Assessment of the Health and Viability of the Mangrove Communities at Whyte Island

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	Synopsis:	This report presents the findings of an assessment of the health and viability of mangrove communities at Whyte Island.

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1 INTRODUCTION

The Port of Brisbane Corporation (PBC) is responsible for the operation and management of the Port of Brisbane facility, located at the mouth of the Brisbane River (Figure 1.1). Extensive areas of mangroves and saltmarshes occur adjacent to the Port, primarily in the Fisherman Islands area (north of the boat Passage) and at Whyte Island (immediately to the south of the Boat Passage). These areas, whilst part of the Moreton Bay Marine Park, are strategic Port land, and responsibility for their management lies with the PBC.

Mangrove communities have high conservation value as they provide food resources and shelter for a range of invertebrates, birds and fish (Chapman and Underwood 1995). Many of the fish species inhabiting mangrove areas are of direct recreational and commercial fisheries value (Morton 1990). Mangroves are also highly productive (Davie 1984), and are important in the stabilisation of bed and banks (Carlton 1974). In recognition of this high ecological value the PBC is committed to ensuring that wetlands adjacent to the Port are not adversely affected by its activities.

Previous environmental reviews undertaken by the PBC identified issues associated with the health and long-term viability of mangroves at Fisherman Islands. Studies carried out at Fisherman Islands included a detailed assessment of the mangroves to determine and accurately map their condition, assessment of the nature and extent of any historical and on-going impacts and provide a preliminary assessment of the potential for remediation works (WBM 2000a, 2002).

Additional areas of degraded mangroves are also present at Whyte Island, to the east of Port Drive. PBC commissioned the present study to investigate the current health and viability status of the mangrove communities at Whyte Island and to complement data gained from the Fisherman Islands studies.

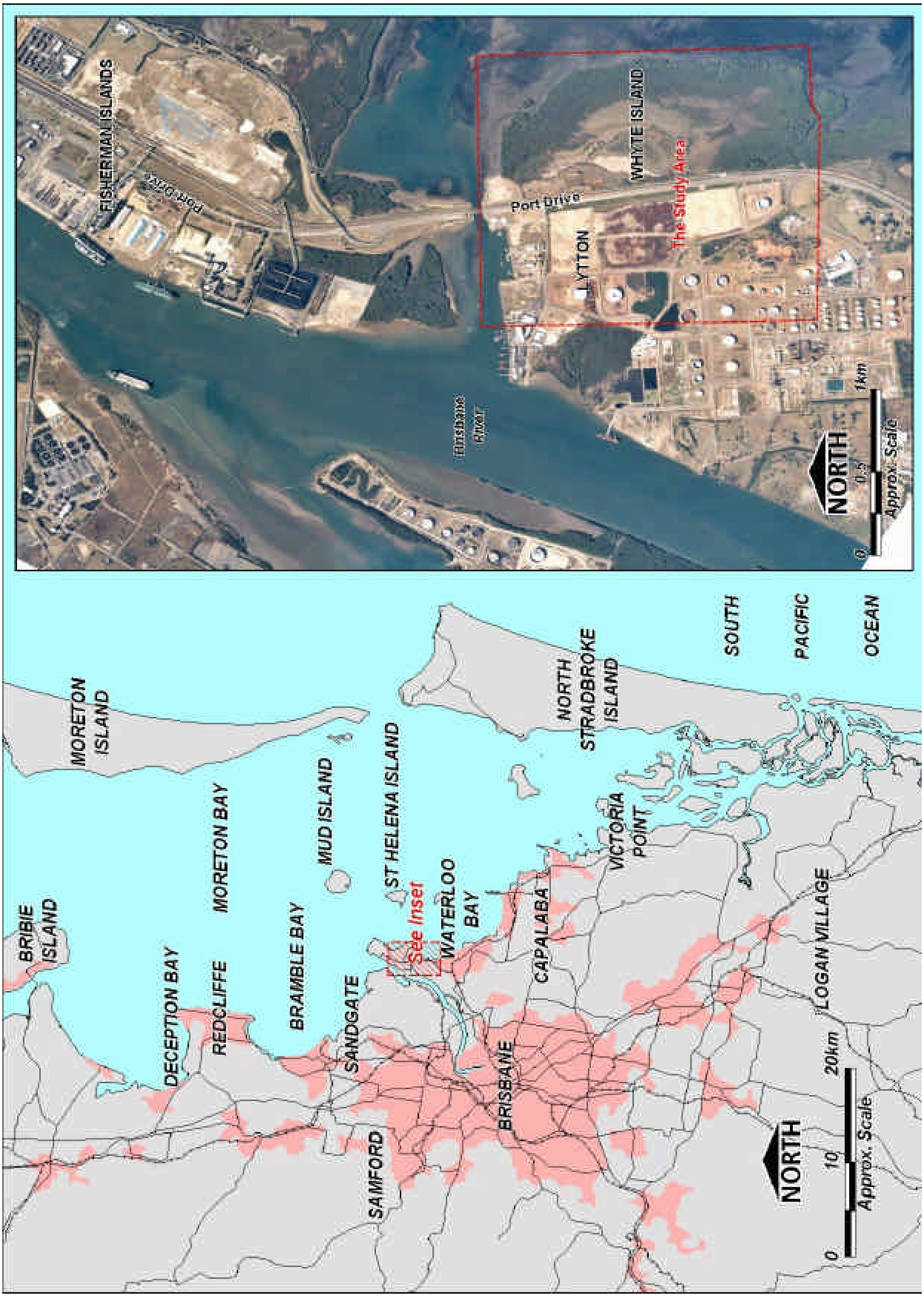

Figure 1.1 Locality Map

2 METHODOLOGY

The present study involved three stages: mapping historical changes, field assessments to identify mangrove health and desktop mapping using aerial photographs and the ground-truthed health and condition data.

2.1 Historical Changes

To develop an understanding of the historical distribution patterns of mangroves at Whyte Island, low level aerial photography was obtained for selected years. This included periods prior to the major development of Port Drive (1972), during initial development of the Port (1978 and 1983), during further expansion of the Port facility (1991) and current photography (2002). Additional photographs were reviewed (1987, 1995 and 1999) but were not included in this report as the listed photographs were considered to provide adequate representation of changes to the mangrove distribution.

The photos were scanned at a high resolution (300 dpi) and imported into a mapping software package (MapInfo Professional Ver 5.5). Using a number of recognisable features (minimum six per image), the photos were then geo-corrected and the accuracy of the final image compared to both data supplied by the PBC and ground control points to ensure a horizontal accuracy of at least 5m.

The photos were then reviewed and the mangrove extent at each time period was mapped. No attempt was made to delineate healthy and stressed mangroves as it was not possible to ground truth the historical photographs. For this reason, professional judgement also had to be used in defining the boundary between mangroves and saltmarsh areas.

The aerial photography was also used to provide a guide to impacting processes, which may have resulted in the current distribution of mangroves. A digital map layer was developed of the current (2002) area of mangroves as mapped during field works (see Section 2.2). This layer was then overlayed on each aerial photograph and any features which may be related to the mangrove distribution noted. When features were noted which may be associated with mangrove degradation, comparison of the areas on subsequent photos was also made, thus providing a indication of the trends in mangrove distribution.

2.2 Field Assessments

Field assessments were conducted to:

- Map the mangrove community in terms of species composition and community structure; and
- Map the health of the mangroves.

2.2.1 Survey Technique

A survey of the study area was undertaken between March and May 2002, over a total of 13 days. The study area was traversed on foot notionally following eight transects running perpendicular to Port Drive (that is, approximately north-east). Assessments were made at approximately 50m intervals, with more frequent observations made in dense areas and/or those containing changes in community structure. Additionally, observations were recorded more frequently in and about the features of interest, such as areas of dead and/or dying mangroves.

The location of the measurements was recorded using a differentially corrected GPS, providing a horizontal accuracy of ± 1m. The GPS was also used to navigate along each transect. Deviations were made from the predetermined route in response to field conditions (such as especially soft sediments) and/or the presence of features of interest. The boundaries of vegetation communities along each transect were also recorded to ground truth the vegetation maps produced from the aerial photographs. The coordinates of each assessment site are listed in APPENDIX A:, which also shows a map of the points overlayed on the 2002 aerial photograph.

2.2.2 Sediment Chemical Analyses

Sediment samples were collected from three sites within the study area, near the Wynnum Waste Water Treatment Plant outfall, in an area of dead mangroves and in an area of stressed mangroves (Figure 2.1). All samples were analysed for the following parameters:

- Heavy metals;
- Organochlorines;
- BTEX/TPH; and
- Nutrients.

Samples were collected from the upper 10cm of the sediment profile and retained in approved containers before delivery to a NATA registered laboratory within accepted holding periods

Figure 2.1 Location of Sediment Sampling Sites

2.2.3 Species Composition, Community Structure and Health of Mangroves

The following parameters were assessed at each station along the survey transects:

- *Species Composition* - the species composition was recorded including an estimate of the proportion of the community represented by various species (eg 100% *Avicennia marina*; 75% *A.marina*, 25% *Rhizophora stylosa*).
- *Community Structure* - at each station, an assessment was made of the following:

⇒ Projective cover of the tree and shrub layers. Projective cover estimates the horizontal coverage of a site by standing plant material. Cover estimates were made in 5 categories, 0-10%, 11-30%, 31-50%, 51-75% and 76-100% cover on the basis of pre-printed sheets providing an example of each cover category.

⇒ Average height of the canopy. Height is a prime indicator of the quality of site conditions for plant growth. Together with basal area (see below) canopy height provides an estimate of standing biomass. The height of the tallest strata of the community was estimated at each location.

⇒ Density of trees, shrubs and seedlings. The density of plants (number of individuals per unit area) in the various layers gives an indication of the serial stage of a plant community and the degree of disturbance or change experienced over time. At each sampling station three random points were selected and the distance from the point to the nearest tree, selected using the T-square method as described by Krebs (1989), measured. The distance from this tree to its nearest neighbour was then also measured. The analysis of the resultant data set was then used to provide an estimate of plant density.

⇒ Girth of tall shrubs and trees. Girth can be used to calculate diameters and basal areas. The number of individuals of various diameter size classes is indicative of population structure, whereas basal area can be used to estimate standing biomass. The trees selected in the above process (T-square method) were also measured for girth at breast height.

Mangrove Health - along the survey transect, a visual assessment of the health of the mangroves was made at each site based on criteria developed in conjunction with the PBC for the 1999/2000 survey. Criteria for each category are listed in Table 2.1 and examples of each category are shown in Figure 2.2 to Figure 2.6.

Table 2.1 Mangrove Health Categories

Category	Condition	Description
1	Good	Leaves green. No abnormal leaf loss evident. No epicormic growth. No leaf curling.
2	Fair	Leaves green. Some yellowing of leaves and/or curling, but <20% of canopy affected. Some epicormic growth apparent.
3	Poor	Many leaves yellow, brown and/or curled. Substantial reduction in canopy. Abundant leaf curling and/or epicormic growth apparent.
4	Dead	Leaves brown or absent. Little or no canopy remaining.
5	Regrowth	Canopy reduced but regrowth evident in the form of new trees. Disturbance event generally evident (ie. constructed bund).

Figure 2.2 Mangrove Health Category - GOOD

Figure 2.3 Mangrove Health Category - FAIR

Figure 2.4 Mangrove Health Category - POOR

Figure 2.5 Mangrove Health Category - DEAD

Figure 2.6 Mangrove Health Category - REGROWTH

2.2.4 Macroalgae

At each of the sampling stations along the survey transect, a visual estimation of the coverage of macroalgae was recorded. This estimation was based on the four categories listed in Table 2.2. Examples of each of the categories are shown in Figure 2.7 to Figure 2.10.

Table 2.2 Macroalgae Coverage Categories

Category	Condition	Description
1	Very Abundant	>75% coverage of pneumatophores and/or sediments, heavy coating/carpet
2	Abundant	50-75% coverage, most surfaces coated, easily visible
3	Common	10-50% coverage some macroalgae visible
4	Rare	<10% coverage, no macroalgae

Figure 2.7 Macroalgae Category - RARE

Figure 2.8 Macroalgae Category - COMMON

Figure 2.9 Macroalgae Category – ABUNDANT

Figure 2.10 Macroalgae Category – VERY ABUNDANT

2.2.5 Macrofauna

At each of the sampling stations, an estimation of the relative abundance of visible macrofauna was recorded, based on four categories shown in Table 2.3. Estimations were based on direct (observations of animals) and indirect (eg crab holes) observations.

Macrofauna included crabs and epi-fauna such as snails. The measurement was made to provide a qualitative indication of the biological utilisation of the subject area. It should be noted that no differentiation between abundances of different functional groups was made (eg abundant crabs recorded same as abundant snails or combinations of each group).

Table 2.3 Macrofauna Observation Categories

Category	Condition	Description
1	Very Abundant	>50 individuals sighted
2	Abundant	20-50 individuals sighted
3	Common	<20 individuals
4	Rare	No Macrofauna evident

2.2.6 Other Observations

The presence of other salient features at each of the sampling locations or encountered during field works was also recorded as required, for example, the margin between dead and stressed mangroves. The location of the features was recorded using the GPS described above.

3 RESULTS

3.1 Historical changes

The Whyte Island area has undergone significant changes as a result of the development of Port Drive, the major access to the Port of Brisbane facility as evident in the series of photographs shown in Figure 3.2 to Figure 3.6.

Between 1972 and 1978 Port Drive was constructed linking Whyte Island and Fisherman Islands via a bridge across the Boat Passage. Expansion of the Oil Refinery to the west of Port Drive also occurred during this period. By 1991 major changes had occurred at the north-western end of Whyte Island for the construction of facilities such as the Port of Brisbane Operations Base, tug berths and the Water Police base. The 2002 photo shows the completed Queensland Rail Refuelling Depot at the southern end of Whyte Island and the ongoing development of the land immediately west of Port Drive.

Between 1972 and 2002 there was a 55% decline in the extent of mangroves at Whyte Island, which decreased from 133 ha in 1972 to 60 ha in 2002. The largest losses occurred in the periods 1972 to 1978 (28 ha) and 1978 to 1983 (27 ha) (Figure 3.1). Between 1983 and 1991 there was little change in mangrove area, however between 1991 and 2002 a further 18 ha was lost.

Mangrove loss at Whyte Island can be separated into 2 categories based on the process responsible – intentional, authorised removal and mangrove death caused by other factors. The loss of mangroves through the construction of Port Drive and subsequent development to the west of the road falls into the first category and accounts for approximately 60% of the overall mangrove decline between 1972 and 2002. Approximately 45 ha of mangroves were cleared, in this period, as a result of the construction of Port Drive and subsequent development.

The remaining loss appears to be due to mangrove decline to the east of Port Drive and was not a result of intentional clearing for development. In the 1978 photograph there were two small areas to the east of Port Drive where mangroves appear to have been lost (immediately adjacent to the road just south of the Boat Passage and just north of the creek at the southern end of Whyte Island) however most mangroves in this area remained intact. In 1983 it is evident that while the two small patches had recovered slightly a large patch (16 ha) of mangroves east of the existing claypan had died. By 1991 this patch extended slightly southwards and covered approximately 18 ha. Mangroves surrounding this area appeared to be in poor health as evidenced by gaps in the canopy. In the 2002 photograph the dead area had expanded considerably to the south, east and west and covered approximately 32 ha.

Potential impacting processes responsible for the decline of mangroves east of Port Drive are discussed in Section 4.2.

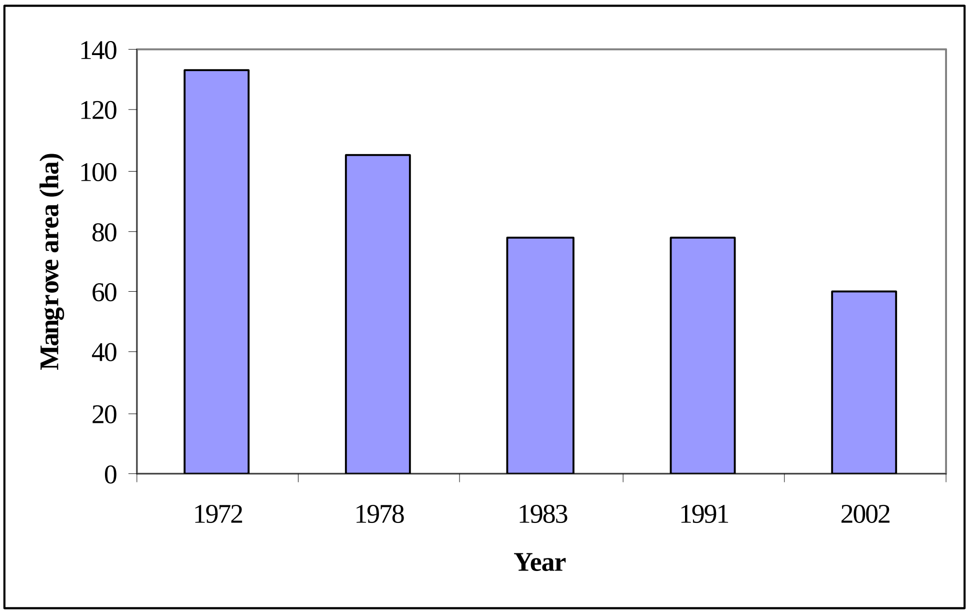

Figure 3.1 Whyte Island mangrove area, 1972 - 2002

Figure 3.2 Whyte Island mangrove distribution - 1972

Figure 3.3 Whyte Island mangrove distribution – 1978

Figure 3.4 Whyte Island mangrove distribution – 1983

Figure 3.5 Whyte Island mangrove distribution – 1991

Figure 3.6 Whyte Island mangrove distribution – 2002

3.2 Chemical Measurements

Results from the chemical analyses of sediment samples are presented in Table 3.1 to Table 3.4.

Heavy metal concentrations (Table 3.1) at Sites 1 and 2 were within acceptable levels for all elements except Mercury, which was found in concentrations more than 1.5 times the Maximum Level listed in National Ocean Disposal Guidelines for Dredged Material (Environment Australia 2002). These guidelines give effect-based levels for heavy metals in sediments. Values below the Screening Level are considered safe, concentrations above the Screening Level but below the Maximum Level require further investigation on a case-by-case basis and concentrations above the Maximum Level are considered to be detrimental to biological processes.

Compared to Sites 1 and 2, Site 3 had elevated levels of Copper, Nickel, Lead and Zinc. Concentrations of Copper, Mercury, Nickel and Zinc at Site 3 were above EA (2002) screening levels. Furthermore, mercury concentration at all three sites was above the maximum level outlined in the guidelines. The elevated heavy metal concentrations at Site 3 may be linked to the sewage outfall, however additional investigations would be required to confirm this and to identify reasons for the elevated Mercury levels at all three sites at Whyte Island.

It should be noted that the current study presents a one-off snap-shot of sediment quality based on a small number of samples. The Ocean Disposal Guidelines provide recommendations for appropriate sampling strategies based on sediment areas and volumes and a more detailed survey is required to better understand sediment quality at Whyte Island.

Table 3.1 Heavy metal concentration in sediments from Whyte Island

Analyte	Units	Detection Limit	Site 1	Site 2	Site 3	Fisherman Islands[1]	EA[2] Screening level	EA[2] Maximum level
Arsenic	mg/kg	0.1	13.0	3.1	9.2	2.8 – 9.7	20	70
Cadmium	mg/kg	0.1	<0.2	<0.5	0.2	<0.05 – 0.1	1.5	10
Chromium	mg/kg	0.1	37.1	15.4	52.1	39.4 – 93.1	80	370
Copper	mg/kg	0.1	21.2	21.8	**84.5**	5.65 – 24.7	65	270
Mercury	mg/kg	0.1	**1.7**	**1.7**	**1.2**	<0.05 – 0.15	0.15	1
Nickel	mg/kg	0.1	17.4	10.3	**21.2**	7 – 23.1	21	52
Lead	mg/kg	0.1	17.0	10.5	45.5	4.05 – 24.2	50	220
Zinc	mg/kg	0.1	63.2	29.6	**212**	23.8 – 68.4	200	410

1= WBM (2000a); 2 = Environment Australia (2002)

Nutrient levels (Table 3.2) at all three sites were similar to those recorded at Fisherman Islands (WBM 2000a) and Bulwer Island (Mackey *et al* 1992). Elevated concentrations are expected given the high levels of organic matter present in the sediments. Additionally, Site 3 (closest to the Wynnum WWTP outfall) had higher levels of Nitrite, Nitrate and Phosphorous than Sites 1 and 2.

Table 3.2 Nutrient concentration in sediments from Whyte Island

Analyte	Units	Detection Limit	Site 1	Site 2	Site 3	Fisherman Islands[1]
Nitrite & Nitrate as N	mg/kg	0.1	2.0	2.8	6.1	<0.05 – 1.2
Tot Kjeldahl Nitrogen as N	mg/kg	20	3230	2520	2590	260 – 2540
Total Nitrogen	mg/kg	20	3230	2520	2590	260 – 2540
Phosphorus as P - Total	mg/kg	20	216	134	1080	150 – 460

1= WBM (2000a)

Organochlorine pesticide (Table 3.3) and BTEX concentrations (Table 3.4) were low at all three sites however elevated levels of Petroleum Hydrocarbons were recorded at Sites 2 and 3.

Table 3.3 Organochlorine Concentration in Sediments from Whyte Island

Analyte	Units	Detection Limit	Site 1	Site 2	Site 3	Fisherman Islands[1]
Moisture content	%	0.1	66.7	80.8	70.5	
ORGANOCHLORINE PESTICIDES						
alpha-BHC	mg/kg	0.05	<0.25	<0.25	<0.25	<0.05 - <0.1
HCB	mg/kg	0.05	<0.25	<0.25	<0.25	<0.05 - <0.1
beta-BHC & gamma-BHC	mg/kg	0.1	<0.5	<0.5	<0.5	<0.1 - <0.3
delta-BHC	mg/kg	0.05	<0.25	<0.25	<0.25	<0.05 - <0.1
Heptachlor	mg/kg	0.05	<0.25	<0.25	<0.25	<0.05 - <0.1
Aldrin	mg/kg	0.05	<0.25	<0.25	<0.25	<0.05 - <0.1
Heptachlor epoxide	mg/kg	0.05	<0.25	<0.25	<0.25	<0.05 - <0.1
Chlordane – trans	mg/kg	0.05	<0.25	<0.25	<0.25	<0.05 - <0.1
Endosulfan 1	mg/kg	0.05	<0.25	<0.25	<0.25	<0.05 - <0.1
Chlordane – cis	mg/kg	0.05	<0.25	<0.25	<0.25	<0.05 - <0.1
Dieldrin	mg/kg	0.05	<0.25	<0.25	<0.25	<0.05 - <0.1
DDE	mg/kg	0.05	<0.25	<0.25	<0.25	<0.05 - <0.1
Endrin	mg/kg	0.05	<0.25	<0.25	<0.25	<0.05 - <0.1
Endosulfan 2	mg/kg	0.05	<0.25	<0.25	<0.25	<0.05 - <0.1
DDD	mg/kg	0.05	<0.25	<0.25	<0.25	<0.05 - <0.1
Endrin aldehyde	mg/kg	0.05	<0.25	<0.25	<0.25	<0.05 - <0.1
Endosulfan sulfate	mg/kg	0.05	<0.25	<0.25	<0.25	<0.05 - <0.1
DDT	mg/kg	0.2	<1.0	<1.0	<1.0	<0.2 - <0.5
Endrin ketone	mg/kg	0.05	<0.25	<0.25	<0.25	<0.5 - <0.1
Methoxychlor	mg/kg	0.2	<1.0	<1.0	<1.0	<0.2 - <0.5
ORGANOCHLORINE PESTICIDE SURROGATE						
Dibromo-DDE	%	1	96	98	82	58 – 95

1= WBM (2000a)

Table 3.4 Total Petroleum Hydrocarbon and BTEX Concentrations in Sediments from Whyte Island

Analyte	Units	Detection Limit	Site 1	Site 2	Site 3	Fisherman Islands[1]
Moisture content	%	0.1	66.7	80.8	70.5	
Total Petroleum Hydrocarbons						
C6-C9 fraction	mg/kg	2	<4	<4	<4	<2 - <5
C10-C14 fraction	mg/kg	50	<100	1030	332	<50 - <125
C15-C28 fraction	mg/kg	100	<200	2600	1580	<100 – 435
C29-C36 fraction	mg/kg	100	<200	3190	1610	<100 – 565
BTEX						
Benzene	mg/kg	0.2	<0.4	<0.4	<0.4	<0.2 - <0.5
Toluene	mg/kg	0.2	<0.4	<0.4	<0.4	<0.2 - <0.5
Chlorobenzene	mg/kg	0.2	<0.4	<0.4	<0.4	<0.2 - <0.5
Ethylbenzene	mg/kg	0.2	<0.4	<0.4	<0.4	<0.2 - <0.5
Meta & para-Xylene	mg/kg	0.2	<0.4	<0.4	<0.4	<0.2 - <0.5
Ortho-Xylene	mg/kg	0.2	<0.4	<0.4	<0.4	<0.2 - <0.5
Volatile TPH/BTEX						
1.2-Dichloroethane-D4	%	1	55	53	61	31 – 88
Toluene-D8	%	1	47	46	52	27 – 87
4-Bromofluorobenzene	%	1	44	36	44	32 – 82

1= WBM (2000a)

3.3 Mangrove Species Distribution

Three species of mangroves were recorded within the study: They were, in decreasing order of abundance:

- Grey mangroves (*Avicennia marina* var *australasica*)
- Yellow mangroves (*Ceriops australis*) and
- Red mangroves (*Rhizophora stylosa*).

Four additional species are known to occur in Moreton Bay (Dowling 1979): Orange mangrove (*Bruguiera gymnorhiza*), River mangrove (*Aegiceras corniculatum*), Milky mangrove (*Excoecaria agallocha*) and Black mangrove (*Lumnitzera racemosa*), however none of these species were recorded in the study area. Orange and River mangroves have been reported at Fisherman Islands (immediately north of the study area) (WBM 2002) and it is likely that these species are present at Whyte Island in small numbers.

Figure 3.7 shows the distribution of mangrove species throughout the study area. *A. marina* was the most abundant species at Whyte Island, both in terms of areal extent and number of individuals. *C australis* was found at the northern end of the study area and isolated patches of *R.stylosa* occurred mainly on the seaward fringe of the mangroves, primarily along small creeks and drainage lines.

Figure 3.7 Species Distribution of Mangroves at Whyte Island – 200

3.4 Mangrove Health

Figure 3.8 shows the distribution of mangrove health classifications at Whyte Island in 2002. The area of mangroves within each classification is presented in Table 3.5.

Table 3.5 Extent of Mangroves Within Each Health Classification at Whyte Island

CATEGORY	Area in ha (proportion of total study area)
Good	31.6 (32.6%)
Fair	13.7 (14.2%)
Poor	18.5 (19.2%)
Dead	26.6 (27.5%)
Bare/claypan	6.3 (6.5%)
TOTAL	96.7 ha

Figure 3.8 Mangrove Health at Whyte Island - 2002

3.5 Mangrove Community Structure

3.5.1 Mangrove Densities

Figure 3.9 shows the average stem density for each health classification. Mean stem density appears to be highest in mangroves classified as Poor, however no statistically significant difference between categories is evident due to the high degree of variability.

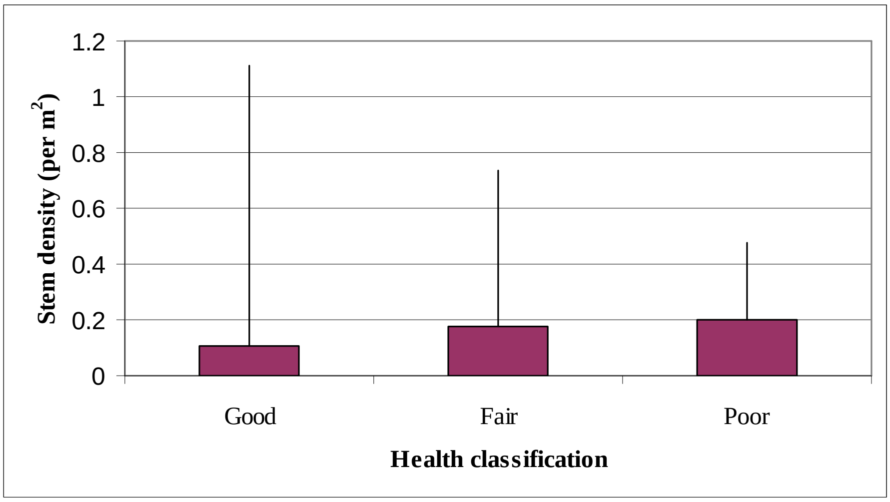

Figure 3.9 Average Mangrove Stem Density for Each Health Classification

3.5.2 Mangrove Girth and Canopy Height

Figure 3.10 shows the relationship between Girth at Breast Height (BGH) and canopy height for mangroves within each health classification. The trend of canopy height increasing approximately linearly with GBH up to a GBH of 65 cm is consistent with that reported for other mangrove communities in the region (Mackey and Monsur 1994; WBM 2002).

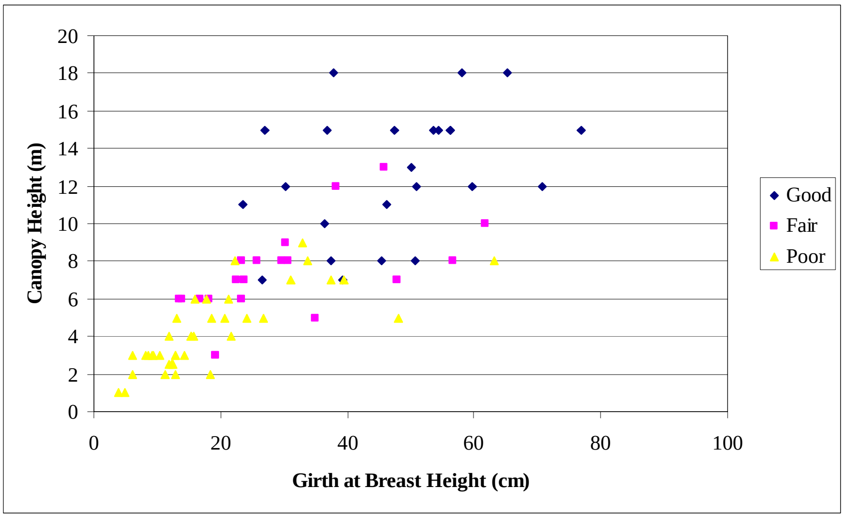

Figure 3.10 Average Girth at Breast Height and Canopy Height of Mangroves at Whyte Island

4 DISCUSSION

4.1 Status of Whyte Island mangroves

The physical characteristics of the mangroves at Whyte Island were similar to those of other nearby communities (for example, Bulwer Island (Mackay and Monsur 1994) and Fisherman Islands (WBM 2000a, 2002)). Plant density varied considerably but showed a possible trend of being lowest in healthy areas. Individual trees were largest (both height and girth) in the healthy areas.

There was a distinct zonation evident in the health classification of the mangroves of Whyte Island. Mangroves around the perimeter of the community were in good condition, while in the middle of the island a large area of dead mangroves was mapped. This dieback had occurred over a prolonged period, and the existence of a zone of stressed mangroves adjacent to the dead area indicates that the impacting process/es is ongoing. Approximately 50%of the remaining mangroves are exhibiting signs of stress.

The following section discusses possible impacting processes responsible for the degradation of the Whyte Island mangroves.

4.2 Impacting Processes

The results of the mangrove health assessment combined with the review of historical aerial photography indicate that the impacting processes responsible for the degradation of the Whyte Island mangrove community first became evident between 1978 and 1983 and appear to be continuing to the present.

Areas of degraded mangroves were generally well defined, with rapid transitional zones from degraded areas to apparently healthy areas. This indicates that the factors causing the degradation were not operating across the entire area, as would be expected with widespread fungal and/or insect infestations.

Three potential impacting processes have been identified as possibly causing the mangrove degradation at Whyte Island:

1. Water stress;
2. Elevated heavy metal concentrations; and
3. Elevated Total Petroleum Hydrocarbons.

4.2.1 Water stress

Whilst mangroves require regular inundation by saltwater to survive, excessive periods of immersion can be detrimental to mangrove health. Ponding of water can lead to asphyxia of mangroves as the ponded waters reduce the ability of the aerial components of the roots (pneumatophores in *A.marina*) to take up oxygen. Indications of water stress include the development of water shoots and adventitious roots growing directly from the tree trunk (Hutchings and Saenger 1987). Water shoots in particular were evident on plants in the zone of Poor mangroves at Whyte Island.

Reduction in soil aeration as a result of increased moisture content, impeded drainage and/or reduced water movement can also lead to the exhaustion of major plant nutrients in interstitial water surrounding the plant roots. Furthermore, the development of anaerobic conditions in the immediate vicinity of the roots can lead to pH changes, which can alter the bio-availability of nutrients (Hutchings and Saenger 1987).

Water stress generally occurs as a result of changes to the hydraulic regime of a particular area, for example through alterations to drainage patterns. At Luggage Point, on the north-western side of the Brisbane River, water ponding around the roots of the mangroves was identified as the likely cause of the loss of approximately 35 ha of *A. marina* (WBM 1998a). Nutrient inputs from the adjacent Waste Water Treatment Plant caused algal blooms, which resulted in the formation of dense algal mats. These mats accumulated in drainage lines in the area, blocking flow paths and causing water to be permanently ponded about the roots of the mangroves. This process was self-perpetuating as the ponded areas themselves (being shallow and stagnant) provided ideal conditions for algal growth resulting in further blooms and the additional accumulation of algal mats.

At Whyte Island, effluent from the Wynnum Waste Water Treatment Plant (WWWTP), which began operations in the mid 1960’s, flows into the creek that originally separated the island from the mainland. In the construction of Port Drive, this creek was filled in along almost its entire length with only a 50m stretch remaining at the southern (downstream) end. This infilling reduced the tidal prism of the creek and hence decreased flushing and tidal exchange at the point where the outfall flows into the creek. This would have resulted in the concentration of nutrients within the creek with tidal flushing reduced but nutrient inputs maintained (or possibly increased as a result of the increasing population).

Algal blooms are likely to have occurred under these conditions (high nutrients and reduced tidal exchange) resulting in the same impacting process evident at Luggage Point. That is, ponded areas developing as a result of drainage lines being blocked by algal mats. In this process, mangrove dieback would not necessarily commence close to the outfall. Decaying algal mats are likely to have been washed into the centre of Whyte Island on large tides and gradually accumulated around mangrove roots and in drainage lines, eventually resulting in areas becoming separated from the normal flow paths with water unable to drain away during each tidal cycle. Thick algal mats were observed in the degraded areas at Whyte Island (Figure 4.1 and Figure 4.2).

Figure 4.1 Loose algal mat

Figure 4.2 Algae growing in ponded area

4.2.2 Elevated heavy metal concentrations

Chemical analysis of sediments from Whyte Islands revealed elevated levels of some heavy metals. Concentrations were highest close to the WWWTP outfall for all elements tested except Arsenic, which was present in elevated concentrations at all sites tested. Elevated levels of copper, nickel, lead and zinc have been reported from sediments near a Waste Water Treatment Plant outfall in Tallow Creek, in northern New South Wales (WBM 2000b) and at Luggage Point elevated copper and zinc levels have been reported (WBM 1998b). Reduced tidal flushing, as discussed in the previous section, increases the potential for pollutant accumulation and the two processes may interact at Whyte Island to impact upon the health of the mangroves in the area.

4.2.3 Elevated Total Petroleum Hydrocarbons

Elevated TPH levels were recorded at two of the three sites sampled however the reason for these levels is difficult to ascertain from the limited data collected in this study. Possible sources may include surface runoff from Port Drive, accumulation from marine sourced spills washing into the area on prevailing winds, accidental spills/leakage from the Queensland Rail Whyte Island Refuelling Depot or effluent from the WWWTP. No conclusions can be drawn about the source of the elevated TPH's without additional investigations including further sampling.

It is, however, considered unlikely that elevated TPH's is the primary impacting process operating at Whyte Island due to the pattern of mangrove dieback. Mangrove dieback has also occurred at the northern end of Whyte Island were low TPH levels were recorded.

4.3 Management Options

The following sections provide a preliminary assessment of options available for the future management of the mangroves at Whyte Island.

4.3.1 Option 1: No Action

This option involves no active management by either the PBC or statutory authorities. Whilst the areas directly flushed by oceanic waters (ie those in close proximity to the edges and/or creeks) may experience little direct effects (as little opportunity to pond waters in these areas exists), the degradation of the mangroves within the "central" areas is likely to continue. Given the deteriorated health of mangroves, the ongoing nature of the impacting processes and the lack of current recovery in affected areas, it is likely that most mangroves within the "Poor" and "Fair" category will die. This may pose a range of environmental issues, such as sediment remobilisation, loss of habitat, nutrient inputs and loss of primary production for both the adjacent areas and wider Moreton Bay.

The ponded waters within Whyte Island currently provide suitable habitat for breeding mosquitos. Mosquito control is currently conducted by the Brisbane City Council via aerial spraying of the control agent BTI. The expansion of degraded areas may increase the need for mosquito control in these areas.

Advantages : No short-term management requirements.

Disadvantages : Continual degradation and likely loss of large areas of mangrove resources within Whyte Island, with possible associated secondary effects to adjacent areas. Continued, and possibly increased, need for mosquito management.

Cost : No short-term expenditure required

4.3.2 Option 2: Reinstatement of drainage and tidal regime

This option involves the reinstatement of drainage to areas which are currently ponded. It is likely that the natural drainage lines have been disturbed to such an extent that they are no longer evident, and a new network would have to be developed.

This option would require detailed survey work to identify the appropriate areas and configurations for the constructed channel(s). The topography of the area makes the selection of potential drainage lines a critical factor in this management option. WBM Oceanics Australia is currently involved in a similar project at Luggage Point for the Brisbane City Council where rehabilitation works have been carried out and a monitoring program is underway to assess their effectiveness.

Rehabilitation works are unlikely to be successful, in this or any other case, unless existing impacting processes are removed. For example, the Luggage Point Rehabilitation works were not undertaken until nutrient inputs were reduced as a result of upgrades to the Luggage Point Treatment Plant and improved solid waste management. It is recommended that investigations into reducing nutrient outputs from Wynnum WWTP be carried out prior to undertaking any rehabilitation works.

Initial investigations into the feasibility of drainage works should endeavour to develop a thorough understanding of water movements in the area. WBM undertook a dye release to successfully monitor water movements at Luggage Point and the same technique could readily be used at Whyte Island. Brightly coloured dye is released at a number of points throughout the area and movement of the dye is monitored throughout the tidal cycle via aerial surveillance

Advantages: Reinstatement of tidal flushing to degraded areas is likely to bring about a rapid increase in mangrove health. The area contains an abundant supply of parent stock material and adequate recruitment is likely. By draining the ponded areas, the areas of suitable mosquito breeding habitat would also be reduced.

Disadvantages : The construction of the channels is likely to disturb other areas of mangroves during the construction process. Some care would need to be taken to ensure that existing drainage lines are not disrupted by channel construction. Additionally, the issue of exposure of potential acid sulphate soils by either draining areas or reducing local water tables will need to be addressed. Some maintenance of the channels may be required to ensure they do not become blocked.

Due to the relatively small-scale changes in topography across the study area, substantial additional investigations would be required to assess the feasibility of this action.

Costs: The total cost of implementing a rehabilitation plan (including investigations, approvals, construction and monitoring) is likely to be in the order of $150,000 to $200,000. Preliminary investigations into the feasibility of drainage works (eg. dye release) are likely to cost $5,000 to $10,000.

5 CONCLUSIONS

A large proportion of the mangroves at Whyte Island are highly degraded. Thirty-two hectares are dead and a further 30 hectares are exhibiting signs of stress and are likely to continue to degrade in the absence of management intervention. This represents approximately 60% of the mangroves present at Whyte Island following the construction of Port Drive.

The process causing the deterioration is considered most likely to have resulted from a combination of reduced tidal flushing/altered drainage patterns following construction of Port Drive and elevated nutrients from the Wynnum WWTP. Reduced tidal exchange at the point where the WWWTP outfall flows into the creek and continued nutrient inputs are likely to have resulted in the concentration of nutrients within the area. These conditions may have led to algal blooms and the formation of dense algal mats. Gradual accumulation of these algal mats could have altered drainage paths and caused water to pond around the roots of the mangroves resulting in water stress leading directly, or indirectly, to plant death.

The processes implicated in the deterioration are on-going and there appears to be little or no natural recovery in most degraded areas. In the absence of management intervention, the future viability of a large proportion of the mangroves within the study area is considered to be threatened. While Whyte Island is not the largest mangrove community within western Moreton Bay, its continued decline is a matter of concern for the wider area. It should be noted that the Whyte Island mangroves are not isolated in decline, but part of a wider area from Wynnum to Hayes Inlet and Redcliffe, which exhibits severe stress and significant mangrove loss.

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APPENDIX A: SURVEY DATA 2002

Point	Lat	Long	Health	Spp comp	FPC	Ht	Algae	Fauna	Dist fr Point	Spp	GBH	Dist to NN	Spp	GBH NN	Dist fr Point	Spp	GBH	Dist to NN	Spp	GBH NN	Dist fr Pt	spp	GBH	Dist to NN	spp	GBH NN
1	516751.47	6968207.11	DEAD																							
2	516875.69	6968267.29	P	Av 100	1	2	A	R	0.8	Av	5	0.5	Av	3	1.2	Av	8	0.8	Av	5	0.9	Av	8	0.5	Av	8
3	516885.22	6968275.3	P	Av 100	4	3	C	R	0.4	Av	8	0.5	Av	8	0.8	Av	10	0.5	Av	8	1.6	Av	10	1.2	Av	8
4	516904.02	6968285.42	P	Av 100	4	4	C	R	1.7	Av	20	1.4	Av	15	1.4	Av	18	1.6	Av	15	0.7	Av	12	0.6	Av	12
5	516922.85	6968291.2	P	Av 100	3	5	C	R	1.9	Av	29	2	Av	20	2	Av	46	2.2	Av	25	1	Av	10	1.3	Av	15
6	516948.55	6968300.22	P	Av 100	2	7	R	R	2	Av	62	2.3	Av	19	1.8	Av	47	1.9	Av	29	2	Av	38	2.1	Av	42
7	516982.15	6968309.11	P	Av 100	2	8	R	R	1.8	Av	56	1.5	Av	56	1.6	Av	54	2.2	Av	38	2	Av	135	2.4	Av	40
8	517011.31	6968312.84	F	Av 100	4	8	R	R	1	Av	47	0.8	Av	42	0.5	Av	64	0.3	Av	69	1.5	Av	70	1.3	Av	48
9	517055.15	6968325.81	F	Av 100	4	8	R	R	0.8	Av	28	0.6	Av	35	1.1	Av	40	1.2	Av	18	1	Av	35	1.2	Av	28
10	517028.46	6968389.95	G	Av 100	5	8	R	R	0.7	Av	40	0.5	Av	20	1.4	Av	38	1.5	Av	52	1.7	Av	30	1.8	Av	45
11	517017.8	6968427.49	G	Av 100	5	7	C	R	0.8	Av	48	0.8	Av	32	1.3	Av	42	1	Av	50	0.8	Av	30	1.2	Av	33
12	516976.11	6968438.55	G	Av 95 R 5	4	7	C	R	0.8	Av	30	0.5	Av	28	0.5	Av	17	0.3	Av	28	0.7	Av	25	1	Av	32
13	516918.54	6968482.55	F	Av 95 C 5	2	7	C	R	1	Av	12	1.3	Av	21	0.7	Av	10	0.9	Av	17	1.5	Av	21	2.1	Av	54
14	516850.21	6968494.23	P	Av 100	2	5	C	R	1.4	Av	5	2	Av	38	1.2	Av	20	1.2	Av	15	1.4	Av	18	1.8	Av	28
15	516827.66	6968466.13	P	Av 100	2	4	C	R	0.5	Av	18	0.6	Av	15	0.7	Av	12	0.8	Av	17	1.7	Av	48	2.2	Av	20
16	516811.3	6968458.77	P	Av 100	2	3	V	R	1.4	Av	10	1.2	Av	14	1.8	Av	8	1.5	Av	12	1.6	Av	18	1.3	Av	24
17	516793.66	6968447.21	P	Av 100	1	2.5	V	R	1.1	Av	12	1	Av	18	0.6		5	1	Av	12	1.5	Av	10	0.9	Av	18
18	516773.78	6968429.44	north west end of 'island'																							
19	516731.87	6968453.97	DEAD																							
20	516708.04	6968466.34	P	Av 100	1	2	V	R	1.3	Av	17	1	Av	28	1.3	Av	5	1.2	Av	8	1	Av	11	1.4	Av	8
21	516682.55	6968483.66	P	Av 100	1	3	V	R	0.8	Av	10	1	Av	8	0.9	Av	17	0.8	Av	5	1.3	Av	8	1	Av	15
22	516675.1	6968491.27	DEAD																							
23	516654.46	6968498.38	DEAD																							
24	516617.29	6968506.62	P	Av 100	1	3	V	R	1.4	Av	4	1	Av	12	0.8	Av	5	0.7	Av	8	0.7	Av	8	0.8	Av	12
25	516584.51	6968498.83	P	Av 100	1	1	V	R	1	Av	4	0.8	Av	3	2	Av	3	2.5	Av	3	0.9	Av	5	1.2	Av	5
26	516558.57	6968495.25	DEAD																Av							
27	516488.72	6968605.13	DEAD																							
28	516492.51	6968672.41	P	Av 100	1	3	V	R	1.1	Av	5	0.8	Av	3	0.7	Av	5	1	Av	9	1.3	Av	5	1.1	Av	10
29	516513.91	6968711.37	P	Av 100	3	3	V	R	0.9	Av	8	0.5	Av	10	1.1	Av	9	0.7	Av	7	1.5	Av	12	1	Av	10
30	516538.78	6968702.24	P	Av 100	4	1	V	C	1.3	Av	3	1	Av	5	0.6	Av	5	0.8	Av	5	1.1	Av	8	0.9	Av	3
31	516565.75	6968711.94	P	Av 95 C 5	1	5	C	R	2	Av	29	2.4	Av	38	1	Av	52	1.3	Av	48	1	Av	53	1.1	Av	68

32	516581.25	6968733.89	F	Av 50 C 50	2	6/2	C	R	1	C	3	1.2	C	5	2	Av	22	2.1	Av	63	0.8	Av	3	1	C	5
33	516606.88	6968748.26	F	Av 50 C 50	2	6/2	C	R	0.6	C	3	0.4	C	5	1.2	Av	48	1.2	C	8	0.2	Av	12	0.9	C	8
34	516672.04	6968737.95	F	C 75 Av 25	3	6/2	C	R	1.4	C	10	1.1	Av	8	0.8	C	10	0.8	Av	22	1.8	C	13	1.8	Av	18
35	516736.93	6968782.04	G	Av 100	4	8	C	C	1.4	Av	69	1.5	Av	38	0.7	Av	11	0.5	Av	28	0.4	Av	33	0.8	Av	94
36	516609.38	6968797.08	F	C 50 Av 50	3	6	C	C	0.7	Av	18	0.9	Av	24	1	Av	8	1	C	12	0.9	Av	32	1.2	C	15
37	516547.38	6968773.04	G	Av 100	4	8	C	C	1.6	Av	48	1.4	Av	57	0.9	Av	40	0.7	Av	64	0.7	Av	51	0.6	Av	44
38	516518.93	6968762.92	F	Av 95 C 5	3	6	R	C	1.3	Av	22	1.2	C	15	0.6	C	18	0.4	Av	27	0.9	Av	32	0.8	Av	26
39	516510.26	6968736.23	F	Av 100	3	3	R	C	0.7	Av	20	0.5	Av	18	0.6	Av	15	0.6	Av	15	1	Av	22	0.8	Av	25
40	516488.79	6968708.7	P	Av 100	1	2	R	C	0.8	Av	25	1	Av	15	1	Av	18	1.2	Av	23	1.2	Av	15	1.4	Av	15
41	516459.38	6968654.28	DEAD																							
42	516455.06	6967969.54	DEAD																							
43	516455.02	6967868.09	DEAD																							
44	516453.6	6967822.33	edge of mangroves																							
45	516486.32	6967814.25	DEAD																							
46	516549.34	6967802.13	DEAD																							
47	516608.83	6967793.16	DEAD																							
48	516683.18	6967798.66	P	Av 100	2	2.5	V	R	2	Av	10	1.2	Av	8	1.8	Av	15	1.1	Av	18	2.1	Av	15	1.4	Av	8
49	516716.03	6967784.79	DEAD																							
50	516745.9	6967779.42	edge of stressed mangroves																							
51	516764.9	6967781.15	P	Av 100	1	2.5	V	R	3.2	Av	8	1.6	Av	15	1.4	Av	18	1	Av	12	2.4	Av	8	1.9	Av	10
52	516797.59	6967775.16	margin of dead and stressed mangroves																							
53	516870.16	6967758.53	margin of dead and stressed mangroves																							
54	516893.1	6967751.59	P	Av 100	1	5	V	R	1.7	Av	15	0.4	Av	28	2	Av	38	1.2	Av	15	2.2	Av	28	1	Av	37
55	516937.99	6967739.57	F	Av 100	3	5	C	C	2.5	Av	30	1.3	Av	25	2.4	Av	32	1	Av	38	1.8	Av	37	2.5	Av	48
56	516992.27	6967705.77	F	Av 100	4	10	C	C	3	Av	105	2.8	Av	115	2.2	Av	28	1.7	Av	17	3.6	Av	40	2.8	Av	65
57	517067.79	6967682.2	G	Av 100	4	12	A	C	2.1	Av	92	2	Av	84	3.1	Av	42	3.5	Av	90	2.8	Av	47	3.1	Av	70
58	517120.31	6967664.79	G	Av 100	4	12	A	C	2.2	Av	83	1.8	Av	20	2.3	Av	95	2.3	Av	78	4.3	Av	52	2.5	Av	30
59	517059.32	6967580.93	G	Av 100	4	10	A	C	1	Av	28	1.2	Av	35	2.4	Av	55	0.8	Av	23	1.5	Av	50	1.8	Av	28
60	516993.26	6967563.52	P	Av 100	3	7	C	R	1.3	Av	18	0.8	Av	27	1.8	Av	25	2.6	Av	43	2	Av	31	1.5	Av	42
61	516936.67	6967552.86	DEAD																							
62	516948.63	6967521.04	DEAD																							
63	516934.16	6967482.34	DEAD																							
64	516935.13	6967451.64	F	Av 100	3	7	C	R	1	Av	20	1.8	Av	31	0.8	Av	35	2.1	Av	20	1.2	Av	17	1.9	Av	19
65	516898.5	6967545.08	DEAD																							
66	516866.82	6967591.76	P	SHRUBS<2M tall - dense bushy some sarcocornia																						

67	516845.83	6967588.16	margin of dead and stressed mangroves																							
68	516832.04	6967579.45	P	Av 100	1	4	C	R	1	Av	20	2.2	Av	8	1.4	Av	15	1.9	Av	10	0.9	Av	15	1.2	Av	24
69	516805.58	6967562.74	P	Av 100	2	7	C	R	1.1	Av	18	1.4	Av	20	1.8	Av	25	2.6	Av	30	1	Av	78	2	Av	54
70	516788.63	6967577.19	DEAD																							
71	516796.22	6967471.29	F	Av 100	3	7	C	R	2.1	Av	10	3.8	Av	45	2.6	Av	77	1.2	Av	94	2.8	Av	20	2.2	Av	41
72	516738.14	6967395.8	G	Av 100	4	11	R	R	3.4	Av	48	2.7	Av	36	2.1	Av	41	2	Av	57	3	Av	45	1.9	Av	50
73	516675	6967366.71	G	Av 100	5	15	A	R	1.9	Av	35	3	Av	62	2.5	Av	87	2.9	Av	48	1.7	Av	32	3.2	Av	58
74	516624.48	6967345.47	G	Av 100	5	15	A	R	1	Av	40	1.3	Av	38	1.7	Av	28	3.2	Av	67	2	Av	125	1.2	Av	28
75	516599.23	6967391.87	G	Av 100	5	15	A	R	4.2	Av	65	2.3	Av	68	3.3	Av	52	5.1	Av	115	3.1	Av	74	2	Av	87
76	516578.17	6967465.01	G	Av 100	5	15	A	R	3.6	Av	54	2.1	Av	74	2.5	Av	48	3.8	Av	37	2.9	Av	60	2	Av	65
77	516563.87	6967533.43	G	Av 100	5	15	A	R	2.8	Av	48	1.4	Av	62	2.1	Av	22	2.2	Av	50	1.9	Av	47	3.9	Av	56
78	516521.77	6967620.71	G	AV 95 R 5	5	15	A	R	1.7	Av	38	1.5	Av	30	2.3	Av	45	1.8	Av	38	2.7	Av	42	1.4	Av	28
79	516460.64	6967645.62	out of mangroves																							
80	516480	6967690	F	Av 100	4	8	R	R	1.3	Av	30	1.5	Av	25	0.9	Av	25	1.2	Av	33	1.2	Av	18	1	Av	24
81	516487.13	6967752.03	P	Av 100	2	6	C	R	1.5	Av	15	3.2	Av	18	1.9	Av	15	0.8	Av	21	1.4	Av	15	1.2	Av	12
82	516518.87	6967751.46	P	Av 100	1	5	A	R	0.8	Av	18	2.4	Av	25	1	Av	18	0.5	Av	18	1.2	Av	19	1.4	Av	14
83	516651.52	6968132.08	edge of island																							
84	516720.86	6968145.29	DEAD																							
85	516863.51	6968204.58	DEAD																							
86	516876.99	6968213.71	P	Av 100	5	2	C	R	0.7	Av	10	0.5	Av	12	1.1	Av	8	0.9	Av	10	1.4	Av	15	1	Av	13
87	516887.14	6968183.45	P	Av 100	5	3	C	R	1.3	Av	15	0.4	Av	8	1	Av	10	1.4	Av	14	1.1	Av	12	1.5	Av	18
88	516892.3	6968169.8	DEAD																							
89	516903.17	6968171.64	P	Av 100	3	4	C	R	0.5	Av	8	1.3	Av	10	0.9	Av	12	0.5	Av	14	0.7	Av	15	0.9	Av	12
90	516918.74	6968184.41	P	Av 100	1	5	R	C	1.5	Av	18	0.9	Av	13	1.8	Av	20	1.1	Av	15	1	Av	8	0.6	Av	5
91	516941.17	6968192.65	P	Av 100	1	6	R	C	2.1	Av	14	2.5	Av	35	1.4	Av	48	2	Av	12	0.9	Av	13	1.4	Av	5
92	516956.6	6968219.96	P	Av 100	2	6	R	C	1.3	Av	28	1.7	Av	19	1	Av	8	0.4	Av	27	0.3	Av	10	2.7	Av	15
93	516995.04	6968229.45	F	Av 100	3	8	R	C	1.7	Av	43	1.1	Av	48	1.3	Av	29	0.6	Av	24	1	Av	12	3.1	Av	22
94	517040.71	6968232.34	G	Av 100	4	11	R	R	1.2	Av	18	1.4	Av	30	0.3	Av	19	1.2	Av	43	1.9	Av	10	0.4	Av	21
95	517070.84	6968234.94	G	Av 100	4	12	R	R	0.5	Av	15	0.4	Av	27	1.1	Av	55	2.1	Av	47	0.8	Av	17	0.6	Av	20
96	517095.72	6968250.26	edge of mangroves																							
97	517087.34	6968161.06	G	Av 100	5	12	R	R	3.1	Av	50	1.7	Av	42	2.4	Av	71	2.5	Av	64	1.8	Av	32	2.4	Av	47
98	517105.79	6968080.77	G	Av 100	5	15	C	R	1.8	Av	47	1.9	Av	54	2.8	Av	56	1.9	Av	81	1	Av	52	1.9	Av	47
99	517056.26	6968064.71	G	Av 95 R 5	5	15	R	R	1	Av	30	1.4	Av	18	1.2	Av	22	0.5	Av	44	1.4	Av	15	1	Av	33
100	516985.76	6968048.79	G	Av 100	4	13	C	A	0.4	Av	63	2.2	Av	54	1.7	Av	36	2.3	Av	48	1.3	Av	47	0.9	Av	53
101	516961.58	6968031.71	F	Av 99 C 1	2	8	R	A	1.2	Av	26	1.3	Av	30	2.1	C	8	0.7	Av	39	1	Av	15	3.4	Av	22

102	516946.73	6968020.15	P	Av 100	1	8	R	A	0.9	Av	5	0.6	Av	7	3.4	Av	37	2	Av	47	2.5	Av	30	1.6	Av	8
103	516897.93	6967999.67	P	Av 100	1	3	C	R	3	Av	8	3.5	Av	10	1	Av	15	1.7	Av	11	1.2	Av	14	1	Av	19
104	516872.47	6967983.18	DEAD																							
105	516841.03	6967980.08	P	Av 100	1	3	V	R	0.5	Av	5	0.7	Av	10	0.6	Av	7	1.2	Av	12	1	Av	10	1.9	Av	11
106	516821.02	6967974.73	DEAD				V																			
107	516717.1	6967763.45	DEAD				V																			
108	516725.32	6967666.58	DEAD				V																			
109	516676.41	6967624.03	margin of dead stumps and stressed mangroves																							
110	516663.78	6967614.7	F	Av 100	2	9	C	R	2	Av	28	2.2	Av	25	1.2	Av	10	0.9	Av	47	1	Av	38	1.7	Av	33
111	516635.15	6967596.13	F	Av 100	4	13	C	R	1.2	Av	47	2	Av	39	1	Av	67	3.4	Av	44	1.6	Av	27	3	Av	51
112	516611.14	6967572.37	G	Av 100	4	18	C	C	0.6	Av	40	3.1	Av	10	1.9	Av	39	2.2	Av	44	1.9	Av	30	1.7	Av	64
113	516558.85	6967560.49	G	Av 100	4	18	A	C	1.1	Av	55	1.3	Av	60	2.1	Av	45	0.5	Av	79	3	Av	38	1	Av	72
114	516529.18	6967598.77	G	Av 100	4	18	R	A																		
115	516505.16	6967655.53	G	Av 100	5	18	A	C	1.2	Av	48	1.4	Av	35	1.3	Av	105	4.7	Av	68	2.7	Av	51	3	Av	84
116	516565.92	6967667.41	F	Av 100	3	12	C	R	2	Av	33	1.3	Av	49	2	Av	38	1.2	Av	42	1.4	Av	37	2.7	Av	30
117	516612.55	6967688.52	P	Av 100	3	9	C	R	1.4	Av	38	1	Av	30	1	Av	42	1.9	Av	28	0.4	Av	20	1.1	Av	39
118	516624.04	6967695.52	margin of dead and stressed mangroves - stressed zone is approx 30-50m wide																							
119	516545.45	6967720.07	P	Av 100	2	8	A	R	1.8	Av	45	1.4	Av	35	1.7	Av	22	0.4	Av	38	2.7	Av	15	1.8	Av	47
120	516463.05	6967775.51	P	Av 100	2	4	V	R	2.2	Av	15	1.7	Av	20	1.2	Av	10	1.4	Av	21	1.9	Av	8	1.4	Av	20

Figure A-1 Whyte Island Survey Points