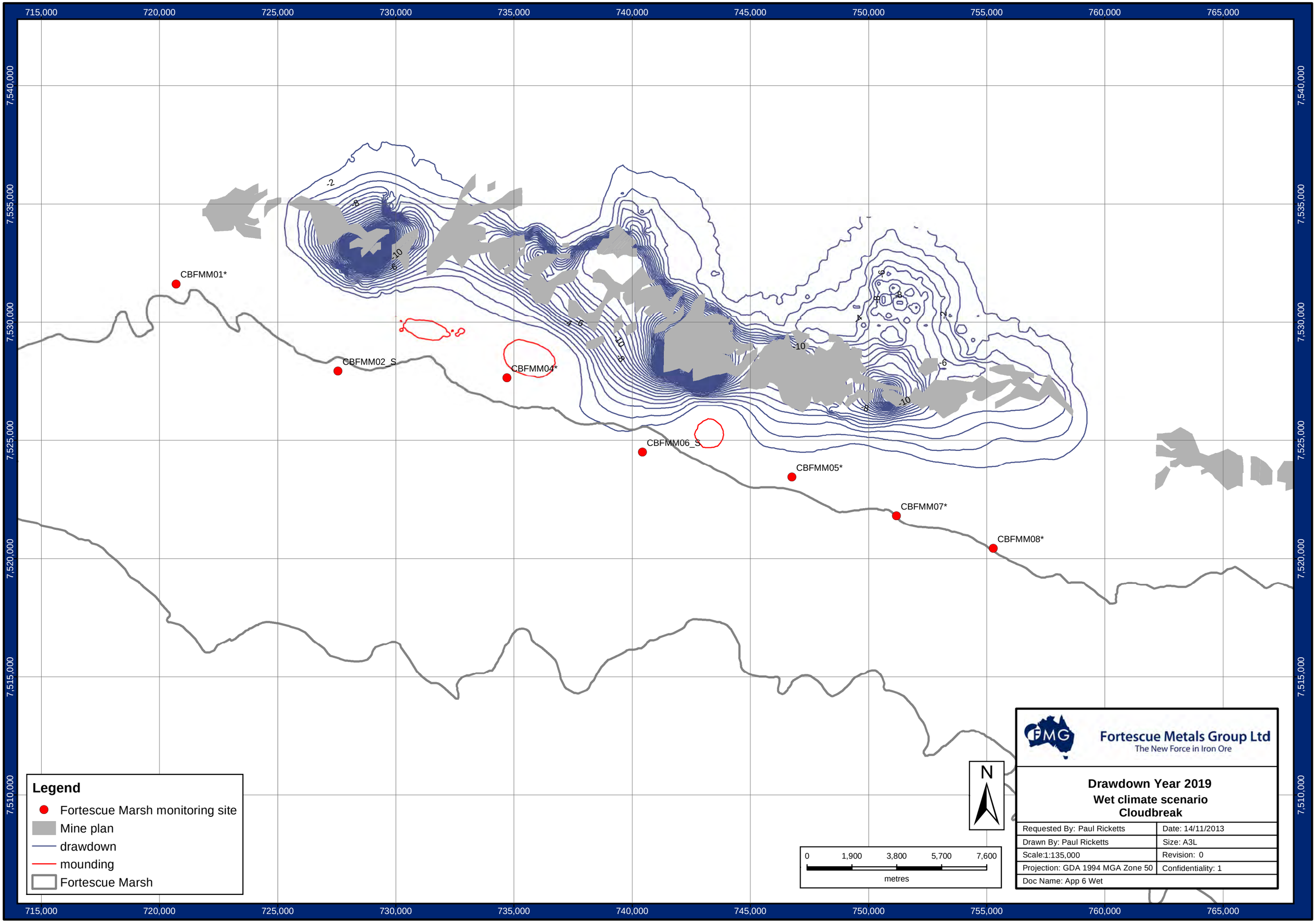
Drawdown Year 2023
Wet climate scenario
Cloudbreak

Requested By: Paul Ricketts	Date: 14/11/2013
Drawn By: Paul Ricketts	Size: A3L
Scale:1:135,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: App 6 Wet	


715,000
720,000
725,000
730,000
735,000
740,000
745,000
750,000
755,000
760,000
765,000
7,540,000
7,535,000
7,530,000
7,525,000
7,520,000
7,515,000
7,510,000
CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*
Legend
Fortescue Marsh monitoring site
Mine plan
drawdown
mounding
Fortescue Marsh
N
0
1,900
3,800
5,700
7,600
metres
Fortescue Metals Group Ltd
The New Force in Iron Ore
Drawdown Year 2022
Wet climate scenario
Cloudbreak
Requested By: Paul Ricketts
Date: 14/11/2013
Drawn By: Paul Ricketts
Size: A3L
Scale:1:135,000
Revision: 0
Projection: GDA 1994 MGA Zone 50
Confidentiality: 1
Doc Name: App 6 Wet


715,000
720,000
725,000
730,000
735,000
740,000
745,000
750,000
755,000
760,000
765,000
7,540,000
7,535,000
7,530,000
7,525,000
7,520,000
7,515,000
7,510,000
CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*
Legend
Fortescue Marsh monitoring site
Mine plan
drawdown
mounding
Fortescue Marsh
N
0
1,900
3,800
5,700
7,600
metres
Fortescue Metals Group Ltd
The New Force in Iron Ore
Drawdown Year 2021
Wet climate scenario
Cloudbreak
Requested By: Paul Ricketts
Date: 14/11/2013
Drawn By: Paul Ricketts
Size: A3L
Scale:1:135,000
Revision: 0
Projection: GDA 1994 MGA Zone 50
Confidentiality: 1
Doc Name: App 6 Wet


715,000
720,000
725,000
730,000
735,000
740,000
745,000
750,000
755,000
760,000
765,000
7,540,000
7,535,000
7,530,000
7,525,000
7,520,000
7,515,000
7,510,000
CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*
-2
-4
-6
-8
-10
Legend
Fortescue Marsh monitoring site
Mine plan
drawdown
mounding
Fortescue Marsh
N
0
1,900
3,800
5,700
7,600
metres
FMG
Fortescue Metals Group Ltd
The New Force in Iron Ore
Drawdown Year 2020
Wet climate scenario
Cloudbreak
Requested By: Paul Ricketts
Date: 14/11/2013
Drawn By: Paul Ricketts
Size: A3L
Scale:1:135,000
Revision: 0
Projection: GDA 1994 MGA Zone 50
Confidentiality: 1
Doc Name: App 6 Wet


715,000
720,000
725,000
730,000
735,000
740,000
745,000
750,000
755,000
760,000
765,000
7,540,000
7,535,000
7,530,000
7,525,000
7,520,000
7,515,000
7,510,000
CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*
-2
-8
-10
-6
-4
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
-32
-34
-36
-38
-40
-42
-44
-46
-48
-50
-52
-54
-56
-58
-60
-62
-64
-66
-68
-70
-72
-74
-76
-78
-80
-82
-84
-86
-88
-90

Appendix 7: Groundwater level recovery after mine closure

This page has been left blank intentionally

715,000 720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

CBFMM01*

CBFMM02_S

CBFMM04*

CBFMM06_S

CBFMM05*

CBFMM07*

CBFMM08*

-2

-1

-2

-2

Legend

- Fortescue Marsh monitoring site
- Fortescue Marsh
- Mine plan
- drawdown
- mounding

N

0 1,800 3,600 5,400 7,200

metres

Fortescue Metals Group Ltd

The New Force in Iron Ore

Recovery - Drawdown Year 2084

Average climate scenario
Cloudbreak

Requested By: Paul Ricketts	Date: 15/11/2013
Drawn By: Paul Ricketts	Size: A3L
Scale:1:125,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Recovery	

715,000 720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

CBFMM01*

CBFMM02_S

CBFMM04*

CBFMM06_S

CBFMM05*

CBFMM07*

CBFMM08*

-2 -2 -2 -3 -2 -2 -1

Legend

- Fortescue Marsh monitoring site
- Fortescue Marsh
- Mine plan
- drawdown
- mounding

N

0 1,800 3,600 5,400 7,200

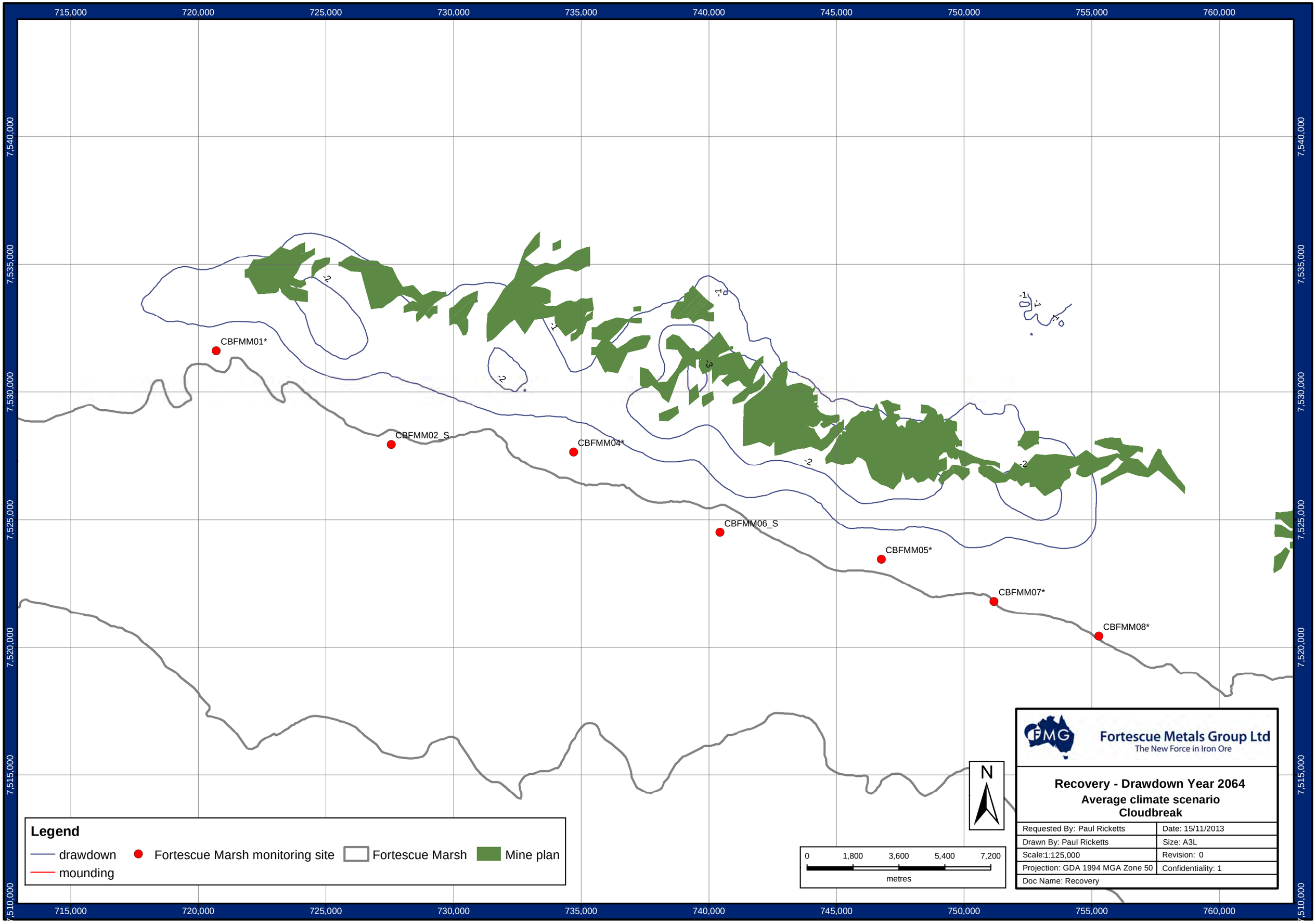
metres

Fortescue Metals Group Ltd
The New Force in Iron Ore

Recovery - Drawdown Year 2074

Average climate scenario
Cloudbreak

Requested By: Paul Ricketts	Date: 15/11/2013
Drawn By: Paul Ricketts	Size: A3L
Scale:1:125,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Recovery	


715,000
720,000
725,000
730,000
735,000
740,000
745,000
750,000
755,000
760,000
7,540,000
7,535,000
7,530,000
7,525,000
7,520,000
7,515,000
7,510,000
CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*
-1
-2
-3
Legend
drawdown
mounding
Fortescue Marsh monitoring site
Fortescue Marsh
Mine plan
N
0
1,800
3,600
5,400
7,200
metres
Fortescue Metals Group Ltd
The New Force in Iron Ore
Recovery - Drawdown Year 2064
Average climate scenario
Cloudbreak
Requested By: Paul Ricketts
Date: 15/11/2013
Drawn By: Paul Ricketts
Size: A3L
Scale:1:125,000
Revision: 0
Projection: GDA 1994 MGA Zone 50
Confidentiality: 1
Doc Name: Recovery

715,000 720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*

-1
-2
-3

Legend

- Fortescue Marsh monitoring site
- Fortescue Marsh
- Mine plan
- drawdown
- mounding

N

0 1,800 3,600 5,400 7,200
metres

Fortescue Metals Group Ltd
The New Force in Iron Ore

Recovery - Drawdown Year 2054

Average climate scenario
Cloudbreak

Requested By: Paul Ricketts	Date: 15/11/2013
Drawn By: Paul Ricketts	Size: A3L
Scale:1:125,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Recovery	

715,000 720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*

-1 -2

Legend

drawdown
mounding
Fortescue Marsh monitoring site
Fortescue Marsh
Mine plan

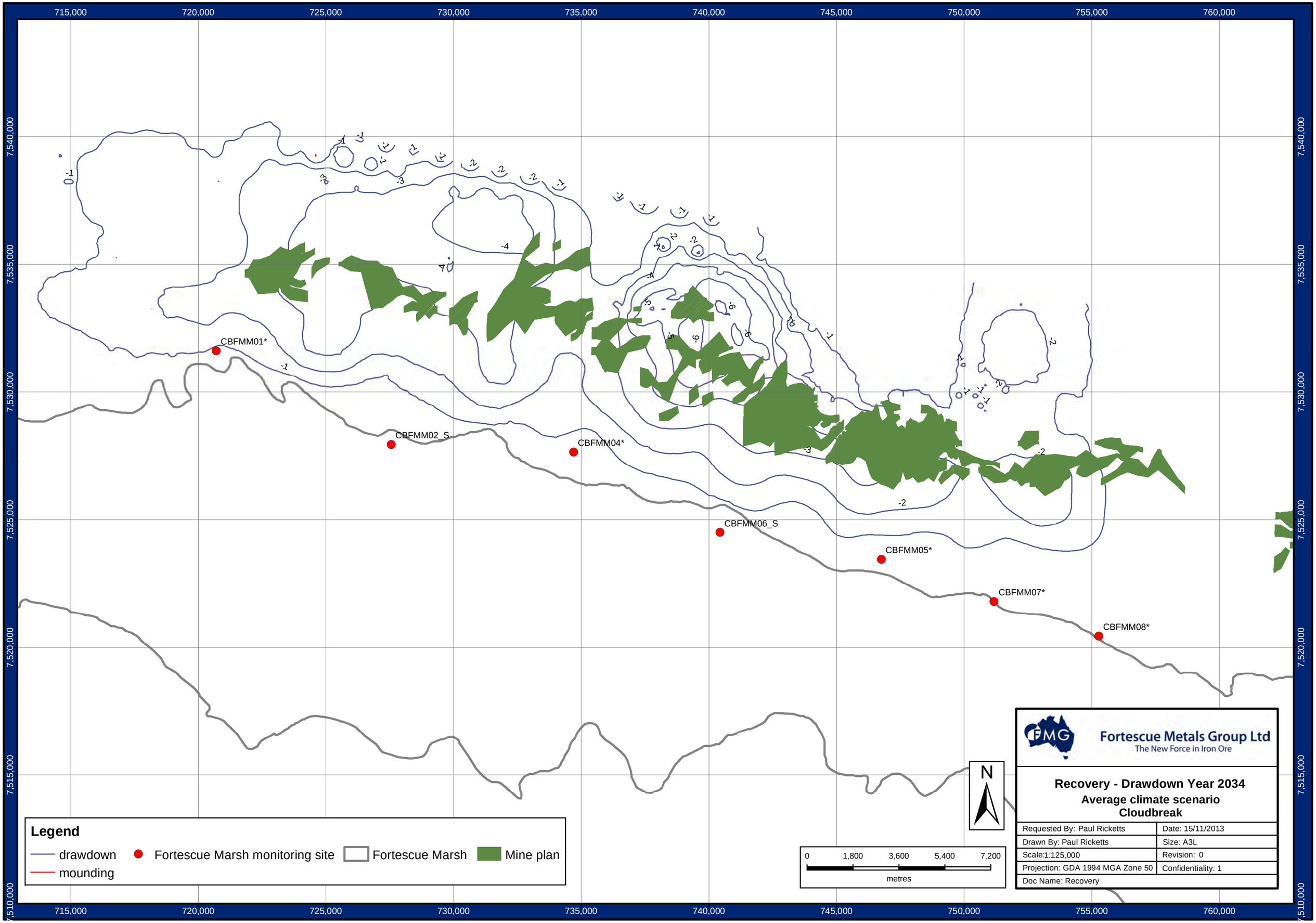
N

0 1,800 3,600 5,400 7,200
metres

Fortescue Metals Group Ltd
The New Force in Iron Ore

Recovery - Drawdown Year 2044
Average climate scenario
Cloudbreak

Requested By: Paul Ricketts	Date: 15/11/2013
Drawn By: Paul Ricketts	Size: A3L
Scale:1:125,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Recovery	


715,000
720,000
725,000
730,000
735,000
740,000
745,000
750,000
755,000
760,000
7,540,000
7,535,000
7,530,000
7,525,000
7,520,000
7,515,000
7,510,000
CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*
Legend
drawdown
mounding
Fortescue Marsh monitoring site
Fortescue Marsh
Mine plan
N
0
1,800
3,600
5,400
7,200
metres
Fortescue Metals Group Ltd
The New Force in Iron Ore
Recovery - Drawdown Year 2034
Average climate scenario
Cloudbreak
Requested By: Paul Ricketts
Date: 15/11/2013
Drawn By: Paul Ricketts
Size: A3L
Scale:1:125,000
Revision: 0
Projection: GDA 1994 MGA Zone 50
Confidentiality: 1
Doc Name: Recovery

715,000 720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

CBFMM01*

CBFMM02_S

CBFMM04*

CBFMM06_S

CBFMM05*

CBFMM07*

CBFMM08*

Legend

drawdown

mounding

Fortescue Marsh monitoring site

Fortescue Marsh

Mine plan

N

0 1,800 3,600 5,400 7,200

metres

Fortescue Metals Group Ltd

The New Force in Iron Ore

Recovery - Drawdown Year 2029

Average climate scenario

Cloudbreak

Requested By: Paul Ricketts	Date: 15/11/2013
Drawn By: Paul Ricketts	Size: A3L
Scale:1:125,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Recovery	

715,000 720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*

Legend

- Fortescue Marsh monitoring site
- Fortescue Marsh
- Mine plan
- drawdown
- mounding

N

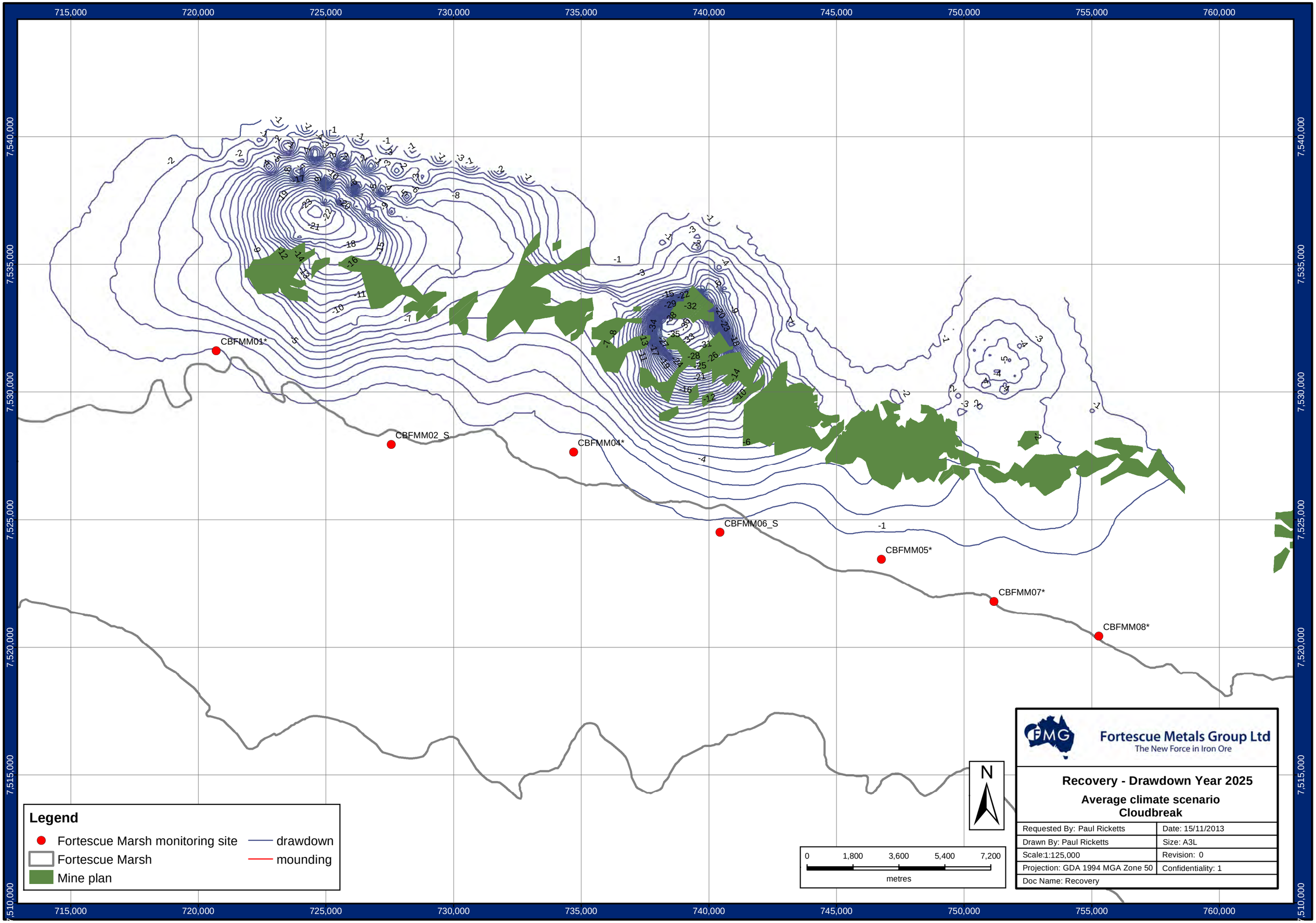
0 1,800 3,600 5,400 7,200
metres

Fortescue Metals Group Ltd
The New Force in Iron Ore

Recovery - Drawdown Year 2026

Average climate scenario
Cloudbreak

Requested By: Paul Ricketts	Date: 15/11/2013
Drawn By: Paul Ricketts	Size: A3L
Scale:1:125,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Recovery	


715,000
720,000
725,000
730,000
735,000
740,000
745,000
750,000
755,000
760,000
7,540,000
7,535,000
7,530,000
7,525,000
7,520,000
7,515,000
7,510,000
CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*
Legend
Fortescue Marsh monitoring site
Fortescue Marsh
Mine plan
drawdown
mounding
N
0
1,800
3,600
5,400
7,200
metres
Fortescue Metals Group Ltd
The New Force in Iron Ore
Recovery - Drawdown Year 2025
Average climate scenario
Cloudbreak
Requested By: Paul Ricketts
Date: 15/11/2013
Drawn By: Paul Ricketts
Size: A3L
Scale:1:125,000
Revision: 0
Projection: GDA 1994 MGA Zone 50
Confidentiality: 1
Doc Name: Recovery

715,000 720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

CBFMM01*
CBFMM02_S
CBFMM04*
CBFMM06_S
CBFMM05*
CBFMM07*
CBFMM08*

-2
-1
-2
-2

Legend

- Fortescue Marsh monitoring site
- Fortescue Marsh
- Mine plan
- drawdown
- mounding

N

0 1,800 3,600 5,400 7,200
metres

Fortescue Metals Group Ltd
The New Force in Iron Ore

Recovery - Drawdown Year 2124

Average climate scenario
Cloudbreak

Requested By: Paul Ricketts	Date: 15/11/2013
Drawn By: Paul Ricketts	Size: A3L
Scale:1:125,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Recovery	

715,000 720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

CBFMM01*

CBFMM02_S

CBFMM04*

CBFMM06_S

CBFMM05*

CBFMM07*

CBFMM08*

-2

-1

-2

-2

Legend

- Fortescue Marsh monitoring site
- Fortescue Marsh
- Mine plan
- drawdown
- mounding

N

0 1,800 3,600 5,400 7,200

metres

Fortescue Metals Group Ltd

The New Force in Iron Ore

Recovery - Drawdown Year 2104

Average climate scenario
Cloudbreak

Requested By: Paul Ricketts	Date: 15/11/2013
Drawn By: Paul Ricketts	Size: A3L
Scale:1:125,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Recovery	

Appendix 8: Effect of hydraulic property of backfilling materials on model predictions

This page has been left blank intentionally

Effect of the Hydraulic Properties of Pit Backfilling Materials

Based on FMG's mine closure plan, all mined pits will be backfilled with waste materials. The hydraulic properties of the backfilling materials are usually different from those of the original overburden and the ore. Although not actually measured, the hydraulic conductivity of the backfilling materials is likely larger than the conductivity of the original overburden, but smaller than that of the original ore. Since backfilling materials cannot be packed as dense as the original overburden, its specific yield should be larger than that of the original overburden.

Assuming that the conductivity of backfilling materials is 10 m/day (between overburden (2.5 m/day and ore (70 m) conductivities) and specific yield is 0.052 (30% larger than overburden), a simulation was setup. The results from this simulation are compared to those from the simulation that didn't consider the change of hydraulic properties after mining and the difference in dewatering volumes is presented in Figure H.1. The difference in dewatering volumes between these two simulations is less than 2.5 GL/a, except in year 2020 (3.9 GL/a). The average difference in annual dewatering volumes is only bout 4%, which is small compared to prediction uncertainties associated with other factors, such as spatial variations in hydraulic conductivity. Similarly, the difference in the spatial distribution of groundwater drawdown/mounding between the two simulations are marginal (not shown here).

In summary, neglecting the change in hydraulic parameters after mining in our model setup would not significantly change our model predictions. Therefore, all numerical simulations were conducted without considering the temporal change in hydraulic properties before and after mining.

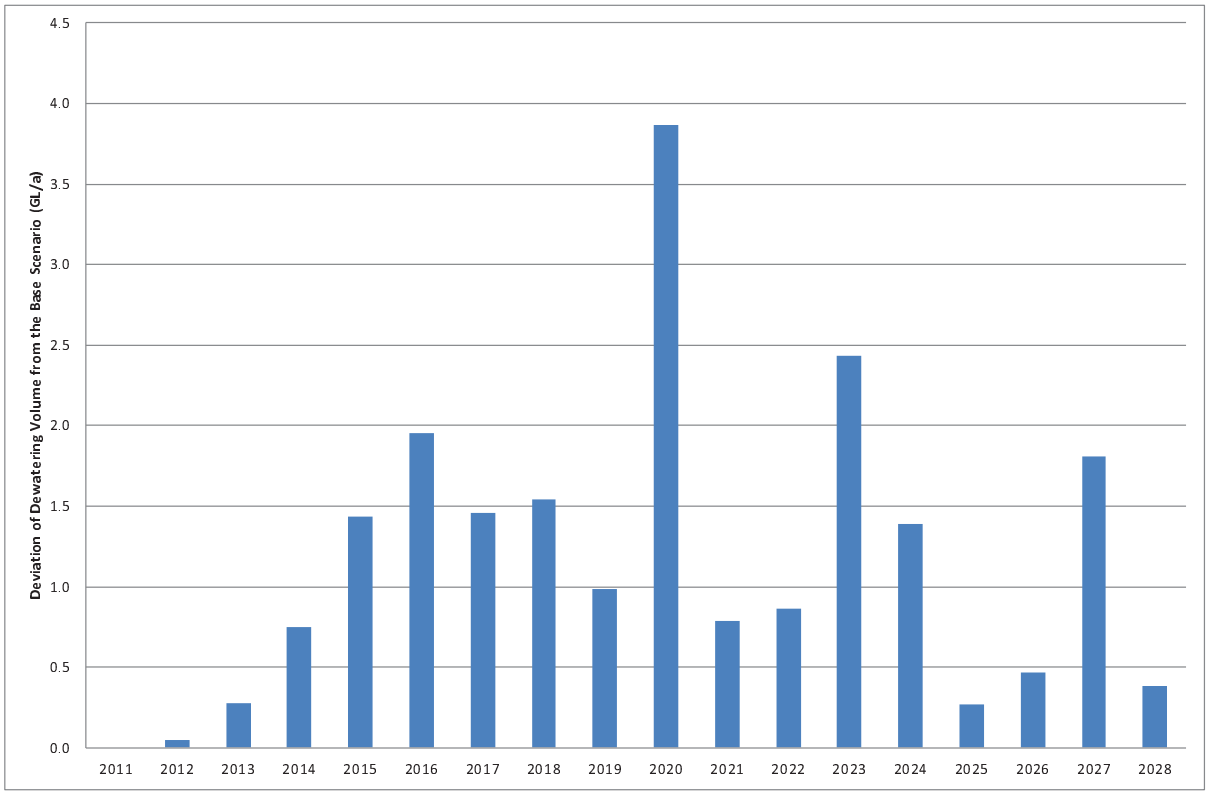


Figure H.1: Dewatering volume differences between the Base Scenario simulation and the simulation considering the changes in hydraulic properties after pits being backfilled.

Mr Paul Ricketts

Fortescue Metals Group Ltd

Level 2, 87 Adelaide Terrace

East Perth WA 6004

19 December 2013

Dear Paul

Comments from peer review – Cloudbreak LOM

HydroConcept has completed a peer review of the FMG (Fortescue Metal Group) hydrogeological assessment relating to the Cloudbreak life of mine management scheme. The review was undertaken by Mr Seth Johnson (Principal Hydrogeologist) with a focus on ensuring the conceptualisation is a realistic representation of the water regime; the numerical modelling provides reliable predictive outputs; and the water resource management strategy integrates and considers the findings.

The document presents a technical discussion on the water management approach associated with the life of the Cloudbreak operation. It has been completed to a high standard and is acceptable for submission to the different Government agencies for their review and consideration.

There has been nearly ten years of field investigations and data collection along the Chichester Range associated with Cloudbreak, as outlined in Table 1. The collection of water level and quality data since 2008 has provided a useful dataset for understanding water system response to dewatering and injection, and calibration of the numerical model. The investigation methodologies employed are appropriate and align with industry standards.

The progressive improvement in understanding of the water resources has resolved the connectivity between surface water hydrology, flooding/drying cycles of the Fortescue Marsh, and water levels within the groundwater system. Recent studies of the ecohydrology by Equinox Environmental have better explained the water regime functioning and dependency of fringing vegetation at the Marsh edge. It has been found that the Mulga species are surface water dependent, Samphire species are tolerant to more than 3 m of drawdown, and surface water processes dominate compared to groundwater.

The interpreted conceptual hydrogeology is valid for the current knowledge of the system, and forms the basis of the numerical groundwater flow model. The hydrostratigraphy is well defined with descriptions and some appreciation of variability within each unit. There is recognition of the significance of hydraulic connectivity between the Oakover Formation and ore body, as this is important for understanding potential inflows of hypersaline water from beneath the Marsh resulting in higher volumes of dewatering, injection and recirculation. Areas of improvements to the conceptual model are detailed in Table 11.

There is a proven understanding of salinity distribution, based on interpretation of an airborne electromagnetic survey, density flow modelling, and actual data from monitoring bores. The spatial

HydroConcept Pty Ltd
U12a, 7 The Esplanade, Mt Pleasant WA 6153
Tel: 0401 35 15 10
Email: seth@hydroconcept.com.au

appreciation and ongoing monitoring of the transitional saltwater interface is critical for long-term maintenance of water quality in the mining operations.

Mine dewatering and reinjection has provided opportunities to gain understanding of hydraulic response, as well as operational learning about dewatering rates and design. The water level data that has been collected, particular in 2010, 2011 and 2012, has improved hydraulic parameter determination and these results have been incorporated into the LoM assessment

The water management approach employed by FMG is considered best practice for the mining industry. The system is extensive with a comprehensive network of dewatering and injection bores linked via pipeline conveyance. The use of managed aquifer recharge has proven to be an effective method for the mitigation and management of water levels beneath and at the edge of the Marsh.

Despite the lack of groundwater monitoring beneath the Fortescue Marsh, FMG have been able to develop a conceptualisation for water processes associated with the Marsh. The conceptual approach seems appropriate, logical and representative of hydraulic functioning and interactions between flooding and drying stages. Studies related to the Fortescue Marsh by UWA and Rio Tinto Iron Ore will provide opportunities to improve the conceptual understanding of Marsh functioning.

The numerical groundwater model is based on the conceptualisation. It was developed to the requirements of the Australian Groundwater Modelling Guidelines, and the use of finite element (FeFlow) enables consideration of density-driven flow. The model has been progressively reviewed, refined and calibrated for reliable predictions of abstraction and injection volumes, assessment of potential impacts, and sizing of the water management system.

The initial model developed in 2010 was reviewed by HydroConcept. Since then, the model has been slight refined with respect to recharge distribution and some hydraulic parameters. The limited changes highlight the robustness of the conceptual model, and that the numerical model is representative and provides meaningful predictions.

The model area is sufficiently large for no boundary effects and to not compromise model outputs in the vicinity of the Marsh. There is a high level of confidence in the numerical model simulations in terms of accuracy, usefulness for water management planning, and regulatory approval. The monitoring data provided in Appendix 4 highlights the good match between actual versus modelled water levels providing confidence in the representativeness of the model. Ongoing monitoring and progressive upgrading of the model is recommended and considered an important part of operational water management.

The model has been used for a range of water management scenarios. Given the variability in climate and lack of actual rainfall data in the project area, FMG has developed a synthetic rainfall data set using a stochastic approach. This aims to represent the variability in rainfall between years and over a long timeframe, and provides the basis for scenario evaluation between wet and dry seasons.

Below are a number of the key observations from the modelling process and generated model outputs that are of importance and significance for life of mine water management at Cloudbreak.

- Water levels at the edge of the Marsh are naturally variable. In places, the water level may range from near surface to 5 m below ground level, and change by 2 to 5 m in response to differing recharge scenarios.

- As the project develops, there will be substantial volumes and water handling requirements in terms of dewatering and injection. The average dewatering (110 GL/a) and peak dewatering volume of 136 GL in 2019 are significant and will require considerable management.
- There are four years (2017, 2019, 2021 and 2024) with large dewatering and injection volumes that will prove challenging for water management, in particular injection into the Oakover Formation. It is recommended that mine planning and scheduling be reviewed to reduce these higher volumes and have a more balanced dewatering rate.
- Water recirculation will need to be closely monitored and progressively assessed over time. Opportunities for different injection approaches to reduce double handling should be considered.
- Modelling of water levels, as well as operational data, has demonstrated that aquifer injection has minimised drawdown and is an effective mitigation tool for protection of the Marsh. Aquifer injection is an important management strategy that will be an ongoing requirement and obligation.
- Demand projections suggest that brackish water will need to be managed carefully. There is potential that mine planning and dewatering schedules will need to be aligned to ensure that brackish water availability is maintained. In light of this scenario, a range of contingency measures have been suggested for consideration.
- The overall water balance is largely driven by recharge and discharge processes at the Marsh. The modelling and ecohydrological studies have demonstrated that the Marsh is a surface water dominated system and that the fringing vegetation is dependent on sheetflow and streamflow for its survival. As such, mining activities are likely to have minimal impact on the Marsh at the regional scale.
- Post-closure recovery of water levels will take many decades to reach a new equilibrium. The rate of recovery will be largely dependent on recharge, as well as the hydraulic response to backfilled materials.
- An understanding of heterogeneity is a major challenge for representation with the numerical model – there have been improvements in this area since 2010. Appendix 8 highlights that the hydraulic conductivity of the backfill material is not a major consideration in water level recovery, when compared with other factors in the overall water balance.

The lack of monitoring beneath the Marsh is problematic with the peer reviewer stressing that Marsh can only be protected once its functioning is truly understood. It is recommended that FMG continue with ongoing development and calibration of the model to improve confidence in dewatering and injection volumes, as well as ensuring alignment with actual responses.

Conclusion

The Cloudbreak life of mine water management strategy builds on operational experiences, as well as nearly ten years of investigations and data collection. FMG appear committed to improve its understanding of the water resources and progressively integration of new knowledge into its predictive modelling. This approach has been demonstrated through the integration of modelling predictions into operational water management decision making, and ongoing calibration of model output with actual responses.

The numerical groundwater model is considered representative and is based on a robust conceptual understanding. There will be a need for ongoing model calibration against actual responses, as per

Appendix 4, and progressive improvement in understanding from operation observations, so that water management is as optimal as possible.

The predictions for the life of mine are within bounds and of sufficient accuracy for water management and mine planning. The volumes of dewatering and injection are significant and it is considered that ongoing monitoring and management will be critical for project success. This is highlighted as FMG were handling 59 GL in 2012, which less than half of the peak volumes in 2019 and 2021.

The peak volumes in 2017, 2019, 2012 and 2024 will create challenges with recirculation, injection capacity in the Oakover Formation and the conveyance system – efforts should be made to reduce these peaks. It will be important to ensure that the system has sufficient capacity to handle the necessary volumes of injection.

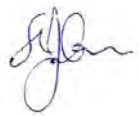
The connectivity of the Oakover and mineralised Marra Mamba Formations is important for understanding dewatering and injection volumes, as well as the extent of recirculation. The success of the injection process will be limited by the capacity of the Oakover Formation; as such the ongoing monitoring of aquifer response will be necessary. FMG have recognised the importance of saline water injection into the Oakover Formation as an integral part of continued operations with a recommended future work program, as outlined in Section 7.3, to confirm long-term injection rates and develop additional contingency measures.

FMG have demonstrated a whole of system approach, with consideration for interaction between the Cloudbreak and Christmas Creek operations. There are no immediate issues with cumulative impacts as Brockman Resources' Marillana and RHIO's Roy Hill operations are too distant.

There has been careful consideration of the Fortescue Marsh throughout the whole life of mine planning stage and in FMG's water management strategy. It is considered that impacts to the Marsh will be minimal and that injection is a valid mitigation approach. The peer reviewer would again reiterate the lack of monitoring beneath the Marsh is problematic and there should be ongoing discussion with Government agencies to approve the installation of a monitoring network.

The peer reviewer is satisfied that the 'Hydrogeological assessment of the Cloudbreak life of mine management scheme' report provides an accurate and representative appreciation of the water resources, and potential impacts associated with the future mining operations. There will be substantial challenges associated with mine dewatering and injection at Cloudbreak requiring pro-active management including monitoring, mitigation via injection and comparison between modelling predictions and actual data.

Yours sincerely



Seth Johnson
Principal Hydrogeologist / Director
B.App.Sc., M.Eng.Sc., RPGeo (10106), mIAH, mIAG

The peer review has been completed by Mr Seth Johnson, a Registered Practising Geoscientist (Number 10106), who is bound by the Australian Institute of Geoscientists' Code of Ethics. It has been produced independently being based on information provided by Fortescue Metals Group Ltd. All comments are considered accurate and provided in good faith.

HydroConcept Pty Ltd
U12a, 7 The Esplanade, Mt Pleasant WA 6153
Tel: 0401 35 15 10
Email: seth@hydroconcept.com.au

Appendix 2: Cloudbreak Groundwater Operating Strategy

This page has been left blank intentionally

Strategy

Cloudbreak Groundwater Operating Strategy

Water Management

30/06/13
CB-PH-HY-0009

Fortescue
The New Force in Iron Ore

Disclaimer:
This document is protected by copyright, no part of this document may be reproduced or adapted without the consent of the originator/company owner, all rights are reserved. This document is "uncontrolled when printed", refer to electronic copy for up to date version.

	Cloudbreak Groundwater Operating Strategy – Stage 7		**CB-PH-HY-0009**
Revision Number	**REV 1**		**28/06/2013**
Status	**IFU - ISSUED FOR USE**		
Author	Jon Leech	Signature	18/06/2013
Checked	Paul Ricketts	Signature	21/06/2013
Approved	Bobak-Willis-Jones	Signature	21/06/2013
Confidentiality	**PUBLIC USE (ACCESS TO ALL)**	**Publish on Extranet**	☐ Yes ☒ No
Review Date	**21/06/2013**		

Revision History *(to be completed for each version retained by Document Control)*

Author	Checker	Approver	Rev No.	Status	Issued Date
M Short	**I Brandes de Roos**	**B Willis-Jones**	0	**IFU**	20/12/2012
J Leech	**Paul Ricketts**	**B Willis-Jones**	1	**IFU**	21/06/2013

Fortescue
The New Force in Iron Ore

TABLE OF CONTENTS

1. INTRODUCTION 7
1.1 Background 7
1.2 Approvals 8
1.3 Document Scope 8
2. ADMINISTRATIVE REQUIREMENTS 12
3. CLOUDBREAK OPERATING PLAN 14
3.1 Project Development 14
3.2 Dewatering System 14
3.3 Conveyance system 15
3.3.1 Transfer ponds and settlement ponds 15
3.3.2 Bulk flow and conveyance pipelines 15
3.4 Water Supply System 15
3.4.1 Ore processing and tailings 16
3.4.2 Dust suppression 16
3.5 Injection system 16
3.5.1 Brackish injection 16
3.5.2 Saline injection 17
3.6 Cloudbreak Village water system and potable water system 17
3.7 Contingency Operations 17
3.7.1 Alternative Water Supply 17
3.7.2 Cloudbreak and Christmas Creek Connectivity 17
3.7.3 Water supply optimisation 18
3.7.4 Water level optimisation 18
4. OPERATING RULES 19
4.1 Mine water balance 19
4.2 Abstraction Licence Allocation 20
4.3 Injection Licence Allocation 21
5. WATER INFRASTRUCTURE MONITORING, CONTROL AND MAINTENANCE 22
5.1 Monitoring and controls 22

5.1.1 Bulk pipelines and storage ponds 22
5.1.2 Leak detection 22
5.2 Maintenance schedule 22
6. DEWATERING/INJECTION SYSTEM MONITORING PROGRAM 23
7. ENVIRONMENTAL IMPACT MANAGEMENT 25
7.1 Potential environmental impacts 25
7.1.1 Overall environmental management approach 25
8. TRIGGER LEVELS AND CONTINGENCY PLANS 27
8.1 Project zoning 27
8.2 Two-tiered trigger level system 27
8.3 Framework for selecting appropriate trigger values 28
8.3.1 Groundwater level and EC triggers 28
8.3.2 Near-marsh water level assessment 28
8.4 Trigger Level Response 31
8.5 Contingency plans 32
8.5.1 Insufficient brackish water 32
8.5.2 Insufficient injection capacity 32
9. EFFICIENT WATER USE INITIATIVES 33
10. MANAGEMENT COMMITMENTS SUMMARY 34
11. REFERENCES 37
12. GLOSSARY 38

List of Tables

Table 1: **Key regulatory Issues to be addressed in the Operating Strategy** 9
Table 2: **Scope changes for this Operating Strategy** 11
Table 3: **Administration requirements** 12
Table 4: **Reporting requirements** 12
Table 5: **Summary site water balance** 19
Table 6: **Groundwater abstraction licence details** 20
Table 7: **Groundwater injection licence details** 21
Table 8: **Cloudbreak monitoring summary** 23
Table 9: **Near-marsh bore assessment process** 29
Table 10: **Trigger level framework** 30
Table 11: **Summary of licensee's commitments** 34
Table 12: **Environmental Impact Management** 35

LIST OF FIGURES

Figure 1: Regional Location Plan 40
Figure 2: Existing Cloudbreak water management infrastructure 42
Figure 3: Hydrogeological section 44
Figure 4: Regional production bores 46
Figure 5: Injection bores 48
Figure 6: Monitoring location plan 50
Figure 7: Cloudbreak trigger level zones and monitoring bores 52

LIST OF APPENDICES

Appendix 1: Groundwater abstraction licences
Appendix 2: Tenements
Appendix 3: Non-pit region abstraction bore details
Appendix 4: Pit-region abstraction setup
Appendix 5: Injection bore details
Appendix 6: Proposed abstraction rates at Cloudbreak
Appendix 7: Cloudbreak conceptual water balance
Appendix 8: Monitoring locations
Appendix 9: Project trigger levels
Appendix 10: Trigger reporting procedure

1. INTRODUCTION

The Cloudbreak mine (Cloudbreak) and Christmas Creek mine (Christmas Creek) are located on the southern slopes of the Chichester Range and north of the Fortescue Marsh. Collectively, the two mine sites are referred to as the Chichester Operations. This Operating Strategy relates to Cloudbreak only, for further details on operations at Christmas Creek, approximately 30 km east of Cloudbreak mine (Figure 1), see Christmas Creek Operating Strategy (FMG, 2013).

1.1 Background

The water quality in the Cloudbreak area (between the Fortescue Marsh and Chichester Range) is variable due to the influence and mixing of both topographic-driven Chichester Range brackish water and density driven Fortescue marsh saline water. Groundwater in the resource area is generally brackish and becomes increasingly saline towards the Fortescue Marsh and with depth, as shown in Figure 3. Based on the water quality distribution and beneficial use considerations, two classes of groundwater quality are defined for the purpose of groundwater management:

- Brackish: ≤6000 milligrams per litre (mg/L), total dissolved solids (TDS), which occurs in shallow aquifer zones within the mineralised Marra Mamba Formation (MMF) and overlying Tertiary Detritals sediments located on the upper slopes of the Chichester Range.

- Saline - hypersaline: ≥6000 mg/L to 150,000 mg/L TDS, where the lower limit applies to recharge areas, with an increase in salinity within all aquifers found further south and at greater depth. The aquifer within the Oakover Formation, which overlies the MMF to the south of the resource area, is entirely of saline quality (monitored up to 150,000 mg/L).

Dewatering and injection activities commenced at Cloudbreak in 2008. Groundwater is abstracted under Department of Water (DoW) 5C licences GWL166200, GWL166354 and GWL166465. This Operating Strategy supersedes the previous version dated 30 July 2012. It has been updated to align with the EPA approval of the Life of Mine expansion under Ministerial Statement 899 and SEWPaC approval dated 29 November 2012 (EPBC reference 2010/5696). This approval allows up to 100 gigalitres per annum (GL/a) of dewatering and up to 85 GL/a of groundwater injection. Further updates to the Operating Strategy will be in accordance with any approved changes required by the DoW or as a result of a significant change to the operation of the Cloudbreak water management system.

Dewatering is required to facilitate mining below the water table. The current rate of dewatering is 100 GL/a. To assist in managing the operational requirement of additional dewatering, the Cloudbreak Water Management Scheme has been developed with the following objectives:

- manage excess groundwater;

- minimise potential environmental impacts; and
- conserve the groundwater resource.

The key component of this scheme is the disposal of abstracted water via injection into nearby suitable aquifers.

Further updates to the Operating Strategy (OS) will be in accordance with any approved changes required by the DoW or as a result of a significant change to the development and operation of the Cloudbreak water management scheme.

1.2 Approvals

Fortescue Metals Group Limited (Fortescue) has commenced operation of the Pilbara Iron Ore and Infrastructure Project (the Project), which consists of several iron ore mines and associated rail and port infrastructure in the Pilbara region of Western Australia (Figure 1). The primary environmental approvals for the Project have been obtained in four stages:

- Stage A, consisting of an iron ore export facility at Port Hedland and a north-south railway from the central Pilbara to Port Hedland (approved under Ministerial Statement 690);
- Stage B, consisting of two iron ore mines in the eastern Pilbara (Christmas Creek and Mindy Mindy) and an east-west spur rail line connecting to the Stage A railway (approved under Ministerial Statement 707);
- Cloudbreak iron ore mine (approved under Ministerial Statement 899 and Commonwealth Assessment Environment Protection and Biodiversity Conservation Act 1999 2010/5696);

Port facility upgrade of the third berth at Anderson Point, Port Hedland: Dredging and wharf construction (approved under Ministerial Statement 771).

1.3 Document Scope

This document outlines the planned operation of dewatering, injection and water supply systems at the Cloudbreak Mine and the management systems that will be employed to monitor and mitigate potential impacts. This OS is anticipated to be relevant for a period of 12 months from the date of approval.

Fortescue is required to produce a detailed OS due to the Project operating in an environmentally sensitive area and its large water allocation. The OS has been prepared to meet the requirements of "*Operational Policy 5.08, Use of Operating Strategies in the Water Licensing Process*"' (DoW, 2010) and ensure monitoring and compliance requirements specified in Part IV and Part V approvals are addressed. The relevant issues highlighted in the DoW 2010 policy and Part IV and Part V approvals and the corresponding sections of this Operating

Strategy that address each issue are outlined in Table 1.. Scope changes from the Stage 6 Operating Strategy are presented in Table 2.

Table 1: Key regulatory Issues to be addressed in the Operating Strategy

Operating Strategy	Key Regulatory Issues Addressed
1. Introduction	Outlines the scope of operations including abstraction and injection volumes. • RIWI - Addresses administrative requirements (Section 1) of DoW Policy 5.08.
2. Administrative Requirements	Provides details of key personnel responsible for implementation of the operating strategy and the key reporting deliverables and frequencies. • RIWI - Addresses administrative requirements (Section 1) of DoW Policy 5.08. • Part IV - MS899 – Conditions 7.3, 7.4, 7.6. • Part V - L8199/2007/2 – DEC CCWMS requirements.
3. Cloudbreak Operating Plan	Provides a high level outline of the water management scheme and key definitions. • RIWI - Addresses administrative requirements (Section 1) and Water source description (Section 2) of DoW Policy 5.08. • Part V - L8199/2007/2 – DEC CCWMS requirements.
4. Operating rules	Outlines how the water management scheme will be operating in order to comply with existing regulatory requirements and provides an overview of project development. • RIWI - Addresses the water source description (Section 2) and monitoring and reporting (Section 5) requirements of DoW Policy 5.08. • Part IV - MS871 – Conditions 7.1. Information required for the Department of Environment and Conservation (DEC) to assess the works in accordance with Part V of the Environmental Protection Act 1986 (EP Act) are included in the Water Management Scheme Document (FMG2013a).
5. Water Infrastructure Monitoring, Control and Maintenance	Sections 5 & 6 outline the monitoring and control measures which are in place to ensure continued operation and compliance of the system. Details are also provided of the locations, parameters and frequency of monitoring across the whole system. • RIWI - Addresses the identifying and managing impacts (Section 3) and monitoring and reporting (Section 5) requirements of DoW Policy 5.08. • Part IV - MS871 – Conditions 7.2. • Part V - L8199/2007/2 – DEC CCWMS requirements.
6. Groundwater Monitoring Programme	
7. Environmental Impact Management	Outlines the potential environmental risks associated with the project and mitigation measures which are in place to ensure compliance with regulatory guidelines. • RIWI - Addresses the identifying and managing impacts (section 3) and environmental impact management (Section 6) requirements of DoW Policy 5.08. • Part IV - MS871 – Conditions 7.1. • Part V - L8199/2007/2 – DEC CCWMS requirements.
8. Trigger levels and Contingency Plans	Outline the rational and logic for the monitoring network, the methodology for assessment and reporting procedure for exceedances. Contingency plans are also discussed to ensure impacts are mitigated. • RIWI - Addresses the monitoring and reporting (Section 5) and the contingency programme (Section 7) requirements of DoW Policy 5.08. • Part IV - MS871 – Conditions 7.1, 7.2, and 7.4. • Part V - L8199/2007/2 – DEC CCWMS requirements.
9. Efficient Water Use Initiatives	Water efficiency initiative, currently in place and proposed, are presented. • RIWI - Addresses the water use efficiency (Section 9) requirements of DoW Policy 5.08.
10. Management Commitments Summary	Summary of environmental commitments presented in this document. • Addresses the summary of licensee's commitments (Section 12) of DoW Policy 5.08. • Part IV - MS871.

Operating Strategy	Key Regulatory Issues Addressed
	• Part V - L8454/2010/1 – DEC CCWMS requirements.

Table 2: Scope changes for this Operating Strategy

Scope change	Description
Removal of Hillside East	Hillside East is now covered by the *Christmas Creek Groundwater Operating Strategy* (FMG, 2013)
Improvements to trigger network (see Section 7 and 9)	Near-marsh bores have been assigned new Class 1 triggers to more closely align with Ministerial Statement 899 (see Section 8)
	SRM05_D and SRM05_S have been removed from the trigger network and replaced by additional near-marsh monitoring sites. See the most recent *Cloudbreak Quarterly Groundwater Monitoring Review* (FMG, 2012b) for details
	All saline injection area monitoring bores have now been assigned relevant, Zone B, water level triggers (previously, only a selection of saline injection area monitoring bores were included in the trigger network)
	Zone A now extends from the northern fringe of Fortescue Marsh to the 410 m elevation contour to reflect the positioning of monitoring sites outlined in MS899
	Additional near-marsh (Zone A) bores have been proposed
	The addition of the Zone A control bore (CCFMM05 – 794939E, 7504202N)
	Brackish injection bulk flow has now been assigned a Class 1 trigger of 9,000 µS/cm, to increase brackish aquifer monitoring. See Section 9.
	Class 1 trigger on the zone B deep monitoring bores have been increased to 2.2m in line with observations and model predictions.
	Wording of zone A trigger to align more closely with MS871
	Inclusion of additional zone B trigger locations following completion of new saline injection locations
	Zone B monitoring bores screening the shallow aquifer (alluvium and tertiary detritals) have been assigned Class 1 water quality triggers, to increase brackish aquifer monitoring. See section 8.
	Update of trigger reporting procedure to align with new FMG organisational structure
Addition of new injection pipeline sample points	A number of previously monitored samples points have now become redundant or no longer exist. Additional injection pipelines have also been constructed since OS Stage 6. As a result, a new list of representative injection sample points has been compiled (see Section 5)
Addition of pastoral bores	Pastoral bores that are currently being monitored have been included (see Section 6)
Alignment of monitoring to DEC licence requirements	Monitoring commitments have been aligned with DEC licence requirements relating to brackish and saline injection (see Section 6 and 8)
Administration requirements	Change of persons responsible for implementation of this document
Chemical sampling	Bores sampled biannually for chemical analysis have been listed and analytes specified

2. ADMINISTRATIVE REQUIREMENTS

Cloudbreak currently operates under two Ground Water Licences (GWLs) to a combined abstraction allocation of 100,000,000 kL/yr (Appendix 1). Water is currently abstracted up to 100 GL/a from existing mining areas and Hillside West and injected up to 85 GL/a at locations to south of the mining area (saline) and Hillside West.

The required administrative arrangements to ensure compliance with this Operating Strategy are outlined below in Table 3.

Table 3: Administration requirements

Requirement	Administrative Arrangement
Duration	12 months from the date of approval
Contact details of persons responsible for implementation of this document	Mine Services Manager, Utilities Department, Cloudbreak Mr Wally Lombard wlombard@fmgl.com.au
Definition of water year	1 August – 31 July
Reporting commitments	See Table 4
Review	As required

Reporting will be conducted as outlined in Table 4. The reports will be prepared in accordance with the Operational Policy 5.08 in "*Use of Operating Strategies in the Water Licensing Process*" (DoW, 2010).

Table 4: Reporting requirements

Frequency	Contents
Quarterly	• monthly monitoring data, including groundwater levels, water quality and abstraction and injection volumes; • groundwater trigger level compliance; • groundwater level contour plans; and • any proposed changes to groundwater management.
Annual[1]	• a compilation and hydrogeological assessment of the quarterly report data; • an assessment of the borefield operation's compliance with the Groundwater Licence (GWL) terms and conditions; • an assessment of the borefield operation's compliance with the Operating Strategy commitments; • any proposed changes to groundwater management and the Operating Strategy; • a description of the effectiveness and accuracy of the monitoring program (where appropriate); and • the submission of the report to the Department of Water annually within two months of

Frequency	Contents
	the completion of the water year.
Triennial	The Triennial Aquifer Review will be submitted in place of the Annual Aquifer Review discussing the data for the previous three-year period in greater detail. This review will: • place more emphasis on historical trends and anomalies; and • to be submitted every three years to the Department of Water within two months of the completion of the relevant water year, with the next Triennial review due in 2013.
As required	Trigger level exceedances will be reported to the DoW, EPA, SEWPaC and DEC as outlined in Section 9.

[1]Fortescue's Environment Team is also required to produce an Annual Environmental Report for the DEC and EPA, which include an assessment of groundwater monitoring data.
Monthly monitoring and assessment of the near marsh bores (Condition 7.2 (3) of Ministerial Statement 899) is undertaken as described in Section 8 of this operating strategy.

In addition to the external reporting requirements detailed in Table 4, Fortescue also completes numerous internal assessments of hydrogeological data in relation to short term mining plans.

3. CLOUDBREAK OPERATING PLAN

Groundwater is abstracted from dewatering borefields to enable dry pits, to provide water for dust suppression, ore processing, earthworks and construction, and potable water supply for the Mine Village. Excess groundwater abstracted from the dewatering operation is injected into suitable aquifers (managed aquifer recharge (MAR)), in accordance with the *Operational Policy 1.01 Managed Aquifer Recharge in Western Australia* (DoW, 2011).

3.1 Project Development

The location of existing water infrastructure is shown on Figure 2. A high level description of the system is provided below. Water infrastructure has been and will be developed to meet the needs of the business, the environment and stakeholders whilst aiming to maximise flexibility in operations. Planned expansion of the dewatering and injection system over the next 12-18 months is outlined in the Cloudbreak Water Management Scheme (FMG 2013a).

3.2 Dewatering System

The dewatering system includes up to three water streams: the brackish, the saline and sump water. Separate systems exist for both brackish and saline dewatering systems. Dewatering bores and interconnecting pipelines are located along mine pit perimeters and in some cases within mine pits.

For the purpose of this OS groundwater abstraction bores are classified as:

- General purpose water supply bores: bores established for purpose of dust suppression and construction purposes (Appendix 3)
- Potable water supply bores: bores established for purpose of potable water supply only (Appendix 3)
- Pit dewatering bores; bores established for purpose of mine dewatering. These bores generally have a short life span.

This differentiation is adopted based on the short life of dewatering, whereby pit-region bores can be ‘mined out’ (decommissioned) within about six months, rendering a list of pit-region bores out of date before it is published. Fortescue’s pit-region dewatering methodology and set-up is described in Appendix 4. The tenements from which water will be abstracted and used are highlighted in Appendix 2.

The location of abstraction bores are displayed in Figure 4. More detailed information on the hydrogeology of the Cloudbreak area can be found in the *Hydrogeological Assessment for the Cloudbreak Water Management Scheme* (FMG, 2010) produced as part of the primary approvals.

3.3 Conveyance system

The conveyance system is designed to move water across the site from areas of abstraction (dewatering system) to areas of injection or use. Water is conveyed via separate brackish, saline and sump pipelines via ponds.

3.3.1 Transfer ponds and settlement ponds

Transfer ponds and settlement ponds consist of water storage facilities for the purpose of facilitating bulk flow transfer and/or settlement of suspended material. Separate facilities exist for handling of brackish, saline and sump water.

3.3.2 Bulk flow and conveyance pipelines

Pipeline sizes and routes have been designed to:

- Optimise hydraulic performance in combination with pump duties;
- Meet connectivity requirements; and
- Comply with relevant regulatory approvals and licence requirements.

3.4 Water Supply System

Average predicted water demand throughout the next 12 month period is expected to be relatively constant following the implementation of the wet front end to the existing Ore Processing Facility, scheduled for early 2013. Following this stage of development, average annual water demand is estimated to increase from 7 GL/a (220 L/s) to 13 GL/a (400 L/s). Given the climatic variation within the Pilbara (directly related to dust suppression) and the variable operational requirement, actual operational water demand is likely to range between 4 GL/a and 15 GL/a. No additional increase in groundwater abstraction is predicted for the next 12 months.

The majority of this water demand is anticipated to be supplied from active dewatering; however with the increasing salinity of abstracted water alternative contingency measures are to be implemented should water supply not meet predicted demand. These include:

- **Inter-mine transfer**: movement of surplus water between the Cloudbreak and Christmas Creek mine sites to manage supply/demand at a Chichester scale. This will allow Fortescue to minimise groundwater abstraction across operations.
- **Managed aquifer recharge (MAR):** water previously injected into brackish injection borefields will be recovered by abstracting water from existing or newly constructed abstraction locations.

- **Existing infrastructure:** utilise existing production bores (not for active dewatering) across Cloudbreak to supplement water demand.
- **External borefield:** consideration for a long term (life of mine) abstraction borefield or remote to operations or reverse osmosis (RO) plant for ongoing brackish supply. Not applicable for this Operating Strategy.

3.4.1 Ore processing and tailings

A bulk flow conveyance line delivers water to a process water pond adjacent to the OPF for use in ore processing operations. The transfer pond receives raw water from the brackish conveyance system and from the tails decants water.

The tailings from the OPF are conveyed to the tailings storage area as slurry. The tails are disposed of within the active mining areas. Supernatant water from tailings is collected using decant systems such as decant towers and returned to the system for reuse.

3.4.2 Dust suppression

For dust suppression, water cart fill points are maintained across the Cloudbreak area. These systems are supplied by the water conveyance system to a quality required by the DEC licence. A pump and standpipe assembly is used to fill the water trucks.

3.5 Injection system

Excess groundwater abstracted from the dewatering operation is returned to compatible aquifers by injection methods in accordance with the DoW's *Operational Policy in Managed Aquifer Recharge* (DoW, 2011). Injection systems consist of networks of injection bores and interconnected pipelines. Water is injected to the bore via a downhole flow control valve, which eliminates air from entering the bore. Details of bores used for injection are presented in Appendix 5. The location of injection bores are displayed in Figures 5.

3.5.1 Brackish injection

Aquifer storage via injection is undertaken with brackish water in areas west of the active mining area and typically targets the Marra Mamba Formation (MMF). There is currently one area identified for brackish injection: the Hillside West Injection borefield.

3.5.2 Saline injection

Saline injection is undertaken between the southern limit of the resource area and the northern limit of the Fortescue Marsh. The Oakover Formation is the target aquifer of the injection. The Oakover Formation has high transmissivity due to the presence of calcretes and silcretes.

The saline network is being developed and expanded to meet the increasing injection requirement.

3.6 Cloudbreak Village water system and potable water system

At the camp, potable water supply is treated at the camp RO plant and is sourced from three local bores CBC01, CBC02 and “Knobs Bore”. Future supply will be sourced from points selected from 17 proposed bores, which are presented on Figure 4 and Appendix 3. Currently, the water is stored in a separate tank and fed across the mine via an independent distribution network. This abstraction is licenced under GWL166465 and is not included under this operating strategy.

At the mine, a water treatment facility is located adjacent to the process water tanks for treatment of water for potable use. Potable water is stored in a separate tank and fed across the mine via its own distribution network.

3.7 Contingency Operations

3.7.1 Alternative Water Supply

Moving forward, with continuing increase in salinity of water from the dewatering system, additional options may be required to ensure suitable water supply to operations. These options may include;

- **External borefield**: consideration for a long term (life of mine) abstraction borefield remote to operations; or
- **Reverse osmosis (RO)**: On-site RO plant which will reduce the salinity of abstracted water for ongoing brackish supply.

3.7.2 Cloudbreak and Christmas Creek Connectivity

The integration of Christmas Creek and Cloudbreak water systems offers significant opportunity to address optimisation of water management at the Chichester operations to meet both operational and environmental objectives. This optimisation is delivered through operational planning and review. Two key areas identified for optimisation are: conservation of the brackish water resource and management of water levels.

3.7.3 Water supply optimisation

Operations and activities at Christmas Creek require low EC, brackish water. As dewatering operations progress abstracted water is becoming increasingly saline. If the water management strategy described above is unable to supply a sufficient source of brackish water for operations, a series of contingency water supply programmes have been developed, including the transfer of water between adjacent mine sites, see Section 3.7.1.

3.7.4 Water level optimisation

The water management strategy utilises groundwater injection as the main destination for excess water from operations. For compliance reasons (water level and volume limits), if injection capacity is limited or reduced, the following contingency measures will be implemented:

- blend water within system to allow alternative use/disposal route;
- transfer water between sites;
- review mine plan to reduce dewatering requirement; and
- discuss with regulatory authorities potential to increase injection volume.

Both of Fortescue's Chichester Range mines (Cloudbreak & Christmas Creek) are designed to operate independently. However, the contingency to transfer water between sites will not only improve operational flexibility but also allow increased environmental protection to the Marsh.

4. OPERATING RULES

For the purpose of this document, operating rules describe:

- The planned water balance in terms of volumes and water quality for the duration of the OS;
- Abstraction licence allocation requirements; and
- Injection licence allocation requirements.

Specific requirements with regards to the groundwater and infrastructure monitoring and maintenance requirements are detailed in Section 5 and Section 6, respectively.

4.1 Mine water balance

Bores are operated in accordance with the terms and conditions of the relevant 5C licence (Section 2). Abstraction during the respective licence periods is undertaken within the prescribed annual water entitlement. Proposed water abstraction and usage rates for Cloudbreak mine are presented in Appendix 6 and a conceptual mine water balance is presented in Appendix 7. A summary tabular water balance for the site is provided in Table 5.

Table 5: Summary site water balance

Water Year	Date	Dewatering System		Water Supply System		Injection System	
		Abstraction Rate (ML/d)	Cumulative Volume (ML)	Consumption Rate (ML/d)	Cumulative Volume (ML)	Injection Rate (ML/d)	Cumulative Volume (ML)
2013	Jul-3	347	56,100	32	12,100	315	44,000
2014	Aug-13	295	9,143	41	1,271	254	7,872
	Sep-13	320	18,743	41	2,501	279	16,242
	Oct-13	330	28,973	41	3,772	289	25,201
	Nov-13	325	38,728	41	5,002	284	33,726
	Dec-13	330	48,958	41	6,273	289	42,685
	Jan-14	270	57,328	41	7,544	229	49,784

Water Year	Date	Dewatering System		Water Supply System		Injection System	
	Feb-14	275	65,028	41	8,692	234	56,336
	Mar-14	243	72,549	41	9,966	202	62,583
	Apr-14	240	79,749	41	11,195	199	68,554
	May-14	220	86,572	41	12,475	179	74,097
	Jun-14	220	93,180	41	13,717	179	79,464
	Jul-14	220	100,000	41	15,000	179	85,000

4.2 Abstraction Licence Allocation

Details for the Ground Well Licences (GWLs) are listed in Table 6 and a copy of the existing licence is presented in Appendix 1.

Table 6: Groundwater abstraction licence details

Licence no.	Area	Purpose	Aquifer	Allocation (GL/a)	Expiry date
GWL166200	Cloudbreak	Dewatering and site usage	Pilbara Hamersley - Fortescue	100	TBA
GWL166354			Pilbara Hamersley – Fractured Rock		
GWL166465		General campsite purposes	Not covered by this Operating Strategy		

4.3 Injection Licence Allocation

The injection of surplus brackish and saline groundwater at Cloudbreak is licensed by the Department of Environment and Conservation (DEC). Details of the DEC groundwater injection licence are presented in Table 7.

As part of Fortescue's DEC licence commitments, selected monitoring bores in the brackish (Zone C) and saline (Zone B) injection areas have been assigned relevant Class 1 and 2 triggers (see Section 7 and 9).

Table 7: Groundwater injection licence details

Licence no.	Area	Purpose	Allocation (GL/a)	Expiry date
L8199/2007/2	Cloudbreak	Injection of surplus groundwater	85	TBA

Details of brackish and saline injection bores operated at Cloudbreak are outlined in Appendix 5 and locations presented in Figure 5.

5. WATER INFRASTRUCTURE MONITORING, CONTROL AND MAINTENANCE

5.1 Monitoring and controls

Fortescue monitors abstraction, injection and water consumption infrastructure via a network of flow meters at abstraction and injection bores, sumps, pipelines, water-demand points and transfer ponds.

Fortescue uses telemetry and automated data collection in conjunction with electromagnetic flow meters and downhole water level sensors for some saline injection infrastructure. The automated and telemetry systems will be further developed to assist with operational control and monitoring of all appropriate water systems.

5.1.1 Bulk pipelines and storage ponds

Valves are regularly installed along bulk lines to allow for isolation of sections should damage occur, or for maintenance activities. Flow meters and pressure gauges in the transfer pipelines provide the ability to assess leak detection. Flow meters located throughout the water delivery and distribution network are installed in accordance with the DoW Guidelines for Water Meter Installation (DoW, 2009a).

5.1.2 Leak detection

Leak detection is undertaken via regular visual inspections of pipework, ponds and fittings. Comparison of meter readings at various points between abstraction and consumption points are used to identify losses from the system.

5.2 Maintenance schedule

The maintenance schedule is as follows:

- all water storage facilities and water conveyance infrastructure are inspected daily by the maintenance personnel, checking for water leaks, controls and condition of containment dams. Problems are rectified as they arise; and
- flow meters on all bores are tested to accuracy and calibrated by in-situ validation, twice a year or as per manufacturer specifications.

6. DEWATERING/INJECTION SYSTEM MONITORING PROGRAM

The Mining Services team are responsible for monitoring as outlined in Table 8. The locations of monitoring sites are shown on Figure 6. Monitoring bore locations, not included on the trigger network, are provided in Appendix 8.

In addition to the monitoring summary outlined in Table 8 additional near pit monitoring is undertaken at frequencies ranging from daily to weekly to assess the success and ongoing requirements for dewatering operations.

Table 8: Cloudbreak monitoring summary

Frequency	Monitoring parameter	Comments	Monitoring locations
Injection discharge pipelines[3]			
Daily	Visual inspection	As a DEC licence requirement and to assist in characterising hydrogeological conditions, samples are analysed for major ions (Na, K, Ca, Mg, Cl, alkalinity and SO_4), metals (Al, B, Fe, Cu, Zn, Ag, As, Cr, Pb, Cd, Hg, Ni, Sn, Mn), electrical conductivity, total dissolved solids and total suspended solids.	Active[3] brackish pipeline infrastructure
Monthly	Field electrical conductivity		See Appendix 8
	Volumes		
Six monthly[1]	Chemical analysis		
Abstraction and injection bores[3]			
Monthly	Field electrical conductivity	Bore head works will be equipped with water quality measurement points	Active[3] production/injection bores
	Volumes	Via bore meter data	
	Bore status (flow)	If the bore is currently operational	
Monitoring bores			
Monthly	Groundwater level monitoring	For drawdown/mounding assessments	See Appendix 9
	Field electrical conductivity	At a designated measurement depth	
Six Monthly[1]	Chemical analysis	As a DEC licence requirement and to assist in characterising hydrogeological conditions, samples are analysed for major ions (Na, K, Ca, Mg, Cl, alkalinity and SO_4), metals (Al, B, Fe, Cu, Zn, Ag, As, Cr, Pb, Cd, Hg, Ni, Sn, Mn), electrical conductivity, total dissolved solids and total suspended solids.	See Appendix 8

Frequency	Monitoring parameter	Comments	Monitoring locations
Water use volumes			
Monthly	Meter readings for each water use type	Sub-metering will be implemented where possible to assist in quantifying water use at individual locations across the mine site.	See Appendix 8
	Sub-meter reading with monthly abstraction volumes		
Monitoring bores/inactive production bores			
Fortnightly[2]	Groundwater level	Water levels monitored fortnightly at selected monitoring bores and inactive production bores to assist in hydrogeological understanding and numerical model calibration.	See Appendix 8
Pastoral bores			
Monthly	Groundwater level	Selected pastoral bores are monitored monthly to assist in hydrogeological understanding and ensure the water resource is maintained.	See Appendix 8
	Field electrical conductivity		
Contingency discharge monitoring			
Varying times and frequencies, refer to DEC licence	Field electrical conductivity	As a DEC licence requirement in the event that reuse, injection, in pit disposal and temporary storage are not available or have been exhausted. Refer to the Dewatering Discharge Contingency Procedure (Fortescue Metals Group, 2009).	See Appendix 8
	Nephelometric turbidity (NTU)		
	Flow meter readings		

[1]Six monthly samples are collected nominally in February and August.
[2]These locations do not form part of Fortescues regulatory commitment. Monitoring locations and frequencies are reassessed regularly.
[3]Active bores and pipelines only. Active infrastructure is classified as that which is currently operating or that have been operated during the previous month.

Groundwater levels are measured using a field groundwater probe. Salinity is measured using a field electrical conductivity (EC) measurement probe that is lowered to a designated depth within the screen interval. In some cases, automatic bore loggers are also deployed. EC measurement procedures include the calibration of EC meters before each monitoring round and water samples for these readings will be collected when the pump is operational.

The Water Services team is responsible for collecting water samples from potable supply bores (including bores CBC01, CBC02 and Knob's Bore.

7. ENVIRONMENTAL IMPACT MANAGEMENT

The Cloudbreak water management scheme is operated in such a way as to prevent or minimise any potential environmental impacts. Environmental values that may be affected by groundwater abstraction activities are detailed in the following sections.

7.1 Potential environmental impacts

Fortescue has submitted an application to the Environmental Protection Authority (EPA) for the Cloudbreak Water Management Scheme Environmental Review (FMG, 2011). The PER described the potential environmental impacts associated with the scheme and the management measures to be implemented to mitigate these impacts.

The primary environmental issues likely to result from construction and operation of the infrastructure comprise of vegetation clearing, dust and changes to hydrology. Other potential impacts include vegetation impacts due to drawdown and mounding, and surface water flow disturbance.

A summary of the management and mitigation strategies which are to be applied are described in the environmental impact management table presented in section 10.

7.1.1 Overall environmental management approach

The groundwater management infrastructure is located within Fortescue's Chichester Range operations area and will be managed in accordance with environmental management plans for this area. Plans of particular relevance include the following[1]:

- Chichester Operations Surface Water Management Plan (45-PL-EN-0015)
- Chichester Operations Groundwater and Bore Management Plan (45-PL-EN-0005)
- Groundwater Discharge Management Plan (45-PL-EN-0019)
- Mulga and Other Flora and Communities Management Plan (45-PL-EN-0017)
- Fortescue Marshes Management Plan (45-PL-EN-0009);
- Weed Hygiene and Management Plan (45-PL-EN-0013);
- Chichester Operations Fauna Management Plan (45-PL-EN-0007);
- Chemical and Hydrocarbon Management Plan (45-PL-EN-0011);
- Chichester Operations Dust Environmental Management Plan (CB-PL-EN-0009);
- Construction Dust Management Plan (45-PL-EN-0012); and

[1] Environmental plans will be updated, management of operations will be based on the latest iteration of each document.

- Fire Management Plan (45-PL-EN-0020).

These and other management plans for the Cloudbreak area are available at www.fmgl.com.au.

8. TRIGGER LEVELS AND CONTINGENCY PLANS

Fortescue has developed a system for assigning and managing an appropriate distribution of monitoring points and associated trigger levels for groundwater levels and groundwater quality (salinity). The system takes into consideration the spatial extent of the project, operational activities, sensitive environmental receptors and beneficial water use. The distribution of trigger monitoring bores is presented in Figure 7 and listed in Appendix 9. This section describes the trigger level system and the responses that are initiated when trigger levels are exceeded.

8.1 Project zoning

Due to the significant spatial extent of the project, a system of zoning has been developed, which takes in to consideration the hydrogeological complexity and different functional areas of the project.

There are four zones (Figure 7):

- **Zone A:** near-marsh region;
- **Zone B:** saline injection region;
- **Zone C:** brackish injection region; and
- **Zone D:** phreatophytic vegetation region.

Zone A extends from the northern fringe of Fortescue Marsh up to the 410 mAHD topographic elevation contour (three metres beyond the maximum marsh flooding level of 407 mAHD). Zone B includes the saline injection area and the saline injection region of influence. Zone C includes the brackish injection area and the brackish region of influence. Zone D includes selected locations where suitable habitat for phreatopytic vegetation has been identified.

The following sections describe the application of a two-tiered trigger level system within the four zones, a framework for assigning appropriate trigger levels, calculation of trigger level values and response plans.

8.2 Two-tiered trigger level system

A two-tiered trigger level system has been developed:

Class 1 trigger levels serve as an early warning for groundwater level and quality changes from a calculated baseline value. Refer to Appendix 10 for details of the internal trigger reporting process.

Class 2 trigger levels are aligned with groundwater level changes that may potentially impact upon the environment and future beneficial use of the aquifer.

Appropriate triggers are assigned to both the shallow aquifer (alluvium and Tertiary Detritals) and to the deeper aquifers (Marra Mamba, Oakover and Wittenoom Formations).

8.3 Framework for selecting appropriate trigger values

The framework builds on the project zoning and the two-tier trigger value system which provides a means for determining if Class 1 or Class 2 trigger levels are appropriate. This framework is presented in Table 10.

8.3.1 Groundwater level and EC triggers

The basis for assigning Class 2 trigger level values in each project zone takes into consideration baseline conditions, estimates of uncertainty and impact assessments. Table 8 summarises the basis for each of the Class 2 trigger values assigned.

Class 1 groundwater level triggers are an early warning indication of change such that a Class 2 breach will be avoided.

The 'baseline' value from which EC triggers are assessed are based on data that is first 'pre-conditioned' (checked for veracity), then assessed statistically (average, maximum, minimum, etcetera). A baseline level is set based on the maximum value over the 'pre-conditioned' data range. Groundwater quality trigger levels are established only for bores with a statistically valid number of measurements.

8.3.2 Near-marsh water level assessment

A monthly hydrogeological assessment of near-marsh monitoring bores is undertaken for near-marsh bores. This assessment is a comparison of individual bore trends against regional, non-abstraction- and non-injection related groundwater trends. One tool used in this assessment is described in Table 9. Other assessment methodologies may also be employed where appropriate. The 'control bore' is one piece of data used to undertake the assessment of seasonal trends; other data may include climate data and other appropriate bore data.

Table 9: Near-marsh bore assessment process

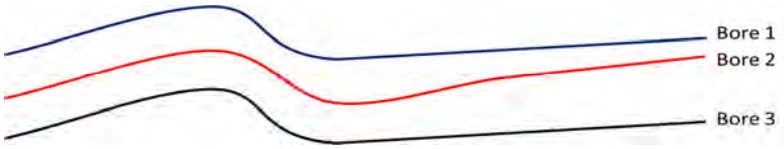
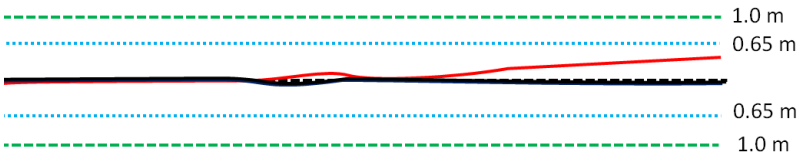
Step	Description (together with a pictorial representation)
1. Initial data	Monitoring data collated 
2. Reduce all hydrographs to a common datum	Subtract the time series groundwater levels from a set point in time (currently December 2011) groundwater level for each respective bore. This results in groundwater changes that commence at zero at this set point in time. These monitoring data are overlayed on the same graph and assessed in this manner.
3. Calculate average of all data	Where data are recorded at a resolution higher than monthly, data are averaged using a symmetrical 5-day moving filter. For example, for daily-measurement data, datum are averaged with the preceding two days' and the following two days' data. The average measurement for each similar-aquifer datum is then calculated.
4. Subtract average from data	Subtracted the average from each bore's time series data
5. Assess trend against trigger levels	In this synthetic example, Bore 2 (red) is trending towards a Class 1 trigger exceedance 

Table 10: Trigger level framework

Zone	Region	Aquifer	Groundwater level trigger		Water quality trigger	Trigger Basis
			Class 1	Class 2	Class 1	
A	Near-marsh[1]	Tertiary Detrital	Change of ±0.65 m with regard for climatic trends and seasonal variation	Change of ±1 m with regard for climatic trends and seasonal variation	N/A	• Class 1 groundwater level trigger to provide early warning and to signal potential future Class 2 conditions • Class 2 groundwater level trigger as stipulated in Condition 7 of Ministerial Statement 899 (groundwater levels – Fortescue Marsh) '*The proponent shall manage the injection of surplus water to ensure that groundwater levels do not rise or drop more than 1 metre at FMM02_S, FMM06_S, CBX02_WT, CBX04_S, CBX07_S, CBX10a_WT, CBX13_WT, as shown in Figure 2 and delineated by co-ordinates in Schedule 2, from baseline groundwater level, having regard for climatic trends and seasonal variation, unless prior written authorisation of the CEO has been received'.*
B	Saline injection	Tertiary Detrital	3 m below ground level	2.2 m below ground surface	9,000 µS/cm (unless the baseline[2] is higher than 6,000 µS/cm, then 50% increase from baseline)[3]	• Class 1 groundwater level trigger to provide early warning and to signal potential future Class 2 conditions • Class 2 groundwater level trigger as stipulated in Condition 6 of Ministerial Statement 899 (conservation significant vegetation – indirect impacts) *'The proponent shall manage the proposal in a manner that ensures there is no adverse impact to conservation significant vegetation as a result of implementing this proposal'.*
		Oakover Formation	2.2 m below ground level	N/A	N/A	
C	Brackish injection	Tertiary Detrital	3 m below ground level	2.2 m below ground surface	9,000 µS/cm (unless the baseline[2] is higher than 6,000 µS/cm, then 50% increase from baseline)[3]	• Class 1 groundwater level trigger to provide early warning and to signal potential future Class 2 conditions • Class 2 groundwater level trigger as stipulated in Condition 6 of Ministerial Statement 899 (conservation significant vegetation – indirect impacts) *'The proponent shall manage the proposal in a manner that ensures there is no adverse impact to conservation significant vegetation as a result of implementing this proposal'.* • Class 1 EC trigger assigned to ensure baseline aquifer water quality is maintained as defined in Part V DEC licence (L8199/2007/2).
		Marra Mamba Formation	3 m below ground level	N/A		
		Bulk flow	N/A	N/A	9,000 µS/cm	
D	Phreatophytic vegetation[4]	Tertiary Detrital	16 m below ground level	18 m below ground level	50% increase from baseline[2]	• Class 1 groundwater level trigger to provide early warning and to signal potential future Class 2 conditions • Class 2 groundwater level defined to prevent environmental impact at areas where phreatophytic vegetation may be susceptible to drawdown. *Groundwater level where phreatophytic vegetation may be susceptible to drawdown of the groundwater level of more than 20 m from the ground surface. Ecoscape's impact assessment for dewatering (Ecoscape, 2009). A 10% precautionary factor has been applied.* • Class 1 E.C. trigger assigned to ensure baseline aquifer water quality is maintained as defined in Part V DEC licence (L8199/2007/2).
		Marra Mamba Formation	16 m below ground level	18 m below ground level	50% increase from baseline[2]	

1 The locations defined in Table 9 are the near-marsh bores currently approved under Ministerial statement 899. These bores have not been constructed and installed specifically to observed variation in the groundwater table and alternative sites are being assessed by the EPA (see Figure 7). Once finalised, Ministerial Statement 899 and this Operating Strategy will be updated accordingly.

2 Baseline EC based on pre-injection and/or pre-dewatering-impact time series data.

3 If baseline groundwater quality is greater than 9,000 µS/cm no trigger is applied.

4 Other assessment techniques such as projected canopy cover and remote sensing technology are being developed to help assess the impact to phreatophytic vegetation zones and compliment these groundwater monitoring data

8.4 Trigger Level Response

Due to the large volume of data being captured, Fortescue's groundwater database (EnviroSys™) has an automated tracking system to identify trigger level exceedances. Trigger level exceedances will be reported quarterly to the DoW as part of the quarterly aquifer review outlined in Table 4. The assigned trigger levels are presented in Appendix 9 and the locations of the trigger monitoring bores are shown Figure 7.

Where a trigger level is exceeded, parameter(s) are re-measured to confirm the exceedance. Where the reading is confirmed, Fortescue will implement the following where a:

Class 1 trigger level is exceeded;

- initiate a hydrogeological assessment with the objective of determining the reason(s) for the divergence and if necessary increase monitoring frequency or extent;
- if necessary, implement changes to the water management system; and
- explore improvements in the trigger levels based on new data;

Class 2 trigger level is exceeded;

- initiate a hydrogeological assessment with the objective of determining the reason(s) for the trigger level breach;
- modify operational activities to ensure that the groundwater level and or salinity changes do not continue to breach the trigger value. This includes;
    i. reduce volumes of water piped to the affected area by redirecting water to other injection areas;
    ii. redirect water from the appropriate transfer pond and other injection areas where drawdown exceeds the trigger in the phreatophytic zones (Zone D);
    iii. redirect disposal to transfer and/or infiltration ponds;
    iv. redirect disposal to void mine pits (where available); and
    v. implement the Dewatering Discharge Contingency Procedure allowing the discharge of up to 20,000 k/L per day (FMG, 2009).
- for Class 2 triggers associated with the Zone A (near-marsh) monitoring bores (CBFMM02_S, CBFMM06_S, CBX02_WT, CBX04_S, CBX07_S, CBX10a_WT, CBX13_WT) , any exceedance will initiate a thorough review of the vegetation health assessment and efforts will be made to maintain, or improve, the divergent groundwater level. Should adverse vegetation health be detected, the DEC will be informed.

The DoW will be notified within 72 hours and the matter will be reported in the annual groundwater review. Appendix 10 further outlines Fortescue's trigger reporting procedure and protocol.

8.5 Contingency plans

Operational contingency plans associated with groundwater levels and quality trigger levels are outlined in Section 9. Should unforseen demands and/or situations for the following events occur, contingencies have been developed to ensure that potential for impact to the environment is minimised.

8.5.1 Insufficient brackish water

If it is found that the brackish water supply varies from the expected volume and is insufficient to meet demand, the demand may be met by:

- abstraction from current brackish injection borefields and/or existing pastoral bores;
- movement of excess water provided from/to Christmas Creek; and/or
- approval may be sought for alternate sources such as external borefields.

8.5.2 Insufficient injection capacity

If it is found that either brackish or saline water injection capacity and/or licensed disposal volume is insufficient for the volume abstracted, Fortescue's contingency plans are as follows:

- initiate a hydrogeological assessment with the objective of determining the reason(s) for the divergence;
- movement of excess water from/to Christmas Creek;
- discuss with regulatory authorities potential to increase injection volume; and
- if necessary, implement changes to operations to ensure volume of water for injection can be managed with existing injection infrastructure.

9. EFFICIENT WATER USE INITIATIVES

A number of measures are utilised to reduce the demand on fresh/brackish water for dust suppression at the mine site. These include:

- the use of non-toxic, biodegradable dust suppression additives such as Rainstorm;
- utilising lower-quality water for road dust suppression where possible;
- the use of treated wastewater for dust suppression activities;
- process water recycling (associated with crushing and screening);
- ongoing investigations into further use of treated wastewater around the mine site; and
- the use of low-flow taps, shower head and sprinkler systems.

Fortescue is also assessing the efficiency of storing excess stormwater in existing ponds/tanks for appropriate site use to help reduce the demand for the use of fresh-brackish water. The site water balance will be assessed by the Water Management Team on an annual basis and together with the site Water Management Team. Any potential improvements to water efficiency will be investigated and implemented where practical.

10. MANAGEMENT COMMITMENTS SUMMARY

Tables 11 and 12 highlight the environmental commitments that have been made by Fortescue throughout the content of this document.

Table 11: Summary of licensee's commitments

Section	Subject	Commitment	Timing
3	Reporting requirements	Fortescue will fulfil various reporting requirements to the DoW on the operation of the System on a quarterly, annual, triennial, and as required basis. See Section 4 for details.	On a quarterly, annual, triennial or as required basis after System commencement.
5.1	Compliance with 5C licence	Abstraction bores will be operated in accordance with the terms and conditions of relevant 5C licences. Abstraction levels during the relevant licence periods will be within the respective prescribed annual water entitlement.	Ongoing after commencement.
5.4.2	Maintenance of the System	All water storage facilities and other water infrastructure associated with the System are inspected weekly by maintenance personnel checking for water leaks, controls and condition of containment dams with problems rectified as they arise. Water meters on all bores are tested as per manufacturer's specifications to ensure accuracy.	Weekly or as per manufacturer's instructions.
6	Operations monitoring program	Fortescue will fulfil various monitoring requirements on a monthly or six monthly basis in respect of abstraction bores, monitoring bores and water use volumes.	On a monthly or six monthly basis after commencement.
8	Groundwater trigger levels	As part of groundwater monitoring, Fortescue will implement a trigger system to initiate, where necessary, changes to abstraction. See Section 8 for specific details.	Ongoing after commencement.
8	Electrical Conductivity trigger levels	Trigger levels will be included for recently commissioned bores within six months of commissioning.	Ongoing after commencement.

Table 12: Environmental Impact Management

Trigger Zone	Environmental Factor	Operating Strategy Management Objectives	Existing environment	Management Strategies / Proponent Commitments
Zone A – Near Marsh	Groundwater	*The proponent shall manage the injection of surplus water to ensure that groundwater levels do not rise more than 1.5 metres at MB1 and 1 metre at MB2, MB3 and MB4 from the baseline groundwater level having regard for seasonal variation.*	There are two aquifers in the vicinity of the Fortescue Marsh, Shallow alluvium and the Wittenoom Dolomite at depth.	Class 1 groundwater level trigger to provide early warning and to signal potential future Class 2 conditions Class 2 groundwater level trigger as stipulated in Condition 7 of MS871 (Fortescue Marsh) to ensure protection of identified vegetation, flora, fauna and heritage areas.
	Vegetation & Flora		Samphire and marsh communities, which are locally significant and are associated with the Fortescue Marsh PEC (P1).	
	Conservation and Natural Heritage Areas		The Fortescue Marsh is listed on the Register of National Estate as an unusual type of wetland, its conservation significance to waterbirds and other cultural values, both indigenous and non-indigenous (DSEWPC 2010a). In addition, the Fortescue Marsh has been identified as a 'Nationally Important Wetland' as it a good example of an extensive, inland floodplain system which is regularly inundated and is a unique wetland in Western Australia (DSEWPC 2010b).	
	Matters of National Environmental Significance		Only one Migratory species of National Significance has been confirmed as being present in the Proposal area.	
Zone B – Saline Injection	Groundwater	*The proponent shall manage the injection of surplus water to ensure that groundwater level within the impacted zones but outside of the exclusion area does not result in groundwater levels rising within 2 meters of the surface.* *The proponent shall manage groundwater abstraction and disposal (dewatering and injection) for the project in a manner that ensures:* 1. *There is no adverse impact on native vegetation communities attributable to the project outside the predicted impact areas; and* 2. *Within the proposed impact area there is no mortality of keystone plant species or significant change sin habitat characteristics attributable to the project.*	There are two aquifers in the vicinity of Zone B, shallow Alluvium and the Wittenoom Dolomite. The Nammuldi member of the Marra Mamba Iron formation is expected at depth but has not been intersected.	Class 1 groundwater level trigger to provide early warning and to signal potential future Class 2 conditions Class 2 groundwater level trigger as stipulated in Condition 8-1 of MS871 (groundwater mounding) Class 1 EC trigger assigned to shallow aquifer to ensure baseline aquifer water quality is maintained.
	Vegetation & Flora		Vegetation types mapped in Zone B are consider to be locally significant, including: • Mulga communities, which are potentially sheet flow dependent; • Samphire and marsh communities, which are locally significant and are associated with the Fortescue Marsh PEC (P1).	
	Fauna		Two fauna habitat types – Mulga and Coolibah/River Red Gum communities have the potential to be affected by the Proposal. These habitat types are not restricted to the Proposal area and are generally widely represented throughout the region.	
Zone C – Brackish Injection	Groundwater	See Zone B above.	There are two aquifers in the vicinity of Zone C shallow Alluvium and the Nammuldi member of the Marra Mamba Iron formation.	Class 1 groundwater level trigger to provide early warning and to signal potential future Class 2 conditions

Trigger Zone	Environmental Factor	Operating Strategy Management Objectives	Existing environment	Management Strategies / Proponent Commitments
	Vegetation & Flora		Vegetation types mapped in Zone C are consider to be locally significant, including: • Mulga communities, which are potentially sheet flow dependent;	Class 2 groundwater level trigger as stipulated in Condition 8-1 of MS871 (groundwater mounding) Class 1 EC trigger assigned to shallow aquifer to ensure baseline aquifer water quality is maintained.
	Fauna		Two fauna habitat types – Mulga and Coolibah/River Red Gum communities have the potential to be affected by the Proposal. These habitat types are not restricted to the Proposal area and are generally widely represented throughout the region.	
Zone D – Phreatophytic Vegetation	Groundwater	*The proponent shall manage groundwater abstraction and disposal (dewatering and injection) for the project in a manner that ensures:* 1. *There is no adverse impact on native vegetation communities attributable to the project outside the predicted impact areas; and* 2. *Within the proposed impact area there is no mortality of keystone plant species or significant change sin habitat characteristics attributable to the project.*	There are two aquifers in the vicinity of Zone D shallow Alluvium and the Nammuldi member of the Marra Mamba Iron formation.	Class 1 groundwater level trigger to provide early warning and to signal potential future Class 2 conditions Class 2 groundwater levels defined to prevent environmental impact at areas where phreatophytic vegetation may be susceptible to drawdown. Class 1 E.C. trigger assigned to ensure baseline aquifer water quality is maintained as required by DEC (L8454/2010/1).
	Vegetation & Flora		Vegetation types mapped in Zone D area are consider to be locally significant, including: • Mulga communities, which are potentially sheet flow dependent; • Potentially groundwater dependent species.	
	Fauna		Two fauna habitat types – Mulga and Coolibah/River Red Gum communities have the potential to be affected by the Proposal. These habitat types are not restricted to the Proposal area and are generally widely represented throughout the region.	

11. REFERENCES

Department of Minerals and Energy, 1999, *Guidelines on the safe design and operating standards for tailings storage*, Department of Minerals and Energy, Western Australia

Department of Water, 2009, *Guidelines for water meter installation,* Department of Water, Perth.

Department of Water, 2010, Operational policy 5.08 Use of operating strategies in the water licensing process, DWPF 5.08, Department of Water, Perth.

Department of Water, 2011, Operational Policy 1.01 Managed aquifer recharge in Western Australia. Department of Water, Perth

Ecoscape, 2009, Flora and vegetation impact assessment for dewatering at Fortescue Cloudbreak mine (Revised), report prepared for Fortescue Metals Group Limited.

Fortescue Metals Group, 2009*, Dewatering discharge contingency procedure revision* 3, Document No. M-PR-EN-0001, Fortescue Metals Group, Perth.

Fortescue Metals Group, 2010, *Hydrogeological assessment for Cloudbreak water management scheme,* Document No. CB-RP-HY-0019, Fortescue Metals Group, Perth.

Fortescue Metals Group, 2011, *Christmas Creek Water Management Scheme Environmental Review,* CC-RP-EN-0011-Rev2, Fortescue Metals Group, Perth.

Fortescue Metals Group, 2012b, Cloudbreak Quarterly Groundwater Monitoring Review, CB-RP-HY-0034, Fortescue Metals Group, Perth.

Fortescue Metals Group, 2013, *Christmas Creek Groundwater Operating Strategy,* CC-PH-HY-0003, Fortescue Metals Group, Perth.

Fortescue Metals Group, 2013a, *Part V Licencing L8199/2007/2 Supporting Document – Cloudbreak Water Management Scheme*, CB-RP-EN-1038, Fortescue Metals Group, Perth.

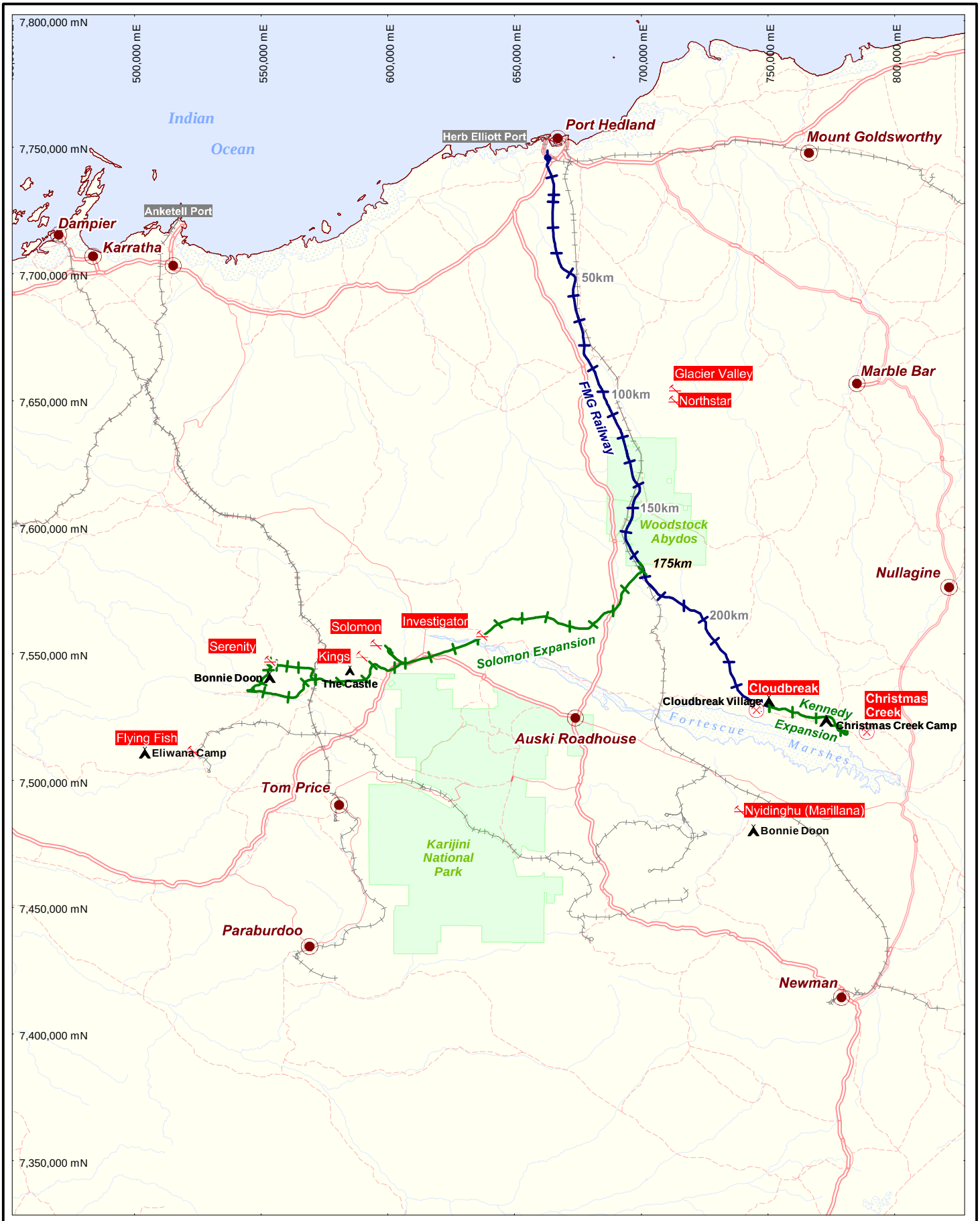
12. GLOSSARY

Acronym	Description
mbgl	Metres Below Ground Level
DEC	Department of Environment and Conservation
DoW	Department of Water
EC	Electrical Conductivity
EPA	Environmental Protection Authority
EP Act	Environmental Protection Act 1986
Fortescue	Fortescue Metals Group Limited
GL/a	Gigalitres Per Annum
GDP	Ground Disturbance Permit
GWL	Groundwater Licence
ha	Hectare
HDPE	Heavy Density Polyethylene
kL	Kilolitre
km	Kilometres
L/s	Litres Per Second
m	Metres
mm	Millimetres
MMF	Marra Mamba Formation
mg/L	Milligrams per Litre
ND	Nominal diameter (measured in Millimetres)
µS/cm	Microsiemens per Centimetre
Operating Strategy	Christmas Groundwater Operating Strategy
OPF	Ore Processing Facility
PN	Pressure Nomination (measured in Bar at 20^{o}C)
PVC	Polyvinyl Chloride
The Project	Pilbara Iron Ore and Infrastructure Project
RO	Reverse Osmosis
RIWI Act	Rights in Water and Irrigation Act 1914
SP	Settlement Pond
The System	Cloudbreak Dewatering and Injection
TDS	Total Dissolved Solids
TN	Turkey Nest
TP	Transfer Pond

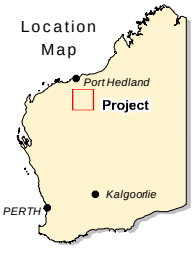
[This page has been left blank intentionally]

Figure 1: Regional Location Plan

[This page has been left blank intentionally]



Location Map



Legend

- Towns
- Major Roads/Tracks
- Creeks
- FMG Railway
- FMG Proposed Railways
- Other Railways
- FMG Mines
- FMG Resources

N

0 20 40 80

kilometres

Fortescue Metals Group Ltd

Regional Project Location

Author: T.Edwards	Date: 11/11/2010
Drawn By: PM	Revision: 7
Doc No: 100_MP_EN_0003	Confidentiality: 1
Projection: MGA Zone 50 (GDA 94)	Scale: 1:2million

Figure 2: Existing Cloudbreak water management infrastructure

[This page has been left blank intentionally]

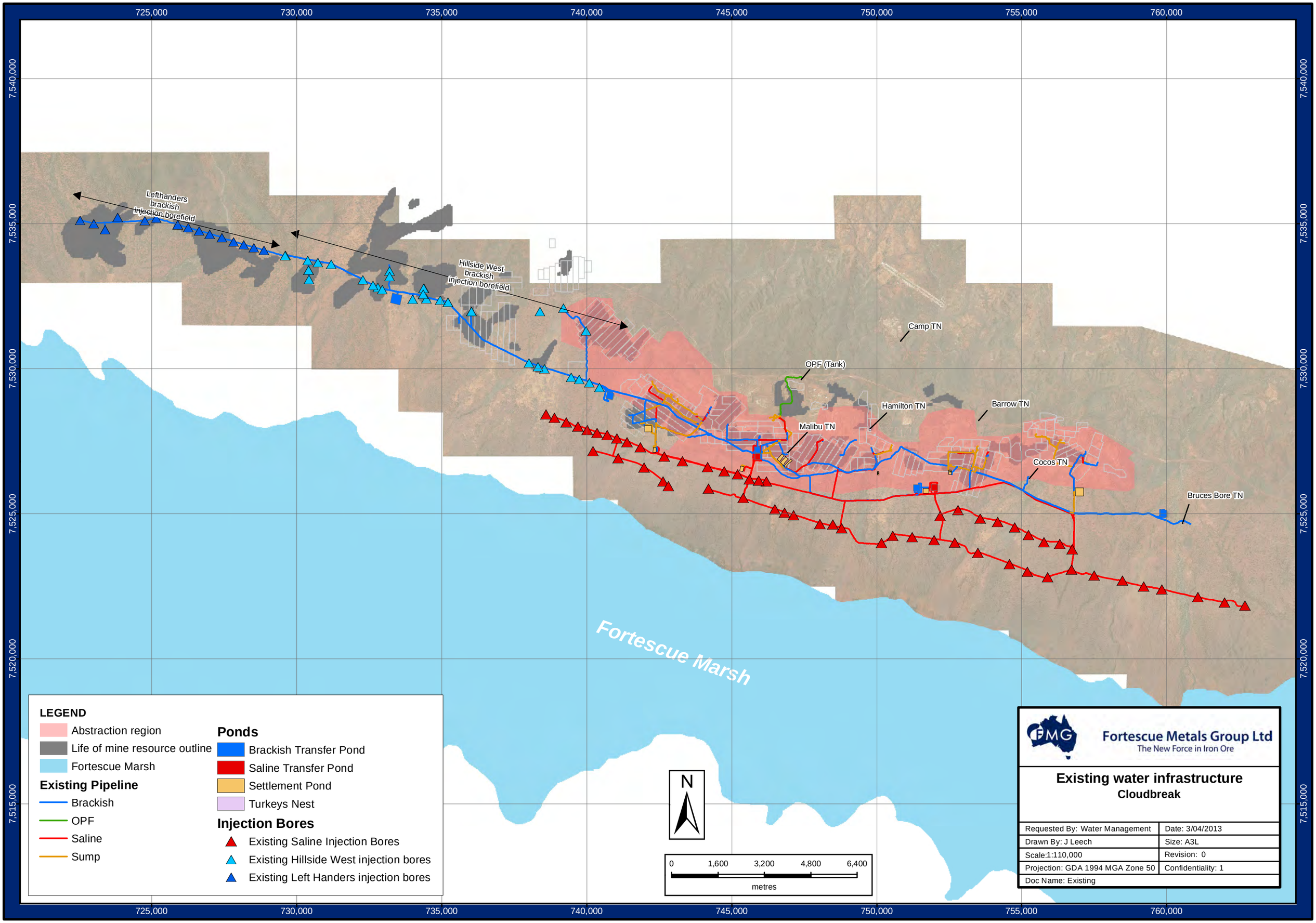
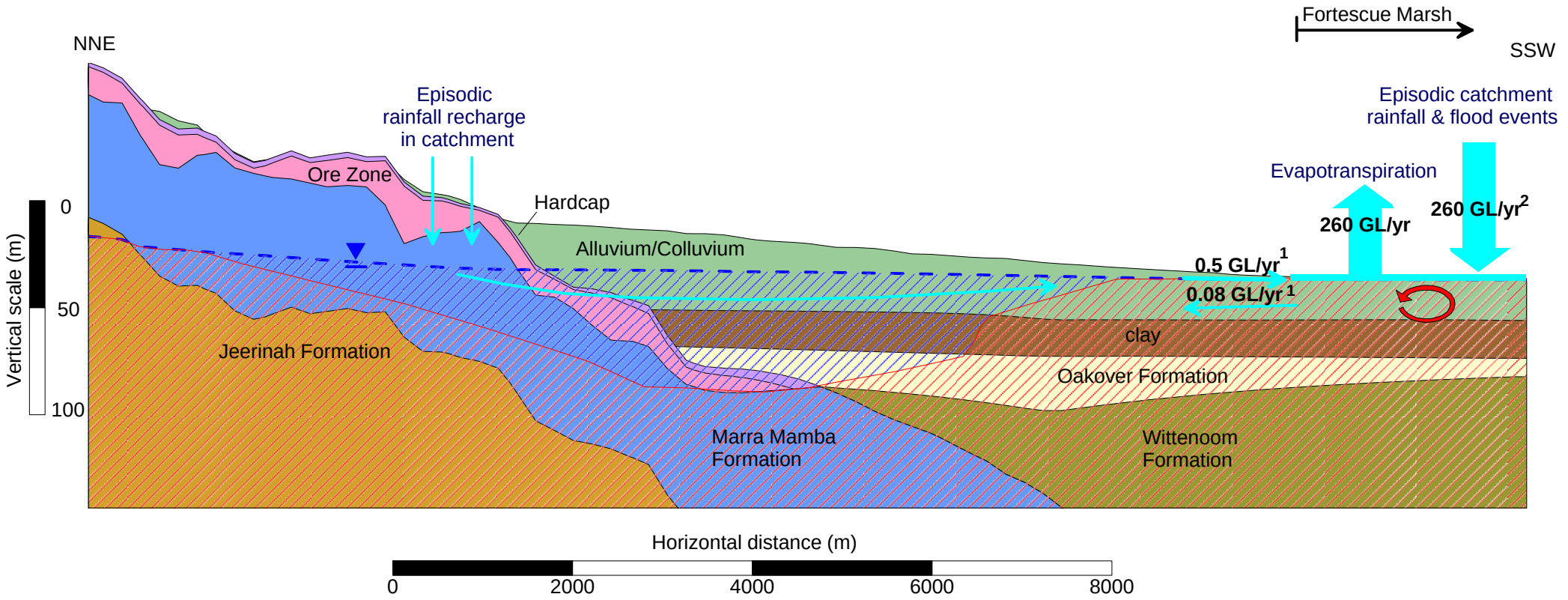

725,000
730,000
735,000
740,000
745,000
750,000
755,000
760,000
7,540,000
7,535,000
7,530,000
7,525,000
7,520,000
7,515,000
Lefthanders brackish injection borefield
Hillside West brackish injection borefield
Camp TN
OPF (Tank)
Hamilton TN
Barrow TN
Malibu TN
Cocos TN
Bruces Bore TN
Fortescue Marsh
LEGEND
Abstraction region
Life of mine resource outline
Fortescue Marsh
Existing Pipeline
Brackish
OPF
Saline
Sump
Ponds
Brackish Transfer Pond
Saline Transfer Pond
Settlement Pond
Turkeys Nest
Injection Bores
Existing Saline Injection Bores
Existing Hillside West injection bores
Existing Left Handers injection bores
N
0
1,600
3,200
4,800
6,400
metres
Fortescue Metals Group Ltd
The New Force in Iron Ore
Existing water infrastructure
Cloudbreak
Requested By: Water Management
Date: 3/04/2013
Drawn By: J Leech
Size: A3L
Scale:1:110,000
Revision: 0
Projection: GDA 1994 MGA Zone 50
Confidentiality: 1
Doc Name: Existing

Figure 3: Hydrogeological section

[This page has been left blank intentionally]

Cloudbreak conceptual hydrogeology



Brackish groundwater

Saliine groundwater

260 GL/yr Project-scale flux estimate

Groundwater table

Evaporative concentration and salinisation of groundwater due to the upper Fortescue Marsh catchments' internal drainage

Footnotes:

1 Annual groundwater discharge to the marsh and recharge from marsh flooding (average rates along the marsh edge, south of the Cloudbreak pits [about 36km strike length], calculated from a calibration numerical model with a simulation period from January 2007 to June 2011)

2 Based on Worley Parsons (2012): Christmas Creek Life of Mine Expansion - Fortescue Marsh Catchment Water Balance Study. Average inflow based on a water balance from 1984 to 2011. Other time periods will yield different average inflows.

Figure 4: Regional production bores

[This page has been left blank intentionally]

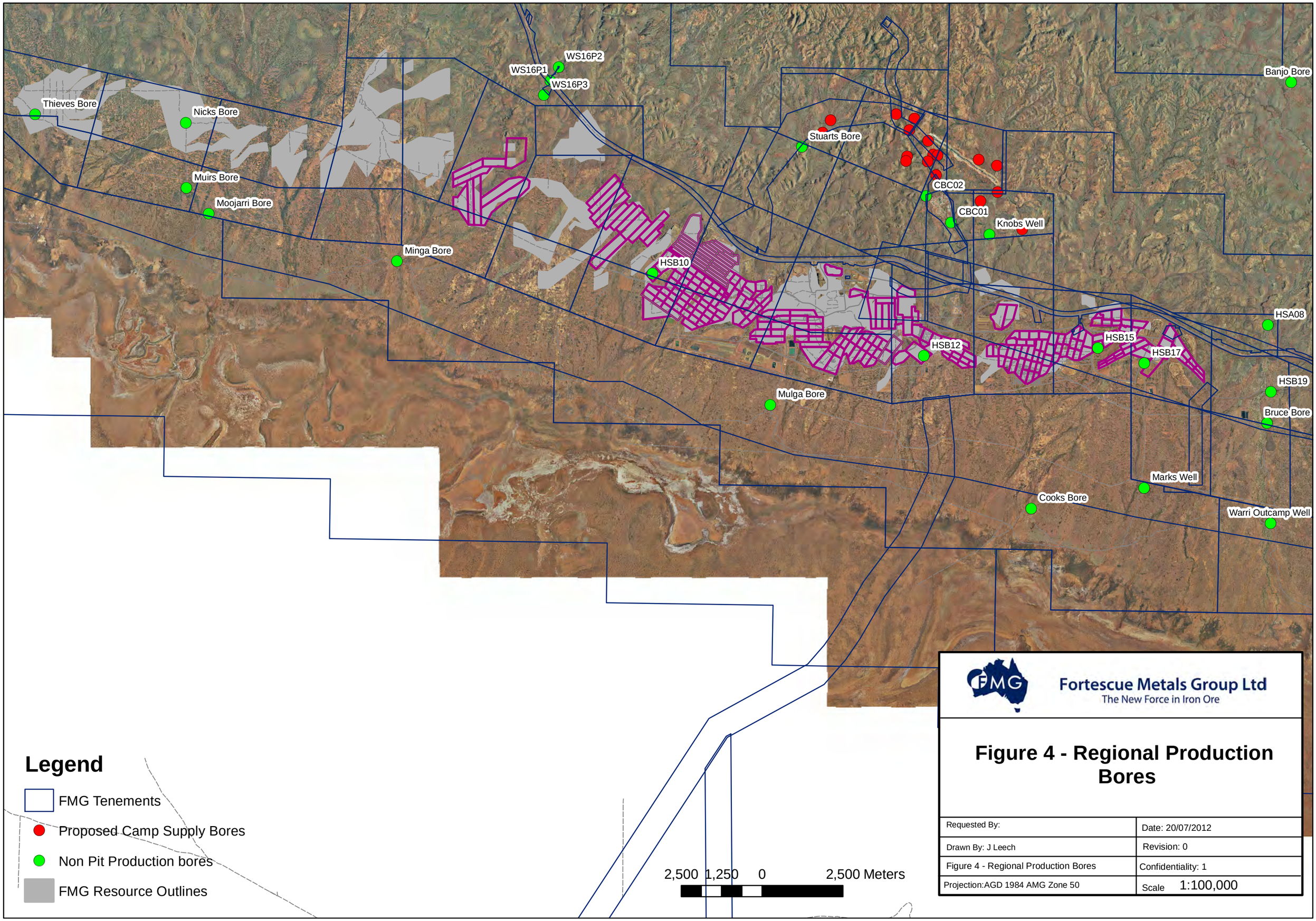
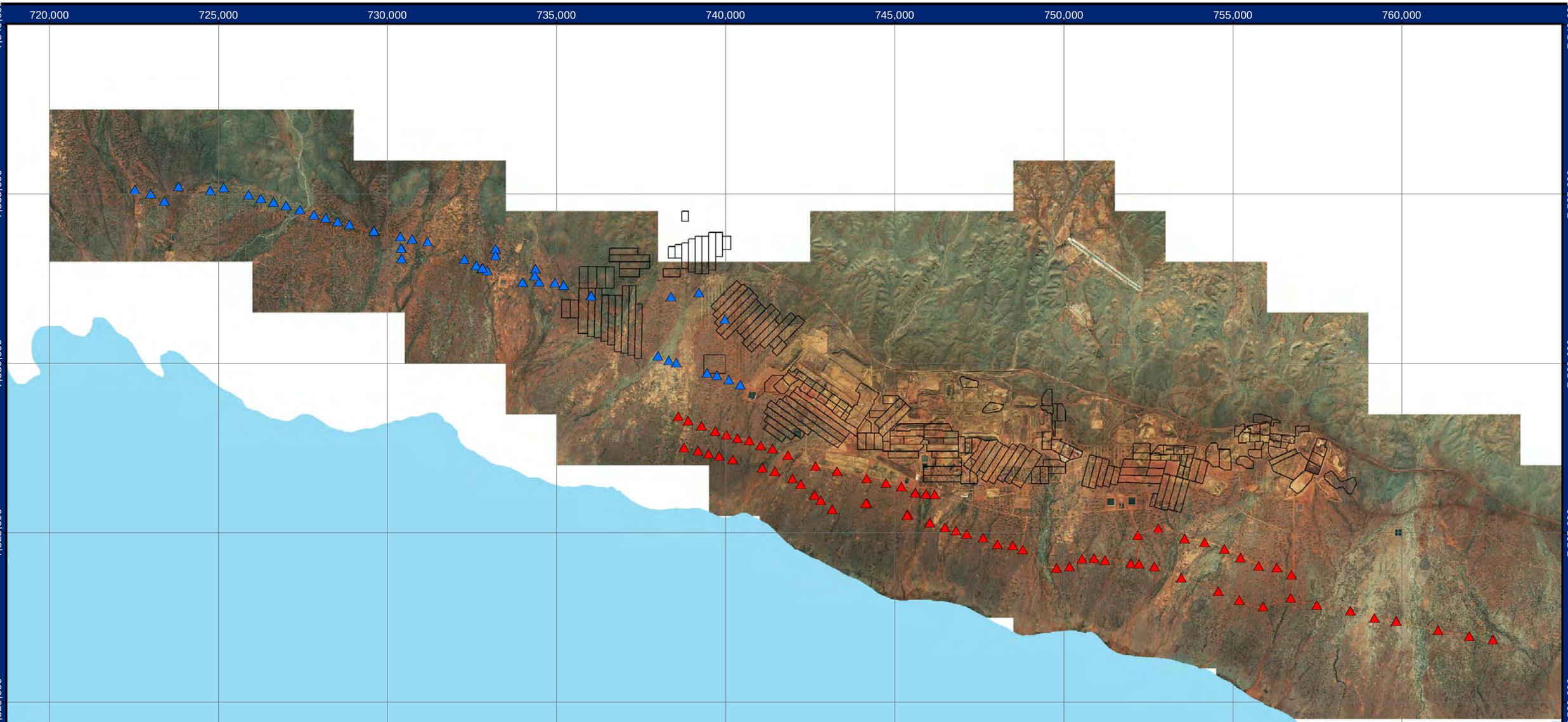

WS16P2
WS16P1
WS16P3
Thieves Bore
Nicks Bore
Muirs Bore
Moojarri Bore
Minga Bore
HSB10
Stuarts Bore
CBC02
CBC01
Knobs Well
Banjo Bore
HSA08
HSB15
HSB12
HSB17
HSB19
Mulga Bore
Bruce Bore
Marks Well
Cooks Bore
Warri Outcamp Well
Legend
FMG Tenements
Proposed Camp Supply Bores
Non Pit Production bores
FMG Resource Outlines
2,500 1,250 0 2,500 Meters
Fortescue Metals Group Ltd
The New Force in Iron Ore
Figure 4 - Regional Production Bores
Requested By:
Date: 20/07/2012
Drawn By: J Leech
Revision: 0
Figure 4 - Regional Production Bores
Confidentiality: 1
Projection:AGD 1984 AMG Zone 50
Scale 1:100,000

Figure 5: Injection bores

[This page has been left blank intentionally]

720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000



LEGEND

- Fortescue Marsh
- Brackish Injection Bores
- Saline INjection bores *Dewatering bulk flow meters*

N

0 1,600 3,200 4,800 6,400

metres

Fortescue Metals Group Ltd
The New Force in Iron Ore

Injection locations
Cloudbreak

Requested By: Water Management	Date: 17/06/2013
Drawn By: J Leech	Size: A3L
Scale:1:115,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Injection locations 17-06-13	

Figure 6: Monitoring location plan

[This page has been left blank intentionally]

720,000 725,000 730,000 735,000 740,000 745,000 750,000 755,000 760,000

7,540,000 7,535,000 7,530,000 7,525,000 7,520,000 7,515,000 7,510,000

LEGEND

- Fortescue Marsh

Monitoring_Locations_17-06-13

- Chemical Analysis
- Contingency Discharge
- Reinjection Sample Point (flow meter)
- Bulk Pipeline (flow meter)
- Pastoral_bore
- Model Calibration
- Pit dewatering monitoring
- Trigger Network

N

0 1,600 3,200 4,800 6,400

metres

Fortescue Metals Group Ltd
The New Force in Iron Ore

Monitoring locations
Cloudbreak

Requested By: Water Management	Date: 17/06/2013
Drawn By: J Leech	Size: A3L
Scale:1:115,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Monitoring Locations 17-06-13	

Figure 7: Cloudbreak trigger level zones and monitoring bores

[This page has been left blank intentionally]

720,000 730,000 740,000 750,000 760,000

7,540,000 7,530,000 7,520,000 7,510,000

LEGEND

- 410 m contour
- Fortescue Marsh
- Zone A
- Zone B
- Zone C
- Zone D
- Roy Hill Tenement boundary
- Pit Regions

Trigger Locations

- Zone A (control bore)
- Zone A (existing)
- Zone A (proposed)
- Zone B
- Zone C
- Zone D

Proposed replacement location

Proposed replacement location

Proposed replacement location

Proposed replacement location

Proposed replacement location

Fortescue Marsh

Cloudbreak

Christmas Creek

Fortescue Marsh

CCFMM05 (control bore)

N

0 2,400 4,800 7,200 9,600

metres

Existing Zone A locations will be monitored in accordance with Ministerial Statement 899 until EPA approval is received to amend these key monitoring locations (As per request CB-AP-EN-0041, April 2013)

Fortescue Metals Group Ltd
The New Force in Iron Ore

Project trigger zones

Cloudbreak

Requested By: Water Management	Date: 10/06/2013
Drawn By: J Leech	Size: A3L
Scale:1:125,000	Revision: 0
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Triggers_June2013	

Appendix 1: Groundwater abstraction licences

This page has been left blank intentionally

LICENCE TO TAKE WATER

Granted by the Minister under section 5C of the Rights in Water and Irrigation Act 1914

Licensee(s)	Fortescue Metals Group Ltd		
Description of Water Resource	Pilbara Hamersley - Fractured Rock	**Annual Water Entitlement**	100000000 kL
Location of Water Source	M46/406, M46/403, M46/410, M46/411, M46/412, M46/413, M46/414, M46/402, M46/408, M46/450, M46/451, E46/590, M45/1103, M45/1104, M45/1105, M45/1106, M45/1107, M45/1124, M45/1125, M46/409 M46/404, L46/99		

Authorised Activities	**Taking of water for**	**Location of Activity**
	Dewatering for mining purposes Earthwork and construction purposes Mineral ore processing and other mining purposes	M46/404, L46/99
	Dewatering for mining purposes Earthwork and construction purposes Mineral ore processing and other mining purposes	M46/406, M46/403, M46/410, M46/411, M46/412, M46/413, M46/414, M46/402, M46/408, M46/450, M46/451, E46/590, M45/1103, M45/1104, M45/1105, M45/1106, M45/1107, M45/1124, M45/1125, M46/409

Duration of Licence	From 15 April 2013 to 30 June 2021

This Licence is subject to the following terms, conditions and restrictions:

1 That water drawn during dewatering operations shall be utilised where possible by the licensee in the mining and treatment operations.

2 The licensee shall submit to the Department of Water an annual report by 30th September each year and a triennial report by 30th September 2013 containing the information as required by Operational policy 5.12 'Hydrogeological Reporting associated with a groundwater well licence'.

3 Quarterly Technical reports are to be submitted to the Department of Water for assessment by 31st March, 30th June, 30th September (combined into AAR/TAR) and 31st December each year.

4 The licensee must install a cumulative water meter of a type approved under the Rights in Water and Irrigation (Approved Meters) Order 2009 to each water draw point under this licence.

5 The meter(s) must be installed in accordance with the provisions of the document entitled "Guidelines for Water Meter Installation 2009" before any water is taken under this licence.

LICENCE TO TAKE WATER

Granted by the Minister under section 5C of the Rights in Water and Irrigation Act 1914

This Licence is subject to the following terms, conditions and restrictions:

6 The annual water year for water taken under this licence is defined as 12:00 pm at 31 July to 12:00 pm at 31 July twelve months later.

7 The licensee must submit to the Department of Water the recorded meter readings and the volume of water taken within the water year by 30 September each year.

8 The licensee shall comply with the 'Cloudbreak Groundwater Operating Strategy - Stage 7 (Rev 0) CB-PH-HY-0009' as prepared by Fortescue Metals Group Limited and approved by the Department of Water on 15 April 2013, including any modifications to the 'Cloudbreak Groundwater Operating Strategy - Stage 7 (Rev 0) CB-PH-HY-0009' as approved during the term of the licence.

9 That the combined total draw under this licence and groundwater licence number 166200 shall not exceed 100,000,000 kilolitres per annum.

10 The licensee is to provide a revised water resource Operating Strategy to the Department of Water by 30 June 2013.

End of terms, conditions and restrictions

LICENCE TO TAKE WATER

Granted by the Minister under section 5C of the Rights in Water and Irrigation Act 1914

Licensee(s)	Fortescue Metals Group Ltd		
Description of Water Resource	Pilbara Hamersley - Fortescue	**Annnal Water Entitlement**	100000000 kL
Location of Water Source	M46/356, M45/1103, M46/357, M46/409, M46/410, E46/590, M45/1104, M45/1105, M45/1106, M45/1107, M45/1124, M45/1125, M46/403, M46/406, M46/411, M46/412, M46/413, M46/414, M45/1102		

Authorised Activities	**Taking of water for**	**Location of Activity**
	Dewatering for mining purposes Mineral ore processing and other mining purposes	M46/356, M45/1103, M46/357, M46/409, M46/410, E46/590, M45/1104, M45/1105, M45/1106, M45/1107, M45/1124, M45/1125, M46/403, M46/406, M46/411, M46/412, M46/413, M46/414, M45/1102
Duration of Licence	From 15 April 2013 to 30 June 2021	

This Licence is subject to the following terms, conditions and restrictions:

1 That water drawn during dewatering operations shall be utilised where possible by the licensee in the mining and treatment operations.

2 The licensee shall submit to the Department of Water an annual report by 30th September each year and a triennial report by 30th September 2013 containing the information as required by Operational policy 5.12 'Hydrogeological Reporting associated with a groundwater well licence'.

3 Quartery technical reports are to be submitted to the Department of Water for assessment by 31st March, 30th June, 30th September (combined into AAR/TAR) and 31st December each year.

4 The licensee must install a cumulative water meter of a type approved under the Rights in Water and Irrigation (Approved Meters) Order 2009 to each water draw point under this licence.

5 The meter(s) must be installed in accordance with the provisions of the document entitled "Guidelines for Water Meter Installation 2009" before any water is taken under this licence.

6 The annual water year for water taken under this licence is defined as 12:00 pm at 31 July to 12:00 pm at 31 July twelve months later.

7 The licensee must submit to the Department of Water the recorded meter readings and the volume of water taken within the water year by 30 September each year.

8 The licensee shall comply with 'Cloudbreak Groundwater Operating Strategy - Stage 7 (Rev 0) CB-PH-HY-0009' as prepared by Fortescue Metals Group Limited and approved by the Department of Water on 15 April 2013, including any modifications to 'Cloudbreak Groundwater Operating Strategy - Stage 7 (Rev 0) CB-PH-HY-0009' as approved during the term of the licence.

9 That the combined total draw under this licence and groundwater licence number 166354 shall not exceed 100,000,000 kilolitres per annum.

This Licence is granted snbject to the Rights in Water and Irrigation Regulations 2000

LICENCE TO TAKE WATER

Granted by the Minister under section 5C of the Rights in Water and Irrigation Act 1914

This Licence is subject to the following terms, conditions and restrictions:

10 The licensee is to provide a revised water resource operating strategy to the Department of Water by 30 June 2013.

End of terms, conditions and restrictions

Appendix 2: Tenements

Tenements – Dewatering Bores	Tenements – Injection
M45/1082	E45/2652
M45/1102	E46/590
M45/1103	E46/612
M45/1104	M45/1103
M45/1105	M45/1104
M45/1106	M45/1105
M45/1124	M45/1106
M45/1125	M45/1107
M45/1126	M45/1082
M45/1139	M45/1083
M46/356	M45/1124
M46/357	M45/1125
M46/401	M45/1126
M46/402	M45/1127
M46/407	M45/1138
M46/408	M46/403
M46/409	M46/404
M46/410	M46/405
M46/411	M46/406
M46/450	M46/409
M46/451	M46/410
	M46/411
	M46/412
	M46/413
	M46/414
	M46/415
	M46/416

This page has been left blank intentionally

This page has been left blank intentionally

Appendix 3: Non-pit region abstraction bore details

Bore Name	Date Drilled	GDA94, Zone 50		Tenement	Casing Diameter (ND, mm)	Total Bore Depth (m)
		Easting	Northing			
Banjo Bore	Jan-08	761344	7535255	E46/724	155mm PVC	41m
Bruce Bore	Dec-06	760602	7524732	M46/402	155mm PVC	84m
CBC01	Nov-06	750836	7530933	M46/451	155mm PVC	82m
CBC02	Nov-06	750064	7531749	M46/451	155mm PVC	76m
Cooks Bore	-	753314	7522102	E46/590	-	-
Damos Bore	Oct-12	-	-	M46/450	300mm PVC	52m
HSA08	July-07	760621	7527768	E46/612	155mm PVC	78m
HSB10	Nov-07	741610	7529358	M45/1102	200mm PVC	65m
HSB12	Oct-07	749999	7526813	M46/409	200mm PVC	65m
HSB15	Oct-07	755369	7527053	M46/407	200mm PVC	84m
HSB17	Oct-07	756805	7526587	M46/401	200mm PVC	80m
HSB19	Nov-07	760720	7525698	M46/402	200mm PVC	61m
Knobs Well	Jan-08	752016	7530560	M46/450	155mm PVC	54m
Marks Well	-	756803	7522730	E46/590	-	-
Minga Bore	-	733719	7529738	E46/590	-	-
Moojarri Bore	-	727900	7531200	M45/1138	-	-
Muirs Bore	-	727212	7532001	M45/1139	-	-
Mulga Bore	-	745256	7525303	E46/590	-	-
Nicks Bore	-	727197	7534016	M45/1082	155mm PVC	57m
Stuarts Bore	-	746225	7533270	M45/1142	-	-
Thieves Bore	-	722537	7534269	M45/1083	-	-
Warri Outcamp Well	-	760711	7521638	E46/612	-	-
WS16P1	-	738465	7535310	E45/2498	-	-
WS16P2	-	738712	7535734	E45/2498	-	-
WS16P3	-	738259	7534873	E45/2498	-	-
CBC06	-	747112	7534093	M45/1141	-	-
CBC07	-	746869	7533707	M45/1141	-	-
CBC08	-	749138	7534274	M46/449	-	-
CBC09	-	749710	7534143	M46/449	-	-
CBC10	-	749549	7533781	M46/449	-	-
CBC11	-	750133	7533459	M46/449	-	-
CBC12	-	750285	7533030	M46/449	-	-
CBC13	-	750415	7533002	M46/451	-	-
CBC14	-	750116	7532809	M46/449	-	-
CBC15	-	750374	7532395	M46/451	-	-
CBC16	-	751692	7532874	L46/46	-	-
CBC17	-	752260	7532683	L46/46	-	-
CBC18	-	752275	7531875	M46/450	-	-

Bore Name	Date Drilled	GDA94, Zone 50		Tenement	Casing	Total Bore
CBC19	-	751749	7531590	M46/450	-	-
CBC20	-	749483	7532971	M46/449	-	-
CBC21	-	749446	7532827	M46/449	-	-
CBC22	-	753040	7530722	M46/450	-	-

This page has been left blank intentionally

Appendix 4: Pit-region abstraction setup

Infrastructure		Key Characteristics	Comment
End-of-strip pit perimeter bores		Typically up to 110 m depth. ND = 200 or 300 mm. Typically screened from the watertable to about 15 m below the base of ore.	Installed prior to below-watertable mining. Typically mine out (decommissioned) in a timeframe of about six months.
Strip-edge dewatering points	In-pit abstraction bores	Typically up to 40 m depth. ND = 200 or 300 mm. Typically screened from the top hardcap to about 15 m below the base of ore.	Resistant to blasting if sufficient distance is maintained from the edge of the blasting front
	In-pit sumps	Excavated with existing mining fleet. Typically up to 5 m deep. Suction pump use to abstract sump water to settlement pond.	The excavation of sumps is the responsibility of the mining contractor
	Strip-edge abstraction bores	Typically up to 110 metres depth. ND = 200 or 300 mm. Typically screened from the watertable to about 15 m below the base of ore.	Installed prior to below-watertable mining. Typically have a longer active abstraction period compared to end-of-strip perimeter bores.
Connecting pipeline	Brackish	Typically >=ND110 mm HDPE poly-welded pipelines. Typical pressure rating range is from pressure nomination (PN) of 6.3 bar at 20°C (PN6.3) to PN12.5	The bulk of initial-mining connecting pipeline
	Saline		May be installed at a later stage if/when saline upconing is evident
	Sump		Separated due to its extra requirement of sediment-settling prior to injection
Settlement ponds	Sump/brackish	Typically 160 x 100 m	May also be used to break the pressure of non-sump abstraction
	Saline		
Mining strip		Typically 150 m wide and 700 m long. Surface miners require that at least two ore strips be open at one time (within the one mining region).	Various strip orientations

Appendix 5: Injection bore details

This page has been left blank intentionally

Usage	Area	Bore ID	Easting	Northing	Zone	Casing Diameter (nominal)	TOC Elevation (mAHD)	Stick Up (magl)	Screened Interval (mbgl)	Total Depth (mbgl)
Fresh to Brackish Disposal	Hillside West	BRP36	740432	7529369	50	300 mm Steel & open hole	423.64	0.33	57 - 66	66
		BRP37	740091	7529519	50	300 mm Steel & open hole	424.93	0.28	48 - 78	78
		BRP38	739742	7529640	50	300 mm Steel & open hole	425.81	0.30	53 - 70	70
		BRP39	739452	7529721	50	300 mm Steel & open hole	424.82	0.35	48 - 64	64.4
		BRP40	738533	7530014	50	300 mm Steel & open hole	424.64	0.59	54 - 66	66
		BRP41	738312	7530084	50	300 mm Steel & open hole	424.39	0.28	42 - 53	53
		HSB01R	729593	7533910	50	300 mm Steel & open hole	421.00	0.43	15 – 45	46
		HSB02A	731188	7533609	50	200 mm PVC PN12	422.68	0.50	26-62	64
		HSB02BR	730401	7533410	50	300 mm Steel & open hole	421.92	0.34	48-72	72
		HSB03	733184	7533579	50	200 mm PVC PN12	424.13	0.68	21.79-59	65
		HSB04A	733995	7532396	50	200 mm PVC PN12	420.37	0.60	33-52	62
		HSB04B	734371	7532786	50	200 mm PVC PN12	423.82	NA	24 – 54	53.64
		HSB05R	735205	7532307	50	300 mm Steel & open hole	419.39	0.44	22 – 58	63
		HSB06R	736024	7531988	50	300 mm Steel & open hole	423.82	0.36	21 - 44	59
		HSB07	738000	7530212	50	200 mm PVC PN12	423.60	NA	24 – 66	67
		HSB20	736033	7531565	50	300 mm Steel & open hole	423.04	0.20	33 - 59	58.94
		HSB21	736032	7531789	50	300 mm Steel & open hole	423.82	0.38	24 - 48	48
		HSB22	732274	7533074	50	300 mm Steel & open hole	432.47	0.42	47-72	72
		HSB23	732944	7532743	50	300 mm Steel & open hole	420.52	0.39	36 - 54	54
		HSB24	734480	7532410	50	300 mm Steel & open hole	420.86	0.37	52 - 70	70
		HSB25	733200	7533383	50	300 mm Steel & open hole	423.46	0.44	30 - 66	66
		HSB26	733190	7533180	50	300 mm Steel & open hole	422.76	0.46	36 - 66	66
		HSB27	732622	7532896	50	300 mm Steel & open hole	423.34	0.50	42 - 66	66
		HSB28	730377	7533745	50	300 mm Steel & open hole	422.81	0.38	40 - 64	64
		HSB29	730726	7533679	50	300 mm Steel & open hole	423.10	0.37	35 - 54	54
		HSB30	736057	7531321	50	300 mm Steel & open hole	422.78	0.34	36 - 52	52
		HSB31	735583	7531585	50	300 mm Steel & open hole	421.09	0.34	42 - 56	56
		HSB32	734947	7532381	50	300 mm Steel & open hole	420.33	0.42	46 - 70	70
		HSB33	734357	7532588	50	300 mm Steel & open hole	421.93	0.40	40 - 58	58
		HSB34	730412	7533097	50	300 mm Steel & open hole	421.08	0.40	52 - 71	71
		HSB35	736230	7531166	50	300 mm Steel & open hole	423.78	0.36	47 - 66	66
		HSB65	736604	7530889	50	300 mm Steel & open hole	424.63	0.49	36.1 - 56.1	56
		HSB66	737028	7530695	50	300 mm Steel & open hole	424.95	0.55	30.0 - 54.0	54
		HSB67	737420	7530494	50	300 mm Steel & open hole	425.37	0.59	36.0 - 55.6	56
	Left Handers	HSB36	722516	7535122	50	300 mm Steel & open hole	417.44	0.42	36 - 60	60
		HSB37	722992	7535016	50	300 mm Steel & open hole	415.69	0.64	36 - 60	60
		HSB38	723394	7534801	50	300 mm Steel & open hole	413.64	0.62	36 - 60	60
		HSB39	723816	7535229	50	300 mm Steel & open hole	414.64	0.57	36 - 60	60
		HSB40	724753	7535117	50	300 mm Steel & open hole	415.88	0.42	42 - 60	60

Usage	Area	Bore ID	Easting	Northing	Zone	Casing Diameter (nominal)	TOC Elevation (mAHD)	Stick Up (magl)	Screened Interval (mbgl)	Total Depth (mbgl)
		HSB41	725148	7535196	50	300 mm Steel & open hole	417.55	0.48	36 - 60	60
	Left Handers	LHP01	723349	7535038	50	Bores are yet to be completed/drilled. Details will be updated when availble.				
		LHP02	723705	7535055	50					
		LHP03	725508	7535085	50					
		LHP04	725886	7534977	50					
		LHP05	726252	7534870	50	300 mm Steel & open hole	419.41	0.56	36-62	62
		LHP06	725891	7534981	50	300 mm Steel & open hole	419.57	0.57	40.5-53.6	54
		LHP07	726254	7534873	50	300 mm Steel & open hole	421.38	0.60	36-54	54
		LHP08	726627	7534766	50	300 mm Steel & open hole	422.71	0.60	36-60.85	61
		LHP09	726999	7534659	50	300 mm Steel & open hole	424.34	0.56	18-55	55
		LHP10	727408	7534542	50	300 mm Steel & open hole	424.61	0.42	42-66	66
		LHP11	727817	7534394	50	300 mm Steel & open hole	426.50	0.71	30-51	51
		LHP12	728170	7534293	50	300 mm Steel & open hole	425.04	0.62	36-56	56
		LHP13	728515	7534194	50	300 mm Steel & open hole	424.33	0.55	40-58	58
		LHP14	728868	7534093	50	300 mm Steel & open hole	423.12	0.61	42-66	66
		LHP15	729185	7534000	50	300 mm Steel & open hole	422.41	0.54	42-66	66
		INJ01R	745613	7526187	50	300 mm Steel & open hole	418.83	1.17	51 - 71	71
		SRP01	743151	7524794	50	300 mm Steel & open hole	410.80	0.14	46-62	62
		SRP02	743870	7524848	50	300 mm Steel & open hole	412.70	0.35	47-65	65
		SRP03	744532	7524719	50	300 mm Steel & open hole	412.34	0.54	42-66	66
		SRP04	745376	7524445	50	200 mm PVC PN12	411.90	0.48	46-101	101
		SRP05	746002	7523853	50	300 mm Steel & open hole	409.94	0.23	47-64	64
		SRP07	744195	7525859	50	300 mm Steel & open hole	417.54	0.55	53 - 71	71
		SRP08	745395	7525545	50	300 mm Steel & open hole	416.14	0.37	54 - 70	70
		SRP10	742668	7526962	50	300 mm Steel & open hole	419.00	0.53	57 - 78	78
		SRP11	743299	7526816	50	300 mm Steel & open hole	420.50	0.55	57 - 78	78
		SRP13	744168	7526609	50	300 mm Steel & open hole	420.74	0.43	60 - 77	77
		SRP14	748788	7524494	50	300 mm Steel & open hole	417.04	0.51	60 - 78	78
		SRP15	744742	7526466	50	300 mm Steel & open hole	420.70	0.34	60 - 78	78
		SRP16	747129	7524950	50	300 mm Steel & open hole	416.10	0.51	54 - 65	72
		SRP17	745202	7526361	50	300 mm Steel & open hole	420.35	0.39	60 - 84	84
		SRP19	745923	7526149	50	300 mm Steel & open hole	418.12	0.55	54 - 72	72
		SRP20	746186	7526119	50	300 mm Steel & open hole	418.72	0.55	54 - 70	70
		SRP21	750546	7524235	50	300 mm Steel & open hole	416.18	0.51	48 - 57	57
		SRP23	751977	7524096	50	300 mm Steel & open hole	417.70	0.46	60 - 78	78
		SRP26	755193	7523006	50	300 mm Steel & open hole	417.27	0.52	54 - 72	72
		SRP28	756721	7523069	50	300 mm Steel & open hole	418.04	0.56	54 - 71	71
		SRP30	753481	7523660	50	300 mm Steel & open hole	416.07	0.60	60 - 72	72
		SRP32	759199	7522477	50	300 mm Steel & open hole	418.70	0.32	54 - 72	72

Usage	Area	Bore ID	Easting	Northing	Zone	Casing Diameter (nominal)	TOC Elevation (mAHD)	Stick Up (magl)	Screened Interval (mbgl)	Total Depth (mbgl)
Saline Disposal	Saline Injection	SRP34**	761076	7522120	50	300 mm Steel & open hole	418.74	0.36	78 - 90	90
		SRP36**	762695	7521830	50	300 mm Steel & open hole	417.01	0.68	60 - 78	78
		SRP37	741850	7527295	50	300 mm Steel & open hole	417.19	0.50	49 - 65	65
		SRP38	741369	7527495	50	300 mm Steel & open hole	415.99	0.45	59 - 67	67
		SRP39	741023	7527495	50	300 mm Steel & open hole	415.18	0.29	60 - 64.9	65
		SRP40	740703	7527721	50	300 mm Steel & open hole	415.40	0.29	47 - 66	66
		SRP41	740332	7527806	50	300 mm Steel & open hole	415.37	0.30	52 - 65	65
		SRP42	740000	7527903	50	300 mm Steel & open hole	416.66	0.46	47 - 59	59
		SRP43	739673	7528018	50	300 mm Steel & open hole	416.65	0.42	50 - 65	65
		SRP44	739268	7528170	50	300 mm Steel & open hole	416.76	0.46	56.1 - 61	61
		SRP45	738869	7528329	50	300 mm Steel & open hole	417.73	0.50	54 - 65	65
		SRP46	746485	7525151	50	300 mm Steel & open hole	415.65	0.50	56 - 67	67
		SRP47	748042	7524655	50	300 mm Steel & open hole	415.73	0.50	44 - 64	64
		SRP48	751217	7524183	50	300 mm Steel & open hole	417.39	0.50	52 - 66	70
		SRP49	752687	7524005	50	300 mm Steel & open hole	415.90	0.50	43 - 64	64
		SRP50	754579	7523269	50	300 mm Steel & open hole	417.27	0.50	46 - 65	65
		SRP51	755892	7522810	50	300 mm Steel & open hole	417.51	0.50	48 - 62	62
		SRP52	757490	7522867	50	300 mm Steel & open hole	417.78	0.50	50 - 67	67
		SRP53	758480	7522696	50	300 mm Steel & open hole	418.34	0.50	50 - 66	66
		SRP54	759831	7522387	50	300 mm Steel & open hole	419.16	0.50	55 - 70	71
		SRP55	761999	7521934	50	300 mm Steel & open hole	417.85	0.50	47 - 65	65
		SRP67	738592	7528426	50	355mm PVC & Open hole	417.43	0.50	50 - 65	65
		SRP56	752189	7524926	50	300 mm Steel & open hole	420.13	0.54	57 - 67	67
		SRP57	752797	7525117	50	300 mm Steel & open hole	420.83	0.50	48 - 66	66
		SRP58	753568	7524826	50	300 mm Steel & open hole	419.06	0.50	42 - 65	68
		SRP59	754167	7524717	50	300 mm Steel & open hole	421.50	0.40	53 - 66	66
		SRP60	754753	7524522	50	300 mm Steel & open hole	422.05	0.53	51 - 61	65
		SRP61	755233	7524268	50	300 mm Steel & open hole	421.83	0.46	49 - 65	65
		SRP62	755765	7524022	50	300 mm Steel & open hole	422.55	0.44	54 - 65	65
		SRP63	756311	7523963	50	300 mm Steel & open hole	421.67	0.24	52 - 71	71
		SRP64	756742	7523761	50	300 mm Steel & open hole	421.08	0.56	52 - 71	71
		SRP68	738770	7527502	50	355mm PVC & Open hole	413.93	0.47	31.2 - 53.2	53
		SRP69	739500	7527328	50	355mm PVC & Open hole	413.83	0.50	37.7 - 53.7	53
		SRP70	740211	7527155	50	355mm PVC & Open hole	413.06	0.39	38.1 - 59.1	61
		SRP71	741080	7526911	50	355mm PVC & Open hole	413.12	0.51	44.9 - 54.9	56
		SRP72	741977	7526593	50	355mm PVC & Open hole	414.67	0.50	45.5 - 65.1	66
		SRP73	742223	7526420	50	355mm PVC & Open hole	414.75	0.50	49.6 - 65.6	65
		SRP74	742624	7526110	50	355mm PVC & Open hole	415.43	0.55	50.6 - 59.6	60
		SRP75	742816	7525950	50	355mm PVC & Open hole	415.50	0.47	49.2 - 61.2	61

Usage	Area	Bore ID	Easting	Northing	Zone	Casing Diameter (nominal)	TOC Elevation (mAHD)	Stick Up (magl)	Screened Interval (mbgl)	Total Depth (mbgl)
		SRP76	743158	7525676	50	355mm PVC & Open hole	414.67	0.47	47.0 - 60.0	60
		SRP77	746818	7525044	50	355mm PVC & Open hole	415.43	0.49	49.0 - 72.0	70
		SRP78	747619	7524854	50	355mm PVC & Open hole	415.81	0.41	52.0 - 66.0	72
		SRP79	748491	7524620	50	355mm PVC & Open hole	416.01	0.13	49.5 - 62.0	66
		SRP81	749784	7523949	50	355mm PVC & Open hole	414.67	0.13	41.5 - 55.5	58
		SRP82	750164	7523986	50	355mm PVC & Open hole	415.04	0.23	40.4 - 65.4	65
		SRP83	746047	7525278	50	355mm PVC & Open hole	415.00	0.51	47.0 - 72.0	72
		SRP84	750896	7524235	50	355mm PVC & Open hole	416.61	0.53	44.0 - 65.0	66
		SRP85	751533	7524158	50	355mm PVC & Open hole	416.42	0.52	47.0 - 71.2	70
		SRP86	752221	7524071	50	355mm PVC & Open hole	417.43	0.50	41.0 - 72.3	74
		SRP87	739183	7527412	50	355mm PVC & Open hole	413.56	0.50	43.0 - 57.7	58
		SRP88	739812	7527255	50	355mm PVC & Open hole	412.81	0.40	47.0 - 54.4	55
		SRP89	741464	7526801	50	355mm PVC & Open hole	413.63	0.60	47.0 - 59.3	60
		SRP90	743529	7525695	50	355mm PVC & Open hole	415.78	TBC	TBC	TBC
		SRP91	743850	7525772	50	355mm PVC & Open hole	416.85	TBC	TBC	TBC
		SRP92	744463	7525734	50	355mm PVC & Open hole	416.61	TBC	TBC	TBC
		SRP93	744840	7525624	50	355mm PVC & Open hole	416.10	TBC	TBC	TBC
		SRP96	TBC	TBC	50	355mm PVC & Open hole	TBC	TBC	TBC	TBC
		SRP97	TBC	TBC	50	355mm PVC & Open hole	TBC	TBC	TBC	TBC
		SRP98	TBC	TBC	50	355mm PVC & Open hole	TBC	TBC	TBC	TBC
		SRP99	TBC	TBC	50	355mm PVC & Open hole	TBC	TBC	TBC	TBC

Appendix 6: Proposed abstraction rates at Cloudbreak

Source	Use	Estimate volume (kL/year)
CBC01 CBC02 Knobs Bore Damos Bore 17 Proposed Supply Bores (see Figure 4)	Accommodation Village	Not covered by this Operating Strategy
Banjo Bore Bruce Bore CBC01 CBC02 Cooks Bore Damos Bore HSA08 HSB10 HSB12 HSB15 HSB17 HSB19 Knobs Well Marks Well Minga Bore Moojarri Bore Muirs Bore Mulga Bore Nicks Bore Stuarts Bore Thieves Bore Warri Outcamp Well WS16P1 WS16P2 WS16P3 Pit-region bores & sumps	OPF, Dust Suppression & Construction	Up to 100,000,000

Appendix 7: Cloudbreak conceptual water balance

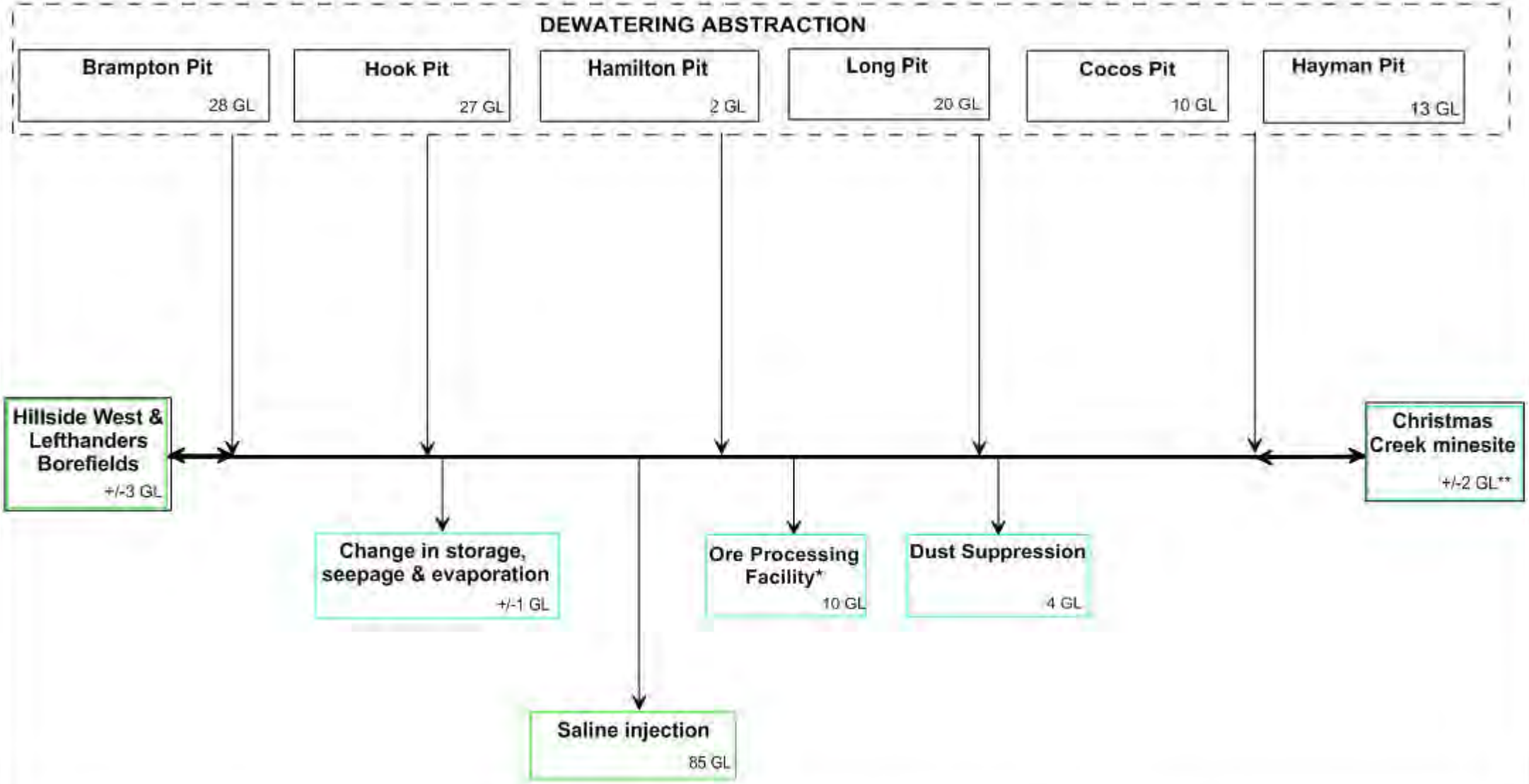
This page has been left blank intentionally

CLOUDBREAK CONCEPTUAL MINE WATER BALANCE Aug 2012 - July 2013

CATEGORY	AREA (RATE) ML/d	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14
		31	30	31	30	31	31	28	31	30	31	30	31
DEWATERING PLAN (ML/Day)	BRAMPTON	70	75	80	120	115	70	65	65	65	65	65	65
	COCOS	50	50	50	25	20	20	20	15	15	15	15	15
	HAMILTON	10	10	10	10	10	10	10	0	0	0	0	0
	HAYMAN	50	50	50	40	40	35	40	33	30	30	30	30
	HOOK	80	75	80	75	85	80	80	80	80	60	60	60
	LONG	35	60	60	55	60	55	60	50	50	50	50	50
	Total (ML/d)	**295**	**320**	**330**	**325**	**330**	**270**	**275**	**243**	**240**	**220**	**220**	**220**
	Monthly Total (ML/m)	**9,143**	**9,600**	**10,230**	**9,755**	**10,230**	**8,370**	**7,700**	**7,521**	**7,200**	**6,823**	**6,609**	**6,820**
	Cumulative Total (ML)	**9,143**	**18,743**	**28,973**	**38,728**	**48,958**	**57,328**	**65,028**	**72,549**	**79,749**	**86,572**	**93,180**	**100,000**
SITE USE PLAN (ML/Day)	CB OPF	28	28	28	28	28	28	28	28	28	28	28	28
	CB Dust Suppression	10	10	10	10	10	10	10	10	10	10	10	10
	Seepage/Storage/Evaporation	3	3	3	3	3	3	3	3	3	3	3	3
	CC Use	0	0	0	0	0	0	0	0	0	0	0	0
	Total Water (ML/d)	**41**	**41**	**41**	**41**	**41**	**41**	**41**	**41**	**41**	**41**	**41**	**41**
	Monthly Total (ML/m)	**1,271**	**1,230**	**1,271**	**1,230**	**1,271**	**1,271**	**1,148**	**1,274**	**1,229**	**1,280**	**1,242**	**1,283**
	Cumulative Total (ML)	**1,271**	**2,501**	**3,772**	**5,002**	**6,273**	**7,544**	**8,692**	**9,966**	**11,195**	**12,475**	**13,717**	**15,000**
REINJECTION PLAN (ML/Day)	Hillside West	0	0	0	0	0	0	0	0	0	0	0	0
	Lefthanders	0	0	0	0	0	0	0	0	0	0	0	0
	Hillside East (CB)	0	0	0	0	0	0	0	0	0	0	0	0
	Saline Injection	254	279	289	284	289	229	234	202	199	179	179	179
	Total (ML/d)	**254**	**279**	**289**	**284**	**289**	**229**	**234**	**202**	**199**	**179**	**179**	**179**
	Monthly Total (ML/m)	**7,872**	**8,370**	**8,959**	**8,525**	**8,959**	**7,099**	**6,552**	**6,247**	**5,972**	**5,543**	**5,367**	**5,537**
	Cumulative Total (ML)	**7,872**	**16,242**	**25,201**	**33,726**	**42,685**	**49,784**	**56,336**	**62,583**	**68,554**	**74,097**	**79,464**	**85,000**

License application is for 100 GL abstraction, 85GL Injection

CLOUDBREAK CONCEPTUAL SCHEMATIC MINE WATER BALANCE
July 13 - July 14



Abstraction location

Injection location

Water use/destination

^ Fortescue is operating within its abstraction limit of 100GL/yr as per license. An application for an update of the Operating Strategy will be submitted if allocated license limit extend beyond June 2014.

* Includes office & workshop use in the ore processing facility

**+/-2GL is an indicative potential use to/from CC for OPF use, which would lead to reduction in other injection areas.

Appendix 8: Monitoring locations

Sample point	Sample point type	Easting (m)	Northing (m)
SP0021_HSW_INJ (Hillside West)	Brackish injection discharge pipeline	736,054	7,531,321
SP0010_HSE_INJ (Hillside East)		746,642	7,527,689
SP0005_TSF_DW (north transfer pond)		743,750	7,527,850
SP0020_TSF_DW (Brampton inflow north transfer pond)		745,802	7,527,077
SP0009_STP_SINJ (saline injection)	Saline injection discharge pipeline	745,878	7,527,067
SP0114_BRP_SINJ (Brampton saline)		742,101	7,527,163
SP0115_LOO_SINJ (Long saline)		753,253	7,526,505
SP0126_LOO_SINJ (Long saline pond outflow)		752,001	7,525,719
CBFMM02_S	Monitoring bore (chemical analysis)	727,559	7,527,940
CBFMM06_S		740,436	7,524,558
CBX02_WT		727,186	7,530,125
CBX04_S		734,438	7,528,317
CBX05_WT		739,997	7,530,212
CBX07_S		738,241	7,526,272
CBX10a_WT		744,596	7,524,709
CBX13_WT		752,432	7,521,988
HSMB01_WT		730,412	7,533,086
HSMB20_WT		733,218	7,532,997
LHMB02_WT		723,397	7,534,789
SRM22		745,912	7,526,184
SRM25		747,149	7,524,923
SRM32_S		759,205	7,522,454
SRM43_D		739,638	7,528,028
SRM43_S		739,628	7,527,997
SRM48_D		751,196	7,524,192
SRM48_S		751,196	7,524186
SP0001_TSF_DW (north transfer pond)	Water use volumes (flow meter)	745,818	7,527,077
SP0002_TSF_SDW (south transfer pond)		745,965	7,527,063

Sample point	Sample point type	Easting (m)	Northing (m)
SP0004_BRP_INJ (Brampton west pipeline)		741,900	7,529,000
SP0011_BRP_DW (Brampton dirt dam)			
SP00012_OPF_SU (OPF standpipe)		746,638	7,527,688
SP0016_HAM_DW (Hamilton TN)			
SP0017_HAM_DW (Hamilton pond)			
SP0022_TSF_DW (Cocos/Long inflow north transfer pond)		745,893	7,527,286
SP0023_BRP_DW (Brampton sump water)			
SP0024_BRP_DW (Brampton settlement pond)			
SP0033_HOO_DW (Hook settlement pond)			
SP0120_BRP_DW (Brampton brackish pipeline)		745,887	7,527,280
SP0121_TSF_DW (Hook settlement pond inflow)			
SP0122_TSF_DW (Hook settlement pond outflow)			
SP0123_LOO_SUDW (Long sump water)		751,770	7,525,687
SP0124_LOO_DW (Long sump pond outflow)		751,831	7,525,905
SP0125_LOO_DW (Long saline pond inflow)		751,887	7,526,069
SP00127_LOO_DW (Long brackish pond outflow)		751,392	7,525,716
SP00128_LOO_DW (Long brackish pond inflow)			
SP0129_CO_SUDW (Cocos settlement pond inflow)		756,873	7,525,776
SP0130_CO_DW (Cocos settlement pond outflow)		756,898	7,525,724
SP0131_HAM_SUDW (Hamilton pond inflow)			
SP0133_HSW_DW (West 2 transfer pond outflow)		733,464	7,532,549
SP0134_HSW_DW (West 2 transfer pond inflow)		733,474	7,532,552
SP0135_TSF_DW (East 2 transfer pond outflow)			
SP0136_DW_DW (East 2 transfer pond inflow)			
B05	Model Calibration monitoring points (bores)	745803	7527396
B13		745041	7527304
B17		746810	7526601
B19		747402	7526600
B20		747803	7526761
BRP12		743609	7527677

Sample point	Sample point type	Easting (m)	Northing (m)
BRP15		742404	7528288
BRP21		741440	7528411
CBX12_D		752805	7525973
CBX12_S		752805	7525973
GPM01_D		753591	7525981
GPM01_I		753591	7525981
GPM01_S		753591	7525981
GPM01_WT		753591	7525981
GPM05_D		753188	7525902
GPM05_I		753188	7525902
GPM05_S		753188	7525902
GPM05_WT		753188	7525902
GPP31		752424	7526400
GPP48		754185	7526913
GPP59		752383	7526746
GPP61		752337	7526592
HPDW116		746880	7527388
HSB12		749999	7526813
HSB15		755369	7527053
HSB20		736033	7531565
HSB21		736032	7531789
HSB30		736055	7531321
HSB31		735589	7531585
HSB35		736230	7531166
HSB65		736641	7530890
HSB66		737028	7530695
HSB67		737420	7530494
HSMB23_D		756787	7525621
HSMB23_I		756787	7525621
HSMB23_S		756787	7525621
Cooks Bore	Pastoral bore	753,314	7,522,102
Moojarri Bore		727,900	7,531,200
Minga Bore		733,719	7,529,738

Sample point	Sample point type	Easting (m)	Northing (m)
Mulga Bore		745,256	7,525,303
DP01	Contingency discharge site	740,412	7,529,310
DP02		741,688	7,528,009
DP03		742,623	7,527,872
DP04		746,046	7,526,809
DP05		746,710	7,526,534
DP06		746,710	7,526,332
DP07		749,666	7,526,735
DP08		752,843	7,525,870
DP09		752,843	7,525,899
DP10		752,843	7,525,619
HSDP01		730,849	7,533,683
HSDP02		732,936	7,532,758
HSDP03		732,936	7,532,555
HSDP04		734,371	7,532,490
HSDP05		736,381	7,531,027
HSDP06		737,100	7,530,646
HSDP07		737,897	7,530,257
CCFMM05_D	Zone A (near-marsh) control bore	794,939	7,504,202
CCFMM05_S		794,939	7,504,202
BRM13_D	Pit water level monitoring (bores)	742167	7529490
BRM14		743306	7528346
BRM15		742734	7528809
BRM16		742367	7529040
BRM20		741465	7529162
BRM21		741853	7529125
BRM22		741986	7529332
BRM23		741525	7528953
BRM24		741753	7528731
BRM25		742130	7528792
BRM26		742292	7528354

Sample point	Sample point type	Easting (m)	Northing (m)
BRM27		742620	7528440
BRM28_R		742670	7528095
BRM29		743056	7528148
BRM30_R		743063	7527820
BRM31_R		743323	7527932
CBX37_D		746215	7527294
COM01_D		757645	7526870
COM05_D		755702	7527643
COM08		755206	7527631
COM09		756324	7526594
COM10		756117	7526825
COM12		757349	7526437
COM15		758029	7526388
COM16		758244	7526189
COP22		757132	7526784
GPM02_D		753480	7526585
GPM03_D		753733	7526728
GPM04_D		753098	7526690
HAMM04_I		749692	7527343
HAMM07_D		750333	7527155
HAYMB23_I		746935	7526989
HAYMB24		747157	7526844
HAYMB25		747335	7526696
HPM03		746207	7527522
HPMB05		746641	7527495
HPMB06		745012	7527520
HPMB07		745483	7527538
LNP06		744157	7528407
LPMB01		753840	7527195
LPMB02		753794	7526962
LPMB04		752866	7526860

Appendix 9: Project trigger levels

This page has been left blank intentionally

Zone	Monitoring Bore	Easting (mE)	Northing (mN)	Trigger target aquifer [3]	Groundwater level trigger			Groundwater quality trigger	
					Baseline groundwater level (mbgl)	Class 1 trigger (+/- m)	Class 2 trigger (+/- m)	Baseline EC (µS/cm)	Class 1 trigger (µS/cm) [2]
Zone A	CBX02_WT[5]	727186	7530125	Tertiary Alluvium	405.82 - 406.71	0.65^	1^	25,000	-
Zone A	CBX04_S[5]	734438	7528317	Tertiary Alluvium	405.97 - 406.76	0.65^	1^	90,000	-
Zone A	CBX07_S	738241	7526272	Tertiary Alluvium	405.21 - 406.32	0.65^	1^	100,000	-
Zone A	CBX10a_WT[5]	744596	7524709	Tertiary Alluvium	406.07 - 406.81	0.65^	1^	50,000	-
Zone A	CBX13_WT[5]	752432	7521988	Tertiary Alluvium	405.15 - 406.18	0.65^	1^	70,000	-
Zone A	CBFMM02_S	727559	7527937	Tertiary Alluvium	405.16 - 406.69	0.65^	1^	120,000	-
Zone A	CBFMM06_S	740440	7524500	Tertiary Detritals	404.81 - 406.32	0.65^	1^	120,000	-
Zone A	CBFMM01*	720703	7531612	Tertiary Detritals	*	0.65^	1^	*	-
Zone A	CBFMM04*	734697	7527655	Tertiary Detritals	*	0.65^	1^	*	-
Zone A	CBFMM05*	746758	7523454	Tertiary Detritals	*	0.65^	1^	*	-
Zone A	CBFMM07*	751176	7521806	Tertiary Detritals	*	0.65^	1^	*	-
Zone A	CBFMM08*	755273	7520434	Tertiary Detritals	*	0.65^	1^	*	-
Zone B	CBX11_I	749129	7524843	Oakover Fmn.	10.3	2.2	-	-	-
Zone B	CBX11_WT	749129	7524843	Tertiary Detritals	10.1	3	2.2	2,900	9,000
Zone B	SCX08_D	758400	7523008	Oakover Fmn.	9.1	2.2	-	-	-
Zone B	SCX08_S	758400	7523008	Tertiary Detritals	10.2	3	2.2	20,100	-
Zone B	SRM06_I	742686	7526944	Oakover Fmn.	10.5	2.2	-	-	-
Zone B	SRM06_S	742686	7526944	Tertiary Detritals	10.4	3	2.2	16,500	-
Zone B	SRM07_I	744131	7526621	Oakover Fmn.	12.6	2.2	-	-	-
Zone B	SRM07_S	744131	7526621	Tertiary Detritals	12.4	3	2.2	33,200	-
Zone B	SRM08R_D	745389	7525505	Oakover Fmn.	7.4	2.2	-	-	-
Zone B	SRM08R_S	745389	7525505	Tertiary Detritals	5.3	3	2.2	85,000	-
Zone B	SRM14_I	762701	7521795	Oakover Fmn.	9.6	2.2	-	-	-
Zone B	SRM14_S	762701	7521795	Tertiary Detritals	8.1	3	2.2	14,100	-
Zone B	SRM19	743309	7526792	Tertiary Detritals	12.0	3	2.2	-	-
Zone B	SRM20	744712	7526472	Tertiary Detritals	12.4	3	2.2	10,900	-
Zone B	SRM21	745171	7526370	Tertiary Detritals	11.9	3	2.2	-	-
Zone B	SRM22	745912	7526184	Tertiary Detritals	9.7	3	2.2	3,200	9,000
Zone B	SRM25	747149	7524923	Tertiary Detritals	7.2	3	2.2	2,300	9,000
Zone B	SRM26	750574	7524257	Tertiary Detritals	7.6	3	2.2	6,900	10,350
Zone B	SRM27	751948	7524114	Tertiary Detritals	9.0	3	2.2	4,800	9,000
Zone B	SRM28	755173	7523033	Tertiary Detritals	8.5	3	2.2	11,800	-
Zone B	SRM29	761045	7522091	Tertiary Detritals	9.9	3	2.2	19,900	-
Zone B	SRM30_S	753518	7523649	Tertiary Detritals	7.0	3	2.2	2,000	9,000
Zone B	SRM32_S	759205	7522454	Tertiary Detritals	9.7	3	2.2	11,000	-
Zone B	SRM37_D	741861	7527285	Oakover Fmn.	6.6	2.2	-	-	-
Zone B	SRM37_S	741877	7527278	Tertiary Detritals	7.0	3	2.2	1,200	9,000
Zone B	SRM38_D	741367	7527487	Oakover Fmn.	5.9	2.2	-	-	-
Zone B	SRM38_S	741342	7527481	Tertiary Detritals	6.3	3	2.2	4,900	9,000
Zone B	SRM39_D	740984	7527602	Oakover Fmn.	5.1	2.2	-	-	-
Zone B	SRM39_S	740985	7527608	Tertiary Detritals	5.1	3	2.2	2,700	9,000
Zone B	SRM40_D	740674	7527740	Oakover Fmn.	11.3	2.2	-	-	-
Zone B	SRM40_S	740666	7527742	Tertiary Detritals	6.4	3	2.2	6,900	10,350
Zone B	SRM41_D	740332	7527806	Oakover Fmn.	6.0	2.2	-	-	-
Zone B	SRM41_S	740332	7527806	Tertiary Detritals	5.8	3	2.2	2,300	9,000
Zone B	SRM42_D	739973	7527908	Oakover Fmn.	5.6	2.2	-	-	-
Zone B	SRM42_S	739977	7527913	Tertiary Detritals	5.9	3	2.2	2,000	9,000
Zone B	SRM43_D	739638	7528028	Oakover Fmn.	6.8	2.2	-	-	-
Zone B	SRM43_S	739628	7527997	Tertiary Detritals	6.8	3	2.2	3,240	9,000
Zone B	SRM44_D	739236	7528180	Oakover Fmn.	6.4	2.2	-	-	-
Zone B	SRM44_S	739239	7528188	Tertiary Detritals	6.8	3	2.2	2,230	9,000
Zone B	SRM45_D	738869	7528329	Oakover Fmn.	8.5	2.2	-	-	-
Zone B	SRM45_S	738869	7528329	Tertiary Detritals	7.3	3	2.2	1,500	9,000
Zone B	SRM46_D	746462	7525161	Oakover Fmn.	4.7	2.2	-	-	-
Zone B	SRM46_S	746457	7525165	Tertiary Detritals	6.5	3	2.2	1,000	9,000
Zone B	SRM47_D	748012	7524662	Oakover Fmn.	6.5	2.2	-	-	-
Zone B	SRM47_S	748007	7524667	Tertiary Detritals	8.5	3	2.2	1,800	9,000
Zone B	SRM48_D	751196	7524186	Oakover Fmn.	7.6	2.2	-	-	-
Zone B	SRM48_S	751196	7524192	Tertiary Detritals	9.1	3	2.2	14,300	-
Zone B	SRM49_D	752686	7523977	Oakover Fmn.	5.6	2.2	-	-	-
Zone B	SRM49_S	752691	7523977	Tertiary Detritals	6.9	3	2.2	4,700	9,000
Zone B	SRM50_D	754544	7523283	Oakover Fmn.	6.1	2.2	-	-	-
Zone B	SRM50_S	754559	7523278	Tertiary Detritals	7.4	3	2.2	730	9,000
Zone B	SRM51_D	755853	7522803	Oakover Fmn.	5.9	2.2			
Zone B	SRM51_S	755845	7522801	Tertiary Detritals	8.9	3	2.2	4,700	9,000
Zone B	SRM52_D	757449	7522880	Oakover Fmn.	6.7	2.2			
Zone B	SRM52_S	757438	7522884	Tertiary Detritals	8.9	3	2.2	3,100	9,000
Zone B	SRM53_D	758532	7522667	Oakover Fmn.	7.7	2.2	-	-	-
Zone B	SRM53_S	758508	7522673	Tertiary Detritals	9.3	3	2.2	21,400	-
Zone B	SRM54_D	759834	7522365	Oakover Fmn.	9.5	2.2	-	-	-
Zone B	SRM54_S	759834	7522366	Tertiary Detritals	9.2	3	2.2	13,500	
Zone B	SRM55_D	762003	7521901	Oakover Fmn.	6.8	2.2	-	-	-
Zone B	SRM55_S	762004	7521917	Tertiary Detritals	8.3	3	2.2	8,500	12,750
Zone B	SRM56_D	752193	7524930	Oakover Fmn.	10.2	2.2	-	-	-

Zone	Monitoring Bore	Easting (mE)	Northing (mN)	Trigger target aquifer [3]	Groundwater level trigger			Groundwater quality trigger	
					Baseline groundwater level (mbgl)	Class 1 trigger (+/- m)	Class 2 trigger (+/- m)	Baseline EC (µS/cm)	Class 1 trigger (µS/cm) [2]
Zone B	SRM56_S	752193	7524930	Tertiary Detritals	10.6	3	2.2	9,000	-
Zone B	SRM57_D	752797	7525117	Oakover Fmn.	10.2	2.2	-	-	-
Zone B	SRM57_S	752821	7525062	Tertiary Detritals	10.8	3	2.2	3,500	9,000
Zone B	SRM58_D	753553	7524786	Oakover Fmn.	8.3	2.2	-	-	-
Zone B	SRM58_S	753558	7524791	Tertiary Detritals	8.5	3	2.2	2,600	9,000
Zone B	SRM59_D	754137	7524659	Oakover Fmn.	9.9	2.2	-	-	-
Zone B	SRM59_S	754122	7524657	Tertiary Detritals	9.9	3	2.2	3,000	9,000
Zone B	SRM60_D	754684	7524517	Oakover Fmn.	10.4	2.2	-	-	-
Zone B	SRM60_S	754684	7524517	Tertiary Detritals	10.2	3	2.2	600	9,000
Zone B	SRM61_D	755214	7524212	Oakover Fmn.	10.4	2.2	-	-	-
Zone B	SRM61_S	755214	7524209	Tertiary Detritals	10.3	3	2.2	1,700	9,000
Zone B	SRM62_D	755749	7523962	Oakover Fmn.	10.6	2.2	-	-	-
Zone B	SRM62_S	755755	7523980	Tertiary Detritals	11.0	3	2.2	3,100	9,000
Zone B	SRM63_D	756321	7523907	Oakover Fmn.	9.5	2.2	-	-	-
Zone B	SRM63_S	756325	7523908	Tertiary Detritals	10.5	3	2.2	8,700	13,050
Zone B	SRM64_D	756748	7523749	Oakover Fmn.	9.2	2.2	-	-	-
Zone B	SRM64_S	756748	7523749	Tertiary Detritals	10.5	3	2.2	8,300	12,450
Zone B	SRM67_D	738608	7528396	Oakover Fmn.	7.8	2.2	-	-	-
Zone B	SRM67_S	738614	7528402	Tertiary Detritals	7.4	3	2.2	*	*
Zone B	SRM68_D	738820	7527495	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM68_S	738822	7527501	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM69_D	739541	7527316	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM69_S	739544	7527320	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM70_D	740253	7527142	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM70_S	740255	7527146	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM71_D	741129	7526896	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM71_S	741130	7526901	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM72_D	742008	7526575	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM72_S	742007	7526572	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM73_D	742255	7526402	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM73_S	742256	7526406	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM74_D	742656	7526080	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM74_S	742660	7526083	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM75_D	742852	7525926	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM75_S	742854	7525929	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM76_D	743193	7525650	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM76_S	743196	7525654	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM77_D	746858	7525035	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM77_S	746852	7525037	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM78_D	747569	7524874	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM78_S	747567	7524869	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM79_D	748441	7524631	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM79_S	748440	7524627	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM81_D	749822	7523948	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM81_S	749823	7523954	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM82_D	750205	7523999	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM82_S	750211	7524001	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM83_D	746098	7525261	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM83_S	746101	7525266	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM84_D	750943	7524234	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM84_S	750944	7524239	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM85_D	751580	7524156	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM85_S	751581	7524160	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM86_D	752269	7524066	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM86_S	752270	7524069	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM87_D	739233	7527405	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM87_S	739230	7527398	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM88_D	739861	7527249	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM88_S	739866	7527252	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM89_D	741517	7526787	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM89_S	741518	7526791	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM90_D	743572	7525708	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM90_S	743570	7525710	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM91_D	743896	7525784	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM91_S	743893	7525789	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM92_D	744511	7525720	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM92_S	744511	7525725	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM93_D	744892	7525607	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM93_S	744892	7525613	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM96_D	TBC	TBC	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM96_S	TBC	TBC	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM97_D	TBC	TBC	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM97_S	TBC	TBC	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM98_D	TBC	TBC	Oakover Fmn.	*	2.2	-	-	-

Zone	Monitoring Bore	Easting (mE)	Northing (mN)	Trigger target aquifer [3]	Groundwater level trigger			Groundwater quality trigger	
					Baseline groundwater level (mbgl)	Class 1 trigger (+/- m)	Class 2 trigger (+/- m)	Baseline EC (µS/cm)	Class 1 trigger (µS/cm) [2]
Zone B	SRM98_S	TBC	TBC	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone B	SRM99_D	TBC	TBC	Oakover Fmn.	*	2.2	-	-	-
Zone B	SRM99_S	TBC	TBC	Tertiary Detritals	*	3[1]	2.2[1]	*	*
Zone C	CBD027	735005	7532789	Marra Mamba Fmn.	9.0	3[1]	-	1,000	9000
Zone C	CBX05_D	739997	7530212	Marra Mamba Fmn.	21.3	3[1]	-	-	-
Zone C	CBX05_WT	739997	7530212	Tertiary Detritals	19.7	3[1]	2.2[1]	670	9000
Zone C	HSMB01_D	730412	7533086	Marra Mamba Fmn.	9.4	3[1]	-	-	-
Zone C	HSMB01_WT	730412	7533086	Tertiary Detritals	9.1	3[1]	2.2[1]	2,900	9000
Zone C	HSMB03_D	734396	7532192	Marra Mamba Fmn.	8.8	3[1]	-	-	-
Zone C	HSMB03_WT	734396	7532192	Tertiary Detritals	8.0	3[1]	2.2[1]	890	9,000
Zone C	HSMB04_D	735988	7530786	Marra Mamba Fmn.	10.3	3[1]	-	-	-
Zone C	HSMB04_S	735988	7530786	Tertiary Detritals	10.1	3[1]	2.2[1]	2,400	9000
Zone C	HSMB05_D	738400	7529905	Marra Mamba Fmn.	12.7	3[1]	-	-	-
Zone C	HSMB05_WT	738400	7529905	Tertiary Detritals	12.6	3[1]	2.2[1]	1,300	9000
Zone C	HSMB06_D	740014	7530992	Marra Mamba Fmn.	23.9	3[1]	-	-	-
Zone C	HSMB06_S	740014	7530992	Tertiary Detritals	23.7	3[1]	2.2[1]	4,700	9,000
Zone C	HSMB07_D	739188	7531710	Marra Mamba Fmn.	21.3	3[1]	-	-	-
Zone C	HSMB07_S	739188	7531710	Tertiary Detritals	21.2	3[1]	2.2[1]	1,095	9000
Zone C	HSMB19_I	732800	7531601	Oakover Fmn.	9.0	3[1]	-	-	-
Zone C	HSMB19_WT	732800	7531601	Tertiary Detritals	9.1	3[1]	2.2[1]	750	9000
Zone C	HSMB20_D	733218	7532997	Marra Mamba Fmn.	9.9	3[1]	-	-	-
Zone C	HSMB20_WT	733218	7532997	Tertiary Detritals	9.6	3[1]	2.2[1]	600	9000
Zone C	HSMB21_I	735990	7531422	Marra Mamba Fmn.	10.4	3[1]	-	-	-
Zone C	HSMB21_WT	735990	7531422	Tertiary Detritals	10.2	3[1]	2.2[1]	2,000	9000
Zone C	LHMB01_D	722516	7535109	Marra Mamba Fmn.	7.5	3[1]	-	-	-
Zone C	LHMB01_WT	722516	7535109	Tertiary Detritals	7.6	3[1]	2.2[1]	3,300	9000
Zone C	LHMB02_D	723397	7534788	Marra Mamba Fmn.	4.8	3[1]	-	-	-
Zone C	LHMB02_WT	723397	7534788	Tertiary Detritals	5.1	3[1]	2.2[1]	3,800	9000
Zone C	LHMB03_I	725136	7535191	Marra Mamba Fmn.	7.7	3[1]	-	-	-
Zone C	LHMB03_WT	725136	7535191	Tertiary Detritals	7.1	3[1]	2.2[1]	3,000	9000
Zone C	SP0021_HSW_INJ	736054	7531321	-	-		-	-	9,000
Zone C	SP0010_HSE_INJ	746642	7527689	-	-	-	-	-	9,000
Zone D	Phreato1	756860	7529222	Tertiary Detritals	-	16	18	*	50% change
Zone D	Phreato2	752018	7529380	Tertiary Detritals	-	16	18	*	50% change
Zone D	Phreato3	744848	7530148	Tertiary Detritals	-	16	18	*	50% change
Zone D	Phreato4	749501	7525524	Tertiary Detritals	-	16	18	*	50% change
Zone D	Phreato5	755060	7525544	Tertiary Detritals	-	16	18	*	50% change

Notes:

1 Where groundwater baselines depth is 3m (Class 2 trigger) or 2.2m (Class 1 trigger) or less then trigger will be set at 20% increase in groundwater levels.

2 If baseline is higher than 6000 µS/cm then trigger is set at 50% increase from baseline. In these zones despite elevated EC the target injection water quality is still ~9000 µS/cm

3 Baseline above 9,000 µS/cm; no quality trigger assigned

4 Target aquifer for trigger but bore may be screened over other aquifers.

5 To be replaced by a more appropriate near-marsh bore after EPA approval (see Figure 7)

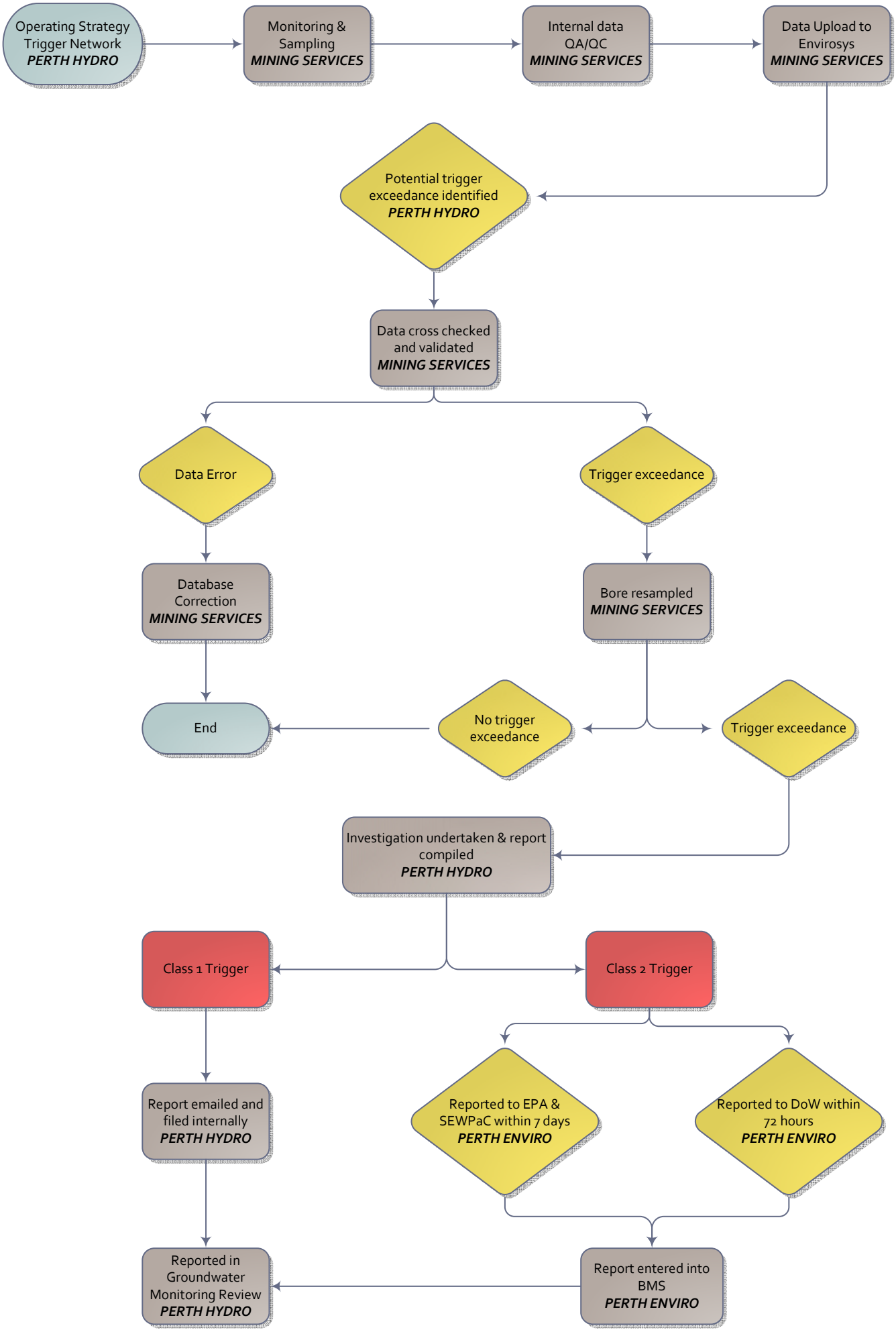
^ Absolute change having regard for seasonal and climatic variation. Divergences from seasonal and climatic dynamic levels are assessed from ongoing hydrogeological assessments of the Fortescue Marsh and control bore water levels

* Recently commissioned or proposed bores without baseline values. A baseline value will be calculated after bores have been running for a 6 month period.

MS - Ministeral Statement

Appendix 10: Trigger reporting procedure

This page has been left blank intentionally


Operating Strategy Trigger Network PERTH HYDRO
Monitoring & Sampling MINING SERVICES
Internal data QA/QC MINING SERVICES
Data Upload to Envirosys MINING SERVICES
Potential trigger exceedance identified PERTH HYDRO
Data cross checked and validated MINING SERVICES
Data Error
Trigger exceedance
Database Correction MINING SERVICES
Bore resampled MINING SERVICES
End
No trigger exceedance
Trigger exceedance
Investigation undertaken & report compiled PERTH HYDRO
Class 1 Trigger
Class 2 Trigger
Report emailed and filed internally PERTH HYDRO
Reported to EPA & SEWPaC within 7 days PERTH ENVIRO
Reported to DoW within 72 hours PERTH ENVIRO
Reported in Groundwater Monitoring Review PERTH HYDRO
Report entered into BMS PERTH ENVIRO

Appendix 3: Vegetation Types in the Cloudbreak Area

This page has been left blank intentionally

Vegetation Type	Description	Local Conservation Significance Description
	Creek line and Drainage lines – Coolibah and River Red Gum Dominated	
1	Open Woodland of *Eucalyptus victrix, E. camaldulensis* with pockets of *Acacia coriacea* subsp. *pendens* over *Grevillea wickhamii* subsp. *aprica, Petalostylis labicheoides* and *A. tumida* over *Triodia longiceps, Chrysopogon fallax, Themeda triandra* and *Aristida* species.	Groundwater Dependent Ecosystem Priority 3 & 4 Flora Species
Creek line and drainage lines – Mulga dominated		
2	Low Woodland to Low Open Forest of *Acacia aneura* var. *aneura, A. citrinoviridis, A. pruinocarpa* over *A. tetragonophylla* and *Psydrax latifolia* over *Chrysopogon fallax, Stemodia viscosa, Blumea tenella, Themeda triandra* and species of *Triodia* and *Aristida*.	Priority 1, 3 & 4 Flora Species
Creek line and drainage lines – other Acacia dominated		
8	Closed Scrub to Tall Shrubland of *Acacia pruinocarpa, A. tumida, A. ancistrocarpa, A. maitlandii, A. kempeana, A. tetragonophylla* with occasional *Eucalyptus gamophylla* and *Corymbia deserticola* over *Triodia epactia, Themeda triandra* and *Aristida* species.	Samphire Priority 3 & 4 Flora Species
9	Closed Scrub to Shrubland of *Acacia ancistrocarpa*, *A. maitlandii*, *A. kempeana*, *A monticola* with occasional *Eucalyptus gamophylla* and *Corymbia desrticola* over *Senna* species, *Triodia basedowii* and *Aristida* species.	Samphire Priority 3 & 4 Flora Species
Flats and broad plains containing Mulga		
3	Low Woodland to Low Open Forest of *Acacia aneura* var. *aneura, A. pruinocarpa, A. tetragonophylla, A. tenuissima, Grevillea wickhamii* subsp. *aprica, Psydrax latifolia* over *Dodonaea petiolaris* and species of *Triodia* and *Aristida.*	Surface Water Dependent Mulga Samphire Priority 3 & 4 Flora Species
4	Low Open Woodland of *Acacia aneura* var. *aneura, A. pruinocarpa, A. xiphophylla, A. victoriae* over *A. tetragonophylla, Psydrax latifolia* and *P. suaveolens* over *Ptilotus obovatus* and mixed species of *Maireana* and *Sclerolaena.*	Surface Water Dependent Mulga Samphire Priority 3 Flora Species
10	Low Open Woodland of *Acacia xiphophylla, A. victoriae, A. aneura* var. *aneura* over *A. tetragonophylla, Ptilotus obovatus, Senna* species and mixed species of *Maireana* and *Sclerolaena.*	Surface Water Dependent Mulga Priority 4 Flora Species
Flats and broad plains without Mulga		
15	Low Open Woodland *of Acacia xiphophylla*, *Acacia cictoriae*, *Acacia aneura* var. *aneura* over Acacia tetragonophylla, *Ptilotus obovatus*, *Senna* species and species of *Maireana* and *Sclerolaena.*	
Ranges, Hills and Hillslopes		
7	Hummock Grassland of*Triodia basedoii* with emergent patechs of *Eucalyptus gamophylla, E. Leucophyloia, Corymbia deserticola* over *Acacia ancistrocarpa, A sclerosperma* subsp. *Sclerosperma, A. kempeana, A. arida, Grevillea berryana, G wickhamii* subsp. *Aprica, Calytrix carinta* over *Goodenia stobbsiana* and mixed *Poaceae* species.	
16	Hummock Grassland of *Triodia basedowii* with pockets of *T. epactia* and *T. lanigera* with emergent patches of *Eucalyptus leucophloia, Corymbia deserticola* over *Acacia ancistrocarpa, A. hilliana, A. acradenia, A. pyrifolia, Hakea lorea* subsp. *lorea* over *Goodenia stobbsiana* and mixed *Senna* species.	
17	Hummock Grassland of *Triodia basedowii* with pockets of *T. epactia* and *T. lanigera* with emergent patches of *Eucalyptus leucophloia,*	Samphire

Vegetation Type	Description	Local Conservation Significance Description
	Corymbia deserticola over *Acacia ancistrocarpa, A. pyrifolia, Hakea lorea* subsp. *Lorea* over *Goodenia stobbsiana* and mixed *Senna* and *Ptilotus* species.	Priority 3 & 4 Flora Species
18	Hummock Grassland of *Triodia angusta* with emergent patches of *Eucalyptus leucophloia* over *Acacia ancistrocarpa, a. pyrifolia, Hakea lorea* subsp. *lorea* over *Goodenia stobbsiana* and mixed *Senna* and *Ptilotus* species.	
Fringes of Samphire Flats Containing Samphire		
12	Low Halophytic Shrubland of *Tecticornia auriculata, T. indica* subsp. *leiostachya* with associated *Maireana* species and *Atripex flabelliformis* with *Muehlenbeckia florulenta* with patches of *Acacia victoriae* and *A. sclerosperma* subsp. *sclerosperma.*	Samphire
13	Low Halophytic Shrubland of *Tecticornia auriculata, T. indica* subsp. *leiostachya, T. halocnemoides* subsp. *tenuis* with patches of *Frankenia* species.	Samphire
22	Low Shrubland of *Tecticornia indica* subsp. *bindens* and *Nicotiana occidentalis* over grasses with occasional stands of *Sesbania cannabina* and *Cullen cinereum.*	Samphire Priority 1 & 4 Flora Species
25	Low Shrubland of *Tecticornia auriculata, T. indica* subsp. *bidens* and *Frankenia ambita* over *Eragrostis dielsii.*	Samphire
26	Low Shrubland of *Muellerolimon salicorniaceum* and *Tecticornia indica* subsp. *bidens*.	Samphire Priority 1 & 4 Flora Species
Fringes of Samphire flats without Samphire		
11	Hummock Grassland of *Triodia angusta* with patches of *Acacia victoriae, A, anerura* var. *aneura, A. Xiphophylla* over *Atriplex codonocarpa, Eremophila cuneifolia* and mixed *Chenopodiaceae* species.	
14	Hummock Grassland of *Triodia angusta* with patches of *Acacia victoriae* over *Atriplex codonocarpa* and mixed *Chenopodiaceae* and *Poacaeae* species.	
20	Scrub of *Acacia sericophylla* over *Muellerolimon salicroniaceum, Nicotiana occidetalis* and *Mimulus gracillis.*	
27	Low Shrubland of Maireana caronos, Attriplex codoncarpa and Sclerolaena cuneata over Eragrostis dielsii and *Triantherma turgidfolia*.	

Appendix 4: Priority Flora Recorded in the Proposal Area

This page has been left blank intentionally

Taxa	Conservation Status	Vegetation Communities Recorded	Notes
Eremophila spongiocarpa	Priority 1	2, 22, 26	A compact, succulent leaved shrub, to 1 m with white flowers in May and September. Known to occur on weakly saline alluvial plains on the margins of marshes. Known from 16 records from the Western Australian Herbarium (**WAH)** (2010) and has been recorded in five locations within or adjacent to the Proposal area.
Gymnanthera cunninghamii	Priority 3	17	An erect shrub to 2 m with cream to yellow flowers. Known from 15 records from WAH (2010). Species has been recorded once in the Proposal area.
Phyllanthus aridus	Priority 3	1, 2, 3, 4, 8, 9, 17	An erect, much branched shrub to 0.25 m with cream to green flowers. Known from 23 records from the WAH (2010). Species has been recorded throughout the Proposal area (60 records) in a range of vegetation communities.
Rostellularia adscendens var. *latifolia*	Priority 3	4	A prostrate shrub to 0.3 m with blue, purple and violet flowers from April to May. Known from 12 records from the WAH (2010). On the basis of these records it appears that species is relatively widespread locally in a range of habitats from alluvial fringes of creek lines to rocky hillslopes (Mattiske 2005a). Species has been recorded once in Proposal area.
Thermeda sp. Hamersley Station (M.E. Trudgen 11431)	Priority 3	9	A perennial grass restricted to the Pilbara Bioregion, and is found in red clay in clay pans or on grass plains. May form tussocks or take on an herbaceous habit between 90 and 180 cm in height (Mattiske 2005a). Known from 13 records from the WAH (2010).
Eremophila youngii subsp. *lepidota*	Priority 4	10, 22, 26	A dense spreading shrub to 3 m with purple, red and pink flowers from January to March and June to September. Known from 25 records from the WAH (2010) from the Pilbara, Gascoyne and Carnarvon Bioregions. Herbarium records appear to indicate the species is associated with a range of habitats including well drained stony sandy loam, semi-saline floodplains, mudflats and clayflats. Has been recorded in two locations in Mulga woodland on the flats and plains, and on the fringes of the Fortescue Marsh.
Goodenia nuda	Priority 4	1, 2, 3, 4, 8, 9, 10, 17	An erect to ascending herb to 0.5 m with yellow flowers. Known from 42 records from the WAH (2010). Species has been recorded throughout the Proposal area and its surrounds (66 records in survey area) in a range of vegetation communities including hummock grassland, creek and drainage lines, flats and plains.

An additional 11 species listed as Priority Flora have not been recorded within the Proposal area, but may occur in the vicinity of the Proposal area. This list is based on the DEC database search (DEC 2010) and recent survey results from the adjoining survey area of Christmas Creek and Fortescue Marsh:

- *Eremophila pilosa* (Priority 1) (Biota 2004b)
- *Helichrysum oligochaetum* (Priority 1) (Biota 2004b)
- *Myriocephalus scalpellus* (Priority 1) (Biota 2004b)

- *Peplidium* sp. Fortescue Marsh (S. van Leeuwen 4865)(Priority 1) (DEC 2010c)
- *Nicotiana heterantha* (Priority 1) (Mattiske 2007)
- *Tecticornia* sp. Christmas Creek (K.A. Shepherd & T. Colmer et al. KS 1063) (Priority1) (ENV 2011)
- *Tecticornia* sp. Fortescue Marsh (K.A. Shepherd et al. KS 1055) (Priority 1) (ENV 2011)
- *Stylidium weeliwolli* (Priority 2) (DEC 2010c)
- *Atriplex flabelliformis* (Priority 3) (ENV 2011)
- *Rhagodia* sp. Hamersley (M. Trudgen 17794) (Priority 3) (ENV 2011)
- *Tecticornia* sp. Roy Hill (H. Pringle 62) (Priority 3) (ENV 2011).

Appendix 5: Summary of Potential Presence of Conservation Significant Species

This page has been left blank intentionally

Species	EPBC ACT	EP Act	Habitat	Likely Presence in Proposal Area
Pezoporus occidentalis (Night Parrot)	EN	S1	Hummock grassland on the fringe of the Fortescue Marsh Triodia hummock grassland or chenopod shrublands. Thick unburnt vegetation most suitable.	Recorded from Minga Well and likely to occur in the Samphire and Spinifex country of the Fortescue Marsh.
Dasyurus hallucatus *(Northern Quoll)*	EN	S1	Rocky escarpments. Creek lines and wells with Acacia shrubland and/or Eucalypt woodland.	Previously recorded near Proposal area in 1980 (NatureMap). Limited areas of rocky breakaways that may provide a small amount of suitable habitat.
Macrotis lagotis (Greater Bilby)	VU	S1	Hummock grassland Low Mulga, Snakewood and Acacia woodland	Records to recent active burrows within the Proposal area (Bamford 2005a). Areas of suitable habitat present along the Fortescue Marsh and in Mulga Woodland.
Rhinonicteris aurantius (Orange Leaf-nosed Bat)	VU	S1	Rocky escarpments. Roosts in caves with high humidity and temperature.	Recorded at Thieves Well. No suitable roosting habitat but may forage within the Proposal area.
Liasis olivaceus barroni *(*Pilbara Olive Python*)*	VU	S1	Rocky escarpments. Gorges and escarpments, area of permanent water.	May be present within the rocky areas in the north of the Proposal area.
Dasycerus cristicauda (Crest-tailed Mulgara)	VU	S1	Hummock grassland Spinifex covered hills and ranges	May occur within the Proposal area. Potential burrows in Proposal area observed but no evidence of individuals. Small amount of suitable habitat in Proposal area.
Apus pacificus (Fork-tailed Swift)	Mig	S3	Almost entirely aerial, particularly associated with storm fronts.	Will occasionally overfly Proposal area, but will not utilise it directly.
Haliaeetus leucogaster (White-bellied Sea-eagle)	Mig	S3	Coastal and near coastal water bodies.	Recorded at Fortescue Marsh. Uncommon in area, although suitable habitat present along the marsh where water present. Unlikely to be suitable habitat within the Proposal area.
Merops ornatus (Rainbow bee-eater)	Mig	S3	Open country, most vegetation types, dunes, banks.	Recorded within Proposal area. Suitable habitat for hunting and breeding.
Ardea alba (Great Egret)	Mig	S3	Floodwaters, rives, shallows of wetlands, intertidal mud-flats.	Suitable hunting habitat when surface water present in Fortescue Marsh and some potential habitat along creek lines within Proposal area.
Tringa glareola (Wood Sandpiper)	Mig	S3	Freshwater swamps, river pools, claypans, salt lakes.	Recorded at Fortescue Marsh. Suitable habitat present in marsh especially after rain. Some potential habitat along creek lines within the

Species	EPBC ACT	EP Act	Habitat	Likely Presence in Proposal Area
				Proposal area.
Tringa nebularia (Common Greenshank)	Mig	S3	Coastal and inland lakes.	Recorded at Fortescue Marsh. Suitable habitat present in marsh especially after rain. Some potential habitat along creek lines within the Proposal area.
Calidris ruficollis (Red-necked Stint)	Mig	S3	Coastal and inland shorelines.	Few records, but suitable habitat present in Marsh especially after rain. Some potential habitat along creek lines within the Proposal area
Falco peregrinus (Peregrine Falcon)		S4	Coastal cliffs, riverine gorges and wooded watercourses	Recorded hunting within Proposal area. Suitable hunting habitat along rivers and gorges. Some potential breeding habitat in rocky areas.
Ramphotyphlops ganei (Blind Snake)		Priority 1	Unknown, but possible associated with moist gorges and gullies.	Species rarely recorded but suitable habitat present in gullies throughout area of Spinifex hillslopes within the northern areas of the Proposal area.
Ctenotus nigrilineatus		Priority 1	Spinifex at the base of granite outcrops	May occur as suitable habitat exists in the Proposal area.
Ctenotus uber johnstonei		Priority 2	Small outcrops on sandy and stony plains	Likely to occur around small outcrops on sand and stony plains in the Proposal area.
Falco hypoleucos (Grey Falcon)		Priority 4	Lightly wooded coastal and riverine plains.	Recorded near Proposal area at Sandy Creek. Wide- ranging species. Some suitable habitat for hunting and breeding along creek lines in the Proposal area.
Ardeotis australis (Australian Bustard)		Priority 4	Open grasslands, chenopod flats and low heath.	Recorded within Proposal area and surrounds. Suitable habitat present throughout Mulga woodland.
Burhinus grallarius (Bush Stone-curlew)		Priority 4	Lightly wooded country next to day time shelter of thickets or long grass.	Recorded within Proposal area and surrounds. Suitable habitat present along creek lines through Mulga woodland.
Neochmia ruficauda subclarescens (Star Finch)		Priority 4	Vegetation around watercourses, particularly thick reed beds	Recorded at Minga Well. No other suitable habitat present within the Proposal area.
Sminthopsis longicaudata (Long tailed Dunnart)		Priority 3	Rocky escarpments.	May occur in suitable habitat such as rock hill-slopes within and around the Proposal area. However. Very few records within 100km of the Proposal area.
Pseudomys chapmani (Western Pebble-mound Mouse)		Priority 4	Spurs and rocky hills with many small pebbles vegetation by Spinifex.	Numerous active mounds recorded within the Proposal area. Large amount of suitable habitat along Spinifex hill slopes within and surrounding the Proposal area.

Species	EPBC ACT	EP Act	Habitat	Likely Presence in Proposal Area
Leggadina lakedownensis (Northern Short-tailed Mouse)		Priority 4	Spinifex and tussock grassland on cracking clays. Also *Acacia* shrubland, Samphire, woodlands and stony ranges.	Likely to occur within the Proposal area. Recorded at Christmas Creek in tussock grassland on cracking clay and in other habitats. Similar habitats are present in the Proposal area.
Dasycercus blythi (Brush-tailed Mulgara)		Priority 4	Sandy areas with moderately dense spinifex with 'runways' between clumps	May occur within the Proposal area. Potential burrows previously observed in the Proposal area but no evidence of individuals. Small amount of suitable habitat within the Proposal area.
Macroderma gigas (Ghost Bat)		Priority 4	Caves, rockpiles and abandoned mines	Record of individual foraging along edge of Fortescue Marsh. No suitable roosting habitat within the Proposal area.