PUBLIC ENVIRONMENTAL REPORT

BLACKMORE RIVER (EAST) AQUACULTURE PROJECT MIDDLE ARM, DARWIN HARBOUR NORTHERN TERRITORY

for
Phelps/Panizza Holdings

URS (AUSTRALIA) PTY LTD
Ref: 43817- 002- 073
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Blackmore River (East) Aquaculture Project
Public Environmental Report

Public Comment Invited

The Phelps/Panizza Holdings proposes to construct an aquaculture farm at a site east of the Blackmore River on Middle Arm Peninsula to grow and process black tiger prawns.

In accordance with the provisions of the Northern Territory *Environmental Assessment Act* (1982), a Public Environmental Report (PER), which describes the project proposal and its potential environmental effects has been prepared by URS Australia Pty Ltd. This document will be available for Public Review for a four week period from Saturday, 7 April 2001 to Friday, 4 May 2001. During this period the PER and appendices for this proposal can be examined at the following locations:

- Department of Lands, Planning and Environment, Ground Floor, Cavenagh House, 38 Cavenagh, Darwin.
- State Reference Library, Parliament House, Darwin.
- Darwin City Library, Harry Chan Avenue, Darwin.
- Casuarina Public Library, Bradshaw Terrace, Darwin.
- Palmerston Town Council Library, Civic Plaza, cnr University Avenue and Chung Wah Terrace, Palmerston.
- Litchfield Shire Offices, 7 Bees Creek Road, Bees Creek.

The full PER and appendices can be purchased for $85.00 and the PER without appendices on CD-ROM can be purchased for $22.00 from:

URS Australia Pty Ltd,
1st Floor, Arkaba House,
The Esplanade,
Darwin, Northern Territory, 0800

The PER excluding appendices can be viewed on the Internet for the duration of the public review period at http://www.lpe.nt.gov.au/eia. Interested persons and organisations wishing to make comment on the PER for the Blackmore River (East) Aquaculture Project are invited to make written submissions by the close of business on Tuesday, 8 May 2001, to:

Ms Lisa Banks
Environment and Heritage Division
Department of Lands, Planning and Environment
GPO Box 1680
DARWIN NT 0801

Fax: 8924 4053
Email: lisa.banks@nt.govt.au

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EXECUTIVE SUMMARY

INTRODUCTION

Phelps/Panizza Holdings proposes to construct an aquaculture development on the western side of Middle Arm, Darwin Harbour, adjacent to the Blackmore River. This document is a summary of the Public Environmental Report (PER) for the development. The PER has been submitted by Phelps/Panizza Holdings (Phelps/Panizza) to provide the Northern Territory Government and the public with concise and comprehensive information regarding the design, construction and operation of the proposed venture and associated facilities. It is designed to provide the information necessary to allow an informed appraisal of the environmental acceptability of the proposed development.

PROPONENT DETAILS

Phelps/Panizza Holdings
PO Box 1023
GOONDIWINDI QLD 4390

Ph: (07) 4676 2812
Fax: (07) 4676 2070

Phelps/Panizza Holdings, the lessee of this site, is a registered business in the Northern Territory, and is a Partnership of five individuals as listed:

Helen Antoinette PANIZZA	*15%*
Albert John PANIZZA	*15%*
Benedict James PANIZZA	*15%*
Mark Joseph PANIZZA	*15%*
Gregory Vincent PHELPS	*40%*

Phelps/Panizza Holdings is a land holding entity, which has been set up to purchase and develop aquaculture sites, for lease to our associated entity, Phelps/Panizza Partnership.

Phelps/Panizza Partnership (ABN# 43 190 784 216), also registered in the Northern Territory is a Partnership of two companies:

Lombard Farms Pty Ltd	*60%*
Phelps Aquaculture Pty Ltd	*40%.*

EXPERIENCE OF PROPONENT AND KEY PERSONNEL

Proponents

Mr Greg Phelps*is a Partner in Phelps/Panizza Holdings and a Director of Phelps Aquaculture Pty Ltd, which holds the management agreement to the aquaculture operations. Greg Phelps has a background of management in agricultural-based business, initially in irrigation design and construction, corporate cotton farming and, most recently, international cotton trading.*

Mr Albert Panizza BE (Hons) MBA*represents the Panizza family members of Phelps/Panizza Holdings and is the Managing Director of Lombard Farms Pty Ltd, a Brisbane based family company with various interests in primary production. The Panizza family holds extensive interest in property investments, civil construction, pre-casting and agriculture. Albert Panizza has acted as Chief Executive of the family's operations for the past ten years.*

Phelps/Panizza has worked for five years towards developing a significant aquaculture venture, with the majority of this work focused on the Darwin region.

Key Personnel

A management structure is planned to allow smooth transition to the full-scale development over six years. Some key personnel have been selected and others will be appointed when the project is cleared through Native Title and environmental processes.

A General Manager will be appointed, with applicants expected to have a strong technical background in aquaculture or related disciplines. This position is planned to complement the more general management skills of Greg Phelps, who will act as Managing Director.

The structure will include a Manager of Project Assets (responsible for the construction, installation and maintenance of all buildings and machinery) and an Operations Manager (to run daily activities on the farm under instructions from the General Manager). Both these positions will report to the General Manager.

The Managing Director will be responsible for product marketing and the development of new markets off-shore.

In addition, it is expected that another six to nine permanent staff will be required during Stage 1.

PROOF OF LEASE PROJECT AREA

The development area is currently under offer of lease by the Minister for Lands, Planning & Environment to Helen Panizza, Albert Panizza, Benedict Panizza, Mark Panizza and Greg Phelps (Phelps/Panizza Holdings). Once the lease is established Phelps/Panizza Partnership will sublease from Phelps/Panizza Holdings.

PROPOSAL BACKGROUND AND JUSTIFICATION

Phelps/Panizza have extensively researched the aquaculture industry with study of various existing operations in Australia and abroad. Their research, including aerial surveys of the Darwin region, has led them to choose the Blackmore River site for the production of marine species, mainly the black tiger prawn (Penaeus monodon). Based on primary data, including climate and ocean statistics, Phelps/Panizza has concluded that the Darwin region offers conditions optimum for the success of their proposal.

The commercial success of the project will be based on:

- *increasing world demand, especially in South East Asia, for seafood production conducive to maximum growth of warm water marine species;*
- *plateaued supply of seafood from the worlds natural fish stocks; and*
- *tightening legislation with respect to exploitation of natural fish stocks.*

The Northern Territory has been selected for establishment of the aquaculture development for the following reasons:

- *climate conducive to maximum growth of warm water marine species;*
- *availability of sufficient land and water resources at cost effective prices;*
- *location of Darwin on established trade and freight routes and proximity to South East Asian markets;*
- *readily available educated technical workforce; and*
- *supportive government policies.*

The Blackmore River Aquaculture Development site has been selected for the following reasons;

- *readily accessible seawater with minimal impact to mangroves;*
- *close proximity to Darwin;*
- *soil types and topography are satisfactory for construction requirements;*
- *suitable dam catchment area and construction site;*
- *adjacent electricity supply; and*
- *existence of potable groundwater.*

PROPOSAL OBJECTIVES

Phelps/Panizza are proposing to construct and operate an aquaculture farm at Blackmore River (East), Middle Arm, Darwin Harbour. The proposal is intended to be a long-term profitable investment with recognition that the following issues must be carefully managed to sustain the success of the project into the future:

- *preservation of the surrounding natural environment;*
- *formation of an effective workforce, offering job satisfaction and real long-term career prospects for employees;*
- *operational and cost efficiencies, achieved by well-researched design, professional management and application of modern technology; and*
- *the presentation for sale of a consistently high quality product in sufficient quantity to establish a brand of preference in target markets.*

DESCRIPTION OF PROPOSED DEVELOPMENT

The project is expected to be developed in two stages, over a five-year period.

Stage 1 of the project will involve the construction of 22 production ponds (total water area of approximately 27 ha), a saltwater pump jetty into the Blackmore River, a saltwater supply channel, a 20 ha exchange water treatment pond, a 20 ha freshwater dam, associated supply channels, access roads and buildings.

Stage 2 (full-scale development) will comprise a total of 93 production ponds (approximately 115 ha), a 186 ha freshwater dam (with a holding capacity of approximately 5,500 ML), four exchange water treatment ponds (80 ha in total) and a 26 ha pasture area. This infrastructure will be serviced by a network of saltwater supply channels, three saltwater intake pumps (installed on the original jetty), channeling and pipe work required for supply and drainage, three above ground fuel (diesel) storage tanks, power generators and supply lines. A packing/processing factory, hatchery, office building and managerial/staff housing will be built. Fencing, access roads and farm roads will also be constructed.

PHYSICAL ENVIRONMENT

Locality

The lease site occupies an area of approximately 796 ha on Middle Arm, Darwin Harbour, approximately 25 km south of Darwin. The site is bound to the south and west by mangrove margins of the Blackmore River, and generally consists of woodland areas between the 4 m and 24 m Australian Height Datum (AHD). The northern boundary of the site fronts the Middle Arm Boat Ramp Road and the eastern border parallels Finn Road.

Climate

The Darwin region has a tropical monsoon climate with two distinct seasons - the Wet Season from November to March and the Dry Season from May to September, with April and October being transitional months. Average annual rainfall is 1702 mm, most of which falls during the Wet Season when humidity averages 70-80%. In the Dry Season humidity is often below 40% and there is virtually no rainfall. Mean annual evaporation is 2661 mm.

Between November and April tropical depressions, which may develop into cyclones, pass through the Darwin region. Surface wind stress, lowered atmospheric pressure and wave set-up combine to elevate sea levels during the passage of a cyclone.

Oceanography

The lease area lies within Darwin Harbour. Tides are predominantly semidiurnal (two high waters and two low waters per day), with a slight inequality between tides during a single day. Tidal amplitudes are greatest during equinoctial tides in May and November/December, when the tidal range can reach 8.0 m.

Topography

The lease area encompasses:

- *Undulating rises and gentle slopes, present across the majority of the lease area.*
- *Gently undulating upland surfaces, in a thin strip at the north-east of the lease area.*
- *Gently undulating lower slopes (along minor streams).*
- *Alluvial plains and drainage lines/minor levees (along major streams).*

Geology and Soils

The Blackmore River is underlain by meta-sediments of the Early Proterozoic Finniss River Group, which generally consists of shale, siltstone, sandstone, greywacke, schist and gneiss. The Finniss River Group was deposited by turbidity currents in a submarine fan environment. The member of the Finniss River Group present beneath the site is the Burrell Creek Formation.

The majority of the site is underlain by unconsolidated sand, ferruginous, clayey and gravelly soil, common limonite pisolites, or pisolitic and mottled laterites, ferricrete, in-situ and reworked remnants of standard laterite profile. The lower lying mangrove areas to the west of the lease area are underlain by mud, clay and intertidal marine alluvium and the watercourses that drain the upper catchment are underlain by sand, shelly sand, coralline sand and cheniers.

Numerous outcropping quartz dykes exist across the lease area. In addition, there are small occurrences of outcropping shale, siltstone and phyllite, in places colour-banded, fine to very coarse sandstone, quartzite, quartz pebble conglomerate, minor graphic phyllite, quartz-mica schist and gneiss.

Only a small portion of the development area (approximately 1 ha) is underlain by marine clays, which may contain acid sulfate soils (ASS). As there will be minimal disturbance to the underlying marine clays as a result of construction works, ASS are not considered a management issue for the Blackmore River (East) Aquaculture Development.

Groundwater and Surface Hydrology

The groundwater regime of the lease area comprises a near-surface seasonally affected groundwater table, and a deeper groundwater aquifer associated with the underlying Burrell Creek Formation.

The weathered soil profile at the site can generally be expected to have high permeability, which will readily facilitate recharge to a shallow watertable. Laterite profiles, which are typical of the area, include porous laterite that typically absorbs groundwater recharge during the Wet Season and then gradually releases the stored water during the Dry Season as the water table slowly drains.

The Burrell Creek Formation that underlies the site is relatively impermeable, holding limited quantities of water in fractures of defined spatial and vertical extent. Groundwater bores located on the site are expected to yield 0.5 L/s to 2.0 L/s.

BIOLOGICAL ENVIRONMENT

Vegetation

Vegetation within the lease area forms recurring spatial patterns that closely reflect the interplay of topography and soils and the influence of seasonal and temporal fluctuations of salt and fresh water supply. Of the total lease area, approximately 99% (794 ha) comprises upland woodland habitats lying above the 4 m AHD contour, which marks the upper limit of tidal inundation. A minor area of the proposed development (approximately 1 ha) occurs below the 4m contour and this mainly comprises saltflats and mangroves of the upper intertidal zone.

Key aspects of the vegetation in the lease area are:

- *The terrestrial vegetation communities are typical of the woodlands of the Darwin region and are well represented in reserves elsewhere.*
- *The mangrove communities are broadly similar to assemblages elsewhere in Darwin Harbour and the region generally.*
- *No endangered plant species or plant communities of conservation significance have been recorded, but one species (Grevillea longicuspis) currently listed as rare, occurs within the lease area. This Grevillea is restricted in distribution but is locally common within its range and botanists from the Northern Territory Herbarium consider that this species no longer warrants rare status. It is anticipated that the aquaculture development will have a minor effect on the overall population of this species.*
- *While four introduced plant species have been recorded, three of which are declared Class B noxious weeds, the vegetation of the lease area is in relatively intact, natural condition and is free from widespread weed infestations.*
- *Frequent, extensive wildfires play a major role in determining overall vegetation types in the local area.*

Terrestrial Fauna

Examination of international, national and state lists of threatened species indicate that there is little likelihood of any endangered species occurring in the project area and none of the "Specially Protected" species listed under the Territory Parks and Wildlife Conservation Act 1997 are expected in the project area. However, some species in the area are of some conservation significance.

One mammal and two bird species listed as 'low risk, near threatened' are known or expected to occur within the lease area. Five reptile species classified as "insufficiently known" are common or expected to occur in the Blackmore River area. However, other than the mangroves, the area does not support specialist or significant habitats such as monsoon forest, paperback swamp or wetlands and no significant breeding, roosting or feeding sites have been recorded.

The habitats occurring on the project area are in good condition, evidenced by the number and diversity of small mammals trapped in the limited time available. Feral animals, including pigs and cattle, are in low numbers. Feral cats in the area may be a threat to native small mammal populations.

Fisheries Resources

Barramundi is an important commercial and recreational species in the Northern Territory. Spawning occurs at river mouths and larval fish are carried by tides into supralittoral swamps at the interface of salt and freshwater, at or near the upper high tide level. These swamps are vegetated by seasonal plants, including saltwater grasses and various sedges, and can provide nursery habitat for the young fish. The swamps are very productive, providing barramundi with conditions for rapid growth and with shelter from predators. Towards the end of the Wet Season, before the swamps dry out, the fish move out into adjacent rivers or creeks and usually migrate upstream into permanent freshwaters.

It is considered that the proposed aquaculture development has no potential to significantly impact upon the Darwin Harbour barramundi population. There is very little suitable nursery habitat within the harbour and no supralittoral swamps have been identified within the lease area. There will be minimal disturbance of the intertidal salt flats, over which barramundi may periodically feed. The proposed development will not prevent the migration of barramundi into the upper fresh water reaches of rivers upstream from the site.

Biting Insects

Mosquitoes and biting midges were recorded within the lease area and potential breeding habitats identified. The major source of mosquitoes in the lease area are: the upper tidal sections of creek lines near the mangrove margins, tidally filled depressions near the high tide mark, and disturbed area at the tidal limit. Farm design and management measures will be implemented to minimise the creation of new breeding grounds for biting insects and information with respect to mosquitoes/midges will be provided to all staff.

SOCIAL ENVIRONMENT

Recreational

The Blackmore River is a popular fishing area, however the development, other than the pump jetty will be screened from view from the river by mangroves. The lease area is used by the public for recreational purposes on an irregular basis. The main apparent use of the lease area, mainly around the mangrove fringe, is for off road motorcycle riding.

The lease area contains no permanent freshwater habitat, limiting the recreational use of the lease area for many activities.

Heritage Sites

A total of six archaeological sites, comprising three shell scatters and three stone artefact scatters, were identified across the study area. All sites consisted of small, low density, surface scatters of archaeological material, including shells and quartz flakes, retouched flakes and bifacial points.

In addition to the archaeological sites, a total of 60 isolated artefacts were recorded within the proposed lease area. These included flakes, retouched flakes, cores, unifacial and bifacial points made almost exclusively from quartz, which as noted above, crops out extensively across the area. A single chert flake was also identified as part of the background scatter. Isolated artefacts were generally found on the mangrove/hinterland boundary or along creek banks.

ENVIRONMENTAL EFFECTS

The environmental effects of the proposed development are summarised in the Environmental Effects and Management Register, presented later in the Executive Summary. This summary lists the:

- *existing environmental status of the lease area;*
- *potential or actual impacts of the development;*
- *environmental factors of concern;*
- *management tasks proposed to mitigate any adverse effects; and*
- *predicted outcomes of the management strategies.*

In summary, the predicted environmental effects associated with the development of the Blackmore River site from unimproved land to an intensive agriculture site will be:

- *loss of vegetation, including minor losses of mangrove habitat ;*
- *loss of habitat for fauna;*
- *alteration to surface and sub-surface drainage patterns;*
- *destruction of six archaeological sites;*
- *increased road traffic during the operation phase (mainly during Stage 2) and increased demand on infrastructure; and*
- *restricted public access to the site;*

Potential environmental effects that will require management relate to erosion, weeds, fire, biting insects and waste water discharge.

ENVIRONMENTAL MANAGEMENT AND MONITORING

The PER includes details of management strategies that will be adopted. The objectives of the management strategies are to establish procedures that ensure the actual and potential adverse impacts associated with the construction and operation of the development are minimised.

A summary of management commitments is presented in Environmental Effects and Management Register.

The aim of the environmental monitoring programs will be to test and validate the main predictions regarding the effects of the development which have the potential to adversely impact the environment. The monitoring will also ensure that potential environmental effects are minimised and that the development complies with any regulations governing particular activities.

Monitoring conducted during construction and operation of the Stage I project will be used to assist in the design of subsequent stages of the development as it progresses towards Stage 2. Monitoring will include:

- *water quality;*
- *mangroves;*
- *weeds, and*
- *biting insects.*

BENEFITS

The development will provide significant benefits to the local community and economy of the Darwin area. The farm will provide short-term employment during construction phases of Stages 1 and 2 and long-term employment during the operational phase of the development. Through the establishment of a viable local industry the development will also result in the diversification of the local economy base.

Environmental Effects and Management Register

Environmental Factor	***Existing Environment***	***Potential Impact***	***Environmental Management***	***Predicted Outcome***
BIOLOGICAL				
Vegetation clearing *Refer Section 3.9 and 4.2*	*Extensive Eucalypt woodlands dominate the hinterland vegetation with open woodlands fringing a narrow riparian corridor along the seasonal drainage lines.* *Mangrove communities of the Blackmore River and its tributary creeks fringe the upland woodlands of the lease area.* *Narrow grasslands occur in the transitional area between the hinterland and the mangrove margin.* *No endangered plant species or special vegetation communities have been recorded in the lease area. However, several populations of Grevillea longicuspis, an endemic species of restricted distribution occurs in Open Woodland habitat within and adjacent to the lease area.* *The proposed production ponds will be located entirely within upland woodland habitat.*	*Loss during construction will result in clearing of:* *~200 ha during Stage 1* *~290 ha during Stage 2*	*Farm layout designed to minimise loss of vegetation.* *Construction adjacent to mangrove areas will aim to protect intertidal areas from negative impacts including siltation and changes in drainage.* *Clearing within the freshwater dam will be selective and limited to those communities that will be permanently flooded to a level considered lethal to the trees. Trees fringing the upper levels of the dam will be retained to reduce disturbance and loss of habitat.* *Restriction of construction activities to specified areas. Movement of construction vehicles will be managed to ensure that tree loss is minimised.* *Should areas of the development be decommissioned appropriate vegetation will be reestablished.*	*Total loss due to clearing through to Stage 2 development:* *~420 ha of eucalypt woodland;* *~61 ha of drainage line communities;* *~8 ha of grassland community; and* *~1 ha of mangroves.* *The communities to be cleared are well represented elsewhere within the lease area and surrounding region. No significant adverse ecological impacts are anticipated.*

Environmental Factor	***Existing Environment***	***Potential Impact***	***Environmental Management***	***Predicted Outcome***
Inundation of vegetation *Refer Section 3.9 and 4.2*	*The proposed production and exchange water treatment ponds will be located within upland vegetation communities.* *Stage 1 freshwater dam will inundate riverine open woodland and associated drainage line communities and some Eucalyptus woodlands.* *Stage 2 freshwater dam will inundate riverine open woodland and associated drainage line communities and some mixed species woodlands.* *The Stage 2 dam will inundate Eucalyptus dominated open woodland, including limited areas with Grevillea longicuspis, a Darwin region endemic currently listed as rare.* *Tracts of similar habitat are present outside the southern boundary of the lease area.*	*Approximately 200 ha of vegetation will be effected by dams. Some areas of woodland not cleared prior to dam construction may be permanently or seasonally inundated.*	*Clearing for freshwater dam construction will be kept to the minimum necessary and fringing vegetation in the upper levels of the proposed dam will be retained.* *Similarly, clearing along the dam spillway will be selective and minimised to prevent erosion and habitat loss.* *Regular surveys of freshwater dams will be undertaken to control the introduction and spread of aquatic weeds.* *The staged approach to the development will enable an assessment of Stage 1 of development to be conducted prior to clearing and inundation of the Stage 2 freshwater dam.*	*If the development proceeds to Stage 2 approximately 200 ha of vegetation will be effected by seasonal and permanent inundation to 14 m AHD.* *Increased diversity of aquatic, semi-aquatic and fringing wetland plant species, including Melaleuca spp. and Lophostemon spp.*
Indirect vegetation changes *Refer Section 3.9 and 4.2*	*Mangrove communities fringe the estuarine creeks adjoining the lease area.*	*Changes to the pattern of drainage, seepage and sedimentation may lead to the loss of some trees within the mangrove fringe in the vicinity of the exchange water treatment dams and saltwater supply channel. Gradual shifts in species composition may also occur over time.*	*The saltwater supply channel and the wall of the exchange water treatment dams are designed to minimise impacts on natural hydrological and sedimentary regimes, especially within adjacent mangroves.*	*The transitional grassland communities will be most asffected (8 ha cleared).* *The hinterland margin of the mangroves may be effected by changes in drainage, but this community is well represented elsewhere within the surrounding region. No significant ecological impacts are anticipated.*

Environmental Factor	***Existing Environment***	***Potential Impact***	***Environmental Management***	***Predicted Outcome***
Colonising native vegetation *Refer Section 3.9 and 4.2*	*Mangrove communities occur between the Blackmore River and the hinterland along the alignment of the saltwater supply channel.*	*Mangrove seedlings can be expected to colonise the bund walls and mangrove growth may be encouraged downstream of the dam spillway.* *Increased waterlogging and possibly raised groundwater levels in the vicinity of the freshwater dams may encourage the expansion of paperbark and Lophostemon communities in this area.* *Native reeds such as Eleaocharis spp. may proliferate in the swampy areas created along the margins of the freshwater dams.*	*Growth of native species will be encouraged, except where this may exacerbate biting insect problems.*	*Minor, regionally insignificant, colonisation of parts of the lease area by native vegetation can be expected.*
Weeds *Refer Section 3.9 and 4.2*	*The lease area is free from large weed infestations. Four introduced species recorded, three of which are declared noxious weeds (Class B).*	*Clearing of native vegetation and terrain disturbance may create conditions favourable for the proliferation of weed species.* *The new and extensive freshwater aquatic habitats created by the freshwater dams may provide conditions suitable for the proliferation of aquatic and semi-aquatic weed species.*	*Weed management and prevention measures will include:* • *earthmoving equipment washed-down prior to entering the lease area during construction works to prevent spread of seeds;* • *rapid draw-down of water in the freshwater dam early in the Dry Season to discourage formation of semi-aquatic reed swamps along the dam margin;* • *selection of native species for the pasture production area and for landscaping around farm buildings;* • *weed removal from areas around farm buildings;* • *during the operational phase, off site vehicles will not be permitted to enter the site other than to park at designated parking bays outside the prawn farm;* • *slashing of fire breaks; and* • *annual weed surveys.*	*Management of weed issues will result in low risk of occurrence spread of weeds.*

Environmental Factor	***Existing Environment***	***Potential Impact***	***Environmental Management***	***Predicted Outcome***
Fire regime *Refer Section 3.9.5 and 4.9*	*Frequent, extensive burning of lease area and surrounds.*	*Reduction in frequency, timing and spread of fires.*	*A fire management plan will be developed, which will include:* • *fire break alignment and construction;* • *reduction of flammable fuel loads around farm infrastructure;* • *protection of fire-sensitive species and communities; and* • *promotion of habitat heterogeneity.*	*A shift in vegetation species composition may occur towards a more dense mid-stratum layer, possibly including fire-sensitive monsoon forest species.* *Frequency, timing and spread of fires will be reduced due to site access restrictions and construction of fire breaks. Habitat heterogeneity may increase due to protection of fire-sensitive vegetation.*
Terrestrial fauna *Refer Section 3.10 and 4.3*	*One mammal and two bird species listed as 'low risk, near threatened' and five reptile species classified as 'insufficiently known' were identified within the lease area. However, the lease area is not considered to contain significant sites for these species. No significant breeding, roosting or feeding sites have been recorded.* *Feral animals are present in low number in the lease area.*	*Removal of terrestrial fauna habitat.* .	*Feral animals will be managed on an 'as required' basis.* *Bird nets will be installed on the production ponds if water birds cause significant stock losses.*	*Vegetation clearing will reduce available terrestrial fauna habitats within the lease area.* *The freshwater dam may increase the extent of habitats favoured by fauna such as wading birds and frogs.* *Increased habitat heterogeneity through improved fire management practices may improve wildlife habitat quality.* *Loss of ~1 ha of mangrove habitat is likely to be insignificant to mangrove fauna, given the extensive area of similar habitat in the immediate vicinity.*
Fisheries resources *Refer Section 3.11 and 4.3*	*No supralittoral swamps (potential barramundi nursery habitat) have been identified within the lease area.*	*Minor disturbance to intertidal salt flats and mangrove creek banks during construction of the saltwater supply channel and exchange water discharge channel.* *Low potential for increases in nutrient levels or depletion in dissolved oxygen levels in Middle Creek due to exchange water discharge.* *Low potential for infection of wild prawn stocks by disease outbreaks.*	*Restriction of construction activities to the minimum required for construction of the channels.* *Treatment of exchange water to minimise nutrient loads and to return dissolved oxygen to background levels prior to discharge.* *Disease control management measures will be implemented to minimise the potential for significant impacts upon stocks of wild prawns and mud crabs.*	*No significant adverse impacts to fisheries resources are anticipated.*

Environmental Factor	***Existing Environment***	***Potential Impact***	***Environmental Management***	***Predicted Outcome***
Biting insects *Refer Section 3.12, 4.10 and 5.4.4*	*Significant numbers of mosquitoes and biting midges have been recorded.* *Areas where mangroves border brackish supralittoral swamps can become major mosquito breeding habitats during the late Dry and early Wet Seasons.*	*Mosquito breeding habitat may: increase along the shallow margins of the freshwater dam if growth of aquatic vegetation is enhanced; and/or decrease on the tidal flats to the west and south-west of the dam wall due to reduced seasonal fresh water flow* *The production ponds and exchange water treatment ponds are unlikely to provide suitable breeding habitats for biting insects.*	*Management of biting insect problems will include:* • *drainage designed to prevent ponding of water in low-lying areas;* • *native fish populations will be maintained in the freshwater dams to assist in control of larval mosquito numbers;* • *farm buildings positioned away from low-lying areas;* • *regular clearing of vegetation in vicinity of buildings;* • *clothing, repellants and antiseptic creams will be available to all personnel on site;* • *screening of staff facilities; and* • *staff induction.*	*Staff will receive adequate protection against biting insects.*
PHYSICAL				
Soil erosion *Refer Section 4.8.2*	*The existing hydrology of the site includes ongoing natural erosion and deposition processes.*	*Increased erosion associated with altering natural hydrological patterns.*	*The following measures will be adopted to minimise erosion:* • *all development will be undertaken in the Dry Season;* • *minor access roads will be formed so as not to impede or divert sheet flow drainage or channel drainage;* • *roads will be drained with side gutters and runoff drains;* • *embankments will be compacted and have a cover of lateritic gravel; and* • *channels will be lined with rock rip-rap.*	*Erosion will be minimised by the implementation of management measures. Some localised erosion may be expected as the natural hydrological patterns are reestablished. Current dynamic erosion patterns will continue.*

Environmental Factor	***Existing Environment***	***Potential Impact***	***Environmental Management***	***Predicted Outcome***
Hydrological regime *Refer Section 3.7 and 4.5*	*The existing hydrology of the site includes ongoing natural erosion and deposition processes.*	*Increased erosion associated with altering natural hydrological patterns*	*The following measures will be adopted to minimise hydrological changes:* • *scouring will be prevented through implementation of erosion control measures;* • *farm alignment/design will avoid interruption to tidal movement;* • *drainage channels will be constructed around buildings and stormwater will be directed towards natural drainage lines;* • *overflow from the freshwater dam spillway will be directed back into the natural channel; and* • *main farm infrastructure will be constructed above the 1 in 100 year peak combined sea level prediction for the area.*	*The freshwater dams will significantly alter the natural hydrological processes.* *There will be a limited impact on the natural hydrological processes by the construction of the remaining structures.*
POLLUTION MANAGEMENT				
Dust generation *Refer Section 4.8.4*	*The existing Middle Arm Boat Ramp Road generates significant dust during the Dry Season.*	*Farm traffic will increase dust generation along the Middle creek Boat Ramp Road and the site access roads.*	*Management procedures will be put in place to minimise the volumes of traffic generated from the aquaculture farm.*	*Minimal increase in dust generation from Stage 1 development.* *Moderate increase in dust generation from Stage 2 development.*
Discharge water quality *Refer Section 3.8, 4.6 and 5.4.1*	*No discharge waters are currently released into the environment at the site.*	*Water quality (nutrients, recreational)*	*Management procedures will be put in place to minimise the nutrient load of waste discharge water. Discharge water will be passively treated in pond(s) prior to release. Active treatment of discharge water will, if required, be implemented.* *Discharge water will be released on outgoing tides to maximise dilution.* *Stocking levels, water exchange, feed and aeration times will be determined with reference to water quality parameters.* *Accidental or unauthorised release of discharge water will be prevented by use of valve locks.* *Water quality monitoring of discharge water will be regularly undertaken.*	*Minimal impact on water quality of the Blackmore River system.*

Environmental Factor	***Existing Environment***	***Potential Impact***	***Environmental Management***	***Predicted Outcome***
Waste disposal *Refer Section 4.7*	*No waste is presently generated at the site.*	*The following general wastes will be produced on site:* • *sludge from the production ponds;* • *vehicle washdown water;* • *disinfectants and detergents from cooking and packing factory;* • *domestic sewage effluent;* • *diseased prawns;* • *used parts, sump oil, etc from farm machinery; and* • *domestic waste;* *Potential impacts include localised on-site contamination.*	*Sewage and domestic discharge water will be treated by septic systems designed in accordance with Territory Health guidelines.* *General waste material will be either buried onsite or disposed off-site.* *Sludge will not be transferred from the desalination bays to the pasture area until in-situ conductivity measurements indicate a sufficient reduction in salinity levels. A bund wall will be constructed to contain runoff from the pasture area. Tail water drains will be constructed to collect excess stormwater from the pasture area for diversion into the exchange water treatment ponds.* *A TIT will be installed to remove potentially oily discharge water from vehicle/plant wash-down* *Waste oil will be disposed off-site by a licenced waste management contractor.*	*No reduction in water quality from the domestic sewage effluent disposal systems.* *Minimal adverse effects on the ecosystem from the on-site operations and waste disposal.*

Environmental Factor	***Existing Environment***	***Potential Impact***	***Environmental Management***	***Predicted Outcome***
Disease control and quarantine *Refer Section 4.4*	*Present level of prawn related disease within wild stocks unknown.*	*Introduced diseases could cause total loss of crop.* *Movement of introduced diseases could damage wild prawn stocks.*	*Quarantine facilities will be utilised for new stock.* *Broodstock will be certified as 'disease-free' prior to transfer to growing ponds.* *Dead and diseased stock will be collected and buried with a heavy application of lime to increase decomposition.* *Stock escape will be prevented by pond design measures.*	*No adverse impact to wild stocks is anticipated.*
SOCIAL ENVIRONMENT				
Sacred sites *Refer Section 3.13 and 4.12*	*There are no identified sacred sites within the lease boundaries.*	*No impact.*	*No management required.*	*No adverse outcome*
Heritage sites *Refer Section 3.13 and 4.12*	*There are 6 archaeological sites that have been identified at the site.* *Sixty isolate artefacts were identified on the lease area.*	*All 6 archaeological sites will be destroyed as a result of the development, either through physical destruction or inundation.* *Isolated artefacts are likely to be destroyed/inundated.*	*Ministerial consent to destroy the 6 archaeological sites will be sought prior to construction activities. No management measures required.*	*Destruction of the 6 archaeological sites on the lease area. Each of the sites is considered to be of low archaeological significance.*
Public access *Refer Section 3.14 and 4.13*	*The lease area is currently accessed on an occasional basis by off-road motorcycle riders.*	*Loss of access*	*Boundary fencing will prevent public access to the lease area for recreational purposes.*	*Public access to the site for off-road motorcycle riding will be prevented. Areas adjacent to the property will remain available to motorcycle riders. The impact of access restrictions to recreational users is limited.* *The development will have no effect on access to the adjacent waterways by recreational fishers.*

Environmental Factor	***Existing Environment***	***Potential Impact***	***Environmental Management***	***Predicted Outcome***
DECOMMISSIONING				
Site rehabilitation *Refer Section 4.15*	*The site is currently relatively undisturbed.*	*The site is abandoned or partly decommissioned and not subsequently rehabilitated.*	*The rehabilitation program will include:* • *leveling of earthen structures;* • *removal of miscellaneous construction items;* • *revegetation of cleared areas, where practical;* • *feasibility study on potential to convert freshwater dam into a conservation area;* • *removal of buildings; and* • *regeneration of access roads.*	*If the site is abandoned or partly decommissioned project infrastructure will be cleared and disturbed areas revegetated.*

STRUCTURE AND SCOPE OF THE PUBLIC ENVIRONMENTAL REPORT

This Public Environmental Report (PER) has been prepared to satisfy the requirements of the Northern Territory *Environmental Assessment Act (1982)*, and in accordance with the guidelines issued by the Northern Territory Minister for Lands Planning and Environment.

The PER comprises the following main sections:

SECTION 1 Introduction

This section introduces the project and provides background information on the development.

SECTION 2 Description of Proposed Development

This section describes the proposed development and the specific elements of the project, including the design, construction and operation of the facilities.

SECTION 3 Description of Existing Environment

This section describes the existing environment occurring at and in the vicinity of the site.

SECTION 4 Environmental Effects, Assessment and Management

This section predicts the potential environmental impacts arising from construction and operation of the development and outlines the proposed management strategies.

SECTION 5 Environmental Management Plan

This section outlines the framework for the establishment of a site-specific Environmental Management Plan.

SECTION 6 References

This section lists the references consulted and researched during the preparation of the PER.

PHELPS/PANIZZA HOLDINGS
BLACKMORE RIVER (EAST) AQUACULTURE PROJECT
MIDDLE ARM, DARWIN HARBOUR, NORTHERN TERRITORY

PUBLIC ENVIRONMENTAL REPORT

1. INTRODUCTION

1.1 PURPOSE OF THIS DOCUMENT

This document is a Public Environmental Report (PER) for a proposal to construct an aquaculture project to the east of the Blackmore River, Middle Arm, Darwin Harbour, Northern Territory. It is submitted by Phelps/Panizza Holdings (the proponent) to provide the Northern Territory Government and the public with the information necessary to allow an informed appraisal of the environmental acceptability of the proposed Blackmore River (East) Aquaculture Development.

The PER has been prepared in general accordance with the Northern Territory *Environmental Assessment Act (1982)* and guidelines prescribed by the Minister for Lands, Planning & Environment and the Department of Lands, Planning & Environment (DLPE). These guidelines are included as **Appendix A.**

1.2 DOCUMENT STRUCTURE

The PER comprises two volumes. The first volume includes the Executive Summary and main report. Technical appendices, which contain detailed information on many aspects of the project, are presented in Volume 2.

1.3 STUDY TEAM

The URS study team for this project included:

- Peter Mueller Project Manager
- Ian Baxter Marine Biology
- Keith Martin Fauna
- Anthony Maxwell Soils and Hydrology
- Michael Raymond Hydrology

The PER was undertaken in association with:

- Kirsten Metcalfe Environmental Consultant - flora survey
- Scott Mitchell Heritage Surveys - archaeological study

- Peter Whelan — Medical Entomology Branch - Territory Health Services, biting insects survey
- Gwenda Hayes — Medical Entomology Branch - Territory Health Services, biting insects survey
- Greg Phelps — Managing Director, Phelps/Panizza Holdings (Phelps/Panizza)
- Stuart Higgins — Phelps/Panizza

Additionally, specific advice was obtained from Nigel Preston, Commonwealth Scientific and Industrial Research Organisation (CSIRO) Marine Research, Cooperative Research Centre (CRC) on discharge water treatment strategies.

1.4 PROOF OF LEASE AND OTHER AUTHORISATIONS

A Letter of Authorisation has been presented to Phelps/Panizza by the Director for Lands, Planning & Environment. A copy of the Letter of Authorisation is presented in **Appendix B**.

A copy of the Authority Certificate for the development issued by the Aboriginal Areas Protection Authority (AAPA) is presented in **Appendix C**.

1.5 PROJECT JUSTIFICATION

Phelps/Panizza are proposing to construct and operate an aquaculture farm in the Middle Arm, Darwin Harbour area, on land adjacent to, and east of, the Blackmore River, south of Darwin. Primarily this venture is to be based on the commercial production of black tiger prawns *(Penaeus monodon)* with intention to consider other species as the farm is established.

The world's population is increasing at around 80 million people per year, that is, 219,000 people per day. The consequent energy requirement is increasing by 1.83 GJ per day, with protein needs increasing at a daily rate of 1.4 x 104 kg (Wheaton, 1993). The demand for high quality seafood, including prawns is increasing for a number of reasons including: an increasing world population; improving economies in neighbouring South East Asian countries; and improved diet education in the western world, highlighting the positive aspects of seafood.

Market supply from the world's natural fisheries appears to have plateaued in the 1970s at around 90 million tonnes. It is now generally accepted that natural fish catches are declining and that the deficit of natural fish stocks will be replaced by increasing farmed production. It is predicted that by 2010, global aquaculture production will contribute over 24% of total fisheries production (IAF 1985) and that over the next 50 years aquaculture production will come to equal, if not surpass, the harvest of wild fish (Larkin, 1988).

Australia's climate, land and water resources, combined with systematic research programs and technical knowledge have enabled the development of cost-efficient and environmentally acceptable aquaculture farms.

After extensive study into the potential and current status of aquaculture overseas, in New South Wales

and Queensland, Phelps/Panizza identified the Northern Territory as having several positive attributes:

- Climatically the Northern Territory offers temperature ranges that will facilitate maximum growth of warm water marine species for most of the year; this is projected to result in additional production of approximately 25% over farms in southern locations elsewhere in Australia.

- Sufficient land and water resources are available at reasonable expense and are suitably removed from associated chemicals and pollutants common to intensive agriculture/manufacturing production.

- The City of Darwin is ideally positioned geographically, and established trade and freight channels are open to southern Australian States and Singapore as a hub to Europe, USA and South East Asia.

- The Northern Territory government and bureaucracy are supportive of progressive industry, and efficient and ecologically sustainable utilisation of the region's resources.

1.6 PROJECTED MARKETS

Produce from the aquaculture project will initially be distributed to the Australian capital city markets. As production increases the market focus will move to establishing international export markets. The long-term viability of the project will depend on establishing international markets.

Emphasis will be placed on the quality and presentation of the product with utilisation of the Individual Quick Freezing (IQF) method of processing and packing. This method allows for presentation of an individually frozen product, with a constant and assured quality but without the risk associated with shipping unfrozen produce should delays in transportation be experienced.

The main international target markets in order of intended priority will be United Kingdom, Europe, USA, Japan and Hong Kong. Phelps/Panizza have established contacts in the United Kingdom and Asia that have expressed interest in distributing Australian farmed prawns.

1.7 ECONOMIC IMPACTS

The proposal is expected to create substantial economic benefits to the greater Darwin community.

1.7.1 Development and Construction

In the initial development it is estimated that $2.846 million will be outlaid for capital works, most of which will be spent with local contractors, suppliers or additional staff. Most items of equipment purchased to date have been sourced from Darwin suppliers. Local Darwin firms have provided all consultancy work in engineering, environment and legal aspects of the project.

Over the period until the project reaches full scale it is conservatively calculated that $8.2 million will be channeled into construction.

1.7.2 Employment

Phelps/Panizza have set a policy of employing local management and staff, whenever possible. Three management positions have already been offered to individuals situated in Darwin.

Initially, nine to twelve permanent employment positions will be created. As the project reaches full scale up to 40 permanent positions will be created.

With the high levels of mechanisation, automation and computerisation intended for this development, many of the permanent positions will be technically based and require intensive training, creating real career opportunities for local people.

1.7.3 Operational Expenditure

Annual operational expenditure for the farm at initial scale is in the order of $2.7 million. The largest single cost is the pelletised prawn feed which constitutes approximately one third of budget and is not available locally. Other major items of cost are salaries, fuel/power, equipment maintenance and repairs.

As the pond area increases it is projected that annual operational expenditure will grow upwards of $10.5 million.

A summary of the projected economic benefits to Greater Darwin is presented in **Table 1**.

Table 1

Projected Economic Benefits to Greater Darwin

Item	Amount - Stage 1	Amount to Completion	% $ Spent in Greater Darwin
Construction	$2.846 million	$8.2 million	75
Full time staff positions	9 – 12	Up to 40	100
Casual employment	1,500 hours/year	Up to 9,900 hours/year	100
Operational expenditure	$2.7 million/year	Upwards of $10.5 million/year	60

2. DESCRIPTION OF PROPOSED DEVELOPMENT

2.1 SITE DESCRIPTION

The proposed Blackmore River (East) Aquaculture lease occupies an area of approximately 796 ha on Middle Arm, Darwin Harbour, approximately 25 km south-east of Darwin. The site is bound to the west by the woodland/mangrove margin of the Blackmore River and to the north by the existing road to the Middle Arm boat ramp. The eastern boundary is matched to the shape of the proposed freshwater dam and is the vicinity of Finn Road, which runs south to Berry Springs. The lease area is predominantly woodland. The land immediately surrounding the Blackmore River Aquaculture site consists of undeveloped Crown Land, within the Litchfield Shire.

The location of the proposed aquaculture development site is presented in **Figure 1**. The proposed development, overlaid onto an aerial photograph of the area, is presented as **Figure 2**.

2.2 SITE SELECTION

An assessment of the fundamental attributes of a suitable site was made with the following factors considered to be of highest importance:

- Tropical climate for optimum water temperatures for best growth of selected species.
- Access to seawater with sufficient channel depth to draw off on all tides with minimum interference to mangrove populations.
- Close proximity to a large population centre for staffing, supplies and access to a major airport for chilled, frozen and live exports.
- Suitable soil types and topography for pond, dam and road construction.
- Suitable site and catchment area to construct a freshwater dam to hold sufficient supply for salinity adjustments in the production ponds to an eventual scale of 115 ha of production pond area.
- Viable access to the Power and Water Authority (PAWA) electricity grid.
- Viable access to PAWA reticulated water, or alternatively potable groundwater.
- Site area to enable effective layout of up to 115 ha of production ponds and 80 ha of exchange water treatment ponds.

Initially, a site on the Howard River (Northern Territory) was considered for the project. However, in co-operation with the Northern Territory Government, with consideration for issues raised by community interest groups, the Howard River site was abandoned in favour of this Blackmore River (East) site. The Blackmore River (East) site is considered by Phelps/Panizza to possess the following attributes:

- Tropical climate.

- Access to seawater with the Blackmore River running closely adjacent to the farm area, allowing saltwater supply with minimal impact to mangroves.
- Reasonable proximity to Darwin (with minor Wet Season access limitations).
- On site material that will be satisfactory for construction requirements. Suitable site for the construction of a freshwater dam.
- Suitable areas within the lease enabling construction of the project's required infrastructure.
- Reasonably accessible domestic electricity supply (approximately 4 km from the proposed pond area). Connection is planned home time after the initial development is operational.
- Identified potable groundwater reserves in the area.

2.3 PROJECT SCHEDULE

It is proposed that the aquaculture development be undertaken in two stages. Stage 1 will comprise the initial establishment of twenty-two production ponds (approximately 27 ha in total). It is proposed to commence the construction of Stage 1 in July 2001, for completion in early 2002. Phelps/Panizza propose to spend the first three years working with 22 ponds to establish appropriate economic and environmental management practices. During this period full analysis of many aspects of the aquaculture farm will be conducted, including:

- species for production;
- water and discharge water management, evaluating closed circuit systems;
- computer systems, remote sensing and controls;
- pond number/size and layout;
- aeration type, size and configuration;
- requirement for own hatchery;
- feed distribution; and
- potential markets.

Phelps/Panizza foresee sufficient production and revenue to operate profitably from Stage 1. This is based upon detailed cash flow projections on six monthly yields of 4 and 5 tonnes of prawns per hectare. If Stage 1 of the project is deemed economically and environmentally appropriate, expansion of the farm to reach full-scale (Stage 2) is expected to occur at a fairly constant rate over the following three years. Prior to any such expansion Phelps/Panizza undertake to complete additional environmental assessment in consultation with the Environment and Heritage Division of DLPE, Fisheries Division of the Department of Primary industries and Fisheries (DPI&F), and CSIRO Marine Research CRC.

When operating at full-scale, aquaculture production is expected to occur within a total of 93 production ponds, encompassing an area of approximately 115 ha.

2.4 PROJECT LAYOUT

The proposed layout of Stages 1 and 2 of the aquaculture project, overlaid onto an aerial photograph of the area, is provided in **Figure 2**.

In summary, the final development (Stages 1 and 2) will comprise a total of 93 production ponds (approximately 115 ha) and a saltwater supply, settling and storage channel. A freshwater dam (186 ha in area, with a holding capacity of approximately 5,500 ML), four exchange water treatment ponds (80 ha in total) and 26 ha of pasture area will also be incorporated in the project design. This infrastructure will be serviced by a network of saltwater supply channels, three saltwater intake pumps installed on a pump jetty in the Blackmore River, channeling and pipe work required for supply and drainage, three above ground fuel (diesel) storage tanks, power generators and supply lines. A packing/processing factory, hatchery, office building and managerial/staff housing will be built. Fencing, access and farm roads will also be constructed.

Construction activities required to complete Stage 1, and the additional development requirements of Stage 2, are listed below.

Stage 1 (Initial)**:**

- A 350 m above ground supply channel and pump jetty, installed with 2 x 600 mm pumps, on the Blackmore River;
- 5 ha saltwater settling channel and storage dam for salt water supply to farm;
- twenty-two production ponds, with each pond having an area of 1.24 ha (approximately 27 ha in total);
- on-site freshwater dam with a planned water area of 20 ha and holding capacity of approximately 460 ML, built to 15m Australian Height Datum (AHD), and lift pump(s);
- 1.6 km of on farm saltwater supply channels, equipped with a pumps re-lifting water from the settling channel;
- a 20 ha exchange water treatment pond;
- channeling and pipework for supply and drainage;
- three 55,000 L above ground fuel tanks;
- a 12 m x 24 m workshop and office;
- aquaculture shed, incorporating holding tanks and quarantine;
- a 12 m x 24 m packing factory;
- demountable style single-person's quarters and amenities, to accommodate two to four people;
- 5 km of access and farm roads;
- fencing; and

- power generators and power supply lines.

Stage 2 (Completed)**:** Additional works:

- the installation of a third 600 mm lift pump on the pump jetty;
- the construction of a further 71 production ponds (93 in total), each pond with an area of 1.24 ha (approximately 115 ha in total);
- the addition of a second larger freshwater dam, constructed to the 14m AHD covering a 186 ha area (holding capacity approximately 5,500 ML);
- 4.8 km of on farm saltwater supply channels and the addition of a third lift pump to re-lift water from the saltwater settling channel;
- three exchange water treatment ponds, with a further area of 60 ha;
- channeling and pipework for supply and drainage as required;
- 5 ha desalination bays for solid pond waste;
- pasture area of 26 ha;
- expansion of workshop, office and packing and storing facilities; manager's residence, 5-10 houses for married staff and 10-20 single staff quarters;
- additional power generators and/or supply lines, or connection to grid power; and
- further access and farm roads (approximately 2 km) to Stage 2 structures.

2.5 MAJOR COMPONENTS

2.5.1 Pump Jetty and Supply Channel

The Stage 1 development will commence with the construction 350 m long raised earthen road and raised channel through the mangroves to reach the Blackmore River, to enable the installation of a 30 m long pump jetty. This will permit the installation of 2 x 600 mm salt water supply pumps in a deep channel (around 8 m based on a mid tide). The water will be pumped into pipework for movement along the jetty structure to enter the supply channel.

The jetty will be constructed of steel and concrete.

The channel will be of earthen construction, with suitable clayey soils available for borrow out of the adjacent pond area. A concrete headwall will be installed at the head of the channel closest to the pumps.

An access road will be constructed to run either side of the supply channel and will be capped with approximately 150 mm of lateritic gravel material available from within the farm area. The road surface will be constructed to a level of 6.5 m AHD (2.5-3.0 m in height above existing mangrove mud surface) to ensure that there is sufficient free board from peak tide levels.

The seaward walls of the channel and roads will be lined with rock as required to prevent erosion from wave action and tidal surge. Suitable rock is available on site for this purpose.

To ensure conservative design estimates, Darwin Harbour peak combined sea level predictions were adopted for design calculations. The predicted 100-year peak combined sea level for Channel Island is 5.1m AHD (DLPE, 1994). However, the site is approximately 15 km upstream in the Blackmore River from Channel Island and is not expected to experience as high a storm surge as predicted for Channel Island. In addition, the mangrove fringe between the site and the Blackmore River is likely to retard the actual storm surge at the site.

2.5.2 Production Ponds

Production ponds associated with Stage 1 will be located towards the northern end of the site in the woodland area adjacent to the mangroves (**Figure 3a**). The Stage 1 development will include twenty-two ponds. Each rectangular pond will be 138 m in length and 90 m wide, covering an area of approximately 1.24 ha and having a capacity of approximately 18.5 ML. The ponds will be aligned in four rows of 5 or 6 ponds each and will utilise a network of supply channels (**Figure 3b**). The Stage 1 supply and drainage system, including construction details, are provided in **Figures 3c** and **3d**.

Stage 2 of the development will incorporate and eventual total of 93 production ponds that will cover an area of approximately 115 ha, extending to the south, east and north from the Stage 1 ponds (**Figure 4a**).

Pond walls will be constructed to a height of 1.5 m above the existing terrain. It is anticipated that each pond will be excavated into the soil to an average depth of approximately 0.5 m. The bottom surface of the pond will be sloped to allow drainage to one point. This slope, at approximately 0.7% is consistent to the existing average slope of the proposed pond site. Depth of water in the operational production ponds will be approximately 1.5 m, with 0.5 m freeboard between the water surface and the top of the pond walls. The Stage 2 supply and drainage system, including construction details, is provided as **Figure 4b**.

Once the lease area is sufficiently dry (following the end of the Wet Season), the pond walls will be constructed, primarily from clayey lateritic soils excavated during pond floor construction using dozers and self-elevating scrapers. Details of construction cut and fill quantities are detailed in **Section 2.6.2**. The excavated clays will be compacted to sufficient density to ensure stability. Between 0.l m and 0.2 m of lateritic gravel will be compacted on the crests and sides of the pond walls to enable vehicular access and to minimise erosion. The laterite material will be transported to location by dump truck and spread using a laser-controlled grader.

Each pond will be filled by a single 450 mm intake pipe drawing from the end supply channel running off the main supply channel at the head (southern end) of the ponds. Discharge will be through 500 mm pipes connected to concrete drainage structures ('monks'). The floor to the ponds will be gently sloped (0.7%) to the discharge point to facilitate drainage of the ponds during harvest. A cross section of the proposed pond supply and drainage channels is presented as **Figure 5**.

Each pond will have a concrete bay constructed at the base of the pond to be used for harvest of the prawns. The concrete bay will be of sufficient size to accommodate two harvest cages.

As an alternative to mud pond floors, the floors may be lined with a synthetic liner. The advantages of using a synthetic liner include reduced pond cleaning costs and reduced potential for the harbouring of disease pathogens in the soil of the pond floor. The viability of using synthetic pond floor liners will be investigated by establishing a trial pond with a synthetic liner during Stage 1 operations.

2.5.3 Saltwater Settling, Storage and Supply Channel

The raised channel from the Blackmore River will run to an in-ground channel constructed adjacent to the mangrove margin area, running approximately 2 km to the second stage saltwater lift pumps. This channel will be constructed to an average water width of 30 m allowing the incoming water to slow down and for suspended solids in the water to settle out in the water column, significantly improving the clarity of the water being supplied to the production ponds.

This channel structure will have a storage capacity of approximately 56 ML, which will assist in flexibility of farm management making available a buffer of water for supply to the ponds even on low tides. The settling channel will be of similar construction to the production ponds, with the height of the wall being approximately 2 m above the natural ground level of the 4 m AHD. The channel will follow the alignment of the natural contour, adjacent to the mangroves, to the second stage lift pumps, matching the level of the roads along the channel from the pump jetty.

The channel walls will be constructed using material from the channel floor and using both dozer and self-elevating scraper. The walls will be capped with laterite material transported to location by dump truck and spread using a grader. Maximum excavation depth within the channel may be as much as 1.5m to remove higher knobs of terrain to leave an evenly graded flat bottom to the channel, allowing complete drainage for future maintenance.

Pumps to provide a second lift from the settling channel to the production ponds will be installed at the eastern end of the settling channel to lift the salt water to the farm saltwater supply channel. These pumps will be selected to match the capacity of the first stage pumps installed on the pump jetty in the Blackmore River.

2.5.4 Freshwater Storage Dam

The Darwin region has a definite Dry Season each year, in which generally a period of six months will pass with little rainfall. During this period evaporation will cause steadily increasing salinity in the production ponds with associated slower growth rates. To maintain growth rates and stock health a supply of freshwater will be required. A freshwater dam will be constructed for this purpose.

During Stage 1 development a 20 ha freshwater dam (holding capacity 460 ML) will be constructed to the south-east of the production ponds, at the headwaters of the north arm of Middle Creek, in centre of the lease (**Figure 6a)**. The freshwater dam will have a catchment area of approximately 75 ha.

The dam wall (approximately 628 m in length) will be constructed to a height of approximately 15 m AHD (a maximum wall height of 7.5 m). The wall of the freshwater dam will be constructed of clay material from the dam floor and will be excavated using dozers and self-elevating scrapers (**Figure 6b**). Calculations of Stage 1 dam construction volumes are included in **Figure 6c**. A spillway will be located at the southern end of the dam wall.

Overflow design for the Stage 1 dam construction will include a 40 m long, low spillway at the southern end of the dam wall. The spillway will be capped with a layer of compacted gravel.

A second freshwater dam will be constructed before expansion of the farm to full scale, possibly in Year 3 of development, at the headwaters of the south arm of Middle Creek. This dam will have a surface area of approximately 186 ha and a storage capacity of approximately 5,500 ML (**Figure 7a**). The catchment area for the Stage 2 freshwater dam will be approximately 1,170 ha.

Construction of the Stage 2 freshwater dam will incorporate the use of several material types laid down in zones. Preliminary dam design details are presented in **Figure 7b**. The dam wall will be constructed to a height of approximately 14m AHD (a maximum wall height of 13 m). The base of the fully constructed dam wall will be keyed into the underlying material to a depth that will be determined following appropriate geotechnical investigations of underlying material. The extent of excavation elsewhere on the dam floor (at 5.0 – 9.0 AHD) will depend on fill requirements, and will be taken in such way to ensure that the entire dam area is self-draining.

Overflow design for the fully constructed dam will include the construction of a spillway, at approximately 13m AHD, at the dam's southern end. The spillway will be excavated into shallow laterite (<lm depth below surface level) and will be designed to release overflow water in a manner that will minimise channeling and erosion. Appropriate erosion control measures will be adopted to minimise scouring from spillway runoff. The spillway design will be included as part of the Stage 2 freshwater dam design that will be finalised at a later date.

The Stage 2 freshwater dam will be constructed primarily by scrapers. Excavation of material for the clay core will be from the dam floor. Laterite material will be excavated from the spillway area and other construction material will be obtained from within the dam boundary. All excavation areas will self-drain back into the floor of the dam.

High Voltage Tower

One tower of the NT high voltage grid stands in the reaches of the Stage 2 freshwater dam. At the time this dam is constructed (year 3), measures will be taken to ensure that PAWA have uninterrupted access to this tower for inspection and/or repair. The dam water will flood the area around the tower to a depth of 1.5 m, typically, for the period from February to May each year.

In consultation with PAWA, the proponents will take the following steps, depicted in **Figure 7c**, to ensure that the tower is not damaged by increased rust and is permanently accessible whilst the dam is full:

1. Encase the currently exposed base section of the tower legs with concrete to a height of 1.7 m above the existing concrete footings giving the steel members protection from rust to a level 300 mm above the highest water level of the dam. The old concrete footing will be 'scabbled' so that the new concrete adheres and seals, preventing moisture reaching the steelwork.
2. Construct a compacted earthen road above the dam water line to and around the tower base,

enabling vehicular access at all times during the wet season. This road will be built up to 2.2 m around the tower, a level equivalent to 14 m AHD and 700 mm above the highest water level and will be continued back to the northern reaches of the dam. This road will be 6 m wide at the top and be aligned with the power line.

3. The area within the base of the tower will be filled with earth to a level equal to the height of the new concrete footings, 300 mm above the highest water level, to enable free movement of personnel around the base of the tower. This area will be permitted to drain back into the dam, to prevent pooling of water around the steelwork of the base.
4. The road and other earthen surface will be topped with suitable gravel material to minimise bogging and slipping for both vehicles and personnel.

5. The work will be carried out in consultation with PAWA management to ensure it is completed to the satisfaction of PAWA.

2.5.5 Finn Road Access through Stage 2 Freshwater Dam

Water in the southern reaches of Stage 2 freshwater dam will inundate a part of Finn Road. The Planning Division of the DLPE intend to realign this road in the near future such that new alignment will not conflict with the dam in its proposed form. However, if at the time this dam is constructed authorities require Finn Road to remain open, the following steps are proposed to ensure continuing use by the public:

- The existing culvert will be extended to accommodate building up of the roadway.

- A compacted earthen road, 8 m in width, will be constructed.

- Signage and guide rails will be installed as required.

The proposed earthworks for the Finn Road crossing are detailed in **Figure 7d**. All work will be done in consultation with Litchfield Shire Council.

2.5.6 Exchange Water Treatment Ponds

The production of marine species in semi-intensive aquaculture production ponds will produce discharge water with increased levels of nutrients and suspended solids. To minimise the amount of nutrients and suspended solids released from the farm, exchange water treatment ponds will be installed to provide "passive treatment" of the effluent. Stage 1 development will include a single 20 ha exchange water treatment pond and Stage 2 development will include four exchange water treatment ponds.

The discharge water ponds have been designed in accordance with the latest research in aquaculture discharge water treatment. The proposed discharge water treatment regime will have the highest ratio of treatment pond area to production pond area of any aquaculture development in Australia.

Details of the anticipated composition of the discharge water discharge from the production ponds and the effectiveness of exchange water treatment ponds are discussed in **Section 4.6.2**.

Construction of the exchange water treatment pond will commence once the lease area is sufficiently dry (following the end of the Wet Season). The Stage 1 exchange water treatment pond will be constructed alongside the western edge of the production ponds (**Figure 8**) with dimensions of the walls being similar to the production pond wall construction.

Since the treatment ponds are to be situated at a lower level than the production ponds discharge water from the Stage 1 production ponds will flow into the exchange water treatment pond. The treatment pond is designed so that discharge water will pass along a distance in excess of 2 km at a slow velocity, improving rehabilitation of the water through allowing solid material to settle out.

Discharge water outflow from the treatment pond will be controlled by a valve fitted to a 1200 mm diameter waste discharge pipe at the south-eastern corner of the treatment area. This will permit the released discharge water to flow into an existing natural channel in the mangroves (Figure 3). Erosion prevention measures will be adopted where the released discharge water enters the natural creek channel.

The number of exchange water treatment ponds associated with Stage 2 of the development will depend on the performance of the Stage 1 treatment pond. Current design for Stage 2 is based on a ratio of 80 ha of exchange water treatment ponds to 115 ha of production ponds, with the construction of three additional exchange water treatment ponds during Stage 2 (**Figure 9**). Additional treatment ponds, to be located on alignments between the 4m and 6m AHD, will be of similar principle and construction to the Stage 1 treatment pond.

Following construction of the additional Stage 2 treatment ponds, discharge water will be released to the north arm of Middle Creek. Discharge, at the southern side of the north arm of Middle Creek, will be controlled with piping and valves similar to the proposed Stage 1 outlet. To prevent scouring or erosion a discharge channel will be constructed to discharge into the creek.

2.5.7 Solids Desalination Bays and Pasture

The process within the production ponds results in the generation of a solid waste material, sludge, which needs to be removed from the pond, after harvest. This material will be removed for holding and desalination in a 5 ha area, referred to as the Solids Desalination Bays. This will be an area positioned around the 10 m AHD, adjacent to the small freshwater dam, which will be bunded with a low earthen wall and a release wall, to slow the run off of water from the impoundment.

Any run off water will be directed to the discharge treatment ponds for eventual release after treatment.

Once the solid waste material has spent several seasons in the solids desalination bays, being turned over in each Dry season, it will be removed to a 26 ha pasture area where it will be spread over the land for any remaining nutrient value and to build the topsoil.

2.5.8 Buildings

All buildings will be positioned between the 16 m AHD and 30 m AHD contours (Figure 4a). Sufficient parking areas will be constructed adjacent to all buildings and dressed with suitable gravel material.

Buildings associated with Stage 1 development will include:

- a processing factory (12 m x 24 m);
- a farm workshop and office (12 m x 24 m);
- an aquaculture shed, incorporating holding tanks and quarantine; and
- accommodation for 2-4 single workers.

The processing factory and workshop will be built with a concrete base, steel frame and colourbond cladding.

The aquaculture shed will have a concrete base and floor, steel frame and cladding and will be fitted with tanks and water supply for the holding of juvenile stock.

Accommodation will consist of demountable buildings connected to power and sewerage. Permanent residences will be constructed once the project becomes operational and it is feasible to establish suitable conditions for the accommodation of a larger number of staff including families.

Buildings associated with Stage 2 development will include: packing and storage facilities, office and expanded workshop; a Manager's residence, 3 to 8 houses for married staff and 5 to 12 single staff quarters.

Lawns and garden beds will be established around the factory, office and residences.

2.5.9 Roads

Access to the proposed development will be via the existing Middle Arm Boat Ramp Road. The Middle Arm Boat Ramp Road is considered to be an acceptable access road for the types of traffic generated by the development. Middle Arm Boat Ramp Road and other gravel roads in the area have the following limitations:

- Flooding preventing passage after large rainfall events. Temporary closure of the road usually lasts for relatively short periods, with 4WD passage generally possible at all times.
- Reduced visibility from dust generation during the Dry Season when passing or overtaking other vehicles can result in dangerous driving conditions. All staff and families will be advised of these dangers.

Roads constructed as part of the Blackmore River (East) Aquaculture Development will provide:

- access from Middle Arm Boat Ramp Road to the property boundary;
- access from the property boundary to the housing/production area;
- access along the pond/bund walls; and
- general access within the farm area.

Roads constructed on the lease will comprise all-weather access gravel roads, lined with compacted laterite material applied at a thickness of 100-200 mm. Roads will be designed to minimise erosion through the provision of table drains installed across the natural slope where possible. All construction material will be sourced from a borrow pit located within the boundaries of the lease area.

2.6 EXTRACTIVE MATERIALS

2.6.1 Soil Suitability

Clayey soils (including clayey sand and clayey gravel) and gravel will be required for construction purposes at the Blackmore River (East) Aquaculture Development.

Soils with sufficient clay content to limit infiltration will be used to form the base of the production ponds, supply channel, exchange water treatment ponds and freshwater dams. Suitable soils may include sandy clay, silty clay, clayey sand and clayey gravel. Significant quantities of clayey sand and clayey gravel are anticipated to be available on-site, in the lateritic profile generally encountered in this area.

Lateritic gravel will be used for the following purposes:

- Prevention of erosion by lining of bund walls.
- Construction of roads along the surface of the pond walls, the bund walls, the channel walls and freshwater dams.
- Construction of access roads within the lease area.
- Miscellaneous construction, including car park surfacing and general fill.

The lateritic gravel will be obtained from on-site sources where available. The available quantities of material on the lease area and the location of potential borrow pits has not been investigated. Where necessary, suitable gravel will be imported from off-site sources.

A preliminary geotechnical investigation of the lease area conducted by Ullman & Nolan (1996), identified silty sands, clayey sand/clayey gravel and clays on the lease area. It is considered that the silty sands (identified in isolated areas) is suitable for use as general fill, however due to low fines content is not suitable for embankment construction. The clayey sand/clayey gravel (occurring across the majority of the lease area) may be suitable for embankment construction and sealing of the ponds while the clays may be suitable for lining water retaining structures. Clays are present in the vicinity of the proposed Stage 2 Freshwater Dam as surface sandy clay and deeper (>2m depth) silty clay derived from weathering of underlying siltstone bedrock.

There is potential that leakage may occur through gravel layers at the base of water holding structures (ponds, channels or freshwater dam). Should highly permeable gravel layers be encountered at the base of water holding structures the gravel will be removed to a minimum depth of 0.5m and replaced with compacted clay material.

The pump jetty and initial section of the saltwater supply channel will be constructed over mangrove clays present in the vicinity of the Blackmore River. These clays will not be excavated and will undergo some consolidation. While the depth and spatial extent of mangrove clays in this area has not been investigated, isolated rock outcrops observed indicate that the mangrove clays are likely to be relatively shallow reducing the potential for settlement.

The subsurface profile of the Blackmore River at the location of the proposed saltwater pump jetty will be investigated prior to final construction design.

2.6.2 Volumes

The fill required for both Stage 1 and Stage 2 development will be sourced from the borrow areas as listed in **Table 2**.

Table 2

Source of Fill

Requirement	Source of Fill
Freshwater dam wall	Freshwater dam floor
Main supply channel through mangroves	Main supply / settling channel floor
Main supply / settling channel wall	Main supply / settling channel floor
Supply and drainage channels to ponds	Floor of drainage channels & floor of exchange water treatment dam
Production pond walls	Production pond floors
Exchange water treatment pond walls	Exchange water treatment pond floor

Preliminary earthworks calculations indicate that there will be sufficient material available from proposed excavations (cut) to satisfy construction requirements (fill). However a shortfall in lateritic gravel for road and embankment wall surfacing and erosion control may occur. It is envisaged that this shortfall will be sourced from borrow areas located within the water-holding structures of the development (production ponds, freshwater dam, the exchange water treatment ponds and the supply and drainage channels) or from other on-site borrow areas. Excavation in these areas will be designed in such a way as to minimise the possibility stagnant water ponding.

Accurate cut/fill calculations are difficult to currently determine due to variations in occurrence of on-site materials and ground slope. While preliminary calculations indicate sufficient material is available on-site should a shortfall be encountered material will be imported from off-site.

2.7 PROPOSED OPERATIONS

2.7.1 Species

The development is based primarily on production of black tiger prawn *(Penaeus monodon).* This species is produced in existing aquaculture farms in the Northern Territory, Queensland and northern New South Wales. However, rotating production species has both financial and husbandry benefits associated. The feasibility and environmental acceptability of farming other species will be investigated in the future. The following species may be considered:

Prawn Species

- Banana prawns (*Penaeus merguiensis*, *P. indicus*)
- Brown tiger prawn (*Penaeus esculentus*)
- Kuruma prawn (*Penaeus japonicus*)

Fish Species

- Barramundi (*Lates calcarifer*)
- Golden snapper (*Lutjanus johnii*)
- Barramundi cod (*Cromileptes altivelis*)

2.7.2 Sources of Juvenile Prawns

Stage 1 of the development will be established as a "production-only" farm. In accordance with current standard industry practice in the Northern Territory the juvenile prawn stock ('post-larvae') will be purchased initially from selected Queensland hatcheries.

Quarantine facilities, set up for the arrival of post-larvae to the farm, will be positioned adjacent to the production area, with access to both saltwater and freshwater. The installation will consist of several large holding tanks housed within a steel frame shed. Using recirculated water these tanks will be designed to keep the new arrivals in favourable conditions for a period of five days whilst the technical staff check them for disease. The water supplied to these ponds will be moved first to a holding tank and not discharged to the farm drainage system until the new batch of post-larvae has been declared disease-free and has been placed in the production pond.

Consideration will be given to the establishment of a hatchery during the Stage 2 development.

2.7.3 Stocking Rates

Lower stocking rates will generally simplify pond management, reduce yield potential and reduce costs. Stocking rates in the Australian prawn farming industry vary widely, from 8 to 40 prawns/m^2. Stocking rates will depend on management techniques adopted and water quality issues.

The current proposal is based on an initial stocking rate of 28 post-larvae/m^2. This rate will be refined during operations. Based on a conservative survival rate of 80% to maturity and harvest, the estimated yields per crop per hectare are presented in **Table 3**.

Table 3

Estimated Crop Yields

Prawn size at harvest (g)	Prawns/ha	Yield/ha (kg)	Yield/1.24 ha pond (kg)
17.5	224,000	3,920	4,860
20.0	224,000	4,480	5,555
22.5	224,000	5,040	6,250
25.0	224,000	5,600	6,944
27.5	224,000	6,160	7,638
30.0	224,000	6,720	8,333

Note: Stocking rate at 28 prawns/m^2, assuming 80% survival to harvest.

2.7.4 Farming Techniques

The production ponds will be laid out in uniform lines as depicted in Figure 4. The supply of salt and freshwater will be gravity fed from an elevated supply channel, distributing to ponds through a 450 mm supply pipe. Discharge water from each pond will be released to the discharge water channels at the opposite ends of the ponds to the supply channel to flow into the exchange water treatment pond.

The production ponds will be aerated using a combination of paddlewheel and airjet style aeration. During the initial stages of the crop cycle four 1.5 kW units will be used per pond, increasing to twelve 1.5 kw units per pond during the final stages of the crop cycle. A schematic of the proposed aerator placement is presented as **Figure 10**.

Stock will be placed in the ponds as juveniles and feed will be provided in pellet form with the use of blower spreaders. Suitable feeds are manufactured in Australia, whilst some feeds are imported into Australia. Various brands of feed will be trialled to establish the best conversion and growth rates with the lowest waste, to gain cost efficiency and minimise nutrient build-up in the pond water.

There are several stages of growth in the life cycle of *P. monodon* that require different forms of pelletised feeds. Indicative feed requirements for *P. monodon* are presented in **Table 4**.

Table 4

Indicative Pelletised Feed Requirements for *P. monodon*

Feed stage	Feed type	Feed size (mm)	Composition (%)			
			Protein	Fat	Fibre	Moisture
PL 1	Mini pellets	0.2 x 0.4	37.0	3.0	3.0	11.0
PL 2	Mini pellets	1.0 x 1.5	37.0	3.0	3.0	11.0
Starter 1	Mini pellets	2.0 x 2.5	36.0	3.0	3.0	11.0
Starter 2	Pellets	2.3 x 3.5	36.0	3.0	3.0	11.0
Production	Pellets	2.3 x 6.5	35.0	3.0	3.5	11.0
Finisher	Pellets	2.3 x 8.0	35.0	3.0	3.5	11.0

Feeding rates will vary through the course of the production cycle. Feed trays set on predetermined positions of the pond floor will be lifted at intervals after feeding to establish the percentage of the feed used in the last feed. This will allow adjustment to the rate of the next feed to prevent wastage and nutrient build up, and to maximise growth rates. Estimated feeding rates for *P. monodon*, assuming optimum growth conditions and health, are presented in **Table 5**.

Table 5

Feeding Rates for *P. monodon*

Prawn Body Weight (g)	Feed Rate - % of body Weight per Day	Feeds per Day	Time after Feeding to Check Feed Usage (hrs)
PL - 0.1	20 – 40	4	2.5
0.1 - 0.5	15 – 20	4	2.5
0.5 - 2.0	8 – 15	4	2.5
2.0 - 3.0	7 – 8	4	2.5
3.0 - 5.0	5.5 – 7	4	2.5
5.0 - 10.0	4.5 – 5.5	5	2.0
10	4.5	5	1.5 - 2.0
15	3.9	5	1.5 - 2.0
20	3.2	5	1.5 - 2.0
25	3.1	6	1.0 - 1.5
30	2.7	6	1.0 - 1.5
35	2.4	6	1.0 - 1.5
40	2.2	6	1.0 - 1.5

At the beginning of a crop cycle, lime will be added to the newly prepared pond to adjust pH and to disinfect the pond. Through the crop cycle, lime may be added to maintain a stable pH.

Small amounts of fertilisers such as Dynamic Lifter and/or a combination of Urea and NPK (16:20:0) will be applied (at rates of approximately 6 kg/ha) to initially promote algal growth in the early stages of a crop cycle. Algal bloom is important to young prawns as algae:

- produces oxygen by photosynthesis;
- shades the pond bottom and impedes the growth of harmful benthic algae;
- provides a darker environment, which is less stressful to the young prawns;
- utilise nitrogen and phosphate wastes; and
- reduce rapid fluctuations in water temperature.

The pond walls having a freeboard of around 0.5 m prevent the escape of stock from the production ponds. This will prevent the passage of stock from one pond to another.

Each pond will be drained via a monk structure. This structure will be screened with suitable size mesh, matched to the size of the stock, to prevent any passage from the pond to the waste drain as part of water exchange or storm overflow.

A structure will be constructed at the discharge point to hold the discharge back at certain times of the day, depending on the tide. This structure will also be screened as a secondary measure for escape prevention. Should there be an accidental loss of large numbers of stock from the pond, the escapees will be collected at this second structure.

2.7.5 Harvest

Black Tiger prawns have an approximate 120 to 150 day crop cycle, at which time they will be harvested. Harvest of the prawns will take place adjacent to the waste drain at a concrete bay (able to accommodate two harvest cages) at the bottom of each pond. The pond water will be discharged via the outlet pipe through one of the harvest cages; the prawns will run with the flow of water and become trapped within the cage. The water flow will be alternated between the cages, with the full cage being lifted onto a waiting crane truck and immersed in water for transportation to the cooking and packing facility.

2.7.6 Processing and Packaging

A grading, cooking and packing factory will be constructed on-site. The factory will conform to all relevant health regulations. Refrigeration facilities will be established on-site for product storage and ice making.

When harvested, the prawns will be taken immediately to the cooking and packing facility. The prawns in the harvest cage will be emptied into a hopper feeding to a grading machine. Prior to entering the grading machine, the prawns will pass over a manual sorting table where four to six workers will remove foreign material (other species or inert objects) from the incoming prawns. The grading machine will sort the prawns into as many as five sizes and drop them into separate bins. The produce in these bins will be manually moved to the cooker, where cooking will be effected by immersion in boiling brine for a period of just under three minutes. The bins of cooked produce will be dropped temporarily into sub-zero brine for chilling, then removed and packed into heavy-duty plastic bags, then placed into styrofoam boxes with ice, marked for size and sealed. The styrofoam boxes will hold approximately 17.5 kg of produce and 1.5 kg of ice. A conveyor will move these boxes to a stacking area where the sizes will be sorted onto pallets for storage in the cool room(s). A schematic of the packing shed operation is presented as **Figure 11**.

The grading machine will have a capacity of 1 tonne per hour and processing from harvesting to packing is expected to take a maximum of three hours, with an expected daily throughput of 10 tonnes.

2.7.7 Water Supply

2.7.7.1 Water input to production ponds

Water input to the production ponds will include the following:

- saltwater from the Blackmore River via the saltwater supply channels;
- freshwater from freshwater storage dam(s); and

- freshwater from direct precipitation.

Whilst the species of prawns to be cultured can live in good health in a range of salinities from <7,000 ppm to about 40,000 ppm, optimum growth rates are achieved at salinity levels between 15,000 ppm and 25,000 ppm. Depending on the time of year, management objectives will be, first to keep salinity to a safe level, and next to adjust to mid-range to promote faster growth rates. In the Dry Season, targets will be to keep the salinity at 25,000 ppm or below and in the Wet Season, the target will be set at 15,000 ppm or above. However, in practice it is expected the range will extend between 10,000 and 35,000 ppm with the extremes reached in the peak of the Wet Season and at the end of the Dry Season.

Saltwater Supply

The saltwater supply for the Stage 1 production ponds will be pumped from the Blackmore River via the supply channels being fed individually through the 450 mm supply pipe at the head of each pond. It is estimated that saltwater pumping will be possible from the Blackmore River at almost any tide level but will be undertaken mainly above the 4.5 m tide level permitting approximately two five-hour periods of pumping per day (average tides are approximately 4 m AHD).

Saltwater supply for Stage 2 will be obtained also from the Blackmore River, with the addition of extra pumps at the pump jetty. The channel system will be designed and constructed to accommodate the full volume required for the completed farm.

During the Wet Season the water in the Blackmore River will vary markedly in salinity levels, with a large freshwater influence from overland runoff into the river. In the area adjacent to the pump jetty the river has been observed to form salinity strata in the water column with predominantly freshwater (eg: 5,000 ppm) flowing across the river surface, with higher salinity water moving 4 to 5 m lower in the water column. The phenomenon is referred to as "saltwater wedging". To ensure that the water with the most favourable salinity available is pumped from the river, the jetty is positioned to place the pumps in a deep channel. The pumps will be fitted with an intake pipe, which can be adjusted to draw water from different levels of the water column (**Figure 12**).

Freshwater Inflow from Dam

Freshwater inflow requirements to the production ponds will be sourced from direct rainfall or gravity fed/pumped from the freshwater dam. Volumes of freshwater required would depend on the maintenance of salinity in the production ponds. A monthly summary of the predicted water management techniques is presented in **Section 2.7.7.4**. Freshwater requirements are calculated as follows:

- **Stage 1**

In Stage 1, the aim of management will be primarily to replace evaporation, to keep the salinity at a safe level. With the benefit of freshwater available from periodic rainfall events and lower salinity water from the Blackmore River through the late Wet to early Dry Seasons, management will hold salinity of ponds to approximately 30,000 ppm until 1st July.

The Stage 1 freshwater dam will be used to replace evaporation lost from the Stage 1 production ponds during the July to October period. Assuming a maximum average daily evaporation rate of 8.5 mm, a maximum of approximately 277 ML (2.3 ML/day) of freshwater will be required to replace

evaporation from the 27 ha of production ponds during July to October of the Dry Season.

The capacity of the freshwater dam is approximately 460 ML. Evaporation from the Stage 1 dam is dependent on the surface area of the dam as the reservoir depletes during the Dry Season. The actual annual evaporation is difficult to determine, as the dam surface area is dependent upon topography, progressive water demand, annual rainfall, wind effects and monthly rainfall. In the absence of sophisticated modeling a conservative approximation of 170 ML evaporation has been derived from an estimated reduction in the surface area of the reservoir through the July to October period.

Assuming the Stage 1 freshwater dam fills annually with evaporation of approximately 170 ML from the 460 ML freshwater dam, a total of approximately 290 ML will be available to replace the 277 ML evaporation predicted from the production ponds.

Should freshwater supply periodically be insufficient for demand, management will consider allowing the salinity level of production ponds to increase, utilising water from Blackmore River, increasing catchment of the dam through the construction of catchment drains and/or reducing the number of active production ponds.

- **Stage 2:**

The Stage 2 freshwater dam (186 ha) will be used to replace evaporation lost from production ponds during the Dry Season. Assuming a maximum evaporation rate of 8.5 mm/day from the 115 ha of Stage 2 production ponds through July to October, approximately 1,175 ML (9.78 ML/day) of freshwater will be required to replace evaporation from the production ponds.

The large freshwater dam has a catchment area of approximately 1,170 ha. Modeling by PAWA (1996), using the Boughton (AWBM) rainfall runoff model, indicates that the Stage 2 freshwater dam will provide sufficient freshwater to replace evaporation from the production ponds between 80% and 90% of the time. Should freshwater demand exceed supply, either the salinity level in the production pond will be allowed to increase, or the number of active production ponds decreased. The results of the PAWA Boughton model are presented in **Appendix D**.

When the large dam is completed and the project is at full scale, surplus water will be used to reduce salinity in the production ponds, to achieve higher growth rates. Aiming to lower operating salinity to 27,000 ppm, closer to best growth optimum, the seasonal freshwater requirement would be in the order of 3,575 ML.

Precipitation

Volumes of direct precipitation of rainwater onto the production ponds will vary considerably between the Wet Season and the Dry Season. The mean annual precipitation for the Darwin region is 1,702 mm (Bureau of Meteorology, 1999). The mean annual volume of direct precipitation expected to fall onto the Stage 1 production ponds is 464 ML and the mean annual volume of direct precipitation onto the Stage 2 production ponds is 1,976 ML.

Inflow water will be supplied from either the main freshwater supply channel or the main saltwater supply channel into the pond supply channel using a 700 mm supply pipe. Depending upon water requirements, salt or freshwater will be fed into the pond supply channel and then into the ponds using a 450 mm supply pipe. The layout of the ponds including the location of the main freshwater channel, the main saltwater channel, the pond supply channel and the waste drainage channel are presented in Figure

4a.

2.7.7.2 Water output from production ponds

Water output from the production ponds will include the following:

- daily water exchange;
- harvest release;
- evaporation; and
- stormwater overflow.

The daily water exchange is a production process conducted to reduce nutrient load from the ponds and maintain dissolved oxygen (DO) and salinity levels. A maximum daily water exchange for the farm of approximately 5% is anticipated with an overall average daily water exchange of between 3% and 5%. Accordingly, the Stage 1 development will involve a maximum daily water exchange of approximately 20.4 ML, and Stage 2 a maximum daily water exchange of approximately 86 ML.

During harvest, all water from the pond(s) being harvested is moved to the exchange water treatment pond. Each production pond has a capacity of approximately 18.5 ML. Assuming two harvests per year, Stage 1 will generate an annual harvest release of approximately 815 ML, and Stage 2 will generate an annual harvest release of approximately 3,441 ML. The production ponds will be harvested on a rotational basis throughout the year.

The mean daily evaporation rate for the Blackmore River region is 7.3 mm (Bureau of Meteorology, 1999). Accordingly, the average annual evaporation from Stage 1 and Stage 2 production ponds will be approximately 720 ML and approximately 3,065 ML, respectively.

The discharge from the production ponds will be gravity fed into the exchange water treatment ponds and after moving through the treatment system, over an average period of 16 days, will then be released to Middle Creek at the designated discharge point. Alternatively, the treated water will be gravity fed from the exchange water treatment ponds into the supply/settling channel and then pumped for return to the production ponds and recycled as saltwater supply.

The discharge water from the treatment area will be piped under the supply settling channel to a discharge point, which will be located on the adjacent estuarine creek, flowing to the Blackmore River. The discharge point will be the same in Stage 1 and Stage 2, as shown in Figure 4.

A flowchart summarising water movement through the aquaculture production system is presented as **Figure 13.**

2.7.7.3 Estimated production water requirements

The estimated production water requirements for the Stage 1 development is presented in **Table 6**.

Table 6

Stage 1: Estimated Production Water Requirements

Saltwater Supply	
Maximum daily saltwater requirement	60 ML *(pumps at full capacity filling saltwater supply/settling channel)*
Annual saltwater requirement	5,304 ML *(two refills plus average 3% daily exchange)*
Average daily saltwater requirement	14.5 ML
Freshwater Supply	
Maximum daily freshwater requirement	6 ML
Annual freshwater requirement	277 ML *(replacement of evaporation only)*
Average daily freshwater (120 days Dry Season)	2.3 ML *(replacement for evaporation only)*

The estimated production water requirements for the Stage 2 development (115 ha of production ponds) is provided in **Table 7**.

Table 7

Stage 2: Estimated Production Water Requirements

Saltwater Supply	
Maximum daily saltwater requirement	75 ML *(pumps at full capacity pumping to saltwater supply /settling channel)*
Annual saltwater requirement	22,590 ML *(two refills plus average 3% daily exchange)*
Average daily saltwater requirement	62 ML
Freshwater Supply	
Maximum daily freshwater requirement	25 ML
Annual freshwater requirement	3,575 ML *(target salinity 27,000 ppm)* 1,175 ML *(replace evaporation only)*
Average daily freshwater (120 days Dry Season)	29.8 ML *(target salinity 27,000 ppm)* 9.8 ML *(replace evaporation only)*

2.7.7.4 Water management

The predicted monthly account of water management during farm operation is outlined in **Table 8**.

Table 8

Predicted Monthly Water Management

Month(s)	Conditions	Action
November	Sporadic rain may fall. Estuary will have normal salinity. High water exchange requirement.	Use freshwater & Blackmore River for exchange. Aim to have ponds at maximum operational salinity (35,000 ppm) in preparation for Wet Season rainfall events.
December	Rain will be increasing. Estuary will have lower salinity. Rain will decrease need for water exchange.	Use Blackmore River saltwater for exchange. Lower the intake of the pumps to take in higher salinity water. Pond salinity will start to fall.
January – February	Peak Wet Season. Estuary will run fully fresh for many days. Low water exchange requirement.	Use Blackmore River saltwater for exchange. Pump highest possible salinity water in estuary for water exchange
March – April	Wet Season finishing. Estuary will have run-off keeping salinity down. Water exchange requirement will increase.	Use Blackmore River saltwater storage for exchange. Aim to have ponds at minimum operational salinity (12,000 ppm) in preparation for Dry Season.
May – June	Dry Season. Still small amounts of runoff into estuary. Water exchange requirement high.	Use Blackmore River saltwater for exchange. Increase salinity in production ponds.
July – October	Dry Season. High salinity in estuary. Water exchange requirement high.	Use Blackmore River and freshwater for exchange.

2.7.8 Sludge

When the production ponds are drained during prawn harvesting, a volume of solid waste sediment (referred to as sludge) is left as a deposit on the pond floor. Studies on Australian prawn farms (Smith, 1996) have indicated:

- the sediment is black, glutinous and superficially similar to some soils found in mangrove habitats;
- the sediment accumulates at between 20 x 10^3 kg ha^{-1} to 180 x 10^3 kg ha^{-1};
- the main source of the sludge is soil eroded from the production pond walls and base;
- the sludge additionally contains prawn feed, faeces and decaying plankton with organic content ranging from 13.9 mg g^{-1} to 22.8 mg g^{-1}; and
- fresh and dried sediment has a neutral pH.

Past and current practice within the Australian aquaculture industry for handling this sludge is to remove it from the pond floors and spread it around the outside of pond walls and other parts of the farm. Because of the scale of the proposed project it is considered that the volume of sludge created would render this approach impractical and problematic.

The proposed practice for dealing with this material at Blackmore River (East) Aquaculture Development is as follows:

1. Once a pond is drained, allow a period of drying time.

2. Stockpile material adjacent to the pond wall (and road) with a swamp dozer.

3. Load the sludge onto a dump truck using an excavator.

4. Transport sludge to the solids desalination bays, an on-farm holding area.

5. Allow Wet Season rainfall to desalinate the sludge, turning it over in the Dry Season for several seasons.

6. As the holding area fills, move the desalinated material to the pasture area (Stage 2).

2.7.9 General Wastes

General wastes generated within the lease area will include:

- sewage and domestic effluent.
- washdown water from the vehicle cleaning area, which may be saline and contain suspended solids and petroleum hydrocarbons;
- washdown water from the grading, cooking and packing factory, which will contain disinfectants and detergents;
- used cooking brine from the factory;
- diseased prawns;
- used parts, sump oils etc from farm machinery;
- miscellaneous items such as bags from feed and fertiliser supplies; and
- domestic garbage and food waste.

Sewage and domestic effluent will be treated by septic tank systems designed in accordance with Territory Health guidelines. The residences will be equipped with a minimum of one toilet installation each and will be connected to an independent or combined septic system. The single staff quarters will have a minimum of one toilet installation per four persons. The office and workshop will be equipped with both male and female facilities and conform to workplace codes.

Other sources of domestic waste on the lease will be dealt with in the following manner:

- *Vehicle washdown*
  Potentially contaminated washdown water from vehicle and plant cleaning will be directed through a triple interceptor trap (TIT), located adjacent to the workshop. Discharge from the

TIT will be directed to either an absorption trench or lagoon system. The TIT will be installed by a licensed waste management contractor and regularly maintained.

- *Factory washdown*
  Washdown water from the factory area will pass to a grease trap prior to discharge to an absorption trench or lagoon system.

- *Used cooking brine*
  Spent cooking brine will be discharged to the discharge water channel.

- *Waste oil*
  Waste oil from vehicle maintenance will be collected and periodically disposed by a licensed waste management contractor.

- *General waste*
  General waste including hard rubbish and food scraps, will be temporarily stockpiled in an allocated area and either buried or disposed to municipal landfill in accordance with DLPE and Shire of Litchfield guidelines.

The proposed method for the disposal of diseased prawn stock is discussed in **Section 4.4**.

2.8 UTILITIES

Utility requirements of the project will include power and potable water.

An electricity supply will be required for pumps, aerators, processing and cool-rooms, the workshop, office and domestic consumption. Expected power consumption for Stage 1 development is detailed in **Table 9**.

Table 9

Stage 1: Expected Power Consumption

Item	Consumption		
	Average Daily (kw.hrs)	Average Monthly (kw.hrs)	Total Annual (kw.hrs)
Aerators	2,310	69,300	843,150
Pumps	1,125	33,750	410,625
Other	1,250	37,500	456,250
Total	**4,685**	**140,550**	**1,710,025**

During Stage 1 diesel powered generators will be installed for all power requirements. These will be situated between the workshop and the production ponds, with overhead wiring to all fixtures. Connection to the electricity grid is planned some time after Stage 1 is operational.

Expected power consumption for Stage 2 development is detailed in **Table 10**.

Table 10

Stage 2: Expected Power Consumption

Item	Consumption		
	Average Daily (kw.hrs)	Average Monthly (kw.hrs)	Total Annual (kw.hrs)
Aerators	9,840	295,200	3,591,600
Pumps	4,800	144,000	1,752,000
Other	5,325	159,750	1,943,625
Total	**19,965**	**598,950**	**7,287,225**

Diesel will be stored on-site in three 55,000 L above ground fuel tanks, which will be located within a concrete bunded area. The configuration of the storage tanks is presented in **Figure 14**.

Potable water will be required for domestic purposes, drinking, cooking and ice making. Potable water will be sourced from groundwater. Test bores will be drilled along the ridge adjacent to the access road within the leasehold area until a suitable supply is located. Detail of the potential groundwater supply is provided in **Section 3.6.2**.

2.9 STAFFING

The operation of the aquaculture farm will require both permanent and casual personnel. Stage 1 operations will require nine to twelve permanent personnel (including managerial and security staff) and 60-hours per week of casual labour. Additionally, approximately nine personnel will be required on harvest days for cooking and packing operations. The limitations of access via Middle Arm Boat Ramp Road (**Section 2.5.9**) will determine whether staff live on or off-site and will also determine the farm's ongoing organisation of supplies and services.

2.10 TRAFFIC

2.10.1 Construction Traffic

Traffic will primarily be limited to on-site movement of heavy machinery and other vehicles, most of which will remain within the lease area for the duration of the construction phase. As earth fill for construction will be sourced from within the lease area, there will be minimal construction traffic entering and leaving the lease area.

Traffic entering and leaving the lease area during the construction phase is largely expected to be limited to light vehicles for construction workers and site personnel. This traffic will access the lease area via Channel Island Road, left turn to Jenkins Road, right turn to Finn Road and right turn to Middle Arm Boat Ramp Road, to the lease area off this road. Alternate access, particularly after heavy rain is right turn off Cox Peninsula Road to Middle Arm Boat Ramp Road, to the lease area off this road. A limited volume of heavy vehicles will be required to transport construction machinery and materials to the development.

2.10.2 Operation Traffic

For Stage 1 development it is envisaged that approximately nine to twelve full time staff will be employed on the farm. Two staff will live permanently on the farm. Staff will access the lease area on an average of five days per week with an average occupancy rate of 1.5 persons per vehicle.

Casual employees will be required for cooking and packing at a rate of 1 person hour per 200 kg of production. The average duration of a casual shift is 5 hours, with an average occupancy rate of 2.5 persons per vehicle.

The farm produce (prawns) will be transported from the farm in lots of around 5 to 7 tonnes and an average of approximately one load per week will leave the farm. A light 4WD truck will be used for produce transport.

The main deliveries to the farm are prawn feed and diesel fuel. The requirement for diesel fuel will be reduced when the prawn farm is connected to the Northern Territory power grid. After connection to the power grid diesel use will be restricted to emergency electricity generation. Diesel will be stored on-site in three 55,000 L above ground fuel tanks. Sufficient diesel will be stored for up to 6 weeks of operation, reducing the requirement of fuel delivery during times when the access roads are difficult to negotiate following heavy rains.

Other deliveries will include small amounts of fertiliser, petrol and oils, packing boxes, machinery parts and miscellaneous farm supplies. These deliveries will often be conducted in conjunction with regular staff movement.

As the pond area is expanded (Stage 2) additional traffic will be generated for the farm's operation. Measures will be taken to reduce the amount of traffic over the Middle Arm Boat Ramp Road, including:

- Connection to Northern Territory power grid, reducing the amount of diesel deliveries.
- On-farm accommodation for staff.
- Use of mini buses to convey staff back and forward from town.
- Operation of school bus to Berry Springs/Palmerston for any children living on-site.
- Roster for shopping and supplies delivery to on-farm staff by off-farm staff.
- Possible transfer of cooking, packing and storing functions to a facility in Darwin.

Projected operation traffic movement on the Middle Arm Boat Ramp Road during Stage 1 and Stage 2 is detailed in **Table 11**.

Table 11

Estimated Operational Traffic, Middle Arm Boat Ramp Road

Road User	Vehicle Type	Comment	Round Trips per Month	
			Stage 1	**Stage 2**
Staff				
Permanent off-farm	Light passenger	Off–farm staff–transport to work.	90–130	380–550
Permanent on-farm	Light passenger	On–farm staff–transport to town.	24	102
Casual off-farm	Light passenger	Staff–transport to work.	9	38
Deliveries				
Farm produce transportation	Light truck (10 tonnes)		4	17
Prawn feed deliveries	Light truck (10 tonnes)	Occasionally back loads for produce deliveries.	6	25
Fuel deliveries	Fuel tanker		1.5	3
	Total Vehicle Movements	**- Per month** **- Per day**	**135 - 175** **4.5 –6**	**565 – 735** **18 – 24**

3. DESCRIPTION OF EXISTING ENVIRONMENT

This section describes the physical, biological and social environment in which the proposed project will be constructed and operated. The majority of the information presented in this section has been obtained by field survey of the lease area, review of readily available information and discussions with persons having specific knowledge of the region. It should be noted that due to timing constraints field surveys for flora, fauna and biting insects were conducted during the Wet Season only. Consequently the documentation of migratory or seasonally abundant species could not be undertaken.

The following report was previously prepared for the Blackmore River (East) Aquaculture Development and was reviewed as part of this assessment:

- Ullman & Nolan Pty Ltd, Blackmore East Aquaculture Project: Preliminary Geotechnical Investigation, 15 February 1996.

3.1 CLIMATE

The closest meteorological station to the development site with comprehensive climatic data is Darwin Airport, a distance of approximately 25 km to the north-west. The project area is within the monsoon tropics of Northern Australia and experiences two distinct seasons: the Wet Season from November to March: and the Dry Season from May to September. April and October are transition months between the Wet and Dry Seasons (Parkinson, 1996).

The distinct seasonality of the rainfall is the most distinguishing feature of the regional climate. There is a pre-Wet Season transitional period, commonly known as "the build up", during October and November. This period is characterised by thunderstorms occurring at irregular intervals prior to the onset of the more general rain systems associated with the monsoon trough during the Wet Season. Darwin has an average rainfall of 1702 mm (110 rainy days), most of which falls during the Wet Season (Darwin City Council, 1997). Humidity over this period averages 70-80 %. In the Dry Season humidity is often below 40 % and there is virtually no rainfall.

While the maximum temperatures are defined as hot all year round, November is the hottest month with a range of 25°C to 33°C. The lowest monthly temperatures are normally experienced in June and July, when the range is 19°C to 30°C. Darwin has a yearly average of 8.5 sunshine hours per day with the highest monthly average (10.2 hours per day) in August (Darwin City Council, 1997).

Prevailing winds during the Wet Season are light west to north-westerly, freshening in the afternoon due to sea breezes. In the Dry Season, the prevailing winds are the south-easterly trade winds (Parkinson, 1996).

The monsoonal tropics also experience cyclonic activity. The cyclone season in northern Australia extends from October to April (Darwin City Council, 1997). Tropical cyclones cause most damage within a distance of 50 km from the coast. Once a cyclone has passed onto landfall it weakens rapidly, but resultant storm surge can be of concern to coastal developments and flood damage can result from associated squally rains.

Monthly evaporation and precipitation for the Darwin Meteorological Station are presented in **Appendix E**. Values for monthly precipitation (ram) at Darwin Airport are presented in **Table 12**.

Table 12

Monthly & Annual Precipitation and Evaporation (ram) - Darwin Airport

Monthly Precipitation (mm)													
	Jan	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Highest	940	815	1014	357	299	41	10	84	130	339	371	665	2777
Lowest	136	103	88	1	0	0	0	0	0	0	17	19	1025
Mean	428	347	322	99	21	1	1	6	16	72	142	250	1702
Median	389	330	289	78	3	0	0	0	7	54	141	215	1684
Records (yr)	59	59	59	59	59	59	59	59	59	58	58	58	58
Monthly Evaporation (mm)													
Highest	257	273	233	255	260	249	276	338	291	313	303	276	2976
Lowest	161	112	152	156	174	171	189	164	201	217	198	174	2460
Mean	208	186	192	207	223	213	226	239	246	264	237	220	2712
Median	205	189	192	204	223	213	223	236	243	260	237	226	2712
Records (yr)	35	38	34	32	35	34	34	33	33	34	34	36	31

3.2 OCEANOGRAPHY

3.2.1 Regional Tides

The lease area lies within Darwin Harbour. Tidal levels (AHD) and relative to Lowest Astronomical Tide (LAT) at Darwin are presented in **Table 13**.

Table 13

Tide Data – Darwin

Tide	**Australian Height Datum AHD (m)**	**Relative to Lowest Astronomical Tide LAT (m)**
Highest Astronomical Tide	3.9	8.0
Mean High Water Spring	2.8	6.9
Mean High Water Neap	0.9	5.0
Mean Sea Level	0	4.1
Mean Low Water Neap	-0.9	3.2
Mean Low Water Spring	-2.8	1.3

In the Darwin region, AHD is equivalent to Mean Sea Level (4.1m above LAT). Therefore, for example, the Highest Astronomical Tide of 8.0 m above LAT is equivalent to a level of 3.9m AHD. Tide Charts are presented in LAT whereas Peak Sea Level Predictions used for construction design are presented in AHD.

Tides are predominantly semidiurnal (two high waters and two low waters per day), with a slight inequality between tides during a single day. Tidal amplitudes are greatest during equinoctial tides in May and November/December, when the tidal range can reach 8.0 m (Department of Defence 2001).

3.2.2 Cyclone Effects

Between November and April tropical depressions, which may develop into cyclones, pass through the Darwin region, usually in a west to south-west direction but in southerly or easterly directions infrequently (for example, Cyclone Tracy, 1974). Surface wind stress, lowered atmospheric pressure and wave set-up combine to elevate sea levels during the passage of a cyclone.

3.3 TOPOGRAPHY

The proposed Blackmore River (East) Aquaculture development encompasses the following land terrain units:

- Undulating rises and gentle slopes.
- Gently undulating upland surfaces.
- Gently undulating lower slopes.
- Alluvial plains and drainage lines/minor levees.

The 'undulating rises and gentle slopes' terrain unit occurs across the majority of the lease area and includes:

- Low rounded hills, slopes of 0 – 4 %, shallow gravelly lithosols, Eucalypt open woodland to mixed woodland.
- Gentle sideslopes, slopes of 2 – 5 %, moderately deep, gravelly, yellow massive earths, Eucalypt open woodland to woodland.

The 'gently undulating upland surfaces' terrain unit occurs in a thin strip at the north-east of the lease area, and includes flat to gently undulating upland surface, slopes of 1 – 3 %, shallow, very gravelly, yellow massive earths and mixed Eucalypt woodland to open woodland.

The 'gently undulating lower slopes' terrain unit occurs along minor streams and includes gentle lower slopes of 0.5 - 1.5 %, slow drainage, deep mottled lateritic grey earths and *Eucalypt* open woodland to mixed species woodland.

The 'alluvial plains and drainage lines/minor levees' terrain unit occurs along major streams in the area of the proposed Stage 2 freshwater dam and includes:

- Narrow upland alluvial plains, slopes of <1%, hard apedal mottled yellow duplex soils, grassland with scattered trees.
- Drainage lines, incised within upland terrain, slopes of <1%, mottled grey earths and hard mottled yellow duplex soils, mixed open woodland to open shrubland.

3.4 GEOLOGY

The Bynoe 1:100,000 Geological Map Sheet issued by the Department of Mines and Energy (1986) indicates that the Blackmore River is underlain by meta-sediments of the Early Proterozoic Finniss River Group, which generally consists of shale, siltstone, sandstone, greywacke, schist and gneiss.
The Finniss River Group was deposited by turbidity currents in a submarine fan environment. The

member of the Finniss River Group present beneath the lease area is the Burrell Creek Formation. Borehole data (Ref Nos: 279, 287, 280) from drilling conducted approximately 1.5 km to the east of the lease area by the Department of Defence (DoD) in 1944 (compiled by DLPE) indicate the area to be generally underlain by 'slate'.

3.5 SOILS

3.5.1 Soil Types

The Bynoe 1:100,000 Geological Map Sheet (DME 1986) indicates that:

- The majority of the lease area is underlain by unconsolidated sand, ferruginous, clayey, clayey and gravelly soil, common limonite pisolites, or pisolitic and mottled laterites, ferricrete, *in-situ* and reworked remnants of standard laterite profile.

- The lower lying mangrove areas to the west of the lease area are underlain by mud, clay and intertidal marine alluvium.

- The watercourses that drain the upper catchment are underlain by sand, shelly sand, coralline sand and cheniers.

Numerous outcropping quartz dykes exist across the lease area. In addition, there are small occurrences of outcropping shale, siltstone and phyllite, in places colour-banded, fine to very coarse sandstone, quartzite, quartz pebble conglomerate, minor graphic phyllite, quartz-mica schist and gneiss.

Borehole data at three locations 1.5 km to the east of the lease area (DoD 1944) was consistent with that depicted on the geological map for the area.

Preliminary investigative works undertaken by Ullman & Nolan (1996) included the excavation of nine test pits within the lease area. Laboratory testing of a limited number of soil samples was undertaken. A summary of the subsurface soils encountered in test pits completed is presented in **Table 14**, and the complete Ullman and Nolan report is included as **Appendix F**.

Table 14
Summary of Test Pit Logs
(Ullman & Nolan, 1996)

Test Pit	Depth (m)	Material
Production Pond Area		
TP1	0.00-0.45	Silty SAND
	0.45-1.90	Clayey Gravelly SAND
TP2	0.00-0.45	Sandy Silty GRAVEL
	0.45-2.15	Sandy Clayey GRAVEL
TP3	0.00-0.30	Silty Gravelly SAND
	0.30-0.60	Sandy Clayey GRAVEL
	0.60-1.90	Sandy Clayey GRAVEL

Table 14 (continued)

Test Pit	Depth (m)	Material
TP4	0.00-0.20	Silty SAND
	0.20-2.00	Sandy Clayey GRAVEL
	0.70-1.50	Sandy Clayey GRAVEL
TP5	0.0-0.50	Silty Gravelly SAND
	0.50-2.10	Clayey SAND
TP6	0.00-0.20	Clayey SAND
	0.20-0.50	Sandy CLAY
	0.50-1.70	Sandy Clayey GRAVEL
Freshwater Dam Wall (Stage 2)		
TP7	0.00-0.30	Clayey Gravelly SAND
	0.30-2.80	Sandy Clayey GRAVEL
TP8	0.00-0.60	Clayey SAND
	0.60-0.90	Gravelly Sandy CLAY
	0.90-1.80	Clayey SAND
	1.80-3.40	Silty CLAY
TP9	0.00-0.50	Clayey SAND
	0.50-1.30	Gravelly Sandy CLAY
	1.30-2.10	Clayey SAND
	2.10-3.30	Clayey Silty SAND

Cross sections indicating the inferred stratigraphy for the lease area are presented in **Figure 15**.

3.5.2 Acid Sulfate Soils

3.5.2.1 Background

Coastal sediments containing iron sulfides are widespread throughout the northern and eastern seaboard of Australia. The presence of sulfidic sediments, or acid sulfate soils as they are commonly known, have been recognised along the Australian coastline for the last thirty years. However acid sulfate soils have only recently become important in land use planning as the understanding of their potential environmental impact has developed. Thus, techniques for identifying, classifying and treating these sediments are still evolving.

The following terms are used within this report when referring to Acid Sulfate Soils:

- Acid Sulfate Soils (ASS) - this is a generic term that refers to any soil which has an actual and/or potential acidity;

- Potential Acid Sulfate Soils (PASS) - this term refers to a soil that has the potential to generate acid on oxidation, but which has not yet been oxidised. These soils do not pose a significant environmental risk if left in an unoxidised state and typically have a near neutral pH; and
- Actual Acid Sulfate Soils (AASS) - this term refers to ASS that has undergone oxidation and have therefore developed acidity. They typically have a pH less than 4.

Australian ASS is commonly found in Holocene sediments deposited within the past 11,000 years. ASS is generally found below 5 m AHD and may be deeply deposited and covered by other sediments. The ideal environment for development of ASS is in marine sediments in wetlands replenished by tidal flooding or in brackish estuaries. Thus soft, saturated, organic rich, marine clay sediments on coastal floodplains are common deposits of PASS. Pyrite is commonly formed from anaerobic decomposition of organic material in the presence of a source of sulfate (generally from seawater) and iron sourced from terrestrial sediments and is a source of potential acidity. Pyrite often accumulates heterogeneously, which leads to significant variability in sulfuric acid formation in soils that are superficially similar.

The oxidation of PASS releases sulfuric acid that can strip aluminium, iron and other heavy metals from soil. Both the sulfuric acid and the dissolved metals are readily leached to groundwater and transported to local waterways and estuaries with potentially significant environmental consequences.

Potential problems associated with acid sulfate soils derived from the release of harmful volumes of acid include:

- corrosion of steel and concrete structures;
- clogging of aquifers due to iron hydroxide precipitation; disease or death of aquatic life;
- leaching of heavy metals from the soil (especially aluminium); and
- human health risk due to increased aluminium concentrations in water and fish.

The rate of oxidation of exposed PASS depends on the rate at which oxygen can enter the soil. A broad characterisation of oxidation rates for PASS is as follows:

- In fine-grained soils (clays) which do not freely drain, oxidation can take prolonged periods. In *insitu* clay soils which oxidise primarily around old plant root channels and fissure planes the process can take from months to hundreds of years.
- In coarse grained soils (sands) where oxygen moves more rapidly into the soil, oxidation can occur rapidly, often within days, weeks or months. Although they may contain lesser quantities of pyrite overall, sandy soils pose a significant potential for environmental impact,

The magnitude and duration of effects from the oxidation and leaching of PASS depends on the amount of pyrite present in the soil, oxidation and leaching rates, the soil's inherent buffering capacity and other site-specific factors.

3.5.2.2 Impact of Acid Sulfate Soils

No testing for ASS was conducted as part of this PER. Only a small portion of the development area (approximately 1 ha) is underlain by marine clays, namely the proposed salt water supply channel embankment, extending to the jetty on the Blackmore River. It is considered that the mangrove clays in this area may contain ASS, similar to that evident in soils in similar geomorphological zones within the Darwin Harbour.

There will be minimal disturbance to the underlying marine clays as a result of construction of the salt water supply channel and jetty. As such, ASS are not considered a management issue for the Blackmore River (East) aquaculture development.

3.6 GROUNDWATER

The groundwater regime of the Blackmore River (East) Development comprises a near-surface seasonally effected groundwater table, and a deeper groundwater aquifer associated with the underlying Burrell Creek Formation.

3.6.1 Near-Surface Water Table

The weathered soil profile at the lease area can generally be expected to have a high permeability, which will readily facilitate recharge to a shallow watertable. Laterite profiles, which are typical of the area, include porous laterite at shallow depths that will readily accept water infiltration. The laterite profile typically absorbs groundwater recharge during the Wet Season and then gradually releases the stored water during the Dry Season as the water table slowly drains. Near-surface groundwater movement can be expected to flow from the higher ground at the east of the lease area towards Blackmore River.

As the porous laterite profile and the weathered soil profile become saturated, reserves of groundwater may be released in the form of seepage zones along the lower reaches of the hills. The release of groundwater in the form of seepage zones may continue into or through the Dry Season, depending on the storage capacities and release characteristics of the lateritic profile, and may supply base flow for minor freshwater streams into the Dry Season.

The near-surface water table at the lease area is not considered to comprise a significant extractable groundwater resource. Any near-surface groundwater can be expected to be of relatively low yield and be seasonably variable in both quantity and quality.

3.6.2 Burrell Creek Formation

The Burrell Creek Formation that underlies the lease area is generally impermeable, holding limited quantities of water in fractures of defined spatial and vertical extent.

Aquifer testing results from three bores drilled approximately 1.5 km to the east of the lease area (DoD 1944) is presented in **Table 15** and the complete groundwater drilling data is included as **Appendix G**.

Table 15
Aquifer Testing Results
(Department of Defence, 1944)

Bore	Depth intersected water (m)	Standing Water Level (SWL) (m)	Pump Test Yield (L/s)
RN 279	9.2	13.8	1.9
RN 287	-	21.3	<0.25
RN 280	24.4	15.2	2.1

The DLPE Natural Resources Division Provisional Groundwater Supply Prospects of the Litchfield Shire (February 2000) planning map, indicates that the Blackmore River (East) Aquaculture lease area lies within an area having a potential yield of less than 0.5 L/s.

A limited number of pump tests conducted by DLPE, inferred geology of the lease area and discussions with DLPE staff indicates that the occurrence of groundwater may be variable and of limited yield. Groundwater bores with yields of 0.5 L/s to 2.0 L/s may be located on the lease area.

Phelps/Panizza propose to obtain potable (eg. drinking, showering, septic), landscaping and factory production water requirements from the groundwater supply. Initial estimated water requirements include:

Potable Water	Stage 1 (250 L/person/day, 9 staff)	2,250 L/day
	Stage 2 (250 L/person/day, 40 staff)	10,000 L/day
Landscaping	Stage 2	35,000 L/day
Factory Production	Stage 2 (one day/week operation)	160,000 L/week

Factory production water will be required for one day a week, with the majority being supplied from a 100,000 L storage tank that will be progressively filled from the groundwater bores during the week. Multiple bores (minimum two) will be established to guarantee supply in the event of collapse or malfunction of the main supply groundwater bore.

The daily groundwater requirement for Stage 2 of the development is estimated at 70 kL. A groundwater bore with a sustainable yield of 2.0 L/s will provide a daily water supply of 170 kL/day. While the occurrence of sustainable groundwater in the Burrell Creek Formation is anticipated to be variable and of relatively low yield, it is expected that sufficient groundwater supplies will be available for domestic potable useage and possibly for landscaping and commercial requirements. Multiple bores may need to be installed to obtain sufficient reliable yields of groundwater.

3.7 SURFACE HYDROLOGY

3.7.1 Catchment Characteristics

The Blackmore River (East) Aquaculture Development is situated in a water catchment of approximately 2,255 ha. The catchment drains in a westerly direction across the lease area through tidal creeks and into Blackmore River. The catchment area and inferred drainage patterns across the lease area are presented in **Figure 16**.

The generation of stormwater run-off is seasonally dependent with minimal runoff occurring during the Dry Season and the early Wet Season, when the catchment will largely absorb the sporadic rainfall events. Runoff rates will be high during the Wet Season as the ground becomes saturated and the catchment will remain in parts largely waterlogged until the end of the Wet Season. Rainfall during the Wet Season is characterised by high intensity, short duration events that maximise overland flow.

The upper catchment to the east of the lease area encompasses gently sloping gradients through woodland habitats. The area will generally be responsive to stormwater runoff and is expected to have volumetric runoff coefficients between 0.3-0.4, increasing up to 0.9 for high intensity rainfall events during the Wet Season. The upper catchment is generally underlain by shallow soils over a lateritic profile. The laterite will absorb substantial volumes of water during the Wet Season and will release the groundwater during the Dry Season. No permanent freshwater watercourses have been observed on the lease area, however delayed near-surface groundwater release can be expected to contribute to catchment runoff during the late Wet and early Dry Seasons.

There is approximately 310 ha of tidally inundated low-lying land adjacent to the Blackmore River

within the catchment. The area is primarily covered in mangroves with minor salt flat areas adjacent to the boundary of the upper catchment. Tidal channels intersect the low-lying areas.

3.7.2 Hydrological Flow Patterns

Runoff across the elevated areas to the east of the lease area is anticipated to consist of sheet flow draining to minor streams. Inferred drainage characteristics are shown in Figure 16.

The low-lying tidally inundated areas adjacent to Blackmore River receive both saltwater tidal intrusion from the Blackmore River and freshwater drainage from the elevated eastern areas of the catchment.

Tidal inundation of the mangrove areas depends on the tide height and the network of tidal channels through the mangroves. During neap tides only the tidal channels will be inundated. However, during spring tides the tidal waters will inundate the mangrove area. There are small isolated areas of salt flats at the land side of the mangrove areas. The minor salt flat areas may be connected by small channels that will provide preferential movement of tidal waters.

The soils of the mangrove areas and the minor salt flats are typically of low permeability. The soils are generally saturated (from tidal inundation or Wet Season rainfall events) and may dry to a relatively shallow depth below ground level (generally less than 300 mm). Water movement through the mangrove/minor salt flat areas is therefore generally via sheet flow with minimal infiltration.

Freshwater runoff from rainfall events in the upper catchment will inundate the mangrove areas by one of the following mechanisms:

- Sheet flow from areas directly upslope of the mangrove areas.
- Stream flow accumulated in the upper catchment.

Stream flow is anticipated to be greater than 90 % of the freshwater contribution to the low lying mangrove areas. Stream flow from the surrounding catchment will generally be channeled directly into the existing tidal channels and subsequently into Blackmore River. The volume of freshwater that will enter the greater mangrove area is dependent on the following:

- Volume of sheet flow entering the mangrove area directly from adjacent slopes.
- Intensity, duration and sequence of rainfall events and the tide levels. This will determine the volume of freshwater stream flow that will either flow directly to Blackmore River through existing tidal channels or overflow the tidal channels and enter the greater mangrove area.
- Volume of direct rainfall onto the mangrove area.
- Infrequent backwater flooding from Blackmore River.

3.7.3 Watercourses

The following watercourses traverse or are adjacent to the proposed Blackmore River (East) Aquaculture Development:

Blackmore River

The Blackmore River runs along the western boundary of the lease area. All runoff from the lease area will drain to the Blackmore River through tributary tidal creeks.

Middle Creek

Middle Creek is the main tributary for the Blackmore River for the adjacent catchment area. Middle Creek includes a north and south arm. The north arm of Middle Creek is the proposed site for the exchange water discharge outlet and the south arm directly drains the catchment of the proposed Stage 2 dam.

Unnamed Tributary

An unnamed tributary of the Blackmore River collects runoff from the northern areas of the proposed aquaculture development.

3.8 SURFACE WATER QUALITY

On 4 December 2000 and 1 February 2001, surface water samples were collected from seven locations on the lease area and analysed to provide baseline water quality data. Locations sampled are presented in **Figure 17** and laboratory results are presented in **Appendix H**. The following testing was undertaken:

- *In-situ* analysis for physicochemical parameters (pH, salinity, electrical conductivity, turbidity and temperature).

- Laboratory analysis for phosphate (P), sulphate (S) and the metals, aluminium, antimony, arsenic, beryllium, cadmium, chromium, copper, iron (tot), lead, mercury, nickel, selenium, silver and zinc.

The majority of parameters tested were either not detected or were detected at concentrations less than their respective guideline levels (where available) as provided in the Australian Water Quality Guidelines for the Protection of Marine waters (ANZECC 1992). The concentrations of copper and zinc detected in some samples tested were equivalent to or slightly exceeded their respective guideline levels. A significantly elevated concentration of lead was detected in one of the samples tested (SW7: 73 ug/l, guideline level: 5 ug/l).

3.9 FLORA

Aerial photograph interpretation and field surveys were used to describe the vegetation of the lease area between November 2000 and January 2001. A total of 155 plant species from 57 different families were recorded during field surveys. A vegetation map is presented as **Figure 18a** and a full report of the vegetation survey, including methodology, is included as **Appendix I**.

Vegetation was noted to form complex spatial patterns principally determined by local variations in Dry Season moisture supply and Wet Season soil aeration. Vegetation within the proposed aquaculture lease appears to closely reflect the interplay of topography and soils and the influence of temporal fluctuations of salt and freshwater supply. Cyclonic storms and frequent fires also play a major role in determining overall vegetation types in the local area (Wilson & Bowman 1987).

Within the 796 ha lease area, approximately 99 % (794 ha) comprises terrestrial woodland habitats lying above the 4 m AHD contour. The remaining 1 % of the proposed development area (1.1 ha) is

vegetated by mixed and grassy open woodland, mangroves and saltflats. While little of the actual lease area is vegetated by mangroves, most of the eastern margin closely follows the mangrove fringe. The 4 m contour corresponds with the mangrove fringe and marks the upper limit of tidal inundation, reached only by the highest spring tides of around 7.8 m.

A description of the flora in each community within the proposed leasehold area is provided below.

3.9.1 Upland Communities

The majority of upland terrestrial vegetation within the study area comprises extensive *Eucalyptus*–dominated woodlands. The Eucalypt woodlands typically comprise a relatively sparse tree layer over a more or less continuous grass layer, a formation commonly known as "savanna". This vegetation type covers vast areas of northern Australia and the monsoonal tropics generally, where highly seasonal rainfall and annual fire result in the formation of savanna landscapes. Other species assume dominance in areas of higher soil moisture resulting in several distinct upland woodland communities.

3.9.1.1 Mixed Eucalypt woodland

The majority of the hinterland habitat supports *Eucalyptus*-dominated woodlands or open forest communities. The dominant upper stratum species is typically *Eucalyptus tetrodonta* (Darwin Stringybark), with canopy trees up to 10-15 m high. The dominant Eucalypt species varies with changing topographic conditions and associated variations in drainage and soil type. *Eucalyptus tetrodonta* open forests to 20 m high tend to occur in areas of deep, reddish soils with *Eucalyptus miniata* (Darwin Woollybutt) becoming co-dominant to dominant on shallower, yellowish soils of the low plateau surface. In rocky areas and on low crests *Eucalyptus bleeseri* may be locally abundant to dominant with *E. foelsheana, E. polycarpa* and *E. confertiflora* common in low-lying areas.

Common canopy-forming species throughout the upland woodland habitat include *Erythrophleum chlorostachys* (Ironwood) and *Eucalyptus tectifica.* A mid-stratum layer of mixed species, approximately 4-6 m high commonly includes *Planchonia careya, Terminalia ferdinandiana, Cochlospermum fraseri* and *Acacia* spp.

3.9.1.2 Open woodland communities

Open woodland communities dominate the lease area, covering 590 ha and are Eucalypt dominated. Communities are typically dominated by *Eucalyptus miniata* with *E. tetrodonta, E. foelsheana,* and *E. confertiflora* sometimes present.

The upper stratum is predominantly *Eucalyptus* species 8-14 m high over a sparse to medium density middle stratum. Plant species vary in dominance with varying topography, soils and drainage. Secondary tree species include *Buchanania obovata, Terminalia grandiflora, Planchonella pohlmaniana* and *Terminalia ferdinandiana*.

Mid stratum communities are mixed species from 2-8 m high, commonly including *Planchonia careya, Cycas armstrongii, Acacia* spp. and *Pandanas spiralis*. Communities closely reflect highly localised substrate and drainage variations. Rocky shallow soils support *Calytrix exstipulata* (Turkey Bush) and *Petalostigma quadriloculare*, while *Gardenia megasperma* and *Xanthostemon paradoxus* are commonly found on deeper soils. *Terminalia grandiflora* is a mid-stratum species common in poorly drained areas.

The understorey is dominated by dense grass and subshrub species such as *Petalostigma quadriloculare*. There is abundant Eucalypt regrowth from lignotubers, promoted by frequent fire events. Herbs (*Pachynema* sp., *Flemingia trifoliastrum* and *Tephrosia nematophylla*) and vines (*Ampelocissus* spp.) are sometimes locally abundant. *Sorghum* sp. is widespread throughout the lease area but introduced grasses are restricted to roadsides and disturbed areas.

Patches of low open woodland in which dense species of *Grevillea longicuspis* occur are also present in this community within the lease area.

3.9.1.3 Grassland

Grasses are a significant component of the understorey of upland woodland communities in the lease area. The majority of categorised grassland occurs along the mangrove fringe and species present must endure freshwater inundation and waterlogging for several months of the year. Common grasses in this zone include *Ischaeum australe, Imperata cylindrica, Germainia grandiflora, Heteropogan triteceus, Eriachne burkitti* and *Sorghum* spp. Sedges (*Fimbristylis* spp. and *Cyperus* spp.) are abundant in waterlogged areas.

Shrubs associated with these low-lying areas include *Grevillea pteridifolia, G. decurrens, Persoonia falcata, Livistonia humilis* and *Syzgium eucalyptoides* ssp. *bleeseri*. With the exception of *Melaleuca leucadendra* and *M. viridiflora, M. nervosa* and *Pandanus spiralis*, waterlogged conditions prevent the establishment of tree species. Where grassland intergrades with woodland habitats, *Erythrophleum chlorostachys*, *Eucalyptus polycarpa* and *Lophostemon lactifluus* become more common.

3.9.2 Drainage Areas

Drainage areas within the lease area include several distinct habitats that retain or carry water during the Wet Season. Transitional areas (between upland woodlands and lowland mangroves), drainage ways and narrow alluvial plains within upland areas are characterised by seasonal inundation and waterlogging. Drainage lines are typically surrounded by grassy open woodland areas and become waterlogged sometimes but are not prone to lengthy periods of inundation. Generally site drainage is slow with substrates containing clay at depth. Three main vegetation types have been identified in drainage areas: *Eucalyptus polycarpa* open woodland, mixed species woodland and riverine open woodland.

3.9.2.1 *Eucalyptus polycarpa* open woodland

Eucalyptus polycarpa-dominated open woodland typically fringes the main drainage lines and covers approximately 79 ha of the lease area. The tree layer is from 8-12 m high, sparse, and often intergrading with grassland communities. *E. polycarpa* is characteristically found in seasonally inundated alluvial flats and low areas with shallow soils.

Eucalyptus polycarpa is found commonly in transitional zones (between upland and lowland areas) often in association with *Lophostemon lactifluus* (Water gum). *L. lactifluus* is similarly well adapted to waterlogged conditions and can establish monospecific stands under conditions of prolonged seasonal inundation. Patches of *L. lactifluus* were found in alluvial basins and drainage ways, notably towards the eastern boundary of the lease area.

Associated tree species include *Melaleuca nervosa, M. leucadendra* and *Erythrophleum chlorostachys*. Medium to low trees and shrubs associated with this habitat are *Banksia dentata, Pandanus spiralis* and *Grevillea pteridifolia*.

3.9.2.2 Mixed species woodland

The mixed species woodland covers approximately 15 ha of the lease area, forming a broad band in the most upstream sections of the two drainage ways, roughly delineating the extent of the drainage basin.

The headwaters of two major drainage lines within the lease area are heavily vegetated with a mixed species woodland exposed to seasonal inundation and waterlogged soils. Species composition is variable, with dense monospecific stands of *Lophostemon lactifluus* intergrading with areas of *Eucalyptus papuana* (Ghost Gum) and *Erythrophleum chlorostachys* (Ironwood). Dense *L. lactifluus* woodland is present upstream of the high voltage power lines, extending upstream for approximately 500 m.

Monsoonal forest species are found scattered throughout the mixed woodland habitat, including *Ficus virens* (Banyan), *Canarium australianum* and *Alphitonia excelsa*. Mid-stratum layer is sparse or absent but may include species such as *Planchonia careya* and *Exocarpus latifolius*.

3.9.2.3 Riverine open woodland

Two small seasonal tributaries of Middle Creek (north arm and south arm) flow through the lease area and drain into the mangroves at the eastern bank of the Blackmore River. The south arm comprises two major incised channels 1-4 m deep, clearly delineated by dense riparian vegetation.

The riparian (creek bank) vegetation of these three drainage lines typically comprises *Syzygium armstrongii, Acacia auriculiformis, Melaleuca leucadendra, Lophostemon lactifluus, L. grandis* and *Eucalyptus polycarpa*, forming a band of trees 8-14 m high. The dense riparian community merges with sparser fringing vegetation, distinguished as riverine open community. This community, although not extensive, is distinct and was found to have the highest species richness of all defined communities.

Common mid-stratum species include *Pandanus spiralis, Antidesma ghasembila, Brachychiton megaphyllus, Dodonaea platyptera, Breynia cernua* and *Planchonia careya* with *Barringtonia acutangula* (Freshwater Mangrove), *Carallia brachiata* and *Timonius timon* on creek banks. A mid-

dense ground layer includes the subshrub *Petalostigma quariloculare* and vines such as *Tinospora smilacina, Ampelocissus spp.* and *Gymnanthera oblonga.*

3.9.3 Mangrove Communities

Mangrove vegetation is well developed along the coastline of Northern Australia with particularly extensive mangroves in sheltered embankments such as Bynoe and Darwin Harbours. In these areas, mangroves are notable for both their species diversity and extent, despite being relatively species-poor in comparison with terrestrial habitats. Thirty-eight of the forty-eight mangrove species known from the Northern Territory have been recorded in the Darwin region (Wightmann, 1989). Twenty-two mangrove and salt flat species were recorded within the project area.

Mangroves typically show distinct patterns of zonation particularly in areas of macrotidal range and low relief. Mangrove mapping for the DLPE regional mapping program indicates that the Blackmore River, its tributaries and numerous small tidal channels show distinct and predictable patterns of zonation with bands of species aligned roughly parallel to the shore.

The distribution of mangrove species and the predictable pattern of zonation of mangrove vegetation is primarily a result of the interplay of climatic and geomorphological factors, combined with the frequency of tidal inundation and the availability of freshwater. Consequently mangrove communities will have their own individual character, according to the specific local conditions, despite sharing similar basic species composition and zonation patterns.

Mangroves flanking the western boundary of the lease area are typical of upstream mangroves in Darwin Harbour. Two major mangrove zones, the tidal creek bank and tidal flat, have been identified fringing the eastern bank of the Blackmore River. Very little mangrove vegetation actually occurs within the lease area.

3.9.3.1 Tidal creek bank

The tidal creek bank zone is well developed along the main Blackmore River channel and extends along the banks of numerous smaller tributaries and tidal channels. Tidal creeks are generally narrow and steeply sloping, sensitive to erosion and bank slump. This zone is characterised by regular tidal flushing and supports a distinct mangrove assemblage including *Rhizophora stylosa, Camptostemon schultzii* and *Bruguiera parviflora*.

Closer to the proposed development area, minor tidal creeks are characterised by tall *Rhizophora stylosa* and occasional large *Avicennia marina* and *Camptostemon schultzii*. In the transitional zone between the tidal creek banks and tidal flats there is commonly dense stands of *Bruguiera parviflora* which gives way to *Bruguiera exaristata* in the tidal flat zone.

The tidal creek bank has been found to have the highest biomass and be most productive as measured by leaf litter fall (Woodroffe *et.* al 1988; Metcalfe, unpublished 1999).

3.9.3.2 Tidal flat

The tidal flat is the most extensive zone both within the Blackmore River system and along the regional coastal area. It is typically comprised of relatively monospecific closed forest of *Ceriops australis*, often 2-4 m high. Associated species include *Bruguiera exaristata*, scattered *Avicennia marina* and

Exoecaria ovalis. Although the tidal flats are extensive in area, they support very low biomass and low productivity (Woodroffe *et.* al 1988, Metcalfe, unpublished 1999).

Tidal flats typically include numerous hypersaline salt flats due to consolidated substrates that contain high proportions of sand and gravel. Salt flats are a prominent feature of northern Australian mangrove habitats (Semeniuk, 1985). Mangrove zones adjacent to the lease area encompass such salt flats, which due to their hypersaline conditions are generally devoid of vegetation, excepting algal films and patches of samphire.

The hinterland/tidal flat margin is thin and not extensive but can be quite diverse, especially in seepage zones or in areas with abundant seasonal freshwater runoff. *Lumnitzera racemosa* is characteristic of this zone, and is one of only few species that occurs almost exclusively above HWN (high water neap). This mangrove area lies closest to the proposed development.

3.9.4 Rainforest

3.9.4.1 Monsoon vine forest

There are no springs or areas of perennial freshwater (that typically support evergreen monsoon forest or rainforest species) in the lease area. An off-site small rocky hill area of dry rainforest is located within the mangroves, approximately 50 m north of the proposed saltwater supply channel (Figure 18). This hill supports a diverse, non-Eucalypt community with species characteristic of monsoon vine-forest habitats. A number of these 'hinterland islets' occur within Darwin Harbour mangroves (EcoSystems 1993), where the level of the terrain lies above the high tide mark (4 m AHD), creating suitable conditions for the development of coastal monsoon vine forest/thicket assemblages.

Such islets typically have high species richness (34 species were recorded during this survey), supporting abundant vines and mesophyll species not found in other upland woodland habitats. Unlike most of the landscape, these areas are well protected from fire, being completely surrounded by mangroves that do not burn. It follows that these areas may contain a high proportion of fire-sensitive rainforest species and occasionally plant species of botanical or conservation significance.

The dominant upper stratum species in this vine forest is *Brachychiton diversifolius* with *Acacia auriculiformis* and *Mimusops elengi* to 8 m high. Associated tree species include *Vitex glabrata* and *Strychnos lucida,* between 3 m and 5 m high. Common mid-stratum species include *Allophyllus cobbe, Premna acuminata, Canthium* sp., *Drypetes lasiogyna* and *Croton harbrophyllus*. Both evergreen and semi-deciduous species occur in this location. Abundant vines include *Flagellaria indica, Abrus precatorius* and *Adenia heterophylla*.

Habitat degradation in rainforests is common and is often due to disturbances from cyclones, human activity, feral animals and fire (Wilson and Bowman, 1987). However, this site appears to be relatively undisturbed except for the presence of the weed *Hyptis suaveolens* (Horehound).

3.9.5 Weeds

Overall, the flora survey of the lease area found the area to be in relatively natural condition and free from weed infestations. Four introduced species were recorded within the area, three of which are declared noxious weeds Class B; *Hyptis suaveolens* (Horehound), *Sida cordifolia (*Flannel Weed) and *Pennisetum polystachion* (Mission Grass). These species are common and widespread in the region. Within the lease area weeds were most abundant in riverine areas where naturally high soil moisture

levels and disturbance from seasonal flooding encourages weed proliferation. The tall grass *Pennisetum polystachion* (Mission Grass) occurred sporadically on road verges and *Hyptis suaveolens* was widely distributed throughout several habitats within the lease area.

It should be noted that noxious weed species common in the Darwin region were not evident in the lease area. Such weeds include *Lantana camara* (Lantana), *Mimosa pigra* (Prickly Mimosa), *Salvinia molesta* (Salvinia), *Senna alata* (Candlebush), *Leucaena leucocephala* (Coffee Bush), *Andropogon gayanus* (Gamba Grass), *Echinochloa polystachya* (Aleman Grass) and *Hymenachne amplexicaulis* (Olive Hymenachne).

3.9.6 Fire Regime

Similar to tropical savannas throughout the world, fire is an annual event in the landscape of Northern Australia, with up to 50 % of the region burnt each year (Williams, 1995). Consistent with this trend, field surveys of the lease area indicated a pattern of frequent, extensive burning with roughly 60 % of the lease area burnt during the 2000 Dry Season. Such a regime is not planned, but rather a consequence of the *ad hoc* land use and the prevalence of sporadic, deliberately lit fires in the Darwin region.

Fires lit by people visiting the area in the mid to late Dry Season can form large fronts, particularly when fanned by strong south-easterly winds. With little to stop them, such fires consume large tracts of natural vegetation. Intertidal areas do, however, present a definite barrier and consequently the lease area is well protected from the west where mangroves border the lease area.

3.9.7 Conservation Significance

The lease area is in a relatively undisturbed condition, with little physical disturbance and few weed species present. There is no significant degradation by either natural or anthropogenic means including grazing, weed invasion and clearing. There are no registered flora sites of conservation significance in the lease area identified in the Northern Territory Oil Spill Response Atlas, (DLPE 1999).

The conservation significance of vegetation in natural habitats can be considered on different levels (that is, at the level of the individual species, or the plant community) and at several different spatial scales (for example, local, regional or national).

3.9.7.1 Individual species with conservation significance

No endangered species were observed during field surveys, nor were any listed for the lease area.

Six species endemic to the Northern Territory were recorded within the lease area during the field work for the flora survey including, *Eucalyptus porrecta*, *Pachynema* spp. and *Livistona humilus*. These species do not have declared rare status.

Rare Species

Grevillea longicuspis (Holly Leaf Grevillea) occurs within the lease area (**Figure 18b**) and is considered rare, listed as 3RC (Leach *et*. Al, 1992). *G. longicuspis* is restricted in distribution, known only from the Darwin/Litchfield region, but is locally common within its range. This species is distinctive but poorly known. *G. longicuspis'* rare status may be an artifact of under collection.

Botanists from the Northern Territory Herbarium consider that this species no longer warrants rare status and new categorisation should reflect this. Additionally, *G. longicuspis* has been recorded in cleared and drainage areas, suggesting resilience to disturbance. However, its current rare status should still be acknowledged and respected.

Intermittent flooding to 14m AHD resulting from the proposed dam construction will impinge on the habitat of this species. It is anticipated that inundation from the dam will have a minor effect on the overall population, affecting approximately 5-10 % of the population in the local area.

A more comprehensive botanical survey would provide detailed information on the distribution of this species and the precise impact of the proposed development on the local population.

Protected species

Cycas armstrongii (Cycad), is a protected species that is commonly found in the mid stratum of open woodland communities in the lease area, growing to heights of 3-4 m. Although classified as protected this species is widespread and relatively common in the region.

The protected status of cycads prevents collection or removal from bushland unless part of lawful land use. Thus, although cycads are protected, with intrinsic ecological value, their presence does not preclude development in areas with appropriate approval or zoning. The presence of cycads within the proposed development area is unlikely to be of significance.

Undescribed Species

One undescribed species, *Notelaea* sp. nov. (Family: Oleaceae), was collected from within the proposed lease area, but this species, common in sandstone areas, does not have declared conservation status. It was collected from a small off-site rocky outcrop covered with dry rainforest on the western margin of the lease area. Approximately seven other collections of this plant have been made from the Darwin/Shoal Bay area. Its 'undescribed' status is most likely due to limited botanical focus in northern Australia (the Northern Territory and Kimberley region of Western Australia have been much less studied than southern Australia) rather than a case of rarity.

3.9.7.2 Plant communities of significance

A small off-site area of dry rainforest is located approximately 50 m north of the saltwater supply channel. Located within the mangroves, it is protected from fire and supports a diverse, non-Eucalypt community with species characteristic of monsoon vine-forest habitats. Although not within the bounds of the lease area, this rainforest community holds significant ecological value and should be protected from adverse effects of the proposed development.

An extensive and well-developed mangrove community borders the western edge of the lease area. The proposed aquaculture development is largely located within upland areas, impinging on mangrove areas only at locations for the salt water supply pump and the discharge water outlet. The development will impinge on approximately 1 ha of mangroves, representing roughly 0.02 % of the total Middle Arm mangroves. It is anticipated that the proposed development will have a negligible impact on the conservation values of mangrove vegetation in the area. Damage to mangroves including increased siltation from dam construction in adjacent habitats will be avoided.

3.9.7.3 Local conservation significance

The lease area encompasses extensive open woodland with some mangrove, grassland and rainforest habitats with minor drainage lines. The area is currently utilised by local people for off-road motorcycle riding, hunting, and fishing. Its recreational and tourist value is enhanced by its proximity to a major urban centre.

The mangroves of the Blackmore River could be considered to have intrinsic ecological significance at the local scale. The proposed aquaculture development will impinge on a small area of mangroves so is suspected to have minimal direct impact.

The area contains a diversity of habitats with intrinsic conservation significance that is difficult to quantify and sometimes not recognised. The high value of natural, undisturbed ecosystems is widely accepted and believed to greatly enhance our standard of living, contributing to clean air and water, biological diversity and environmental stability.

3.9.7.4 Regional conservation significance

The terrestrial vegetation communities within the proposed development area are typical of Eucalypt forests and woodlands of the Top End, comprising part of an extensive bioregion. Thus, in the regional context, the conservation value of terrestrial flora found on the lease area is not special. Further, 15.8 % of the bioregion is currently reserved predominantly for conservation purposes (Woinarski et al., 1996) so these woodland habitats are well represented in reserves elsewhere in the region.

An extensive and well developed mangrove community borders the western edge of the lease area. The mangroves of the Blackmore River, as part of the extensive Darwin Harbour system, are listed on the 'Directory of Important Wetlands' in Australia (ANCA 1997), but have no declared conservation significance at the regional or national scale. The mangroves of the Blackmore River system are in relatively pristine condition and are broadly similar to assemblages found on tidal rivers across the Top End. The species present and the general zonation patterns are relatively predictable in these tidal systems, although each has its own distinctive features. The proposed aquaculture development is largely located within upland areas, impinging on mangrove areas only at locations for the salt water supply pump and the discharge water outlet. The conservation significance of the mangroves of the Blackmore River should remain unaffected by the development.

3.10 TERRESTRIAL FAUNA

3.10.1 Studies Undertaken

The terrestrial fauna of the Phelps/Panizza project area was assessed through field surveys and reference to existing information on Darwin coastal areas. A detailed report of the fauna investigation, including methodology, is included as **Appendix J**.

The survey encompassed all major habitats occurring on the lease area and quantitative data was collected on fauna of the three broad habitat types, comprising upland communities, drainage areas and mangrove communities. Taxonomy and common name usage generally conformed to the following standard references: reptiles & amphibians - Cogger (1996); birds - Christidis & Boles (1994); and mammals - Strahan (1983).

3.10.2 Reptiles and Amphibians

Nine frog species were recorded during the field survey. Most species were found along the perennial streamlines within the dam area, although frogs were also commonly encountered in the other habitats. As heavy rains had fallen the week previous to the survey, standing water was present in the area, resulting in increased frog activity. Frogs were heard calling from freshwater soaks and creek lines at night.

The most common species encountered were Bicolor Tree Frog (*Litoria bicolour*), Floodplain Toadlet (*Uperoleia inundata*), Bilingual Froglet (*Crinia bilingua*) and Marbled Frog (*Limnodynastes convexiusculus*), all of which were recorded from two or more sites. Bicolor Tree Frogs were found in grassy situations throughout the woodlands and in sedges bordering the mangroves. Species such as *Litoria tornieri*, *Litoria pallida* and *Litoria inermis* were confined to the streams.

Eleven frog species are recorded in the NT Fauna Atlas (PWCNT 2000) for the area. All but one of the species observed during the field survey are listed in the Fauna Atlas.

A total of sixteen reptile species were recorded in the area, including fourteen lizards and two snakes. Small skinks of the genus *Carlia* were abundant throughout the area, with four species being recorded. The commonest species was *Carlia gracilis*, which was found along the streamlines. Northern Water Dragon (*Lophognathus temporalis*) and Merten's Water Monitor (*Varanus mertensi*) were present along the creeks, indicating the presence of semi-permanent aquatic habitats in these areas. Frilled Lizards (*Chlamydosaurus kingi*) were frequently encountered along the roads through woodland habitat.

In the drier, stony woodland habitat, *Carlia triacantha*, *Varanus scalaris* and *Ctenotus borealis* were encountered. Sand monitor (*Varanus panoptes*) diggings were evident in softer soils along the creek lines. The King Brown Snake (*Pseudechis australis*) and Common Tree Snake (*Dendrelaphus punctulatus*) were both observed in riverine areas.

Numerous other species are expected in the area, and the NT Fauna Atlas (PWCNT 2000) lists a further 32 species. Lizards such as the Northern Blue-tongue Skink (*Tiliqua scincoides*), Bynoe's Gecko (*Heteronotia binoei*) and Douglas's Skink (*Glaphromorphus douglasi*) are common in coastal areas near Darwin, as are snakes such as Children's Python (*Bothrochilus childreni*) and Black Whip Snake (*Demansia atra*). Most, if not all of the species listed in the Atlas could be expected to be present in the project area.

Few reptile species inhabit mangrove areas, although the Estuarine Crocodile (*Crocodylus porosus*) is fairly common in the Darwin Harbour estuaries. Four species of water snake are specialised to mangrove habitat and although they were not observed in the current study and do not appear on the NT Fauna Atlas (PWCNT 2000) list, they are very likely to occur in this area. These species are Bockadam (*Cerberus rhynchops*), White-bellied Mangrove Snake (*Fordonia leucobalia*), Richardson's Mangrove Snake (*Myron richardsoni*) and Little File Snake (*Acrochordus granulatus*).

3.10.3 Birds

A total of 49 bird species were recorded during field surveys. Of these, the greatest variety (26 species) was recorded in the woodlands at Site 2, followed by mangroves (22 species) and the woodlands and riverine habitats near the proposed dam (18 and 17 species, respectively).

The most abundant species overall was the Little Friarbird, which was recorded on 37% of all counts, and was recorded from three sites. Rainbow Bee-eater and Bar-shouldered Dove were also commonly

encountered. In the woodland habitats, Rainbow Bee-eater, Little Friarbird, Brown Honeyeater and Golden-headed Cisticola were commonly encountered. Along the streamlines Sulphur-crested Cockatoo, White-gaped Honeyeater, White-throated Honeyeater, Lemon-bellied Flycatcher and Northern Fantail were common. In the mangrove margins Bar-shouldered Dove, Little Friarbird, Helmeted Friarbird, Brown Honeyeater, Dusky Honeyeater, Red-headed Honeyeater and Black Butcherbird were most common. Overall, the mangrove habitat had the highest number of individual birds recorded.

Some bird species recorded in the mangroves are specialised to that habitat. These being Chestnut Rail, Red-headed Honeyeater, Black Butcherbird and Mangrove Golden Whistler. Most of the woodland and riverine birds are unspecialised forms, which are widely distributed in northern Australia.

As the survey was conducted during the Wet Season, it could be expected that if migratory waders were in the area they would have been encountered. As no habitats for wading birds were found, it is considered that the area is not important for migratory birds. The seaward mangrove fringe would provide feeding habitat for migratory waders at low tide. Dry Season species, such as the Fork-tailed Kite, were noticeably absent during the survey.

The NT Fauna Atlas (PWCNT 2000) records 178 bird species for the area. As the database records encompass habitats that are not present on the lease area, such as monsoon forest, freshwater swamp and perennial streams, many of the species listed would not be expected in the project area.

In general, the mangrove habitat appears to be the most important for birds because of the high quality and extensive nature of mangroves in the area. The presence of several specialist birds, such as Chestnut Rail are an indication of good mangrove habitat.

3.10.4 Mammals

Seventeen species of mammal were recorded in the survey, including three introduced species.

A total of 320 trap nights caught eight animals of four species. The Northern Quoll (*Dasyurus hallucatus*) was trapped in woodland and mangrove margins. Three individuals of this species were trapped, all of which were juveniles. One specimen of the Kakadu Dunnart (*Sminthopsis bindi*) was trapped in grassland along the creek near the proposed dam wall. Two rodents, the Grassland Melomys (*Melomys burtoni*) and the Western Chestnut Mouse (*Pseudomys nanus*) were trapped in woodland and creek habitats.

Northern Brown Bandicoots (*Isoodon macrourus*) are abundant in the project area, particularly along the creek lines and in the grassy areas of the mangrove margins. This species was observed several times during night surveys and its distinctive digging marks were obvious in most areas. Agile Wallaby (*Macropus agilis*) tracks were seen along the mangrove margins.

Seven species of microchiropteran bats were detected by Anabat calls. The most commonly recorded species in woodland habitats was the Northern Pipistrelle (*Pipistrellus westralis*), with seven sequences recorded. The Yellow-bellied Sheathtail-bat (*Saccolaimus flaviventris*) and Little Northern Freetail-bat (*Mormopterus loriae ridei*) were the least commonly recorded species, recorded from single sequences from the open woodland site. Gould's Wattled Bat (*Chalinolobus gouldii*) was recorded in the open woodland habitat.

Tracks of pigs and cattle were present in the wetter parts of the project area, especially along the mangrove margins. A feral cat was also seen along the mangrove margins in the north of the project area.

Twenty-five mammal species (including four introduced) are recorded from the region in the NT Fauna Atlas (PWCNT 2000). Most of these species could be expected to occur in the project area, although it should be noted that the Brush-tailed Tree Rat record is an historical record. This species no longer occurs in the Darwin area.

3.10.5 Conservation Values

Examination of international, national and state lists of threatened species indicate that there is little likelihood of any endangered species occurring in the project area. However, some species, which are known or considered likely to be present in the area, are of some conservation significance and these are described below.

The Partridge Pigeon is classified as Vulnerable (ANZECC 2000; Environment Australia 1999). Internationally, it has been listed in the lower "low risk, near threatened" category (IUCN 2000). Partridge pigeons were formerly widespread across northern Australia, but have suffered a recent decline in the southern parts of their range. Partridge Pigeons are regularly observed in the Berry Springs area and, although they were not recorded during the field surveys, there is a strong likelihood that they are found in woodland habitats in the project area.

The Bush Stone Curlew is listed by IUCN (2000) in the "low-risk, near threatened" category. It was observed during the surveys and is likely to be a resident of the project area. Stone curlews are susceptible to human disturbance.

The Northern Quoll is a species listed by IUCN (2000) in the "low-risk, near threatened" category. Northern Quolls have suffered a recent decline in populations across northern Australia. Three individuals, all juveniles, were trapped in woodland and mangrove margin habitats on the project area. The species is likely to be present throughout the area in moderate numbers.

A total of 44 vertebrate fauna species in the Top End Coastal bioregion have been considered rare or threatened (Connors et al 1996). Of these species, one bird (Partridge Pigeon) and five reptiles are classified as "insufficiently known" are common or expected to occur in the Blackmore River area. The reptiles include the Estuarine Crocodile (a management plan for which is active for Darwin Harbour), three mangrove snakes (Bockadam, Richardson's Mangrove Snake and the Port Darwin Sea-snake - all of which are expected to occur in the mangrove creeks adjacent to the project area), and a small monitor, *Varanus primordius* (known to occur in the Berry Springs area and suitable habitat is present on the project area).

None of the "Specially Protected" species listed under the Territory Parks and Wildlife Conservation Act 1997 are expected in the project area.

The Kakadu Dunnart, a small and poorly known carnivorous marsupial, was trapped during the fauna survey in a grassy situation along a small creek line near the proposed dam location. This species was only discovered in 1989, and was at first thought confined to the stony woodland habitats in Kakadu National Park Stage III. However, it has since been recorded in a number of other locations across the Top End, including Bradshaw Station, Gregory National Park, Litchfield National Park, Coomalie

Creek and the Humpty Doo area (NT Museum register). This species is probably sparsely distributed across the NT, and as it is known in several major conservation reserves its status is probably secure.

McKean & Martin (1986) identified mangrove birds found in Darwin Harbour such as Chestnut Rail, Large-tailed Nightjar, Little Kingfisher, Mangrove Golden Whistler, White-breasted Whistler, Little Shrike-thrush and Mangrove Fantail as being "rare", or of conservation significance. These species are either known or expected in the mangroves adjacent to the lease area.

Other than the mangroves, the area does not support specialist or significant habitats such as monsoon forest, paperbark swamp or wetlands. No significant breeding, roosting or feeding sites for fauna were discovered during the field surveys.

The habitats occurring on the project area are commonly found throughout the Darwin region, and on a local scale, are not regarded as significant for threatened fauna. However, the habitats do not appear to have suffered seriously from degradation by fire or feral animals and are in good condition.

The number and diversity of small mammals trapped in the limited time is an indication of high quality habitat. Feral animals, including pigs and cattle are in low numbers and no non-native rodents were found. Feral cats in the area may be a threat to native small mammal populations.

3.11 FISHERIES RESOURCES

Fisheries production in Northern Territory coastal waters is centred on a small number of species of high unit value, including barramundi (*Lates calcarifer*), prawns (*Penaeidae*) and mud crabs (*Scylla serrata*). These species are all either caught near mangroves or are associated with mangrove areas for significant parts of their life cycles. Production of barramundi and prawns in particular is likely to be very much dependent on conditions in the mangrove and coastal wetland environments (Griffin, 1984).

3.11.1 Barramundi

Barramundi is an important commercial and recreational species in the Northern Territory. The commercial fishery is restricted to inshore waters seaward of river mouths (except within Darwin Harbour and Shoal Bay, where it is excluded) while recreational fishing takes place over the entire range of habitats, although it is concentrated in freshwater and upper tidal waters (Pender & Griffin, 1996). Recent commercial landings of barramundi have been in the vicinity of 600 tonnes per annum, with the 1999/2000 catch worth an estimated $4.5 million (DPI&F, 2000).

Barramundi is the most targeted fish by recreational anglers in the Northern Territory (Coleman, 1998). Near Darwin, barramundi can be caught in the harbour arms, in the creeks and estuaries of Shoal Bay, at Leader's Creek and in Bynoe Harbour.

The life cycle of barramundi is generally known (Moore, 1982; Moore & Reynolds, 1982; Davis, 1985, 1986). Spawning occurs in marine areas at river mouths away from the major influence of fresh water runoff, where the water is relatively clear and the salinity appropriately high. The barramundi stock of Darwin Harbour probably spawn in the vicinity of Lee Point and Shoal Bay with the extensive wetlands fringing much of Shoal Bay providing most of the nursery swamp habitat (Griffin 2000).
Barramundi undergo a prolonged breeding season which starts just before the summer monsoon, with the onset of spawning apparently variable with geographic location. Davis (1985) found larval barramundi in Van Diemen Gulf (to the north-east of Darwin Harbour) from September through to

February. In Leanyer Swamp (outside of Darwin Harbour) the size distribution of larvae collected by Griffin (1985) indicated that, in 1984, significant spawning had occurred as early as August.

The eggs of barramundi are pelagic and hatch in less than 24 hours, therefore it is probably critical that the spawning area is located close to suitable nursery habitats or within the path of currents which will carry the eggs and larvae towards nursery habitats (Garrett, 1987). The nursery habitats occupied by barramundi through the first few months of life are primarily wetland areas at the interface of salt and fresh water, at or near the upper high tide level (Moore, 1982; Russell & Garrett, 1983; Davis, 1985; Griffin, 2000).

In the Darwin region, these supralittoral swamps generally occur where salt water reaches on tides greater than 7.3 m. These swamps are typically vegetated by seasonal plants including the salt water grasses such as *Sporobolus* sp. and various sedges such as *Eleocharis* spp. and *Schoenoplectus littoralis* (Griffin, 2000). While the sedge *Eleocharis* may occur in the grasslands at the upper tidal limit, no areas of supralittoral swamp habitat have been identified within the proposed aquaculture lease.

During the Dry Season the swamp plants are normally dormant and the landscape can have a somewhat barren appearance. When the Wet Season rains commence and the areas are inundated by very high tides the dormant plants rejuvenate and provide cover for aquatic life (Griffin, 2000).

During the late Dry Season or early Wet Season months (September to December) the high tides penetrate into the supralittoral swamps, bringing with them barramundi up to two weeks of age. In some areas, frequently at the very upper reaches of small tidal channels, the tide leaves behind shallow pools when it recedes. The small barramundi remaining in these pools prey upon the coexisting abundant insects, other fish and crustaceans (Makaira, 1999, Griffin, 2000). The pools are also the primary hatching and breeding areas for the saltmarsh mosquito, *Aedes vigilax*, and mosquito larvae probably form a substantial dietary component of small barramundi (Griffin, 2000).

As the Wet Season progresses the supralittoral swamps, which were initially only filled by tidal incursion, fill with fresh water and expand considerably in area, thereby increasing the habitat available to small barramundi. The swamps are very productive, providing barramundi with conditions for rapid growth and with shelter from predators. They also provide important habitat for the early stages of many other species of fish and also for crustaceans, including penaeid prawns. These, along with insects and frogs, form an integral part of the diet of young barramundi (Griffin, 2000).

Towards the end of the Wet Season, before the swamps dry out, the barramundi (up to 25cm long at this time) move out into adjacent rivers or creeks and usually migrate upstream into permanent fresh waters. The period of rapid growth in the supralittoral swamp habitat allows the young barramundi to more successfully compete and survive in the open estuary or river. Young barramundi (1–10cm in length) have rarely been located in large numbers outside of supralittoral swamp habitat, indicating that it may not only be advantageous for them to have access to swamp habitat, it may be essential if they are to flourish (Griffin, 2000). However, Pender & Griffin (1996) suggested that this life cycle may not be obligatory, as their studies provided strong indications that purely marine populations of barramundi may exist in areas remote from fresh water.
After leaving the supralittoral swamps, the barramundi move upstream as far as possible in their first year, generally remaining in the upper fresh water reaches of the rivers until they mature (Griffin, 1985). After three to four years, maturing fish move back to spawning areas adjacent to river mouths during the late Dry Season (Griffin 1987). Adult fish then remain in the estuarine or upper tidal sections of rivers (Davis, 1986; Makaira, 1999).

It is considered that the proposed aquaculture development has no potential to significantly impact upon the Darwin Harbour barramundi population.

3.11.2 Prawns

The fishery for penaeid prawns is the largest and most valuable of all the Northern Territory fisheries. The Northern Prawn Fishery extends from Cape Londonderry (north Kimberley coast, Western Australia) to Cape York, Queensland, and is managed by the Commonwealth through the Australian Fisheries Management Authority (AFMA). The estimated catch in 1999/2000 was 5,600 tonnes, with a production value of $107 million (AFMA website).

The main commercial species are white banana (*Fenneropenaeus merguiensis*), red-legged banana (*F. indicus*), brown tiger (*Penaeus esculentus*), grooved tiger (*P. semisulcatus*), blue endeavour (*Metapenaeus endeavouri*), and red endeavour (*M. ensis*). Units operating out of Darwin mainly target banana prawns, trawling mostly within 30 nautical miles of the coast (S. Bolton, AFMA, pers. comm.).

Banana prawns spawn offshore, with larvae moving inshore and entering the mouths of rivers on flood tides as post-larvae, mainly in November. The juvenile prawns remain in the rivers, where they are distributed according to salinity. When river salinities are decreased by rainfall at the commencement of the Wet Season, the prawns move towards the mouths of the rivers and into adjacent coastal waters (Staples, 1979, 1980a, 1980b; Vance et al., 1983).

It is not expected that the proposed aquaculture development will impact upon the prawn populations of Darwin Harbour. Water quality issues are discussed in **Section 4.6**, and disease management and stock containment in **Section 4.4**.

3.11.3 Mud Crabs

The mud crab fishery is the most valuable wild harvest commercial fishery managed by the Northern Territory. Recent annual commercial landings have been around 500-600 tonnes, with the 1999/2000 catch worth just under $10 million (DPI&F, 2000). The recreational catch in 1995 was estimated at around 50 tonnes. The majority of commercial activity is focussed in the Gulf of Carpentaria, while recreational activity is highest in the southern Gulf and in the vicinity of Darwin (DPI&F website).

The life cycle of the mud crab is similar to that of the banana prawn, with spawning taking place at sea and larvae moving inshore to settle in mangrove areas. Small shallow mangrove creeks provide important habitats for juvenile mud crabs (Hill, 1982). These habitats will experience very little disturbance during the construction and operation of the proposed aquaculture facility (**Section 4.2.1**).

3.12 MOSQUITOS AND OTHER BITING INSECTS

The Medical Entomology Branch of THS undertook an initial assessment of biting insects associated with the proposed Blackmore River (East) Aquaculture Project. Field survey works were undertaken over a three-day period in early December 2000. The potential biting midge breeding sites were assessed from aerial photographs using information on the biology of biting midges. An assessment of the actucal and potential mosquito breeding sites were made from aerial photographs, site inspection, field survey works and an evaluation of the proposed aquaculture development plans.

Outlined below are findings of the report titled *"Biting Insect Survey and Assessment, Blackmore River*

Prawn Farm, December to March 2000-2001" relating to the existing, undeveloped lease area. A complete copy of the report, including all figures, is included as **Appendix K**.

3.12.1 Mosquitoes

3.12.1.1 Species present

There are over 100 species of mosquitoes recorded in the Northern Territory. Over 60 have been recorded from Palmerston (Liehne et al. 1985). In the Fairway Waters study 39 species were recorded from carbon dioxide baited traps. The 17 species recorded in the current survey is a reflection of trapping over a small period when many species may be seasonally absent or not present in sufficient numbers to be recorded. The species recovered however include most of the common or most relevant pest and potential disease vectors in the Top End of the NT (Whelan 1988a).

Aedes vigilax and *Culex annulirostris* are the most important potential vectors and pests in the development area and are discussed below.

3.12.1.2 Breeding sites

Aedes vigilax

The topography of the coastal margin in the study area is relatively steep, with no extensive breeding areas of *Ae. Vigilax*, such as the large coastal marshes east of Darwin. However there were a number of potential productive breeding sites associated with the creek lines entering the mangrove margin, and disturbed areas at the mangrove margin. The most extensive and productive site will be the upper tidal section of the creek, down stream from the proposed fresh water dam. The other significant breeding site is located in an extensive *Eleocharis* reed habitat.

There is also likely to be smaller, localized breeding sites around the mangrove margin. The smaller breeding sites will be relatively small depressions, vehicle disturbed areas or small drainage lines at the upper high tide mark. Brackish water reeds or salt tolerant grasses indicate small depressions at the end of drainage lines. Other breeding sites will be in residual pools in the beds of the larger creek lines that are flooded only by the highest tides of the month in the late Dry Season. Any disturbance of the mangrove landward margin that creates tidal pooling will produce additional breeding sites.

Culex annulirostris

Potential breeding sites include the seasonally rain flooded low lying areas around the mangrove margin and small creeks, as well as the seasonally flooded grass floodways associated with the two arms of the largest creek. These creeks are relatively well defined and well drained, and do not contain any large areas of persistent or perennial swamps. They are intermittent and cease flowing soon after the Wet Season. The present *Cx. annulirostris* productivity of these sites appears limited.

3.12.1.3 Seasonal abundance

Aedes vigilax is a major pest species in the Palmerston and Darwin South area, where the coastal topography is similar to that of the lease area. This species is likely to be most abundant in the late Dry Season and the early Wet Season (August to January). Generally the numbers increase after each succeeding spring tide from August to December and reach their highest numbers after the early heavy rains in December or January. The pattern and levels of abundance can vary from one year to another,

due to the variable height of the spring tides each year and the amount and timing of rain in relation to the tides.

Culex annulirostris

The topography of the lease area is similar to that of a previous study undertaken at the Weddell site near Elizabeth River, and hence the seasonal abundance pattern is expected to be similar. The Weddell pattern of abundance indicates seasonal breeding in temporary Wet Season filled depressions, followed by breeding in longer lasting creeks and floodways as grass growth and receding water levels hinder the impact of aquatic mosquito predators. Abundance is expected to increase coinciding with the start of the Wet Season, followed by a steady post Wet Season rise to a peak in July.
The highest numbers of *Cx. annulirostris* trapped in the western-most section of the lease area and on the power line easement in the north-east corner. It is considered that floodways associated with flooded areas of grass, Paperbark and *Pandanus* are likely to provide mosquito breeding habitats in the Wet Season. They are unlikely to be the sources of mosquitoes by the mid Dry Season in June or July, as they would either be dry or the water restricted to narrow channels, with fish populations limiting the number of mosquito larvae.

3.12.2 Biting Midges

3.12.2.1 Species present

Eight species of *Culicoides* were collected during this study. Thirty-three (33) species of *Culicoides* have been recorded in the Darwin area (A. Dyce pers. comm.) and nearer to the present study area there were 11 species recorded in the Weddell study (Whelan et al 1988). In the light of these previous collections, additional species are likely to be present in the lease area. However they are not likely to include any additional species that will pose a significant human pest problem for this development.

C. ornatus, collected during this study, is by far the main potential human pest species of biting midge in the Top End of the Northern Territory. This is the species that is most likely to cause a pest problem in this area.

It is possible that both *Culicoides flumineus* and *C. immaculatus*? could exist in relatively high numbers within the nearby mangroves. They could pose pest problems for development immediately adjacent to or inside extensive mangrove areas. However, as these two species very rarely occur in high numbers outside of mangrove areas, they will not be of pest importance in most of the proposed development area.

Culicoides undescribed species (Ornatus gp.) No. 6, while occurring in very high numbers in other areas of Darwin Harbour, rarely bites humans, and is not likely to pose any problems at the proposed development.

3.12.2.2 Breeding sites

In the proposed development area, the main *C. ornatus* Dry Season breeding sites are likely to be on the small tidal branches of Blackmore River, particularly the tributaries nearest to the Middle Arm boat ramp and the proposed salt water pump jetty. Breeding sites also include the extensive mangrove tributaries further north and on the opposite side of the Blackmore River. The frontal *Sonneratia* zone along the Blackmore River is also a probable *C. ornatus* breeding site. The back edge of the mangroves around the Blackmore River mangrove margin would offer significant Wet Season breeding sites.

This evaluation is supported by the current trapping results, which confirm that a major breeding site for *C. ornatus* is present in the vicinity the vicinity of the Blackmore River boat ramp. However relatively high numbers were present at all other sites, indicating that there are appreciable breeding sites around the entire mangrove margin of the development.

Culicoides flumineus and *C. immaculatus*? are thought to breed inside the mangroves in the neap tide zone with the adults not dispersing far from the mangroves (M. Shivas pers. comm.). *Culicoides immaculatus* ? appears to be more common in the lower reaches of larger creeks and hence breeding sites are probably present in the larger creek south of the pond development and relatively close to the saltwater pump jetty.

3.12.2.3 Spatial abundance and dispersal

The highest collections of *Culicoides ornatus* in the study area were from the vicinity of the Blackmore River boat ramp and nearest to the most extensive dendritic area of mangroves north of the boat ramp, and at the head of the tidal creek in the western-most portion of the lease area. Other relatively high numbers occurred at the tidal headwaters of the other mangrove creeks in the area. The high numbers of midges recorded near the proposed residence on the slope of the escarpment facing Blackmore River boat ramp, indicates that the midges recorded at in the mangrove fringe are capable of dispersing in high numbers in a broad area into the northern section of the development.

3.13 ARCHAEOLOGY

3.13.1 Ethnographic Background

Blackmore River falls within the traditional territory of the Larrakia people (Tindale, 1974). The tribal boundaries of this group apparently extended from the Finniss River and Fogg Bay in the south-west to Middle Arm, Darwin Harbour in the north-east.

The Larrakia people were heavily dependent on marine resources such as fish, crabs, and shellfish (Foelsche, 1881; Curr, 1886; Basedow, 1907). Dugout canoes were used to hunt large marine animals including turtle, dugong and crocodile (Brown, 1906). Parkhouse (1895) mentioned that beaches were favoured places for camping and such places were likely to contain midden deposits.

Permanent sources of freshwater, particularly waterholes, were important camping areas for the inhabitants of the region (Foelsche, 1881). Ducks, geese, crustaceans and water lilies were obtained at waterholes, while kangaroos and wallabies could be ambushed on animal tracks leading to these features (Foelsche, 1881, Wildey, 1876). Fish were poisoned at waterholes through the use of the bark from certain trees (Foelsche, 1881; Curr, 1886). Other food resources included snakes, emus, lizards, roots, fruits, honey and insect larvae (Basedow, 1907, Foelsche, 1881; Curr, 1886; Wildey, 1876).

Documented items of material culture have included shells and sharp stones used for cutting and carving, red ochre, and ground stone hatchets (Foelsche, 1881; Curr, 1886). Small nets and bags were manufactured from tree bark fibre, while bark paintings, fighting sticks and message sticks have also been recorded. Large trumpet and bailer shells were used as drinking cups, water vessels and canoe bailers (Basedow, 1907). Spears included two pronged fishing spears, wooden spears with a carved barbed head, short reed spears and wooden spears tipped with a sharp stone spear head (Basedow, 1907).

Items of Larrakia material culture likely to be preserved in the archaeological record include stone

spearheads, stone hatchets and hearths made from stone or lumps of termites nest. Shell tools used for cutting and scraping activities and for pressure flaking stone may also be preserved (Foelsche, 1881, 1885; Basedow, 1907).

Foelsche (1881) recorded that the Larrakia buried their dead in shallow graves, and it is therefore possible that prehistoric skeletons may be found in sandy areas such as beach ridges adjacent to the coast. While the Larrakia are also known to have deposited their dead in tree burials (Wildey, 1876), archaeological remnants of such activities are less likely to have survived.
Ethnographic data highlights a number of elements within the landscape which appear to have been focal points for hunter-gatherers living in the Darwin region. As such, permanent sources of water and the coastline could be considered particularly likely to contain archaeological materials. In the Blackmore River area the coastline and the adjacent higher ground might be expected to be particularly archaeologically sensitive.

3.13.2 Archaeological Sites

Archaeological investigations of the project area were undertaken by Heritage Surveys in November 2000. The investigations included identification and assessment of the archaeological significance of all sites likely to be impacted by the proposed development. All identified archaeological sites are shown in **Figure 19**. A report on the findings of the investigations is included as **Appendix L**.

3.13.2.1 Previously Recorded Sites

A search of the Northern Territory Museum Site Register (now held by DLPE) revealed that no archaeological sites have previously been recorded within a 5 km radius of the proposed Blackmore River aquaculture lease area.

3.13.2.2 Archaeological surveys

A survey of the entire lease area was undertaken as part of the archaeological investigations. Across the study area as a whole, ground surface visibility ranged between 90% and 0% and was greater than 30% across approximately two thirds of the surveyed area. In general, ground surface visibility was lowest in the centre of the study area where vegetation had not been burned off for some time and a thick grass cover obscured the ground.

For the purposes of this survey an archaeological "site" was defined as a concentration of "artefactual materials with a high density relative to the background scatter of similar types of cultural debris at those or similar points in the landscape" (Hiscock 1995:3). In particular, clusters of shell and/or stone were defined as “sites” if the following criteria could be met (after Hiscock 1995:3):

- more than ten shells or artefacts;
- an area of at least 2m²; or
- an average density of artefacts or shells at least five times that of the background scatter.

A total of six archaeological sites, three shell scatters and three stone artefact scatters, were identified during the archaeological survey. The location and characteristics of these sites are summarised in **Table 16** and shown in Figure 19. The three shell scatters are distributed along the mangrove/hinterland boundary on the western side of the study area and the three artefact scatters are located close to watercourses in the study area’s south-east corner. All sites consisted of small, low density, surface

scatters of archaeological material. Each of the archaeological sites is described in greater detail in Appendix L.

Table 16

Characteristics of Archeological Sites in the Proposed Project Lease

Name	Type	Easting*	Northing*	Size (m)	Contents
BR1	Shell scatter	715012	8601234	15 x 10	Quartz flakes, *T. telescopium*
BR2	Shell scatter	714924	8601111	20 x 20	Quartz retouched flake, *T. telescopium*
BR3	Shell scatter	714710	8600833	70 x 10	T. telescopium, Nerita *sp*.
BR4	Artefact scatter	717101	8598924	50 x 5	Quartz flakes and cores, *T. telescopium*
BR5	Artefact scatter	718107	8598522	10 x 10	Quartz flakes and bifacial points
BR6	Artefact Scatter	717234	8599086	10 x 10	Quartz flakes

Note: * GPS reading, WGS84

In addition, a total of 60 isolated artefacts were identified during the archaeological survey (**Tables 17** and **18**). These included flakes, retouched flakes, cores, unifacial and bifacial points made almost exclusively from quartz, which as noted above, crops out extensively across the area. A single chert flake was also identified as part of the background scatter. Isolated artefacts were generally found either on the mangrove/hinterland boundary or along creek banks.

Table 17

Isolated Artefacts identified within the Study Area

Easting[1 & 2]	Northing[1 & 2]	Artefacts
715150	8601200	1 quartz flake
714850	8600200	6 quartz flakes, 1 quartz bifacial point
716100	8600300	2 quartz flakes, 1 quartz bifacial point
716250	8599250	4 quartz flakes, 2 quartz cores
717700	8599800	2 quartz flakes
716250	8598350	1 quartz flake, 1 quartz unifacial point
71750	8598700	7 quartz flakes, 1 quartz core

Table 17 (Continued)

716950	8598700	2 quartz cores
717200	8598850	6 quartz flakes, 2 quartz bifacial points
717400	8598600	1 chert flake, 1 quartz core, 3 quartz flakes
717500	8598550	8 quartz flakes, 2 quartz cores, 2 quartz retouched flakes
718150	8598350	1 quartz bifacial point
718400	8598400	2 quartz flakes, 1 quartz bifacial point

Notes: [1] GPS reading, WGS84

[2] Accuracy within 200 m radius

Table 18

Summary of Isolated Artefacts

Artefact type	Quartz (n)	Chert (n)	Total (n)	Total (%)
Flake	42	1	43	71.7
Retouched flake	2	0	2	3.3
Bifacial point	6	0	6	10
Unifacial point	1	0	1	1.7
Core	8	0	8	13.3
Total (n)	59	1	60	-
Total (%)	98.3	1.7	-	-

3.14 RECREATIONAL ACCESS

The lease area is used by the public for recreational purposes on an irregular basis. The main apparent use of the lease area, mainly around the mangrove fringe, is for off road motorcycle riding. Future access for off road motorcycle riding will not be possible.

Adjacent waters are used by recreational fisherman, who launch their boats from the Middle Arm boat ramp, which is approximately 2 km by road from the western boundary of the lease area. The project area is and will remain out of view of fishermen passing along the Blackmore River by craft. The pump jetty will be the only visible part of the farm from the river.

The lease area contains no permanent freshwater habitat, limiting the recreational use of the lease area for many activities.

4. ENVIRONMENTAL EFFECTS, ASSESSMENT AND MANAGEMENT

4.1 SYNTHESIS OF EFFECTS

The lease area is relatively undisturbed, with its main habitats in good condition. The area is relatively free of weed infestations and feral animals are present in low numbers. Only occasional recreational use of the lease area is made by members of the public. A synthesis of anticipated effects from construction and operation of the proposed aquaculture development is provided below.

Construction of the development will alter some components of the biophysical environment within the lease area. Significant surface soil disturbance will occur during construction of the production ponds, exchange water treatment ponds, saltwater channels and freshwater dams. Approximately 200 ha of vegetation will be cleared during Stage 1 construction works, with an additional 290 ha requiring clearing for Stage 2. No endangered plant species or plant communities of conservation significance have been recorded in the lease area. One species found within the lease area is listed as rare, however it is anticipated that the aquaculture development will have a minor effect on the overall population of this species. The development will result in minimal direct disturbance of mangrove populations.

There is likely to be a reduction in the frequency and intensity of fires within the lease area as a result of the proposed development and the fire management strategies employed.

Clearing works will result in loss of habitat for fauna within the lease area. It is unlikely that the lease area provides habitat for any endangered or 'specially protected' species. One mammal and two bird species identified in survey works are listed as 'low risk, near threatened' and five reptile species are classified as 'insufficiently known'. However, no significant breeding, roosting or feeding sites were recorded and the habitats present are well represented in the region. The development will not have a significant impact upon the Darwin Harbour barramundi population. There will be no impediment to barramundi movements and no loss of barramundi breeding grounds. The development is likely to result in an increase in the available breeding grounds for mosquitoes. Infrastructure design and management strategies will be employed to reduce this impact.

Areas within the freshwater dam, production ponds and exchange water treatment ponds will be inundated, replacing vegetation communities with marine and aquatic habitats. Currently there is no body of freshwater within the lease area. Construction of the freshwater dam will provide fauna with a permanent supply of fresh water and is likely to be colonised by a number of wildlife species.

The presence of the freshwater dam, and the walls of the production/treatment ponds will alter the surface water hydrology of the area. These changes may affect some of the vegetation communities and associated fauna within the lease area. Construction activities will result in minor alterations to tidal water flow. Alteration to the existing natural drainage characteristics of the lease area and the redirecting of rainfall runoff may lead to increased erosion which, if not managed, would increase the suspended solids content of runoff water released into the receiving environment. Management strategies will be adopted to prevent the occurrence of erosion and reduce sedimentation.

The exchange water treatment ponds will be designed to reduce suspended solids and nutrients generated during the production process. This will minimise the potential for impacts on the receiving environment, including vegetation and fauna communities, from release of the discharge water. Monitoring of discharge water quality will be undertaken on a regular basis.

Construction activities will not disturb significant deposits of ASS, and so no detrimental effect to downstream flora and fauna communities from acid runoff is expected.

Each of the six archaeological sites and many of the 60 isolated artefacts identified within the lease area will be destroyed as a result of construction activities. The archaeological significance of the archaeological sites was assessed to be low and Ministerial consent to disturb the sites will be sought.

Recreational access to the Blackmore River, other off-site waterways and the Middle Arm boat ramp will not be effected by the development. However, the public will not be permitted to access the lease area. This will limit the activities of off-road motorcycle riders who currently utilise the area on an occasional basis. Areas adjacent to the lease will still be available for motorcycle riding and the restriction is not expected to have a significant impact. Visual amenity as a result of vegetation clearing and construction activities is not expected to be significantly compromised.

A summary of potential impacts and environmental management and monitoring methods associated with the project is provided in **Table 19** and an outline of an Environmental Management Plan (EMP) for the development is included in **Section 5**.

Table 19

Environmental Effects and Management Register

Environmental Factor	Existing Environment	Potential Impact	Environmental Management	Predicted Outcome
BIOLOGICAL				
Vegetation clearing Refer Section 3.9 and 4.2	Extensive Eucalypt woodlands dominate the hinterland vegetation with open woodlands fringing a narrow riparian corridor along the seasonal drainage lines. Mangrove communities of the Blackmore River and its tributary creeks fringe the upland woodlands of the lease area. Narrow grasslands occur in the transitional area between the hinterland and the mangrove margin. No endangered plant species or special vegetation communities have been recorded in the lease area. However, several populations of Grevillea longicuspis, an endemic species of restricted distribution occurs in Open Woodland habitat within and adjacent to the lease area. The proposed production ponds will be located entirely within upland woodland habitat.	Loss during construction will result in clearing of: ~200 ha during Stage 1 ~290 ha during Stage 2	Farm layout designed to minimise loss of vegetation. Construction adjacent to mangrove areas will aim to protect intertidal areas from negative impacts including siltation and changes in drainage. Clearing within the freshwater dam will be selective and limited to those communities that will be permanently flooded to a level considered lethal to the trees. Trees fringing the upper levels of the dam will be retained to reduce disturbance and loss of habitat. Restriction of construction activities to specified areas. Movement of construction vehicles will be managed to ensure that tree loss is minimised. Should areas of the development be decommissioned appropriate vegetation will be reestablished.	Total loss due to clearing through to Stage 2 development: ~420 ha of eucalypt woodland; ~61 ha of drainage line communities; ~8 ha of grassland community; and ~1 ha of mangroves. The communities to be cleared are well represented elsewhere within the lease area and surrounding region. No significant adverse ecological impacts are anticipated.

Table 19 (continued)

Environmental Factor	Existing Environment	Potential Impact	Environmental Management	Predicted Outcome
Inundation of vegetation Refer Section 3.9 and 4.2	The proposed production and exchange water treatment ponds will be located within upland vegetation communities. Stage 1 freshwater dam will inundate riverine open woodland and associated drainage line communities and some Eucalyptus woodlands. Stage 2 freshwater dam will inundate riverine open woodland and associated drainage line communities and some mixed species woodlands. The Stage 2 dam will inundate Eucalyptus dominated open woodland, including limited areas with Grevillea longicuspis, a Darwin region endemic currently listed as rare. Tracts of similar habitat are present outside the southern boundary of the lease area.	Approximately 200 ha of vegetation will be effected by dams. Some areas of woodland not cleared prior to dam construction may be permanently or seasonally inundated.	Clearing for freshwater dam construction will be kept to the minimum necessary and fringing vegetation in the upper levels of the proposed dam will be retained. Similarly, clearing along the dam spillway will be selective and minimised to prevent erosion and habitat loss. Regular surveys of freshwater dams will be undertaken to control the introduction and spread of aquatic weeds. The staged approach to the development will enable an assessment of Stage 1 of development to be conducted prior to clearing and inundation of the Stage 2 freshwater dam.	If the development proceeds to Stage 2 approximately 200 ha of vegetation will be effected by seasonal and permanent inundation to 14 m AHD. Increased diversity of aquatic, semi-aquatic and fringing wetland plant species, including Melaleuca spp. and Lophostemon spp.
Indirect vegetation changes Refer Section 3.9 and 4.2	Mangrove communities fringe the estuarine creeks adjoining the lease area.	Changes to the pattern of drainage, seepage and sedimentation may lead to the loss of some trees within the mangrove fringe in the vicinity of the exchange water treatment dams and saltwater supply channel. Gradual shifts in species composition may also occur over time.	The saltwater supply channel and the wall of the exchange water treatment dams are designed to minimise impacts on natural hydrological and sedimentary regimes, especially within adjacent mangroves.	The transitional grassland communities will be most asffected (8 ha cleared). The hinterland margin of the mangroves may be effected by changes in drainage, but this community is well represented elsewhere within the surrounding region. No significant ecological impacts are anticipated.

Table 19 (continued)

Environmental Factor	Existing Environment	Potential Impact	Environmental Management	Predicted Outcome
Colonising native vegetation Refer Section 3.9 and 4.2	Mangrove communities occur between the Blackmore River and the hinterland along the alignment of the saltwater supply channel.	Mangrove seedlings can be expected to colonise the bund walls and mangrove growth may be encouraged downstream of the dam spillway. Increased waterlogging and possibly raised groundwater levels in the vicinity of the freshwater dams may encourage the expansion of paperbark and Lophostemon communities in this area. Native reeds such as Eleaocharis spp. may proliferate in the swampy areas created along the margins of the freshwater dams.	Growth of native species will be encouraged, except where this may exacerbate biting insect problems.	Minor, regionally insignificant, colonisation of parts of the lease area by native vegetation can be expected.
Weeds Refer Section 3.9 and 4.2	The lease area is free from large weed infestations. Four introduced species recorded, three of which are declared noxious weeds (Class B).	Clearing of native vegetation and terrain disturbance may create conditions favourable for the proliferation of weed species. The new and extensive freshwater aquatic habitats created by the freshwater dams may provide conditions suitable for the proliferation of aquatic and semi-aquatic weed species.	Weed management and prevention measures will include: • earthmoving equipment washed-down prior to entering the lease area during construction works to prevent spread of seeds; • rapid draw-down of water in the freshwater dam early in the Dry Season to discourage formation of semi-aquatic reed swamps along the dam margin; • selection of native species for the pasture production area and for landscaping around farm buildings; • weed removal from areas around farm buildings; • during the operational phase, off site vehicles will not be permitted to enter the site other than to park at designated parking bays outside the prawn farm; • slashing of fire breaks; and • annual weed surveys.	Management of weed issues will result in low risk of occurrence spread of weeds.

Table 19 (continued)

Environmental Factor	Existing Environment	Potential Impact	Environmental Management	Predicted Outcome
Fire regime Refer Section 3.9.5 and 4.9	Frequent, extensive burning of lease area and surrounds.	Reduction in frequency, timing and spread of fires.	A fire management plan will be developed, which will include: • fire break alignment and construction; • reduction of flammable fuel loads around farm infrastructure; • protection of fire-sensitive species and communities; and • promotion of habitat heterogeneity.	A shift in vegetation species composition may occur towards a more dense mid-stratum layer, possibly including fire-sensitive monsoon forest species. Frequency, timing and spread of fires will be reduced due to site access restrictions and construction of fire breaks. Habitat heterogeneity may increase due to protection of fire-sensitive vegetation.
Terrestrial fauna Refer Section 3.10 and 4.3	One mammal and two bird species listed as 'low risk, near threatened' and five reptile species classified as 'insufficiently known' were identified within the lease area. However, the lease area is not considered to contain significant sites for these species. No significant breeding, roosting or feeding sites have been recorded. Feral animals are present in low number in the lease area.	Removal of terrestrial fauna habitat. .	Feral animals will be managed on an 'as required' basis. Bird nets will be installed on the production ponds if water birds cause significant stock losses.	Vegetation clearing will reduce available terrestrial fauna habitats within the lease area. The freshwater dam may increase the extent of habitats favoured by fauna such as wading birds and frogs. Increased habitat heterogeneity through improved fire management practices may improve wildlife habitat quality. Loss of ~1 ha of mangrove habitat is likely to be insignificant to mangrove fauna, given the extensive area of similar habitat in the immediate vicinity.
Fisheries resources Refer Section 3.11 and 4.3	No supralittoral swamps (potential barramundi nursery habitat) have been identified within the lease area.	Minor disturbance to intertidal salt flats and mangrove creek banks during construction of the saltwater supply channel and exchange water discharge channel. Low potential for increases in nutrient levels or depletion in dissolved oxygen levels in Middle Creek due to exchange water discharge. Low potential for infection of wild prawn stocks by disease outbreaks.	Restriction of construction activities to the minimum required for construction of the channels. Treatment of exchange water to minimise nutrient loads and to return dissolved oxygen to background levels prior to discharge. Disease control management measures will be implemented to minimise the potential for significant impacts upon stocks of wild prawns and mud crabs.	No significant adverse impacts to fisheries resources are anticipated.

Table 19 (continued)

Environmental Factor	Existing Environment	Potential Impact	Environmental Management	Predicted Outcome
Biting insects Refer Section 3.12, 4.10 and 5.4.4	Significant numbers of mosquitoes and biting midges have been recorded. Areas where mangroves border brackish supralittoral swamps can become major mosquito breeding habitats during the late Dry and early Wet Seasons.	Mosquito breeding habitat may: increase along the shallow margins of the freshwater dam if growth of aquatic vegetation is enhanced; and/or decrease on the tidal flats to the west and south-west of the dam wall due to reduced seasonal fresh water flow The production ponds and exchange water treatment ponds are unlikely to provide suitable breeding habitats for biting insects.	Management of biting insect problems will include: • drainage designed to prevent ponding of water in low-lying areas; • native fish populations will be maintained in the freshwater dams to assist in control of larval mosquito numbers; • farm buildings positioned away from low-lying areas; • regular clearing of vegetation in vicinity of buildings; • clothing, repellants and antiseptic creams will be available to all personnel on site; • screening of staff facilities; and • staff induction.	Staff will receive adequate protection against biting insects.
PHYSICAL				
Soil erosion Refer Section 4.8.2	The existing hydrology of the site includes ongoing natural erosion and deposition processes.	Increased erosion associated with altering natural hydrological patterns.	The following measures will be adopted to minimise erosion: • all development will be undertaken in the Dry Season; • minor access roads will be formed so as not to impede or divert sheet flow drainage or channel drainage; • roads will be drained with side gutters and runoff drains; • embankments will be compacted and have a cover of lateritic gravel; and • channels will be lined with rock rip-rap.	Erosion will be minimised by the implementation of management measures. Some localised erosion may be expected as the natural hydrological patterns are reestablished. Current dynamic erosion patterns will continue.

Table 19 (continued)

Environmental Factor	Existing Environment	Potential Impact	Environmental Management	Predicted Outcome
Hydrological regime Refer Section 3.7 and 4.5	The existing hydrology of the site includes ongoing natural erosion and deposition processes.	Increased erosion associated with altering natural hydrological patterns	The following measures will be adopted to minimise hydrological changes: • scouring will be prevented through implementation of erosion control measures; • farm alignment/design will avoid interruption to tidal movement; • drainage channels will be constructed around buildings and stormwater will be directed towards natural drainage lines; • overflow from the freshwater dam spillway will be directed back into the natural channel; and • main farm infrastructure will be constructed above the 1 in 100 year peak combined sea level prediction for the area.	The freshwater dams will significantly alter the natural hydrological processes. There will be a limited impact on the natural hydrological processes by the construction of the remaining structures.
POLLUTION MANAGEMENT				
Dust generation Refer Section 4.8.4	The existing Middle Arm Boat Ramp Road generates significant dust during the Dry Season.	Farm traffic will increase dust generation along the Middle creek Boat Ramp Road and the site access roads.	Management procedures will be put in place to minimise the volumes of traffic generated from the aquaculture farm.	Minimal increase in dust generation from Stage 1 development. Moderate increase in dust generation from Stage 2 development.

Table 19 (continued)

Environmental Factor	Existing Environment	Potential Impact	Environmental Management	Predicted Outcome
Discharge water quality Refer Section 3.8, 4.6 and 5.4.1	No discharge waters are currently released into the environment at the site.	Water quality (nutrients, recreational)	Management procedures will be put in place to minimise the nutrient load of waste discharge water. Discharge water will be passively treated in pond(s) prior to release. Active treatment of discharge water will, if required, be implemented. Discharge water will be released on outgoing tides to maximise dilution. Stocking levels, water exchange, feed and aeration times will be determined with reference to water quality parameters. Accidental or unauthorised release of discharge water will be prevented by use of valve locks. Water quality monitoring of discharge water will be regularly undertaken.	Minimal impact on water quality of the Blackmore River system.

Table 19 (continued)

Environmental Factor	Existing Environment	Potential Impact	Environmental Management	Predicted Outcome
Waste disposal Refer Section 4.7	No waste is presently generated at the site.	The following general wastes will be produced on site: • sludge from the production ponds; • vehicle washdown water; • disinfectants and detergents from cooking and packing factory; • domestic sewage effluent; • diseased prawns; • used parts, sump oil, etc from farm machinery; and • domestic waste; Potential impacts include localised on-site contamination.	Sewage and domestic discharge water will be treated by septic systems designed in accordance with Territory Health guidelines. General waste material will be either buried onsite or disposed off-site. Sludge will not be transferred from the desalination bays to the pasture area until in-situ conductivity measurements indicate a sufficient reduction in salinity levels. A bund wall will be constructed to contain runoff from the pasture area. Tail water drains will be constructed to collect excess stormwater from the pasture area for diversion into the exchange water treatment ponds. A TIT will be installed to remove potentially oily discharge water from vehicle/plant wash-down Waste oil will be disposed off-site by a licenced waste management contractor.	No reduction in water quality from the domestic sewage effluent disposal systems. Minimal adverse effects on the ecosystem from the on-site operations and waste disposal.

Table 19 (continued)

Environmental Factor	Existing Environment	Potential Impact	Environmental Management	Predicted Outcome
Disease control and quarantine Refer Section 4.4	Present level of prawn related disease within wild stocks unknown.	Introduced diseases could cause total loss of crop. Movement of introduced diseases could damage wild prawn stocks.	Quarantine facilities will be utilised for new stock. Broodstock will be certified as 'disease-free' prior to transfer to growing ponds. Dead and diseased stock will be collected and buried with a heavy application of lime to increase decomposition. Stock escape will be prevented by pond design measures.	No adverse impact to wild stocks is anticipated.
SOCIAL ENVIRONMENT				
Sacred sites Refer Section 3.13 and 4.12	There are no identified sacred sites within the lease boundaries.	No impact.	No management required.	No adverse outcome
Heritage sites Refer Section 3.13 and 4.12	There are 6 archaeological sites that have been identified at the site. Sixty isolate artefacts were identified on the lease area.	All 6 archaeological sites will be destroyed as a result of the development, either through physical destruction or inundation. Isolated artefacts are likely to be destroyed/inundated.	Ministerial consent to destroy the 6 archaeological sites will be sought prior to construction activities. No management measures required.	Destruction of the 6 archaeological sites on the lease area. Each of the sites is considered to be of low archaeological significance.
Public access Refer Section 3.14 and 4.13	The lease area is currently accessed on an occasional basis by off-road motorcycle riders.	Loss of access	Boundary fencing will prevent public access to the lease area for recreational purposes.	Public access to the site for off-road motorcycle riding will be prevented. Areas adjacent to the property will remain available to motorcycle riders. The impact of access restrictions to recreational users is limited. The development will have no effect on access to the adjacent waterways by recreational fishers.

Table 19 (continued)

Environmental Factor	Existing Environment	Potential Impact	Environmental Management	Predicted Outcome
DECOMMISSIONING				
Site rehabilitation Refer Section 4.15	The site is currently relatively undisturbed.	The site is abandoned or partly decommissioned and not subsequently rehabilitated.	The rehabilitation program will include: • leveling of earthen structures; • removal of miscellaneous construction items; • revegetation of cleared areas, where practical; • feasibility study on potential to convert freshwater dam into a conservation area; • removal of buildings; and • regeneration of access roads.	If the site is abandoned or partly decommissioned project infrastructure will be cleared and disturbed areas revegetated.

4.2 FLORA

Of the 155 plant species recorded during the field vegetation survey, one species (*Grevillea longicuspis)* is listed as rare and of restricted distribution (Leach et al, 1992). This species is however, no longer considered by botanists of the NT Herbarium to warrant rare status, being locally common and well represented in several nature reserves in the region. Intermittent flooding to 14m AHD resulting from dam construction will impinge on the habitat for this species but it is anticipated that this will have a minor impact, potentially affecting approximately 5-10% of the population in the local area. A more comprehensive botanical survey would provide more detailed information on the distribution of this species and the predicted impact of the development on the local population.

One protected species (*Cycas armstrongii*) was identified within the lease area. Although classified as protected this species is widespread and relatively common in the region and their presence does not preclude development in areas with appropriate approval or zoning.

In the regional context, the proposed development area does not have special ecological or conservation significance. No plant communities of conservation significance or registered sites for flora are located within the lease area. The proposed aquaculture development will not affect any vegetation communities of special conservation significance. No rainforest communities and only very minor areas of mangrove vegetation will be cleared. The *Eucalyptus* woodlands and vegetation within drainage areas is widespread and well represented in conservation reserves elsewhere.

Although the flora of the area does not appear to have special local conservation significance, its value as a habitat and its proximity to Darwin confers considerable local significance in terms of its intrinsic ecological value as a habitat and its educational and recreational values.

4.2.1 Vegetation Clearing

Construction activities will involve clearing large areas of vegetation for farm facilities and linear tracts of vegetation along boundaries and firebreaks (**Figure 20**). The approximate area of land required to be cleared during construction is outlined in **Table 20**.

Table 20
Vegetation Clearing Requirements (ha)

Vegetation Unit	Stage 1	Stage 2	Total (ha)
Upland Communities			
Mixed Eucalypt Woodland	6	8	14
Open Woodland	177.9	228	405.9
Grassland	5	3	8
Drainage Areas			
E. polycarpa open woodland	9	24	33
Mixed species woodland	0	13	13
Riverine Open Woodland	1	14	15
Mangrove Communities			
Tidal Flat Zone	0.9	0	0.9
Tidal Creek Zone	0.2	0	0.2
Rainforest			
Monsoon Vine Thickets	0	0	0
Total (ha)	**200**	**290**	**490**

Vegetation cleared will be pushed into windrows and progressively burnt, minimising adverse effects on air quality in the immediate area.

The clearing of vegetation may lead to habitat degradation from the spread of weeds and erosion, which commonly results from terrain disturbance associated with clearing. The management and control of these issues is discussed in **Sections 4.2.4** and **4.8.2,** and the effects of construction and operation activities on specific vegetation communities is provided below.

4.2.1 Mangrove Communities

Mangrove communities in the lease area will be affected by the proposed development through localised clearing of approximately 1 ha of vegetation. Mangrove communities in and adjacent to the lease area may be indirectly affected by the development, through increased sedimentation (if uncontrolled), alterations to surface water and groundwater flow, and minor alterations in the tidal regime. Infrastructure design parameters will be implemented to minimise potential adverse impacts and a mangrove monitoring program is proposed (**Section 5.4.2)**.

4.2.1.1 Clearing

The clearing of mangroves will be confined to that area necessary for the establishment of required infrastructure for the proposed development. The Hinterland Margin Zone is a diverse and highly productive mangrove zone that is relatively limited in extent (Metcalfe 1999). Where possible, the mangroves bordering the hinterland will be avoided during construction.

Approximately 1 ha of mangroves will be cleared to enable the construction of the pump jetty and supply channel. The construction of channels leading to discharge outlets may also require clearing of a small area of mangroves (approximately 0.1 ha).

It is expected that the gently sloping batters of the supply channel will be rapidly colonised by mangroves.

4.2.1.2 Indirect impacts

Seasonal freshwater inflow and seepage to the mangrove fringe dilutes soil salinity levels and creates conditions more favourable for plant growth. The aquaculture development may result in a reduction of the amount of seasonal freshwater supply to some areas, potentially resulting in mangrove dieback in areas that were previously seepage zones, creek lines or where the exchange water dams have a significant effect on surface and groundwater flow. The supply channel alignment will avoid traversing and truncating any minor tidal channels to reduce interruption to surface water flow. Overland flow of freshwater from the freshwater dam spillway may promote the growth of mangroves in the area.

Construction of the supply channel, pump jetty and 20 ha of exchange water treatment dams (Stage 1) may have indirect impacts on adjacent mangroves. Minor changes in patterns of tidal inundation may result in a gradual shift in species composition over time and dieback can occur if sedimentation (resulting from construction or during operation) reduces aeration within plant root systems (Blasco et. *al,* 1996). To minimise the potential for adverse impact on mangroves:

- Vegetation clearing and construction of earthen bunds will be undertaken in a manner that will minimise the potential for erosion and hence sedimentation in runoff.

- The supply channel will be kept to the minimum width required and will be constructed in a raised embankment, such that the potential for exposure of underlying PASS will be minimised.

Erosion and sedimentation control measures are further detailed in Section 4.8.1.

Mangrove communities have been observed to thrive around prawn farm outlets (Foster & Robertson, 1999). Microbial, algal and macrophyte (large plants and trees) production have been found to increase in response to nutrient inputs (Foster and Robertson, 1999). Hanley and Caswell (1997) studied the impacts on mangroves of nutrient rich flows from sewage outfalls at Buffalo Creek, approximately 25 km to the north of the lease area. Increases in primary production were found in mangrove species monitored over a two-year period, though the increases were only significant during periods of high humidity and rainfall in the early Wet Season.

If nutrient discharges from pond effluent downstream of the proposed prawn farm, reached similar levels to sewage effluent in Buffalo Creek, the impacts on the biota are expected to be very similar. That is, mangrove productivity and growth would show seasonal increases. However, changes in diversity of invertebrate species, particularly crabs, could be expected (Hanley Caswell 1997), which may have associated impacts on mangrove vegetation. Crabs play a significant role in soil aeration, nutrient cycling and seed predation in mangrove areas and shifts in crab species diversity and abundance may have consequences for mangrove vegetation (Robertson 1991).

4.2.2 Woodland Communities

Clearing will be minimised for infrastructure development and fire protection. Predicted direct and indirect impacts on the flora of the survey area are discussed below.

4.2.2.1 Clearing

Clearing of vegetation will be necessary for construction of the production ponds, exchange water treatment pond, freshwater dam, farm buildings, housing, roads, the power plant and the establishment of a pasture area.

Construction of the of Stage 1 and Stage 2 production ponds will involve clearing of approximately 115 ha of *Eucalyptus*–dominated open woodland with minor areas of mixed species woodland associated with a small seasonal creek. The area to be cleared is quite substantial and represents a notable loss of habitat in the local area.

The Stage 1 freshwater dam is located on a small tributary that flows into the north arm of Middle Creek. Although the dam will cover a total area of 20 ha, the amount of clearing necessary will be somewhat less than this. The main vegetation communities affected will be riverine open woodland, which forms a linear corridor along the creek line, and the surrounding *E. polycarpa* open woodlands that fringe the creek.

Woodland vegetation, within a corridor approximately 100 m wide and 0.6 km long, will be affected by the construction and operation of the dam spillway. Vegetation clearing will be restricted to the centre of the spillway area and vegetation to either side and downstream will be retained.

Overall, the estimated maximum area of vegetation to be cleared for both Stage 1 and Stage 2 freshwater dams is 206 ha. Prior to dam construction, all vegetation along the lower levels of the impounded drainage lines will require clearing. In these areas the vegetation will be permanently

flooded to a depth considered lethal to the trees. The main vegetation types affected will be open woodland, *E. polycarpa* open woodland and riverine open woodland communities. These communities do not have special conservation significance. Much of the vegetation fringing the upper levels of both

freshwater dams (at around 13-15 m AHD) will probably be retained as it is expected to survive post-construction hydrological changes.

An area of 26 ha of terrestrial vegetation may be cleared for dryland sludge disposal and pasture production in Stage 2 of the project. The vegetation of this area is uniform open woodland with variable dominant species including *Eucalyptus miniata, E. tetrodonta* and *Erythrophleum chlorostachys.* Clearing of vegetation will be selective and kept to the minimum necessary for waste recycling for each stage of the development.

During Wet Seasons when the dam fills completely, the local water level will be raised to the 14 m contour, but it is unlikely that this level will be maintained for any longer than one to two months. In drier years, this water level may not be reached in the course of the Wet Season. As the Dry Season progresses, evaporation and draw down for operational use will result in a relatively rapid fall in water level to a base level at around 8 m AHD.

4.2.2.2 Indirect impacts

The Freshwater Dam

Environmental conditions created by dam construction are anticipated to take some time to stabilise. The initially unstable freshwater dam system could encourage the introduction and proliferation of exotic species and terrain disturbance arising from construction of the 1 km dam wall may create conditions suitable for woody weed introductions. Weed management is discussed in Section 4.2.4.

The freshwater dam will create different habitat opportunities for a variety of animal and plant species, by altering natural resources and adding a perennial water supply. Indeed, the dam may contribute to increased biodiversity in an area that currently contains little or no standing fresh water during the late Dry Season.

- *Upstream areas*

  In upstream areas, where existing vegetation may experience only intermittent periods of inundation to depths of several metres, it is likely that a good proportion of the existing vegetation, particularly the Paperbarks (*Melaleuca* spp.) will tolerate the new regime. *Melaleuca* species naturally occur in areas subject to extended seasonal inundation, lasting from 3 to 6 months or more depending on the season. They tolerate such conditions with water-repellent bark and aerial roots to aid aeration during lengthy periods of inundation.

  Upstream areas most affected by the Stage 2 freshwater dam will include the three main drainage area communities (**Section 3.9.2**), which occur along the two branches of the most southerly seasonal creek. Collectively they mainly comprise open woodland and woodland communities in which *Eucalyptus polycarpa, Melaleuca* spp. and *Lophostemon lactifluus* are common to abundant. In Eucalypt-dominated open woodland habitat, which requires well-drained substrates, tolerance of the vegetation to new groundwater conditions (flooding) is less likely.

  Flooding of upstream habitats is expected to have a significant impact on flora of the freshwater dam area. The impact will vary with the level of tolerance of each species to

  periodic waterlogging and altered ground water levels. An increase in water table level may have a negative impact on surrounding Eucalypt woodlands adapted to seasonal drought and rapidly draining substrates.

- *Downstream areas*

  Hydrological changes from freshwater dam construction may impact on downstream flora in several ways. Changes to the pattern of seepage from the hinterland, groundwater flows and surface runoff may alter the supply of water to downstream vegetation. Substantial diversion of seasonal freshwater flows by the dams may cause an increase in soil salinity and water stress in mangroves and brackish creek bank vegetation where previous water regimes diluted the water supply. Conversely, increases in the supply of freshwater, within spillway areas for example, will encourage the growth of downstream mangroves, sedges and wetland vegetation.

The Pasture Area

Sludge from the production ponds will be highly saline and rich in nutrients, particularly nitrogen and phosphorous. After desalinisation and spreading onto suitably prepared land, the sludge will be used to fertilize pasture species and recycle nutrients.

Native grass species and pasture species will be planted to biofilter the runoff from high nutrient sludge and to stabilise the substrate in cleared areas. The species selected for this purpose will be carefully chosen, excluding known environmental weeds.

The sludge disposal area will be adequately bunded to contain high salt/nutrient sediments. However, peak storm events may cause flooding which would potentially overflow these bunds. Tail water drains will be designed to collect excess stormwater from recycling areas for diversion into the exchange water treatment dams.

Other

Associated impacts on flora may result from broad changes in drainage and the potential for increased erosion and downstream sedimentation from clearing and terrain disturbance. However, the majority of the production pond area is well contained by bund walls, thus the potential for erosion and sedimentation to impact on surrounding vegetation both within and outside the project area is greatly minimised. Results of monitoring of the impacts of Stage 1 will be used to modify Stage 2 operations if required.

4.2.3 Other Impacts

Fire management measures employed on the lease area (**Section 4.9**) will result in a reduction in the frequency of widespread, high intensity fires. This will result in a gradual decrease in annual grasses such as *Sorghum* that provide abundant fuel for annual fires. Reduced fire frequency will also lead to shifts in species composition towards a denser mid-stratum layer that will most likely include fire-sensitive monsoon forest species (J Brock, pers. comm.). The grading of extensive linear corridors for fire breaks and trails may encourage the spread of weeds into areas where they were previously absent. Annual weed surveys will allow the identification of any spread of exotic grasses including *Pennisetum polystachion* and *Andropogon gayanus* and, if required, management measures will be employed to limit their proliferation.

Flooding of upstream habitats is expected to have a significant impact on the flora of the proposed freshwater dam areas. However, habitat creation may in fact ensue, with increases in natural resources from the extra water. Consequently new supplies of food and water will then be available to fauna. The freshwater dams are likely to be colonised by a number of wetland plant species and wildlife species, being particularly attractive to many wading birds and frogs. It is anticipated that environmental

conditions within the new wetland created by construction of the freshwater dam will take some time to stabilise and this potentially unbalanced freshwater ecosystem may encourage the introduction and spread of exotic species such as *Salvinia molesta*.

Native plant species such as the reed *Eleocharis* spp., *Melaleuca* spp., and *Lophostemon* may proliferate in the swampy areas along the margin of the dam. Seepage from the freshwater dam may provide an increased supply of freshwater to some downstream areas depending on volumes and direction of seepage. Increased seasonal freshwater supplies will increase the distribution of upper tidal flat mangroves, reeds and sedgeland.

Management commitments to control or minimise potential adverse effects that the project's construction and/or operation may have on vegetation are outlined below.

Vegetation Management (non-weed species)
Ponds, dams and infrastructure will be located such that areas to be cleared are minimised. **All dam walls will be constructed with the toe graded, and compacted to avoid smothering of mangrove pneumatophores in adjacent mangrove forests.** **The saltwater supply channel will be constructed in a raised embankment, such that the potential for exposure of underlying potential acid sulfate soils will be minimised.** **The saltwater supply channel will be constructed across contours to minimise disturbance to tidal flows and to reduce the likelihood of water ponding.** **Construction design measures to minimise the effects of erosion and sedimentation will be implemented.**

4.2.4 Weeds

Overall, the lease area is relatively free of weed infestations.

Terrain disturbance, clearing of native vegetation and nutrient enrichment of normally nutrient poor substrates could facilitate the proliferation of weed species. In particular, clearing linear tracts of vegetation for fire breaks and roads may lead to habitat degradation from erosion and the spread of weeds. The introduction of weeds could lead to environmental decline and loss of biodiversity through the exclusion of native plant species.
Of primary concern are the introduced grasses such as *Pennisetum polystachion, P. pedicellatum* (Mission Grass) and *Andropogon gayanus* (Gamba Grass). The floating aquatic fern, *Salvinia molesta,* could also become established in the freshwater dam area. Aquatic weed growth such as

Typha, will be minimised by the expected rapid draw down of water in the freshwater dams early in the Dry Season for production requirements, resulting in an unstable margin. Native species such as the reed *Schoenoplectus* sp. and *Eleocharis* spp. may also proliferate in the swampy areas of the freshwater dam margin.

A number of management strategies will be employed to minimise the potential for the establishment of new weed species. The following priorities will be adopted:

- prevention of weed introduction into intact natural habitats and areas disturbed by construction and operational activities; and
- minimisation of environmental changes that will encourage the spread and proliferation of non-native species.

These priorities will be achieved by adopting the following management commitments.

Weed Management
Weeds will be removed from areas around farm buildings and controlled in accordance with DPI&F requirements. **Heavy equipment to be used in earthmoving will be washed down prior to entering the lease area.** **When equipment is being used in areas with existing infestations, care will be taken not to spread seed to new areas, particularly for Class B species.** **Species for pasture production will be selected in consultation with Parks and Wildlife Commission of the Northern Territory and the DPI&F.** **Production usage will draw down the freshwater dam on a seasonal basis, discouraging growth of aquatic and semi aquatic species.** **Annual weed monitoring will be undertaken.**

4.3 FAUNA

4.3.1 Terrestrial Fauna

The proposed project would involve the clearing of approximately 490 ha of woodland habitat. This is a significant amount of habitat loss, which will result in the displacement of most fauna species occurring there. However, the lease area is not considered to be a significant area for fauna, and is not a significant habitat for any threatened species. The woodlands habitat which occurs on the project area is very widespread in the Darwin region.

No wildlife habitats or sites of high conservation importance, such as monsoon forest or wetlands, were found on the project area. The most important wildlife habitat in the area is the mangroves. Since the project is designed to minimise any loss of mangroves, there will be little direct impact on this habitat. Flow on effects, such as loss of freshwater input and nutrient rich discharges may affect

mangrove habitats at a local level, but these effects are not expected to be widespread, and thus terrestrial fauna inhabiting the mangroves would not be significantly affected.

The freshwater dam is likely to be colonised by a number of wildlife species. The dam would be attractive to many wading birds, and development of the dam would likely result in the enhancement of the area for water birds and frogs.

4.3.2 Marine Fauna

It is considered that the proposed aquaculture development has no potential to significantly impact upon the Darwin Harbour barramundi population. Griffin (2000) indicated that the Darwin Harbour barramundi stock probably spawn in the vicinity of Lee Point and Shoal Bay as there is very little suitable nursery habitat within the Darwin Harbour. No supralittoral swamps have been identified within the lease area. There will be minimal disturbance of the intertidal salt flats, over which barramundi may periodically feed. Exchange water discharges will be managed to minimise impacts on any barramundi that may be in the vicinity of the outflow during discharge events (**Section 4.6.2**) and the proposed development will not prevent the migration of barramundi into the upper fresh water reaches of rivers upstream from the lease area.

Disease control management will be used to minimise the potential for significant impacts upon stocks of wild prawns and mud crabs. Construction of the saltwater supply channels and the exchange water discharge ponds will be managed to minimise the physical impact upon wild prawn and mud crab habitat (**Sections 4.4** and **4.6.2**). Quality of the discharged exchange water will be managed to minimise the potential for significant impacts upon marine fauna in the receiving environment.

Hanley Caswell (1997) noted a decreased diversity and abundance of invertebrates downstream of nutrient rich flows from sewage outfalls at Buffalo Creek. Increased numbers of *Perisesarmid* crabs were noted and thought to be a consequence of algal growth encouraged by elevated nutrient levels as a result of the discharge of wastewater.

1. Fauna Management

Quality of water discharge from the treatment ponds will be monitored prior to release and appropriate mitigation/management measures employed to protect the receiving waters.

Disease control management measures will be implemented to minimise the potential for significant impacts upon stocks of wild prawns and mud crabs.

4.4 PRAWN STOCK - QUARANTINE, DISEASE MANAGEMENT AND CONTAINMENT

All post larvae will be purchased from hatcheries that can provide veterinarian certification of ‘disease free’ status. As an additional safeguard, quarantine facilities comprising large holding tanks (within a steel frame shed) will be utilised for the arrival of post-larvae to the farm. The post-larvae will be kept in the holding tanks for a period of five days whilst technical staff check them for disease. The water supplied to these ponds will be recirculated and the prawns, and associated water, will not be released until the prawns have tested as "disease-free".

Any dead stock, or stock suspected of being disease-carrying, will be removed and buried. The buried prawns will be heavily limed to increase decomposition.

All quarantine and disease control (including disposal of diseased stock) will be carried out in accordance with the Aquavet Plan (in preparation) prepared by the Ministerial Council on Forestry, Fisheries & Aquaculture.

Stock escape from the production ponds will be prevented by a pond wall freeboard of 0.5 m. Each pond will also be drained via a monk structure, which will be screened with suitable size mesh (matched to the size of the stock). The monk will be designed to ensure that stock do not escape during a maximum rainfall event. In addition, a screened structure will be constructed at the discharge point to hold the discharge back at certain times of the day, depending on the tide.

2. Disease and Stock Management

All post larvae will be purchased from hatcheries that can provide veterinarian certification of 'disease free' status.

Quarantine facilities will be utilised for new stock.

Water utilised in the quarantine facilities will be recirculated, and only released when the new stock has been declared "disease free".

Stock escape will be prevented by pond design measures.

Dead and/or diseased stock will be collected and buried, with a heavy application of lime to assist decomposition.

4.5 HYDROLOGY

4.5.1 Stage 1 Development

Stage 1 includes the following construction that will alter the natural hydrological patterns of the lease area:

- A freshwater dam at the headwaters of the north arm of Middle Creek, with a surface area of 20 ha and a storage capacity of approximately 460 ML. The dam wall will be constructed to a height of approximately 15m AHD (a maximum wall height of 7.5 m) including a spillway located at the southern end of the dam wall.
- A 20 ha exchange water treatment pond, located between the mangroves and the proposed production ponds.
- A saltwater supply channel.
- Production ponds (27 ha).
- Farm infrastructure including buildings, roads, canals and cleared areas.

The construction of the Stage 1 freshwater dam will remove a significant proportion of the annual freshwater streamflow into the north arm of Middle Creek. The dam will divert streamflow away from

the natural drainage line directly downstream of the proposed dam wall. Overflow from the spillway will be directed back into the natural channel approximately 400-500 m downstream of the proposed dam wall. All stream inflows in excess of the reservoir capacity will flow through the dam and spillway and return to the natural drainage paths.

The exchange water treatment pond will consist of low earthern embankments adjacent to the mangrove fringe at the base of the proposed production ponds. The embankments of the exchange water treatment ponds will block natural drainage lines for the catchment directly to the north-east of the embankment. The runoff from this area will be collected in stormwater canals and redirected to culverts under the exchange water treatment pond embankments or to discharge points at the end of the embankments. Runoff that would naturally enter the mangrove areas as sheet flow will now enter as stream flow at defined discharge points. There is a potential for increased erosion at these locations due to concentration of flow. Where required channels will be lined to minimise erosion.

The saltwater supply channel will consist of a 30 m wide canal extending through approximately 300m of mangrove area. The channel will have raised embankments on each side with vehicular access along the embankments. While some alteration to the natural tidal movement can be expected, the main tidal movement in the area is considered to be along the proposed alignment of the saltwater supply channel, therefore minimising erosion potential. The channel embankments will block any lateral tidal movement across the alignment of the channel. Lateral tidal movements will occur through either tidal channels or by sheet flow through the mangroves/minor salt flats. Some scouring along the base of the saltwater supply embankment may occur as the tidal waters create new tidal channels to adjust to altered hydrological conditions. Due to the potential for erosion the saltwater supply channel will be protected by rock armour and a compensatory tidal channel will be constructed if required. Additional proposed management techniques to control erosion are outlined in Section 4.8.1.

Construction of production ponds will provide a barrier to natural drainage patterns. Stormwater will be diverted around the production ponds by stormwater channels of sufficient design capacity to accommodate the probable maximum precipitation (PMP) event.

Other proposed farm infrastructure includes farm buildings, access roads and cleared areas (eg carparking). These facilities will have the following effects on the hydrological characteristics of the area:

- Construction of farm buildings and cleared areas (eg. carparking areas) will slightly increase the volume and peak flows of storm runoff for these areas. The anticipated increase in runoff volume is anticipated to be minor and will be compensated by the capture of direct rainfall onto the producation ponds and freshwater dams.

- Construction of farm buildings will divert natural drainage patterns. Sufficient drainage channels will be constructed around buildings and where possible stormwater will be redirected towards natural drainage lines with appropriate hydraulic design to transition flow to the downstream natural landform.

- Access tracks constructed across the lease area may impede or divert natural drainage.

4.5.2 Stage 2 Development

Stage 2 development includes the following construction that will affect the hydrological regime of the lease area:

- A freshwater dam at the headwaters of the south arm of Middle Creek. The freshwater dam will have a surface area of 186 ha and a storage capacity of approximately 5,500 ML. The dam wall will be constructed to a height of approximately 14m AHD (a maximum wall height of 13 m).

- Extension of production pond area to 115 ha and exchange water treatment ponds to 80 ha.

- A freshwater supply channel connecting the Stage 2 freshwater dam and the production ponds.

- Additional farm infrastructure, including farm buildings, roads, cleared areas, pasture areas and pond sediment stockpiles.

The Stage 2 freshwater dam will consist of a dam wall approximately 1 km in length. A spillway will be located at the southern end of the dam wall. The dam is anticipated to intercept a significant proportion of the stormwater stream flow that would naturally drain into Middle Creek. In addition, the dam will divert streamflow away from the natural drainage line directly downstream of the proposed dam wall. Overflow from the spillway will be directed back into the natural channel approximately 500m downstream of the proposed dam wall.

The extension of the production ponds and exchange water treatment pond will divert natural drainage patterns. Stormwater will be managed around the production ponds with drainage designed for the PMP event.

The additional farm buildings, cleared areas and access tracks will increase the volume and peak flows of storm runoff for these areas and divert natural drainage patterns. Drainage channels will be constructed around buildings and where possible stormwater will be redirected towards natural drainage lines with appropriate hydraulic design to transition flow to the downstream natural landform.

The freshwater supply channel to be constructed between the Stage 2 freshwater dam and the production ponds will impede the natural drainage paths for the catchment to the east of the channel. Stormwater drains will be constructed along the edge of the channel to direct stormwater into either the Stage 2 freshwater dam or through a culvert placed under the freshwater supply channel that will connect to natural drainage lines flowing into the north arm of Middle Creek.

4.5.3 Storm Surge and Flood Levels

The Vipac report (No: 24113-1) *Greater Darwin Cyclone Storm Surge Risk*, Northern Territory Department of Lands, Housing & Local Government, August 1994, analyses the peak combined sea level predictions for numerous locations in the Greater Darwin region. The nearest location to the lease area is Channel Island, where the 1 in 100 year and 1 in 1000 year peak combined sea level prediction is 5.1 m AHD and 6.4 m AHD, respectively. The saltwater settling channel, adjacent to the mangroves, will be constructed to a height of 6.5 m AHD (4.0 m AHD base, with 2.5 m embankment). The main infrastructure of the proposed development will therefore be constructed above the 1 in 100 year peak combined sea level prediction for Channel Island. The peak combined sea level prediction for the aquaculture development lease area is anticipated to be less than for Channel Island.

There are no streamflow gauges currently located on the Blackmore River and DLPE has not produced flood level information for the Blackmore River (pers. comm DLPE). However, it is considered that the relatively low topography of the catchment, the relatively wide tidal channel, the close proximity to Darwin Harbour and the attenuation effect of the mangroves would reduce the likelihood of the lease area being flooded from Blackmore River. To accurately determine flood level heights of the Blackmore

River a complete catchment analysis would be required.

4.5.4 Groundwater

Multiple bores (a minimum of two) will be established within the lease area to obtain potable (eg drinking, showering, septic), landscaping and factory production water requirements from the groundwater supply. An estimated 2,250 L/day will be required for Stage 1 and approximately 70,000 L/day for Stage 2.

The water quality of the groundwater from the Burrell Creek Formation in the region and the potential for saltwater intrusion into the underlying aquifer has not been assessed. Extraction of groundwater for potable water supplies at the Blackmore River lease area is not expected to have significant impact on saltwater intrusion into the underlying aquifer. However, any proposal to extract the quantities of groundwater proposed in Stage 2 of the development will require the analysis of the potential for saline intrusion into the underlying aquifer.

4.5.5 Adjacent Developments

Future planning schemes for the Greater Darwin Area include the construction of a new suburb 'Weddell' to be located to the east of the lease area. The construction of residential suburbs in the catchment of the proposed Stage 2 freshwater dam will have the following effects on the hydrological characteristics of the area:

- Runoff from urban areas is typically greater than for equivalent natural bushland sites. If runoff from Weddell is released into the catchment of the Stage 2 dam there will be a subsequent increase in runoff to supply the dam.

- If the runoff from Weddell is released into the catchment for the Stage 2 dam it is likely that water quality in the reservoir will deteriorate. The highest concentration of contaminants in urban runoff can generally be expected at the beginning of the Wet Season ie "first flush" phenomenon.

- If stormwater runoff from Weddell is diverted away from the Stage 2 dam catchment there will be a decrease in runoff to supply the dam.

If urban development occurs in the upper catchment of the Stage 2 freshwater dam, a program of water quality monitoring will be instigated.

3. Surface Water and Groundwater Management

Erosion control measures (Section 4.8.1) will be implemented in areas where diversion of flow may result in scouring.

Project layout will be designed to minimise adverse impacts on surface water drainage.

Farm alignment/design will avoid interruption to tidal movement.

Sufficient drainage channels will be constructed around buildings and stormwater will be directed towards natural drainage lines, with appropriate hydraulic design to transition flow to the downstream natural landform.

Overflow from the freshwater dam spillway will be directed back into the natural channel, downstream of the dam wall.

The main infrastructure of the proposed development will be constructed above the 1 in 100 year peak combined sea level prediction for the region.

An analysis of the potential for saline intrusion into the underlying aquifer will be undertaken prior to the development of Stage 2 of the project.

If urban development occurs in the upper catchment of the Stage 2 freshwater dam, a program of surface water quality monitoring will be instigated.

4.6 WATER QUALITY

4.6.1 Production Water Quality

The nutrient content of the pond water will be determined by feed and fertilizer inputs and by water exchange. Water quality within the ponds will be systematically monitored, with samples being tested on a six-hourly basis. Parameters to be monitored are pH, DO, temperature, salinity and turbidity. Data will be stored and processed in a central farm computer system.

The regime of feed will be determined by the results of water quality analysis (in particular, dissolved oxygen). It is intended to run the farm on the computer program “Pondman 2” a system

developed by the CSIRO Marine Research, CRC. Stocking levels, water exchange, feed and aeration regimes will be set with reference to the water quality parameters.

4. Water Quality (Production Ponds) Management

A program of water quality testing will be undertaken.

Stocking levels, water exchange, feed and aeration times will be determined with reference to water quality parameters.

4.6.2 Waste Water Discharge

Discharge of discharge water to the environment will occur during operation of the aquaculture project. Accordingly, an application for a Waste Discharge Licence under the *Northern Territory Water Act (1992)* will be sought form DLPE.

4.6.2.1 Discharge water composition

Natural TSS levels in the Blackmore River system experience substantial fluctuations depending on total suspended solid (TSS) levels of rainfall runoff and the existing tidal conditions. Therefore the intake water from the Blackmore River for aquaculture production may contain existing high TSS levels. This suspended solid matter will predominantly be settled out of the water column in the wide, slow flowing saltwater supply channel before placement into the production ponds.

Production pond effluent can potentially contain high levels of nutrients and suspended solids. Final discharge of water from the aquaculture development will be into Middle Creek via a drainage channel. The environmental impact of such release on flora and fauna in the area will depend upon the discharge water composition after treatment, and the propensity of the discharge water to be diluted by its receiving waters.

Following consultation with CSIRO Marine Research, CRC, the management of discharge water quality will involve preventative and minimisation measures, supported by appropriate environmental monitoring.
Stocking levels in the production ponds and the water exchange, feeding regime and fertilisers inputs to these ponds will be determined with reference to water quality monitoring. Discharge from the production ponds will be channeled to the exchange water treatment pond(s) where the concentration of nutrients and suspended solids will be reduced. The potential amount of suspended solids and nutrient removal by the exchange water treatment pond(s) will be variable. Management aim to continually improve the environmental management of the lease area by incorporating the latest waste prevention and treatment technology.

In order to quantify the amount of nutrients that are released by the production process into the environment water samples will be collected from the discharge channel prior to release and analysed for TSS, total nitrogen (TN) and total phosphorous (TP). The monitoring of TSS, TN and TP is standard industry practice for the quantification of the environmental impact of prawn farm discharge water on receiving waters.

CSIRO Marine Research estimates of the reductions in levels of TSS, TN and TP from the implementation of a properly functioning water exchange treatment pond is presented in **Table 21**.

Table 21

Estimated Reduction in TSS, TN, and TP after Treatment

Water Quality Parameter	Volume Generated from Stage 1 Pond (kg/day)	Volume Reduced Via 20 ha Treatment Pond (kg/day)	Net Increase/(Reduction) (kg/day)
Total Suspended Solid	Unable to be quantified	Unable to be quantified	Projected net reduction
Total Nitrogen	30 to 60	33 to 100	27 / (70)
Total Phosphorous	3 to 6	4 to 10	2 / (7)

Note: 1. Derived from data obtained from CSIRO Marine Research, CRC.

The discharge water will be released to Middle Creek between 20 minutes and 5 hours after the Darwin high tide (when the outgoing tidal range is greater than 2m) in order to maximise the flushing and dilution into the Blackmore River receiving waters. By releasing on an outgoing tide, movement of the discharge water into the mangrove system (which will also be draining) will be minimised.

Release will occur when the outgoing tide is of sufficient height to allow drainage into Blackmore River and Darwin Harbour. Discharge water will undergo substantial dilution in Blackmore River and Darwin Harbour and the flushing characteristics of Blackmore River will provide substantial water exchange.

5. Discharge Water Management

Management measures will be implemented to minimise the nutrient load and level of suspended solids generated in the production pond water.

Exchange water treatment pond(s) will be used to reduce the concentration of nutrients and suspended solids from the production pond effluent.

Prior to release of water into the receiving environment, a program of discharge water testing will be undertaken.

Discharge water will only be released during outgoing tides when the tidal range is greater than 2 m.

Accidental or unauthorised release of discharge water will be prevented by the use of locks on all critical valves.

4.7 GENERAL WASTES

4.7.1 Sludge

When the solid material (sludge) builds up in the supply channel and the discharge water pond to the point where desilting is required, the material will be removed and deposited into the solids desalination bays. At this stage, the sludge is expected to be highly saline and have elevated nitrogen and phosphorous levels.

The sludge is likely to remain in the desalination bays for several Wet Seasons, such that salinity levels are reduced through rainfall infiltration. As only a sparse coverage of vegetation will exist in area any leachate from the sludge is considered unlikely to have any significant environmental impact.

In-situ conductivity readings of the sludge material will be taken periodically. Once salinity levels are sufficiently reduced the weathered sludge material will then be transferred and spread over the established pasture area. Established pasture vegetation species will minimise run-off, assist with stabilisation, and act as a biofilter.

A bund wall to contain runoff during most storm events will isolate the pasture area. However, peak

storm events may cause flooding which could potentially overtop the bund. To accommodate this, tail water drains will be designed to collect excess storm water from the pasture area for diversion into the farm discharge. If overflow occurs, the impact associated with elevated nutrient loads in runoff waters will be minimised through dilution during peak storm events.

4.7.2 Sewage, Domestic Discharge water and Miscellaneous Wastes

Sewage and domestic discharge water will be treated by septic tank systems designed in accordance with Territory Health guidelines. It is anticipated that there will be no significant impact on the biophysical environment from the on-site disposal of sewage and domestic discharge water.

Potentially contaminated washdown water from vehicle and plant cleaning will be directed through a TIT and discharged to either an absorption trench or lagoon system.

Domestic waste, including hard rubbish and food scraps, will be temporarily stockpiled in an allocated area of the borrow pit and either buried or disposed to municipal landfill in accordance with DLPE and Shire of Litchfield guidelines.

6. General Waste Management

Sludge will not be transferred from the solids desalination bays to the pasture area until *in-situ* conductivity measurements indicate a sufficient reduction in salinity levels.

A bund wall will be constructed to contain runoff from the pasture area.

Tail water drains will be constructed to collect excess stormwater from the pasture area for diversion into the exchange water treatment ponds.

Sewage and domestic waste water from residences and buildings will be treated by septic tank systems designed in accordance with Territory Health guidelines.

A triple interceptor trap (TIT) will be installed to remove potentially oily waste water from vehicle and plant washdown.

Waste oil will be disposed off-site by a licenced waste management contractor.

4.8 SOIL DISTURBANCE

4.8.1 Erosion and sedimentation control

All construction works will be undertaken in the Dry Season.

The majority of the production pond area will be well contained by bund walls, minimising the potential for erosion and sedimentation. Access roads constructed on the lease area will be drained with side gutters and runoff drains. These drains will be constructed parallel to the contours to prevent scouring and erosion. Ongoing maintenance of all road surfaces and embankments will be undertaken to ensure their integrity.

To minimise erosion all embankments will be compacted during construction and between 0.1 m and 0.2m of lateritic gravel will be compacted on the crests and sides of the pond walls. The embankment to the saltwater supply channel will be armoured with rock rip-rap. Ongoing maintenance of the saltwater supply channel embankment constructed through the mangrove fringe will include:

- Raising the level of the embankment, should settlement occur due to consolidation of underlying mangrove clays.
- Repairs to cracks in the embankment due to differential settlement as a result of consolidation of underlying mangrove clays.

To ensure that the flow of discharge water does not cause scouring or erosion, discharge channels to the north arm of Middle Creek will be constructed using rock rip-rap.

The spillways for both the small and large freshwater dams will be stabilised to prevent erosion. The spillways will be excavated into shallow laterite and will be designed to release overflow water in a manner that will minimise channeling and erosion. All excavation areas in the

freshwater dam will self-drain back into the floor of the dam. If required, the flowpath from the spillways to the natural drainage lines will be stabilised to prevent erosion. This may consist of a

0.75 m deep discharge channel excavated to bedrock, drop structures to reduce velocities, channel protection or construction of protective bund walls.

Cleared areas around buildings will be landscaped and maintained to minimise the potential for erosion.

4.8.2 Dust control

The majority of construction activities will be undertaken during the Dry Season. If problematic levels of dust are generated during construction a water cart will be used for dust suppression purposes. Dust will be suppressed with a water cart if any of the following situations occurs:

- Complaints are received from neighbours legitimately affected by the generation of dust from the lease area.
- Dust generation creates an unsafe working environment during construction activities.

The majority of construction activities will be undertaken during the Dry Season. If dangerous levels of dust are generated during construction a water cart will be used for dust suppression purposes.

7. Erosion, Sedimentation, Drainage and Dust Management

All construction works will be undertaken in the Dry Season

Roads will be drained with side gutters and runoff drains.

Embankments will be compacted and have a cover of lateritic gravel.

A lined catchdrain will surround the ponds to collect and channel stormwater runoff.

Where required, channels will be lined with rock rip-rap and the saltwater supply channel protected with rock armour.

Farm alignment/design avoids interruption to tidal movement and surface water flow.

Appropriate dust suppression measures will be instigated where a significant hazard exists.

4.9 FIRE REGIME

It is expected that fire management strategies associated with the proposed development will result in a reduction in the frequency of widespread, high intensity fires in the remaining vegetation. This will result in a gradual decrease in annual grasses such as *Sorghum* that provide abundant fuel for

annual fires. Reduced fire frequency also leads to consequent shifts in species composition towards a denser mid-stratum layer that includes fire sensitive monsoon forest species (Brock *pers comm*).

A Fire Management Plan will be developed in consultation with the Bushfires Council of the Northern Territory and in accordance with Litchfield Shire requirements. The Fire Management Plan will have a number of key objectives, including reduction of flammable fuel loads around housing

and farm infrastructure for fire protection and to prevent extensive, destructive wildfires. Fire management of the lease area will also incorporate broader, landscape–scale objectives including the protection of fire-sensitive species and communities (eg. dry rainforest) and to create a mosaic of burnt and unburnt country that will encourage habitat heterogeneity. Ecologically, patchy burning creates conditions more suitable for a diverse range of fauna and flora, which encourages ecosystem stability.

Firebreaks will be regularly slashed. The alignment and construction of firebreaks will be in accordance with the Fire Management Plan for the lease area, to ensure that negative impacts are reduced. Fire management of the lease area will involve clearing of vegetation along a 4 m wide easement around the perimeter of the lease area. A 20 m firebreak will surround all accommodation buildings and the fenced boundary of each 2 ha allotment will also involve maintenance of a 4 m wide firebreak. A 50 m break will be cleared around all other farm buildings and these wider firebreaks will be landscaped to reduce erosion.

Overall, given that approximately 60 % of the lease area will be cleared for the aquaculture project combined with the natural protection afforded by the mangroves to the west, the boatramp road to the north and the freshwater dam to the south-east, the lease area is relatively well protected from fire.

8. Fire Management

Firebreaks will be formed and regular maintenance of vegetation around infrastructure on the site will be undertaken to reduce flammable fuel loads.

Fire reduction and prevention methods will be coordinated within a Fire Management Plan, which will be formulated in consultation with the Bushfires Council of the Northern Territory.

4.10 BITING INSECTS

The proposed Blackmore River (East) Aquaculture Development will generate permanent and semi permanent bodies of both fresh and saltwater that may constitute breeding sites for biting insects. Whilst existing areas around the farm site are known to act as breeding grounds for insects, it is important that the creation of new breeding habitats is minimised.

On-going monitoring of biting insects will be undertaken, as detailed in **Section 5.4.4**.

4.10.1 Biting Midges

The prime breeding habitat of the principal pest species (*Culicoides ornatus*) is in the upper reaches of the small tidal creeks or at the seaward fringe of extensive mangrove areas, and will generally be at the margin and under a canopy of mangrove vegetation. As the production ponds are to be constructed above the tide margin and not within the mangrove zone, the development is not likely to impact on any of the major pest biting midge breeding sites.

The development of the large area of production ponds, particularly during Stage 2, will create an effective buffer zone between the most productive biting midge sites (the mangrove margins) and the

area to the east of the production ponds. The production pond area will be relatively free of vegetation, and as a consequence wind action will further disrupt biting midge dispersal. In addition, lights will be installed at the mangrove margin of the pond development to attract midges away from sensitive areas such as residential or night use areas.

The project layout maximises the distance between sensitive areas and biting midge sources. However, during periods of extreme pest numbers there is a potential that biting midges may represent nuisance value to staff working within 1.5 km of the mangrove margin.

Insecticide treatment of biting midge larvae in this habitat is unproven, highly impractical and likely to be environmentally unacceptable. Aerosol application for the effective control of adult biting midge also poses practical problems. These include the timing of control, the necessary environmental and weather conditions, access requirements, the non-specificity of most adulticides, and the failure of aerosols to penetrate thick vegetation. During periods of high levels of midge activity it is unlikely that insecticide control of biting midge adults will be able to achieve a significant reduction in pest numbers.

The most practical method to avoid or reduce pest problems in the lease area is to implement personal protection strategies. There are a number of avoidance and personal self-protection measures that can be taken to reduce biting midge pest problems. These include:

- installation of fine insect screens and light proof curtains;
- avoidance of areas of high biting midge activity;
- avoidance of problem areas during peak biting insect activity; and
- application of personal protective clothing and personal repellents at times or locations of exposure to biting insects.

Contractors and permanent staff will be made aware of the biting midge issue during an induction program. Personal protection against biting midges will almost certainly be required over extended periods.

4.10.2 Mosquitos

4.10.2.1 Potential effects of development on mosquito numbers

Earthworks in the tidal area during the construction phase have the potential to create isolated pools of fresh and saltwater. Any retention of water and particularly the colonization of reeds and grasses in temporary or perennial flooded drains or depressions in the lease area could lead to the creation of new mosquito breeding sites. Prolific breeding of both brackish and freshwater species of mosquitoes may occur in these areas unless features are suitably constructed and maintained.

- The proposed location for the exchange water treatment ponds has the greatest potential for tidal margin disturbance and the creation of new mosquito breeding sites. The pond/channel wall will be designed to reduce salt marsh areas adjacent to mangroves (**Figure 21**) and so reduce available mosquito breeding grounds. The water level in the exchange water ponds is likely to be stable thereby providing a habitat that promotes the growth of *Schoenoplectus* and *Eleocharis* reeds. As the water in these dams will probably be brackish, they are likely to breed *Ae. funereus* and *Ae. vigilax* when first flooded, and *Cx. sitiens, Cx. annulirostris, An. hilli, An farauti* and *Cq xanthogaster* if maintained as flooded dams.

- New mosquito breeding sites may be created through the impoundment of freshwater in the proposed dam. The potential for the freshwater dam to form mosquito breeding sites

- depends on vegetation growth, the rate of draw down of water, the presence of fish and the presence of non-draining depressions as the dam level recedes. A stable dam level will encourage *Eleocharis* reed growth around the margins and promote mosquito breeding.

- The salt water supply channel is likely to be colonized by mangroves. This mangrove growth may lead to silt build up in sections of the supply channel and will result in ponding of salt water during periods when there is no supply water conveyed in the channel. If this ponding occurs for periods greater than seven days, it is likely to breed salt-water mosquitoes including *Cx. sitiens* and *An. hill.*

- If ponding occurs in unfilled borrow pits these can become appreciable sources of *Cx. annulirostris* and *Anopheles* species.

- Unlined open stormwater drains containing organically polluted water will breed mosquitoes if there are low flows from leaking ponds or other wastewater sources. Any stormwater drain likely to have continuous Dry Season flow will become a mosquito breeding site. Problem drains will be characterized by extensive grass growth and stagnant pools with green filamentous algae.

4.10.2.2 Management measures

Biting insect management techniques will focus on minimisation of breeding grounds and personal protection rather than insect eradication. Management of biting insect problems will include:

- **Farm Infrastructure Design**

The exchange water discharge point will dispose exchange water direct to a tidal creek. The discharge will be to Middle Creek, which is free draining at low tide and so will reduce the potential of creating new mosquito breeding sites. The internal drainage system and supply channels will be designed to be free draining and will discharge to the exchange water treatment ponds.

Access roads will be constructed along high ground, minimising the need for culverts and the potential for puddle formation. Run-off drainage will be installed to ensure the side drains of the access road do not pond, with run-off drains having sufficient slope to ensure self-emptying without scouring.

Residences and farm buildings will be positioned away from the low-lying areas of the farm and above the 16 m AHD contour. Areas around all buildings will be selectively cleared,

leaving shade trees but opened up sufficiently to enable slashing. All buildings will be gauzed and air conditioned such that insects can be excluded from living areas.

Any borrow pits within the development will be filled or made free draining.

Areas likely to be permanently under water will be cleared of all trees and other vegetation to reduce the organic levels that will promote mosquito breeding. Silt traps will be constructed in the north arm of Middle Creek to trap and remove silt. This will prevent disruption to the free draining nature of the creek. Any appreciable ponding in isolated pools after draw down of water in the freshwater dam will be drained into the central channels. Annual inspections will be undertaken to identify these isolated pools.

- **Farm operation and maintenance**
  On-going management practices to reduce breeding areas for mosquitoes will include aeration of ponds, weed control, regular grading of roads (to avoid the formation of puddles after rainfall) and regular flushing of channels.

  Maintenance of the production ponds should prevent excessive growth of reeds and hence reduce refuge for mosquito larvae from predators. An annual assessment of the extent of reed growth in the freshwater dam will be undertaken to identify potential mosquito-breeding sites that may have developed. Reduction or elimination by weediciding or formalized margins may be required if mosquito-breeding sites have developed. Native fish populations will be maintained in the dam to assist with the control of larval mosquito numbers.

  A field survey of the tidal margin of the development area will be undertaken to locate any *Ae. vigilax* breeding sites. If practical, these sites will be rectified, preferably by filling or draining.

  Regular slashing of cleared areas around buildings will be undertaken to create a less favourable habitat for biting insects in their vicinity. Management will ensure that miscellaneous items, such as used tyres, pipe fittings, oil drums waste plastic sheets and bags, are not left in the open to collect rainwater and create mosquito breeding potential.

- **Induction of staff**
  As part of farm induction, new staff will be advised of the risks associated with mosquitoes and other biting insects. Information provided will include the risk of viral disease, the farm's prevention policy, seasonal variation in insect densities and advice on clothing and repellants. Appropriate clothing, insect repellant and antiseptic cream will be supplied to staff by management on an as-needs basis.

9. Biting Insect Management

Farm buildings and infrastructure will be designed and maintained to minimise the creation of new biting insect breeding grounds.

Native fish populations will be maintained in the freshwater dam to assist with the control of larval mosquito numbers.

Regular clean up of farm grounds will be undertaken to remove potential water containing rubbish.

Drainage will be designed to prevent ponding of water in low lying areas.

All staff will be informed of risks associated with biting insects and the preventative measures available.

Appropriate clothing, repellants and antiseptic creams will be available to all personnel on site.

4.11 EXOTIC SPECIES

Feral animals, especially pigs, have a potential to cause damage to the aquaculture ponds and may require control measures. These measures would depend on the level of the problem, and would be implemented in consultation with the Northern Territory Parks & Wildlife Commission.

Rodents, cats and dogs will be dealt with as the need arises by means of fencing or eradication. Whilst it is not intended to install bird nets from the outset, netting will be installed if water birds cause significant stock losses.

4.12 ARCHAEOLOGY

4.12.1 Background

Section 4 of the *Northern Territory of Australia Heritage Conservation Act 1991,* defines an 'archaeological place' as a "...place pertaining to the past occupation by Aboriginal or Macassan people that has been modified by the activity of such people and in or on which the evidence of such activity exists...". To this end, prescribed archaeological places or objects are "...deemed to be a place or object in respect of which an interim conservation order is in force and shall be deemed to remain so until the Minister...makes or refuses to make a declaration [as a heritage place] in respect of the place or object" (Section 39(1)). This mechanism provides temporary protection to an archaeological site while a decision can be made regarding whether or not it should be preserved.

All six of the archaeological sites and the background scatter identified by Heritage Surveys within the project area fall into the definition of a "prescribed archaeological place or object" as defined in Section

4 of the Act. All of these sites should therefore be regarded as being legally protected under the Act.

Prior to the commencement of construction Phelps/Panizza will seek a permit, under Sections 29 and 39 of the *Northern Territory of Australia Heritage Conservation Act 1991,* to disturb or destroy all archaeological sites likely to be affected by construction and/or operation activities.

4.12.2 Potential Impacts of Aquaculture Farm Construction and Operation

The impact of the proposed aquaculture development upon the archaeological sites located in this study is summarised in **Table 22** below. All six archaeological sites identified during this survey will be destroyed by the proposed development. Isolated artefacts identified during the survey are also likely to be destroyed.

Table 22

Impact of Project Development on Archaeological Sites

Site name	Relationship to proposed development	Impact of proposed development
BR1	Exchange water treatment dam	Destruction
BR2	Exchange water treatment dam	Destruction
BR3	Exchange water treatment dam	Destruction
BR4	Freshwater dam	Inundation
BR5	Freshwater dam	Inundation
BR6	Freshwater dam	Periodic inundation

One of the reasons archaeological resources are regarded as significant is because "they constitute a unique, non renewable data base for reconstructing the cultural past and for testing propositions about human behaviour" (Moratto and Kelly 1978:5). As such a site's scientific significance depends on two characteristics, its representativeness and its research potential.

1. *Representativeness.* This criterion concerns the extent to which the archaeological remains within a particular site are represented at other localities within the region. Unusual or unique sites are normally accorded a higher archaeological significance than sites that are very common. Given that all sites are in a sense unique (Bowdler 1984:2), they are normally considered in terms of categories (such as "quarry" or "knapping floor") when determining how common they are.

2. *Archaeological research potential.* This criterion concerns the potential of a site to contribute to timely and specific research questions. A site's potential to contribute towards the resolution of research questions may depend on a number of factors such as its state of preservation and the range of past human activities reflected at that site.

Archaeological sites at Blackmore River are small in size and contain a limited diversity and quantity of archaeological materials. These characteristics, together with the absence of stratified archaeological deposits ensures that the information potentially available from the archaeological sites in the study area is relatively limited. In terms of their morphology, contents and environmental context the sites cannot be regarded as unique or unusual in the context of the Darwin region as a whole. Surface shell scatters and stone artefact scatters represent site types recorded widely across the Darwin region and the type of information available from them is therefore likely to be repeated at many other localities. It

is also relevant to note that sites BR1, BR2 and BR4 have been impacted by erosion and other disturbance associated with vehicle traffic, while Site BR3 is likely to be quite recent in age.

Given these considerations, the archaeological significance of all six of the archaeological sites identified during this study is assessed to be low.

Isolated artefacts of the kind found within the study area are ubiquitous throughout the greater Darwin region (e.g. Hiscock 1994, 1995; Heritage Surveys 1995, 1997a, 1997b). While such materials could potentially make a minor contribution to the resolution of archaeological research questions such as the nature of prehistoric subsistence strategies, such information is likely to be available at many other localities. The archaeological significance of the isolated artefacts identified during this study is therefore regarded as minimal.

4.12.3 Archaeological Management

Ministerial consent to disturb the six archaeological sites will be sought prior to construction. The appointed archaeological consultant advised that no mitigative action is required with respect to the archaeological materials located in the project area.

4.13 RECREATIONAL ACTIVITIES AND SOCIAL ISSUES

The lease area confers limited local significance in terms of its intrinsic recreational values. The area encompassing the proposed development is used by off road motorcycle riders for recreational purposes, on an occasional and informal basis.

Security is of critical importance for the project operation because of the high value of the stock in

ponds and on farm equipment. Once the lease has been finalised, public access to the development area will be closed, limiting in particular the activities of off road motorcycle riders. Areas adjacent to the lease, which will be unaffected by the proposed development, remain available for motorcycle riding.

Recreational fishermen use the adjacent off-site waterways. There will be no limitation to fishermen because of the development. The access to the Middle Arm boat ramp remains as is and the waterways around the farm site will be unchanged and unobstructed other than the installation of the pump jetty. No access to the farm via the jetty will be permitted.

Given the dense population of mangroves between the Blackmore River and the development area and the relatively low elevation of the production ponds in both Stages 1 and 2, adverse affects to the visual amenity of area to boat-borne fishers will be limited solely to the view of the jetty.

The social impacts of traffic generated from the Stage 1 aquaculture development are expected to be minimal. Construction traffic will be generally maintained on-site and operational traffic will generally be below 6 daily vehicular movements. This degree of traffic movement is not expected to contribute significantly to the deterioration of the local road infrastructure and is expected to have minimal impact on local residents.

Operational traffic associated with final development is estimated to be between 18 and 24 vehicles per day. The increased volume of traffic, representing two vehicular movements per hour, based on 12 hours of daylight, is considered to have potential for minor change only and unlikely to increase the deterioration of the local road infrastructure. However, techniques that will be adopted in order to minimise the volumes of traffic generated by the Blackmore River Aquaculture Development will

include:

- on-farm accommodation for staff;
- use of mini buses to convey staff back and forward from town;
- operation of school bus to Blackmore Springs\Palmerston for any children living on-site;
- connection to Northern Territory power grid, reducing the amount of diesel fuel delivered;
- roster for shopping and supplies delivery to on-farm staff by off-farm staff; and possible transfer of cooking, packing and storing functions to a facility in Darwin.

10. Management of Recreational/Social Issues

Farm operation will be organised to minimise the volume of local traffic generated by the aquaculture development.

4.14 HEALTH, SAFETY AND EMERGENCY ISSUES

4.14.1 Security

Security at the entry of the farm will be closely managed on a 24-hour basis with controlled passage for all personnel onto the lease area. Similarly, the boundary of the farm will be fenced and maintained so as to prevent uninvited entry and unlawful removal of stock and/or equipment.

The pump jetty, which will extend 30 m into the Blackmore River, will be signed to warn the public away from the structure. Lighting will be installed along the jetty length, incorporating a solar-powered navigation light. The pumps will be shielded with steel mesh to ensure that the danger of people or objects being drawn into the pump intake is removed.

Unless authorised, no public vehicle will be permitted to enter the farm. Vehicle occupants will be obliged to park and alight from their vehicle and check-in as they pass the gate and transfer to a farm-based vehicle. A similar check-out procedure will apply on departure. No farm-based vehicle will be permitted to leave the lease.
These measures will be put in place for:

- disease isolation (a vehicle from another farm or coastal area cannot contaminate the farm);
- rust prevention (the salt effects will be confined to farm-based vehicles);
- keeping of accurate staff hours;
- prevention of theft of stock (anything removed from the farm will be carried by hand);
- prevention of theft of equipment, fuel and supplies; and
- accurate record keeping for supplies and production.

All critical valves will be secured with locks as required to prevent accidental or unauthorised release of water.

4.14.2 Isolation during the Wet Season

Flooding of the Middle Arm Boat Ramp Road can occur after large rainfall events during the Wet Season. This flooding usually lasts for reasonably short periods of time, with 4WD access generally still possible.

As a contingency against being isolated from town and services and any associated adverse impacts on the health and safety of personnel or on farm operations, management policy will include:

- two weeks minimum supply of all farm necessities, including fuel, prawn feed, food and medical supplies;
- a majority of farm vehicles to be 4WD, including the provision of a small (5-10 tonne) 4WD low ground pressure truck to carry essential supplies;
- a readiness to utilise helicopter services to bring staff in and out;
- provision of on-farm temporary accommodation for workers required or forced by road blockage to stay overnight; and
- staff induction to include flood procedures.

11. Health and Safety

Lighting, signage and mesh barriers will be utilised at the pump jetty on Blackmore River to ensure the pump does not represent a risk to public safety.

Security issues on the farm will be managed by well-maintained fencing and regulated access requirements.

Sufficient medical and food supplies will be kept on-site in the event of short-term isolation due to limitation in access via Middle Arm Boat Ramp Road.

4.15 DECOMMISSIONING AND REHABILITATION

The proposed development is considered to be a permanent development, which will be retained in its entirety. Should abandonment of the aquaculture development (or parts thereof) be required, then the following decommissioning and rehabilitation practices will be applied.

The pumps and jetty will be decommissioned and removed from the Blackmore River. The supply channel, production and treatment ponds will be leveled with a D8 dozer or similar. Concrete and piping will be removed for salvage. Miscellaneous materials such as power lines, pumps, above ground storage tanks and small concrete structures will be removed from the lease area.

In the initial stage, the wall of the freshwater dam will be around 7.5 m in height and this would be leveled by dozer back to the surrounding ground level. The Stage 2 freshwater dam will have a

maximum wall height of 13 m and would be difficult to flatten. Should the dam be decommissioned from its full-scale size a feasibility study will be conducted, in consultation with relevant Authorities, to evaluate the potential benefits of converting the structure into a conservation and recreational area.

All buildings (except concrete footings) and equipment will be removed. On-site access roads will be ripped and graded flat and the regeneration of the vegetation encouraged.

5. ENVIRONMENTAL MANAGEMENT PLAN

5.1 TERMS OF REFERENCE

This Environmental Management Plan (EMP) will be structured to address potential environmental impacts identified in the PER for the construction and operation phases of the proposed prawn farm. Management of other aspects of the proposal, such as workplace health and safety, domestic hard rubbish and AQIS regulations relevant to the packing factory, are discussed in the PER.

5.2 INTRODUCTION

Phelps/Panizza is committed to achieving and maintaining environmental standards, such that any adverse environmental impacts resulting from the construction and operation of the aquaculture project are minimised. Phelps/Panizza is committed to the implementation of on-going environmental monitoring programs to ensure the farm does not detrimentally impact its natural surrounds.

In addition to Phelps/Panizza's responsibility to the preservation of the immediate environment of the proposed project, the proponents are committed to working in partnership with the community and other stakeholders to ensure the preservation of the adjacent Blackmore River and mangrove systems. It is recognised that the long term success of the prawn farm is highly dependent on the quality of the receiving water.

The prawn farm will be operated in accordance with Territory and Commonwealth legislation and regulations, and in accordance with the Phelps/Panizza's objective of sustainable development. To this end, Phelps/Panizza has investigated current environmental best practice methods for prawn farming through a variety of professional organisations, including:

- Department of Lands Planning & Environment, Northern Territory.
- Department of Primary Industry & Fisheries, Northern Territory.
- CSIRO Marine Research, Cleveland, Queensland.
- Co-operative Research Centre (CRC) for Aquaculture.
- Great Barrier Reef Marine Park Authority (GBRMPA).
- Australian Prawn Farmers Association (APFA).
- Queensland Environment Protection Agency.

The principals of Phelps/Panizza, Greg Phelps and Albert Panizza, have traveled extensively in Australia to investigate environmental management practices and reported environmental impacts of established aquaculture projects. Prawn farms in Central America (Belize, Panama and Mexico), reputed to employ world's best practice, have also been inspected. Information relating to disease control was obtained during these site visits, and during a visit to Thailand (March 2001) the "damage control" measures undertaken by large prawn farming operations in response to the White Spot Syndrome Virus (WSSV) were reviewed.

Many of the farm design parameters and management commitments outlined in the EMP are consistent with advice received from the above-mentioned sources. However, the EMP also recognises and acknowledges the influence of site-specific factors, and recognises that the EMP will be dynamic, requiring some alteration/refinement if unforseen site-specific environmental considerations are encountered.
For each developmental stage of the prawn farm the EMP will:

- identify potential environmental impacts associated with the development;

- incorporate a planned strategy to minimise/prevent adverse environmental impact;
- provide a schedule for the implementation of management strategies;
- detail a program for on-going monitoring;
- require periodic reporting to relevant government agencies, detailing works undertaken and an assessment of the effectiveness of the management strategies employed; and
- specify site management roles and responsibilities with respect to management procedures.

Expansion of the pond area to Stage 2 will only be undertaken if results of the monitoring programs indicate that no significant detrimental impact has occurred, and if analysis of data indicates that such an expansion will not lead to significant detrimental impact.

5.3 ENVIRONMENTAL MANAGEMENT MEASURES

Environment management measures relating to the farm's intake water, production ponds and discharge are outlined in the following sections. These measures will be implemented to minimise adverse environmental impact resulting from the prawn farm's operation.

5.3.1 Intake Water Settlement

The level of suspended solids in the Blackmore River water varies considerably due to a large variation in tidal range. However, the water will be of a more consistent quality with a lower level of solids after it has passed along the supply channel to the prawn farm's production ponds. The supply channel is greater than 2,000 m in length and approximately 30 m wide. Given these dimensions, water will flow through the channel at a rate of less than 0.1 m/s, even when the farm has reached full scale of 115 hectares of production ponds. The length of channel and slow rate of flow will result in the settling of suspended solids from the intake water prior to the water's release into the production ponds.

When the sediment is cleaned from the channel the material can be removed to the solids desalination bays for desalination.

Water samples will be collected from the Blackmore River at the pump jetty and at the second stage lift pumps on a daily basis and tested for pH, DO, EC, salinity and temperature. The proposed monitoring of water quality is discussed in **Section 5.4.1**.

Management Commitments

- All material removed from the intake channel is to be deposited in the desalination bays.
- Intake water testing and logging will be undertaken daily, prior to pumping in the Blackmore River.

5.3.2 Production Pond Operation

Pond Sludge

Research by the CRC for Aquaculture has found that the majority of sediment accumulated on the floor of aquaculture ponds originates from erosion of pond walls (Robertson 2000). To reduce erosion and so minimise the volume of solid pond waste consideration will be given to planting vegetation on the pond walls, the type of aerator employed and its placement. Water flow through the ponds will be directed to maintain flow and destratification but to avoid scouring of the banks.

The management of sludge produced in the production ponds is outlined in **Section 5.3.4**.

Water Quality

Management of DO levels within the production ponds will, where practical, be achieved through aeration before the use of water exchange. This will result in a more constant water quality, a more stable algal bloom and a reduction in the quantity of water discharged. The employment of this management strategy on some prawn farms in Queensland over the last decade has resulted in a reduction of water exchange.

In the production pond, overfeeding is one of the major causes of poor water quality, ill health of prawns and elevated nutrient levels. To avoid overfeeding the feed uptake rates will be closely monitored by farm management personnel, and feed rates adjusted to maintain a minimal feed supply to ensure that quality of water and health of stock is not compromised.

Phelps/Panizza will aim to adopt new developments, as they are made available, relating to prawn feed types that reduce wastage and so reduce the build up of nutrient levels. For example, Phelps/Panizza are currently investigating a program to develop a new variation of pelletised prawn feed, with the aim to reduce the waste of feed and the subsequent build up of nutrient levels. This is a project, in collaboration with leading nutrionalists and experienced prawn farmers, which is expected to produce higher efficiencies in the medium term.

Management Commitments

- Aerators are to be positioned to avoid the scouring of banks.
- Pond DO levels will, where practical, be achieved through aeration before the use of water exchange.
- All pond discharge is to be directed to the discharge water treatment ponds.
- Overfeeding of prawn stock will be avoided to reduce the build up of nutrients in the pond water.

5.3.3 Discharge Water Treatment

Discharge water from the 27 hectares of production ponds operational during Stage 1 will flow to a 20 hectare exchange water treatment pond, providing a ratio of production to treatment of 1:0.74, or 74 %. It is proposed to expand the production pond area to 115 hectares in Stage 2, discharged into an 80 hectare exchange water treatment pond. The ratio of production to treatment in Stage 2 would be 1:0.7, or 70 %. The ratio of production to treatment varies from farm to farm, and although an

ideal ratio has not been determined, work undertaken by the Queensland EPA and CRC for Aquaculture has nominated targets of 10 % to 30 % as being effective.

The area of the exchange water treatment pond proposed for the prawn farm exceeds the current status in Queensland of existing prawn farms and the targets set by the EPA for new farms. In addition, the greater tidal range of the Blackmore River lease area (approximately 8.0 m) as compared to that of most prawn farms in Queensland (approximately 3.0 m) will aid the dilution and flushing of any discharge from the Phelps/Panizza farm.

The discharge water from the production ponds will spend an average of 16 days passing from the production pond, through the discharge treatment pond, to eventual discharge into Middle Creek. In this time the settling out of solids will be extensive and the reduction of nutrients significant. Discharge water quality will be tested on a daily basis, as detailed in **Section 5.4.1**. Data obtained will be reviewed in consultation with DLPE, and the requirement (if any) for improved environmental performance will be addressed.

To ensure that the quality of the discharge water is known and within acceptable ranges and to maximise the flushing and dilution characteristic of the receiving waters, the release of water from the exchange water treatment pond to Middle Creek will be controlled by the following conditions.

- Discharge will only be permitted when the DO and pH levels of the discharge water have been tested, logged and found to be within an acceptable range (as determined by DLPE in consultation with Phelps/Panizza).

- Release of discharge water is to be effected only between 20 minutes and 5 hours after the Darwin high tide (based on Tidal Predictions from the published charts of DTW).

- Release of discharge water is to be effected only when the outgoing tidal range will be greater than 2m.

- Release will only occur if it has been authorised by management.

Implementation of these management commitments will reduce the chance of undiluted discharge water lying for an extended period in the adjacent mangrove stand.

Other possible measures, which will be considered, are:

- Re-use of discharge water; once the water discharged from production ponds has passed through the discharge treatment pond it may be pumped back to the production ponds for re-use. This may be difficult at certain times during the Dry Season, because it could lead to escalating salinity, but it has both economic and environmental benefits and the re-use of discharge water will be incorporated into the farm's operation where practical.

- Convert the discharge treatment pond from passive to active. The treatment pond will be first used in a passive capacity, relying on the settling action to reduce solids and nutrients absorbed by the particles of solids. It is planned to trial the introduction of marine species into the discharge system to make the treatment active. Such marine species may include a low stocking density of crustaceans (including prawns), finfish, biovalves and/or seaweed.

Management Commitments

- The quality of discharge water from the production ponds will be tested on a daily basis when any release is made to Middle Creek.
- Water will not be released from the exchange water treatment pond unless –
  - levels of DO and pH are within acceptable limits;
  - the release occurs between 20 minutes and 5 hours after the Darwin high tide;
  - the release occurs when the outgoing tidal range is greater than 2m; and
  - the release has been authorised by management.
- All pond discharge is to be directed to the exchange water treatment pond.
- All solid waste from ponds is to be removed to the solids desalination bays.

5.3.4 Waste Disposal

Solid Waste (Pond Sludge) Disposal

The operation of the farm will generate solid waste or sludge in the settling channel and the production ponds.

Suspended marine sediment will settle out in the supply channel, especially on days when the Blackmore River water has a high turbidity due to heavy rain or large tides. After a period of time, possibly a number of years the supply channel will need to be desilted to maintain proper function. This material will contain salt and will require desalinating. The material will be removed from the settling channel by excavator and hauled to the solids desalination bay by dump truck.

A small volume (approximately 50 m^3 per crop) of solid waste material will require removal from the production ponds after each harvest. The sludge in the production ponds will contain higher levels of nutrients. An excavator will be used to remove the sludge from the ponds, and a dump truck will transport and deposit the sludge to the solids desalination bays.

The desalination bays, covering an area of 5 hectares, will be bunded and divided. The sludge from the production ponds will be deposited into these bays sequentially, so seperate bays will contain material from different seasons. Once dumped the material will be spread to a shallow depth (approximately 200 -300 mm) and left to be exposed to Wet Season rains. The sludge material will be retained in the solids desalination bays for up to five years and turned over in the Dry Season to enhance desalination by Wet Season rains. Once the salinity is lowered the material will be removed by front end loader and spread over a 26 hectare pasture area as a soil improver. Runoff from the desalination bays will be directed to the exchange water treatment ponds.

The emphasis of farm management will be to reduce the amount of solid waste, by vegetation on production pond banks and aeration placement as well as avoidance of overfeeding. Whilst it is anticipated that the volume of pond sludge will be able to be handled in the proposed desalination bays and pasture area, if more area of these structures is required the lease area holds sufficient space to expand as needed.

Run-off from the desalination area will be contained by a low bund (approximately 750 mm in height) and flow discharge via regulated release through drop structures (500 mm) and 150 mm piping. This will act to slow the rate of flow, minimising the carriage of solids. This water will be directed into the discharge treatment ponds and will be released with other farm discharge after settling.

Other Wastes

Packaging and production waste generated during farm operations will be either disposed on-site through burial or off-site by licenced contractor. Handling of solid and process wastes will be conducted in accordance with relevant regulatory requirements and Shire of Litchfield by-laws.

Domestic sewage effluent will be treated by septic tanks and associated absorption trench systems in accordance with the relevant Territory Health Services Code of Practice.

Management Commitments

- Sludge from the production ponds will be deposited sequentially and retained in the desalination bays for up to five years.
- All rainwater run-off from the desalination bays is to be directed to the discharge treatment pond.
- The placement of any deposit of solid waste in the desalination bays must be undertaken with instruction from the General Manager.
- All relevant legislative requirements, by-laws and codes of practice with respect to waste disposal will be adhered to.

5.3.5 Post Larvae Quarantine

Post larvae will be purchased only from hatchery suppliers who provide a veterinarian certificate of disease free status. However, as a precautionary measure a quarantine facility will be established on farm for the holding of new post larvae (juvenile) prawns to safeguard against the introduction of disease to the farm. The quarantine facility will consist of a covered steel frame shed, with a series of holding tanks. Each batch of new arrivals will have isolated reticulation and discharge to prevent the spread of disease to the farm or to natural waterways.

The post larvae will be tested for disease on arrival, held in the quarantine tanks until laboratory results are obtained and retested immediately prior to stocking. Disease testing will be carried out with the cooperation of the Darwin Aquaculture Centre of DPI&F.

Management Commitments

- Post larvae will be purchased only from hatchery suppliers who provide a veterinary certificate of disease-free status.
- Post larvae will be tested for disease upon arrival at the farm, held at the quarantine and re-tested prior to release into the production ponds.
- Post larvae will not be placed into or removed from the quarantine facility without instruction and authority from the General Manager.
- Reticulation and discharge from the quarantine facility will be isolated.
- No water discharge from the quarantine holding pond is to be released without instruction and authority from the General Manager.

5.3.6 Fuel Storage

Diesel required for power generation for the farm's operation will be stored in three 55,000 L above ground storage tanks. The tanks and associated bunding will be constructed in accordance with AS1940-1988 *The Storage and Handling of Flammable and Combustible Liquids.*

5.3.7 Archaeological Sites

Six archaeological sites have been identified as prescribed archaeological places or objects and are legally protected under the *Northern Territory of Australia Heritage Conservation Act, 1991*. These sites have been assessed to be of low archaeological significance. Phelps/Panizza intend to seek approval for the destruction of these sites.

Phelps/Panizza will consult with Heritage Branch of DLPE on an "as needs" basis with regard the archaeological sites and associated issues.

5.4 ENVIRONMENTAL IMPACT MONITORING

To assess the effectiveness of the environmental management measures implemented, on-going monitoring of key environmental indicators, such as water quality, mangrove health and aquatic communities will be conducted. Data obtained from these monitoring programs will be used to assess the need for any variations to the environmental management measures being employed at the farm.

Recent on-going research by CRC for Aquaculture has concentrated on the use of "ecological health indicators". This system of monitoring is currently being undertaken as part of a Prawn Discharge Study Program being conducted by the University of Queensland. This work will be tracked by management of the Blackmore River development and, if practical, will be included with conventional ecological assessment as the practical application of ecological health indicators is better developed.

5.4.1 Water Quality Monitoring

An on-going Water Quality Monitoring Program will be conducted to monitor nutrient levels and general variables in Middle Creek, the Blackmore River and at control locations. This program will be developed in consultation with DLPE, DPI&F and CSIRO Marine Research, CRC. The purpose of the monitoring program will be to identify any changes to baseline water quality resulting from the aquaculture farm's operation.

One of the key objectives for the proposed water quality monitoring program will be the protection of the aquatic ecosystem into which discharge water is released. Retaining water quality parameters within specified criteria levels will assist in ensuring the protection of aquatic wildlife. Criteria levels will be developed in accordance with the principles of the draft National Water Quality Management Strategy guidelines (NWQMS 1999), which provide guidance in the setting of site-specific water quality objectives.

Sampling will be undertaken at a total of ten locations: one in the Blackmore River (SW1), four along Middle Creek (SW2-SW5), two from unnamed creeks (SW6 & SW7) and three from various locations within the farm area. Sampling from these locations enables the collection of background water quality data (from Middle Creek and the control creek) and the collection of data from water at various points along the farm's production stream (at intake, production ponds and discharge points).

Recent research by the CRC for Aquaculture, demonstrated that the quality of discharge water from production ponds is highly variable over short time periods (daily or even hourly). The function of the

exchange water treatment ponds is expected to buffer quality variations of discharged water to Middle Creek. In order to compile representative water quality results, the water at the Middle Creek discharge point will be tested on a daily basis, as will samples from the pump jetty.

The monthly water testing is to be carried out on the half moon day as listed in published tidal prediction data. Samples will be collected in numerical order, that is SW 1 to SW 7, with the first sample (SW 1) to be drawn 2 hours after the late morning high tide. This tide event has been chosen as the starting point for sampling as it is at the beginning of the neap tide period and should enable the full effect of a month of discharge to be measured. Monthly on-farm discharge water testing will be undertaken at this time.

Samples will be tested for a range of the following parameters: DO, pH, EC, temperature, salinity, TSS, TN and TP. Measurement of DO, pH, EC and temperature levels will be determined on-site through *in-situ* testing at the time of sampling.

Sampling will be undertaken using portable multi-probe water quality testing equipment (Horiba or similar). Samples requiring laboratory testing will be dispatched to a NATA accredited laboratory for analysis.

A summary of the proposed Water Quality Monitoring Program, detailing sampling frequency, locations and analytical schedule, is presented in **Table 23**.

Table 23

Stage 1 - Proposed Water Quality Monitoring

Sampling Location	Site Reference	Site Description	Sampling Frequency	Testing Schedule
Blackmore River	SW 1	Pump jetty.	Monthly	TSS, TN, TP, DO, pH, EC, temperature, salinity.
			Daily	DO, pH, EC, temperature, salinity.
Middle Creek	SW 2	Upstream from discharge.	Monthly	TSS, TN, TP, DO, pH, EC, temperature, salinity.
Middle Creek	SW 3	Downstream from discharge.		
Middle Creek	SW 4	Downstream from discharge.		
Middle Creek	SW 5	Downstream from discharge.		
"Control Creek"	SW 6	Creek discharging to Blackmore River on opposite bank.		
Unnamed Creek (North of jetty)	SW 7	Creek adjacent to farm ponds & structures.		
On Farm	Discharge	Discharge from treatment ponds to Middle Creek.	Monthly	TSS, TN, TP.
			Daily	DO, pH, EC, temperature, salinity.
On Farm[1]	Supply Channel	2nd Stage lift pumps.	Daily	DO, pH, EC, temperature, salinity.

Note: 1. Proposed Stage 2 sampling location.

Management Commitments

- A Water Quality Monitoring Program will be undertaken at designated locations on Blackmore River, Middle Creek, unnamed creeks and farm areas, and will be utilised as an indication of aquatic ecosystem health.
- Samples will be collected and analysed on either a daily or monthly basis.
- Monthly samples will be tested for a range of parameters, including DO, pH, EC, TSS, TN and TP.
- Daily samples will be tested for a range of parameters, including DO, pH and EC.
- Develop appropriate water quality criteria levels in accordance with NWQMS guidelines.

5.4.2 Mangrove Monitoring

A mangrove monitoring program will be developed by Phelps/Panizza in consultation with DLPE. The objective of the program will be to monitor mangrove health, structure and composition.

It is proposed to conduct mangrove community monitoring in the area of Middle Creek and a second control creek approximately 2 km to the north of the pump jetty (Figure 17). A monitoring round will be undertaken prior to commencement of development to obtain background data and subsequently on an annual basis. Photographic records will be compiled at the time of each monitoring event. Data collected will be considered prior to any expansion of pond area beyond Stage 1.

Management Commitments

- Survey works involving an assessment of mangrove health, structure and composition in the area of Middle Creek and subsequent comparative surveys will be undertaken annually.
- The prawn farm will not be developed to Stage 2 until any significant environmental impacts identified through survey works have been addressed.

5.4.3 Weed Species

Annual weed surveys will be conducted in consultation with DPI&F, DLPE and Parks and Wildlife Commission of the Northern Territory, to monitor species composition and spread. Areas to be monitored will include all fire breaks and trails to reduce the possibility of destructive fires fuelled by exotic grasses.

Management Commitments

- Weed survey works will be undertaken annually. Survey works will involve data collection relating to species composition and spread.

5.4.4 Biting Insect Monitoring

Biting insect monitoring will be undertaken by Phelps/Panizza personnel in consultation with the Medical Entomology Branch of' THS.

The most likely structures on the farm that may lead to an increase in the numbers of biting insects, most notably mosquitoes, are the proposed freshwater dams. The potential for mosquito infestation in the freshwater dams is considered limited, but monitoring of insect numbers will be periodically undertaken in this area by trapping and logging.

Management Commitments

- Survey works involving trapping and logging will be undertaken to monitor the numbers of biting insects, in particular mosquitoes.

5.5 DECOMMISSIONING AND REHABILITATION

The proposed development is considered to be a permanent development, which will be retained in its entirety. Should abandonment of the aquaculture development (or parts thereof) be required, then the following decommissioning and rehabilitation practices will be applied.
The pumps and jetty will be decommissioned and removed from the Blackmore River. The supply channel, production and treatment ponds will be leveled with a D8 dozer or similar. Concrete and piping will be removed for salvage. Miscellaneous materials such as power lines, pumps, above ground storage tanks and small concrete structures will be removed from the lease area.

In the initial stage, the wall of the freshwater dam will be around 7.5 m in height and this would be leveled by dozer back to the surrounding ground level. The Stage 2 freshwater dam will have a maximum wall height of 13 m and would be difficult to flatten. Should the dam be decommissioned from its full-scale size a feasibility study will be conducted, in consultation with relevant Authorities, to evaluate the potential benefits of converting the structure into a conservation and recreational area.

All buildings (except concrete footings) and equipment will be removed. On-site access roads will be ripped and graded flat and the regeneration of the vegetation encouraged.

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GLOSSARY

AAPA	Aboriginal Areas Protection Authority
AHD	Australian Height Datum
AASS	Actual Acid Sulfate Soils
ASS	Acid Sulfate Soils
ASSMAC	Acid Sulfate soils Management Advisory Committee
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific & Industrial Research Organisation
dbh	Diameter at Breast Height
DLPE	Department of Lands, Planning and Environment
DO	Dissolved Oxygen
DPI&F	Department of Primary Industry & Fisheries
EMP	Environmental Management Plan
IQF	Individual Quick Freezing
LAT	Lowest Astronomical Tide
MAGNT	Museums & Art Galleries of the Northern Territory
NPK	Nitrogen Phosphorous Potassium
PASS	Potential Acid Sulfate Soils
PAWA	Power and Water Authority
PER	Public Environmental Report
POCAS	Peroxide Oxidation Combined Acidity & Sulfate
ppm	Parts Per Million
TDS	Total Dissolved Solids
TIT	Triple Interceptor Trap
TN	Total Nitrogen
TP	Total Phosphorous
TP1	Test Pit 1
TPA	Total Potential Acidity
TSS	Total Suspended Solids