BROCKMAN RESOURCES LIMITED

MARILLANA IRON ORE PROJECT

SUPPLEMENT TO RESPONSE TO PUBLIC SUBMISSIONS

EPA ASSESSMENT NO. 1781

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resources.

SEPTEMBER 2010

Document Status						
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Appendices

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1.0 Introduction

In accordance with the *Environmental Protection Act 1986* (WA), a Public Environmental Review (PER) has been prepared which describes the Marillana Iron Ore Project (the Project) and its likely effects on the environment. The PER was available for public review for a period of 4 weeks between 10th May and 8th June 2010 (EPA Assessment No. 1781).

A report containing Brockman's response to the six public submissions received was submitted to the Office of EPA on the 27th July. Following assessment of the report, the Office of EPA requested further information relating to four of the response items (letter dated 26th August). This supplementary report presents Brockman's response to the requirement to provide further information.

An overview of the information requested in outlined in **Table 1.1** below.

Table 1.1 – Supplementary information requested

Item Ref in OEPA letter (dated 26 August 2010)	Item Ref in Response to Public Submissions (dated 27 July 2010)	Information Required
1	20	Please provide further details regarding management and monitoring actions proposed in relation to groundwater dependant vegetation.
2	10	Please provide a brief description of any infrastructure related to the proposal which has not been included in the scope of the proposal. This should include any key environmental impacts associated with the infrastructure, required approvals, and current status of approvals
3	7	Please provide information regarding the potential impacts related to the location of the accommodation waste disposal facility during a flood event. Additionally, please provide a summary of design features and management actions proposed to mitigate these impacts as well as monitoring programmes to assess the effectiveness of these measures.
4	22	Please provide details of proposed monitoring and additional management actions to be undertaken, with particular regard to blasting occurring during flood events in the Fortescue Marsh. If Brockman is unable to access the Fortescue Marsh in order to monitor impacts of blasting on birds, evidence should be provided of this: for example, written refusals from existing pastoral lessees.

2.0 Supplementary Information to Response to Public Submissions

2.1 Reference 20 – Groundwater Dependant Ecosystems (GDE's)

Please provide further details regarding management and monitoring actions proposed in relation to groundwater dependant vegetation. This should include:

- *Clear spatial identification of any GDE which could potentially be impacted by the proposal;*
- *An outline of the proposed monitoring programme for GDE's including methodology and schedule;*
- *Criteria and trigger values to be assessed by the monitoring program; and*
- *Contingency actions to be taken in the event that trigger levels are exceeded.*

2.1.1 Spatial identification of GDE's

As indicated in the PER (Appendix E), groundwater levels beneath the orebody at the base of the Hamersley Ranges are naturally deep, and generally do not support phreatophytic vegetation. There is the potential for groundwater drawdown to affect a proportion of the vegetation lining the Weeli Wolli Creek (phreatophytic). However, the drawdown effects in this area are expected to be mitigated by channel flow events numerous times per year that will recharge the creek channel groundwater level.

Groundwater levels in relation to vegetation types across the Marillana site are shown in Figure 2.1. As identified in Section 6.7 of the PER, two sub-units containing one potentially phreatophytic species, *Eucalyptus victrix,* were recorded within the survey area

The degree to which *E. victrix* is dependent upon groundwater has not been clearly established and is likely to vary from location to location, and seasonally at a particular location. Froend (2009)[1] states that *E. victrix,* though described elsewhere as a vadophyte (Batini, F , 2009)[2], (i.e. a species which access the unsaturated soil layer above the water table) could more accurately be described as a facultative phreatophyte. Whilst vadophytic at many locations it is capable of accessing the water table where available, whereas true vadophytes rarely use groundwater even when readily available. Greater reliance on deep soil water and/or ground water is likely to be greatest during drought periods when there is insufficient rainfall to recharge the shallow soil water.

The predicted impact of groundwater drawdown on vegetation over the 20 year mine life is shown in Figures 2.2 – 2.5. The drawdown is at a maximum of 40 m below pre mining levels in the western end of the orebody to facilitate dry mining conditions and reduces with distance from the main pit area. Whether the extent of the drawdown proposed is likely to significantly affect the potentially phreatophytic vegetation lining the Weeli Wolli Creek is yet unknown, given the predicted natural variability in groundwater underneath the creek.

Drawdown impacts extend elliptically in a north-west – south-east direction, in alignment with the general strike of the detrital orebody. As outlined the Section 7.4.3 of the PER, the lateral extent of the dewatering zone of influence as represented by the model represents the "worst case" scenario, and is considered unlikely to eventuate.

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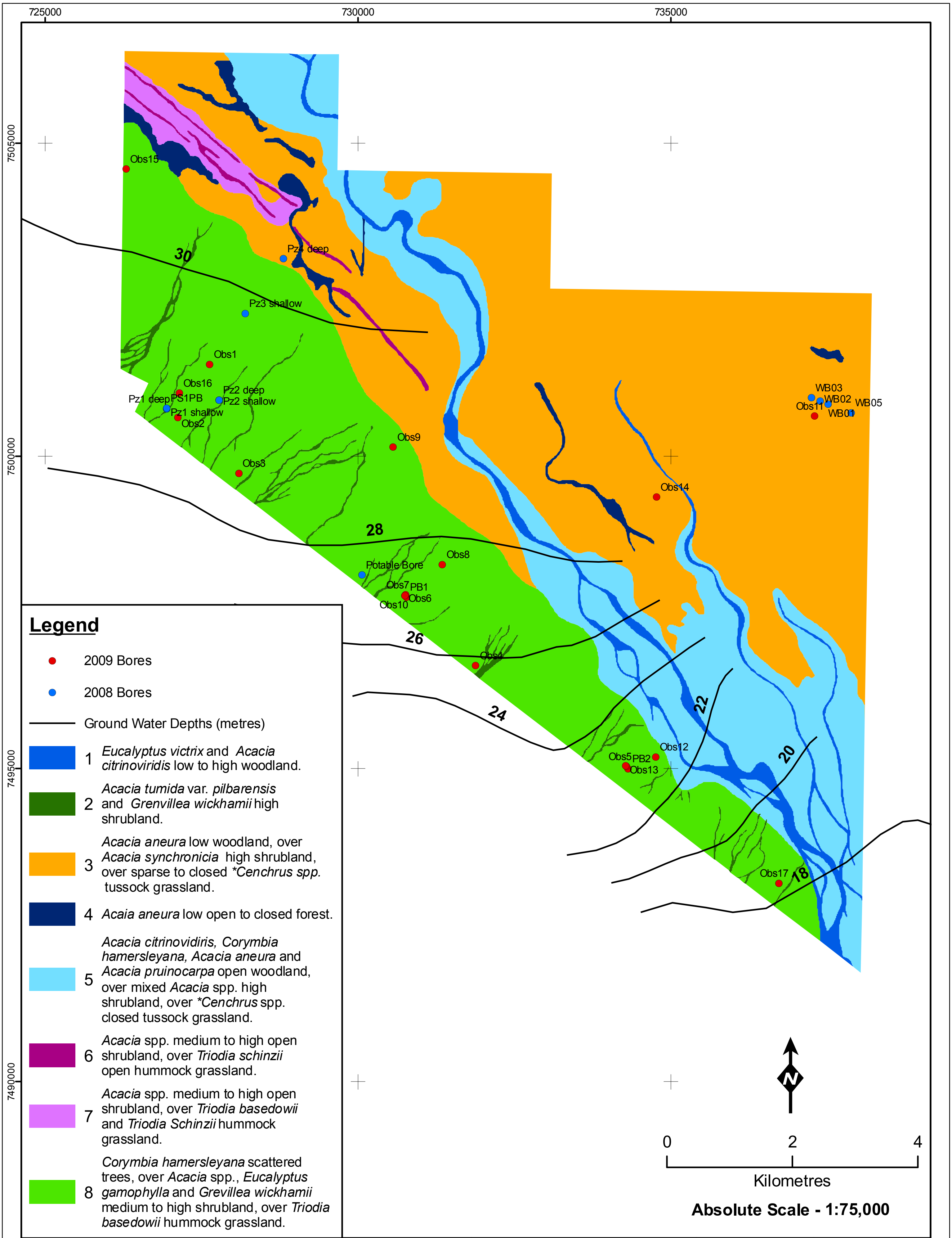
[1] Froend, R. (2009) *Peer Review of the Mt. Bruce Flats Woodland State of Knowledge Report.* Unpublished report commissioned by Rio Tinto Iron Ore
[2] Batini, F. (2009) *Eucalyptus victrix, Karinjini National Park.* Report to Environmental Protection Authority

At the end of the 20 year mining period, the 20 m drawdown extends 8 km across the Weeli Wolli Creek. The 10 m drawdown extends across the remainder of the Weeli Wolli creek to just beyond the tenement boundary. The current water table in within the drawdown zone varies between 18 to 30 m. Brockman has a drilling program underway on the Marillana tenement to investigate the interaction between surface water flows and groundwater near Weeli Wolli Creek. This will provide further information to be fed into the Phreatophytic Vegetation Monitoring Plan and results (see Section 2.1.2 below).

Previous excavations of *E. victrix* have demonstrated that it has a strongly dimorphic root system, with an extensive shallow “feeder” root system that extends well beyond the canopy, combined with one or several taproots (Adams *et al,* 2005)[3]. It is therefore feasible that in at least some locations within the current area of interest, *E. victrix* is accessing the water table and/or the zone of soil immediately above the table to which moisture is drawn by capillary action. However, given that the degree to which this is occurring and contributing to the survival of the trees during periods of moisture stress is unknown, the impact of drawdown to the species is also unclear at present.

[3] Adams, M., Grierson, P. and Stoddart, J. (2005) Proceedings on a workshop on riparian tree health and the impacts of translocation of water in the Pilbara. University of Western Australia.



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Vegetation Types and Groundwater Levels (metres below ground level)

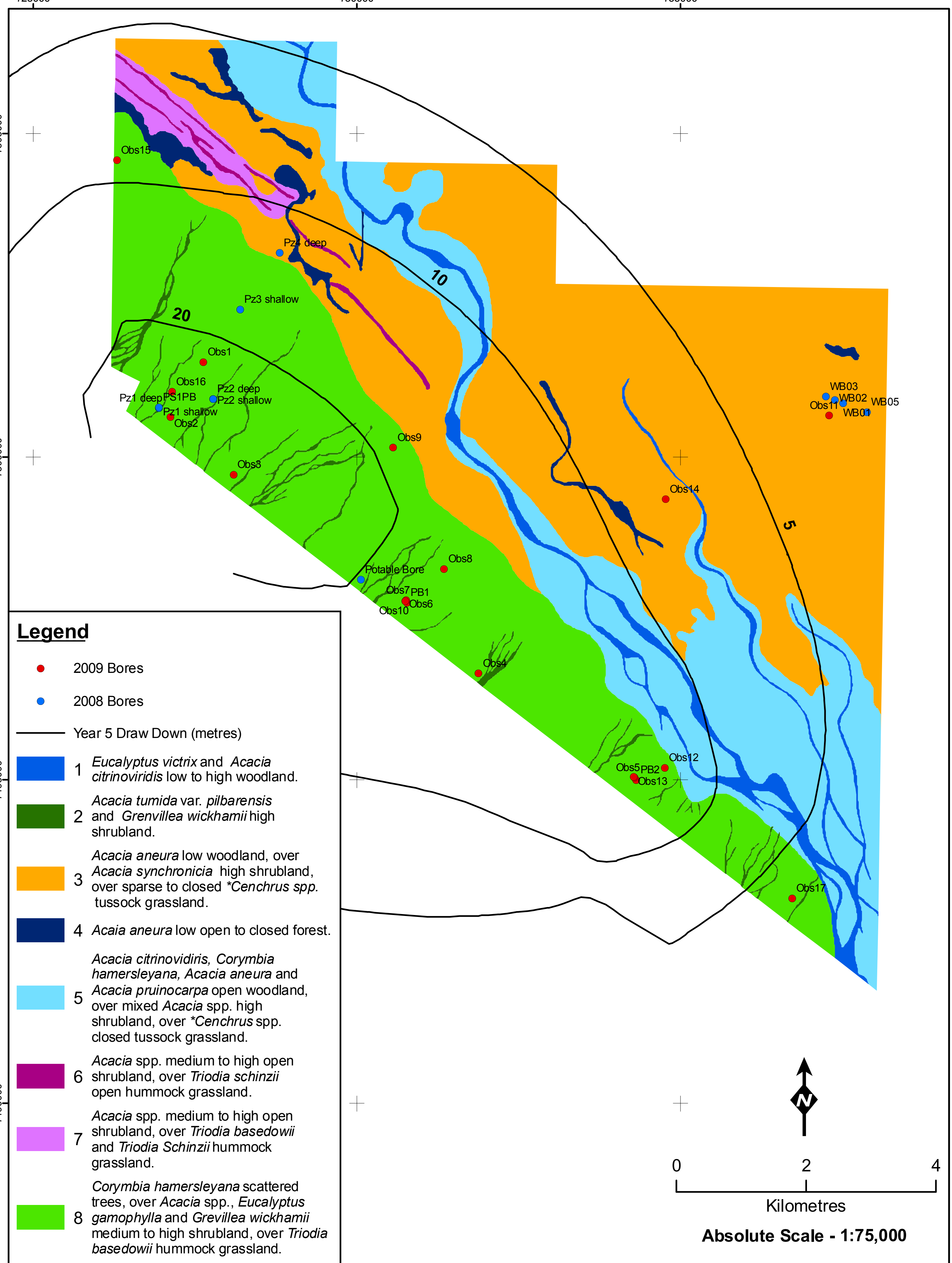
Figure: 2.1
Project ID: 1140

Drawn: SG
Date: 01/09/10

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: S174

A4



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Predicted Impact of Groundwater Drawdown on Vegetation after 5 years

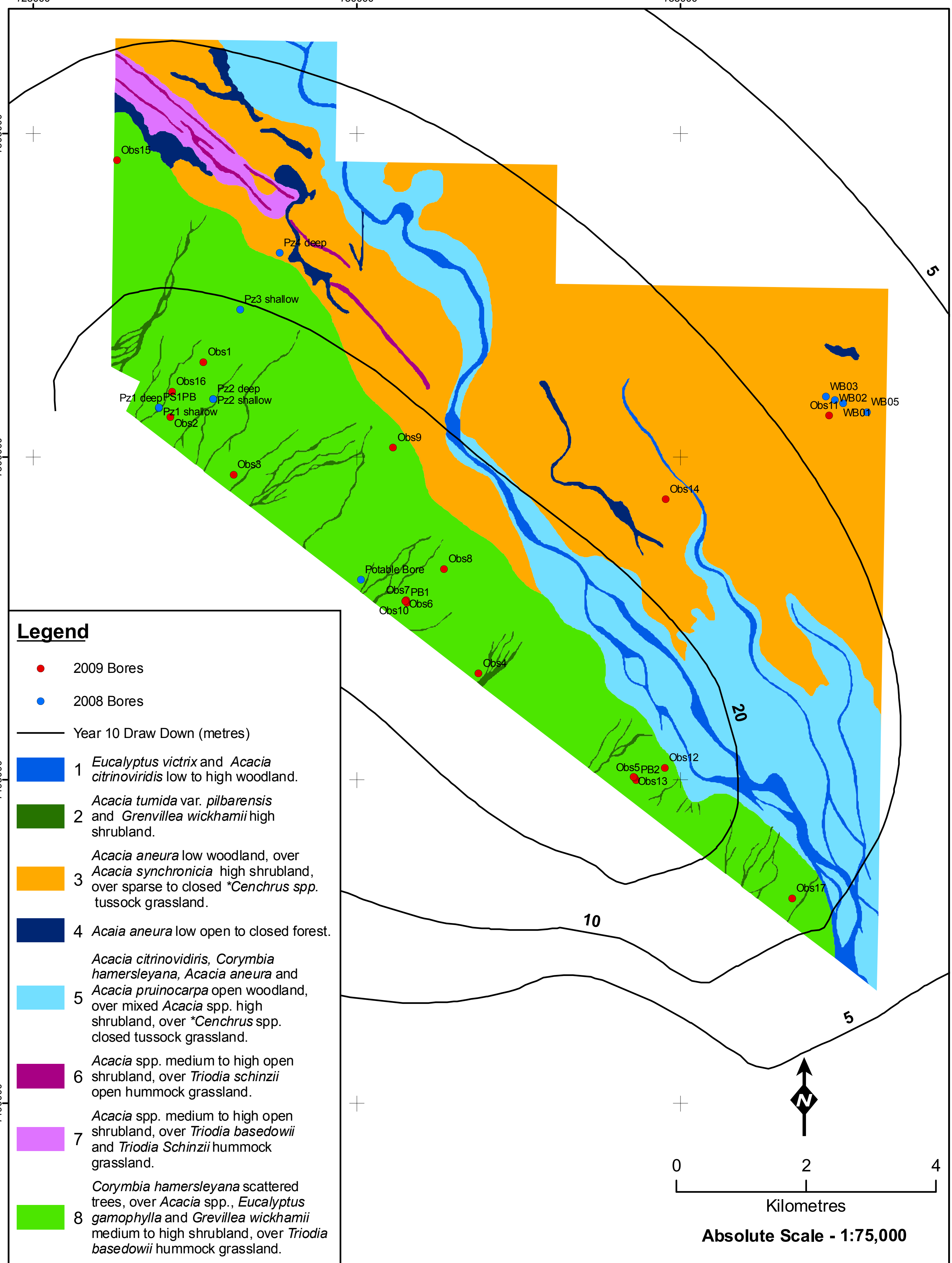
Figure: 2.2
Project ID: 1140

Drawn: SG
Date: 01/09/10

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: S175

A4



Legend

- 2009 Bores
- 2008 Bores
- Year 10 Draw Down (metres)
- 1 *Eucalyptus victrix* and *Acacia citrinoviridis* low to high woodland.
- 2 *Acacia tumida* var. *pilbarensis* and *Grenvillea wickhamii* high shrubland.
- 3 *Acacia aneura* low woodland, over *Acacia synchronicia* high shrubland, over sparse to closed **Cenchrus spp.* tussock grassland.
- 4 *Acaia aneura* low open to closed forest.
- 5 *Acacia citrinovidiris, Corymbia hamersleyana, Acacia aneura* and *Acacia pruinocarpa* open woodland, over mixed *Acacia* spp. high shrubland, over **Cenchrus* spp. closed tussock grassland.
- 6 *Acacia* spp. medium to high open shrubland, over *Triodia schinzii* open hummock grassland.
- 7 *Acacia* spp. medium to high open shrubland, over *Triodia basedowii* and *Triodia Schinzii* hummock grassland.
- 8 *Corymbia hamersleyana* scattered trees, over *Acacia* spp., *Eucalyptus gamophylla* and *Grevillea wickhamii* medium to high shrubland, over *Triodia basedowii* hummock grassland.

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Predicted Impact of Groundwater Drawdown on Vegetation after 10 years

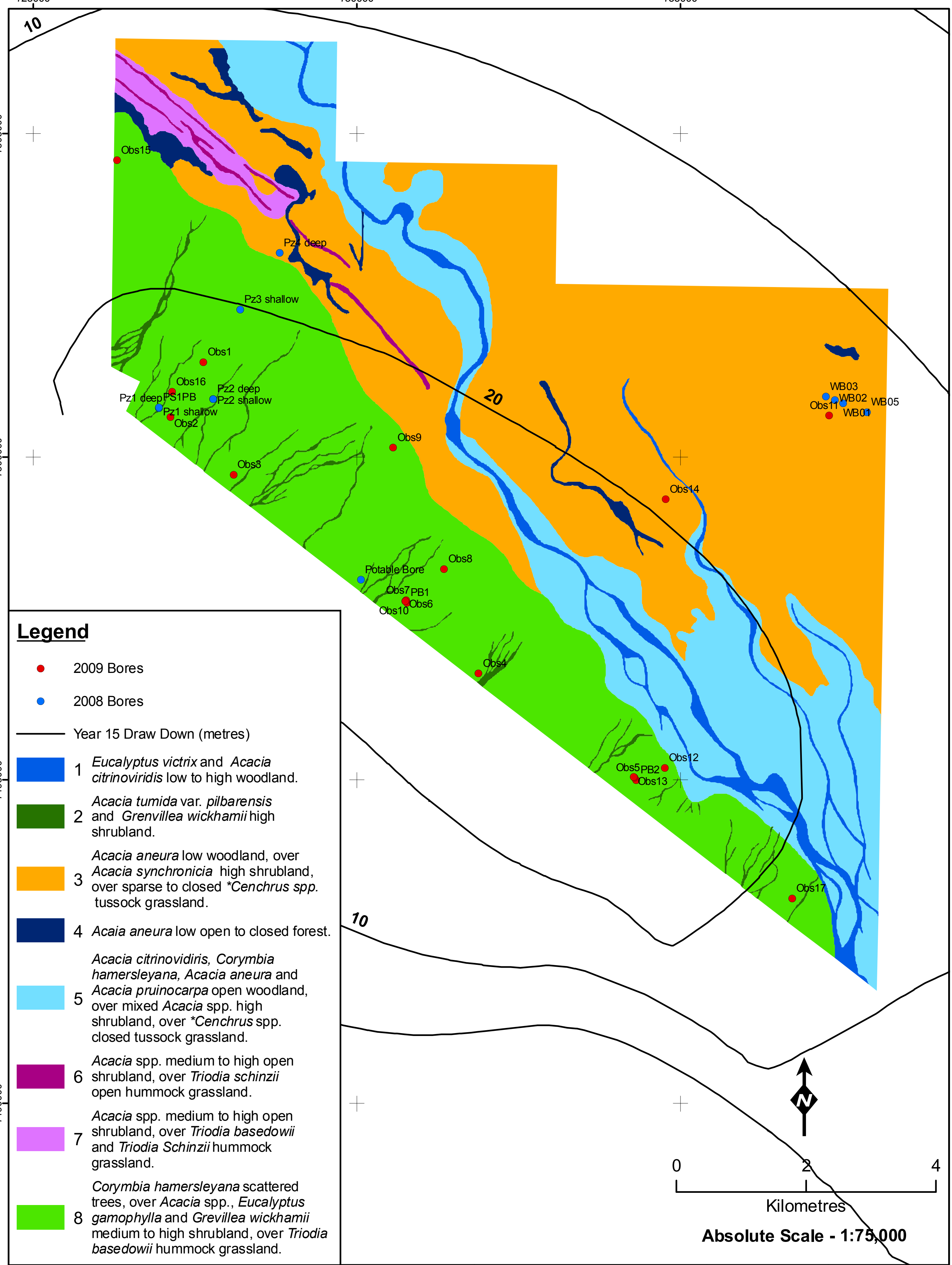
Figure: 2.3
Project ID: 1140

Drawn: SG
Date: 01/09/10

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: S176

A4



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Predicted Impact of Groundwater Drawdown on Vegetation after 15 years

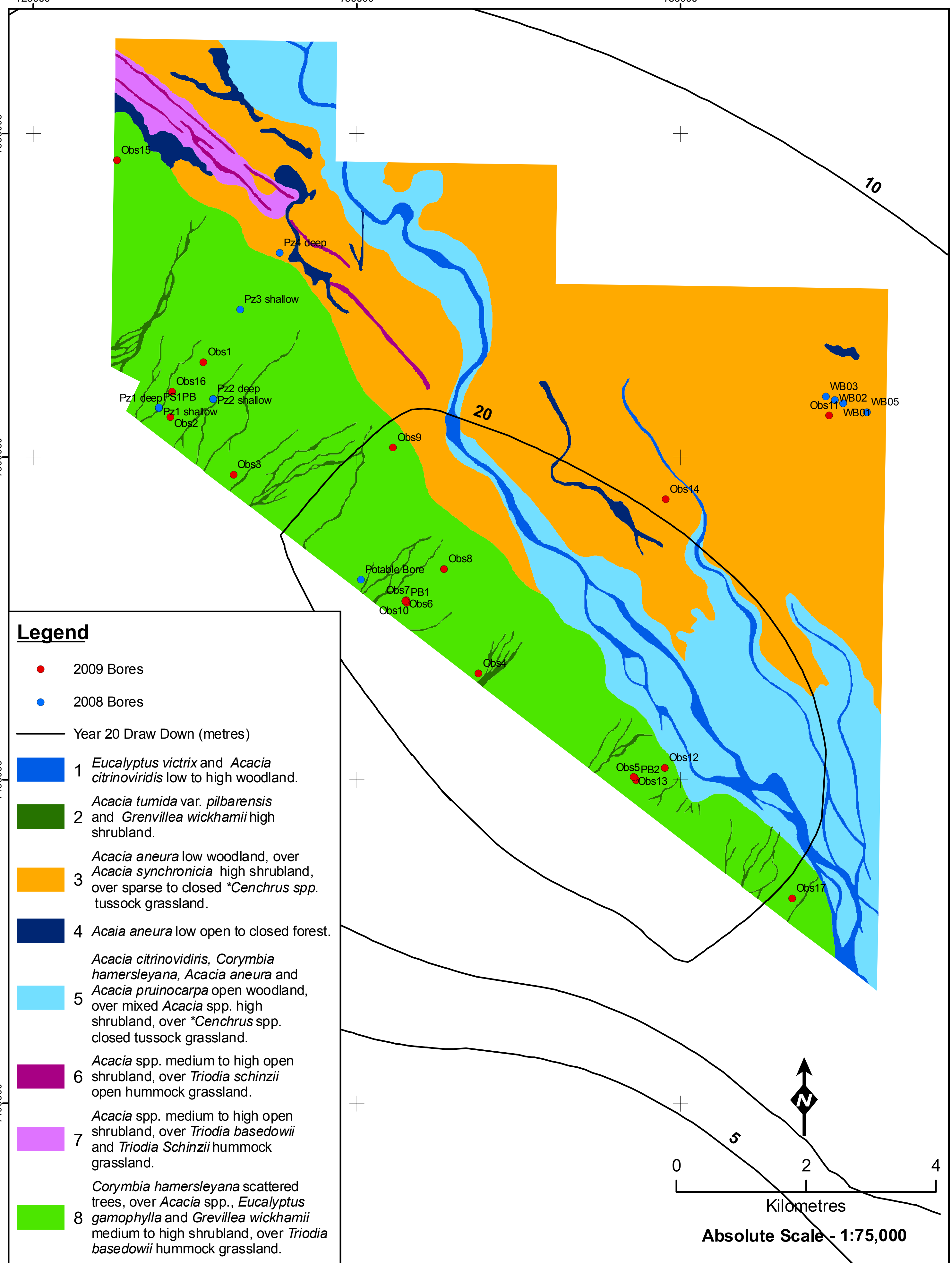
Figure: 2.4
Project ID: 1140

Drawn: SG
Date: 01/09/10

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: S177

A4



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Predicted Impact of Groundwater Drawdown on Vegetation after 20 years

Figure: 2.5
Project ID: 1140

Drawn: SG
Date: 01/09/10

Coordinate System
Name: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994

Unique Map ID: S178

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2.1.2 Outline of monitoring programme for GDE's

Brockman's Strategy to manage impacts to potentially phreatophytic vegetation from stress or death due to groundwater drawdown is described below.

Phreatophytic Vegetation Monitoring Plan	
Objective	Ensure that phreatophytic vegetation occurring within Weeli Wolli creek on Brockman's Marillana Iron Ore Project is protected from stress or death due to groundwater drawdown
Key Performance Indicator	No significant change to the health of vegetation lining Weeli Wolli creek attributable to Brockman's operations.
Monitoring	

Groundwater Monitoring

The groundwater monitoring programme will include:

- Regional groundwater levels on a monthly basis;
- Pumping bore water levels and pumping volumes from abstraction bores on a monthly basis;
- Reinjection bore water levels and re-injection volumes on a monthly basis;
- Installation of monitoring piezometers between the Project and the southern Fortescue Marsh boundary to allow for ongoing assessment of background seasonal fluctuations in groundwater levels and quality, monitoring of longer -term drawdowns and confirming the nature of the calcretes;
- Recharge volumes to the MAR operations on a monthly basis;
- Quarterly water quality sampling and analysis from pumping bores and a selection of piezometers (screened in alluvial and basement sequences). Samples to be analysed for major ions, salinity and pH as a minimum.
- Annual review and assessment of all monitoring data, including validating and updating the groundwater model to confirm that predictions remain valid on the basis of operational data.

The groundwater monitoring will be reviewed in consultation with the Department of Water (DoW) via the 5C Operating Strategy process.

Vegetation Monitoring

The vegetation monitoring programme will include:

1.0 VEGETATION CONDITION MONITORING

Brockman will undertake annual groundwater dependent vegetation condition monitoring at ten sites at Marillana. This involves photographing *Eucalyptus victrix* at designated monitoring points and assessing the condition of the vegetation against a set of vegetation condition assessment parameters.

1.1 Methodology

Monitoring of phreatophytic vegetation will entail assessment of tree health at a range of monitoring sites. A criterion will be used to evaluate tree health (Table 2.1).

Table 2.1 Criteria used to evaluate tree health.

Ranking	Criteria
0	Dead.
1	Most branches dead, tree largely defoliated.
2	Condition poor, most leaves wilted or damaged and some defoliation.
3	Condition moderate, some defoliation and/or a significant amount of leaf damage or stress evident.
4	Healthy but a few dead branches, limited defoliation or a small amount of damage or stress to leaves evident.
5	Excellent (healthy), with no leaf stress or damage evident. Some branches may be dead (this is often a consequence of flood damage and is therefore a poor indicator of tree health). New growth evident.

1.2 Site selection and experimental design:

Ten monitoring sites will be established across the drawdown zone within Vegetation unit 1 shown on Figure 2.1. The sites will be established at varying distances along Weeli Wolli Creek. The location of the monitoring sites will be finalised during initial field studies, trees will be selected based on their maturity, vigour and location.

Selected trees will be tagged and numbered to enable sampling repetition and ensure data consistency over the duration of the monitoring programme. The locations will be recorded using a Global Positioning System (GPS), and the trees photographed. Photographs of each tree will be taken from the same angle and at the same time of day as the initial survey to facilitate comparison with the initial survey.

Two control sites will be established upstream and two downstream from the centre of groundwater drawdown (mine pit), subject to access constraints.

A baseline survey will be carried out prior to commencement of operations.

Other features such as the state of maturity of specimens, dead limbs and physical damage, any evidence of pests or diseases, and previous fire damage will also be recorded where noteworthy.

1.2 Assessment:

Tree condition will be used to compare tree condition between years, within individual sites, using a Student's paired t-test of mean tree condition to assess change.

2.0 ESTIMATION OF LEAF AREA INDEX, COVER AND FOLIAGE

Brockman will undertake annual estimation of leaf area, cover and foliage at ten sites at Marillana. This involves photographing *Eucalyptus victrix* at designated monitoring points and assessing the leaf area index (LAI). A subset of the trees used in the monitoring described above (1.0) will be selected for measurement.

2.1 Methodology

Leaf area index (LAI) is an essential input into many models of eucalypt growth and water use.

This method will estimate crown cover from canopy photographs obtained with a consumer grade digital camera as described by C. Macfarlane (see Appendix 1).

One advantage of the method is that the area of vegetation sampled is clearly defined so that the method is suitable for small plots and plots surrounded by clearings.

Cover images are less sensitive to exposure and choice of threshold, and can detect smaller gaps than methods using fisheye imagery. Another advantage of the cover method are that images can be collected under clear or cloudy sky conditions during normal working hours.

2.2 Assessment

Estimation of leaf area index will be carried out as per studies included in Appendix 1.

Triggers and Contingency Actions

Trigger levels are established to provide advanced warning so that management responses can be implemented.

Trigger levels, to account for seasonal variation, are categorised as follows:

- 20% change in vegetation condition which is not attributable to other external influences such as insect, disease, fire – Level 1
- 40% change in vegetation condition which is not attributable to other external influences such as insect, disease, fire – Level 2
- 50% change in vegetation condition which is not attributable to other external influences such as insect, disease, fire – Level 3

Level 1:

- Notify DEC in writing (and as part of the Annual Environmental Review).

Level 2:

- Notify DEC within 5 days of monitoring results in writing.
- Initiate an assessment with the objective of determining the reason(s) for the change:
  - Assess results in relation to groundwater monitoring data; and
  - Seek regional information on vegetation condition from third parties.

Level 3:

- Where the decline can be attributed to dewatering, Brockman will, where possible, reverse any impacts by artificial watering, carried out according to best practice, in liaison with the DEC and in line with Brockman's ongoing groundwater investigation and modelling.
- If deemed appropriate on consultation with the relevant regulatory authorities, in the event of major phreatophytic vegetation loss, a rehabilitation plan will be prepared and implemented. This may include the replacement of phreatophytic vegetation in areas of significant death.

Reporting

Annual reporting will include details of tree health monitoring and Leaf Area Index photography plus field observations. The report will assess whether the objective is being achieved and whether trends in groundwater drawdown meet those predicted by modelling.

Reporting will continue over the life of mine, unless otherwise determined by the relevant regulatory authorities.

Review

The Monitoring Plan will be reviewed at least every five years, or when significant additional information comes to hand. The review will be based on achieving approval requirements, Brockman commitments, and progress in implementing the management plan and will incorporate any new investigations, information, techniques and advice from experts and regulatory authorities.

Upon review, the document will be revised where appropriate and the revision status will be updated in accordance with Brockman's document control procedures.

2.2 Reference 10 – related infrastructure not included in the scope of assessment

Please provide a brief description of any infrastructure related to the proposal which has not been included in the scope of the proposal. This should include any key environmental impacts associated with the infrastructure, required approvals, and current status of approvals.

Further details have been provided in **Table 2.3** below.

Table 2.3 – Description of related infrastructure not included in the scope of assessment

Infrastructure Description	Assessment and Approval Process	Key Environmental Impacts	Current Status
Railway: Brockman has obtained a Miscellaneous Licence (L 45/225) under the *Mining Act 1978* for a rail corridor. Brockman proposes a 70 km long railway linking the Marillana tenement M47/1414 to FMG's existing rail infrastructure in the region. The railway is proposed to transport iron ore from the Marillana project to Port Hedland.	Brockman intends to submit a referral to the Environmental Protection Authority (EPA) as per Section 38(1) of the *Environmental Protection Act 1986* for a decision on whether or not it requires assessment under the Act and if it is to be assessed, the level of assessment. At initial discussions in June 2010, the OEPA advised that the Chichester Rail Route (Option 1 or 2) would likely be assessed by the EPA at an ARI level of assessment. It was noted that BHP's Chichester Deviation Rail Project, which is similar, had been assessed by the EPA as the ARI level of assessment.	The potential environmental impacts associated with the proposal will be thoroughly identified and ranked via a qualitative environmental risk assessment (ERA) based upon the methodology in AS/NZS 4360 and HB 203:2000. Initial assessment of potential impacts indicates the key environmental factors may include: • terrestrial flora and vegetation; • terrestrial fauna; • weed management; and • surface hydrology. Other relevant factors requiring management may include: • rehabilitation; • dust; • fire; • waste management; • greenhouse gas emissions; and • noise and vibration.	Three potential railway route options were designed and feasibility studies undertaken to determine the constraints and viability associated with each option. The Department of Environment and Conservation (DEC) and OEPA were consulted in June 2010 and their advice has been considered in the route selection process. Investigations are underway for social, heritage and environmental constraints covering a 2 km wide corridor, although a reduced corridor width will be implemented. Environmental investigations began in April 2010 and include: • A two-phase Level 2 Flora and Vegetation survey:. Phase 1 completed July 2010 • A two-phase Level 2 Fauna survey. Phase 1 completed June 2010 • Short-range Endemic survey completed June-July 2010. Findings of Phase 1 surveys are currently being documented and will be included in the EPA Referral document.

Infrastructure Description	Assessment and Approval Process	Key Environmental Impacts	Current Status
Services Corridor: Brockman has obtained a Miscellaneous Licence under the *Mining Act 1978* for a services corridor to enable the installation of a gas lateral from the Marillana mining lease (M47/1414) to existing infrastructure near Newman. The infrastructure is expected to include an underground gas pipeline and access track, and potentially include overhead powerlines subject to third party negotiations and agreements, which are ongoing.	Brockman intends to submit a referral to the Environmental Protection Authority (EPA) as per Section 38(1) of the *Environmental Protection Act 1986* for a decision on whether or not it requires assessment under the Act and if it is to be assessed, the level of assessment. At initial discussions held in June 2010, the OEPA and the DEC identified two potential issues requiring further investigation relating directly to the overhead power line infrastructure. An assessment has since been carried out and a report produced outlining findings on the two issues; visual impact analysis and the risk to birdlife utilising Fortescue Marsh. If the OEPA, in consultation with DEC, find that Brockman has adequately addressed these key issues, then it is likely that the other environmental impacts, such as trenching issues regarding fauna, could be adequately managed under Part V of the *Environmental Protection Act 1986.*	The potential environmental impacts associated with the proposal will be identified and ranked via a qualitative environmental risk assessment (ERA) based upon the methodology in AS/NZS 4360 and HB 203:2000. The identification and assessment of risk is embedded within Brockman's Environmental Management System (EMS) and publicly available Environmental Policy. Initial assessment of potential impacts indicated the key environmental factors may include: • terrestrial flora and vegetation; • terrestrial fauna; • visual amenity; and • weed management. Other relevant factors may include: • rehabilitation; • dust emissions; • fire; • waste management; and • noise and vibration.	Investigations are underway for social, heritage and environmental constraints covering a 200 m wide corridor, although a reduced corridor width will be implemented. Environmental investigations began in April 2010 and include: • A two-phase Level 2 Flora and Vegetation survey:. Phase 1 completed in April 2010 • A two-phase Level 2 Fauna survey. Phase 1 completed in May 2010 • Short-range Endemic survey completed in May 2010. Fortescue Marsh is located approximately 17 km to the north of the Project Area. Findings of Phase 1 surveys are currently being documented and will be included in the EPA Referral documentation.
Aerodrome facility and airport access road: location currently under negotiation – will utilise	A Vegetation Clearing Permit may potentially be required if extension of the existing airstrip is required.	Unable to be assessed in detail until location has been decided. In relation to clearing of native vegetation, potential impacts to key environmental factors may include:	At the time of submitting the PER response to submissions, negotiations regarding the Aerodrome facility were under negotiation and further details could not be included

Infrastructure Description	**Assessment and Approval Process**	**Key Environmental Impacts**	**Current Status**
an existing facility in the region.		• terrestrial flora and vegetation; • terrestrial fauna; • surface water; and • noise and dust.	due to lack of commercial arrangements being in place. This is still the case.
Supplementary water source after year 9.	On the basis of further studies associated with Definitive Feasibility Study (DFS)-level mine plans and associated groundwater modelling, dewatering operations now provide self-sufficient water supply until year 16 of operations. As outlined in Section 5.7.5 of the PER, along with PER Appendix E Groundwater Management Plan, it is the preference of Brockman, in alignment with DoW's hierarchy of water management options, to seek supplementary water source after year 16 from nearby operations that are discharging significant surplus water. There are also multiple potential on-tenement and off-tenement borefield solutions in the vicinity of the Project that have been identified for water supply development should it be required, and requisite studies and approvals would be undertaken in due course as required.	Off-take utilising surplus water volumes is likely to have a positive mitigating influence on the overall catchment water balance cumulative impacts. The off-take agreement would require the installation of a water pipeline between the third party and the Marillana Project. Potential impacts arising from pipeline installation to key environmental factors may include: • terrestrial flora and vegetation; • terrestrial fauna; and • weed management. Other relevant factors may include: • rehabilitation; • dust emissions; • waste management; and • noise and vibration.	It is acknowledged by Brockman that assessment of the environmental impacts associated with this additional supply (if any) will need to be addressed as part of a separate impact assessment and approval process. Brockman will continue to seek agreement from nearby operations regarding a water source after year 16.

Infrastructure Description	Assessment and Approval Process	Key Environmental Impacts	Current Status
Port: Brockman is a member of the North-West Iron Ore Alliance (NWIOA). Currently, the NWIOA has three members, each of which is aggressively exploring and developing new iron ore projects in the Pilbara region. The members are: • Atlas Iron Limited • Brockman Resources Limited • FerrAus Limited The North-West Iron Ore Alliance (NWIOA) Port Development located at South West Creek in the inner harbour of Port Hedland, comprises two berths, as well as supporting infrastructure and dedicated materials unloading and stockpiling facilities.	The NWIOA has worked with the Port Hedland Port Authority (PHPA) in relation to key design principles and the location of facilities. Work has started on the dredging approvals with the execution of a joint dredging agreement between NWIOA, other proponents and the Port Hedland Port Authority. The environmental approval/assessment process for Port Hedland harbour berths at South West Creek have commenced. Dredging approvals are being submitted in conjunction with PHPA. Referral documents for landside infrastructure are being prepared for submission to the EPA.	Under investigation and assessment.	NWIOA is completing studies into the development of two inner harbor berths and associated material handling infrastructure at Port Hedland to accommodate the Alliances 50 million tonne per annum export capacity allocation. NWIOA have commenced Definitive Feasibility Study with SKM. Negotiations with PHPA are close to finalisation regarding land tenure.

2.3 Reference 7 – location of waste disposal area within 1 in 10 ARI flood plain

Please provide information regarding the potential impacts related to the location of the accommodation waste disposal facility during a flood event. Additionally, please provide a summary of design features and management actions proposed to mitigate these impacts as well as monitoring programmes to assess the effectiveness of these measures.

Email from Vanessa Angus 27/08/10 - Please respond for the wastewater treatment site, which is noted in the PER as being near the accommodation camp, and also provide information regarding the location of the landfill, which is not specified in the PER.

Email from Vanessa Angus 06/09/10 - this query relates to both the wastewater treatment and landfill locations. The information required includes the location of the facilities, how the locations would be impacted in a 1 in 10 or 1 in 100 ARI event, and any design or management actions which would be implemented to prevent the facilities impacting the environment, with particular regard to surface water quality.

2.3.1 WASTE WATER TREATMENT SITE

As outlined in the PER section 7.15.3, the Project will require two packaged sewage treatment plants, one located 500 m north of the camp accommodation and 12.4 km from the Fortescue Marsh, the other 500 m from the main office buildings and > 100 m from the Weeli Wolli Creek..

As outlined in the PER section 7.15.4, treated waste water will be disposed of via two spray fields, and the locations of the two plants and spray fields are identified in PER Appendix C.

Appendix 1 and 2 in Appendix C of the PER (Waste Water Treatment) adequately cover in detail the design features and management criteria which have been implemented and conclude the likelihood of impacts to be highly negligible in relation to any potential risk relating to inundation of the WWTP spray fields. Please find a copy of the memo's in Appendix 2.

A summary of design features and management actions to mitigate potential for impacts, as well as monitoring is provided below.

- The size of the two spray fields have been designed to address the maximum likely throughput and are estimated to be 5 ha for the accommodation village and 1 ha for the mine site (processing plant).
- The sizing of the spray field has been calculated conservatively, using the lowest monthly evaporation rate (June) as the control for sizing the facility. Therefore, it is considered unlikely that water logging would occur during the summer months (when water-logging is of more concern), as the evaporation rates are two to three times higher during summer months than the June design basis.
- The surface irrigation disposal systems have been planned and will be managed in such a manner as to encourage rapid evaporation, prevent spray drift, misting, pooling and run-off from the surface irrigation disposal area.
- Flood protection bunding, (extending from the sand dune located north of the proposed area southwards, connecting onto higher ground), will be utilised at the mine site irrigation area to prevent ponding after a flood.
- To ensure that the surface irrigation disposal areas operates at maximum efficiency, media such as pinebark, wood chips, scoria etc may be applied to the soil and suitable plants capable of effecting a high evapo-transpiration rate, will be maintained. Vegetative buffers may be utilised to separate the mine site spray area from the Weeli Wolli Creek.

- Monitoring will include frequent inspection of the disposal area to confirm the absence of surface water ponding. Inspections will be scheduled to take account of seasonal conditions, for example, it would be more important to check for ponding during the cyclone season, when flow events are much more likely to occur, and will also be affected by local rainfall adding further water to the soil.
- Management Commitment C23 (PER) states 'The surface irrigation waste water disposal systems shall be managed in such a manner as to encourage rapid evaporation, prevent spray drift, misting, pooling and run-off from the surface irrigation disposal area'.

2.3.2 WASTE DISPOSAL (LANDFILL) SITE

A minor Class II landfill will be established on the tenement to manage the disposal of both putrescible and inert wastes. Approval will be sought under Part V of the *Environmental Protection Act 1986* for Works Approval for a prescribed premise Category 64; Class II Putrescible Landfill. Class II landfill is defined in the *Landfill Waste Classification and Waste Definitions 1996* (DEC) as 'an un-lined landfill designed to accept putrescible and inert wastes'. This includes including wastes that contain organic materials such as food wastes or wastes of animal or vegetable origin, which readily bio-degrade within the environment of a landfill.

2.3.2.1 Location

The landfill will be located in an area that poses minimal impact on surface and ground water, reducing the potential for impacts such as pollution. The location of the landfill site is shown on the Site Layout Plan provided in Appendix 3. The landfill is situated between the current Roy Hill Munjina Road and the proposed diversion, and sits within the rail loop area.

If not well sited, constructed and managed, landfill sites can contaminate water resources both during their operational life and after the landfill has closed. Other potential impacts include surface water contamination from runoff and airborne emissions caused by dust during the operation process.

This location has been selected in consideration of the site conditions and meets the following design criteria in order to avoid potential impacts:

- A minimum vertical separation distance of two metres for loam soils and three metres for granular soils to the maximum (wet season) groundwater table:
- This location has a significant depth to groundwater (>20 m). Refer to the Groundwater Study and Management Plan (PER Appendix E) and the Waste Water Treatment Effluent Disposal Study (PER Appendix C) for more detailed information on the hydrogeological studies carried out for the Project.
-
- Class II (and III) landfills should not be located within 100 metres of any surface waters, ephemeral waterways and watercourses:
- This location is more than 200 m away from the natural minor creek to the north, and over 400 m from the diversion drain that goes between the Fine Rejects Storage and Waste Storage areas. Refer to the SWMP (PER Appendix S) for detailed information relating to the design features and management in place to control surface water through the proposed mine and infrastructure areas.
-

- In remote areas such as mining camps and remote communities, landfill sites should be located with a buffer distance of at least 700 metres down gradient (down stream of groundwater flow) and not be placed between production bores used for drinking water supply and the camp or community:
- This location is more than 700m down gradient from plant offices and is not located within the range of any drinking water production bores.
- The installation and operation of monitoring facilities, such as groundwater monitoring bores, may be required by regulatory authorities where there is reason to suspect that hazardous, putrescible or contaminating materials may have entered the landfill, escaped from the site into local soils or a landfill is located near a sensitive water resource:
- Groundwater monitoring bores and recovery bores from the FRS will be in suitable locations to monitor the landfill site should it be required.

However, with good controls on surface water around the landfill, a low permeability lining in the landfill pit, combined with over 20m of unsaturated soil profile, it is considered unlikely that any contamination of groundwater would occur. In the unlikely event that the landfill facility becomes inundated (with the risk on mobilizing contamination to the groundwater), a groundwater monitoring programme (monthly sampling of nearby piezometers for the 3 months after the event) would be undertaken to identify the impacts (if any) on water quality.

The rail loop situated south of the landfill site will act as a bund and therefore protect the site from flooding. Brockman intends constructing a 2 metre high topsoil bund to the north of the landfill, to manage incident rainfall with the rail loop area and more importantly, visual screening from Roy Hill Munjina Road.

2.3.2.2 Landfill Design:

The landfill will consist of a dug rectangular trench which will be filled from one end to the other. Soil from trench excavations will be used to fill over the trench cell once it is full of waste.

The landfill site will incorporate a landfill cage, commonly called a Bellan cage (**Figure 2.6**) in order to minimise the spread of windblown rubbish and also to prevent animals foraging. The Bellan Cage has been adopted by many mine sites and has solved a common problem in Western Australia. When placed over landfill sites, the cage deters scavenging animals, reduces odours and prevents rubbish from being blown about by the wind. The Bellan cage can be mounted on wheels to travel along the trench as it is filled.

Figure 2.6 – Example of the Bellan Cage Design

2.3.2.3 Landfill Management

As outlined in the PER, the mine site has the potential to be impacted upon by flooding from overflow from Weeli Wolli Creek and sheet/overland flow from streams off the Hamersley Ranges. Aquaterra were engaged by Brockman to address water management requirements and designs at the Marillana project, specifically, flood protection and Hamersley Range surface water diversions.

A 100 year ARI flood from Weeli Wolli Creek was adopted as the design flood for mine site infrastructure. In order to manage the potential for flooding around the mine site, use of bunds, earth pads and diversions have been designed and modelled (details in PER Appendix S).

The landfill site selected falls within the project footprint that is protected by 1:100 ARI flood protection design, and the existing surface water management designs therefore address protection of this landfill facility. Minor bunding around the landfill facility will ensure that incident rainfall drains away from the landfill and conforms with the existing over-arching surface water management plan.

As stated in PER section 7.15.4, The site will be managed so that waste is confined to the landfill trench location. While in operation the following will be undertaken to ensure the landfill site impacts are managed:

- Only inert, general and putrescible waste will be disposed of in the landfill. All hazardous material will be disposed of according to government guidelines and legislation.
- The landfill has been sited and designed to prevent surface water from draining into the landfill. Diversion drainage structures will be used to divert stormwater flows away from the landfill area.
- Adequate separation distance will be maintained between the base of the landfill and the water table.
- To facilitate consolidation of the landfill to minimise subsidence, waste material will be compacted in layers not exceeding 500 mm thickness. Each deposit of waste will be covered by a depth of soil no less than 230 mm and compacted. Not only will this facilitate consolidation of the waste material but ensure other impacts such as fire, pests and odour are minimised.

2.3.2.4 Landfill Monitoring

Monitoring will be carried out regularly to ensure that the tip cage is functioning correctly and that no waste is exiting the landfill.

Waste inputs to the landfill trench will also be monitored to make sure that no chemical waste or hydrocarbons are entering the landfill.

Existing surface water management should be adequate, as incident rainfall water management is already addressed under the existing SWMP

With controls in place on surface water management around the landfill site, a low permeability lining in the landfill pit, combined with over 20m of unsaturated soil profile, it is considered unlikely that any contamination of groundwater would occur. In the unlikely event that the landfill facility becomes inundated, a groundwater monitoring programme (monthly sampling of nearby piezometers for the 3 months after the event) would be undertaken to indentify the impacts (if any) on water quality.

2.3.2.5 Rehabilitation and Closure

Section 7.7 of the PER and the Conceptual Closure Plan (PER Appendix T) provides details on the decommissioning, rehabilitation and closure of the site.

2.4 Reference 22 – monitoring of impacts to bird behaviour in the Fortescue Marsh as a result of blasting activity

Please provide details of proposed monitoring and additional management actions to be undertaken, with particular regard to blasting occurring during flood events in the Fortescue Marsh. If Brockman is unable to access the Fortescue Marsh in order to monitor impacts of blasting on birds, evidence should be provided of this: for example, written refusals from existing pastoral lessees.

Recent geotechnical studies completed as part of the Marillana Definitive Feasibility Study (DFS) have indicated a very low compressive rock strength and lead to a classification of the Marillana Detrital ore and overburden as “Free Dig” meaning that no drill and blast is required to mine this material. Brockman does not expect or intend to employ drill and blast mining methods on Marillana Detrital Ore or overburden.

The Detrital ore component represents approximately 94% of the presently defined 700-750 Mt Marillana ore reserve, which is mined over 20 years. The Detrital ore is underlain by a harder CID ore, which is exclusively 40 metres below natural ground level with a majority of the ore occurring greater than 50 metres below natural ground level. This extremely minor ore component will require a <u>*light*</u> blast to facilitate mining activities <u>*but only when it is mined*</u> in years 5, years 10 to 12 and years 18 to 22 in the current mining schedule. As such, there will only be light blasting activities for 9 out of the 20 years mine life, which will occur at depths in the pit greater than 40m below natural ground level. In addition less than 6%of the total ore body over the life if mine requires a light blast application.

Noise modelling undertaken for the environmental impact assessment (PER Appendix U) suggests that blast noise occurring at the nearest points within the Fortescue Marsh area may range from 89 to 109 dB Linear peak (assuming a confined blast with a charge mass per delay of 3,300kg). The noise study assumed confined blasting at zero depth below ground level. In reality, no blasting will occur above 40m below natural ground level, hence there will be significant attenuation of the noise impacts associated with blasting activities in the instance when it is employed.

However, the construction and operational stage of the Project is designed and will be managed to best minimise any potential impacts on waterbird behaviour when large numbers of birds congregate on the Fortescue Marsh.

Brockman commits to implementing the management actions outlined below with respect to minimising impacts to birds utilising the Fortescue Marsh during flood events. This includes:

- Blasting under favourable meteorological conditions;
- Modify blasting practices to minimise noise; and
- Monitor bird behaviour during blasting activities.

Results of monitoring would be documented in the Annual Environmental Report (AER), and made available to the DEC.

2.4.1 MANAGEMENT ACTIONS

2.4.1.1 Blasting Protocol

Brockman will implement the following blasting protocol in order to have sufficient management steps in place to reduce potential impacts at times where large numbers of birds are present at the Fortescue Marsh:

- Prior to scheduling blasting events, Brockman will check the regional climatic conditions to assess the likelihood of a flood event. Where possible, blasting will be timed to occur prior to, or avoid, major rainfall events.
- If a flood event is likely to occur, or is underway, at the time blasting is scheduled, Brockman will identify whether large numbers of waterbirds are present at the Fortescue Marsh.
- If large numbers of waterbirds are present at the Fortescue Marsh, Brockman will monitor bird behaviour in the vicinity of the Fortescue Marsh during blasting activities to the degree that access permits.

2.4.1.2 Control Measures

Blasting activities will be designed in line with the procedures described in Australian Standard 2187.2-1993, *Explosives—Storage, Transport and Use.* However, the following control measures will be employed where possible in order to reduce the impacts from blasting. In addition to reducing noise, many of these control techniques will maximise rockbreaking efficiency, which in turn results in the use of less explosives and an associated cost saving.

- Reducing the maximum instantaneous charge (MIC) by using delays, reduced hole diameter and/or deck loading. Blast vibration research shows the level of ground vibration is proportional to the Scaled Distance (vibration) which is defined as the distance to the blast divided by the square root of the MIC. So, at a given distance, reducing the MIC will generally result in lower levels of vibration.
- The optimum use of explosives in blasting occurs when the available energy is efficiently used in fragmenting and moving the rock. When the hole inclination (relative to the force angle) is decreased or the burden and/or opening are increased, the explosive energy cannot fully fracture the rock and the energy instead dissipates through the ground in the form of vibration.

- Restrict blasts to favourable local weather conditions. The propagation of airblast emissions is subject to meteorological conditions including refractions by wind and temperature gradients. Wherever possible blasting should be confined to between 0900 hours to 1700 hours to minimise the noise-enhancing effects of temperature inversions.
- Use a hole spacing and burden which will ensure that the explosive force is just sufficient to break the ore to the required size.

2.4.1.3 Monitoring

Bird behaviour will be monitored if blasting occurs when large numbers of waterbirds are present at the Fortescue Marsh.

The monitoring location will be situated at the nearest southern boundary of the Fortescue Marsh, at the closest accessible point. If access to this area cannot be obtained, the monitoring location will be the furthest accessible point from the Marillana site to the Fortescue Marsh. The monitoring location will be identified by recording the GPS waypoint.

Alterations in bird behaviour at Fortescue Marsh will be observed during and 30 minutes after blasting and recorded according to a scale of disturbance such as:

- High level of disturbance: Individuals prepare to fly off, or fly off.
- Moderate level of disturbance: Individuals show alert behaviours such as head turning or orienting to noise source.
- Low to no disturbance: No noticeable change to behaviour

Records will include details such as the number of birds present, the percentage that show the above behaviours, and time taken for birds that flew off to return to the area. Other notable bird reactions, such as noises, will be recorded.

Brockman will keep records of the blast plan, time and location. These will be referenced to the bird behaviour monitoring. Details of any complaints regarding noise and vibration and the response to complaints including corrective actions will also be recorded.

2.4.1.4 Community Liaison

Liaison between Brockman and the community is important at every point, from the beginning of the proposal stage, throughout the investigative, assessment and approval processes, and throughout the mine's operation.

Brockman will pre-notify the relevant pastoral lease holders of their intention to blast and request access to the monitoring location.

Brockman will continue to liaising with the relevant stakeholders, such as the DEC, and is an active member of Fortescue Marsh Working Group.

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APPENDIX 1: ESTIMATION OF LEAF AREA INDEX (LAI) FROM COVER PHOTOGRAPHY

ESTIMATION OF LEAF AREA INDEX (LAI) FROM COVER PHOTOGRAPHY

Craig Macfarlane

Theory

LAI can be estimated from cover or its inverse, the gap fraction, using Beer's law:

$$\mathrm{LAI} = \ln(1 - f_f) / k \quad (1)$$

where f_f is foliage cover, the fraction of ground covered by the vertical projection of foliage, and k is the light extinction coefficient.

k is typically 0.5 but can be larger for canopies with horizontal foliage and smaller for canopies with vertical foliage. If f_f includes branches then k also accounts for woody cover and can be thought of as a local calibration factor. For jarrah grown on rehabilitated mine sites, k is between 0.45 and 0.5.

Equation 1 assumes that foliage is randomly distributed but, in reality, foliage clumping results in underestimation of LAI from equation 1. Most clumping is at the crown level in broadleaf forests, hence, for these forests LAI can be more accurately estimated from:

$$\mathrm{LAI} = f_c \ln (1- f_f / f_c) / k \quad (2)$$

where f_c is crown cover, the fraction of ground covered by the vertical projection of solid crowns.

Brief procedure for cover photography

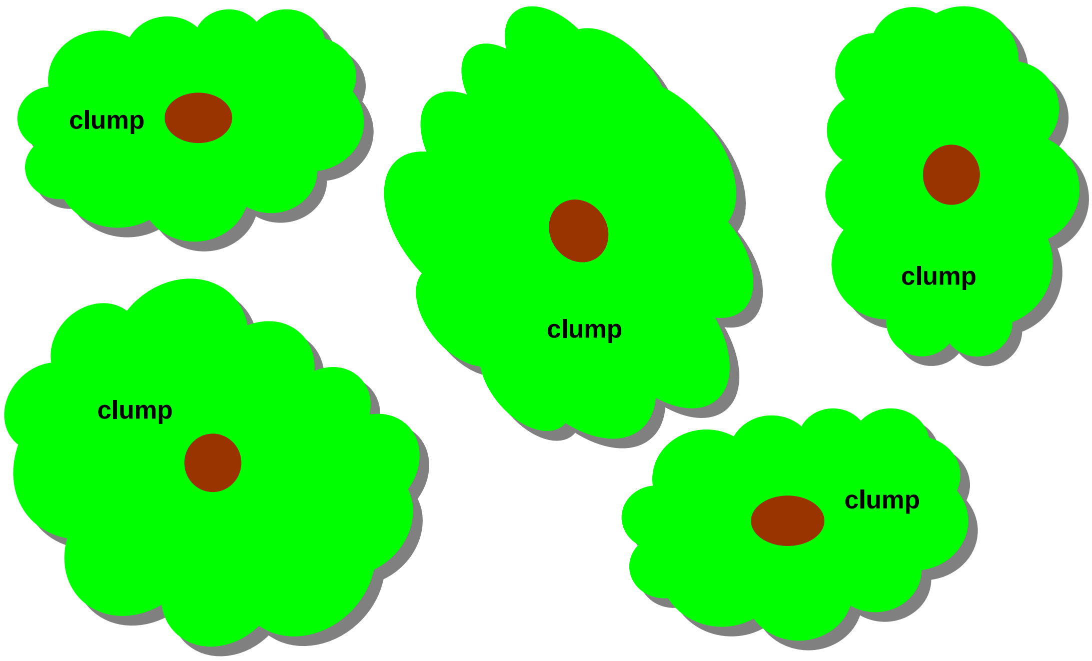
Both f_c and f_f can be estimated from digital photos taken with a narrow angle lens (30-35° field of view) pointed directly upwards. Collect digital photographs as FINE JPEG images with maximum resolution (3,871,488 pixels for the Nikon Coolpix 4500). Set the CP4500 to F2 lens, automatic exposure, Aperture-Priority mode and minimum aperture (*f*/9.6). Mount the camera on a tripod and point the lens directly upwards; level the camera/lens using a bubble level, either fixed to an aluminium plate fitted between the camera and tripod, or placed directly over the lens. Depending on vegetation height, space photos about 10 m apart. Avoid midday sun as this causes glare in the lens. If possible, avoid patchy cloud as this complicates image analysis; clear or uniformly overcast skies are recommended.

Colour images analysed manually using Adobe PhotoShop and greyscale images analysed automatically using WinSCANOPY give similar results. The automatic analysis treats all gaps larger than 1% of the total image area as "between-crown" or "non-random" gaps. The manual analysis is simple and rapid and can easily be done by the user, but I also offer an analytical service for $4/image.

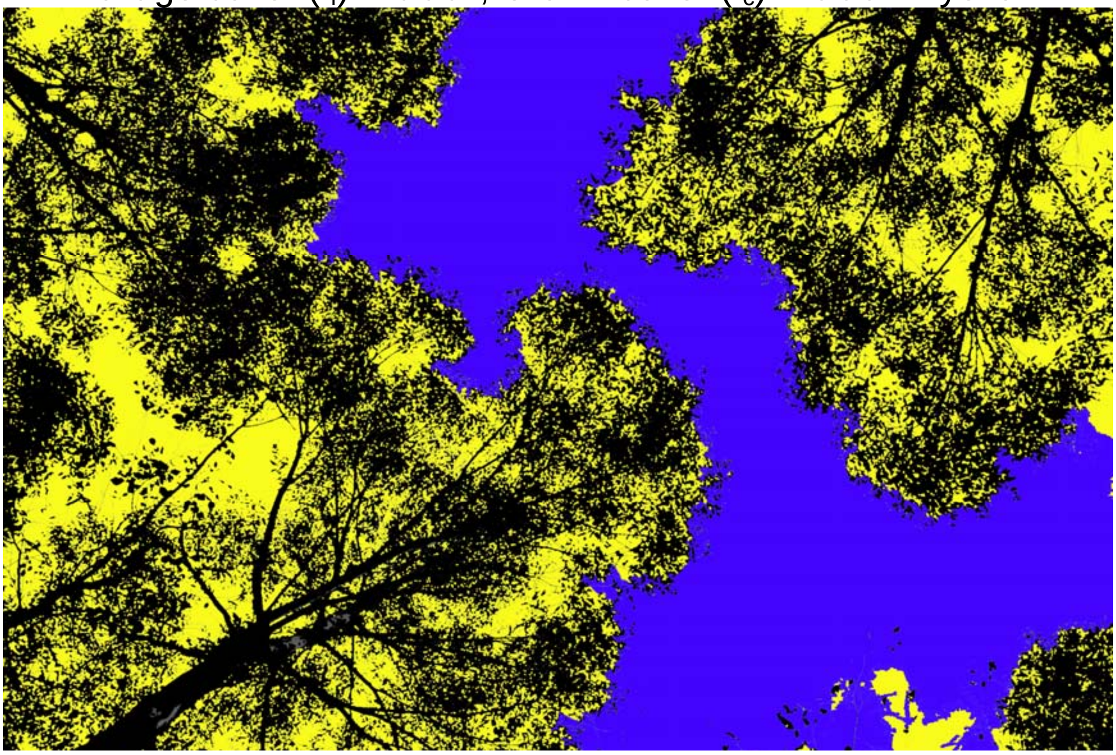
Regressions ($P < 0.0005$) of crown attributes obtained from PhotoShop (colour images, Y axis) and WinSCANOPY (greyscale images, X axis). Asterisks indicate intercepts whose 95 % confidence interval did not include zero or slopes that differed from one ($P<0.05$, t-test).

Crown attribute	n	Slope	Intercept	R^2
crown cover	138	1.02*	0.0156*	0.99
foliage cover	138	1.00	0.0190*	0.99
leaf area index	138	0.932*	0.175*	0.95

In broadleaf stands, the largest gaps are between trees and these are largely responsible for underestimation of LAI from cover



Foliage cover (f_f) = black, Crown cover (f_c) = black + yellow



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leaf area index	138	0.932*	0.175*	0.95

Advantages of cover photography compared to fisheye photography:

- High resolution images detect small gaps better and are less sensitive to exposure
- Less restrictive sky conditions for sampling
- Well-defined and flexible plot size (depends on focal length and vegetation height)
- No lens calibration needed

Disadvantages of cover photography:

- Single zenith angle is sampled - *k* assumed
- More images needed to cover large area

Cautions for cover photography:

- The smaller *k* is, the larger the errors will be that result from using the wrong value of *k*. This is a problem for species with very vertical foliage e.g. bluegums.
- *k* will also change with the angle of view, so the same, narrow focal length should always be used.

Foliage cover of individual trees, derived from digital photography, is also being used by:

- Pilbara Iron (Rio Tinto) to monitor crown health of riparian vegetation near dewatering zones.
- UNSW to monitor crown damage from overgrazing by koalas on Kangaroo Is. and crown recovery after removal of koalas.
- Department of Natural Resources Environment and the Arts (NT) to monitor canopy dieback across stands of *Eucalyptus tetradonta* in east Arnhem Land.

Craig MacFarlane: expertise, current research and publications

- BSc (Natural Resource Management) and PhD (Botany) at UWA
- Currently Research Associate (lvl B) at UWA Plant Biology in a position part funded by ENSIS (CSIRO)
- Research interests are water use and productivity of forest vegetation

Current Projects

- Mechanisms underlying the relation of NPP to water availability. ARC Discovery project lead by Derek Eamus (UTS), Mark Adams (UNSW) and Ross McMurtrie (UNSW).
- Development of photographic methods for estimating leaf area index of jarrah forest overstorey. Collaboration with Naomi Kerp (ALCOA) and Andrew Grigg (ALCOA). Supported by ALCOA, UWA and ARC.
- Effect of tree spacing on overstorey and understorey leaf area index in ex-mined rehabilitated jarrah forest, and development of simple methods for assessing understorey LAI. Collaboration with John Koch (ALCOA), Sam Ward (ALCOA), Karl Grant (ALCOA) and Andrew Grigg (ALCOA). Supported by ALCOA and UWA.
- Calibration of Landsat TM NDVI for jarrah and wandoo forest. Collaboration with Matthias Boer (UWA). Supported by Bushfire CRC and UWA.
- Water uptake by deep rooted vegetation as a mechanism for developing surface mineral anomalies. CSIRO project lead by Ravinder Anand. Supported by CSIRO Exploration and Mining, and numerous mining companies via AMIRA International.
- Effect of thinning on stand and catchment water balance in the Perth Hills. CSIRO project lead by Richard Silberstein. Supported by Premier's Water Foundation.
- Relationship of productivity and biodiversity to fire history. PhD project of Burak Pekin. Primary supervisor Pauline Grierson. Supported by Bushfire CRC and Australian Greenhouse office.

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APPENDIX 2: WWTP and Spray Fields Memo's

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aquaterra

Memo

To	Brendan Hynes	**Company**	Brockman Resources Ltd
From	Vince Piper	**Job No.**	832F/F1
Date	21 November 2008	**Doc No.**	015a
Subject	Marillana Village & Mine Site: Effluent Irrigation		

With development of the Brockman mine site and associated Marillana village, sewerage treatment facilities will be installed and it is proposed to discharge the treated effluent by spray irrigation over a selected area of native vegetation. An assessment of the areas required for the effluent disposal has been undertaken and the details of this assessment are given below.

Discharge Volumes

The estimated discharge volumes to the treatment plants (provided by Engenium) are 60KL/d from the village and 2.5KL/d from the mine site. It is assumed that these same volumes will require disposal by spray irrigation to separate areas. It is understood that the project is under review and hence it is unlikely that these quoted volumes will be the final volumes. However the areas calculated will be able to proportioned to the updated discharge volumes.

Evaporation Area Requirements

The design aim when discharging effluent by irrigation is to ensure that the average evaporation rate equals or exceeds the irrigation rate so not to waterlog the discharge area or promote runoff. Based on data published by the Bureau Of Meteorology (Climatic Atlas of Australia, Evapotranspiration, 2001), point potential evapotranspiration can be used as a preliminary estimate for evaporation from small storages. From this reference, the monthly average point potential evapotranspiration rates for the Brockman mine area are given in Table 1. This data has been conservatively adopted as the average monthly evaporation applicable for sprayed effluent. In reality, spray evaporation would be higher than that from a water storage surface.

Table 1: Average Evaporation

Month	Evaporation (mm)
January	380
February	290
March	290
April	200
May	137
June	105
July	115
August	170
September	230
October	320
November	380
December	410

As shown in Table 1, evaporation in the Pilbara region is relative high for most of the year with the highest rates typically in November, December and January and the lowest rates typically during May, June and July. These lower average evaporation rates are appropriate for sizing the minimum area required for spray irrigation, with the lowest average monthly evaporation rate of 105mm (June) being the control.

Based on 105mm/month evaporation, the village (60KL/d) would require a minimum effluent irrigation area of 1.72ha and the mine site (2.5KL/d) would require a minimum effluent irrigation area of 0.07ha.

Nutrient Area Requirements

The treated sewerage effluent water will contain nutrients which when irrigated over vegetation will be taken-up by the vegetation and promote growth, plus be consumed by soil microbial action. Guidelines on the acceptable rates of nutrient application to native vegetation are not available, though some design guidance on the application of irrigated wastewater and the maximum nutrient application rates are given in the publication "Department of Water - Water Quality Protection Note (WQPN 22, July 2008), Irrigation with Nutrient-Rich Wastewater". This reference has been prepared for stabilised nutrient-rich wastewater from industries such as abattoirs, animal holding yards, aquaculture, breweries and food processors and specifically comments that it does not apply to treated municipal wastewater (sewerage) which requires specific approval under the Health Act 1911. However in the absence of a more pertinent guideline, criteria from this publication (WQPN 22) have been used to provide design guidance and to assess the minimum irrigation areas required.

Pertinent design guidance recommendations for the Brockman effluent irrigated sites include:

- Locate remote from areas where odours or spray drifts may cause nuisance
- Locate where depth to water table exceeds two metres
- Locate where surface slopes are less than one in twenty
- Locate in areas not subjected to seasonal flooding
- Locate away from natural waterways and water sources
- Locate away from conservation zones and wetlands
- Ensure vegetative buffer zones between the irrigation site and sensitive areas
- Ensure irrigation is applied uniformly and avoid waterlogging
- Implement a water quality monitoring programme

Assuming that the irrigation sites have fine grained surface soils and that the eutrophication risk to surface water within 500m of irrigation site is low, then the WQPN 22 guideline ranks the effluent irrigation sites with a eutrophication Risk Category D being the lowest risk category. Adopting this risk ranking, the guideline provides a maximum recommended application rate for Inorganic Nitrogen (as N) at 480kg/ha/yr (assuming a concentration less than 30mg/L) and for reactive Phosphorus (as P) at 120kg/ha/yr (assuming a concentration less than 7.5mg/L).

Typical treated sewerage effluent has an Inorganic Nitrogen (as N) of 10mg/L and Phosphorus (as P) of 2mg/L. Using these application rates, the village (60KL/d) would require a minimum effluent irrigation area of 0.46ha and the mine site (2.5KL/d) would require a minimum effluent irrigation area of 0.02ha. These minimum application areas are less than 30% of the areas required for effluent disposal by evaporation of 1.72ha and 0.07ha respectively.

Adopting the minimum irrigation areas required for effluent disposal by evaporation, the nutrient loadings to the disposal zones would be less than 30% of the maximum recommended application rates given in WQPN 22 guideline for Inorganic Nitrogen (as N) and for reactive Phosphorus (as P). In the absence of more specific application guidelines, these application rates are considered acceptable with the condition that the sites are appropriately monitored.

Summary

When determining the area required to discharge effluent by irrigation, evaporation and nutrient loading should be considered. Adopting evaporation during the month with the lowest evaporation and providing no allowance for spray or seepage losses results in a required area of 1.72ha for the village (60KL/d) and 0.07ha for the mine site (2.5KL/d). These areas can be adjusted proportionally when updated discharge volumes are available. Dependent on the treatment process and design of the irrigation system, nutrient loading is unlikely to be a limiting factor on the irrigated area.

We trust this memo is adequate for you current project needs, should you require any additional information please do not hesitate to contact the undersigned.

Yours sincerely
Aquaterra

Vince Piper

Vince Piper
Principal Civil/Water Resources Engineer

Iain Rea

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Memo

To	Brendan Hynes	**Company**	Brockman Resources
From	Damien Janssen	**Job No.**	832G
Date	18 August 2009	**Doc No.**	175b
Subject	Effluent Irrigation - 1 in 10 year ARI Flooding Considerations		

Brendan,

As requested, we present here a discussion of the likely effects of inundation as it relates to the two proposed effluent irrigation disposal areas.

1. INTRODUCTION

With development of the Marillana mine site and associated Marillana village, sewage treatment facilities will be installed. It is proposed to discharge the treated effluent by spray irrigation over selected areas of vegetation. Aquaterra provided Brockman with a brief report (Aquaterra, 2008) outlining the requirements of such a system. Here we look at the potential effects that inundation of such spray-fields, at the locations selected for the Project (Ausenco, 2009), may have on the receiving environment.

2. RELEVANT DESIGN CRITERIA

We list here several of the design criteria (outlined in more detail in Aquaterra 2008) which are pertinent to the discussion of potential impacts in the event of inundation of effluent irrigation disposal areas:

- Effluent discharged by irrigation should ensure that the average evaporation rate equals or exceeds the irrigation rate so as not to waterlog the discharge area or promote runoff. All calculations for the required disposal area were undertaken with this consideration.
- The treated sewage effluent water will contain nutrients which when irrigated over vegetation will be taken-up by the vegetation and promote growth, while also being consumed by soil microbial action. Therefore the nutrients have relatively limited residence times within the soil profile rather than accumulating over time.
- By adopting the minimum irrigation areas required for effluent disposal by evaporation, the nutrient loadings to the disposal zones would be less than 30% of the maximum recommended application rates (Department of Water, 2008). This will allow increased opportunities for microbial action and vegetation pick-up to reduce the nutrient load in the soil profile.

3. INUNDATION OF SURFACE IRRIGATION DISPOSAL AREA

The locations of the potential disposal areas are shown and discussed in Ausenco (2009).

In a 1 in 10 year ARI flood event, the village disposal area would be inundated by less than 1m of water (Aquaterra, 2009a), which would drain away to the northeast as sheet flow. Without the use of flood protection bunding, the mine site disposal area would be inundated by 1 to 2m of water, and would tend to drain internally and pond in an area to the southwest of the disposal site.

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However flood protection bunding is proposed to extend from the sand dune located immediately north of the proposed areas southwards past the eastern edge of the proposed area, connecting into higher ground. Consequently, this area will not be impacted by flooding during events up to the bund design ARI.

Groundwater levels have been measured at 11-12 metres below ground level (mbgl) at these locations (Aquaterra, 2009b).

3.1 SURFACE WATER EFFECTS

In terms of the likely surface water effects, the risk to Weeli Wolli Creek and the Fortescue Marsh are deemed to be low. With the low floodwater velocities and the absence of surface water ponding associated with the irrigation (a design aim of a well-managed effluent irrigation disposal system), it is anticipated that only minor mobilisation of nutrients into the surface water would occur. The processing plant location area would be protected from flooding by bunding incorporating an appropriate freeboard during a 1 in 10 year event. Also, due to the drainage directions at the selected sites, little to none of this flood water would make its way directly to Weeli Wolli Creek.

At both of these locations, when flooding does occur; it occurs as a combination of overland and channel flow. Floodwater velocities at the proposed locations area are low (calculated to be less than 1m/second) and overland flow would ensure rapid dilution. When combined with the likely limited mobilisation of nutrients from the soil profile into the surface water, this suggests that the effects of a 1 in 10 year ARI event would be limited.

3.2 GROUNDWATER EFFECTS

In a 1 in 10 year ARI flood event, there is potential that any residual nutrients and coliforms present in the soil profile may be mobilised downward, and perhaps reach the local groundwater system. In the event of these nutrients reaching the water table, the general groundwater flow (and any suspended nutrients) is towards the north at approximately 0.1 to 1.0m/d. With this low groundwater gradient groundwater takes at least 25 years (up to hundreds of years) to reach the Fortescue Marsh (approximately 12km to the north), far longer than the anticipated lifespan of the nutrients in the system, and the potential for effect upon the Marsh is deemed low to negligible.

Future potable water supplies (camp and offices) would be located up-gradient of the proposed spray-fields to ensure that they are not at risk of any mobilised nutrients entering the potable supply. It is important to note that, to the north of the proposed spray-fields, the groundwater becomes progressively more saline with proximity to the Fortescue Marsh. Just to the north of the project tenement, the groundwater is brackish, and is suitable only as a stock water supply, so any potential down gradient effects would not be upon a potable water supply.

It is also worth noting the lack of other receptors down gradient of these locations, with the only groundwater users between the project and the Fortescue Marsh being sparsely located stock watering points of brackish quality (the closest of which is approximately 3km to the northeast – and therefore across gradient). It is deemed unlikely that there would be any effect on the beneficial use of groundwater at these locations associated with the spray-fields.

4. FURTHER WORK

As part of ongoing investigations, numerical groundwater modelling is being undertaken. This will be utilised to target potable water supply bores for both the village and the mine site at locations where the nutrient loading of effluent irrigation disposal areas will not affect the source potable supply.

Prior to submission of application for installation of such a system, soil testing should be undertaken at both spray-field locations to confirm the soil category and subsequent nutrient load limitations. This should be undertaken upon confirmation of spray-field locations, to ensure that soil samples will be representative of the actual receiving soils.

5. CONCLUSIONS

In summary, the effects that inundation of proposed effluent irrigation disposal areas is anticipated to be minimal for the following reasons:

- A correctly operated spray field will not have any ponding or run-off, so there will be no liquids that could be easily mobilised in the event of inundation. Low floodwater velocities will also contribute to the limited mobilisation of nutrients and coliforms from the soil profile.
- Any nutrients and coliforms that may be mobilised by inundation will be significantly diluted by the large volumes of water associated with such an inundation event, and will tend not to flow towards the Weeli Wolli Creek channel.
- Any nutrients introduced to groundwater would move only slowly towards the north, as the underlying aquifer has low flow gradients and increasing salinity towards the Fortescue Marsh, therefore potential for impacts upon the Marsh or the beneficial use of the groundwater are deemed low to negligible.

6. REFERENCES

Aquaterra 2008, *Marillana Village & Mine Site: Effluent Irrigation*. Memo prepared for Brockman Resources Ltd, Perth, Western Australia, November 2008.

Aquaterra 2009a, *Marillana Surface Hydrology Assessment*, Report prepared for Brockman Resources Ltd, Perth, Western Australia, July 2009.

Aquaterra 2009b, *Marillana Groundwater Pre-Feasibility Report*, Report prepared for Brockman Resources Ltd, Perth, Western Australia, July 2009

Ausenco 2009, *Marillana Project Waste Water Treatment Effluent Disposal*. Doc reference 1872-RPT-004, July 2009.

Department of Water 2008, *Irrigation with nutrient-rich wastewater*. Water Quality Protection Note No. 22, July 2008, pp20.

We trust this memo is adequate for your current requirements, should you require any additional information please do not hesitate to contact the undersigned.

Yours sincerely
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APPENDIX 3: Site Layout Plan (including location of Landfill)

Marillana Iron Ore Project Preliminary Site Layout