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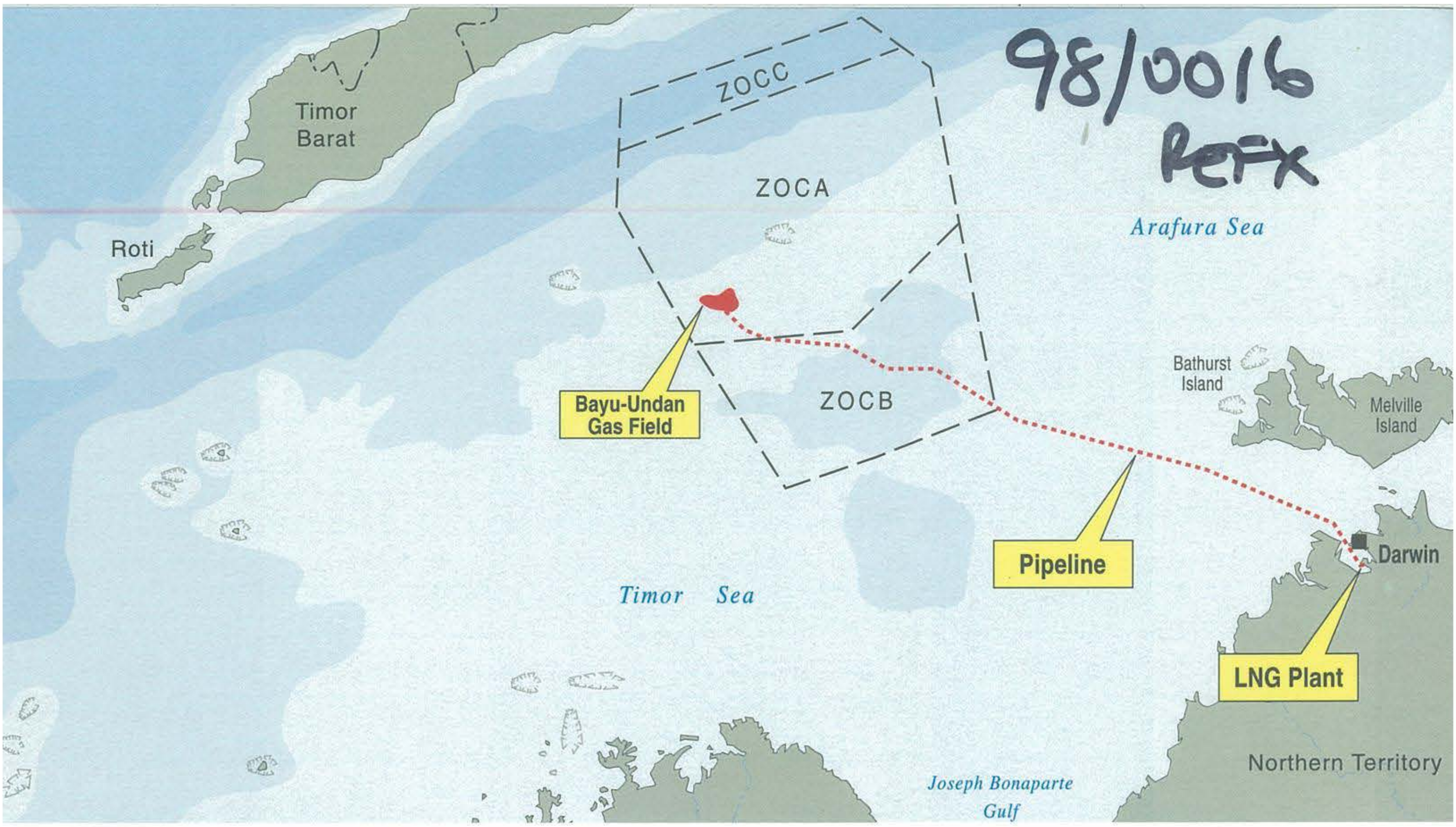

DARWIN LNG PLANT

Draft Environmental Impact Statement

Volume 3 - Appendices H-P

DAMES & MOORE PTY LTD
A DAMES & MOORE COMPANY

PHILLIPS OIL COMPANY AUSTRALIA

DARWIN LNG PLANT

Draft Environmental Impact Statement

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APPENDICES

VOLUME 3 OF 3

Appendix

Appendix H

Ecoz-AUSTRALIA

REPORT

Darwin LNG Plant
Environmental Impact Statement

Appendix H
Vegetation and Flora
Fire Management of Natural Vegetation

for

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PART 1: VEGETATION AND FLORA

INTRODUCTION

The survey area occurs on a central peninsula of Darwin Harbour, lying at the mouth of East Arm (the Elizabeth River) and Middle Arm (the Blackmore River). It occurs just to the north of Channel Island, the site of Darwin's gas fired power station. The access road to the proposed LNG site will branch off from the main road constructed to the Channel Island Power Station, several kilometres before the bridge crossing of Middle Arm.

Previous vegetation mapping of the Middle Arm peninsula has been undertaken as part of several land resource surveys. These surveys defined the landscape in terms of recurring patterns of landform, drainage, soil type and associated vegetation.

The Land Systems of the Darwin Region (Wood, Fogarty and Day 1985) mapped the region including the survey area at 1:100,000 scale, delineating two major land systems.- the Littoral Land System (L) and the Keefer's Hut Land System (Kf). The Littoral map unit includes level tidal flats and stable coastal dunes. Composed largely of saline muds, this land system supports mainly samphire and mangrove forests. The Keefer's map unit encompasses most of the survey area above the tidal limit and includes dissected rolling terrain with remnants of the Koolpinyah plateau surface. Yellow massive earths are common, often being gravelly and shallow and typically supporting *Eucalyptus* woodland.

A more detailed level of description at the regional scale is found in the Land Resources of the Elizabeth, Darwin and Blackmore River Catchments (Fogarty, Lynch & Wood 1984). Vegetation of the current survey area is described in relation to landform and soils and mapped at a scale of 1:25,000. Three map units within the hinterland habitats are distinguished and the intertidal area is broadly classified into upper and lower tidal regions. This level of stratification provides a useful baseline for broad topographic classifications, but does not adequately describe the detailed pattern of vegetation within the site for the purposes of this report. For example, *Eucalyptus* woodland is mapped for the islands on which monsoon rainforests (here expressed as dense stands of viney thickets) actually occur.

The mangrove communities of Darwin Harbour have been mapped at 1:25,000 and described in some detail by the Parks and Wildlife Commission of the Northern Territory (P&WCNT) (Brocklehurst, in press). Nine (9) distinct mangrove zones are delineated within the survey area which is surrounded by very extensive intertidal mangrove forests and mudflats, particularly to the north and south of Wickham Point.

The mangrove communities of the harbour generally have been the focus of a number of resource assessment and delineation studies (Dames & Moore 1981; 1984, 1985a, 1985b, 1987). A comprehensive environmental report describing the marine and tidal flora was also compiled prior to the construction of the power station on Channel Island (Caldwell Connell 1983).

A small number of environmental reports undertaken for specific projects have described or mapped vegetation on the harbour's foreshore, usually in response to development proposals for specific locations. Only one previous study of the survey area was found, that of a site near Peak Hill which was surveyed by Russell-Smith and Lucas as part of a comprehensive survey of NT rainforests (Russell-Smith 1991). The information collected during that survey is outlined in the Terrestrial Vegetation section below and discussed in the section below, Conservation Significance of Vegetation at Wickham Point.

METHODOLOGY

Preliminary mapping by interpretation of 1996 colour and aerial photography at 1:12,000 scale was undertaken prior to field survey. Six (6) distinct non-tidal (ie dry land) vegetation communities were identified from aerial photograph interpretation, mapped onto a base map at 1:10,000 scale, and further refined by ground truthing during field surveys. A location map of the wider survey area at 1: 25,000 scale was also compiled (Figure V.1). This map shows the distribution of the major vegetation types, and shows the extent of monsoon rainforests in the local region.

Field survey of vegetation was undertaken during both the dry and wet seasons to document seasonal variability and to assess vegetation structure and composition during both seasons. The dry season survey was undertaken in September and October 1996. The wet season flora survey in mid January and mid February 1997 followed a period of record rainfall and corresponding vigorous plant growth. Access to the areas was by boat, helicopter and vehicle.

Intertidal areas were ground truthed and minor refinements made to the classification and mapping delineated in the P&WCNT map of Darwin Harbour Mangroves (Brocklehurst, in press).

Within each of the major plant communities in the hinterland habitat, one or more permanent survey sites were established and this baseline data recorded on site data sheets. At each survey site, a photopoint was established and within a 20m radius of the marker, the following data and information were recorded:

- data on species composition, dominance, growth form and community structure
- vegetation community descriptions
- crown cover estimates to enable structural classification
- plant collection for species identification
- observations on evidence of fire, disturbance, and weed infestation.

Documentation included descriptions and height estimates of the major taxa contributing to the various strata, and of common taxa throughout the strata. Random traverses of the survey area were made to further describe and document the vegetation of the survey area and to examine the site for the presence of restricted or rare plant species.

The ground survey focussed mainly on the western island of Wickham Point, where 8 sites were established, particularly within that area in which the proposed LNG plant is to be located (Figure V.2).

Two survey sites were located on the middle island at the entry/exit points for the proposed access road (LNG-09 and LNG-10). The proposed access road was traversed as far as possible from the Channel Island road to its destination including mangrove traverses between upland areas. Appendix 4 contains a description of the vegetation along the proposed access road route.

Species were identified in the field or collected and identified by Ian Cowie and Clyde Dunlop of the Northern Territory Herbarium and referred to the Checklist of Vascular Plants of the Northern Territory (Dunlop *et al.* 1996).

VEGETATION COMMUNITIES AND SPECIES COMPOSITION

A vegetation map of Wickham Point at 1:10,000 scale is presented in Figure V.3. The vegetation of the Wickham Point peninsula comprises extensive intertidal areas supporting mangrove forests and salt flats which completely surround two upland or hinterland areas rising to a maximum elevation of 34m at Peak Hill. These islands of hinterland are largely vegetated with monsoon rainforest (which is expressed as dense vine forest) covering an area of approximately 181.9 ha (P&WCNT GIS estimates 178.2 ha). Limited areas of Paperbark *Melaleuca* dominated forest occur also on the western island.

Within the survey area, 161 species from 138 genera (Appendix 1) were recorded during the dry season survey. Of these, 44 species or 27% of the total were recorded during the wet season surveys, indicating they were stimulated to growth by the wet season. The Rainforest was the richest vegetation formation (and the largest dryland vegetation on the islands) with 99 species, followed by Melaleuca Woodlands with 37 species, Mangroves with 28 species, and Eucalypt woodlands with 24 species.

Mangrove Vegetation

The Wickham Point survey area covers 1,515 ha (15.15 km^2) of mangrove and salt flat vegetation. Within the intertidal zone, 9 distinct plant communities or floristic zones are found. These zones are arranged roughly parallel to the shore or tidal creeks and rivers, often comprising almost monospecific stands at predictable topographic elevations above mean sea level. The pattern of zonation of the 9 mangrove communities has been mapped by Brocklehurst (in press) and is shown in Figure V.3 (Map Units 1 to 9).

The seaward zone (Map Unit 1), at approximately -1.0 to 1.0 m AHD consists of an almost monospecific band of *Sonneratia alba* aligned roughly parallel to the shore of Wickham Point. The seaward mangrove zone receives inundation twice daily, by every tide, and consists of woodland 4 to 8 m tall in unconsolidated soft mud substrates.

To landward, the seaward zone typically merges with either the shoreline zone (Map unit 2) or the tidal creek community (Map unit 3). In both zones *Rhizophora stylosa* is the dominant mangrove species, typically forming a closed canopy forest from 6 to 10 m tall. The tidal creek habitat often extends a fair distance to landward, lining the banks of meandering tidal creeks. This zone contains a number of associated species including *Camptostemon schultzii, Avicennia marina* and *Bruguiera parviflora.* Lying between approximately 1.0 and 2.5 m AHD, this zone receives regular tidal inundation and has deep root-structured muds.

The most extensive mangrove communities occur on the broad tidal flats flanking the taller, more frequently inundated seaward zones. Both the mid tidal flat (Map Unit 4) and the upper tidal flat (Map Unit 5) have *Ceriops tagal* as the dominant and often monospecific mangrove species. In these communities *Ceriops tagal* forms dense, low forests typically with a closed canopy 2 to 4 m high. The mid and upper tidal flats lie between 2.5 and 3.5m AHD and receive tidal inundation every fortnight by spring tides. Substrates are firm sandy to gravelly muds with seasonally high soil salinities. Tree height varies in response to salinity and fresh water inflow, height being greater where fresh water inflow is greatest.

Also within the upper tidal flat, extensive bare hypersaline flats occur where salinity rises above that tolerated by mangroves. These salt flats may support scattered patches of samphire and are typically fringed by stunted *Avicennia marina* and *Ceriops tagal* (Map Unit 8).

The landward fringe of the extensive Wickham Point mangroves is often the location of seepage areas. Freshwater inflow and very infrequent tidal inundation in these areas leads to the formation of taller, mixed species mangrove stands such as the Hinterland zone (Map Unit 6) and Mixed species low woodland (Map Unit 7). *Ceriops tagal* is often the dominant species, typically forming dense closed canopy forests to 6m along the landward margin. *Lumnitzera racemosa, Bruguiera exaristata* and *Excoecaria ovalis* are common species in the hinterland zone. Common species in the mixed species low woodland areas include *Avicennia marina* and *Lumnitzera racemosa.*

Appendix 1 contains a list of species recorded within mangrove habitats at Wickham Point. More detailed description of mangrove species composition, position in relation to tidal inundation, and structural formation of the Wickham Point mangroves are described in Appendix 2.

Terrestrial Vegetation

The dry land or terrestrial plant communities have been mapped in Figure V.3 at 1:10,000 scale. The major plant community is monsoon rainforest, also known as rainforest, vine forest or vine thicket, which covers the majority of the survey area. Four other minor plant associations which also occur within the survey area are mapped in Figure V.3 and are described briefly below.

Beach

A narrow peninsula which is often little more than a sandy spit lying just above the tidal limit and extending to the western tip of Wickham Point supports a sandy beach habitat with a distinct floristic community (Map Unit 9). The beach habitat comprises an open woodland with well separated trees to 8 m tall and includes a number of pantropical species such as *Gyrocarpus americanus, Hibiscus tiliaceus* and *Cordia subcordata.* Patches of vine forest with *Drypetes lasiogyna, Micromelum minutum* and abundant vine species (*Tinospora smilacina, Capparis sepiaria, Abrus precatorius* and *Gymnema geminatum*) tend to occur on the upper dune areas. Strand plants such as *Ipomoea pes-caprae* and *Sesuvium portulacastrum* are found on the lower dune areas.

Monsoon rainforest

Monsoon rainforest, or rainforest (Russell-Smith 1991) vegetation in the Northern Territory comprises a variety of structural forms ranging from closed canopy evergreen forests on perennial water to semi-deciduous low vine-thickets on seasonally dry sites. The survey area is characterised by well drained substrates with no perennial water and supports 182 ha of rainforest vegetation. However, local variation within this rainforest association occurs and two structural forms have been mapped and described within the survey area.

Dense, closed canopy, vine-rich rainforests occur on low hilly rises and the northwestern ridge including Peak Hill at the western edge of Wickham Point's westernmost island. These dense semi-deciduous forests also occur on the major longitudinal ridge of the middle hinterland island (Map Unit 10). Covering a total estimated area of 51 ha, the dominant species include *Acacia auriculiformis* and *Sterculia quadrifida* as scattered emergents in the upper stratum. *Drypetes lasiogyna, Diospyros compacta* and *Glycosmis trifoliata* are the dominant species in the mid-stratum.

Vine thickets with a more open canopy comprising a higher proportion of semi-deciduous species generally occur on the well drained substrates found over the majority of the hinterland area (Map Unit 11). This vegetation association covers an estimated 132 ha within the survey area. Scattered emergent species include *Acacia auriculiformis, Eucalyptus tectifica* and *E. polycarpa*. Dominant mid stratum species include *Dodonaea platyptera, Hakea arborescens* and *Strychnos lucida*. Appendix 1 contains a list of species recorded within rainforest habitats at Wickham Point. More detailed descriptions of the species composition and structural characteristics of these rainforest communities are found in Appendix 2.

Species richness of the 10 sites surveyed on the two islands is tabulated in the Appendix 2.

Woodland habitats

Minor areas of *Eucalyptus*-dominated woodlands occur on areas of shallow, skeletal soils particularly on the coastal margins (Map Unit 12). The dominant species include *Eucalyptus tectifica* and to a lesser extent *Eucalyptus polycarpa*. Similar to the majority of terrestrial habitats in the survey area, *Acacia auriculiformis* is a ubiquitous canopy species in this community.

Melaleuca spp. (paperbarks) become dominant in areas of freshwater flow or seepage and a *Melaleuca* woodland community occupying approximately 11ha occurs along the main drainage way that bisects the western island (Map Unit 13).

On the eastern island, a small area with a perched water table supports a sedgeland and grassland community with low trees and shrubs capable of withstanding brackish conditions (Map Unit 14).

VEGETATION COMMUNITIES TRAVERSED BY THE ACCESS ROAD

The main access road branches from the Channel Island road and follows the alignment of an existing bush track before branching off to the west along the surface of a low hinterland plateau until it reaches the mangrove margin. The vegetation of this low hinterland plateau is generally *Eucalyptus* dominated woodland to open woodland with a sparse to mid-dense understorey layer. Dominant species include *Eucalyptus miniata, E. tetrodonta* and *Erythrophleum chlorostachys.* Typical of much of the Darwin region, the vegetation is burnt regularly if not annually which maintains the open nature of the understorey layer. The mid stratum layer typically comprises juveniles of the dominant tree layer, the sand palm *Livistona humilis, Acacia* spp. and *Cycas armstrongii.*

At the northwestern tip of this mainland peninsula the access track traverses the mangrove zone. The recommended alignment will mainly traverse the upper tidal flat zone of the mangroves in which *Ceriops tagal* is the dominant species. In this community, *Ceriops* forms dense thickets 2 to 4 m tall in relatively consolidated sandy to gravelly muds. Where minor tidal creeks cross the proposed road alignment the mangrove vegetation changes dramatically. Within a distance of several metres species composition changes from *Ceriops* -dominated low forests to a transition zone comprising *Ceriops tagal* and *Bruguiera exaristata* between 4 and 6 m tall.

The main tidal channels are clearly defined by dense *Rhizophora stylosa*, with its arching, looping prop roots (6 to 8 m tall). Along the larger creeks *Camptostemon schultzii* also occurs as a bushy low tree, often overhanging the muddy creek channel.

A description of the vegetation and a photographic record of the access road alignment are contained in Appendix 4.

WEEDS

Very few weed species were recorded during the flora survey. Within the rainforest habitat the most abundant weed was *Lantana camara. Lantana* is a declared noxious weed and in other areas of Australia is a serious threat to native vegetation. It is an invasive species that smothers native plants and makes access difficult. In the Northern Territory, *Lantana* is not yet a major problem (Smith 1995). At Wickham Point and within other rainforests locally, this species typically coexists with native flora as a rambling understorey shrub. In some areas with a more open canopy, dense *Lantana camara* thickets occur. Minor areas of *Hyptis suaveolens*, the vine Wild Passion Fruit *Passiflora foetida* and the declared noxious weed Mission Grass *Pennisetum polystachion* were also observed. These species were confined largely to open areas with high light intensity such as the beach habitat and littoral woodland or the fringes of dry rainforest areas. The dense canopy rainforest is relatively free of introduced species.

The lack of disturbance, either from feral animals, fire or cultural impact contributes to the resilience of natural habitats to weed invasion. The lack of weeds within such an extensive area of rainforest greatly adds to its integrity and conservation value.

CONSERVATION SIGNIFICANCE OF VEGETATION AT WICKHAM POINT

Mangrove Forests

The survey area includes significant intertidal areas that typically support dense closed canopy mangrove forests and extensive bare, hypersaline saltflats. Over 19,000 ha of mangroves in a relatively pristine condition occur within Darwin Harbour. Wightman (1989) identified approximately 38 mangrove species from the Darwin region and notes "the diversity and extent of the mangrove community places it amongst the most significant mangrove resources in the Northern Territory". The Wickham Point area is surrounded by very extensive mangroves totalling an area of 1,515 ha.

Several reports have been commissioned to document the mangrove resources of the harbour (Dames & Moore 1984, 1985a, 1985b, 1987; Le Provost, Semeniuk & Chalmer 1982). These reports acknowledged the present integrity and value of the resource. Mangroves play an important role in the healthy functioning of estuaries and the significance of mangroves to fisheries and coastal food chains has long been recognised (McGuinness 1992). Mangroves are extremely productive environments in terms of their primary production and their contribution to detrital based food webs (Woodroffe et al 1988).

Mangroves also represent an important feeding, breeding and nursery habitat for a great variety of fauna (Hutchings and Saenger 1987).

Monsoon Rainforests (Vine Forests)

Northern Territory rainforests, in the wet-dry tropics, are typically found as small disjunct patches, scattered within a vast expanse of mostly eucalypt-dominated woodland or savanna (Russell-Smith 1991; Russell-Smith & Lee 1992). These rainforests are characteristically less than 5 ha in extent with a maximum species richness of around 135 species per patch. Patch size is extremely variable, ranging from extensive coastal tracts of over 2,000 ha to small groves on rocky outcrops. Within each patch, populations of adult plants are typically very small, with most species represented by fewer than 50 plants (Russell-Smith & Lee 1992). Substrate types include coastal dunes, lateritic soils and rock and sandstone or quartzite outcrops.

Russell-Smith (1991) defined 16 different types of monsoon rainforest in the Northern Territory based on floristic and environmental parameters. Half of these groups were associated with perennial moisture and half with seasonally dry landforms. Much of the rainforest vegetation in the Darwin Harbour region falls into Group 9, described as a very large group of semi-deciduous rainforests associated with a variety of freely drained coastal and subcoastal landforms (Russell-Smith 1991).

Overall, rainforest vegetation, also known as monsoon forests, have the smallest distribution of any of the major Top End plant communities (W. Panton pers. comm. 1996). The total area of rainforest in the NT is estimated at 34,359 hectares with 2,060 ha within the Darwin region (between Mandorah and Shoal Bay). Rainforests associated with springs and perennial moisture (Type 1) comprise 465 ha and dry rainforests (Type 11) constitute the remaining 1,595 ha (P Brocklehurst, Parks and Wildlife Commission NT). Figure V.1 shows the distribution of riverine, dry and spring rainforests in the Darwin region (source NT Parks and Wildlife rainforests database 1996).

GIS mapping of rainforest reserves based on the 1991 NT Rainforest Survey (Russell-Smith 1991) indicated that the Wickham Point site represents not only one of the largest stands of this vegetation type in Darwin Harbour but represents 11% of the dry rainforest (or dry vine forests) reserves in the Darwin region between Shoal Bay and Mandorah (see Fig V.4). An estimated 182 ha of dry rainforest occurs within the survey area. Of that area, 50ha is dense closed canopy forest (Map unit 10) and 132ha has a more open canopy comprising more semi-deciduous species (Map unit 11).

The dry and wet season botanical surveys listed 97 species of plants in the monsoon rainforests. The vine forests are thus floristically rich and constitute an important resource to local fauna, particularly frugivorous birds and bats. From this point of view they are of high botanical and conservation interest.

Fire Sensitivity of Rainforests

Fire plays an important role in the spatial distribution of monsoon rainforests, as well as edaphic (soil) and moisture differences from adjacent forests (Bowman & Fensham 1991; Bowman 1991). Certain rainforest species are killed by fire but recent research indicates that fire may not necessarily be a catastrophic event for these habitats. Many species have been found to be resilient to fire, recovering vegetatively after late dry season fires (Bowman

1991). Despite considerable regenerative capacities, intense, late dry season fires do inflict significant damage to the margins of rainforest patches and are considered highly destructive to rainforest vegetation (Russell-Smith and Bowman 1991).

It is apparent from existing fuel loads and the almost complete absence of fire scars and charcoal that the Wickham Point rainforest vegetation has not been burnt for a considerable period of time. Given the frequency of fire in the Darwin region, where the great majority of savanna and woodland habitats are burnt by frequent, sometimes annual or biennial fires (Dunlop & Webb 1991), an area of unburnt country represents an unusual habitat or refuge.

Recent reports have highlighted the fire protection that rainforest pockets on hinterland islets are afforded when completely surrounded by mangroves -which do not burn (Dames & Moore 1993). This habitat represents a refuge for fire-sensitive vegetation. On these hinterland islets rainforest species which are killed by fire (including *Aidia racemosa, Cupaniopsis anacardioides, Myristica insipida, Terminalia sericocarpa* and *Strychnos lucida)* can occur (Bowman 1991). Unburnt areas provide both resources and habitat for a variety of wildlife throughout the dry season.

Importance to Fauna

Rainforests provide important resources to species that forage or roost in this habitat and to migratory species such as the Torres Strait Imperial Pigeon that depend on rainforests as a seasonal food resource (C Bach pers comm.). Over 60% of vine forest species have fleshy, brightly coloured or exposed seeds suitable for dispersal by birds (Wightman and Andrews 1989). Flying foxes and birds are important pollinators and dispersers of seed and play a role in maintaining the genetic viability of rainforests generally - particularly with their typically disjunct distribution of small isolates.

Recent research indicates that the phenology (flowering and fruiting times) of 'wet rainforests' (ie spring jungles and sites of perennial moisture) and 'dry rainforests' (occurring on seasonally dry sites) are substantially different (C Bach pers. comm.). Wet rainforests concentrate their reproduction during the wet season and dry rainforests have a staggered sequence of flowering and fruiting, providing a supply of resources over an extended period. Consequently frugivorous birds and bats concentrate their foraging in wet jungles during the monsoon period and forage more widely, dispersing into dry rainforests throughout the dry season (unpublished data, C Bach PhD thesis).

Declining Distribution

The total area of dry coastal and subcoastal rainforest vegetation in the Northern Territory was estimated at approximately 34,359 ha in 1991 (Russell-Smith and Lucas, NT Rainforest Survey). The Darwin region has an estimated 1,595 ha of dry rainforests comprising 4.6% of this total area. Studies of the distribution of rainforests in the Darwin region have shown that there has been a 60% reduction in the cover of this vegetation type in the 45 year period to 1993 (Panton 1993). Urban development has contributed 40% of the loss, while fire and cyclone damage, and weed incursion were noted as major factors in the declining distribution.

Susceptibility to Environmental Decline

The small size of most rainforest patches leaves them vulnerable to disturbance, and a study over the NT as a whole noted that approximately one third of rainforest survey sites were severely disturbed by fire, 20% were severely disturbed by cattle and buffalo and 10% by pigs (Russell-Smith and Bowman 1992).

Other factors contributing to the vulnerability of rainforest vegetation include the fragmented nature of their distribution and the relative fire-sensitivity of the plant species. The interrelated factors of fire, feral animals and weed invasion are also important determinants of site condition, particularly for those sites with perennial moisture - providing water and shade in a seasonally dry landscape.

The vine forests of Wickham Point contain very few species of introduced plants and those weeds present tend to occur in very low densities. The scarcity of weeds indicates low habitat disturbance and environmental degradation, and is an indication of the high integrity of these patches at Wickham Point.

One of the most significant threats to the integrity of rainforest vegetation is the combined threat of fire and weeds. The noxious weed *Pennisetum polystachion* is a common introduced grass found on the edges of rainforest patches, and in (at least) one patch at Wickham Point. Unlike the native annual *Sorghum* species, *Pennisetum* is a tall perennial grass that remains green and non-flammable until late in the dry season. If fire occurs at this time this species will support a high intensity fire with flame heights to 5m (Panton 1993).

Other weed species include the vines *Passiflora foetida* and *Calopogonium mucunoides* (the latter not present on site at the time of survey), but which can cause changes to the vegetation by increasing shading of the understorey.

Weed invasion and the impact of their fire ecology poses significant threats to the margins of rainforests and in areas of canopy disturbance. Long term, repeated high intensity fires cause the erosion of rainforest boundaries and habitat decline, whereas fires of low intensity do not appear to inflict significant damage to rainforest patch margins provided that fuel levels and standing fuel flammabilities are low (Russell-Smith & Bowman 1992).

Regional Context

The Wickham Point monsoon forests are unusual in the local region because of their extent, the paucity of weeds, the diversity of species, their isolation from fire and their relative protection from feral animals.

Most rainforest patches are typically less than a few hectares in extent (Russell Smith & Bowman 1991). Therefore the relatively large expanse of 'dry' rainforest in the survey area (approx 180 ha) establishes the environmental significance of this site. Large patch size also confers integrity to the ecosystem generally as larger patches are more able to survive disturbance.

Current research by Owen Price (Parks and Wildlife Commission) indicates that because these habitats are dependent on flying vectors (birds and bats such as flying foxes) for pollination and seed dispersal, they need to be considered in a regional context. Their conservation requires ensuring that they are close enough to other patches for these vectors to utilise them. When one rainforest completes its fertile phase, the resources of another rainforest or adjacent hinterland area needs to be accessible to these animals

(O. Price pers. comm.). Management is thus needed at the regional level to ensure that their distribution remains reasonably contiguous.

IMPORTANT ECOLOGICAL RELATIONSHIPS

Mangroves

Mangroves are the basis of extensive detritus-based coastal food webs. Studies on mangrove productivity from the tidal creek habitat in nearby East Arm have shown that up to 1.4 kg m^{-2} per year of organic matter is produced by certain species (Woodroffe *et al.* 1988). Mangroves also play an important role in coastal stabilisation and act as significant nursery and breeding areas for many species of fish and prawns (Dames & Moore 1988).

Monsoon Rainforests

Monsoon rainforests such as the Wickham Point vine forests contain a large number of fruit-bearing plant species of significance to fauna (Wightman & Andrews 1989). The Orange Lacewing Butterfly (*Cethosia penthsilea paksha*) is dependent on the vine-forest species *Adenia heterophylla* ssp. *australis* (W Panton pers. comm.). The larvae of this poorly known butterfly feed gregariously on this native vine from the passionfruit family. Other species such as the Rose-crowned Fruit Dove, Rainbow Pitta, Torres Strait Imperial Pigeon and Black Butcherbird observed at Wickham Point utilise the rainforest patches for at least part of the year.

Recent research on the phenology or sequence of fruiting and flowering of monsoon vine forest species has indicated that discrete patches of vine forest tend to have sequential flowering and fruiting times (C Bach pers. comm. 1996). This provides a relatively constant food supply to local fauna, but highlights the need to conserve a number of these areas to ensure the supply of food annually.

Rainforest ecology requires consideration at the landscape scale due to the small population sizes of many component species. Frequently less than 50 (and often less than 20 adult plants) occur per patch (Wightman & Andrews 1989; Russell-Smith & Lee 1992). Therefore, to effectively conserve monsoon forest plants and animals, the protection of plant populations within several local patches may be necessary. Russell-Smith and Bowman (1992) observed that the maintenance of long-term genetic viability of small, widely scattered patches requires conservation at the landscape scale. Effective conservation of NT rainforest isolates also requires active fire and feral animal management.

The long term viability of rainforest habitat type requires that the diffuse connections between isolates are maintained. For example, reasonably contiguous distribution of rainforest patches along the coast or migration routes is important for vagrant species. Adequate food supply for pollinators and seed dispersal vectors is required for continued genetic exchange between patches.

RARE, ENDANGERED AND POORLY KNOWN PLANTS

The Herbarium of the Northern Territory was consulted regarding the presence of rare plant species within the survey area. No rare, endangered or threatened species were recorded for the site (I Cowie, NT Herbarium). However, density of plant collections for the local area are extremely low, with only 7 plant species previously recorded for the survey area. Herbarium records for Channel Island, which has been better surveyed and which has similar substrates and vegetation were also consulted, but no rare species were listed.

A potentially very rare plant, Dutchman's pipe, *Aristolochia* sp D50244, known only from the type locality and collected from nearby Channel Island, may occur also on Wickham Point, although it was not observed despite extensive surveys. It is currently thought that further botanical collections and taxonomic review of *Aristolochia* may however, lead to a reclassification of this species (D Liddle, I Cowie pers comm.). It is probable that this species is an exotic, possibly a garden 'escapee' dating back to the days of the island's early settlement.

POTENTIAL IMPACTS ON VEGETATION

Mangroves

Construction of LNG plant infrastructure, main jetty and construction dock

The environmental impacts on the mangrove environment of Wickham Point will include clearing of mangrove vegetation and the infilling of mangrove areas for the construction of the main jetty and the construction dock. The main jetty will be between 1.2 and 1.5 km long to access deep water in the Middle Arm channel. A corridor of mangroves up to 50m long will need to be cleared for the construction of the main jetty on the south-west corner of Wickham Point. Assuming this corridor will be up to 15 m wide, about 0.08ha will need to cleared.

Up to two spill impoundment areas, one west of the plant and one south, of about 45,000 square metres or 4.5 hectares total will also be placed at low points near the plant and within mangrove or saltflat areas. One circular area for a marine flare of about 8,000 square metres or 0.8 hectares on the south-western corner of the island, and two circular areas of up to 2.9 hectares each for the main flares on the north-eastern side of the western island, opening onto East Arm, will be cleared within mangrove areas. The westernmost of these will be used initially for a landing area for plant and equipment at the landward end of the construction dock. This construction dock on the north-eastern side of the peninsula will be built within the mangrove habitat. This dock, which will service barges which will carry equipment from the mainland, will be 200 metres long and 50 metres wide. The area of mangroves cleared for the construction dock will total approximately 10.1 ha. The area of mangroves cleared for the two flares and the construction landing area will therefore total 2.9 ha plus 10.1ha.

Construction activity within mangrove areas will alter the patterns of local drainage. Tidal flats have very minor relief, and the intertidal zone is sculpted and levelled by regular tidal flushing. Freshwater seepage and runoff from the hinterland through these extensive tidal flats reaches a balance in natural mangrove areas. Terrain disturbance can result in the ponding of tidal and fresh water. Impoundment of water in mangrove areas creates ideal breeding habitat for saltmarsh mosquitoes, which are of major significance as pests and as potential vectors of disease. Ponding of saline or fresh water for extended periods around living mangroves will cause vegetation death due to increasingly anaerobic soil conditions.

Construction within mangrove areas is complicated by soft substrates and the disposal of potentially acid sulphate spoil dredged up from the mangrove muds. Slight changes in local drainage may have impacts on the wider mangrove area. Changes in topographic elevation affect the frequency of tidal inundation and thus soil salinity. The combined effects of these factors then determine the mangrove species composition.

A minimum area of 18.4 ha of mangroves will be cleared for the construction of Stage 1 and Stage 2 of the LNG plant. This area represents roughly 1.2% of the total mangrove area of Wickham Point (1515 ha) and slightly less than 0.1% of the total mangrove resources of Darwin Harbour (19,000 ha).

Construction of access road

In addition to the construction of the plant itself, minor areas of mangrove will be cleared for the access road between the islands. Between the western and centre islands the road will traverse about 1km of mangrove and salt flat, and between the centre island and the mainland peninsula about 1.1km. This should be minimised because of the proposed alignment. For the western section, about 41% is covered by mangrove, 59% by salt flat, resulting in about 1.2ha of mangrove being cleared (assuming 30m easement). For the eastern section of the access road through mangroves, 95% is mangrove, resulting in about 3.1ha being cleared.

Construction of the access road to the plant has potential for negative impacts on mangroves. Road construction will require substantial quantities of fill to raise the level of the road above that of the highest tides. Each mangrove zone is closely adapted to the frequency and duration of tidal inundation. Alteration of this pattern of tidal flow particularly by blocking tidal creeks or the impoundment of tidal water may have a rapid and substantial effect on the surrounding areas of mangrove. Although tolerant of several hours of inundation, mangroves will die if subjected to prolonged submersion or waterlogging.

Alterations to the frequency of tidal inundation will also change the soil salinity regime. Mangrove distribution is closely tied to soil salinity. For example, in upper tidal zones where tidal flushing is infrequent and evaporation is high, salinity levels rise to several times that of seawater and bare hypersaline flats develop. Construction of roads through intertidal areas may result in changed patterns of tidal flows and consequently altered soil salinities.

Dry-land (terrestrial) vegetation

Vegetation clearance for the proposed LNG plant will be concentrated on the western island. Part of the development will involve clearing dry vine rainforest (with dominant species including *Acacia auriculiformis, Drypetes lasiogyna*, *Cupaniopsis anacardioides* and *Glycosmis trifoliata*). This will result in the loss of approximately 44 ha of this habitat, or about 43% of that occurring on the western island. This represents a loss of 24% of the rainforest of the survey area of the two islands, and about 2.8% of the 1595ha of dry rainforest reserves in the Darwin area.

The main axis of the development runs along the eastern flank of the western ridge and down to the central drainage way between the eastern and western ridges. This shallow valley is vegetated with a *Melaleuca leucadendra* and *Acacia auriculiformis* woodland association which merges on both sides with rainforest vegetation on the surrounding ridges. Clearing of vegetation for the LNG plant will have the most significant impact on vegetation on this part of the island and will result in a loss of approx 10.5 ha, the total area of *Melaleuca* woodland on site.

A perimeter road proposed for the western edge of the Peak Hill ridge, on the western margin of the outer island is approximately 1200 metres long from the edge of the construction platform to the pipeline joining the westernmost spill impoundment area. This would involve clearing some important rainforest along the lower slopes of the ridge, and may impede or affect drainage and canopy openness, as well as cause some changes to the soils and bedrock and adjacent mangroves. The route may be visible from Darwin harbour and Darwin. The total area which would be affected is about 3.6 hectares, depending on the optimised alignment. Alternatives to this perimeter road around the western margin of the plant, to traverse the east of the ridge where the plant is built will be investigated as part of the refinement of the design of the plant.

The main access road which runs through the centre of the centre island and along the south-east arm of the western island is approximately 700 metres long over dry land on the western island and 1.5km over the centre island. Assuming the easement is approximately 30 metres wide on average (but will be only about 15 metres wide when operational in most places), this will result in the loss of dry rainforest of about 4.5 ha on the centre island and 2.1ha on the western island through which it traverses.

The access road from the Channel Island power station road to the end of the mainland peninsula is approximately 4.2km long. Of this, 1.4km follows an existing bush track which will require only limited clearing to form the new road. The remaining 2.8km will need to be cleared, resulting in approximately 8.4 ha of eucalypt woodland being cleared, assuming an average of 30 metres clearance alignment.

MITIGATION MEASURES AND SAFEGUARDS

Construction Phase

Clearing and burning of vegetation

Clearing of natural vegetation (in both hinterland and mangrove habitats) will be kept to the minimum necessary for the development, and the boundaries of clearing delineated prior to clearing. Vegetation removed as part of site clearing will be stock-piled on site and burnt as soon as possible after clearing. A permit from the Bushfires Council NT will be obtained prior to burning. The vegetation pile will be located so as to be as far as possible from all natural vegetation. Burning will be done under supervision and a fire fighting unit will be present to ensure that the fire does not spread into the adjacent natural vegetation.

The dry rainforest of the peninsula has not burnt for several decades and this has resulted in an uncommon vegetation association. Burning of this vegetation during the construction phase is to be prevented. Construction staff will be briefed about the impacts of fire and burning of natural areas. A fire fighting unit will be available at all times during construction to prevent fires starting and spreading.

Earthworks, earth materials and stockpiles

Preliminary earthwork requirement calculations indicate that the volumes of earth and rock involved will be 1,000,000m^3 of “cut”, and 100,000 m^3 of “fill” on the LNG plant site. The excess material will be used in the construction of the access road. The boundaries of the areas to be excavated and the boundaries of quarries and borrow areas will be clearly demarcated to contractors. Similarly, the location of dumping sites for spoil resulting from site clearance and levelling will be clearly indicated to contractors to avoid unnecessary degradation of natural areas. Wherever possible, rock and soil won from excavations will be retained and stock-piled on the sites to be used for the final construction so as to avoid damage to that natural vegetation which will be retained. These stock-piles will be moved around the construction sites as required, as the material is used to fill areas, such as the plant site and the access road.

Top soil stripped from the area within the limits of stripping which contains organic material, debris and other material which is not suitable for permanent engineered fills will be removed from site to the mainland where it will be dumped at a place to be determined.

Fill material which is sourced from outside the two islands, that is on the mainland, will be examined for noxious weeds and other weeds, and where possible sources which are weed-free will be used. Where this is not possible, a weed monitoring and control program will be implemented during and after the construction phase to ensure that weeds will not be introduced into the disturbed and natural areas.

Weeds and fungal pathogens
Before entering the islands, plant and vehicles which will be used during construction will be treated in a quarantine area offsite which is to be determined to avoid the introduction of weed and flora propagules and pathogens. Treatment will include hosing down of the plant and vehicles, and use of steam pressure spray for plant and equipment which retains soil or mud which is difficult to remove. Each item will be inspected and a certificate issued by a supervisor on site to verify the cleanliness of the plant and vehicles.

Retention and protection of natural vegetation
Areas of natural vegetation to be retained will be clearly marked by temporary fencing during the site development phase. Access into and through these areas by workers and machinery would reduce the integrity of these areas and will be prohibited.

The western island will have a strict fire control and management strategy to prevent any fire in the vicinity of the LNG plant. The retained natural vegetation will be protected from fire as a result of this strategy.

The main road will provide access to the previously inaccessible centre island. This area will be too distant from the monitoring system, controls and infrastructure to prevent fires on the western island and will require a different approach to fire management (see section on Fire Management of Natural Vegetation). It is clear that to maintain the current diversity and integrity of this area, fire needs to be excluded. Discussions will be held with the Northern Territory Department of Transport and Works to develop a strategy aimed at managing access to the centre Island.

Visual amenity
Due to its location (7 km S/SE of Darwin City) there is significant potential for major negative visual impact of this development. The plant will as far as possible be contained behind (to the east of) the Peak Hill ridge. The batters of the construction dock will be landscaped as soon as possible after construction to screen them from view. Salt-tolerant native vines such as *Ipomoea pes-caprae* or *Canavalia rosea* from the local province would be suitable for this purpose. Mangrove vegetation adjacent to the construction dock will provide some screening.

Road alignment optimisation and design parameters
Road alignment through mangrove areas will be designed to follow the highest possible topographic elevation. The small salt flats within the mangroves are a useful indicator of the upper tidal zone and road alignment will be optimised to connect these areas as far as practicable. Road construction will avoid traversing tidal channels and densely vegetated tidal creeks wherever possible. This will facilitate road construction, reduce construction and maintenance costs and have less potential for negative impacts on mangroves by avoiding interruption of tidal flows. Salt flat areas and the upper tidal flat is also the least productive mangrove area and clearing for road works will have less impact on primary production there than in the more productive lower tidal zones.

Where roads through mangrove areas do cross tidal channels, culverts will be installed to simulate natural flows and maintain adequate tidal flushing. If construction involves pushing out fill into mangrove areas, culverts will be placed in tidal channels prior to construction, to maintain tidal flows. Impoundment of water by a bund or road structure or preventing tidal inundation of mangrove areas will cause the rapid or gradual decline of these areas.

Landscaping
Landscaping of any areas such as around the administration buildings will be done on expert advice and will be restricted to species native to the island and from the local province.

Operational phase

Effluent and waste discharge
NT standards for effluent discharge and solid waste disposal will be followed to ensure that negative impacts on surrounding natural vegetation do not occur.

Protection of natural vegetation
Flora of the two islands needs to be protected from fire. On the western island where the LNG plant will be, total fire prevention will be required for the protection of the plant. This will preclude all fire from the retained natural vegetation. Options for fire management on the centre island are detailed in the section on fire management of natural areas.

Monitoring of discharges into natural vegetation and of weed introduction
During the operational phase there should be monitoring of reclaimed areas, land fill sites and surrounding vegetation for acid leachate and environmental decline. Adequate monitoring of all discharges from the plant should be undertaken to ensure the plant operates according to current environmental standards.

Monitoring of weeds in the retained natural vegetation will be undertaken at least annually and all noxious weeds removed or poisoned. Other weeds of significance to the integrity of the natural vegetation will be considered for removal or control on the advice of experts in the field.

PART 2: FIRE MANAGEMENT OF NATURAL VEGETATION

Management of the natural vegetation to prevent fire has been discussed in the vegetation section. The integrity or naturalness of this vegetation would be compromised and diminished by fires entering the rainforests. The natural vegetation on the two islands which will be retained during and after construction of the facility will be protected from fire. In order to prevent fire in these vegetation formations, the following practices will be implemented. During the operational phase, a number of alternatives for fire management will be considered for implementation. The best option will be determined after further consideration.

CONSTRUCTION PHASE

During clearing of the site, earthworks, and construction of the facility, and during construction of the access road, fire in the adjacent natural vegetation will be prevented by the following means:

- A fire fighting unit with crew will be on standby at all times to extinguish any and all fires
- Care will be taken when plant and equipment are operating adjacent to natural vegetation
- Spark arrestors will be fitted to earthmoving equipment exhausts
- Special care will be taken when tracked vehicles are working on rock to avoid production of ignition sparks
- Operators will be briefed on protection of the natural vegetation from fire
- No cooking fires will be permitted in or near the natural vegetation.

OPERATIONAL PHASE

During the operational phase, fire prevention will be absolute in the vicinity of the LNG plant. This will include the whole western island where the plant is located. As a result, the natural vegetation will be protected from fire on this island.

The centre island will have a road running through the middle of it. The road will have a verge of 3 to 5 metres on either side which will need to be managed to prevent fire starting on the verge and spreading into the natural vegetation. Management of fire will be coupled with measures to prevent weeds from invading the natural vegetation, as some of the most significant weeds such as Mission Grass *Pennisetum polystachion* are likely to promote fire.

The following options for long-term management of the road verge are presented for consideration, with evaluations of their attributes.

Option	Costs	Benefits and risks
1. Cleared verge planted with grass	Short term establishment costs likely to be moderate due to construction phase earthworks; long-term maintenance costs moderate, but requiring mowing and grounds maintenance	Risk of spread of planted grass, which is certain to be an exotic species, into the natural vegetation, which will compromise the integrity of the rainforest; disturbance of ground surface to plant grass, encouraging introduction of weeds
2. Landscaped verge	Costs of establishment very high - would require surfacing with material to be selected (natural mulch surface, gravel or geotech or similar to prevent weeds establisment), planting of landscape species, irrigation system and water supply; long-term high maintenance costs (irrigation etc.) moderate to high	Benefits include complete prevention of fire; use of disturbed top soil immediately which will prevent introduction of weeds; landscape plants would be native species of local province
3. Slashed and burnt verge	Short term costs low; long-term maintenance costs of annual slashing and burning moderate to low	Very small risk of igniting parts of the adjacent bush; requirement to have fire unit standing by; benefit of not allowing introduction of weeds through the verge

Each of these options has potential benefits and risks. The least preferred option is a grassed, mown verge because the grass will eventually invade the adjacent bush, increasing the risk of fire in the natural vegetation and compromising the naturalness of the bush. The maintenance costs, however, are not very high.

The other two alternatives have equal merit with regard to prevention of fire in the natural vegetation. A landscaped verge will provide immediate stabilisation of the earth disturbed during construction and prevent the establishment of weeds. A suitable surfacing material would need to be cost-effective and not introduce weeds. Mulch available commercially will almost certainly contain weed propagules and possibly also pathogens. Even the vegetation on the islands cannot be used because of the presence of weeds such as Lantana, albeit at low densities. The establishment and long-term maintenance costs are likely to be relatively high, but possibly affordable.

A slashed and burnt verge will take some time to establish vegetation after the construction phase, and may require assistance such as watering to establish plants, but has the benefit of producing the most natural vegetation in the long-term and will cost the least to establish. Maintenance would require annual slashing at the end of each wet season with a tractor-driven slasher or mower, followed some weeks later when the fuel dries out by a controlled burn of the residue to remove any fuel and prevent fires starting on the verge. Growth of natural vegetation after the wet season is minimal in most cases. The slashed and burnt verge would require the services of a bushfire consultant or the Bushfires Council NT each year to implement and supervise the burning.

Considering the length of road through the middle island, about 1.5 km, the best option may be to slash and burn the verge every year.

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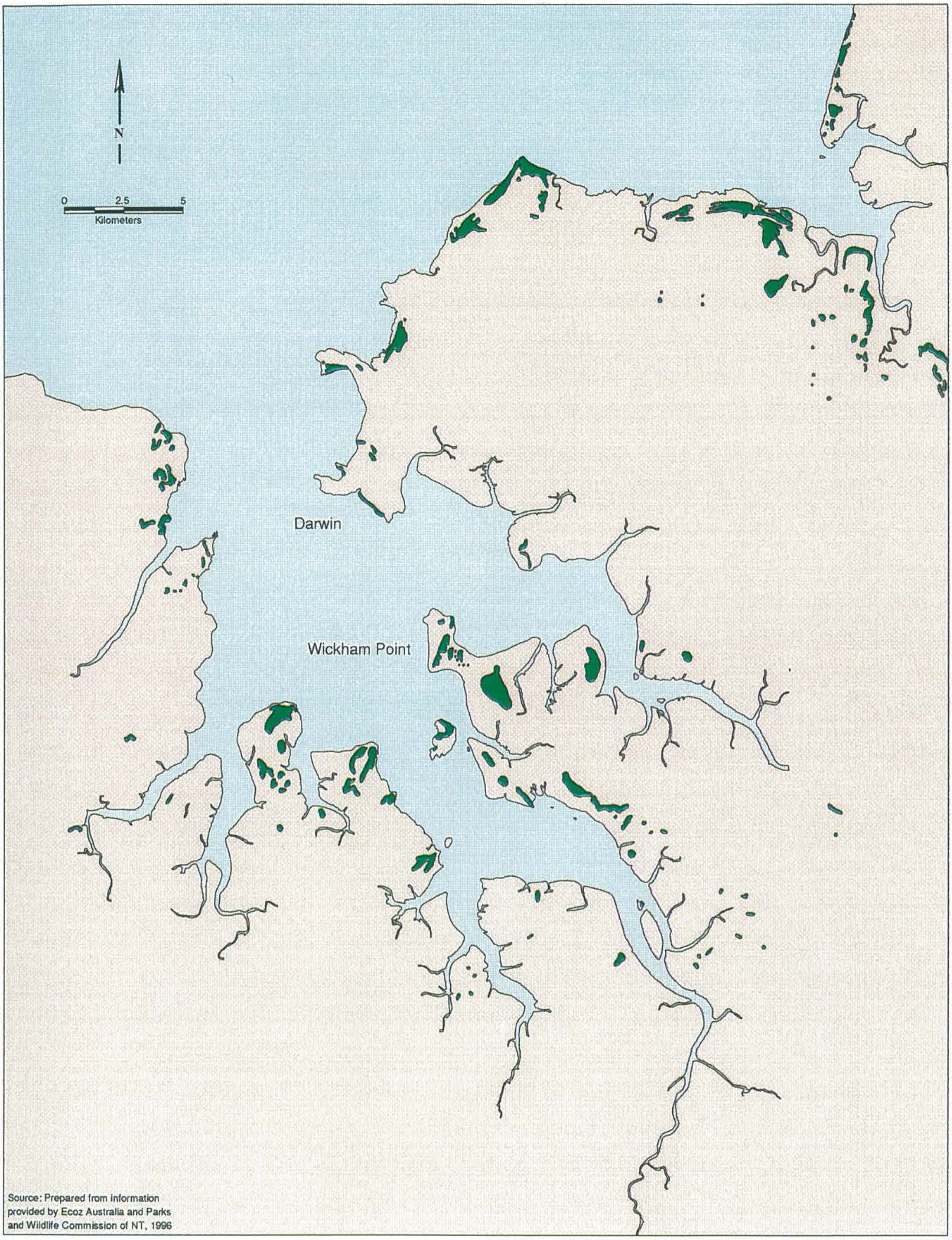

Dry Rainforest

Phillips Oil Company Australia

DARWIN LNG PLANT, DRAFT EIS

DRY RAINFORESTS DARWIN REGION

Figure V1

Phillips Oil Company Australia
DARWIN LNG PLANT, DRAFT EIS

VEGETATION COMMUNITIES OF WICKHAM POINT

Phillips Oil Company Australia

DARWIN LNG PLANT, DRAFT EIS

DRY RAINFORESTS DARWIN REGION

Figure V1

DAMES & MOORE PTY LTD
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DARWIN LNG PLANT, DRAFT EIS

VEGETATION COMMUNITIES OF WICKHAM POINT

DAMES & MOORE PTY LTD
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FIGURE V2

Phillips Oil Company Australia
DARWIN LNG PLANT, DRAFT EIS

LOCATION OF WICKHAM POINT SHOWING FLORA SURVEY SITES

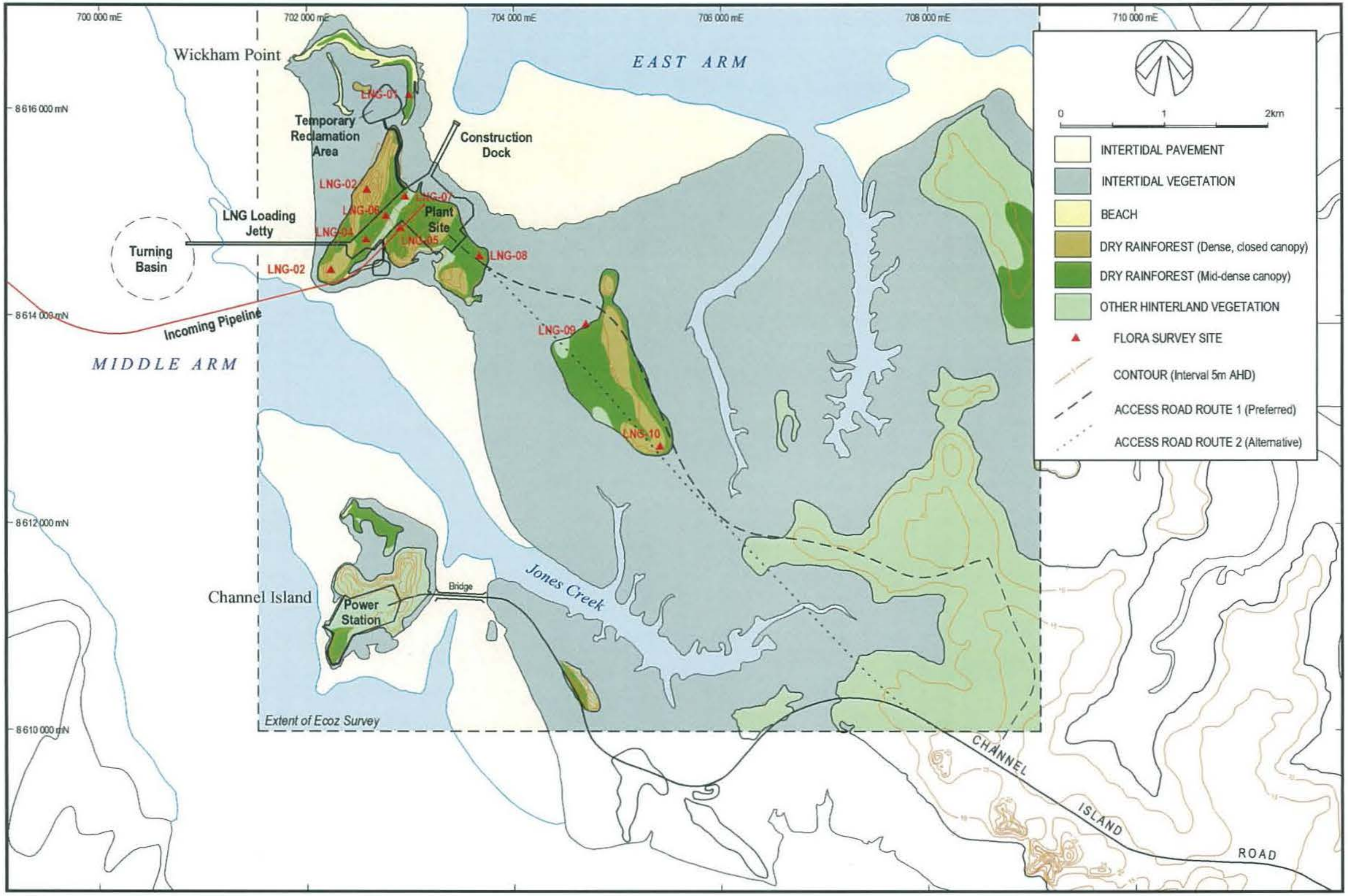

FIGURE V3

Appendix 1

Plant Species List
Wet and Dry Season Flora Surveys

The following is a checklist of plant species observed within the survey area in late September and October 1996 and during January and February 1997. Species from both hinterland 'islands' on Wickham Point and the area traversed by the proposed access track are listed by habitat. This listing is an accurate indication of floristic composition but is not a complete floristic inventory.

* denotes introduced species

Monsoon rainforest (vine-forest)

Abrus precatorius
Acacia auriculiformis
Adenia heterophylla
Aidia racemosa
Allophyllus cobbe
Alyxia spicata
Amorphophallus paeoniifolius
Ampelocissus acetosa
Antidesma ghesaembilla
Bombax ceiba
Brachychiton megaphyllus
Breynia cernua
Bridelia tomentosa
Caesalpinia bonduc
Calytrix sp.
Canarium australianum
Canthium sp.
Capparis sepiaria
Carthormion umbellatum
Cassytha filiformis
Celtis philippensis
Cheilanthes nitida
Cheilanthes sp.
Cissus adnata
Cissus reniformis
Clerodendrum inerme
Clerodendrum tatei
Commelina ensifolia
Cordia subcordata
Crinum angustifolium
Croton argyratus
Cupaniopsis anacardioides
Cynanchum carnosum
Dioscorea bulbifera
Dioscorea transversa
Diospyros calycantha
Diospyros compacta
Diospyros cordifolia
Dodonaea platyptera
Drypetes lasiogyna
Dysoxylum acutangulum
Ficus hispida

Elaeocarpus arnhemicus
Eucalyptus polycarpa
Eucalyptus tectifica
Exocarpus latifolia
Flacourtia territorialis
Flagellaria indica
Flueggia virosa
Ganophyllum falcatum
Glycosmis trifoliata
Gmelina schlechteri
Gymnanthera oblonga
Gymnema geminatum
Gyrocarpus americanus
Guettarda speciosa
Habernaria sp. affine elongata
Hakea arborescens
Helicteres hirsuta
Hibiscus tiliaceus
Hypoestes floribunda
Ichnocarpus frutescens
Jasminum molle
* Lantana camara
Litsea glutinosa
Livistona humilis
Lysiphyllum binatum
Opilia amentaceae
Malasia scandens
Maranthes corymbosa
Melicope elleryana
Micromelum minutum
Mimusops elengi
Myristica insipida
Nervilia holochila
Parsonsia velutina
* Passiflora foetida
Peltophorum pterocarpum
Pleomele angustifolia
Polyalthia australis
Polygala orbicularis
Pogonolobus reticulatus
Pouteria sericea
Premna acuminata
Sarcostemma sp.
Smilax australis
Sorghum sp
Stenocarpus verticis
Sterculia quadrifida
Strychnos lucida
Tabernaemontana orientalis
Tacca leontopetaloides
Tarenna dalachiana
Tinospora smilacina
Trema tomentosa
Vitex acuminata
Vitex glabrata

Whiteochloa capillipes
Zanthoxylum parviflorum
Ziziphus oenopolia

Mangrove

Acrostichum speciosum
Aegialitis annulata
Aegiceras corniculatum
Amyema sp.
Avicennia marina
Bruguiera exaristata
Bruguiera parviflora
Camptostemon schultzii
Ceriops decandra
Ceriops tagal var. australis
Cordia subcordata
Cymbidium canaliculatum
Cynanchum carnosum
Cynodon dactylon
Excoecaria ovalis
Fimbristylis sp. 1
Fimbristylis sp. 2
Hibiscus tiliaceus
Lumnitzera racemosa
Osbornia octodonta
Peltophorum pterocarpum
Rhizophora stylosa
Rhynchospora sp.
Sesuvium portulacastrum
Sonneratia alba
Tecticornia australasica
Thespesia populneoides
Xylocarpus mekongensis

Eucalyptus woodland

Alstonia actinophylla
Buchanania obovata
Brachychiton diversifolius
Cycas armstrongii
Cymbopogon sp.
Eucalyptus tectifica
Eucalyptus bleeseri
Eucalyptus clavigera
Eucalyptus miniata
Eucalyptus tetrodonta
Erythrophleum chlorostachys
Hakea arborescens
Ipomoea pes-caprae
Gardenia sp.(prob. megasperma)
Grevillea decurrens
Livistona humilis
Lophostemon lactifluus
* Pennisetum polystachion
Petalostigma quadriloculare

Sarcostemma australis
Themeda triandra
Terminalia ferdinandiana
Vitex glabrata
Xanthostemon paradoxus

Melaleuca woodland

Acacia auriculiformis
Acacia holosericea
Alphitonia excelsa
Ampelocissus acetosa
Cassytha filiformis
Cheilanthes sp.
Clerodendrum tatei
Commelina ensifolia
Cupaniopsis anacardioides
Dioscorea transversa
Elaeocarpus arnhemicus
Eucalyptus polycarpa
Eucalyptus tectifica
Flagellaria indica
Gardenia megasperma
Grevillea decurrens
Gymnanthera oblonga
Helicteres A78389
* Hyptis suaveolens
Ipomoea abrupta
Jasminum molle
Melaleuca acacioides
Melaleuca cajuputi
Melaleuca viridiflora
Melaleuca leucadendra
Persoonia falcata
Pandanus spiralis
Premna serratifolia
Protoasparagus racemosus
Sauropus sp.
Smilax australis
Syzygium eucalyptoides ssp. bleeseri
Tacca leontopetaloides
Tarenna dalachiana
Urena lobata
Vitex acuminata
Xanthostemon paradoxus

Appendix 2

Plant Community Descriptions

Mangrove (Intertidal) Areas

<u>Seaward Zone (Map unit 1)</u>
The seaward zone occurs as an almost continuous band lying roughly parallel to the shore of Wickham Point. Within the survey area this zone varies in width from several trees to almost 200 m. The seaward zone lies close to mean sea level between -1 and 1.0 m AHD. Inundated twice daily, substrates are deep unconsolidated muds contoured with deep drainage channels.

This zone typically comprises large, well spaced trees of *Sonneratia alba* characteristic of the seaward shore of Darwin Harbour generally. Associated species include low, shrubby *Aegialitis annulata* to 1.5 m and patches of *Aegiceras corniculatum* to 2.5m. *Rhizophora stylosa* becomes common to landward but *Sonneratia* typically forms a monospecific stand with a woodland structural formation and average canopy height of 4 to 6 m (Wightman 1989).

<u>Shoreline mangrove (Map unit 2)</u>

To landward, the seaward zone typically merges with either the shoreline zone (Map unit 2) or the tidal creek community (Map unit 3). In both zones *Rhizophora stylosa* is the dominant mangrove species, typically forming a closed canopy forest from 6 to 10 m tall. On rocky shoreline areas a mixture of mangrove species occurs. Here *Rhizophora stylosa* grows in association with *Sonneratia alba, Osbornia octodonta* and *Aegialitis annulata* forming an irregular closed to open forest community 3 to 7 m high.

Fully developed shoreline mangrove comprises *Rhizophora* dominated forests which are the tallest mangrove forests within Darwin Harbour, often forming stands to 10 m high with diameter at breast height (dbh) to 20 cm and branching prop roots up to 2.5 m above the ground surface. Access and construction through these dense forests is extremely difficult and the soft substrate hampers the use of heavy machinery.

<u>Tidal creek (Map unit 3)</u>

Rhizophora stylosa is the dominant species along the numerous winding tidal channels, and being the tallest mangrove formation, clearly demarcates the location of major channels within the tidal flat. Amongst *Rhizophora stylosa* which forms a closed canopy forest, large *Avicennia marina* trees occur to 15m high. A mid-stratum layer of *Bruguiera parviflora*, forming a dense band of trees to 4m tall commonly occurs on the crests of tidal channels. *Camptostemon schulzii* becomes the dominant mid-stratum tree on the slopes of the numerous tidal channels and small creeks and often overhangs the larger channels. Lying between 1.0 and 2.5 m AHD this zone receives regular tidal inundation and has deep root-structured muds.

<u>Mid tidal flat (Map unit 4)</u>
The most extensive mangrove communities occur on the broad tidal flats flanking the taller, more frequently inundated seaward zones. The mid tidal flat zone occurs between 2 and 3.5 m AHD and supports an almost monospecific low closed forest of *Ceriops tagal*. *Ceriops* forms dense, low forests typically with a closed canopy 2 to 4 m high. The mid tidal flat zone is inundated every fortnight by spring tides, and substrates tend to be firm sandy to gravelly muds with very high soil salinities. Tree height varies in direct response to salinity and freshwater inflow.

Upper tidal flat (Map unit 5)

The upper tidal flat is also a community in which *Ceriops tagal* is dominant forming dense largely monospecific stands 1.5 to 4 m high. Occurring between 2.5 and 3.5 m AHD this zone receives inundation during spring tidal cycles. *Avicennia marina* is a common species in this community occasionally becoming co-dominant, particularly to landward.

Also within the upper tidal flat, extensive bare hypersaline flats occur where salinity rises above that tolerated by mangroves (Map unit 8).

Hinterland (Map unit 6)

At the junction between the mangroves and the hinterland a variable mangrove community occurs. In areas of freshwater seepage, the *Melaleuca* and dry rainforests of the hinterland typically abut a dense closed canopy forest dominated by *Ceriops tagal* 6 to 8 m high. In areas devoid of freshwater input a low shrubland of *Avicennia marina* may occur.

Lying roughly between 3.5 and 4.0 m only the highest tides inundate this area and its species composition is heavily influenced by edaphic conditions on the adjacent hinterland. Associated species include *Bruguiera exaristata, Lumnitzera racemosa* and *Excoecaria ovalis.*

Mixed species low woodland (Map unit 7)
Typically occurring between the mid and upper tidal flats and the high water mark this zone comprises a low woodland mangrove association with *Avicennia marina, Lumnitzera racemosa* and *Ceriops tagal* (2 to 4 m high). This community is found on highly saline, infrequently inundated substrates between 2.5 and 4 m AHD.

Samphire/Salt flat (Map unit 8)

These extensive hypersaline flats occur between 2.5 and 3.5 m AHD. Salt flats are either devoid of vegetation or support scattered samphire species including *Suaeda arbusculoides, Halosarcia halocnemoides* and *Tecticornia australasica*. Very infrequent tidal inundation and high evaporation rates boost the soil salinity to levels toxic even to mangroves and mangrove species. However *Avicennia marina, Aegialitis annulata* and *Ceriops tagal* may occur as stunted trees often less than 1m tall fringing the edge of salt flat areas.

Upland or Hinterland Vegetation Communities

Beach (Map unit 9)
A low beach ridge, approximately 60 m wide, composed of fine sand and shell grit with scattered shell middens occurs on the northern tip of Wickham Point. At flora site LNG-01 woodland to open woodland structural formation occurs (CSR 1.08, 20% crown cover) with dominant species including *Acacia auriculiformis, Sterculia quadrifida* and *Gyrocarpus americanus*. The upper stratum layer contains a large proportion of deciduous species adapted to the excessively drained sandy substrates. The average canopy height is 5 m with a top height of 8 m.

A variable mid-stratum layer (CSR 1.8, 11% crown cover) at 2 to 3 m high comprises dominant species including *Diospyros cordifolia, Dodonaea platyptera* and *Drypetes lasiogyna*. During the wet season, this community supports dense growth of entwining vines (see Photographs, Site LNG-01 in Appendix 3). Common vine species include *Abrus* *precatorius, Tinospora smilacina, Capparis sepiaria, Gymnema geminatum* and *Gymnanthera oblonga.*

The high light conditions and relatively unstable substrates in the beach habitat are suitable conditions for several weed species including *Lantana camara* and the grass *Pennisetum polystachion.* On lower beach dune areas the vine *Ipomoea pes-caprae* was common and the yam *Tacca leontopetaloides* became seasonally abundant beneath the beach woodland canopy.

Dry rainforest - closed canopy (Map unit 10)
The majority of the survey area is vegetated with dry rainforest. Aerial photography of the site reveals two distinct formations within this vegetation type which have been mapped and are broadly referred to and as dense, closed canopy dry rainforest (Map unit 10) and mid-dense canopy dry rainforest (Map unit 11).

Within the closed canopy forests the dominant emergent trees at 4 to 7 m in height include *Acacia auriculiformis, Sterculia quadrifida, Canarium australianum* and *Cupaniopsis anacardioides.* These sparse emergents (Crown Separation ratio 0.78 or 26 % crown cover) are typically semi-deciduous and in this formation grow just above a dense mid-stratum layer with a relatively closed canopy (estimated up to 90% crown cover). *Sterculia quadrifida* is the most common emergent tree on ridge tops with *Eucalyptus bleeseri* often found on rocky sideslopes.

The mid-stratum is dominated by *Drypetes lasiogyna* with *Glycosmis trifoliata, Cupaniopsis anacardioides, Diospyros compacta* and *Micromelum minutum* as co-dominant or locally abundant species. Many evergreen species were observed in extremely wilted form during the late dry season survey. Numerous deciduous species including vines and shrubs were partially or completely leafless at this time.

Vine species were particularly abundant often forming a dense entwining mass over and through the mid-stratum canopy during the wet season. Dominant vine species in Map Unit 10 include *Adenia heterophylla, Ichnocarpus frutescens, Ampelocissus acetosa* and *Dioscorea transversa.*

Many vine species grew from yams or bulbs after the onset of seasonal rains. Other ground stratum species including *Tacca leontopetaloides* and the fern *Cheilanthes* sp regrew from bulbs or perennial rootstock during the wet season. The increased species richness and canopy cover is clearly apparent in the photographs taken from the permanent site pegs during wet and dry season surveys (Appendix 3).

Sites LNG- 02, LNG-03 and LNG-10 are located within this vegetation formation which appear on preliminary investigation to be characterised by steep to gently inclined terrain, sandy loam soils with high rock content and dense leaf litter. The abundance of evergreen species such as *Diospyros compacta, Cupaniopsis anacardioides, Drypetes lasiogyna* (estimated 30 to 40 % cover), and *Glycosmis trifoliata* (to 55% cover) appear to distinguish this formation floristically as well as structurally from the less dense dry rainforest areas.

Small pockets of tall more luxuriant evergreen rainforest occur, particularly on the westernmost major ridge incorporating Peak Hill. Tall *Maranthes corymbosa* trees (to over 15 m) and species indicative more moist conditions such as *Polyalthia australis, Myristica insipida* and *Ficus hispida* were found in this location.

Dry rainforest -mid dense canopy (Map unit 11)

Sites LNG-04, LNG-05, LNG-08 and LNG-09 are located within dry rainforest formation with a less dense mid-stratum canopy. As Figure V.3 indicates, this vegetation type (Map unit 11) is more widespread than Unit 10 which is largely restricted to the ridges and rocky rises on the two islands.

This formation is characterised by gently to very gently inclined terrain on mid to lower slopes with sandy loam soils with high gravel (rather than rock) content. Our survey indicates that the upper stratum is invariably dominated by *Acacia auriculiformis* to an average height of 6 m with scattered eucalypts such as *Eucalyptus polycarpa*, and *Eucalyptus tectifica* (CSR 1.0 or 20% crown cover).

The estimated dry season crown cover of the mid-stratum varies between 15 to 30% with a highly variable floristic composition which largely appears to reflect varying soil moisture conditions. In areas of apparently higher soil moisture content the vine *Flagellaria indica* and the low evergreen tree *Drypetes lasiogyna* are dominant. On excessively drained substrates the slender semi-deciduous trees *Hakea arborescens* and *Dodonaea platyptera* assume dominance of the mid-stratum canopy. Deciduous species including *Strychnos lucida, Sterculia quadrifida* and *Vitex glabrata* and common in this vegetation type. The introduced woody shrub, *Lantana camara* is a common component of scrubby areas and the more open canopy allows the growth of sparse grasses in the ground layer. The presence of dense thickets of spiny *Lantana* to 2m high and vigorous and abundant growth of vines makes access through this terrain quite difficult.

Littoral Woodland (Map unit 12)

Small areas of *Eucalyptus*-dominated woodlands occur as a relatively narrow band fringing mangrove areas on the western island. Substrates are highly variable but include shallow, gravelly soils of sandstone, shale and phyllite origin. The general cover of dry rainforest thins out to a woodland and open woodland structural formation in these areas with *Eucalyptus tectifica* the dominant upper stratum tree 6 to 8 m tall. Common secondary trees include *Brachychiton diversifolius* and *Sterculia quadrifida.*

The complex mid-stratum layer to 6 m high is mainly composed of low trees, and dominant species may include *Dodonaea platyptera, Hakea arborescens* and *Acacia auriculiformis.* Other mid-stratum species include *Strychnos lucida, Drypetes lasiogyna, Exocarpus latifolia and Pandanus spiralis. Melaleuca leucadendra* is locally abundant adjacent to the mangroves. Vine species include *Gymnanthera oblonga, Opilia amentacea* and *Ichnocarpus frutescens.*

Melaleuca woodland (Map unit 13)

A broad seasonal drainage way traverses the western island occupying the low valley between two roughly parallel ridges. The dominant species along the drainage way is *Melaleuca viridiflora* and *Melaleuca leucadendra.* Both species form a low woodland community with an average height of 5 to 6 m. *Pandanus spiralis*, indicative of seasonally wet conditions is a common to co-dominant species. Eucalypts including *Eucalyptus polycarpa* and *E. tectifica* are common scattered along the fringes, the former being the most abundant. *Acacia auriculiformis* may become co-dominant with *M. viridiflora.*

Sites LNG-06 and LNG-07 are located within this habitat. The terrain is typically very gently inclined with large areas of bare ground evidence of scour from surface water flow. Soils include light clays and very fine sandy loams. The only pooling of fresh water on the two islands was observed here during the wet season. At that time, Agile Wallabies were abundant in this habitat.

Mid stratum species include the low trees and shrubs *Acacia auriculiformis, Elaeocarpus arnhemicus* and *Drypetes lasiogyna.* Common component species also include *Pandanus spiralis, Pouteria sericea* and *Persoonia falcata.* During the wet season the clay loam soils remain damp for extended periods supporting the growth of mosses and ferns *(Cheilanthes* sp.)

Sedgeland and grassland (Map unit 14)

A small area of grassland/sedgeland occurs on the northwestern tip of the central hinterland island (see Vegetation Map). This area is roughly basin shaped and vegetated with grasses and sedges (*Cyperus* spp.) tolerant of brackish conditions and seasonal waterlogging. Scattered shrubby trees include *Thespesia populnea* (a mangrove species) and *Melaleuca viridiflora* (broad-leaved paperbark) - both indicative of seasonally wet and possibly brackish conditions. It is probable that this area becomes a seasonal swampland and may be underlain by shallow rocks, resulting from a perched water table. The entwining vine, *Flagellaria indica* was also present, amongst the scattered low *Thespesia populnea*.

Species richness

Species richness for each of the survey sites is shown in the following table. One site, LNG-08 was not re-surveyed during the wet season due to lack of time.

Species richness of the survey sites

Survey site	Map Unit	Vegetation type	Species richness		
			Dry season	Wet season	Wet & dry season total
LNG-01	9	Beach	20	+8	28
LNG-02	10	Dry rainforest - dense	20	+6	26
LNG-03	10	Dry rainforest - dense	28	+9	37
LNG-04	11	Dry rainforest - mid-dense	21	+11	32
LNG-05	11	Dry rainforest - mid-dense	21	+13	34
LNG-06	13	Melaleuca woodland	11	+10	21
LNG-07	13	Melaleuca woodland	19	+7	26
LNG-08	11	Dry rainforest - mid-dense	19	- (not re-surveyed)	-
LNG-09	11	Dry rainforest - mid-dense	14	+11	25
LNG-10	10	Dry rainforest - dense	16	+17	34

Appendix 3 Photographs of survey area, plant communities and flora survey sites.

Aerial view of southwestern tip of Wickham Point peninsula - the main location of the proposed LNG plant. The main jetty will extend from the point (front right hand of photo) and the majority of the plant will be located behind the main rocky ridge (to left). The mangrove zone separating the western hinterland island from the eastern can be seen at centre right.

Aerial view of Wickham Point from northernmost tip showing extensive areas of mangroves and saltflats. The beach habitat is visible in the foreground and the main longitudinal ridge including Peak Hill is seen at centre back. Channel Island and Darwin's Gas-fired Power Station is visible at back right.

Southwestern are of Wickham Point showing clear zonation within mangroves (seaward, Rhizophora, tidal flat and hinterland margin zones from left to right); areas of dense and mid-dense canopy vine thicket and salt flats.

Wickham Point Vegetation Communities

Pandanus spiralis in Melaleuca woodland habitat with thick 'skirt' of unburnt dead leaves and old leaf bases - evidence that fire has been absent from this area for a long period of time.

Unburnt leaf bases on *Pandanus spiralis*. It is thought that there has been no fires at Wickham Point for several decades.

Habitat : Dry rainforest typical of Wickham Point

Dry rainforest habitat (mid-dense canopy) is thhe most widespread vegetation association containing a high proportion of deciduous and semi-deciduous species. Species such as *Strychnos lucida* becomes completely leafless during the dry season.

Dry rainforest, mid-dense canopy on the Eastern island of the peninsula. Common trees in this vegetation association include *Hakea arborescens* and *Dodonaea platyptera*.

Habitat : Dry rainforest typical of Wickham Point

Dry rainforest comprises decidous and evergreen species. During the dry season certain evergreen species such as *Aidia racemosa* (background at left) retain their leaves in extemely wilted form.

Mangrove Habitats

Low closed forest of *Ceriops tagal*. The most extensive mangrove community surrounding Wickham Point. *Ceriops tagal* forms monospecific stands 2 to 4 m high on consolidated muds in the upper tidal zone. These areas receive tidal inundation by spring tides reaching above 2.5m AHD, every fortnight.

Rhizophora stylosa is the dominant mangrove species lining tidal creeks, its distribution clearly defines the location of tidal channels. A band of *Rhizophora stylosa* also occurs to landward of the Sonneratia or Seaward mangrove zone, lying roughly parallel to the shore.

Map Unit 9 **Habitat : Beach**

Site LNG-01 Dry season flora survey 27 September 1996

Site LNG-01 Wet season flora survey 14 January 1997

Map Unit 9 Habitat : Beach

Site LNG-01 Dry season flora survey 27 September 1996

Site LNG-01 Wet season flora survey 14 January 1997

Map Unit10 Habitat : Dry rainforest (Dense, closed canopy)

Site LNG-02 Dry season flora survey 27 September 1996

Site LNG-02 Wet season flora survey 14 January 1997

Map Unit10 Habitat : Dry rainforest (Dense, closed canopy)

Site LNG-02 Dry season flora survey 27 September 1996

Site LNG-02 Wet season flora survey 14 January 1997

Map Unit 11 Habitat : Dry rainforest (mid-dense canopy)

Site LNG-04 Dry season flora survey 26 September 1996

Site LNG-04 Wet season flora survey 14 January 1997

Map Unit 11 Habitat : Dry rainforest (mid-dense canopy)

Site LNG-04 Dry season flora survey 26 September 1996

Site LNG-04 Wet season flora survey 14 January 1997

Map Unit 11 Habitat : Dry rainforest (mid-dense canopy)

Site LNG-05 Dry season flora survey 26 September 1996

Site LNG-05 Wet season flora survey 14 January 1997

Map Unit 11 Habitat : Dry rainforest (mid-dense canopy)

Site LNG-05 Dry season flora survey 26 September 1996

Site LNG-05 Wet season flora survey 14 January 1997

Map Unit 13 Habitat : Melaleuca woodland

Site LNG-06 Dry season flora survey 29 September 1996

Site LNG-06 Wet season flora survey 14 January 1997

Map Unit 13 Habitat : Melaleuca woodland

Site LNG-06 Dry season flora survey 29 September 1996

Site LNG-06 Wet season flora survey 14 January 1997

Map Unit 13 Habitat : Melaleuca woodland

Site LNG-07 Dry season flora survey 29 September 1996

Site LNG-07 Wet season flora survey 14 January 1997

Map Unit 13 Habitat : Melaleuca woodland

Site LNG-07 Dry season flora survey 26 September 1996

Site LNG-07 Wet season flora survey 14 January 1997

Appendix 4 Description and Photographs of Vegetation Communities traversed by the Main Access Road

The main access road branches from the Channel Island road at the location of an existing bush track leading to the north. Large electricity transmission towers are situated adjacent to the track, and the easement crosses the alignment from NW to SE.

0 to 1.4 km - The access road traverses northwards over a well-drained, low plateau surface with pale yellow sandy loam soils. The dominant vegetation is Eucalyptus dominated woodland community 14 to 18 m tall, a vegetation association typical of much of the Darwin region generally. The dominant species include *Eucalyptus miniata* and *E. tetrodonta* on the shallow yellow and deeper red plateau soils respectively. *Erythrophleum chlorostachys* (Ironwood) is a common canopy forming species which occasionally becomes co-dominant, particularly on sideslopes. Other *Eucalyptus* species include *Eucalyptus bleeseri* on the rocky plateau surface, and *Eucalyptus clavigera* and *Eucalyptus tectifica* on skeletal soils particularly on the plateau margins.

The mid-stratum layer includes juvenile trees from the upper stratum layer and the palm *Livistona humilis* and the cycad *Cycas armstrongii. Acacia* spp and *Pandanus spiralis* are also common components of the understorey layer. This vegetation appears to have been burnt regularly if not annually, and annual grasses with abundant regrowth from lignotubers are common components in the ground stratum.

A minor drainage way occurs at 0.4 km where *Eucalyptus polycarpa, Lophostemon lactifluus* and *Erythrophleum chlorostachys* comprise the dominant species. Also fringing the drainage way are areas of paperbark (*Melaleuca viridiflora*) and abundant *Pandanus spiralis.*

1.4 km to approx 2.5 km The access road branches off from the existing dirt track to the west at approx 1.4 km. The road then continues in a relatively straight course to the edge of the low plateau surface and the mangrove margin. Vegetation appears to be largely similar to the first section of the track with Eucalyptus dominated woodlands on well drained soils.

The hinterland peninsula ends amongst *E. tectifica* open woodland to 8 m . A sparse mid stratum layer with scattered *Pandanus spiralis* and *Cycas armstrongii* occurs over a dense grass layer. This community merges with a narrow grassland including *Themeda* spp which fringes the mangroves.

2.5 to 3.0 km approx. The edge of the mangrove zone comprises a low woodland of *Ceriops tagal* (2 to 4 m) and *Lumnitzera racemosa* on the hinterland fringe. Substrates are saline gravelly to sandy muds and small salt flat areas are common in the vicinity.

The access road alignment through the mangroves will largely traverse the upper tidal zone comprising low closed forests of *Ceriops tagal* . This community is characterised by dense monospecific stands (2 to 4 m high) on consolidated muds interspersed with occasional bare salt flat areas. In locations where the access road crosses tidal creeks the tidal creek zone will be traversed. Here, *Rhizophora stylosa* is dominant, forming dense closed forests. The lower tidal zone (below 2 m AHD) is inundated by regular tides and this community typically occurs on deep, root structured muds.

Main Access Road

Start of main access road at its junction with Channel Island road. *Eucalyptus* dominated woodland to open forest community typical of this part of the survey area. Dominant species include *E. bleeseri* and *E. miniata* (to 15 m) with *Erythrophleum chlorostachys* on gentle sideslopes. Substrates include well drained yellow sandy loams with abundant lateritic gravel.

1.1 km along access road. Well drained plateau surface with *E. tetrodonda* and *Erythrophleum chlorostachys* woodland community (to 15 m), with a sparse to mid-dense understorey. Pale yellow sandy loam soils.

Main Access Road

1.4 km. Area where access road branches from existing bush track. *E. miniata* woodland to open woodland, with *Erythrophleum chlorosachys, E. clavigera* and *E. tetrodonta*. Sparse understorey layer over shallow gravelly soils.

2.5 km approx. Edge of low plateau surface and western tip of hinterland peninsula. *Eucalyptus tectifica* open woodland (to 8 m tall) merges with grasslands on edge of mangroves (see next photo)

Main Access Road

Edge of mangrove zone where main access road traverses upper mangrove zone to the 'second island'. Mangrove vegetation includes low woodland of *Ceriops tagal* (2 to 4 m) and *Lumnitzera racemosa* on hinterland fringe. Substrates are saline gravelly to sandy muds.

Approx 2.8 km . Low closed forest of *Ceriops tagal* . This community is characterised by dense monospecific stands (2 to 4 m high) on consolidated muds interspersed with occasional bare salt flat areas.

Main Access Road

Closed forest of *Bruguiera parviflora* and *Rhizophora stylosa*. This community occurs as a narrow transition zone fringing tidal creeks. The transition zone separates the extensive *Ceriops* dominated tidal flats from the *Rhizophora* dominated creek lines.

Rhizophora stylosa community forms dense closed forests in the lower tidal zone (below 2 m AHD). Inundated by regular tides *Rhizophora* typically occur on deep, root stuctured muds. The access road will traverse these habitats where tidal creeks must be crossed.

Appendix I

DAMES & MOORE PTY LTD
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REPORT

Darwin LNG Plant
Draft Environmental Impact Statement

Appendix I
Terrestrial Fauna Study, Wickham Point

for

Phillips Oil Company Australia

Ref: 00533-164-073
Report No. R635
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REPORT

**TERRESTRIAL FAUNA STUDY
WICKHAM POINT
for
PhillipsOil Company Australia**

1. INTRODUCTION

Dames & Moore has been commissioned to conduct a series of detailed baseline environmental studies of the Wickham Point area, in Darwin Harbour, Northern Territory. These studies relate to a proposal by Phillips Petroleum Company to establish a Liquefied Natural Gas (LNG) plant at the site and the requirement for preparation of an Environmental Impact Statement (EIS).

This report provides information on the terrestrial vertebrate fauna found or expected in the vicinity of the proposed LNG Plant site at Wickham Point, including the main island (where the plant and jetty will be located), and the central island and mainland Middle Arm Peninsula (which the proposed access route will traverse). The information has been obtained through reference to existing data and direct field observations.

2. SCOPE AND METHODOLOGY

2.1 OBJECTIVES

The objectives of the fauna study were to:

- describe the terrestrial vertebrate fauna (amphibians, reptiles, birds and mammals) of the area, and to provide information on the relative abundance and habitat requirements of each species;
- determine the presence of any species of special conservation significance, such as migratory, rare, threatened or restricted species, and assess their local and regional status;
- assess the ecological significance of the area as a wildlife refuge, roosting or breeding habitat, a corridor for wildlife movement and habitat for migrating species.

2.2 HABITATS AND SAMPLE SITES

The survey area comprises two small islands and the adjacent mainland peninsula located between East Arm and Middle Arm in Darwin Harbour. The islands and mainland are fringed by mangroves and mudflats, which are inundated at high tide. The vegetation of the site includes various mangrove associations, beach vegetation, monsoon vine forest and woodland habitats, which are described in EcOz (1997). Five habitat types were recognised for the purpose of the fauna survey. The characteristics and extent of these habitats are briefly described below.

Eucalyptus Open Forest (EOF). Open forest and woodland dominated by *Eucalyptus* species is mostly confined to the mainland peninsula, but occurs as very small patches on the two islands. Some minor, patchy areas of grassland and sedgeland around the edge of the mainland peninsula have been included in this habitat. This habitat supports fauna species not generally associated with coastal environments.

Mangroves, Margins and Samphires (MAN). The islands and mainland areas are fringed with extensive mangrove communities in most areas. The mangrove fringe areas include the interface with adjacent landward habitats such as monsoon vine forest and *Melaleuca* forest. Extensive samphire flats with occasional mangrove patches and sedge patches occur especially in the areas between the islands and across the northwestern side of the main island.

Monsoon Vine Forest (MVF). Dense, closed vine forests cover most of the elevated areas of the main and central islands. This vegetation is most dense along the ridge tops of the two hills on the main island and is relatively sparse in other areas.

Paperbark Woodland (PAW). Where wet season freshwater flow or seepage areas occur, a *Melaleuca* dominated woodland is present. This habitat is common along the mangrove margins around the perimeter of the main island and in the low-lying central section between the two hills.

Intertidal Flats (ITF). This habitat includes the extensive mudflats and small rocky reefs which are exposed, principally around the main island at low tide.

2.3 SURVEY METHODS

Prior to undertaking field surveys, a review of existing information was undertaken, including gathering of relevant reports and papers. Databases consulted included the Department of Lands, Planning & Environment's (DPLE) Coastal Resources Atlas and the Biological Records Scheme.

Two field surveys were undertaken to the site. The first was in September 1996, and was designated as a "dry" season survey. The second survey was undertaken during the wet season, in February 1997. The main limitations of the surveys were the difficult access to the site and difficulty in traversing areas due to the dense vegetation. Access was gained to the main and central islands either by boat or helicopter, while the mainland peninsula was accessed by vehicle and on foot.

Small mammals and reptiles were surveyed using a number of live trapping methods under a Parks and Wildlife Commission of the Northern Territory "Licence for Scientific Research or Investigation" (No.3809). Live capture/release methods included aluminium type A Elliot box traps, aluminium type B Elliot box traps and wire cage traps for medium sized mammals. Elliot traps were placed at ten metre intervals along transects in an index-line method. Traps were baited with a varied mixture of peanut butter, rolled oats, fish and dog food. Traps were operated over a two-night period at each trap site. Locations of traplines are shown in Figure 1.

Microchiropteran bat echolocation calls were recorded using an ultrasonic bat call detector (Anabat II; Titley Electronics). This method enables individual species to be determined by comparison with computer based reference calls. Ultrasonic detection was undertaken throughout the mainland portion of the proposed access corridor and on the margins of mangroves in the central island access corridor.

Birds were identified as encountered, and the habitat and site recorded. Specific bird surveys were conducted throughout representative habitats mainly during the early morning. Surveys were conducted by traversal of transects within selected habitats, with counts divided into 10 minute periods. Point census counts were also taken in mangrove locations from a boat. Notes on species, numbers and activity of birds observed were recorded. Additional bird species records were compiled incidentally, during spotlight survey and from vocalisations. Nocturnal species were recorded during spotlight surveys and identified from characteristic calls.

Active searching for reptiles, amphibians and small mammals included scanning of trees and ground, removal of cover such as rocks and fallen logs and peeling the bark from trees. Large mammals were recorded when encountered during trapping, bird survey and spotlight survey, and along roads and tracks throughout the study area. Observations of wildlife outside the main sampling sites were recorded according to the habitat in which they were observed.

Spotlighting on foot using 50-watt hand-held spotlights was undertaken throughout mainland areas of the proposed access corridor. Spotlighting from a slow moving vehicle was undertaken along the main tracks through this area. Low watt hand held torches were also employed during foot surveys to detect nocturnal reptiles and amphibians.

Indirect fauna records were compiled from evidence of fauna presence, including tracks, traces, scats, tree marks, nests, skeletal remains or other signs. Searches of predator scats suitable for analysis of hair and bone fragments were also undertaken. A hair tube was set in some locations to gather mammalian hair samples.

Taxonomy and common name usage in this report generally conforms to the following standard references: reptiles & amphibians – Cogger (1996); birds - Christidis & Boles (1994); and mammals – Strahan (1995).

3. RESULTS

3.1 REVIEW OF EXISTING DATA

Although the study area is close to the city of Darwin, it is very difficult to access. Consequently, no previous studies on the fauna of the region include primary data from Wickham Point. Nevertheless, a number of studies have been conducted on the terrestrial fauna of the Darwin Harbour area and these are directly relevant to the study site.

Significant studies undertaken prior to 1993 have been reviewed by Dames & Moore (1993a). These include a number of survey reports undertaken as components of EIS studies including Channel Island (Caldwell Connell 1983), Bayview Haven (Dames & Moore 1991), Darwin South (Dames & Moore 1993b) and East Arm (Dames & Moore 1990). McKean & Martin (1986) assessed the bird fauna of Darwin Harbour and provided information on habitat quality and a list of 128 species which regularly occur in littoral areas. A long-term study of mangrove birds near Palmerston (East Arm) documented ecological information on about 50 species (Noske 1996). Other general sources of information on the birds of Darwin were consulted, including Thompson & Goodfellow (1987) and Goodfellow (1996).

In summary, the bird fauna of Darwin Harbour is relatively well known, while data on the amphibians, reptiles and mammals are restricted to scattered reports and observations obtained mostly during the course of other EIS studies.

3.2 SPECIES DIVERSITY AND HABITAT PREFERENCES

3.2.1 Survey Results

A total of 123 terrestrial vertebrate species were recorded during field surveys of the study area (Table 1). Detection of bat echolocation calls (Anabat II) produced four insectivorous bat species and the trapping program produced one reptile and three mammal species (Table 2).

3.2.2 Amphibians

Seven frog species were recorded during the survey (Table 1). All were found only during the wet season survey in the Eucalyptus open forest habitat of the mainland peninsula. Frogs were common in waterlogged sedge areas and especially around a seasonally flooded gravel quarry near the proposed access route. The most common species were Brown Tree Frog (*Litoria rothi*) and Dwarf Tree Frog (*Litoria bicolor*).

No amphibians were observed on the main or central islands. These habitats are hostile to amphibians, which generally require freshwater for breeding, and are intolerant of saline conditions. Some seasonal freshwater areas do exist on the islands, so it is possible that frogs may occur there. Four species, Dwarf Tree Frog, Green Tree Frog (*Litoria caerulea*) Desert Tree Frog (*Litoria rubella*) and Marbled Frog (*Limnodynastes convexiusculus*) have been previously recorded in mangrove margin and littoral habitats in the Northern Territory (Milward 1982; Dames & Moore 1991; 1993b).

3.2.3 Reptiles

Eleven species of reptile were recorded during the survey, including one crocodile, and ten lizards (Table 1).

The most common species were small skinks of the genus *Carlia*, of which three species were observed. *Carlia munda* was the most abundant species and was found in all non-marine habitats. *Carlia amax* was only observed around rocky areas within the monsoon vine forest. Two skinks, *Glaphromorphus darwiniensis* and *G. douglasi* were generally confined to the monsoon vine forest and paperbark forest habitats. The latter species, which was common at Wickham Point, is the only reptile species known to have a preference for rainforest habitats in the Darwin area (Martin & Freeland 1988).

Estuarine Crocodiles (*Crocodylus porosus*) occur in Darwin Harbour and a management program for this species is in effect in the area. Crocodiles were occasionally seen on the mudflats and in the small mangrove creeks around Wickham Point.

TABLE 1

TERRESTRIAL FAUNA OF WICKHAM POINT

EOF=Eucalyptus Open Forest; MVF=Monsoon Vine Forest; MAN= Mangroves, Margins & Samphires; PAW=Paperbark Woodland; ITF=Intertidal Flats.

D = Dry Season Survey; W = Wet Season Survey

For bird records, overall abundances are given as pecentage occurrence on census counts:

* = uncommon - <5% of counts; ** = common - 5-15% of counts; *** = abundant - >15% of counts

Common Name	Scientific Name	Habitats					
		EOF	MVF	MAN	PAW	ITF	Abund (birds)
AMPHIBIANS							
Frog	*Crinia bilingua*	W					
Marbled Frog	*Limnodynastes convexiusculus*	W					
Frog	*Cyclorana australis*	W					
Dwarf Tree Frog	*Litoria bicolor*	W					
Green Tree Frog	*Litoria caerulea*	W					
Rocket Frog	*Litoria nasuta*	W					
Brown Tree Frog	*Litoria rothi*	W					
TOTAL AMPHIBIANS =	**7 species**	**7**	**0**	**0**	**0**	**0**	
REPTILES							
Estuarine Crocodile	*Crocodylus porosus*					D	
Bynoe's Gecko	*Heteronotia binoei*	D/W		D			
Zig-zag Gecko	*Oedura rhombifer*				D		
Skink	*Carlia amax*		W				
Skink	*Carlia rufilatus*				D/W		
Skink	*Carlia munda*	W	W	D	D/W		
Fence Skink	*Cryptoblepharus plagiocephalus*	D			D/W		
Port Essington Ctenotus	*Ctenotus essingtoni*			W			
Skink	*Glaphyromorphus darwiniensis*				D		
Skink	*Glaphyromorphus douglasi*		D/W				
Monitor	*Varanus panoptes*	D		D			
TOTAL REPTILES =	**11 species**	**4**	**3**	**4**	**5**	**1**	

TABLE 1 (cont'd)

TERRESTRIAL FAUNA OF WICKHAM POINT

Common Name	Scientific Name	Habitats					
		EOF	MVF	MAN	PAW	ITF	Abund (birds)
BIRDS							
Orange-footed Scrubfowl	*Megapodius reinwardt*		D/W	D/W			**
Pied Cormorant	*Phalacrocorax varius*					D	*
White-faced Heron	*Egretta novaehollandiae*					D	**
Great-billed Heron	*Ardea sumatrana*			D			*
Striated Heron	*Butroides striatus*			W			*
Australian White Ibis	*Threskiornis molucca*	D		D			*
Black-necked Stork	*Ephippiorhynchus asiaticus*			D		D	*
Black Kite	*Milvus migrans*	D					*
Whistling Kite	*Haliastur sphenurus*	D		D			*
Brahminy Kite	*Haliastur indus*			D/W		D	*
White-bellied Sea-eagle	*Haliaeetus leucogaster*		D/W	D/W		W	**
Chestnut Rail	*Eulabeornis castaneoventris*			W			*
Little Curlew	*Numenius minutus*			D			*
Whimbrel	*Numenius phaeopus*					D/W	**
Eastern Curlew	*Numenius madagascariensis*					D/W	*
Common Sandpiper	*Actitis hypoleucos*			W		D/W	**
Ruddy Turnstone	*Arenaria interpres*					D	*
Great Knot	*Calidris tenuirostris*					W	*
Curlew Sandpiper	*Calidris ferruginea*					D	*
Ruff	*Philomachus pugnax*					D	*
Beach Stone-curlew	*Esacus neglectus*			D			**
Black-fronted Dotterel	*Elseyornis melanops*					D	*
Masked Lapwing	*Vanellus miles*			D			*
Gull-billed Tern	*Sterna nilotica*					D	*
Crested Tern	*Sterna bergii*					D	*
Little Tern	*Sterna albifrons*					W	*
Peaceful Dove	*Geopelia striata*	D/W		D/W			**
Bar-shouldered Dove	*Geopelia humeralis*	D/W	W	D/W	W		***
Rose-crowned Fruit-dove	*Ptilinopus regina*		W	W			*
Emerald Dove	*Chalcophaps indica*				W		*
Pied Imperial-Pigeon	*Ducula bicolor*			W			*
Sulphur-crested Cockatoo	*Cacatua galerita*	W	W	D			**
Red-collared Lorikeet	*Trichoglossus haematodus*	D/W	W	D/W	W		***

TABLE 1 (cont'd)

TERRESTRIAL FAUNA OF WICKHAM POINT

Common Name	Scientific Name	Habitats					
		EOF	MVF	MAN	PAW	ITF	Abund (birds)
Red-winged Parrot	*Aprosmictus erythropterus*	D/W	W	D			**
Pallid Cuckoo	*Cuculus pallidus*	D					*
Little Bronze-Cuckoo	*Chrysococcyx minutillus*			W			*
Common Koel	*Eudynamys scolopacea*	D					*
Pheasant Coucal	*Centropus phasianus*	W		W	W		***
Large-tailed Nightjar	*Caprimulgus macrurus*	D		D/W			*
Azure Kingfisher	*Alcedo azurea*			W			*
Blue-winged Kookaburra	*Dacelo leachii*	D/W					**
Forest Kingfisher	*Todiramphus macleayii*	W			D		*
Sacred Kingfisher	*Todiramphus sanctus*			W			*
Collared Kingfisher	*Todiramphus chloris*			D/W		D	**
Rainbow Bee-eater	*Merops ornatus*	D		D/W	D		**
Dollarbird	*Eurystomus orientalis*	W	W		D		**
Rainbow Pitta	*Pitta iris*		D/W		D		*
Red-backed Fairy-wren	*Malurus melanocephalus*	W					**
Weebill	*Smicrornis brevirostris*	W					*
Large-billed Gerygone	*Gerygone magnirostris*			D			*
Green-backed Gerygone	*Gerygone chloronotus*			D			*
Helmeted Friarbird	*Philemon buceroides*	D	W	D/W	W		***
Little Friarbird	*Philemon citreogularus*	W		W			**
Silver-crowned Friarbird	*Philemon argenticeps*	W		W	W		**
White-throated Honeyeater	*Melithreptus albogularis*	D					*
Brown Honeyeater	*Lichmera indistincta*			D			*
Rufous-banded Honeyeater	*Conopophila albogularis*			D/W	D		**
Dusky Honeyeater	*Myzomela obscura*			W	D		**
Red-headed Honeyeater	*Myzomela erythrocephala*			D/W	D		**
Lemon-bellied Flycatcher	*Microeca flavigaster*			D/W			**
Mangrove Robin	*Eopsaltria pulverulenta*			W			*
Mangrove Golden Whistler	*Pachycephala melanura*			D			*
Grey Whistler	*Pachycephala simplex*			D			**
White-breasted Whistler	*Pachycephala lanioides*			D/W			**
Little Shrike-thrush	*Colluricincla megarhyncha*	W		D			*
Broad-billed Flycatcher	*Myiagra ruficollis*			D/W	D		*
Leaden Flycatcher	*Myiagra rubecula*	W					*
Shining Flycatcher	*Myiagra alecto*			D/W			**

TABLE 1 (cont'd)

TERRESTRIAL FAUNA OF WICKHAM POINT

Common Name	Scientific Name	Habitats					
		EOF	MVF	MAN	PAW	ITF	Abund (birds)
Magpie-lark	*Grallina cyanoleuca*	W					*
Rufous Fantail	*Rhipidura rufifrons*			D			*
Northern Fantail	*Rhipidura rufiventris*	W					*
Spangled Drongo	*Dicrurus bracteatus*	D		D	D/W		**
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	D		W			**
White-bellied Cuckoo-shrike	*Coracina papuensis*			D	W		*
Cicadabird	*Coracina tenuirostris*			W			*
White-winged Triller	*Lalage sueurii*	D					*
Varied Triller	*Lalage leucomela*			D	W		**
Yellow Oriole	*Oriolus flavocinctus*	D	W	D/W	W		***
Figbird	*Sphecotheres viridus*	D	W	W			*
White-breasted Woodswallow	*Artamus leucorhynchus*	D					*
Black Butcherbird	*Cracticus quoyi*		D	D/W			**
Pied Butcherbird	*Cracticus nigrogularis*	D/W		D			**
Grey Butcherbird	*Cracticus torquatus*	W					*
Torresian Crow	*Corvus orru*	D/W					*
Great Bowerbird	*Chlamydera nuchalis*			D	D/W		**
Double-barred Finch	*Taeniopygia bichenovii*	D/W		W			**
Mistletoebird	*Dicaeum hirundinaceum*	D					*
Golden-headed Cisticola	*Cisticola exilis*	W					*
Clamorous Reed-warbler	*Acrocephalus stentoreus*	D					*
Yellow White-eye	*Zosterops luteus*			D/W			**
TOTAL BIRDS =	**90 species**	**39**	**13**	**57**	**19**	**17**	
	Dry Season = 67 species						
	Wet Season = 62 species						
	Both Wet & Dry Seasons = 38 species						

TABLE 1 (cont'd)

TERRESTRIAL FAUNA OF WICKHAM POINT

Common Name	Scientific Name	Habitats					
		EOF	MVF	MAN	PAW	ITF	Abund (birds)
MAMMALS							
Short-beaked Echidna	*Tachyglossus aculeatus*	D					
Northern Quoll	*Dasyurus hallucatus*	D					
Northern Brown Bandicoot	*Isoodon macrourus*	D/W		D/W	W		
Northern Brushtail Possum	*Trichosurus arnhemensis*	D			D/W		
Sugar Glider	*Petaurus breviceps*	D					
Agile Wallaby	*Macropus agilis*	D/W		D/W	D/W		
Black Flying-fox	*Pteropus alecto*	D		W			
Little Northern Freetail-bat	*Mormopterus loriae*	D		D			
Common Bentwing-bat	*Minopterus schreibersii*	D					
Large-footed Myotis	*Myotis moluccarum*			D			
Little Broad-nosed Bat	*Scotorepens greyi*	D					
Grassland Melomys	*Melomys burtoni*			D	W		
Feral Pig	*Sus scrofa*	D/W	D	D/W	D		
Dingo	*Canis lupus dingo*	D/W		W	D/W		
Feral Cat	*Felis catus*		D				
TOTAL MAMMALS =	**15 Species**	**12**	**2**	**8**	**6**	**0**	

TABLE 2
RESULTS OF TRAPPING PROGRAM

Trapline	Habitat	Date	Trap-nights	Result
Dry Season				
1	Vine thicket/Mangroves	26-27/9/96	50 Elliots	*Glaphromorphus douglasi x 1*
2	Melaleuca Forest	26-27/9/96	50 Elliots 10 large cage	*Trichosurus arnhemensis x 1*
3	Mangrove margins	26-27/9/96	50 Elliots 3 large Elliots	*Isoodon macrourus x 1*
4	Mangrove margins	26-27/9/96	50 Elliots	
	Total trapnights -	**Dry Season**	**200 Elliots** **10 large cage** **3 large Elliots**	
Wet Season				
5	Mangrove Margins	7-8/2/97	20 large Elliots	
6	Vine Thicket	7-8/2/97	50 Elliots	*Glaphromorphus douglasi x 2*
7	Melaleuca Forest	7-8/2/97	50 Elliots	
8	Mangrove Margins	7-8/2/97	50 Elliots	
9	Melaleuca Forest	7-8/2/97	50 Elliots	*Melomys burtoni x 1*
10	Vine Thicket	7-8/2/97	50 Elliots	*Glaphromorphus douglasi x 1*
	Total trapnights -	**Wet Season**	**250 Elliots** **20 large Elliots**	

Four species of water snake are specialised to mangrove habitat and although they were not observed in the current study, they are very likely to occur in this area. These species are Bockadam (*Cerberus rhynchops*), White-bellied Mangrove Snake (*Fordonia leucobalia*), Richardson's Mangrove Snake (*Myron richardsoni*) and Little File Snake (*Acrochordus granulatus*). Two species of sea snake are also reported to be mangrove dwellers (O'Gower, 1979). These are the Port Darwin Sea snake (*Hydrelaps darwiniensis*) and the Elegant Sea snake (*Hydrophis elegans*).

Additional reptile species known to occur in littoral habitats in the Darwin area include the Northern Bluetongue Skink (*Tiliqua scincoides*), Northern Water Dragon (*Gemmatophora temporalis*), Mitchell's Water Monitor (*Varanus mitchelli*), Common Keelback (*Amphiesma mairii*) and Children's Python (*Liasis childreni*) (O'Gower 1979; Hegerl *et. al.* 1979). 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 (K. Martin. pers. obs.) and would be expected to occur at least on the mainland peninsula.

3.2.4 Birds

Ninety species of birds were recorded in the study area (Table 1). An additional 93 species are known to occur in littoral habitats within Darwin Harbour and are likely to also be present at Wickham Point (Table 3). The commonest birds observed during surveys were Bar-shouldered Dove (*Geopelia humeralis*), Sulphur-crested Cockatoo (*Cacatua galerita*), Helmeted Friarbird (*Philemon buceroides*) and Yellow Oriole (*Oriolus flavocinctus*). All of these species were frequently observed in both surveys, and were found in a range of habitats.

More bird species were observed in mangrove associated habitats (57) than in any of the other habitats. The next richest habitat was Eucalyptus open forest, with fewer species observed in the other habitats. Because of the small area of the study site, many of the species recorded could be expected to move between several habitats.

A number of birds are more or less restricted to mangroves. These include Chestnut Rail (*Eulabeornis castaneoventris*), Collared Kingfisher (*Todiramphus chloris*), Red-headed Honeyeater (*Myzomela erythrocephala*), Mangrove Robin (*Eopsaltria pulverulenta*), Mangrove Golden Whistler (*Pachycephala melanura*), Melville Cicadabird (*Coracina tenuirostris melvillensis*) and White-breasted Whistler (*Pachycephala lanioides*). Some of these species are uncommon and restricted to well developed mangrove stands, so the occurrence of so many specialised species is indicative of high quality habitat.

Some bird species live primarily in monsoon vine forest. These species include Rainbow Pitta (*Pitta iris*), Rose-crowned Fruit-dove (*Ptilinopus regina*), Emerald Dove (*Chalcophaps indica*) and Orange-footed Scrubfowl (*Megapodius reinwardt*). Many of the mangrove and vine forest specialists freely move between these two habitats, so the occurrence of good representative examples of each habitat in close proximity at Wickham Point is beneficial to those species. For example, Rose-crowned Fruit-doves were frequently observed or heard in mangroves during the survey.

TABLE 3
ADDITIONAL BIRD RECORDS FROM THE DARWIN HARBOUR AREA

Common Name	Scientific Name	McKean & Martin (1986)	Dames & Moore (1993b)
Brown Quail	*Coturnix australis*		x
Plumed Whistle-duck	*Dendrocygna eytoni*		x
Pacific Black Duck	*Anas superciliosa*		x
Grey Teal	*Anas gracilis*		x
Pink-eared Duck	*Malacorhnchus membranaceus*		x
Green Pygmy Goose	*Nettapus pulchellus*		x
Australian Grebe	*Tachybaptus ruficollis*		x
Radjah Shelduck	*Tadorna radjah*	x	x
Brown Booby	*Sula leucogaster*	x	
Darter	*Anhinga melanogaster*	x	x
Little Pied Cormorant	*Phalacrocorax melanoleucas*	x	
Little Black Cormorant	*Phalacrocorax sulcirostris*	x	
Australian Pelican	*Pelicanus conspicillatus*	x	x
Great Frigatebird	*Fregata minor*	x	
Little Egret	*Egretta garzetta*	x	x
Eastern Reef Egret	*Egretta sacra*	x	x
Pied Heron	*Ardea picata*	x	x
Great Egret	*Ardea alba*	x	x
Intermediate Egret	*Ardea intermedia*	x	x
Nankeen Night Heron	*Nycticorax caledonicus*	x	x
Black Bittern	*Ixobrychus flavicollis*	x	x
Straw-necked Ibis	*Threskiornis spinicollis*		x
Royal Spoonbill	*Platalea regia*	x	x
Osprey	*Pandion haliaetus*	x	x
Pacific Baza	*Aviceda subcristata*		x
Brown Goshawk	*Accipiter fasciatus*	x	x
Grey Goshawk	*Accipter novaehollandiae*		x
Collared Sparrowhawk	*Accipiter cirrhocephalus*		x
Brown Falcon	*Falco berga*		x
Australian Hobby	*Falco longipennis*		x
Eurasian Coot	*Fulica atra*		x
Black-tailed Godwit	*Limosa limosa*	x	
Bar-tailed Godwit	*Limosa lapponica*	x	x
Marsh Sandpiper	*Tringa stagnatilis*	x	
Common Greenshank	*Tringa nebularia*	x	x
Terek Sandpiper	*Xenus cinereus*	x	

TABLE 3 (cont'd)

ADDITIONAL BIRD RECORDS FROM THE DARWIN HARBOUR AREA

Common Name	Scientific Name	McKean & Martin (1986)	Dames & Moore (1993b)
Grey-tailed Tattler	*Heteroscelus brevipes*	x	x
Red Knot	*Calidris canutus*	x	
Sanderling	*Calidris alba*	x	
Red-necked Stint	*Calidris ruficollis*	x	
Sharp-tailed Sandpiper	*Calidris acuminata*	x	x
Broad-billed Sandpiper	*Limicola falcinellus*	x	
Swinhoe's Snipe	*Gallinago megala*		x
Bush Stone-curlew	*Burhinus magnirostris*		x
Pied Oystercatcher	*Haematopus longirostris*	x	x
Sooty Oystercatcher	*Haematopus fuliginosus*	x	
Banded Stilt	*Cladorhynchus leucocephalus*	x	
Grey Plover	*Pluvialis squatarola*	x	
Red-capped Plover	*Charadrius ruficapillus*	x	
Lesser Sand Plover	*Charadrius mongolus*	x	
Greater Sand Plover	*Charadrius leschenaultii*	x	
Oriental Plover	*Charadrius veredus*	x	
Australian Pratincole	*Stiltia isabella*	x	
Pomarine Jaeger	*Stercorarius pomarinus*	x	
Silver Gull	*Larus novaehollandiae*	x	x
Caspian Tern	*Sterna caspia*	x	
Lesser Crested Tern	*Sterna bengalensis*	x	
Common Tern	*Sterna hirundo*	x	
Whiskered Tern	*Chlidonias hybridus*	x	x
White-winged Black Tern	*Chlidonias leucopterus*	x	x
Common Bronzewing	*Phaps chalcoptera*		x
Rock Dove	*Columbia livia*		x
Red-tailed Black Cockatoo	*Calyptorhynchus banksii*		x
Galah	*Cacatua roseicapilla*		x
Little Corella	*Cacatua sanguinea*		x
Varied Lorikeet	*Psitteuteles versicolor*		x
Northern Rosella	*Platycercus venustus*		x
Oriental Cuckoo	*Cuculus saturatus*	x	
Brush Cuckoo	*Cacomantis variolosus*	x	x
Horsfield's Bronze-Cuckoo	*Chrysococcyx basalis*	x	
Tawny Frogmouth	*Podargus strigoides*		x
Australian Owlet-nightjar	*Aegotheles cristatus*		x
Fork-tailed Swift	*Apus pacificus*		x

TABLE 3 (cont'd)

ADDITIONAL BIRD RECORDS FROM THE DARWIN HARBOUR AREA

Common Name	Scientific Name	McKean & Martin (1986)	Dames & Moore (1993b)
Little Kingfisher	*Alcedo pusilla*	x	x
Striated Pardelote	*Pardalotus striatus*		x
Mangrove Gerygone	*Gerygone levigaster*	x	x
Blue-faced Honeyeater	*Entomyzon cyanotis*		x
White-gaped Honeyeater	*Lichenostomus unicolor*	x	x
Rufous-throated Honeyeater	*Conopophila rufogularis*	x	
Bar-breasted Honeyeater	*Ramsayornis fasciatus*		x
Mistletoebird	*Dicaeum hirundinaceum*		x
Rufous Whistler	*Pachycephala rufiventris*		x
Grey Shrike Thrush	*Colluricincla harmonica*		x
Restless Flycatcher	*Myiagra inquieta*	x	
Mangrove Grey Fantail	*Rhipidura phasiana*	x	x
Willie Wagtail	*Rhipidura leucophrys*		x
Olive-backed Oriole	*Oriolus sagittatus*		x
Crimson Finch	*Neochmia phaeton*		x
Long-tailed Finch	*Poephila acuticauda*		x
Chestnut-breasted Finch	*Lonchura castaneothorax*		x
Yellow-rumped Mannikin	*Lonchura flaviprymna*		x
Tree Martin	*Hirundo nigricans*	x	x
Fairy Martin	*Hirundo ariel*		x
TOTAL BIRDS =	**93 Species**	**55**	**59**

A great deal of seasonal variation was observed in bird species and numbers between the two surveys. Similar numbers of species were observed in each seasonal survey (67 in the dry; 62 in the wet), but only 38 species were recorded on both field surveys. This indicates that the area has a very high proportion of transient or seasonal migrant species compared to residents. These species are made up of groups such as migratory waders, (e.g. Little Curlew *Numenius phaeopus*, Curlew Sandpiper *Calidris ferruginea* and Ruff *Philomachus pugna*) and other wet season visitors such as Pied Imperial Pigeon (*Ducula bicolor*), Rainbow Bee-eater (*Merops ornatus*) and Dollarbird (*Eurystomus orientalis*). A number of "wet" season visitors were recorded during the September survey, which is the usual time for the arrival of seasonal migrants.

One prominent feature of the site is the occurrence of many large nesting mounds of the Orange-footed Scrubfowl. This species was commonly seen, often in pairs near the mounds during both surveys. The mounds were all located along the beach - mangrove margin interface, especially in areas proximate to monsoon vine forest.

3.2.5 Mammals

Fifteen mammal species (including two introduced species) were recorded during the field surveys (Table 1). Small mammal trapping rates were low; only 0.5% in the dry season and 0.4% in the wet. The only rodent observed was the Grassland Melomys (*Melomys burtoni*), which was trapped in paperbark woodland, and was observed at night in sedgelands bordering mangroves. This species is common in littoral habitats around Darwin and has been recorded from mangroves previously (Dames & Moore 1993b).

The Northern Brown Bandicoot (*Isoodon macrourus*) is a common species in the study area. Diggings, disturbances and tracks were observed in many locations around the mangrove margins and in the Eucalyptus open forest. Tracks across the samphire flats indicate that this species forages in these areas at low tide. A Northern Brushtailed Possum (*Trichosurus arnhemensis*) was trapped in paperbark forest on the main island, and tracks of this species were also frequently encountered. Agile Wallabies (*Macropus agilis*) were occasionally observed around the mangrove fringes and their tracks were also seen on the samphire flats.

Microchiropteran bats were recorded frequently in Eucalyptus open forest, over tributaries and water bodies and using flyways on mangrove/open forest ecotones. Survey of microchiropteran (insectivorous) bat species within open forest recorded three species using ultrasonic call detection (Table 1). The most commonly encountered species was the Little Northern Freetail-bat (*Mormopterus loriae*). The Little Northern Freetail-bat and the Large-footed Myotis (*Myotis molluccarum*) were also recorded over mangroves and tidal creeks in the vicinity of the proposed access route. One species recorded during the survey, the Common Bentwing-bat (*Miniopterus schreibersii*) is known to regularly roost in caves or similar structures (Dwyer 1995). A large "camp" of Black Flying Foxes (*Pteropus alecto*) was observed in the mangroves along the northwestern edge of Wickham Point during the wet season.

3.2.6 Aquatic Fauna

There are no permanent freshwater habitats on the main and central islands or the adjacent mainland peninsula. However, wet season freshwater habitats are present in some areas of the mainland peninsula along the proposed access route. No pure freshwater fish species were observed in these areas, but juvenile Ox-eye Herring (*Megalops cyprinoides*) were observed in one small runoff stream. It is likely that these seasonal freshwater areas provide breeding sites for some other estuarine and coastal freshwater fishes.

3.3 INTRODUCED SPECIES

Evidence of Feral Pigs (*Sus scrofa*), in the form of tracks, diggings and a skull was found on the main island. However, very little disturbance was noted and it appears that there are no permanent populations of this species on the islands. It is probable that individual animals occasionally cross the mudflats to the islands in the wet season and forage for brief periods before returning to the mainland. One Feral Cat (*Felis catus*) was observed in the monsoon vine forest at Wickham Point. Numbers of this species are also probably low, but the presence of cats in the area is of concern given that numbers of mammals such as bandicoots and possums seem relatively high.

No introduced amphibians, reptiles or birds were observed during the field surveys although the Rock Dove (*Columbia livia*) and the Asian House Gecko (*Hemidactylus frenatus*) do occur in the Darwin area and the latter species is found in littoral habitats.

4. DISCUSSION

4.1 SIGNIFICANT SPECIES

The conservation status and significance of species referred to in this report is based on a number of State, national and international legislation and reports including Garnett (1992), Cogger et al (1993), IUCN (1995) and the Commonwealth *Endangered Species Protection Act* 1992 (ANCA 1996).

Significant species known or expected to occur in the area are listed in Table 4. The list includes eleven bird and two mammal species, of which three are in the higher categories of Endangered or Vulnerable.

4.1.1 Endangered or Vulnerable Species

Little Tern (Endangered – ANCA 1996; Vulnerable – Garnett 1992)

The Australian population of the Little Tern (*Sterna albifrons*) has declined in the south and remains small in northern Australia. However, birds from populations in Asia migrate to northern Australia during the summer, and the species is apparently common in the Darwin area (Garnett 1992). There are no suitable nesting locations at Wickham Point for this species and it rarely breeds in Darwin Harbour (McKean & Martin 1986). During surveys, individual birds were seen flying over the intertidal flats.

Melville Cicadabird (Endangered – ANCA 1996; Special Concern – Garnett 1992)

The northwestern Australian subspecies of the Cicadabird (*melvillensis*) is considered to be Endangered in the Kimberley region, where it is restricted to mangroves and monsoon forest patches. In the Northern Territory, where more habitat is available, it can be considered secure (Garnett 1992). Cicadabirds prefer pristine tall stands of *Rhizophora* mangroves (McKean & Martin 1986), and in the Wickham Point area, were observed only in this habitat along a small creek near the southern tip of the main island (Figure 1).

Beach Stone-curlew (Vulnerable – Garnett 1992)

The Beach Stone-curlew (*Esacus neglectus*) is distributed throughout northern Australia and internationally. It frequents beaches associated with estuaries or mangroves, and generally occurs at low densities (Garnett 1992). Only a few pairs are known in the Darwin area and it is a species vulnerable to disturbance (McKean & Martin 1986). A pair of Beach Stone-curlews were found nesting on a small beach in the vicinity of the proposed jetty site at Wickham Point in September 1996 (Figure 1).

4.1.2 Bird Species Listed as Special Concern

Nine bird species (including the Cicadabird and Beach Stone-curlew mentioned in 4.1.1) found in the area are listed as of “Special Concern” by Garnett (1992) (Table 4). This is the lowest risk category and these species can generally be considered secure in northern Australia.

The Great-Billed Heron (*Ardea sumatrana*) is a species which requires large territories for feeding and breeding (McKean & Martin 1986) and is scarce in the Darwin area. Chestnut Rail (*Eulambeornis castaneoventris*) is an uncommon species, which has a requirement for high quality mangrove habitat.

4.1.3 Migratory Bird Species Listed in International Treaties

Some bird species listed in international agreements and conventions such as the Japan-Australia Migratory Bird Agreement (JAMBA), the China-Australia Migratory Bird Agreement (CAMBA) and the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) were recorded in tidal and mangrove areas of the site. Listed species found at Wickham Point include White-bellied Sea-eagle (*Haliaeetus leucogaster*), Eastern Curlew (*Numenius madagascariensis*), Little Tern and Rainbow Bee-eater.

4.1.4 Other Significant Species

McKean & Martin (1986) identify the following additional birds found in Darwin Harbour as being "rare", or of conservation significance: Greater Frigatebird (*Fregata minor*), Spectacled Oystercatcher (*Haematopus opthalmicus*), Broad-billed Sandpiper (*Limicola falcinella*), Ruff (*Philomachus pugnax*), Large-tailed Nightjar (*Caprimulgus macrourus*), Little Kingfisher (*Ceyx pusillus*), Mangrove Golden Whistler (*Pachycephala melanura*), White-breasted Whistler (*Pachycephala lanoides*), Little Shrike-thrush (*Colluricincla megarhyncha*), Mangrove Fantail (*Rhipidura phasiana*) and Great Reed Warbler (*Acrocephalus arundinaceus*). Most of these species are known from, or could be expected to visit the Wickham Point area.

Two mammal species found in the area have been identified by IUCN (1995) as "Near-threatened", which is a low risk category. The Northern Quoll (*Dasyurus hallucatus*) has suffered a recent decline in populations in northern Australia (Braithwaite & Begg 1995), while the Common Bent-winged Bat (*Miniopterus schreibersii*) appears to be secure.

There is an unconfirmed report of the False Water Rat (*Xeromys myoides*) occurring in the area, through the discovery of a possible nest (J. Woinarski pers. com.). This species is rarely recorded in the Northern Territory and has not yet been recorded from the Darwin area. The main populations occur on the southern and central Queensland coast (Strahan 1985). No animals were caught during the surveys despite setting traps baited with fish (a successful method used in southern Queensland) at several potential locations. During the survey, "nests" possibly attributable to this species were found, but these grass arrangements could have been attributable to bandicoot activities. If the species was on the site, it would be expected to occur mainly along the mangrove margin and freshwater sedge areas.

None of the reptile or amphibians occurring in the area is listed in any threatened categories.

4.2 CONSERVATION VALUES

The Wickham Point area contains an excellent representation of coastal habitats found in the Darwin area. The area, at least on the main and central islands, is relatively free of feral animals and recent human disturbance, and appears to be well protected from fire. There is however, much evidence of wartime and post-war activities in the area, including old camps, debris and shell craters The mangrove margins and beaches are also strewn with flotsam.

TABLE 4
SIGNIFICANT FAUNA SPECIES KNOWN OR EXPECTED TO OCCUR IN THE WICKHAM POINT AREA

* = Endangered Species Protection Act (1992); Schedules 1,2, & 3 - 1996

Common Name	Scientific Name	Garnett (1992)	ANCA (1996)*	IUCN (1995)
BIRDS				
Radjah Shelduck	*Tadorna radjah*	Special Concern		
Great-billed Heron	*Ardea sumatrana*	Special Concern		Low Risk
Black-necked Stork	*Ephippiorhynchus asiaticus*	Special Concern		
Black Bittern	*Ixobrychus flavicollis*	Special Concern		
Osprey	*Pandion haliaetus*	Special Concern		
Chestnut Rail	*Eulabeornis castaneoventris*	Special Concern		
Eastern Curlew	*Numenius madagascariensis*	Special Concern		Low Risk
Beach Stone-curlew	*Esacus neglectus*	Vulnerable		
Bush Stone-curlew	*Burhinus magnirostris*	Special Concern		
Little Tern	*Sterna albifrons*	Vulnerable	Endangered	
Cicadabird	*Coracina tenuirostris melvillensis*	Special Concern	Endangered	
MAMMALS				
Northern Quoll	*Dasyurus hallucatus*			Low Risk
Common Bent-winged Bat	*Minopterus schreibersii*			Low Risk

The extensive mangrove and mudflat habitats are listed as being of "good" quality for birdlife, and are ranked Grade 2 (of 3) in McKean & Martin (1986). The mangroves in this area are not considered to be as good a bird habitat as the two adjoining areas of upper Middle Arm and East Arm. Nevertheless, it is clear that the mangroves and mudflats around Wickham Point contain almost all of the more specialised mangrove bird species found in the region, including Cicadabird, Chestnut Rail, White-breasted Whistler and Mangrove Golden Whistler. The intertidal mudflats do not appear to support large numbers of migratory waders or shorebirds, although these areas would be an important feeding resource at some times. Most of the more significant species in this group, including Little Tern, Ruff and Eastern Curlew have been recorded in the area.

The best developed mangrove areas tend to have more of the rarer bird species present. In this respect, the upper reaches of the mangrove creeks were most important. The creek draining west between the main and central islands had, for example, species such as Great-billed Heron, Chestnut Rail, Cicadabird and White-breasted Whistler present (Figure 1).

The mangrove margin habitats, including the interface between the mangroves and landward habitats such as monsoon vine forest and paperbark woodland are particularly important for wildlife. A number of large nesting mounds used by the Orange-footed Scrubfowl occur along this interface. Some of these mounds are quite spectacular, being in excess of eight metres in height and ten metres across the base. All mounds seem to be active, and nesting was observed in the wet season. Some of the aboriginal shell middens in the area have also been utilised by Orange-footed Scrubfowl as nesting mounds. The same mounds may be used by several pairs of birds. Some of these mounds may be thousands of years old and are of some scientific and public interest. The area holds a high density of these birds. They are not considered a threatened species and are generally not susceptible to human disturbance (they frequently forage in suburban gardens around Darwin) although interference with the nesting mounds would inhibit breeding.

The Beach Stone-curlew roosts and nests along the sandy beach interface at Wickham Point. A pair, with nest and eggs were discovered just to the north of the proposed jetty landfall site (Figure 1). This species is susceptible to disturbance and has disappeared from most beach areas closer to Darwin.

There appears to be good populations of medium and large-sized mammals, such as Northern Brown Bandicoot, Northern Brushtailed Possum and Agile Wallaby. These populations are centered on the mangrove - paperbark interface zone, where freshwater sedge communities are developed. These species are probably more abundant in this area than in similar habitats close to Darwin as a consequence of the site being fire-protected to a large degree, and to the low levels of human disturbance.

The monsoon vine thickets on the island are amongst the most extensive found around Darwin. However, this habitat is not considered of high significance for rare or threatened fauna. Most of the resident birds known to occur in this habitat around Darwin, including Rainbow Pitta, Orange-footed Scrubfowl, Rose-crowned Fruit Dove and Emerald Dove are found at Wickham Point. This habitat appears to be an important food resource during the wet season, when increased numbers of fruit-eating birds were present.

The close proximity of good quality mangroves and monsoon vine forest habitat to each other has added to the relative value of each as bird habitat. Mangrove bird species were often observed in adjacent vine forest and vice versa. The staggered fruiting cycle of mangrove and vine forest plants would enable a year round food supply in this area that may not be available in areas where only one or the other habitat was present.

The Eucalyptus open forest habitats, which are present mostly on the mainland peninsula contained species typical of those found throughout the Darwin area. This is a common habitat in the region.

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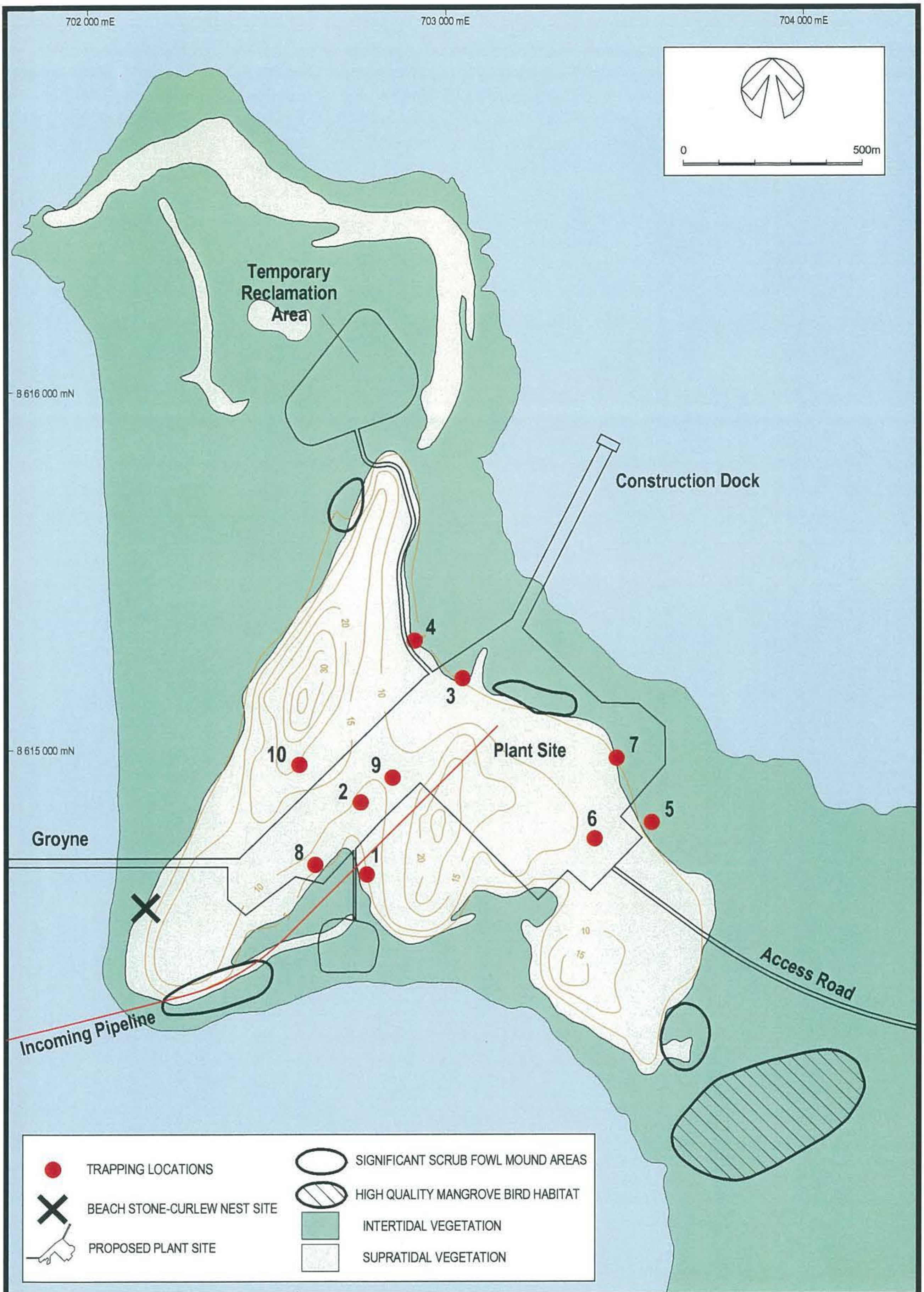

Phillips Oil Company Australia

DARWIN LNG PLANT, DRAFT EIS

LOCATIONS OF TRAPPING SITES AND SIGNIFICANT FAUNA LOCATIONS

DAMES & MOORE PTY LTD
A DAMES & MOORE COMPANY

FIGURE 1

Appendix J

TERRITORY HEALTH SERVICES

REPORT

Darwin LNG Plant
Draft Environmental Impact Statement

Appendix J
Biting Insects of Medical Importance at Wickham Point, Darwin Harbour

for

Phillips Oil Company Australia

Ref: 00533-164-073
Report No. R635
Appendix J
July 1997

Medical Entomology Branch
Territory Health Services
Tel.: 08 8922 83333

BITING INSECTS OF MEDICAL IMPORTANCE

AT

WICKHAM POINT

DARWIN HARBOUR

February 1997

Peter Whelan, Brian Montgomery, Gwenda Hayes, Ross Nowland, Barbara Love and Jane Carter
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1.0 INTRODUCTION

Phillips Oil Company Australia plans to construct a Liquefied Natural Gas (LNG) plant at Wickham Point in Darwin Harbour to process gas delivered by pipeline to the site from the Timor Sea. In the guidelines for an Environmental Impact Statement (EIS), the Department of Lands, Planning & Environment (DLP&E) requested biting insect baseline information in order to assess the potential biting insect problems and the associated pest and disease problems faced by both construction workers and the permanent workforce.

Dames & Moore were requested by Phillips to prepare a draft EIS. In January 1997 Dames & Moore discussed with the Medical Entomology Branch the possibility of carrying out an assessment of the biting insect problem at Wickham Point in a short time frame, and in February 1997 requested the Medical Entomology Branch (MEB) of the Territory Health Services (THS) to carry out such an assessment. It was clarified by MEB that a baseline assessment of the biting insects problems could not be carried out in the short time frame, although a brief assessment, including both trapping at the time of the full moon, and a ground inspection could provide information for a partial assessment of both biting midges and mosquitoes.

The trapping and ground survey of actual and potential biting insect problems were conducted by Peter Whelan of the Medical Entomology Branch of THS on 24 - 25 February 1997. This report outlines the methods, results and conclusions of the survey and assessment and discusses aspects necessary to reduce the biting insect pest and mosquito borne disease in the project area.

2.0 METHODS

2.1 Mosquito and biting midge trapping.

Mosquito and biting midge trapping were conducted on 24 - 25 February. Preliminary sites for trapping were selected from aerial photographs and actual sites were selected by a site assessment by helicopter and ground inspection on 24 February. Four sites were chosen to assess the crepuscular and overnight biting midge and mosquito activity at widely separate points around the main island area of Wickham Point where the facility would be constructed. A further 4 trap sites were selected to assess day time biting midge and mosquito activity in a number of vegetation types at various locations on the main island (Fig. 1). The trap positions are outlined in Figure 1 and results of the trapping are shown in Table 1 (mosquitoes) and Table 2 (biting midges).

The biting insect trapping was carried out using modified CO_2 EVS light traps (Rohe & Fall 1979). The overnight traps were set between 1500 hrs and 1630 hrs on 24 February after a ground assessment of the island coastline. Traps were positioned in sheltered positions in vegetation from 10 to 30 m inland from the maximum tide limit.

The day time traps were set at various sites around the island for varying trap times that were determined by ground access during the available time.

All traps were set at chest height, with approximately 0.8 kg of dry ice. Overnight traps were picked up between 0840 hrs and 0930 hrs the following day. The other trap times are outlined in Table 1 & Table 2.

All trap collections were killed on site with CO_2 and transported back to the MEB laboratory for identification.

All mosquito specimens were identified.

Biting midge collections of less than 150 per trap were all identified. Collections of over 150 per trap had a subsample of 100 identified. For collections of less than 1000, all the specimens were counted to give a total. Collections of over 1000 had a volume estimate made to arrive at a total.

An estimate of total numbers was made from the subsamples. For trap collections of less than 1000, the bulk of the collection was examined for species that were not represented in the subsample. For collections of over 1000, a bulk sample of 600 was examined for other species and an estimate made of the total number in the collection.

2.2 Mosquito and biting midge human biting survey.

Any biting mosquitoes or biting midges attracted to the investigator were captured during the survey by aspiration into labelled vials and killed (as above) for later identification.

2.3 Mosquito breeding site surveys.

The coast of the island and inland areas were inspected on foot on 24 - 25 February for actual and potential mosquito breeding sites. Potential mosquito breeding sites were sampled with a standard dipper and collected larvae were transported live to the MEB laboratory in labelled vials. Larvae were preserved in 70% alcohol and identified in the MEB. A selection of larvae were reared to adults for confirmation of larval identification.

2.4 Mosquito and biting midge breeding site assessment.

Areas offshore from the main island were assessed visually by helicopter on 24 - 25 February and later with the aid of aerial photographs to assess potential mosquito and biting midge breeding sites. The assessment of the potential biting midge breeding areas was guided by recent work in other parts of Darwin Harbour.

3.0 RESULTS

3.1 Mosquito trapping.

The results of the mosquito trapping are shown in Table 1. There was a total of 96 mosquitoes recovered, representing 11 species with the highest totals represented by *Aedes funereus* (29), *Ae. kochi* (21), *Anopheles farauti* (12), and *Culex sitiens* (10).

The highest number in any one trap was *Ae. kochi* (15) in the all night catch from site 3, followed by *Ae. funereus* (14) from the day time trap at site 6 (Fig. 1). The highest number of *An. farauti* (7) was from site 5. There were only very low numbers of *Cx. annulirostris* (3) and *Ae. vigilax* (1) present in the collections.

The biology, pest and public health significance of these species are outlined in Whelan (1995).

3.2 Mosquitoes biting.

The only species of mosquito recovered biting were *Ae. funereus.* The sites, location and times of biting are shown in Table 3. The highest number of *Ae. funereus* biting was in a dense monsoon vine forest adjacent to a brackish breeding site at site 6 (Fig. 1).

3.3 Mosquito larval survey of Wickham Point Island.

The larval survey was carried out during a monsoonal episode in a wet season when Darwin received its highest rainfall on record. During the survey it was raining and many of the coastal areas of the island had small streams and seepage discharging from the land margin through to the beach fringe. Most streams and seepage margins were being regularly flushed or flooded with little opportunity for mosquito breeding.

Only *Ae. notoscriptus* and *Ae. funereus* larvae were recovered during the larval survey. The collection sites and details of the collections are shown in Table 4.

A number of sites around the island were inspected by ground observations for their potential mosquito breeding sites. These observations at the various locations are outlined below, with the site localities shown in Figure 1.

Site A, Trap Site 4.

A mixed monsoon vine forest/paperbark fringe at a beach seepage zone bordering a laterite sand flat. This was the most favourable helicopter landing area on the inaccessible and very densely vegetated island.

There was a relatively large, swift flow of water through a small area of medium density paperbark forest (site 4), which flowed into a well developed mangrove area. There was little opportunity for mosquito breeding in the paperbark area, as the surface flows would dry up relatively quickly after the wet season.

There may be some *Cx. annulirostris* and other *Culex* species breeding in some of the deeper pools low down near the high tide mark as the area dries out toward the end of the wet season. There were only a few depressions in the drainage line just below high tide mark, which means there is only a limited opportunity for *Ae. vigilax* breeding sites to occur in the late dry season tidal inundations.

There were numerous depressions (approximately 500-700 mm diameter) throughout locality A which were filled with water. Many of these depressions were in rocky, quartz gravel which would have proved difficult for a small animal to excavate. In approximately one third of these depressions, there were native grape vines (probably *Ampelocissus* sp., Family Vitaceae) growing from the depressions, indicating that the agent of excavation was seeking the underground tubers. It was assumed that the excavations were done by pigs during the preceding dry season, but there was no other evidence of pigs.

There was no mosquito breeding in any of the depressions, but it is possible that when they are filled at the start of the wet season, they could be breeding sites for some of the ground pool breeding *Aedes* species, such as *Ae. phaecasiatus, Ae. lineatopennis,* or *Ae. alboscutellatus.*

Site B.

A relatively steep, rocky quartz gravel shore. There was considerable seepage into the mangrove fringe, and in some of the wider seepage areas, a paperbark fringe was developed. Even the deeper flooded paperbark fringe afforded little opportunity for mosquito breeding in the wet season. The flooded margins would dry up rapidly in the dry season to become a sub soil seepage zone of little consequence as a mosquito breeding site.

Site C.

A relatively large area of poorly draining mangroves which has impeded drainage because of the development of the sand spit E. The area was shallowly flooded by the recent tide, but was also receiving considerable freshwater flow from site D, with the water slowly flowing to the east. There were numerous fish in the flooded area and no mosquito breeding was evident in the mangrove area. This area could become a significant *Ae. vigilax* breeding site in the late dry season after tidal inundation or in the early wet season when first flooded by rain. It would be the most significant source of mosquitoes on the island.

Site D, Trap Site 6.

An extensive flooded area of *Peltophorum* sp. forest grading into mangrove. The water depth was up to 200 mm deep and 50 m wide. The water was clear and fresh, with freshwater aquatic beetles and bugs and a lot of floating leaf litter. This was the principal site of recovery of mosquito larvae during the present survey, and together with site C, is one of the major potential sources of mosquitoes at Wickham Point. When first flooded by wet season rain or very high spring tides, this site could be a major source of *Ae. vigilax*, as well as *Ae. funereus*. All larvae recovered were *Ae. funereus* and were principally associated with the leaf litter. The breeding site was well shaded, with the beach fringe of the flooded area comprised of dense monsoon vine forest thickets with stunted *Cupaniopsis anacardiodes* and *Smilax* sp. vines and other monsoon vine thicket species.

The flooded area was narrowly separated from a steep rock/sand beach which had its base considerably lower than the flood level of the *Peltophorum* sp. area. Near the shoreline adjacent to trap site 6 were two sections of an old rainwater tank previously used as temporary shelters and some old square four gallon tins that may be of World War II vintage. In their present state these containers are not likely to be mosquito breeding sites.

Site E.

The base of the spit of land at site E has a large active orange footed scrub fowl nest. The sand spit was very narrow and had numerous depressions similar to those at site A, but due to the nature of the sand, contained no water. It did not appear as if the depressions were made by the scrub fowl, which had made extensive surface scrapings rather than relatively deep excavations.

There were a number of 200 litre drums and other containers on the sand spit that could become artificial breeding sites for mosquitoes at a later date if they are turned upright and collect water.

Site F.

The slope of the shoreline was steep and rocky. Immediately above the shoreline was a relatively level ground surface and in the thick monsoon vine forest there were approximately twenty, 16 litre plastic buckets with thin bamboo stakes in peat enriched soil. Nearby was a cache of fertiliser and implements consistent with a small, camouflaged horticultural enterprise. Some of the buckets were full of soil with a shallow layer of surface water, but no mosquito breeding was evident in the small number of buckets examined. These could become mosquito breeding sites if partly emptied of soil and refilled by rain.

Site G.

This area was a rocky clay/siltstone headland with quartz reefs. There were numerous rain filled depressions in the rocks which were filled by tide and rain. There was no mosquito breeding in any of the rock pools. It is probable that *Ae. vigilax* could breed in some of the rock pools when flooded by the first rainfall of the wet season or late dry season tides, to create a minor source of this species.

Between Site G and Site L.

Most of the shoreline in this area is very steep with a dense fringe of mangroves between the narrow sandy beach and the steep upland slope. The upland slope was very densely vegetated with well developed monsoon vine forest. The narrow beach fringe has a very thick accumulation of mangrove leaves and branches, and artificial flotsam, including numerous containers, plastic rubbish and timber.

Site H.

A small creekline flowed around a short, sandy shore spit orientated to the shoreline. The creekline was freely flowing by sheet flow above the tidal limit and flowed freely across the tidal limit, across a short section of beach to the well developed mangrove area seaward of this section. There were no tidal or rain retention pools in the creekline which could become mosquito breeding sites.

Site I.

A small flow line which was free draining with relatively small volume, crossed the steep tidal limit shoreline to a well developed mangrove area seaward of the freshwater flow. There was no opportunity for tidal or rain filled depressions at this site to become mosquito breeding sites. A 20 litre open top black plastic container was found near the upper tide limit on the steep beach slope with mosquito larvae (see Table 3).

Site J, Trap Site 1.

This site was a very steep hill slope which abutted the tidal limit shoreline. The hill was very densely forested with dense, relatively short monsoon vine forest vegetation. The beach shoreline was very steep and narrow.

Trap site 1 was approximately 20 m vertically up the slope of the hill in the dense monsoon forest.

Site K.

Seaward of the thin mangrove shore fringe in the section from J to L was a wide, very shallowly flooded *Halosarcia* sp. samphire mud flat. The mud flat contained no depressions and was not conducive to mosquito breeding. Near site K there was a red sheet plastic cross on the mud flat to serve as an aerial indication point.

Site L.

At site L a narrow, sandy spit projected from the steep sided shore line. The sand spit had fringing mangroves and seaward of the spit was a wide mud flat that was well drained and contained no potential mosquito breeding sites.

Site M.

Between the sand spit and the landward margin of the spit there was an area of poorly drained mangroves that was shallowly flooded. Although there was no mosquito breeding at this site during the survey, the poorly draining nature of the mangroves resulting from the sand spit has created a potential *Ae. vigilax* breeding site following late dry season spring tides or when first flooded by early wet season rains. This area would be a relatively small source of salt marsh mosquitoes but because of its proximity to the proposed facilities could be a significant source.

From Site M to Trap Site 3.

This area contained a relatively gentle sloping landward margin which was free draining with no significant development of tidal retention pools. There were various very small flow lines and seepage lines along the margin, with the largest freshwater flow near site Y. There was very little likelihood of any *Ae. vigilax* mosquito breeding in this area, although the relatively small poorly draining area of mangroves near the western base of the sand spit just east of site Y could be an *Ae. vigilax* breeding site following the highest tides of the months in the late dry season. The verification of this site to breed *Ae. vigilax* would need to be checked following a spring tide of over 7.6 m ACD in October or November. If it did prove to be a breeding site, it would be very significant because of the proximity to the proposed facilities.

Trap site 2 was in a relatively well drained, short, open, mixed forest approximately 30 m inland from the tidal limit.

Trap Site 3.

Trap site 3 was in a gently sloping area of open fringing woodland of mixed monsoon forest and open *Eucalyptus* forest vegetation. The area was well drained to the tide limit, with a relatively well drained mangrove fringe. There was considerable seepage from the land into the mangrove fringe. Just south of the trap site was a small sand spit which partly enclosed a small area of poorly draining mangroves. This area was shallowly flooded and fish were present. Although no mosquito larvae were present, this site could be a minor source of *Ae. vigilax* after high tides in the late dry season, or early wet season flooding rain.

Between Trap Site 3 and Site N.

Most of this shore line was very steep, with a rocky siltstone cliff face. There were erosion and wave cut pools near the tide limit. There was no mosquito breeding in the rock pools, but some of these could be a very minor source of salt marsh mosquitoes in the late dry season or early wet season.

Site N.

This site was near a very steep headland. Well above the tide limit was a small cockle shell midden with a few pieces of old bottles that included a piece of an old black square gin bottle (probably of pre World War II vintage). The position above the tide indicates that the cockle shells were not wave washed and the glass artefacts indicate that the midden was probably of relatively recent Aboriginal or early European settler origin.

Trap Site 7.

This trap site was 1 m inside a dense monsoon vine thicket at the edge of a narrow sand spit. The base of the spit had considerable cockle shell accumulations that were probably of human origin.

Site O.

The inside margin of the sand spit at this site was relatively clear of mangrove branch and leaf debris and was well drained, with no development of potential mosquito breeding sites. This is primarily due to the very small catchment associated with the sand spit.

Site P, Trap Site 8.

This site was adjacent to a small free flowing stream discharging through the gently sloping beach margin on the southern side of the small mangrove bay adjacent to the steep hill associated with site N. The stream was shallow and braided through small *Melaleuca* and *Pandanus* vegetation with a boggy clay substrate. There was no evidence of mosquito breeding in the stream or associated margins. This site could become a series of erosion pools which could breed mosquitoes if the upper catchment was disturbed to cause increased stormwater run off and increased stream velocity.

Trap site 8 was approximately 150 m inland from the tide margin in medium density mixed *Pandanus*, open forest, monsoon vine forest vegetation.

Site Q.

There was another small stream draining the north side of this gully. This stream was again shallow, well draining and not conducive to mosquito breeding. There was a quartz outcrop and a well developed cockle shell midden with quartz artefacts near the upper tide limit between the two stream lines at this site. The cockle shells held small amounts of water after recent rain but will not breed mosquitoes.

Site R.

There were two stream lines in this area. The easterly one was very small and of low flow velocity, with a deep 1 m artificial pool just above the high tide mark with water gently overlapping the pool directly over the steep beach margin. There was no mosquito breeding in the pool, but it would be a potential minor mosquito breeding site in the early wet season when it first fills with water. It would breed *Ae. alboscutellatus* and possibly other ground pool *Aedes*.

The west stream was a relatively wide, very shallow, ill defined flow line of sheet flow through light density vegetation including *Pandanus* and *Grevillea*. There were no significant depressions and this site is not likely to be a mosquito breeding area. However due to the boggy clay substrate, this stream flow is very vulnerable to disturbance and the creation of artificial depressions that could lead to mosquito breeding sites. If significant development in the catchment increases the volume and velocity of run off, this flow line could become a significant new mosquito breeding site.

Site S.

There was a small area of restricted drainage in a mangrove area at the base of the sand spit T. This area receives considerable seepage from the nearby hill and has the potential to be a minor salt marsh mosquito breeding site in the late dry and early wet season.

Site T.

This site was near a relatively narrow, thickly vegetated sand spit. If site S proves to be a significant mosquito breeding site, improved drainage could be achieved by installing a sub soil pipe with appropriate erosion control precautions through the base of the sand spit to the lower tidal areas.

Site T to Site U.

Most of the shoreline in this area around the headland of this hill and extending toward site U had a narrow steep beach between thick monsoon vine forest and dense mangroves. The narrow beach zone was very heavily littered with dead mangrove branches, mangrove leaf debris and rubbish flotsam including large numbers of plastic containers. There was a seepage zone across the narrow beach but no potential mosquito breeding sites.

Site V.

On a relatively steep slope of the hill above site W was a long (4-5 m), narrow (1 m), deep (2-3 m) trench filled with clear water. It was an old excavation of possibly World War II vintage or earlier and appears to be a mining exploration excavation or a military trench rather than a well. There was no mosquito breeding in the trench but it could be an occasional mosquito breeding site, particularly if there is increased organic matter in the water.

Site W.

Near the head of the bay was a significant area of well developed *Melaleuca* forest with very shallow sheet flow water with seepage zones laterally around the head of the bay. At the time of the survey the water flow was considerable and there was little opportunity for mosquito breeding. In the early dry season a series of seepage pools in the area could be possible sources of *Cx. annulirostris* and *An. bancroftii*, but they would be very minor sources.

There were no appreciable depressions in the area, but if development in the saddle area of the catchment between the two hills in this vicinity increases the velocity and volume of rain run off to this area, there could be erosion and consequent depressions that could become breeding sites for *Cx. annulirostris*. If there is organic pollution (from septic tanks or fertilisers) into this flow line, these potential mosquito breeding sites could become significant breeding sites. The stream flow through site W to the head of the bay was the most significant on the island.

Site X.

The saddle area between the two hills is a mixture of open *Eucalyptus* forest with a dense understorey including monsoon vine thicket species. The area is very well drained and forms the catchment for the streams either side of the saddle to site W and site Y.

Site Y.

A significant freshwater flow occurs near site Y to the mangrove margin, but drains freely to the mangroves. This drainage area is vulnerable to mechanical disturbance and could become a significant mosquito breeding area if artificial depressions and organic laden stream flows occur in the lower drainage area.

3.4 Mosquito breeding site assessment of the general area.

Wickham Point Area.

The extensive mudflat area with short samphire salt marsh vegetation on the north-west end of Wickham Point is not a salt marsh mosquito breeding site. The narrow isolated beach dune area on the north and north-east tip of the general Wickham Point is a stratified frontal dune system and relatively free draining with no appreciable mosquito breeding sites. There is an area near site G (Fig. 2) at the rear of the frontal beach where there is impeded tidal drainage which is a potential salt marsh mosquito breeding site. It is not likely to be a breeding site during most of the wet season but is a potential site when flooded by high tides in the late dry or when flooded by rain in the early wet season. If salt marsh mosquito problems occur at Wickham Point, this site could be a possible principal source.

Other areas.

There does not appear to be any major salt marsh mosquito breeding sites on the other islands or the adjacent mainland areas in the vicinity of Wickham Point that are likely to cause a significant pest problem on Wickham Point.

There is an area at site H (Fig. 2) that has impeded tidal drainage that could be an *Ae. vigilax* breeding site, but as it is approximately 4 km away from Wickham Point, it should not result in an appreciable problem on the main island. Similarly, there are no major potential breeding sites for other species of mosquitoes in nearby areas that are likely to influence Wickham Point.

However the planned road route to Wickham Point (Fig. 2) does have the potential to create new breeding sites for the salt marsh and other brackish or salt tolerant mosquito species. In particular, the proposed road route and resultant bunding between sites A and B and south of site F (Fig. 2) will form areas of restricted tidal flow that will result in mangrove death and redistribution, and pooling of tidal water. A suggested road route has been delineated to avoid tidal mangrove areas and reduce the potential for tidal impoundment and new mosquito breeding sites (Fig. 2).

3.5 Biting midge trapping.

The results of the biting midge trapping are shown in Table 2. There were 11 species of biting midges recovered from the traps, with the majority (87.74 %) being *C. ornatus*. The biology and pest significance of this and other species is outlined in Whelan (1995).

The site of highest *C. ornatus* recovery (5,400 per trap) was in the all night trap collections at trap site 3 on the south-east end of the island, with trap site 2 (514) at the north-east end of this island next in magnitude.

The highest number of *Forcipomyia peregrinator* (91 per trap) was at trap site 6 on the west end of the island in a day time collection. The highest number of *Forcipomyia townsvillensis* (40 per trap) was at site 3. The other species of *Culicoides* were not in significant numbers, and are not likely to be pests.

3.6 Biting midge day biting collections.

The only biting midge species recovered biting during the day collections was *F. peregrinator* (Table 3). This species was relatively numerous at site 4. There were a number of biting midges flying around the trap at trap site 6 when the trap was collected, but no biting collection was carried out at this location.

3.7 Biting midge breeding site assessment.

The results of the trap collections indicated that trap site 3 was nearest to the most significant *C. ornatus* breeding site, while trap site 1 was probably near the area of lowest *C. ornatus* activity. This information, and conclusions from an examination of the aerial photography, indicate that the most significant potential sources of *C. ornatus* closest to Wickham Point are located in the neap tide zones of area A and area B (Fig. 2). Both of these sites have a significant width of neap tide habitats with small tidal creeks that do not receive wet season freshwater run off.

The major sources of *C. ornatus* in the general area are likely to be associated with the large dendritic areas of mangroves in the creeks at area D and area E, with a third, although less significant source, likely in the creek near area C. These sources are over 1 km from the main island of Wickham Point, but are still within effective flight range of Wickham Point Island under favourable wind conditions.

The area of least *C. ornatus* activity on Wickham Point Island is likely to be in the western half of the island from trap site 4 around to site L (Fig. 1). The narrow mangrove fringe around the western end lacks extensive neap tide habitats, and is unlikely to be a significant breeding habitat. The north-western margin of the island has an open broad area of mud flats between the island and the nearest mangrove areas which have a neap tide zone to the north-west. These mangroves however do not have any narrow creek lines which may be the most productive type of habitat for *C. ornatus* (Shivas et al 1997). This open area is likely to be disruptive to flight activity for any *C. ornatus* originating from the probably less productive mangrove habitats on the western side of Wickham Point.

4.0 DISCUSSION

4.1 Mosquito species and breeding sites.

The most mosquito breeding on Wickham Point Island at the time of the survey was in the brackish flooded *Peltophorum* forest at site D. The numbers of *Ae. funereus* larvae at this site were relatively low, and the trap results did not indicate high adult numbers. However, when the area is first flooded by rain or very high tides, it is probable that there would be much higher numbers of this species.

This site is probably the major source of this species on the island, although there are probably minor sources nearer to trap site 2, which could include areas associated with the stream flow near site Y or the nearby sand spit to the east of site Y. Other minor seasonal sources could be associated with the probable *Aedes vigilax* breeding sites indicated in Figure 1.

Aedes funereus does not usually fly far from its breeding site (up to 1 km) and is usually not found in the day outside humid, well shaded areas such as mangroves and monsoon vine forest.

The most significant mosquito breeding sites at Wickham Point are the probable *Ae. vigilax* sites outlined in Figure 1. These sites are all in restricted drainage sites in tidal areas associated with mangroves which are inundated by the highest tides of the month (probably tides over 7.4 m ACD). There may be a number of small minor sites in rock pools (eg. site G and site N) but these will be relatively minor sources. There are no extensive areas of potential *Ae. vigilax* breeding sites such as the large brackish marsh sites in other areas around Darwin. This is because of the steep topography and the small catchment and transient stream lines on the island.

The most productive *Ae. vigilax* breeding site on the island is likely to be at site C and site D, although the other sites on the island could be locally very significant if they are in close proximity to personnel areas during construction or under normal operations. Other sites on the areas to the north-west (site G, Fig. 2) and the east (site H, Fig. 2) of the main island are possible significant sources and, due to the relatively large flight range of this species, could be sources of pest problems on the main island. It is likely that there will be a major seasonal pest problem due to *Ae. vigilax* at Wickham Point because of a high productivity of this species from relatively small breeding sites, and the particular biting habits of this species.

The verification of the potential areas as actual breeding sites for *Ae. vigilax* would need to be determined by surveying the areas after high spring tides in October to December.

The numbers of *Ae. kochi* from trap site 3 is an indication of a nearby patch of *Pandanus*. This species breeds in the small amount of rainwater collected in *Pandanus* axils and usually reach a seasonal peak during the wet season. There were other sites associated with sites P, Q, W and Y which would have *Pandanus* vegetation, but which had no overnight trap nearby. These sites could have similar numbers of *Ae. kochi* as at site 3.

Aedes kochi does not fly in appreciable numbers far from its breeding sites, and is not likely to be an appreciable pest on the island, as the overall number of *Pandanus* trees is relatively small and the adult numbers at site 3 was relatively small at a time when a seasonal peak could be expected.

The numbers of *Ae. notoscriptus* at site 5 was an indication that there were natural or artificial water filled containers nearby. It is possible that some of the plantation buckets were breeding this species. There were also old tyres and other flotsam around the beach line which could collect rain water and become breeding sites. However unless new artificial sites are created by development, this species is not likely to be an appreciable pest. It would be worthwhile to conduct a beach clean up campaign around the beach to remove all the artificial containers that are potential breeding sites for this species.

A principal potential malaria vector mosquito *Anopheles farauti* was found in the highest numbers at site 5. This is not far from the flooded *Peltophorum* forest area, which is a brackish water site. This species is a member of a species complex of at least three species in the NT and includes *Anopheles farauti* sp.1 which is a brackish water breeder. As the highest numbers of this species were found near a relatively large brackish water site it is likely to be *An. farauti* sp. 1. The most significant potential breeding site for this species on this island is the *Peltophorum* forest area near site 6.

There may be other small localised sources of this species near site 2 and site 3 and they are probably associated with small brackish areas near the tidal boundary in the vicinity of the probable *Ae. vigilax* breeding sites.

The number of *Cx. annulirostris* trapped was very low. This is partly a reflection of the time of the survey, when most freshwater pools have been regularly flushed by recent rains, and the lack of any extensive areas of freshwater pooling on this island. This species is not likely to be present in significantly higher numbers at other times of the year.

Both *Aedes* sp. 76 and *Tripteroides magnesianus* are natural tree hole breeding mosquitoes which breed after the holes are flooded by rain. They are not likely to be present in appreciable numbers on the island.

4.2 Mosquito pest and human health implications.

The greatest potential pest and disease problems on the island will be due to *Ae. vigilax*. This species is a persistent and vicious biter and can bite by night and during the day in shaded situations. It can reach very high adult pest numbers from relatively small localised breeding sites. It is a confirmed vector of Ross River virus (RRV) and Barmah Forest virus (BFV) (Whelan *et al.* 1993, Russell 1995). At Wickham Point the population of *Ae. vigilax* is likely to persist for longer after adult emergence episodes than most other areas near Darwin because of the extensive sheltering monsoon vine forest. This increased longevity means that a higher proportion of *Ae. vigilax* at Wickham Point may be infected with RRV. In Darwin, *Ae. vigilax* is responsible for numerous cases of RRV in the late dry season and early wet season. Any personnel at Wickham Point exposed to attacks of this species during this period will be faced with the risk of arbovirus infection.

Both *Ae. funereus* and *Ae. notoscriptus* have been implicated as possible vectors of RRV (Russell 1995; Whelan 1995). *Aedes funereus* is only likely to be a major pest in the close vicinity of site D, but could be present at other localities in monsoon forest areas and abutting shaded areas during the day in sufficient numbers to cause a pest problem. *Aedes notoscriptus* could be abundant near personnel areas if artificial breeding sites such as old tyres, machinery and other containers are nearby and allowed to fill with rain water.

Anopheles farauti sp. 1 is a potential malaria vector (Whelan 1981; 1995). There is currently no indigenous malaria transmission in the NT (or mainland Australia). Malaria was eradicated in the NT in 1962. However the NT is still receptive and vulnerable to malaria re-introduction (Whelan 1981).

It has been recognised that mining and development ventures pose a potential threat for the introduction of malaria by often having overseas personnel as part of their workforce. If cases of imported malaria occur in the vicinity of a population of *An. farauti*, there is a potential for the parasite to be picked up by the local mosquitoes and transmitted to other people. For this reason all suspected cases of malaria should receive medical attention as soon as possible to ensure that they are treated to prevent them infecting local mosquitoes. The THS has a comprehensive malaria policy to prevent malaria re-introduction, but it relies on patients seeking medical advice as soon as possible.

The size of the breeding sites and the expected numbers of *An. farauti* at Wickham Point is likely to be relatively small. However if the company has appreciable numbers of personnel recently arrived from overseas, and if the personnel are exposed in the evenings and night near breeding sites, particularly near site C and D, there is a potential for subsequent malaria transmission. The company should be alert to the possibility of malaria in recently arrived personnel from overseas or in personnel returning from overseas holidays. The company should have an education strategy to inform personnel of the potential for contracting malaria overseas, and the public health risk if they remain untreated in the vicinity of mosquito breeding sites when they return to Darwin.

Culex annulirostris is a potential vector of various arboviruses including RRV, BF and Murray valley encephalitis (MVE) (Whelan *et al.* 1993, Russell 1995). In other areas of Darwin it is a major pest species. At Wickham Point this species is unlikely to be in pest numbers and hence may have a relatively small potential to cause disease. However if new breeding sites are created by development, this species could become locally abundant and pose a risk for arbovirus disease.

The other species of mosquitoes detected during the current survey are not likely to reach pest numbers and are not significant in relation to human disease.

4.3 Construction activities and new mosquito breeding sites.

The greatest potential for the creation of new mosquito breeding sites will arise with disturbances by construction activities in or near tidal areas. The THS has drawn up specific guidelines to reduce the possibility of creating mosquito breeding sites in these areas (Whelan 1988). The company is urged to examine all construction plans with these guidelines in mind.

The greatest potential for new mosquito breeding sites will be in the construction of access roads across tidal areas. The preliminary plans show roads across considerable sections of mangroves (Fig. 2). These roads have the potential to impound tidal water. Even relatively small impoundments and tidal restriction can create mosquito breeding sites. If tidal water is impounded it will probably lead to new breeding sites for *Ae. vigilax, Cx. sitiens, An. hilli,* and *An. farauti*. The extent of new breeding sites for the latter species will depend on the degree of freshwater run off into the impounded area.

A suggested alternative road route has been indicated to reduce the potential for tidal impoundments (Fig. 2). Any road embankment in or near a tidal area should include specific construction and design details to prevent tidal restriction or impoundment of tidal water.

There will be a potential to create new breeding sites for *Cx. annulirostris* if any development increases the volume and velocity of stormwater run off through sites W, Y, P, Q, R, H and D. There should be design consideration given to prevent or reduce increased run off to these sites, and stormwater erosion control and water retention structures should be installed wherever necessary to reduce or eliminate potential erosion problems.

The freshwater flow paths at sites X, W, R, Q, and P have a clay substrate and have a high potential to become new mosquito breeding sites if machinery and vehicle access cause disturbances in these areas. Precautions should be taken to ensure that these areas do not become quagmires of disturbed areas that breed mosquitoes.

New mosquito breeding sites can also be created with the installation of rainwater tanks, septic tanks, oil tank safety bunds, catch basins at roadside entry pits, and the incorrect disposal of unused or disused containers capable of holding water. These sites are potential breeding sites of *Ae. notoscriptus, Cx. quinquefasciatus* and *Cx. annulirostris* and specific measures should be taken to ensure that these sites do not become new mosquito breeding sites.

4.4 Mosquito control by engineering.

There are a number of existing mosquito breeding sites that could be rectified by engineering measures. These include the poorly draining tidal retention areas at sites C and T (Fig. 1). Impeded drainage in these two sites has resulted from the development of a sand spit, and both have a base of the sand spit on the seaward side that is considerably lower than the flooded water surface of the retention area. A relatively short sub soil pipe through the sand spit, with appropriate erosion prevention structures at either end could be installed to drain these sites.

Other sites where *Ae. vigilax* breeding could occur on this island do not appear to be amenable to this control method because of the flat nature of the general area, and the lack of a suitable and close sink for the retained water. These areas could be shallowly filled during construction activities or drained by very shallow surface ditching.

4.5 Larval mosquito control by insecticides.

If the rectification of the actual mosquito breeding sites on the island cannot be achieved, the company should ensure that they have the capacity to inspect the potential mosquito breeding areas and carry out insecticide larval control operations as necessary. The THS is available for advice on such surveillance and control operations (Whelan 1995). The insecticide of choice for most of these larval control situations will be *Bacillus thuringensis* var. *israelensis.*

4.6 Biting midges and their breeding sites.

It is clear from the trap collections that the major biting midge pest problem will be posed by *Culicoides ornatus* and the area of greatest pest potential will be in the eastern half of the island.

The breeding sites of *C. ornatus* are in the upper neap tide zone in the mud beneath mangroves in wave sheltered shorelines, and are usually associated with small creek lines within the mangroves (Shivas et al 1997). The reason for the higher numbers near the east end of the island is due to the large linear length of neap tide habitat in area A and B due to the number of small tidal creeks in these areas (Fig. 2). There is only a relatively small linear length or width of neap tide habitat around the south, south-west, north and north-east sides of this island.

There are much larger potential breeding sites of this species in areas D and E and C (Fig. 2) which would be close enough to Wickham Point, and with favourable winds, could cause a pest problem at Wickham Point.

The collections from the present survey are likely to be at the bottom end of the scale of magnitude as an indication of the biting midge pest problems likely to be encountered at Wickham Point. While the east side of the island will undoubtedly be the area of principal pest problems, it is probable that when populations of biting midges are much higher in August or September, the pest problem will extend over a much wider area of the island.

The other species of *Culicoides* recovered during this survey are not likely to be significant pests of human in the area (Whelan 1995).

The other potential pest biting midges are *Forcipomyia peregrinator* and *F. townsvillensis*. The biology and available knowledge on these species is relatively limited (Debenham 1983). They are known to attack humans during daylight hours and were minor pests during the day in the present survey. Both species were present in only relatively low numbers and personnel areas away from monsoon forest or dense vegetation may not be subjected to pest problems from this species.

Forcipomyia peregrinator was present in highest numbers in the day time trap at site 6 in the dense monsoon vine forest, and in much lower numbers at the nearby collection site 5. It is clear from these results that trap site 6 is near a principal source of this species, and they are not flying any great distance from their breeding sites. The breeding sites remain unknown, but as they may be associated with dense vegetation or specific swamp situations, the clearing of vegetation or the draining of the brackish swamp at site D could significantly reduce the breeding sites available for these species.

4.7 Biting midge pest problems and avoidance.

Culicoides ornatus will be the major pest species at Wickham Point. *Culicoides ornatus* is a major pest of humans in the NT. Recent work in the NT has revealed new aspects on the biology of this species, including the flight activity, dispersal, and the characterisation of the breeding sites (Whelan et al 1997; Shivas et al 1997).

Culicoides ornatus is likely to be a severe pest in at least the eastern half of the island, and possibly the whole of the island area. They will be most numerous around August to December at the time of the full moon, and principally in the early evening and morning. Elevated sites such as hills may not offer significant escape from pest numbers (Whelan et al 1997). *Culicoides ornatus* is likely to disperse readily throughout the island and persist after emergence longer than other areas near Darwin because of the extensive shelter and higher humidity offered by the monsoon vine forest. People with little or no resistance to the effects of bites of *C. ornatus* could be faced with severe reactions. Major pest episodes could result in industrial action.

The best strategy to reduce the potential pest problem is to avoid the problem areas by siting any high use personnel areas, particularly those having evening and early morning activity, in the south-west section of the island. Any personnel facilities should be constructed with the ability to be screened or sealed from biting midge entry. It should be noted that biting midges will penetrate normal insect screens.

4.8 Adult mosquito and biting midge control by insecticides.

Adult mosquito and biting midge control is not likely to be practical or effective under most circumstances.

Biting midges breed in the neap tide zone of the mangroves under dense mangrove cover, and any ground based adult control is unlikely to be able to reach or penetrate these sites. These sites are a considerable distance from the main island and there is limited access around the margin of the island. Any ground adult control operations around the margin of the island is unlikely to kill biting midges at more than 30 m into the mangrove vegetation, and reinvasion of the treated areas would occur within minutes of fogging.

The only instance when adult control of biting midges may be effective is in the pre-dispersal stage around neap tide emergence. However adult control would need to be by aircraft. Other limitations to this method are that all the neap tide breeding sites would need to be determined, the insecticide would need to penetrate beneath dense mangrove canopy, large areas of treatment would be required, the insecticide of choice would be non-selective, and repeated applications would have deleterious effects on many non-target animals.

Mosquito breeding sites would be better targeted by larval control operations. However there may be instances when adult mosquitoes are present near personnel areas on the island. There is a case for judicious ground fogging operations in some situations, but there would have to be significant mosquito harbouring sites close to personnel areas, and it would only be useful if reinvasion of these sites did not occur immediately. This situation is unlikely to arise at Wickham Point.

4.9 Mosquito and biting midge personal protection.

There will be times when personnel will be exposed to seasonal attack by either biting midges or mosquitoes. The THS has an information paper on personal protection. It is recommended that the company incorporate advice on the pest and health issues, and methods of personal protection from biting insects into their induction procedures for new personnel at Wickham Point. Aspects of particular importance are an awareness of the potential for Ross River virus infection posed by salt marsh mosquito attack, and the necessary protective clothing and repellent measures that may be necessary during periods of mosquito attack.

5.0 CONCLUSIONS

1. The recent mosquito and biting midge survey of Wickham Point has been necessarily limited, and was conducted at a time of the year that was not conducive to indicating the true magnitude of mosquito and biting midge pest problems. It is not likely to give an accurate list of all the mosquito or biting midge species that may occur on the island.

2. The major potential biting insect pest problem on the island will be from the biting midge *Culicoides ornatus*. The principal pest problems are likely to occur on the eastern half of the island, although a general pest problem could seasonably occur over a large area of the island. Pest problems could persist longer than some other areas near Darwin because of the extensive monsoon forest.

3. Significant sources of *C. ornatus* are likely to be from the wide mangrove margins at the south-east end of the island (site A and site B, Fig. 2). Major sources of *C. ornatus* are likely to be in the small dendritic creek lines which form part of the larger mangrove creeks to the east of Wickham Point Island (Site D and Site E, Fig. 2).

4. It is not practical to control the larvae of *C. ornatus*, and adult control of either biting midges or mosquitoes will generally not be practical or effective.

5. The major potential mosquito pest and principal vector of disease will be the salt marsh mosquito *Aedes vigilax*. The principal disease threat posed by this species will be the arbovirus diseases caused by Ross River virus and Barmah Forest virus. Disease risks should persist longer after emergence of *Ae. vigilax* in this area because of the favoured adult harbouring sites in the monsoon vine forest.

6. No larvae of the salt marsh mosquito *Aedes vigilax* were found during the survey because this species has a seasonal occurrence. However a number of potential breeding sites of *Ae. vigilax* were located. The major potential breeding site on the island was the poorly draining *Peltophorum* forest and the upper mangrove area near Site C at the south west corner of the island.

7. There are a number of options for the control of the breeding sites of the salt marsh mosquitoes, but the verification of these sites as breeding sites should be carried out by the company before any engineering rectification work is started.

8. The company should have a capability to detect and control salt marsh mosquito larvae if and when they occur on the main island. If significant pest problems due to *Ae. vigilax* develop on the island, other nearby sources of *Ae. vigilax* should be surveyed and controlled.

9. The company should carry out a general clean up of artificial containers around the shore line. A construction and management strategy should be in place to avoid or reduce containers and other artificial sources of mosquitoes under a mosquito management program.

10. The principal potential new source of mosquitoes will be posed by the construction of an access road to Wickham Point. The company should note the suggested road route and other measures to minimise the creation of new mosquito breeding sites.

11. Other potential sources of mosquitoes will occur with vehicle, machinery, and storm water run off disturbance to the existing fresh water flow lines on the island. The company should avoid

disturbing potential problem sites and construct erosion control structures wherever necessary to avoid creating new mosquito breeding sites.

12. A considerable effort should be made by the company to educate both the construction workforce and the permanent personnel on the potential pest and public health problems posed by biting midges and mosquitoes. The company should publicise and make information and facilities available to ensure that the personnel are protected from pest and potential mosquito borne disease problems.

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TABLE 1

ADULT FEMALE MOSQUITOES CAUGHT USING CO2 BAITED MOSQUITO TRAPS WICKHAM POINT, DARWIN HARBOUR 24 - 25 FEBRUARY 1997

SITE NO.	TRAP LOCATION	TRAP TIME	MOSQUITO SPECIES											TOTALS	% OF TOTALS
			An. (Cel) farauti	*An. (Cel)novaguinensis*	*Ae(Fin) kochi*	*Ae (Fin) notoscriptus*	*Ae (Mac)* sp. 76	*Ae (Och) vigilax*	*Ae (Ver) funereus*	*Cx. (Cux) annulirostris*	*Cx. (Cux) sitiens*	*Cx.(Cux)* Vishnui grp.	*Tp (Trp) magnesianus*		
1	North west side island, base of hill. Thick vine forest. In closed forest 20 m uphill.	All night 1600 - 0840 17 hrs					1	1	1	1	2			6	6.25
2	North-east side of island. Dry sand flat. In open vine forest 30 m inland from tide limit.	All night 1610 - 0850 17 hrs	2		4	1			6	3		1		**17**	**17.71**
3	South side of island. Two nearby mudflats. In open vine forest 30 m inland from tide limit.	All night 1620 - 0900 17 hrs	3	1	15	1	3		1	2	4		1	**31**	**32.29**
4	Camp - centre of island. Laterite rock mudflat - tidal. In medium density vine forest, paperbark forest.	0905 - 1500 6 hrs												**0**	**0.00**
5	West side of island back from headland, near old tin shelter. In thick vine forest, 100 m west of swamp margin and 20 m from beach tidal limit.	All night 1500 - 0930 18 hrs	7		1	4		1	7		3			**23**	**23.96**
6	West side of island back from headland. In dense vine thicket at edge of brackish swamp and 20 m from beach tide limit.	0920 - 1430 5 hrs				3			14					**17**	**17.71**
7	Sand spit, central island coast. In thick vine forest 10 m from beach tide limit.	1100 - 1300 2 hrs									1			**1**	**1.04**
8	Inland from sand spit, central island. 150 m inland from head of bay. Pandanus in area, head of small stream, swampy ground.	1130 - 1330 2 hrs			1									**1**	**1.04**
	TOTALS		**12**	**1**	**21**	**9**	**4**	**2**	**29**	**6**	**10**	**1**	**1**	**96**	**100.00**
	% OF TOTALS		**12.50**	**1.04**	**21.88**	**9.38**	**4.17**	**2.08**	**30.21**	**6.25**	**10.42**	**1.04**	**1.04**	**100.00**	

TABLE 2

ADULT BITING MIDGES CAUGHT USING CO2 BAITED MOSQUITO TRAPS
WICKHAM POINT, DARWIN HARBOUR 24 - 25 FEBRUARY 1997

SITE NO.	TRAP LOCATION	TRAP TIME	BITING MIDGE SPECIES											TOTALS	% OF TOTALS
			Culicoides actoni	*Culicoides austropalpalis*	*Culicoides bundyensis*	*ornatus gp undescribed sp.*	*Culicoides ornatus*	*Culicoides pallidothorax*	*Culicoides papuensis*	*Culicoides pungens*	*victoriae gp undescribed sp.*	*(Lasiohelea) peregrinator #*	*(Lasiohelea) townsvillensis #*		
1	North west side island, base of hill. Thick vine forest. In closed forest 20 m uphill.	All night 1600 - 0840 17 hrs					6							**6**	**0.08**
2	North-east side of island. Dry sand flat. In open vine forest 30 m inland from tide limit.	All night 1610 - 0850 17 hrs	11	6		29	514	1@		11		1@		**573$**	**8.13**
3	South side of island. Two nearby mudflats. In open vine forest 30 m inland from tide limit.	All night 1620 - 0900 17 hrs		10*	10*	360	5,400	60	120	60	10*	20*	40*	**6090$**	**87.36**
4	Camp - centre of island. Laterite rock mudflat - tidal. In medium density vine forest, paperbark forest.	0905 - 1500 6 hrs					6							**6**	**0.08**
5	West side of island back from headland, near old tin shelter. In thick vine forest, 100 m west of swamp margin and 20 m from beach tidal limit.	All night 1500 - 0930 18 hrs					244		10	3		4@	2@	**263$**	**3.74**
6	West side of island back from headland. In dense vine thicket at edge of brackish swamp and 20 m from beach tide limit.	0920 - 1430 5 hrs					13					91	5	**109**	**1.54**
7	Sand spit, central island coast. In thick vine forest 10 m from beach tide limit.	1100 - 1300 2 hrs					11						1	**12**	**0.17**
8	Inland from sand spit, central island. 150 m inland from head of bay. Pandanus in area, head of small stream, swampy ground.	1130 - 1330 2 hrs					8					2		**10**	**0.14**
	TOTALS		**11**	**16**	**10**	**389**	**6202**	**61**	**130**	**74**	**10**	**118**	**48**	**7069**	**100.00**
	% OF TOTALS		**0.16**	**0.23**	**0.14**	**5.50**	**87.74**	**0.87**	**1.84**	**1.05**	**0.14**	**1.67**	**0.68**	**100.00**	

*Estimate of *Culicoides* based on a bulk subsample of 600. # To be verified by specialist. @ In bulk only. $ Subsample of 100.

TABLE 3

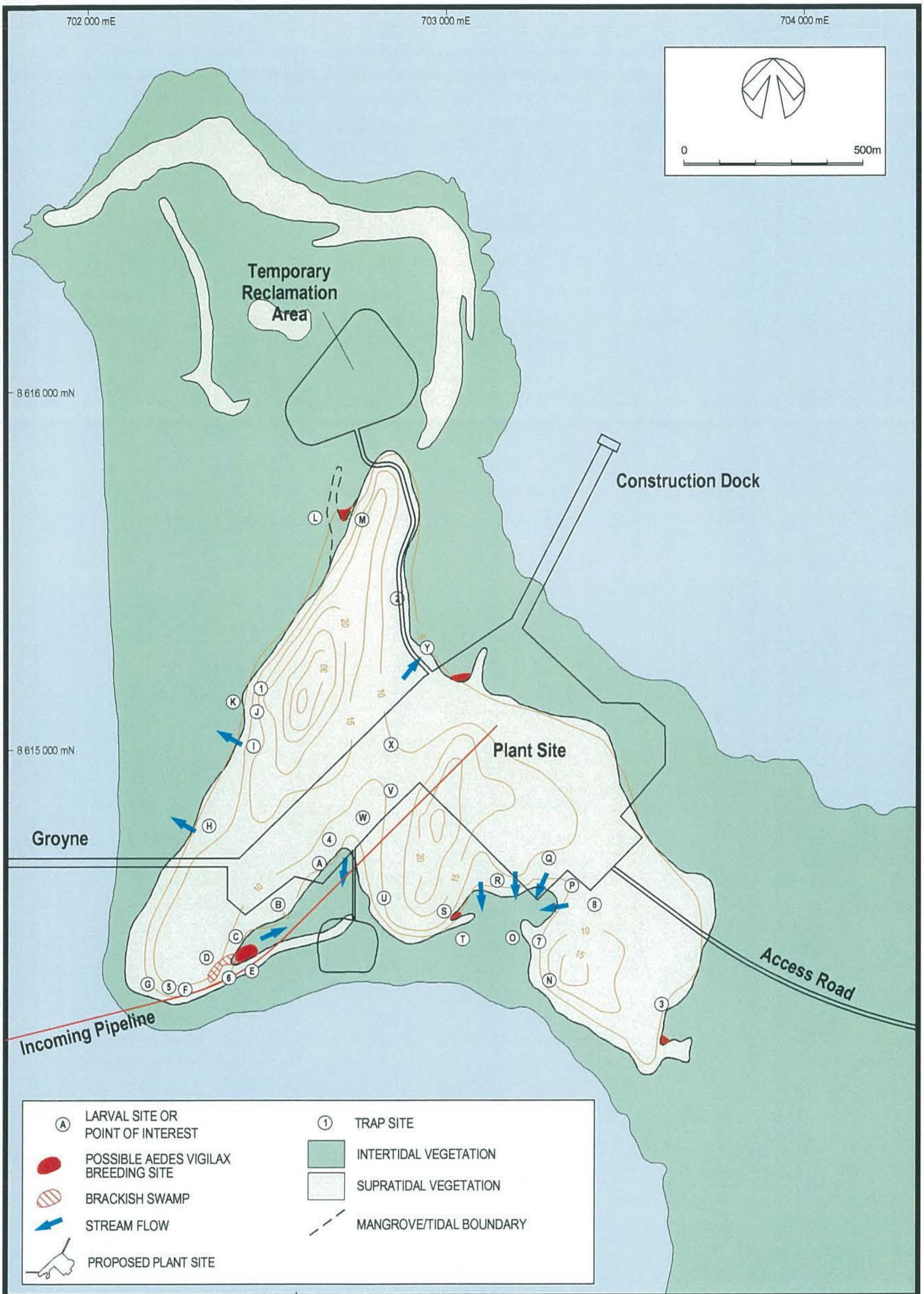
MOSQUITO AND BITING MIDGE HUMAN BITING COLLECTION
WICKHAM POINT, DARWIN HARBOUR 24 - 25 FEBRUARY 1997

SITE NO.	TRAP LOCATION	BITING TIME	MOSQUITO SPECIES	BITING MIDGE SPECIES	NOTES
			Aedes funereus	*Forcipomyia (Lasiohelea) peregrinator*	
6	In dense monsoon vine forest near brackish swamp.	1230 - 1235 24/2/97	5		Biting in dense shade on face and arms and hovering on overalls. No biting in open sun on beach.
4	Centre of island in medium density vine forest and paperbark fringe at edge of swiftly flowing stream, and rock/mud flat.	1100 - 1105 25/2/97		1	In medium shade. Approximately 20 hovering around lower legs. When a leg was exposed only 1 or 2 were biting at one time.
4	As above for site 4.	1600 - 1605 25/2/97	1		In medium shade. Occasional biting with 1 or 2 attracted at one time.
	TOTALS		**6**	**1**	

TABLE 4

MOSQUITO LARVAL COLLECTIONS
WICKHAM POINT, DARWIN HARBOUR 24 - 25 FEBRUARY 1997

SITE NO.	SITE LOCATION	SITE DESCRIPTION	SPECIES & INSTAR	NUMBER/DIP	NOTES
D	Under flooded Peltophorum forest with adjacent dense monsoon vine forest and fringing paperbark forest on landward side.	Shaded clear water with tadpoles and leaf debris. Numerous aquatic predacious water bugs and beetles.	*Ae. funereus* 4th instar	2	At margins and in leaf debris.
I	At high tide mark in shade of overhanging monsoon vine forest and mangroves.	Black plastic 20 litre drum open topped, upright and full of water.	*Ae. notoscriptus* 2nd, 3rd, 4th instars and pupae.	5	Many larvae (few hundred) in the drum with most concentrated at bottom.



Phillips Oil Company Australia
DARWIN LNG PLANT, DRAFT EIS

BITING INSECTS SURVEY SITES

DAMES & MOORE PTY LTD
A DAMES & MOORE COMPANY

FIGURE 1

DAMES & MOORE PTY LTD
A DAMES & MOORE COMPANY

BITING MIDGE BREEDING AREAS

Phillips Oil Company Australia
DARWIN LNG PLANT, DRAFT EIS

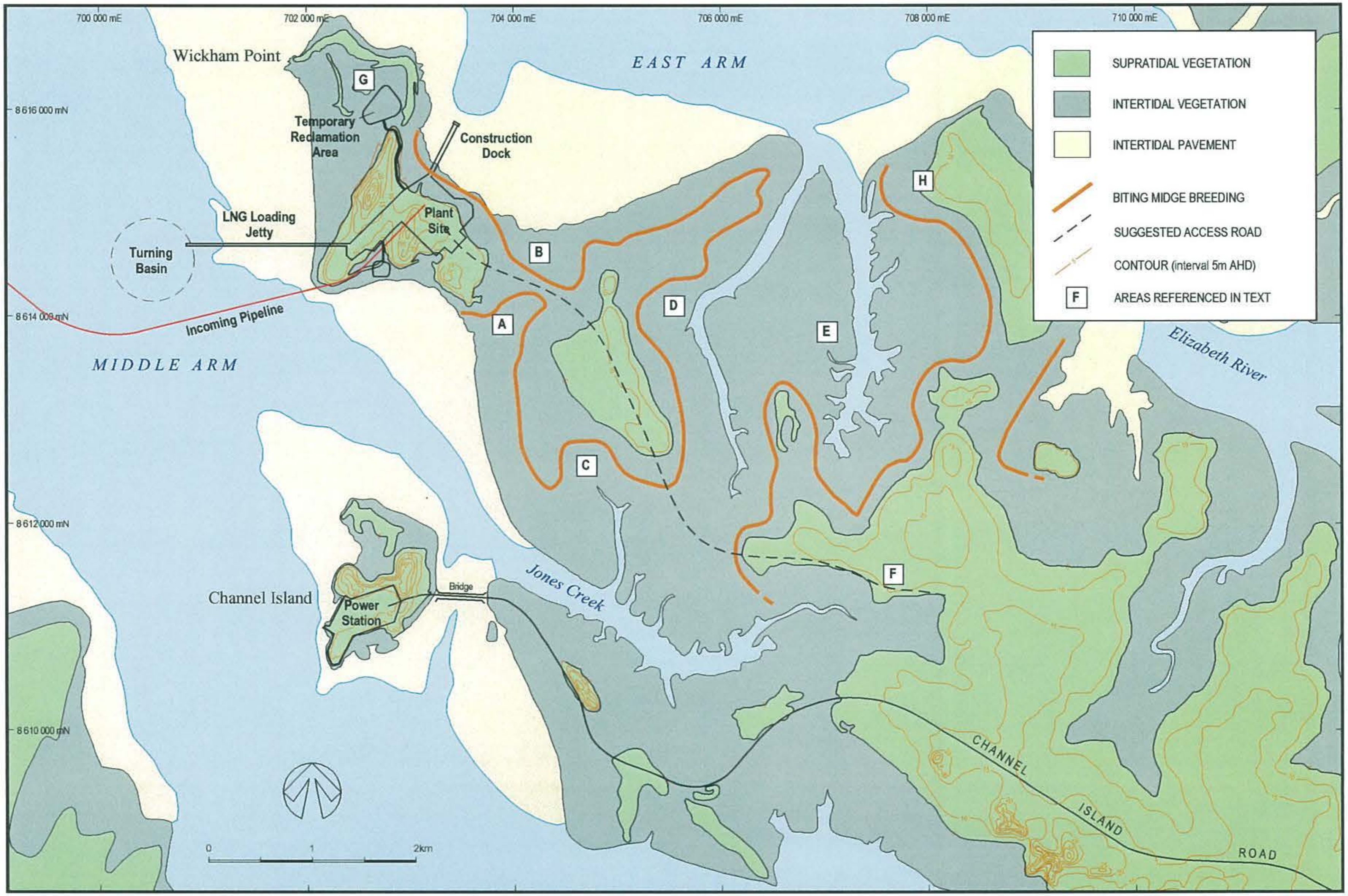


FIGURE 2

Appendix K

LEPROVOST DAMES & MOORE

A DAMES & MOORE AFFILIATE

REPORT

Darwin LNG Plant
Draft Environmental Impact Statement

Appendix K
Darwin Harbour Marine Habitats Survey

for

Phillips Oil Company Australia

Ref: 00533-164-073
Report No. R635, Appendix K
[DK:LDM0315/PER]
July 1997

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1. INTRODUCTION

1.1 THIS DOCUMENT

This document presents the results of a survey of marine habitats within Darwin Harbour conducted between September and November 1996 by LeProvost Dames & Moore (LDM).

1.2 OBJECTIVE AND SCOPE OF WORK

The objective of the survey was to provide biological input for the Environmental Impact Statement (EIS) document being prepared to assist in securing environmental approvals for the construction and operation of a liquefied natural gas (LNG) plant and subsea pipeline within Darwin Harbour. The proponent for the development is Phillips Oil Company Australia (Phillips).

The scope of the survey was to:

- characterise the predominant marine communities of the intertidal and subtidal habitats most likely to be affected by project construction and operation activities;
- collect surface sediments from within the proposed loading facility turning basin, to be analysed for contaminant status and particle size distribution;
- provide summary data for inclusion in the draft EIS.

1.3 BACKGROUND

Phillips proposes to construct a 500 km long subsea pipeline to transport gas from its Bayu-Undan field in the Timor Sea to the proposed LNG plant. The preferred route for the pipeline comprises an easterly to south-easterly alignment from the field to the entrance of Darwin Harbour, and thence through the harbour to the plant site at Wickham Point (Figure 1).

2. METHODS

Intertidal habitats in the vicinity of the plant site and pipeline alignment were accessed by small tender vessel. Walking inspections were undertaken, with habitat types mapped at a broad scale, photographs taken and the predominant macrobiota characterised.

Subtidal habitats were inspected using SCUBA equipment, with a video record made of each site. Poor water clarity precluded the taking of still photographs. The predominant sessile macrobiota were characterised on-site, with some additional information obtained from a review of the video record.

The benthic fauna of the sediments within the area to be dredged for the proposed turning basin were characterised from samples collected using a Van Veen grab with a ~0.15 m^2 gape. Three replicate samples were collected from each of three stations. Samples were passed through 3 mm and 1 mm mesh sieves, with the material retained on the sieves fixed in 10% formalin for at least 24 hours, then preserved in 20% methyl alcohol for transport to Perth. Separation of fauna from the samples, and fauna identification and counts, were undertaken in Perth. Analysis of faunal abundance and diversity within the samples was undertaken using the PRIMER (Plymouth Routines in Multivariate Ecological Research) multivariate statistical package developed at the Plymouth Marine Laboratory, United Kingdom.

Surface sediments were collected by SCUBA diver from three stations within the turning basin area. At each station, sediments typical for the area were collected within three sets of five polycarbonate tubes (four placed at the corners of an imaginary one metre square, the fifth placed at the centre of the square). The upper 2.5 cm of sediment from each set of five tubes was bulked into a single sample within a sterile plastic whirlpack. At each site, one sample of surface sediment for hydrocarbon analysis was collected within a laboratory-prepared glass jar, sealed with a lid lined with aluminium foil to prevent contamination. Samples were frozen and air freighted to Perth for analysis by Analytical Reference Laboratory (ARL).

3. RESULTS

3.1 INTERTIDAL AND SUBTIDAL HABITATS

Habitat surveys were undertaken between 29 September and 7 October 1996. Summary descriptions of the predominant macrobiota characteristic of the habitats are given below. Survey locations are listed in Table 1 and shown on Figure 1. The intertidal habitats of Wickham Point, as derived from interpretation of aerial photography and observations made during the surveys, are shown on Figure 2.

3.1.1 'LNG Point'

For the purpose of this report, 'LNG Point' refers to the southern headland of Middle Point Peninsula, which encompasses the proposed plant site and loadout facility.

Mangroves fringe the entire shoreline of LNG Point and are fronted by expanses of soft mangrove mud, except where a sloping rock shelf extends southwards from the point. On the northern side of the proposed jetty alignment, which extends westwards from LNG Point, is an expanse of pavement supporting three intertidal rock stacks. In general, the mangrove mud was moderately bioturbated, with fiddler crabs (*Uca* spp.), alpheid shrimp and mudskippers (*Periopthalmus* sp.) associated with many of the burrows.

There was a high degree of similarity between the biotic zonation on the southern rock shelf and the zonation on the western pavement and rock stacks. Small oysters (*Saccostrea cuccullata, S. amasa* and *S. echinata*) were abundant on the higher intertidal rocks in both areas, and the calcareous tubes of *Galeolaria* worms (Polychaeta) were common. Barnacles (primarily *Chthamalus malayensis* and *Tetraclita squamosa*, with some *Tetraclita* cf. *rosea* and larger balanids) were abundant on the western rock stacks, particularly on those rock faces with a westerly aspect, but uncommon on the southern rock shelf. The barnacles occupied a zone below the oyster zone, along with an abundance of acmaeid limpets, false limpets (pulmonate *Siphonaria* spp.) and small mussels (Mytilidae). The absence of the barnacle zone from the southern rock shelf was probably due to the presence of an unsuitable substrate type (small, mobile rocks) at the required tidal level.

TABLE 1

SUBTIDAL HABITATS INVESTIGATIONS

SITE	LATITUDE	LONGITUDE	DEPTH (LAT)	COMMENTS
DH01	12° 21.050'	130° 40.216'	-7 m	Charles Point Patches. Sand waves (~3 m high) - rippled coarse sand with silt. One sponge, one hermit crab, one burrow.
DH02	12° 21.019'	130° 39.932'	-5 m	Charles Point Patches. Sand waves (~3 m high) - coarse sand with abundant shell fragments, some silt. One sea pen.
DH03	12° 26.095' 12° 25.922'	130° 46.092' 130° 46.007'	-5 m -3 m	West Point. Pavement with coarse sand and rubble veneer. Sponges, gorgonians, *Dendronephthya*, *Goniopora*, crinoids, bryozoans and colonial ascidians. *Padina* and *Sargassum*.
DH04	12° 26.406' 12° 26.170'	130° 46.012' 130° 46.057'	0 m 0 m	West Point. Pavement with veneer of rubble, medium sand and silt. Abundant algae. Scattered corals - large *Symphyllia* and *Goniastrea favulus*. Also *Porites, Leptastrea, Goniopora, Moseleya* and *Euphyllia*.
DH05	12° 29.132' 12° 29.233'	130° 47.588' 130° 47.738'	+1 m +1 m	Weed Reef (north-east). Pavement with pockets of medium to coarse sands and a silt veneer. Hard corals abundant (but low cover), very high diversity. Also sponges and soft corals.
DH06	12° 28.720' 12° 28.684'	130° 47.126' 130° 47.132'	-15 m 0 m	Plater Rock. Soft bioturbated sediments at base of steep rock slope. Lower slope - diverse gorgonians and sponges. Upper slope - high diversity of hard corals (moderate cover), some large colonies (*Porites* ~3 m diam.).
DH07	12° 29.960' 12° 30.040'	130° 48.272' 130° 48.300'	+1 m -1 m	Weed Reef (south-east). Pavement with rubble, small hard coral colonies and thin veneer of fine sand and silt. Sparse seagrass (*Halophila* cf. *decipiens*) on areas of deeper fine sand and silt, with heavy bioturbation, scattered small hard coral colonies and occasional gorgonian.
DH08	12° 28.520'	130° 48.020'	-19 m	Wreck of John Holland Barge. Prolific soft corals (including *Lemnalia*), hydroids and sponges on wreck, abundant juvenile fish, occasional hard coral (*Tubastrea, Arcohelia* and *Heteropsammia* spp.). Silty coarse sand with shell fragments surrounding wreck - few sponges and burrows.
DH09	12° 29.360'	130° 49.042'	-15 m	Wreck of USAT Meigs. Prolific sponges, gorgonians, hydroids and soft corals (predominantly *Dendronephthya* and *Lemnalia* spp.) on wreck. Scattered hard corals (*Arcohelia* and *Heteropsammia* spp.) and crinoids. Rippled silty coarse sand with shell fragments surrounding wreck, some tube anemones
DH10	12° 33.018' 12° 32.948'	130° 51.497' 130° 51.587'	0 m +1 m	Channel Island (north-west). Soft, silty clay. Burrows of various sizes, ~50/m^2. Scattered stingray feeding depressions.
DH11	12° 32.490' 12° 32.499'	130° 51.784' 130° 51.777'	-1 m +1 m	Channel Island (north). Edge of pavement with thick veneer (>10 cm) of silty fine sand, highly bioturbated. Frequent hard coral colonies (<10% cover), predominantly *Lobophyllia* sp. Scattered soft corals (mainly *Dendronephthya* sp.) and sponges.
DH12	12° 33.150' 12° 33.113'	130° 52.451' 130° 52.454'	+1 m -2 m	Channel Island (north-east). Edge of broken pavement with thin veneer of silt. Frequent hard coral colonies (<10% cover), high diversity. Scattered sponges, colonial anemones, soft corals and gorgonians.
DH13	12° 28.045' 12° 28.116'	130° 48.134' 130° 48.058'	-17 m -11 m	Channel Marker No.9. Pavement with gravel and thin veneer of silt on channel floor, increasing thickness of coarse sand and silt veneer towards base of slope. Lower slope steep and rocky, upper slope with veneer (<10 cm thick) of coarse sand and silt. Abundant sponges, gorgonians and hydroids throughout.
DH14	12° 31.669'	130° 50.546'	-13 m	Coarse sand, shell fragments and silt. Scattered soft corals, low bioturbation (~10 burrows/m^2).

TABLE 1 (cont'd)

SUBTIDAL HABITATS INVESTIGATIONS

SITE	LATITUDE	LONGITUDE	DEPTH (LAT)	COMMENTS
DH15	12° 31.529'	130° 50.583'	-15 m	Coarse sand, shell fragments and silt. Frequent sponges and soft corals, scattered gorgonians. Low bioturbation (~10 burrows/m^2).
DH16	12° 31.675'	130° 50.224'	-15 m	Soft silty clay with coarse sand. Frequent hydroids and crinoids. Moderate bioturbation (~30 burrows/m^2).
DH17	12° 31.520'	130° 50.516'	-15 m	Coarse sand, shell fragments and silt.
DH18	12° 31.502'	130° 50.351'	-15 m	Coarse sand, shell fragments and silt
DH19	12° 31.752'	130° 50.148'	-15 m	Fine to coarse sands, gravel and silt.
FB01	12° 50.200' 12° 50.041'	130° 08.667' 130° 08.697'	-11 m -6 m	Bowra Shoals. Rocky shoals surrounded by pavement with veneer of coarse sand, shell fragments and silty clay. Abundant sponges, soft corals, gorgonians, hydroids and crinoids. Scattered hard corals, predominantly *Turbinaria* and faviids with occasional *Porites* and *Scolymia*.
FB02	12° 52.790' 12° 52.696'	130° 10.484' 130° 10.259'	-3 m 0 m	Blaze Reef. Coral reef with large areas of high (>75%) hard coral cover. Highly diverse hard coral community, dominated by faviids, *Acropora* and *Turbinaria*. *Montipora*, *Symphyllia*, *Hydnophora*, *Goniopora* and *Porites* common. Abundant gorgonians, hydroids, ascidians, sponges and bryozoans.

Soft corals (mainly *Sarcophyton* and *Dendronephthya* species) were abundant, with zoanthids, sponges (including Microcionidae) and large ascidians (cf. Polycitoridae) common on the lower intertidal rocks and adjacent pavement of both areas. The pavements were covered with veneers of rubble, gravel, coarse sand and silt, with scattered hard corals (predominantly the faviid genera *Goniastrea* and *Platygyra*) present. The green algae *Halimeda* and *Caulerpa* occurred in patches across the pavement areas.

The subtidal sediments within the proposed turning basin off LNG Point comprised coarse sand and shell grit with minimal silt. At Station DH14, the substratum was colonised by scattered soft corals and sparse burrows were present (approximately $10/m^2$). At DH15, a similar number of burrows were found and epibenthic fauna (soft corals, sponges and gorgonians) were more common, though still sparse. One hard coral (*Tubastrea*) was found on a small rock. The silty coarse sands on the western side of the Middle Arm channel (DH16) supported a more abundant fauna (30 $burrows/m^2$), and hydroids and crinoids were common. The benthic fauna of the turning basin sediments are detailed in Table 2 and discussed in Section 3.2.

3.1.2 Wickham Point

No subtidal surveys were undertaken in the vicinity of Wickham Point. The faunal communities of the intertidal zone were similar to those at LNG Point.

Many small oysters were present on the upper intertidal rocks of the northern spit, with at least three species represented (*Saccostrea cucculata, S. amasa* and *S. echinata*). *Galeolaria* worms, chitons, grapsid crabs and the skeletal plates of *Chthamalus* barnacles were common, but there were few live barnacles. Soft corals (mainly *Sarcophyton* spp. with some *Dendronephthya* spp.) were prolific on the lower intertidal pavement, sponges were common and there was scattered *Halimeda*.

There was little evidence of burrowing fauna on the sand sheet extending to the west of the Wickham Point rock spit. However, the marginally deeper and softer sediments subtending the sand sheet were highly bioturbated, with abundant gastropod molluscs (predominantly Nassariidae) and hermit crabs (Paguridae) associated with areas of ponded water. Very sparse seagrass (thin-leafed *Halodule uninervis* and *Halophila decipiens*) was present on some of the soft sediments.

A high diversity of hard corals (predominantly faviids, with some large *Oulophyllia* heads) was present on the pavement at the north-western tip of the Wickham Point intertidal area, although overall coral coverage was low. Sponges were common, and there were scattered soft corals (primarily *Dendronephthya*), algae (the brown *Sargassum* and the calcareous green *Halimeda*) and seagrasses (thin-leafed *Halodule uninervis* and *Halophila decipiens*).

3.1.3 Channel Island

The rock stack off the north-western tip of Channel Island supported an abundance of small oysters, barnacles (*Tetraclita* cf. *squamosa*) and hermit crabs, with chitons (*Acanthopleura* spp.) and *Siphonaria* common. The intertidal pavement surrounding the rock stack was largely covered with a veneer of soft sediments, with areas of rubble (where the soft corals *Sarcophyton* and *Dendronephthya* were common) and scattered hard coral heads.

TABLE 2

ABUNDANCES OF BENTHIC FAUNA

Taxon	DH 17			DH 18			DH 19		
	17.1	17.2	17.3	18.1	18.2	18.3	19.1	19.2	19.3
Phylum Porifera	7	2	3	1	-	-	5	10	-
Phylum Cnidaria									
Class Hydrozoa									
Order Leptomedusae	-	-	-	1	1	-	15	25	5
Phylum Nematoda	-	1	1	1	-	-	-	-	-
Phylum Annelida									
Class Polychaeta									
Subclass Errantia	12	12	11	17	11	3	15	30	20
Subclass Sedentaria	11	11	9	16	8	4	30	20	20
Other worms	-	-	-	-	-	-	5	-	-
Phylum Mollusca									
Class Gastropoda									
Family Naticidae	-	1	1	-	-	-	-	-	-
Family Siliquariidae	10	1	1	-	-	-	-	-	-
Family Triphoridae	-	1	-	-	-	-	-	-	-
Class Bivalvia									
Family Mytilidae	-	-	-	-	-	-	-	10	-
Family Tellinidae	1	-	-	-	-	-	-	-	-
Family Veneridae	2	3	1	1	-	-	-	-	-
Family Spondylidae	2	-	-	-	-	-	-	-	-
Family Nuculanidae	-	1	1	-	-	-	-	-	-
Phylum Crustacea									
Class Maxillopoda									
Subclass Cirripedia	5	-	-	2	-	-	-	-	-
Subclass Copepoda	3	-	-	-	-	-	-	-	-
Class Ostracoda	2	1	-	3	-	-	5	10	-
Class Malacostraca									
Subclass Phyllocarida	-	4	1	-	1	-	-	-	-
S/c Eumalacostraca									
Order Cumacea	1	-	-	-	1	-	-	-	-
Order Tanaidacea	4	6	2	2	4	-	5	5	5
Order Amphipoda	52	38	8	5	6	-	20	20	-
Order Isopoda	2	15	7	7	3	1	-	20	-
Order Decapoda									
S/f Penaeoidea	1	-	-	-	-	-	-	-	-
I/o Caridea	5	-	1	3	2	-	-	5	5
I/o Thalassinidae	2	1	2	-	-	-	-	-	-
I/o Brachyura	2	-	-	-	-	-	-	5	5
Phylum Bryozoa	2	-	-	1	-	1	-	10	-
Phylum Echinodermata									
Class Stelleroidea									
Subclass Asteroidea	1	-	-	-	-	-	-	-	-
Subclass Ophiuroidea	13	10	1	-	2	-	-	5	5
Class Holothurioidea	3	-	1	-	-	-	-	-	-
Phylum Chordata									
Class Ascidiacea	-	-	-	-	-	-	-	5	-
S/p Cephalochordata	-	-	1	1	-	-	-	-	-
Class Osteichthyes	-	-	-	-	-	-	5	-	-

One dive (DH10) was conducted along the edge of the intertidal mudflat extending westwards from the mangrove fringe along the north-western shore of Channel Island. The substratum was deep silty clay, burrows were frequent (~50/m^2) and there were occasional stingray feeding depressions.

A second dive (DH11) was conducted along the rocky edge of the intertidal platform extending from the northern tip of Channel Island. Hard corals mainly occurred in a zone extending 1 m either side of the lowest astronomical tide (LAT) level. Hard coral cover was less than 10%, with faviids predominant within a diverse community including *Lobophyllia*, *Goniopora*, *Alveopora*, *Mycedium*, scattered *Acropora*, *Barabattoia* and *Oxypora*. Sponges were also common. The substrate around the rocks was silty clay with moderate bioturbation (~50 burrows/m^2).

The intertidal and shallow subtidal area extending eastwards from Channel Island is listed on the Register of the National Estate. Along the northern edge of this area (DH12), the rocky substrate was covered in silt and colonised by a wide variety of sponges, hard and soft corals, but with low coverage. Hard corals at +1 to -1 m LAT were predominantly faviids (*Goniastrea, Platygyra*, a few *Barabattoia*), and also included *Symphyllia, Herpolitha* and soft corals. At 1-2 m below LAT, very large *Goniopora* were common together with scattered *Acropora*, large *Cyphastrea*, *Turbinaria* and *Montipora*. Sponges, gorgonians (*Ctenocella, Junceella*), soft coral (*Clavularia*) and colonial anemones were also common.

3.1.4 Weed Reef

Faunal abundance was low on the intertidal rocks at the northern end of Weed Reef, and oysters were absent. Zoanthids (cf. *Palythoa*) were widespread and barnacles (mainly *Tetraclita* cf. *squamosa* and small balanids) were common. Few live *Chthamalus* barnacles were recorded, with widespread mortality evident. Scattered soft corals, sponges, gastropod molluscs (especially *Morula* spp.) and chitons (*Acanthopleura* spp.) were present.

A long bank of coarse sand aligned north-south along the western reef edge was devoid of macroalgal cover and epibenthic fauna, and there was little evidence of bioturbation. The rippled appearance of the sand indicated a high degree of mobility of the surface sediments.

The majority of the intertidal area of Weed Reef was a rubble covered pavement with a patchy distribution of fauna. A highly diverse (though low abundance) hard coral fauna was present, comprising mainly fungiids (including *Fungia, Polyphyllia* and *Herpolitha* spp.) and faviids (*Favia, Goniastrea, Cyphastrea, Platygyra daedalea, Moseleya, Barabattoia, Montastrea, Leptastrea*), with areas of high *Porites* (cf. *cylindrica*) cover. Colonies of pectinids (*Oxypora/Echinophyllia, Pectinia paeonia*), poritids (*Goniopora, Alveopora*), oculinids (*Galaxea*), merulinids (*Merulina ampliata*), acroporids (encrusting and plate *Montipora*, corymbose and branching *Acropora*), mussids (*Symphyllia*) and dendrophylliids (*Turbinaria*) were also present. Sponges (including Microcionidae and Niphatidae) and soft corals (*Sinularia, Dendronephthya*) were common.

The macroalgal community of the rubble covered pavement was sparse though diverse, and included browns (*Sargassum, Padina*), foliose reds (*Laurencia*), greens (*Caulerpa, Ulva, Udotea*) and calcareous greens (*Halimeda*). Over the broad areas of reef flat covered with a thin sand veneer, there was a very sparse, patchy coverage of seagrasses, mainly thin-leafed *Halodule uninervis* and *Halophila decipiens*, with some *Halophila ovata* and *Cymodocea serrulata* close to the reef edge.

Along the eastern edge of Weed Reef (DH07) the benthic assemblage on the pavement was dominated by nets of niphatid sponge and a diversity of hard corals, including *Goniastrea favulus, Porites,* *Barabattoia, Symphyllia, Turbinaria,* and *Fungia.* In deeper water (-1 m LAT), branching acroporids were found (?*Acropora nobilis*), as well as *Acropora tenuis*, large encrusting *Montipora, Echinophyllia, Mycedium elephantotus, Pectinia paeonia, Hydnophora exesa, Euphyllia* and *Duncanopsammia.* Gorgonians, sponges and coralliomorpharians were also present. Where the veneer of fine sand and silt over the pavement was thicker, sparse beds of the seagrasses *Halophila* (*H. decipiens* and *H. ovalis*) and *Halodule* (thin-leafed *H. uninervis*) were present.

3.1.5 Plater Rock

Plater Rock is a steep-sided subtidal pinnacle rising from the seabed some 1 km to the north of Weed Reef. Surrounding the rock was silty sand with sparse burrows (1-2 m^{-2}), a few sponges and very sparse gastropod molluscs. From the base of the rock to ~2 m below LAT, the rock walls were colonised by abundant sponges, gorgonians and the hard corals *Tubastrea* and *Arcohelia rediviva.* Gorgonians included *Junceella* (sea whip) and *Ctenocella* (red whip coral). Sponges showed a wide variety of morphologies, including fans, branching and encrusting forms. Bryozoans and crinoids were also found. Some solitary corals (*Cynarina*) and *Turbinaria* were found mid-slope. Soft corals appeared first at approximately 3-4 m below LAT, and included *Sinularia*, nephthyids and other branching colonies. Shallower than 2 m LAT, hard corals (mainly faviids, including *Favia, Favites, Moseleya, Echinopora, Acanthastrea echinata, Platygyra lamellina* and *P. daedalea*) were dominant, Many other genera were also present, including *Euphyllia, Turbinaria, Oxypora/Echinophyllia, Symphyllia, Scolymia, Porites* (some up to 3 m diameter), *Goniopora, Leptoseris explanata,* encrusting *Montipora,* and *Mycedium elephantotus.* Sponges, gorgonians, *Sargassum* and other algae, and soft corals were also present on the upper slope.

3.1.6 West Point

The intertidal rock platform at West Point supported a diverse faunal community. Barnacles (primarily *Chthamalus* cf. *malayensis* and *Tetraclita* cf. *squamosa*) were abundant in the upper intertidal zone, although oyster numbers were low. Hermit crabs (Paguridae) were abundant amongst the rocks, and sponges (particularly Niphatidae, forming dense branching nets), chitons (*Acanthopleura* spp.), *Onchidium* slugs, hirsute crabs (*Pilumnus* cf. *verspertillo*) and large ascidians (cf. Polycitoridae) were common. Gastropods (including *Morula granulata*) and blue portunid crabs (*Thalamita* sp.) were also recorded.

Soft corals, gastropod molluscs (especially Cerithidae) and conspicuous green polychaete worms (cf. *Phyllodoce novaehollandiae*) were common where the pavement was covered with a bioturbated veneer of silty fine sand.

A sparse but diverse hard coral community was present in the lower intertidal zone along the southern edge of the platform. Faviids were predominant, mainly *Goniastrea* and *Platygyra* species with *Favia, Favites, Barabattoia* and *Montastrea* species also represented. Colonies of *Porites* and *Montipora* species were common. Subtidally, biotic cover was dominated by brown algae (*Sargassum, Padina* and *Dictyota*). The calcareous green alga *Halimeda* also occurred. Corals were common, with *Symphyllia* and *Goniastrea* (*G. favulus, G. aspera* and *G. retiformis*) the most abundant genera. Other genera/species included *Porites, Goniopora, Leptastrea, Moseleya latistellata, Barabattoia amicorum, Platygyra, Euphyllia* and *Turbinaria.* Hard coral cover was higher in the deeper water along the eastern edge of the platform, where *Acropora, Montipora* and *Turbinaria* species were dominant.

Further offshore (DH03), in water depths of ~3-5 m below LAT, the seabed comprised a pavement with a veneer of coarse sand and rubble. Brown algae (*Sargassum* and *Padina*) and sponges, of various morphologies, were the predominant biota. Gorgonians (branching fans up to ~50 cm high), soft corals (*Dendronephthya*), hard corals (*Goniopora*), bryozoans, colonial ascidians and crinoids were also present.

3.1.7 John Holland Barge

The John Holland Barge was scuttled in 1982 to form part of an artificial reef in some 20 m of water. The surrounding substratum was coarse sand, shell grit and silt with sparse sponges and burrows. The wreck itself was colonised by a variety of sessile organisms, including sponges, soft corals (predominantly *Lemnalia*), gorgonians, crinoids and the hard corals *Tubastrea* and *Arcohelia rediviva*. During the LDM dive, thousands of baitfish were gathered on the wreck.

3.1.8 USAT Meigs

The USAT Meigs was sunk during WWII in 15 m of water. The surrounding substratum was silty coarse sand with sparse biota (one seapen was noted during the LDM dive). The wreck supported a wide variety of sessile organisms, including gorgonians (whips and fans), sponges (laminar, cup and encrusting), soft corals (*Lemnalia, Nephthya, Dendronephthya*), hard corals (*Arcohelia rediviva, Heteropsammia*), bryozoans and crinoids. Silt covered all surfaces except for the living tissues of upright epibenthic fauna.

3.1.9 Channel Marker No. 9

The channel floor at DH13, at 17 m LAT, comprised a pavement with a veneer of gravel, coarse sand and silt. The edge of the shipping channel was a rocky slope, rising to 11 m LAT to meet a rubble-covered pavement with a veneer of coarse sand and silt. The biota was similar throughout, and consisted of a high coverage of sponges (vase, fan and laminar forms), soft corals, gorgonians, bryozoans and crinoids.

3.1.10 Charles Point Patches

Charles Point Patches is a shoal area outside the mouth of Darwin Harbour. The substratum was deep, coarse soft sand, shell grit and fine silt arranged in sandwaves up to 3 m high. On the trailing edge of the sandwaves were ripples approximately 5 cm high. Biota were very sparse, with one sponge, one seapen, one unidentified burrow and a hermit crab noted at the two dive sites.

3.2 BENTHIC FAUNA

The benthic fauna of the three stations DH17, DH18 and DH19 predominantly comprised polychaete worms (both mobile and sedentary) and amphipod crustaceans (Table 2). The high variabilty in diversity and abundance between replicate grab samples at each station indicates that fauna are patchily distributed on the seabed.

The diversity of benthic fauna was greatest at Station DH17, the closest of the three stations to the proposed dredging area, mainly due to the presence of gastropod and bivalve molluscs which were absent or poorly represented at the other two stations. Abundance of fauna was greatest at Station DH19, on the opposite side of the Middle Arm channel from the dredged area.

Analysis of clustering by PRIMER (Figure 3) showed that there was less variability between replicate samples at Station DH17 than at the other two sites, suggesting the distribution of benthic fauna at this station was more even. A similarity analysis (ANOSIM) revealed the differences in faunal diversity and abundance between stations was significant at the 5% level.

3.3 SEDIMENT ANALYSES

Contaminant levels in sediments are addressed in the draft guidelines for the disposal of dredged materials (ANZECC 1996). For a range of contaminants, the guidelines present screening levels (concentrations below which toxic effects on organisms are not expected) and maximum levels (concentrations at which toxic effects on organisms are probable if the contaminant is in a biologically available form).

Results from the sediment analyses are shown in Tables 3A to 3C. Concentrations of cadmium, chromium, copper, lead, mercury, nickel and zinc were all well below screening levels, while arsenic concentrations lay between the screening and maximum levels.

Sulphur levels ranged from 2800 to 3500 mg/kg, which are common for sedimentary mud near mangrove areas but which warranted further investigation into their potential for acid generation once relocated to the disposal area. Oxidisable sulfur levels of 2.3-3.4 kg H_2SO_4/tonne exceeded the level considered by the Environment Protection Authority of NSW (1995) to constitute a significant risk of acid generation in the absence of significant buffering sources (0.31 kg H_2SO_4/tonne). However, the carbonate content of the sediments (10-12% $CaCO_3$) was sufficiently high to provide a buffer against acid formation, and the net acid generating potential was well below zero (-12).

While analyses of total petroleum hydrocarbon (TPH) content returned high levels (3100-3500 µg/kg), these were due to the presence of unresolvable complex mixtures (UCMs). Further analyses revealed that no polyaromatic hydrocarbons were detectable, raising the possibility that the TPH levels were due to the presence of biogenic hydrocarbons (D. Williams, ARL, pers. comm.).

Due to the low organic content of the sediments to be dredged (0.1-1.2%), biochemical oxygen demand is likely to be low and not pose a significant risk to marine fauna in the vicinity of the dredging operations.

4. REFERENCE

Environment Protection Authority of NSW. 1995. *Assessing and Managing Acid Sulfate Soils.* Environment Protection Authority, June 1995.

TABLE 3A

METALS (mg/kg), TPH[a] (μg/kg) AND TOC[b] IN TURNING BASIN SEDIMENTS

	Screening Level[c]	Maximum Level[d]	DH14	DH15	DH16
As	20	70	24-38	38-49	25-32
Cd	1.2	9.6	0.3	0.1-0.3	0.1
Cr	81	370	16-18	18-23	21-23
Cu	34	270	5	4-7	6
Hg	0.15	0.71	<0.02	<0.02	<0.02
Ni	21	52	8-10	12-14	14-15
Pb	47	218	5.3-6.0	5.6-6.2	6.9-7.6
Se	-	-	<0.5	<0.5	<0.5
Zn	150	410	8-10	10	13-18
Al	-	-	3100-3800	3400-3800	5600-6100
Fe	-	-	16000-18300	19300-22700	19600-20600
Mn	-	-	320-380	420-470	230-240
TPH	-	-	3500	3100	3500
TOC	-	-	0.1-0.4	0.1-0.3	0.8-1.3

a Total petroleum hydrocarbons
b Total organic carbon
c Concentration below which toxic effects on organisms are not expected
d Concentration at which toxic effects on organisms are probable if the contaminant is in a biologically available form

TABLE 3B

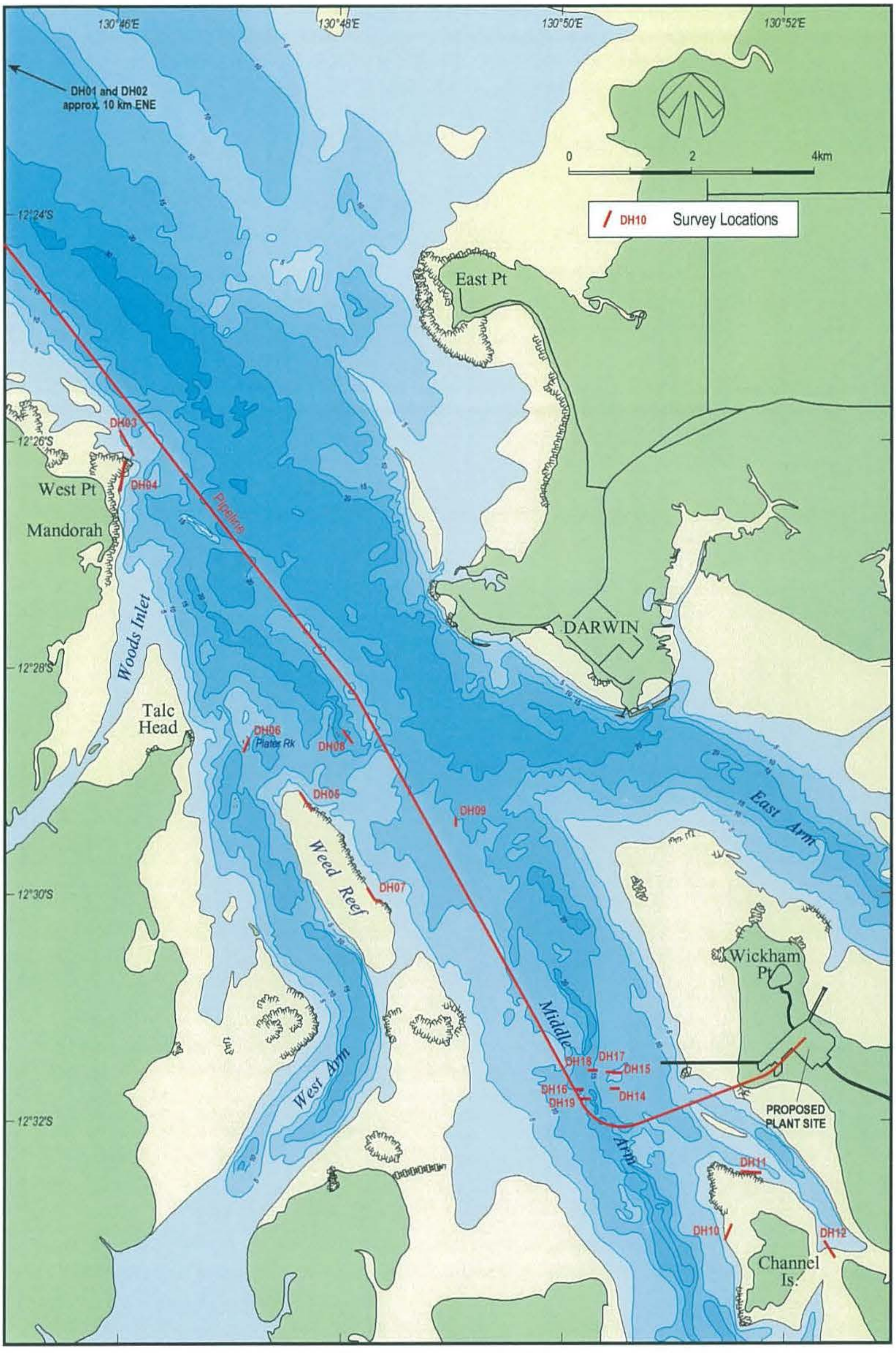
ACID GENERATING POTENTIAL OF TURNING BASIN SEDIMENTS

STATION	TOTAL SULPHUR (mg/kg)	OXIDISABLE SULPHUR (kg H_2SO_4/tonne)	$CaCO_3$ %	NET ACID GENERATING POTENTIAL % $CaCO_3$
DH14	3200 - 3500	2.5	12	-11.7
DH15	2800 - 3000	2.3	12	-11.8
DH16	3300 - 3500	3.4	10	-11.6

TABLE 3C

PARTICLE SIZE DISTRIBUTIONS OF TURNING BASIN SEDIMENTS

STATION	% OF SAMPLE IN SIZE INTERVAL				
	>1000 μ	500-1000 μ	75-500 μ	38-75 μ	<38 μ
DH14	56	16	25	2	1
DH15	57	16	24	2	1
DH16	40	17	39	3	1



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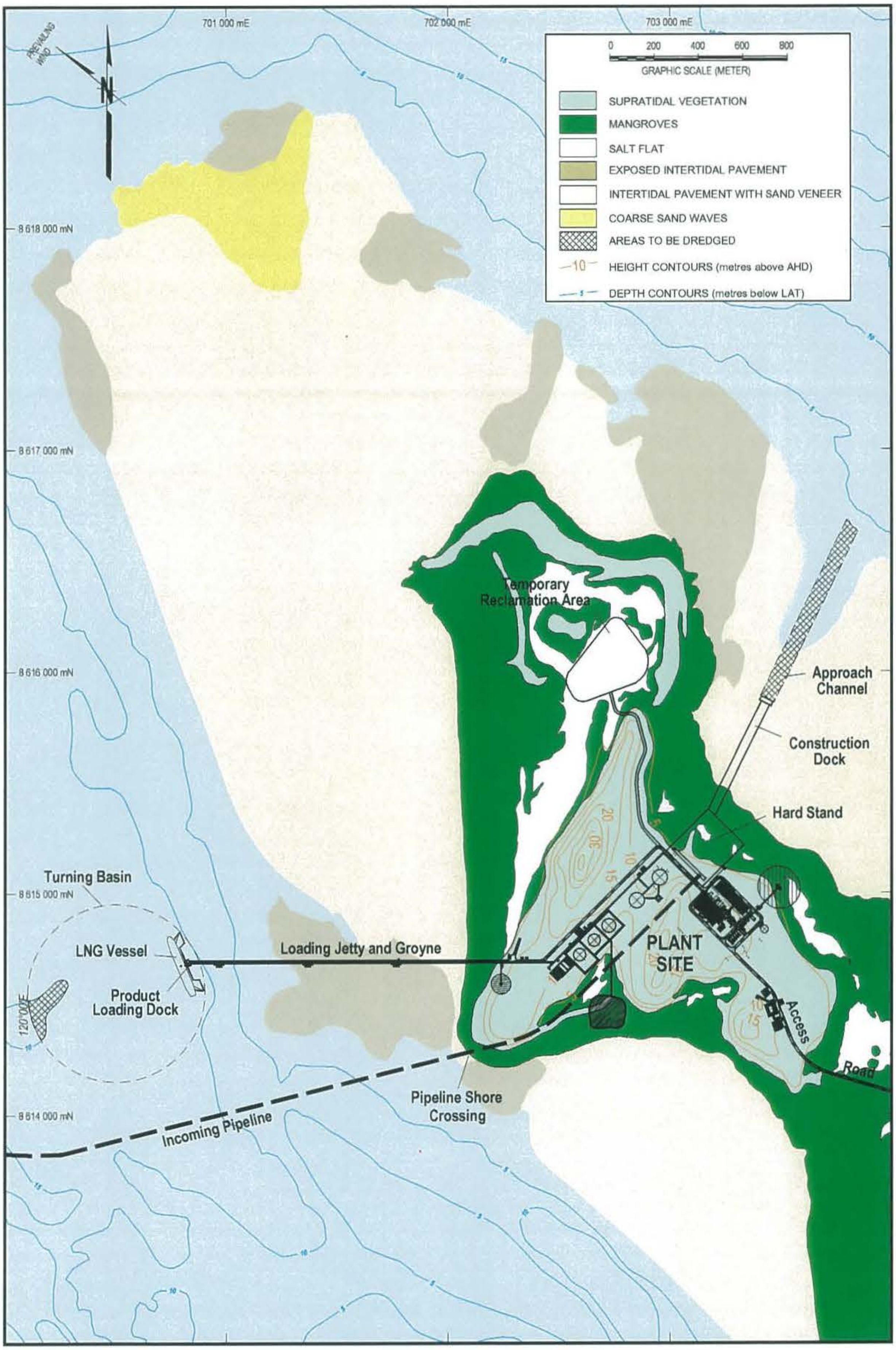
DARWIN HARBOUR SURVEY LOCATIONS



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INTERTIDAL HABITATS OF WICKHAM POINT

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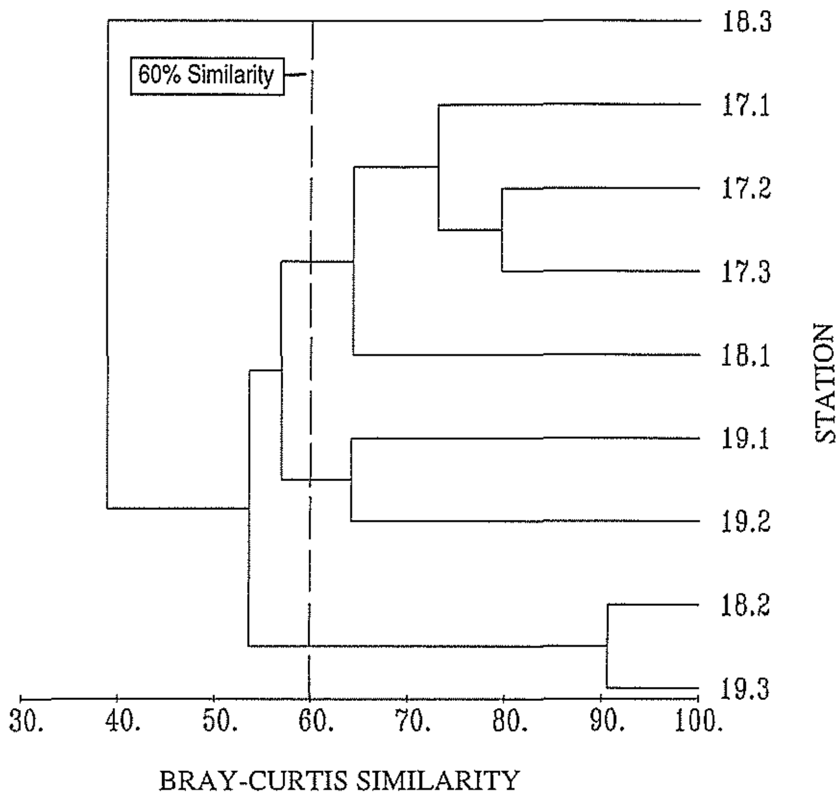
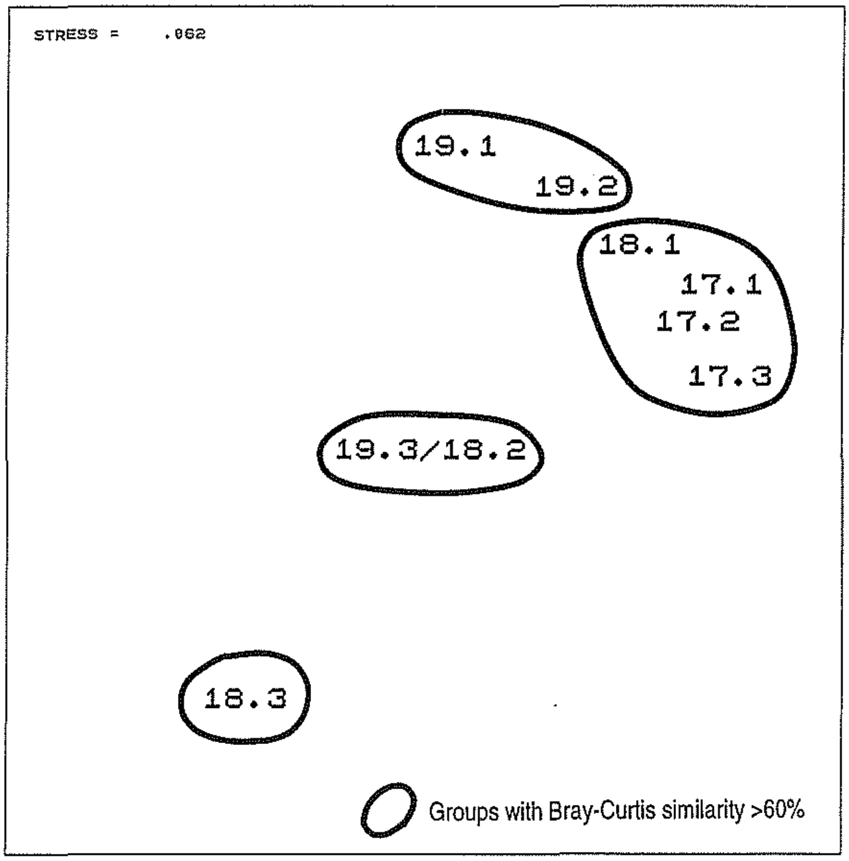
A DAMES & MOORE COMPANY

FIGURE 2





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CLUSTER ANALYSIS OF BENTHIC GRAB STATIONS BY FAUNAL COMPOSITION

Appendix L

Heritage Surveys

REPORT

Darwin LNG Plant
Draft Environmental Impact Statement

Appendix L
Wickham Point Archaeological Survey,
Darwin Harbour, Northern Territory

for

Phillips Oil Company Australia

Ref: 00533-164-073
Report No. R635, Appendix L
July 1997

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EXECUTIVE SUMMARY

This report describes an archaeological survey of a proposed natural gas liquefaction facility and access road at Wickham Point, Middle Arm. The project area is located within Darwin Harbour approximately 7km southeast of the Darwin CBD. Dames & Moore Pty Ltd engaged Heritage Surveys to undertake an archaeological survey of the proposed development area, and to describe the nature and significance of any archaeological materials within it.

A total of nine archaeological sites were identified during the archaeological survey. No archaeological materials were identified along the proposed access road to Wickham Point, with all sites found within or immediately adjacent to the proposed plant area.

Five prehistoric middens, MA13, MA14, MA15, MA16 and MA18 are located directly on the margins of the proposed plant, and it is likely that they will be impacted during the construction process. As these sites are highly significant, it is recommended that there are two strategies suitable for mitigating against damage to them:

1. No heavy machinery should be allowed to operate within a 20m radius of each midden. It is recommended that a fence should be erected around each of the sites in order to restrict access to them during and after the construction phase.

2. If fencing is not feasible, it is recommended that prior to the commencement of construction activities the proponent should seek a permit to disturb/destroy the archaeological materials under Section 29 of the *Northern Territory of Australia Heritage Conservation Act 1991*. It is further recommended that in this case bulk samples of archaeological materials should salvaged from each of the middens which will be impacted. This material should then be analysed and sorted to determine accurately the range and relative frequency of different shell taxa in the deposit and so that samples of the shell can be submitted for radiocarbon dating.

An additional midden, Site MA12, is located approximately 400m to the west of the proposed plant. It is not expected to be impacted as a result of the proposed activities, and as a result it is recommended that no further action is warranted with respect to Site MA12.

Two historic sites, MH2 and MH3 are located within or immediately adjacent to the proposed construction area. As both sites are considered to hold low archaeological significance, and as both have been recorded in adequate detail during this study, it is recommended that no further action is warranted with respect to Sites MH2 and MH3.

One of the key objectives of the archaeological survey was to determine whether there were any remains of the historic "Mud Island" (Middle Point) leprosarium in the area. This facility was occupied by Chinese and Aboriginal lepers between 1884 and 1931, and was subsequently used during the Second World War by an anti-aircraft battery. The remains of these activities, labelled Site MA17, were identified 1500m to the northwest of the project area on the northern tip of Wickham Point. The site is not likely to be impacted by the proposed facility, and as a result no further action is required with respect to Site MA17.

1. INTRODUCTION

This report describes an archaeological survey of a proposed natural gas processing facility and access road at Wickham Point, Middle Arm. The project area is located within Darwin Harbour approximately 7km southeast of the Darwin CBD.

Dames & Moore Pty Ltd engaged Heritage Surveys to undertake an archaeological survey of the proposed development area, and to describe the nature and significance of any archaeological materials within it. Archaeological fieldwork for this project was carried out by Scott Mitchell and Gerard Niemoeller, with assistance from Stephen Sutton and Trish Burns (Heritage Unit, Department of Lands Planning and Environment) over four days in November 1996, February 1997 and March 1997. This report was written by Scott Mitchell.

2. ENVIRONMENTAL BACKGROUND

The study area forms the northwestern tip of the Middle Arm peninsula, and contains several islands which are cut off from the mainland at high tide and surrounded by mangrove flats (Figure 1). In the southwestern corner of the study area the proposed access road crosses an area of low relief formed from Tertiary sands, laterite, and ferricrete (Pietsch 1986). Vegetation within this area consists of open Eucalypt forest with *Sorghum* sp. understorey (Wilson *et al.* 1991).

The remainder of the study area consists mostly of an extensive tidal flat formed from intertidal marine alluvium, mud, clay and silt (Pietsch 1986). Low, closed mangrove forests occur over nearly all of the tidal flats , although there are small areas of saline tidal flats with scattered chenopod low shrubland (Wilson *et al* 1991). Within the tidal flats are two islands, representing slightly higher ground formed on Proterozoic shales, siltstones and phyllites of the Burrell Creek Formation (Pietsch 1986). Vegetation on this higher ground consists of extremely dense low closed vine forest, often with melaleuca and pandanus around the fringes.

In addition to these landforms there are several sandy and shelly chenier ridges, particularly in the northwestern corner of study area adjacent to Wickham Point itself (Pietsch 1986). Several quartz outcrops were observed within the study area, although most did not appear to have been of a quality suitable for the manufacture of stone artefacts. There are no known permanent or semi-permanent sources of surface freshwater in the Wickham Point area.

3. CULTURAL BACKGROUND

3.1 PREHISTORIC ARCHAEOLOGY OF THE DARWIN REGION

Richardson (1996) has recently undertaken an extensive review of the prehistoric archaeological resources within the Darwin area. Sites recorded in the region include human skeletal remains, artefact scatters, stone arrangements and less frequently rock art, knapping floors and quarries. The most common type of site are shell middens located adjacent to the coastline. The most dense concentration of middens have been recorded in the Haycock Reach area where Hiscock and Hughes (in press) found shell mounds in densities of approximately $22/km^2$.

Burns (1996a:37) has made the following observations regarding the distribution of prehistoric sites, in particular middens, in the Darwin region.

- There are large numbers of as yet unrecorded prehistoric sites in the region.
- Middens are the most common type of site.
- Middens are generally located less than 300m from mangrove communities.
- All site types, including middens, are particularly frequent on the boundaries between different biogeographic land units.

A total of eight radiocarbon dates have now been obtained from archaeological sites in the Darwin region, and these are summarised in Table 1. All of these radiocarbon dates were obtained on *Anadara granosa* shell samples. The dates from Bayview Haven 3 indicate that it was initially occupied about 1400 years ago and was abandoned around 900 years ago (Hiscock in press). Samples from the surface of four separate mound sites at Haycock Reach indicate that the mounds ceased to accumulate between 700 and 1000 years ago (Hiscock in press).

Table 1. Radiocarbon dates from shell mounds in the Darwin region
(source: Richardson 1996:4)

Locality	Site name	Sample code	C^{13} adjusted age estimate
Haycock Reach	5	Beta 55467	1420±60
Haycock Reach	14	Beta 55464	1150±50
Haycock Reach	15	Beta 55465	1500±60
Haycock Reach	17	Beta 55466	1380±60
Francis Bay	Bayview Haven 3	Beta 72152	1310±60
Francis Bay	Bayview Haven 3	Beta 72153	1370±50
Francis Bay	Bayview Haven 3	Beta 72154	1520±70
Francis Bay	Bayview Haven 3	Beta 72155	1870±60

At Bayview Haven and Haycock Reach, as well as many other localities across the Darwin region, shell middens and mounds composed predominantly of *Anadara* sp. The overwhelming abundance of *Anadara* sp. in most sites suggests that it was the most abundant mollusc available to prehistoric populations in Darwin Harbour at the time in which the middens were formed.

Hiscock and Hughes (in press) have argued that the cessation of mound building at Haycock Reach was associated with environmental change along the coastline. At the time at which the mounds at Haycock Reach accumulated, the shore is though to have been characterised by open beaches with scattered stands of mangroves. Such an environment is ideal for the growth of *Anadara* sp. However, once the dense mangrove forests which now line Darwin Harbour developed this would have been associated with a sharp decline in the abundance and availability of this taxa. This decline is thought to have led to the cessation of midden formation at Haycock Reach.

In many respects the chronology of human occupation in the Darwin region remains poorly understood. As Hiscock and Hughes (in press) point out, if mound abandonment is associated with a simple environmental shift why did the prehistoric occupants of the region not substitute mangrove shellfish for *Anadara* sp.? It is not clear whether the cessation of mound formation represents a shift towards exploitation of terrestrial rather than marine resources or human abandonment of the region. Further research is also required to determine whether the patterns identified at Bayview Haven and Haycock Research represent a localised phenomenon or whether they represent part of a process that affected the whole of Darwin Harbour.

Archaeological research conducted to date in Darwin Harbour raises a number of intriguing possibilities. In particular, it is likely that the dense mangrove forests lining Darwin Harbour today may have an antiquity of only 700-1000 years, and major shifts in human settlement and subsistence patterns occurred within Darwin Harbour in the recent past.

3.2 PREHISTORIC ARCHAEOLOGICAL SITES IN THE MIDDLE ARM AREA

In order to assess the significance of any archaeological materials that might occur in the project area it is necessary to review previous archaeological research in the Middle Arm region. A number of archaeological sites, predominantly shell middens or mounds, have been recorded in the immediate vicinity of the project area (see Figure 1).

Prehistoric sites at Middle Arm were first described within the Environmental Impact Statement for the Channel Island Power Station (Caldwell Engineers 1983:107-108). An archaeological survey was carried out both at Channel Island and over the access road corridor from Palmerston. Four shell middens, dominated by *Anadara* sp. and containing stone artefacts and bone were identified. Three of the middens had apparently been quarried for shell used in the construction of military camps and roads during the Second World War (Caldwell Engineers 1983:107-8).

Unfortunately the locations of these four middens was not specified in the Caldwell Engineers (1983) report. Although the report states that the Northern Territory Museum was advised of their locations, no reference to the middens could be found on the Northern Territory Museum sites register. As a result, the precise location of these sites remains unclear.

Archaeological materials at Channel Island and Middle Arm are also referred to in a geomorphological study of the island (Fox and Associates 1987 V2). While Fox and Associates (1982 V2:133) state that no prehistoric archaeological sites occur on Channel Island, they do refer to three *Anadara* sp. shell middens on the Middle Arm peninsula. Again the report does not indicate the location of these sites, and it is not clear whether these middens represent the archaeological sites referred to earlier by Caldwell Engineers (1983).

In a recent archaeological survey of the coastline of the Middle Arm peninsula, Burns (1994) recorded a total of eleven prehistoric archaeological sites (Sites MA1 to MA11, Figure 1). These included six stratified shell mounds, one of which was associated with a stone artefact scatter and five relatively shallow (<30cm deep) shell middens, one of which was associated with rock engravings. Two of the middens had previously been listed on the Northern Territory Museum archaeological sites register.

All of the shell middens and mounds identified by Burns (1994, 1996b) were composed predominantly of the bivalve *A. granosa*, specimens of other taxa such as the gastropods *Chicoreus capucinus*, *Nerita* sp., *Telescopium telescopium, Terebralia semistriata* and *Volema cochlidium* occurred in small numbers. These shells derived from either mangrove habitats, or in the case of *Anadara* sp. and *Nerita* sp., in the sandy/mud substrates of the intertidal zone (Broom 1985).

Three of the midden sites at Middle Arm, MA1, MA7 and MA10, have been excavated and analysed in detail (Burns 1994; Burns 1996b). Excavation revealed that these sites are similar in size and composition both to each other and to shell mounds recorded elsewhere throughout Darwin Harbour (see Hiscock 1995a). Cultural material other than shell identified in these sites included stone artefacts (mainly flakes and flaked pieces manufactured from locally available quartz), fish otoliths, macropod teeth and charcoal.

Prehistoric site distribution on the Middle Arm peninsula is highly patterned. Nearly all of the recorded shell mounds and middens are situated on raised rocky knolls or hill slopes directly adjacent to the coastline. The exceptions to this pattern are located on outcropping rock within the mangrove zone itself.

No prehistoric archaeological sites have previously been recorded within the boundaries of the project area.

3.3 HISTORY AND HISTORIC ARCHAEOLOGY

Non-Aboriginal occupation of Wickham Point (then known as "Mud Island") began in the early 1880s when several Chinese lepers were isolated there. The government subsequently used the point as a leprosarium because, despite its close proximity to Darwin, access to and from the site could be readily controlled. The site could not be reached by land, and was accessible by sea only where a small sandy beach presented an approach for small craft (Saunders 1989:24).

A photograph of the area taken in 1890 shows a sign reading "leper station", a corrugated iron hut and a corrugated iron water tank just above the high tide mark on the sandy beach (Sanders 1989:25). Until 1916 the site functioned essentially as a transit station, and facilities were kept to a bare minimum. Chinese lepers were isolated there until they could be repatriated to China, while Aborigines with leprosy were kept there until they could be returned to their tribal communities (Sanders 1989:21).

From 1916 onwards all Northern Territory lepers were interned permanently at Mud Island. Facilities were expanded and several additional buildings and water tanks were placed on the island. The government provided dry and tinned goods to the inmates but no fresh fruit and vegetables. There was no medical attention given to the lepers until 1922, and no permanent medical staff at any time (Sanders 1989:27).

Devoid of natural fresh water, and with limited vegetation and animal life, the lazarette provided extremely poor living conditions. Harney (1945:228) described it as "...an excresence, an island of mud and sand, swarming with mosquitoes and sandflies; a blessing indeed that disease numbed the limbs of these lonely, miserable people and made them proof against the savage bites of insects." Escape attempts and suicides were frequent, and by 1925 it was being condemned by southern newspapers as the "Living Hell Lazarette" (Sanders 1989:28).

In 1929 the former quarantine station at Channel Island was nominated as a suitable location for leprosy patients. Mud Island was abandoned when its 26 residents were transferred to Channel Island in 1931 (Saunders 1989:28).

Because of its close proximity to Darwin Wickham Point was of strategic significance during the Second World War. Anti-aircraft guns and spotlights from the 70th Australian Mobile Searchlight Battery were stationed at the former lazarette site, and a jetty with a tramway was erected on Wickham Point for loading supplies (P. Dermoudy pers. comm. 24/2/1997). Peak Hill, located one and a half kilometres to the south, was used as a training area for Timorese and Dutch insurgents sent to areas under Japanese occupation (P. Dermoudy pers. comm. 24/2/1997).

The most significant set of historic archaeological remains in the Middle Arm area have been recorded at Channel Island. These include a series of buildings, building foundations and graves representing relics of the quarantine station (1884 to 1931) and leprosarium (1931 to 1955) (Caldwell Connell Engineers 1983). With the exception of MH1 (Figure 1), a stone arrangement built very recently (Heritage Surveys 1996), no other historic sites have been documented in the Middle Arm area. Prior to this study the Mud Island Lazarette had not been relocated by archaeologists, and no historic archaeological sites had been recorded in the study area.

4. METHODOLOGY

4.1 SURVEY METHODOLOGY

Difficulties in accessing sections of the study area, and the density of vegetation within it, greatly constrained the nature of the survey methodology. Surveying was carried out both on foot and through the use of a low flying helicopter, as it did not prove possible to access all sections of the study area through pedestrian transects. Areas inspected during this study are illustrated in Figure 1. The following constraints were experienced in carrying out the survey during this project:

1. It did not generally prove feasible to survey the mangrove flats due to the density of vegetation and the inundated nature of the ground surface. The margins of the mangrove flats were inspected wherever a gap in the vegetation allowed access by the archaeologists. It was generally not feasible to penetrate into the mangrove forest for more than of a distance of 40m-50m from its margin. No archaeological remains were identified on the mangrove flats, and it is considered highly unlikely that any archaeological materials would have survived in these areas due to the constant tidal inundation.

2. The proposed plant area could be not inspected through systematic transects. Extremely dense vegetation within the area ensured that it was not possible to carry out an archaeological survey except where tracks had previously been hacked out of the bush and along the margins of the vine forest where it intersected with the mangrove flat.

3. The proposed access road on the central island could not be inspected on foot during this project as wet season conditions made it impossible for the helicopter to land anywhere nearby. The route was inspected from the air and no traces of midden material were identified. Nonetheless, this corridor should ideally be inspected on foot at a future date.

4.2 SITE RECORDING PROCEDURES

On the basis of previous archaeological studies in the region, it was considered possible that at least six types of sites might be discovered during the survey:
Earth mounds: Artificial piles of sediment that may contain stone artefacts or organic material such as stone or bone.

Midden: Accumulations of organic material, usually shells, which represent human food refuse.

Quarry: A location from which stone used to manufacture flaked or ground stone artefacts has been extracted.

Knapping floor: A cluster of stone artefacts that represent the remains of an episode of stone artefact manufacture. Artefacts within a knapping floor can usually be conjoined back together.

Artefact scatter: These sites are locations where a range of activities has occurred such as the reduction of cores, the manufacture and maintenance of tools and the processing of plant foods. These sites will often contain a wider range of lithic materials than quarries and knapping floors.

Stone arrangement: These can range from simple cairns (piles of rocks) to more elaborate arrangements. Some stone arrangements were used by Aboriginal people in ceremonial activities whilst others may represent sacred or totemic sites. Other stone features were constructed for secular purposes. Such features may have acted as route markers, territory markers, the walls of huts, fish traps, hides, or seed traps.

A distinction is drawn between relatively dense, localised concentrations of archaeological materials and the sparsely distributed materials which often surround them. The relatively sparse scatter of artefactual materials is usually known as the "background scatter", while concentrations of such material are termed "sites". For the purposes of this survey an archaeological "site" was defined as a concentration of "...artefactual materials with a high density relative to the background scatter of similar types of cultural debris at those or similar points in the landscape" (Hiscock 1995b:3). In particular, clusters of shell and/or stone were defined as "sites" if the following criteria could be met (after Hiscock 1995b:3):

1. More than ten shells or artefacts.
2. Area of at least $2m^2$.
3. An average density of artefacts or shells at least five times that of the background scatter.

The following details were recorded for each archaeological site identified during the survey: environmental context, site size, the density of artefacts or faunal material, and the range of stone artefacts and other cultural materials present on the site. Sites were marked as accurately as possible onto the 1:50,000 topographic map, and their location was confirmed through the use of a GPS navigation device.

Note that all shell densities in this report are expressed in terms of MNI (minimum number of individuals) per square metre. In the case of bivalves MNI was determined by counting the number of hinges for each taxa and dividing by two. Minimum numbers of gastropods were calculated by counting the number of spires for each shell taxa.

4.3 ARTEFACT IDENTIFICATION PROCEDURES

Stone objects were identified as artefacts if one or more of the following characteristics were present (after Hiscock 1984:128):

1. A positive or negative ring crack.
2. A distinct negative or positive bulb of percussion.
3. A definite eraillure scar beneath a striking platform.
4. Definite remnants of flake scars (e.g. dorsal scars and ridges).

Three types of stone artefacts, flakes, cores and retouched flakes, were identified (after Hiscock 1984:129). A *flake* exhibited one or more of the following characteristics:

1. A ring crack where the percussor struck the core.
2. A positive bulb of percussion.
3. An eraillure scar beneath a striking platform.

A *core* displayed one or more negative flake scars and no positive flake scars. A *retouched flake* exhibited flake scars extending onto the ventral surface and/or deriving from the ventral surface. Since such flake scars may form during use or treadage, as well as during knapping, strict criteria were applied. Only those flake scars displaying a distinct ring crack, and longer than approximately 3mm were recorded as retouch. A flake that has been retouched to form a leaf shaped specimen was termed a *point*. Points were divided into those retouched on one side (called unifacial) and those retouched on both sides (called bifacial).

5. RESULTS

5.1 GENERAL REMARKS

As the study area had not been burned prior to the archaeological survey much of the ground surface was obscured by dense vegetation. Ground surface visibility on the rocky slopes ranged between <1% and 5% except in those areas subject to recent human disturbance where it usually exceeded 80%. On the margins of the mangrove flats ground surface visibility averaged approximately 25%-50% except in small areas where salt pans had formed and the vegetation cover was negligible.

A total of nine archaeological sites were recorded during the survey, all of which are shell middens except for Sites MA17, MH2 and MH3 (Table 2). Site MA17 contains the remains of the Mud Island Leprosarium and a WWII spotlight battery as well as a prehistoric midden, while Sites MH2 and MH3 reflect relatively recent human activity in the area. With the exception of Site MA17, which is located on the northern extremity of Wickham Point, all of the sites were found in the vicinity of Peak Hill in the northwest corner of the study area (Figure 2). Each site is described individually below.

Table 2. Summary of archaeological sites recorded at Wickham Point

Number	Site type	Grid reference[1]
MA12	Prehistoric shell midden and artefact scatter	0270E 1560N
MA13	Prehistoric shell midden	0295E 1530N
MA14	Prehistoric shell midden	0310E 1520N
MA15	Prehistoric shell midden	0260E 1460N
MA16	Prehistoric shell midden	0265E 1470N
MA17	Historic leprosarium site, WWII anti-aircraft site, prehistoric shell midden and quarry	0225E 1680N
MA18	Prehistoric shell midden	0340E 1505N
MH2	Historic structural feature	0320E 1550N
MH3	Historic well	0275E 1500N

[1] Bynoe Harbour 1:100,000 topographic mapsheet.

5.2 SITE MA12

Site MA12 is situated at the base of the western slope of Peak Hill on a low sandy beach ridge adjacent to saline flats which are subject to periodic inundation. Mangrove trees occur along the shoreline but the flats are bare of vegetation except for isolated patches of samphire. By comparison the hill slope and beach ridge are covered in low closed vine forest. The shell midden is located on the boundary between the closed forest and the mud flat. Ground surface visibility at the time of the survey ranged between a maximum of 80% and a minimum of 20% and averaged 50%. The ground surface is sandy across the whole of the site.

Scrub fowls (*Megapodius reinwardt*) were observed on the site at the time of the survey. An abandoned scrub fowl mound is located at the southern end of the site, and an active mound occurs on the western side. Scrubfowl nesting activities have almost certainly caused some disturbance of archaeological deposits at this locality.

Site MA12 covers an area of 120m (north-south) by 15m (east-west) and consists of three relatively discrete components. The first component is a concentration of stone artefacts while the remaining two represent concentrations of marine shell (Figure 3).

- *Component 1.* This scatter of flaked stone artefacts on the slope of the abandoned scrub fowl mound at the southern end of the site.
- *Component 2.* As illustrated in Figure 3, this roughly circular shell scatter measures approximately 3m by 3m in diameter and contains shells in densities of up to $50/m^2$.
- *Component 3.* This midden scatter extends over the crest of a beach ridge and measures 95m in length by 10m in width. Shells occur on the surface of the site in densities of up to approximately $30/m^2$,and there are also stone artefacts in densities of $<1/20m^2$.

The distribution of shell taxa and artefact types is relatively constant across the site. *A. granosa* represents the dominant shell taxa (>95% by MNI), with the remainder of the shell assemblage consisting of *Telescopium telescopium,* plus *Geloina coaxans,* and at least two other types of unidentified gastropod. Several fragments of crab carapace were observed but no vertebrate faunal material occurs within the deposit.

Stone artefacts consist of flakes and retouched flakes of which approximately 80% have been manufactured from quartz and the remainder from silcrete and an unidentified fine grained sedimentary material. Sandstone manuports also occur at Site MA12. Note that quartz fragments occur widely across this site but the great majority display no evidence of having been flaked or modified by humans and are considered to represent a natural outcrop.

Site MA12 appears to be unaffected by recent human activities, although it is likely that some archaeological materials have been incorporated into the scrubfowl mounds.

Relationship to proposed activities

Site MA12 is located approximately 400m to the northwest of the proposed gas plant. It is not expected to be impacted when the proposed facility is constructed.

5.3 SITE MA13

This small, surficial scatter of shell occurs at the base of a gentle slope on the boundary between a mangrove forest and a closed low vine forest. A corridor of paperbark trees runs along the boundary between the vegetation communities. The ground surface consists of a ferricrete pavement, and quartz pebbles also crop out at this locality.

Site MA13 measures 3.5m (north-south) by 5.0m (east-west) and has relatively discrete boundaries. It is a slightly mounded scatter of shell with deposit in the centre of the midden likely to be approximately 10cm deep. The matrix consists of a dark brown loam. No flaked stone artefacts were observed in the site but it does contain quartz and sandstone manuports in densities of approximately 0.5/m^2.

More than 95% of the shells within this site are *A. granosa,* while *T.telescopium* represents the remainder. Some shells appear to have been burnt. Site MA13 exhibits no apparent impacts from recent human land use practices, and does not appear to be subject to active erosion.

Relationship to proposed activities

As indicated in Figure 2, this site is located directly adjacent to the northwestern corner of the proposed gas liquefaction plant. It is possible that the midden will be partly or completely destroyed when construction commences.

5.4 SITE MA14

This shell midden is situated on the eastern side of a low, narrow (15m wide) sandstone promontory which juts out into the surrounding mangrove forest. Vegetation on the promontory consists of closed low vine forest. Ground surface visibility at the time of the survey ranged between 50% and <5% and averaged approximately 25%.

Site dimension are 24m (north-south) by 13m (east-west). Pigs have dug a number of holes within the deposit, and these show that shell extends to a depth of at least 20cm within a matrix of compacted brown silt. The shells within Site MA14 consist almost entirely of *A.granosa* together with small numbers of *T. telescopium.* No stone artefacts were observed on the surface of the midden.

An active scrub fowl mound, 6m in diameter, has been constructed at the northern end of the site and some of the midden deposit has been scraped up into the mound.

Relationship to proposed activities

Because Site MA14 is located on the northeastern margin of the proposed facility, it is likely to be completely destroyed.

5.5 SITE MA15

Site MA15 is a shell midden located on the top of a chenier ridge on the southern side of the study area. This ridge, which extends in an east-west direction, is 10m wide and 1.5m high and is made up of sand and waterworn gravel. Vegetation consists of vine thicket on the ridge itself and dense mangrove forest to either side of the chenier. Approximately 20m to the west of the site, on the crest of the ridge, is an active scrubfowl mound. Ground surface visibility at the time of the survey ranged between a maximum of 80% and a minimum of less than 5%, and averaged approximately 50%.

Cultural deposit covers an area of 7m (north-south) by 25m (east-west), and the main concentration of shell occurs at the western end of the site. The depth of deposit is unknown but it is likely to be at least 10cm. Shell taxa identified on the ground surface included *A. granosa, T. telescopium, Terebralia* sp., *Volegelea* sp. and *Crassostrea* sp.(oyster). *A. granosa* is the dominant taxa representing over 95% of the shell specimens visible on the ground surface.

O'Connor and Sullivan (1994:25-27) have drawn attention to the potential difficulties in distinguishing natural shell deposits and Aboriginal shell middens which have accumulated on chenier ridges. All shell specimens within MA15 appear to be of an edible size, while many of the shells are burnt. The deposit's matrix is a dark brown sand which is markedly different in colour and composition to the sediments elsewhere along the chenier ridge (see above). Shell is absent or extremely infrequent in the sediments comprising the chenier ridge itself, and it is therefore apparent that MA15 represents a cultural rather than a natural deposit.

This midden does not appear to have been impacted as a result of recent human activities.

Relationship to proposed activities

Because Site MA15 is located 150m to the south of the proposed gas liquefaction plant, it is considered possible that it may be impacted as a result of the proposed activities.

5.6 SITE MA16

Site MA16 is a shell midden situated at the northern end of a large mudflat. The mudflat itself is relatively bare of vegetation although mangroves occur around the margin. Vegetation on the site itself consists of low paperbarks and acacias. The ground surface consists of a ferricrete sheet or pavement on which quartz gravel crops out. Average ground surface visibility at the time of the survey was approximately 50%, while it ranged between 40% and 80%.

The midden covers an area of approximately 6.5m (north-south) by 5.0m (east-west), although the precise boundaries of the site are difficult to define as shell densities gradually decrease towards its margins. Most of this site consists only of a thin surface scatter of shell over the underlying rock, although in the centre of the midden a shallow cultural deposit (shell in a matrix of dark brown loam with a depth of perhaps 5-10cm) was identified. Almost all of the shells identified within the midden are *A.granosa* (>95% by MNI), while there are also small quantities of *T.telescopium* and an unidentified gastropod.

Quartz flakes occur across the site in low densities (approximately $0.2/m^2$) but most quartz pieces visible on the ground surface show no evidence of having been flaked. It is not clear whether the quartz which crops out in the immediate vicinity of Site MA16 was used to make artefacts or whether the raw material was carried in from elsewhere. Sherds of bottle glass and rifle cartridges occur within the vicinity of Site MA16, suggesting that recent visitation has taken place in the area.

Relationship to proposed activities

Given that Site MA16 is located directly adjacent to the southwest margin of the proposed facility (Figure 2), it is likely to be completely destroyed once construction commences.

5.7 SITE MA17 (MUD ISLAND LEPROSARIUM)

Site MA17 is believed to represent the remains of the historic Mud Island Leprosarium (Chapter Two). The site contains a wide variety of archaeological remains, and it is apparent that it was also occupied prehistorically as well as in quite recent times.

This site is located on a sandy beach ridge forming the northern extremity of Wickham Point. The Darwin CBD is clearly visible across the water to the north, while mangrove flats occur immediately to the south of the beach ridge. Immediately in front of the site is a steeply sloping beach consisting of sand and highly weathered siltstone outcrops. Vegetation across Site MA17 consists of low grasses and shrubs with patches of dense vine forest.

Based on historic documents, the location of the historic "Mud Island Leprosarium" has been described as follows:

> ... three miles across the harbour from the town of Palmerston. It was not truly an island but rather the tip of the peninsula, cut off from the mainland during high tides and readily accessible only by sea where a little sandy beach presented an approach for small craft. Beyond the narrow beach was a short stretch of scrubland which was backed by mangrove swamps ... (Saunders 1989:24).

The location of Site MA17, which is opposite Darwin and can be approached by small boats, is consistent with this description. Indeed it is the only locality in the immediate area which fits the description, as the remaining areas around Wickham Point are surrounded by dense mangrove forests.

Archaeological materials extend along the top of the beach ridge occur over an area of at least 200m (east-west) by 20m (north-south). At least four phases of occupation appear to be reflected by the archaeological remains at this locality.

1. Prehistoric occupation. An extensive scatter midden deposit, varying greatly in density, occurs throughout the area. *A.granosa* is the dominant shell taxa along with smaller numbers of *T. telescopium*, pearlshell (*Pinctada* sp.) and other unidentified gastropods. While it is possible that some of the midden deposit may have formed during the historic period, two characteristics of the site suggest that it was occupied prehistorically. Firstly the site contains quartz flakes and cores, possibly made from the locally outcropping quartz cobbles. Secondly, the dominant shell taxa, *A. granosa*, is unlikely to occur in any frequency within the local environment as the littoral zone consists of mangrove flats. The midden material is likely to have been deposited before the extensive mangrove forests developed within Darwin Harbour (see Chapter Three above), and is probably at least 500 to 700 years old.

2. Late nineteenth century occupation. A sherd of brown earthenware Chinese pottery and a glass bottle neck with an applied lip were found at Site MA17. Both objects are suggestive of late nineteenth or early twentieth century occupation of the site, and are likely to be linked to its use as a transit station for Chinese lepers.

3. WW2 occupation. Perhaps the clearest archaeological evidence for occupation during WW2 is a 303 rifle cartridge marked "1942" on the base. Traces of the jetty constructed in front of the site are still visible, and there are at least two spotlight foundations represented by circular corrugated iron structures with embankments of sand around them. A number of other objects including rusty flour drums, broken bottles, 44 gallon drums, and sacks of hardened cement are also likely to date to the WW2 period. According to Peter Dermoudy

(pers. comm 14/2/1997) there is also a causeway across the mangroves to the rear of the site which leads to a series of anti-aircraft gun emplacements. The latter consists of five mounds in a semicircle representing a command post and four gun emplacements. These were not observed during the current study as the time available to inspect site MA17 was limited.

4. Recent occupation. Traces of quite recent occupation in the form of abandoned electrical items such as refrigerators are also present

On the beach in front of the site is a large, highly rusted rectangular iron structure consisting of a series of iron plates riveted together to form internal compartments. Rubber components of the feature have not yet perished, suggesting that it is relatively recent in age. The feature is interpreted as part of a barge or a ship washed ashore during Cyclone Tracy.

In addition to these features, a number of structural remains of as yet uncertain antiquity are visible at Site MA17. These include a paving stone floor (largely obscured by mobile sand), a large cement floor with *in situ* wooden stumps, a rock fireplace mortared with cement and the foundation of a corrugated iron water tank. Given the internal complexity of Site MA17, the fact it has been subject to repeated occupation over a long period of time, and that many features may be obscured by mobile sand, detailed historic research and archaeological excavation are required to fully resolve the history of occupation at this site.

Relationship to proposed activities

Site MA17 is well outside the proposed development area, being located approximately 1500m to the northwest of the proposed plant. It is not expected to be impacted as a result of the proposed activities.

5.8 SITE MA18

Site MA18 represents a shell midden extending along the crest and seaward face of a chenier ridge adjacent to a mangrove flat. Vegetation on the site itself consists of closed low vine forest. The midden measures approximately 70m east-west and 15-20m north-south. *A. granosa* represents the dominant shell taxa within the midden, forming in excess of 95% of the shell material. *T. telescopium* and several unidentified gastropods are also present. No stone artefacts were observed on the site, and the likely depth of deposit within this midden could not be determined.

Relationship to proposed activities

As indicated in Figure 2, Site MA18 is located immediately outside the proposed plant area. It is considered to be vulnerable to disturbance or destruction as a result of project development.

5.9 SITE MH2

Site MH2 is a concrete floor on a terraced rock surface located at the northern tip of a rocky sandstone promontory which juts out into a mud flat. The site itself is vegetated by low closed vine forest and dense mangrove forest occurs on either side of the promontory.

As illustrated in Figure 4, the principal feature of this site is a concrete floor underlain by rubble with a drystone retaining wall on the north and west margins. The floor has been constructed on a rock terrace cut into the slope. Approximately 10m to 15m south of the floor on the crest of the promontory are a number of shallow circular depressions (ca 15cm deep) which probably represent craters caused by live firing exercises during the Second World War.

The artefact assemblage from this site consists principally of large number of metal bolts of identical size and shape clustered together in northeast corner of site. It is likely that a sack or crate of these bolts was left on the site when it was abandoned. Other artefacts include a roofing nail, corrugated iron fragments, a star picket and a length of iron pipe. These materials are not readily chronologically diagnostic, and although the age and function of this site is currently unclear it is considered likely to have been in use during or immediately after the Second World War. As noted in Chapter Three, the Wickham Point area was used both for training insurgents and as an anti-aircraft installation, and it is possible that Site MA2 is associated with these activities.

Relationship to proposed activities

Site MH2 is located immediately outside the proposed plant area (Figure 2). It is considered to be vulnerable to disturbance or destruction as a result of project development.

5.10 SITE MH3

Site MH3 represents a well which was not observed by the archaeological team but was found by scientists from Dames and Moore (Keith Martin, Dames and Moore, pers. comm. 10/2/1997). The well is square in shape, measuring 1.5m by 1.5m in width and with a depth of more than 0.5m. No other archaeological materials are associated with it. Site MH3 may relate to WWII activities in the area, although without further historical data the antiquity and origins of the well must remain speculative.

Relationship to proposed activities

As indicated in Figure 2, Site MH3 is located within the boundaries of the proposed plant. As a result, the site is expected to be destroyed.

5.11 DISCUSSION: ARCHAEOLOGICAL SIGNIFICANCE

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

1. *Representativeness*

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

2. *Archaeological research potential*

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

Six prehistoric shell middens were identified at Wickham Point, Sites MA12, MA13, MA14, MA15, MA16 and MA18. These sites contain a similar range of cultural materials, have a similar range of shell taxa, and all exhibit no or little impact from recent human activities. As a result these sites can be regarded as a group in considering their archaeological significance.

All of the middens identified during this study are of great archaeological interest because the dominant shell taxa in each site, *A. granosa,* inhabitants open sandy mudflats. This taxa is uncommon or absent from the mangrove flats which now line Wickham Point. The dominance of *A. granosa* in the archaeological sites suggests that a major environmental shift has taken place since they were deposited.

Elsewhere in Darwin Harbour it has been found that the deposition of middens and mounds dominated by *A.granosa* ceased approximately 500 to 700 years ago. As noted in Chapter Three, it has been hypothesised that this pattern reflects the development of mangrove forests in Darwin Harbour. As a result, it is likely that the middens identified at Wickham point are also at least 500 to 700 years old.

There are many questions which remain to be addressed with respect to environmental change within Darwin Harbour. As a result, the middens identified at Wickham Point represent an important opportunity to address questions regarding the chronology of human occupation in the Darwin region, the environmental history of the area and changes in human use of the coastal environment. As a result of their *research potential*, Sites MA12, MA13, MA14, MA15, MA16 and MA18 can be regarded as possessing a high level of archaeological significance.

In terms of their *representativeness*, however, the middens identified during this study are of moderate significance only. As noted above, shell middens represent the most commonly recorded type of archaeological site in the Darwin region. Middens of the type identified at Wickham Point (ie. dominated by *A.granosa*) have been identified at numerous other localities both at Middle Arm and across Darwin Harbour generally. This observation has important implications for the management strategies which should be applied to the sites at Wickham Point. In the event that the middens at Wickham Point are threatened by the proposed development, other representatives of that type of site will be preserved elsewhere in Darwin Harbour. Priority should therefore be given to retrieving the archaeological information available from sites at Wickham Point before these sites are impacted.

One archaeological site, MA17, was found to contain both prehistoric midden materials and a variety of historic remains. The midden deposit, which is also dominated by *A. granosa*, is considered to hold high research potential for the reasons outlined above. The site also holds significant historical associations as the site of the first leprosarium in the Northern Territory, and as a focal point for defence activities during the Second World War. Site MA17 is regarded as highly significant both in terms of its research potential and its representativeness.

The two other historic sites located during this study, Sites MH2 and MH3 may be associated with Second World War activities, and therefore hold some historical significance. Nonetheless, there is as yet no evidence available to confirm that this is the case. The low diversity of archaeological materials at each site ensures that they hold little potential for archaeological research. In any case, both sites are likely to date to a period for which historic research is better served through reference to oral or documentary sources rather than archaeological evidence. Sites MH2 and MH3 are therefore considered to hold a low level of archaeological significance

6. SUMMARY AND RECOMMENDATIONS

A total of nine archaeological sites were identified during the archaeological survey, and their significance, relationship to the proposed activities and recommended mitigation strategies are outlined below. No archaeological materials were identified along the proposed access road to Wickham Point, with all sites found within or in the immediate vicinity of the proposed plant area.

Five prehistoric middens, MA13, MA14, MA15, MA16 and MA18 are located on the margins of the proposed plant, and it is likely that they will be impacted during the construction process. As these sites are highly significant due to their research potential, it is recommended that there are two strategies suitable for mitigating against damage to the middens:

1. No heavy machinery should be allowed to operate within a 20m radius of each midden. It is recommended that a fence should be erected around each of the sites in order to restrict access to them during and after the construction phase.

2. If fencing is not feasible, it is recommended that prior to the commencement of construction activities the proponent should seek a permit to disturb/destroy the archaeological materials under Section 29 of the *Northern Territory of Australia Heritage Conservation Act 1991*. It is further recommended that prior to construction commencing bulk samples of archaeological materials should be salvaged from each of the middens which will be impacted. This material should then be analysed and sorted to determine accurately the range and relative frequency of different shell taxa in the deposit and so that samples of the shell can be submitted for radiocarbon dating.

One further midden, Site MA12, is located approximately 400m to the west of the proposed plant. It is not expected to be impacted as a result of the proposed activities, and as a result it is recommended that no further action is warranted with respect to Site MA12.

Two historic sites, MH2 and MH3 are located within or immediately adjacent to the proposed construction area. As both sites are considered to hold low archaeological significance, and as both have been recorded in adequate detail during this study, it is recommended that no further action is warranted with respect to Sites MH2 and MH3.

One of the key objectives of the archaeological survey was to determine whether there were any remains of the historic "Mud Island" (Middle Point) leprosarium in the area. This facility was occupied by Chinese and Aboriginal lepers between 1884 and 1931, and was subsequently reused during the Second World War by an anti-aircraft battery. The remains of these activities, labelled Site MA17, were identified 1500m to the northwest of the project area on the northern tip of Wickham Point. The site is not likely to be impacted by the proposed facility, and as a result no further action is required with respect to Site MA17.

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LOCATION OF ARCHAEOLOGICAL SITES ON MIDDLE ARM PENINSULA

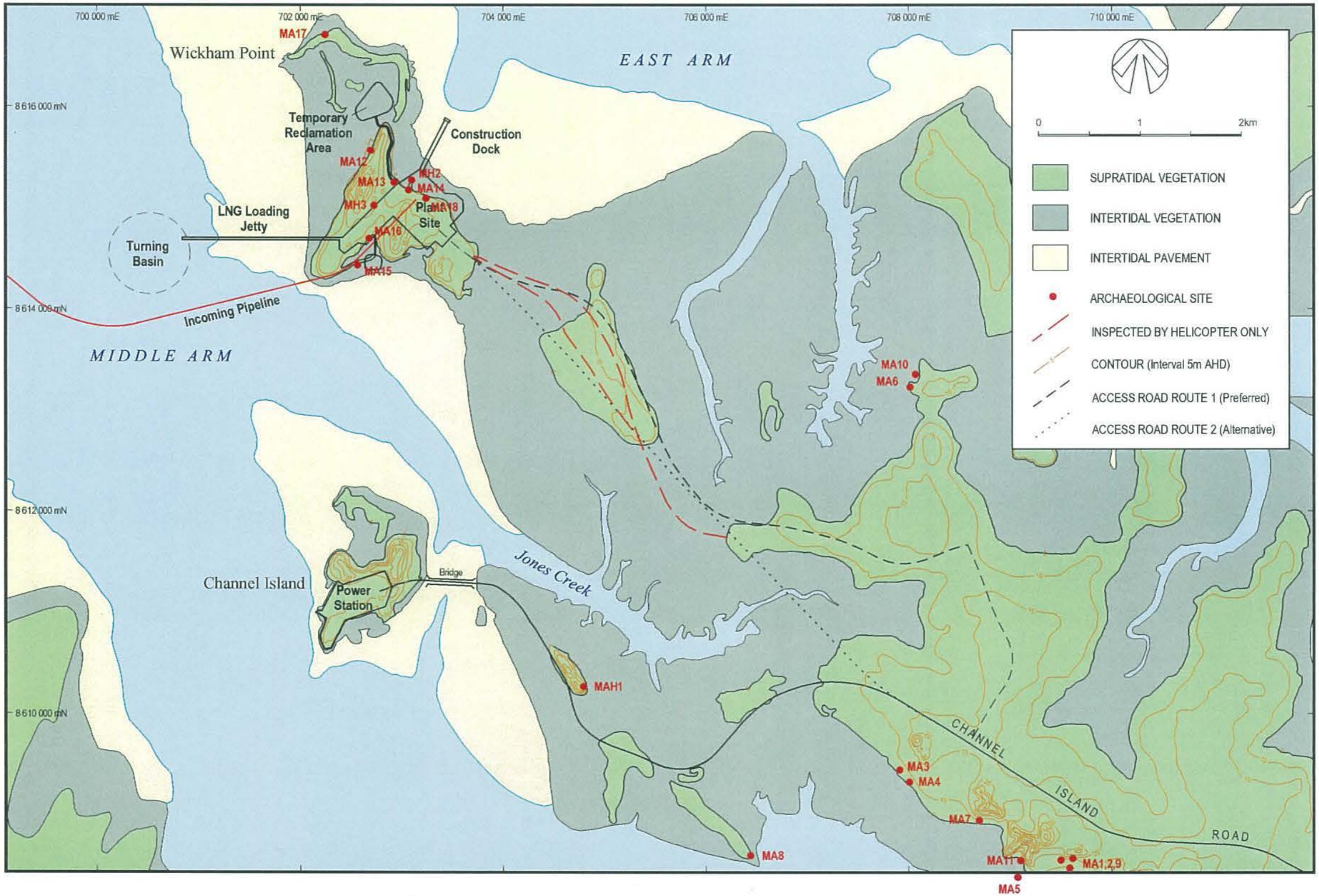
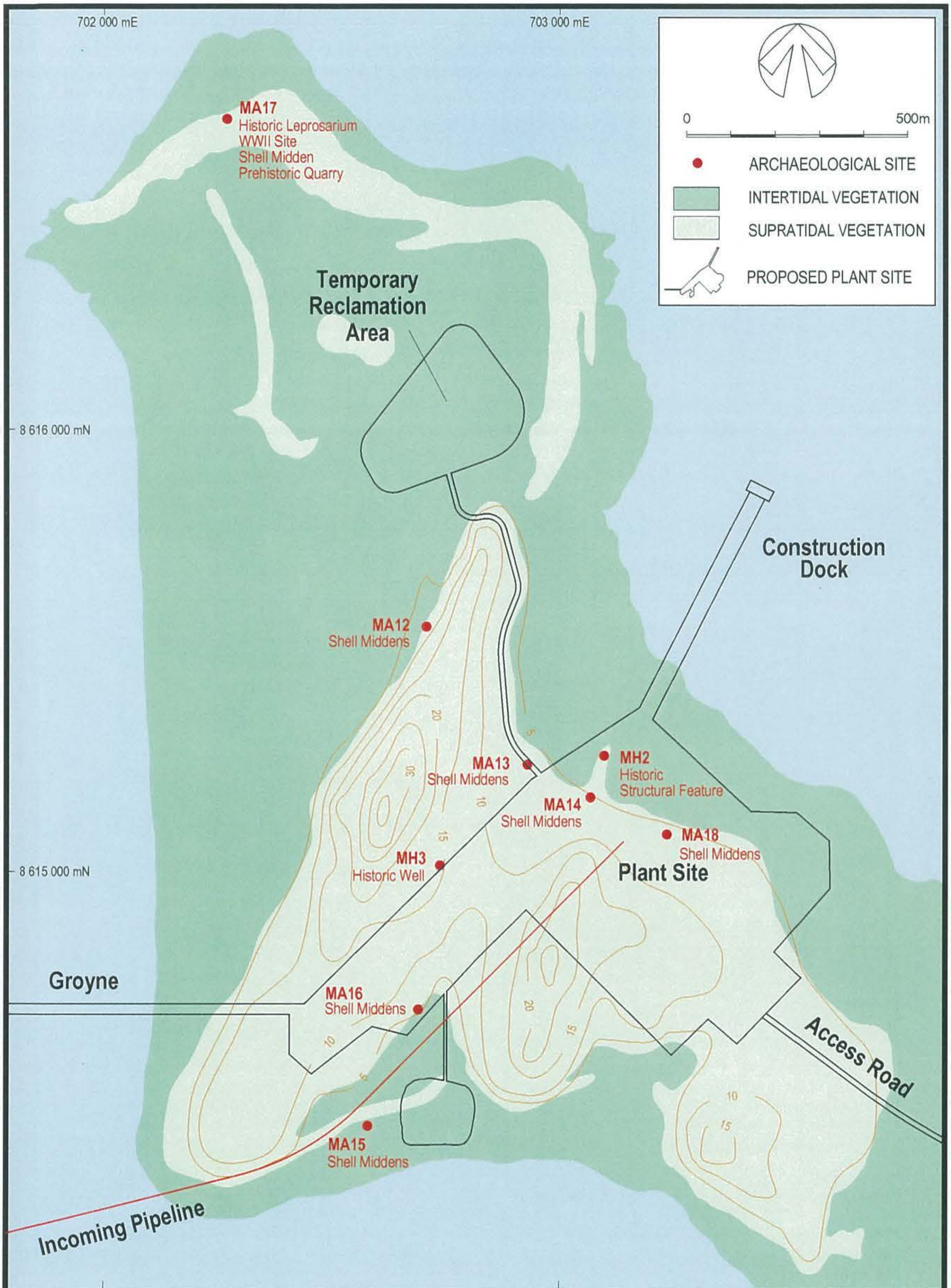


FIGURE 1



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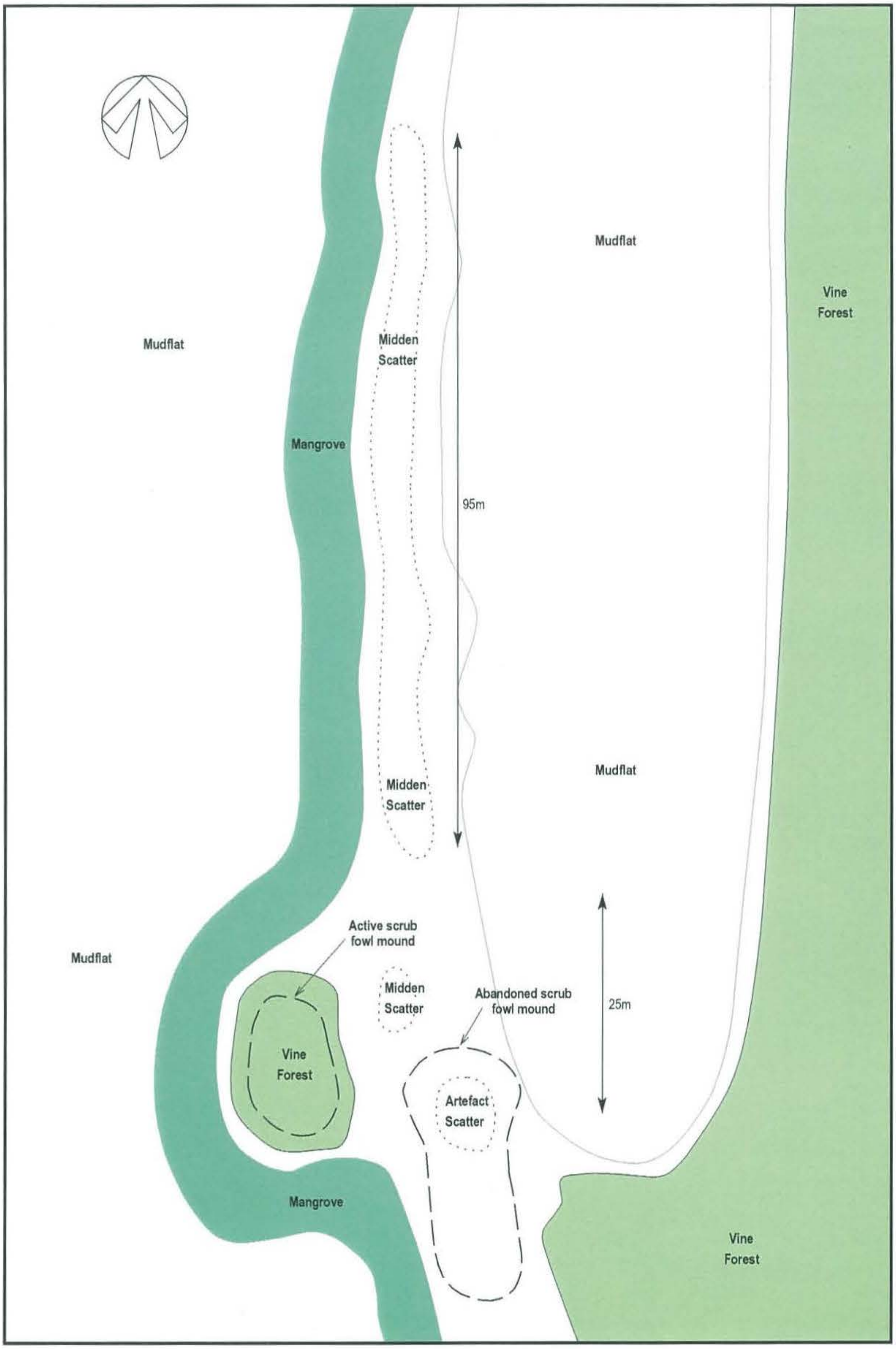
LOCATION OF ARCHAEOLOGICAL SITES ON WICKHAM POINT



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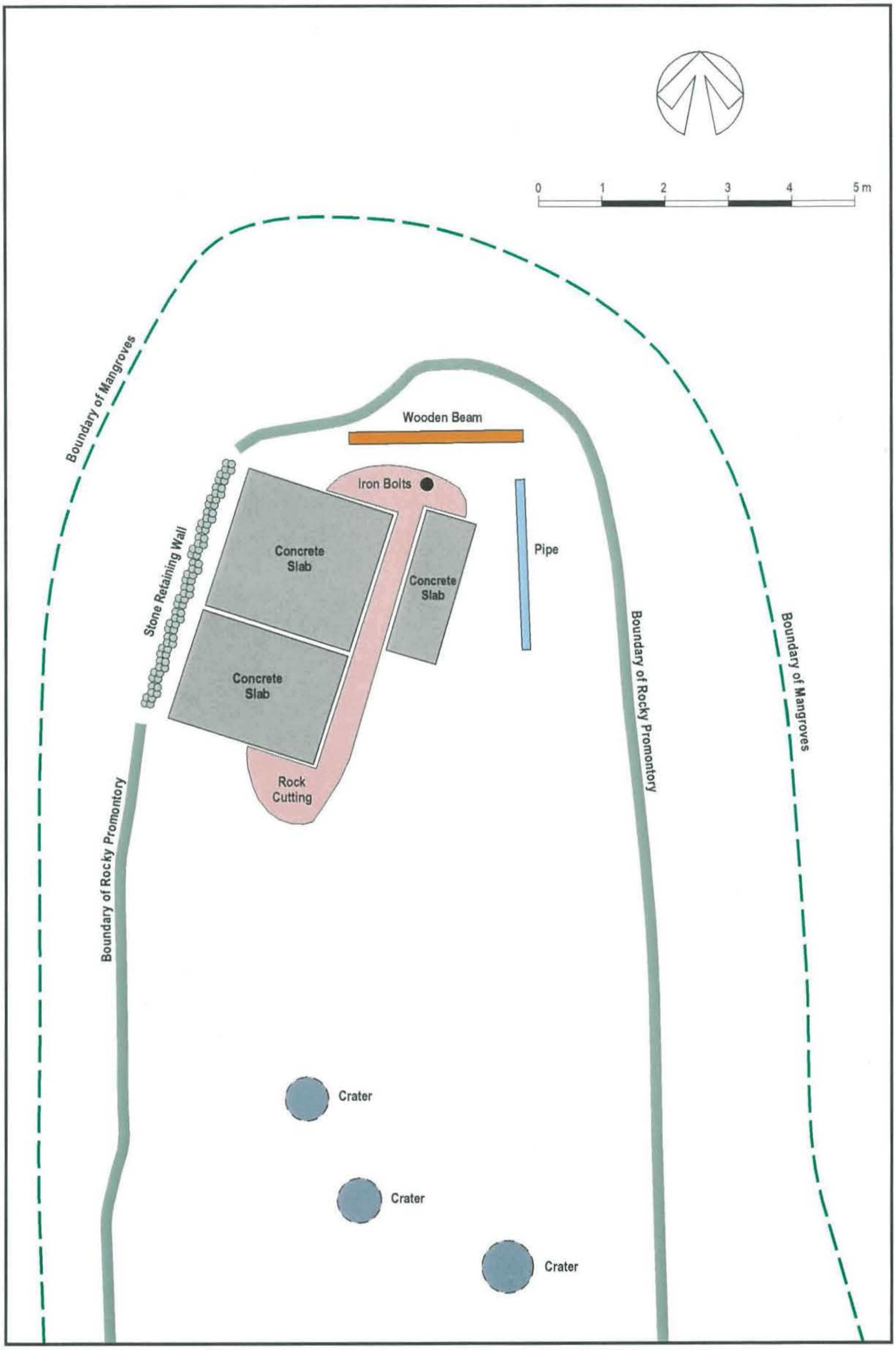
PLAN OF SITE MA12



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PLAN OF SITE MH2

Appendix M

W Murgatroyd

REPORT

Darwin LNG Plant
Draft Environmental Impact Statement

Appendix M
Anthropological Report, Wickham Point

for

Phillips Oil Company Australia

Ref: 00533-164-073
R635
Appendix M
July 1997

W. Murgatroyd
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Tel.: 61 8 8948 4943

CONTENTS

CONTENTS (cont'd)

LIST OF APPENDICES

SYNOPSIS

Wickham Point is perceived by the Larakia and other Aboriginal people around Darwin Harbour as being of some significance to them.

This significance flows from three sources:

- that of a socio-historic nature, in that Wickham Point has played a part in particular periods of Aboriginal history
- including, but of a different nature, the fact that Aboriginal people appear to have been buried on Wickham Point in the recent and distant past although the likelihood of extant Aboriginal burials within the project area is considered to be very low due to a) the nature of the substrate, and b) the severity and nature of taphonomic processes
- as a presently used source of marine food, and the abundance of ethno-botanic floral species on Wickham Point. Evidence from fire/vegetation survey and from consultations indicates that the flora have not been intensively exploited for some time, but which were, from written and oral accounts, crucial to the survival of people as recently as the period of the Channel Island Leprosarium, and which people believe will be exploited again if access is provided.

The Aboriginal people consulted can see that there may be some impacts on their lives as a result of the construction and use of the LNG Plant.

Apart from the loss of the actual project area, Aboriginal people stated that they may lose access to the marine resources around Wickham Point. They did not consider this to be a serious loss.

They considered that the construction of the access road would allow people to visit areas outside the Project Area which are of socio-historical, cultural, scientific, and educational value, to both Aboriginal and non-Aboriginal people - provided that resources were maintained and managed.

Appendix A provides information on sites which have been identified as non-Aboriginal sites of significance which are closest to the Phillips LNG Plant and the pipeline route.

1. THE SCOPE OF THE REPORT

This report was commissioned by Dames & Moore, Darwin, on behalf of Phillips Oil Company Australia, as part of the Draft Environmental Impact Statement for the proposed Wickham Point Liquefied Natural Gas Plant ('Wickham Point', 'LNG' or 'Project').

As an anthropological report, this document is concerned with the interactions of humans with Wickham Point through the past and to the present, and with the impact of the LNG Project on current and future interactions.

The focus is on the relationships between Aboriginal people of Darwin Harbour and the project area. Since at least 1846 the history of Aboriginal people in Darwin Harbour has been linked with, and to large degree, determined by, European history in the area. It is therefore necessary to provide some description of the European activities around Darwin Harbour in order to appreciate the situation of the indigenous people.

It is the understanding of the author that this report discusses aspects as outlined in S7.3 of the Guidelines for an Environmental Impact Statement, by the Environment Protection Division, Department of Lands, Planning and Environment, N. T. ('The Guidelines'), and specifically discusses the potential impacts of the LNG Project on the following:

- sites of significance to Aboriginal people ('significance' is discussed in 5.0 below),
- areas / sites of scientific, educational or cultural significance to Aboriginal and non-Aboriginal people.

The discussion of possible impacts, both during construction (Guidelines 8.2.2), and during operation (Guidelines 8.3.2), therefore focus on the potential impact on the relationships between the Aboriginal people of Darwin Harbour, and places within and around Wickham Point which are of significance because of their connections with the history of Aboriginal people before 1864, and through the interrelationships of Aboriginal and non-Aboriginal people since that time.

2. INTRODUCTION

2.1 Research Methods and Report Methodology

The research for this Report can be broken into three categories:-

- Consultations and fieldwork with Aboriginal informants
- Archival / literary research
- Consultations and discussions with interested parties and / or sources of information.

As far as possible the Aboriginal informants were contacted on at least two occasions. This allows the informant time to consider the issues and their knowledge and response, rather than expecting an immediate unconsidered reply. Working in this way also allows time for the discussion of the issues by a wider group of people around the informant.

Unexpectedly, there is a considerable history to Wickham Point. In preparing this Report I have attempted to highlight the significant periods and locations of human activity on Wickham Point, without being lost in the detail; e.g. the maladministration of Mud Island leprosarium.

The timing of the research, during the middle of Darwin's most severe wet season on record, did not assist. The fieldwork had to be postponed due to high winds and heavy rain. When it did occur, the nature of the terrain and it's waterlogged condition allowed only a cursory inspection. Had conditions been more favourable the following could have been achieved: a greater involvement of custodians, especially the older people, in fieldwork, longer on-ground time and liaison with surveyors/engineers in the field, in-field ethno-botany rather than just literature based information could have been more extensively explored, in-field recording of current Aboriginal perceptions of at least some of the historic and prehistoric material could have been included and the extent of cultural remains further uncovered.

In preparing this report, I have tried to provide some idea of possible Aboriginal interaction with Wickham Point prior to contact. This model is based on

a) the presence and approximate dating of the *Anadara* middens; and

b) other ethnographic and ethnohistorical accounts of the Darwin area, in particular NLC 1979; and Murgatroyd 1995.

2.2 Information Sources and Consultations

The Guidelines at Pt. 10 require that the report should

> "Describe consultations and studies undertaken,...and sources of information and technical data.", and
>
> "Discuss the outcomes of ... discussions with interest groups or communities."

In accordance with that requirement, the following list is supplied.

Northern Land Council:	Paul Hayes, Legal, and Ken Lum, Anthropology: Meeting at NLC, Monday 17 February 1997. Correspondence and reply (see 3. and Appendix C.).
Larakia Association:	Letter (Appendix C.).
Topsy Secretary, Senior Larakia Kullaluk Community Darwin :	Consultations
Prince-of-Wales, Senior Larakia Kullaluk Community Darwin :	Consultations

Richard Barnes Senior Larakia Darwin:	Consultations and Fieldwork
Johnny Singh: Senior Wadjigan / Kiuk, and Spokesperson for some dangalaba Larakia Cox Peninsula	Correspondence and Consultations (Appendix C)
David Dalrymple David Dalrymple & Associates Legal Representative, Tibby Quall dangalaba Larakia:	Correspondence, and discussions 14 February 1997 (see Appendix C)
Robert Graham Anthropologist, Tibby Quall dangalaba Larakia:	Discussions; 15 and 20 February 1997.
Bob Alford CEO. National Trust of Australia (NT)	Discussions 14 February 1997, access to Archives 7 and 18 March
Dr Scott Mitchell, Heritage Consultants:	Discussions, 10 February and 22 March.
Steve Sutton, Senior Heritage Officer, NT Department of Lands, Planning and Environment:	Discussions, 03 March 1997
Suzanne Parry (Saunders)	Telephone discussions, 21 February 1997.
Sylvano Jung Maritime Archaeologist	Discussions, 3 and 5 March 1997 (see Appendix B)

2.3 Consultations and Fieldwork with Aboriginal Informants

Comments made by those consulted, Topsy Secretary and Prince of Wales at Kullaluk, Darwin, Johnny Singh at Mandorah, on the West side of the Darwin Harbour, and Richard Barnes, are incorporated into the Report where relevant.

Topsy Secretary is one of the oldest Larakia[1], probably in her mid sixties. She was a young girl at least by the time of the Second World War and remembers walking around Darwin Harbour and

[1] The current preferred spelling is *LARAKIA* (Richard Barnes, 23 May 1977), however it must be borne in mind that the spelling has varied and works referred to or quoted may have variations. Discussion on the transcription and pronunciation of Larakia works, including "Larrakia" (sic.) are to be found in The Kenbi Land Claim Book (NLC 1979) at pp.xiv to xvii. "Larakia" is a Malay word which probably came into popular use during early European exploration and settlement. In the Larakia language, the Larakia refer to themselves as "Gulumbirigin" (NLC 1979:5). This term is rarely used, and was omitted from the Anthropological Report to avoid further confusion.

hinterland, and crossing the Harbour in canoes, travelling to places on Cox Peninsular to the West and Shoal Bay in the east. Her family, including her deceased brothers, are regarded as senior traditional owners of the dangalaba Larakia clan. Apart from forced movements during the WW II, it seems Topsy has spent all of her life in and around Darwin. (NLC 1979: 25; pers. comm. Topsy).

Prince-of-Wales is an elderly Larakia / Wadjigan man, about sixty years old, whose Senior Larakia status can be traced through his father, King George, his grandfather, King Miranda, to his great grandfather, King Tommy. King Miranda was known as "the king or chief of the Port of Darwin ..." (Wildley 1875:119 in NLC 1979: 27). Prince is also a classificatory sibling to Topsy Secretary (NLC 1979: 25). Prince was an active ceremonial leader and famous dancer. He suffered a stroke and is not able to sing or dance. He is still however, a spritely and animated man, and although he finds it tiring to engage in lengthy conversation, he was present when I spoke with Topsy and indicated his agreement with her statements.

Johnny Singh is a senior Kiuk / Wadjigan man and President of the Belyuen Council. He is regularly consulted as being knowledgeable about the Cox Peninsular side of Darwin Harbour, through his traditional status and his frequent travels by boat and on land through the area. Johnny is married to Olga Singh, the daughter of a deceased senior dangalaba Larakia man. Johnny Singh therefore also speaks on behalf of his dangalaba wife and children (Johnny Singh pers. comm; NLC 1979).

Richard Barnes is a senior Larakia man who is active in the Larakia Association and an accomplished artist. He is employed by the Northern Territory Education Department, Aboriginal Education Unit, Darwin. His senior status is inherited through his uncle, George Mungaloo who was a senior Larakia ceremonial leader.

I received no direct reply from Tibby Quall, however, Robert Graham (Anthropologist) advised me that virtually no ethnographic work had been done on the Larakia or Darwin Harbour, since the Kenbi Land Claim Book (NLC 1979).

The Northern Land Council replied in writing concerning the general affects of Native Title over the Project area. Their comments are included in 3. below.

2.4 Fieldwork

Initially it was anticipated that Richard Barnes, Johnny Singh, and Tibby Quall would participate in helicopter surveys of the project area. Due to extremely wet weather, the survey was postponed from Sunday 23 February, and eventually was carried out on Saturday 08 March 1997. At that time, I had not been able to contact Tibby Quall and Johnny Singh was not well and had been admitted to Darwin Hospital.

Richard Barnes and I flew along the flight path as indicated on Map 2. We landed at the location shown and spent about 10 minutes on the ground. Due to the wet weather, and the density of the vegetation on Wickham Point, it was not possible to land at any other locations.

The area we landed in was directly next to an Aboriginal shell midden and, mixed on top of and around the midden were broken brown glass beer bottles, and expended high calibre rifle cartridges.

As a general note, the spelling and pronunciation of Aboriginal names is an unresolved problem for European recording and using the names. A single name of a person, group, language or place, may have many variations as it appears in different contexts in various Aboriginal languages, European records, including official government documents, and in academic works. Variations in the latter may be due to changes in linguistic theory and style, political pragmatics, the sources of information and the personal choice of the recorder.

This midden is situated within Zone A as marked on Map 1, the area between the fringing mangrove swamps and the higher ground.

The vegetation on the sloping higher ground behind the midden was, as I had been told, very difficult to walk through due its density and the nature of the monsoon vine forest. It was, as anticipated, rich in bush tucker, as Richard identified an edible or useful species at almost every step.

Richard stated that the mangrove, and paperbark swamps around the midden would also be very rich in ethno botanic species.

After taking off from the landing area, we circled the Point. We did not locate any of the large middens identified by Dr Mitchell, however we were able to see the concrete slab on the top of Peak Hill, believed to be a remnant from WW II. (See Appendix A). We then flew over the access road route and out into the Harbour along the pipeline route, before landing in Darwin.

3. NATIVE TITLE

The area of Wickham Point and the sea around it to the low water mark, is currently the subject of a Native Title Claim. Upon enquiring with Jim Godlove of Phillips Petroleum, Darwin, I was advised that this Report should only acknowledge the Claim and not directly address the matter at any length.

The Northern Land Council, in a written reply, stated that "... the Larakia expect that any developments regarding their sea areas will occur after proper consultation and negotiation have occurred." The complete Letter is included in Appendix C.

Richard Barnes also made the following unsolicited statement:

"I don't see us giving up our rights to go in there and use it (Wickham Point and the sea around it) - even despite an agreement. A Native Title agreement is up to other people, but we would retain future rights."

No other discussions were held with regard to Native Title while researching this report.

4. WICKHAM POINT

Wickham Point lies on a Peninsular in the southern part of Darwin Harbour. It sits between the Elizabeth and Blackmore Rivers, where they enter into Darwin Harbour.

The Larakia and Their Neighbours

The area around Darwin Harbour has been recorded as being the country of the Larakia people since the earliest European records of the area. (NLC: 5-7). Since the arrival of Europeans, several periods of dramatically accelerated dislocation have occurred in the Aboriginal populations around Darwin, punctuating the gradual and, supposedly inevitable, alienation of people and land, before the era of Land Rights and Native Title. Those disruptive periods, such as early mining, Missions, War, and the Assimilation Policy are touched on below where relevant.

The result of both the gradual process and the sudden shifts, has seen great forced movements of Aboriginal people around Darwin and other parts of Australia's north coast during the historical period. For the Larakia, having the Capital City of The Northern Territory on their land, has had both beneficial and negative effects. The latter are obvious, however as it was a European centre, Aboriginal people were more easily able to return to Darwin after periods of sever dislocation.

The Larakia's neighbours, the Minitja (Woolna), Wagait, Kunnarakany, and others from far south, west and east, were not always able to return to their own country, and many of these people have, and do, live on Larakia country.

Through discussions with Topsy Secretary and Richard Barnes it is clear that, at present, these senior, Darwin-based Larakia while not relinquishing their own interests, accept that certain Belyuen people, Johnny and Olga Singh, need to be consulted about matters concerned with the western side of Darwin Harbour.

5. ABORIGINAL INVOLVEMENT WITH WICKHAM POINT

5.1 Introduction

It has not been possible to find any ethnographic records dealing directly with Wickham Point. As explained above, Section 5.2 provides a bare model of past Aboriginal involvement with Wickham Point, based on a minimum of archaeological information, provided by Stephen Sutton and Dr Scott Mitchell, and other ethnographic research carried out around Darwin.

The purpose of this model is merely to provide some idea of the likely interactions of Aboriginal people and the land and sea of Wickham Point prior to contact.

5.2 Prehistory to Contact

The only firm evidence yet found of pre-contact Aboriginal involvement with Wickham Point are the shell middens lying in Zone A. These middens are primarily composed of *Anadara grenosa*, a species referred to by Aboriginal people as 'cockles' (S. Mitchell; S. Sutton; R. Barnes; J. Singh; pers. comms).

Middens of similar composition with a similar location, in the zone between mangrove swamps and higher ground, are common around Darwin and in other areas of Australia's north coast. Four such middens are reported to have been located on 'Middle Arm Peninsular' during a 1983 survey related to Channel Island Power Station (Caldwell Connell 1983: 107). Although the exact locations of these middens is not known they are within close proximity to Wickham Point.

The Anadara species requires clean shallow water over sand to successfully survive. Therefore, at the time the Aboriginal people were heavily using the area of Wickham Point, it was a place of pleasant sandy beaches, with easy access to the higher, resource rich areas.

The presence of the mangrove swamps today indicates that a period of siltation occurred, destroying the Anadara beds and providing conditions favourable for the mangroves to colonise the former sandy beaches. The period during which the shell middens were created is dated to prior to 700 to 1,000 years ago. (S. Mitchell, pers. comm.)

At a time well prior to European contact, Wickham Point, and the seas around it, were areas of great attraction to Aboriginal people using the Darwin Harbour. It is likely that people travelled across country, to the beaches, as well as travelling in by water craft, from other parts of Darwin Harbour and possibly the hinterland.

It seems likely that the long bodies of water which reach inland from Middle Arm, would have been used to access the hinterland by coastal people, and vice versa. The location of Wickham Point may therefore have given it some strategic importance at that time.

People visiting or living at Wickham Point in those days would have had a rich and varied selection of marine, littoral zone, and terrestrial resources.

With the passing of the Anadara beds and the appearance of the fringing mangrove swamps, Wickham Point would have lost possibly one its principle attractions, and had become much more difficult to access from the sea and the land. It is possible to state only that, given the paucity of information, it is most likely that Aboriginal people continued to visit Wickham Point, even if only sporadically, after the loss of the Anadara beds.

Johnny Singh is aware of the Anadara middens and understands their significance as sites where Aboriginal people spent a lot of time. He also understands that the Anadara beds were destroyed by changes in the environment. Johnny stated:

"People come straight across (Darwin Harbour) to Wickham Point, it was a travel place, and a main hunting spot. When those cockles were around, then they moved to clean water. Other things, the trumpet shell, they are still there." Later he said, "... when there's those things, debris and stuff (in the water), those shells, cockle shells, they just keep moving."

Johnny, Topsy and Richard all stated that it is likely that, at the time that the middens were formed, the remains of Aboriginal people who died there would have been interred in the beaches and possibly the middens themselves. There is a very definite correlation around Darwin of Aboriginal burials being located in sand dunes and beaches.

5.3 Contact to 1885

The first definite record of Europeans entering Darwin Harbour was in 1846 when Captain Wickham, after whom the Point is known, sailed west from Shoal Bay, where his commanding officer, Stokes and the main exploration party were based (NLC 1979: 78: Knight 1972:14).

NLC 1979 (77-79; and 265 ff), details recorded instances of accounts of Aboriginal people around Darwin from the earliest European records. While Aboriginal life was disrupted by the presence and activities of Europeans in the area, the impact was first felt, most severely in small patches of intense European activity.

After the settlement of Palmerston (Darwin) itself, then restricted mainly to the area above Stokes Hill Wharf, and along the Esplanade, the greatest impact occurred through mining activity, in the hinterland immediately south of Wickham Point, and west along Bynoe Harbour.

A new port arose at Southport to alleviate the long haul of goods from the Palmerston wharf to the mining centres. During the late 1870s and early 1880s, when Southport was an active port, a considerable number of vessels passed close to Wickham Point on their way to and from the mining port. While it seems likely that some explorations were made, and possibly some search for minerals, I have located no direct reference to such activity.

It was during this period however, and as a direct result of mining activity, that Wickham Point was selected as the site for a Leprosarium to house the increasing numbers of Chinese and Aboriginal lepers being found around Darwin and the mining fields, as far south as Pine Creek.

5.4 Mud Island Leprosarium

This section is summarised from Saunders (1986), especially pages 87 ff.

Following the first discovery of a Chinese Leper in 1882, Authorities in North Australia became concerned about the potential spread of the disease through the large Chinese populations on the mining fields into the Aboriginal and European populations. Chinese mine labourers arrived in the Northern Territory from 1869 and while many were reported to be in very poor health, calls for strict and complete quarantine procedures went unheeded.

By 1889 there had been twenty known cases of Chinese with Leprosy in and around Darwin. The reaction of the Authorities had been the declaration of the leper as a criminal, and the use of Police to round up actual and suspected lepers.

In 1885 an area on Wickham Point known as Mud Island was Gazetted as a Leper Station, after having been in use as an isolation area since the previous year. The selection of Wickham Point was very deliberate, following the policy in Australia, and throughout the world, of attempting to place lepers in areas of complete isolation from the rest of the community. The site was also located only three miles across the harbour from Palmerston (Darwin).

At least six of the first twenty Chinese lepers were repatriated to China after being isolated at Mud Island while some remained there for considerable periods of time, and others are believed to have died there, at least one by suicide.

The first two cases of Aboriginal people with Leprosy were diagnosed in 1890 and 1894. Aboriginal sufferers of the disease were also transported to Mud Island to be held indefinitely. These were sometimes brought in from the bush, chained together with other prisoners and witnesses being brought into Darwin.

Saunders (1986: 88), describes the location of the Leper Station, at the extreme tip of Wickham Point (Map 3), thus:

> "It was not truly an island but rather the tip of a peninsular, cut off from the mainland during high tides and readily accessible only by sea ... narrow beach ... dense mangrove swamps ... devoid of natural fresh water ... limited vegetation and animal life it was a desolate site which could in no way ease the burden of ill-health and isolation suffered by the leprosy patient."

Conditions at the Leper Station were deplorable. The patients were essentially left to care for themselves, to build huts, find water and food. Many Aboriginal people preferred to head bush as best they could, even those with missing limbs, rather than to sit and wait to die in the Station.

While attempts were occasionally made to improve conditions on Mud Island, all efforts met with failure. It was not until 1922 that the patients began to receive treatment. Throughout the period of 1884 to 1931 conditions for people incarcerated at Mud Island only deteriorated.

Bill Harney (in Saunders 1986: 91), described it as, "an excrescence, an island of mud and sand, swarming with mosquitoes and sandflies ... lonely, miserable people ...". Suicide was common among the Chinese lepers, people died without being noticed, others went bush, and three large groups of Aboriginal people escaped in 1923, 1925, and 1927, some of whom were never recaptured.

The latter incidents highlighted conditions on Mud Island, described in 1906, as being "unsuitable for any being of the human species" and eventually in 1934 the new leprosarium was opened on Channel Island.

It is not known how many people died on Wickham during the time of Mud Island, and once again there is no information on the locations of graves.

5.5 Channel Island Leprosarium

Unfortunately the pattern of neglect and decay began again, and ironically, Wickham Point became an important resource source for Aboriginal patients on Channel Island. The latter was once again a bleak location. With poor soil, no fresh water, and the rapid use of available trees for firewood, the large Aboriginal population were forced to depend on irregular supplies from the Authorities.

At this time Aboriginal patients began to travel to Wickham Point to hunt and collect bush tucker and medicines to compensate for the desperate state of nutrition in the Leprosarium. Johnny Singh stated that people used to go to Wickham Point in little boats to get bush tucker, to picnic, and sometimes to camp there.

Johnny stated that there were some old people at Belyuen who could remember those days, however when I visited Cox Peninsular on Friday 28 March, Johnny stated that these people were still stuck on outstations in the bush due to the heavy wet season.

5.6 WW II

After the first Japanese air raids on Darwin in February 1942, the staff of Channel Island Leprosarium were evacuated and many of the Aboriginal inmates fled the Island and headed for their own country. Others remained and were again forced to fend for themselves for some time (Lockwood 1972: 186-187).

Wickham Point again assumed strategic importance, this time to serve the defence of Darwin. It was selected to be the site for the 70th Australian Mobile Searchlight Battery (see Map 4). The members of this battery, whose headquarters were based in Berrimah, cut roads through the mangrove swamps to cross the Elizabeth River, and apparently carried out extensive works on the higher parts of Wickham Point (Ogram).

Aboriginal people came under the direct control of the Army for the period 1942 to 1945 and were used extensively on general and military works, from cutting wood and washing uniforms, to building roads and fortifications.

Johnny Singh sates that he remembers several old people from Belyuen who had worked with the 'Airforce' on Middle Point during the War, - Willie Singh, George Maureen, Tommy Lyons, Maudie Bennett, Nim Adelaide and Jimmy Munoo. While it is to be expected that Aboriginal people were working on Wickham Point I have found no other evidence.

Both Lockwood (1972: 181ff) and the Berndts (1987) describe the strict controls exercised by the Army over Aboriginal people. No Aboriginal people were allowed to camp within five miles of an Army camp. All labourers required to work outside the Aboriginal compounds were trucked out and back each day. As the Aboriginal compounds around Darwin were established at Koolpinyah Station, Adelaide River, and Pine Creek, it seems unlikely that it would have been possible to move Aboriginal people in and out of Wickham Point on a daily basis.

Lockwood (1972: 178-179), does point out that many Larakia and other people were moved, or took themselves to Delisaville (now Belyuen), on Cox Peninsular. It is possible that these people, such as those named by Johnny Singh, provided the labour on Wickham Point.

5.7 Recent and Contemporary

After the end of the War, Wickham Point seems again to have been visited only sporadically by Aboriginal and Europeans. The Draft Vegetation and Fire Report (EcOZ: 8), indicates that Wickham Point has not been subject to burning for some time. This supports an almost complete isolation from outside influence, and helps explain the density of the vegetation and the abundance of ethno-botanic species (Appendix B).

Johnny Singh stated that he goes fishing at a favourite and reliable spot off Wickham Point about four or five times a year, especially during the dry, when other areas in the Harbour are being heavily fished. He went fishing there as recently as January 1997. Johnny goes up close to Wickham Point and sometimes goes ashore but he does not attempt to go inland because of the thickness of the vegetation.

Topsy Secretary, Prince-of-Wales and Richard Barnes could not remember having visited Wickham Point.

Johnny explained to me that while fishing mainly involves catching just enough to feed the family for a day or two, it is also something he enjoys doing just as do other recreational fishermen.

Johnny said" When we go fishing, we might get fish, turtle, dugong, we just take enough for a couple of days. We don't want that freezer full. Some people just catch too much, then waste it. We look after the ocean and all these fish. We don't catch dugong in the wet season, that's breeding time. We don't take too much turtle, just one for our family, that's all you need. Then there's still plenty left to catch next time."

6. THE SIGNIFICANCE OF WICKHAM POINT TO ABORIGINAL PEOPLE

6.1 Sources of Significance

Aboriginal people attain affiliation to areas of land or sea, thus embueing the area with significance to them, in a variety of ways. Interest in areas of special significance, such as Sacred Sites, or favoured residential locations, are primarily acquired through direct inheritance from the father and mother and potentially, the grandparents on either side.

Places may also become significant during a person's life - where their parents are buried, where they go through periods of social status change, including marriage, where their in-laws have places of significance.

Rather than deal with the range of types of significance, I will deal with only those relevant to Wickham Point.

6.2 Social and Historical

Wickham Point has seen intense human activity during at least three periods in the past - around 500 to 700 BP, when the *Anadara* middens were formed; 1884 to 1931, Mud Island; and 1942 to 1945 during WW II.

The Aboriginal people I spoke to expressed the feeling that Wickham Point had a significance to them in that it had featured during particularly disruptive periods of their own and their ancestors lives. During the time that Mud Island was in use and Police were actively rounding up real and suspected lepers, Aboriginal peoples' lives in and around Darwin became increasingly disrupted. It was a period when strenuous efforts were being made to control Aboriginal people's access to their land in order to allow European expansion.

1942 to 1945 was a similarly disruptive period for Aboriginal people around Darwin. However, as Lockwood and the Bandits point out, the period under military control is seen as having some beneficial, though possibly intangible, effects, particularly in regard to Aboriginal self esteem. Working for the Australian Army gave Aboriginal workers wages for the first time.

Johnny Singh stated: "You think of that place, and you think of those old people, locked up for leprosy, they had a hard time in those days. Aboriginal people had nothing, couldn't do anything. And then those people worked there for the Airforce, we helped a lot in the War. It was still a hard time. It's special to me, not like a sacred site, my people were there before."

Topsy Secretary stated that Wickham Point had significance to her because "... Those old people were there, not spirits, Aboriginal people who used to live there, the old people".

Richard Barnes said that the area all around Wickham Point was known to him as an important hunting and foraging area. Although he had not seen the middens, he stated that they are of some significance as, apart from physical reminders of past Aboriginal activity, they may contain very old burials.

Richard remembered visiting the Channel Island Leprosarium with his father who drove a supply truck. He remembered seeing the people there and the terrible conditions they lived in. He understood how Wickham Point was important to old people who are still alive because of its involvement with a time when Aboriginal people's lives were severely curtailed, and the victims of Leprosy were "... not allowed to go very far, many of them lived out their lives there."

6.3 Possibility of Aboriginal Burials

It seems likely that there is a possibility of Aboriginal burials, at least in the middens. However, there is no precise information on locations.

It seems highly likely that some people were buried on Wickham Point at the time of Mud Island. These burials may be recorded in surviving Government documents, and it is likely that Aboriginal people who died during that period, may have living relatives.

Attached (Appendix C), is a letter from Stephen Sutton, Senior Heritage Officer, NT Department of Lands, Planning and Environment which explains in detail the situation regarding burials. In summary, Sutton states that, while Aboriginal burials have occurred on Wickham Point, the likelihood of extant Aboriginal burials within the Phillips LNG Project Area is very low due to a) the nature of the substrate, and b) the severity and nature of taphonomic processes.

Sutton also highlights the established protocol and procedures for dealing with Aboriginal skeletal remains should they be disturbed during construction activities.

6.4 A Resource Area

Wickham Point and the seas around it are very rich in marine, littoral zone, and terrestrial resource, traditionally and currently exploited by Aboriginal people. The difficulty in accessing the Terrestrial resources has meant that it has been little exploited in the recent past. The following section addresses this issue further.

7. POTENTIAL IMPACT OF PROPOSED LNG PLANT AND INFRASTRUCTURE

The construction and use of the proposed LNG will bring about a significant change to Wickham Point. The Aboriginal people with whom I spoke did not consider that these changes, nor the operation of the plant, would have any great impact on their lives.

Johnny Singh stated; "It will have no immediate effect ... if there is a pollution effect on the fish, we'll go somewhere else to fish. It will stop us fishing, but we can go somewhere else, that's only a little effect".

Topsy Secretary also knew that people like fishing at Wickham Point, however, she said, "If they can't go fishing there, they can go somewhere else, there's plenty of places for fishing."

Richard Barnes also did not consider that the construction and operation of the plant would have any significant impact, apart from the loss of the land involved and the resources on it.

All three acknowledge that the construction of the plant and particularly the road, would make Wickham Point much more easily accessible, and they could see benefits in this.

Topsy stated that, given the abundance of bush tucker, it would be a good place to teach Aboriginal and non-Aboriginal people about bush craft. She particularly referred to an incident in which one of her relatives had survived in the bush only because he had learnt traditional skills. Topsy also believed it may be a good source of materials to commercially produce artefacts.

Richard agreed with Topsy that the access road would be an advantage. He stated that areas of significance to Aboriginal people should be acknowledged with explanatory signs. He also realised that, for the full potential of the cultural value of the middens and resources to be maintained, sufficient areas of land would need to be protected and managed with the co-operation of the developers and Government.

8. CONCLUSION

Wickham Point and the sea around it are of significance to Aboriginal people through the evident involvement of their ancestors, and it's part in particular periods of recent history. A number of Aboriginal people are believed likely to be buried in the area.

None of the Aboriginal people consulted felt that there would be any great impact through the construction and operation of the LNG Plant at Wickham Point, apart from the loss of the area of and resources of the actual Plant, and the possible loss of a favoured fishing area.

The Aboriginal people did see that, if properly arranged, improved access to Wickham Point could provide opportunities of cultural, scientific and educational value to Aboriginal and non-Aboriginal people.

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Appendix A. Non Aboriginal Sites of Significance In and Around the LNG Project Area. including Submerged Material Culture.

S. Jung and W. Murgatroyd.

Site 4. Concrete Slab on Peak Hill.
This slab, apparently made up of smaller square blocks, was sited during the helicopter survey. No information has been located about this site. It may be remains from the Search Light Battery, or possibly from Commando training operations conducted on Wickham Point during the War (pers. com.: S. Mitchell.

The site would seem to be of some significance if it's context can be ascertained.

Site 5. *Ellengowan* (1888)
The *Ellengowan* shipwreck is an example of nineteenth century maritime history in the Northern Territory. This 79' (25m) iron hull steamer is representative of the transition between sail and steam. Built in Norway in 1866, it was purchased by the London Missionary Society and used in establishing the first mission station in New Guinea. It was also used for survey work and while in this role, became the first European vessel to navigate the Fly and Baxter Rivers in New Guinea and to make contact with the indigenous people there. It's particular historical significance to the Northern Territory is that it was used by the Daly River sugar plantation as a supply vessel and at one stage as a customs boat, that met Macassan trepangers along the NT coast for their customs duty. The vessel sank in Darwin Harbour in 1888 on the night of the 27th of April. At the time of the vessel's sinking, it was used as a quarantine hulk for Chinese immigrants and sank at its moorings when it was forgotten to pump water out of the old and leaking hull.

The wreck's location is near Channel Island in Middle Arm, at Latitude 12^0 32.28' S, Longitude 130^0 52.08' E. The hull is broken-up and corroded, but some structure remains with hull plating still supported by iron frames. The boiler and screw remain, but the engine was not located. The *Ellengowan* is a protected shipwreck under the *Northern Territory Heritage Conservation Act 1991.*

Considering the proximity of the wreck site to the pipe line, it is recommended that the site be marked by a permanent buoy. A protection zone of 50 metres radius extends around the site and the marker buoy would act as a visible reference point by which to gauge the protection zone on the surface.

Site 6. *British Motorist* (1942)
British Motorist was a steel commercial tanker, built in 1924. The vessel was owned by the British Tanker Company and designed for the international petroleum trade. *British Motorist* was under charter to the Allies for the transportation of fuel. It departed Colombo, Ceylon (now Sri Lanka), on 22 January 1942 and arrived in Darwin on 11 February, carrying light fuel oil to replenish the town's storage tanks. The site of *British Motorist* is historically significant in that *British Motorist* was sunk in Darwin Harbour during the Japanese air raid of 19 February 1942. The wreckage of *British Motorist* is a memorial to those who lost their lives in the attack and a relic of Australia's' maritime heritage. The site of *British Motorist* also has an educational and recreational value, as it is a popular dive site for both tourists and local divers, who are able to experience first hand a part of Australia's maritime heritage.

Located at Latitude 12^0 29.86' S, Longitude 130^0 49.16' E, *British Motorist* is a protected shipwreck under the *Northern Territory Heritage Conservation Act 1991.*

Considering the proximity of the wreck site to the pipe line, it is recommended that the site be marked by a permanent buoy. A protection zone of 50 metres radius extends around the site and the marker buoy would act as a visible reference point by which to gauge the protection zone on the surface.

Site 7. USAT *Mauna Loa* (1942)
United States Arm Transport (USAT) *Mauna Loa* was a 5436 (gross tonnage) freighter. Built by the Los Angeles Shipbuilding and Drydock Company in San Pedro, California, in 1919. In 1934 sold by the Matson Navigation Company to the Matson Steamship Company, but later in 1937, the *Mauna Loa* was sold back to Matson Navigation Company. *Mauna Loa* was one of a convoy of three American merchant ships that departed San Francisco on 22 November 1941. The convoy was redirected to

Australia after the attack on Pearl Harbour. *Mauna Loa* arrived in Darwin on 19 February 1942. The site of *Mauna Loa* is historically significant in that *Mauna Loa* was sunk in Darwin Harbour during the Japanese air raid of 19 February 1942. The wreckage of *Mauna Loa* is a memorial to those who lost their lives in the attack and a relic of Australia's maritime heritage. The site of the *Mauna Loa* also has an educational and recreational value, as it is a popular dive site for both tourists and local divers, who are able to experience first hand a part of Australia's maritime heritage.

Located at Latitude 12^0 29.9' S, Longitude 130^0 49.1' E, *Mauna Loa* is a protected shipwreck under the *Northern Territory Heritage Conservation Act 1991.*

Considering the proximity of the wreck site to the pipe line, it is recommended that the site be marked by a permanent buoy. A protection zone of 50 metres radius extends around the site and the marker buoy would act as a visible reference point by which to gauge the protection zone on the surface.

Site 8. USAT *Meigs* (1942)

Meigs was built by the Los Angeles Shipbuilding and Drydock Company in San Pedro, California, in 1921, for the United States Shipping Board. Chartered as a USAT (United States Army transport), *Meigs* departed San Francisco on 22 November 1941 in a convoy of seven transport vessels. The convoy was headed for the Philippines, however, the outbreak of war with Japan diverted them to Australia and they arrived in Brisbane on 22 December. Sailing via Thursday Island, *Meigs* arrived in Darwin on the evening of 19 January 1942. Left Darwin on 14 February bound for Kupang, but returned on 17 February after being attacked. The site of *Meigs* is historically important in that *Meigs* was sunk in Darwin Harbour during the Japanese air raid of 19 February 1942. The wreckage of *Meigs* is a memorial to those who lost their lives in the attack and a relic of Australia's maritime heritage. As an American transport vessel, the wreck of *Meigs* also provides an insight into American military history, and the type of equipment used in World War Two.
The site of *Meigs* also has an educational and recreational value, as it is a popular dive site for both tourists and local divers, who are able to experience first hand a part of Australia's maritime heritage.

Located at Latitude 12^0 29.26' S, Longitude 130^0 49.10' E, *Meigs* is a protected shipwreck under the *Northern Territory Heritage Conservation Act 1991.*

Site 9. USS *Peary* (1942)

USS *Peary* was a United States flush deck destroyer of the Clemson Class. The destroyer was launched 6 April 1920. Arrived Darwin on 19 February with the USS *Houston* from Tjilitjap on the south coast of Java.

The site of the *Peary* is historically important in that *Peary* was sunk in Darwin Harbour during the Japanese air raid of 19 February 1942. The wreckage of *Peary* is a memorial to those who lost their lives in the attack and a relic of Australia's maritime heritage. As an example of one of the flush-deck destroyers in operation during World War Two, the remains of the *Peary* provides insight into American Naval history. The site of the *Peary* also has an educational and recreational value, as it is a popular dive site for both tourists and local divers, who are able to experience first hand a part of Australia's maritime heritage.

Located at Latitude 12^0 28.50' S, Longitude 130^0 49.75' E, *Peary* is a protected shipwreck under the *Northern Territory Heritage Conservation Act 1991.*

Site 10. SS *Zealandia* (1942)

Zealandia was a steel passenger liner built by John Brown and Company of Clydebank, Scotland, for Huddart Parker Ltd of Melbourne in 1910. Commissioned by the Australian Defence Department on 21 June 1940, to be used as a troopship, carrying both troops and supplies. The site of the *Zealandia* is historically important in that *Zealandia* was sunk in Darwin Harbour during the Japanese air raid of 19 February 1942. The wreckage of *the Zealandia* is a memorial to those who lost their lives in the attack and a relic of Australia's maritime heritage. *Zealandia* holds a significant place in Australia's maritime heritage, having served in two World Wars it also operated as an Australian coastal trader for twenty-two years. The site of the *Zealandia* also has an educational and recreational value, as it is a popular dive site for both tourists and local divers, who are able to experience first hand a part of Australia's maritime heritage.

Located at Latitude 12^0 29.00' S, Longitude 130^0 51.05' E, *Zealandia* is a protected shipwreck under the *Northern Territory Heritage Conservation Act 1991.*

Site 11. *Kelat* (1942)
Kelat was built by Duck and Company at Stock on Richardson, England, for Bates and Sons. The vessel was an iron hulled, fully rigged sailing ship with a registered tonnage of 1894 (gross). *Kelat* was a non-commissioned RAN vessel requisitioned for use in July 1941. In February 1942, she was towed from Fremantle to Darwin loaded to capacity with coal. The site of *Kelat* is historically significant in that *Kelat* was sunk in Darwin Harbour during the Japanese air raid of 19 February 1942 as part of RAN operations. The wreckage of *Kelat* is a memorial to those who lost their lives in the attack and a relic of Australia's military history. In addition, *Kelat* was an example of a nineteenth century sailing ship which ended her days as a coal hulk. The site of the *Kelat* also has an educational and recreational value, as it is a popular dive site for both tourists and local divers, who are able to experience first hand a part of Australia's maritime heritage.

Located at Latitude 12^0 30.00' S, Longitude 130^0 52.70' E, *Kelat* is not, currently, a protected shipwreck.

Sites 12 to 16. Catalina Flying Boats (1942...1945)
Seven Catalina flying boats were lost in Darwin Harbour, three United States Navy planes in 1942 and four RAAF planes in 1945. Four Catalina wreck site locations have been verified and another two have not been verified. These wreck sites are:

Site 12. 'Catalina 1'. Unverified site location. Report of Catalina flying boat at 12^0 29.45' S, Longitude 130^0 53.5' E. Location covered over by construction of Darwin Port Expansion - East Arm 1995.

Site 13. 'Catalina 2'. Verified site location of a Catalina flying boat. Located at Latitude 12^0 29.76' S, Longitude 130^0 53.81' E.

Site 14. 'Catalina 3'. Unverified site location. Report of Catalina flying boat at 12^0 29.8' S, Longitude 130^0 54.5' E.

Site 15. 'Catalina 4'. Verified site location of a Catalina flying boat. Located at Latitude 12^0 30.63' S, Longitude 130^0 53.88' E.

Site 16. 'Catalina 5'. Verified site location of a Catalina flying boat. Located at Latitude 12^0 30.64' S, Longitude 130^0 54.16' E.

These wreck sites are unidentified and are archaeologically significant. However, three of them could be United States Navy planes. Should some wreck sites be identified as these planes, they would then be historically significant because they were sunk during the first Japanese air raid on Darwin 19 February 1942. The other four sites (one of which is yet to be located) could then be the RAAF planes. Should some wrecks be identified as the RAAF aircraft, then those sites would be historically significant as they played a significant part in the air war against Japan and are a testament to those who lost their lives in them.

The Catalina wreck sites also has an educational and recreational value, as they are popular dive sites for both tourists and local divers, who are able to experience first hand a part of Australia's maritime heritage.

The Catalina wreck sites are not, currently, protected.

Appendix B. Ethno botanical Survey

As stated above, it was not possible to carry out foot surveys of the area. In order to compensate for the lack of opportunity to carry out a first hand ethno-botanic survey with the custodians obtained a copy of the Draft Vegetation & Fire Report by EcOz and then checked their lists of plant species against the following sources of ethno-botanic information relevant to the Darwin area:

A) Smith and Wightman, 1990

B) Wightman and Andrews, 1989

C) Clark and Traynor, 1987

D) Murgatroyd, (Barnes and Taylor), 1995

This revealed a total of sixty-one species with confirmed ethno-botanic references .The ethnobotanic information is presented in Table 1, the page references as listed A) to D) above.

Monsoon Vine Forest (Thicket)
(Wilson et al: 1990, Unit 1)

Species	**Page Reference**				
	A.	**B.**	**C.**	**D.**	**Aboriginal Use**
Abrus precatorius	3	112			Red/Black seeds - beads
Acacia auriculiformis	3	14	10		Bark burnt - "tji" mixed with chewing tobacco
Amorphophallus paeoniifolius		156			Cheeky Yam
Ampelocissus acestosa	5			14	Wild grape
Bombax ceiba		24			Wood, fibre,food
Canarium australianum	7	28			Seeds eaten
Cassytha filiformis	7				Favoured fruit
Crinum angustifolium			41	15	Lilly - antiseptic
Dioscera bulbifera	10	120		14	Round Yam
Dioscera transversa	12	122			Long Yam
Drypeetes lasiogyna		38			Fruit, leaves, timber
Ficus hispida		42			Fruit
Exocarpus latifolia	12				Fruit, leaves to 'smoke' babies for good health
Flagellaria indica	14	124			Fibre
Flueggia virosa	14	106		14	White currant
Gryocarpus americanus medicine		48			Wood, root and leaves as
Hibicus tilicaceus	14			15	Spear wood; fire drill
Litsea glutinosa	17				Wood for axe handles

Maranthes corymbosa	17	60			Tree trunk for canoe
Micromelum minutum		62			Flowers attract native bees
Passiflora foetida	19	134	116	14	Fruit (introduced species)
Pleomele angustifolia		110			Leaves - medicine
Polyalthia australis		72			Wood, leaves as medicine
Pouteria serica	21	76			Favoured fruit, wood
Premna acuminata	23				Fire drill
Smilax australis		136			Fruit, fire stick, medicine
Sterculia quadrifida		78			Fruit, medicine, fibre
Strychnos lucida		80			Strychnine in fruit and leaves, - medicine, poison, wood
Tacca leontopetaloides	25	158			Tuber eaten
Tinospora smilacina		140			Leaves and roots as medicine
Vitex acuminata				14	Black plum
Vitex glabrata	25				Fruit
Mangrove (Wilson et al , 1990, Unit 105).					
Aegicaris corniculatum	3				leaves for smoke, wood
Avicennia marina	5				Fruit roasted and eaten
Hibiscus tiliacea					As Above
Rhizophora stylosa	23			15	Worms eaten, wood
Eucalyptus woodland (Wilson et al., 1990, Unit 4)					
Alstonia actinophylla	5	20	20	14	Milkwood, sap for binding implements trunks for canoes, sap medicinal
Buchania obovata	7		32	14	Green Plum; wood medicinal
Brachychiton diversifolius	5		28		Seeds eaten, bark fibre
Cycas armstrongi	10		42	14	Nuts eaten after processing
Cymbopogon Sp (procerus ?)	10				Leaves and stems medicinal
Eucalyptus bleeseri			56		Charcoal used as black paint
Eucalyptus miniata	12		64		Hollowed branches good source of native honey

Eucalyptus tetrodonta	12		78		Bark for canoes, paintings, shelters
Erthrophelum chlorostachys	12				Hard timber for clap sticks
Ipomoea pes-caprae	17				Leaves medicianl
Gardenia (prob megasperma)			82		Fruit, gum used as resin
Grevillea decurrens			88		Flower nectar eaten
Livistonia humilis	17		98	15	Heart eaten, fibre
Lophostemon lactifluus			100		Slow burning firewood
Petalostigma quadriloculare	21				Leaves and nuts medicinal
Terminalia ferdinandiana	25		124		Fruit
Vitex glabrata					As Above
Melaleuca woodland					
Acacia holosericea			14		Young roots eaten, seed pods medicinal
Alphitonia excesla	3	18			Leaves medicinal
Ampelocissus acetosa	5				Fruit - currants
Dioscorea transversa					As Above
Eucalyptus polycarpa			72		Gum medicinal, wood, grubs eaten
Gardenia megasperma					As Above
Grevillea decurrens					As Above
Melaleuca cajuputji	17				Leaves medicinal
Melaleuca viridiflora			106		Trunks for canoes, bark for shelters
Melaleuca leucadendra	19		106		Leaves medicinal,
Persoonia falcata	19				Fruit - milky plum
Pandanus spiralis	19		114	15	Fibre string, seed eaten, nuts as slow burning coal
Premna serratifolia	23				Fire drill

Discussion

The abundance and diversity of ethno-botanic species across all vegetation zones on Wickham Point ranks it as a very valuable resource area, which however, has probably not been intensively exploited for some time. It's present significance justifies marking the whole of Wickham Point as Zone B, as shown on Map 1.

Appendix C. Correspondence with Interest Groups and Individuals

M W Murgatroyd
GPO Box
DARWIN NT 0801

27 February, 1997

Mr Tibby Quall
c/-Dalrymple & Associates
GPO Box 4570
DARWIN NT 0801

Dear Sir

Re: Environmental Impact Statement : Wickham Point (Middle Point) Liquified Natural Gas Plant

I am a private consultant who has been engaged by Dames and Moore Darwin, to prepare on Anthropological Report to be included in the Wickham Point Liquified Natural Gas Plant Environmental Impact Statement.

In preparing this report it is necessary for me to consult with all relevant and interested Aboriginal groups. I would like an opportunity to speak with you about this matter.

It must be noted that these consultations relate only to the Environmental Impact Statement.

Dames and Moore are presently completing the EIS and have requested the Anthropological component be completed as quickly as possible, while allowing for full consultation.

Please contact me at the above postal address so that we can arrange consultation about this matter.

Your faithfully

M W Murgatroyd

W J Murgatroyd
GPO Box
DARWIN NT 0801

27 February, 1997

Mr Paul Hayes
Northern Land Council
PO Box42921
CASUARINA NT 0811

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M W Murgatroyd

M W Murgatroyd
GPO Box
DARWIN NT 0801

27 February, 1997

The President
Larrakia Association
GPO Box 254
DARWIN NT 0801

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M W Murgatroyd

W J Murgatroyd
GPO Box
DARWIN NT 0801

27 February, 1997

Mr John Singh
Belyuen Council
BELYUEN NT 08

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Your faithfully

M W Murgatroyd

Northern Land Council

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Our Ref: 97/0260:LO3

28 February 1997

Warren Murgatroyd
GPO Box 3007
DARWIN NT 0801

WITHOUT PREJUDICE

Dear Warren

LARRAKIA NATIVE TITLE CLAIM - AFFECT ON SEAS AND WICKHAM POINT DEVELOPMENT

I refer to your recent attendance at our office and understand you have been engaged by Dames and Moore as part of an Environmental Impact Study into a proposed Liquefied Natural Gas Project proposed for Wickham Point. I understand that Dames and Moore have been engaged by Phillips Oil Company.

You enquire as to the extent of the Larrakia claim which the Northern Land Council has lodged on behalf of the Larrakia. I advise that the claim, insofar as it affects Wickham Point, includes all land and waters subject to the notice of proposed compulsory acquisition issued by the Northern Territory Government on 29 November 1996. A copy of that notice (which includes a map of the land and waters subject to acquisition) is enclosed. I confirm that the claim does extend into the surrounding sea.

I also enclose a copy of maps which were lodged with the native title application, and which detail land and waters in the Darwin area which are subject to claim. These maps are $50 each. An invoice for $100 is enclosed.

You enquire as to our views on the nature of the claim to the extent that it extends over sea areas.

The Larrakia claim that they are the traditional owners of the land, sea, and sea beds referred to in their native application. The Larrakia believe their native title rights to the land and waters include ownership, occupancy, possession and rights of use. To the extent that the claim extends into the sea, it is supported by the existence of sacred sites which are located in the sea and in the sea bed and by use of the seas for sustenance and other purposes. Knowledge as to the existence of such sites is common amongst the Larrakia.

The effect of the claim regarding proposed developments requiring sea access will, to some extent, depend on the results of any mediated agreement or subsequent Federal Court decision.

Consequently it is difficult to provide a definitive response to your inquires. We can however make the general comment that the Larrakia expect that any developments regarding their sea areas will only occur after proper consultation and negotiations have occurred.

I trust the above is sufficient for the purpose of your engagement.

I advise that the above comments are generally applicable to areas of land claimed by the Larrakia. We suggest that a properly prepared environmental impact statement should consider the impact of proposed development upon the social and cultural environment of the Larrakia, and that such impact will be minimised if undertaken in consultation with, and with the consent of, the Larrakia people.

Yours sincerely

Paul Hayes
Solicitor

DEPARTMENT OF LANDS, PLANNING AND ENVIRONMENT

GPO BOX 1680
DARWIN NT 0801
Telephone No.: (08) 89 24 4142
Facsimile No.: (08) 89 24 4053

File Ref.:
Your Ref.:

Mr Warren Murgatroyd
6 Sowden Street
JINGILI NT 0810

RE: POSSIBLE BURIAL REMAINS AT WICKHAM POINT

Dear Mr Murgatroyd

I write regarding your enquiry about possible burials in the Wickham Point area. I would like to make two points in answering your enquiry, the first relates to cultural practices and taphonomic processes pertinent to prehistoric and protohistoric burials and the second to the protection and procedures provided to burial sites under the NT of Australia *Heritage Conservation Act* 1991.

CULTURAL PRACTICES AND TAPHONOMIC PROCESSES

As you are aware, a virtually limitless range of burial techniques were used by aboriginal Australians in the prehistoric and protohistoric period and it is not possible to categorise any particular technique as belonging to Aboriginal people or not. Nevertheless, it is fair to say that examples of excavation for the purpose of interring a body into anything other than soft sediments are rare. There are a number of known prehistoric and protohistoric burial sites in the Darwin area and these are exclusively in sandy beach and dune deposits.

Given the substrate in most of the Wickham Point area, it is unlikely that people lacking metal tools buried their dead in the area.

I do note that the northern end of Wickham Point, in the vicinity of the Lazaret does have sandy dune sediments and it is conceivable that there are burials in this area. It is my understanding that no development is proposed in this area. Further, the range of cultural materials visible on the ground surface at the Lazaret warrant protection for their own sake, negating the need to protect the area because of some possible, unseen, burials.

TAPHONOMIC PROCESSES

Were a burial to have been placed in the Wickham Point area, taphonomic processes would have dealt with them very severely. The sediments in the area tend to be acidic, producing sulphuric acid on exposure to sunlight. Mechanical processes including the high tidal range and relatively frequent cyclone activity would reduce the likelihood of burial remains lasting long period of time. The tropical north of the Northern Territory is also home to a range of termite species which are documented to consume bone.

On this basis then, it is considered highly unlikely that any burial remains will occur within the development area.

LEGAL PROTECTION AND PROCEDURES

The *Heritage Conservation Act* 1991 protects all Aboriginal and Macassan skeletal remains, not being cemeteries under the NT of Australia *Cemeteries Act*. It is a legal requirement that the discovery of any such remains must be reported to the Secretary of this Department (DLPE) or to the Chief Executive Officer of the Aboriginal Areas Protection Authority (AAPA).

Once reported the authorities, a protocol is in place to for action to be taken to ensure sensitive and appropriate handling of the remains. This involves a variety of statutory processes, including a requirement to satisfy the Coroner that there is no requirement to initiate a murder investigation. Following this, appropriate means of managing the burial will be determined through a consultative process with all stakeholders. The outcome of this process can be quite varied, including re-burial on site, re-burial elsewhere, cremation and so on.

Burial sites are, by definition, rare. Two or three are uncovered throughout the entire Northern Territory annually. For the reasons stated above, the location of burial remains in the development area at Wickham Point is unlikely, but in the event they do exist, measures are in place to ensure they are accommodated within any development process.

I trust this satisfies your enquiry.

Yours sincerely

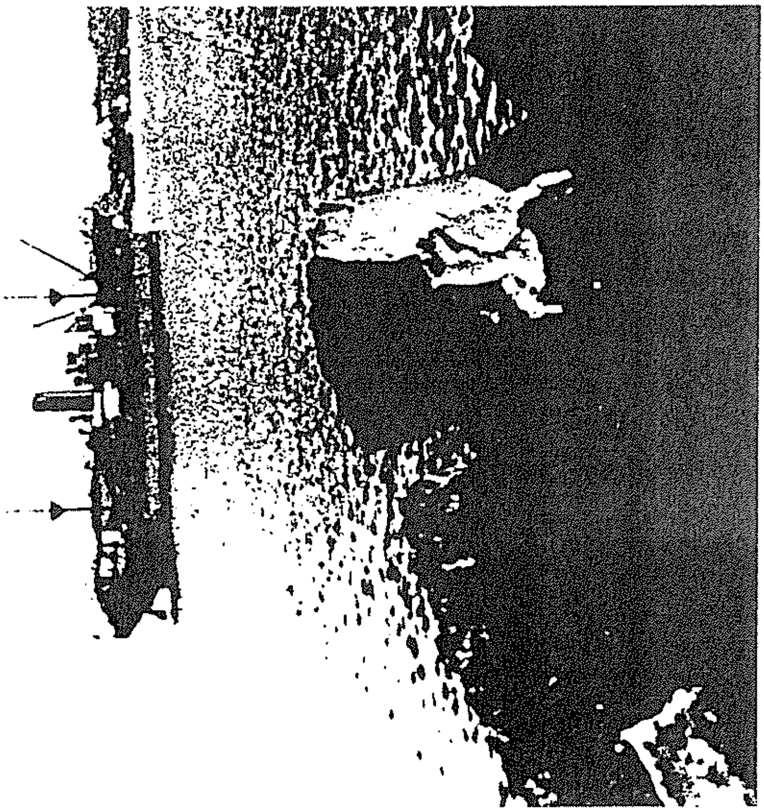
STEPHEN SUTTON
Senior Heritage Officer

23 May 1997

View from near Peak Hill towards Darwin
Note Zone A. between the forest and fringing mangrove swamp.

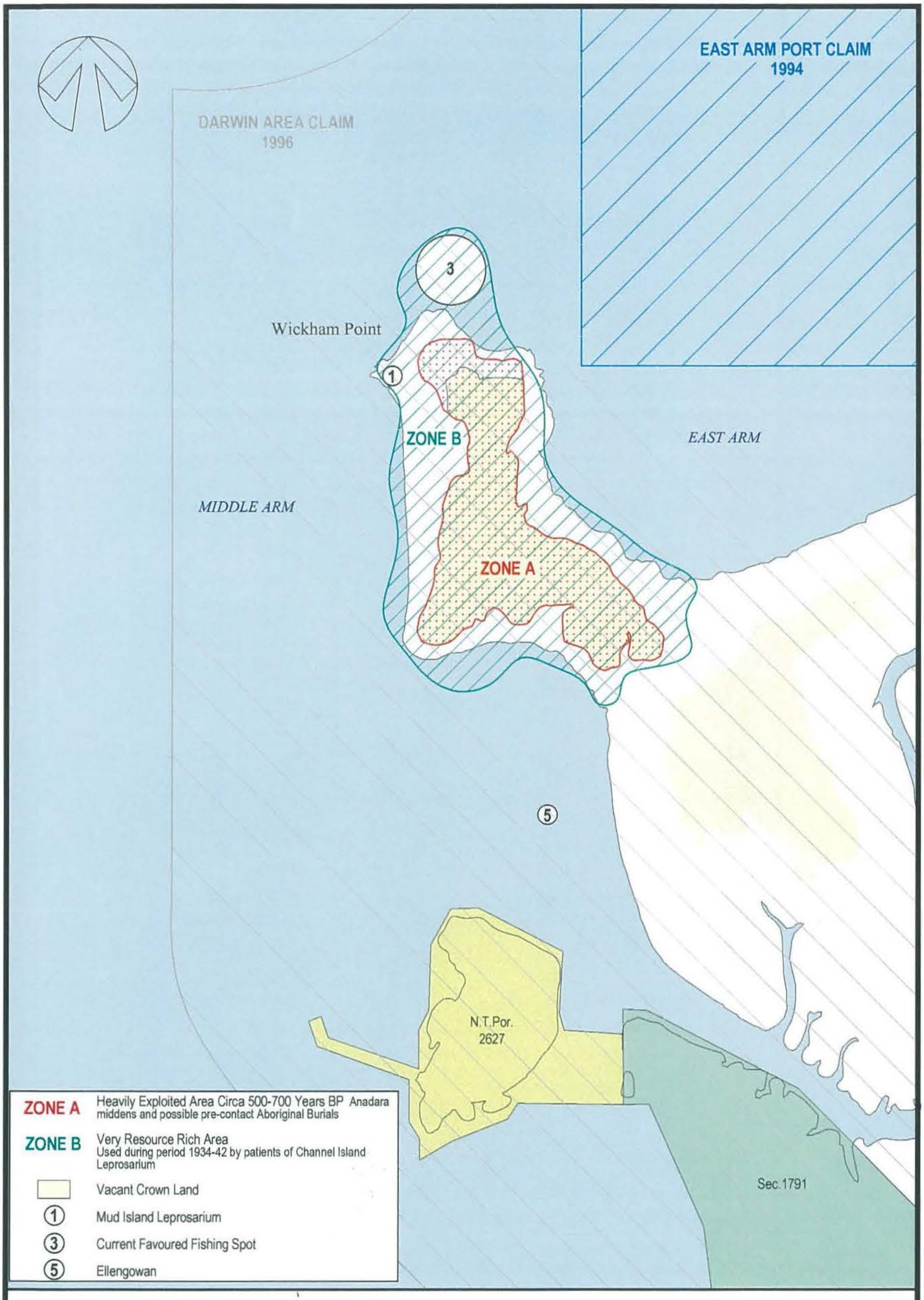
Richard Barnes at Anadara midden, containing broken beer bottles and used rifle casings, adjacent landing area.

Plate 6, and Plate 7, from Merv Ogram / National Trust
WW II views from Wickham Point



Boat stuck in mud at low tide in Darwin harbour
(Possibly Zealandia)

Looking at results of bombings from Middle Arm.



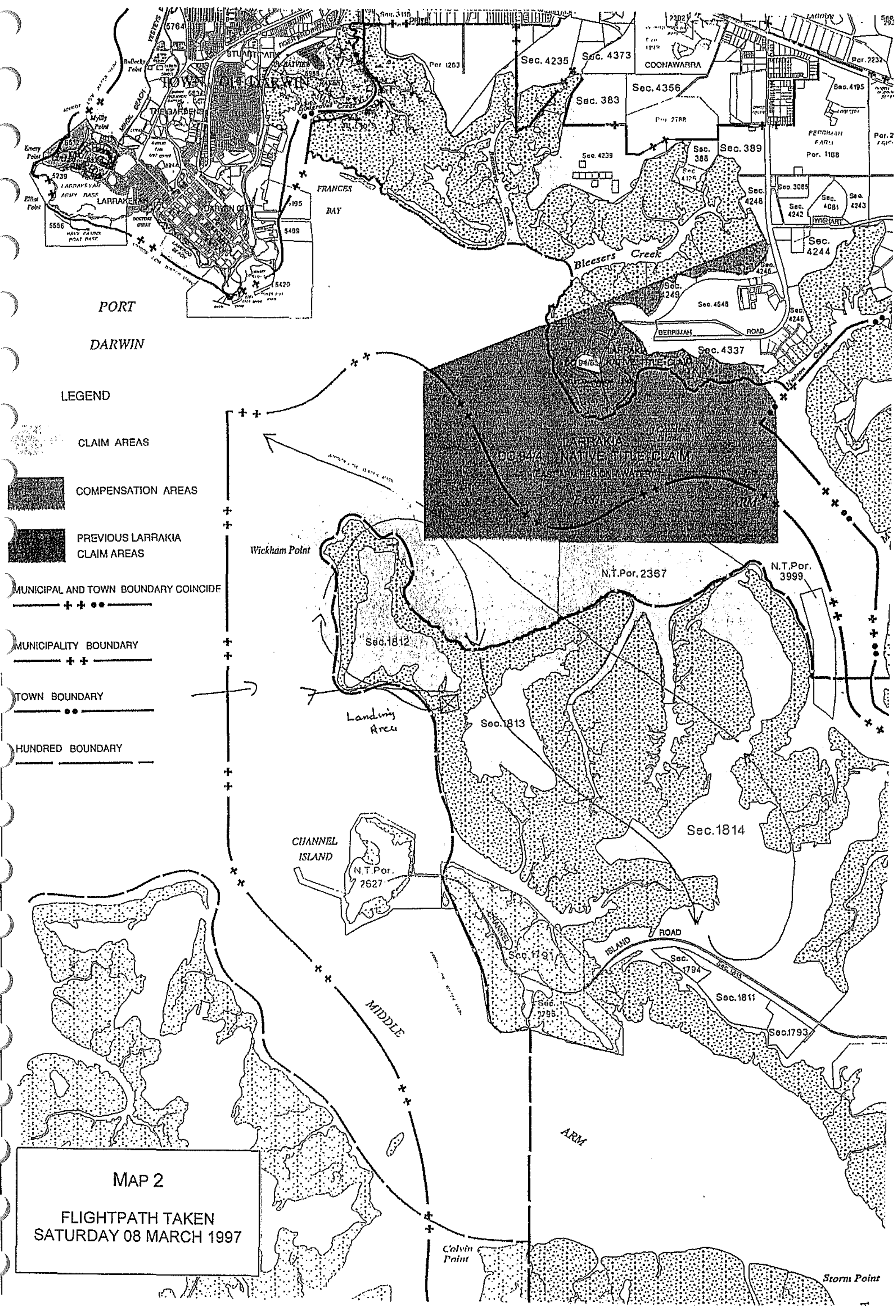
Phillips Oil Company Australia

DARWIN LNG PLANT, DRAFT EIS

WICKHAM POINT AND SURROUNDING AREA SITES OF SIGNIFICANCE

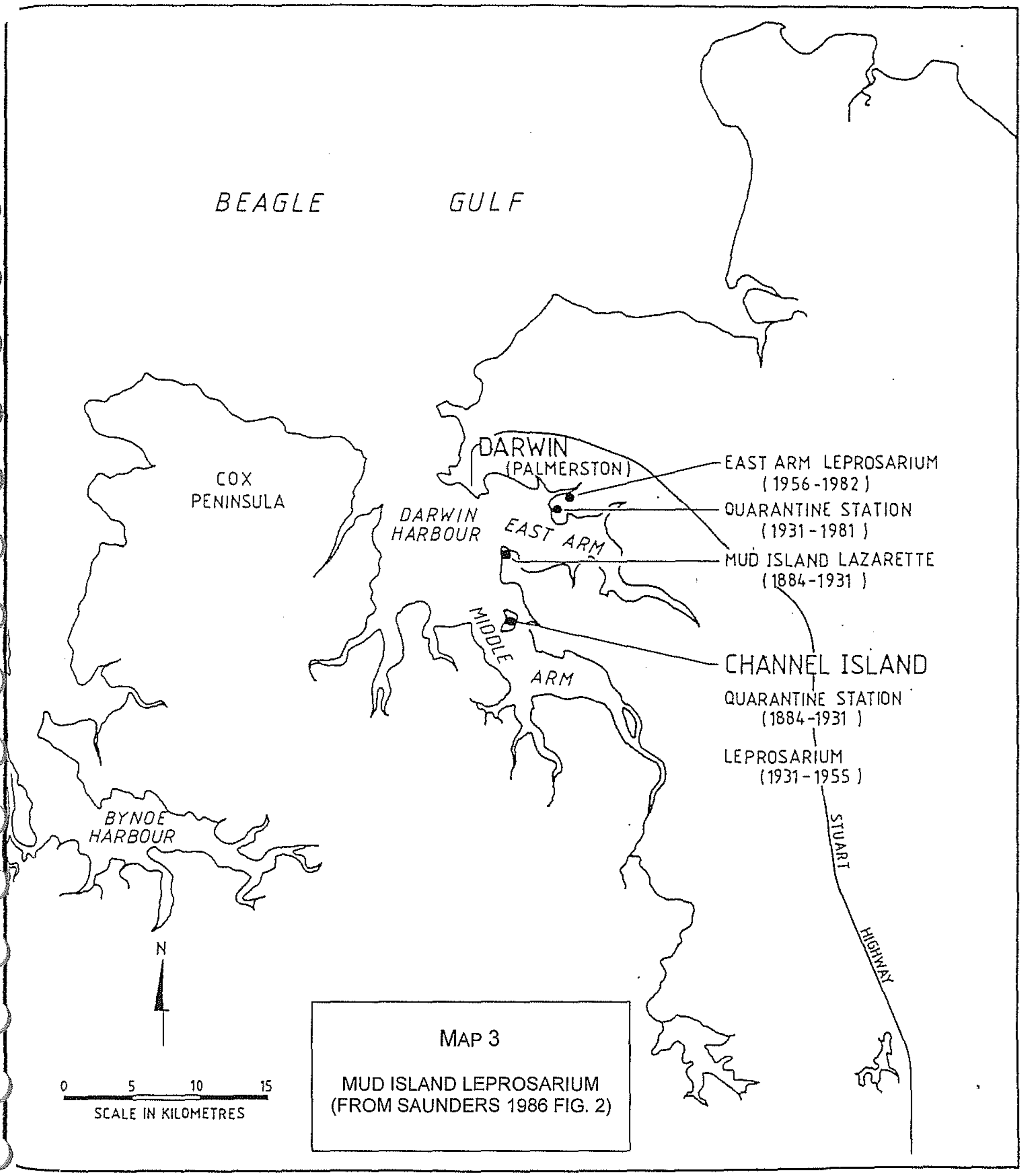
DAMES & MOORE PTY LTD
A DAMES & MOORE COMPANY

MAP 1



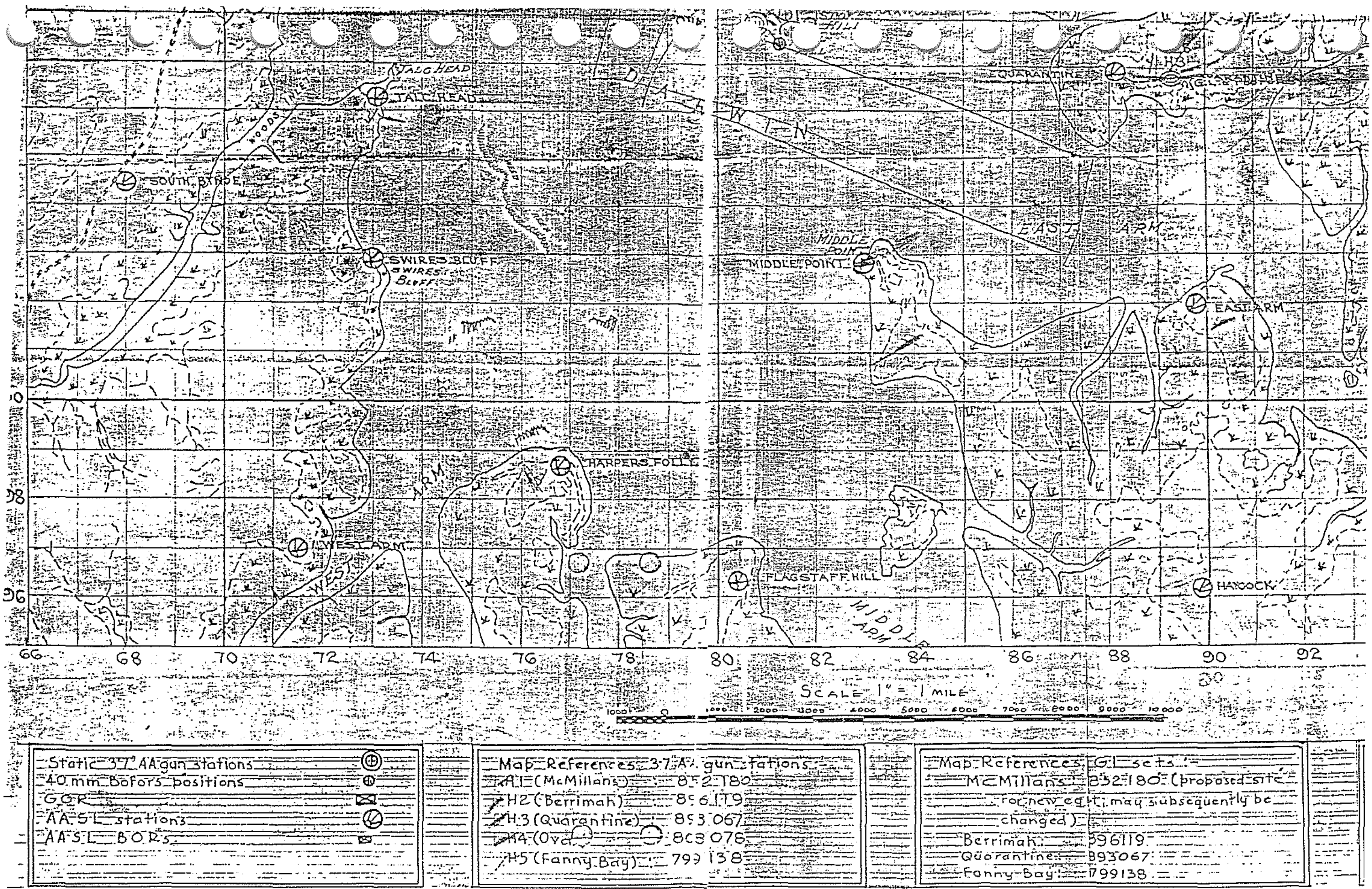
MAP 2

FLIGHTPATH TAKEN SATURDAY 08 MARCH 1997



MAP 3

MUD ISLAND LEPROSARIUM
(FROM SAUNDERS 1986 FIG. 2)



MAP 4 MOBILE SEARCH LIGHT BATTERY AND ANTI-AIRCRAFT INSTALLATIONS DARWIN HARBOUR (MERV OGRAM/NATIONAL TRUST)

Appendix N

ABORIGINAL AREAS PROTECTION AUTHORITY

REPORT

Darwin LNG Plant
Draft Environmental Impact Statement

Appendix N
Aboriginal Areas Protection Authority Certificate

for

Phillips Oil Company Australia

Ref: 00533-143-363
Report No. R635, Appendix N
July 1997

GPO Box 1890, Darwin
Northern Territory Australia 0811
Tel: 61 8 981 4700
Fax: 61 8 981 4700

ABORIGINAL AREAS PROTECTION AUTHORITY

GPO BOX 1890
DARWIN NT 0801
TELEPHONE: (089) 81 4700
FACSIMILE: (089) 81 4169

File: D89/199;90/307 *In Reply Please Quote:* 23015

14 April, 1997

Phillips Oil Company
Level 1, HPPL House
28-42 Ventnor Avenue
WEST PERTH W.A. 6005

ATTENTION: FRED F. STORER

RE: ISSUE OF AUTHORITY CERTIFICATE FOR PROPOSED WICKHAM POINT JETTY, ACCESS ROAD AND GAS PIPELINE FROM THE TIMOR SEA

I refer to your application for an Authority Certificate, received on the 27 February 1997, for the above works.

Accordingly, under the powers delegated to me under Section 19 of the *Aboriginal Sacred Sites Act 1989* I am pleased to issue the attached Authority Certificate.

Please note carefully the conditions outlined in the Certificate. You should also note that the Authority has issued you with two identical copies of the digitized map attached. One copy should be retained with your original Certificate. The second is supplied for use by contractors to avoid unnecessary photocopying of a colour coded document. If you have any further queries regarding this Authority Certificate please contact Mrs Lesley Mearns at this office.

Yours faithfully

DAVID RITCHIE
Chief Executive Officer

encl.

ABORIGINAL AREAS PROTECTION AUTHORITY

AUTHORITY CERTIFICATE

Issued in accordance with Section 22 of the Aboriginal Sacred Sites Act

REFERENCE: D89/199;90/307 (Doc:23015) C97/049

APPLYING TO: Wickham Point a jetty, an access road, and gas pipeline from the Timor Sea as shown on the attached map. The gas pipeline corridor extends 500m either side of the corridor centreline. The road corridor extends 100m either side of the road centreline.

PROPOSED WORK OR USE: The construction of liquified natural gas plant and associated infrastructure, including laying of a gas pipeline on the seabed from the Timor Sea.

ISSUED TO: Phillips Oil Company
Level 1, HPPL House
28-42 Ventnor Avenue
WEST PERTH WA 6005

CONDITIONS:

1. It is the responsibility of the recipient of this Certificate to:
   (i) Include the conditions of this Certificate in any subsequent contract or tender document commissioning works described in this Certificate.
   (ii) Otherwise inform agents and employees of the conditions of this Certificate and obligations under the *Aboriginal Sacred Sites (NT) Act 1989.*

2. The proposed use or works covered by this Certificate must commence within 24 months of the date of issue.

3. The information on the map relates specifically to the areas of the Certificate as marked and the fact that sites are not shown in other areas should not be taken as a definitive indication of the existence or lack of existence of sites in these areas.

4. The map attached to the Certificate forms part of the Certificate.

5. No damage to the underwater sand/rock bar, sacred site 5073-105, marked to the east by No.7 navigation beacon and shown on the attached map.

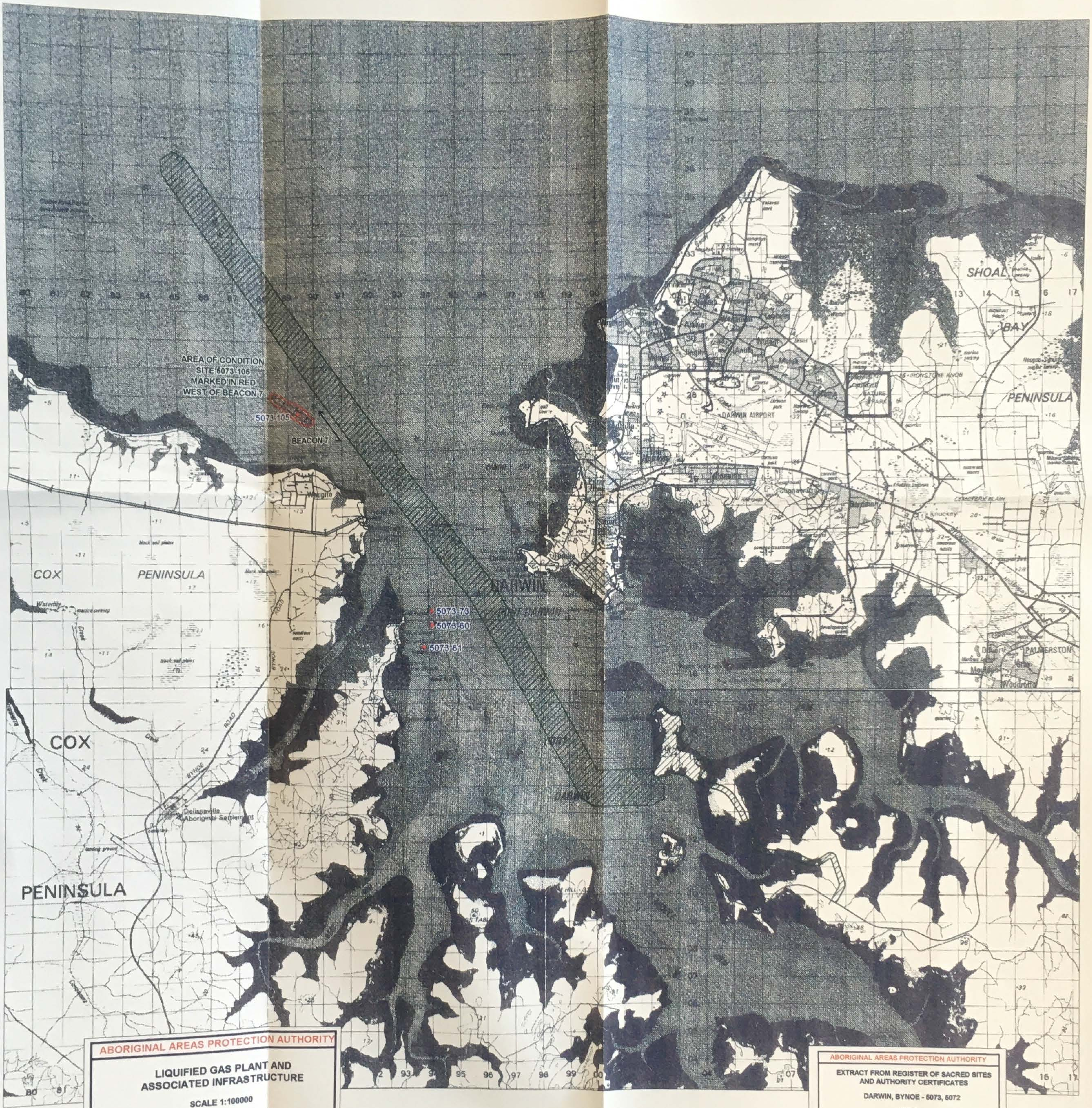
6. No damage to sacred sites 5073-60, 61 and 73.

The COMMON SEAL of the
ABORIGINAL AREAS PROTECTION AUTHORITY
was hereto affixed on the 14th day of
April 1997

ABORIGINAL AREAS PROTECTION AUTHORITY
COMMON SEAL

DAVID RITCHIE
Chief Executive Officer

Appendix O



ABORIGINAL AREAS PROTECTION AUTHORITY

LIQUIFIED GAS PLANT AND ASSOCIATED INFRASTRUCTURE

SCALE 1:100000

MAP FORMING PART OF AUTHORITY CERTIFICATE C97/049

ISSUED TO: Phillips Oil Co

AUTHORISED COPY: NUMBER 2 OF 6

CHECKED BY:
T.HOSIE - SENIOR LAND INFORMATION OFFICER

ON 26.3.97

J97-030

ABORIGINAL AREAS PROTECTION AUTHORITY

EXTRACT FROM REGISTER OF SACRED SITES AND AUTHORITY CERTIFICATES

DARWIN, BYNOE - 5073, 5072

KEY

AREA OF APPLICATION

AREA OF CONDITION

5072-60 RECORDED SITES

ECOSYSTEMS

REPORT

Darwin LNG Plant
Draft Environmental Impact Statement

Appendix O
Visual Impact Assessment

for

Phillips Oil Company Australia

Ref: 00533-164-073
Report No. R635
Appendix O
July 1997

17 Phoenix Street [Post Office Box 737]
Nightcliff, Northern Territory, Australia 0814
Tel: 61 8 8948 1299
Fax: 61 8 8948 1298

PROPOSED PHILLIPS LNG OPERATIONS PLANT AT WICKHAM POINT - NORTHERN TERRITORY

VISUAL IMPACT ASSESSMENT

STUDY APPROACH

The aim of this study is to assess the visual impact of the development of a LNG plant at Wickham Point on the immediate environment and the surrounding region and to identify strategies to minimise this visual impact.

The surrounding region was analysed with the use of topographic and cadastral mapping to locate the areas of primary visual impact. These sites were confirmed during field visits.

The existing site was analysed through the use of topographic maps, vegetation mapping, aerial photography and an oblique aerial photograph.

The nature of the proposed development was assessed with the use of plans of the facilities, discussions with the engineers, the project description and a computer generated perspective.

To define the parameters of the study a number of locations were selected as key vantage points. The existing views from each of these locations has been analysed and compared with the views of the future development from the same location.

Field trips were taken by boat and vehicle to photographically record the site and the existing views from each of the selected vantage points. **(for slides refer Appendix A).**

On the basis of the slides black and white line drawings were prepared to provide an impression of the existing site. The proposed development was then superimposed onto these impressions to enable a comparative analysis from each vantage point. This comparative analysis has been based on an assessment of the following visual elements;

- **Line**
- **Texture**
- **Form**
- **Value**
- **Colour**
- **Scale**

These elements provide a means of analysing the visual character of each view. The anticipated visual impact of the proposed development can then be assessed by comparing the existing and developed site from each vantage point. On the basis of the visual analysis of the existing situation, recommendations for minimising the visual impact have been identified.

VISUAL CONTEXT

The Surrounding Region

Wickham Point lies in Darwin Harbour on the western end of the peninsula separating East Arm and Middle Arm. The region is characterised by long low landforms, flat horizon lines and elevations below 50 m above sea level. The coastal edge is typically fringed with a distinct zonation of mangroves. There are numerous coastal inlets and arms. The mangrove edge reinforces the green "natural" and undeveloped character of the harbour.

Development within Darwin Harbour is generally concentrated around Darwin City where the city buildings punctuate the skyline. The existing dredging and civil works associated with the development of the East Arm Port facility and the adjacent Cement Works are also prominent features. Channel Island is also a prominent feature of the eastern end of the Harbour.

The Existing Site
Wickham Point lies 7 km S/SE of Darwin and can be identified from Stokes Hill Wharf. The site is approximately 2.5 km from Channel Island and 5 km from the East Arm Port Development and is located on the peninsula that divides East Arm from the adjacent waters of Middle Arm.

Wickham Point is the most northerly point of the peninsula which measures approximately 2.6 km long from north to south and averaging 1.2 km wide. The peninsula is marked by three sets of parallel rocky ridges. The ridges are separated by narrow depressions which lie between 4 m and 8 m above sea level. The highest point on the site is Peak Hill which rises to a height of 32 m.

The site is covered with woodland, dry rainforest, grassland communities and areas of salt flats. An extensive zone of mangrove fringes the peninsula.

There is no existing development on the site.

Changing Landscape
The existing character of Port Darwin is of a "natural" environment punctuated with points of concentrated development. This character is however changing, particularly with the continuing development of the East Arm Port Facility.

Wickham Point lies between the Channel Island Power Station to the South West and the East Arm Port Facility to the North East. These developments have a significant visual impact particularly when viewed from the immediate surrounding environment or adjacent areas of the Harbour. The proposed LNG plant and the relocation of Darwin's oil terminals to Wickham Point will be in keeping with the scale and context of this evolving industrial and maritime precinct of the Harbour.

SCOPE AND SCALE

Extent of site disturbance
Approximately 150 hectares of land will be required for the proposed LNG plant including a provision for future expansion to 3 LNG trains.

Height above Sea Level and Existing Vegetation
The site preparation level is the one in one thousand year storm tide level, which is +7.1 m (AHD).

Clearing for Construction
The construction site area will be cleared of trees, down timber, brush, rubbish and vegetation. Trees outside the limits of facilities or roads will remain and be protected during construction.

Land Reclamation
Dredging and land reclamation activities will be performed prior to construction. The location is a sea bed area immediately north west of the site. Approximately 4,000,000 m^3 of spoils will be dredged.

Containment bunds, dikes or levees will be provided for retaining all solids inside the reclamation area. It is proposed to place the bund fill directly on the mangrove swamp mud (after clearing the vegetation) to displace the mud instead of dredging the material.

Fuel Storage Tanks and Flares
The proposed LNG plant contains five fuel storage tanks which will be increased to a total of fourteen tanks in later stages. Each tank is approximately 50 metres diameter and xx metres tall.

To the south west of the site there will be a marine flare xx metres tall. Two main flares xx meters tall will be located on the north east of the site.

Marking lights may be installed on the top of flares and storage tanks.

Processing Facilities
A processing facility approximately 200 metres x 240 metres will by constructed. This will be extended to three times this size in later stages of development. In association with the plant a maintenance warehouse, control room and administrative building will be erected.

Jetty
A 1.5 km jetty with a loading dock for LNG tankers will extend into Middle Arm. The LNG jetty will comprise of a trestle with a conventional 'T' head, supported on an open piled structure. Two liquid loading arms will be used to transfer LNG to ships. A separate transfer arm will convey vapour produced in loading to the shore based recovery system.

Ships will dock at the jetty for intervals of about 3-8 days and will arrive approximately every three to seven days for loading and export.

Barge Dock
A construction dock will extend into East Arm through swampy areas to service barged equipment. The proposed structure utilises steel sheet pile cells to form a bulkhead, backfilled by pushing out a causeway. The dock will be approximately 500 metres long and forty metres wide. It will be established at an elevation that will allow it to receive 7 meter deep barges with allowance for ballasting.

Sewerage Treatment Works
Treated process effluent will be discharged to the Harbour from an outfall located at the north east corner of the proposed LNG plant. The treated sewerage will be discharged through a proposed outfall located on the south side of the plant.

Erosion Control
Erosion controls will be implemented during the construction phase to reduce sediment deposits on the shoreline.

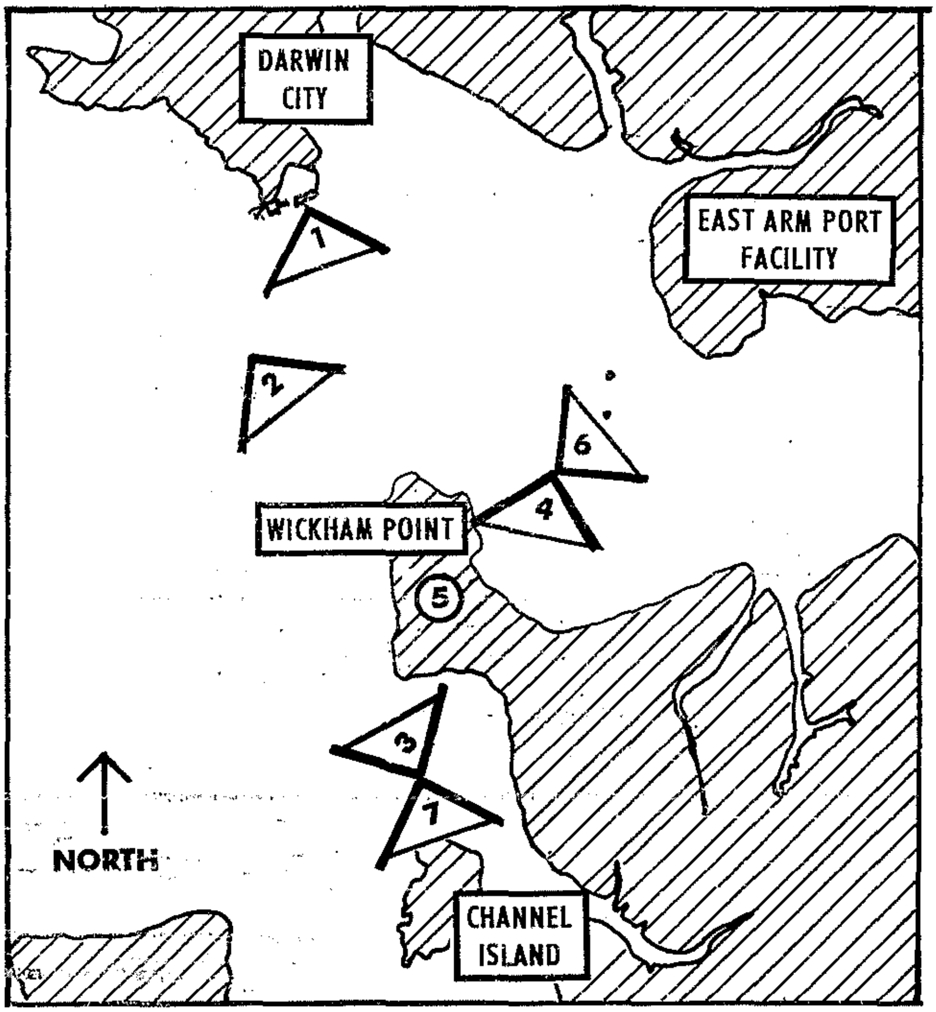
Erosion controls along the shoreline will be provided at locations exhibiting high erosion. Structures such as outfalls, intakes, the jetty shorefall and construction dock areas will be fortified to prevent instability or destruction of these structures. Engineered controls such as breakfalls rip-rap or steel sheet structures will be provided for the protection of the shoreline and structures.

Fencing
The project will provide a perimeter approximately 1.83 m high made of carbon steel wire mesh.

VISUAL IMPACT

A number of vantage points have been selected to assess the potential visual impact of the development. One vantage point on land, three locations on the water and an aerial view have been used as a basis for visual analysis, and comparison between the existing landscape and the future developed landscape. Two additional vantage points were selected to allow an analysis of the visual relationship between the proposed development and other development in the surrounding region. The locations of the vantage points for each view are shown in **Figure 1.**

Figure 1: Location of Vantage Points



COMPARATIVE ANALYSIS

Vantage Point 1

Stokes Hill Wharf - Distance From Site 7 km.

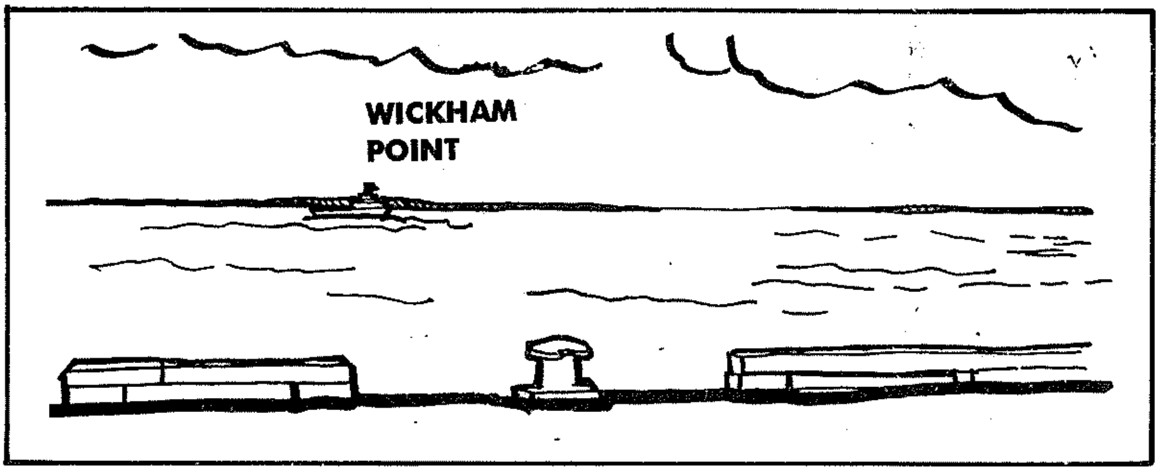


Figure 2: View from Stokes Hill Wharf before development of the site

Existing View - Visual Analysis

LINE	low horizontal lines
TEXTURE	predominant element is the variable texture of the water.
FORM	low elongated land forms
TONE	generally strong contrast between landform, water and sky. Contrast variable with conditions
COLOUR	dominant colours of the sea and skyscape with muted earth colours of the landform
SCALE	vast horizontal scale with considerable distance between prominent land features

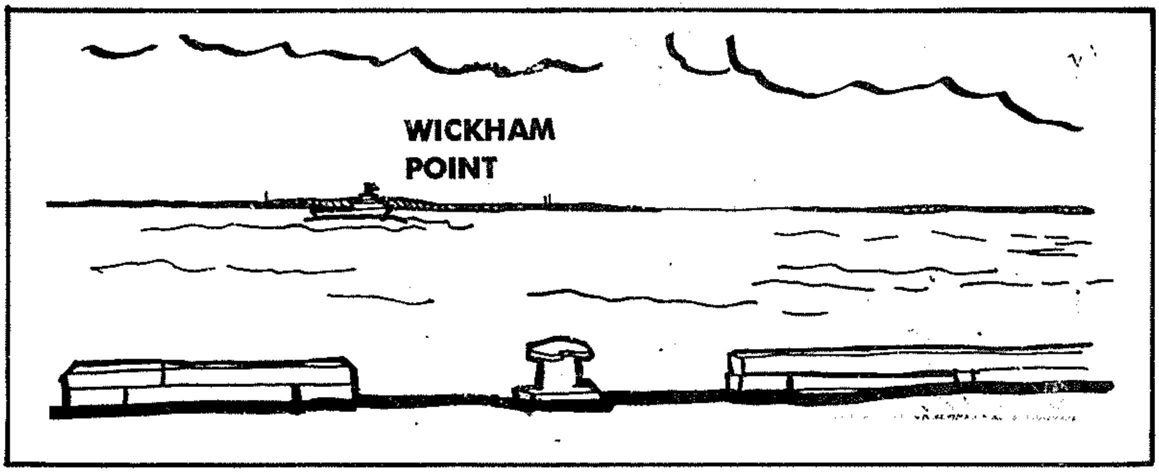


Figure 3: View from Stokes Hill Wharf after development of the site

Proposed Development - Visual Analysis

Visual analysis as for the existing view - no appreciable change

VISUAL IMPACT - NEGLIGIBLE

Vantage Point 2

Harbour View - Distance From Site 3 km

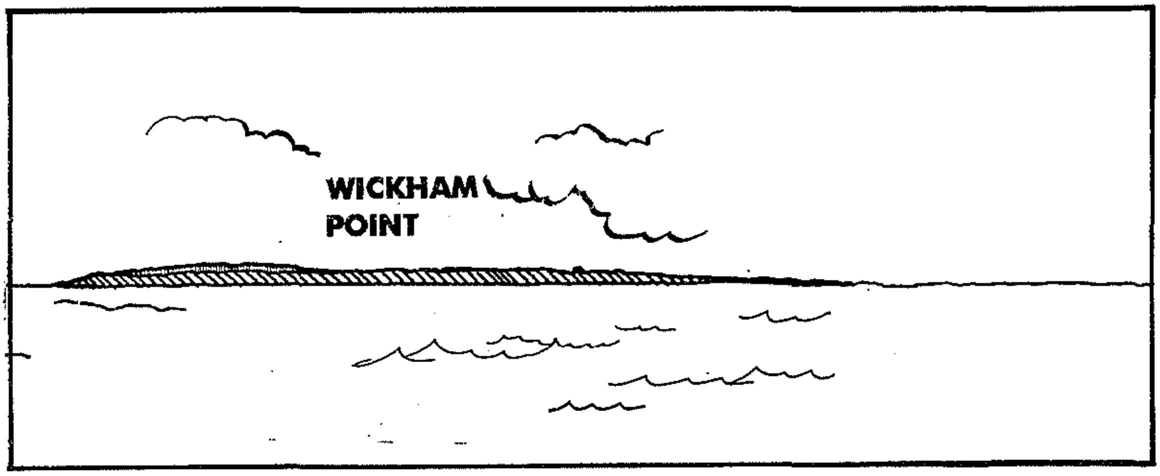


Figure 4: View from Darwin Harbour before development of the site

Existing View - Visual Analysis

LINE	flat horizon line with gently sloping landscape profiles
TEXTURE	dominant texture of waves, some vegetation texture visible
FORM	simple low landforms
TONE	generally strong contrast between landform, water and sky. Contrast variable with conditions.
COLOUR	dominant colours of the sea and skyscape with muted earth colours of the landform
SCALE	wide horizontal scale with little detail definition

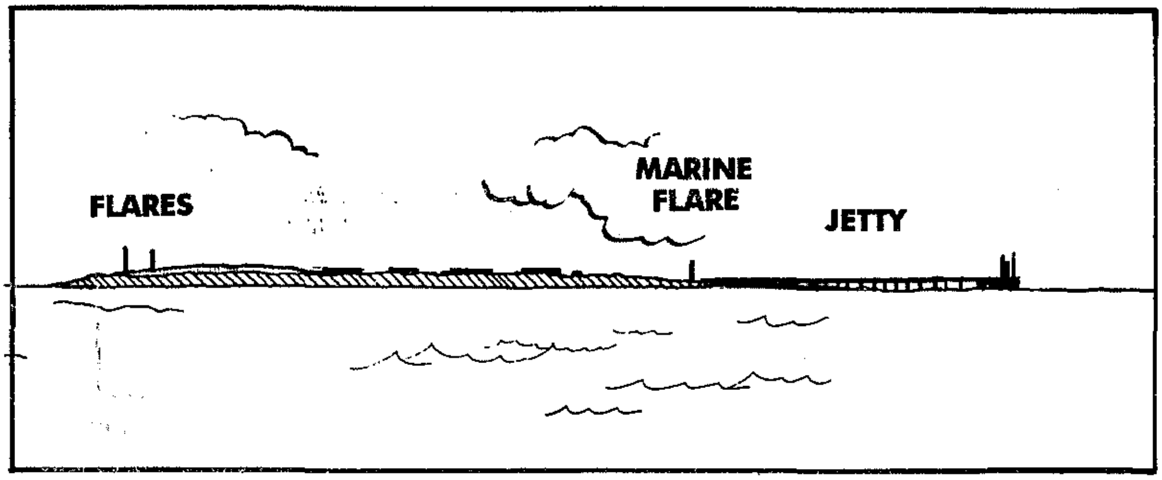


Figure 5: View from Darwin Harbour after development of the site

Proposed Development - Visual Analysis

LINE	flat horizon line with sloping landscape profile punctuated by vertical elements
TEXTURE	irregular vegetation texture contrasting regular texture of jetty piles
FORM	simple low forms, broken by vertical elements
SCALE	wide horizontal scale, broken by vertical elements.

VISUAL IMPACT - MINOR

Vantage Point 3

View of West of Site - Distance From Site less than 300 m

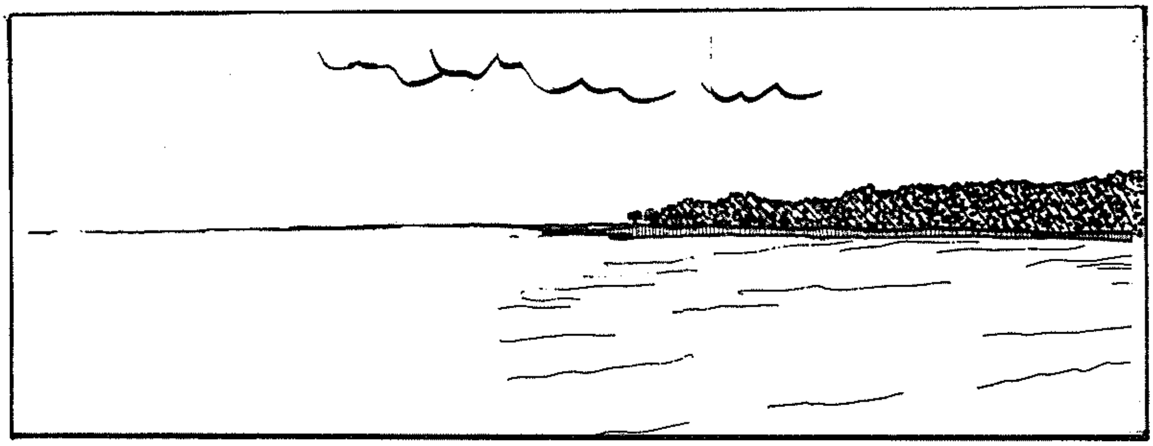


Figure 6: View from western side of the site before development

Existing View - Visual Analysis

LINE	midground; beach/mangrove prominent horizontal line background; strong horizon line broken by landform
TEXTURE	strong contrast between smooth texture of mudflats and dappled vegetation textures behind
FORM	low intertidal zone with ridged skyline behind
TONE	contrast between pale mud flats and backdrop of dark vegetation against light sky
COLOUR	light and dark greens varying to muted grey greens in low light conditions
SCALE	landscape scale reduced to human level by vegetation modulation and foreshore detail.

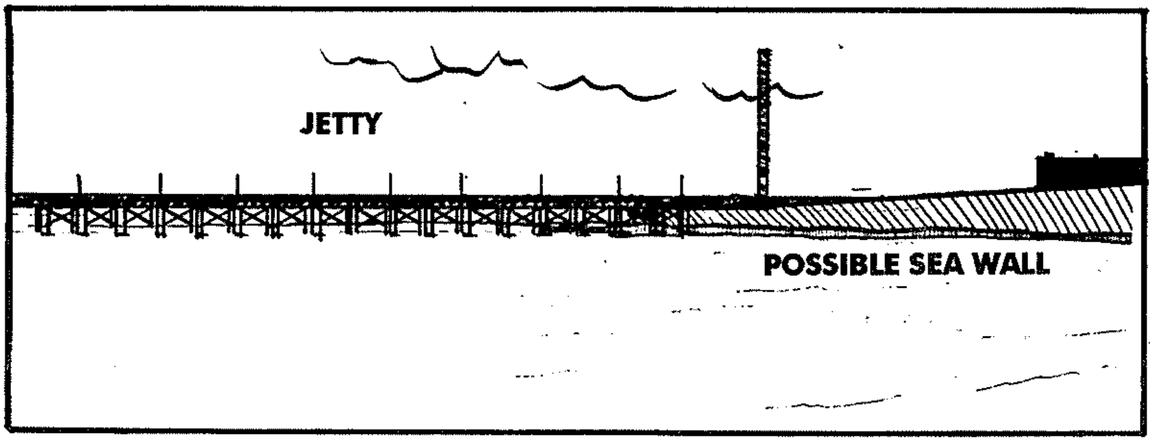


Figure 7: View from western side of the site after development

Proposed Development - Visual Analysis

LINE	dominant line of vertical flare and strong horizontal line of jetty
TEXTURE	dominant texture of regular vertical piles contrasts with the texture of the water and irregular texture of existing vegetation
FORM	horizontal jetty dominates the foreground, solid tank form obvious, both break the natural landform
SCALE	the size and industrial character of the jetty and tanks is out of scale with the surrounding natural landscape

VISUAL IMPACT - SIGNIFICANT

Vantage Point 4

View of East Side of Site - Distance From Site 500 m

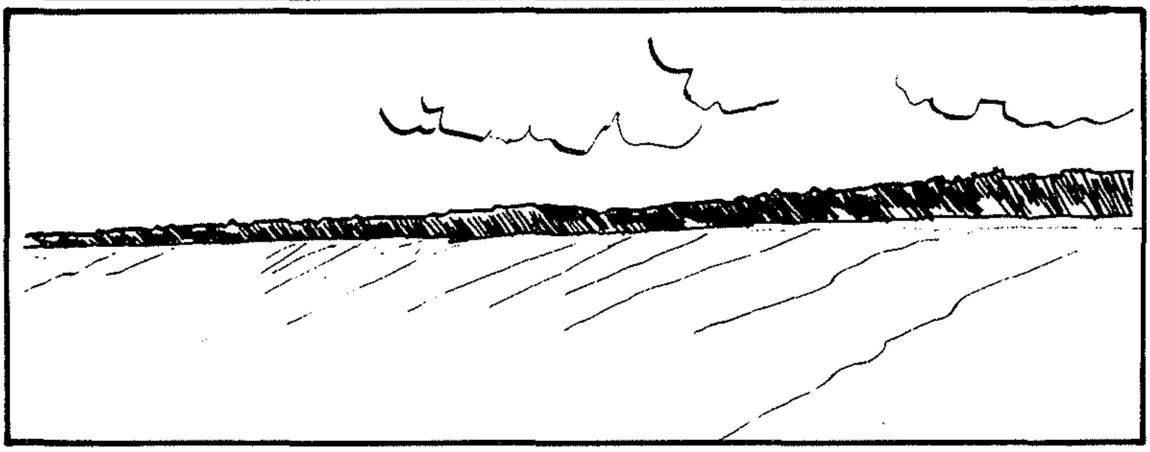


Figure 8: View from eastern side of the site before development

Existing View

LINE	midground; beach/mangrove prominent line background sloping landscape profile punctuated by taller vegetation
TEXTURE	strong contrast between smooth texture of mudflats with dappled vegetation textures behind
FORM	low intertidal zone with ridged skyline behind
TONE	contrast between pale mud flats and backdrop of dark vegetation against light sky
COLOUR	light and dark greens varying to muted grey greens in low light conditions
SCALE	landscape scale reduced to human level by vegetation modulation and foreshore detail

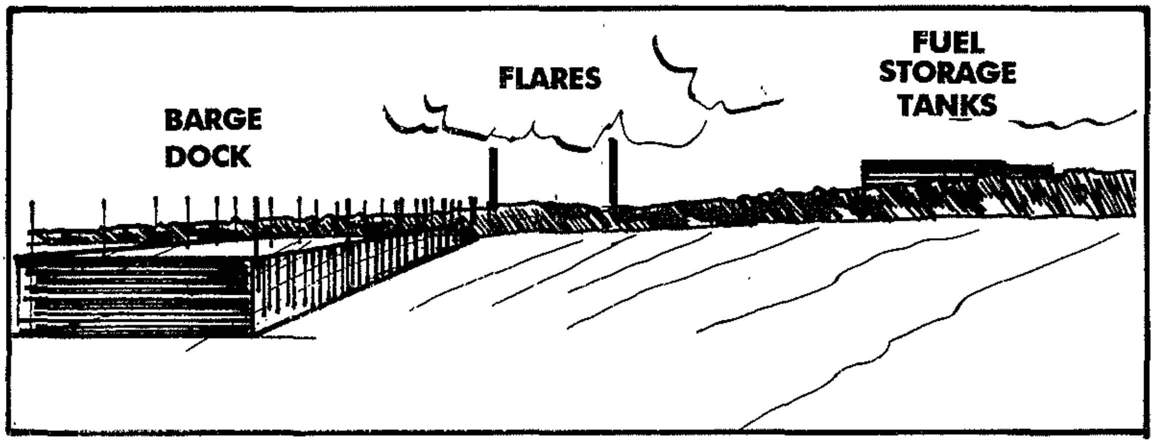


Figure 9: View from eastern side of the site after development

Proposed Development - Visual Analysis

LINE	sloping landscape profile broken by linear dock, vertical flares and tanks
TEXTURE	contrast between irregular vegetation texture and regular geometric texture of dock and tanks
FORM	natural landform is dominated by the geometric dock in foreground
SCALE	the size and industrial character of the dock and tanks is out of scale with the surrounding natural landscape

VISUAL IMPACT - SIGNIFICANT

Vantage Point 5

From Above at 3078 Metres

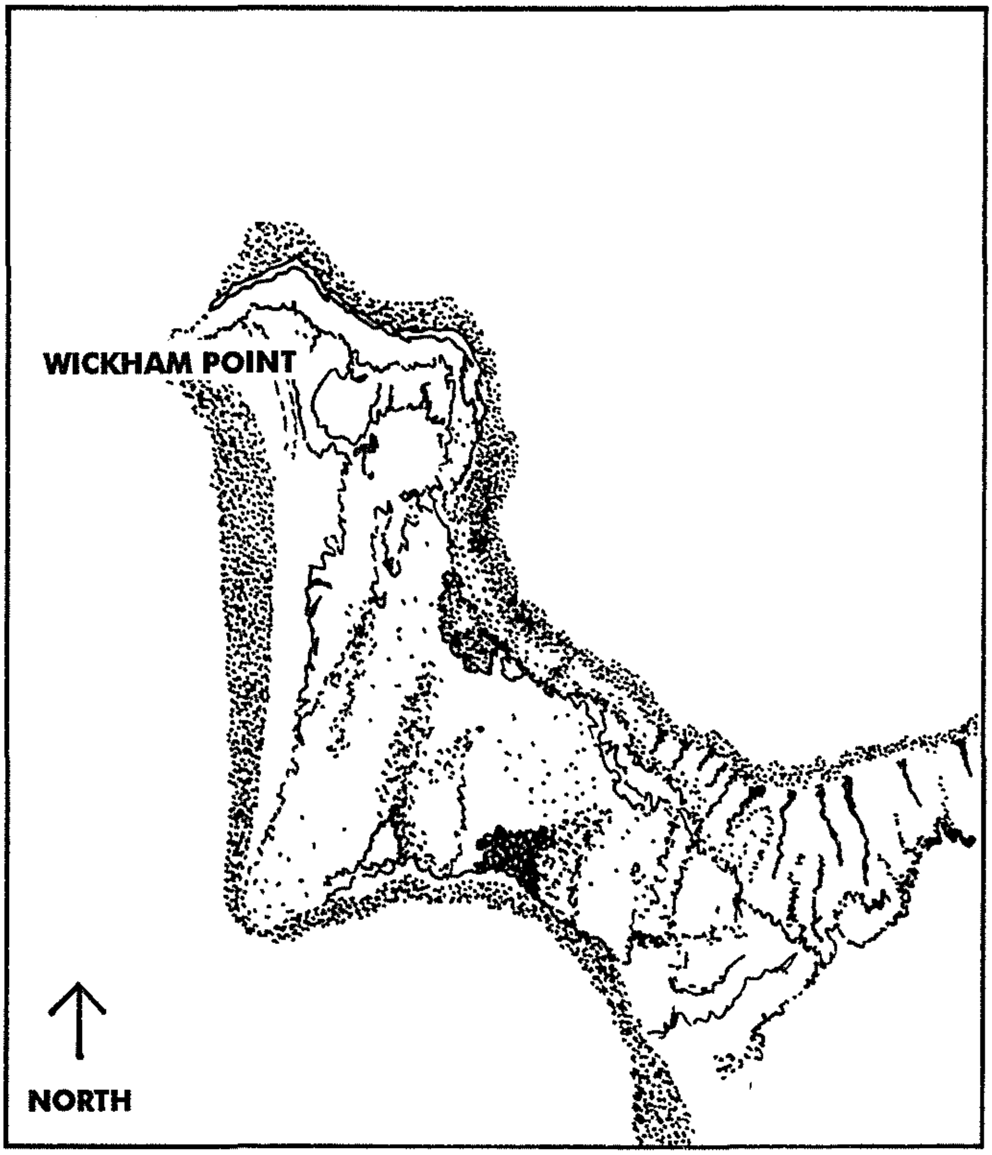


Figure 10: View from above of the site before development

LINE	irregular line of mangroves vegetation around foreshore are dominant with irregular lines defining inland drainage patterns
TEXTURE	contrast between irregular stippling of vegetation and smooth areas of salt flats
FORM	irregular rounded forms
TONE	contrast between pale mud flats fringing of dark vegetation and variable light and dark tones of Harbour waters
COLOUR	not assessed (only black and white photograph available)
SCALE	landscape scale reduced to human level by vegetation modulation and foreshore detail

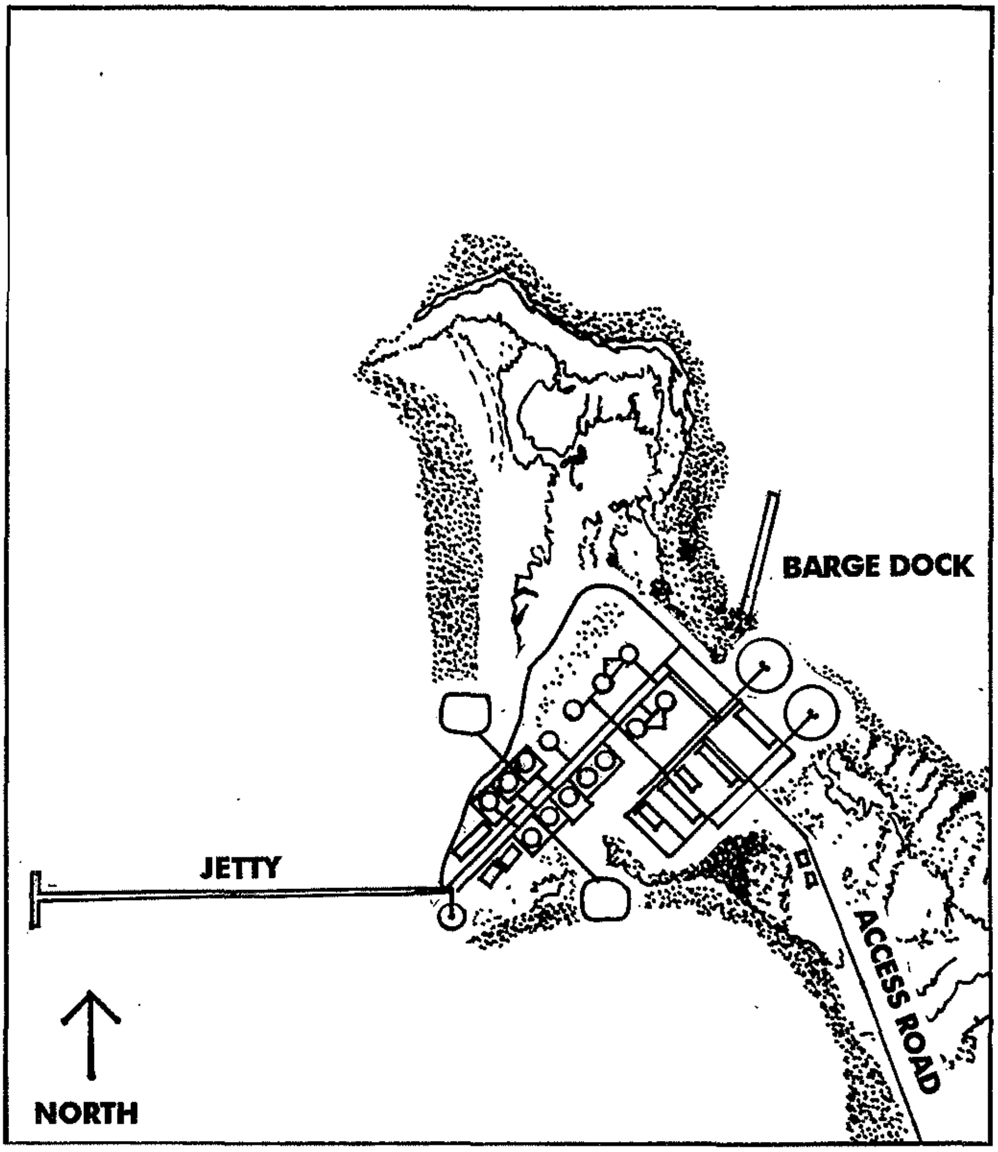


Figure 11: View from above the site after development

LINE	strong contrast between the dominant straight line of the jetty and the irregular line of the foreshore
TEXTURE	strong contrast between the flat areas of cleared land and the facilities against the irregular textures of the vegetation
FORM	contrast between the geometric forms of the facilities and the irregular forms of the foreshore
SCALE	roads and facilities alter the natural scale that is defined by the vegetation and undulating ground plane, to a more industrial scale

VISUAL IMPACT - SIGNIFICANT

VISUAL IMPACTS IN THE CONTEXT OF OTHER DEVELOPMENT

Vantage Point 6

View of East Arm Port Facilities - Distance From Site 2 km

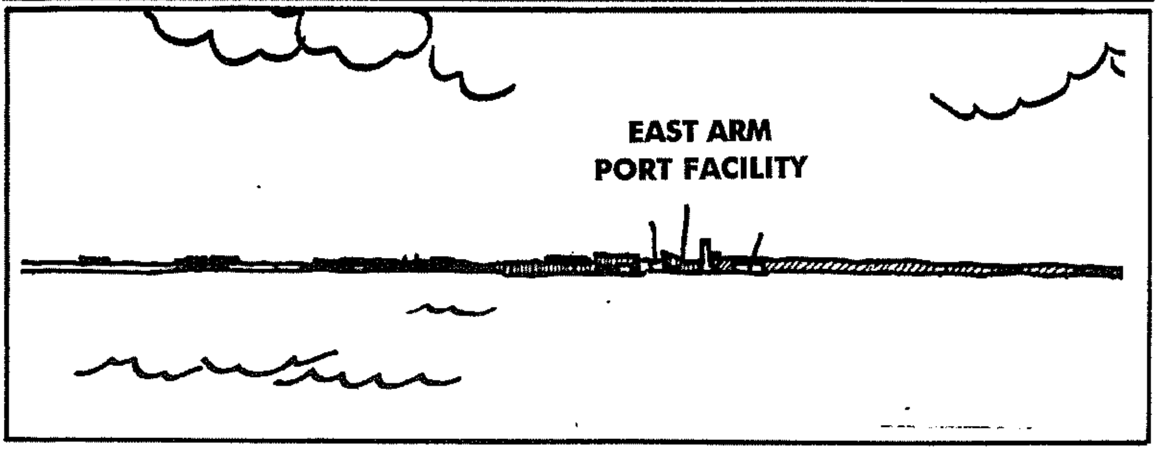


Figure 12: View of East Arm Port Facility

Existing View

LINE	flat horizon line punctuated by vertical lines of cranes and construction facilities
TEXTURE	strong contrast between irregular texture of vegetation and geometrical texture of various facilities and cleared areas
FORM	low horizontal landform interrupted by vertical forms of buildings and construction facilities
TONE	some contrast between pale tones of cleared earth, dark vegetation and light sky
COLOUR	dark greens of vegetation and natural earth colours contrast with ochre colours of cleared earth
SCALE	broad scale accentuated by cranes and large construction plant

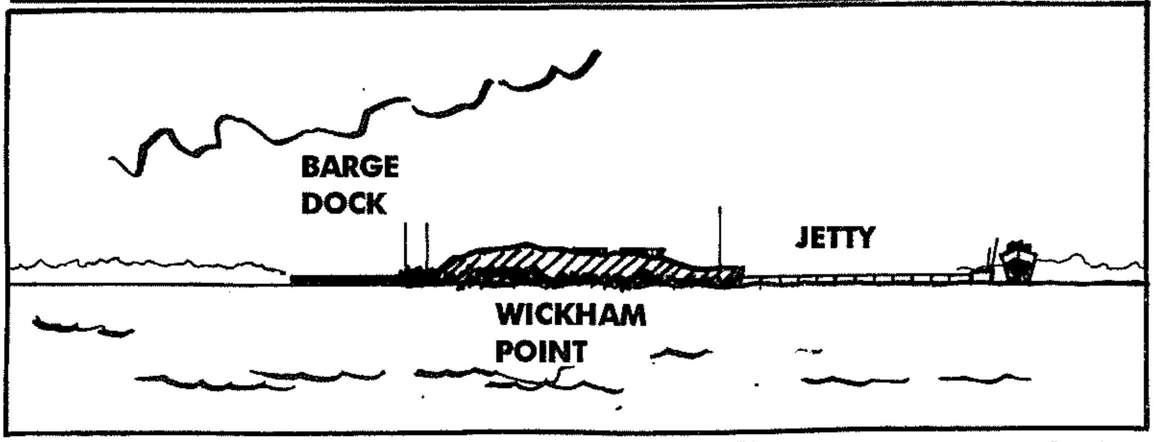


Figure 13: View of LNG Plant

Proposed Development

LINE	gentle slope broken by vertical lines of flares and strong line of jetty
TEXTURE	strong contrast between irregular texture of vegetation and regular texture of jetty piles
FORM	low landform broken by vertical forms of flares and jetty piles
SCALE	broad scale reinforced by flares, jetty piles and building elements

VISUAL IMPACT - COMPARABLE

Vantage Point 7

View of Channel Island - Distance From Site 1 km

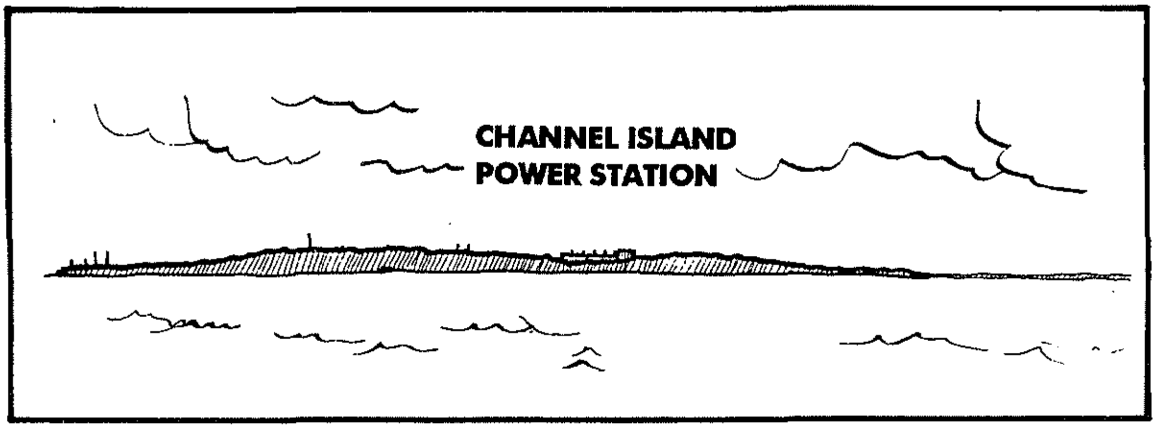


Figure 14: View of Channel Island

Existing View

LINE	flat horizon line punctuated by vertical lines of electricity poles
TEXTURE	geometric texture of power station is softened by the irregular texture of surrounding vegetation
FORM	low horizontal landform punctuated with vertical form of power station
TONE	pale tones of sandy beach and dark tones of vegetation sit comfortably between the intermediate tones of power station
COLOUR	harmonious blends in colour range of the natural landscape
SCALE	broad

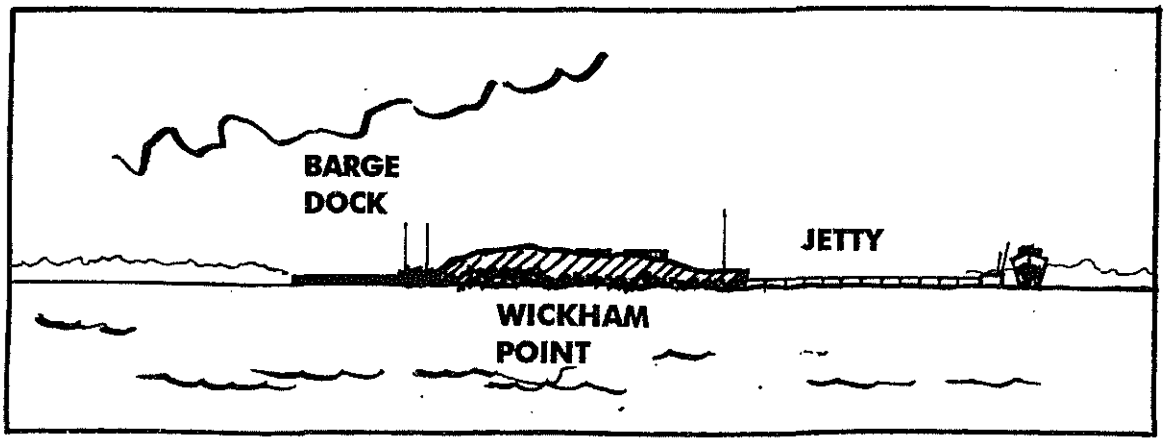


Figure 15: View of LNG Plant

Proposed Development

LINE	gentle slope broken by vertical lines of flares and strong line of jetty
TEXTURE	strong contrast between irregular texture of vegetation and regular texture of jetty piles
FORM	low landform broken by vertical forms of flares and jetty piles
SCALE	broad scale reinforced by flares, jetty piles and building elements

VISUAL IMPACT - POTENTIALLY COMPARABLE

CONSTRUCTION AND OPERATIONAL PHASES

The Construction Phase

The visual impact of development will be greatest during the construction phase of the project. Clearing of mangroves and adjacent terrestrial vegetation and extensive dredging and reclamation works will create a significant visual impact. This visual impact will be particularly significant when viewed from adjacent areas or from above.

The current construction works being undertaken at East Arm provide a ready example of the degree of visual impact that can be expected during the construction phase. There is not a great deal that can be done to mitigate the visual impact of construction other than carefully controlling the extent of disturbance. Staging of the works would also reduce the extent of visual impact however this may not be feasible.

RECOMMENDATION ONE
It is recommended that detailed site planning be undertaken to carefully define the limits of disturbance, the areas of existing vegetation that can be retained and protected and opportunities that may be available for minimising the visual impact of construction works.

The Operational Phase

Once construction work is completed and areas that have been disturbed have been replanted or rehabilitated the visual impact of construction will gradually diminish over time.

The development of Channel Island Power Station provides a relevant example of a similar facility that was developed over a decade ago. Initially the visual impact of clearing and bulk earthworks was very significant, leaving a predominant scar on the eastern end of the harbour landscape.

The site protection works, subsequent rehabilitation and extensive landscape works have reduced the visual impact of development to such an extent that many areas of disturbance now appear like natural areas that were retained. There will be similar opportunities with the development at Wickham Point to use landscape works, rehabilitation and protection works to reduce long term visual impacts. As the vegetation matures the scares of construction will be significantly reduced, as can clearly be seen at the Channel Island Power Station.

RECOMMENDATION TWO
It is recommended that vegetation management, rehabilitation and landscape strategies be developed as an integral part of the planning and detailed design of the facilities. This will ensure that maximum advantage is taken of all opportunities to reduce the visual impact of development.

PLANNING AND DESIGN CONSIDERATIONS

Given the scale and nature of the proposed development it is not surprising that there will be a significant visual impact particularly from vantage points nearby or overhead. On the basis of the comparative visual analysis it is clear that the visual impact of the development will be greater for vantage points within 500m of Wickham Point. In this viewing range there will be clear views of the facilities, barge dock, jetty, sea walls and related infrastructure.

Beyond 500 m distance the visual impact of the development on the viewer will gradually diminish to the point where it is virtually undetectable; as we consider it will be from Stokes Hill Wharf. Detailed site planning and design of the facilities should address specific visual criteria. These criteria will relate to the visual elements that have been used in the foregoing analysis. Each of these elements are considered below with specific recommendations for consideration by the facilities design and planning team.

LINE

It is obviously not feasible to maintain the flat strong line that is defined by the intertidal vegetation, beaches and mudflats, in the context of large scale dredging and construction of the jetty dock and sea walls. Nevertheless it is important to take advantage of every opportunity to use the natural features of the site to reduce the visual impact of the development. This will be achieved through careful site planning, management and site protection works.

On completion of the construction works it may be feasible to reinstate some sections of the intertidal vegetation communities to re-establish the natural line. This will serve to reduce the impact of vertical structures and provide some modulation to structures that break the horizon line of the foreshore.

RECOMMENDATION THREE
It is recommended that detailed site planning be undertaken to maximise the area of natural foreshore that can be conserved and protected. Specific works should be designed to reinstate the 'natural shoreline' wherever possible once the construction works is completed.

TEXTURE

The texture established by the regular geometric pattern of a relatively long jetty can provide a stark contrast to the organic variable textures of the harbour waters and fringing vegetation.

Planting can soften the visual impact of large regular elements by changing the visual texture and breaking the regular pattern established be a repetitive structural grid. This may have application to the design of both the jetty and the barge dock at the junction with the land. However other measures will be required to address this issue on the seaward sections of these structures.

RECOMMENDATION FOUR
It is recommended that innovative designs and finishes be considered for the facilities and associated infrastructure; particularly with a view to establishing a range of visual textures and patterns that will soften structural grids, hard edges and repetitive shapes.

FORM

Clearly the natural landforms and skyline will be significantly interrupted by the proposed development. The degree to which this interruption occurs will depend on the degree to which the design of the facilities acknowledges the form of the surrounding setting.

When viewed from the water or obliquely form the air the low undulating form of Wickham Point is perhaps unremarkable. It is low and gently undulating and the form of the proposed facilities should as far as possible mirror this form.

RECOMMENDATION FIVE
It is recommended that the project designers consider forms which are sympathetic in proportion and shape to the natural landform. All other things being equal, low squat round tanks would be less obtrusive than tall narrow tanks; and this applies to each element of infrastructure and equipment to be located on the site.

TONE

The various elements of infrastructure and facility buildings will be given a tonal value in the landscape according to the lightness or darkness of the materials and/or surface finishes that are used. The selection of tones that are sympathetic with the tonal values of the harbour landscape will significantly reduce the visual prominence of a particular element. As a guide if there is a high tonal contrast then ones attention is generally attracted by that contrast. Using tones of similar value to those of the immediate surroundings will reduce contrast and tend to minimise the visual prominence of a structure of object, even if it is relatively large.

RECOMMENDATION SIX
It is recommended that detailed design of the facilities, buildings, infrastructure and equipment give careful consideration to the tonal values that are to be used, and that tones selected should approximate the tone of the immediate surroundings.

COLOUR

Colours may be borrowed from the natural landscape through a simple colour matching exercise, and this can produce a harmonious relationship between new development and an existing natural environment. This approach can be developed be analysing the existing range of colours that occur naturally on the site and then designing a colour scheme for the facilities that harmonises with the natural hues.

RECOMMENDATION SEVEN
It is recommended that a project colour scheme be developed on the basis of a study of the existing 'natural' colour scheme that is found on the peninsula. This colour scheme will both harmonise with the colours of the natural environment and define in detail the colours to be used for all aspects of the development.

SCALE

When viewed from a long distance away (more than 3.0 kms) the scale of the proposed development is diminished by the broad scale of the harbour and its perimeter landforms. As one approaches a development of this kind the scale increases in relation to the surroundings and to the view. In terms of views of the site from nearby waters, from an aircraft and/or areas of adjacent land, the shear scale of the development will make it very visually imposing.

The more that can be done to break up the scale of the development by separating various elements, using landscape buffers to divide the facility into smaller sections or modulating the building or structure form, the less visual impact will result.

RECOMMENDATION EIGHT
It is recommended that the overall massing and site planning be carefully considered to minimise the scale of the development. Particular considerations are as follows:

- **Create areas of landscape to separate and scale down the facilities**
- **Design facades and structural elements in a way that the parts do not necessarily read as a whole**
- **Use changes in level, or set back elements in plan to reduce the apparent mass of the development**

Appendix P

BECHTEL CORPORATION

REPORT

Darwin LNG Plant
Draft Environmental Impact Statement

Appendix P
Hazard and Risk Assessment

for

Phillips Oil Company Australia

Ref: 00533-164-073
R635
Appendix P
July 1997

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SECTION 1

Introduction

Background

This Hazard & Risk Assessment Report has been prepared in support of an Environmental Impact Assessment (EIA) Study to construct and operate a LNG (Liquefied Natural Gas) Production Plant and Marine Loading Facility at Wickham Point, the Northern Territory (referred to herein as the 'Darwin LNG Plant').

The Application is sponsored by Phillips Oil Company Australia with a potential for participation by other companies at a later date.

This Hazard & Risk Assessment Report provides the basic information necessary to demonstrate that the LNG Plant will be designed, constructed, commissioned, operated and maintained in a safe manner in accordance with recognised standards and codes of practice. "All practicable measures"[1] will be specified and adopted to protect the safety of the public and employees. The safety of the facility will be reviewed throughout the design and construction periods, and an active safety management program will be implemented and continually updated throughout the period of operation of the LNG Plant.

The main features of the LNG plant design comprise: a LNG process train expected to liquefy a nominal 3 million tonnes per year (MTPA) of natural gas; two LNG storage tanks with nominal individual capacities of about 95,000 m^3; a LNG loading jetty designed initially to handle ships with individual capacities up to about 135,000 m^3. Other features include: refrigerant storage vessels; a boil-off gas compressor; two sumps for liquid spillages; a utilities area; and flares. In addition to the LNG, the plant will produce Propane, 700 tonnes per day; Butane, 722 tonnes per day; and Stabilised Condensate, 400 tonnes per day. Space is allocated for possible future LNG storage tanks and two or three LNG process trains.

Notice of Intent (NOI) of the proposed LNG Plant was submitted to the Environmental Protection Division in August 1996. The Final Guidelines for conducting an Environmental Impact Statement, including the scope and concerns that need to be addressed in this Hazard & Risk Assessment Report, were issued by the Government of the Northern Territory in December, 1996.

Purpose and General Basis

The purpose of this Hazard & Risk Assessment is to identify the risk to the people and nearby facilities from the construction and operations of the LNG Plant and terminal. Based on the probable incident scenarios this Hazard & Risk Assessment provides detail of strategies and procedures that will be implemented at the LNG Plant to prevent the incidents and mitigate their consequences. It also identifies the responsibility of staff at the LNG Plant for prevention and mitigation of potential incidents.

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1 The term "all practicable measures" is used throughout this Hazard & Risk Assessment Report to describe actions which will be taken to ensure the safe operation of the LNG Plant and to protect the health and safety of employees and members of the public. The term is used here to define measures which are both practical and whose benefits in terms of enhanced safety justify their implementation.

The aim of this Report is to demonstrate that:

- Phillips is fully aware of the potential hazards associated with the production, storage and handling of LNG, LPG, and condensate;
- the prevention and mitigation of potential hazards are being properly addressed in the LNG Plant design specifications;
- the potential hazards will be covered adequately in equipment fabrication and construction of the LNG Plant;
- the potential hazards will be managed effectively during the commissioning and operation of the LNG Plant.

For the purposes of the Planning Submittal, the principal issue is the acceptability of the selected site location for the operation of the LNG Plant. In this context, the main focus related to hazard assessment is to establish that the safety of the public resident in or using adjacent land areas will not be affected adversely.

Construction activities are not expected to create major hazards affecting the off-site areas, so these are not a significant concern in the context of establishing site suitability with regard to safety. Hence the main areas of concern in this report relate to possible hazards arising from the commissioning and operation of the LNG Plant.

The production, storage and transport of LNG and other products entails the handling of a flammable hydrocarbon fuel in large quantities, and this serves to highlight public awareness of safety and hazards. Phillips recognises the importance of this issue; and has a long history of managing these types of operations.

The safe design of LNG installations, in order to prevent major accidents from occurring, has always been a primary consideration. The safety aspects of LNG operations are the subject of worldwide cooperation, and a number of groups have been set up to exchange information and the establishment of internationally recognised standards. Present day LNG facilities are, after many years of experience, constructed, operated and maintained to the highest standards of safety and reliability.

The principles of safe design and operation of LNG facilities are consolidated into published standards and codes of practice, of which the main reference document is NFPA (National Fire Protection Association) 59A: Production, Storage and Handling of Liquefied Natural Gas (LNG). This standard has been used for LNG plant design in countries throughout the world for many years, and will be used as the basis for the design of the LNG Plant.

Occupational safety procedures will be developed in accordance with the general principles of: Work Health (Occupational Health and Safety) Regulations, NT Australia; OSHA (Occupational Safety and Health Administration) guidelines; and other relevant applicable codes. Liaison will be maintained with the Industrial Inspections Supervisor and other appropriate agencies to ensure adherence to all local and Commonwealth of Australia Government requirements.

A Safety, Health, and Environmental Management manual with policies, procedures and guidelines will be developed for the proposed LNG Plant incorporating local, national, and international standards and guidelines.

The excellent safety record of the LNG industry is a result of the high standards adopted in the design of present day LNG facilities. Since the Kenai LNG Plant was commissioned in 1964, relatively few incidents of LNG spillages have been recorded throughout the world. During this period, no reported LNG plant incident (from over 170 facilities constructed) has caused fatalities or injuries to members of the public. The marine transportation of LNG shares this excellent safety record, and there have been no recorded incidents (in over 11,000 loaded voyages) which have resulted in LNG spillage from a cargo tank failure.

A good historical safety record is not a reason for complacency. It is fully recognised that, in order to demonstrate that an acceptable level of safety will be achieved, the LNG Plant must include in the design all practicable measures to prevent the occurrence of incidents which could cause injuries or fatalities and to mitigate their consequences.

Prevention of incidents with the potential to cause cargo releases from LNG, LPG, and condensate carriers is the main aim in the management of shipping hazards. This is achieved by adherence to established design codes for these vessels, and established international guidelines for berth design, operating procedures and contingency planning. Safety will be further ensured through the definition and enforcement of effective port controls, and these will be developed in liaison with the Harbour Master.

Emergency planning is recognised as a key requisite for the protection of the safety of the public, site employees and ships' crews. Detailed plans will be developed, in liaison with the appropriate civil and port authorities, to cover on-site emergencies, ship incidents, internal and external communications, and off-site impacts. Account will be taken of existing plans and the resources of the local and national emergency services. Plans will be reinforced by training and exercises, and will be continually reviewed and updated in liaison with external authorities and emergency services. During the development of these plans public and non-governmental organisations will also be consulted for their input.

Summary of Principal Issues

Through application of all the above considerations, the LNG Plant will achieve a high standard of safety, and potential hazards to persons, property and the environment will be managed and maintained at an acceptably low level. The overall goal in the safe siting, design, construction, commissioning and operation of the LNG Plant is the protection of persons, property and the environment.

A prime initial consideration in achieving this goal was the selection of a suitable site for the LNG Plant at which any hazards posed to the surrounding population and users of adjacent land would be acceptably low. The selection was based upon the spacing requirements of NFPA 59A and upon consideration of conceivable hazards.

The design specification of the LNG Plant includes consideration of conceivable influences which could, directly or indirectly, have the potential to cause hazardous incidents. The main aim is to ensure that all practicable measures are used to prevent releases of hazardous materials and to minimise the consequences of any which do occur. This is achieved through careful material selection, design and testing, with the application of adequate safety factors. Prevention of incident escalation is one of the key components in the site hazard management plan, and measures are included in the design to keep small unplanned releases of flammable materials away from process plant and storage tanks.

SECTION 2

Policy and Regulatory Framework

Safety Philosophy of Phillips

Phillips has made corporate commitments for protecting the safety of persons (both employees and members of the public), property and the environment beyond specific government requirements which may apply to their activities. Phillips is committed to the philosophy of planning, designing, constructing and operating the LNG Plant in a safe manner, and a full account of the health and safety implications of their operations. This commitment extends to implementing a system of monitoring potential hazards and their impacts in order to ensure that applicable standards are not infringed, that intended levels of safety are met and maintained, and that mitigation and management plans are practical and effective.

Applicable Hazards/Safety Regulations

Various submittals are being progressed formally through The Environment Protection Division (EPD), Department of Lands, Planning and Environment as the primary contact. As notified by EPD, safety and hazards issues will also be addressed in liaison with the Department of Mines and Energy, the Darwin Port Authority and the Industrial Inspections Supervisor. Discussions will also be held with other appropriate local and national authorities and emergency services as required.

All applicable statutory and regulatory requirements of the Government of the Northern Territory and Commonwealth of Australia will be met. It is understood that current Government policy also requires compliance with recognised international codes, standards and guidelines provided that these can be demonstrated to be relevant and adequate. In this context, the specifications for siting, layout, design, material selection, construction, testing and commissioning of the LNG Plant facilities comply with published standards and codes of practice originating from the United States, with reference to United Kingdom policy where relevant, and taking account of the requirements of the Department of Energy and other appropriate authorities. Construction, commissioning, operational and maintenance procedures will be specified in accordance with published guidelines and recognised industry practice as used in the United States and elsewhere. Occupational safety issues will be covered with reference to the requirements of the Industrial Inspections Supervisor. Marine operating procedures will be developed in liaison with the Darwin Port Authority.

Relevant Standards and Codes of Practice

The main reference document covering the principles of safe design and operation of LNG facilities, used for many years in countries throughout the world, is the standard NFPA 59A: Production, Storage and Handling of Liquefied Natural Gas (LNG).

NFPA 59A sets out guidance for siting, layout, equipment fabrication and installation, construction and operation of LNG facilities, and includes provisions for spill containment and measures to protect persons and property from potential hazards arising from accidental releases. The NFPA standard is intended to be applied to the design, location, construction and operation of any installation which produces, stores or handles LNG. Design specifications and construction, testing, commissioning and operation procedures are set down for LNG storage tanks, process equipment, piping systems and marine transfer facilities, with references to the specific standards, codes and recommended practices which should be used.

NFPA 59A is used as the basis for the design of the LNG Plant, in conjunction with other relevant NFPA and API (American Petroleum Institute) codes and standards. The principal documents are included in the References. Appropriate specific design and fabrication codes will be used for process plant and storage equipment, including NFPA, API, ASME (American Society of Mechanical Engineers) and ANSI (American National Standards Institute) standards and recommendations. The basic requirements and recommendations from NFPA 59A will always be met or exceeded.

The main reference code for LPG storage and handling will be AS1596 (LP Gas Storage and Handling). All pipework, valves, vessels, and fittings will comply with this standard. Electrical equipment and instrumentation will be designed to appropriate standards e.g. AS3000 SAA wiring rules, and AS2430 Classification of Hazardous Areas.

LNG ship design is covered by IMO (International Maritime Organisation) codes which are also listed in the References. These cover all aspects of the design and safety systems and procedures for existing and new LNG carriers. Berth design and safety equipment specification will conform to relevant NFPA, OCIMF (Oil Companies International Marine Forum) and SIGTTO (Society of International Gas Tanker and Terminal Operators) guidelines. Port area operational procedures will refer to IAPH (International Association of Ports and Harbours), PIANC (Permanent International Association of Navigation Congresses) and SIGTTO guidelines.

Occupational safety issues will be covered by a project safety program formulated with reference to Work Health (Occupational Health and Safety) Regulations, NT Australia, OSHA (Occupational Safety and Health Administration) and other appropriate guidelines, taking account of the requirements of the Industrial Inspections Supervisor and other statutory provisions.

A dedicated safety management plan will be established and remain in force for the duration of the LNG Project from design through to operation. Designated safety-trained personnel will be present on the site at all times during construction and operation of the LNG Plant.

Contingency plans to cover emergency situations will be developed with reference for general guidance to the OSHA, API and joint ICS (International Chamber of Shipping), OCIMF and SIGTTO publications included in the References.

Summary of Principal Safety Codes and Standards

This listing includes the principal published standards, codes of practice and recommendations which it is anticipated will be used for reference in the design, construction and operation of the LNG Plant. Phillips is committed to using NFPA 59A as the main reference document. Other publications will be used for guidance on matters of principle and points of detail where appropriate. This listing is not intended to be exhaustive at this stage, and may be subject to amendment in the future, although appropriate recognised publications will always be used.

MAIN REFERENCE DOCUMENT

National Fire Protection Association (NFPA)

NFPA 59A:	Production, Storage and Handling of Liquefied Natural Gas (LNG) 1994 Edition.

OTHER PRINCIPAL REFERENCES

National Fire Protection Association (NFPA)

NFPA 30:	Flammable and Combustible Liquids Code 1993 Edition
NFPA 58:	Storage and Handling of Liquefied Petroleum Gases 1992 Edition
NFPA 59:	Storage and Handling of Liquefied Petroleum Gases at Utility Gas Plants, 1992 Edition
NFPA 70:	National Electrical Code, 1993 Edition
NFPA 77:	Static Electricity, 1993 Edition
NFPA 780:	Lightning Protection Code

American Petroleum Institute (API)

API RP 620:	Recommended Rules for Design and Construction of Large, Welded, Low-Pressure Storage Tanks, Edition 1990 (with 1992 Errata)
API RP 2003:	Protection Against Ignitions Arising out of Static, Lightning and Stray Currents, 5th Edition 1991
API Std. 2510:	Design and Construction of Liquefied Petroleum Gas (LPG) Installations 7th Edition, 1993

FURTHER REFERENCES USED FOR GENERAL GUIDANCE

National Fire Protection Association (NFPA)

NFPA 307:	Construction and Fire Protection at Marine Terminals, Piers and Wharves, 1990 Edition
NFPA 497A:	Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas, 1992 Edition
NFPA 497B:	Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas, 1991 Edition

American Petroleum Institute (API)

API RP 500: Classification of Locations for Electrical Installations at Petroleum Facilities, 1st Edition, 1991

API RP 520: Sizing, Selection and Installation of Pressure-Relieving Devices in Refineries, Part 1, 6th Edition, 1993

API RP 521: Guide for Pressure-Relieving and Depressurising Systems, 3rd Edition, 1990

API RP 750: Management of Process Hazards, 1st Edition, 1990 (with 1990 Errata)

API Pub. 2510A: Fire Protection Considerations for the Design and Operation of Liquefied Petroleum Gas (LPG) Storage Facilities, 1st Edition, 1989

Oil Companies International Marine Forum (OCIMF)

Safety Guide for Terminals Handling Ships Carrying Liquefied Gases in Bulk, 1st Edition, 1982.

International Chamber of Shipping (ICS)

Ship/Shore Check List and Guidelines London, 1982

International Chamber of Shipping (ICS)
Oil Companies International Marine Forum (OCIMF)
Society of International Gas Tanker and Terminal Operators (SIGTTO)

A Guide to Contingency Planning for Marine Terminals Handling Liquefied Gases in Bulk, 1st Edition, 1989

A Guide to Contingency Planning for the Gas Carrier Alongside and Within Port Limits, Edition, 1987

A Contingency Planning and Crew Response Guide for Gas Carrier Damage at Sea and in Port Approaches, 2nd Edition, 1989

International Maritime Organisation (IMO)

Code for Existing Ships Carrying Liquefied Gases in Bulk Resolution A329 (IX), with Amendments

Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk Resolution A328 (IX), with Amendments

International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk

IGC Code, 1993 (with 1994 Amendments)

Occupational Safety and Health Administration (OSHA)

Process Safety Management of Highly Hazardous Chemicals Adopted as 29 CFR 1910, 1993 (with 1994 Amendments)

Work Health (Occupational Health and Safety) Regulations

The Northern Territory of Australia

As in force at 14 May 1996

SECTION 3

Outline Plant Description

Site Location and Layout

The selection of a site location for the proposed LNG Plant was based upon the criteria of low adverse impact to the surrounding population, good marine access, and positive economic benefits to the local area, as well as practical considerations of available site area and local infrastructure. Possible hazards to the adjacent off-site population were a primary concern in the selection process.

The location selected for the LNG Plant lies close to Darwin on the north-western coast of Australia at Wickham Point on the Middle Arm Peninsula (Figure 3-l). Wickham Point is located 6 km southeast of Darwin across the harbour on the undeveloped Middle Arm Peninsula and 45 km by road from Darwin through Palmerston by way of the access road to Channel Island gas fired power station.

The principal areas of population lying closest (approximately 6 km) to the LNG Plant site are: Darwin and Palmerston-East Arm, with an estimated population of about 80,907 residents (1996 estimate), otherwise the area near the proposed plant is totally undeveloped and uninhabited.

Wickham Point has been selected in previous studies by the Northern Territory Government as being a potential site for industrial development, and its close location to the current Darwin Port operation and to the new Darwin port facilities now under construction would suggest that it is the favoured site to be developed.

A preliminary layout of the LNG Plant is illustrated in Figure 3-2. The principal LNG plant facilities are: a single LNG process train; two LNG storage tanks; a LNG loading jetty; flares, refrigerant, LPG, and condensate storage vessels; boil-off gas compression; a remote impoundment basin; a utilities area; a control room and administration buildings. Space is allowed for future expansion.

Process Plant

The LNG Plant will incorporate a single process train, occupying a plot measuring approximately 100 x 250 m (Figure 3-3), to liquefy natural gas and to produce LNG, LPG, and condensate. The LNG process plant will receive feed gas from a pipeline system to be constructed and operated by Phillips.

The principal process units in the LNG train will be: feed gas compression; CO_2 removal; dehydration and mercury removal; and liquefaction.

The proprietary Phillips Optimised Cascade Liquefaction technology shall be used as the basis of the process.

Inlet Separation & NGL Recovery

The feed gas from the LNG plant battery limits is initially processed through a vapour-liquid separation system to provide a gas saturated with water and liquid hydrocarbons. The liquid hydrocarbons, if they exist, are further processed in a de-ethaniser to produce NGL, which is further fractionated into propane, butane, and condensate for export. The gas from this de-ethanisation system is sent to the low pressure fuel system.

CO_2 Removal & MDEA Regeneration

The feed gas free of liquids is processed through a Methyldiethanolamine (MDEA) gas treating system to remove the carbon dioxide (below 100 ppm), and any trace amounts of sulfur components that may be contained in the gas.

Dehydration and Mercury Removal

Treated gas from the MDEA system is air cooled and subsequently chilled to 18.33 °C via high stage propane refrigeration where water and hydrocarbon liquids condense. The chilled gas is dried in a three-bed molecular sieve system to remove any final traces of water. The dry gas is further processed through a two bed activated carbon system to remove any mercury that may be found in the feed gas. The molecular sieve beds are regenerated with hot dry gas, which is heated in a direct fired heater.

Phillips Optimised Cascade Liquefaction

The dry, mercury free gas is subsequently fed to the refrigeration system where it is liquefied as the LNG product. The refrigeration or liquefaction system utilises the proprietary Phillips Optimised Cascade Liquefaction LNG Process.

There are three refrigeration services, propane, ethylene, and methane, which are optimally cascaded to maximise LNG production by utilising the maximum available horsepower of the gas turbine drivers. Propane refrigeration is cascaded to condense ethylene, and ethylene refrigeration is cascaded to condense inlet gas and recycled methane flash gas. Each of the three refrigeration systems use two 50 percent capacity compressors driven by gas turbines.

Heavies Removal & NGL Recovery

Cryogenic distillation facilities are provided to remove most aromatic hydrocarbons in the feed gas. This is accomplished by processing the feed gas at an optimum thermal condition during its cooling and condensing trip through the refrigeration system. The removed aromatics together with any recovered liquid hydrocarbons are sent to storage for export after light ends are stripped and recycled back to the liquefaction process.

LPG Fractionation

The NGL from the De-Ethanisers is combined as the feed to the De-Propaniser. The De-Propaniser is a trayed column with a re-boiler, condenser, accumulator and reflux pumps. The vapour from the top of the column is fully condensed in the air cooler. This liquid is collected in the accumulator and then pumped as propane product.

The bottom liquid from the De-Propaniser is sent to the De-Butaniser. The vapour from the top of the column is totally condensed in the air cooler, and the butane liquid is pumped out as butane product.

The bottom product from the De-Butaniser is fed to the Condensate Stabiliser. The Condensate Stabiliser is a packed column. The Condensate Stabiliser overhead product is partially condensed by air-coolers. The bottom stream from the column is the stabilised condensate product which is sent to storage.

Utilities Description

Generally, the LNG facility is self-sufficient as far as utilities are concerned. Most of the utilities consumed in the LNG facility will be produced within the limits of the plant. Likewise most of the waste produced in the LNG facility will be treated within the limits of the plant.

The *Flare and Relief System* will dispose of waste and emergency vents from the process and utilities. The system is composed of several parts: A wet flare to collect and burn streams which may contain moisture, a dry flare to collect and burn streams which could be too cold to combine with streams that contain moisture, a marine vent to dispose of excess methane vapour from the storage and loading system.

The *Refrigerant Storage System* provides storage volume for refrigerant make-up to the process as well as de-inventory volume for the process loop during maintenance.

Miscellaneous Storage is provided for several other fluids used by or available to the process. Diesel fuel, lube oil, hot oil, and Perlite insulation are used for make up to the process.

A two pressure level *Fuel Gas System* is provided to supply the high level users such as the refrigerant turbines and power turbines and the low level users such as the fired heaters and flares.

The facility includes *Effluent Treatment* which treats the waste liquid streams to acceptable standards. The streams include sanitary waste, waste oil, and solid waste.

The plant power requirements are met by onsite *Power Generation* by four (4) turbine driven generators. Three (3) are required by the expected load, the fourth is a rolling spare. A diesel driven emergency generator is provided with enough power to start-up one of the main turbine generators in addition for supplying other emergency power. This additional power is enough for a safe and orderly shutdown and operation of critical utilities as well as for bringing the facility back on-line. If the Northern Territory Power and Water Authority supplies power to the LNG Plant during the construction and operation phases, then only an emergency generator will be provided.

The *Fire and Safety System* includes several parts. The primary system is the firewater system which includes water storage, a pumping facility and an underground distribution loop. The distribution includes hydrants, monitors, hose reels, deluge systems and sprinkler system. One hi-ex foam system for the LNG impoundment area has been provided. Combustible gas and hazardous gas detection systems as well as low temperature detectors are incorporated into the layout design to facilitate rapid response to any uncontrolled release of dangerous materials.

The plant layout philosophy maximises the use of passive protection in the form of equipment spacing and drainage of possible liquid spillages away from critical equipment. Active measures such as fire and gas detection, a fire water system and over-pressure protection are included in the design. Measures are described in detail in Section 5.

A *Hot Oil System* is used as the heating medium for the amine system as well as the LPG fractionation columns. This is a closed loop circulation system with two fired heaters providing the necessary heat.

Compressed air is supplied from two motor driven air compressors and an emergency diesel driven compressor. The air is cooled and dried to a -40 °F dewpoint.

Nitrogen is provided (99.95% pure) from a package unit which includes a pressure swing absorption (PSA) production unit with independent liquid nitrogen storage and vapourisation for header pressure maintenance.

Water System

Fresh Water	Fresh/Potable Water from PAWA *
Drinking Water	Treatment of fresh water
Fire Water	Supplied from fresh water system

* NT Power and Water Authority (PAWA) is premised to supply fresh/potable water to the site via a 6-inch pipeline.

LNG, LPG, and Condensate Storage & Loading

LNG is stored in two conventional double containment storage tanks of 95,000 m^3 capacity. Each tank will comprise an inner container fabricated from 9 % Ni-steel surrounded by approximately 1 meter of perlite insulation, contained within an outer carbon steel shell. The outermost shell is constructed of pre-stressed concrete wall. A small air gap is maintained between the carbon steel shell and the concrete wall. The inner tanks will contain the LNG product at its boiling point of -161 +5°C at a pressure slightly above ambient. No refrigeration will be provided, and heat leakage (minimised by insulation) will produce a small amount of boil-off gas which will be used as fuel.

LNG will be held in the storage tanks until it is transferred to the jetty for loading into marine carriers for export. The LNG will be pumped from the tanks via pipework connections through the roofs using six in-tank pumps (three per tank) to obviate the need for any sidewall penetrations.

Atmospheric, refrigerated storage tanks are provided for the propane and butane products. These tanks provide one month of storage for each product. The propane storage tank has a capacity of 37,700 m^3 and the butane storage tank has a capacity of 38,000 m^3. Internal pumps will be used in these tanks and all liquid and vapour connections will pass through the dome of each tank.

A floating roof storage tank with a 20,000 m^3 capacity provides one month of storage for the stabilised condensate product. External pumps will be used, with liquid connections through the vertical shell of the tank, near bottom.

Safety is a paramount consideration in the design and operation of the LNG storage tanks. The highest standards will be adopted in the design and construction of the tanks to ensure their integrity, and they will be subjected to extensive testing before and during commissioning.

Specific measures are described in Section 5.

LNG Loading System

Loading Design	Piled trestle/bellows/single platform
LNG Loading Rate	10,000 m^3/hr
Loading Arms	2 for LNG, 1 for Vapour
Loading Line Length	Assume 1.5 km (shore to ship)

LNG Tanker

Min./Max.	70,000 m^3 / 135,000 m^3
Fill Time	Approximately 12 hours
Turnaround Time	24 hours

Assume no vapour return blower on tanker (jetty design includes blower)

LNG Export

LNG will be exported from the tanks by pumping through a cryogenic pipeline to a loading jetty (Figure 3-3). LNG will be transferred by in-tank pumps from the storage tanks during ship loading at a total rate of about 10,000 m^3/hr. It is anticipated that the capacity of a LNG ship will be up to about 135,000 m^3. Each loading operation will be completed within approximately 12 hrs. LNG contained in the ship's cargo tanks will be held under similar conditions to the on-site storage tanks.

The LNG jetty will comprise a trestle nominally 1.3 km long with a conventional 'T' head, supported on an open piled structure. The transfer pipeline will be cooled using LNG prior to each ship arrival. Two liquid loading arms will be used to transfer LNG to the ship. A separate transfer arm will convey vapour produced in loading to the shore based recovery system, with excess quantities being flared. The transfer arms will be equipped with suitable couplings to allow disconnection in an emergency. Mooring dolphins will be used to secure the LNG carriers, which will berth starboard side in order to facilitate emergency departures. Tugs will be used whenever a LNG carrier is berthed. Ships will call at intervals of about 3-8 days, depending upon ship capacity and scheduling.

Safety considerations are paramount in the design and operation of the LNG loading jetty and in ship handling procedures. Ship and shore safety systems will be checked before each loading operation, and the plant and ship emergency shutdown (ESD) systems will be linked together (hard-wired or by fibreoptic cables). Intrinsically safe walkie-talkies, and a back-up telephone link, will be used for communications between a berthed carrier and the jetty, and VHF radio when the ship is off-shore. Ship operations within the Sea of Timor will be subject to rigid control procedures.

SECTION 4

General Hazards and Safety Considerations

Approach to Hazard Management

In general terms, the approach adopted to achieve a high standard of safety and a low hazard potential for the LNG Plant may be summarised as:

- measures will be included, through siting, design, manufacture, construction, commissioning and operation, to prevent incidents and accidental releases of hazardous materials which might result in a threat to the safety of persons or property and to mitigate their consequences;
- safety will be an integral part of the LNG Plant design, and will be reviewed continually during the process from initial design through to commissioning by systematic assessment;
- safety, reinforced by training, will be an integral part of the LNG Plant, terminal, and shipping operations, and systematic reviews, assessments and audits will be carried out to ensure that the intended levels of safety are achieved and maintained;
- safe operating procedures based on the 27 years of safe operation at Phillips Kenai LNG Plant, will be developed and implemented;
- emergency procedures will be established in conjunction with the appropriate authorities and emergency services.

This philosophy will serve to ensure that all necessary safety features are identified and specified in the design of the LNG Plant, and that the safety of the workforce and of members of the public will be protected in the extremely unlikely event of a major accident occurring.

Nature of Hazards

Before considering the nature of the hazards which might conceivably arise from a LNG facility, it is useful to define what is meant by the term 'hazard'. A hazard can be defined generally as a situation with the potential to cause harm (harm being fatalities or injuries to personnel or the community, or damage to plant, property or the environment). The term 'risk' (which is often misused) is then defined as the probability or likelihood that the specified level of harm will occur.

The LNG Plant will process, handle and store large inventories of natural gas and LNG, together with ethylene, propane, butane, and condensate; the properties of these substances are summarised in Table 4. The potential hazards associated with uncontrolled releases of flammable hydrocarbons are readily apparent, the principal *types* being: vapour clouds and fires; thermal radiation or flame impingement from jet or pool fires; vapour cloud explosions (VCEs); boiling liquid expanding vapour explosions (BLEVES).

Releases of natural gas from high pressures existing in transmission pipelines or upstream process plant cannot generally produce large vapour clouds, since turbulent *mixing* would quickly dilute the released gas. A release of liquefied hydrocarbon such as LNG or refrigerant may form a vapour cloud which entrains air and disperses in the atmosphere. A portion of the cloud would be likely to be flammable, giving rise to the possibility of ignition and a vapour cloud fire. Personnel hazards from such a fire would be limited generally to the extent of the flammable cloud, and equipment damage would be minimal.

Ignition of a gas or liquid release can produce a jet or pool fire. Direct flame contact may rapidly cause damage to unprotected plant equipment, and personnel hazards from thermal radiation exposure may occur outside the flame envelope.

Delayed ignition of a vapour cloud may lead to a VCE in circumstances where the flammable cloud engulfs a highly congested or confined area of plant. The magnitude of the over-pressure produced upon ignition of such a cloud is dependent upon the degree of congestion and the type of flammable gas. VCEs can cause blast damage hazards within and outside the flammable cloud, with significant equipment damage in the near field and personnel hazards, principally from collapsing structures, at greater distances. There are no confirmed incidence of VCEs occurring on any operating LNG facility.

A BLEVE is the term used to describe the catastrophic failure of a pressure vessel containing a flammable liquefied gas caused by fire exposure. The phenomenon can result from a concurrent increase in internal pressure and weakening of the vessel walls until the point is reached where the pressure cannot be contained. Instantaneous rupture may then occur, with the liquid flashing and burning as a 'fireball'. The two principal hazards from a BLEVE are thermal radiation from the fireball burning and possible impacts from projected vessel fragments. Thermal radiation damage to equipment is generally minimal, but personnel hazards can occur outside the extent of the fireball. Projection of vessel fragments tends to be highly directional, and the likelihood of damage at any given location would be low. There are no recorded incidence of any BLEVES having occurred on LNG facilities.

Siting of LNG Facilities

One of the prime considerations in the selection of a suitable location for a LNG facility is the possible hazards which may be posed to the adjacent residential population and to other users of neighbouring land. It is widely acknowledged that the location selected for a LNG facility is the principal determinant of the hazard which has to be managed during its operation.

While the likelihood that a major accident will occur on a LNG facility is extremely low, the nature and magnitude of the hazards which could conceivably arise from such an occurrence must nevertheless be taken into account when selecting a location. The implications for the offsite population need to be analysed, the requirements for off-site emergency plans need to be developed, and the specification of mitigating features to reduce significant impacts needs to be considered.

On-site (employee) safety issues are also an important consideration, but these are not related specifically to location (the same factors applying broadly regardless of where the LNG facility is sited). Occupational safety issues are outlined at the end of this Section.

A number of possible procedures are available to determine the acceptability of a location for a LNG facility in the context of surrounding land-use. The precise approach adopted depends to some extent upon the requirements and regulations prevailing in the country in which the facility is to be located. A commonly accepted baseline is to use the distances given in NFPA 59A.

The off-site separation distances given in NFPA 59A are based upon calculated thermal radiation levels from LNG fires and upon consideration of the dispersion of unignited vapours arising from designated spillage cases. The basis is to specify safe levels applicable to selected off-site areas. The distances apply to fixed onshore and marine facilities on the LNG site. Figures are provided for distances from impoundment areas, storage tanks and process equipment to the property line and certain types of off-site development. The goal is to ensure that if (in spite of the industry record, stringent design standards and precautions) an accidental spillage of LNG were to occur, the consequences would not have a significant adverse impact upon the neighbouring population.

The siting of the proposed LNG Plant, and the locations of its principal features, are covered in Section 3.

Minimum figures specified in NFPA 59A (section 2-2.3.1) for separation distances to off-site areas can be calculated as: 95m to the property line that can be built upon (3 x √ A1); 200m to the nearest existing educational or residential buildings (2 x √ A2); 300m to outdoor areas in existing use for assembly by 50 or more persons (3 x √ A2). Separations based upon the proposed siting and provisional layout exceed the minimum NFPA 59A spacing by considerable margins.

As proposed, each LNG storage tank has an assumed diameter (D) of 75m. The minimum separation distance specified in NFPA 59A (section 2-2.4.1) is 52 ½ m to the property line (0.7 x D). Once again, the minimum NFPA 59A distance is exceeded in the provisional layout.

The minimum off-site separation distance specified in NFPA 59A (section 2-2.6.1) for other site equipment is generally 15 m to the property line. The distances proposed in the current site layout exceed this figure comfortably in all cases.

For LPG storage, a separation distance of 30 m from pressurised storage tanks is generally sufficient to meet NFPA and API recommendations. Industrial Risk Insurers (IRI), in its publication IM.2.5.2, "Plant Layout and Spacing for Oil and Chemical Plants", dated June 6, 1996, recommends pressurised storage tanks be separated by no less than 30 m from cone roof tanks.

Hazards arising from LNG and LPG shipping operations also need to be considered in the site selection process. It is recognised that the consequences of a large uncontrolled release of LNG or LPG from a ship would be unacceptable under any circumstances. The emphasis in the management of shipping hazards is upon incident prevention. The goal is to reduce to a negligible level the likelihood that any significant incident should occur. Even so, the location of a LNG and LPG marine loading point is important, and separation distances to populated areas need to be maximised.

In addition to meeting, and commonly exceeding, the minimum NFPA requirements, the selected LNG Plant site has a number of important safety advantages:

- the nearest significant housing is located at a safe distance (more than 7 km) from the process plant and storage tank areas;
- the nearest significant industry (Channel Island power station) is located at a safe distance of 2.5 km;
- no hazardous or high occupancy industry is located in the area at present, so planned future industrial land-use can be controlled to ensure mutual compatibility with the LNG Plant and avoid hazards to employees and possible 'domino' effects;

- the jetty head location is in the predominantly downwind/crosswind direction from the closest residential areas, and at a safe distance from these; and

- there are no other large scale shipping operations in the immediate area at present, so it will be feasible to apply controls to planned future movements to eliminate the possibility of LNG carrier collisions at or near the berth.

In spite of these positive points, the potential for public hazards to arise from the operation of the LNG Plant needs to be considered and analysed; the issues are covered in Section 5 and in Section 6. The assessments serve to demonstrate that the potential hazards from the LNG Plant are being addressed and identify the principal impacts which will be included in the hazard management process.

It should be noted that the assessment of potential hazards to the public is based upon the present situation and surrounding land-use. In order to maintain an acceptably low level of hazard, it will be necessary to control future land-use close to the LNG Plant site to restrict encroachment by incompatible development. One way to achieve this would be to establish a 'consultation zone' around the LNG Plant within which planning controls could be established. The size of the consultation zone would be based upon the results of hazard analysis, and might typically extend to about 1 km. In general terms, there should be no need to restrict non-hazardous, low occupancy industrial development anywhere outside the LNG Plant boundary, but consideration should be given to the control of residential housing areas, schools, playgrounds, shops, hospitals and high occupancy or hazardous industries.

Principles of LNG Plant Layout and Spacing

In general terms, the principal factors influencing the layout of equipment and facilities on a LNG site are: safety; process alignment; topography; marine access; constructability. It is acknowledged that safety is the key factor in determining the plant layout.

The safe layout of LNG facilities is generally based upon the distances given in NFPA 59A. These distances are based primarily upon the calculated thermal radiation levels from LNG fires from defined spillage cases. Separation distances are given for LNG tanks, vapourisers, process areas, and fired equipment to other LNG tanks, refrigerant storage vessels, ignition sources, impoundment area spillways and site buildings.

The aim of a safe plant layout is to ensure that, if any accidental release were to occur in one plant area, the consequences would not cause severe damage to plant or essential equipment in adjacent areas which could provide a route for escalation to a larger incident and/or impede the emergency response.

The layout of the proposed LNG Plant is covered in Section 3. The principal in-plant spacings specified in NFPA 59A (sections 2-2.4.1, 2-2.6. 1/2), applied to the LNG Plant, are: 37½m between LNG storage tanks (¼ x 2D). The internal separation distances between process units and storage equipment always meet, and commonly exceed, these minimum figures, providing a sound basis for a safe layout. In particular, the LNG storage tank area is separated from the process plant, and a liquid impoundment area is sited at a distance and downwind from the storage and process areas. In addition, clear spaces are allowed around certain features: 200 m around the impoundment basin and the main flare; 100 m around the loading flare. These are based upon calculated safe thermal radiation fluxes.

Quest Siting and Safety Review*

Preliminary siting/safety review for the proposed LNG Plant and the marine terminal was performed by a qualified independent consultant (Quest). Scope of the study included the following tasks:

1. Calculation of the vapour dispersion and fire radiation exclusion zone distances associated with the LNG design spills specified in NFPA 59A, and for similar spills of LPG and condensate.

2. Determining the minimum allowable land area within the boundaries of the LNG Plant for each combination of tank type and impoundment system, assuming that the plant must meet the siting criteria of NFPA 59A and applying those criteria to LNG, LPG, and condensate.

3. Determining the extent of off-site areas in which it might be necessary to exclude certain types of structures, land uses, or public activities in order to comply with NFPA 59A siting criteria.

4. Determining the realistic minimum spacing between adjacent storage tanks, and between spill impounding areas and process areas.

5. Reviewing the proposed plot plan to determine if the layout and spacing of equipment within the plant boundaries meet applicable NFPA 59A requirements and conform to good engineering practice.

The siting requirements in NFPA 59A are based on the premise that the public should be protected from the hazards posed by credible releases of LNG. The releases that must be considered are defined in the code. The hazards of concern are:

- Exposure to a flash fire created by ignition of a flammable vapour cloud.
- Exposure to the radiant heat from a postulated pool fire.

For each credible release specified in the code the downwind length of the flammable vapour cloud must be computed "in accordance with a suitable model". In order to be in compliance with the siting requirements of NFPA 59A, "Provisions shall be made to minimise the possibility of a flammable mixture of vapours from a design spill reaching a property line that may be built upon", that is, a property line that is inhabited or used by the public.

"Thermal radiation protection distances" must be computed for each design spill and for each LNG spill impounding system required by the code. These computations are to be based on formulas specified in the code. For each LNG tank impounding area, there are three thermal radiation protection distances of interest, each related to a specific radiant heat flux. For all other impounding areas required by the code, there is only one thermal radiation protection distance relevant to siting. Land uses that are not allowed within each of these distances are also specified in the code.

Footnote: Quest Consultants Inc. of the USA is an internationally renowned independent consultant experienced in LNG plant and terminal safety studies. Quest Consultant's personnel have been actively involved in LNG safety programs that include large scale field tests of LNG spills and fires, short courses for training LNG facility personnel, LNG facility inspections and safety audits, consequence modeling of vapour dispersion and fire radiation zone and other safety studies.

This study was undertaken to determine if the code specified requirement regarding thermal radiation protection distances and flammable vapour clouds could be met by the current design of the proposed facility and to determine the plant exclusion zone. In addition, the layout and spacing of equipment within the plant boundaries were reviewed and compared to code requirements and good engineering practices.

The results of the Quest study and a siting/safety review report for the proposed facility is provided below:

Design Spills

LNG Storage Tanks

Per NFPA 59A, section 2-2.3.3(b), the duration of the design spill shall be 10 minutes, provided demonstrable surveillance and shutdown provisions acceptable to the authority having jurisdiction exist.

The ten-minute design spill for LNG tanks with over-the-top connections is based on a spill rate equal to the "full rated capacity" of the internal pumps. According to preliminary project data, the maximum anticipated withdrawal rate from one tank is 5,250 m^3/hr. Specific data for the LNG pumps are not available at this stage of the project. Without LNG pump curves, the maximum discharge rate is assumed as 15,000 m^3/hr (with a 50% pump runup and LNG loading from two tanks occurring simultaneously). For the purposes of computing preliminary site dispersion and fire radiation exclusion zones and impoundment sizes, a design spill rate of 15,000 m^3/hr has been selected.

The volume of LNG that must be impounded for the 15,000 m^3/hr design spill is 2,500 m^3, based on the ten-minute flow criteria. Two impondment sizes are investigated in this report; a deep sump with dimensions of 25 x 25 x 4 m and a shallow sump of 50 x 50 x 1 m.

LPG

LPG tanks do not have a "design" spill defined as do LNG tanks. The maximum ship loading rate for LPG products is expected to be 1,500 m^3/hr. A "severed line" accident scenario would allow liquid to be released at a rate higher than 1,500 m^3/hr due to reduction in backpressure. Assuming a 50% pump runup due to decreased backpressure, a spill rate of 2,250 m^3/hr for a ten minute period has been selected as the LPG design spill. This corresponds to a spill volume of 375 m^3. This could be contained in a sump with dimensions of 20 x 20 x 1 m.

Condensate

Condensate storage tanks do not have a defined "design spill". However, for consistency with LNG requirements, a "one-hour" design spill for bottom connections is recommended. Assuming that the flow of condensate can be shut off within one hour, the design spill would have a flow rate computed using the following equation (NFPA 59A, Paragraph 2-2.3.3(c)):

$$q = 1.33 \times d^2 \times \sqrt{h}$$

where,

- q = flow rate (ft^3/min)
- d = diameter of tank penetration (in)
- h = height of liquid above the penetration when the container is full (ft)

For the condensate tank with a liquid height of 14.6 m (47 ft) and a tank penetration of 0.3 m (12 in) diameter, the design flow rate would be 2,250 m^3/hr.

Fire Radiation Analysis

Paragraph 2.2.3.1 of NFPA 59A requires thermal radiation protection distances be calculated for each required LNG impoundment area. These calculations are based on the assumption that the impounding area contains a volume of LNG equal to the minimum volume computed in accordance with 2.2.2.1 (full LNG tank spill) or 2.2.3.3 (LNG design spill), whichever is applicable, and the LNG is burning. The calculated distances are used for facility siting purposes. Similar calculations were made for fires in the LPG and condensate spill impounding areas, although such calculations are not required by NFPA 58 or NFPA 30.

Results of the thermal radiation calculations required by NFPA 59A, and similar calculations for LPG and condensate fires, are presented in Table 4-1.

Figures 4-1 through 4-5 show the thermal radiation contours for the siting requirements of NFPA 59A. Figures 4-4 and 4-5 show the extent of off-site restricted area defined by the 5 kW/m^2 and 9 kW/m^2 impoundment fire contours.

Table 4-1

Thermal Radiation Protection Distances for Facility Siting

Fuel	Description of Event	Impounding Area	Dimensions of Pool Surface (m)	Distances (m) from Center of Impoundment to Specified Radiant Heat Flux		
				5 kW/m^2	9 kW/m^2	30 kW/m^2
LNG	Full tank spill	Outer tank	66 dia.	250	210	145
LPG	Roof failure	Inner tank	57 dia.	210	175	120
LPG	Full tank spill	Remote	143 x 143 x 4	520	430	290
Condensate	Roof failure	Tank	55 dia.	90	60	*
Condensate	Full tank spill	Large, flat	100 x 125 x 2	150	110	*

* This Flux was not reached.

Thermal Radiation Calculations for In-Plant Separation Distances

NFPA 30, 58, and 59A all contain some criteria for separation distances between certain equipment or areas within the facility, but none of them requires the use of consequence models to set those distances. The European Economic Community (ECC) has proposed an incident heat flux of 15.7 kW/m^2 as the criterion for deciding when plant equipment must be protected from the heat effects of certain fires. The predicted distances from the center of each tank impounding area, and each tank, to an incident heat flux of 15.7 kW/m^2 are presented in Table 4-2.

Table 4-2
Thermal Radiation Protection Distances for In-Plant Separation

Fuel	Description of Event	Impounding Area	Dimensions of Pool Surface (m)	Distances (m) from Center of Impoundment to Specified Radiant Heat Flux 15.7 kW/m^2
LNG	Full tank spill	Outer tank	66 dia.	175
LPG	Roof failure	Inner tank	57 dia.	150
LPG	Full tank spill	Remote	143 x 143 x 4	3600
Condensate	Roof failure	Tank	55 dia.	*
Condensate	Full tank spill	Large, flat	100 x 125 x 2	90

* This Flux was not reached.

Flammable Vapour Cloud Analysis

The design spills for impounding systems serving the process or LNG transfer area are identical to the releases used to determine the minimum volumetric capacities of those impounding systems, a spill of 10-minute duration at the maximum release rate. In this study, the maximum release rate was determined to be one and one-half times the loading rate, 15,000 m^3/hr. The increase in flow from design flow rate is to account for the increased pumping capacity as the discharge pressure of the pump is reduced. The LPG release rate is determined in a similar manner and is 2,250 m^3/hr. The condensate tanks have tank penetrations below the liquid level and do not have internal shutoff valves. The release rate for the condensate spill was taken as 2,250 m^3/hr, and the duration of the spill taken as one hour.

The size of the flammable vapour cloud created by a release of LNG depends on several factors, including the rate at which LNG vapour is released into the air and weather conditions. The rate at which LNG will vaporise upon release to the atmosphere is the sum of the vapourisation rate due to flashing and the rate of vapourisation due to heat transfer from the impounding system. The amount of flash is controlled by the release rate and the temperature of the LNG prior to its release. If the LNG is superheated, even slightly, some of the released LNG will flash to vapour. As the amount of superheat increases, the percentage of LNG that will flash to vapour (upon release) also increases. The rate of vapourisation due to heat transfer from the impounding system to the LNG depends on the release rate; the amount of flash vapourisation; and the size, shape, materials of construction, and surface temperature of the impounding system.

For this study Pasquill-Gifford atmospheric stability Category F and wind speed of 2 m/sec was used, along with an air temperature of 32 °C and a relative humidity of 30%. Table 4-3 summarises the result of the flammable vapour calculations. Figure 4-6 and 4-7 shows the LFL outer limits for each of the spills identified in Table 4-3.

Table 4-3
Flammable Mixture Dispersion for Design Spills

Case	Description of Spill Impounding Area	Release Rate (m^3/hr)	Release Duration (min)	Distance (m)
1	LNG spill into 25 x 25 x 4 m high density concrete sump	15,000	10	375
1a	LNG spill into 50 x 50 x 1 m high density concrete sump	15,000	10	475
2	Propane spill into 20 x 20 x 1 m high density concrete sump	2,250	10	250
3	Butane spill into 20 x 20 x 1 m high density concrete sump	2,250	10	208
4	Condensate spill into 100 x 125 m soil dyke	2,250	60	365

Principles of Spill Prevention and Mitigation

The important goal in the safety of a LNG plant is to prevent any uncontrolled release of potentially hazardous material from occurring. It is also recognised that minor spillages can never be eliminated entirely from a large and complex plant in spite of all precautions taken, and an additional goal is to prevent escalation of these small incidents to cause more major accidents. Hence measures are adopted in the design and operation of LNG plants to prevent failures which could result in hazardous releases and to ensure that the consequences of any minor spillages which might occur are minimised.

The measures adopted include: accident prevention by adoption of rigorous design standards and avoidance of potential sources of failure; release detection and isolation systems to limit spillage volumes; inherent passive protection features such as spacing, shields, channels and impoundment to reduce consequences and limit damage; active protection measures such as firewater monitors, hoses and mobile fire fighting capability.

Process units and equipment generally contain only relatively small inventories of flammable hydrocarbons. However, the multiplicity of machinery, process vessels, heat exchangers, piping and valves can increase the likelihood of failure. Hence particular attention is paid in plant design to the specification of safety systems and features to prevent such failures and to minimise the consequences of any hazardous releases which might nevertheless occur.

LNG storage tanks contain very large inventories of hazardous material, but include relatively few mechanical components which might conceivably fail. Here attention is focused on ensuring that significant spillages of LNG will not occur. However, in spite of the very low likelihood of a major spillage, design features are specified to contain the effects of very large releases. The reason for this is because it is recognised that measures are needed to contain the consequences of very large accidents however unlikely they may be. To this end, LNG storage areas are specified to have secondary containment capable of containing at least the full contents of the largest tank present, designed to minimise the possibility of any accidental discharge endangering persons or property in adjoining areas.

The relevance of specific safety features is developed further in Section 5.

Occupational Safety in Construction and Operation

As part of the preparation for on-site activities, a comprehensive program will be developed to ensure safety through the engineering, fabrication, construction, operation and maintenance of the LNG Plant. The overall aim will be to promote and achieve a 'zero accident' culture through implementation of a positive safety management programme.

Occupational health and safety in construction and operation will be assured through a system of quality and hazard management which will include:

- development of effective health and safety policies based upon positive management control, including systematic approaches to hazard identification and support for initiatives for improvement;
- organisation to establish management control, promote cooperation and facilitate effective communication;
- promotion of a positive health and safety culture, including setting of objectives and performance targets;
- conducting audits and performance reviews to maintain intended standards.

Construction activities on the LNG site will have no potential to affect the safety of the public in off-site areas (except for increased traffic hazards on road and in Darwin harbour) and are thus not relevant to major hazards and siting considerations. However, occupational safety during construction is a key concern and will be addressed. Although not relevant to the question of site acceptability, the issues are outlined here for completeness.

The construction phase of the project will entail site leveling and excavation, erection of temporary plant and accommodation, preparation of foundations, fabrication and placement of process plant and pipework, and construction of the LNG storage tanks and jetty. These activities will expose the workforce to potential hazards, but mostly those normally to be expected in heavy civil engineering.

In addition to the normal hazards associated with such activities, the safety of construction workers could be affected by toxic and flammable gases on the site, and from contaminants and pollutants such as paints and solvents.

The operation of the LNG Plant will, aside from the principal major hazards issues discussed throughout this Report, have implications for occupational safety and health. Although these issues are not immediate, and are not relevant to the issue of LNG Plant siting, they are noted here for completeness.

The permanent workforce needed to operate the LNG Plant will be exposed to potential hazards arising from the presence of pressurised flammable gases (natural gas and refrigerants) and pressurised and/or cryogenic flammable liquids (LNG and refrigerants) in bulk quantities. These hazards are well understood, and the provisions of the relevant standards and codes of practice developed through the extensive experience of the LNG industry will be implemented to protect the safety of the workforce.

The other principal substances likely to be present on the LNG Plant site with implications for occupational safety are: methanol; amine solution; hypochlorite solution; chlorine tablets; sulfuric acid; sodium hydroxide; hot oil; diesel fuel; miscellaneous solid chemicals and catalysts. Additional hazards will be associated with the handling of cold cryogenic liquids.

Hypochlorites, methanol, amines, acids and caustic solutions will have the potential to cause toxic hazards and burns through ingestion and/or skin/eye contact. These substances will be controlled, monitored and treated making reference to OSHA guidelines on exposure limitations and other relevant matters.

Occupational safety matters will be dealt in depth prior to the commissioning and operation of the LNG Plant, in discussion with the Ministry of Mines and Energy, the Industrial Inspections Supervisor and other appropriate Northern Territory Government agencies. In general terms, all practicable measures will be specified and implemented to ensure the continued health, safety and well-being of all members of the permanent LNG Terminal workforce and others required to be present on the site from time to time. An on-site ambulance may be provided as part of the emergency and health care facilities. Accidents will be investigated and reported to The Environment Protection Division, Department of Lands, Planning, and Environment in accordance with regulatory requirements.

Proper measures and precautions for handling and storing chemicals on the site will be incorporated in the design stage and will be carried out in the operation of the plant. The following measures will be used to prevent chemical spills from entering storm drains which discharge to the harbour.

Chemicals and oils used on the site will be stored either inside buildings or in tanks which will have spill containment systems to prevent any contamination to the ground or surface waters.

Areas where chemicals or oils are used in equipment and /or machinery will be segregated and curbed to collect any leakage which may occur. Sand or other absorbent materials will be used to collect small leakages and sumps will be strategically located for any large spills should they occur around process equipment. Propane, Butane, and condensate spills from the storage tanks would drain to a large impoundment basin.

TABLE 4.4

Principal Hazardous Substances Present on the LNG Plant

Natural Gas (Predominantly Methane)

Flammable Asphyxiant Gas	
Molecular Weight:	16.1
Flammable Limits (v/v air):	4.9% / 15.0%
Stoichiometric (v/v air):	9.5%

LNG (Liquefied Natural Gas Product)

Cryogenic Liquid, Flammable Asphyxiant Vapour	
MW, Flammability as Natural Gas	
Flash Point:	- 189 °C
Boiling Point:	- 161.5 °C
Molecular Weight:	16.1
Flammable Limits (v/v air):	4.9% / 15.0%
Stoichiometric (v/v air):	9.5%

LNG will be stored in two tanks of 95,000 m^3 capacity, each.

Ethylene

Flammable Cryogenic Liquid, Flammable Asphyxiant Vapour

Molecular Weight:	28.05
Flash Point:	- 150. 33 °C
Boiling Point:	- 117.94 °C
Flammable Limits (v/v air):	2.75% / 28.6%

Ethylene will be stored in one 50,000 m^3 tank.

Propane

Flammable Pressurised Liquefied Gas, Flammable Asphyxiant Vapour

Molecular Weight:	44.1
Flammable Limits (v/v air):	2.1% / 9.8%
Stoichiometric (v/v air):	4.0%
Flash Point:	- 104 °C
Boiling Point:	- 42.1 °C

Propane will be stored in one 37,700 m^3 tank.

Butane

Flammable Pressurised Liquefied Gas, Flammable Asphyxiant Vapour

Molecular Weight:	57.98
Flammable Limits (v/v air):	1.6% / 8.4%
Flash Point:	- 60 °C
Auto Ignition Temp.	420 °C

Butane will be stored in one 38,000 m^3 tank.

Condensate

Molecular Weight:	81.89
Flammable Limits (v/v air):	1.1% / 7.5%
Flash Point:	- 22 °C
Auto Ignition Temp.	225 °C

Condensate will be stored in two tanks of 20,000 m^3 capacity, each.

Methyl Diethanolamine (MDEA)

Alkanolamine Formulation, translucent white liquid with ammoniacal fishy odour.

Boiling Point	178.5 °C
Specific Gravity	1.072
Flash Point	121.1 °C

MDEA will be stored in an aboveground tank of 450 m^3 capacity.

SECTION 5

LNG Plant Accident Prevention/Mitigation

Introduction

This Section of the Report is concerned with the management of potential hazards arising from the operation of the LNG Plant site - principally the LNG process train, the LNG storage tanks and the LNG jetty/loading lines. Potential hazards arising from the LNG ships are considered separately in Section 6.

The objectives of this Section of the Report are:

- to provide information to demonstrate that the LNG Plant will be designed, constructed and operated to a high standard of safety;
- to consider the influences which might have the potential to cause incidents, and to address the possible hazards which might result;
- to detail and specify the measures which will be implemented both to prevent accidental releases of hazardous materials from occurring on the LNG Plant, and to mitigate their consequences.

The overall goal is to protect the safety of persons, property and the environment. This is achieved through adherence to proper design, construction and operational practices and the identification and adoption of practicable safety features.

Basis for Safe Design and Operation

The basic philosophy in the design of the LNG Plant is to achieve an acceptable standard of safety management by:

- minimising the likelihood of any accidental release of hazardous material;
- minimising the amount of hazardous material released in any incident;
- mitigating the effects of any accidental release incident which may occur.

The basic principles of safe design, construction and operation of LNG facilities are well-established and have been consolidated into international standards and codes of practice of which the main reference document is NFPA 59A. This document, together with other relevant NFPA and API publications, will serve as the basis for the safe design and operation of the LNG Plant.

The most important general consideration in the safety of the LNG Plant is to take all practicable measures in design, construction and operation to prevent any accidental releases of natural gas, LNG or other hazardous material from occurring. However, it is recognised that, in a large and complex facility, it is not possible to eliminate completely the possibility that accidental leakage of process materials might occur on occasions. It is recognised also that, in the very rare instances when major incidents do occur at industrial plants, they invariably arise from smaller incidents which were allowed to escalate and cause damage to plant equipment.

For these reasons, the main thrust of the safety design of the LNG Plant is directed towards the adoption of suitable measures both to prevent any uncontrolled releases of hazardous materials, and to control or minimise the consequences of any small spillages which may nevertheless occur in order to prevent escalation to more serious incidents.

Accident prevention in the LNG Plant is achieved through adherence to recognised standards and codes of practice in plant design, construction, maintenance and operation. Proper material selection, high quality fabrication methods, component design, testing of completed assemblies, and application of design safety factors are most important. Selection of experienced and qualified operators/personnel is also very important for safe plant operations. Preventative measures also include the avoidance of potential sources of failure (e.g. flanged connections) wherever practicable, and specification of over-pressure protection for selected equipment and process vessels.

The LNG Plant is designed to maximise the extent of passive safety measures in the form of safe separation distances between plant equipment and by the use of drainage and remote containment of any spilled liquids. Plant spacings will conform to or exceed the distances laid down in NFPA 59A as a general basis for passive protection to prevent incident escalation. Active measures such as hazard detection and fire control are incorporated into the specifications for the LNG Plant.

Examples of particular measures which will be employed to minimise possible hazards from accidental releases in process and associated areas include:

- on-site surveillance supplemented by spill and fire detection systems;
- hazardous area zoning to prevent ignition of small leakage;
- use of channels and grading to direct liquid spillages away from equipment;
- on-site fire fighting and protection capabilities;
- design of process area buildings to prevent ingress by flammable vapour.

Particular attention is paid to the safety of the LNG storage tanks, because of the large inventories contained. Accident prevention is achieved through adherence to well-established standards for design, material specification, construction, testing, commissioning and operation. Measures employed to minimise possible hazards will include:

- consideration of all conceivable external influences in the tank design;
- specification of an inner tank material (9 % Ni-steel) with proven crack arrest properties in LNG service;
- rigorous quality assurance in material specification and tank fabrication;
- specification of overfill, over-pressure and vacuum protection;
- pre-commissioning leak testing of inner tanks;

- hydrotesting to check foundations under overload conditions.

Mitigation of LNG storage spillages is achieved by the use of grading and channelling the design spills away from the LNG tanks. The remote liquid impoundment area is provided at a safe location to ensure that potential hazards from LPG spills will be minimised in the very unlikely event of a major tank failure.

The LNG berth design will be in accordance with applicable NFPA, OCIMF and SIGTTO standards and guidelines. Accident prevention measures will include adherence to rigid design standards, and the use of alarms and weather forecasting to detect abnormal conditions. Mitigation features will include the use of surveillance, leak detection, emergency shutdown, suitable couplings to limit spillage volumes, and the establishment of effective ship-to-shore communications including linking of emergency systems.

The value of adherence to established LNG industry practices, codes and standards in eliminating the occurrence of major incidents is borne out by the excellent safety record of the modern LNG industry (as noted in Section 1).

Safety reviews will be conducted throughout the design and engineering of the LNG Plant to ensure compliance with specified design standards. Systematic assessments and audits will be conducted continually during its operation to check that practices are maintained to appropriate standards. Additional safety features will be incorporated wherever these are required or where they are shown to be desirable and practicable through the continuing systematic safety analyses.

Initiating Factors and Prevention Measures

The first essential element of the safety design process is accident prevention. This is achieved through the identification of potential hazards which might arise from the LNG facility and analyses of their causes in order to ensure that all possible initiating factors are taken into account in the design and to facilitate the specification of practicable accident prevention features.

An approach to incident identification commonly used in hazard analysis is to utilise an established checklist of possible initiating factors and assess against each the design parameters and responses of plant equipment. This approach serves to ensure that all possible influences are taken into account in the design and that practicable safety features are not omitted.

The checklist is broken down into four categories: natural events; spontaneous failures; abnormal operations; external interference. Each category is then subdivided to include all potential influences which might have the capability to cause releases of hazardous materials, including those which might seem at first sight to be trivial or irrelevant.

Natural Events

Natural events comprise occurrences essentially beyond human control, and include: earthquakes; subsidence; lightning strikes; wind loading; snow loading; flooding; ambient temperature; ambient pressure.

A severe earthquake could have the potential to precipitate releases of hazardous materials through damage to tanks and process equipment and failures of supports and foundations. As required by NFPA 59A and the standards referred to therein, seismic forces are taken into account in the design, and the process equipment, storage tanks and foundations are specified to withstand forces and ground accelerations that could reasonably be expected to occur under the most critical motions envisaged. A seismic investigation will be performed for the Wickham site, and the results will be addressed in the detailed design.

Subsidence would have the potential to precipitate a release of hazardous material through the displacement or distortion of foundations. An extensive ground investigation is being conducted, and the foundations of all process equipment and pipework will be designed to remain stable under the worst predicted conditions. Foundations will be inspected regularly during the operation of the plant. Special consideration has been given to possible settlement of the LNG storage tanks. These are to be located in an area where ground conditions are generally more favourable, and the foundations will be specified to maintain rigidity within design margins under the worst conceivable loading and ground conditions. Tank foundations will be tested under conditions exceeding design loading before commissioning, and regular checks for settlement and/or differential movement will be carried out during the construction, commissioning and operation of the LNG Plant.

Weather conditions are taken into account in the design, with adequate safety margins allowed. Design weather conditions will include ambient temperature and barometric pressure. Wind loading is determined with reference to NFPA 59A and local conditions, including allowances for cyclones. Lightning conductors are specified for tall structures and storage tanks. Drainage is based upon maximum recorded hourly and annual rainfall data. Operating weather conditions will be established to ensure safety in berthing and loading of ships.

Spontaneous Failures

Spontaneous failures concern materials and equipment, and include: design, construction or inherent defects; foundation or support failures; corrosion; fatigue; mechanical or electric failures; low temperature embrittlement.

Prevention of failures caused by defects is essentially accomplished by adherence to relevant standards and codes of practice in design, construction, testing, commissioning, operation and maintenance, and by comprehensive quality assurance to ensure that fabrication and construction meet the design intent. As noted earlier, the value of conforming to the recognised codes and standards is borne out by the excellent safety record of the modern LNG industry. The published codes and standards are based on long experience, and adherence to these, coupled with regular checks, inspections and maintenance, will ensure that the likelihood of defects being present and escaping detection is negligible.

LNG tank, vessel, pipework and equipment foundations and supports will be specified in accordance with relevant codes and standards, and will be subject to regular inspections to detect signs of corrosion, damage, movement or settlement.

Owing to the coastal location of the Wickham Point site, a high potential for atmospheric corrosion is assumed in the design. It is recognised that corrosion can be a route to failure, and a checking and recording system will be used to monitor this. Protective coatings will be applied to pipework and vessels where needed. The process gas streams may be corrosive in some parts of the plant, owing to the presence of water and carbon dioxide. The problems that can arise from the presence of these substances in a high pressure plant are well known, and suitable materials are specified to ensure that equipment integrity will be maintained. Corrosion allowances are included in the design of pressure vessel and pipe walls. Thicknesses will be checked in scheduled inspections.

Fatigue has the potential to lower the critical failure loading of a metal component as a result of repeated reversals of stress. The only items in the process train likely to be subjected to repeated stress cycling are the feed gas dryers, which are designed for the number and amplitude of cycles to be expected during the plant lifetime. Otherwise, significant stress reversals will occur only when the plant is shut down for periodic maintenance and subsequently recommissioned. The LNG storage tanks and loading lines will be subjected to regular stress reversals during filling and loading operations. The stress cycles in the tanks will be of small amplitude, and the loading line design includes allowances for the anticipated cycling with adequate safety margins.

Mechanical or electrical failures would not generally have any direct potential to cause uncontrolled releases of hazardous materials. Some failures (e.g. pump seals or valve glands) could result in small releases which would not in themselves represent major incidents; ignition sources on the site will be strictly controlled, so ignition of such a minor release would be very unlikely. Critical plant equipment will be covered by an emergency electrical supply.

It is well known that unsuitable materials such as carbon steel can become brittle and fail if exposed to contact with cryogenic liquids. All plant equipment handling cryogenic liquids and vapours is specified to be fabricated from proven materials such as stainless or nickel steels. Areas of the outer LNG storage tanks which could be contacted by spillages will be made from suitable materials or protected. Low temperatures can be caused by cooling during repressurization; this effect is well understood, and minimum temperatures are included in the design.

Abnormal Operations

Abnormal operations cover circumstances arising from process upsets or operation outside normal conditions, including: over-pressurisation; vacuum; overheating; overcooking; internal explosion; maintenance.

All of these aspects will be covered in depth through hazard and operability (HAZOP) studies to be carried out during the detailed design of the LNG Plant and equipment. General specifications have been identified, and are noted here. These will be revised as necessary according to the findings of later HAZOP studies.

Over-Pressurisation is one of the most important considerations in the design of the LNG Plant, and a broad specification is included in the design basis. The objective is to protect the integrity of process equipment, pipework and tankage from all conceivable situations where the internal or external pressure could exceed the design condition. Specifications for over-pressure protection are based upon NFPA 59A, with reference to relevant API, ASME and ANSI recommendations and standards.

Possible sources of over-pressure in the process plant are differential pressures in heat exchangers (particularly high pressure natural gas and LNG in the main cryogenic exchange process), and volatile liquids held under subcooled process conditions. High pressures could result also from loss of power, external fire, loss of refrigerant, valve failure, blocked outlets, or operator error. All of these factors are included in the over-pressure protection specification. As a general rule, final over-pressure protection is provided by means of mechanical pressure relieving devices, and all sections of the process plant capable of being isolated are specified to be fitted with such protection, sized for blocked outlet and fire conditions (generally the most onerous cases). Design pressures for compressor casings generally exceed the maximum possible pressures which could be generated by each stage.

The LNG storage tanks are specified with pressure safety valves discharging directly to atmosphere. The capacities of the tank relief systems are based upon plant rundown and failure of the tankage flare system. Over-pressure in the tanks would also trip LNG production. Potentially, one of the more significant sources of over-pressure in a LNG tank could be a 'rollover'. This is a phenomenon that can occur when the LNG in a tank becomes stratified, the normal vapourisation is suppressed, and excess heat is stored in the liquid. After a period of time, mixing of the liquid will occur, the stored heat will be released, and vapour evolved. Often, a LNG rollover may be relatively slow, and the occurrence may even pass undetected; however, the process may sometimes happen quite suddenly, accompanied by a rapid evolution of vapour, although such occurrences are relatively rare. LNG rollover, when it does occur, is usually caused by the introduction of a LNG of a differing density to that already present in a tank during filling. Thus LNG production plants are not generally considered to be subject to the conditions which can cause such phenomena. LNG will be recirculated using the loading pumps in the event of any stratification.

Most of the LNG process equipment and pipework is designed to operate at high pressures significantly above ambient, and internal vacuum is not generally seen as a direct potential cause of failure. Vacuum could occur in the LNG storage tanks as a result of send-out or overextraction of boil-off gas. Protection is specified by trips on loading pumps and the boil-off gas compressor, and by vacuum breaking control valves and atmospheric vents to each tank.

Temperature indicators and alarms will be used to detect overheating or overcooking caused by abnormal process conditions. All process equipment is specified to withstand extreme temperatures achievable in operation.

In order for an internal explosion to occur in the process plant, a flammable atmosphere would need to exist inside the equipment in the presence of an ignition source. Under normal operating conditions, this is not possible. It is conceivable that an internal explosion could occur if equipment were not properly purged before being opened for maintenance or recommissioned. However, provided correct procedures are specified and observed during maintenance and inspections, internal explosions should not be possible.

Maintenance procedures on the LNG Plant will of necessity be wide-ranging and complex. Owing to the high level of direct human involvement in plant maintenance, the potential for human error will exist and is fully understood. Written procedures will be produced and strictly enforced for all operations and maintenance on the LNG Plant to minimise the likelihood of mishaps, and all maintenance will be covered by a rigid permitting system. The obvious importance of strict adherence to procedures at all times is recognised. All practicable measures will be employed to avoid incidents, and procedures will be reviewed and updated continually.

External Interference

External interference covers other influences, and includes: impact damage; pull-away incidents; over-pressure from explosions; thermal radiation or flame contact from fires; unauthorised actions or sabotage.

Possible sources of impact damage to plant equipment are: dropped objects; vehicle collisions; falling aircraft/parts; projectiles generated by explosions.

Objects such as tools could conceivably be dropped onto process plant equipment during maintenance. As noted earlier, maintenance work will be strictly controlled to minimise the likelihood of unfavourable occurrences, and small objects which might nevertheless be dropped from time to time would not be capable of causing significant damage. Personnel would be present during maintenance operations, so rapid action to isolate any leakage would be possible. Lifting operations over operating plant equipment will be avoided wherever possible. When lifting over operating plant equipment is necessary, safe lifting procedures will be developed to ensure safe operation.

Vehicular movements within live process areas will be controlled by a rigidly applied permitting system to restrict access and define permitted routes; all non-essential movements will be prohibited. In addition, vulnerable or high inventory plant equipment will be protected by crash barriers and height gauges.

The Wickham Point site falls within the Darwin Airport Primary Control Zone and is approximately 5.5. nautical miles on the direct approach path for runway 36. This runway is primarily used by smaller training and passenger aircraft. On a yearly basis, approximately 19,000 aircraft use runway 36 with the Southern approach. Under Visual Instrument Flight Rules (VFR) operations, the Southern flight route currently overfly's the plant location at a minimum height of 500 feet.

The Wickham Point site falls within the proximity of the Royal Australian Air Force Base. "Defence Areas Control Regulations-Structure Height Zone" map indicated that, in the vicinity of Wickham Point structures higher than 90 meters above ground level need approval of the Defence Department. The International Civil Aviation Organisation (ICAO) guidelines require the provision of marking or lights on structures more than 60 meters in height above the ground level. None of the structures of the proposed LNG plant have an overall height of 60 meters or more. Since the RAAF base is near the plant's location, marking and/or lights may be required on the structures such as LNG tanks, flares, and stacks. In practice, the only civilian aircraft movements are likely to be occasional helicopter flights bringing personnel to the Wickham Point or Channel Island Power Station.

There are no specific restrictions for a "no-fly zone" around an LNG plant. US Federal Aviation Regulations Part 91, Section 91.119 specifies that the aircraft may not be operated closer than 500 feet to any person, vessel, vehicle, or structure. It is anticipated that military and civilian pilots will be instructed not to overfly (within a 152 meter envelope) the LNG Plant. A safety zone will be established for the LNG Plant in consultation with the Civil Aviation Authority and the RAAF.

Impacts could arise from vessel fragments or debris projected by confined or vapour cloud explosions (VCEs), from sheared parts of rotating machinery, or from valves or fittings broken from high pressure plant equipment. Such circumstances would be extremely unlikely to arise, and the double walled design of the LNG storage tanks would serve to afford additional protection against any impact.

Impact damage might conceivably be caused by a ship striking the LNG jetty pipework or loading arms. As noted in Section 6, suitable controls will be implemented to minimise the likelihood of any such occurrence.

A spillage of LNG, LPG or condensate could possibly arise from excessive movement of a berthed ship, or as a result of a ship pulling away from the berth with the loading arms connected. Measures which will be adopted to prevent such occurrences and to minimise the volumes of hazardous materials released are noted in Section 6.

A release of liquid refrigerant could possibly be caused by truck pull-away during unloading. Established precautions, including the use of wheel chocks, suitable transfer hoses and shut-off valves, will be adopted to prevent incidents and to minimise the quantity of liquid which could be released.

Exposure to thermal radiation could result from ignition of a flammable release. Ignition of a small release would be very unlikely, because the presence of ignition sources will be strictly controlled. If ignition were to occur, adjacent plant or storage tanks could be exposed to thermal radiation or flame contact. The effects of credible ignited releases are included in design specifications, with protection provided to critical equipment by spacing, catchment and fire control.

A high importance will be placed upon training of personnel as a basis for safe operation, reinforced by the preparation of comprehensive written operating procedures and surveillance of plant activities. A permitting system (e.g. Hot Work, etc.) will be implemented, based upon a standard format used in the gas industry worldwide, to provide the necessary control framework to ensure safe working conditions. The operation of the system will be checked on a regular basis to ensure compliance.

Hazard Mitigation

The second essential element in the safety design process is mitigation. This is achieved through consideration of the types of hazard which might conceivably arise from the LNG facility in order that suitable features may be adopted to prevent damage to equipment, possible escalation of the original incident and hazards to personnel and the public. The types of hazard which could arise are described in Section 4.

Unignited high pressure gas releases would have no direct capability to affect off-site areas. Flammable vapour clouds from refrigerated or pressurised liquefied gas releases would not pose direct hazards unless they were ignited; travel distances from smaller releases would not be sufficient to affect public areas, and even very large (extremely unlikely) spillages of LNG, LPG, and condensate or refrigerants would have little potential to cause off-site hazards in normal ambient conditions.

Jet and pool fires from ignited gas or liquefied gas releases would not be capable of causing hazards to the public, because of the remote siting of the process and storage areas in the LNG Plant.

The proposed LNG process train area does not fall into a region of industrial zone in which there would be a possibility of a vapour cloud explosion (VCE) being initiated in certain (unlikely) circumstances. A VCE at the LNG Plant site, therefore, would not cause hazards to the public directly, owing to the remote location of the plant.

It is similarly unlikely that a boiling liquid expanding vapour explosion (BLEVE) could cause hazards to the public in off-site areas directly, owing to the remote locations of the process and refrigerant storage areas.

As noted in Section 4, there have been no confirmed VCE or BLEVE incidents at operating LNG facilities, reinforcing the supposition that such events would be extremely unlikely to occur.

Consideration of the types of potential hazard described above is included in the LNG Plant design. The objective is to ensure that any uncontrolled release of hazardous material that might conceivably occur, in spite of the preventative measures adopted, does not escalate into a major incident. The objective is achieved through specifications for the containment and control of consequences and for the protection of critical emergency equipment and vessels containing large inventories.

The main elements of the hazard mitigation plan are:

- spacing of plant equipment to afford passive protection;
- spill detection and isolation to minimise release quantities;
- drainage and containment of spillages to minimise damage and consequences;
- elimination/control of ignition sources;
- control/extinguishment of fires;
- personnel and equipment protection.

Specification of plant layout to provide for adequate separation distances between equipment is a crucial basis for hazard mitigation. Plant layout for the LNG Plant is in accordance with NFPA 59A. The main safety considerations are the exclusion of all non-essential staff from hazardous areas, together with the provision of access routes for emergency services and escape routes to safe locations for site personnel.

Rapid detection and isolation of any accidental releases of hazardous materials is a prime element in the hazard mitigation plan. Extensive use will be made of the continuous presence of trained operating staff, backed up by automatic devices in critical locations to detect low temperatures, combustible gases, smoke and fire. Process instrumentation will also be used as a means of leak detection. Automatic or manual fail-safe emergency shutdown (ESD) systems will be used at critical points to isolate release sources as quickly as possible.

Drainage of liquid spillages to direct hazards away from critical plant, and containment to minimise hazard distances, are further essential elements of hazard mitigation. It is particularly important that flammable liquids are kept away from vessels containing hazardous inventories and critical safety equipment. Channels, curbs and trenches will be used to direct spillages along predetermined routes to minimise hazards and aid early detection. Any significant liquid spillages arising from process or storage will be collected in the remote impoundment basin described earlier. This will serve to minimise the extent of any vapour cloud or LNG fire and to keep potential hazards away from process plant and storage tanks. Vapour generation will be further reduced by shaping channels to minimise surface contact.

Another important element in the mitigation plan is the control of potential ignition sources. This will be achieved on the LNG Plant site by: electrical area classification (or zoning); suitable specifications for electrical equipment; grounding and bonding of plant; control through permitting of vehicles, welding and cutting; prohibition of smoking in plant areas.

The final line of defence in the hazard mitigation plan is the use of active protection measures to control fires and protect plant equipment from the effects of thermal radiation and flame impingement. It is normal practice to allow a fire involving LNG or other liquefied gas to burn under controlled conditions at a chosen location, rather than extinguish it, to remove the potential hazard from possible re-ignition of the vapour cloud. The primary fire control at the LNG Plant will be the channelling and catchment described above, the remote basin being so located that a fire could burn without posing any threat to personnel. (Other types of fire - not involving liquefied gases - would be extinguished as rapidly as possible using inert gas, water, foam or dry powder as appropriate).

Critical plant equipment will be protected from the effects of any localised fires using strategically located firewater monitors and hand-held hose lines.

Specifications for control measures adopted in the hazard mitigation plan will be based upon the consequences of 'design spills' as defined in NFPA 59A, with reference for general guidance to NFPA 30 and API 2510 as appropriate, but with due consideration given to larger maximum conceivable spills in certain instances. The general baseline is to assume a spillage at the maximum sustainable rate for a minimum period of 10 minutes from process plant or pipework, but to make allowances for total losses from storage tanks and vessels, unless it can be clearly demonstrated that smaller spill quantities apply.

Process Safety Management

The fundamental design principles described in this Section of the Report will be backed by a comprehensive Safety Health and Environmental (SH&E) management program to ensure the overall effectiveness of hazard control through all stages of activity including engineering, construction, commissioning, operation and maintenance - with a high importance placed upon safety at all levels. It is recognised that a high proportion of accidents are caused by human error - lack of knowledge, inattention or thoughtlessness - and the aim of the program will be to eliminate these factors.

The primary elements of the SH&E program will be:

- a statement of SH&E policy;
- a structure for formalised safety reviews;
- procedures for safety in procurement, construction and commissioning;
- site operating and maintenance procedures;
- environmental consideration at every stage of the design, construction, and operation of the plant;
- personnel training;
- emergency procedures;
- a pre-start-up safety review;
- regular audits and reporting.

HS&E policy will cover the basic philosophy, the principal codes and standards to be followed, and targets for safety performance.

A schedule will be drawn up for formal safety reviews, to follow a structured program covering the design, fabrication, construction, testing, commissioning and operation of the LNG Plant. Design reviews will include an initial process hazards review and analysis and detailed HAZOP (hazard and operability) studies and reviews of P&IDs (piping and instrumentation diagrams) and equipment data sheets at key stages.

Procedures for procurement, construction and commissioning will cover compliance with requirements for material selection and service, and will apply to all contractors, fabricators, suppliers and vendors. Written quality control procedures will be produced to cover the fabrication and installation of critical equipment to ensure adherence to design specifications. Precommissioning inspection and testing requirements will be set down, and detailed commissioning procedures drawn up for all plant, equipment and storage tanks.

Site operating and maintenance procedures will be written to cover identification of responsible persons, start-up, normal and abnormal operations and shutdown situations. Safe working practices and training requirements will also be covered.

Emergency procedures will be drawn up to cover plant control actions required to achieve safe holding or shutdown conditions, and to ensure the safety of personnel. These are described in Section 8.

The pre-start-up safety review will be structured to check that all construction meets intended specifications, that written safety, operating, maintenance and emergency procedures are in place, and that training of personnel has been completed.

All safety plans and procedures will be subject to periodic audits and reviews to ensure continued effective performance, with audit findings being contained in written reports. Any hazardous incident which may occur will be investigated to establish the factors contributing to its cause, and recommendations made for any necessary changes to procedures and practices.

Responsibility for project safety will rest ultimately with senior management who will ensure that the safety program is planned and implemented in an effective manner, and that all parties involved comply with policy and procedures at all times.

Summary and Conclusions

The primary goal in the specification for the LNG Plant is accident prevention, achieved through the use of recognised standards, proper material selection, attention to design, high quality fabrication, and comprehensive testing and commissioning procedures, with the application of adequate safety factors. This will be reinforced by strict adherence to established operating and maintenance procedures, incorporated into a formalised safety management program.

The fundamental aim is to achieve a goal of zero accidental releases. This will be complemented by a comprehensive mitigation plan, based on the hazards which could conceivably arise if spillages were to occur. Mitigation will be achieved by plant spacing, release detection and spillage containment, with a back-up fire fighting capability.

Phillips fully recognises and understands the potential hazards from LNG production, and the ways in which accidents might arise. The accident prevention and mitigation measures described will be reviewed and refined through systematic hazard studies. When implemented, the measures will serve to minimise the likelihood that any unplanned releases of hazardous materials will occur, and to control the consequences of any accidental spillages which might conceivably arise in spite of the primary preventative measures.

SECTION 6

LNG Carrier Accident Prevention

Introduction

This Section of the Report is concerned with the management of potential hazards arising from the operation of LNG carriers, particularly in the vicinity of the Wickham Point LNG Plant site.

The objectives of this Section of the Report are:

- to provide information to demonstrate the high standard of safety achieved in the design, construction and operation of LNG carriers;
- to address the potential hazards attributable to LNG carrier operations and the ways in which accidents might arise;
- to specify the measures to be implemented to prevent accidents from occurring.

The overall goal is to identify and adopt all practicable measures to ensure that the continued safety of employees and members of the public will not be jeopardised by the operation of LNG carriers at, and in the vicinity of, the LNG Plant and Terminal.

Basis for Safe Operation

The design and construction of LNG carriers, including the specification of control and safety systems, is covered by the IMO Resolutions A329(IX) and A328(IX) and the IGC Code referenced in Section 2. The promulgation of these codes, and the responsible attitudes of LNG carrier owners and operators, have resulted in a high standard of design, construction and operation.

LNG carriers are equipped with specialised systems for preventing and combating potential hazards associated with LNG spillages in line with the code requirements, including water sprays and dry powder systems for fire protection. LNG and vapour lines are routed above deck. Void and insulation spaces within the hold are monitored continuously for gas leakage, and are either maintained inert, or are capable of being made inert quickly, in order to minimise the likelihood of an explosion causing damage to a cargo tank. Enclosed engine room spaces are equipped with fire control systems and double bulkheads to afford extra protection for the LNG cargo tanks. All LNG carrier cargo tanks are subjected to stringent checks during construction and commissioning, and at regular intervals thereafter, to ensure integrity.

LNG carriers are maintained to the highest standards, and are subject to classification society surveys at regular intervals (including structure, machinery, cargo containment, navigation systems and safety systems). These surveys must be completed, and the LNG carriers must satisfy specific classification society and IMO requirements, before certificates of compliance (which need to be renewed periodically and without which the carriers are not allowed to trade) can be issued.

Safety in the loading of LNG carriers is achieved through standards of equipment design, and by a close mutual understanding between ship and shore personnel. The application of NFPA, OCIMF and SIGTTO guidelines for berth design, mooring systems, procedures and contingency planning serves to provide a secure basis for the safe loading of LNG cargo. Ship safety systems are checked before each loading operation.

The safety of LNG carriers under way or berthed in the Wickham Point area will be enhanced by the enforcement of effective marine controls and procedures through the Darwin Port Authority.

The effectiveness of the high safety standards applied to LNG carrier design, construction and operation in eliminating hazardous incidents is borne out by the excellent historical record (as noted in Section 1).

Initiating Factors and Prevention Measures

It is recognised that the consequences of an uncontrolled release of LNG from a carrier at, or in the vicinity of, the Wickham Point site could be severe, and that the likelihood that such an event might occur must therefore be so low as to be effectively negligible. Thus the principal emphasis in the management of hazards from LNG carrier operations is on eliminating the causes of incidents. In this context the primary concern in the hazard assessment and management process is to identify and analyse potential causes of incidents which could result in releases of LNG from marine carriers.

A number of possible initiating events which could, at first sight, have the potential to cause cargo releases from LNG carriers can be identified. These can be listed as: collisions in transit; grounding; striking fixed objects; striking the jetty; a carrier being struck while berthed; fire/explosion; escalation of transfer spillage; sudden tank failures; environmental influences. The importance of each possible initiating factor, and the preventative measures taken, are considered below.

LNG Carrier - Ship Collision in Transit

The potential of a collision to cause a release of LNG cargo would be dependent upon the likelihood of collision, and upon the speed, displacement and angle of approach of an impacting vessel. In order for such a collision to occur, there would have to be a breakdown in communication, a failure in navigational procedures or equipment, or a failure to observe port traffic controls.

Despite a superficial similarity in size and form to early oil tankers, LNG carriers are structurally very different, having a double hull structure which provides a high degree of resistance to possible damage from impact. (Newer oil tankers are constructed to a similar design to LNG carriers, and have similar strength and damage resistance). Structural analysis can be used to demonstrate that, in order to pose any threat to a cargo tank integrity, a colliding vessel would need to exceed a critical momentum - i.e., for a colliding vessel of a given displacement, a critical speed would need to be exceeded before penetration could occur. Minimum speed figures for an impact on a free floating 135,000 m^3 carrier are: ~12 knots for a striking ship of 10,000 te displacement; ~8 knots for 30,000 te; ~7 knots for 60,000 te. Whilst these figures are not exact, they do serve to provide reasonable guidance. The figures are based upon assumed side-on perpendicular impacts at vulnerable points; higher critical impact speeds would apply in other cases.

At present, there is no other significant shipping using the Wickham Point area. Large vessels do use the deep draught channel to Port of Darwin. The Darwin Port Authority handles approximately one million tonnes of imports and exports each year with more than 700 trading vessel visits. These vessels include livestock carriers, rig tenders (for the offshore oil and gas industry), container and general cargo vessels, petroleum tankers, passenger vessels, car carriers, and barges. A similar number of visits are made by non-trading vessels, comprising fishing, prawning, pleasure vessels, and the Royal Australian Navy ships (mainly during military exercises). The largest vessel to have berthed at Darwin harbour was an 81,000 dwt tanker with a draft of 12.8 meters and 246 meters LOA. A new port facility is now being constructed at East Arm less than 3 km south east of the existing port facilities. Coastal shipping movements between Darwin Port and Wickham Point comprise only small work boats and similar craft, which would not pose any threat to LNG carriers.

The imposition of the marine traffic controls (e.g. prohibition of opposing movements, application of moving safety zones around LNG carriers, enforcement of speed limits) will be discussed with the Darwin Port Authority and the Royal Australian Navy with a view to implementation as necessary in order to eliminate the likelihood of any collision occurring.

Based upon these considerations, reinforced by the implementation and enforcement of effective port area traffic controls, it is concluded that the likelihood of an impact leading to a release of LNG would be extremely low.

LNG Carrier Grounding

The potential of a grounding incident to cause a release of LNG from a marine carrier would depend upon the likelihood of occurrence, and upon the nature of the sea bottom and the length of time (number of tides) needed to refloat the carrier. In order for a grounding incident of a laden carrier to occur in the vicinity of the Wickham Point site, a departing carrier would need to leave the dredged channel (e.g. as a result of steering gear or engine failure and loss of tug control).

As noted earlier, LNG carriers have a double hull structure which affords a high degree of resistance to impact damage; the same would apply in the case of a grounding incident.

The low speed of a departing carrier, together with tug attendance during the manoeuvre, would make it very unlikely that a severe grounding incident could occur. The brunt of a grounding incident while under way would be borne by the strong bow of the carrier and the structure forward of the cargo tanks, while a sideways drifting grounding would unlikely be severe.

One possibility is that a prolonged grounding might overstress the carrier structure owing to repeated tidal movements. It can be shown that, even under the most onerous conditions in an area with significant tidal and wave movement, the hull loads would be well within the permitted operational envelope, and the likelihood of cargo tank failure would be remote even after several tidal cycles. The moderate tidal rise and fall in the Beagle Gulf, and the calm weather conditions and low wave activity, serve further to reduce the likelihood of any damage occurring.

The extreme water level studies that have been conducted for Channel Island Power Station concluded that:

Return Period	Storm Tide Level Above Aus. Height Datum (m)
1,000 years	6.1
10,000 years	7.0

The probability of the 1,000 year level being exceeded in say the 50 year life of the LNG plant would be 4.8%. The probability that the 1/10,000 year level would be exceeded in 50 years is 0.5%.

The resistance of LNG carriers to grounding incidents is demonstrated most effectively by reference to the well known El Paso 'Paul Kayser' incident. This involved the severe grounding of a fully laden carrier, resulting in extensive damage to the ship's keel, but with no leakage of LNG from the cargo tanks.

Based upon these considerations, it is concluded that the likelihood of a LNG cargo release resulting from a grounding incident would be negligible.

LNG Carrier Striking Fixed Object

The potential for a cargo release to arise as a result of a LNG carrier striking a fixed object in the vicinity of the terminal would be dependent upon the likelihood of interaction, and upon the speed and angle of impact. In order for such an incident to occur, there would have to be a failure in navigational procedures or equipment.

Owing to the structural arrangement of the fore-end of a LNG carrier, the head-on impact energy required to cause sufficient damage to threaten the integrity of the cargo containment would be very high. LNG carriers are required to have a watertight collision bulkhead, together with a second bulkhead, forming a cofferdam forward of the cargo area. The impact velocity required to affect the forward cargo tank can be calculated to be around 7-10 knots for the case of an infinitely massive rigid obstacle. A sideways drifting impact would not be likely to be severe, and could occur only if the LNG carrier were disabled and bereft of any necessary tug assistance. When manoeuvring in the Wickham Point area, laden (departing) LNG carriers would be moving at relatively low speeds (probably less than 4-5 knots). Furthermore, the objects which a carrier could conceivably strike would be neither infinitely massive nor rigid.

As noted elsewhere, LNG carriers are provided with extensive fire protection and have a high resistance to fire exposure, so it is unlikely that significant damage would result even if such an incident were to occur.

Based upon the above, it can be concluded that the likelihood of a release of LNG cargo arising from a LNG carrier striking a fixed object in the port area would be extremely low. Any additional measures needed to reduce further the likelihood of an incident occurring will be developed in liaison with the Darwin Port Authority and the RAN.

LNG Carrier Striking the Jetty

It can be shown that a LNG carrier would need to strike a jetty at a sideways velocity in excess of about 6 knots in order to threaten the integrity of the cargo tanks. A head-on impact would be more likely to cause serious damage to the jetty than to threaten the integrity of the cargo tanks (as noted in Section 5).

It would be almost impossible for a laden (departing) carrier to strike the jetty at the LNG Plant in this manner - an exceedingly unlikely combination of circumstances would be required before this could occur - and in general terms, there is little or no potential for a laden LNG carrier to strike the loading jetty at any speed.

LNG Carrier Struck while Moored at the Jetty

The potential for a release of cargo to result from a LNG carrier being struck while moored at the loading jetty could possibly exist, depending upon the types of shipping passing the jetty and the transit speeds. (This can be one of the main possible causes of LNG cargo release in cases where the LNG jetty is located close to a busy waterway.)

This case is similar in some respects to the LNG carrier-ship collision scenario considered earlier, and it can be shown in the same way that a passing ship would need to impact the berthed LNG carrier in excess of a critical speed, dependent upon displacement, before the integrity of the cargo tanks could be threatened. Example minimum figures for an impact on a berthed 135,000 m^3 carrier are: ~11 knots for a striking ship of 10,000 te displacement; ~7 knots for 30,000 te; ~5 knots for 60,000 te. Once again, these figures are not exact, but they serve to provide reasonable guidance. The figures assume a side-on impact at a vulnerable point, and are in this respect conservative.

In the case of the Wickham Point terminal, there is currently no significant shipping using the dredged channel past the proposed berth. If this situation continues, the possibility of a LNG release resulting from a berthed carrier being struck will not be an issue. However, if other large displacement vessels need to use the channel in the future, careful attention will need to be given to the implementation of port regulations and traffic controls (e.g. imposition and strict enforcement of speed limits, banning of other movements in the channel during LNG carrier manoeuvres, regulation of shipping movements in the channel while a carrier is berthed) in order to eliminate the possibility of a LNG carrier being struck and its cargo tanks being damaged. Careful design of the dredged channels could also assist in reducing the likelihood that an errant ship could strike a berthed LNG carrier.

It is concluded that the likelihood of a cargo release resulting from a LNG carrier being struck while berthed would be negligible based upon present local marine traffic densities. Future increases in traffic, especially large vessels, will need to be carefully monitored, and traffic control measures implemented as required in discussions with the Darwin Port Authority.

Fire/Explosion on LNG Carrier

The possibility that a fire or explosion might occur on a LNG carrier and lead to a release of LNG cargo needs to be considered. A fire or explosion might conceivably occur in one of three locations - the cargo area, the personnel accommodations or the engine room.

The historical record tends to support the view that fire and explosion incidents on LNG carriers would not be likely causes of cargo release. Only a few incidents have been reported on LNG carriers in service, and none has resulted in any release of LNG cargo.

A cargo area incident would not normally be possible below deck level, since (as noted earlier) cargo lines are routed above deck, and void spaces are monitored and are either maintained inerted or are capable of being inerted quickly. It is not conceivable that a fire or explosion above the deck could threaten the integrity of the cargo tanks.

The possibility of a fire in accommodation areas cannot be dismissed, owing to the presence of flammable materials and ignition sources. These areas are afforded high levels of fire protection, in accordance with the IMO codes, including fixed fire fighting systems, specification of the forward bulkhead as hydrocarbon fire rated, and elimination of openings to the cargo area. Bearing in mind that any accommodation area fires which might occur would be likely to be relatively minor, and taking account of the extensive fire protection provided in the cargo area, it is not really conceivable that an accommodation area fire could threaten cargo tank integrity.

Perhaps the most likely location for a LNG carrier fire or explosion to occur would be the engine room, and the possibility of an incident cannot be discounted entirely, although it would be very unlikely. IMO codes and classification society rules require the separation of engine and machinery rooms from the cargo area by double bulkheads, affording a very high level of protection. Historically, no engine room explosions which have occurred in LNG and LPG carriers have resulted in hazardous releases through damage to cargo tanks. The use of gas detectors in engine rooms would help to forewarn of any potentially hazardous situations.

Based upon the above considerations, it is concluded that it is extremely unlikely that a fire or explosion on a LNG carrier could lead to a release of LNG from the cargo tanks.

Escalation Following Cargo Transfer Spillage

The possibility of escalation following a spillage of LNG during cargo loading (e.g. as a result of excessive ship movement or pull-away) needs to be addressed in the hazard management process.

The historical record bears out the view that escalation of a cargo transfer spillage would not be likely to lead to a major release of LNG from a ship's cargo tanks. A few incidents have been recorded which caused extensive deck plate cracking, but none escalated further.

Considerable effort and expenditure have been devoted by LNG operators towards the specification of cargo transfer systems and procedures to ensure that both the likelihood of an incident, and the volume of LNG released, are minimised. The application of OCIMF and SIGTTO guidelines for berth and mooring system design would provide a sound basis. The use of emergency shut down (ESD) systems and suitable couplings should serve to ensure that the volume of any LNG spillage which did occur would be minimised. Shutdown and disconnection will be linked through alarms to a defined envelope to prevent significant spillage caused by excess carrier movement, and ship and shore ESD systems will be linked in accordance with SIGTTO recommendations.

A transfer spillage of LNG could possibly originate from the transfer pipework and equipment (loading arms) or through overfilling of a cargo tank. Escalation could conceivably arise through an explosion following ingress of vapour into the engine room or the ballast space.

Flammable vapour could conceivably enter the engine room through air intakes, but only following a large spillage of LNG (which would be very unlikely to occur for the reasons noted). Even if, in spite of precautions, an engine room explosion were to occur, this would in any case be unlikely to threaten cargo tank integrity (as noted earlier).

Flammable vapour could possibly enter ballast spaces through cracked deck plating. However, most LNG carriers have deck protection resistant to LNG temperatures in the vicinity of the cargo manifolds, and there are no ignition sources present in the ballast spaces, so it is most unlikely that a cargo transfer spillage could escalate through this route.

Based upon these considerations, it is concluded that, while the aim is to achieve zero spillages, the possibility of a release of LNG occurring during cargo transfer cannot be ruled out entirely, but a major spillage and escalation of the original incident would be extremely unlikely. Any additional safety features felt to be needed will be identified at a later stage in the design through an interactive safety review process.

Sudden Cargo Tank Failure

The possibility that a LNG cargo tank could fail suddenly needs to be considered in the hazard management process. Postulated failure mechanisms include: design defects; fatigue; over-pressurisation; internal fire/explosion; internal impact.

As noted earlier, the historical record shows that, in over 11,000 laden voyages, there has not been a single incident of LNG cargo tank failure leading to a release of LNG cargo from any cause, and LNG carriers and their cargo containment are subject to the strictest standards of design, construction, operation and maintenance. Spherical tanks are designed to a 'leak before failure' criterion (meaning that small defects would produce minor detectable leaks long before developing into more serious failures), while membrane tanks are provided with complete secondary containment capable of holding the contents.

All LNG carrier cargo tanks are subject to rigorous testing and examination during construction and commissioning and whilst in service. Hence the likelihood that a sudden failure of a cargo tank could occur as a result of a design or fabrication defect, or as a result of fatigue, is extremely remote. In addition, the cargo tanks are designed to cope with the stresses present in a ship on the open sea, so a failure in the relatively calm waters of the Beagle Gulf would be even less likely.

LNG carrier cargo tanks are protected against over-pressure by relief valves sized for fire exposure. Pressures in the insulation spaces of membrane tank liners are carefully controlled and monitored to avoid damage to the primary or secondary barriers. Overfill alarms are also provided for cargo loading. Thus at least two independent failures (i.e. the initial cause of over-pressure/overfill and a failure of the pressure relief system) would be needed before over-pressure damage could occur.

Internal fire/explosion incidents are not conceivable in intact cargo tanks, since these are maintained at positive pressure under LNG vapour with no air present.

Internal cargo pumps are located at a low level in the tanks, and can only be removed when tanks are empty. Other objects are taken into the tanks only when they are emptied for maintenance. LNG transfer lines will be fitted with strainers to prevent the ingress of foreign objects. Thus the possibility of causing damage to the LNG tanks due to an internal impact is minimised.

Based upon these considerations, it is concluded that a sudden cargo tank failure could occur would be extremely remote.

Environmental Influences

Environmental influences which need to be considered in the assessment and management of hazards include severe weather (wind, rain, visibility) and marine conditions (wave, tide, current).

It is not conceivable that these influences could be a direct cause of damage to LNG carrier cargo tanks, although they could possibly be a contributory factor in a collision, striking or grounding incident, or a cause of LNG spillage during cargo transfer operations. All of these cases are discussed earlier.

Darwin is in the cyclone belt and has monsoonal climate. May to September is the Dry Season with the prevailing wind from the South East. The land breeze can be increased to 24 knots by weather systems south of the continent. There is a predictable daily land and sea breeze. The Wet Season starts in November and finishes in April, this is also the period for cyclones. The winds are generally from the North through the West. This season has heavy rain and thunder squalls.

Weather forecasts will be used to provide warning of severe conditions, and, in common with international port practices and in line with OCIMF recommendations, limits will be set, in discussion with the Darwin Port Authority, outside which a LNG carrier will not, for example, be allowed to enter the port, manoeuvre, berth, depart, or remain at the jetty (although periods of poor visibility in the Beagle Gulf are generally brief, and sudden shifts in wind occur very occasionally but only for short periods). The same will apply with regard to marine conditions (although there is only a very moderate tidal rise and fall in the Beagle Gulf, with little wave activity, and current patterns are known). Also, LNG carrier manoeuvres are not generally allowed in port areas outside daylight hours. As noted earlier, excessive movement of a berthed carrier, caused by severe weather or marine conditions during cargo loading, would trigger alarms and initiate shutdown and release of the loading arms.

Based upon these considerations, it is concluded that it is most unlikely that environmental influences could lead to a release of LNG from cargo containment. The specification of operating limits for LNG carrier loading and manoeuvres (wind, tide, current, visibility, etc.) would minimise the likelihood of any incident; these conditions will be developed in liaison with the Darwin Port Authority and with reference to internationally accepted guidelines.

Summary and Conclusions

The overriding goal in the operation of LNG carriers serving the LNG Plant is to prevent any incidents from occurring which could lead to uncontrolled releases of LNG. This is achieved through identification of potential causes of accidents and adoption of measures to prevent their occurrence.

Although the safety record of LNG carrier operations is excellent, this is not taken as a reason to be complacent. Phillips fully recognises and understands the ways in which incidents could conceivably occur, and are committed to specifying and implementing all practicable preventative measures.

The operation of LNG carriers in the Beagle Gulf and the Wickham Point harbour area will be discussed in continual dialogue with the Darwin Port Authority and the RAN to ensure that all necessary controls and measures are put in place and enforced. In particular, future movements of other large vessels in the vicinity of the LNG berth will be subject to the most careful consideration. Port controls will be developed in discussion with the Darwin Port Authority and the RAN, and reviewed and updated through the planning, commissioning and operation of the LNG Plant. In addition, a 'Port Emergency Plan' shall be developed with the Darwin Port Authority and the RAN to cover responses to non-routine or potentially hazardous situations.

It is concluded that the established design and operation practices, reinforced as necessary by port controls and safety measures, will serve to ensure that the likelihood of a major incident occurring and causing a hazardous release from a LNG carrier will be extremely remote.

SECTION 7

Quantitative Risk Assessment

Objectives

The objectives of this semi-quantitative Risk Assessment will be to:

- Rank the development scenarios in terms of risk to personnel (Potential Loss of Life (PLL) over the total lifetime of the facility);

- Establish semi-quantitatively the difference in risk levels between the development scenarios (differences in PLL); and

- Assess the predicted risk levels for the most exposed worker for the development scenarios in comparison to the relevant "Individual Risk" (IR) criteria.

The fundamental unit of measurement of risk is fatalities per year.

The principal elements of the Risk Assessment will include:

- Review of risk/accident scenarios (hazard identification) which has been covered in the earlier sections of this report;

- Assessment of initiating event frequencies;

- Consequence assessment on general basis; and

- Evaluation of severity of consequences and their impact.

Consequences of Hazardous Events

Hazards Associated with Hydrocarbon Releases

Hazards associated with LNG spills and accidental releases have been addressed in Section 4 of this report.

LPG forms flammable mixtures with air in concentration between approximately 2% and 10% v/v. It can therefore be a fire and explosion hazard if stored or used incorrectly. If LPG escapes into a confined space and is ignited an explosion could result. Vapour/air mixtures arising from leakage or other causes may be ignited some distance from the point of escape, and the flame could travel back to the source.

Frequencies of Occurrence of Hazardous Events

In order to assess the total risks imposed by hazardous incidents, it is necessary to calculate the frequency of occurrence. This is carried out in three steps.

i) assessment of frequency of release
ii) assessment of probability of ignition and control
iii) allocation of specific hazardous causes to different areas of the site.

Release Frequencies

Failure rate data from standard sources will be used to assess the frequencies of release from process equipment item failure. Site specific factors can be used, where appropriate to modify these failure rates. The failure rates are applied to equipment items to obtain a range of failure cases.

The probabilities for ignition that were used in previous studies for similar installations were, 0.2 for ignition on site and for the case of tank rupture, the ignition probability was 0.3 to account for the larger spill size. The probability of delayed ignition of the cloud offsite was taken as being zero as the cloud will cross open sea on the North, West, and South of the plant and open land on the East of the plant. It can be further assumed that if a drifting cloud impinged on the LNG plant it would ignite immediately, due to the combustion equipment present.

The probability of VCE occurring, given that ignition occurs can be assumed as 1, due to large inventories of LPGs on the site. If the cloud ignites without a VCE occurring, then a flash fire will result instead. The probability of tank rupture will be approximately 1.34×10^{-5}, per year. Based on this probability the frequency of VCE occurring will be 1.7×10^{-6}, per year. The probability for continuous release from a LPG tank will be approximately 2.15×10^{-4}, per year and the frequency for VCE occurring will be 1.9×10^{-5}, per year. Thus the risk levels to exposed workers and the risk of substantial damage to the LNG Plant are very low and are within acceptable criteria.

It may be noted that the detailed engineering for the design of the LNG Plant and marine terminal has not been performed at this stage of the project. When the Process and Instrumentation Diagrams (P&IDs) and final equipment layout are completed, more in-depth studies such as HAZOP (Hazard and Operability), "what-if" analysis including failure-tree analysis will be conducted. After these studies are concluded, more information will be available for conducting a detailed Quantitative Risk Assessment.

SECTION 8

Basis for Emergency Plans/Procedures

Introduction and Basis

At this stage in the development of the LNG Plant, detailed emergency plans and procedures have not been formulated. These will be developed in liaison with the appropriate civil and maritime authorities through continual dialogue during the detailed specification of the LNG Plant in order to ensure that all the appropriate operational procedures are in place, and the necessary facilities available, before the commissioning of the plant. (It is not envisaged that site construction activities would be capable of generating major emergencies, and procedures required to deal with localised on-site situations will be developed before activities commence as required.)

In the above context, the purpose of this Section of the Report is to explain the bases for the emergency plans and procedures which will be in place when the LNG Plant is operational, rather than to attempt to provide the specific details which will be developed at a later stage.

The principal reference documents used for general guidance in the development of the emergency plans will be API, Work Health, OSHA and ICS/OCIMF/SIGTTO documents referenced in Section 2. These guidelines will be used in conjunction with the requirements of the Government of the Northern Territory. Existing civil and port area emergency plans will be taken into account in order to ensure that a fully compatible and functional plan is developed.

Relevance of Major Accidents

The basis for emergency planning is the response to, and control of, conceivable hazardous incidents. The prime requirement is the early detection of a flammable release or fire, and an appreciation of the possible immediate consequences and any potential for escalation to a larger incident.

As described in this Report, all practicable measures will be adopted to prevent hazardous incidents from occurring and to minimise their consequences. In spite of these precautions, it is necessary to consider the remote possibility that a minor incident could escalate into a more major accident, and to have in place procedures to ensure that site personnel and (in extreme cases) members of the public are not subjected to unnecessary hazards. Understanding situations where control of a minor incident might be lost, with escalation a possible outcome, will be crucial in deciding on the implementation of emergency procedures.

Once the detailed design of the LNG Plant is established, an appraisal will be carried out of the hazardous substances which will be present, their properties and inventories, and the potential for accidental releases to occur. Using this information, a hazard database of conceivable incidents will be drawn up and their consequences analysed. The incidents and consequences will be discussed with the appropriate civil and port authorities (in the context of their potential for occurrence) in order that the necessary emergency plans and procedures may be developed and dovetailed with the capabilities of the local and national emergency services.

Owing to the remote locations of the LNG Plant process, storage and jetty facilities in relation to residential areas, it is very unlikely that anything less than the most extreme conceivable accident on the site would have any capability to affect the public outside the site boundaries. Major "worst conceivable accidents" will be included in the database for emergency planning, this is not a tacit admission that such events would be likely to occur, but an understanding of the need to ensure personnel and public safety in the most extreme circumstances. It is common practice in the LNG and other industries to base emergency plans on the consequences of such major accidents.

On-Site Emergency Plan

A written site emergency plan will be produced to cover conceivable accident situations. The plan will clearly describe the emergency organisation of personnel. The responsibility for deciding when to implement an emergency plan will rest with the site manager, and a key dedicated person (probably the shift supervisor or equivalent) will be designated to coordinate on-site actions.

The emergency plan will comprise a document outlining possible hazards and detailing how each is to be dealt with. Procedures will cover communications, chains of command, marshalling of resources, specific personnel duties, incident control, evacuation, and liaison with external organisations and emergency services. It is recognised that it will not be possible to cover every conceivable eventuality in the emergency plan, and that this should therefore be flexible and provide clear guidance on information to be communicated when a situation develops.

The emergency plan will be supported by written emergency response manuals, relevant sections of which will be available to, and required reading for, all site personnel needing to work in hazardous plant areas, especially those likely to be directly involved in emergency response. The manuals will set down the procedures needed to implement the relevant part(s) of the emergency plan, and will be designed to provide instructions and advice to personnel involved in the response to an emergency on the actions to be taken.

A fundamental prerequisite to the smooth operation of emergency planning is familiarity achieved by thorough training. The normal operational training of site personnel will cover the immediate actions to be taken on detection of an incident in any plant area. Such training will include the use of 'live' exercises to simulate red emergency situations as closely as possible, with full scale exercises conducted perhaps at one or two year intervals supported by more frequent small scale simulations. The written plan and procedures, and particularly the effectiveness of communications, will be reviewed and updated in the light of the findings from these exercises.

LNG Ship Emergencies

Planning for emergencies on LNG carriers will be based upon an understanding of the types of accidents which could occur (in spite of precautions described earlier in this Report) and their possible consequences, together with an effective system of communication. Written procedures will be developed in continual liaison with the Darwin Port Authority and the RAN, and will be based upon ICS/OCIMF/SIGTTO guidelines, with due cognisance of existing regulations and emergency procedures prevailing in the Beagle Gulf and the Darwin Port harbour area.

Emergency procedures for the LNG carriers will cover two situations: cases where the ship is at or close to the LNG berth; cases where the ship is at sea in the Beagle Gulf or in the approaches to the Darwin Port harbour area.

In the first situation, a particularly important aspect of these procedures will be the relationship between the on-site and ship emergency supervisor (e.g. the shift supervisor and the ship's master). Clear definitions of responsibilities and areas of influence will be clarified in the emergency procedures. Instances where a berthed ship should be disconnected and moved away from the site (to protect the ship from a site incident, or vice-versa) will be defined. Both the site and ship operators will be able to request emergency shut-down (ESD) of LNG transfer and each will have the ability to activate this through the hard-linking of ship and shore ESD systems.

In the second case (a LNG carrier at sea), the emergency response would not involve the LNG Terminal directly. However, the movement of LNG carriers in the Beagle Gulf is of concern, and the development of emergency procedures will form part of the overall preparation for the LNG Plant operation.

Emergency plans for ships in the Beagle Gulf will take account of the existing general emergency plans covering the area, and wider procedures laid down for the LNG carrier at sea. It is likely that contingency plans already existing in the Beagle Gulf for oil tankers and chemical carriers will cover many aspects of LNG ship emergency planning; however, owing to the special nature of LNG ships and their cargoes, some adaptation and modification may well be needed. Key elements of the plan will be: speed and effectiveness of response in the context of possible accident consequences; adequacy of resources; assured communications and flow of information; constant control of incident response.

If an incident were to occur on a ship away from the LNG Plant site, the immediate actions would need to be taken by the ship's crew. Each LNG ship will have on board written procedures containing, as a minimum, general guidance on actions to be taken to limit damage following an incident such as a grounding, collision or fire. Ships operating in the Beagle Gulf will also carry instructions relating to communications with the port authorities in the event of an incident occurring.

As in the case of the on-site plan, the ship emergency procedures will be reinforced by training and exercises, and will be reviewed and updated continually in dialogue with the Darwin Port Authority and the RAN.

Emergency Evacuation

The detail on-site and ship emergency procedures will include provisions to evacuate site personnel (and the crew of a berthed carrier) to safe locations from any areas where incidents might occur.

Written procedures will include provisions to instruct staff and key designated personnel of the actions to be taken on activation of audible or visual alarm signals, and safe areas will be defined to cater for circumstances and incident locations. Situations under which areas should be evacuated will be described in written procedures, allowing flexibility for the judgment of operators present at the time.

As an ultimate safeguard, procedures will be developed to evacuate all personnel (other than those required to carry out essential emergency actions) from the LNG Plant site (including a berthed carrier) in an extreme situation, and to ensure the safety of those required to remain. Procedures will include definition of circumstances where such action should be instigated, allowing flexibility for the discretion of the personnel controlling the site/ship response and of the civil/port authorities where present.

The development of the site evacuation plans will be included in discussions with the appropriate civil and port authorities, who will be invited to observe/supervise training and exercises which will be conducted to ensure smooth and efficient operation.

External Liaison

There are three important aspects to liaison between the LNG Plant and ship operators and the appropriate civil and port emergency services: the development and continual review of emergency plans and procedures; joint participation in training and emergency exercises; effective and rapid communications and responses in real emergency situations.

The LNG Plant site and ship emergency procedures will be discussed continually with the appropriate civil and port authorities, and with police, fire and ambulance services, throughout their development and during their enforcement. Liaison with the port authorities will be coordinated through the Darwin Port Authority. Dialogue during the early pre-emergence planning stage will ensure that the external authorities have a full understanding of the nature of the potential hazards to be addressed, and are able to advise on the capabilities and limitations of their resources.

It is recognised that the civil and port emergency services will already have in place their own emergency plans for dealing with situations which could originate from existing sources within their areas of influence. Planning cooperation between the LNG Plant operators and the civil and port authorities will extend to ensuring mutual compatibility between plans.

Training and 'live' exercises will be used to reinforce the effectiveness of the emergency procedures and to identify and rectify any perceived weaknesses. It is envisaged that external emergency services and authorities will be fully involved in the planning and execution of exercises, and participate in ensuing debriefings. The vital importance of effective communication, cooperation and understanding between the site, ship, local and national emergency services is fully recognised, and exercises and training will be designed with this in mind.

If an emergency situation were to arise at the LNG Plant or an LNG ship, the senior duty manager or ship's master would decide, in accordance with the emergency plan, at what point to inform the civil and/or port authorities and at what point to request assistance. It is not practical to attempt to provide complete details of situations and liaison actions required at this stage in the LNG Plant development; it is envisaged that a requirement will be to advise the authorities immediately of any emergency, so that services can be placed on standby, and to remain in contact so that assistance can be provided promptly if needed.

Detailed external liaison arrangements will be established in continual dialogue with the civil and port authorities before the commissioning of the LNG Plant, and written procedures will contain instructions and guidance on what information should be communicated, at what time, by what method, and to whom. In cases where external services do become involved in incident response, and possibly assume control, it is recognised that there should be one overall seat of command, and that this must be clearly identified and acknowledged to avoid possible confusion.

In order to cater for the most extreme cases, where a major accident may have the potential to affect off-site areas, the civil authorities and emergency services may need to plan for safe evacuation or other protective action in certain off-site areas. These cases will be based upon an understanding of possible 'worst conceivable accident' consequences, and will be developed with the civil authorities and incorporated into an off-site emergency plan taking account of existing plans and the capabilities of emergency services and equipment.

Another aspect of external liaison which will need to be considered is communication and cooperation with other existing and planned industrial installations in neighbouring areas. It will be necessary to develop overall emergency plans to deal with possible hazards from new installations proposed for Wickham Point, and these will need to be compatible with the LNG Plant plans.

Effective communications between site operators will need to be established to warn of potentially threatening situations.

Mutual Aid Systems (MAS), to share emergency facilities and provide assistance, will be established with neighbouring Channel Island Power Plant, the Northern Territory Government, the cities of Darwin and Palmerston, and the RAN where appropriate. The purpose of MAS is to establish and develop mutual aid assistance in the event of industrial or community emergency situations. It also engages in education of its members and the public, the establishment of uniform practices, and the promotion of loss control procedures for the control of hazards.

The effective operation of the off-site emergency plan will be dependent upon relevant information being made available to the public in areas which could conceivably be affected by a major incident. The precise scope of the information supplied, and the way in which it is provided, will need to be handled with care to avoid raising unsubstantiated fears. This issue will be discussed with the Environment Protection Division, the Department of Mines and Energy, and other appropriate authorities.

SECTION 9

Conclusions

The overall aim in the siting, design, construction and operation of the LNG Plant is to ensure the safety and protection of persons, property and the environment. This Report demonstrates that the potential hazards which could rise from the operation of the LNG Plant are being addressed in the design, and in the specification of operating procedures and contingency plans, All practicable measures both to prevent hazardous incidents and to mitigate their consequences will be adopted.

An early consideration determining the magnitude of the hazard to be managed was the location of the LNG Plant with respect to off-site population and occupied areas. The Wickham Point site was selected based upon current land-use in the immediate vicinity, and its advantages with respect to marine access.

The keystone of the safety philosophy for the LNG Plant is adherence to established international standards and codes of practice at all stages. The design of the LNG Plant is based upon the widely adopted standard NFPA 59A. LNG ships are designed to established IMO codes. Recognised international guidelines will be used in the design and construction of the LNG berth, and in the establishment of operating procedures for ship manoeuvres and cargo transfer.

The value of adherence to established international codes and guidelines is borne out by the safety record of the modern LNG industry (no injuries or fatalities to the public from over 170 facilities, and no LNG spillages from ships' cargo tanks in over 11,000 laden voyages).

The safety of the LNG Plant will be reviewed continually during detailed design engineering, fabrication, construction, testing and commissioning. The safety review process will continue through the operation of the LNG Plant and shipping.

Contingency plans will be developed in liaison with the appropriate civil and port authorities to protect the safety of employees and members of the public in the extremely unlikely event of a major unplanned emergency situation arising

Liaison will be maintained with the Environment Protection Division, Department of Mines and Energy and other appropriate authorities, the Darwin Port Authority and the Industrial Inspections Supervisor in order to ensure that all requirements of the Government of Northern Territory are met.

It is concluded, based upon all of these considerations, and an appreciation on the part of Phillips of the nature of the hazards associated with LNG production and the possible causes of hazardous incidents, that the potential hazards to the public and site personnel arising from the operation of the LNG Plant will be maintained at an acceptably low level.

FIGURES

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DARWIN LNG PLANT, DRAFT EIS

LOCATION PLAN

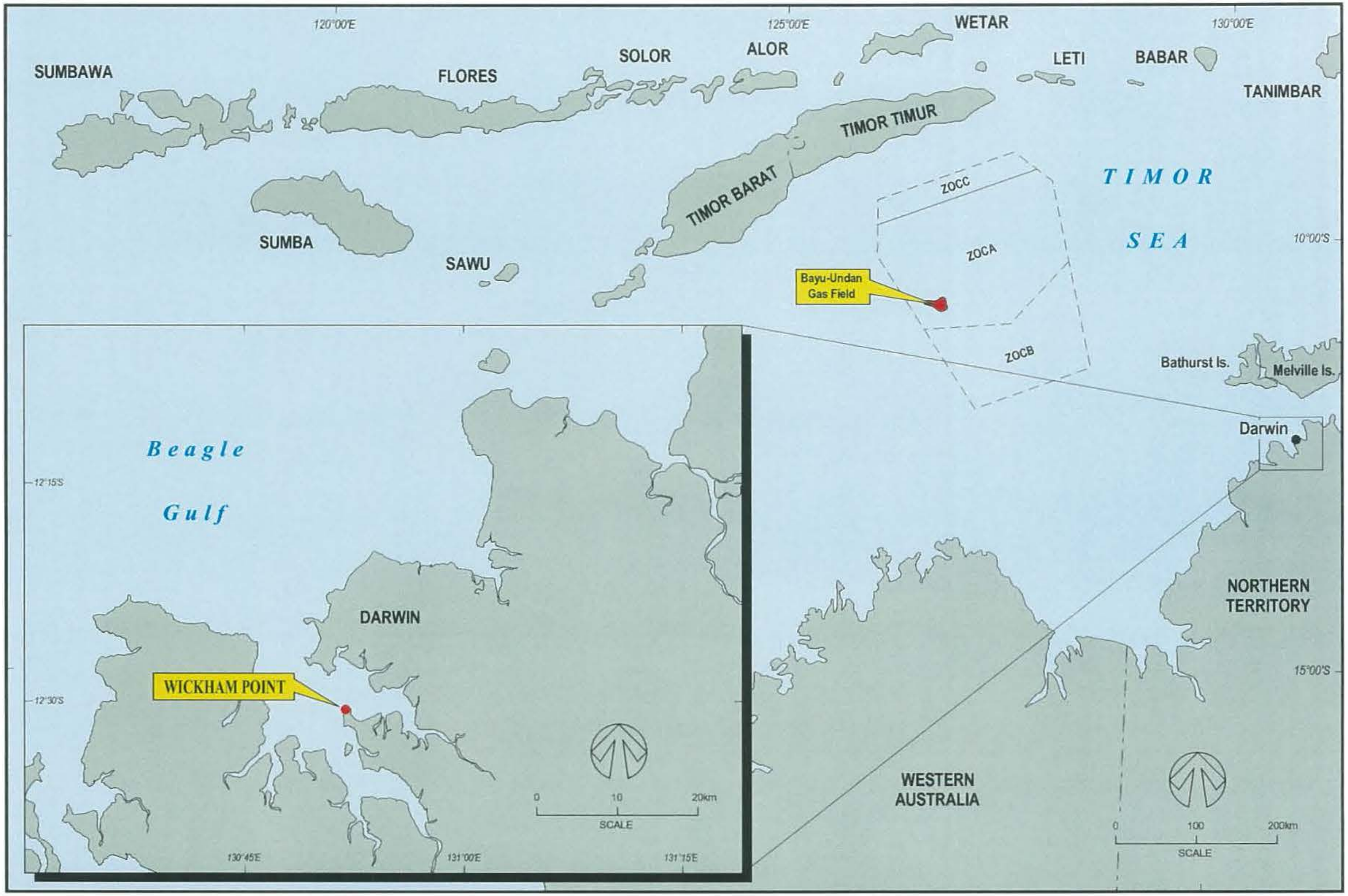
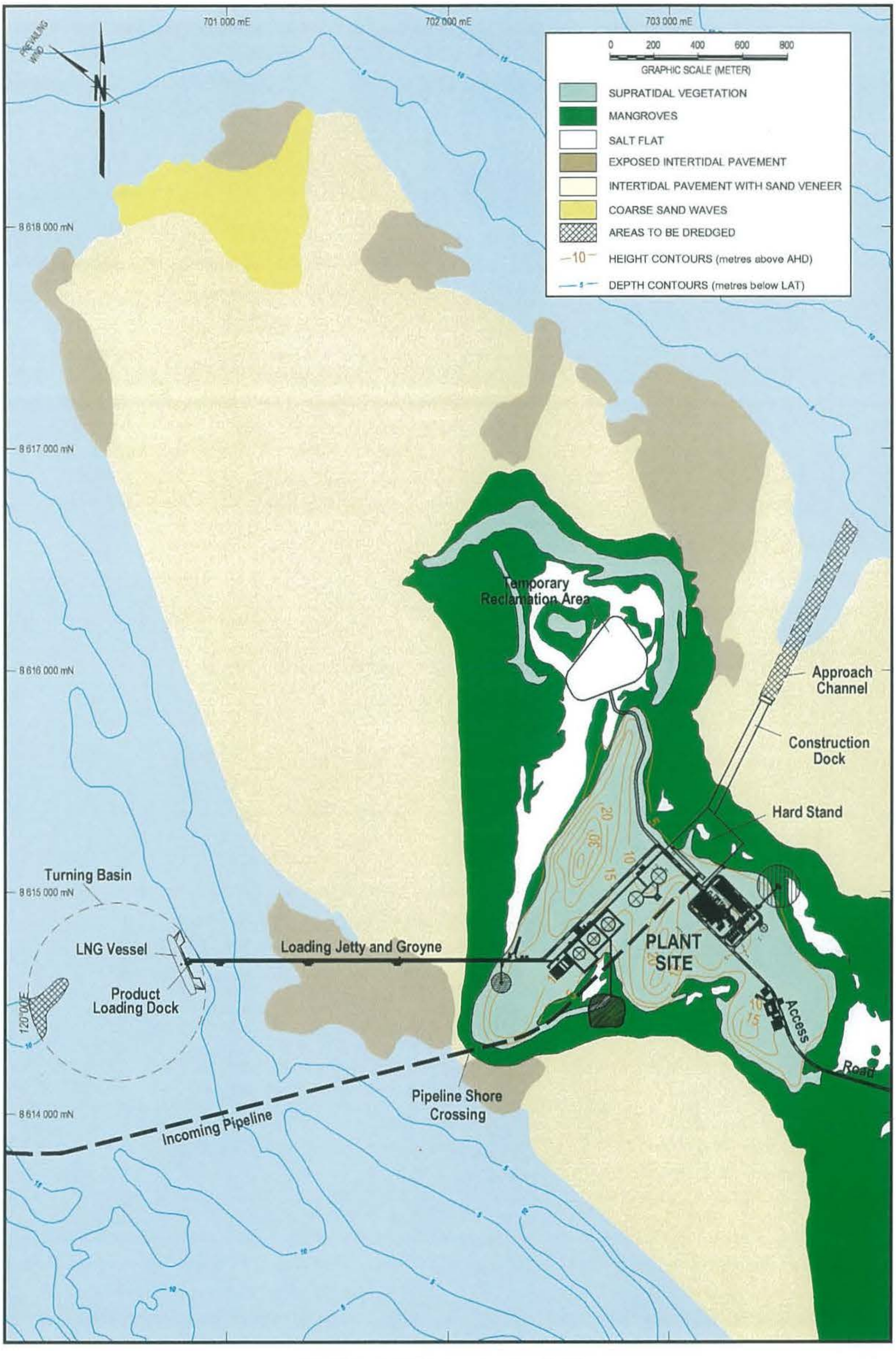


FIGURE 3.1



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LNG PLANT PRELIMINARY LAYOUT

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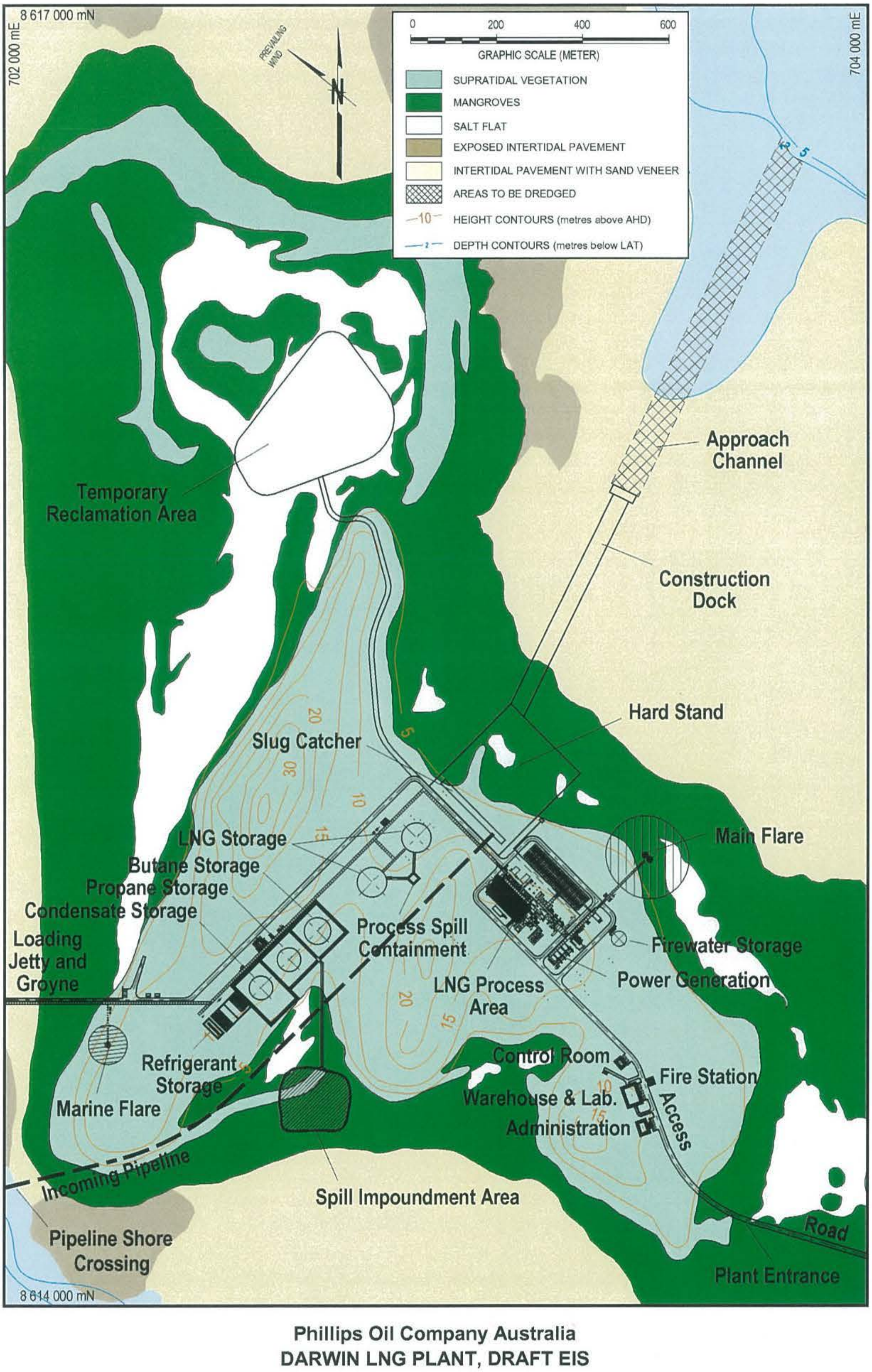
FIGURE 3.2



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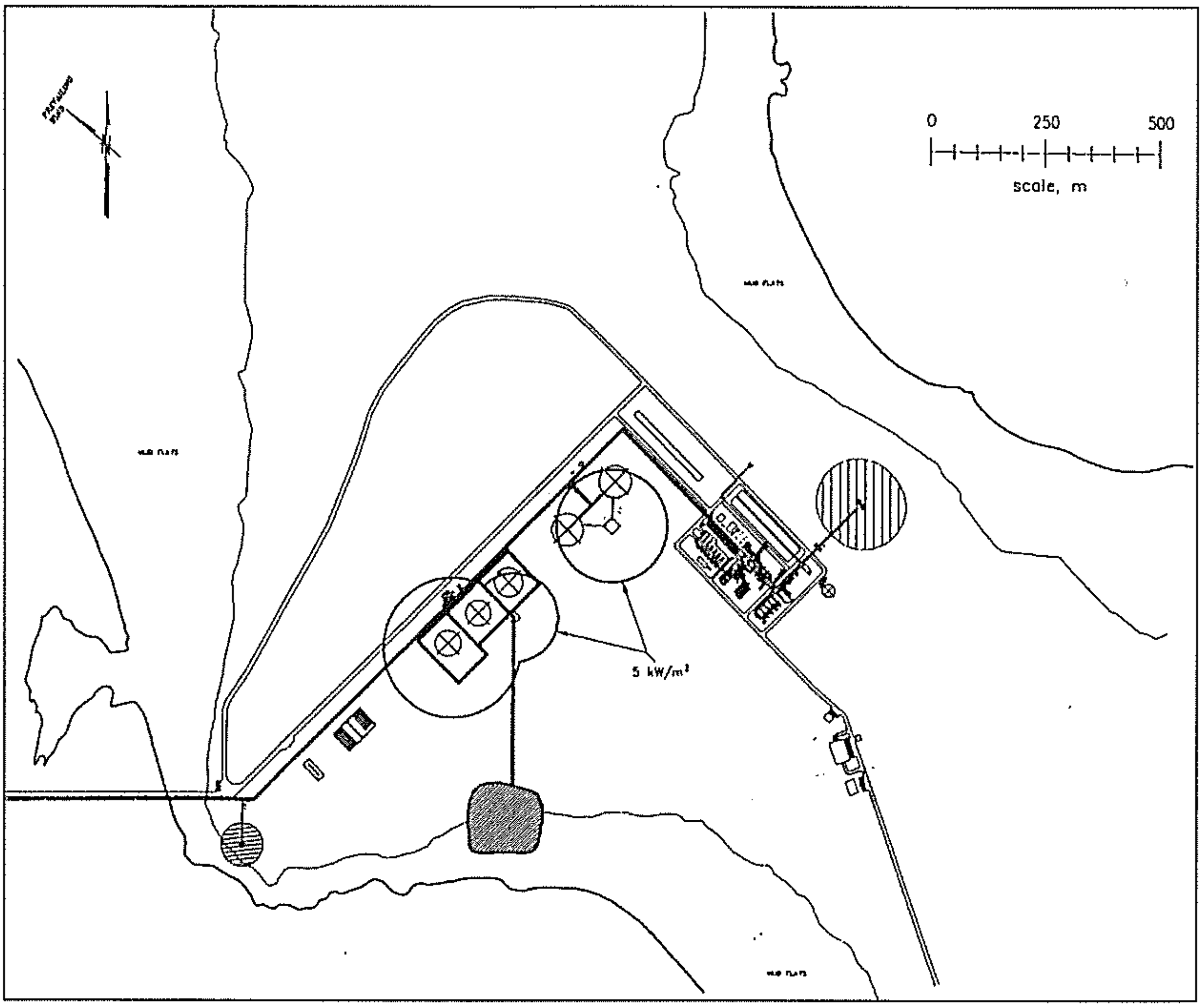
LNG PLANT PROCESS COMPONENTS AND INFRASTRUCTURE



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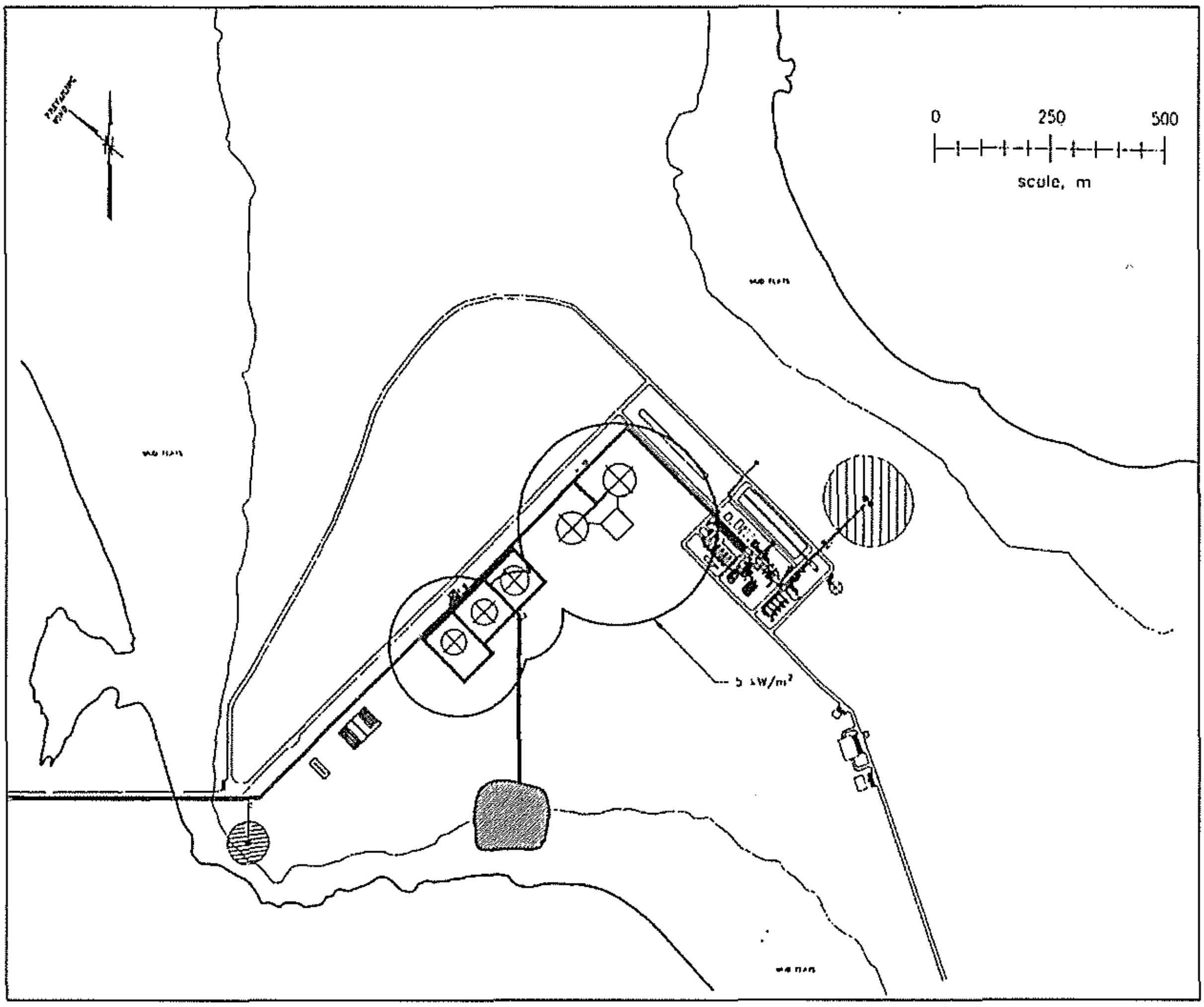
FACILITY BOUNDARY REQUIREMENTS AS DEFINED BY THE 5kW/m² RADIATION CONTOURS FOR DESIGN SPILL IMPOUNDMENTS - 25x25x4m LNG IMPOUNDMENT



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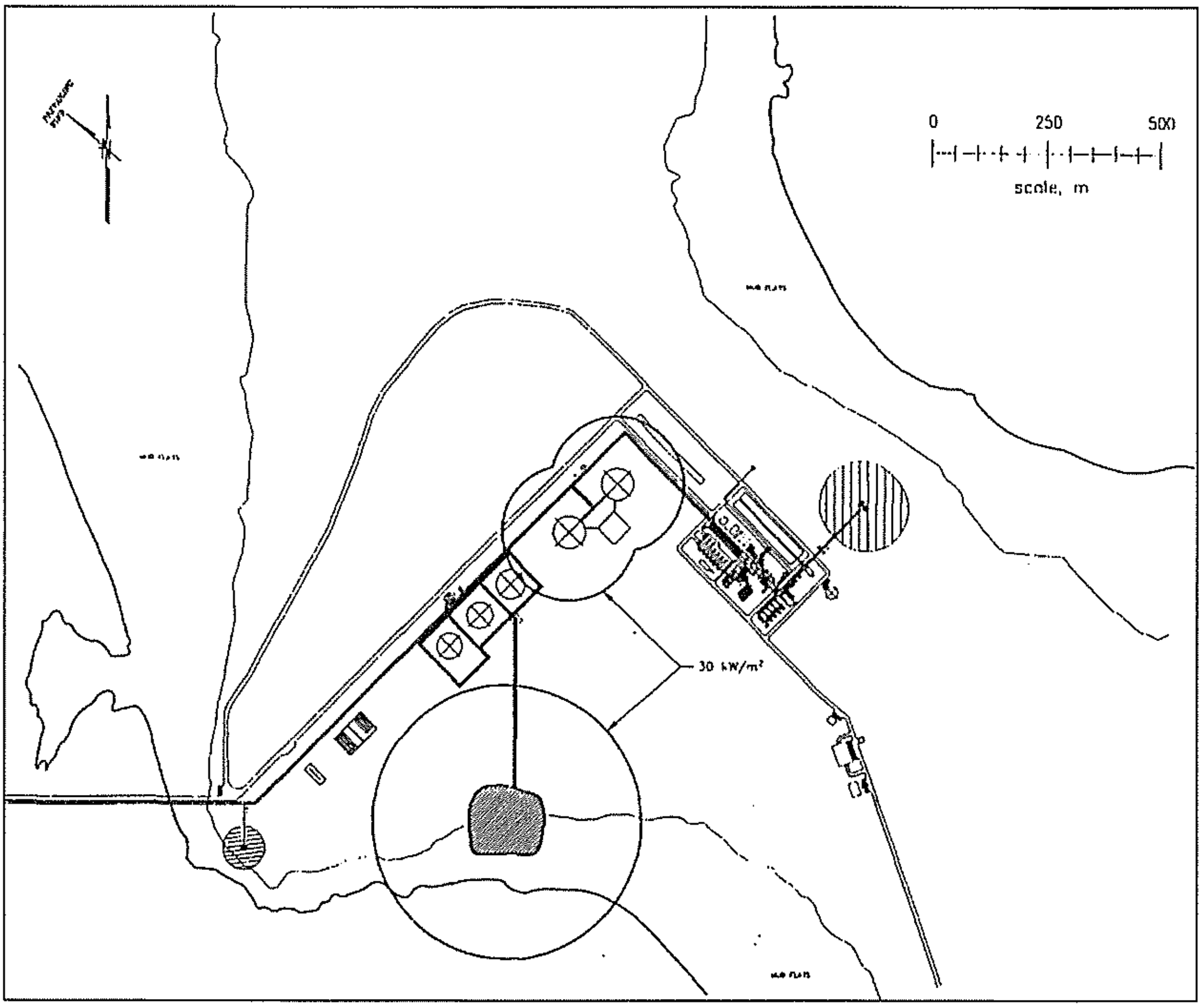
FACILITY BOUNDARY REQUIREMENTS AS DEFINED BY THE 5kW/m² RADIATION CONTOURS FOR DESIGN SPILL IMPOUNDMENTS - 50x50x1m LNG IMPOUNDMENT



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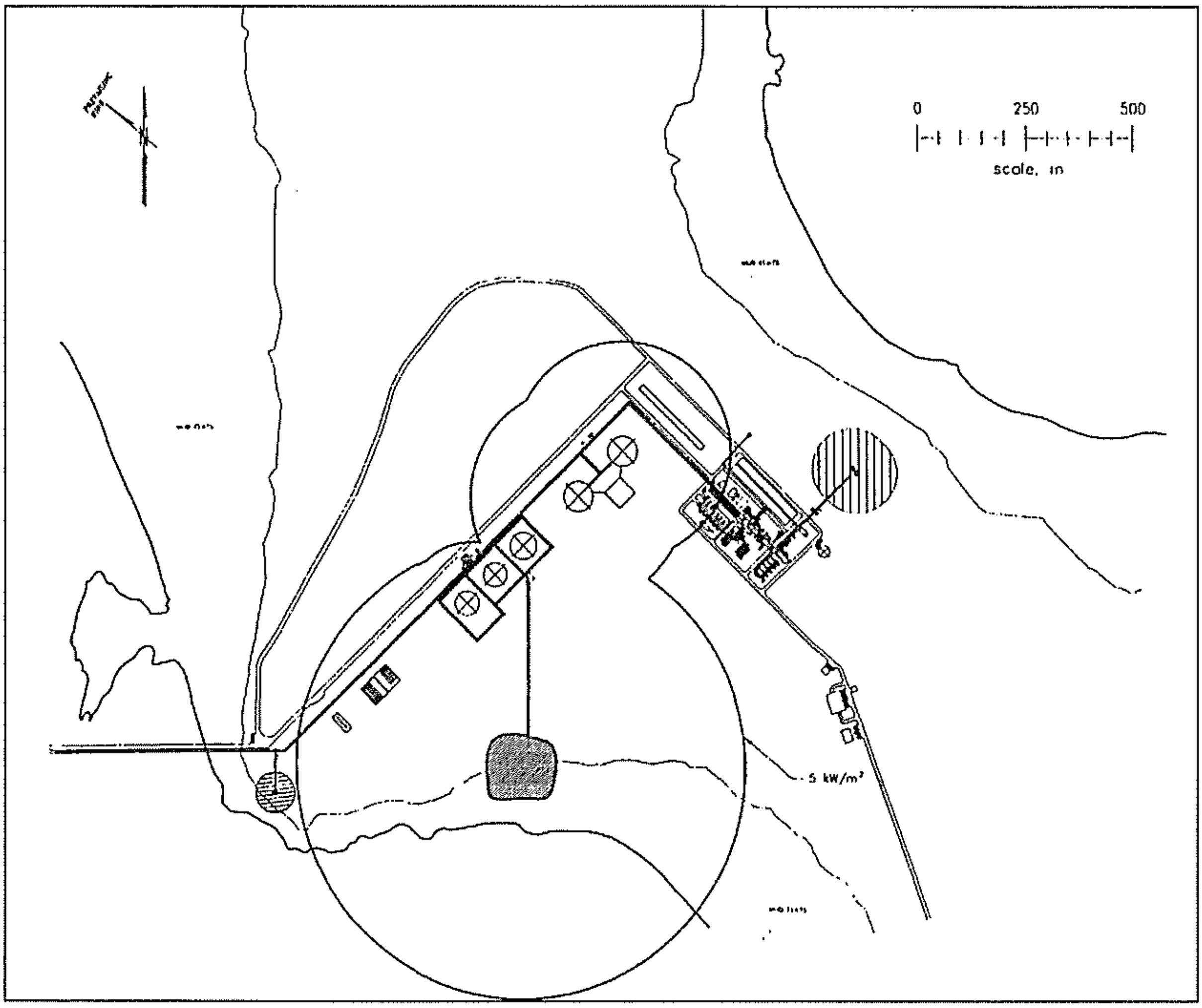
FACILITY BOUNDARY REQUIREMENTS AS DEFINED BY THE 30kW/m² RADIATION CONTOURS FOR TANK IMPOUNDMENT FIRE



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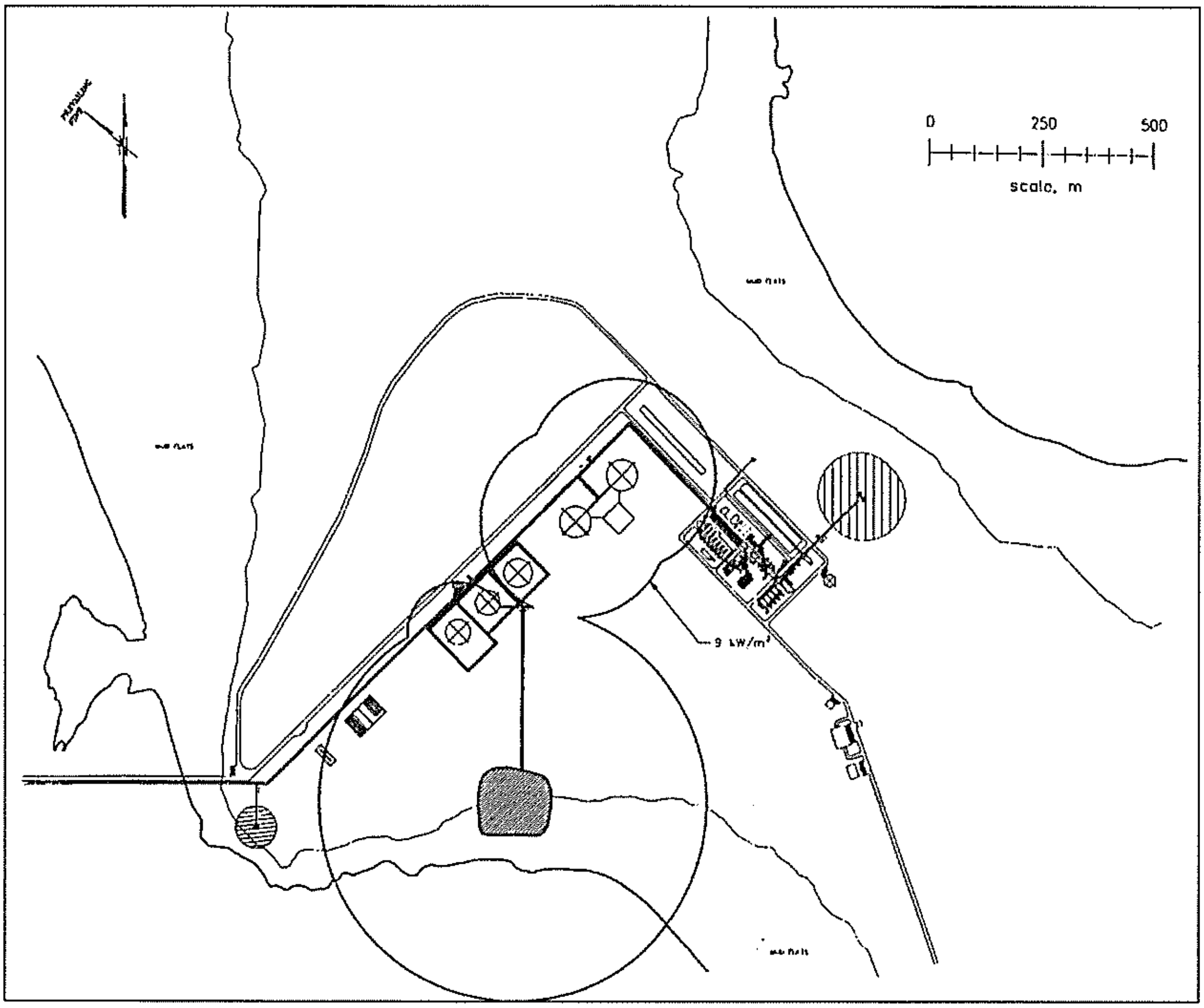
OFF-SITE RESTRICTED AREAS AS DEFINED BY THE 5kW/m² RADIATION CONTOURS FOR THE TANK IMPOUNDMENT FIRE



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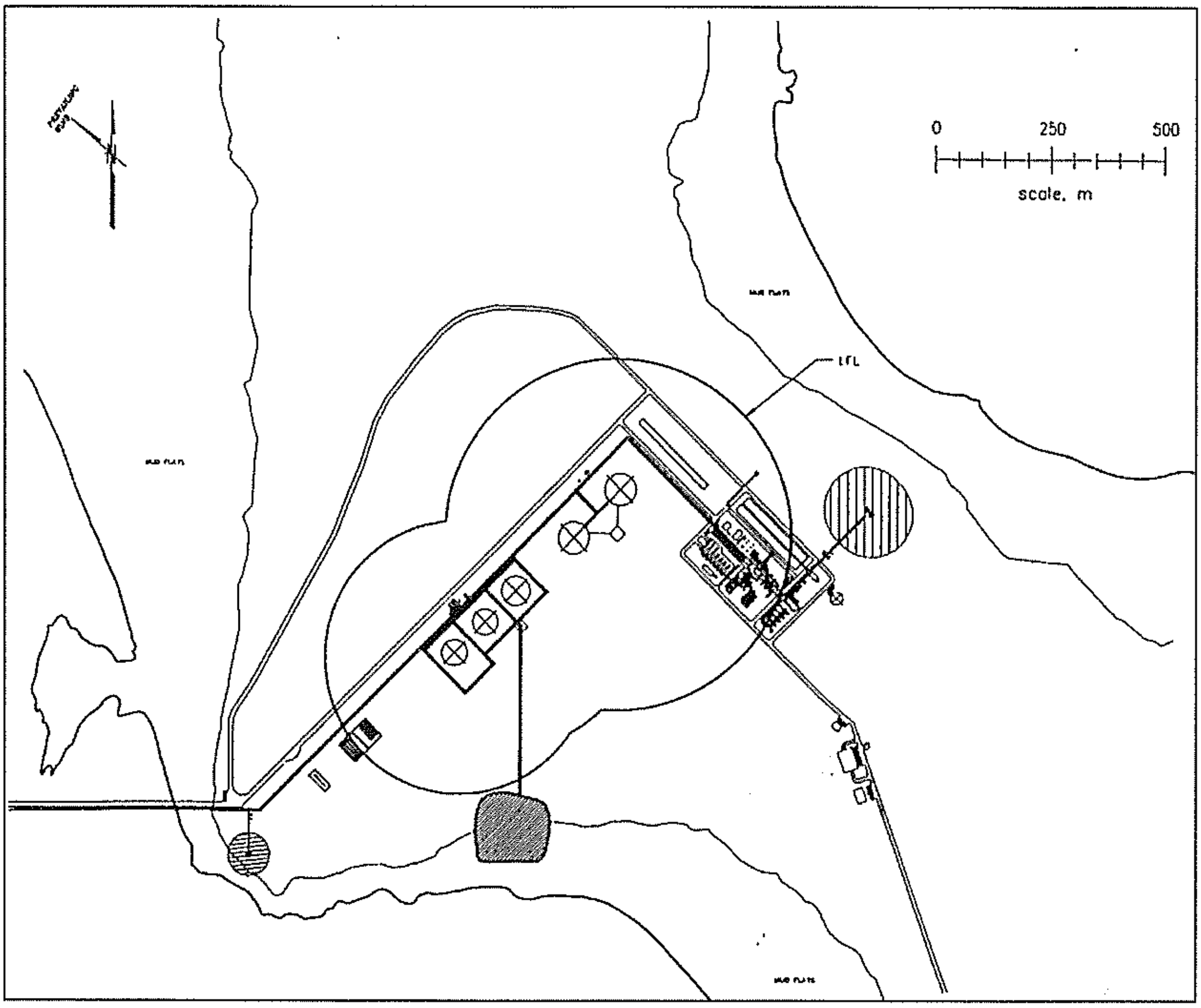
OFF-SITE RESTRICTED AREAS AS DEFINED BY THE 9kW/m² RADIATION CONTOURS FOR THE TANK IMPOUNDMENT FIRE



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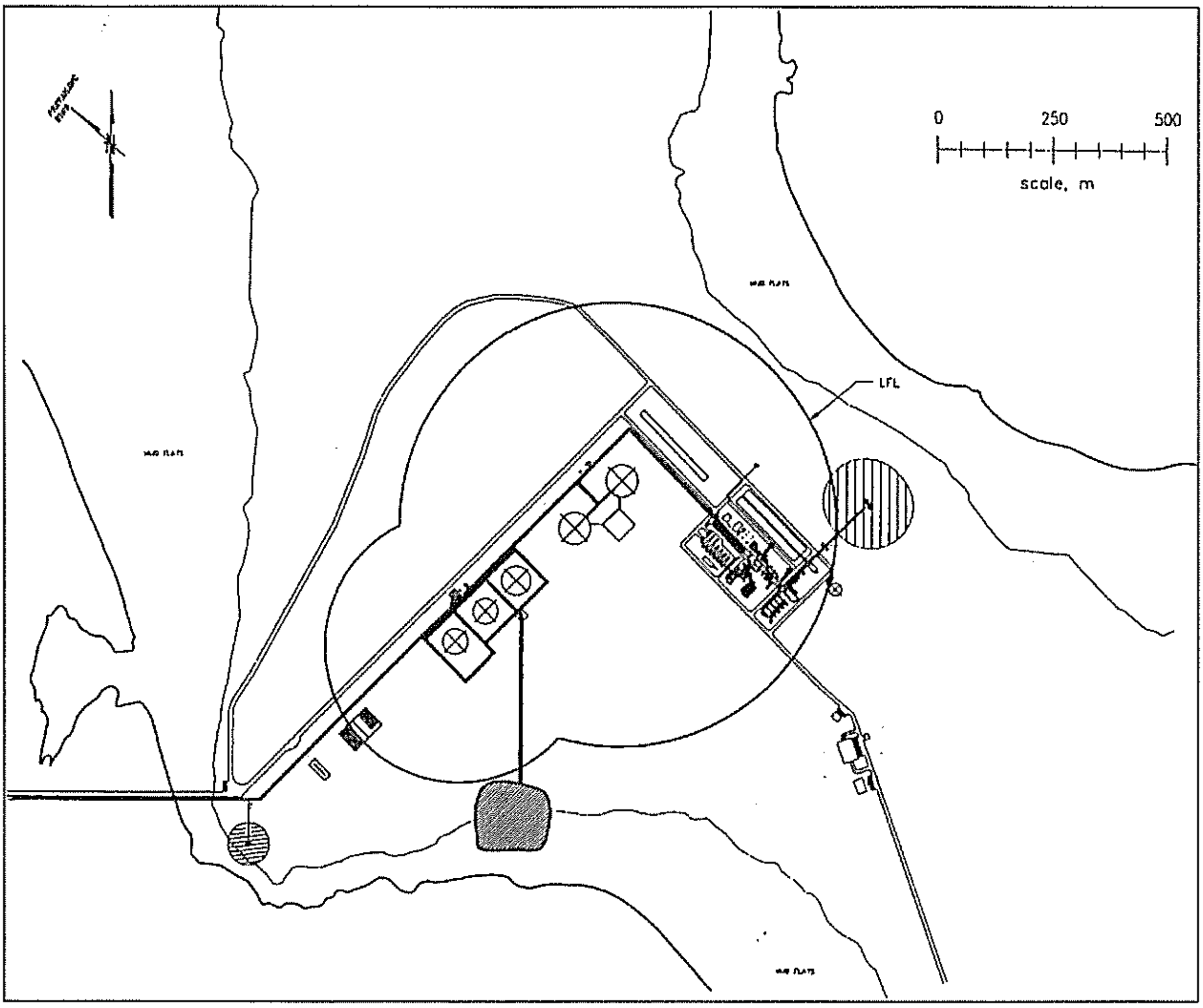
DARWIN LNG PLANT, DRAFT EIS

FACILITY BOUNDARY REQUIREMENTS AS DEFINED BY THE LFL CONTOURS FOR DESIGN SPILL IMPOUNDMENTS - 25x25x4m LNG IMPOUNDMENT



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FACILITY BOUNDARY REQUIREMENTS AS DEFINED BY THE LFL CONTOURS FOR DESIGN SPILL IMPOUNDMENTS - 50x50x1m LNG IMPOUNDMENT