

AUSSIE PRAWNS PTY LTD AQUACULTURE DEVELOPMENT

Public Environmental Report

Prepared for:

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Abbreviations

AHD	Australian Height Datum
APPL	Aussie Prawns Pty Ltd
ASS	Actual Acid Sulfate Soils
CH ₄	Methane
CO	Carbon Monoxide
CO ₂	Carbon dioxide
DIN	Dissolved Inorganic Nitrogen
DIPE	Department of Infrastructure, Planning and Environment
DO	Dissolved Oxygen
DON	Dissolved Organic Nitrogen
EC	Electrical Conductivity
EMP	Environmental Management Plan
EPA	Environmental Protection Agency
FCR	Food Conversion Ratio
GJ	Gigajoules (=10 ⁹ joules)
HSE	Health Safety and Environment
JHA	Job Hazard Analysis
JSA	Job Safety Analysis
ML	Megalitre (10 ⁶ L)
N ₂ O	Nitrous oxide
NMVOC	Non-Methane Volatile Organic Compounds
NOI	Notice of Intent
NO _x	Oxides of Nitrogen
NPI	National Pollutant Inventory
OEH	Office of Environment and Heritage
OHS	Occupational Health and Safety
PASS	Potential Acid Sulfate Soils

PER	Public Environmental Report
ppt	Parts per thousand
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorus
TSP	Triple Super Phosphate
TSS	Total Suspended Solids

1 Introduction

1.1 PROJECT OVERVIEW

This is the Public Environmental Report (PER) for the proposed Aussie Prawns Pty Ltd (APPL) aquaculture development. The development is located at Section 1880, Hundred of Ayers, Channel Island Road, Weddell, Northern Territory. The site was first developed in 1993 for the production of barramundi. However, operations were soon abandoned and converted into prawn farming. The farm consisted of 10 production ponds (50m x 100m), 4 nursery ponds (10m x 50m), a hatchery, a broodstock building, an office and processing shed, a workshop, workers accommodation and an executive residence.

In 1998, APPL went into partnership with a Taiwanese entity. An additional 18 ha of production ponds were constructed but these were never commissioned. Operations ceased altogether in 2001.

The site has recently changed ownership, however the prawn farm will continue to operate as Aussie Prawns Pty Ltd. The new owners, Marine Produce Australia, are proposing to redevelop and expand operations of the existing prawn farm to 42ha.

It is worthwhile noting that previous environmental assessments were carried out, which include a Public Environmental Report (Kinhill Engineers 1992), for the original aquaculture development in the early 1990s, and an Environmental Management Plan (KBR 2004), for a 14ha redevelopment following the 2003 takeover. Both documents were reviewed and approved by the Office of Environment and Heritage (OEH). A number of conditions were set, including:

- Development of an acid sulphate soil management plan in case the proposed improvements to the salt water dam and intake channel were found to involve disturbance of potential acid sulphate soils;
- Development of a decommissioning and rehabilitation plan;
- Implementation of a mangrove monitoring plan; and
- A requirement not to clear remnant vegetation over and above the clearing required to allow for the construction of ponds.

The Biodiversity Unit also raised concerns regarding impacts of prawn farm effluent on water quality and marine ecology adjacent to the discharge point.

Following a decision to increase production pond area to 42 ha, the owners were advised by the OEH that such a development would trigger the Environmental Assessment Act. A Notice of Intent was submitted in December 2004. Following a public review, the Minister for the Environment set the level of assessment at PER, or Public Environmental Report, with the main issues to be addressed as follows:

- A significant increase in scope of the previously approved development;

- Treatment and discharge of wastewater;
- Impact of wastewater on receiving mangrove and marine environment;
- Potential for exposure of acid-forming sediments;
- Erosion and sediment control issues; and
- Proximity to the marine environment.

The final PER guidelines were issued on 8 February 2004 and have been appended (Appendix A).

1.2 PROPONENT DETAILS

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1.3 PROJECT JUSTIFICATION

A 1984-1996 Food and Agriculture Organisation review of global aquaculture (Rana and Immink 2005) reported that "...finfish and other aquatic products will be in shorter supply as domestic and international demand for both high and low valued species increases due to rising populations, living standards and disposable incomes. With globally dwindling yields from many traditional marine and inland capture fisheries, shortfalls in supply of aquatic products will largely need to be met from culture through increased utilisation and output of current and hitherto uncultured species".

The potential of aquaculture to meet the challenges of food security and to generate employment and foreign exchange is clearly demonstrated by the rapid expansion of this sector, which has grown at an average annual rate of almost 10% since 1984 compared with 3% for livestock meat and 1.6% for capture fisheries production.

The Darwin region provides an ideal location for aquaculture development. This is due to:

- A suitable climate for rearing warm water marine species;
- Sufficient land and water resources available at reasonable expense;
- Proximity to Darwin Harbour and the Alice-Darwin railway which facilitates national and international trade; and
- Support from the Northern Territory government for this industry.

1.4 PROJECT BENEFITS

It is believed that the proposed prawn farm expansion will bring the following benefits to the Greater Darwin region:

- Employment of local contractors and suppliers, consultancy engineering and environmental services during the development and construction phase;
- Employment of up to 20 permanent and casual staff during operations; and
- Economic return from operational expenditure on local suppliers for fertilisers, machine spare parts, and miscellaneous goods and services;
- Redevelopment of a derelict site, turning a liability site into an asset.

1.5 PURPOSE OF THIS DOCUMENT

This document is a Public Environmental Report (PER) for a proposal to redevelop and expand operations to 42 ha at the Aussie Prawn farm site at Section 1880, Hundred of Ayers, Northern Territory. It is submitted by Aussie Prawns Pty Ltd (the proponent) to provide the Northern Territory Government and the public with necessary information to allow for appraisal of the environmental acceptability of the proposed Aussie Prawns Pty Ltd Aquaculture Development.

This document has been prepared by Kellogg Brown & Root Pty Ltd on behalf of the proponent, in accordance with the Northern Territory Environmental Assessment Act 1982 and the guidelines prescribed by the Minister for Environment and Heritage (Appendix A).

2 Description of Proposed Development

2.1 SITE LOCATION

The proposed APPL aquaculture development is located at Section 1880, Hundred of Ayers, Channel Island Road, Weddell, Northern Territory. The 288 ha freehold area is situated on Haycock Creek, a tributary of Haycock Reach which forms Darwin Harbour's Middle Arm. Figure 2.1 illustrates the site location.

2.2 LAYOUT AND MAJOR INFRASTRUCTURE

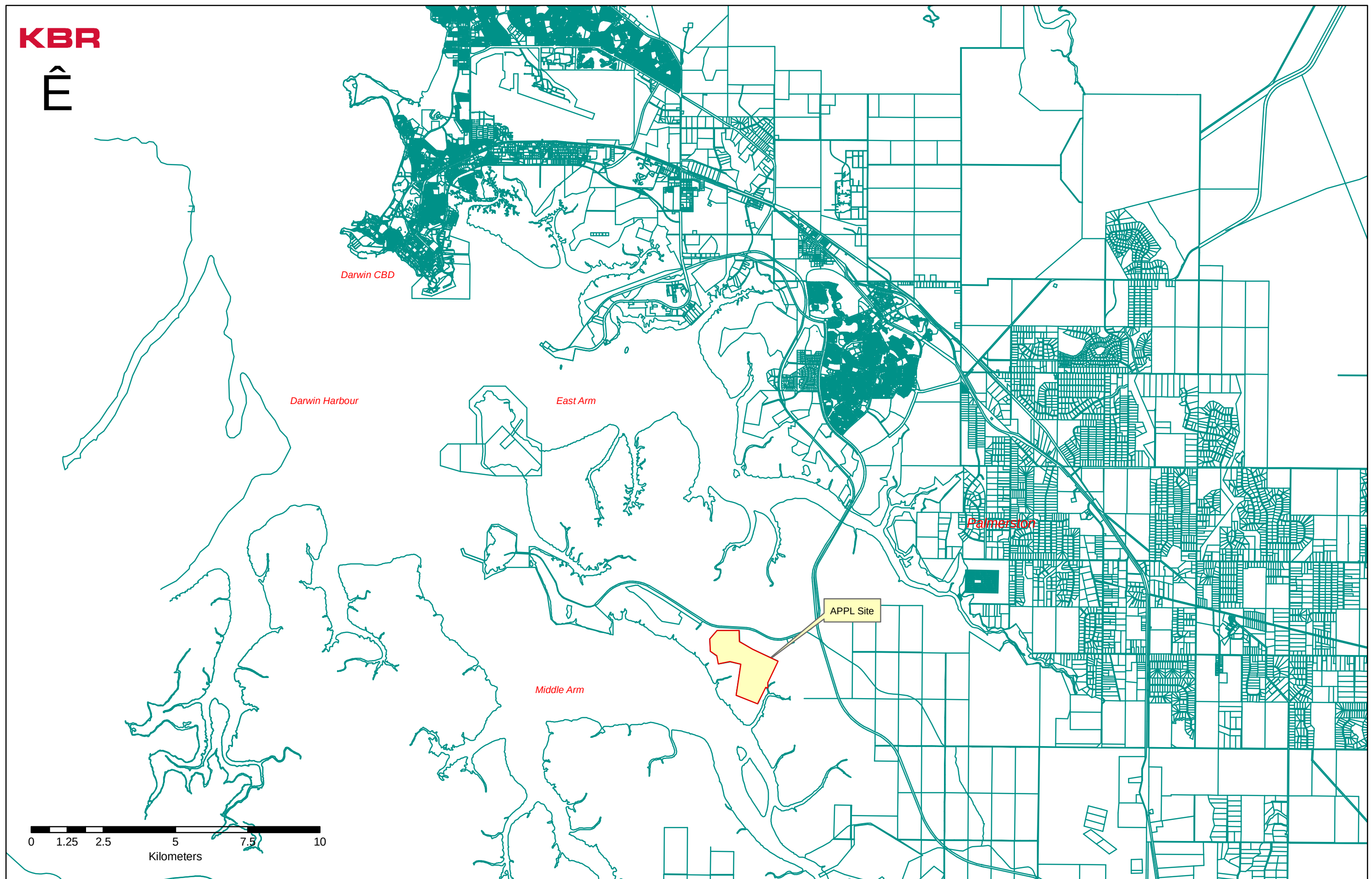
The proposed layout of the prawn farm is illustrated in Figure 2.2, and consists of land usage areas shown in Table 2.1. The proposed redevelopment has been overlaid onto an aerial photograph showing the existing development. Figures 2.3 and 2.4 illustrate cross sections at various locations within the development.

Table 2.1 Proposed land usage areas

Land use description	Areas (hectares)
Area under ponds	42
Roads and embankments around ponds	20
Salt water storage dam	3.5
Salt water intake canals	12
Fresh water storage dam	31
Effluent canals (primary treatment)	9
Effluent sedimentation ponds (secondary treatment)	11
Sludge drying bed	1
Tidal flats and mangroves	96
Access roads	10
Hatchery and farm support	2.5
Unused upland area	50
Total site area	288

Upon completion, the redevelopment will consist of 42 one hectare production ponds (including associated intake and outlet channels), a pump station at the jetty, a second lift pump station at the salt water dam, a pump station at the fresh water dam, two

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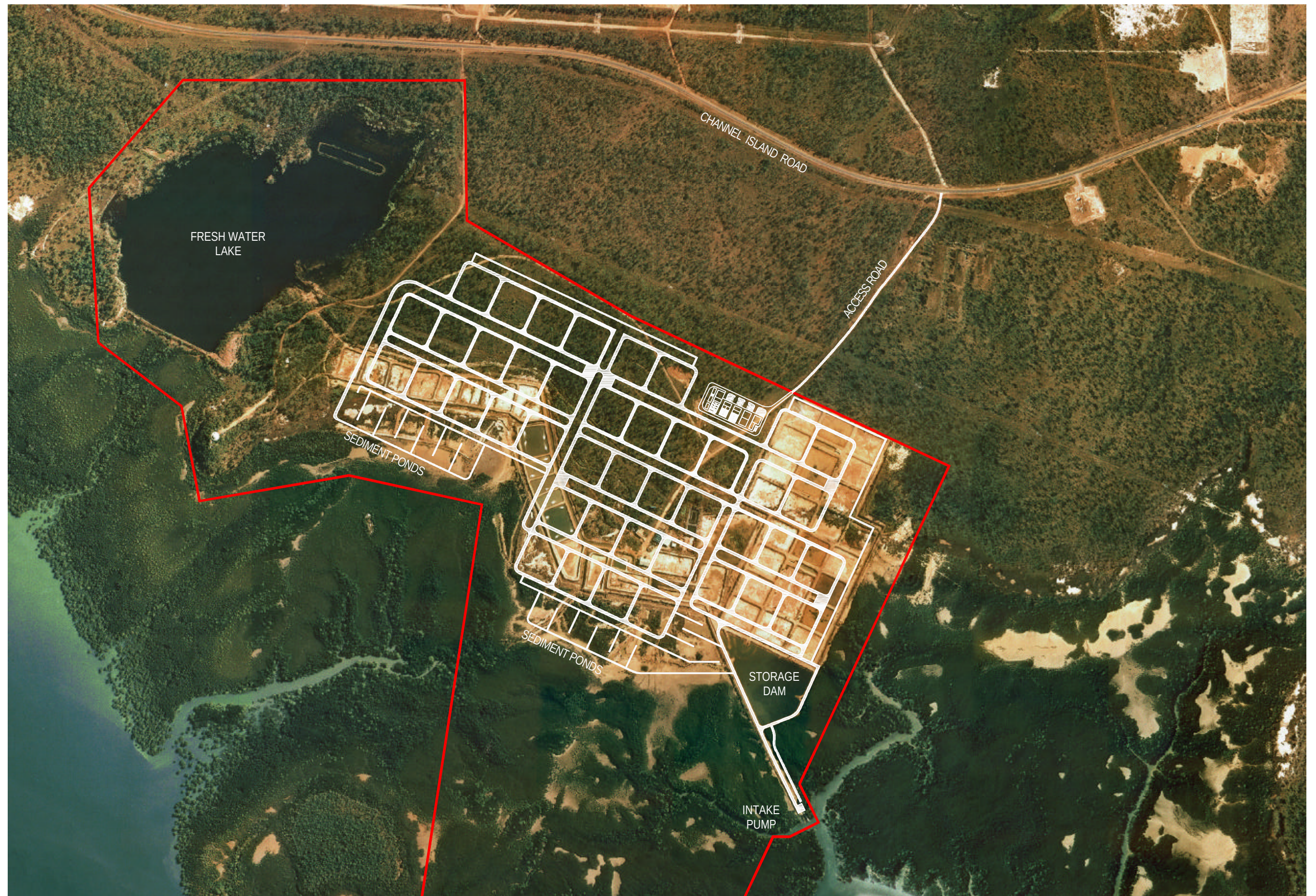
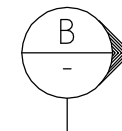
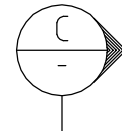
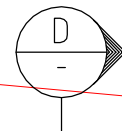
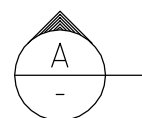


Figure 2.2. - Proposed APPL Aquaculture Development Layout.

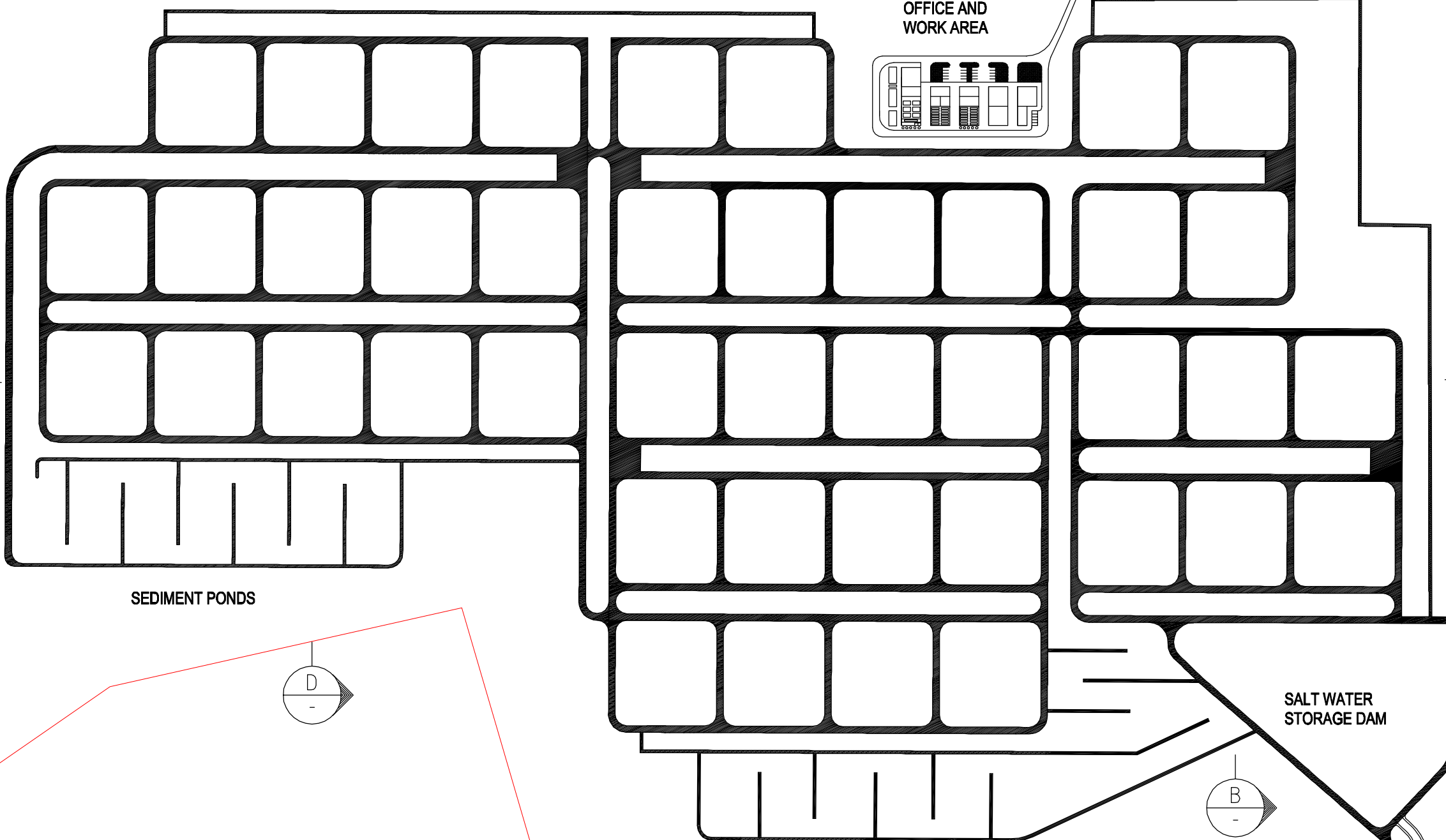
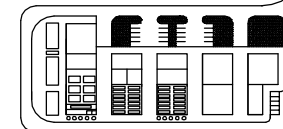
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FRESH WATER LAKE



OFFICE AND
WORK AREA



SEDIMENT PONDS

SALT WATER
STORAGE DAM

SEDIMENT PONDS

INTAKE PUMP

0 25 50 75 100 125
SCALE OF METRES
SCALE 1:2500

Figure 2.3 - Location of Sections

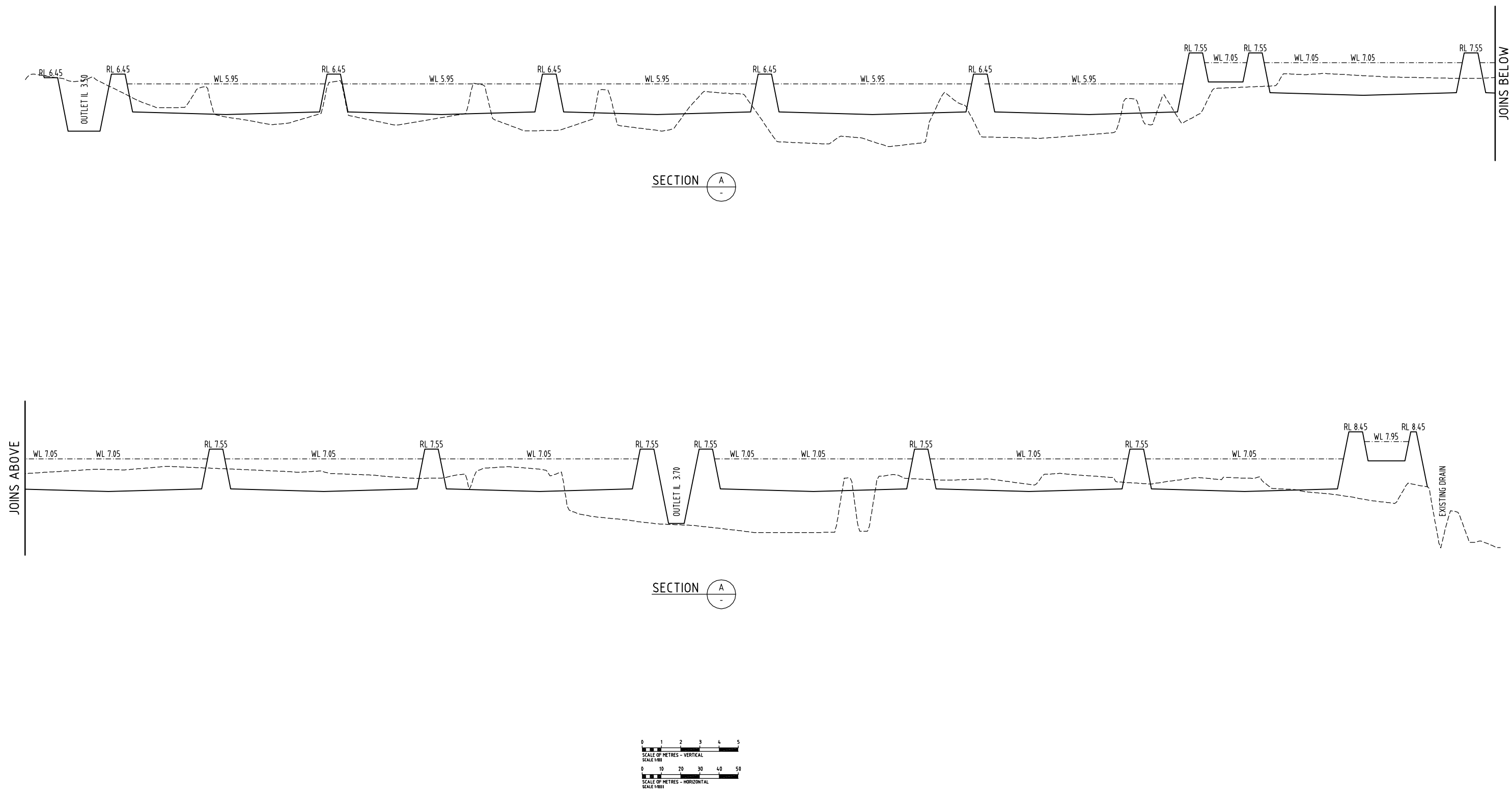


Figure 2.4 - Sections - Sheet 1 of 2

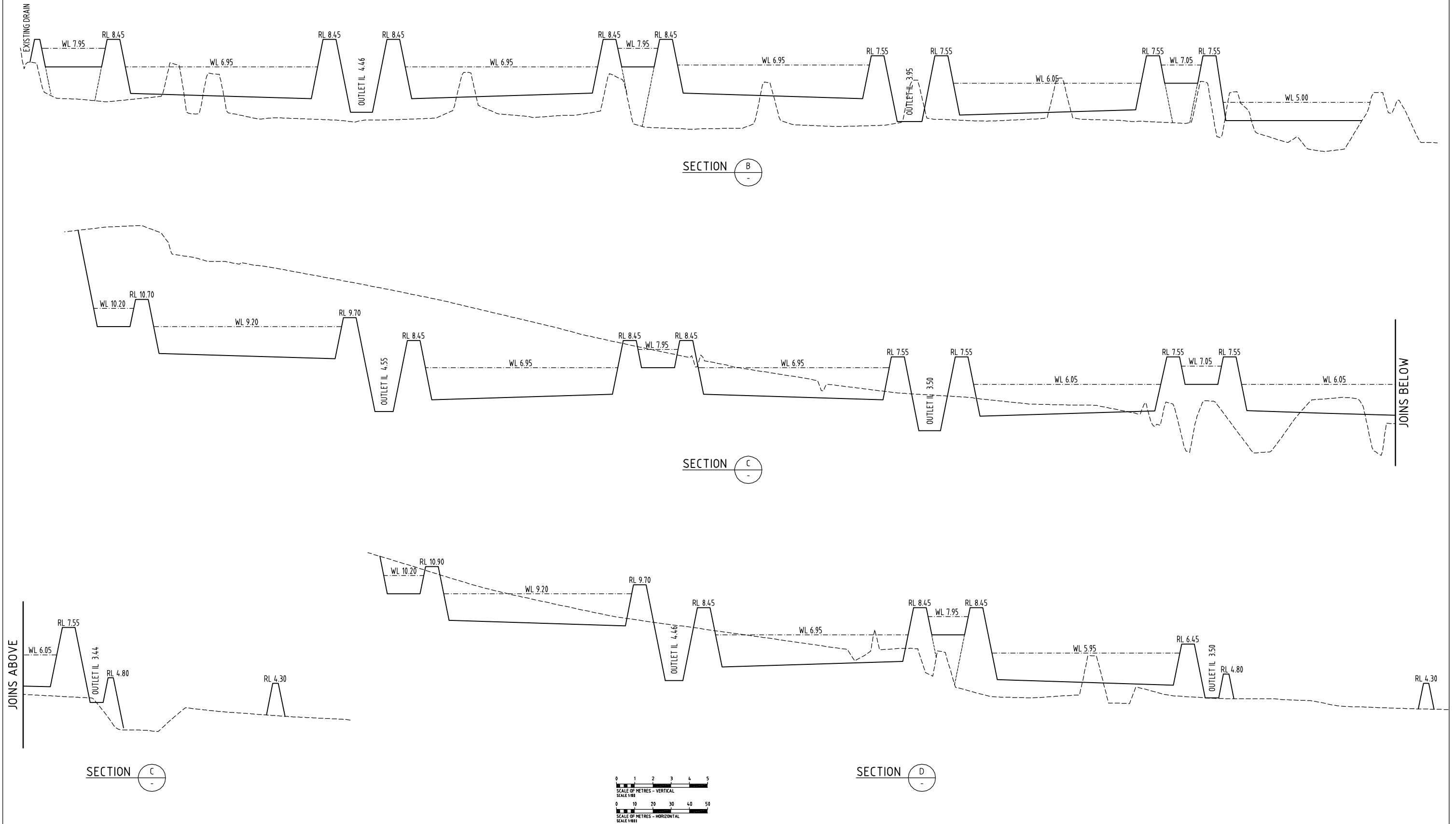


Figure 2.4 - Sections - Sheet 2 of 2

sedimentation ponds, a sludge drying bed, and a new hatchery and farm support buildings.

The redevelopment is trying to reuse as much of the existing infrastructure as possible. The following existing infrastructure will be upgraded:

- Extension of the intake channel to the new ponds,
- The saltwater storage dam, from which the dead vegetation will be removed followed by a build up of the dam walls to increase storage capacity; and
- The freshwater dam, which will be provided with a new spillway and pump station.

The existing production ponds will be reshaped to the proposed design, and most buildings except for the executive residence will be demolished.

It is proposed that the redevelopment occurs progressively subject to funding and weather conditions. The following indicative stages are proposed.

STAGE 1:

- Establish 10-15 new production ponds including associated intake and effluent channels;
- Upgrade the saltwater pump facility at the jetty;
- Raise saltwater storage dam walls and install second lift pump station;
- Establish 1 sedimentation pond;
- Establish the sludge drying bed; and
- Upgrade the fresh water dam spillway and establish pump station

STAGE 2:

- Establish a further 10-15 new production ponds including associated intake and outlet channels;
- Establish the second sedimentation pond; and
- Establish the new hatchery and farm support buildings

STAGE 3:

- Establish the remainder of the production ponds including associated intake and outlet channels.

Major infrastructure on the proposed prawn farm is described in the following sections.

2.2.2 Saltwater System

Saltwater supply for farming practice will be sourced from Castnet Creek, a branch of Haycock Creek via a tidal pumping station. A new pump station and channel will be constructed to deliver saltwater to the saltwater storage dam. This pump station will operate on a tidal basis with pumping only occurring on mid tide up. The pumping station will consist of multiple pumps in a duty standby arrangement. The typical

pumps will need to deliver a total flow rate of approximately 1800 litres per second pumping over a nominal 10 hour period per day.

The saltwater dam wall will be raised to increase its holding capacity. This dam is approximately 3.5 ha in area with a future nominal depth of 2.0 m. This will provide a storage capacity of 70,000 kL or approximately 1 day's saltwater throughput for the 42 ponds.

Saltwater from the storage dam is then pumped into the production ponds via a network of saltwater intake channels. These intake channels are 18 m wide at the base and will store approximately 1.5 days' saltwater throughput for the 42 ponds. The pumps required for this second lift into the intake channels will deliver approximately 730 litres per second. The pump arrangement will also be a duty standby system with 2 or 3 pumps in parallel.

2.2.3 Freshwater System

Freshwater is used on site for seasonal dilution of the saltwater to compensate evaporative losses, and for general use. Freshwater is supplied from an existing freshwater dam located in the northern section of the property. The dam has a surface area of approximately 30 ha and a capacity of 1300 ML. The total catchment area for the dam is 77 ha.

Improvements will take place on the freshwater dam in Stage 1 of the redevelopment. The dam will be repaired and dam wall capped, the existing spillway will be improved, and a second spillway and a pumping station will be constructed between the dam and the production ponds.

During the dry season production months, the average evaporation rates exceed the average rainfall and seasonal dilution will be required to compensate for evaporative losses and subsequent salinity build-up in the pond water.

Freshwater from the dam will be pumped and piped to the production ponds. The pumps required to distribute the water will operate 24 hours a day and will need to deliver approximately 40 litres per second. The pump arrangement will also be a duty standby system with 2 pumps in parallel.

During the wet season production months, the effects of evaporation are compensated by the average rainfall and hence no additional freshwater is required.

2.2.4 Production Ponds

In Stage 1 of the redevelopment, the existing ponds will be decommissioned and absorbed into the new development. Ten to fifteen new one hectare production ponds each with dimensions of 100 m x 100 m will be constructed in the first stage. The ponds will be stepped down to suit the natural topography of the site whilst still maintaining adequate fall to achieve effluent drainage to the sedimentation ponds. The ponds will be constructed to a depth of 1.4 m at the intake side to 1.6 m at the outlet side.

The balance of the 42 production ponds (100m x 100m) will be progressively established following completion of Stage 1.

2.2.5 Sedimentation Ponds and Effluent Channel

Pond effluent will be discharged into effluent channels that direct the effluent to the downstream sedimentation ponds. The effluent channels will be constructed with a nominal 5 m wide earth base constructed at low gradients to minimise erosion within the channel. Effluent will be discharged from the ponds via a concrete collection pit and piped to the effluent channels through the pond embankment walls.

The effluent channels are significantly larger than required to accommodate the effluent volumes. These channels have been sized to enable easy access to harvest the prawns as well as to maintain or repair the ponds.

The sedimentation ponds are located at the lowest part of the development to the south of the ponds. The ponds will be constructed on the fringe of the high tide mangroves with a bund wall around the perimeter to contain the effluent. The spillway height of the sedimentation ponds will be set to restrict tidal inundation. Inundation by high high tides, 1:10 and 1:100 year return storm surges can be avoided through the manual placement of stop logs. The two ponds have areas of 4.5 ha and 6 ha respectively, and represent a total treatment area of approximately 25% of the total production area. Baffles will be constructed within the sedimentation ponds to increase the retention time and maximise optimal sedimentation of entrained solids rich in nutrients. The depth within the sedimentation ponds will vary between 0.6 m to 1.2 m. The discharge regime will be selected such that the retention time in the sedimentation ponds is on average 2 days and at least 24 hours.

2.2.6 Sludge Disposal Facility

A one hectare banded sludge drying bed is located at the northwestern corner of the first stage production ponds.

Pond sludge is likely to accumulate in the prawn ponds, effluent channels and sedimentation ponds. These areas will be desludged on an as needs basis. The pond sludge typically consists of 92-96% clay and silt matter eroding from the pond walls and floor and up to 8% organic matter. Research in Australian aquaculture has found that pond sludge volumes typically range between 20 and 180 tonne/ha. Volumes are highest the first year and drastically reduce thereafter.

The sludge will be transferred to the drying bed, where nutrients and organic matter will gradually biodegrade and stabilise. The sludge is exposed to the wet season rains and/or flushed with fresh water to reduce its salinity. This water is directed to the effluent channels and into the sedimentation pond for treatment prior to discharge. The sludge is left to dry for 3 – 4 weeks. The dry sludge will be removed and used for onsite landfill, repair of pond walls or landscaping purposes.

2.2.7 Buildings

Figure 2.5 shows the proposed layout of buildings and approximate dimensions.

All existing buildings will be demolished, with the exception of the executive residence building, which is located on a hill to the west of the production area. The production and administrative buildings will be located within a separate area to the north east of the site. The following buildings are proposed:

Hatchery and maturation facilities

The hatchery and maturation facilities consist of three buildings to grow the prawns through their early stages of development. The facilities consist of:

- Spawning and maturation tanks;
- Post larvae tanks;
- A blower room;
- A larvae and algae laboratory; and
- An administration/store area.

The maturation and post larvae buildings contain a series of fibreglass holding tanks. The water in the tanks can be heated or chilled and exchanged. Effluent from these tanks passes back into the effluent channels for the ponds and into the sedimentation ponds.

The hatchery also contains algae growing tanks. These algae are used as feed stock for the prawn larvae.

The blower room consists of mechanical plant that provides air under pressure, which is used for aeration of the tanks.

Administration building

The development will include an administration building providing general office space for an anticipated staff number of 20, front counter and crib facilities, toilets, showers etc.

Packaging shed

The packaging shed consists of rapid chiller units for chilling the harvested mature prawns. They are then packed in boxes and stored in cold rooms before being sent off site to market. Prawn processing (other than packing), if required, will be subcontracted to an approved offsite processing facility.

Feed storage shed

The feed store consists of an area for the storing of feed stock. The store also contains weighing and batching equipment which allows the quantity of feed to each pond to be controlled and recorded. The floor of the food store is elevated to allow the easy loading of vehicles that are used to distribute feed stock to the ponds.

Workshop

The workshop will be used to service and maintain farm equipment such as paddle wheels and aerators (used for circulating water in the ponds) and other farm support equipment.

Plastic lined ponds and tanks

Plastic lined ponds and tanks are for the further conditioning of salt water for use in the hatchery and for quarantining and maturation of prawns.

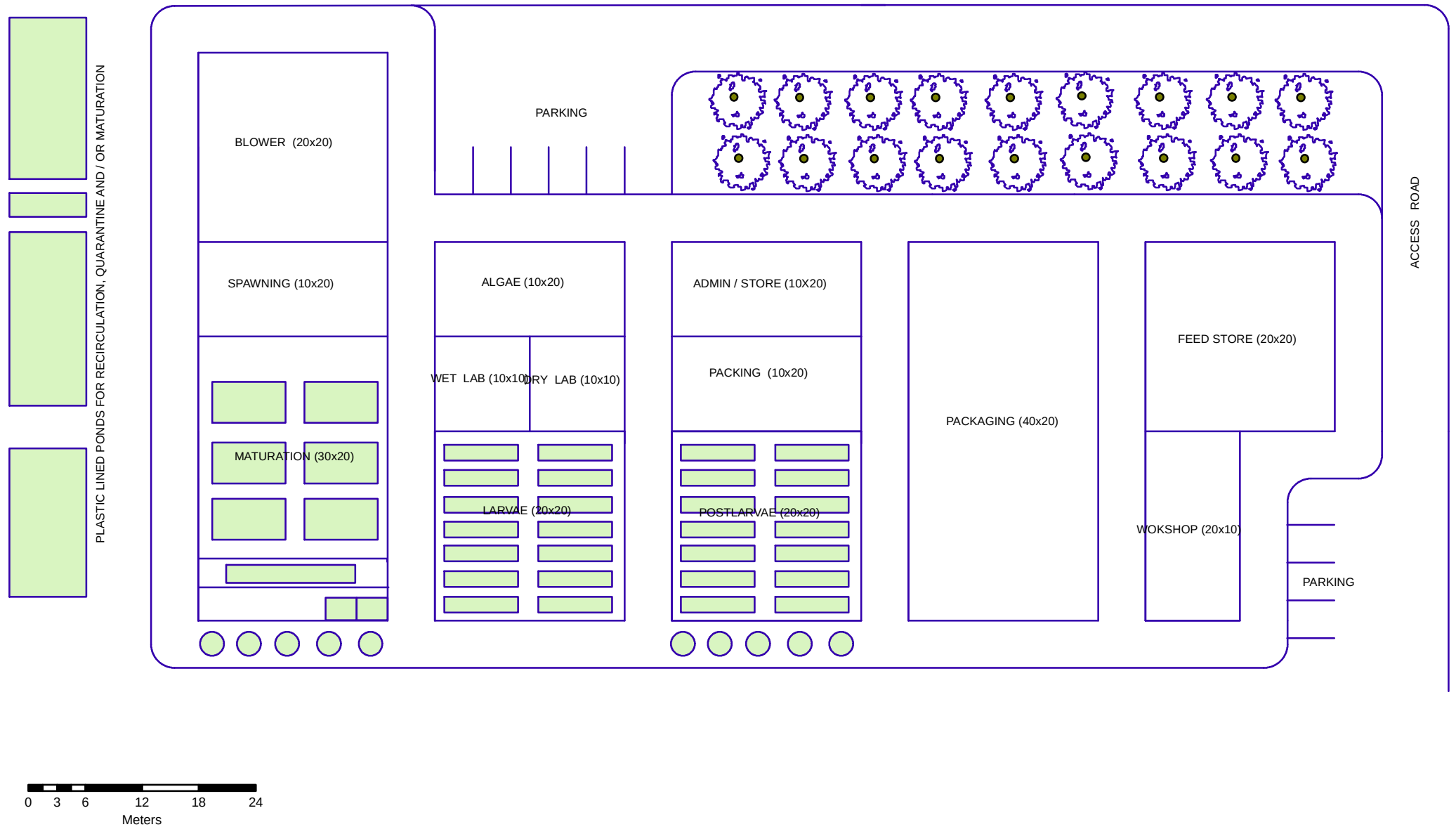


Figure 2.5 - Proposed building lay-out

2.2.8 Roads

There are two access roads from Channel Island Road to the site. The eastern access road will be retained all the way to the building area. This road continues onsite to the existing prawn ponds, with another branch leading back to the northern boundary and to the residence. These internal roads will be largely taken up by the new development.

The second, western access road follows the boundary line and veers off to the right along the freshwater lake perimeter before it merges with the internal road leading to the residence. This road will be retained.

A new internal road will be created from the buildings westward along the northern boundary. It will join the internal road to the residence.

Both access roads and internal roads will be unsealed.

2.3 PROJECT SCHEDULE

The construction of the prawn ponds and associated civil works will take place in the dry season. The ponds will be constructed in stages to enable completion and commissioning of each stage before the onset of the wet season.

The works associated with stage 1 (refer Section 2.2) could adequately be completed within one season. Construction could commence in April/May, depending on the end of the wet season, with completion in four to five months allowing for a possible late year crop.

The future stages would probably not commence until the next dry season unless stage 1 was completed early and the next stage could be satisfactorily completed prior to the onset of the wet season.

The remainder of the ponds would be progressively constructed in the following dry seasons.

The construction of the buildings would also be scheduled to start during the dry season to enable the civil works to be completed prior to the start of the wet season. The construction of the buildings could continue throughout the wet season if required.

2.4 CONSTRUCTION METHODOLOGY

2.4.1 Cut to fill

Topsoil and overburden lying over the material that is to be excavated will be pushed to one side and retained for use in the reinstatement of disturbed areas not required for pond lots in the future.

The design of the 42 ponds has attempted to achieve balanced cut to fill earthworks. This means the amount of filling required to construct the ponds and embankments will be similar to the amount of excavation required to construct ponds on higher ground.

2.4.2 Extractive materials

It is anticipated that some additional fill may be required during construction. Such additional fill could either be won by flattening out batters on the higher ponds or by excavating material from around the fresh water dam. The proposed location around the dam is to the north east corner to avoid damage to any heritage sites. Winning material from this dam would have an added benefit of increasing its storage capacity.

Experience on site indicates the material to be excavated is a clay gravel material that is very suited to earthmoving and construction.

2.4.3 Tidal influences

Construction of the sedimentation ponds and the edge of the lower production ponds will be located within the tidal flat/mangrove area.

During the dry season neap tides there are lengthy periods during which the proposed sediment pond area will not be inundated by tidal waters.

This provides an opportunity to plan construction work for those intervals during the dry season when there is no inundation of the area by tidal waters. As a result, fill material will not be dumped directly into the sea at any time.

The mangrove floor may be damp from recent tidal inundation when filling operations are in progress but surface water, if present at all, will be restricted to small areas of ponding that are expected to be quite shallow. These areas will be monitored to ensure they dry up within three days to avoid mosquito breeding.

2.4.4 Tide Patterns Following Construction of the Bund Wall

Once the new pond area is fully enclosed by the new bund walls no tidal water will enter the work site at any time.

The proposed works will not interfere with normal tide patterns in any of the areas outside the work site.

2.5 PROPOSED OPERATIONS

2.5.1 Species

The primary species to be grown is Black Tiger Prawn (*Penaeus monodon*), but the licence application also includes:

Brown Tiger Prawn	<i>Penaeus esculentus</i>
White Banana Prawn	<i>Penaeus merguensis</i>
Green Tiger Prawn	<i>Penaeus semisulcatus</i>
Karuma Prawn	<i>Penaeus japonicus</i>
Mud crabs	<i>Scylla serrata</i>
Barramundi	<i>Lates calcarifer</i>

2.5.2 Spawning and Juvenile Stages

Wild caught spawners (prawn broodstock) will be collected and transported to the site maturation facility. Eggs will be collected from mature females once they spawn. Day old prawns called nauplii will be collected and stocked into larval rearer tanks which contain 10,000 litres of sterilised aerated seawater. The prawns have a 10 day larval cycle before they metamorphosise by shedding their shell and going through a dramatic physical change to become a post larvae prawn (PL). The post larvae are held in the hatchery for 15 days (PL15) where they grow to about 2 cm in length. The prawns are then collected from the tanks and are ready to stock into ponds.

2.5.3 Production Method

Prior to stocking the prawns, an algal bloom is initiated and stabilised in each of the ponds through the application of a nitrogen and phosphorus fertiliser. The initial bloom typically requires a dose of 6.6 kg urea/ha and 2.7 kg TSP/ha. Once established, the bloom is sustained by the application of 1-2 kg N and 0.5-1 kg P per hectare per week (Fisheries Department, pers.comm.).

The post larvae are stocked at a density of 20-40 prawns per square metre, which is considered to be a semi-intensive stocking rate. Stocking of the 42 ponds will occur in a staggered rotation over a period of a few weeks.

The prawns will be fed a commercial prawn feed several times a day depending on their development stage. The amount and frequency of feeding will be adjusted to the requirement based on the results of feed tray monitoring. Prawn feeds typically consist of protein rich pellets and provide a complete diet for growing prawns. The anticipated crop yield is 5 tonnes per hectare. Using a conservative Feed Conversion Ratio (FCR) of 1kg of prawn per 1.8 kg feed, one crop will require 378 tonnes of feed (= 42 ha x 5 tonne/ha x 1.8 FCR).

Production pond water quality is monitored on a daily basis and adjusted as required (refer Section 2.5.5). As the season progresses, and more nutrients are added to the ponds, it becomes harder to maintain optimal water quality. Phytoplankton biomass can increase quickly and, at night time, reduce oxygen levels in the water to low levels. In order to avoid low oxygen levels in the ponds, and in the discharge environment, on average between 3 and 10% of the pond volume is replenished daily. This practice generally occurs for the last three months of the growing season.

During the dry season, salinity in the production ponds may increase to unacceptable levels due to evaporative losses. Prawn pond water salinity is typically reduced through the addition of freshwater (refer Section 2.5.5).

The prawns grow out within 120 to 160 days and are harvested when they are approximately 35 g. Wing nets and traps can be used in the ponds to harvest prawns. When a total harvest is required, the screens in the pond are removed, a codend sock is placed around the discharge pipe, and as the water is released down the drain, the prawns swim down with it and are caught in the net.

2.5.4 Process and Packaging

Once prawns are harvested, they are washed and chilled on ice immediately. They are then snap frozen, bagged, boxed and stored ready for sale.

If any additional processing is required, the prawns will be taken to a licensed processing facility.

2.5.5 Water Aspects

Intake water quality

Intake water quality may be subject to tidal and seasonal fluctuations. Regular water quality sampling is undertaken by Northern Territory Government in Darwin Harbour and a number of reports have been issued over the years (Padovan 1997, Padovan 2002, Dixon and Padovan 2003).

Sampling sites of relevance to the proposed development include (Figure 2.6):

- Site 3, mouth of Middle Arm, of the Padovan 1997 and 2002 reports; and
- Sites 10 and 11 in the Blackmore Estuary, of the Dixon and Padovan 2003 report.

Main water quality characteristics, including seasonal variation where available, are listed in Table 2.2.

The only parameter of concern may be suspended solids during events of high tidal velocity and if water is drawn from near bottom depth. The intake water will travel down a long (900 m), wide (18 m at the base) and deep (2 m) canal into the saltwater storage dam. The velocity in this intake canal will be around 0.1 m/s. It is anticipated that substantial settlement of suspended solids will take place both in the intake canal and the saltwater storage dam. The internal canals supplying saltwater to the ponds are equally wide and maximum flow velocities in these canals will be 0.04 m/s.

Further pre-treatment of the intake storage water occurs by allowing the water to condition in the intake storage pond. Conditioning the water allows:

- Suspended solids to settle;
- Beneficial phyto and zooplankton to bloom; and
- Any spawn from predatory aquatic fauna to hatch and grow so it can be more effectively filtered before being pumped into the production ponds.

Pond water quality

Optimal water quality in the production ponds is to be maintained as follows:

- pH: 7.2 - 8.5
- DO > 4 mg/L
- Turbidity: Secchi disk reading 30-50 cm
- Salinity: 25 ppt

Water quality in the ponds will be monitored twice daily. As a precautionary measure to ensure adequate water quality is maintained throughout the grow-out period, approximately 3-10 % of the pond water is replenished daily. The exact exchange regime needs to be determined, but it is likely that up to 20 or 30% from between five and ten ponds will be exchanged in any single day, with the intention to complete water exchange in all 42 ponds within a 3 to 5-day rotation.

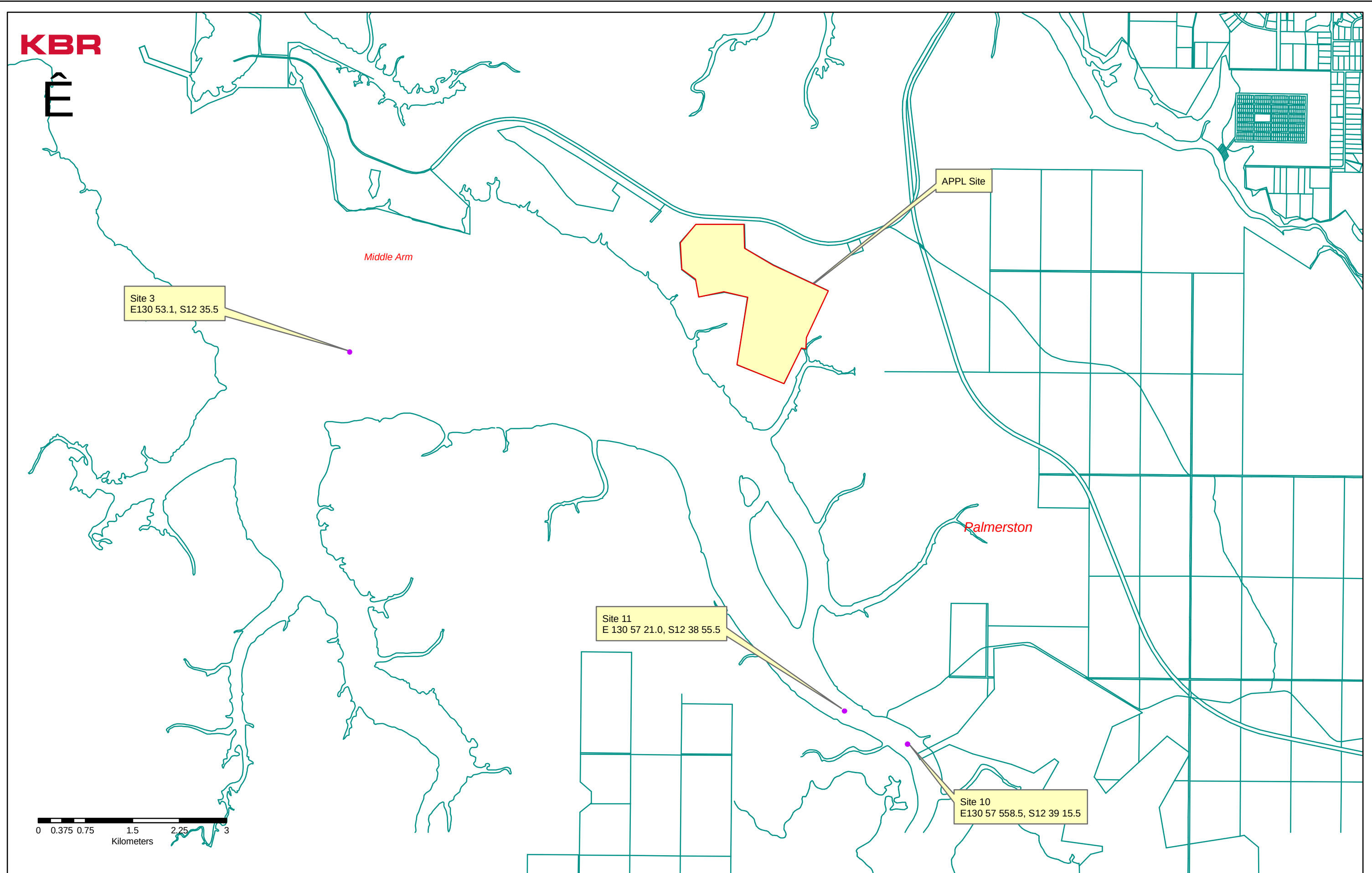


Figure 2.6 - Water quality sampling sites

Table 2.2 Water quality characteristics of Darwin Harbour

	Salinity (ppt)			pH			Temperature (deg C)			DO (% saturation)			TP (mg/L)			TN (mg/L)			TSS (mg/L)		
Month*	Site 3	Site 11	Site 10	Site 3	Site 11	Site 10	Site 3	Site 11	Site 10	Site 3	Site 11	Site 10	Site 3	Site 11	Site 10	Site 3	Site 11	Site 10	Site 3	Site 11	Site 10
Oct	36			8.35			31														
Nov	35.7			8.4			31.7			78			0.011			0.82			5		
Dec										87			0.017			0.25					
Jan	29.5			8.48			31			85			0.01			1.4			7		
Feb																					
Mar	29.8			8.5			31.3			86			0.01			0.42			2		
Apr	32.3			8.65			29.8			80			0.02			0.2			20		
May	34.2	27	25.3	8.55	8.24	8.22	26.8	28.56	28.56	84.5	77	80	0.015	0.015	0.015	0.28	0.19	0.16	3	4	6
Jun	34	29.7	29.3	8.4	8.23	8.21	27.7	27.95	27.95	84.5	79	78	0.008	0.016	0.014	0.62	0.13	0.14	11	5	5
Jul	35.5			8.4			25			85			0.015			0.38			7		
Aug	36			8.43			25			80			0.015			0.58			14		
Sep	36.5			8.42			27.8			80			0.015			0.4			5		
Oct	36			8.3			30			75			0.013			0.65			3		
Nov	36.2			8.38			30.8			82.5			0.018			0.3			6		

* Monitoring at Site 3 was between 1990 and 1991, and monitoring at Site 11 and 10 was in 2001.

In order to maintain DO levels above 4 mg/L, the prawn ponds will be aerated using various implements such as paddlewheels, aerotubes and oxygen injectors. As the prawns grow and the biomass in the ponds increases, the aeration requirement will increase as follows:

Month 1-2	6 kW	(8 hp)
Month 3	9 kW	(12 hp)
Month 4	12 kW	(16 hp)
Month 5	15 kW	(20 hp)
Month 6	18 kW	(24 hp)

This will most likely be realised using up to eight 2.2 kW (3 hp) aerators per pond.

When necessary, pH of the pond water will be adjusted through the addition of lime.

The optimal salinity level for the growth of black tiger prawns is 25 ppt. However, their salinity tolerance ranges from 15 ppt up to 38-40 ppt. With salinity levels in Darwin Harbour ranging between 34-37 ppt in the dry season and 29-32 ppt in the wet season (Padovan 2002), it is not expected that the intake water will require dilution when filling the ponds at the start of a crop. Dilution with freshwater will only be undertaken to compensate for evaporative losses during the dry season months of October through to November (refer Section 2.2.3). In case of a second crop during April to August additional dilution may be required during the months of June and July.

Water Requirements

Saltwater requirements for prawn production include:

- Initial pond filling; and
- Daily exchange water.

Daily water exchange is required in the hatching and production process to reduce nutrient load in the ponds and maintain dissolved oxygen and salinity levels. The daily exchange rate for production ponds is up to 10% of the pond volume, and for the hatchery is 50% of volume in hatchery tanks. Production pond water replenishment only starts after the first thirty or forty days in the grow-out cycle, resulting in 90-120 days of water exchange per crop.

Based on a daily exchange rate of 10%, the daily water exchange requirement for 42 ha of production ponds is 63 ML. This is an overestimation, as on average only 3-5% will be exchanged daily per pond, and exchange rates of 10% are only envisaged in case water quality takes a drastic change for the worse in individual ponds. As a result, the 63 ML/day illustrates the maximum daily exchange water required when all 42 ponds are in production, and is deemed appropriate for the water balance calculations.

Water balance calculations are further complicated by the fact that water exchange will not occur in all ponds on a daily basis. It is much more likely that the ponds will be stocked in a staggered rotation and rather than exchanging 3-10% daily, up to 20-30% of water may be exchanged every 3 to 5 days.

The daily water exchange requirement for the hatchery tanks is 0.12 ML. The water balance on an annual basis, accounting for maximum two crops per year, is summarised in Tables 2.3 and 2.4.

Two harvests are expected annually, during which water from production ponds and hatchery tanks will be emptied. Water required for harvest top-ups is expected to be 1260ML/year and 1.44ML/year for the production ponds and hatchery, respectively.

The tables below summarise the maximum annual water requirements for daily water exchange and initial filling.

Table 2.3 Annual saltwater requirement of production ponds at full development

Description	Quantity
Pond volume (42 ha x 1.5m deep)	630 ML
Daily exchange volume (at an exchange rate of 10%)	63 ML
Total exchange volume per crop (max. 120 days/crop)	63 ML/day x 120 days = 7,560 ML
Total exchange volume per year (2 crops):	15,120 ML
Initial fill volume per year (2 crops)	1,260 ML
<i>Total water required per year (2 crops)</i>	<i>16,380 ML</i>

Table 2.4 Annual salt water requirement of hatchery at full development

Description	Quantity
Tank volume (24 tanks @ 10,000 L)	0.24 ML
Daily exchange volume (at an exchange rate of 50%)	0.12 ML
Total exchange volume per run (20 days)	0.12 ML/day x 20 days = 2.4 ML
Total exchange volume per year (2 crops, 3 runs/crop):	14.4 ML
Initial fill volume per year (2 crops, 3 runs/crop)	1.44 ML
<i>Total water required per year (2 crops)</i>	<i>15.84 ML</i>

Freshwater is required in the production process for salinity adjustment due to evaporative losses in the dry months. It is anticipated that salinity adjustment will be required from October through to mid November during the first crop, and between June and mid July during the second crop.

During the first crop, the net average evaporation (evaporation minus rainfall) over this period ranges from 5.8 mm/day in September to 3.1 mm/day in November (BOM 2005). This equates to 95 ML of freshwater required for seasonal dilution of the 42 ha of ponds. During the second crop, net average evaporation is 7 mm/day in June and 7.2 mm/day in July, requiring approximately 134 ML of freshwater for seasonal

dilution. The extraction of 229 ML of water from the freshwater dam may not be sustainable every year and measures will be put in place to ensure that no second crop is produced in low rainfall years or when water level has dropped below a certain threshold level (refer Section 5.2).

Table 2.5 summarises the salt and freshwater requirement for the production process for the 42 ha farm and two crops per year.

Table 2.5 Annual water requirement for operation of the 42ha prawn farm

Description	Daily Quantity	Annual Quantity
Saltwater		
Production pond daily water exchange	63 ML/day	15,120 ML/year
Hatchery daily water exchange	0.12 ML/day	14.4 ML/year
Production pond initial fill		1,260ML/year
Hatchery tanks initial fill		1.44 ML/year
Total saltwater required	63.12ML/day	16,395.84 ML/year
Freshwater		
Freshwater for seasonal dilution	2.3 ML/day ¹	229 ML/year
Total freshwater required		229 ML/year

¹ Average requirement over 2 x 1.5 months of seasonal dilution, highest in July (2.9 ML/day) and lowest in November (1.3 ML/day)

2.5.6 Wastewater Discharge

Daily water exchange of production ponds and hatchery tanks as well as harvesting, will result in large volumes of wastewater. Pond/tank effluent will be channelled into sedimentation ponds prior to discharging via dedicated effluent discharge canals to the head of the near est tidal creek. The treated effluent will be dispersed in the unnamed creek and further downstream in Haycock Reach.

Wastewater Volume

The annual wastewater release from daily water exchange will be 15,120ML/year and 14.4ML/year from production ponds and hatchery tanks, respectively. At full-scale production, a maximum of 63 ML/day will be released from the production ponds and 0.12 ML/day from the hatchery tanks. As described in section 2.5.5, up to 30% of pond water may be exchanged at once in about a third of the ponds (or 14 ha), which still equates to a maximum daily discharge volume of 63 ML/day, assuming all production ponds are in production. In reality, it is more likely that 20% of pond water will be exchanged in up to 10 ponds each day. As such, 63 ML/day presents a maximum daily wastewater volume, associated with rapidly deteriorating water quality in a number of ponds at the same time. Daily discharge volumes are more

likely to be approximately 40-45 ML, considering a 35% exchange of all ponds on average throughout a typical pond exchange rotation schedule.

Annual water release following harvesting will be 1,260 ML and 1.44 ML from production ponds and hatchery, respectively. These annual volumes are based on the assumption that two crops will be realised per year.

Wastewater Discharge Regime

Typical discharge regimes are yet to be determined, but the design will be such that:

- Discharge from the sedimentation ponds can occur within a 4 to 8 hour timeframe coinciding with high tides;
- Short circuiting of effluent in the sedimentation ponds will be prevented and plug flow can be relied upon (eg. provision of baffles);
- Retention time in sedimentation ponds is approximately 2 days during normal operations, ie. 3-5% exchange; and
- Maximum daily discharge from the sedimentation ponds is limited to their capacity, thus ensuring a retention time of minimum 24 hours (ie. encountered when 10% exchange is required to drastically improve water quality in a number of ponds).

Wastewater Quality and Nutrient Load

Pond effluent typically contains three components which are of concern in terms of discharge to the environment: total suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP).

Numerous literature sources have been consulted to predict pond effluent quality. Sources include:

- Target industry discharge limits (Queensland EPA 2000) for mean TN levels of 0.8mg/L, mean TP levels of 0.1 mg/L and mean TSS levels of 20 mg/L. These are mean levels after treatment;
- Literature reporting typical values of 2-3 mg/L of TN, 0.3-0.45 mg/L of TP and 120-165 mg/L of TSS in Thailand (Briggs and Funge-Smith 1994) and 0.7 mg/L TN and 0.2 mg/L TP in Hawaii (Ziemann et al. 1992);
- Derivations of nutrient concentration based on proposed feed composition, feed conversion rates and fertiliser applications using formula shown in Appendix B. The calculated levels, based on a very conservative FCR of 1.82, are 1.25 mg/L for TN and 0.06 mg/L for TP before treatment;
- Derivations of nutrient concentration based on the following assumptions (refer to Appendix B for calculations):
 - o Fisheries Department estimate of nutrients in pond effluent of 56kg TN/tonne of prawns and 15kg TP/tonne of prawns;
 - o Production of 5 tonnes per hectare of ponds; and
 - o 180ML of wastewater discharged per hectare of pond.

- o Calculated levels are 1.55 mg TN/L and 0.42 mg TP/L

The expected pond effluent quality based on the three methods is listed in the table below for comparison.

Table 2.6 Estimated pond effluent quality

Method of estimation	Pond effluent concentration (mg/L)		
	TSS	TN	TP
Target industry discharge limit - mean	20	0.8	0.1
Target industry discharge limit - maximum	100	3	0.3
Based on FCR	-	1.25	0.055
Based on Fisheries Department data	-	1.55	0.42

However, this is not necessarily the nutrients load that will eventually discharge into the mangrove environment and Haycock Reach as considerable treatment occurs prior to discharging into the environment. The main treatment mechanisms for the pond effluent will consist of:

- Sedimentation and filtration of larger particles;
- Biological assimilation of nutrient loads by macroalgae, benthic organisms, mullets, crabs, filter feeders in the sedimentation ponds;
- Further biological assimilation and chemical processes in the discharge creek and tidal creek mangroves; and
- Mixing and dilution in estuary.

Sedimentation ponds typically reduce the TSS load by 60%, TP load by 30% and TN load by 20% (Preston et al. 2000). Mulletts, crabs and filter feeders including barnacles and welks stocked in the sedimentation ponds typically reduce the nutrient load further. Laboratory studies have shown that nitrogen can be reduced by 70% using a combination of sedimentation, filter feeders such as oysters, and macroalgae as a final absorption step. (CSIRO 2005). Following such a treatment system, the calculated levels based on FCR would be reduced to 0.4 mg/L TN and 0.02 mg/L TP. These levels are well below the Queensland discharge limits for mean nutrient concentrations.

2.5.7 Sludge

Some pond sludge is likely to accumulate in the prawn ponds as a result of pond wall erosion and accumulation of organic matter. Part of the pond sludge will be resuspended when the ponds are emptied following each crop. As such, pond sludge is expected to settle in the production ponds effluent channels and sedimentation ponds.

The prawn and sedimentation ponds, as well as the effluent channels will be de-sludged on an as needs basis. The pond sludge typically consists of 92-96% clay and silt matter eroding from the pond walls and floor and up to 8% organic matter.

Research in Australian aquaculture has found that pond sludge volumes typically range between 20 and 180 tonnes/ha. Volumes are highest the first year and reduce thereafter.

The sludge will be transferred to banded drying beds, where nutrients and organic matter will gradually biodegrade and stabilise. The sludge will be exposed to the wet season rains and/or flushed with fresh water to reduce its salinity. It is then left to dry for 3 – 4 weeks. The dried sludge can be reused onsite for landscaping purposes, maintenance of pond walls or fill. Drying bed effluent will be directed to the effluent canal and sedimentation ponds.

2.5.8 General Wastes

Sources of general wastes from the site include:

- Sewage and domestic effluent;
- Wash down water (vehicles and packing shed);
- Domestic waste;
- Oil, lubricants and empty drums
- Chemical waste

Sewage

The property has two sewage discharge points at the house and office area, respectively. Reticulated sewerage facilities are not available in the area, thus sewage is directed into septic tanks in compliance with the Northern Territory Health guidelines.

Vehicle wash down water

Site vehicles will include 2 quad bikes, a feed truck, a tractor and a slasher for firebreak maintenance purposes. These vehicles will be washed down on a concrete hardstand area which drains into a sump. From the sump, drainage will be directed to a triple interceptor to remove oil. The interceptor will be pumped out by a licensed contractor on an as needs basis.

Domestic waste

Domestic waste volumes will be limited, as it is not proposed to have workers accommodation on the site. Only the site manager will be living on the farm. All domestic waste will be taken to landfill.

Process waste that will require disposal includes the prawn feed bags. These paper feed bags can be either recycled or taken to the local landfill. An estimated 13,200 paper bags will be used per crop.

Used oils and lubricants

Minimal amounts of oils and lubricants will be used on site for the purpose of servicing equipment, including pumps and the emergency generator. Vehicles will be serviced off site.

Drums of used oil and lubricants will be stored in compliance with AS1940-1993. They will be removed by a licensed contractor on an as needs basis.

Chemical waste

The use of chemicals will be limited to the List of Approved Aquaculture Chemicals issued by the National Aquaculture Council and the List of Approved Chemicals issued by the Australian Pesticides and Veterinary Medicines Authority. Chemical waste and empty containers will be removed by a licensed contractor on a regular basis.

2.5.9 Storage of chemicals and hazardous substances

The chemicals and hazardous substances to be kept on site for operations of the farm include:

- Fuel for vehicle refuelling and standby diesel generator;
- Fertiliser and prawn feed;
- Other chemicals eg liquid chlorine for disinfection, prescription medication.

Fuel Storage

A 2,000 L skid mounted tank will be provided for onsite fuel storage to adequately satisfy required usage. The fuel tank will be placed on a concrete pad within a bund which drains into a sump. The capacity of the bund will be 2,200 L or 110% of the tank's volume. Uncontaminated stormwater held in the bund will be directed to the stormwater system, whereas contaminated stormwater following any fuel spill will be directed to a triple interceptor. The treated effluent is then directed to the stormwater system. The interceptor will be pumped out by a licensed contractor on an as needs basis.

Staff will be trained in spill response procedures and spill kits will be made available near the fuel storage area.

Fertiliser and prawn feed

Fertiliser and prawn feed will be stored in a designated store room, which will be adequately ventilated, for protection from mice and moisture.

Chemical Storage

Any chemicals used onsite will be stored in proper chemical storage cabinets and used in accordance with the manufacturers' instructions.

Prescription medicine will be used under veterinary advice and stored in accordance with manufacturer's guidelines.

2.6 CURRENT LICENSES

The initial aquaculture development proposal was assessed by the Conservation Commission of the Northern Territory in 1992 and was subsequently approved.

The following licences are current:

- Surface Water Extraction Licence (salt water) 815389
- Surface Water Extraction Licence (fresh water) 815390
- Water Discharge Licence WDL 101 (expiry date 30/10/2005)
- Sacred Site Clearance Certificate No. C92/72

As larger volumes of saltwater and freshwater will be required to enable increased production rates, applications for additional or increased extraction licences are underway. Similarly, a new discharge licence for larger effluent volumes is being applied for.

2.7 UTILITIES

2.7.1 Power

Power is required for operation of pumps, aerators, processing and cool rooms, the workshop, the administration building and domestic consumption.

The site is connected to the grid. A diesel emergency generator will provide electricity during power outages, which may occur during the wet season. This generator is sized to keep half the aerators going, which equals a power consumption of 370 kW (42 ponds at 12 hp).

2.7.2 Potable water supply

Potable water use will be supplied from two existing water services at the site (20mm and 50mm). Both lines come off an existing DN225 water main. The office of Power and Water Corporation has advised that no further connections can be made to this 225mm water main. However, it is unlikely that the new operations require an upgrade of the existing domestic water supply.

Potable water will be required for domestic purposes and ice production. Domestic water usage is expected to be minimal as it is not proposed to have any accommodation on the site. Only the site manager will be living on the farm.

Prawn chilling and packing requires approximately 1 tonne of ice per tonne of prawns processed. This results in water consumption for ice production of approximately 229 m³ per projected crop of 210 tonnes. This amount will be required over a period of a number of weeks each crop and is not expected to cause a strain on water supply. If insufficient water is available at any one time, additional ice will be purchased.

2.8 STAFFING

A staffing ratio of one person per two hectares of productive pond area is envisaged, resulting in a maximum staff number of 20 at full-scale development. The crew will consist of farm technicians, hatchery operators, machine operators, engineers, electricians, maintenance and administrative staff, and site management.

2.9 TRAFFIC

2.9.1 Construction traffic

Construction traffic will be limited to heavy machinery and vehicles for construction worker transportation. Most traffic will be confined to the project area as earthworks are expected to consist of cut-to-fill operations and no external fill will be sourced. The site has several borrow pit areas for gravel and clay in case in-situ materials are not adequate. The work site itself will be restricted to a small area within the property. The work area will move and change in shape as pond lots are completed and the construction effort moves on to other pond lots.

Other construction traffic includes haul vehicles moving along well defined haul routes within the site.

Traffic entering and leaving the area during the construction phase is likely to be limited to light vehicles for construction workers and site personnel. This traffic will access the main access road and internal service roads via Channel Island Road. A limited number of heavy vehicles will be required to transport construction machinery and materials to the development.

2.9.2 Operational traffic

Traffic during the operation phase includes:

- heavy vehicles transportation of supplies and packaged prawns; and
- light vehicles from staff and maintenance services

The produce will be transported off site in batches of 1-10 tonnes and an average of approximately 7 loads per week will be taken from site during harvest periods (January-February and July - August).

Feed delivery constitutes another source of operational traffic, with 336-378 tonnes of feed being delivered per crop. It is anticipated that these deliveries will occur in 10 tonne batches, resulting in up to 38 trips per crop.

Additional operational traffic includes staff transport and miscellaneous farm supplies, such as fertiliser, fuel oil, lubricants, machine parts, ice and packaging. Apart from daily staff movements, most of these deliveries will be infrequent.

2.10 DECOMMISSIONING AND REHABILITATION

In the event the farm was sold, the existing infrastructure would remain intact and be sold on to the prospective owners.

In case aquaculture operations were to cease completely, the site would need to be decommissioned and rehabilitated to the satisfaction of the authorities. The proposed decommissioning and rehabilitation strategy consists of:

- Decommissioning and removal of all structures, including buildings and equipment;
- Decommissioning and removal of the jetty and pumps;
- Levelling of the supply and discharge channels, saltwater storage, prawn and sedimentation ponds to achieve smooth landforms;

- Ripping and grading of on-site roads;
- Revegetation through seed or tube stock.

Where possible, waste materials will be salvaged for reuse or recycling. Where this is not possible, wastes will be disposed of in an environmentally responsible manner.

The freshwater dam will be retained, as it provides a prime habitat for a number of aquatic birds.

2.11 OTHER INFRASTRUCTURE

APPL received the advice that Power and Water is planning the construction of a sewage treatment plant (pond system) to service the future township of Weddell adjacent to and upstream of the proposed development. The exact dimensions and location of the treatment plant are yet to be finalised.

Given that Power and Water intends to discharge treated wastewater from the ponds to Haycock Reach, some impact on water quality in the area may be expected. The timeframe for development of this plant is approximately 15 years or more from now.

Depending on the degree of water quality impact, APPL may need to consider future pre-treatment of the intake water prior to use in the production ponds. Pre-treatment methods may range from sedimentation to secondary treatment processes such as aeration in order to achieve nutrient load reductions. Some of this pre-treatment may be feasible within the intake channel and saltwater storage dam (ie. sedimentation), whereas advanced treatment may require a larger pond area. Whether additional ponds are constructed for this purpose or whether part of the productive area is sacrificed for the purpose of intake water pre-treatment needs to be decided and agreed upon with the authorities at the time.

3 Alternatives

3.1 ALTERNATIVE SITES AND SITE SELECTION CRITERIA

Alternative sites were considered however the proposed site was chosen as it was deemed beneficial from both environmental and operational perspectives.

3.1.1 Environmental Benefits

The farm site has been neglected for many years and several problems relating to weeds, erosion, stray litter and rusting equipment have been identified. The new owners are committed to cleaning up the site and re-establishing operations, thereby turning a liability into an asset.

The proposed expansion and redevelopment of the site involve minimal additional vegetation clearing. Most of the vegetation to be cleared for pond construction consists of regrowth following clearing for the purpose of the original development. The footprint of the freshwater dam and saltwater storage will not be increased, resulting in no additional clearing. A limited area of degraded salt flat/mangrove vegetation is to be cleared for the purpose of constructing sedimentation ponds.

In summary, clearing requirements for this development are much less than would have been the case for a green field development. In addition, the site is already heavily disturbed due to previous operations.

3.1.2 Physical Attributes

Physical attributes have been mapped and described in detail in the initial PER for the site (Kinhill Engineers 1992). The main physical attributes of this site which make it ideal for prawn farming are:

- Access to saltwater with channel depth sufficient to allow draw-off at neap tides;
- Soil conditions and topography suitable for pond and dam construction;
- Proximity to Darwin;
- Climate;
- Availability of freshwater for pond salinity adjustment from local catchment; and
- Access to power and water services.

3.2 ALTERNATIVE LAYOUT

The farm lay-out has aimed to maximise prawn pond area with consideration for site topography. Cut to fill operations are preferred when compared with bringing in fill from on- or off-site borrow pits, and have been optimised in the current design.

APPL has decided against reinstating the existing prawn ponds as they are in a state of disrepair. They are generally too small, oddly shaped and don't drain well. The ponds in the east of the site are incomplete and have never been commissioned.

3.3 ALTERNATIVE PRODUCTION METHODS

In terms of pond water quality management, there seem to be three options:

- Flow-through systems, consisting of regular water exchange and subsequent discharge of wastewater following treatment;
- Recirculating systems, which divert exchange water to an extensive network of treatment ponds following which the water is returned to the production ponds; and
- Zero discharge systems, which avoid water exchange altogether, apart from freshwater inputs to maintain salinity and stormwater overflows.

Flow-through systems are most widely used in Australia, whereas the other systems are being trialled with varying success. Recirculating systems are being adopted to some extent in Queensland, with 38% of pondage area now having the capacity for water recirculation (C. Robertson, pers.comm.)

Results from a recirculating system trial in Queensland (Robertson 2003) indicated similar yields and taste of the crop as from traditional flow-through ponds. The environmental performance was improved by reducing the volume of water discharged per kilogram of prawn produced. However, at a grow-out to treatment area ratio of 1.55:1, potential yields are reduced due to the fact that potential grow-out area is used for treatment. Moreover, the treatment ponds require aeration, adding to operational costs and greenhouse gas emissions. When operating a recirculating system, vigilance in water quality monitoring, accurate feed management and water exchange are vital to maintain a healthy system. Considerations for farms in the dry tropics may include variations in evaporation rates and access to large volumes of fresh water.

At this stage, APPL is not considering a fully recirculating system as it would drastically reduce the potential grow-out area and thus yield that could be achieved on the 288 ha property. However, partial recirculation of the treated effluent from the sedimentation ponds to the intake pond will be considered subject to effluent quality monitoring. This will reduce both the volume of intake water and discharge to the environment.

Zero discharge systems require harnessing of bacteria and algae metabolic processes, rigorous aeration management and very precise feed management in order to avoid toxic ammonia build up in the ponds (EPA 2000). Until these systems are proven and common practice in the Northern Territory, APPL is not keen to risk the outbreak of diseases or toxic algal blooms that could wipe out an entire crop. Diseases generally break out in prawn populations stressed due to poor water quality.

3.4 OPTIONS FOR EFFLUENT DISCHARGE

Zero discharge and partial to total recirculation systems have been discussed in the previous section.

Due to a general concern about the proposed discharge from the sedimentation pond spillways into the surrounding salt flats, direct discharge to the creek is now being proposed. This could be achieved through the construction of a discharge canal or a pipeline.

The installation of a pipeline catering for the proposed effluent volumes would be prohibitively expensive. Considering the distance to a permanent waterway, an additional pump station would have to be installed.

Discharge canals from the spillways to the head of tidal creeks are the preferred option. The sedimentation pond servicing the 28 ponds to the east of the site will discharge into an existing discharge canal, resulting in minimal construction required. The sedimentation pond to the west of the development could either discharge into a canal that is directed to the existing discharge canal or to the head of the nearest tidal creek. Excavation for the purpose of construction of discharge canals can be avoided by installing a lined (plastic or concrete) discharge canal on top of the mangrove muds. This would prevent acid generation from acid sulphate soils, as well as erosion problems. Where the canal discharges into the creek, erosion will be prevented through the use of appropriate energy dissipators.

4 Existing Environment

4.1 CLIMATE

The Darwin region has a monsoonal climate with two distinct seasons: wet season from October to April and dry season from November to May.

The mean annual rainfall is 1713 mm recorded by the Bureau of Meteorology at the Darwin Airport weather station (BOM 2005). Most rain falls between December to March with thunderstorm activity occurring during October and November. The highest recorded rainfall is 2644 mm and the lowest is 1025 mm.

Temperatures are highest in October and November, when the mean maximum is 33°C and the mean minimum is 25°C. The coolest month is July when the mean maximum is 30.5°C and the mean minimum is 19°C.

Evaporation rate in Darwin is fairly constant throughout the year and fluctuates between 6.1 and 8.3 mm/day.

Monthly rainfall, evaporation and average temperatures as recorded by the Darwin Airport weather station are represented in Figure 4.1.

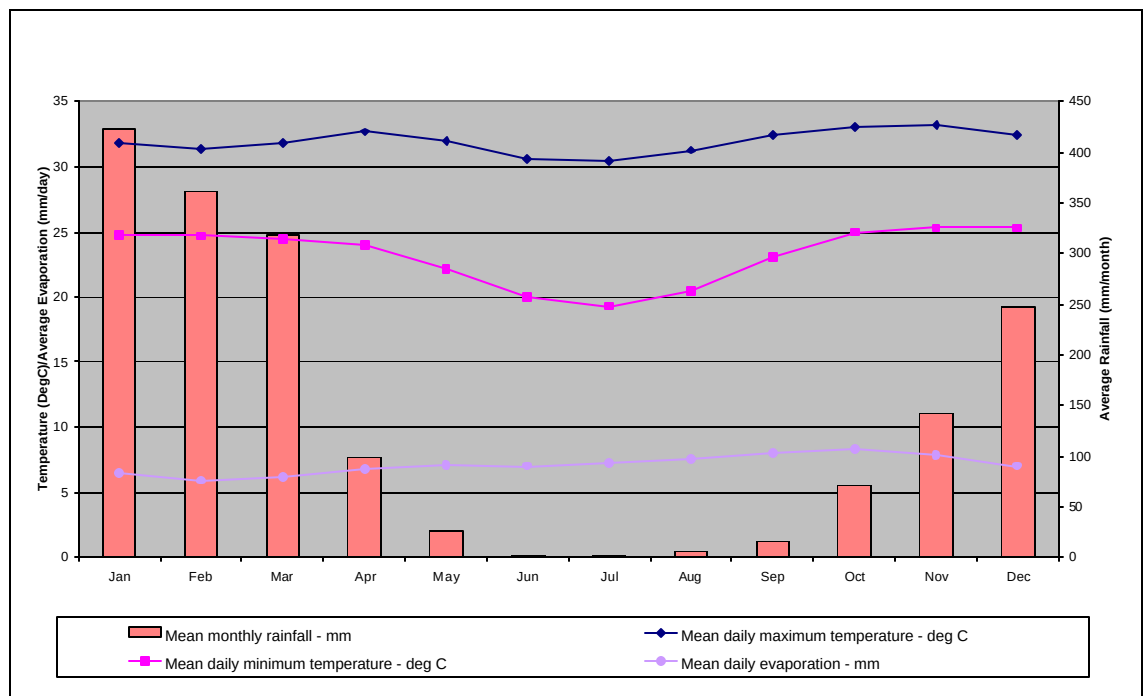


Figure 4.1 Monthly rainfall, evaporation and temperatures recorded at Darwin Airport Meteorological Station.

4.2 TOPOGRAPHY, LANDFORM AND LAND UNITS

The site covers several terrain units including low lying mangrove, up through mudflat and intertidal areas, to terrestrial zones moving northwards. The property undulates with elevation ranging from mean sea level at the southern boundary, abutting the low lying mangroves, to 10 m AHD at its northern boundary in the terrestrial zone. There are several rocky outcrops which strut out in the generally flat landscape. The existing development footprint has altered part of the natural topography of the site.

The land units as described by the Natural Resources Division of the Department of Infrastructure, Planning and Environment (2002a) are illustrated in Figure 4.2 and described in Table 4.1.

Table 4.1 Land units at the proposed aquaculture development site

Land unit	Description
1 b	Steeply sloping ridge terrain; slopes 10-40%; shallow gravelly lithosols; Eucalypt woodland to minor open woodland.
1c	Low scarps & short steep slopes; slopes 10-15%; shallow gravelly lithosols; Eucalypt woodland.
2b1	Gentle sideslopes; slopes 2-5%; moderately deep gravelly yellow massive earths; Eucalypt open woodland to woodland.
4d	Gentle lower slopes; slopes .5-1%; shallow gravelly massive earths; grassland with areas of emergent trees & shrubs.
9a	Estuarine fringes; slopes negligible; tidal inundation; saline muds & clays; usually bare with small areas of samphire & salt tolerant grasses
9b	Estuarine fringes; low closed forest of mangrove species.

4.3 GEOLOGY

The geology of the site is characterised by coastal alluvial muds in the tidal zone, and sandy and gravelly soils in the upland areas. These soils form thin poorly developed veneers over Early Proterozoic shales and siltstones from the Burrell Creek Formation (Finniss River Group) (NT Geological Survey 1987).

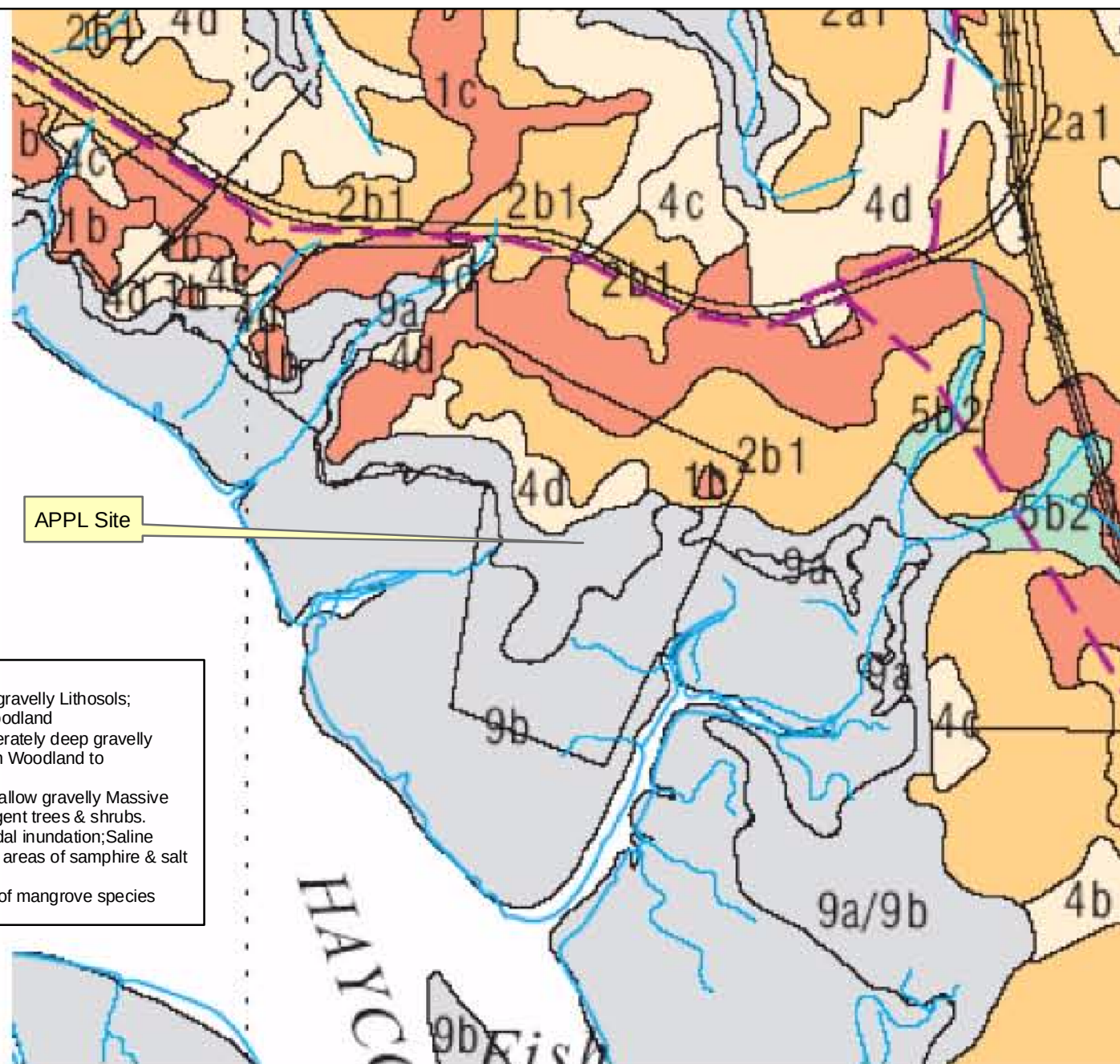
4.4 LAND USE

Section 1880 was rezoned in October 2003 to Zone DV (Development). Intensive animal husbandry, including aquaculture as a commercial enterprise, constitutes a consent use in accordance with the Litchfield Area Plan 2004 (DIPE 2004).

The project area is surrounded by vacant Crown Land. Further towards Channel Island, there is a neighbouring prawn farm 'Golden Prawns'. This prawn farm ceased operations late 2004 and the property is currently for sale. Moving in a southeasterly

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LEGEND

- 1b - Steeply sloping ridge terrain; shallow gravelly Lithosols; Eucalypt Woodland to minor Open Woodland
- 2b1 - Gentle sideslopes; slopes 2-5%; moderately deep gravelly Yellow Massive Earths; Eucalypt Open Woodland to Woodland
- 4d - Gentle lower slopes; slopes .5-1%; shallow gravelly Massive Earths; Grassland with areas of emergent trees & shrubs.
- 9a - Estuarine fringes; slopes negligible; tidal inundation; Saline muds & Clays; usually bare with small areas of samphire & salt tolerant grasses
- 9b - Estuarine fringes; Low Closed Forest of mangrove species

direction from the project area, there is vacant Crown Land, some mostly vacant rural residential lots and the Phelps-Panizza Blackmore River (East) prawn farm.

Marine use in the area includes recreational fishing and prawn farming.

Potential future land uses include a proposed wastewater treatment plant upstream of the redevelopment. The treatment plant would service the future Weddell residential area.

4.5 FLORA

Six main vegetation communities, including two upland communities and four intertidal habitats, were distinguished within and adjacent to the 288 ha APPL property boundary (Metcalf 2004, Appendix C). Figure 4.3 provides a map of the distribution of terrestrial and intertidal vegetation communities within the project lease boundary and the surrounding area, compiled by a combination of previous vegetation mapping (Kinhill Engineers, 1992) and ground-truthing of recent aerial photography. The characteristics of the main vegetation types are described in sections 4.5.1 and 4.5.2. A complete report on flora is provided in Appendix C.

Extensive mangroves occur just south of the lease area with minor areas of savanna woodland between the farm and the Channel Island Road. A large man-made freshwater lake also occurs within the lease area with minor sedgeland/grassland on the fringes and scattered patches of *Melaleuca* spp. (Paperbark).

4.5.1 Upland Vegetation Communities

Upland vegetation communities comprising mixed woodland to open woodland and minor open forests dominated by Eucalypts and *Corymbia* spp. occupy 175 ha or 60% of the lease area. Typical of the large parts of Koolpinyah surface around Darwin, these communities are common and have a widespread distribution. Small patches of monsoon vine forest occur infrequently in this community (Leach and Dunlop 1992) but the vast majority of this vegetation type is characteristic Eucalyptus-dominated open woodland.

Most of the remaining vegetation has been disturbed to some degree following the initial development. The area immediately north of the existing ponds was cleared entirely and is currently characterised by 10-year old regrowth.

Mixed Eucalypt Woodland (Map Unit 5)

Previous terrestrial vegetation surveys report *Eucalyptus miniata* and *E. tetradonta* as the dominant species with canopy height varying from 7 to 15 m. *Corymbia bleeseri* and *E. confertiflora* were common canopy forming species observed during the 2004 survey. Secondary trees including *Erythrophleum chlorostachys* and *Eucalyptus tectifica* are patchily distributed through the woodland area.

Mid-stratum species including *Acacia* spp., *Terminalia* spp., *Buchanania obovate* and *Persoonia falcata* form a sparse to mid-dense understorey layer. Species dominance was observed to vary according to changes in local topography and drainage. *Lophostemon lactifluus*, *Melaleuca viridiflora* and *Pandanus spiralis* are characteristic species of seasonal waterlogging of low lying terrain, drainage lines and



the freshwater seepage zone along the margins of the high ground adjacent to the mangrove communities.

Monsoon Vine Thickets (Map Unit 6)

A dense monsoon vine thicket, also containing Eucalypt woodland species, occurs on Haycock Hill, a small low rise situated 70m from the western side of the boundary and 1.5 km from the pond development site. The hill is completely surrounded by mangroves and thus forms one of several 'hinterland islets' in Darwin Harbour. These areas are completely fire protected and characteristically support fire-sensitive vine forest species.

Species of monsoon thicket found on Haycock Hill include: *Mimusops elengi*, *Memecylon pauciflorum*, *Antidesma ghaesembilla*, *Premna acuminata*, *Exocarpos latifolius*, *Jasminum aemulum*, *Sterculia quadrifida*, *Croton arnhemicus* and the vines *Adenia heterophylla*, *Parsonsia velutina* and *Flagellaria indica* (Leach and Dunlop 1992).

Weed species

A total of six declared weed species were identified during the 2004 flora survey. They are mostly grasses, including Gamba Grass (*Andropogon gayanus*), Purple-top Chloris (*Chloris inflata*), Annual Mission Grass (*Pennisetum pedicellatum*), and Perennial Mission Grass (*Pennisetum polystachion*). The herb Hyptis (*Hyptis suaveolens*) and the woody climber Stinking Passion Flower (*Passiflora foetida*) also occur on site.

4.5.2 Intertidal Vegetation Communities

Mangrove vegetation is well developed along the coastline of Northern Australia with particularly extensive mangroves in sheltered embayments 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. Mangroves of the Darwin region have 38 of the 48 mangrove species known from the Northern Territory (Wightman 1989). Twelve mangrove and salt flat species were recorded from mangroves within and adjacent to the project area during this survey (Appendix C).

In areas of macrotidal range and low relief, mangroves typically show distinct patterns of zonation. Within Darwin Harbour, these patterns of zonation, with bands of species aligned roughly parallel to the shore have been mapped by DIPE (Brocklehurst and Edmeades 1996) and occur at particular topographic elevations (Figure 4.4). This predictable pattern of zonation is a result of the interplay of climatic and geomorphological factors, combined with the frequency and duration of tidal inundation and the availability of freshwater.

The project lease is located south of the Channel Island road on a relatively narrow peninsular fringed to the north and south by extensive mangrove systems. The mangroves to the south of the ponds are over 1.5 kilometres in width (from the landward to seaward margin). However, the redevelopment associated with the project will require only minimal clearing of mangroves (11.8ha) mainly comprising

regrowth and disturbed hinterland margin habitat. Construction will involve 4.1ha of salt flat habitat. Existing mangrove communities downstream of the development may, however, play an important role in bio-filtration and assimilation of release waters from aquaculture ponds and consequently are the focus for a comprehensive mangrove monitoring program (Section 6).

Four distinct mangrove zones have been mapped within the project area and are described below. These zones correspond to floristically distinct mangrove associations that are easily distinguishable in the field and from aerial photographs.

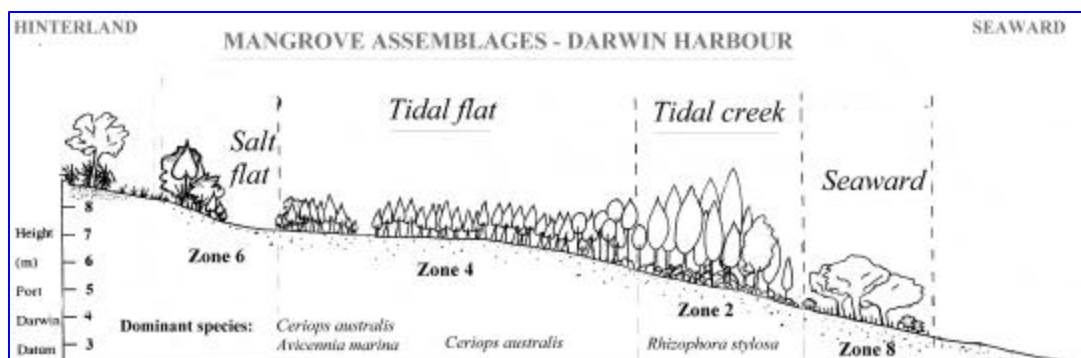


Figure 4.4 Schematic diagram of mangrove zonation in Darwin Harbour indicating topographic elevation of tidal creek and tidal flat zones (source: Brocklehurst and Edmeades 1996)

Tidal creek mangrove (Map Unit 1)

This zone characteristically occurs between 1.0 and 2.3 m AHD (Metcalf, 1999). Forest height is variable but ranges between 6 and 12 m. In general, tidal creeks are relatively narrow, with sloping muddy banks prone to bank slump and erosion. This zone receives regular tidal flushing and supports a distinctive mangrove assemblage.

High soil moisture levels in the deep muds of the tidal creek support luxuriant growth of a variety of mangrove species. Common creek bank species include *Rhizophora stylosa*, *Camptostemon schultzei* and *Bruguiera parviflora*. Massive individuals of *Avicennia marina* to 15 m can also occur in this zone (EcoSystems 1993). The tidal creek has the highest biomass of all mangrove zones and is also the most productive in terms of primary production, as measured by annual leaf litter fall (Metcalf 1999; (Woodroffe et al. 1988).

The tidal creek bank zone is well developed along the main channels of Haycock Reach and the larger tidal creeks in the local area. The seaward margin of the larger tidal channels is typically fringed by *Sonneratia alba* forests, characterised by large, well-spaced trees growing from between -1.0m and +1.0m AHD. This most seaward zone is largely confined to the fringes of Haycock reach and is discontinuous along the smaller channels and so has been mapped here with the tidal creek assemblage.

Tidal creek mangroves also extend along the banks of numerous smaller tributaries and tidal channels. The middle to upper reaches of the smaller tidal creeks within the survey area are fringed by a mixed mangrove association typically dominated by *Rhizophora stylosa* in association with *Camptostemon schultzei*, *Avicennia marina* and *Bruguiera parviflora*. The tidal creek zone is the tallest community, typically forming

a closed canopy forest ranging in height from 9 to 14 m. The ground surface is normally a dense tangle of arching prop roots and stilt roots to several metres height.

Tidal flat mangrove (Map Unit 2)

The *tidal flat* mangrove zone occurs on the mud flats between approximately 2.3 and 2.6m AHD. As indicated by the very narrow range in topographic elevation, and unlike the *tidal creek* zone, this is a zone of extremely low relief. Surprisingly it is, however, the most extensive zone both within the local area and within Darwin Harbour generally.

In contrast with the deep mud of the *tidal creek* zone, substrates are relatively consolidated and may contain a high proportion of sand and gravel in the noticeably flat terrain. *Ceriops australis* forms almost monospecific closed forests with an average height of between 2 to 6 m. Other associated species include *Bruguiera exaristata* and *Aegialitis annulata*. *Avicennia marina* tends to become locally abundant to co-dominant with *Ceriops australis* as salinity increases towards the salt flats.

Tree height in the *tidal flat* zone varies in direct response to soil salinity and freshwater inflow. Low shrubby *Aegialitis annulata* to 1.5 m tall is a widespread ground layer species, tolerant of high salinity levels and is frequently found on the fringes of salt flats.

Hypersaline conditions on the edges of saltflats also influences the habit of *Ceriops australis* which may become extremely stunted. In addition, under these highly saline conditions, *Avicennia marina* typically becomes multi-stemmed and thus shrub-like.

Hinterland margin mangrove (Map unit 3)

The hinterland margin is a variable, multi-species mangrove community that occurs at the junction of the mangroves and the terrestrial vegetation of the hinterland. Lying roughly between 3.5 and 4.0 m AHD, only the highest spring tides inundate this area. Within the lease area, this mangrove zone has been heavily modified during previous development of the site. Clearing for ponds, bund wall and channel construction has resulted in a mosaic of cleared, regenerating and disturbed *hinterland margin* mangrove areas.

Hinterland margin species composition is heavily influenced by edaphic conditions, particularly the availability of freshwater, on the adjacent hinterland. Sand and quartz gravel is often washed in from the hinterland and is often embedded with mud (Ecosystems 1993). In areas of freshwater seepage, vine-forest and *Melaleuca* (Paperbark) communities typically abut a dense, closed-canopy mangrove forest 6 to 8m high, with *Ceriops australis* dominant.

This is typically the most diverse mangrove zone with associated species including *Lumnitzera racemosa*, *Excoecaria ovalis*, *Bruguiera exaristata*, *Thespesia populnea* and *Scyphiphora hydrophyllacea*. The hinterland margin may be only several trees in width, and is therefore too detailed to map at a small scale, but may be quite diverse and tall, particularly in seepage zones or in areas with abundant seasonal freshwater runoff. *Lumnitzera racemosa* is characteristic of this assemblage, preferring areas with freshwater input. *Lumnitzera* is one of only a few species that occurs almost

exclusively in the high tidal zone. A low shrubland of *Ceriops australis* and *Avicennia marina* typically occurs in areas devoid of freshwater input.

Salt flat (Map Unit 4)

Salt flats are typically found on the landward side of the *tidal flat* zone, occurring between 2.5 and 2.9m AHD. Salt flats are either devoid of vegetation or support scattered samphire species including *Suaeda arbusculoides* and *Halosarcia indica*. Infrequent tidal inundation and high evaporation rates during the dry season boost the soil salinity to levels toxic even to mangroves. Consequently hypersaline conditions prevail and salt flats characteristically remain bare of vegetation with only stunted fringing species comprising *Ceriops australis* and *Avicennia marina*.

Visible in aerial photography as a distinctive ring of bare areas in the upper tidal flat, salt flats form a discontinuous band of bare areas varying widely in size and extent. In the project area, several quite large salt flats are located between the development site and the mangroves. Salt flats also form a rough line, extending over 1 km directly south of the prawn farm (towards the Blackmore River) representing not only the highest elevation in this vast *tidal flat* area but effectively demarcating the shared boundary of two small catchments. Networks of salt flats are scattered throughout the mangroves surrounding the lease area at elevations that receive infrequent tidal inundation (Figure 5).

4.5.3 Conservation Significance

The redevelopment site supports vegetation communities of varying degree of conservation significance. Conservation significance of vegetation can be considered at different levels (individual species or plant community) and spatial scales (local, regional and national). The conservation significance of vegetation within the proposed redevelopment has been assessed as follows (Metcalf 2004).

Plant Communities of Significance

Mangroves

Mangroves have high conservation significance both locally and regionally. The Oil Spill Response Register (formerly the Coastal Resources Atlas NT Department of Lands Planning and Environment) notes the importance of mangroves for their high primary production, ecological value as a habitat and their intrinsic social and natural resource values. The mangroves of Darwin Harbour are notably diverse and are important habitats in terms of breeding, feeding and nursery grounds for a variety of marine and terrestrial species. The Darwin Harbour mangroves are listed in the Directory of Important Wetlands in Australia (ANCA 1997) and on the Register of the National Estate (DEH 2005b).

Mangroves cover approximately 39% (112ha) of the leased area. The proposed redevelopment and area for pond expansion is located within the previously disturbed or regenerating hinterland mangroves and bare salt flats, and no further clearing of mangrove communities is proposed. Mangroves within the lease area are very typical of the greater Darwin Harbour mangrove system, with species present and general zonation patterns being predictable and relatively consistent throughout the tidal

system. As such, mangroves within the project area do not have any special conservation or ecological significance.

Upland Communities

The proposed redevelopment will involve some expansion into the area of remaining terrestrial vegetation towards the northern boundary. Vegetation in this area is dominated by *Eucalyptus* species, either as woodland or open woodland formations. This vegetation is not restricted in distribution and is highly unlikely to contain any rare or endangered species.

Cycads present in the lease area are of some botanical importance. These plants are common understorey species in Eucalypt communities and have a rare status, and are thus generally considered to have some ecological value. This species is listed in the Northern Territory Environmental Legislation as a protected species (Schedule 8, Regulation 15 of the Territory Parks and Wildlife Conservation Act 1994), which precludes the species from being collected or removed from bushland unless it is part of the lawful use of the land. However, this does not preclude development in areas with appropriate development approval.

Minor areas of grassland, *Pandanus* communities and Paperbark also occur within the sites, but these communities are common and widespread in the region. It follows that the majority of vegetation communities present do not have special conservation significance and are well represented in the Darwin region and elsewhere within the Top End.

Vine Forest

Monsoon vine forest occurs in small patches in the savanna woodland throughout the Darwin area. These forests provide habitat and resources for frugivorous fauna. Over the years, vine forest habitats have declined markedly due to fire and feral animals. As such, conservation is important for maintaining diversity and integrity of the interrelated network of Top End rainforests. However, these habitats are not protected under any current legislation.

From a regional context, the fire-protected community of Haycock Hill and small areas within the lease area have considerable ecological and conservation significance. However, the proposed redevelopment will not impinge on vine forests and thus will not have any negative impacts on any vine-forest habitats.

Local Conservation Significance

Vegetation of the lease area comprises mangrove communities and upland communities that are in relatively natural condition except for the surrounds of the previously developed area. The lease area contains healthy natural habitats of importance to a range of different fauna and contributes to intrinsic values of providing clean air and water, biological diversity and environmental stability. However these values are difficult to quantify, and are often not recognised.

Regional Conservation Significance

Upland vegetation in the lease area is typical of Eucalypt forest and woodland of the Top End and forms part of an extensive bioregion covering 68,000km². As such, the conservation value of the terrestrial flora found on the site does not have high regional significance. Furthermore, 15.8% of the bioregion is currently reserved, mostly for conservation purposes. As such, these woodland habitats are well represented elsewhere in the region.

The mangroves of the extensive Darwin Harbour system have ecological and conservation significance at the regional and national scale. The mangroves within and around the lease area are very similar to assemblages found elsewhere in the harbour; the species present and the general pattern of zonation is predictable and relatively consistent in these tidal systems. Thus in the regional context, the mangroves adjacent to the proposed development area do not have special ecological or conservation significance.

4.6 FAUNA

For the purpose of this assessment, fauna surveys were limited to the intertidal zone, as this is the area which is likely to be impacted most by the development. A desktop review was undertaken to describe terrestrial and marine fauna species likely to be present within and adjacent to the project area.

4.6.1 Terrestrial Fauna

The 1992 PER identified several species which are potentially present at the site. Further information on fauna in the area was obtained from the Channel Island power plant EIS (Caldwell Connell Engineers 1983), the Blackmore River (East) Aquaculture Project PER (URS 2001) and the Darwin LNG Plant EIS (Dames & Moore 1997).

Mammals

The Darwin LNG Plant EIS (Dames & Moore 1997) reported fifteen mammal species, including two introduced species. Species commonly observed included the Grassland Melomys (*Melomys burtoni*), Northern Brown Bandicoot (*Isodon macrourus*), Northern Brushtailed Possum (*Trichosurus arnhemensis*), Agile Wallaby (*Macropus agilis*) and microchiropteran (insectivorous) bats. These species were also reported to be potentially present in the 1992 PER (Kinhill Engineers 1992).

Amphibians

Various frog species are likely to be associated with the freshwater dam and the Eucalypt open forest habitat during the wet season. The Darwin LNG Plant EIS (Dames & Moore 1997) identified the Brown Tree Frog (*Litoria rothi*) and the Dwarf Tree Frog (*L. biocolor*) as the most common species within the Wickham Point area, approx. 10 km northwest from the APPL site. Other frog species that have been recorded in mangrove margins and littoral habitats in the Northern Territory include the Green Tree Frog (*Litoria caerulea*), the Desert Tree Frog (*L. rubella*) and the Marbled Frog (*Limnodynastes convexiusculus*).

Reptiles

Common reptiles in the area include goannas, skinks, western brown snakes (*Pseudonaga affinis*) and death adders (*Acanthopsis praelongus*) (Kinhill Engineers 1992).

Dames & Moore (1997) found that skinks of the genus *Carlia* were the most common reptile species within the Wickham Point area. Four species of water snake are specialised for life in mangroves, including Bockadam (*Cerberus rhynchops*), White-bellied Mangrove Snake (*Fordonia leucobalia*), Richardson's Mangrove Snake (*Moron richardsoni*) and Little File Snake (*Acrochordus granulates*). Two species of sea snake are also reported to be mangrove dwellers. These are the Port Darwin Sea Snake (*Hydrelaps darwiniensis*) and the Elegant Sea Snake (*Hydropsis elegans*).

Additional reptile species known to occur in littoral habitats in the Darwin area include the Northern Bluetongue Skink (*Tiliqua scincoids*), Northern Water Dragon (*Gemmatophora temporalis*), Mitchell's Water Monitor (*Varanus mitchelli*), Common Keelback (*Amphiesma mairii*) and Children's Python (*Liasis childreni*). Species such as Burton's Legless Lizard (*Lialis burtonis*), Children's Python, King Brown Snake (*Pseudechis australis*), Moon Snake (*Furina ornata*) and Common Tree Snake (*Dendrelaphis punctulatus*) are common in the East Arm and Palmerston area (Dames & Moore 1997).

Birds

Up to thirty bird species were recorded at Channel Island during the preparation of the power plant EIS (Caldwell Connell Engineers 1983). Birds were found to be especially abundant in the mangroves, although most species were common throughout the coastal mangrove and open forest region of the Top End. The scrub fowl (*Megapodius freycinet*) is common in the mangrove regions however no nesting mounds have been observed within the project area.

Bird surveys conducted for the Darwin LNG Plant EIS (Dames & Moore 1997) recorded ninety species of birds in the Wickham Point area, with an additional 93 species known to occur in littoral habitats within Darwin Harbour. The commonest birds observed during surveys were Bar-shouldered Dove (*Geopelia humeralis*), Sulphur-crested Cockatoo (*Cacatua galerita*), Helmeted Fiarbird (*Philemon buceroides*) and Yellow Oriole (*Oriolus flavocinctus*).

Introduced species

There have been no sightings of feral cats within the property boundary, but there are a number of wild pigs roaming around. The house lizard is also common in the buildings and the residence.

4.6.2 Estuarine and Marine Fauna

Invertebrate fauna

Invertebrates which are well represented in the estuarine environment in Darwin Harbour include: foraminifera, nematodes, polychaetes, crustaceans (including crabs,

shrimps and prawns) and molluscs. Mud crabs and penaeid prawn fisheries are important from both a recreational and commercial perspective.

A field survey carried out in late October 2004 identified 43 invertebrate species (Metcalf 2004). Crustaceans were the dominant group accounting for 51% of the total, of which 19 crab species including *Perisesarma darwinensis*, *P. semperi*, *Parasesarma moluccensis* and the Fiddler crab *Uca signata*.

Molluscs were also well represented in the invertebrate fauna with 17 species recorded. Gastropods were more common than bivalves (82%). Two worm species were recorded in the mangrove mud. Large gastropods from the Potamididae ('Creepers') family were common within the tidal flat zone. *Telescopium telescopium* (Long Bum), *Terebralia palustris* and *Terebralia semistriata* were common to extremely abundant in the mid-tidal zone, and some were observed in discharge channels of the prawn farm.

Epifauna (living on the surface of trees and roots) were recorded and comprised mainly molluscs and crustaceans. *Littoraria filosa* (Periwinkles) were common in *Ceriops australis* foliage. *Nerita balteata* and *Chicoreus capucinus* (Mangrove Murex) were common epiphytic molluscs in the *Rhizophora stylosa* forests along tidal creeks.

Corals in Darwin Harbour are scattered as individual coral heads or colonies, and do not form reefs. They are restricted to a very small vertical region extending from just above the low tide zone to a depth of 2-3 m below it (Hanley and Caswell 1995).

The coral communities that have developed on the Channel Island Reef, the reef nearest to the proposed development (approx. 10 km to the northwest), are representative of coral communities which have developed under conditions of high turbidity, strong tidal current, and seasonally low salinity. The communities also contain a high diversity of corals which is not consistent with its location well inside a large ria (or drowned river valley) system characterised by substantial depression of salinity during the wet season, high turbidity and deep fine muds over much of its area. The high diversity of corals, the clear reef zonation, the location of permanent plots, and its accessibility, make the area important for research and education (DEH 2005a). The Channel Island Reef is listed on the Register of National Estate.

Vertebrate Fauna

Fishes

More than 340 species of fish are known from Darwin Harbour (Larson 1988). The preferred habitat for 29 species is mangroves, and almost half the species can be found on rocky reefs as well as in mangroves and/or rivers (Kinhill Engineers 1992).

Darwin Harbour is an important recreational resource. Recreational fishing is one of the major activities and fish taken include barramundi, threadfin salmon, mangrove jack, catfish, bream, shark, mullet, stingray, flathead and trevally.

Reptiles

The mangrove areas on the peninsula provide suitable habitat for the saltwater crocodile (*Crocodylus porosus*). Crocodiles have been seen within the lease area.

Turtles occur throughout the harbour, with Flatback Turtles (*Chelonia depressa*) known to nest at Channel Island and at Mica beach near the entrance. Green turtles (*Chelonia mydas*) and Hawksbill Turtles (*Eretmochelys imbricata*) also occur in the harbour but there are no significant nesting sites (Dames & Moore 1997). Turtles are not expected to occur in the tidal creeks nearby the proposed development.

Mammals

Indo-Pacific Hump-backed Dolphins (*Sousa chinensis*) and Irrawaddy River Dolphins (*Orcaella brevirostris*) are commonly observed within the harbour. Dugongs (*Dugong dugon*) occur in densities of 0.01 to 0.1 animals per square kilometre. They are known to occur in East and Middle Arms except in small tidal creeks (Dames & Moore 1997).

4.6.3 Conservation Significance of Fauna

Faunal communities found within the proposed redevelopment area appear to have no regional significance as vegetation does not differ from communities of the surrounding Darwin region.

4.6.4 Mosquitoes and Biting Insects

Information on the presence of biting insects was compiled from surveys and reports for projects in the vicinity of the proposed aquaculture development.

There are over 100 species of mosquitoes recorded in the Northern Territory, with over 60 recorded in the Palmerston area. *Ochlerotatus vigilax* and *Culex annulirostris* are the most important potential vectors and pests likely to be present in the area (Dames & Moore 1997).

Ochlerotatus vigilax is a persistent and vicious biter and bites by night and in shaded areas during the day. It can reach very high adult numbers from small, localised breeding sites and is a known vector of Ross River virus and Barmah Forest virus. *Culex annulirostris* is a known transmitter of Ross River virus, Barmah Forest virus and Murray Valley encephalitis.

Potential *Ochlerotatus vigilax* breeding sites include creek lines entering the mangrove margin, disturbed areas at the mangrove margin and downstream from the freshwater dam. Any further disturbance of the mangrove landward margin that creates tidal pooling will produce additional breeding sites. The species seems to be most abundant during the late dry season and the early wet season (August to January).

Culex annulirostris typically breeds in seasonally rain flooded low-lying areas around the mangrove margin and small creeks. Their productivity appeared limited during surveys undertaken for the Darwin LNG project (Dames & Moore 1997) and the Blackmore River (East) Aquaculture project (URS 2001). This species seems to be

most abundant during the wet season followed by a steady post wet season rise to a peak in July (URS 2001).

The Northern Territory Government Department of Health and Community Services also advised that the salt marsh mosquito *Ochlerotatus vigilax* is common in the vicinity of the site. The species *Culex sitiens* is also likely to be present in the upper tidal areas, but is regarded as a pest mosquito only.

In terms of biting midges, both surveys found *Culicoides ornatus* to be the dominant species, which is by far the main potential human pest species of biting midges in the Top End of the Northern Territory. The species' dry season breeding sites include small tidal creeks, whereas typical wet season breeding sites include the landward edges of mangroves.

4.7 SURFACE HYDROLOGY

4.7.1 Water Courses

There are no permanent or ephemeral creeks within the property. A drainage line located to the west of the property has been dammed to provide a freshwater storage reservoir for the original aquaculture development. The dam has a catchment area of 77 ha, a surface area of approximately 30 ha and a capacity of nearly 1,300 ML.

Channel Island Road and the northern property boundary constitute a high point in the landscape. As a result, the site receives little external stormwater run-off. A stormwater drain was constructed during the original development to drain the eastern section of the property.

The site abuts Castnet Creek and Haycock Creek, a small tidal creek and a tributary of Haycock Reach respectively. Prawn farm discharge will be directed to an unnamed creek which discharges into Haycock Reach downstream of the intake.

4.7.2 Oceanography

Tidal Regimes

Darwin Harbour is characterised by a macrotidal regime with a maximum range of 7.8 m. The mean neap tidal range is 1.9 m, while spring tides average 5.5 m. Tides are predominantly semidiurnal (two highs and two lows per day), with a slight inequality between the successive tides during a single day. Nearly diurnal tides occur for a two day period during the neaps. The lowest spring tides of the year occur during October, November and December. Tidal excursions range from 8 to 15 km during springs and 2 to 8 km during neaps (Semeniuk 1985).

Cyclone Effects

Extreme high water levels at Channel Island, taking into account cyclone storm surge, cyclone wave set-up and astronomical tide, were estimated by VIPAC (1994) to be 5.1 m AHD (100 year return period) and 6.4 m AHD (1,000 year return period) respectively. Exact levels for the project site are not known, but are expected to be slightly lower due to the site's sheltered location.

4.7.3 Water Quality

Intake water quality has been discussed in Section 2.5.7 based on long-term monitoring of Darwin Harbour by Conservation and Natural Resources Group of the Department of Infrastructure, Planning and Environment.

Prior to purchasing the property, APPL undertook a limited sampling exercise of the surface water sources on site, ie. the freshwater dam and saltwater storage reservoir, on 15 October 2003. The results are summarised below.

Table 4.2 Onsite surface water quality

Parameter	Castnet Creek (jetty head)	Saltwater dam	Freshwater dam
pH	7.9	8.2	7.7
EC (µs/cm)	46,800	29,900	1580
As (mg/L)	< 0.05	< 0.05	0.002
Cd (mg/L)	< 0.005	< 0.005	0.0001
Cr (mg/L)	< 0.005	0.010	0.002
Cu (mg/L)	< 0.050	< 0.050	< 0.001
Ni (mg/L)	< 0.050	< 0.050	< 0.001
Pb (mg/L)	< 0.005	0.008	< 0.001
Zn (mg/L)	< 0.050	< 0.050	0.04
Hg (mg/L)	< 0.0001	< 0.0001	< 0.0001

The water samples were also analysed for organochlorine and organophosphorus pesticides. All results were below the limit of reporting (LOR).

4.8 GROUNDWATER

The Natural Resources Division's "Groundwater Supply Prospects of the Litchfield Shire" (DIPE 2002b) indicates that the majority of the site is underlain by groundwater with high salinity (TDS > 1000mg/L), which is unsuitable for human consumption. There is only limited access to good quality groundwater nearby the central northern boundary. Potential yields range between 0.5 and 5 L/s.

As there is access to town water supply, the project does not anticipate extracting groundwater for its operations.

4.9 ACID SULFATE SOILS

Acid sulfate soil is the common name given to naturally occurring soil and sediment containing iron sulfides, or pyrite.

In Australia, the acid sulfate soils of most concern are those that formed in the Holocene geological period (the last 10,000 years) after the last major sea level rise. During the sea level rise new coastal landscapes were created as a result of rapid sedimentation, and acid sulfate soils were created when bacteria in these organically rich waterlogged sediments converted the sulfate from the seawater, and iron from the

sediments, into iron sulfides. These naturally occurring iron sulfides are generally found in a layer of waterlogged soil or sediment, and are benign in their natural state. When disturbed and exposed to air, however, they oxidise and produce sulphuric acid, iron precipitates, and concentrations of dissolved heavy metals such as aluminium, iron and arsenic (WAPC 2003).

Acid sulfate soils can be classified into the following (Thomas et al. 2003):

- **Actual acid sulfate soils (ASS)** consist of coastal sedimentary material that once contained iron pyrites, and may still contain some, but which has been exposed to the atmosphere by drainage or disturbance so that the pyrite has oxidised to form sulfuric acid, thereby decreasing the pH of the soil to less than 3.5. This material is also characterised by bright yellow or straw-coloured mottles of the mineral jarosite and often contain dark reddish-coloured streaks of iron oxide; and
- **Potential acid sulfate soils (PASS)** consist of a coastal sedimentary material that contains iron pyrites that have not been oxidised. Consequently, the pH is usually near neutral (approximately 7).

Acid sulfate soils have been identified within the intertidal zones of the property, with net acidity estimated between 16 moles/tonne nearby the existing ponds and 755 moles/tonne in the mangrove area (ALS Environmental 2003). Development in these areas will be minimal, consisting of the construction of the sedimentation ponds, an upgrade of the saltwater storage dam and increase in capacity of the intake channel. Appropriate measures will be taken to avoid acid generation due to exposure of the potential acid sulfate soils identified.

4.10 HERITAGE AND ARCHAEOLOGY

4.10.1 Background

Larrakia lands extend up to 50 kilometres inland in some areas of the Top End region, and traditional boundaries cover most of the Cox Peninsula, Shoal Bay, Darwin and Palmerston Cities, and much of Gunn Point.

Historically the Larrakia people moved about their country, hunting and fishing in accordance with cultural requirements, seasonal patterns and availability of freshwater.

There are currently over 120 named and registered Larrakia Sacred Sites, in Darwin Harbour and its catchment. Equally Larrakia archaeological heritage is very rich and diverse, including hundreds of 'shell middens' dotted along the mangrove fringes of the harbour coastline, including artefact scatters, historical campsites and gathering places. The abundance of these sites in the region indicates that generations of people lived within this resource rich environment for many thousands of years (Darwin Harbour Advisory Committee 2003).

4.10.2 Archaeological Sites

As part of the 1992 PER process, an archaeological survey was undertaken on the site. The survey found eighteen sites of archaeological interests, most of which are aboriginal shell middens. Due to the lack of comparative data from the NT Museum accurate assessments of significance of these sites could not be made. However, an

assessment for scientific significance of the sites was undertaken based on: 1) the research potential of a site or suite of sites and 2) the representativeness of the site or sites. Results of the archaeological survey are available in Appendix D.

A follow up survey was conducted by the Office of Environment and Heritage in May 2004 as part of the assessment process for the 14ha development application submitted in April 2004 (refer to Appendix 1 of the PER guidelines (Appendix A of this document)). This survey provides a condition assessment for these sites, but not a reassessment of archaeological significance. One site located under the dam wall was destroyed by construction works in 1992. This midden was salvage excavated with the appropriate consent. The remainder of the sites were found to be in good condition.

Archaeological reassessment was not required as none of the sites will be disturbed or impacted by this expansion, provided that proper mitigation measures are put in place. The survey reported that the significance of these sites is likely to have changed since they were originally recorded. While scientific significance may have decreased in light of further survey work and discovery, cultural and education significance may have increased due to greater development pressures in Darwin Harbour and higher levels of visitation to these places.

The table below provides a description of the sites and incorporates current condition and assessment of significance for the sites from the two surveys. Figure 4.5 shows location of these sites in relation to the proposed redevelopment.

Table 4.3 Archaeological sites found within the project area.

Site No.	Site Type	Site Description	Topographic setting	Condition & Significance
1	Stratified shell midden	Dense concentration of shell, +30cm thick. Mainly Anadara. Quartz artefacts.	On low rock outcrop	Destroyed due to 1992 construction works. Salvage excavated. High significance
2	Stratified shell midden	Dense concentration of shell, +20cm thick. Mainly Anadara	On top of steep hill 15m above estuary	Undisturbed. High significance
3	Surface scatter of shell midden	Sparse scatter of shell	On low ridge near estuary	Undisturbed. Low significance
4	Surface scatter of shell midden	Dense scatter of shell, mainly Anadara	On low ground near estuary	High disturbed by road grading. May have been transported from another source. Low significance.

Site No.	Site Type	Site Description	Topographic setting	Condition & Significance
5	WW2 gun emplacement constructed from shell midden material	Semi circular embankment of crushed shell 11x8m & up to 30cm high	On slight rise above road	Undisturbed. High significance
6	WW2 building	Concrete slab overlying disturbed shell midden (probably transported to the site as fill). 2 sheets of corrugated nearby, otherwise no other remains of building	On slight rise adjacent to road	Concrete slab intact, otherwise little else remains. Moderate significance
7	Stratified shell midden & WW2 observation post	Largely intact compact shell midden +20cm thick with disturbed area with low stone wall, star pickets & empty 1942 303 bullet cartridges	On 8m high hilltop immediately behind Site 5	Concrete slab intact, otherwise little else remains. Moderate significance
8	Surface scatter of shell midden	Sparse, discontinuous scatter of shell, mainly Anadara	On broad, flat spur overlooking estuary	Disturbed by vehicle tracks. Low significance
9	Surface scatter of shell midden	Sparse scatter of shell (Anadara & Terebralia) & quartz artefacts	On 4m high top on ridge protruding into estuary	Undisturbed. Low significance
10	Stratified shell midden	Dense concentration of shell, +20cm thick. Mainly Anadara. Numerous quartz artefacts	On 6m high hill top on ridge adjacent to estuary	Undisturbed. High significance
11	Stratified shell midden	Dense concentration of shell, +20cm thick. Mainly Anadara. Numerous quartz artefacts	On 5m high hill top on ridge adjacent to estuary	Undisturbed. High significance
12	Stratified shell midden	Dense concentration of shell, +20cm thick. Mainly Anadara. Numerous quartz artefacts	On 5m high hill top on ridge adjacent to estuary	Undisturbed except north end has been cut by access track. High significance
13	Surface scatter shell midden	Sparse scatter of shell (Anadara)	On top of 8m high ridge adjacent to estuary	Disturbed by animals. Low significance

Site No.	Site Type	Site Description	Topographic setting	Condition & Significance
14	Stratified shell midden	Dense concentration of shell in form of mound 10m across & 1m thick. Mainly Anadara. Quartz artefacts	On low rise 6m above estuary	Undisturbed. Very high significance
15	Stratified shell midden	Dense concentration of shell in form of mound 16m across & 1m 1.5m thick. Mainly Anadara. Quartz & quartzite artefacts	On low rise 6m above estuary	Undisturbed except for large pit on one side where shell has been quarried. Very high significance
16	Surface scatter of shell midden	Sparse scatter of shell	On low ridge near estuary	Disturbed due to construction works in 1992. Low significance
17	Surface scatter and stone artefacts	Stone artefacts, mainly quartz. No shell	On scree slope at base of hill	Some evidence of disturbance. Moderate significance
18	Surface scatter of shell midden and stone artefacts	Sparse scatter of shell and quartz artefacts. Possible quarry	On crest of prominent hill	Much of this will be quarried. Not disturbed since 1992 construction works

4.11 ABORIGINAL SACRED SITES

In preparation of the 1992 PER, an anthropological investigation of the project area was undertaken. The investigation found no Aboriginal sacred sites within the project area, and an Authority Certificate was then issued to the previous proponent in accordance with the Aboriginal Sacred Sites (NT) Act 1989. This Certificate is still current.

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Figure 4.5 - Archaeological Sites.

5 Environmental Impact Assessment

5.1 INTRODUCTION

This chapter aims to describe and, where possible, quantify potential impacts on the biophysical and, to a lesser extent, socio-economic environment resulting from the proposed APPL aquaculture development project.

Construction and operational impacts are discussed in separate sections, with each section subdivided into impacts on the biophysical environment and socio-economic environment. Where impacts are repeated, reference is made to the relevant section in order to avoid duplication.

The final section discusses impacts associated with decommissioning and rehabilitation.

5.2 CONSTRUCTION IMPACTS

5.2.1 Impacts on the biophysical environment

Effects of site clearing on flora and fauna

Flora

Land clearing will result in a permanent loss of vegetation communities and the habitat it provides for fauna. The proposed redevelopment will result in clearing of mostly terrestrial woodland (39 hectares) to the north of the site for construction of production ponds, access roads and buildings to assist operations.

Sixteen hectares of mangroves to the south of the site will also be cleared for construction of sedimentation ponds and discharge channels. Two mangrove communities will be affected: salt flat (4 hectares) and hinterland mangroves (12 hectares).

Most of the vegetation within the lease area has in some way been disturbed by the previous development, as evidenced by the presence of weeds, areas of regrowth and stunted growth of mangrove species. Apart from the monsoon vine forest on Haycock Hill, none of the vegetation communities was found to be of significance on a regional scale. When compared to the total area of similar habitat types available in the region, the loss of mangroves, salt flats and Eucalypt woodlands is considered to be of minor significance.

One protected species, *Cycad armstrongii* was identified within the lease area. However, this species is widespread and relatively common throughout the region, and its presence does not preclude development with the relevant statutory approval (ie. a Permit to Clear from the Land Assessment Unit).

Vegetation of the monsoon thickets on Haycock Hill has significant conservation value. However, the proposed development will not impinge upon this plant community.

Fauna

Vegetation clearing will result in habitat loss for fauna inhabiting the affected areas. As the amount of clearing required in comparison to the total available areas of similar habitat in the direct vicinity is very small, it is unlikely that the effects on fauna will be significant.

Following the required clearing, the site will still be able to sustain mangrove species as less than 15% of the total mangrove area within the property will be removed. Moreover, the mangrove and salt flat area to be cleared is degraded and does not provide prime habitat for any species.

Apart from a buffer zone around the freshwater dam, the terrestrial woodland habitat will be mostly removed to make place for the project infrastructure, resulting in a significant loss of habitat for local fauna. Due to the abundance of Eucalypt woodland in the immediate vicinity of the project area, sufficient habitat will remain and most species will be able to migrate to areas not impacted by the development.

Effects of earthworks

Extensive earthworks have the potential for significant impacts, especially in tropical climates characterised by heavy rainfall over a well-defined period of time. In general, earthworks have the potential to lead to:

- Soil erosion;
- Dust generation;
- Disturbance of Potential Acid Sulfate Soils;
- A change in hydrological patterns;
- Introduction and spread of weeds and pests; and
- Changes in fire regime.

Soil erosion

All earthworks are expected to consist of cut-to-fill operations and it is not anticipated that external fill will need to be sourced. The site has several existing borrow pit areas for gravel and clay in case in-situ materials are not adequate.

Earthworks will be undertaken during the dry season, thus limiting the potential for soil erosion as a result of stormwater run-off. Soil erosion will need to be prevented through the implementation of proven land management procedures as detailed in the Environmental Management Plan (Section 6). This will be particularly important for construction works in the upper tidal zone, ie. construction of the sedimentation ponds.

Dust generation

Earthworks undertaken during the dry season, have the potential to create significant dust nuisance. Dust will need to be suppressed so as not to create nuisance in accordance with the *Public Health Act 1995*. This will be achieved by implementing proven land management procedures as detailed in the EMP.

Due to the substantial distance between the prawn farm and the neighbouring property, it is unlikely that nuisance from dust generation will cause an off-site impact. However, onsite impacts on construction workforce, fauna and flora equally need to be avoided.

Disturbance of Potential Acid Sulfate Soils

Some of the proposed earthworks and construction activities have the potential to disturb Potential Acid Sulfate Soils, especially those works associated with the saltwater storage dam, intake canals and sedimentation ponds. These areas are all located below 4 m AHD and have been identified to contain PASS material.

The layout of the project has aimed at minimising disturbance of the lower areas of the site, both because of the significance of mangrove habitats for the sustainability of the Darwin Harbour ecosystem and because of the likely presence of acid sulfate material

The majority of the required earthworks in PASS areas will consist of building up pond walls (ie. saltwater storage, sedimentation ponds and intake canals) using clean, non-acid sulfate generating fill from upland areas.

The proposed removal of dead vegetation from the saltwater storage dam will require the dam to be drained following which the bottom can be ripped and vegetation removed. Acid generation will be avoided by a combination of timing the works such that the period of exposure between draining and refilling the dam is limited, and the addition of a neutralising agent, as detailed in the EMP.

No excavation will be required in order to achieve adequate depth in the sedimentation ponds and construction will be limited to building bund walls using clean fill.

In case discharge over the sedimentation pond spillway into an excavated discharge channel leading to the tidal creek is preferred in comparison to a concrete structure built on top of the mangrove muds, some impact on PASS may be expected. Preliminary ASS testing of the mangrove area has indicated that the soils have substantial acid generating potential (net acidity 755 moles/tonne, requiring the application of up to 57 kg CaCO₃ per tonne of acid sulfate material for neutralisation purposes) (ALS Environmental 2003). If a discharge channel is to be excavated, further testing will be carried out prior to the execution of the earthworks and again following neutralisation.

As discussed above, the alternative to an excavated channel would be a plastic or concrete lined “raft” structure on top of the mangrove sediments, thus avoiding exposure of PASS material. Lining would also be useful in avoiding scouring and erosion. For these reasons, a lined structure is the preferred option.

Change in hydrological patterns

Changes to hydrological patterns in excess of those already introduced by the previous development will be limited, as all the major hydrological features of the development such as the freshwater dam, saltwater storage reservoir and intake canal will not be changed dramatically.

The freshwater dam limits freshwater inflows to the downstream mangrove areas to the occasional spillway overflow during the wet season. Except for the repair of the spillway, no changes to the freshwater dam are proposed. However, a substantially larger volume of freshwater will be drawn from the dam for seasonal dilution of the production pond water. Hydrological calculations (Appendix E) have indicated that in some years, freshwater extraction for two consecutive crops may not be sustainable. As in the 1992 PER (Kinhill Engineers 1992), the calculations have been based on 9 years of historical run-off and meteorological data for a nearby, comparable catchment area (Corney's Creek in Palmerston). As a result, a risk assessment will need to be undertaken each year to determine whether a second crop can be achieved or not. It is proposed not to draw water from the freshwater dam if water depth falls below 1.5 m.

However, it has to be noted that the hydrological calculations are based on replenishment of the dam by means of catchment run-off only. It is likely that groundwater recharge is a quite significant contributing factor as well. Due to the absence of bore data, no conclusions can be drawn at this stage and operational control based on the conservative hydrological calculations and visual assessment is the suitable approach.

Stormwater run-off from the site will be collected into compacted drainage channels that will either discharge into a water body, ie. the freshwater dam or saltwater storage reservoir, or in the mangroves via a gravel-lined outfall to prevent erosion. Rain falling directly onto the production areas will be ultimately directed to the sedimentation ponds. Due to the fact that the upland areas will be largely taken up by infrastructure and that run-off will be channelled and enter mangroves as stream flow from discrete discharge points, natural sheetflow of stormwater run-off into the salt flat and mangrove areas will be further reduced when compared with the previous development. This may have an impact on mangrove communities that are dependent on freshwater inflow, such as the hinterland margin mangroves. The only remaining hinterland margin mangrove area extends between the western edge of the production ponds and the freshwater dam. This area will continue to receive natural freshwater inflow from run-off.

Weeds

The weeds of primary concern to this redevelopment are Annual and Perennial Mission Grass, Gamba Grass, Hyptis, Stinking Passionflower and Purple-top Chloris (refer Section 4.5.1).

Terrain disturbance, clearing of native vegetation and nutrient enrichment of normally nutrient poor substrate could facilitate the proliferation and introduction of new weed species. Weed infestation will lead to environmental decline and loss of biodiversity through exclusion of native species.

Mitigation measures will focus on managing existing weed infestations and prevention of further weed introduction into undisturbed habitats. Environmental changes that encourage proliferation of non-native species will need to be minimised.

Biting insects

- *Biting Midges:*

Major breeding sites for biting midges are in upper reaches of small tidal creeks or at seaward fringes of extensive mangrove areas, generally under a canopy of mangrove vegetation. Thus potential sources of biting midges within the lease areas are at the effluent discharge point and supply intake channels. These areas are quite some distance away from production ponds and sensitive areas such as the administration buildings. The areas mostly occupied by workers are generally free of vegetation, and wind action will reduce dispersal of biting midges.

It is highly unlikely that biting midge outbreaks and resulting nuisance to workers can be avoided. The use of insecticides to reduce numbers of adult midges has not been very successful to date. It is likely that during certain periods, workers will have to resort to personal protection against midges and mosquitoes. A number of measures have been outlined in the EMP.

- *Mosquitoes:*

Earthworks in the tidal area have the potential to create isolated pools of fresh and brackish water. Any temporary drains or depressions in the project area also constitute potential mosquito breeding sites. Water volumes that remain stagnant for up to 3 days have the potential to breed large quantities of mosquito larvae.

The saltwater supply channel and saltwater dams, particularly where siltation and reed beds occur, constitute potential breeding sites for brackish mosquito species. The freshwater dam and sedimentation ponds are unlikely to provide significant mosquito breeding habitat as they will contain fish and macro invertebrates.

Farm design can play a significant role in preventing the creation of mosquito breeding habitats and dispersal of mosquitoes by:

- Ensuring all drainage systems are self-draining to avoid ponding;
- Ensuring adequate water depth and steep walls in 'permanent' water bodies such as the saltwater dam and production ponds; and
- Provision of screens to doors and windows of administration buildings and accommodation.

During operations, regular monitoring and corrective actions will need to be undertaken. Proposed monitoring and management measures are described in the EMP.

Fire regime

As a result of land clearing and extensive earthworks, it is expected that the frequency of widespread, high intensity fires in the remaining vegetation will be reduced. This may lead to a shift in species composition towards a denser mid-stratum layer that includes fire sensitive monsoon forest species.

A fire management plan will be developed in consultation with the NT Bushfire Council regulations.

5.2.2 Impacts on the socio-economic environment

Construction activities have the potential to create nuisance to or impact the socio-economic environment in a number of ways. Likely impacts relevant to the proposed aquaculture development include:

- Disturbance of archaeological sites;
- Increased traffic; and
- Temporary restricted access to Castnet Creek during pumping station upgrade.

The significance of these impacts is discussed in the following sections.

Socio-economic benefits associated with the project's construction phase include the employment of local contractors undertaking design and construction works, and the purchase of building materials and equipment such as pumps, aerators, diesel generator etc.

Disturbance of archaeological sites

Construction and operational activities are likely to create minor disturbance to some archaeological sites identified within the project area. Management strategies have been developed to mitigate any potential impacts according to the level of significance of each site. The table below summarises potential impacts and management practices, which have been taken from the previous PER (Kinhill Engineers 1992) and incorporating additional information following the May 2004 site visit by an officer of the Office of Environment and Heritage. Further details are contained in the Cultural Heritage Management Report drafted by OEH and appended to the PER Guidelines which constitute Appendix A of this report.

Table 5.1 Potential impacts and management measures for archaeological sites within the lease area

Site No.	Site Type	Potential Impact	Management recommendations
1	Stratified shell midden	Destroyed during construction of dam wall in previous development	Was salvage excavated
2	Stratified shell midden	No impact	No action required
3	Surface scatter of shell midden	No impact	No action required
4	Surface scatter of shell midden	No impact	No action required

Site No.	Site Type	Potential Impact	Management recommendations
5	WW2 gun emplacement constructed from shell midden material	No direct impact	Should be fenced off during works on dam wall (proposed capping and second spillway construction)
6	WW2 building	No impact	No action required
7	Stratified shell midden & WW2 observation post	No impact	No action required
8	Surface scatter of shell midden	No impact	No action required
9	Surface scatter of shell midden	Margins may be flooded at times when dam is full	No action required
10	Stratified shell midden	No impact	No action required
11	Stratified shell midden	No impact	No action required
12	Stratified shell midden	No impact	No action required
13	Surface scatter shell midden	No impact	No action required
14	Stratified shell midden	No impact, but potential disturbance	Fencing be undertaken as per OEH guidelines
15	Stratified shell midden	No impact, but potential disturbance	Fencing be undertaken as per OEH guidelines
16	Surface scatter of shell midden	Damaged during previous construction work	Remediation actions carried out by previous proponent. No further action required
17	Surface scatter and stone artefacts	Disturbance from installation of power line	Fencing if construction works are carried out on western side of the spill way
18	Surface scatter of shell midden and stone artefacts	No impact	No action required

Additional management measures as per OEH recommendations have been included in the EMP.

Increased traffic

As discussed in Section 2.9, anticipated construction traffic will be limited to:

- Delivery of heavy machinery (one off events);
- Delivery of building materials and equipment (ie. pumps, pipes); and
- Construction workers transportation.

No external fill is required, except for small volumes of rock needed to reinforce spillways and stormwater drainage outfalls.

Construction traffic will be minor and it is considered that Channel Island Road is of adequate standard and capacity for this level and mix of traffic.

Restricted recreational traffic access

Recreational boat access, if any, to Castnet Creek may be restricted for a short period of time during the installation of the intake pipe to the new pumping station. This activity can be completed within a matter of days and the resulting nuisance to recreational fishermen is expected to be negligible.

Access to Haycock Creek will not be affected throughout construction.

5.3 OPERATIONAL IMPACTS

5.3.1 Impacts on the biophysical environment

The discharge of effluent from the sedimentation ponds is expected to constitute the main impact from the development, leading to localised impacts on water quality and mangrove species composition.

Other, less significant impacts resulting from prawn farm operation, include:

- Noise generation;
- Odour generation;
- Atmospheric emissions;
- Liquid and solid waste disposal; and
- Spread of pests and diseases.

Effluent discharge

Hydrodynamic regime

The channelling of effluent from the sedimentation ponds to the head of the creek via a lined or suitably compacted channel will avoid potential scouring and erosion of the intertidal area just downstream of the sediment ponds. Erosion at the discharge point into the creek will be avoided by means of energy dissipators and gentle slopes, which reducing flow velocities to acceptable levels.

Coarse bathymetry and width of the discharge creek were obtained from the owner to allow for the assessment of the depth profile and calculation of creek volumes. The width of the creek varies between 5 m upstream and 120 m at its confluence with Haycock Reach, Middle Arm. Depth at mean tide varies between 2 m upstream and 3.5 m downstream. At high tide, depth varies between 3.2 and 5.5 m. The creek volume at high tide is approximately 38,500 m³, not including its numerous small tidal tributaries.

Discharge will coincide with high and receding tides for periods of 6 to 8 hours. Total discharge volumes over that 6-8 hour timeframe will vary between 35-45 ML (typical

for all ponds in production) and 63 ML (maximum for all ponds in production), contributing significantly to the creek flows for the duration of the discharge. As a result, the creek is likely to drain less rapidly during the receding tide. This should not have an impact on 'normal' tidal processes during the next tide, during which no discharge will occur. In summary, during those periods of the growth cycle that require discharge, the tidal creek will be subject to one normal tidal cycle per day and may not drain to the full extent during the second tidal cycle.

Impacts on water quality

The project aims to reduce nutrient and sediment loads in pond effluent via a series of sedimentation ponds that will discharge over a spillway. From there, the discharge will be channelled to the head of the unnamed creek nearest to the discharge points.

The impact assessment on water quality includes an overview of expected nutrient loads originating from the prawn farm operations, a comparison with Darwin Harbour nutrient loads and results of a hydrodynamic modelling exercise.

- *Nutrient loads:*

A recent nutrient budget study in a commercial prawn farm using both recirculating and flow-through ponds reported the following nutrient and suspended solid concentrations in a flow-through system (Robertson et al. 2003). These data would be indicative of concentrations in the discharge to the settlement pond.

Table 5.2 Typical nutrient and suspended solids concentrations in pond effluent

Parameter	Average (mg/L)	Range (mg/L)
Total Nitrogen	1.68 ± 0.11	0.8 - 3.0
Dissolved Organic Nitrogen	0.45 ± 0.06	N/A
Particulate Nitrogen	0.97 ± 0.09	N/A
Dissolved Inorganic Nitrogen	0.29 ± 0.07	N/A
Ammonia	0.27 ± 0.07	N/A
Nitrite	0.012 ± 0.004	N/A
Nitrate	0.019 ± 0.01	N/A
Total Phosphorus	0.16 ± 0.01	0.06 - 0.28
Free Reactive Phosphorus	0.007 ± 0.002	N/A
Total Suspended Solids	N/A	50 - 220

N/A Not Available

The nutrient budgets indicated that in the flow-through system, 22% of total nitrogen inputs to the ponds (eg. prawn feed, fertiliser, intake water) was retained in the water column, 20% in the prawn bio mass, 25% in the sediment, 0.3% was lost through evaporation and 5% was lost through denitrification. Twenty-seven percent of total nitrogen inputs were destined for 'other' destinations, including ammonia evaporation, leakage, etc.

The predominant fate of phosphorus was entrapment in the pond sediments (82%). The discharge water retained 7% of total P input, whereas prawn biomass accounted for 11%. Less than 1% of total P inputs was estimated to be lost through leakage.

Nitrogen in the water column consisted largely of particulate nitrogen (55%), mostly bacteria, phytoplankton, zooplankton as well as detritus. Ammonia was the major component of the mean dissolved inorganic nitrogen pool (95% of DIN). The proportion of mean DIN was 17% and of mean dissolved organic nitrogen (DON) was 28%. Total Phosphorus consisted predominantly of particulate phosphorus (96%), most likely bound up in plankton and detritus as well as sorbed to inorganic particles.

A large proportion of particulate nitrogen and phosphorus in the water column is expected to settle in the sediment pond over the proposed multiple day retention time. CSIRO research has found that most settlement occurs within the first 1-2 days, after which suspended solids in effluent increases again (CSIRO 2005). Up to 60% of TSS has been reported to settle in sedimentation ponds. Assuming the discharge data above (Table 5.2), a conservative 50% settlement ratio of suspended solids and no reduction in dissolved nutrients, the following concentrations would be present in the discharge over the spillways (Table 5.3).

Table 5.3 Expected concentrations of nutrients and suspended solids in the spillway discharge.

Parameter	Average (mg/L)	Range (mg/L)
Total Nitrogen	1.22	0.57 - 2.13
Total Phosphorus	0.08	0.03 - 0.15
Total Suspended Solids	N/A	25 - 110

N/A Not Available

It has to be noted that these estimates are higher than the concentrations calculated based on Food Conversion Ratio (FCR) (Refer Section 2.5.6 and Appendix B). Total nutrient loads from the prawn farm operations to Darwin Harbour were calculated using the average concentrations in Table 5.3 and the generous estimate of water volumes required on an annual basis to allow for two crops (refer Table 2.5). These loads were then compared to the NPI nutrient load data for Darwin Harbour (NPI 2005).

Table 5.4 APPL nutrient contributions to Darwin Harbour

Source	TN load (kg/yr)	APPL % contribution	TP load (kg/yr)	APPL % contribution
APPL	20,000		1,312	
Undisturbed – Darwin Harbour	340,000	5.9	24,000	5.5
Sewerage	310,000	6.4	77,000	1.7
Total loads to Darwin Harbour	890,000	2.2	120,000	1.0

The above table illustrates that Darwin Harbour is a nutrient rich system naturally, and that the APPL nutrient loads are very small in comparison to the loads contributed by sewerage, water supply and drainage services. When compared to total nutrient inputs to the Harbour by natural and anthropogenic sources, the APPL operations are expected to contribute maximally 1 % for total phosphorus and 2% for total nitrogen. Considering that the APPL contributions are based on conservative estimates of water volumes and residual nutrient concentrations, these percentages reflect maximum contributions unlikely to be observed.

The fact that APPL's contribution to nutrient levels in the Harbour will be limited and should not result in a significant shift in the trophic state of Harbour waters, was confirmed by means of a Vollenweider model assessment. Details of the assessment can be found in Appendix F. As expected, the current trophic status of Darwin Harbour is oligotrophic and based on the estimated contribution by APPL operations, only a small change in the trophic status will be experienced. Harbour waters are expected to remain highly oligotrophic.

- : Hydrodynamic modelling

Hydrodynamic modelling was undertaken to evaluate dispersion of the effluent discharged from the prawn farm. The effluent is discharged directly into an unnamed mangrove creek, some 700 m long, which flows into the Middle Arm of the Darwin Harbour, as shown in Figure 1.1 in Appendix G.

Due to the large discharge volumes involved, only limited dispersion is expected to occur within the discharge creek. Accordingly it was decided to concentrate on dispersion of the effluent once it reaches the main water body, i.e. the Middle Arm.

For full details of the model and assumptions, refer to Appendix G. Due to the absence of data on nutrient uptake and conversion rates, nutrient discharges were modelled as 'conservative tracers'. As a result, the dispersion modelling quite accurately describes dispersion within a tidal cycle, but would not be appropriate to draw long-term conclusions on water quality in the Harbour from, as the model does not account for natural conversion and biological processes.

For the purpose of this report, the zone of influence is the area around the discharge point characterised by a measurable increase in ambient pollutant concentrations, i.e. over and above natural variability. Following discharge, total nitrogen concentrations fall to 25% of the discharge concentration (0.30 mg/L, refer Table 5.3) within 1 km downstream of the discharge point, which, when added to an average background level of 0.53 mg/L (refer Table 2.2), results in a concentration within the limits of natural variation (standard deviation of TN levels in Darwin Harbour is 0.33 mg/L).

In terms of total phosphorous, concentrations fall below 10% of the discharge concentration (<0.008 mg/L, refer Table 5.3) within 4 km downstream of the discharge point. When added to an average background level of 0.013 mg/L (refer Table 2.2), this would result in a concentration within the limits of natural variation (standard deviation of TN levels in Darwin Harbour is 0.005 mg/L) just beyond 4 km downstream of the discharge point.

The distances at which the APPL discharge would result in a non-measurable increase of ambient TN and TP concentrations, are well below the separation distance between the proposed discharge and sensitive ecosystems such as the Channel Island Reefs

(approx. 10 km). As such, it is believed that the APPL operations will not have a direct impact on the reef's health.

Even at the highest discharge concentrations expected (refer Table 5.3), TN concentrations would be back to levels observed within natural variation limits 4-5 km downstream. Likewise, natural TP concentrations would be achieved within 6 km downstream of the discharge point.

It has to be noted that these dispersion scenarios are very conservative, as biological and chemical processes resulting in reductions of dissolved nutrient concentrations were not considered. Likewise, flows from the Blackmore River were not considered. Discharges during the first crop from September to February will incur better than modelled flushing and dispersion due to substantial flows from the river into the harbour.

Impacts on mangroves

Observations by Boyd (1995) have indicated that Australian prawn farmers are amongst the most environmentally sustainable in the world. Accurate levels of environmental impacts in the long term have not yet been adequately defined, although anecdotal reports and preliminary research (Trott, 1996), suggests adverse impacts to water quality and indirect impacts to aquatic flora and fauna by well-planned and managed prawn farms, are yet to be demonstrated.

Potential impacts within intertidal areas are expected to be focussed on the mangroves downstream of the two discharge spillways. On average 35-45 ML/day of discharge water will be released intermittently, with effluent flowing over a spillway into a canal leading to the nearby creek. Any impacts on mangrove vegetation due to increased nutrient loads would be most pronounced in the tidal creek mangroves nearest to the discharge point. It is anticipated that some bio-filtration of effluent will occur in the *tidal flat* mangroves—the increase in nutrients may in fact be of potential benefit to these forests. Indeed, mangroves have been observed to proliferate adjacent to prawn farms in north Queensland (Foster and Robertson, 1999). Mangrove wetlands are efficient nutrient recyclers, removing sediments and dissolved nutrients from the water column. The microbial communities in the sediments are responsible for most of this nutrient uptake, because even in an efficient system, only around 10% of nutrient uptake can be attributed to plants. The ability of mangroves to transport oxygen into sediments via their roots greatly extends the habitat for nitrifying bacteria (Danis and O'Sullivan 2000).

Russell Hanley (NT Museum) made an assessment of the potential impacts of the original farm development on mangrove communities (Kinhill, 1992). He likened the farm effluent to nutrient-rich sewage effluent and reported that in studies of the effects of sewage on mangrove invertebrates at Brimah in Darwin Harbour, there had been no difference between impact sites and control sites (Hanley and Couriel, 1992). However, later studies of mangrove invertebrates downstream of sewage outfalls on Buffalo Creek indicated a decrease in diversity and elevated abundance of some crab species (Hanley Caswell and Associates, 1997). The ecological impacts of prawn farm effluent on mangrove communities are not well understood and APPL's proposed monitoring program should increase our understanding in this area and thereby will assist in future environmental assessment.

Discharge events will be coordinated with high tides to facilitate the dilution of effluent and to maximise the benefits of tidal flushing. Effluent water will be close to or slightly less than the salinity of seawater (20-35 ppt) during the dry season and less saline than seawater (5-20 ppt) during the wet season. These salinities are unlikely to have a major detrimental effect on mangroves downstream.

The redevelopment of this site will increase the number of prawn farms on the Blackmore River to four. However, two of these four farms are currently inactive. Impacts from the proposed development are clearly not limited to potentially negative effects on the natural environment. Indeed, habitat modifications resulting from the previous development -including construction of the freshwater reservoir and the shallow brackish water habitats provided by the maze of old ponds - has created a rich habitat for birds. Further, it is widely thought that mangroves may benefit from increased nutrients and will proliferate in habitats downstream from pond effluent outlets. The knowledge and baseline data gained from the proposed long-term monitoring of mangrove flora, fauna, soils and water quality will be of benefit for future aquaculture proposals and to coastal management generally.

Noise generation

Sources of noise emissions on site will be limited to the use of operational vehicles, emergency generators, blowers and pumps. All equipment will comply with relevant standards and a superintendent will be employed to ensure it is maintained in good working order.

Noise nuisance is not expected to be an issue as the nearest neighbours live more than 5 km away. As most of the noise, except for the intake pumps, will be generated in the upland areas, impacts on recreational water users and fauna in the mangrove areas are expected to be minimal.

Odour generation

If not properly managed, the sludge drying beds and waste materials from the packing shed have the potential to create considerable localised odour problems. However, it is believed odour nuisance can be avoided through the implementation of a number of odour control procedures as described in the EMP.

Atmospheric emissions

During normal operations, power will be supplied by the grid, resulting in no on-site atmospheric emissions other than combustion emissions from site vehicles. The emergency diesel generator will only be used during power outages in the wet season. The generator will be able to supply power to operate 50% of the aerators, equivalent to 394kW. It is estimated to be operational for maximum 40 hours per year. This equates to approximately 16,000 kWh or 57.6 GJ.

The emissions of greenhouse gases from the operation of the diesel generator are summarised in Table 5.4. (Australian Greenhouse Office 2004)

Table 5.5 Summary of greenhouse gas emissions from emergency diesel generator operations

Pollutant	Emission Factor	Total Annual Emission
CO ₂	69.7 kg/GJ	4015 kg CO ₂
CH ₄	4 g/GJ	230 g CH ₄
N ₂ O	0.6 g/GJ	35 g N ₂ O
NO _x	1,322 g/GJ	76 kg NO _x
CO	349 g/GJ	20 kg CO
NM VOC	45 g/GJ	2.6 kg NM VOC

The level of greenhouse gas emissions associated with the operation of the diesel generator is very small when compared to total greenhouse gas emissions from power generation in the Northern Territory. In 1995, NT energy and transformation industries produced 972,000 tonnes of CO₂, 100 tonnes of CH₄, 6700 tonnes of NO_x, 1700 tonnes CO and 2200 tonnes of NM VOCs (National Greenhouse Gas Inventory Committee 1998). Consequently, greenhouse gas emissions are not considered to constitute a relevant environmental factor under the NT Environmental Assessment Act 1994, and as such, have not been considered further for the purpose of this document.

Liquid and solid waste disposal

Other than the production pond effluent, volumes of operational waste streams will be minimal and will not result in significant environmental impacts if managed in accordance with the relevant regulations, including, but not limited to, the Dangerous Goods Act 1981; Litter Act 1972; Public Health Act 1995; and Waste Management and Pollution Control Act 1999.

Wastes generated will include pond sludge, domestic sewage, domestic garbage, packaging waste, wash down water (vehicles and packing shed), lubricants, empty drums and chemical containers, and semi-hazardous waste such as paint, solvents. The focus on waste management will be to minimise waste volumes generated.

Pond sludge

Some pond sludge is likely to accumulate in the prawn ponds as a result of pond wall erosion and accumulation of organic matter. Part of the pond sludge will be resuspended when the ponds are emptied following each crop. As such, pond sludge will also settle in the sedimentation ponds.

The sludge will be transferred to banded drying beds, where nutrients and organic matter will gradually biodegrade and stabilise. The sludge is exposed to the wet season rains and/or flushed with fresh water to reduce its salinity. It is then left to dry for 3 – 4 weeks. The dried sludge can be reused onsite for landscaping purposes, maintenance of pond walls or fill. Drying bed effluent will be directed to the effluent canal and sedimentation ponds.

Sewage, domestic discharge water, hazardous and miscellaneous wastes

Sewage and domestic discharge water including wash down water will be directed to seepage pits and sump on site, and be disposed of via septic tanks as per the health regulations. Triple interceptor trap will be placed in the sumps to remove potential oil waste from wash down water.

Domestic waste volumes will be limited, as it is not proposed to have workers accommodation on the site. Process waste that will require disposal includes the prawn feed bags. The feed bags are made of paper and can be either recycled or taken to the local landfill. An estimated 13,200 paper bags will be used per crop. Packaging waste (boxes and plastic bags) will be recycled or taken to landfill. Damaged prawns will be sold as 'seconds' if possible, or taken to landfill.

Minimal amounts of oils and lubricants will be used on site for the purpose of servicing equipment, including pumps and the emergency generator. Vehicles will be serviced offsite. Oil waste will be disposed off-site by a licensed contractor on an as needs basis.

Spread of pests and diseases

Any animals brought onto the farm will:

- Comply with translocation policies from NT Fisheries;
- Be tested for known pathogens (PCR testing and viruses), and secure Health Certification from the Fish Pathology Authority;
- Have statutory declaration completed and signed supporting disease status; and
- Allow Fisheries officers to inspect shipment and take any quarantine actions that may be necessary.

In the event of any disease outbreaks, NT Director of Fisheries will be informed and the site will be quarantined by restricting personnel access to the disease area and ceasing discharge of effluent water by internal circulating. Stock escaping will be prevented by suitable free board on all ponds, and screens installed at outlets and drains. The affected stock will be treated with drugs and chemicals permitted for use under Commonwealth and NT legislation and as prescribed by a registered veterinarian. Dead stock or suspected disease carrying prawns will be removed and buried.

5.4 IMPACTS FROM DECOMMISSIONING AND REHABILITATION

Environmental impacts associated with decommissioning will be very similar to those experienced during earthworks, ie. erosion, acid generation from PASS material, noise and dust. These impacts have been assessed in Section 5.2.

Decommissioning will result in a substantial amount of waste materials of various composition. Waste management will require careful planning and should consider alternatives to disposal such as reuse and recycling.

The ultimate rehabilitation of the site will have a positive impact in terms of both ecological and heritage values. Depending on the site's future land use, public access to the archaeological sites may be reinstated.

6 Environmental Management Plan

6.1 POLICIES AND RESOURCING

The following quotes are extracted from Marine Produce Australia (MPA)'s website. MPA is the owner of the APPL development.

“Marine Produce Australia is a diversified primary producer farming sustainably grown aquacultural produce in Australia's North”

The company defines sustainability as “... identifying, planning, developing, operating, harvesting and processing in an environmentally responsible manner, using best practice thus maintaining the environment for present and future generations”.

The company is committed to managing its operations in accordance with the Australian Prawn Farmers Association's Environmental Code of Practice (Donovan 2001). Ultimate responsibility for HSE management will rest with the company's directors. Day-to-day management responsibility is delegated to the site manager, and he/she will be the custodian of the Environmental Management Plan (EMP).

All staff will receive environmental awareness training, as well as task-oriented, competency-based training to ensure they execute their tasks in an environmentally acceptable manner. Contractors and casual workers will receive a site induction prior to being allowed to perform their tasks.

The EMP accounts for the construction activities and proposed operating regimes for the full-scale 42 ha aquaculture development. The EMP is a living document. It will be reviewed and resubmitted to the Office of Environment and Heritage in case its content becomes redundant due to minor changes in operations or the use of new technologies.

A new EMP will be prepared and submitted to OEH for future developments that warrant a development application.

A report outlining the performance of the project against the objectives stated in the EMP will be submitted to OEH on an annual basis. This report will include results of mangrove and water quality monitoring as required by licence conditions.

6.2 ENVIRONMENTAL MANAGEMENT MEASURES

The following sections discuss proposed management procedures to reduce and/or mitigate environmental impacts identified in Chapter 5.

Sections 6.2.1 through to 6.2.8 address environmental management measures during construction, in response to the impacts discussed in Section 5.2. Sections 6.2.9 to 6.2.16 address operational environmental management, in response to issues raised in Section 5.3. Finally, Section 6.2.17 addresses environmental management measures

associated with decommissioning and rehabilitation of the site. A complete EMP will be developed nearer to the time the prawn farm is ceasing operations.

Tables 6.1 and 6.2 document the existing environment, potential impacts along with management measures and expected outcomes for each environmental aspect identified.

Table 6.1 Existing environment, potential impacts and management measures during construction phase

Environmental Factor	Existing Environment	Potential Impact	Management Measures	Predicted Outcome
Biophysical Environment				
Site clearing and Flora <i>Section 4.5, 5.2.2 and 6.2.1</i>	Eucalyptus woodland covers extensive areas to the north of the lease site. The majority of the area has been cleared for the original development and now consists of 10-year old regrowth. Mangrove communities cover the southern boundary of the site towards Haycock Reach. The salt flat and hinterland mangrove communities nearest to the original development exhibit signs of disturbance. A narrow grassland area occurs in the transition zone between terrestrial woodland and mangroves. Monsoon vine forest is found adjacent to the lease area on Haycock Hill. This plant	Construction of production ponds and sedimentation ponds will lead to loss through clearing of: - 39 hectares of Eucalyptus woodland and - 12 hectares of hinterland and salt flat mangroves	Infrastructure layout is designed to minimise clearing of mangrove vegetation. Only areas required for operations will be cleared. Construction activities are to be restricted to areas that have been cleared. Movement of construction vehicles are managed within designated access roads. Rehabilitation of areas no longer required for construction.	Loss of 39 hectares of Eucalyptus woodland and 12 hectares of mangroves. Vegetation to be cleared does not have conservation or ecological significance at a regional scale, and is well represented elsewhere in the Top End. Impact of vegetation clearing is not deemed to be significant at a regional scale.

Environmental Factor	Existing Environment	Potential Impact	Management Measures	Predicted Outcome
	community is to be conserved. <i>Cycad armstrongii</i>, a protected species is relatively common throughout woodland within the lease area. The remaining species or plant communities within the lease area do not have any conservation significance. Vegetation within the lease area is typical and relatively common in the Top End region.			
Site clearing and fauna <i>Section 4.6 and 5.2.2</i>	Agile Wallaby and Grassland Melomys are commonly found mammals. Reptiles eg goannas, skinks, western brown snakes and death adders are common in the area. Scrub fowl is a common bird in the mangroves. Crustaceans dominate the invertebrate estuarine/marine fauna. Commons species include Fiddle crab. In the molluscs, gastropods dominate in the tidal flat zone, <i>Telescopium telescopium</i> in the	Loss of habitats and displacement of fauna as a result of vegetation clearing. However impacts will be minimal as cleared areas are small compared with the total habitat areas in the region, thus migration to non-impacted areas is possible. Minimal impacts due to mangrove clearing as the cleared zones of hinterland and salt flat are degraded and do not provide prime habitats for any	Minimise areas of vegetation to be cleared for infrastructure.	Loss of habitats and displacement of fauna. Freshwater dam provides habitat for aquatic birds and frogs. Vegetation clearing in the hinterland/ salt flat mangrove zones will lead to minimal loss of fauna as this zone supports few species.

Environmental Factor	Existing Environment	Potential Impact	Management Measures	Predicted Outcome
	mid-tidal flat zone. Abundant vertebrate fauna including over 340 species of fish. Nearest coral reef is found at Channel Island (Register of National Estate). Marine mammals and reptiles are common in Darwin Harbour, but not so much in tidal creeks.	species. Construction is not expected to impact Harbour habitats (reef) and species.		
Earthworks and soil erosion <i>Section 5.2.2 and 6.2.2</i>	Erosion of creek banks downstream of wastewater discharge point from previous operations.	Earthworks during construction and loss of vegetation cover can result in soil erosion.	All construction will be carried out during dry season. Earthworks are cut-to-fill with no external fill to be sourced. Erosion controls such as compacting pond walls, canals and roads; rock protection at stormwater discharge points, etc. Provision of adequate drainage structures.	Little erosion expected during construction and operation phases as adequate controls and appropriate drainage infrastructure will be provided.
Earthworks and dust generation <i>Section 5.2.2 and 6.2.3</i>	Dust generation is currently a problem on access roads during dry season.	Dust generation from earthworks during construction.	Minimise vegetation clearance and revegetate any areas not required for construction.	Minimal dust generation from construction and operation phases.

Environmental Factor	Existing Environment	Potential Impact	Management Measures	Predicted Outcome
		Dust generation from traffic accessing unsealed roads on the site.	Water down unsealed roads and apply speed limit. Any construction activities due to take place during the dry season will also be watered down to suppress dust generation. Wind conditions will also be taken into considerations when planning construction activities.	
Earthworks and acid sulphate soils <i>Section 4.9, 5.2.2 and 6.2.4</i>	Not expected to pose a problem in areas between 6 - 10mAHD. Potential acid sulphate soils are present in areas below 4m AHD where limited earthworks will take place.	Cleaning and expansion of the saltwater storage dam, which involves draining of the reservoir, ripping of reservoir bottom and raising dam wall, could disturb potential acid sulphate soils underlying the reservoir. Earthworks and construction activities for the sedimentation ponds is unlikely to result in acid generation as there will be no excavation. Excavation of a potential discharge channel between the spillway and the nearest creek	All works to be completed within 2 weeks to minimise oxidation of reservoir bottom. A neutralising agent will also be added. If a discharge channel is excavated, the acid generating material will be neutralised through the application of lime. In case of a lined structure, the PASS material will be capped and acid generation could be avoided.	Low risk of acid sulphate soils generation.

Environmental Factor	Existing Environment	Potential Impact	Management Measures	Predicted Outcome
		may cause acid generation.		
Hydrology	No permanent or ephemeral creeks on the property. Hydrology is already largely changed by previous development, ie. freshwater dam and spillway, stormwater drains, saltwater storage dam.	Potential impacts on existing hydrological patterns stormwater runoff from the site.	No changes to the spillway level and capacity of the freshwater dam. Freshwater will not be drawn from the dam to prevent depth to fall below 1.5m in the dam. No changes to the saltwater intake channel alignment. Stormwater run off will be collected and diverted by catch drains, and discharged via a gravel-lined outfall structure.	Minimal changes to the existing hydrological pattern.
Earthworks and Weeds <i>Section 4.5.1, 5.2.2 and 6.2.6</i>	Mission Grass, Gamba Grass, Hyptis, Stinking Passionflower and Purple-top Chloris are common in the area.	Infestation with weed species due to the clearing of native vegetation and import of construction equipment to the site. There is potential for loss of biodiversity through exclusion of native species.	Frequent weed control through mechanical slashing. Equipment used in the area previously infested will be washed down and care will be taken to prevent spread of new seeds. Provide a four metre fire break around the site perimeter, thus preventing spread of weeds on or off site Monitor.	Management measures will ensure low spread of weeds.

Environmental Factor	Existing Environment	Potential Impact	Management Measures	Predicted Outcome
Mosquitoes and Biting Insects <i>Section 4.6.4, 5.2.2 and 6.2.7</i>	Species such as <i>Ochlerotatus vigilax</i> , <i>Culex annulirostris</i> are common in the area. <i>Culicoides ornatus</i> is a dominant midge species.	Potential breeding sites for biting midges at effluent discharge point and supply intake channels. Earthworks during construction, any depressions creating isolated pools of water and temporary flooded drains, create potential for mosquito breeding.	Constant aeration of ponds and water depths kept greater than 1.5m. Design open drains to minimise pooling of water. Installation of incandescent or UV lights between potential breeding sites and work/living areas. Screening of living areas. Personal protection for staff.	Adequate mitigation of mosquitoes and biting insects breeding. Staff will receive adequate protection against mosquitoes and biting insects.
Fire regime <i>Section 4.5.1 and 6.2.9</i>	Area around Haycock Hill appears to have not been burnt in a long time due to the fringing mangroves and monsoon thickets.	Reduction in frequency of high intensity and widespread fires due to fire management on site. This may lead to a shift in species composition towards a denser mid-stratum layer.	Provide a four metre fire break and a buffer around the perimeter of the property. Regular maintenance of fire breaks. Reduction of flammable fuel loads to prevent extensive, destructive wildfires. Placement of fire fighting equipment at strategic locations.	A vegetation shift toward denser mid-stratum layer. Reduction in frequency, timing and spread of fire.

Environmental Factor	Existing Environment	Potential Impact	Management Measures	Predicted Outcome
Socio -Economic Environment				
Heritage sites <i>Section 4.10, 5.2.3 and 6.2.8</i>	18 sites identified, 1 was destroyed during previous construction works. The remainder are undisturbed since previous operations.	Potential disturbance of sites adjacent to freshwater dam due to construction of spillway.	Fencing of site likely to be disturbed. Not to impact on Sites 2 - 8 when upgrading fence line. Incorporate 'no go' induction policy. Further assessment of Site 16, 17 and 18.	Minimal impacts/disturbance on archaeological sites.
Traffic <i>Section 2.9 and 5.2.3</i>		Increased traffic to Channel Island Road due to construction and operational activities.	Minimise length of construction time.	Minimal impacts as Channel Island Road has adequate capacity to handle increased traffic volume.
Public/Recreational access <i>Section 5.2.3</i>	Public access to Castnet Creek and Haycock Reach by boat for recreational fishing.	Short-term restriction of recreational boat access to Castnet Creek for installation of intake pipe and new pumping station.	Minimise length of construction activities.	Negligible impacts for recreational fishermen as activities can be completed within days.

Table 6.2 Existing environment, potential impacts and management measures during operation

Environmental Factor	Existing Environment	Potential Impact	Management Measures	Predicted Outcome
Biophysical Environment				
Effluent discharge and hydrodynamic regime <i>Section 5.3.2 and 6.2.16</i>	Tidal flat mangroves adjoin the lease boundary to the south. Tidal creek mangroves are found along creek banks south of the lease area.	Large volumes of wastewater discharge direct to the mangrove creek may result in temporary changes to tidal levels during discharge, erosion and sedimentation, which may create a hydrodynamic shift and hence gradual shift in species composition over time.	Implement erosion control measures such as rock protection at the discharge point. Discharge of wastewater during high tides only for maximum dilution and flushing. Regular monitoring to identify any changes early so corrective action can be taken. Monitor water quality, mangrove communities, sediments and benthic fauna for any impacts.	Erosion can be prevented by lining or compacting the canal leading effluent from the sedimentation pond to the creek.
Effluent discharge and water quality <i>Section 5.3.2 and 6.2.16</i>	Water quality in Darwin Harbour is very good.	Discharge of nutrients and suspended solids may alter existing water quality of receiving environment.	Provide adequate wastewater treatment including sedimentation ponds to reduce loads of nutrient and suspended solids discharged; and ensure appropriate pond water quality management to reduce loads in wastewater. Sediment pond area is 25% of	Substantial reduction of nutrients and suspended solids loads following biological treatment and sedimentation. Minimal impacts on mangroves and water quality at Haycock Reach. Some impacts on water quality

Environmental Factor	Existing Environment	Potential Impact	Management Measures	Predicted Outcome
			total production pond area. Carry out monitoring to ensure performance of sedimentation ponds. Discharge during high tides for dilution and improved flushing. Install stop valves to prevent accidental release of wastewater and during quarantined events. Monitoring of discharge for performance and environmental impacts.	in the unnamed discharge creek can be expected.
Effluent discharge and Mangroves <i>Section 5.3.2 and 6.2.16</i>	Intact mangrove fauna and flora, except for some disturbed areas of salt flat and hinterland margin mangroves near the sedimentation ponds.	No impacts on salt flat mangroves downstream of effluent discharge spillway due to construction of channel from the spillway to the nearest creek. Potential impacts on tidal creek mangroves further downstream. Impacts may even be positive with proliferation of mangroves and elevated abundance of benthic species. Species	Treatment of effluent to reduce nutrients in the discharge. Discharge of effluent during high tides to facilitate dilution and tidal flushing. Monitoring of water quality and mangroves to investigate effects of effluent discharge on flora and fauna diversity and abundance	Potential impact on tidal creek mangroves. There may be proliferation of mangroves due to increased nutrients from the discharge. Wastewater discharge may result in some change in benthic fauna. Effects may include decrease in species diversity and elevated abundance of some species.

Environmental Factor	Existing Environment	Potential Impact	Management Measures	Predicted Outcome
		diversity may decrease.		
Noise generation <i>Section 5.3.2 and 6.2.10</i>	Limited noise generated.	Some noise generated from vehicle usage, pumps and emergency generators.	Maintain good working order of all motor equipment.	Minimal noise generation and no noise nuisance anticipated.
Atmospheric emissions <i>Section 5.3.2 and 6.2.11</i>	Currently there are no atmospheric emissions generated on site.	Some odour from sludge drying bunds. The only source of greenhouse gases is from emergency power generation and onsite vehicle use. Minimal impact.	Flushing of sludge. Power supply from grid during normal operations.	Minimal odour and greenhouse gases emitted.
Liquid and Solid Wastes <i>Section 2.5.8, 5.3.2 and 6.2.12</i>	Not applicable	General wastes produced at the site: - sludge from production ponds - sewage, domestic discharge water - equipment and vehicle wash down water - domestic waste - packaging waste - oil, hazardous and chemical wastes If not properly managed, waste materials have the potential to	Minimise waste generation. Sludge will be transferred to sludge drying bed to biodegrade and stabilise, and where rain water will reduce salinity. It will then be left to dry and reused onsite for landscaping, maintenance of pond walls and fills. Effluent from drying bed will be directed to sedimentation pond. Sewage will be treated by septic tanks. Wash down water will drain into a sump with triple	Minimal adverse effects from on-site operations and waste disposal.

Environmental Factor	Existing Environment	Potential Impact	Management Measures	Predicted Outcome
		pollute soils and water resources.	interceptor trap fitted to remove oil. Disposal of domestic garbage will be off-site at landfill site. Packaging waste will be recycled or taken to landfill. Oil and hazardous wastes will be disposed off site by a licensed collector.	
Quarantine and Diseases Control. <i>Section 5.3.2 and 6.2.13</i>	Currently there are no introduced pests or diseases.	Introduction of diseased prawn stock onto farm. Escape of diseased stock or contaminated prawns into surrounding environment. Potential trapping of wild prawns through saltwater intake.	All animals brought onto farm will be tested and comply with translocation policies of NT Fisheries. Quarantine measures during disease outbreaks include: screenings at outlets and drains to prevent stock escaping, recirculation of water and cease discharge; treatment of affected stock with drugs and chemicals; remove dead stock. Saltwater intake will be screened to prevent introduction of wild prawns.	Ade quate measures will be implemented to prevent disease outbreak and contamination. No adverse impacts on wild stocks.

6.2.1 Vegetation Management

Objective

It is APPL's objective to:

- Minimise clearing requirements to those areas taken in by ponds and associated infrastructure; and
- Restrict development in the mangroves to those areas already disturbed by the previous development.

Management measures

- Clearing of vegetation will be kept to the minimum required for each stage of the development;
- The area of disturbance will be limited to the immediate construction area;
- Clearing for construction access will be minimised and, where possible, restricted to development area. If this is not possible, construction access will be rehabilitated upon completion of works;
- Vegetation clearing and disposal shall be in accordance with DIPE guidelines;
- Relevant permits will be obtained for clearing of *Cycas armstrongii*;
- Construction in intertidal areas will be kept to the minimum necessary for the proposed project.

6.2.2 Soil erosion

Objective

It is APPL's objective to prevent soil erosion and associated siltation from occurring during the construction works and operations.

Management measures

- Earthworks will be carried out during the dry season;
- Stripped top soil will be stored in bunded areas if left during the wet season;
- Excess soil will not be permanently stored on-site without OEH's approval;
- Habitats downstream of construction works will be monitored for siltation and erosion;
- Existing erosion gullies will be rehabilitated;
- New structures (ie. pond walls, roads, canals) will be adequately compacted to minimise erosion from occurring. Compaction testing will be carried out by a geotechnical engineering consultant to ensure that the specifications are met.;
- A catchdrain will surround the ponds to collect and divert stormwater run-off. Where necessary, drain outfalls will be protected by rock rip-rap.

Ongoing erosion control during operations will be required and will consist of the following measures:

- Ensure adequate compaction of bund walls and roads prior to start of operations;
- Repair of erosion gullies as they arise in the wet season;
- Vegetation of the pond walls; and
- Direction of stormwater into freshwater dam or to compacted stormwater drainage canal which discharges in the effluent discharge area.

6.2.3 Dust generation

Objective

It is APPL's objective to minimise nuisance from dust generation during construction.

Management measures

As earthworks will be undertaken during the dry season, dust will need to be suppressed so as not to create a nuisance in accordance with the *Public Health Act 1995*. This will be achieved by:

- Minimising vegetation clearance to those areas required for the development;
- Revegetating areas that are no longer required for construction;
- Ensuring that unsealed roads and exposed areas are watered when dust generation is evident;
- Applying speed restrictions; and
- Ensuring reclamation and construction activities take into consideration the prevailing wind conditions.

6.2.4 Disturbance of potential acid sulfate soils

Objective

It is APPL's objective to minimise disturbance of potential acid sulfate soils during construction. Where disturbance is unavoidable, works will be carried out in strict compliance with the management measures below. Acid generation will be avoided or remediated at all times.

Management measures

- Removal of marine muds will be avoided where possible (ie. works in intertidal areas will consist largely of fill using non-acid generating material);
- All works affecting PASS areas will be completed as fast as practicable, preferably within two weeks, so as to minimise oxidation of the disturbed material.
- There will be no permanent stockpiling of PASS materials on site.
- Following the drainage of the saltwater storage reservoir, a layer of highly alkaline red mud, a residue from bauxite refining, will be spread over the reservoir bottom.

This layer will prevent further ingress of oxygen and will neutralise any acid formed.

- Where excavation of PASS materials is required for the construction of the discharge canal to the creek, the excavated material will be neutralised using lime or an equivalent material following representative sampling and analysis of the soil's acid generation potential. The neutralised material can be reused as fill subject to testing. The remaining material will not undergo further oxidation as it will be lined and inundated with water for extended periods each day.

6.2.5 Changes in hydrological patterns

Objective

It is APPL's objective to:

- Prevent additional impacts to hydrological patterns beyond those associated with the existing development; and
- Draw sustainable yields from the freshwater dam.

Management measures

- There will be no changes to the spillway level and capacity of the freshwater dam;
- There will be no changes to the saltwater intake channel alignment;
- Stormwater run-off will continue to be collected and diverted by catch drains, which will discharge into a water body or the mangroves via a gravel-lined outfall structure; and
- No freshwater will be drawn from the dam when the water level drops below 1.5 m depth.

6.2.6 Weed control

Objective

It is APPL's objective to:

- Eradicate current weed infestations; and
- Prevent introduction and spread of additional weeds onsite.

Management measures

- During construction, trucks and heavy machinery entering the site will be inspected for weed and seed containing materials. Vehicles coming from known infested areas will be washed down prior to entering the site.
- A four metre fire break around the perimeter fence will prevent the introduction of weeds from neighbouring properties, as well as the spread of weeds offsite.
- The property caretaker will monitor and control weeds. Weed control will be mechanical (slashing) rather than chemical to prevent contaminated run-off from reaching the ponds.

6.2.7 Biting insects control

Objective

It is APPL's objective to prevent the creation of biting insect breeding sites due to inappropriate land management practices.

Management measures

Natural levels of biting insect breeding are elevated due to the nature of the site. Measures to minimise biting insect nuisance, as well as additional breeding due to the project include:

- Personal protection for staff (repellent, clothing);
- Screening of all living and office areas;
- Use of yellow incandescent and fluorescent lighting in work areas;
- Installation of incandescent or UV lights between breeding areas and work/living areas to attract insects away from people and ponds;
- Constant aeration of ponds;
- Maintaining water depth in ponds in excess of 1.5 m which is unsuitable for mosquito breeding;
- Construction of open drains such that ponding is prevented and stagnant open water surfaces are minimised;
- Regular emptying of sumps;
- Presence of fish and macro invertebrates in the freshwater dam to control mosquito larvae populations.

6.2.8 Heritage site management

Objective

It is APPL's objective to avoid disturbance of remaining heritage sites within the lease area.

Management measures

In accordance with OEH recommendations, the following heritage management strategy will be adopted:

- Identification and designation of conservation areas containing the sites to be protected;
- Sites to be fenced prior to construction and throughout operations;
- Incorporation of a "no go" induction policy during the construction and operations phases; and
- Regular monitoring during the construction and operations phases.

Furthermore, APPL commits to the following actions:

- A further assessment of Sites 16 and 18 at a time of higher visibility (ie. end of dry season, preferably following burn off);
- Fencing in consultation with an OEH officer or qualified archaeologist of Sites 14, and 15 and potentially sites 16 and 18 following a visual assessment. Fencing will be undertaken prior to construction commencing;
- An inspection of Site 17 (artefact scatter) during the dry season and fencing in case any works are carried out on the western side of the dam spillway;
- Not to impact on the hill beyond the current extent of disturbance in order to prevent damage to Site 18 (artefact and shell scatter);
- Not to impact on Sites 2 to 8 during the installation, maintenance or upgrade of the fence line;
- To notify the OEH should the current proposal be altered or should any activity have the potential to impact or disturb the sites; and

To inspect the archaeological sites following the construction works and on a biennial basis during operations.

6.2.9 Fire management

Objective

It is APPL's objective to prevent destructive wild fires on site.

Management measures

- A 4 m firebreak will be maintained around the perimeter fence.
- Vegetation around buildings will be slashed regularly to reduce flammable fuel loads.
- Fire fighting equipment will be kept at strategic locations and will be checked annually in accordance with Bushfire Council guidelines.

6.2.10 Noise management

Objective

It is APPL's objective:

- to prevent noise nuisance to neighbours and other users of the immediate vicinity; and
- to comply with OH&S standards with respect to noise exposure of staff and contractors.

Management measures

- Noise nuisance to neighbours and other users of the immediate vicinity of the prawn farm is unlikely due to the distance from the farm to the nearest development.

- Noise emissions on site will be limited to vehicles, emergency generators, blowers and pumps. This equipment will comply with relevant standards. The superintendent will ensure all equipment is maintained in good working order.

6.2.11 Odour management

Objective

It is APPL's objective

- to prevent odour nuisance to neighbours and other users in the immediate vicinity; and
- to comply with OH&S standards with respect to odour exposure of staff and contractors.

Management measures

- Anaerobic conditions will be prevented from developing in sludge drying bed through regular turning of the sludge mass.
- Waste from the packing shed will be stored in bins/containers with lids and will be removed from site on a regular basis.

6.2.12 Waste management

Objective

It is Aussie Prawns P/L's objective to minimise waste volumes generated during the prawn farm's operations. All waste generated is to be treated or disposed of in compliance with the following Northern Territory legislation:

- Dangerous Goods Act 1981;
- Litter Act 1972;
- Public Health Act 1995; and
- Waste Management and Pollution Control Act 1999.

Management measures

Pond sludge

- The prawn and sedimentation ponds will be de-sludged on an as needs basis.
- The sludge will be transferred to a bunded drying bed, where nutrients and organic matter will gradually biodegrade and stabilise.
- The sludge will be exposed to the wet season rains and/or flushed with fresh water to reduce its salinity. It is then left to dry for 3 – 4 weeks.
- The dried sludge can be reused onsite for landscaping purposes, maintenance of pond walls or fill.
- Drying bed effluent will be directed to the effluent canal and sedimentation ponds.

Sewage

Sewage from the two sewage discharge points (house and office area respectively) will be directed into individual septic tank systems in compliance with Department of Health regulations.

Domestic waste

All domestic waste will be taken to the City of Palmerston landfill. Packaging waste (boxes, plastic bags) will be recycled or taken to landfill. Damaged prawns will be sold as 'seconds' if possible, or taken to landfill.

Used oils and lubricants

Drums of used oil and lubricants will be stored in compliance with AS1940-1993. They will be removed by a licensed contractor on an as needs basis.

Hazardous waste

Any hazardous waste will be removed by a licensed contractor on a regular basis.

Vehicle wash down water

Wash down water will be directed to a triple interceptor to remove oil. The interceptor will be pumped out by a licensed contractor on an as needs basis.

6.2.13 Disease management

Objective

It is Aussie Prawns P/L objective to comply with regulations regarding disease control and prevent the spread of disease on and off the farm.

Management measures

Quarantine and disease control procedures will be compliant with NT Fisheries Department requirements and follow the Queensland Department of Primary Industries guidelines for on-farm health management for prawn farms (1999).

On-farm protocols in case of disease

- Aussie Prawns Pty Ltd will immediately report any disease or significant mortalities of stock to the NT Director of Fisheries.
- The company will implement quarantine measures by restricting personnel access to the disease area.
- Equipment only to be used in the diseased pond will be identified and kept separate.
- Water quality measuring instruments will be disinfected when changing between ponds.
- Normal management tasks will be carried out in clean ponds before working in/around diseased or suspected ponds.

- Adequate disinfection points will be provided around the farm.
- Sick or dead prawns will be removed and disposed of safely in consultation with the Fisheries Department.
- Traffic and visitor movement around the farm will be minimised.
- Predatory animals, especially birds, will be controlled.
- Signs will be placed identifying parking or restricted access.
- Fence barriers will be placed to control movement around the farm.

Between farm protocols

- Bird predators entering ponds will be controlled.
- Sick prawns will be removed from ponds to discourage bird visits.
- Hatchery discharges will be treated appropriately.
- Escape prevention devices on discharge points will be kept in good condition.
- Protocols will be established for visiting commercial vehicles.
- Visitors to the hatchery or growout area will be required to go through a footbath.
- PLs will be tested prior to entering the growout area or stocking ponds.

Farm stocking procedures

- Broodstock entering the hatchery area will be visually checked for their state of health and will undergo testing for known pathogens (PCR testing for viruses).
- Any importations of animals onto the farm will comply with NT Fisheries translocation policies.
- Broodstock will be placed in a quarantine area separate from the hatchery for the longest possible period before placing them in the spawning tanks.
- Dead or moribund animals will be disposed of in such a way that they can not infect either the hatchery equipment, water supply or growout area of the farm.

Pond and water management

- A plan on how to handle a disease outbreak in each pond will be developed.
- APPL will ensure that water from the processing areas can be treated on a daily basis prior to discharge.

6.2.14 Intake water quality management

Objective

It is APPL's objective to ensure intake water quality is appropriate for optimal prawn growth. In case intake water quality deteriorates in the future, adequate treatment will be provided prior to filling the growout ponds.

Management measures

Current measures

- Intake water quality will be tested on a weekly basis (refer Section 6.3.1).
- The saltwater intake will be screened to prevent intake of animals and debris.
- The saltwater storage reservoir will allow for sedimentation of suspended solids.
- An algal bloom will be initiated in the saltwater storage reservoir to stabilise the water chemistry and to avoid shock to prawns during pond water exchange events.
- Eggs of predatory species are allowed to hatch during the period that intake water is retained in the storage reservoir. As the outlet of the reservoir is screened, these predators will be retained in the reservoir and will not be transferred to the growout ponds.

Future measures

Depending on the nature of future intake water quality issues, adequate pre-treatment facilities will be installed on site. Pre-treatment may include physical, biological or chemical methods.

6.2.15 Pond water quality management

Objective

It is APPL's objective to maintain pond water quality to ensure optimal prawn growth.

Management measures

When the ponds are in production, intake and pond water will be monitored daily for dissolved oxygen, pH, temperature, salinity and turbidity. Details of the water quality monitoring plan can be found in Section 6.3.1.

These parameters will be maintained at the following optimal levels:

- pH: 7.2 - 8.5
- DO > 4 mg/L
- Turbidity: Secchi disk reading 30-50 cm
- Salinity: 18-25 ppt (optimally, but Tiger Prawns also grow in more saline conditions, up to 37 ppt)

As a precautionary measure to ensure adequate water quality is maintained throughout the grow-out period, up to 10 % of the pond water will be replenished daily.

In the event that pond water quality is not optimal for prawn growth, the water quality will be rectified by means of aeration, pH adjustment, seasonal dilution or flushing and replenishing with salt water.

6.2.16 Discharge water quality management

Objective

Aussie Prawns P/L's objectives with regard to discharge water management are:

- to not adversely affect water quality in Haycock Reach as a result of effluent discharges; and
- to not adversely affect mangrove, intertidal and subtidal ecosystems in Haycock Reach as a result of its operations.

Management measures

Management measures related to wastewater discharge focus on reducing volume of and nutrients in discharged wastewater. The management practices adopted are:

- Minimising nutrient load and suspended solids generated in production pond through appropriate feed regime;
- Dilution of nutrient load and suspended solids through daily water exchange;
- Reduction of nutrient load and suspended solids through treatment in sedimentation ponds (25% of production area);
- An adequate retention time of wastewater in the sedimentation ponds (generally 2 days and at least 24 hours);
- Discharge of wastewater during high tides only;
- Measures to prevent accidental release of wastewater and during quarantined events;
- Monitoring of wastewater discharge to ensure performance of sedimentation pond;
- Monitoring of mangroves, sediments and benthic fauna for environmental effects; and
- Discharge from the spillway to the head of the nearest creek via a lined channel rather than through sheet flow, to prevent erosion and eutrophication of upper tidal areas that are not flushed daily.

6.2.17 Decommissioning EMP

For environmental management measures associated with the required earthworks and waste management, refer to sections 6.2.2 to 6.2.10 and 6.2.12 respectively.

A detailed rehabilitation plan will be prepared when the farm is approaching the end of its operations.

6.3 MONITORING AND REPORTING STRATEGIES

It has been determined that monitoring should not be limited to water quality only, and a comprehensive mangrove monitoring plan, including both floristic and benthic fauna monitoring, has been prepared.

6.3.1 Water quality monitoring

Construction

During construction, some baseline water quality data will be collected for the purpose of future impact monitoring. As construction is to be undertaken during the dry season, no run-off and resultant siltation is expected to occur, and construction impacts are expected to be negligible in terms of water quality.

A reduced monitoring program to that proposed during operations (see next section) will be undertaken as demonstrated in Table 6.1. For sampling locations, refer to Figure 6.1.

Table 6.1 Water quality monitoring program during construction

Sampling Location	Site Reference	Site Description	Frequency	Analysis
Castnet Creek	Control (C1)	Upstream from jetty	Monthly	TSS, TN, TP, DO, pH, EC, t°
Outlet Creek	Impact Site 3 (IS3)	Main Creek	Monthly	DO, pH, EC, t°, TSS, TN, TP
Haycock Reach	Control (C2)	Control site	Monthly	DO, pH, EC, t°, TSS, TN, TP

For more information regarding sampling procedures, refer to the following section.

Operations

Water quality will be monitored on an ongoing basis to assess any changes in nutrient levels and physical water quality parameters in Castnet Creek, the unnamed outlet creek and Haycock Reach. The water quality program will also entail on-farm monitoring, both for environmental and operational purposes.

The monitoring program will be confirmed in consultation with the Office of Environment and Heritage. A proposed program is described below. The proposed sampling sites have been indicated on Figure 6.1.



Table 6.2 Water quality monitoring program during operations

S a m p l i n g L o c a t i o n	S i t e R e f e r e n c e	S i t e D e s c r i p t i o n	S a m p l i n g F r e q u e n c y	A n a l y s i s
Castnet Creek	Intake (I)	Jetty	Weekly	DO, pH, EC, t°
Castnet Creek	Control (C1)	Upstream from jetty	Monthly	TSS, TN, TP, DO, pH, EC, t°
On farm	Supply channel (S)	2 nd stage lift pumps	Daily	DO, pH, EC, t°
On farm	Prawn pond (P)	Prawn pond	Daily	DO, pH, EC, t°
			Weekly	TSS, TN, TP
On farm	Discharge 1 (D1)	Overflow from sedimentation pond 1	Daily	DO, pH, EC, t°
			Weekly	TSS, TN, TP
On farm	Discharge 2 (D2)	Overflow from sedimentation pond 2	Daily	DO, pH, EC, t°
			Weekly	TSS, TN, TP
Outlet Creek	Impact Site 1 (IS1)	Branch that collects Discharge 1 effluent	Monthly	DO, pH, EC, t°, TSS, TN, TP
Outlet Creek	Impact Site 2 (IS2)	Branch that collects Discharge 2 effluent	Monthly	DO, pH, EC, t°, TSS, TN, TP
Outlet Creek	Impact Site 3 (IS3)	Main Creek	Monthly	DO, pH, EC, t°, TSS, TN, TP
Haycock Reach	Control (C2)	Control site	Monthly	DO, pH, EC, t°, TSS, TN, TP

Water will be sampled from nine discrete locations, as well as from the prawn ponds in operation. Prawn pond water quality monitoring is an operational necessity to ensure optimal prawn growth and does not actually form part of the environmental monitoring program.

For the purpose of impact monitoring, water quality data are collected representative of:

- Background water quality: Haycock Reach (C2), Castnet Creek (C1). The sampling point at the jetty (I) represents intake water quality;
- Discharge water quality: discharge points D1 and D2 at the respective sedimentation pond spillways; and
- Impact sites: one sampling point in the creek where the effluent ultimately discharges (IS1 and IS2), and one where the creek discharges into Haycock Reach.

The on-farm water quality monitoring program entails the whole production process, from intake (I), through supply (S), to the production ponds (P) and ultimately the sedimentation pond effluents (D1 and D2).

The monthly water monitoring program will be scheduled on the half moon day, as listed in tidal prediction data. Sampling will start at the jetty (I), along Castnet Creek (C1), up Haycock Reach (C2), and up the unnamed outlet creek (IS3, IS2 and IS1 respectively). Samples are to be collected 2 hours after the late morning high tide. Monthly on-farm discharge water testing (D1 and D2) will also be undertaken at this time. GPS coordinates for the proposed sampling points will be established on the first sampling round.

Temperature, salinity (EC), pH and dissolved oxygen (DO) will be field tested by means of a field probe. Additional samples will be collected in plastic bottles for the determination of total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS) in the farm laboratory. These parameters will be analysed using a HACH spectrometer. The monthly samples will be sent to a NATA accredited laboratory for analysis.

6.3.2 Mangrove monitoring

A mangrove monitoring plan has been developed and a pre-impact data set has been collected (Metcalf et al 2004, Appendix C).

The site contains two mangrove communities that may be affected by the discharge:

- Hinterland margin - *Avicennia marina* and *Ceriops australis* dominant
- Tidal creek - *Rhizophora stylosa* dominant.

Mangrove flora and invertebrate fauna will be examined within permanent quadrats established in both mangrove communities. The Hinterland Margin zone will receive constant discharge in the form of sheet flow, whereas the Tidal Creek zone is the nearest tidal channel downstream of the outlet into which the discharge water will eventually flow. Two impact sites and two control sites have been established in each zone (total of 8 quadrats as illustrated in Figure 6.2).

Control sites are located relatively close to the development but within a different tidal creek to ensure that a balanced experimental design is implemented that provides statistically rigorous data. Multiple controls are necessary to adequately distinguish between natural changes or variations in the environment and changes due to impacts.

Flora

The techniques used for monitoring the mangrove vegetation match those currently being applied to other developments in Darwin Harbour. Within each of the eight 20m x 20m quadrats, the following vegetation characteristics will be recorded, measured or estimated:

- Species composition;
- Tree density;
- Tree status (alive/dead);



Figure 6.2 - Mangrove monitoring sites

- Average height of each tree species;
- Diameter at breast height;
- Canopy cover;
- Seedling and sapling density.

Stand structure

Thirty trees will be randomly selected within each 20m x 20m quadrat or study site and these trees will be labelled with a numbered tag. The diameter at breast height, condition and height of each tree will be recorded. These 30 tagged trees will be remeasured annually during comprehensive monitoring. Forest density and species composition will be measured during the establishment of the program but will not be remeasured unless required in future.

Canopy cover (an indication of forest health) will be measured using a densiometer and seedling and sapling numbers counted within 5 randomly placed 1m x 1m quadrats. Environmental characteristics - including disturbance and sediment levels will also be recorded in each quadrat.

Photo-monitoring

The centre of each 20m x 20m quadrat functions as the photo-point and 4 photographs (portrait format) will be taken while looking toward the 4 corners of each plot. Four (permanent) aluminium stakes will be placed 3m from the centre post to assist in accurate relocation of photo-monitoring points. The site marker board is placed on these aluminium stakes for photographic monitoring indicating the site ID, date and number of each quadrant.

Sediment gauges

The four corners and the centre of each quadrat are to be marked by PVC posts which also function as sediment gauges. 1.5m lengths of PVC are hammered into the mud until exactly 1,000 mm of PVC remains above the surface. Subsequent 6 monthly measurements of exposed PVC (5 gauges per plot) will indicate whether sediment accretion or erosion is occurring within the plots.

Invertebrate fauna

The invertebrate monitoring program follows a standard scientific approach to monitoring environmental impacts referred to as a “BACI” design which incorporates measurements Before (B) and After (A) the changes are imposed on the environment, involving comparisons between Control (C) and Impact (I) sites.

A rapid assessment of invertebrate biodiversity will be undertaken within the same 20 m x 20m quadrats established for flora monitoring. Invertebrates within a sub-plot (1m x 1m quadrats) are identified in the field and noted or collected in sample jars containing 70% ethanol for later identification. Quadrats are placed at the base of trees and epifauna sampled to a height of 2m. Three randomly located replicate quadrats are placed at each sampling site.

The number of crab burrows within each quadrat is counted as an indicator of crustacean numbers and correlated with crab abundance (per 1m x 1m quadrat). Specimens collected in the field are sorted into major taxonomic groups and identified to species level where possible and otherwise to species unit. A reference collection of specimens has been established for future monitoring.

Monitoring frequency

During construction, mangrove monitoring will be undertaken on a 6-monthly basis. Once construction is complete and the farm is in operation, by the end of 2005, it is proposed to conduct the mangrove monitoring program once a year.

6.3.3 Archaeological sites impacts monitoring

Monitoring of vulnerable sites (Site 2 to 8) will be undertaken through out the construction and operation phases of the project. An appropriate time to undertake monitoring of archaeological sites may be during the annual EMP review and can be incorporated into this process.

Monitoring during the operational phase of the project is, however, only considered to be necessary on a biennial basis.

6.4 REPORTING

Results of pre-development mangrove baseline monitoring are appended to this report (Appendix C: Mangrove Monitoring Report).

During construction, a 6-monthly monitoring report will be submitted to OEH, containing mostly mangrove monitoring results, some baseline water quality data from Castnet Creek, Haycock Reach and the outlet creek and results of heritage site monitoring.

During operations, an annual monitoring report will be prepared, containing results of the annual mangrove monitoring program, routine water quality monitoring and biennial archaeological site assessments. Any issues related to weeds or biting insects will also be addressed.

6.5 SOCIAL ISSUES AND PUBLIC COMMUNICATION

6.5.1 Social Issues

The likely social issues associated with the redevelopment are confined to impacts on public access, recreational activities, and odour and noise nuisance associated with construction and operational activities.

There is no public access to the site as it is a private property. Most of the surrounding area is covered with thick vegetation with no access roads or tracks. Thus it is unlikely that the redevelopment will impact on public access to the site or surrounding sites for recreational purposes or others.

The estuarine environment abutting the lease area however has some intrinsic recreational value in terms of fishing. The redevelopment will have limited impacts on recreational fishing as intake of saltwater is from the small Castnet Creek. Most fishing takes place in Haycock Reach which will not be impacted by operations apart

from some noise nuisance during pumping. Discharge of treated wastewater from the operation is unlikely to cause any adverse impacts on fishing.

The site and proposed infrastructure are shielded from both Channel Island Road and Haycock Creek by an uncleared native vegetation buffer. The only visible infrastructure from Haycock Creek is the jetty and water intake pumps. As such visual impact is expected to be minimal.

The site is located in a zone with compatible land use, and away from any residential build-up. As such, the minimal noise and odour emissions from the operations are unlikely to cause public nuisance.

6.5.2 Public Communication and Consultation

APPL has consulted with a number of organisations and individuals regarding the proposed development. Comments from the wider public will be sought as part of the PER approval process.

Numerous local and state government agencies were consulted about the redevelopment in identifying issues likely to be of constraints to the development. The guidelines/recommendations from each department consulted are summarised below, as well as APPL's response to the issues raised.

- *Department of Infrastructure, Planning and Environment (DIPE) - Office of Environment and Heritage.* The Office was issued with a Notice of Intent (NOI) from APPL in September 2004 in regards to the proposed redevelopment of the existing prawn farm. Along with the NOI, a copy of the previous PER for the 14ha development was included and an EMP for the redevelopment. The Office determined that the 1992 PER was no longer applicable as the development is now significantly larger (42ha), and hence the magnitude of impacts is likely to change accordingly. The Office issued a statement to conduct formal Environmental Impact Assessment at the level of a Public Environmental Review with guidelines.
- *Department of Infrastructure, Planning and Environment (DIPE) - Heritage Conservation Services - Office of Environment and Heritage.* The Office conducted a site visit to assess integrity of heritage sites previously identified within the lease area in May 2004. The Office issued recommendations of further assessment of 3 sites when accessibility permits, and management of others which is to be incorporated in the Environmental Management Plan. These recommendations have been incorporated into this PER under Section 5.10 and Section 6.3.3.

In November 2004, numerous local and state government agencies were consulted to provide information to the Development Consent Authority in regards to the proposed 14ha redevelopment. The recommendations/guidelines from each agency are summarised below along with APPL's response:

- *Department of Infrastructure, Planning and Environment.* The Department had a number of concerns which apply to various aspects of the environment:
 - Planning: Any native vegetation clearing which occurs on site must be in accordance with the Litchfield Area Plan 2004 and not the redundant 1992

Plan. Earthworks should also be carried out in accordance with Clause 16.10 of the Litchfield Area Plan 2004.

APPL intends to liaise closely with the Council and the Department to gain necessary approvals for vegetation clearing and earthworks.

- o Water quality: The Department has concern over the effects of effluent discharge on marine environment, especially water quality of Darwin Harbour. The Department suggested hydrodynamic modelling be carried out to investigate mixing regimes of the effluent discharge and quantify any impacts on adjacent marine environment.

As part of this PER, hydrodynamic modelling has been carried out and results have been incorporated in the body of the PER. The hydrodynamic modelling report is attached in Appendix G..

The Department also wanted APPL to investigate other methods of managing wastewater eg zero discharge.

Section 3 of this PER addresses discharge alternatives and justify APPL's position on the chosen discharge method.

The Department has raised a question over how diseased stock and pond water will be managed in the event of an outbreak.

This issue is addressed in the PER under Environmental Impact Assessment as well as in the Environmental Management Plan.

- o Land use and vegetation: The Department requested that issues such as acid sulphate soils, erosion and sediment control, fire and weeds management be considered.

APPL has already commissioned acid sulphate soil tests in areas where proposed excavation will be below 4mAHD. Acid sulphate soils, erosion and sediment control, fire and weeds have all been considered as part of the Environmental Management Plan in the body of this PER.

- o Road network: The Department made recommendations to seek appropriate approvals prior to commencing proposed works which will access Channel Island Road, and to fence any parts of the property with Channel Island Road frontage, which are currently unfenced.

APPL will seek a works approval prior to commencement of any proposed works.

- o Land administration: The Department advised that access to the freshwater dam is on Crown Land, outside of the current lease. It is the responsibility of APPL to maintain this access road. Currently there are two proposals for acquisition of this Crown land, for a fuel and gas corridor and installation of high voltage power lines.

APPL will liaise with the Land Administration Division to discuss the impacts, if any, on the freshwater catchment area.

- **Fisheries Group.** This Department fully supports the redevelopment as it is seen as beneficial to the NT and an appropriate land use for the site. However, Fisheries

raised concerns about discharge of effluent in the mangrove zone and quarantine issues.

Both issues have been addressed in the PER, a comprehensive mangrove monitoring programme has been developed, and quarantine control has been incorporated in the design of the hatchery.

- *Department of Health and Community Services.* This Department supported the proposal outlined in the NOI with the following recommendations:

- Effluent discharge: the proposed type is acceptable so long as it is not a standard septic tank with ground adsorption.

The proposed effluent discharge is via a spillway from the sedimentation ponds onto the mangrove area.

- Entomology aspects outlined below. Mosquito and midges breeding has been considered in the EMP.

- Sedimentation ponds and saltwater storage dam should have steep slopes (1:3 or greater) to prevent mosquito breeding.

This advice has been considered in the design.

- Sedimentation, freshwater and saltwater dam should be stocked with native mosquito control fish if possible.

APPL is proposing to stock native fish in the sedimentation ponds. The freshwater dam is already stocked.

- All drainage structures on the site should be designed to be free draining to prevent pooling of water and mosquito breeding.

This advice has been considered in the design.

- Demonstrate that discharge from the sedimentation ponds will be sufficiently flushed to prevent ponding and breeding sites for the Ross River virus mosquito *Ochlerotatus vigilax*. A formal drainage channel would be required if there is potential ponding of the discharge.

APPL proposes to construct a formal drainage channel for effluent discharge down to a regularly flushed level.

- *Bushfires Council NT.* The Department requested that a fire break of 4m wide, slashed to a height of 25 - 50mm, be maintained around the boundary of the property; and reminded that the property falls within a Fire Protection Zone where no burning may take place without a permit to burn.

This recommendation has been considered in the EMP.

- *Litchfield Shire Council.* This Council did not have any requirements for traffic, and requested that the Roads Division of the Department of Infrastructure Planning and Environment be approached for any recommendations. The Council has concerns over clearing of mangroves for sedimentation ponds.

As addressed in Section 4.5 and 5.2.2 of the PER, only hinterland and saltflat mangroves will be cleared. This zone has been disturbed previously and supports little marine fauna life. The mangroves to be cleared are also well represented elsewhere in the Top End.

- *Power and Water Corporation.* The Department provided the following comments for consideration in the proposed redevelopment:
 - Reticulated potable water is available. However new connections to the existing water main are not available, and should this be required, expansion of water supply demand may trigger construction of water mains at the developer's costs.

In response to this issue, it is unlikely that the redevelopment will demand more than the existing water provisions.

- Reticulated sewage services are currently not available in the area. On-site sewage treatment must be provided by the developer in accordance with the Department of Health and Community Services.

APPL proposes to collect and treat sewage in septic tanks and emptying of septic tanks will be carried out by a licensed contractor.

- A wastewater treatment plant (ponds) is proposed immediately upstream of the lease area to service the adjacent Weddell township. The Department is concerned that the proposed discharge of treated wastewater from the treatment plant into the creek will affect water quality of saltwater proposed as supply for the prawn production ponds. The Department has made recommendations to address this potential conflict in the PER.

This issue has been addressed in Section 6.6 of this PER document.

On-going consultation

Communication and consultation with the Department of Infrastructure, Planning and Environment will be maintained throughout construction and operation of the prawn farm.

6.6 RISK ASSESSMENT

This section presents an assessment of risks to the project from externalities in accordance with AS/NZS4360:1999. External factors that may have a significant impact on operations and viability of the proposal include:

- Natural disasters such as cyclones;
- Fire;
- Importation of diseased broods tock;
- Deterioration of intake water quality.

6.6.1 Impact from cyclone storm surges

The storm surge risk report for Greater Darwin (Vipac 1994) predicts a 1 in 10 year, 1 in 100 year and 1 in 1000 year peak combined sea level of 3.8 m AHD, 5.1 m AHD and 6.4 m AHD respectively for both Channel Island and Wickham Point, which are the assessed sites closest to the project site. The exact storm surge levels for the site are not known, but would probably be less severe due to its sheltered location.

The bund wall of the sedimentation ponds will be raised to 5.1 m AHD. The sediment pond weirs will be provided with manual stop logs. These would be placed across the sediment pond weir when warning of a potential storm surge is given. This would effectively prevent sea water entering the sediment ponds up to a 1 in 100 year storm event, unless the bund wall is breached.

A 1 in 1000 year event has not been catered for in the design. These storm surges will enter the sediment pond with water flowing into the discharge canals. Storm surges will not be able to enter the prawn ponds as the lowest pond walls are at 6.45 m. As such, these high storm surges may result in resuspension and export of sediment from the sedimentation pond, but would not result in the release of prawns into the environment.

The residual risk associated with storm surges is considered to be low.

6.6.2 Fire

Fire has the potential to cause considerable destruction, although it is believed that both the likelihood and consequence of a major fire can be reduced by applying thorough design and vegetation management principles.

Where a 4 m firebreak around the site perimeter is maintained adequately, it is unlikely that a wildfire could encroach on the property. An on-site fire would be most damaging around the buildings area, so the reduction of fuel loads in those areas is critical. Staff should be trained in fire safety (prevention of fires) as well as fire fighting. The provision of fire extinguishers in strategic locations will be critical.

It is considered that the likelihood of a fire occurring can be reduced to 'rare' and that the consequence of a fire could be reduced to 'moderate' (on-site containment with outside assistance, high financial loss). The associated risk is rated 'medium'. With adequate measures in place the consequence could be reduced to 'minor' resulting in a residual 'low' risk.

6.6.3 Importation of disease

The importation of diseased broodstock or post-larvae could potentially lead to the destruction of an entire crop. This would result in a considerable financial loss, as well as environmental problems in terms of the treatment and discharge of pond water.

Applying the proposed risk assessment classification of the AS/NZS 4360:1999 (Appendix E), the consequence of such an event could be labelled 'major' (Loss of production capability, major financial loss). The primary means of reducing the associated risk is to reduce the likelihood of such an event occurring. When applying strict quarantine measures and testing of all imported broodstock and PL's, the likelihood can be reduced to 'rare' (may occur only in exceptional circumstances). The

associated risk is still classified as 'high' and requires senior management attention. This result emphasises the extreme importance of strict quarantine procedures and disease emergency response procedures (also refer section 6.2.13).

Following implementation of such measures, it is believed residual risk can be reduced to 'medium' or even 'low'.

6.6.4 Deterioration of intake water quality

A future threat to intake water quality is posed by the proposed wastewater treatment plant that will service the Weddell community. Its proposed discharge will be upstream of the APPL aquaculture development, which means that in the medium to long term, the farm's intake water quality may deteriorate in terms of total suspended solids and nutrient levels.

Even though the likelihood of the wastewater treatment plant being built is quite realistic, it is considered that the likelihood of the plant's discharge significantly altering the quality of the intake water can be labelled as 'rare', as it would be expected that the plant discharge would have to meet certain standards in order to protect Blackmore Estuary's ambient water quality.

The consequence of reduced intake water quality is considered to be 'major' as it would have a direct impact on production capability and financial viability. Depending on the nature and degree of contamination, additional storage and treatment area would need to be provided on site, which would probably encroach on some of the proposed production area.

As a result, the associated risk is rated 'high' and requires senior management attention.

6.7 HEALTH AND SAFETY

6.7.1 Introduction

Table 6.5 lists potential health and safety risks associated with construction and operations of the prawn farm. The table assigns risks to each of the hazards in accordance with AS3460:1999 and provides a number of preventative and mitigative controls, followed by a residual risk assessment.

6.7.2 Emergency Management

Detailed emergency response procedures will be developed as part of the construction and operations planning. These procedures will be centrally located and staff will be inducted accordingly.

Emergency procedures will be drawn up for situations including:

- Fire;
- Traffic accident;
- Drowning accident;
- Injuries;

- Cyclone.

Table 6.3 Risk assessment

Hazard description	Hazard analysis	Risk Assessment			Preventative Controls	Mitigative Controls	Residual Risk
		Likelihood	Consequence	Risk			
Injuries from swinging loads/dropped objects	Swinging loads/dropped objects due to use of incorrect procedures, insufficient training, mechanical failures, etc.	Unlikely	Moderate (level 3)	Medium	Engineering and procedural controls Certified lifting equipment Inspections JHA/JSA Restricted access	Emergency response procedures First aid and medical provisions	Low
Road traffic accidents (material supply, worker transport)	Fatality or serious injury due to traffic accidents	Rare	Major (level 4)	High	Journey management plan Job/worksite planning and scheduling. Substance abuse policy.	Emergency response procedures First aid and medical provisions	Medium
Occupational accidents. Personal injury.	Occupational incidents (trips, slips, falls, burns and electrocution, heat exposure, material handling, hazardous fauna/flora, machinery operation) due to incorrect procedures, lack of training or awareness, fatigue.	Possible	Minor (level 2)	Medium	JHA/JSA Work procedures Familiarisation and induction Training Safety encouragement schemes Contractor selection	Emergency response procedures First aid and medical provisions Personnel Protection Equipment	Low

Hazard description	Hazard analysis	Risk Assessment			Preventative Controls	Mitigative Controls	Residual Risk
		Likelihood	Consequence	Risk			
Potential for injuries or fatality due to structural failure during construction	Structural failure due to exceedance of design envelope, natural causes (cyclone, earthquake), fire	Rare	Catastrophic (level 5)	High	Design Material specification standards and inspection	Emergency response procedures First aid and medical provisions Personnel Protection Equipment	Medium
Risk of drowning	Risk of drowning in production ponds	Rare	Catastrophic (level 5)	High	Fencing around property Restricted access to pond area	Personnel to be competent swimmers Provision of life buoys Emergency response procedures First aid and medical provisions	Low
Hazards associated with adverse weather (cyclone)	Loss of life due to flying objects, collapsing structures, drowning, etc.	Possible	Catastrophic	Extreme	Structures designed to cyclone standard Identification of critical stages and contingency planning	Emergency response procedures First aid and medical provisions	High

Hazard description	Hazard analysis	Risk Assessment			Preventative Controls	Mitigative Controls	Residual Risk
		Likelihood	Consequence	Risk			
					Evacuation if necessary		

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