Vegetation Monitoring Plan

Iron Ore Mine and Downstream Processing, Cape Preston, Western Australia

Mineralogy Pty Ltd

June 2005

MAUNSELL | AECOM

Vegetation Monitoring Plan

Prepared for

Mineralogy Pty Ltd

Prepared by

Maunsell Australia Pty Ltd
Level 1, 629 Newcastle Street, PO Box 81, Leederville 6902, Western Australia
T +61 8 9281 6100 F +61 8 9281 6295 www.maunsell.com
ABN 20 093 846 925

June 2005

74500300.03

Quality Information

Document	Vegetation Monitoring Plan
Ref	74500300.03
Date	June 2005
Prepared by	Kellie Honczar
Reviewed by	Paul Holmes

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
A	30/09/2004	First draft for review	Paul Homes, Principal Environmental Planner	
B	16/12/2004	Draft incorporating client comments	Paul Homes, Principal Environmental Planner	
C	25/02/05	Final draft for submission to EPA	Paul Holmes Principal Environmental Planner	
D	01/06/2005		Paul Holmes Environmental Manager	

Table of Contents

Executive Summary i
1.0 Introduction 1
1.1 Background 1
1.2 Relevant Legislation and Guidelines 1
1.3 Objectives of this Document 2
1.4 Responsibilities and Reporting 2
1.5 Consultation 2
2.0 Project Description 3
2.1 Project Outline 3
2.2 Description of Vegetation 3
3.0 Predicted Impacts on Vegetation 5
3.1 Impacts on Phreatophytic Vegetation 5
3.2 Impacts from Dust 5
3.3 Impacts on Mangrove Communities 5
3.4 Weed Infestations 6
4.0 Monitoring Plan Scope 8
5.0 Methods 12
5.1 Monitoring Impacts of Dewatering 12
5.1.1 Monitoring Tree Health 12
5.1.2 Tree Water Use 13
5.1.3 Other Monitoring 13
5.2 Monitoring Impacts of Dust 14
5.3 Monitoring Impacts on Mangroves 14
5.4 Monitoring Weed Infestations 15
6.0 References 17
Appendix A Tree Transects - Riparian Vegetation (Data Sheet) 19
Appendix B Understorey Quadrats - Riparian Vegetation (Data Sheet) 21
Appendix C Mangrove Quadrats - Infrastructure Corridor / Dust Impacts (Data Sheet) 23
Appendix D Mangrove Defoliation – Within Mangrove Quadrats (Data Sheet) 25
Appendix E Accretion, Erosion, Recruitment, Mortality (AERM) Transects (Data Sheet) 27
Appendix F Weed Quadrants (Data Sheet) 29

Tables

Table 3.1 Landholder Obligations to Control Mesquite at the P4 Requirement for Control Level (Dept. of Agriculture, 2004) 7
Table 4.1 Predicted Impacts and Associated Monitoring Programs to be implemented to Assess Vegetation Health Decline, Cape Preston Development 8
Table 4.2 Proposed Vegetation Monitoring Schedule, Cape Preston Development 11

Figures

Figure 1 Regional Setting. 4

Executive Summary

Mineralogy Pty Ltd commissioned Maunsell Australia Pty Ltd (Maunsell) to prepare a Vegetation Monitoring Plan to assess fluctuations in vegetation condition and function as a result of mining activities at it's Cape Preston Operations. The proposed Cape Preston development includes open pit mining, stockpiling export product, waste and tailings, a process plant, a gas-fired power station, an infrastructure corridor to Cape Preston, a seawater desalination plant and port facilities at Cape Preston and off Preston Island and other mining related facilities.

Major impacts from these operations predicted to adversely affect native vegetation in the area include:

- altered hydrological regime (reduced ground water levels) as an indirect result of dewatering;
- altered tidal flux as a result of the infrastructure corridor;
- dust from construction;
- erosion caused by vegetation clearing for construction; and
- weed infestations due to various disturbances.

Phreatophytic vegetation is groundwater dependent and proposed pit dewatering activities are predicted to negatively impact the creek line vegetation within the project area. The extent of this impact will be assessed by monitoring the health of phreatophytic species (*Eucalyptus camaldulensis, Eucalyptus victrix* and *Melaleuca argentea*) and of the understorey associated with these trees. Factors such as groundwater levels and stream flow will be monitored as part of the detailed Pit Dewatering and Vegetation Monitoring Plan (Maunsell 2005). This will allow inferences to be drawn as to the direct cause of predicted phreatophyte decline.

Vegetation adjacent to areas predicted to receive relatively high amounts of dust, such as haul roads, will be monitored to assess fluctuations in health and function. Visual dust monitoring, combined with results from dust monitoring stations will allow inferences to be drawn as to whether any decline in vegetation health can be attributed to dusty conditions.

As mangroves are sensitive to changes in tidal conditions, the presence of the infrastructure corridor may potentially have negative impacts on mangroves in the vicinity of the creek crossing. Clearing of mangroves in this location may also have subsequent negative effects, including additional changes in tidal flux. These modifications may additionally cause changes in erosion and accretion of the creek banks which can disrupt the normal recruitment and mortality of mangrove communities. In order to assess these predicted changes and the impacts on mangrove health and function, monitoring of tidal patterns, stream flow and bank modifications in conjunction with mangrove condition and cover will be carried out. This will allow any declines in mangrove populations to be attributed to identified impacts.

As the disturbances associated with proposed mining activities have the potential to exacerbate weed infestations, monitoring of weed presence will be carried out at all locations monitored for factors already outlined. In addition to this, weed assessment will be carried out in areas of high disturbance, such as waste dumps. Opportunistic weed assessments will also be carried out in transit over site and particular weed occurrences will be duly documented and assessed.

1.0 Introduction

1.1 Background

Mineralogy Pty Ltd (the proponent), proposes the development of an iron ore mine and downstream processing facilities at Cape Preston, 80km south west of Karratha.

In response to project environmental impact assessment requirements as determined by the Environmental Protection Authority (EPA), a Public Environmental Review (PER) was submitted to the Authority in December 2000 (HGM, 2000). The PER was supplemented with a Supplementary Environmental Review (SER) in February 2002 to address changes to the project design being sought by the proponent (HGM, 2002). Under the proposal assessed by the EPA pursuant to the PER and SER, and a subsequent successful application for a non-substantial change to the assessed project pursuant to Section 45(c) of the *Environmental Protection Act 1986,* the project would entail an annual mining rate of approximately 67.4 Mt and annual production of the following:

- Concentrate – approximately 19.6 Mt;
- Pellets – approximately 13.8 Mt; and
- Direct reduced/hot briquetted iron – approximately 4.7 Mt.

Through the Section 45 (C) process seeking Ministerial approval for a non-substantial change to the assessed project, it was made clear that the stockpiling and export of concentrate was intended and in this regard, it should be noted that the Minister's approval of the proposed change was unconditional.

The proponent commissioned Maunsell Australia Pty Ltd (Maunsell) to prepare a Vegetation Monitoring Plan to assess the impact of iron ore mining on native vegetation at the proposed Cape Preston Development.

1.2 Relevant Legislation and Guidelines

State Government Legislation	**Application**
Environmental Protection Act 1986	PER assessment and Ministerial approval process, and Section 45 (C) non-substantial change
Iron Ore Processing (Mineralogy Pty Ltd) Agreement Act, 2002	Act under which the project is developed
Agriculture and Related Resources Protection Act	Management of declared plants (weeds)
State Government Guidelines	
EPA Guidance Statement No 1: *Protection of Tropical Arid Zone Mangroves Along the Pilbara Coastline*	Management of development proposals impacting on regionally significant Mangrove populations

1.3 Objectives of this Document

The objective of the vegetation monitoring plan is to assess the impact that various activities associated with all operations at Cape Preston may have on local native vegetation. This assessment will be achieved by establishing baseline data, prior to the commencement of operations. Subsequent monitoring of vegetation factors will be done in conjunction with monitoring of identified impacting factors, such as dust and groundwater levels, to determine the degree of alteration to natural conditions which may result in vegetation decline. This will allow isolation of the cause/s of vegetation decline to maximise remedial management actions. This document is to be read in conjunction with the project Environmental Management System and Construction Environmental Management Plan.

1.4 Responsibilities and Reporting

Overall responsibility for ensuring that site environmental management requirements are met during the construction phase of the project will rest with the proponent's Construction Manager. During the operational phase of the project, this responsibility will rest with the proponent's Environmental Manager. In respect of this Vegetation Monitoring Plan, this responsibility will include:

- ensuring that all mine personnel, both the proponent's workforce and contract personnel, conform with requirements pursuant to the Management Plan;
- ensuring that contractor staff are fully inducted and aware of their environmental responsibilities and obligations; and
- ensuring that monitoring requirements are being met.

Contracting companies undertaking site works will be required to appoint an environmental representative. The key responsibilities of this representative will be to:

- maintain routine contact with the proponent's Environmental Manager to ensure that environmental objectives of this plan are being met;
- provide monthly reports to the proponent's Environmental Manager on environmental issues and conduct regular audits; and
- ensure that all management aims and monitoring requirements of this Vegetation Monitoring Plan are being met.

1.5 Consultation

Pursuant to Environmental Impact Assessment requirements under the *Environmental Protection Act (1986)*, Comprehensive consultation with stakeholders and members of the community has been undertaken. The outcomes of these negotiations were used to develop the commitments provided by Mineralogy and presented in the Public and Supplementary Environmental Review documents (HGM 2000, 2002) and, ultimately, in the development of this environmental management plan.

2.0 Project Description

2.1 Project Outline

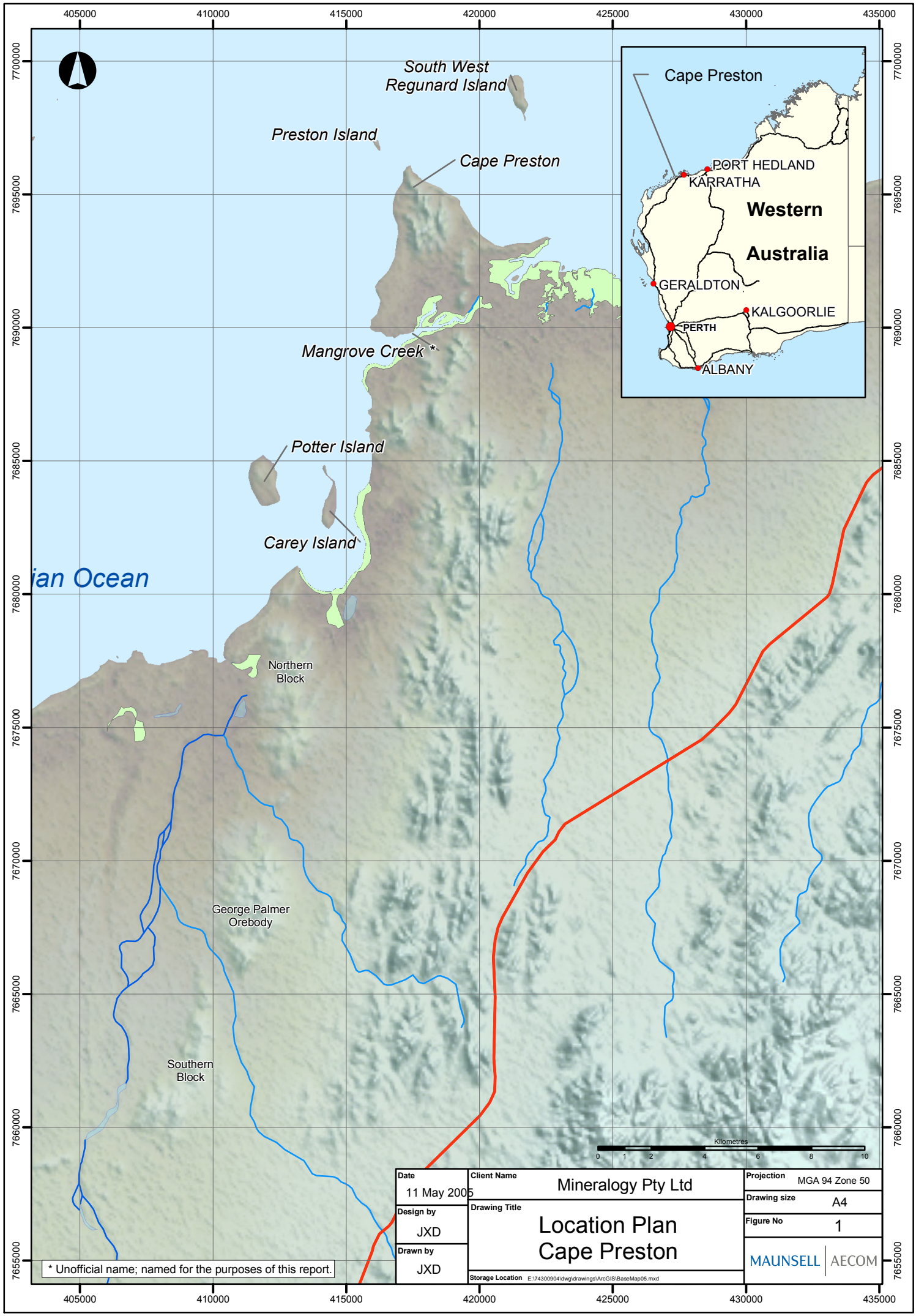
The proponent plans to mine the George Palmer Orebody, which is located approximately 80km south west of Karratha and 25 km south of Cape Preston in the Pilbara region of Western Australia. A stockyard and laydown area will be constructed at Cape Preston. Preston Island is the intended location for the port facilities. Figure 1 depicts the location of the site in a regional context. The major components of the project are:

- open pit mine;
- desalination plant;
- HBI (Hot Briquetted Iron) plant;
- DRI (Direct Reduced Iron) plant;
- pellet plant;
- concentrator plant;
- tailings dam;
- system of conveyors and a service road to Cape Preston;
- product stockpile (HBI, DRI, pellets, concentrate) and adjacent general laydown areas at Cape Preston
- causeway to Preston Island;
- jetty to the load out / port facilities;
- port facilities; and
- accommodation for employees and construction staff.

2.2 Description of Vegetation

Cape Preston falls within the northern limit of the Onslow Coastal Plain, a subunit of the Fortescue Botanical District as described by Beard (1975) and on the boundary of the Carnarvon and Pilbara IBRA regions (CAR1 & PIL4 subregions, respectively). The region has been mapped by the Department of Agriculture WA from 1:50,000 aerial photography and this mapping provides the largest scale interpretation of vegetation units for the project area available (Van Vreeswyk *et al*. in print).

Sixty four terrestrial vegetation units, comprising nine land systems, have been described by Van Vreeswyk *et al*. for the study area. In general terms, the vegetation comprises various *Acacia* shrublands over *Triodia spp* hummock grasslands on the more rugged, shallow soiled habitats, with *Eragrostis xerophila* tussock grasslands dominating the heavy clay soils found within the project area. Drainage lines are dominated by *Eucalyptus spp* over *Melaleuca* and *Acacia* shrublands. They also tend to be heavily infested with *Cenchrus ciliaris* (Buffel grass), which is a highly invasive weed introduced by pastoralists for its high grazing value. A biological survey carried out in April 2000 (HGM *et al.*), identified one Priority 1 species and five Priority 3 species.


405000
410000
415000
420000
425000
430000
435000
7700000
7695000
7690000
7685000
7680000
7675000
7670000
7665000
7660000
7655000
South West
Regunard Island
Preston Island
Cape Preston
Mangrove Creek *
Potter Island
Carey Island
ian Ocean
Northern
Block
George Palmer
Orebody
Southern
Block
Cape Preston
PORT HEDLAND
KARRATHA
Western
Australia
GERALDTON
KALGOORLIE
PERTH
ALBANY
Kilometres
0 1 2 4 6 8 10
* Unofficial name; named for the purposes of this report.
Date
11 May 2005
Design by
JXD
Drawn by
JXD
Client Name
Mineralogy Pty Ltd
Drawing Title
Location Plan
Cape Preston
Storage Location
E:\74300904\dwg\drawings\ArcGIS\BaseMap05.mxd
Projection
MGA 94 Zone 50
Drawing size
A4
Figure No
1
MAUNSELL AECOM

3.0 Predicted Impacts on Vegetation

Various Management and Monitoring Plans, prepared by Maunsell, in compliance with commitments outlined in the Public Environmental Review (HGM, 2000) identify a range of potential impacts on native vegetation as a result of proposed development. The major impacts which may adversely affect native vegetation and therefore require monitoring have been identified as:

- impacts on phreatophytic vegetation as a result of pit dewatering;
- dust impacts on areas of vegetation in close proximity to ground disturbances, such as haul roads;
- impacts on mangrove populations as a result of construction of the causeway from Cape Preston to Preston Island; and
- exacerbation of existing Mesquite (**Prosopis pallida* hybrid) and other weed infestations via various disturbances.

3.1 Impacts on Phreatophytic Vegetation

Mining operations will necessitate dewatering of the proposed pit area, with consequent effects of the water table level. The groundwater dependent ecosystems within the project area were identified by determining which species utilise groundwater (are phreatophytic). These species have been identified as *Eucalyptus camaldulensis* (River Red Gum), *Eucalyptus* victrix (Coolibah) and *Melaleuca argentea* (Cajeput) and are regarded the key indicators of Riparian Vegetation (Maunsell, 2005). The Pit Dewatering and Vegetation Monitoring Plan (Maunsell, 2005) for the project details the predicted impacts on phreatophytic vegetation, as a result of dewatering.

3.2 Impacts from Dust

During the construction phase, the disturbance of soil and rock, and the handling of bulk construction materials will result in the generation of dust. During construction, the cover of vegetation and stable soil which would normally form a seal against wind dispersion is removed. Consequent environmental effects are usually localised and depend on the size of the dust particles and the strength of distributing factors and usually decrease rapidly with separation from the source. In the immediate vicinity of the source, dust can smother vegetation causing stomata blockages and reducing light availability (Maunsell, 2005).

3.3 Impacts on Mangrove Communities

The Environmental Protection Authority (EPA) Guidance Statement No. 1 – *Guidance Statement for the protection of tropical arid zone mangroves along the Pilbara coastline* (2001) includes the Cape Preston mangroves as one of several populations that occur within areas that have been designated for industrial development, associated ports or related uses. Within this context, the Cape Preston populations are considered to be "Mangrove areas of very high conservation value (designated *regionally significant*)" and are classified under Guideline 3 as outlined in the Guidance Statement. The EPA's operational objective for Guideline 3 areas is that no development should take place that would significantly reduce the mangrove habitat or ecological function of the mangroves in these areas.

In accordance with the objectives of Guideline 3, the outcomes in terms of managing impacts on the Cape Preston Mangrove populations would include:

- mangroves should not decline because of altered water flow or salinity (no significant alteration of tidal flow to mangroves with the key objective being to maintain existing tidal patterns);
- water quality in undisturbed mangrove areas adjacent to the development should meet the ANZECC Water Quality Guidelines, unless there is ecological justification for it not doing so;
- existing groundwater flow, freshwater inflows and quality should be maintained in undisturbed mangrove areas;
- mangrove decline should not occur through secondary effects such as shading or dust settlement; and
- sedimentation patterns should be maintained so that erosion and deposition within mangrove habitats is within natural variations.

These desired outcomes have the potential to be compromised due to the construction of the infrastructure corridor to link Cape Preston with Preston island, which requires direct removal of mangroves for construction, is likely to alter tidal processes and the associated use of this the corridor is likely to result in significant quantities of dust dispersal. In addition to this, pit dewatering is likely to alter stream flow upstream, thus altering the current freshwater inflow received at the tidal flats.

3.4 Weed Infestations

The detailed Biological Survey (HGM, 2001), identified several introduced (weed) species in the project area. One of these species, Mesquite (**Prosopis pallida* hybrid), was reported to be listed as a Declared Plant, according to the Department of Agriculture (2004). One other weed species recorded within the survey area, Mexican Poppy (**Argemone eochroleuca*), is also listed as a Declared Plant (Dept. of Agriculture, 2004). Declared Plants (weeds) are classified under different categories in different areas of the state, depending on factors such as invasive potential and local land use. These categories relate to varying requirements for control and eradication under landholder obligations, which Landholders are required to adhere to under Subsection (2) of Section 35 of the *Agriculture and Related Resources Protection Act, 1976.* Mesquite is listed as a P4 Declared Plant within the project area. A summary of Landholder Obligations to control Mesquite under P4 Category Requirements are summarised in Table 1.

P4 **REQUIREMENTS** Aims to prevent infestation spreading beyond existing boundaries of infestation	The infested area must be managed in such a way that prevents the spread of seed or plant parts within and from the property on or in livestock, fodder, grain, vehicles and/or machinery. Treat to destroy and prevent seed set of all plants: • within 100 metres inside of the boundaries of the infested property • within 50 metres of roads and high-water mark on waterways • within 50 metres of sheds, stock yards and houses Treatment must be done prior to seed set each year. Properties with less than 2 hectares of infestation must treat the entire infestation. Additional areas may be ordered to be treated.
Special considerations	In the case of P4 infestations where they continue across property boundaries there is no requirement to treat the relevant part of the property boundaries as long as the boundaries of the infestation as a whole are treated. There must be agreement between neighbours in relation to the treatment of these areas.

Table 3.1 Landholder Obligations to Control Mesquite at the P4 Requirement for Control Level (Dept. of Agriculture, 2004)

The control requirements for Mexican Poppy (**Argemone eochroleuca*) within the project area are less stringent and prohibit the movement of plants or seed, including contaminated machinery and produce including livestock and fodder.

Monitoring impacts on vegetation shall include weed monitoring, which will take place as a component of programs to monitoring other impacts.

4.0 Monitoring Plan Scope

The Vegetation Monitoring Plan encompasses:

- identification of the impacts from mining operations which may have a detrimental effect on native vegetation;
- identification of the areas of vegetation which may be adversely affected by mining operations and the nature of these impacts;
- design of a program to monitor fluctuations in vegetation health for the various types of vegetation which may be experience project-related impacts;
- initiation of monitoring prior to commencement of operations to gather baseline data;
- continuation of monitoring following commencement of operations to gather initial comparative data;
- comparison of subsequent data with baseline data and note fluctuations in vegetation health;
- identification of the cause/s of any decline in vegetation health; and
- reporting of the findings of monitoring.

The impacts to be investigated, the vegetation areas likely to be impacted and the monitoring program to be implemented are summarised in Table 2:

Table 4.1 Predicted Impacts and Associated Monitoring Programs to be implemented to Assess Vegetation Health Decline, Cape Preston Development

Impact	Vegetation/ Area	Monitoring Program	Plot dimensions	Parameters to be monitored
Groundwater drawdown from pit dewatering	Riparian Vegetation	Transects at a range of sites selected for their vegetation type and distance for the centre of the "cone of groundwater drawdown"	Tree plots: 10m wide x 50m long	• species • height • DBH • % alive canopy • health score • photograph (for visual health) • site conditions including; site photograph, erosion, visible dust deposits, cattle degradation and weed presence (if significant)
Ground water drawdown from pit dewatering	Riparian Vegetation	Quadrats within transects as above	Understorey plots (at each end of each tree plot): 10m x 10m	• species (including weeds) • height • no. alive plants (ea sp.) • no. dead plants (ea sp.) • % cover alive plants (ea sp.) • % cover dead plants (ea sp.)

Impact	Vegetation/ Area	Monitoring Program	Plot dimensions	Parameters to be monitored
Mangrove clearing/ changes to tidal regime at infrastructure corridor crossing	Surrounding Mangroves	Quadrats at sites surrounding the infrastructure corridor crossing	10m x 10m quadrats	• no. mature trees (ea sp.) • no. saplings (ea sp.) • no. seedlings (ea sp.) • no. each health factor (H, SS, S, VS, D) of each of the above • no. alive leaves on selected branch of selected mangroves • site conditions including; site photograph, soil conditions, erosion, visible dust deposits, cattle degradation and weed presence (if significant)
Accretion and Erosion vs Mangrove Recruitment and Mortality	Creek banks within mangrove communities	Transects parallel to creek banks	10m x 2m	• distance from outer edge of transect to bank edge (established at 2m) • no. mature mangroves (ea sp.) • no. saplings (ea sp.) • no. seedlings (ea sp.) • no. alive and dead of each of the above • site conditions including; site photograph, visible dust deposits, cattle degradation and weed presence (if significant)
Dust from roads, etc.	Surrounding Mangroves	Quadrats at sites surrounding the roads and other ground disturbances	10m x 10m quadrats	• no. mature trees (ea sp.) • no. saplings (ea sp.) • no. seedlings (ea sp.) • no. each health factor (H, SS, S, VS, DR, DO) of each of the above • no. alive leaves on selected branch of selected mangroves • site conditions including; site photograph, erosion, visible dust deposits, cattle degradation and weed presence (if significant)

Impact	Vegetation/ Area	Monitoring Program	Plot dimensions	Parameters to be monitored
Dust from roads, etc.	Various vegetation adjacent to roads and other ground disturbances	Quadrats at a range of sites in close proximity to ground disturbances	10m x 10m	• species (including weeds) • height • no. alive plants (ea sp.) • no. dead plants (ea sp.) • % cover alive plants (ea sp.) • % cover dead plants (ea sp.) • site conditions including; site photograph, erosion, visible dust deposits, cattle degradation and weed presence (if significant)
Weed Infestations	Various vegetation adjacent to, haul roads, roads, waste dumps and other disturbances	Quadrats at a range of sites selected for their vegetation type and proximity to disturbances	10m x 10m	• species of weeds • % cover alive weeds (ea sp.) • % cover dead weeds (ea sp.) • site conditions including; site photograph, erosion, visible dust deposits and cattle degradation
Weed Infestations	Over entire site	Opportunistic visual assessment	NA	• location • species of weeds • % cover alive weeds (ea sp.) • % cover dead weeds (ea sp.) • site conditions including; erosion, visible dust deposits and cattle degradation
All Impacts	All vegetation	Aerial photography	NA	Photography taken at biannual intervals, compared for: • density (cover) • extent (cover) • health (cover, colour)

Following the regime for the monitoring of phreatophytic vegetation implemented at the BHP Iron Ore operations at Orebody 23, near Newman (Woodward-Clyde, 1999), quarterly vegetation monitoring is proposed for Cape Preston. This will enable monitoring during both wet and dry seasons and the intermediates. Should the first year of monitoring reveal very little variation between each of the four samplings, this schedule will be reviewed and potentially reduced to biannual samplings, once in each of the rainfall seasons. The current proposed schedule for monitoring times is presented in Table 3.

Table 4.2 Proposed Vegetation Monitoring Schedule, Cape Preston Development

Sample	Rainfall Season	Timing
1	Wet Season	Late December to early January
2	Post-Wet Season	Late March to early April
3	Dry Season	Late June to early July
4	Pre-Wet Season	Late September to early October

5.0 Methods

5.1 Monitoring Impacts of Dewatering

To order to assess the impacts of groundwater drawdown from pit dewatering on vegetation, monitoring sites will be established across the drawdown zone. Wherever possible, monitoring sites will be established immediately adjacent to existing sites established by Aquaterra (2001) for groundwater modelling, to enable relationships between changes in vegetation health and groundwater levels to be drawn. Control transects will also be established upstream from the predicted groundwater drawdown zone. At each monitoring site, permanent transects 10 metres wide and 50 metres long, will be established, pegged and labelled. Within each of the 500m^2 transects, all phreatophytic trees (*Eucalyptus camaldulensis, Eucalyptus victrix* and *Melaleuca argentea*) will be numbered, tagged and measured for parameters summarised in Table 2 and detailed in Appendix A. In order to obtain sufficient data for statistical analysis, a minimum of 20 trees will be measured at each site. In the event that the 500m^2 transect does not encompass at least 20 phreatophytic tree species, transects will be extended accordingly.

Within each of the 10m x 50m tree transects, two 10m x 10m understorey quadrats will be established at each end. Monitoring of understorey vegetation within the riparian zone is intended to monitor the effects of groundwater drawdown and other impacts on non phreatophytic species occurring within phreatophytic vegetation communities, as a subsequent result of potential impacts on canopy species. Understorey species will be measured for parameters outlined in Table 2 and detailed in Appendix B.

As for all components of the Vegetation Monitoring Plan, sampling will be carried out under the BACI (Before After Control Impact) Sampling Design (Green, 1979). If possible, two sampling events will take place over a twelve month period to establish baseline data for both wet and dry season conditions, prior to the commencement of operations.

5.1.1 Monitoring Tree Health

Tree health monitoring will be conducted quarterly to represent wet (summer) and dry (winter) seasons and intermediate periods. The monitoring programme will entail the collection of baseline data prior to commencement of pit dewatering. In order to achieve effective representation of species' populations within each monitoring site, trees selected for analysis will be chosen based on their age, stress, vigour and location. Selected trees (*E. camaldulensis, E. victrix* and *M. argentea*) at each monitoring site will be numbered and tagged to enable sampling repetition and ensure data consistency over the duration of the monitoring programme.
The following parameters will be monitored as a measure of tree health:

- Visual health - to be assessed via established photo points.
- Health ranking - to be derived from visual assessment, ranging from healthy to dead with various degrees of stress as intermediates.
- Alive canopy foliage cover (%) - to be used as a visual measure of tree stress.
- Height (m) - to be used as a measure of growth.
- Diameter at Breast Height (DBH) - to be used as a measure of growth.
- Isotopic analysis - to be used as a quantitative measure of tree stress.

Isotopic analysis uses relative concentrations of 13C and 18O of leaf organic matter to determine the physiological responses (e.g. changes in photosynthetic capacity, stomatal conductance, humidity, rate of evapotranspiration) of plants to water stress. Analysis of

naturally occurring gradients in stable isotopes in water can determine the baseline proportion of groundwater, soil water and rain water in plant water (via xylem sap) (Thorburn, *et al.* 1992; Landman, 1994; Busch *et al.*, 1992). Error associated with the sampling, extraction and analysis is generally <5%.

Other benefits of this technique include:

- it is an established International Standard (IS Standard VPDB);
- it is a quantitative technique, which results in greater result confidence and therefore a better baseline on which to assess impacts of mine dewatering and assist application of Best Management Practices (BMPs);
- it provides an early indication of tree stress;
- it is an indicator of water stress, not factors such as leaf pests or disease; and
- research conducted in the Pilbara supports the use of this technique for the monitoring of water-stress in *E. camaldulensis* and *M. argentea* (Landman *pers. comm.* 2002*).*

In conjunction with the above monitoring, aerial surveys, using Digital Multi-Spectral Video (DMSV) system, will be conducted to assist assessment of tree health. This method allows detection of any changes in vegetation health before such would be apparent to through ground observations, and will be used to assist in the determination of tree health prior to and following (on an annual basis) the commencement of pit dewatering.

Additional monitoring of site conditions including erosion, weed invasion, extent of stock disturbance and pathogen attack is to be conducted in at each monitoring site in association with tree health monitoring.

5.1.2 Tree Water Use

Water use of creekline Eucalypts to detect the effects of dewatering has been carried out near Newman by Marcam Environmental (Marshall, 2000). Water use by *Eucalyptus camaldulensis* and *Eucalyptus victrix* was measured using the heat-pulse technique. In this technique, heat is used as a tracer for the movement of water. The sap velocity of the tree is measured by inserting a heat probe and sensors into the trunk and this data is multiplied by the conducting wood area of the tree, to give tree water use – typically as litres per day (L/d). These measurements can continue for years unless interrupted by problems caused by heat, cattle, floods or human interference. This method will be used during the monitoring programme to measure the amount of water being used by representative trees at selected sites.

5.1.3 Other Monitoring

Other data related to changes in groundwater due to dewatering will also be collected as part of the Pit Dewatering and Vegetation Monitoring Plan. These parameters include:

- groundwater levels;
- groundwater quality;
- streamflow;
- meteorological data; and
- tree irrigation rates.

Details of these parameters and the methods of collection of them are outlined in the Pit Dewatering and Vegetation Monitoring Plan (Maunsell, 2005).

5.2 Monitoring Impacts of Dust

To assess the impacts of dust on vegetation during construction and operations of the project, monitoring sites will be established at locations from which dust lift is anticipated. Control sites will be established in areas of similar vegetation where dust is not expected to occur from processes other than natural wind disturbance. At each monitoring site, permanent quadrats 10 metres wide and 10 metres long will be established, pegged and labelled. Within each of the $100m^2$ quadrats, all species will be measured for parameters summarised in Table 2 and detailed in Appendix B.

As for all components of the Vegetation Monitoring Plan, sampling will be carried out under the BACI Sampling Design (Green, 1979). If possible, two sampling events will take place over a twelve month period to establish baseline data for both wet and dry season conditions, prior to the commencement of operations.

5.3 Monitoring Impacts on Mangroves

Mangrove communities within the Cape Preston project area will potentially be impacted by:

- dust generated during construction and operational activities; and
- tidal changes associated with the infrastructure corridor crossing of Mangrove Creek.

To enable monitoring of these impacts, background information on the following will need to be collected and interpreted:

- tides;
- stream flow; and
- dust deposition

in the vicinity of the mangroves near the infrastructure corridor crossing, at other mangrove sites where adverse impact is anticipated and at control sites, removed from areas of predicted impact.

Monitoring of the health and function of mangroves in the vicinity of the infrastructure crossing and elsewhere as necessary will entail:

(i) review of aerial photography; and
(ii) permanent quadrat monitoring

A review of aerial photography will involve visual analysis of the mangal control areas (ie. areas not affected by mining operations) and impact areas (ie. areas likely to be affected by mining operations, including the infrastructure corridor and dust). Due to the cost of aerial photography and the low level of variation expected, it is proposed that this monitoring take place biannually, during the wet and dry seasons, rather than quarterly, as is proposed for other vegetation monitoring components.

Permanent quadrats are will be established within a range of mangrove communities, including at a minimum of two control sites and a number of impact sites in various areas including the vicinity of the infrastructure corridor crossing and other roads and haul roads likely to be significant dust sources. Site conditions within mangrove communities, may pose difficulty in terms of access such areas for on-the-ground monitoring purposes. While the objective is to monitor the mangroves as comprehensively as possible, due to potential access difficulties, it is not possible to stipulate the number of sites proposed to be established in each location until an initial site visit has been conducted. Access to most of the mangal area within the Cape Preston area for the Biological Survey (HGM, 2001) was done by boat and this is likely to be necessary for the mangrove component of the Vegetation Monitoring Program.

At each mangrove monitoring site, permanent quadrats 10 metres wide and 10 metres long will be established, pegged and labelled. Within each of the $100m^2$ quadrats, all mangroves will be measured for parameters summarised in Table 2 and detailed in Appendix C. Within each of the permanent monitoring quadrats, the four healthy mature mangrove trees, closest to the north-west corner peg of the plot will be selected and labelled on a representative branch. The number of alive leaves on each of these branches will be counted and recorded as a method of monitoring defoliation, as this is a preliminary indicator of stress in mangroves (Le Provost Dames and Moore, 1992). Data to be collected for this assessment is detailed in Appendix D.

In addition to the monitoring of permanent quadrats, accretion and erosion of creek banks and associated recruitment and mortality of mangroves will be monitored. This will be done by establishing transects 10m long and 2m wide, parallel to the bank edge. At a range of points along the transect, the distance to the edge of the bank will be recorded to measure accretion (indicated by increases in bank width) and erosion (indicated by decreases in bank width). Within the transect, the number of mature, sapling and seedling mangroves will also be recorded as a measure of recruitment (indicated by increases in seedling numbers) and mortality (indicated by a decrease in mangrove numbers). Data to be collected for this assessment is detailed in Appendix E.

As for all components of the Vegetation Monitoring Plan, sampling will be carried out under the BACI Sampling Design (Green, 1979). If possible, two sampling events will take place over a twelve month period to establish baseline data for both wet season and dry season conditions, prior to the commencement of operations.

5.4 Monitoring Weed Infestations

In order to monitor potential weed infestations in the project area, in particular infestations of Declared Plants (Department of Agriculture, 2004) Mesquite (**Prosopis pallida* hybrid) and Mexican Poppy (**Argemone eochroleuca*), a range of weed monitoring methods will be carried out. The primary method for monitoring weed presence within the project area will involve the inclusion of weed monitoring in all permanent plots established to monitor the other impacts outlined in this plan. That is, monitoring plots established to assess:

- riparian vegetation condition (to monitor impacts from dewatering);
- vegetation adjacent to ground disturbing activities (to monitor impacts from dust);
- mangrove community condition (to monitor impacts associated with the infrastructure corridor crossing, dust and other disturbances); and
- controls of all of the above.

Details of the weed monitoring parameters to be applied are summarised in Table 2 and detailed in Appendices A to C and E.

Permanent quadrats to monitor weed presence will also be established at various sites, selected for their proximity to disturbances, such as roads, the pit and waste dumps. Monitoring of these plots will record only weed species. Data to be collected for this assessment is summarised in Table 3 and detailed in Appendix E.

In addition to theses methods of assessment within permanent plots, general observations of the entire project area will be made during field investigations and any notable areas of weed infestation will be recorded, investigated further, reported and addressed as appropriate. It should also be noted that the control of Mesquite (**Prosopis pallida* hybrid) will also form part of the project Conservation Estate Management Plan, as required pursuant to 15-2 of Ministerial Statement 000635.

6.0 References

Aquaterra (2001) *Mineralogy Iron Ore Project – Prediction of Groundwater Level Drawdown.* Unpublished report prepared for Halpern Glick Maunsell Pty Ltd

Beard, J.S. (1975). *Vegetation Survey of Western Australia.* Pilbara 1:1000000 Vegetation series. Explanatory Notes to Sheet 5. University of Western Australia Press.

Busch D.E., Ingraham N.L. & Smith S.D. (1992), 'Water Uptake in Woody Riparian Phreatophytes of the Southwestern United States: A Stable Isotope Study', *Ecological Applications*, Vol 2 (4), pp 450-459.

Department of Agriculture Western Australia (2004) *Declared Plant List.* http://www.agric.wa. gov.au/

Environmental Protection Authority (2001) *Guidance Statement 1 - Guidance Statement for the protection of tropical arid zone mangroves along the Pilbara coastline.* Guidance for the Assessment of Environmental Factors Statement. Environmental Protection Authority, Perth.

Green, R.H. (1979) *Sampling Design and Statistical Methods for Environmental Biologists* John Wiley & Sons, New York

Halpern Glick Maunsell (HGM), Biota & M.E. Trudgen & Associates (2000). *Austeel Biological Survey Phase I.* Unpublished internal report.

Halpern Glick Maunsell (HGM), (2000), *Iron Ore Mine and Down Stream Processing, Cape Preston, WA, Public Environmental Review, December 2000.* Unpublished report prepared for Mineralogy Pty Ltd, December 2000.

Halpern Glick Maunsell Pty Ltd (2001) *Mineralogy Biological Survey – Phase 1* Unpublished report prepared for Mineralogy Pty Ltd

Halpern Glick Maunsell (HGM) (2002), *Iron Ore Mine and Downstream Processing, Cape Preston, WA. Supplementary Environmental Review, February 2002.* Unpublished report prepared for Mineralogy Pty Ltd.

Landman, P.A. (1994), 'Root Architecture and Sources of Water used by Riparian Vegetation Growing in the Pilbara Region', in *Management of Groundwater Dependent Vegetation in the Central Pilbara Iron Ore Mining Province,* The University of Western Australia.

Landman, P.A (2002), Manager - Environment, Hamersley Iron, Pty Ltd. Personal communication.

Le Provost Dames and Moore (1992) *Cargill Salt Environmental Management Programme – Mangrove Monitoring Programme and Rehabilitation Plan.* Cargill Salt

Marshall J.K. (2000), 'Water Use by Creekline Eucalypts near Newman to Detect the Effects of Dewatering', in *Management of groundwater dependent vegetation in the Central Pilbara iron ore mining province*, The University of Western Australia, Perth.

Maunsell Australia Pty Ltd (2005*) Pit Dewatering and Vegetation Monitoring Plan – Cape Preston Development*. Unpublished report prepared for Mineralogy

Maunsell Australia Pty Ltd (2005*) Dust Management Plan – Cape Preston Development.* Unpublished report prepared for Mineralogy

Thorburn P.J., Walker G.R., Hatton T.J. (1992), 'Are River Red Gums taking water from soil, groundwater or streams?', in *Proceedings of the Catchment of Green: A National Conference on Vegetation and Water Management*, Adelaide, pp 63-68.

Van Vreeswyk, A.M.E., A.L. Payne, K..A. Leighton and P. Henning. (2003). *An Inventory and Condition Survey of the Pilbara Region, Western Australia.* Department of Agriculture, Western Australia, Technical Bulletin No 92. (In prep).

Woodward-Clyde (1999) Orebody 23 Tree Monitoring Programme. Unpublished report prepared for BHP Iron Ore

Appendix A Tree Transects - Riparian Vegetation (Data Sheet)

Appendix A: Tree Transects - Riparian Vegetation (10m x 50m)

Field Data Sheet

Site No.: RT……. Date: ……/……/……. Recorder: …….. Photo No.: …….

GPS: ……mE ……..mN Bearing of Transect from start: ……..°

Landform: FLAT SLOPE RIDGE
OTHER: ……..

Erosion: NONE LO MED HI V HI

Dust: NONE LO MED HI V HI

Cattle Deg'n: NONE LO MED HI V HI

Weed inf'n: NONE LO MED HI V HI

Weeds:

Sp.	%CA	%CD

Site Comments: ……

……

……

Tree health scores: Healthy = **H** Slightly Stressed = **SS** Stressed = **S** Died Recently = **DR** Dead (long time) Old = **DO**

Tree No.	Species	Ht (cm)	DBH	%A cnpy	Health	Photo	Comment

Appendix B Understorey Quadrats - Riparian Vegetation (Data Sheet)

Appendix B: Understory Quadrats - Riparian Vegetation (10m x 10m)

Field Data Sheet

Site No.: RU……. Date: ……/……/……. Recorder: …….. Photo No.: ……

GPS: ……mE ……..mN

Landform: FLAT SLOPE RIDGE
OTHER: ……..

Erosion: NONE LO MED HI V HI

Dust: NONE LO MED HI V HI

Weed inf'n: NONE LO MED HI V HI

Cattle Deg'n: NONE LO MED HI V HI

Site Comments: ……..……

……..

Coll No.	Species/Field Name	Ht (cm)	No. A	%CA	No. D	%CD	Comment

Appendix C Mangrove Quadrats - Infrastructure Corridor / Dust Impacts (Data Sheet)

Appendix C: Mangrove Quadrats - Infrastructure Corridor / Dust Impacts (10m x 10m)

Field Data Sheet

Site No.: IM / DM……. Date: ……/……/…… Recorder: …….. Photo No.: ……

GPS: ……mE ……mN

Weed inf'n: NONE LO MED HI V HI

Weeds:

Sp.	%CA	%CD

Erosion: NONE LO MED HI V HI

Dust: NONE LO MED HI V HI

Cattle Deg'n: NONE LO MED HI V HI

Soils: DRY DAMP WET INUND'D

Site Comments: ……..……..……

……

Tree health scores: Healthy = **H** Slightly Stressed = **SS** Stressed = **S** Died Recently = **DR** Dead (long time) Old = **DO**

Mature Mangrove Numbers (>/=130cm):		**Tally**					
Coll No.	**Species/Field Name**	**H**	**SS**	**S**	**VS**	**DR**	**DO**

Sapling Numbers (30-129cm):		**Tally**					
Coll No.	**Species/Field Name**	**H**	**SS**	**S**	**VS**	**DR**	**DO**

Seedling Numbers (1-29cm):		**Tally**					
Coll No.	**Species/Field Name**	**H**	**SS**	**S**	**VS**	**DR**	**DO**

Appendix D Mangrove Defoliation – Within Mangrove Quadrats (Data Sheet)

Appendix D: Mangrove Defoliation - Within Mangrove Quadrats (10m x 10m)

Field Data Sheet

Site No.: IM / DM……. Date: ……/……/…….

Recorder: …….. Photo No.: …….

Tree health scores: Healthy = **H** Slightly Stressed = **SS** Stressed = **S** Died Recently = **DR** Dead (long time) Old = **DO**

Defoliation Test

Representative Tree No.	No. alive leaves on selected (tagged) branch	General health of tree	Other comments
1			
2			
3			
4			

Appendix E Accretion, Erosion, Recruitment, Mortality (AERM) Transects (Data Sheet)

Appendix E: Accretion, Erosion, Recruitment, Mortality (AERM) Transects (10m x 10m)

Field Data Sheet

Site No.: AT……. Date: ……/……/…… Recorder: …….. Photo No.: ……

GPS: ……mE ……..mN

Weed inf'n: NONE LO MED HI V HI Dust: NONE LO MED HI V HI

Weeds:

Sp.	%CA	%CD

Cattle Deg'n: NONE LO MED HI V HI

Site Comments: ……..……

……..

……..

Peg (m)	(m) from bank	Species/Field Name	Mature		Saplings		Seedlings	
			No. A	No. D	No. A	No. D	No. A	No. D
0								
2.5								
5 (centre)								
7.5								
10								

Appendix F Weed Quadrants (Data Sheet)

Appendix F: Weed Quadrats (10m x 10m)

Field Data Sheet

Site No.: WQ……. Date: ……/……/……. Recorder: …… Photo No.: ……..

GPS: ……mE ……..mN

Landform: FLAT SLOPE RIDGE OTHER: …… Erosion: NONE LO MED HI V HI

Cattle Deg'n: NONE LO MED HI V HI Dust: NONE LO MED HI V HI

Site Comments: ……..……..……..……

……

Coll No.	Weed Species/Field Name	Ht (cm)	%CA	%CD	Comment