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Impact of Proposed Townsville Ocean Terminal Development on the Water Quality of Cleveland Bay

Report for: City Pacific Limited

Date: 25th June 2007

"IMPORTANT NOTE"

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Signed on behalf of
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Director	Date

EXECUTIVE SUMMARY

Introduction

The Townsville Ocean Terminal site is located on and adjacent to the existing Townsville foreshore and incorporates the existing Townsville Port western and northern breakwaters, the existing perimeter of the land around the Townsville Casino and the Townsville Convention Centre and Mariners Drive Peninsula. Initial works are expected to include dredging and infilling in the areas directly to the west of the current breakwall, the construction of a breakwater further to the west and other construction works. The area potentially affected will depend on tides, currents and weather patterns, as well as the timing of the works and the prevention methods implemented.

The Terms of Reference requires consideration be given to potential impacts on National Parks, Conservation Parks, Declared Fish Habitat Areas, Aquatic Reserves, World Heritage Listings, sites covered by International Treaties or Agreements (such as Ramsar, JAMBA, CAMBA, etc), Areas of Cultural Significance and Scientific Reserves. This baseline study evaluates the current status of the water quality that supports these environments (eg: seagrass beds, coral reefs, etc.).

The baseline study encompassed all the major habitat types and species found in Cleveland Bay, and includes the identification of environmentally sensitive habitats and species, the identification of potential impacts of the Townsville Ocean Terminal development, the compilation of a risk assessment, and recommendations for mitigation methods and a monitoring program. The area targeted for the baseline study includes primarily the near shore coastal habitats of Cleveland Bay (particularly seagrass beds), the coral reefs around Magnetic Island and the mouth and lower reaches of the Ross River. The baseline study was conducted according to a Before-After-Control-Impact (BACI) sampling design.

Baseline field investigations included a range of techniques from visual assessments to collection of material and laboratory analyses. Water quality sampling was conducted at the sites chosen for seagrass sampling and within the development area; the objectives of this investigation are to describe the water quality of Cleveland Bay and to assess the potential impacts of the Development on water quality.

An additional goal of sediment and water quality studies is to provide a locally based set of guidelines against which the impacts of the Townsville Ocean Terminal can be assessed.

Sampling Strategies

On the basis of a statistically designed sampling regime, water and sediment samples were taken at 11 points in the Bay co-incident with sea-grass sampling sites S1-S4, S6-S8, C1-

C3 and SUN. At these points bottom sediment, bottom water and surface water were taken according to appropriate protocols. They were analysed for a broad range of chemical species including selected major, minor and trace metals, metalloid, and nutrient species with approximately 34 chemical parameters being assessed in the sediment samples and 30 in the water samples. Limited, in-situ analyses was also undertaken of the three groundwater bores sunk in the area of the development.

Analytical Assessment

All results obtained from the chemical analysis were treated statistically to obtain means and standard divisions. These data indicated no, overall significant differences between the control sites and the other sample sites. Overall results were then compared with a range of standard guidelines including ANZECC, 2000 Water and Interim Sediment Quality Guidelines, ANZECC, 2001 Ocean Disposal Guidelines, Queensland Water Quality Guidelines 2006 and other internationally accepted guidelines (eg: USEPA and Ontario).

Modelling

Water Quality modelling was undertaken on the waters of the Bay using the PHREEQC programme of the United States Geological Survey. This was coupled with the run-off water quality obtained from the MUSIC programme for the constructed catchment area. Mixing and flushing and mixed water quality models were developed to mimic worst water quality case scenarios for the development. This modelling included first flush scenarios for the total dissolution of the dust falling on the development over a nine month period and/or the total incorporation of this dust into the bottom sediment of the development area.

Results

1. Spatially, even though the development area is currently impacted from external dust sources, the sediment quality in the area is within the range of that in the Bay. This overall quality is consistent within Queensland HIL-A soil guidelines. Both for the Bay area and the development zone currently do exhibit minor, occasional inconsistencies within the ANZECC 2000 Interim Sediment Quality Guidelines and ANZECC 2001 Ocean Disposal Guidelines. Modelling indicates all current sediment quality parameters will be maintained.

2. Spatially, even though the water quality in the Bay is impacted, it is currently generally good to moderate when compared to ANZECC, 2000 Guidelines. The detailed modelling indicates, given the flushing mechanism proposed, that current ambient water quality will be maintained. Even under worst case first flush scenarios the water quality for all parameters assessed will be within the ambient range already in the Bay or within the 95% (or in some cases 99%) ANZECC Species Protection Guidelines or both. Thus, the water quality emanating from the development will have no additional impacts on the water quality in the Bay. Recommended water quality discharge criteria are given in the attached table. The recommended values for water quality given are consistent within both ANZECC 2000 Guidelines and current ambient levels in the Bay.

3. It is vital for the maintenance of water and sediment quality of the development that flushing be maintained at proposed and modelled levels. To achieve this annual

dredging and monitoring will be required for sediments accumulated in the western channelway and the north east and south east arms of the development. The dredge spoil material will meet HIL-A standards and must be disposed of to appropriate land areas.

4. All groundwaters lie within ambient seasonal ranges from others in comparable situations in the vicinity.

Mitigation Measures and Monitoring

Within the development area the major risk is that of deterioration of water quality. Unless the development areas remains well flushed and maintained it is almost certain that water quality will deteriorate to unsustainable levels with possibly catastrophic consequences. However, the development will be well flushed and maintained through annual maintenance dredging and monitoring and thus the risk of deterioration of water quality will be minimised.

In Cleveland Bay itself, high risk activities associated with the development, are those that adversely affect water quality through increased turbidity, causing light attenuation and sediment deposition onto seagrass and corals. Further high risk activities are those that can lead to contamination of seagrasses, corals, benthic communities and water quality from oil, chemical or sewerage spills. Medium risk activities in the Bay are those that will elevate nutrient contents in the water and sediments, endangering seagrasses and corals through the increased growth and shading by macroalgae, and through an increase in contaminants in the water and sediments. There is a low risk of damage to seagrasses and benthic communities through contaminated sediments.

During the construction phase, it is recommended that regular, continuous monitoring be undertaken at both mobile and fixed locations. Generally, this monitoring should be for gross physical water quality parameters including pH, turbidity, salinity and temperature. Monitoring should be undertaken using permanent electrode stations down loaded to site or other suitable locations.

During the operations phase, it is recommended that a limited continuous monitoring programme be undertaken for gross physical water quality parameters. This should be supplemented by seasonal and event based water quality sampling for a broad range of analytes. Additionally, this should be coupled within bottom sediment sampling for a similar broad range of analytes associated with the annual maintenance dredging.

It is considered that this monitoring regime will ensure the maintenance of good quality bottom sediment and ambient waters.

Conclusions

1. All data indicate that all the flushed water quality exiting the development will be within current ambient range or 95% ANZECC 2000 Species Protection Guidelines or both.

2. All data indicate that all sediments produced from the development will be within current ambient ranges.

3. Regular maintenance dredging of parts of the development will be essential to maintain flushing, water and sediment quality. The dredge spoil thus obtained will meet HIL-A standards and must be disposed of to land.

4. Should the dredging and monitoring options proposed be undertaken then there are no reasons existing at present that the water quality or sediment quality derived from this development should impact on the environmental values of adjacent areas.

5. It is recommended that the above conclusion be accepted and recognised and that there are no grounds relating to water and sediment quality for the development to be disallowed.

Water Quality – Project Site Ocean Terminal

Analyte	Range in Bay µg/L	Level in Project Site µg/L		Level after first flush event µg/L			ANZECC Species protection Guidelines (SPG) µg/L			Recommended level µg/L	Comments
		Top	Bottom	12.5mm	25mm	50mm	95%	90%	80%		
Hg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	0.7	1.4	0.1	Within range in Bay. Better than 95% SPG
As	1.5 – 2.8	1.9	1.7	1.75	1.75	1.75	ID 13	ID 42	ID 140	3.0	Within range in Bay. Better than 95% Freshwater guidelines for As(V) - green
							SQ	23			Better than SQUIRT chronic marine - Red
Ba	6-9	6	6	5.8	5.8	5.8	NV	NV	NV	10.0	Within range in Bay. Better than SQUIRT Maximum contamination level (MCL)
							2000				
Be	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	ID 4	ID	ID	0.1	Within range in Bay. Better than SQUIRT MCL
Cd	<0.2-0.4	<0.2	<0.2	1.6	1.6	1.6	5.5	14	36	2.0	Above range in Bay but better than 95% SPG
C&R	<0.5-1.8	<0.5	<0.5	3.49	3.39	3.35	27.4	48.6	90.6	5.0	Above range in Bay but better than 95% (& 99%) SPG
Co	<0.2-3.8	<0.2	<0.2	2.78	2.70	2.67	1	14	150	3.8	Within range in Bay. Better than 90% SPG
Cu	<1-2.0	2	<1	2.68	2.02	1.69	1.3	3.0	8.0	3.0	At range in Bay. Better than 90% SPG
Pb	2.0-20.6	9.4	6.8	8.63	8.25	8.05	4.4	6.6	12	10	Within range in Bay. Better than 80% SPG. Values in Bay much less than 80% SPG
Mn	6.3-32.9	9.4	9.8	9.03	9.03	9.03	1900 50	2500	3600	20	Within range in Bay. Better than 95% SPG. Better than SQUIRT MCL
Ni	<0.5-1.2	<0.5	<0.5	4.11	3.99	3.94	70	200	560	7	Above range in Bay but better than 95% (& 99%) SPG
V	1.4-3.2	1.8	1.6	1.7	1.7	1.7	100	160	280	3.2	Within range in Bay. Better than 95% (& 99%) SPG
Zn	<5.0-7.0	<5.0	<5.0	4.29	4.08	3.98	15	23	43	7	Within range in Bay. Better than 95% (& 99%) SPG
Total N	<500-700	<500	600	550	550	550	700 300	3400 1600	17000	600	Within range in Bay. Within ANZECC 95% SPG for nitrate (purple). Above Queensland Total N of 300 (Blue). Inconsistency between ANZECC & Queensland values. Within ANZECC TN Lowland River (Mauve)
TRP	<10	<10	<10	7.79	7.79	7.79	8			8	Within range in Bay. At Queensland value (orange)

EXECUTIVE SUMMARY APPENDIX (RESPONSE TO TOR)

Townsville Ocean Terminal Project
Direct Response to TOR
Relating to Water and Sediment Quality Factors

Impact on the World Heritage Property

From water and sediment quality monitoring and water flushing, water and sediment quality modelling it is considered that all waters and sediments emanating from the development will be within ambient ranges already existing within Cleveland Bay adjacent to the project. Analytical data indicate that water quality moving out of the development will be either within ambient ranges already present in the Bay or better than the ANZECC (2000) 95% Species Protection Guidelines or both. For example, levels of lead (Pb) present in the waters of the Bay range fro 2.0 to 20.6µg/L. Maximum, worse case scenario levels emanating from the development will be approximately 8.0µg/L. This level compares with levels of 6.6µg/L for a 90% and 12µg/L for an 80% Species Protection Guideline. It should therefore be emphasised that there are ambient levels already that are consistent with species protection levels of less than 80%. For the worse case discharge water scenario, the water quality emanating from the development will be superior to that already existing at some sites in the Bay.

Given the high quality of the waters flowing from the development, it is anticipated that there will be no modifications to the values of the World Heritage property resulting from the quality of the waters emanating from the development.

Impacts on the Values of Wetlands of International Importance

Given the high quality of the waters flowing from the development the general hydrodynamics of the Bay and the separation distances involved, it is considered that there will be no impacts, resulting from water quality, on the wetlands of international importance in the area.

All water flows from the development will be within ambient water quality ranges or better than ANZECC 95% Species Protection Guidelines or both. Specifically, there will be no substantial or measurable changes in the water quality of the wetlands. Levels of salinity, pollutants (both naturally and anthropogenically derived), nutrients (both naturally and anthropogenically derived) and water temperature ranges will be within the current ambient for the already impacted Cleveland Bay ecosystems. The development, itself, will not impact the biodiversity, ecological integrity, social amenity or human health aspects of the wetlands of international significance of the area.

Impact on a Listed Threatened Species

Given the high quality of water flowing from the development, there will be no impacts on listed or threatened species resulting from water quality. All measures should be undertaken to ensure there is no unauthorised (illegal) use of environmentally unfriendly anti-foulants (eg: tri-butyl tin – TBT) to ensure there are no disruptions to breeding cycles of some organisms within the water bodies of the development.

Impact on a Listed Migratory Species

Given the high quality of the water flowing from the development, there will be no impacts on listed migratory species resulting from water quality. There will be no changes, outside current ambient ranges, to nutrient or hydrological cycles as a result of the water quality within and flowing from the development.

Emissions Associated with Port Operations

The report on air quality (dust, fumes, particulates. and odours – organic and inorganic) impacting on the project site based on current and future port developments did, as is customary, include no chemical analytical information on the dust collected. However, chemical information on the composition of the dust was obtained from other available sources. Two, worst case scenarios were modelled using the PHREEQC chemical equilibrium dissolution and precipitation program. These cases modelled potential water quality and sediment quality coming from the development, into the marina arms, after a 9 month dry period, different flushing frequencies from roofs, gardens and infrastructure (roads) and differing first flush volumes. The two cases modelled were:

- All material dissolved ~ greatest impact on water quality
- All material insoluble ~ greatest impact on sediment quality

For the first case, and in minimal (most concentrated) flush volumes, all water quality present in and flushing from the development was found to be either within ambient ranges in the Bay or better than 95% Species Protection Guideline or both. Thus, the impact of dust and a stormwater flush event on water quality in the development, given the adequate flushing now inherent in the design, will be minimal.

The second case, where all material is not dissolved, was found to have minimal impacts on sediment quality within the development and in the Bay. That this is the case may be ascertained empirically in that the sediment quality, currently present within the footprint of the development, is within the ambient range of the whole the Bay.

For the flushing to be successful, annual dredging will be required for the access channel. The outcome of the sediment chemical modelling indicates that in order to ensure long term sediment quality, then small areas in the extreme north east and south east of the development area, adjacent to the current western breakwater of Ross Creek (the eastern breakwater of this development), should also be dredged on an annual basis.

All sediment dredged in the annual works should be disposed of to land. All actual analytical data of the bottom sediment already present in the area and in the chemically modelled data indicate that the dredged material should meet HIL-A standards (Health Investigation Level A, normal urban residential).

Environmental Values and Management of Impacts

Background data relating to the impacts of water and sediment quality facets of the development on existing environmental values of the bay are described in the appended report "Impact of Proposed Ocean Terminal Development on Water Quality of Cleveland Bay" as shown in tables in sections 4.3, 4.4 and Appendix 1A and 1B, the water quality flushing into the Bay from the development will be:

- Either within the ambient range in the Bay, or
- Better than the ANEZECC 95% Species Protection Guidelines, or
- Both

Thus, from the perspective of water quality it is considered that the water quality flushing from the development will have little to no effect on that already existing in the Bay. This conclusion is based on a range of worst case scenarios. All intermediate cases will have appreciably less impact than the worse case scenarios.

Generally, the sediment quality already existing within the development area and within the Bay is either of marginally lower quality or within sediment quality guidelines and ocean dumping guidelines. Also in the vast majority of cases the sediment quality is better than HIL-A Guidelines. These levels will not deteriorate as a result of the development and the material used to create the land for the construction will be better than HIL-A criteria (normal urban residential). Levels for critical analytes within the existing sediments are given as an Appendix 1 to the attached report.

Elsewhere, it has been recommended that annual maintenance dredging be carried out in order to maintain the flushing efficiency of the development. This, dredged material should be disposed of to land as indicated by regular monitoring. Should this occur, then the quality of the bottom sediment will be maintained to match or improve on that already present in the Bay. Thus, decline in environmental values due to the quality of sediment input from the development will not occur.

- Given the quality of the water and sediment flushed from the pond and the regime of annual maintenance dredging, there will be no harm to current environmental values. All current values relating to water and sediment quality will be maintained.
- As sediment and water quality will be within ambient ranges currently existing in the bay, there will be no additional cumulative impacts on the environmental values caused by the Project either in isolation or combination with other known existing or planned sources of contamination.
- The environmental protection objectives of the Project are to ensure that the relatively high water quality and sediment quality currently present in the impacted aqueous environments of the Bay are maintained. This can be achieved by regular monitoring (at least annually for sediment and seasonally plus event based for water). The data obtained from the monitoring program should then be assessed against the sediment quality currently existing and the recommended investigation levels given for water quality in Appendix 1. These levels are based on both existing ambient levels and generally, the 95% ANZECC 2000, Species Protection Guidelines.

Details of environmental protection objectives relating to water and sediment quality including:

- Environmental elements and values affected and impacted
- Cumulative impacts on environmental elements and values
- Indicators to be assessed and criteria to be used
- Monitoring and auditing programs proposed
- Quality control assessment,

are given in the attached report.

It should be noted that since the water and sediment quality will be within current ambient or guideline levels, it is considered that additional impacts of environmental values will not occur. However, to ensure that the likelihood of impact is minimised during both the construction and operations phases of the development, a program of rigorous water and sediment monitoring will be undertaken to ensure all current appropriate environmental protection criteria are maintained.

4.2 LAND

4.2.1. POTENTIAL IMPACTS AND MITIGATION MEASURES

Chapters 4, 5, 6 and 7 apply.

- Spatially, even though the development area is currently impacted from external dust sources, the sediment quality in the area is within the range of that in the Bay. This overall quality is consistent within Queensland HIL-A soil guidelines. Both the Bay area and the development zone currently do exhibit minor, occasional inconsistencies within the ANZECC 2000 Interim Sediment Quality Guidelines and ANZECC 2001 Ocean Disposal Guidelines. Modelling indicates all current sediment quality parameters will be maintained.
- Spatially, even though the water quality in the Bay is impacted, it is currently generally good to moderate when compared to ANZECC, 2000 Guidelines. The detailed modelling indicates, given the flushing mechanism proposed, that current ambient water quality will be maintained. Even under worst case first flush scenarios the water quality for all parameters assessed will be within the ambient range already in the Bay or within the 95% (or in some cases 99%) ANZECC Species Protection Guidelines or both. Thus, the water quality emanating from the development will have no additional impacts on the water quality in the Bay. Recommended water quality discharge criteria are given in the Appendix 1. The recommended values for water quality given are consistent within both ANZECC 2000 Guidelines and current ambient levels in the Bay.
- It is vital for the maintenance of water and sediment quality of the development that flushing be maintained at proposed and modelled levels. To achieve this annual dredging and monitoring will be required for sediments accumulated in the western channelway and the north east and south east arms of the development. The dredge spoil material will meet HIL-A standards and must be disposed of to appropriate land areas.
- All groundwaters lie within ambient seasonal ranges from others in comparable situations in the vicinity.
- Within the development area the major risk is that of deterioration of water quality. Unless the development areas remain well flushed and maintained it is almost certain that water quality will deteriorate to unsustainable levels with possibly catastrophic consequences. However, the development will be well flushed and maintained through annual maintenance dredging and monitoring and thus the risk of deterioration of water quality will be minimised.
- In Cleveland Bay itself, high risk activities associated with the development, are those that adversely affect water quality through increased turbidity, causing light attenuation and sediment deposition onto seagrass and corals. Further high risk activities are those that can lead to contamination of seagrasses, corals, benthic communities and water quality from oil, chemical or sewerage spills. Medium risk activities in the Bay are those

that will elevate nutrient contents in the water and sediments, endangering seagrasses and corals through the increased growth and shading by macroalgae, and through an increase in contaminants in the water and sediments. There is a low risk of damage to seagrasses and benthic communities through contaminated sediments.

- During the construction phase, it is recommended that regular, continuous monitoring be undertaken at both mobile and fixed locations. Generally, this monitoring should be for gross physical water quality parameters including pH, turbidity, salinity and temperature. Monitoring should be undertaken using permanent electrode stations down loaded to site or other suitable locations.
- During the operations phase, it is recommended that a limited continuous monitoring program be undertaken for gross physical water quality parameters. This should be supplemented by seasonal and event based water quality sampling for a broad range of analytes. Additionally, this should be coupled within bottom sediment sampling for a similar broad range of analytes associated with the annual maintenance dredging.

It is considered that this monitoring regime will ensure the maintenance of good quality bottom sediment and ambient waters.

1) All data indicate that all the flushed water quality exiting the development will be within current ambient range or 95% ANZECC 2000 Species Protection Guidelines or both.

2) All data indicate that all sediments produced from the development will be within current ambient ranges.

3) Regular maintenance dredging of parts of the development will be essential to maintain flushing, water and sediment quality. The dredge spoil thus obtained will meet HIL-A standards and must be disposed of to land.

4) Should the dredging and monitoring options proposed be undertaken then there are no reasons existing at present that the water quality or sediment quality derived from this development should impact on the environmental values of adjacent areas.

5) It is recommended that the above conclusion be accepted and recognised and that there are no grounds relating to water and sediment quality for the development to be disallowed.

4.2.2.2 SOIL EROSION SEDIMENT EROSION

- Preventing significant degradation of waterways by suspended soils, nutrients and other contaminants.

Mitigation strategies should be developed to achieve acceptable... levels of sediment in rainfall and wind generated dust concentrations …

Chapters 4, 5, 6 and 7of attached report the GEM's Hydrodynamic Study and section 4.2.2 of this report apply.

Water Quality modelling was undertaken using the PHREEQC program of the United States Geological Survey. This was coupled with the run off water quality obtained from the MUSIC program for the export of nutrients from the constructed catchment area. Mixing and flushing and mixed water quality models were developed to mimic worst case scenarios for the development. The modelling included first flush senarios for the total dissolution of the dust falling on the development and/ or the total incorporation of the dust into the bottom sediment of the development area.

All data, both raw and modelled indicate that all flushed water exiting the development will be within current ambient range of ANZECC, 95% Species Protection Guidelines or both. A series of recommended levels for investigation and intervention have been developed for a range of aqueous analytical species.

All data indicate that all sediments produced from the development will be within current ambient levels of Cleveland Bay.

Regular annual maintenance dredging of the main channel and north eastern and south eastern parts of the development will be essential to maintain water and sediment quality at proposed, desired and modelled levels. The dredge spoil material will meet HIL-A standards and must be disposed of to land.

4.2.2.4 ACID SULPHATE SOILS

The potential for acid generation from disturbances of acid sulphate soils during earthworks and construction have been dealt with in (GOLDERS REPORTS). Given the current construction methodology and the inferred zonation of PASS material in and around the development area, it is highly unlikely that here will be any disturbances of this material. Regular field testing pH field/ pH oxidized will be undertaken using standard hydrogen peroxide techniques during initial stages of construction prior to dewatering.

Should any potential acidity be generated during peroxide treatment then the excavated material will be:

- Treated to maximum levels indicated from the Golders Reports
- Immediately replaced into a non-oxidising environment by burial. This is possible as the material will be used immediately to construct the arms of the development.

When the exact construction sequence is determined as the bunded excavation has been largely developed, systematic acid sulphate assessment will be undertaken on the exposed floor to determine the extent of ASS and PASS. When this excavation has been completed and if it is likely that any PASS will be disturbed then:

- Appropriate management measures will be given in an Acid Sulphate Soils Management Plan prepared in accordance with QASSIT Guidelines and the requirements of SPP 2/02
- This Management Plan will be prepared in consultation with NR&W and EPA.

4.2.2.5 CONTAMINATED LAND

The development area is reclaimed from marine submersion. No known contaminated sites exist in the area. Consequently no management plan is necessary.

Should contamination be encountered during the course of construction, the appropriate procedures as outlined in the Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland will be followed.

4.4.2.3 STORMWATER DRAINAGE

The effects of stormwater drainage on the water quality of the development area have been modeled using a combined MUSIC and PHREEQC approach. Models have related to worst case, first flush scenarios after an extensive period (9 months) of dry weather within a minimal flushing event of 12.5mm. Likely compositions of the atmospheric dust were input into this scenario assuming total dissolution of the dust material or total incorporation of the dust material into the bottom sediment.

These data are discussed in chapters 4, 5, 6 and 7 of the report and in sections 4.2.2 and 4.2.2.2 of this report. In summary: Providing regular maintenance dredging is undertaken to ensure adequate flushing then all data indicate that all flushed water quality exiting the development will be within current ambient range or 95% ANZECC 2000 Species Protection Guidelines or both and that all sediments produced from the development will be within current ambient ranges (HIL-A Compliant).

4.5.1.2 LIQUID WASTE

Given the depth of excavations it is highly unlikely any groundwater aquifers will be intersected during the construction or operations of the development. Thus, no groundwaters will be discharged from the excavations. Once the development area is dewatered, this conclusion will be re-examined in the light of data obtained from the new base-level surface. Should any groundwater flows be observed then this water, of necessity, will be mixed with any seepage of ambient marine waters and discharged. The discharge water will meet all current ambient conditions and the recommended levels given in Chapter 4 of the report.

The likely compositions of any rain falling on the development and incorporated into runoff is discussed in sections 4.2.2 and 4.2.2.2.

4.6 WATER RESOURCES: (Taking marine water as a potential resource)

4.6.1 DESCRIPTION OF ENVIRONMENTAL VALUES

The environmental values of Cleveland Bay are built upon the moderate to good chemical properties of the current ambient waters and sediments. The waters and sediments of the Bay are impacted by anthropogenic activities in the region and currently the ambient waters are largely consistent with ANZECC 2000 Species Protection Guidelines. It is believed that one component (lead) may, however, at time be below 80% Species Protection Guidelines. As mentioned elsewhere, given the predicted flushing and chemical models, it is anticipated that all waters emanating from the development will be consistent with ambient conditions at better than 95% ANZECC 2000 Species Protection Guidelines or both. Thus, water quality of the development will not impact on water resource aspects of current environmental values.

4.6.1.1 SURFACE WATERWAYS

No water resources relating to surface waterways exist in the area.

4.6.1.2 GROUNDWATERS

The area of the development is currently submerged beneath approximately 1 to 2m of sea water and no groundwaters are used as water resources. No use of these waters from a resource point of view is anticipated. Saline (30-40%) waters are present as inderstitial waters, of probable marine origin, are present beneath the subsurface of the proposed development. These waters are too saline for any agricultural, stock waters or potable uses. Neighbouring areas are either sea-bed or reclaimed area for the earlier construction of the Breakwater Casino and Marina. No use of these groundwaters occurs in these areas

- The groundwaters (interstitial waters) of the development fluctuate in the level in response to the daily tidal cycle, with the level fluctuating from a depth of -4 to 5m below current surface to -7 to 8m below this level. These levels are beyond those envisaged for any excavation during the development and, thus these waters will not be disturbed. As stated, the groundwaters are within the ranges of coastal waters marine salinities (30-40%). Recharge is almost exclusively from marine sources and the flow is generally south to north during outgoing tides with reversals north to south during incoming tides.

  During these studies three groundwater monitoring bores have been installed. These will be regularly monitored for salinity (conductivity), pH and turbidity during construction and operations to ensure the current marine-related, saline water quality are maintained. During construction, monitoring and impact assessment will be on a weekly basis and during operation a seasonal schedule is suggested.
- From the monitoring data obtained, principally pH and salinity, it is considered that the groundwater is marine related and its composition will be similar, overall, to the average composition of marine bottom waters.
- The groundwater will not be used, consequently the sustainability of both quality and quantity are not an issue. Recharge will occur daily during tidal cycles and quality will be replenished from the ambient waters of the Bay.
- Since evacuation will not intercept the known aquifers, the physical integrity, morphology of subsurface flow paths and processes will not be compromised.
- Direct pollution of the subsurface flow paths is highly unlikely as excavation will not intersect the shallow aquifers. During construction, any contamination to sub-surface aquifers is dealt with in the Construction Management Plan. During operations, maintenance of efficient water flushing and annual dredging will ensure maintenance of good water and sediment quality. In turn this will ensure the risk of groundwater

pollution is highly unlikely from water and sediment sources. Other potential sources of pollution resulting during operation is dealt within an Operations Management Plan.

4.6.2 POTENTIAL IMPACTS AND MITIGATION MEASURES

There are no water resource uses indicated or planned for the marine waters of the Bay or the marine related shallow groundwater system. Issues relating to potential impacts and mitigation are given in section 4.6.1.2 including

- Protection of the marine environment
- Protection of local aquifers and waters.

The quality and quantity of surface waters will be maintained to ensure protection of downstream uses, marine biota and the littoral zone.

The consequences of discharge to the waters of the development using PHREEQC and MUSIC approaches are considered elsewhere. These investigations indicate that even under worst case scenarios the water and sediment quality of the development are maintained to be consistent with ANZECC 2000 Water Quality and HIL-A Soil and Sediment Standards.

If water quality is maintained, then it is considered that all other environmental values will be retained as a direct consequence. Thus, preservation of water quality by adequate flushing and maintenance dredging are vital to the viability of the project. Monitoring strategies involving continuous water monitoring during the construction phase is proposed. A mixture of continuous seasonal and event monitoring for water quality and annual monitoring for sediment quality, in association with the annual maintenance dredging is also proposed.

4.6.2.1 SURFACE WATER AND WATER COURSES

- There are no surface and water course implications for this project relating to water resources. Marine water quality within and exiting the development will be within ambient ranges. This is consistent with the current environmental values of Cleveland Bay.
- During construction the waters exiting the development will be continuously monitored principally for pH, salinity and turbidity. This will assist in the protection of seagrass areas adjacent to the development.
- Studies involving PHREEQC and MUSIC modelling approaches indicate that water and sediment quality will be maintained under worst case scenarios. Maintenance of these qualities is vital to the sustainability of the project.
- Similarly, PHREEQC and MUSIC modelling approaches indicate:
  - ~ Water quality meets ANZECC 2000, 95% Species and Protection Guidelines of ambient ranges within the Bay or both
  - ~ Sediment quality meets Queensland HIL-A Guidelines.

4.6.2.2 GROUNDWATER

Details of saline groundwater (interstitial water) characteristics are given in section 4.6.2.1 including sustainability and monitoring aspects. In the section 4.6.2.1 an assessment of the potential of the project to contaminate the groundwaters is regarded as highly unlikely. Since it is also highly unlikely that any use will be made of the groundwater resource, the proposed project is also highly unlikely to have any impacts of groundwater sustainability, depletion or recharge. Regular weekly monitoring of groundwater bores for pH, salinity (conductivity) and turbidity will ensure that groundwater quality is maintained.

Given the nature of the development, the shallow depths of any excavation and that no extractive activities relating to groundwater will occur, it is highly unlikely that land disturbance will impact on local groundwater regimes by changing subsurface porosity and permeability conditions.

4.7 COASTAL DEVELOPMENT

4.7.1 DESCRIPTION OF ENVIRONMENTAL VALUES

With respect to coastal zones, detailed descriptions of environmental values relating to Nature Conservation and Water Quality aspects are given in the two attached C&R Reports. All results relating to water and sediment quality and their compliance with respect to appropriate ANZECC 2000 Water Quality Guidelines, Queensland Water Quality 2006 and Queensland Draft Soil Guidelines, 1998 is given in Chapters 4, 5 and 6 of the attached report.

Generally:

- Water quality existing in and emanating from the development area will be better than that required by the 95% ANZECC, 2000 Species Protection Guidelines or be consistent with current ambient ranges in the Bay or both.

4.7.1.1 WATER QUALITY

- Details of the marine water and co-existing sediment quality of the Bay and the development area are provided in Chapters 4, 5 and 6 of the report and in the Appendix 2 of results from the NATA accredited habaritones of ALS, Brisbane. In these details of nutrient levels, heavy metals, acidity and total petroleum hydrocarbons / benzene, toluene, ethyl benzene and xylenes (TPH/BTEX) are provided. Ranges and means of these data are provided in Tables in sections 4.3 and 4.4 and Appendix 1. Data relating to ranges of suspended solids and turbidity are provided in the GEMS Hydrodynamic Investigation.
- The existing water quality of surround marine waters and of the development area are given in Tables and Appendices of the Report. In terms of physical and chemical characteristics:
  - Water quality in the surrounding areas and within the development are consistent with either existing ambient water quality or 95% ANZECC species Protection Guidelines with respect to physical parameters, heavy metals, acidity and TPH/BTEX.
  - Sediment quality co-existing with the waters of the area is consistent with the current ambient waters and Queensland HIL-A Soil Guidelines Criteria. Any disposal of dredged sediment will consequently be to land.
  - Potential pollutants generally found in the area are those related to the operations of the Port of Townsville and those coming from the widespread activities of Townsville City itself. It is these sources that have combined to define the current ambient qualities of both waters and sediments in the Bay. Water and sediment quality going into the waters of the development and hence, after mixing in the marine arms, into the Bay, have been modeled using PHREEQC (for metals and metalloids in waters and sediments) and MUSIC (for nutrients). These models have examined a range of first flush, stormwaters – marine water, mixes. Models included:
    - Total dissolution of dust settled after a nine month dry and minimal flush volume and
    - Total sedimentation, no dissolution, of this dust after a nine-month period.

In all cases, since the dust survey for the current project only included particle size information, chemical species present in the dust were obtained from other studies undertaken outside this current project.

When modelled, even under worst case scenarios, contaminants and pollutants present in the flows from the development after a minimal first flush will, assuming adequate annual maintenance dredging:

~ For water quality, meet ANZECC, 2000 95% Species Protection Guidelines or be within current ambient ranges or both

- ~ For sediment quality, meet Queensland HIL-A Soil Guidelines

- Details of historical water and sediment quality are provided in chapters 4, 5 and 6.

[CC Comment – There are a number of issues in this section which relate to issues that should be in GEMS and CES reports eg: currents, tides, storm surges, freshwater flow, sediment plume migration and pollutant migration. Are these there?]

4.7.2 POTENTIAL IMPACTS AND MITIGATION MEASURES

4.7.2.1 WATER QUALITY

Water and sediment quality within the development will be maintained and achieved by adequate flushing and annual maintenance dredging to ensure depth is maintained to 5.5m in the western channel way. Standards of the water quality will be consistent with existing ambient water quality or ANZECC, 2000 95%, Species Protection Guidelines or both. Sediment quality will meet Queensland HIL-A Standards and any dredge spoil must be disposed of to land.

Water quality parameters will be:

- Monitored during construction by five continuous water quality monitoring status sited strategically around the perimeter of the site. Investigation levels will be set as listed in Appendix 1, so that as soon as turbidity goes above +10% of ambient levels or pH goes + or – 10% of ambient levels or salinity goes – 10% of ambient levels investigations are carried out to ascertain and rectify causes of the non-compliance.

  Intervention levels will be set as listed in Appendix 1. As soon as intervention levels are exceeded, all work on the site must cease until the causes of the non-compliance are rectified and levels are below the +/- 10% criterion.

- During construction auditing will be carried out by full, real-time observations of the outputs from the continuous monitoring stations. This will ensure all decisions made are done so on the basis of up to date factual information. Levels will be assessed against recommended guidelines.

- Management of water and sediment quality issues during the construction phase will be fully documented in the Construction Management Plan. Management decisions during construction will be on the basis of real-time monitoring data, audited against the recommended investigations and intervention levels

- During operations, monitoring will be undertaken for water quality parameters from three continuous monitoring stations strategically sited. Parameters measured and assessment levels used will be as for the construction phase.

- As during construction, auditing during operations will be carried out by real-time observations against recommended Guidelines levels

- Management of water and sediment quality issues during operations will be fully documented in the Operations Management Plan. Management decisions will be based on the real time monitoring data assessed against recommended intervention and investigation levels. For water and sediment quality to be maintained annual maintenance dredging will be undertaken to ensure adequate flushing is achieved. At the time of this annual dredging full, multi-element chemical analysis will be undertaken on a number of sediment samples (1 per 100m_ of dredge spoil) together with comprehensive analysis (including heavy metals) of co-existing waters.

- As indicated in Chapters 4, 5, 6 and 7, current ambient water quality in the Bay, is, variable and is not always consistent with ANZECC, 2000 and QUEENSLAND 2006 Water Protection Guidelines. A series of investigation and intervention levels have been proposed (Appendix 1). All waters emanating from the development will be better than 95% Species Protection Guidelines or current ambient levels or both. All sediments accumulating in the development will be consistent with QUEENSLAND HIL-A Soil Guidelines.

Potential threats to water and sediment quality to the surrounding waters associated with construction and operations are discussed above and in Chapters 4, 5,6 and 7 of the Report. These threats and their possible remedies include:

- During construction, dewatering activities must be such that turbidity levels of the discharge are kept to below + 10% ambient at the discharge points. These discharge points should be systematically shifted every 3-5 days to ensure points of impact are spread out rather than being concentrated in particular zones. The preferred sites for the majority of the dewatering discharge lie along the northern breakdown wall. All discharge points should be sited to, as far as possible, avoid areas of obvious seagrass.
- Dredging will occur annually to ensure adequate flushing is always maintained. The dredge spoil obtained will be fully assessed chemically to ensure safe disposal. It is believed that all sediment will meet HIL-A standards and that land disposal is the best option. In any land disposal adequate bunding will be employed to ensure dewatering of the spoil will not cause any contamination or acidity problems.
- Potential accidental discharges of contaminants during construction and operation of the Project will be fully documented in the Construction and Operations Management Plans.
- Release of contaminants from marine structure and vessels, including anti-foulant coatings will be managed as specified in the Operations Management Plan. Detailed chemical analyses of the sediments will be undertaken associated with the annual maintenance dredging. This assessment will include analysis for anti-foulants. Disposal of sediments will be to land and consequently levels of anti-foulants are not an issue.
- Stormwater run off from developed areas has been fully assessed using PHREEQC and MUSIC modeling incorporating dust compositional water. These studies indicate waters in and emanating from the development will always meet water and sediment quality objectives with exiting waters always being within 95% ANZECC Species Protection Guidelines or ambient ranges in the Bay or both.
- The accumulation of nuisance / harmful algal blooms will be avoided by adequate flushing. Maintenance of adequate flushing will be assured by annual maintenance dredging. Flushing and chemical modeling indicate that turn-over times and nutrient levels are such that algal blooms should not be a problem providing adequate flushing is maintained.
- Strategies to limit impacts to acceptable levels include:
  - ~ Detailed physical and chemical modelling
  - ~ Annual maintenance dredging to ensure adequate flushing
  - ~ Continuous real time monitoring of waters
  - ~ Detailed regular monitoring of both sediments and co-existing water
  - ~ Best practices documented in both Construction and Operations Management Plans

All data indicate that all aspects of current ambient water and sediment quality will be maintained if adequate annual maintenance dredging occurs. This will ensure that water and sediment quality meets the defined objectives and that:

  - ~ Water quality is better than 95% ANZECC, 2000 Species Protection Guidelines or within current ambient ranges or both.
  - ~ Sediment quality remains at current ambient value and within HIL-A Soil Guidelines criteria.

- Potential impacts on adjacent fisheries habitat will be ameliorated if:

- During construction, dewatering is undertaken in an environmentally sensitive manner involving both a regular shifting of the discharge points and suitable siting of such discharge points to minimise the exposure of seagrasses to continuous levels of elevated turbidity.
- During operations, all sediment and water quality objectives are achieved and maintained by annual maintenance dredging to achieve adequate flushing.

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1 BACKGROUND INFORMATION

(Sections 4 and 1.7 of Terms of Reference [TOR])

1.1 INTRODUCTION

This report describes the baseline study of the water and sediment characteristics in an area potentially affected by the proposed Townsville Ocean Terminal development. The requirement to protect water and sediment quality has been identified by the Terms of Reference issued by The Coordinator General, Queensland Government, under Part (4) of the *Queensland State Development and Public Works Organisation Act 1971*.

The proposed project is expected to include:

- A dedicated terminal and wharf to attract cruise ships and naval vessels, located on the Western Breakwater, adjacent to the Port of Townsville;
- An integrated residential and tourism development, allowing for public access to the Breakwater and future open space areas for land to be reclaimed to the north of the existing Townsville Casino and Entertainment Centre; and
- An increase in marina berths for the marine industry, general recreational vessels, and berthing facilities for superyachts.

All of the above have the potential to negatively impact on the nature conservation values associated with Cleveland Bay and adjacent areas.

1.2 DESCRIPTION OF THE ENVIRONMENT

The physical characteristics and ecology of Cleveland Bay have been subject to a large number of studies in the past, particularly in relation to dredging activities around the Townsville Port (Benson et al. 1994). Studies conducted before 2001 were reviewed extensively by Kettle et al (2002) and Anderson et al (2002), and some aspects of Cleveland Bay were included in the assessment of the conditions of marine, coastal and estuarine resources in the Burdekin Dry Tropics region (Scheltinga and Heydon 2005). Few published studies exist from after 2002, although the habitats (seagrass beds, coral reefs) and species (dolphins, dugongs, turtles) most susceptible to disturbance have been subject to some form of monitoring. Baseline studies for the Townsville Ocean Terminal will take previous research into account, but will also focus on areas that were poorly studied in the past, such as soft-sediment benthic communities.

Townsville's coastal zone is already subject to extensive urban development (Schelting A and Heydon 2005). This makes it difficult to distinguish the impact of individual developments from the large number of anthropogenic influences already present (eg: recreational fishing and collecting, dredging, shipping noise, urban and industrial runoff). The current baseline studies aim to establish links with previous datasets to provide a temporal framework.

1.3 HYDROGEOMORPHOLOGY

Understanding both the current and the historic climate of the region is critical to the assessment of the site. The sediments within Cleveland Bay and along the adjacent coastal strip are typical of those produced from the surficial weathering of neighbouring geological formations by a seasonally arid and tropical climatic regime. These sediments are subsequently removed from the weathering face by overland flow and deposited on the flood plains and within the channelways of the rivers, creeks and gullies draining the geological formations. Ultimately, this sedimentary material emerges into Cleveland Bay where it encounters the saline environment of ambient seawater. This aqueous medium will act, in terms of chemical exchange, entirely differently to that of the original freshwater transporting mechanism. Consequently, the local baseline water and sediment chemistry of the bay reflects the weathering, transportation, deposition and storage of these sediments.

For this reason a short overview of climate and climate variability, and the interplay between these factors and the surficial and stratigraphic geomorphology of the region over time, is necessary.

1.3.1 Implication of Climate on the Waters and Sediments of Cleveland Bay and the Adjacent Coastline (Section 4.1 of tor)

The geographical location of Townsville in Queensland's seasonally arid tropics indicates the area is subjected to a rainfall pattern that is notoriously unreliable in its intensity, duration, and location, both temporally and spatially. Located towards the southern extent of the Inter-tropical Convergence Zone, the influence of the monsoons is often reduced by:

a. the intensity and location of the Indian Ocean atmospheric pressure cell that forms one half of the Southern Oscillation, and

b. the rain-shadow effect created by the Hervey and Paluma Ranges to the west-northwest. To the east and south Cape Cleveland and Mount Elliott shield the region from convergence fronts moving in from the southeast.

Hot humid summers and mild dry winters are normal, with rainfall distribution, intensity and duration highly variable. For example, although mean annual rainfall measured at Townsville is around 1140mm, rainfall distribution is highly seasonal with approximately 70% of the annual rainfall occurring in the January to March period, and the sum of the average values for April to November well below the average figures for either January or February (Murtha 1975).

Local rainfall variations are often extreme with rainfall distribution occurring as a series of distinct, spatially separated 'cells'. Under these conditions, rain events can dominate a single catchment, or a single section of a catchment. Sediment type, sediment transport, and sediment deposition then reflects (a) catchment geology, (b) depositional history, (c) rainfall quantity, and (d) rainfall location.

The variation between annual average rainfall is also large, ranging from approximately 270 mm minimum to 2370 mm maximum. Around 60% of the years receive less than 75% of the average annual rainfall with only a 40-50% probability of greater than average rainfall occurring in January or February. In addition, it is not uncommon to receive half the annual rainfall in a single rain event of 3 – 5 days. Rain free days are high, averaging around 300 per year, and even during the wet season when the mean number of rain days is around 15 for February (greatest average number of wet days), the average daily sunshine hours is still 7.2 (Bureau of Meteorology data base). Thus, as would be expected with these climatic conditions, evaporation rates are also high, in the order of 1.5 to 2.5 times the mean average rainfall, and even during the wet season evaporation may, on most days, exceed rainfall, with monthly average rainfall only exceeding evaporation in January and February, and then only by a negligible amount in January (~2%). Under these conditions chemical and physical surface crusts may form, affectively sealing off the soil profile. Hence, unless preceded by periods of gentle wetting to disrupt the surface seal, run-off is high.

Rainfall intensities are also high, averaging about 20mm/wet day for the period December – April. However, it is now recognised that the use of "average" figures blurs the impact of rainfall in the seasonally arid tropics. For example, in the 50 year period 1910-1960 daily falls of >75 mm were recorded on 124 occasions, >130 mm on 50 occasions, and >255 mm twice (Murtha 1982). Short period intensities of 25-50 mm per hour are common and are of particular significance when they occur early in the 'wet season' and ground cover is sparse after the long dry winter. During these periods the surface soils are highly susceptible to erosion and any material transported into Cleveland Bay will carry with it pollutants and/or contaminants adsorbed on to the soil particles via anthropogenic activity within the catchment.

In normal years, when significantly less than average rain falls and high intensity rainfall events are absent, river flows are small and sediment transport very low. Conversely, in wet years, and during times of major flooding following high intensity rainfall events, flow is large and sediment transport rates potentially very high. Sediments are removed from the weathering profile and transported through stream and river channels in concert with this variability in flow.

Across the flat coastal plains of North Queensland, the relatively shallow river and creek systems transport comparatively large quantities of sediment through the waterways in a stop-start process that has been likened to the movement of a conveyor belt. Under these circumstances, sediments often build up in the channelway, choking flow through the river system and forcing the river to break its banks, creating new channels at weakened locations along the banks. Whilst this scenario can be easily recognised in today's landscape, similar events have taken place over many thousands of years, gradually building a sedimentary profile over a base geology that resembled that currently surrounding the area. River morphology and stream location on the landscape, therefore, have altered as a response to high energy events, sediment deposition, climate change, sea level variability, and tectonic movement. Thus the current location of river channels is only temporary within time and space. For example, the Black, Burdekin, Haughton and Ross Rivers have been shown to have taken numerous pathways towards the sea throughout time (Murtha 1975, 1982), including, in the case of the Burdekin and Haughton Rivers, between Cape Cleveland and the mainland.

In addition to the above hydrogeomorphologic sea processes, historical fluctuations in sea level have caused considerable retreat and progradation of the coastline, both seawards and landwards from its current location (Hopley et al. 1983). Given the low elevation of the relatively flat coastal plain between the ranges and the coastline, even the small increases in sea level contiguous with the accepted increase of 1.5 to 2.0m approximately 6000 ybp would have caused the coastline to migrate some distance landwards of its current position. Variation in the distance of traverse across the coastal plain significantly alters the geomorphic regime of streams and rivers. Abandoned channels are infilled by the processes of terrestrial progradation and marine recession and by drowning of river channels as sea level rises and encroaches onto the coastal plain during marine transgression. These ancient channels act as conduits, transporting groundwaters through the system to the lower catchment, and into the marine environment. The expression of these ancient systems is known to fishermen as "Wonky Holes" and identified as freshwater intrusions into marine waters, often many kilometers offshore. The nutrient and heavy metal load transported through these ancient channels is often geochemically similar to the surface waters of the current waterways, although the nutrient and heavy metal load of the ancient channels may be elevated.

In addition to these processes, depressions in the landscape retain waters for long periods. These depressions are often associated with distinct clay mineralogical differences. Vegetable matter accumulates as moist conditions, usually associated with a greater percentage of montmorilonitic (smectitic) clays, encourage an increase in vegetation around and within the waterhole or lagoon, developing a heavy, black, peaty substrate with time. During the Pleistocene and Hololcene, periods of higher sea levels have usually been associated with periods of higher rainfall and greater flow in the streams and rivers. Under these circumstances it is highly probable that sediment deposition between the hills and the coast would have been considerably greater than at present. The current topography of meandering rivers and streams and associated lagoons, wetlands, waterholes and swamps, would have been enhanced by (a) higher precipitation rates, (b) increased river flow, and (c) greater moisture retention in the soils (the hyporhoeic zone) overlying a relatively impermeable base soil sequence and geology. As sea level retreated and the coastline prograded forward, the coastal complex of dunes, swales, lagoons, wetlands and associated fresh and marine vegetation, followed behind, creating new ecosystems seaward of the scars of the previous landscape.

Along the North Queensland coast the dominant southeasterly trade winds force currents and wave action to move in a northwesterly direction parallel to the coastline. Within this dominant process, tidal action carries a proportion of the sediments towards the coastline, depositing the material along the foreshore. Around October / November this southeasterly domination reverses, During this period, sediments and any adsorbed contaminants, are forced backwards in a southeasterly direction, parallel to the coastline.

Wave action combs and redistributes the foreshore material to form the beaches common to the North Queensland coastline. The breaking and retreating action of the waves combs the material, sorting the sediments and moving the grains in a zig-zag action along the beach in response to the relative strength of the winds (wave), currents, or tidal action in a process known as longshore drift. This combination of events causes the heavier materials to drop out of the water column first with the finer sediments carried further along the coast until progress is hindered by an intervening barrier. Barriers can take a number of forms. For example:

(a) A rocky land mass or groyne;
(b) The physical redirection of tides and currents around an island; or
(c) Quiet, sheltered areas at the landward end of promontories (eg: the Townsville end of Cape Cleveland).

The scalloped shoreline and areas of sand deposition created by these processes is clearly visible along the Townsville strand (Cross Reference Hydrodynamic Study).

It is the combination of these actions that provide the sediments of Cleveland Bay, lead to the formation of beaches and headlands along the foreshore, and consequently need to be considered when developing local water quality guidelines.

1.4 SEDIMENT TRANSPORT

The primary source of sediment to Cleveland Bay is the Ross River estuary, although since the damming of its upper reaches in the 1970s, sediment supply reaches a maximum of 0.3 Mt yr^{-1} (Doherty et al. 2000). The Burdekin River, 75 km to the south of Cleveland Bay, also discharges sediment which is carried into the Bay by longshore currents generated by the predominant southeasterly trade winds (Orpin and Ridd 1996). Sediment in Cleveland Bay is generally very fine and mud rich, and includes minor calcium carbonate rich facies. In general, fine grained sediments accumulate in areas protected from wind and wave action, but are carried by prevailing currents away from exposed areas, leaving coarser grained sediments in place (Doherty et al. 2000).

Tidal circulation in Cleveland Bay is believed to travel primarily in an anticlockwise direction, but given the shallow water depth of the Bay, in wind speeds greater than 7-10 ms^{-1}, the water column moves in the wind direction irrespective of tidal currents (Doherty et al. 2000). Given that fine grained sediment resuspension occurs primarily under high wind conditions (Lou and Ridd 1996), these sediments are transported in to the northwest of Cleveland Bay (Doherty et al. 2000).

1.5 DESCRIPTION OF THE DEVELOPMENT - (SECTION 1.2 OF TOR)

The proposed project, a joint venture between TABCORP and Consolidated Properties Group, was initiated in March 2006. The Townsville Ocean Terminal (TOT) is expected to include:

- A dedicated terminal and wharf to attract cruise ships and naval vessels, located on the Western Breakwater, adjacent to the Port of Townsville;
- An integrated residential and tourism development, allowing for public access to the Breakwater and future open space areas for land to be reclaimed to the north of the existing Townsville Casino and Entertainment Centre; and
- An increase in marina berths for the marine industry, general recreational vessels, and berthing facilities for superyachts.

The TOT site is located on and adjacent to the existing Townsville foreshore and incorporates the existing Townsville Port western and northern breakwaters, the existing perimeter of the land around the Townsville Casino and the Townsville Convention Centre and Mariners Drive Peninsula (Figure 1). The TOT and future residential areas will gain vehicular and pedestrian access from Entertainment Drive, and is in close proximity to the Strand. The existing western breakwater forms the western side of the navigation channel known as the “Platypus Channel”, the main access channel for the Townsville Port. This channel forms an extension to Ross Creek and is currently dredged to a level of 11.7m below Lowest Astronomical Tide (LAT).

Figure 1. Artist's impression of the proposed Development. Obtained from http://www.citypac.com.au/property_development/projects/townsville_ocean_terminal.

A requirement of the project is the reclamation of land for the cruise ship terminal and proposed residential area, requiring approximately 2,000,000m^3 of fill material. The site is noted on the Great Barrier Reef zoning maps as being outside the Great Barrier Reef Marine Park (GBRMP) boundaries. However, the site is adjacent to the GBRMP. The intent of the Future Development Area (FDA) is to provide a residential waterfront community comprising a mixed range of dwelling types, including detached dwellings, attached dwellings and apartment buildings between one and eight storeys in height. The main proposed elements of the FDA will be:

- The augmentation of the existing northern breakwater wall to the seaward side of the FDA;
- Open space adjacent to portions of the western breakwater wall and the northern breakwater wall;
- A range of land uses, including apartments, attached dwellings, detached dwellings, medium density detached dwellings, cafes, car park, caretakers residence, childcare

centre, commercial services, convenience shop, display home, estate sales office, home occupation, home office, indoor recreation facility, medical centre, office, park, restaurant, shop, landscaping and public utilities;

- 275 detached dwellings and 500 medium density attached and/or detached dwellings/apartments;
- Private recreational vessel berthing moorings, jetties and pontoons, moorings for super yachts, and boardwalks to waterways.

The potential impacts on the Marine Park of construction and operational activities will be assessed as part of the EIS process. The primary construction and operational elements of the TOT that may affect the marine environment are:

- Indentation of the Port of Townsville western breakwater and the construction of a dedicated berth, seaward of the current front lead in the Ross Creek navigational channel and some 46m clear of the Platypus Channel centre line, measured from the side of a 33m (extreme breadth) vessel at the waterline;
- Construction of the wharf;
- Land reclamation and the terminal building;
- Associated road works, car parking and infrastructure services;
- Increase in movements of large ships (an estimated 20 cruise ships and 18 military vessels per year)
- Dredging associated with the construction of the FDA waterway and access channels, 2.5m-3.5m LAT);
- In-filling associated with the FDA; and
- The potential for accidents or spills from both the TOT and the FDA; and
- Impacts associated with the day-to-day human habitation and use of the FDA.

2 OBJECTIVES AND SCOPE

(Section 1.3 and 4 of TOR)

The objectives of this report are to present the results of the water and sediment quality baseline study conducted in Cleveland Bay for the Townsville Ocean Terminal EIS. We describe the background knowledge about the characteristics of the Bay, define the methodologies used to collect data, and present the results. The results are designed to describe the present water and sediment quality status of the Bay, and to provide the baseline for the monitoring program. The report includes the interpretation of results, the identification of potential impacts of the Development, the compilation of a risk assessment, and recommendations for practical measures for protecting or enhancing coastal environmental values through the achievement of quantitative standards and indicators. Recommendations are also made for the monitoring, auditing and management of water quality. It ties in closely with the Nature Conservation Baseline Study for the ecological characteristics of Cleveland Bay, and some overlap is expected to occur between the two studies. The study will address *The State Planning Policy – Planning and Managing Development involving Acid Sulfate Soils 2002*, the *State Coastal Management Plan 2001* and the QDPI Guidelines for Marine Areas.

Specific elements in the description of water quality, specified from the Terms of Reference, include:

- Information on water quality in the sea and estuaries below the limit of tidal influence, including nutrients, suspended solids, heavy metals, acidity, turbidity and oil in water (Section 0).
- Description of the environmental values of the coastal seas of the project area including values identified by the Environmental Protection (Water) Policy and the State Coastal Management Plan.
- Description of the existing characteristics and condition of marine waters, including:
  - ~ Description of surrounding marine waters in terms of physical, chemical (Section 0) and biological (see Nature Conservation and EPBC Act studies) characteristics;
  - ~ Potential sources and nature of pollutants to the marine environment (Section 0);
  - ~ Description of existing water quality (Section 0); and
  - ~ Effects of coastal processes including the currents, tides, storm surges, freshwater flows and pollutant migration on water quality (Section 0).
- A review of background turbidity levels and any historical water quality data including a developed understanding of the extent of sediment plume migration (Sections 0 and 0).
- A review of nutrient levels carried into the river(s) (where sand is to be extracted) via freshwater flows for comparison in relation to expected concentration levels and ecological significance associated with any dredged material. This assessment will also require the integration of the results of hydrodynamic and geomorphological studies (no longer applicable).

Specific issues and potential impacts addressed, specified in the Terms of Reference, include:

- A description of the water quality objectives used and how predicted activities will meet these objectives (referring to the Environmental Protection (Water) Policy and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000) (Sections 0, 0 and 0).
- Potential threats to the water quality and sediment quality within surrounding waters associated with the construction and operation of the facilities. This assessment considers:
- Method and timing of the extraction including treatment and haulage of excavated materials and tailwater.
- Dredging and dredge material disposal, including disturbance of layers of coffee rock, fine grained sediments and contaminated material with particular attention to: suspended solids, pH, dissolved oxygen, phosphorus and nitrogen (Section 0).
- Potential accidental discharges of contaminants during construction and operation of the Project (Section 0).
- Release of contaminants from marine structures and vessels, including antifouling coatings (Section 0).
- Stormwater runoff from developed areas.
- The accumulation of nuisance/harmful algal blooms within the artificial waterways (Section **Error! Reference source not found.**).
- Strategies to limit impacts to acceptable levels are provided (Section 0)
- Potential impacts on adjacent fisheries habitats (ie: seagrass beds) (see Nature Conservation study).

•

3 METHODS

3.1 STUDY AREA

The area targeted for the baseline study includes the nearshore coastal habitats of Cleveland Bay and the coral reefs around Magnetic Island (Figure 2). Cleveland Bay is a shallow bay defined by Cape Pallarenda to the North, Cape Cleveland to the south and Magnetic Island to the east. It lies within the seasonally dry tropics, with a summer rainfall maximum (more than 80% of rainfall occurs between October and March) associated with the Australian summer monsoon. The rainfall regime of Cleveland Bay is characterised by very high inter-annual variability (between 80mm in 1901-1902 and 2,646mm in 1939-1940), and tropical cyclones occur at a rate of approximately six per decade. A number of watercourses drain into Cleveland Bay, including Alligator Creek, Crocodile Creek, Cocoa Creek, Sandfly Creek, Ross Creek, Ross River, and Three Mile Creek, as well as Gustav Creek and a number of other ephemeral creeks on Magnetic Island.

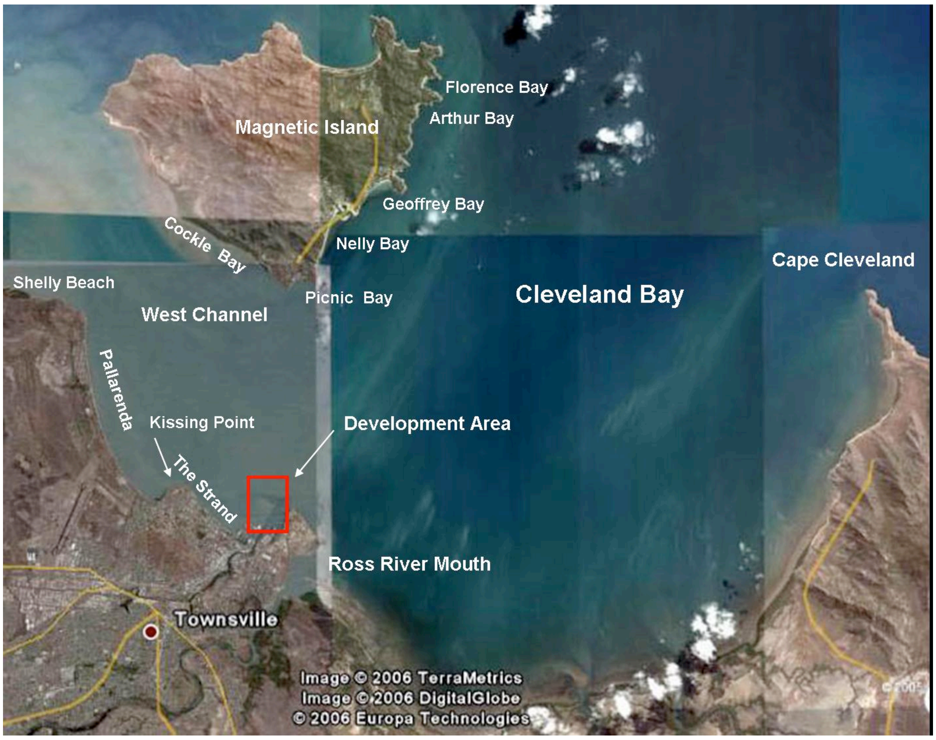

Figure 2. Map of Cleveland Bay, showing the Development Site.

Currents in Cleveland Bay are driven both by tides and by the prevailing south-easterly trade winds. Flood tide currents enter the bay between Cape Cleveland and Magnetic Island and flow southwest, while ebb tides generally move in the opposite direction. In West Passage there are zones of very little water movement, but flood tides are directed southeast close to Pallarenda, and in a westerly direction close to Townsville. Maximum tidal currents tend to be no stronger than 50 cm/s. The trade winds generate a northward longshore current entering the Bay at Cape Cleveland and exiting through West Passage. During average conditions of 15 knot winds, wind-driven currents are approximately 5 m/s and flush the entire Bay in 5 days.

3.2 SAMPELING DESIGN

This baseline study was designed with a view to being a lead-in for a regular monitoring program, and is therefore structured like a full Environmental Impact Assessment. The sampling design followed a Before-After-Control-Impact (BACI) design, with modifications relevant to the specific environments found in Cleveland Bay. The BACI design proposes that sampling is undertaken at a number of times before and after construction of the TOT begins, and ideally also during the construction phase. Furthermore, it is proposed that samples are taken from locations expected to be affected by the TOT ('Impact' sites) and from equivalent locations that are expected to remain unaffected by any activities associated with the TOT ('Control' sites).

Due to the nature of the development (which presents a single Impact site) and the potential impact (plumes of sediment or contaminants), the sampling design included one Impact and three Control locations. The locations were stratified according to the three target habitats: seagrass beds, soft-bottom benthos and coral reefs. Seagrass beds and soft-bottom benthos were prevalent throughout the Bay and could be sampled at the impact location itself, and at eight further sites established with increasing distance from the development site on a logarithmic distance scale (Figure 3).

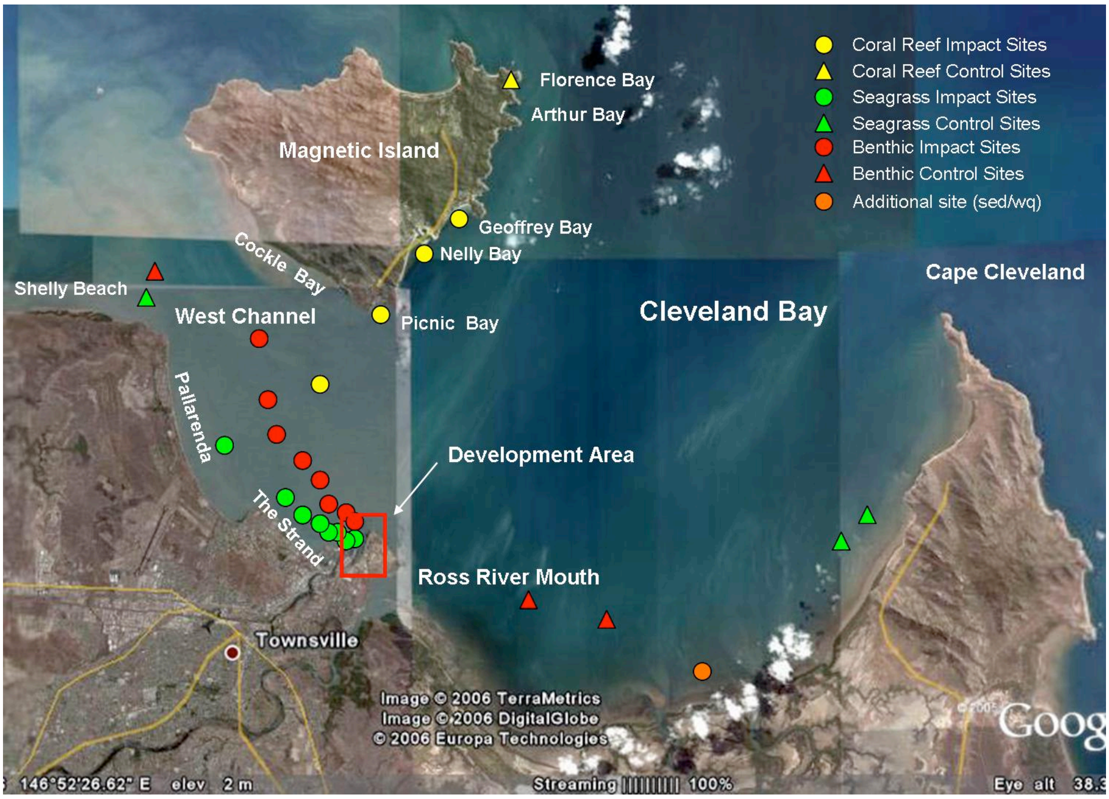

Figure 3. Map of sampling sites. Distances between points represent approximate locations.

3.3 WATER AND SEDIMENT QUALITY INVESTIGATIONS

Samples of bottom sediment, surface and bottom waters were collected at seagrass survey sites (Figure 3). As soon as samples were collected by divers, sediment samples were transferred into acid wash glass jars, while water samples were separated according to the specific analytes to be tested and placed in ice-chests at less than 4°C.

All samples were stored under refrigeration prior to shipment to the laboratory. Shipment to the NATA accredited laboratories of ALS, Brisbane, was made in ice-chests at less than 4°C.

Samples of bottom sediment were collected directly by divers at the same sites as the seagrass survey. Samples of marine waters were collected through the water column above the seagrass survey sites by divers opening containers at the prescribed depths. Prior to filling, where appropriate all containers were triple washed with ambient water from each depth (<50cm from surface; middle of the water column; and at the bottom - minimum depth 5.5 m), immediately above the sediment sampling site.

Although three water samples were collected at each depth, ultimately only top and bottom samples were analysed due to the shallow nature of the system. Analysis, collection and storage of all samples followed appropriate protocols (eg: AS 5567 Series; Queensland Water Quality Sampling Manual; ALS Sample Storage Protocols).

Analytes assessed were:

(a) Sediments:

pH	Electrical Conductivity					Moisture Content					
As	Ba,	Be	Cd	Cr	Co	Cu	Pb	Mn	Ni	V	Zn
Ammonia as N		NO_2^- as N		NO_3^- as N		Total Kjeldahl Nitrogen (TKN)		Total Nitrogen as N		Total P	
Reactive P (dissolved)		Total Petroleum Hydrocarbons (TPH),				Benzene (BTEX)		Toluene	Ethyl - Benzene		Xylenes

Particle size distribution in the fine fraction (<2mm) was assessed by Laser Light Scattering (provided by Microns To Measure, under sub-contract to ALS).

(b) Waters:

Note: metals analysed in waters were undertaken by methods suitable for saline/marine waters

Mg	As	Ba,	Be	Cd	Cr	Co	Cu	Pb	Mn	Ni	V	Zn
Ammonia as N		NO_2^- as N		NO_3^- as N		Total Kjeldahl Nitrogen (TKN)		Total Nitrogen as N		Total P	Reactive P (dissolved)	
Total Petroleum Hydrocarbons (TPH),							Benzene (BTEX)	Toluene	Ethyl - Benzene		Xylenes	

(c) Groundwaters:

Groundwaters from three monitoring boreholes drilled through the sediments in the "Project Site". In order to assess any stratification in the water column in the hole, assessment was made of water at top and bottom of the monitoring bore. The holes were fully purged 24 hours prior to sampling. This period was considered adequate for stratification to develop, if present, Conductivity and pH relationships clearly indicated these waters were of marine origin and should be considered as interstitial waters rather than groundwaters sensu stricto. Similar analytical methods were also used.

Thus, results are available for a broad range of analytes including base metals, nutrients, TPH/BTEX and particle sizing for a range of locations across the Bay. These results provide an excellent basis for the provision of a baseline for the Townsville Ocean Terminal.

3.4 RISK ASSESSMENT

This risk assessment was compiled using tables commonly used and accepted by the Department of the Environment and Water Resources (DEW) for Marine Reserve assessments (Appendix 2, Table 7). They are considered appropriate here, as the primary concern is the impact of activities related to the Development on habitats and species directly adjacent to or inside the Great Barrier Reef Marine Park.

4 WATER AND SEDIMENT QUALITY

(Section 4 TOR especially sections 4.6 and 4.7)

4.1 INTRODUCTION

Numerous investigations have been carried out over the last 30 years into sediment and water quality of Cleveland Bay. Authors of these investigations range from Cuff (1975) to Doherty et al. (2000). While sediment quality guidelines for the Bay have been fairly extensively developed, few attempts have been made to develop water quality criteria for the area in general, and the zone to the west of the Port Western Breakwater in particular.

Studies exist dating from 1994 to 2005 (Port of Townsville, previously Townsville Port Authority) that document overall levels of analytes and temporal and spatial compositional changes for sediments from a number of sites, predominantly to the east of the Port access channels. To the west, the current zone of interest, little long term systematic analytical data for sediment quality exists.

Water quality in Cleveland Bay is subject to spatial and temporal compositional change. However, systematic investigations of water quality variations were only commenced by the Port Authority in 2004/2005. As with the sediments, these analyses were predominantly collected from areas subject to the activities of the Authority, rather than from the area to the west of the Port Western Breakwater. Thus, in spite of numerous time-limited investigations of water quality in the Bay, data suitable for providing a temporal and spatial baseline are scarce.

Studies undertaken for this study again only represent a single time slice, but they were the first to investigate water quality at the top and bottom of the water column, together with the spatially associated sediment quality and biota.

The current investigations are to provide a baseline for both sediment and water quality against which potential impacts of the development can be assessed.

To date investigations into sediment composition have –

- Determined existing levels for a range of analytes, assessed their compliance with relevant standards, and used the data to propose local guidelines suitable for use as a baseline;
- Developed appropriate strategies to minimise possible environmental harm resulting from anthropogenic activities;
- Determined options for disposal of dredge spoil;
- Documented temporal trends in sediment quality;
- Assessed impacts of current activities and practices;
- Identified potential and actual sources of sediment contamination and devised appropriate remediation strategies as necessary.

Additionally, the less extensive investigations into water quality have –

- Monitored on a wet season / dry season basis, the water quality within the Port of Townsville to provide comparison with Local and Statutory Guidelines;
- Provided data to permit improved environmental management;
- Assessed current impacts and management strategies for the purposes of determining potential effects on water quality from future developments;
- Assessed effectiveness of current management strategies;

- Determined point and non-point sources of analyte input that may influence water quality in the area.

The current sediment and water quality data sets provide information that complements existing information. Furthermore, although currently temporally limited, the data supplies specific baseline information against which, with the existing data, the potential impacts of the proposed development can be impartially assessed.

4.2 SEDIMENT QUALITY

Sediment Quality: Key Findings

The sediment quality in Cleveland Bay is generally high and within accepted guidelines. The results of the baseline study indicate that nutrients exceed investigation and intervention levels outside the development site at a series of sites immediately off Kissing Point. Metals levels are generally all within accepted criteria. Results indicate that all sediments are compliant with HIL-A levels of the Queensland Soil Guidelines.

4.2.1 General:

For the development to be compliant it is necessary that existing sets of guideline criteria are met. For Cleveland Bay two existing guideline sets apply (Table 1). For Cleveland Bay specifically, and for the elements investigated, the average levels found by Doherty et al. (2000), together with their standard deviations, are consistent with the TPA Background Levels.

In general the TPA Background Levels are below the ANZECC (2000) ISQG Low Levels. It is believed that to satisfy local requirements, the appropriate TPA Background Levels are appropriate for this development.

Levels in some other areas (eg: Ross Creek) are well above TPA and ISQG – High Guidelines. Guidelines for specific analytes are given in Appendix 1.

Table 1. Sediment quality guidelines relevant to Cleveland Bay.

ANZECC (2000) Marine Interim Sediment Quality Guidelines (ISQG).	These essentially lead to the following levels of assessment:
ISQG – Low: ISQG – High:	Below which there is a low probability of effects on benthic fauna and flora; High probability of toxic effects on benthic fauna and flora. Levels falling between these values have an intermediate probability of effects on benthic fauna and flora.
Local (Townsville Port Authority) Guidelines.	These involve a set of background and screening levels against which analyte values are assessed.
Doherty (2000)	Sediment data analysed from a variety of locations in Cleveland Bay.

4.2.2 Total Petroleum Hydrocarbons (TPH) and Benzene, Toluene, Ethylbenzene, Meta and Para Xylene, and Ortho Xylene (BTEX)

No specific standard guidelines exist for these analytes in tropical marine sediments.and soils. Consequently, the guideline values given below are based on Professional Knowledge and analysis of the current data set (Table 2).

In the current investigation all levels assessed for all TPH and BTEX analytes were below the limit of analytical range and no real values were measured. Given these low levels, in setting the proposed guidelines, Investigation Levels were set at 1.5 times the lower limit of analytical range and Intervention Levels set at levels consistent with Best Professional Judgement.

Table 2. Recommended investigation levels of TPH and BTEX.

Analyte	Guideline	Value
$C_6 - C_9$	Ocean Terminal Recommended Investigation Level:	3 mg/kg
	Ocean Terminal Recommended Intervention Level:	10 mg/kg
$C_{10} - C_{14}$	Ocean Terminal Recommended Investigation Level:	75 mg/kg
	Ocean Terminal Recommended Intervention Level:	150 mg/kg
$C_{15} - C_{28}$	Ocean Terminal Recommended Investigation Level:	150 mg/kg
	Ocean Terminal Recommended Intervention Level:	300 mg/kg
Benzene	Ocean Terminal Recommended Investigation Level:	0.3 mg/kg
	Ocean Terminal Recommended Intervention Level:	1 mg/kg
Toluene	Ocean Terminal Recommended Investigation Level:	0.3 mg/kg
	Ocean Terminal Recommended Intervention Level:	1 mg/kg
Ethyl benzene	Ocean Terminal Recommended Investigation Level:	0.3 mg/kg
	Ocean Terminal Recommended Intervention Level:	1 mg/kg
Meta- and Para-Xylenes	Ocean Terminal Recommended Investigation Level:	0.3 mg/kg
	Ocean Terminal Recommended Intervention Level:	1 mg/kg
Ortho-Xylenes	Ocean Terminal Recommended Investigation Level:	0.3 mg/kg
	Ocean Terminal Recommended Intervention Level:	1 mg/kg

4.2.3 Nutrient N and P Species:

Guideline values for nitrogen and phosphorus (N and P) species in marine sediments are not well documented. Consequently, the levels found in this baseline study will be used to develop appropriate Investigation and Intervention Levels specific to this project. As for the trace metals, levels for N and P species will be created in terms of discrete clusters with the control sites given greater weighting for the establishment of Background (not Investigation) Levels.

The results of the baseline study indicate that ammonia, nitrite, and nitrate (except in the Development site) are generally found at levels below the recommended investigation and intervention levels. TKN and Total P exceed recommended investigation levels at sites S2-S4, and TKN exceeds recommended intervention levels at sites S6-S8 (Appendix 1). These pre-existing anomalies will require further investigation.

4.3 MARINE WATER QUALITY – SURFACE AND BOTTOM

Surface Water Quality: Key Findings

Water quality data collected for this baseline study revealed a number of existing levels outside ANZECC, 2000 Water Quality Guidelines. Impact samples S1 to S8 and control sample CS1 (all to the west of the Port Western Breakwater) show very high levels of total P, often associated with above average metals levels in the waters.In spite of these anomalies, all water samples analysed are better thn 95% ANZECC 2000, Species Protetion Guidelines or within currently existing ambient ranges or both. Due to the nature of the sampling, which allowed for a single time-slice, these results must be interpreted carefully. The results indicate levels which can be achieved due to background processes already acting in the waters, including variations in wind strength and direction. Additionally, differences were noted in some chemical species between surface and bottom waters, with the bottom water holding lower concentrations of some ions than the surface waters. This makes definition of ambient levels to be achieved by flushing of the waters of the development very difficult to define. Further monitoring investigations, especially temporal sampling, are strongly recommended to define satisfactory operating levels for this development. These will be obtained from annual monitoring

4.3.1 General

In spite of numerous previous investigations, few attempts have been made to develop specific water quality criteria for Cleveland Bay in general and the area to the west of the Port Western Breakwater in particular. Additionally, given the hydrodynamics and seasonal climatic conditions in the Bay, it is believed that water quality conditions will vary spatially and temporally. Thus, most existing data merely relate to conditions for a single time-slice.

The data collected for this investigation are similarly limited temporally. They are, however, possibly the first data set to indicate a likely difference in water compositions at the top and bottom of the water column in a fairly shallow bay. This has implications for water mixing models.

Given the lack of site specific water quality criteria for the Bay, and the overarching interest of the Commonwealth Government in the area, documents used to provide Water Quality criteria include:

- ANZECC (2000) Water Quality Guidelines
- DEH Water Quality Targets
- Queensland water quality Guidelines (2006)
- West Australian water quality Guidelines (2003)
- USEPA / NOAA Screening quick Reference Tables (1999)
- ANZECC (1992) Water Quality Guidelines
- Dutch Standards (2005)
- NSW and Queensland EPA, Hydrocarbon (Petrol Station) Guidelines (1994 and 1999)
- Existing Local Data (Cleveland Bay Consortium)
- Data collected for this project.

In this section it is assumed that the target is the protection of the environmental values of the aquatic ecosystem. In Cleveland Bay as a whole, the system is assumed to be slightly too moderately disturbed. Consequently, an Ecosystem Protection Probability of 95% is assumed to be a minimum viable target. However, for some parts of the system, given the nature of current, pre-construction activities, a secondary target of only 80% Ecosystem Protection Probability may be necessary. It is against these targets that the potential impacts of the development should be addressed (Appendix 1).

Water Quality – Project Site Ocean Terminal – Selected Investigation Levels – Marine Waters

Analyte	Range in Bay µg/L	Level in Project Site µg/L		Level after first flush event µg/L			ANZECC Species protection Guidelines (SPG) µg/L			Recommended level µg/L	Comments
		Top	Bottom	12.5mm	25mm	50mm	95%	90%	80%		
Hg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	0.7	1.4	0.1	Within range in Bay. Better than 95% SPG
As	1.5 – 2.8	1.9	1.7	1.75	1.75	1.75	ID 13	ID 42	ID 140	3.0	Within range in Bay. Better than 95% Freshwater guidelines for As(V) - green
							SQ	23			Better than SQUIRT chronic marine - Red
Ba	6-9	6	6	5.8	5.8	5.8	NV	NV	NV	10.0	Within range in Bay. Better than SQUIRT Maximum contamination level (MCL)
							2000				
Be	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	ID 4	ID	ID	0.1	Within range in Bay. Better than SQUIRT MCL
Cd	<0.2-0.4	<0.2	<0.2	1.6	1.6	1.6	5.5	14	36	2.0	Above range in Bay but better than 95% SPG
Cr	<0.5-1.8	<0.5	<0.5	3.49	3.39	3.35	27.4	48.6	90.6	5.0	Above range in Bay but better than 95% (& 99%) SPG
Co	<0.2-3.8	<0.2	<0.2	2.78	2.70	2.67	1	14	150	3.8	Within range in Bay. Better than 90% SPG
Cu	<1-2.0	2	<1	2.68	2.02	1.69	1.3	3.0	8.0	3.0	At range in Bay. Better than 90% SPG
Pb	2.0-20.6	9.4	6.8	8.63	8.25	8.05	4.4	6.6	12	10	Within range in Bay. Better than 80% SPG. Values in Bay much less than 80% SPG
Mn	6.3-32.9	9.4	9.8	9.03	9.03	9.03	1900 50	2500	3600	20	Within range in Bay. Better than 95% SPG. Better than SQUIRT MCL
Ni	<0.5-1.2	<0.5	<0.5	4.11	3.99	3.94	70	200	560	7	Above range in Bay but better than 95% (& 99%) SPG
V	1.4-3.2	1.8	1.6	1.7	1.7	1.7	100	160	280	3.2	Within range in Bay. Better than 95% (& 99%) SPG
Zn	<5.0-7.0	<5.0	<5.0	4.29	4.08	3.98	15	23	43	7	Within range in Bay. Better than 95% (& 99%) SPG
Total N	<500-700	<500	600	550	550	550	700 300	3400 1600	17000	600	Within range in Bay. Within ANZECC 95% SPG for nitrate (purple). Above Queensland Total N of 300 (Blue). Inconsistency between ANZECC & Queensland values. Within ANZECC TN Lowland River (Mauve)
TRP	<10	<10	<10	7.79	7.79	7.79	8			8	Within range in Bay. At Queensland value (orange)

In making any assessments at any given time, the role of *Trichodesmium* (a cyanobacteria or blue-green algae), which often blooms in the Bay, should not be underestimated. *Trichodesmium* has been demonstrated to play a significant role in the elevation of many nutrient and trace metal species to levels well in excess of the ANZECC (2000) Guidelines. *Trichodesmium* was encountered in the sampling for this study.

4.3.2 Total Petroleum Hydrocarbons (TPH) and Benzene, Toluene, Ethylbenzene, Meta and Para Xylene, and Ortho Xylene (BTEX)

No definitive guideline standards exist for these components. Consequently the levels proposed are based on a number of secondary sources, including ANZECC (1992), NSW (Petroleum and Hydrocarbons) Guidelines, Dutch Standards, and Best professional Judgement. For all analytes in this group, all samples from both surface and bottom waters were below the limit of analytical range (Table 3).

Table 3. Proposed levels of TPH and BTEX in surface water quality samples. More detailed information is given in Appendix 1.

Analyte	LOR	Investigation Level	Intervention Level
$C_6 – C_9$ (Gasoline)	20 μg/L	20 μg/L	100 μg/L
$C_{10} – C_{14}$ (Kerosine)	50 μg/L	50 μg/L	100 μg/L
$C_{15} – C_{28}$ (Diesel)	100 μg/L	100 μg/L	500 μg/L
$C_{29} – C_{36}$ (Heavy Oil)	50 μg/L	50 μg/L	500 μg/L
Benzene	1 μg/L	1.0 μg/L	500 μg/L
Toluene	2 μg/L	2.4 μg/L	300 μg/L
Ethylbenzene	2 μg/L	2.4 μg/L	300 μg/L
Beta and para-xylene	2 μg/L	3.0 μg/L	200 μg/L
Ortho-xylene	2 μg/L	3.0 μg/L	200 μg/L

4.3.3 Nutrients (N and P) Species:

All levels found in this study for N and P analytes were below the limit of reporting. Highest levels were found in the surface waters of some of the Control sampling sites, and at the Impact sites I6 to I8 (Appendix 1).

4.3.4 TKN, TKN – Ammonia, Total Nitrogen as N (TKN + NO_X)

All real values (ie: above the limit of reporting) for these components occur for TKN results. Such are the levels of this analyte, relative to ammonia and NO_X that:

- TKN = TKN – Ammonia = Total Nitrogen as N (TKN+NO_X).

The results will be considered in terms of Total Nitrogen, as this is the component for which Guidelines exist.

Data obtained in this study, particularly Impact samples S1 to S8 and control sample CS1 (all to the west of the Port Western Breakwater) show very high levels of total P (Appendix 1). These values (often associated with above average metals levels in the waters) need further definition before accurate Investigation and Intervention Levels can be provided. It is believed that the levels may represent either the occurrence of *Trichodesmium* in the water column, or the input of anthropogenic run-off into the Bay.

The results indicate levels which can be achieved due to background processes already acting in the waters, including variations in wind strength and direction. This makes definition of ambient levels to be achieved by flushing of the waters of the development very difficult to define. Further monitoring investigations, especially temporal sampling, are strongly recommended to define satisfactory Investigation and Intervention Levels for this Development.

4.3.5 Other Analytes Not Directly Assessed, But Assessed From Accepted Literature Guideline Levels:

Chlorophyll-a, pH, Dissolved Oxygen, conductivity, salinity, turbidity, organochlorides and pesticide levels were not measured directly, but available data were reviewed and found to contain sufficient information for the establishment of preliminary guidelines. Investigation and intervention levels are suggested for each analyte (Appendix 1).

Turbidity will vary greatly depending upon wind and tidal conditions in the Bay. Due to a high proportion of fine material (<20μ) in the majority of the sediments, high turbidity values are frequent, but associated with relatively low (<25 mg/L) suspended sediment. Thus, definition of appropriate Investigation and Intervention Levels are difficult.

4.4 GROUNDWATER QUALITY

4.4.1 General:

Groundwater Quality: Key Findings

The shallow aquifers of the Townsville Coastal Plain often have a complex inter-relationship with surface waters. Ammonia levels vary from 1.20 to 1.56 μg/L, which is well above the ANZECC (2000) Marine 95% species protection level of 0.91 μg/L. It is unclear whether the origin of this relatively high level of ammonia in the groundwaters relates to natural origins alone. The resulting nitrate ions may affect aragonitic precipitation of some marine organisms (eg: corals and clams) so that the overall mechanical integrity of the hard parts is reduced. Additionally, levels of some metal ions may be outside the ANZECC 95% guidelines. It is therefore imperative to avoid activities that facilitate the intrusion of these groundwaters into the marine environment.

Few systematic investigations have been undertaken into detailed groundwater compositions of the Townsville region in general. The majority of investigations have been carried out by Cuff and his co-workers, ranging from Reid, Weller and Radford in the early 1970s to work for clients, Maunsell, BHP Billiton, Australian Airports and Townsville City Council in 2005/2006. These studies have attempted to provide a set of local guidelines for the groundwaters of the region that take into account:

- The parent rock material – predominantly acid volcanics and intrusives to andesites;
- The nature of the climate;
- The nature of the weathering processes involving year-round high temperatures, a wet season, a dry season, and evaporation exceed precipitation by a factor of 2 to 3. These features result in the production of clay minerals with relatively high adsorbtive capacities and particle sizes, when totally dispersed, of less than 1.0μ and the production of a range of colloids of hydrated oxyhydroxides of silicon, aluminium, iron and manganese. These colloids are generally easily able to pass through a 0.45μ filter and consequently are present in the 'soluble', dissolved' fraction. The colloids, with their differing surface charges, are able to adsorb high levels of both cations ('metals') and anions (phosphate).

- The geomorphological contexts of the last 120,000 years whereby sealevels may have changed by as much as –120m (approximately 120,000 YBP) to +2m (approximately 6000-7000 YBP). Thus, areas currently marine were once terrestrial and coastal areas now terrestrial were once marine. This means that the coalescing colluvial/alluvial fan aquifers and, more particularly, the ribbon (old infilled stream channel) aquifers may extend well beyond the current shoreline. These pathways may lead to submarine seeps of relatively fresh, but generally nutrient enriched, waters to occur offshore ("wonky holes").

In addition to sources of assessment criteria listed in Section 4.8.3.1, one other secondary source has been used. Surface waters are generally equilibrated with the atmosphere and its contained CO_2. The chemical buffers, if present, are, in part at least, controlled by carbonate equilibria. In contrast, in the absence of limestone (calcium carbonate) in the geological succession of the immediate hinterland to the development, groundwaters are not in contact with the atmosphere and the chemical buffers, if present, are largely Si-OH or Al-OH based. They may be considerably different to surface waters with their analyte compositions being controlled by the rocks and sediments through which they pass, and their rate of passage.

Thus, in the first instance guidelines such as ANZECC (2000) may not apply to groundwaters. To this end, the current authors have developed a set of groundwater guidelines specifically for Townsville City Council. It is against these Secondary Guidelines that the groundwaters encountered in this investigation are assessed. It is believed that assessment against a region-specific set of groundwater guidelines is more applicable than assessment against a generalised set of predominantly surface water guidelines. Levels for groundwater assessment are provided below. In instances where analytical information does not exist, the conservative levels quoted in the ANZECC (2000) Guidelines are generally used by default.

Table 4 provides suggested analyte guideline levels for the shallow groundwaters beneath the "Project Site". These data are comparable to those provided to the Townsville City Council for Groundwater Impact Assessment. It should be noted that the shallow aquifers of the Townsville Coastal Plain often have a complex inter-relationship with surface waters. It is likely that the shallow groundwaters may emerge as submarine seeps in the shallow waters of Cleveland bay ("Wonky Holes"). For this reason, suggested guideline levels for the shallow groundwaters beneath the "Project Site" are kept as consistent as possible with the ANZECC 95% Species Protection Levels. This is consistent with the approach provided to Townsville City Council. Below investigation levels, analyte concentrations are most probably natural. Between Investigation and Intervention Levels the causes of analyte concentrations need to be defined since they can be either nature or anthropogenic in origin. At, or above, Intervention Level, analyte concentrations are considered more likely to be due to contamination effects. Natural causes are not specifically excluded, but it shold be required to demonstrate to Regulatory Authorities that, on the balance of probabilities, such levels are not anthropogenically relevant.

Table 4. Proposed Investigation and Intervention Levels, Townsville Ocean ` Terminal Development

(a) Australian Ecosystem Guidelines
(b) Department of Environment and Heritage (DEH), and Queensland Water Quality Guidelines (QWQG 2006)
(c) Australian Drinking Water Guidelines 2004
(d) Local Groundwater Ranges, and
(e) Suggested Groundwater Quality Guidelines.

Analyte	(a) Australian Ecosystem Guidelines mg/L	(b) DEH And QWQG (2006) mg/L	(c) Australian Drinking Water Guidelines (2004) mg/L	(d) Local Groundwater Ranges mg/L	(e) Suggested Groundwater and Saline Water Quality Guidelines (Project Site) mg/L	(e) Suggested Intervention Values (Project Site) mg/L
Al[1]	0.055	–	0.2	–	0.06 (as discrete solution species only)	
As	0.024	? <0.05	0.007	0.001–0.003 Mean=0.005	0.003:	0.024
Ba			0.700	0.010–0.100	0.010	0.100
Be			[0.004]	<0.0001–0.002	0.0001	0.001
Cd[H]	0.0002	? 0.003	0.002	0.0001–0.0016	0.002	0.0055
Cr[H]	0.008	? <0.01	0.05	0.001–0.004 Mean=0.004	0.005	0.030
Co[H]	0.001			0.001–0.030	0.0038	0.030
Cu[H]	0.0014	? 0.006	1.0	0.003–0.114* Mean=-0.018	0.003	0.040
F	NV	NV	1.5	0.05–3.3	1.5	
Fe[1]	NV	? <0.5	0.3	0.07–6.3	0.3 (as discrete solution species only)	0.3
Hg	0.0006	? 0.00005	0.001	<0.001	0.0001	0.001
Mn[1]	1.89	<0.01	0.1	0.27–0.01	0.05 (as discrete solution species only)	0.1
Ni[H]	0.011	<0.01 Soft <0.04 Hard	0.02	0.003–0.016	0.007	0.070

Analyte	(a) Australian Ecosystem Guidelines mg/L	(b) DEH And QWQG (2006) mg/L	(c) Australian Drinking Water Guidelines (2004) mg/L	(d) Local Groundwater Ranges mg/L	(e) Suggested Groundwater and Saline Water Quality Guidelines (Project Site) mg/L	(e) Suggested Intervention Values (Project Site) mg/L
NO_2^-					0.015	0.030
NO_3^-	0.7	NV	10	<0.5–4.3	0.100	1.5
Ammonia	0.9	NV	0.5	0.01–0.56	0.060	0.9
Total N	0.3 – 1.2	0.1 – 1.2		0.1–3.5	0.600	3.5
`Total P	0.010 – 0.050	0.015 – 0.050		0.01–0.30	0.050	0.1
Reactive P					0.008	0.050
Pb^H	0.0034	<0.03	0.01	0.001–0.570 Mean=0.043	0.010	0.020
V	50			0.001–0.010	0.003	0,100
Zn^H	0.008	0.03 – 0.06 Soft	3	0.050–0.510 Mean+0.168	0.007	0.300
pH	4 – 9	5.5 – 9.0	6.5 – 8.5	4.45 -7.5	Fresh 5.5 – 8.5 Saline 7.0 – 8.5	4.5 and 9.0 6.5 and 9

Legend:

H Hardness correction applicable

* Value at height of dry season. Possibly colloid related.

1 Al, Fe and Mn - Often present in colloidal forms. High levels after passing through 0.45μ filter may reflect colloidal rather than solution species.

Note:

Numerous data sources have been accessed ito obtain values for use in the above table, including:

- ANZECC (2000) Guidelines
- USEPA Water Quality Criteria (May 2005)
- Dutch Water Quality Guidelines (June 2005)
- Ontario guidelines (2005)
- vQueensland Water Quality Guidelines (2006)
- Department of Environment and Heritage guidelines (2006).
- Australian Drinking Water Standards 92004)
- Professional Judgement based on Groundwater Analyses in the Townsville Region, 1971 – 2006

4.4.2 Total Petroleum Hydrocarbons (TPH) and Benzene, Toluene, Ethylbenzene, Meta and Para Xylene, and Ortho Xylene (BTEX)

No apecific standard guidelines exist for these components in tropical groundwaters. Consequently, the levels proposed are based on a number of secondary sources including ANZECC (2002), NSW (Petrolem and Hydrocarbon) Guideline (1994), Dutch Standards (2005), and Best Pprofessional Judgement.

For all analytes in this group, all samples were below the limit of analytical reporting (LOR, Table 5).

Table 5. Proposed Guideline Levels of TPH and BTEX in Groundwater.

Analyte	LOR	Investigation Level	Intervention Level
$C_6 – C_9$ (Gasoline)	20 µg/L	20 µg/L	100 µg/L
$C_{10} – C_{14}$ (Kerosine)	50 µg/L	50 µg/L	100 µg/L
$C_{15} – C_{28}$ (Diesel)	100 µg/L	100 µg/L	500 µg/L
$C_{29} – C_{36}$ (Heavy Oil)	50 µg/L	50 µg/L	500 µg/L
Benzene	1 µg/L	1.0 µg/L	500 µg/L
Toluene	2 µg/L	2.4 µg/L	300 µg/L
Ethylbenzene	2 µg/L	2.4 µg/L	300 µg/L
Beta and para-xylene	2 µg/L	3.0 µg/L	200 µg/L
Ortho-xylene	2 µg/L	3.0 µg/L	200 µg/L

4.4.3 Nutrients (N and P) Species in Groundwater:

Unlike surface and marine waters in the earlier section, real values (above LOR) were reported for a number of analytes in this group (Table 6).

Table 6. Results of Nutrients (N and P) Species sampled for this Baseline Study

Nutrient	Range
Ammonia as N: Range	1.20 – 1.56 mg/L
Nitrite as N	<0.101 – 0.012 mg/L
Nitrate as N	0.041 – 0.069 mg/L
Organic Nitrogen as N (total kjeldahl nitrogen – ammonia)	0.2 – 1.2 mg/L
TKN	1.4 – 2.7 mg/L
Total phosphorous as P	<0.05 – 0.11 mg/L

Reactive phosphorous as P	All less than 0.050 mg/L

Ammonia levels vary from 1.20 to 1.56 μg/L which is well above the ANZECC (2000) (2000) Marine 95% species protection level of 0.91 μg/L The origin of the relatively igh levels in the groundwaters is problematical, but possibly relates to the natural formation of the ammonium ions in the subsurface palaeo representative of anaerobic organic rich freshwater wetland environments. These environments are an essential component of the beach / dune / swale / estuary / alluvial flat geomorphological complex of the Holocene and current coastline. Alternatively, the ammonia levels may be anthropogenic in origin.

In these situations the ammonium ion is readily adsorbed on to smectitic / illitic clays. This ion may be readily desorbed into solution and thus flow out along the aquifers. As long as it is contained in the aquifer, the ammonia is of little direct concern to the development. However, should the aquifer be breached beneath the Project Site, particularly after the construction of the canal, then, unless flushing is adequate, nitrogen based nutrient species (ammonia, NH_3 / NH_4^+ and by oxidation, nitrite NO_2^- and nitrate NO_3^-) may build up in the area. Alternatively, if the aquifer is breached in the construction of the channelway, there is the possibility of the formation of an artificial “wonky hole”.

The ammonia released in this submarine seep is likely to be oxidised to nitrate (NO_3^-). This ion will then move as a plume, together with other components, until background levels are reached The impact of nitrate on the downflow biological species is conjectural. However, it is known that the nitrate ions may affect aragonitic precipitation of some marine organisms (eg: corals and clams) so that the overall mechanical integrity of the hard parts is reduced. The effects are considerably enhanced at low phosphate levels (Belda et al. 1993).

Therefore, during the construction of the canals, and the excavation of channelways, every effort must be made to ensure that the shallow aquifer system is not breached

4.4.4 Other Groundwater Analytes

As was shown above in Table 4, levels of analytes found for most other components are consistent with those occurring in relatively unimpacted groundwaters in the Townsville region. Investigation and Intervention Levels proposed in Table 4 were formulated based on this experience. Consequently, if levels monitored in the groundwater bores of the development are above the Investigation Levels, then Further monitoring investigations (eg: resampling) will be necessary. If levels above intervention Levels are detected, then considerable further investigations may beed to be undertaken to determine possible origins.

4.4.5 Manganese

An exception to the statements made in Section 4.8.4.4 is manganese which rangese in value from 3.00 to 3.97 mg/L. As such, this is above the levels usually found in groundwater systems of the region (typically 1 - 2 mg/L or less). As indicated in Table 4 and elsewhere, manganese will occur in these waters as “dissolved” and “colloidal” components. The high levels of this analyte found in these groundwater samples probably represents the passage of considerable amounts of colloidal material through the 0.45μ filter used in sampling. Generally, it is believed that the bio-availability of manganese from colloidal sources is low.

The high levels of manganese, whether "dissolved" or "colloidal", is consistent with the origin of the groundwaters in a relatively anaerobic, freshwater, organic rich palaeo wetland. In these environments manganese is often associated with humic and other organic components. It is considered that the high levels of manganese found in these borewaters are unlikely to be of anthropogenic origin.

4.4.6 Summary – Sediment and Water Quality results

The emphasis in this study has been to provide a locally based set of Guidelines against which the impacts of the proposed development can be assessed. However, there are several features of the data sets that could be developed to provide useful information of a more fundamental nature.

The data analysed to date indicate differences:

- Possible existing minor from ANZECC, 2000 with respect to water quality with a probability of differences between bottom and surface waters;
- The bottom sediments meet Queensland HIL-A standards; and
- The general fine nature of the bottom sediments (25% plus <25μ in size).

Note:
The values set for Investigation and Intervention Levels are often deliberately more stringent than those given in the ANZECC (2000) Guidelines. Reasons for this include:

- They are consistent with local values;
- They are achievable and defendable;
- They are locality dependent, and hence are better than ANZECC Guidelines;
- They are low and "environmentally friendly", and will therefore permit simpler and cheaper monitoring and remediation strategies than would be required under the generally higher ANZECC (2000) values;
- They will permit proactive rather than reactive mitigation strategies; and
- They will provide buffer-time for corrective and remedial strategies prior to possible intervention by Authorities which can require temporary intervention to development activities.

4.5 *MODELLING DATA*

Chemical modelling of stormwater flushing from the development into the adjacent marina areas was modelled using:

- Catchment specific data for nutrients (N and P) flowing across the area in a stormwater event as calculated using MUSIC modelling (Refer Stormwater Report) and
- Catchment specific date using PHREEQC modelling, for a wide range of chemical species, present in solution and reacting with or in equilibrium with co-existing solid phases.

PHREEQC is a commonly used chemical mass balance/ equilibrium / kinetic programme used (particularly in the mining industry) to define water quality reaction and evolution over extended time periods. It is a programme developed by the U.S. Geological Survey.

PHREEQC Version 2 is a computer programme for simulating chemical reactions and transport processes in natural or polluted water. The programme is based on equilibrium chemistry of aqueous solutions interacting with minerals, gases, solid solutions, exchangers, and sorption surfaces, but also includes the capability to model kinetic reactions with rate equations that are completely user-specified in the form of Basic statements.

Kinetic and equilibrium reactants can be interconnected, for example by linking the number of surface sites to the amount of a kinetic reactant that is consumed (or Produced) during the course of a model period. A 1D transport algorithm comprises dispersion, diffusion, and various options for dual porosity media. A powerful inverse modelling capability allows identification of reactions that account for observed water compositions along a flowline or in the time course of an experiment. An extensible chemical data base allows application of the reaction, transport, and inverse-modelling capabilities to almost any chemical reaction that is recognised to influence rain-, soil- ground and surface water quality.

Input data into the modelling included in the first instance:

- The MUSIC data for N and P species
- The areas of land, roof area and road area present in the catchment
- The total area of marine water present in the catchment
- The average depth of the water present in the catchment

It was assumed that the dust collected from the four collectors (see Air Quality Report) was representative of the air quality as a whole. Area weighed averages for dust inputs from the four collection positions were also assumed.

For the modelling scenarios involving a nine month flush just the roof area and one month flushes for road and land areas were assumed. This permitted actual calculations of the mass of dust possibly available for flushing into the water areas of the development to be calculated for the different scenarios.

As is usual for all quality data, while mass of dust was assessed, its chemical composition calculated represented worst case scenarios with possible reactive components in the dust representing 10% of the total mass. Both undiluted and diluted cases were modelled for chemical components included in the modelling included:

Copper	Raw value	1020mg/Kg	Diluted value	102mg/Kg

Lead	Raw value	597mg/Kg	Diluted value	59.7mg/Kg
Zinc	Raw value	310mg/Kg	Diluted value	31mg/Kg
Cadmium	Raw value	7.54mg/Kg	Diluted value	0.754mg/Kg
Nickel	Raw value	174.3mg/Kg	Diluted value	17.4mg/Kg
Cobalt	Raw value	118mg/Kg	Diluted value	11.8mg/Kg
Chromium	Raw value	148mg/Kg	Diluted value	14.8mg/Kg

That these diluted values are consistent with the sediment quality is born out by the current compositions of the bottom sediments present on the bottom of the proposed development area.

Other data put into the models included:

- Compositions of rainfall for the area (Generalised)
- Specific compositions of marine waters for the area (Actual)
- Volumes for first flush rainfall events of:

12.5mm total	Most concentrated
25mm total	Most likely
50mm total	Least concentrated

- Volume of marine water present in the development allowing for all constructed areas.
- Modelling was then undertaken involving two scenarios:
- Total dissolution of all reactive components present. This represents the worst case for water quality, and
- No dissolution of the reactive components present. This represents the worst case for sediment quality.

A range of models was then developed involving simple mixing of stormwater and marine waters composition and volumes, mixing plus diffusional transport, mixing plus advective transport and reactive/kinetic processes. These results are given, in brief, in Appendix 3 and below for total N and total P.

The total dust falling on land area is, minimum 6.88 tonnes/annum, maximum 9.80 tonnes / annum.

This material will be mainly locally derived natural mineral matter and is likely to be at least 98.5% insoluble and will finish up in the sediment. The rest is likely to be reactive to some degree and partially dissolve into the aqueous phase, either the stormwater or when it is discharged into the marina.

For the dissolved material, the solubility into controls chosen are apatite and a lead phosphate. Both are exceedingly insoluble.

The total P falling on the land area (contained mainly in apatite) is minimum 2.45 kg/annum, maximum 20.01kg/.annum, most likely 8.79kg/annum.

This material will mainly be in highly insoluble apatite related phases. Even if it all dissolves in the most concentrated first flush scenario, it will only contribute approximately 4.4µg/ L to the solution. This is well below the total P investigation level of 50µg/L. However, it is likely that only 1% of the apatite will dissolve, the rest going into the bottom sediments. At this level of dissolution the level of phosphorus input will be 0.044µg/L. This is approximately 0.5% of the reactive P level of 8µg/L

The total P content of the bottom sediments in the vicinity of the development area is approximately 300mg/Kg.

The total N falling on the land area is minimum 3.42kg/annum, maximum 27.97kg/annum, most likely 12.29kg/annum.

This material is likely to be reasonably soluble but under the worst first flush event it will only contribute a maximum of 6.2µg/L to the total N investigation level of 600µg/L for the marine waters.

The total N content of the bottom sediments in the vicinity of the development area is approximately 400mg/Kg.

All modelling indicated that, under all scenarios investigated:

- Water quality present in and emanating from the development was always within ambient ranges in the Bay or better than ANZECC 2000 and other water quality guidelines or both, and
- Sediment quality was always better than HIL-A Queensland Soil Guidelines. The implication of this assessment is that when dredged this material must be disposed of to land.

Thus, providing the project is adequately flushed, annual maintenance dredging occurs in the specified locations, and that the monitoring strategies proposed are implemented in full, then water and sediment quality factors do not provide reasons to disallow the construction and operation of the Development.

4.6 INTEGRATION OF ECOLOGICAL AND CHEMICAL DATA

Sites I6 to I9 had highest species richness of benthic invertebrates, while sites I7 to I9 had the highest invertebrate and seagrass densities compared with all other sites. These sites also showed anomalous levels of chemicals in the surface waters. This is likely to be an important area for benthic-feeding fishes, but the prevailing local tidal movements and current patterns need to be more extensively explored at the appropriate scale to explain the low water quality in this area. It appears that the source of these high concentrations of chemicals is not the sediment, as the water close to the seabed is of higher quality than that near the surface. One possible explanation is that seagrass takes up nutrients and accumulates metals, removing these contaminants from the water immediately surrounding them. Water quality was high at the sampling site closest to Sandfly Creek, which is potentially influenced by the Sun Metals refinery, suggesting that measures in place to reduce impact on water quality are successful.

5 RISK ASSESSMENT OF THE POTENTIAL IMPACTS OF THE DEVELOPMENT ON CLEVELAND BAY

5.1 INTRODUCTION

In this section, quantitative extensions to standard risk assessment levels are implicit in the terminology used. Use of the terminology is consistent with those often used in major organisations (eg: Department of Defence) to assess probability, political consequences, and financial magnitude of risk. This terminology is:

1: Likelihood

Highly unlikely	Probability of occurrence	0 – 20%
Unlikely	Probability of occurrence	20 – 40%
Moderately likely	Probability of occurrence	40 – 60%
Highly likely	Probability of occurrence	60 – 80%
Almost certain	Probability of occurrence	80 – 100%

The implications of this quantification are that events classed as likely (moderately likely) may still have a better than even chance of occurren ce. Thus, their inclusion in risk assessment matrices as significant events is necessary.

2: Political Consequences are based on the level of reporting of the particular event.

Minimal significance	Publication of event in "yellow" literature
Minor significance	Publication of event in local news media
Significant	Publication of event in States media
Major significance	Publication of event in National news media
Maximum significance	Publication of event in International news media

3: Economic Significance			
Minimal significance	Rectification costs		< $ 10,000.00
Minor significance	Rectification costs	$ 10,000.00 -	$ 100,000.00
Significant	Rectification costs	$ 100,000.00 -	$ 1,000,000.00
Major significance	Rectification costs	$1,000,000.00 -	$10,000,000.00
Maximum significance	Rectification costs		> $10,000,000.00

Generally, a catastrophic event will be one with a greater than 60% probability of occurrence, have major to maximum political consequences, and be of maximum economic significance.

5.2 PROJECT CONSTRUCTION IMPACTS

The primary construction component of the Development is the reclamation of currently submerged land for the cruise ship terminal and proposed residential area, now requiring approximately 1,650,000m^3 of rock, sand and engineered fill material.

With reference to the Hyder Consulting Construction Methodology Report, also provided with the EIS, the proponent's preferred option of re-use of approximately 1,650,000 m^3 of on-site materials, thereby reducing the need to bring in such material from off-site has been a significantly beneficial change since the Initial Advice Statement for the project was released, abrogating the need for new external extraction sites and their inherent environmental Impacts.

This methodology will be further discussed subsequent in the mititagtion sections.

The major construction activities for the TOT project include:

- construction of the Strand breakwater on the western side of the Development site and extensions to the northern breakwater;
- sealing off and draining of the site itself:
- construction of the reclaimed land: and
- reintroduction of water into the site.

There are potential impacts associated with each of these stages. The construction of the Strand breakwater will include the disturbance of sediments). Draining the Development site will lead to the exposure of the benthos and the mortality of seagrasses and algae. During the draining of the site, marine animals trapped inside the site may suffer injury, stress or mortality as the water levels drop and water quality and dissolved oxygen levels decline. Once dry, the habitat will be unavailable to marine animals, but seabirds and shorebirds may target exposed benthic invertebrates and may therefore be at risk from construction machinery.

After construction of the reclaimed land is completed, water will be reintroduced to the site. Sediments inside the site consist of extremely fine 'ooze', which is easily resuspended when disturbed and may take a long time to re-settle. A portion of this ooze will remain exposed to the inflow of water and may be disturbed. Once the site is filled with water, there may be a high level of suspended ooze, delaying access to the site for re-colonising organisms. Continuing construction works on the reclaimed land may also introduce spills, contaminants (Section **Error! Reference source not found.**), noise (Section **Error! Reference source not found.**) and garbage (Section **Error! Reference source not found.**) to the development site.

5.3 DREDGING

Dredging activities affect water quality (eg: turbidity), and if contaminated sediments are disturbed and transported, dredging activities will also affect sediment quality. Declines in both sediment and water quality are likely to have their greatest negative effect on seagrass beds (eg: contamination, macroalgal growth, smothering, shading), benthic invertebrates (eg: contamination) and coral reefs (eg: light attenuation, sediment deposition, pollution). Declines in the quality and health of seagrasses, benthic invertebrates and corals will have flow-on effects on all dependent species (Table 7).

Initial construction requirements for the project will require the dredging of an external access channel (refer Construction Methodology Report). However modeling of flushing and water quality indicates that regular annual maintenance dredging will be required in the internal channelway, and in the northeastern and southeastern arms of the Development. This will ensure that water and sediment quality are maintained to the recommended investigation and intervention levels provided in the Water Quality Report, principally in Appendices 1a and 1b. All annual maintenance dredging will be conducted within the marina areas of the Development itself. The Construction Methodology is such that the area of the Development will be totally dewatered during construction, with all flora and fauna removed. Thus no impacts will be sustained to the marina basin as a consequence of dredging. Since both flushing and water and sediment quality modelling indicate that appropriate guideline levels will be met, it is likely that marine flora and fauna will begin to reestablish in the marina areas. However, in order to maintain both water and sediment quality, annual maintenance dredging is vital, any flora and fauna present will be disrupted on an annual basis.

5.4 OIL AND CHEMICAL SPILLS

Accidental spills (oil or chemicals) can occur during both the construction and operation phases of the Development. Due to the proximity of the TOT to sensitive marine habitats and communities, even a small spill can be damaging in certain weather and tidal conditions. A large oil or chemical spill can cause a slick, trapping inshore-dwelling organisms in a situation where their exposure to toxic compounds could be prolonged (Volkman et al. 1994).

The potential risk to wide-ranging pelagic species is smaller, and they are less likely to suffer significant exposure and any lasting toxic effects (Bannister et al. 1996). Heavier, longer lasting petroleum compounds can become incorporated into sediments and affect benthic communities. Marine mammals and reptiles may be particularly vulnerable to the effects of oil pollution, as they spend time on the ocean's surface to breathe (Volkman et al. 1994, Bannister et al. 1996)

Spilled oil and chemicals can affect air-breathing marine species by contaminating the skin and mucous membranes, blocking the digestive tract, and causing acute and chronic poisoning by inhaled and ingested toxic compounds. Marine mammals, turtles and fish may also be indirectly affected by oil and chemicals damaging their habitats and reducing populations of staple prey. Many species of zooplankton absorb dissolved hydrocarbons (from spilled oil) directly from the water and ingest contaminated food. Species feeding exclusively on these crustaceans (eg: baleen whales) could be exposed to this source of contamination (Bannister et al. 1996).

5.5 RELEASE OF CONTAMINANTS

Marine structures and vessels can release biological and chemical contaminants into the marine environment, especially harmful antifouling agents. The most commonly used antifouling agent has been tributyltin (TBT), which is a highly effective antifoulant, but is also extremely toxic in the marine environment. There is still no suitable alternative that can be widely used, although many trials are in progress.

Many countries have banned TBT since the late 1970s, but traces of TBT continue to be found in the tissues of oceanic organisms (Lewis 2001). Areas with high shipping traffic, such as ports, are particularly at risk from accumulated antifouling pollution (IMO 1991). The most widely reported impact of TBT is its role as the cause of 'Imposex' in shellfish. Imposex leads to the development of a penis in females, resulting from a disruption in endocrine function and reproduction. It occurs in over 100 shellfish species, and is irreversible (Mortimer 2004).

Through bioaccumulation, TBT becomes concentrated in organisms at higher trophic levels, leading to illness and mortality in large predators such as sharks, dolphins and toothed whales (Kannan et al. 1996). It can accumulate in the tissues of marine organisms, even long distances away from the source. A further concern is the accumulation of TBT in shellfish and large pelagic fishes that are targeted and consumed by humans. TBT in the water column dissolves into less harmful substances within days. In areas of high shipping traffic, however, micro layers of TBT have been detected in open waters. TBT also accumulates in sediments, where it takes over ten years to break down.

In Australia, the accumulation of TBT and its associated problems primarily affect areas around ports with shallow water and heavy shipping traffic. Since 1987, all States and Territories in Australia either restricted the use of TBT antifouling paint on vessels over 25m length, and/or reduced the leaching rate of TBT from the paint to 5 $mg/cm^2/day$. The sale of this paint and its removal and reapplication is also restricted. Additionally, most Australian States have adopted legislation that prohibits the in-water cleaning of hulls (in order to prevent marine debris and TBT paint flakes accumulating on the seabed), and requires ship maintenance facilities to contain and dispose of hull marine debris in an approved manner. It appears that TBT levels in sediments around many Australian ports have declined as a result of these measures (Mortimer 2004).

The Australian Shipowners Association (ASA) advises that since 2003, commercial ships have ceased using exposed TBT on their hulls. According to the Convention, by 2008 all commercial vessels will have either adopted different anti-fouling agents, or covered the TBT on their hulls with substances to prevent the TBT from leaching into marine environments. The use of TBT on stationary marine structures and on smaller vessels is difficult to determine, but leaching of TBT into the marine environment can be avoided through the careful development of the management plan.

Other contaminants that may be introduced into the marine environment from the TOT development include a range of heavy metals in stormwater runoff. Refer to Section 5.5 and Section 4.5 in the Water Quality Report.

5.6 STORMWATER RUNOFF

The effects of stormwater drainage on the water quality of the development area have been modeled using a combined MUSIC and PHREEQC approach. Models have related to worst case, first flush scenarios after an extensive period (9 months) of dry weather within a minimal flushing event of 12.5mm. Likely compositions of the atmospheric dust were input into this scenario assuming total dissolution of the dust material or total incorporation of the dust material into the bottom sediment.

These data are discussed in Sections 4, 5, 6 and 7 of the Water Quality Report. In summary: Providing regular maintenance dredging is undertaken to ensure adequate flushing then all data indicate that all flushed water quality exiting the development will be within current ambient range or 95% ANZECC 2000 Species Protection Guidelines or both and that all sediments produced from the development will be within current ambient ranges (HIL-A Compliant).

Marine scientists agree that blooms of toxic and / or nuisance marine microalgae, cyanobacteria or dinoflagellates are becoming more frequent around the Townsville region. The prevalence of slicks of the algae *Trichodesmium* (colloquially known as 'red tide') has become more frequent. The blooms develop in coastal areas and are washed onto beaches and headlands, creating unpleasant smells. The accumulation of these blooms in inshore waters and on the shore can be a hazard to humans, to whom they can cause irritation and allaergic reactions, and to marine life, as they use up the available oxygen and can cause mortality to fishes and invertebrates. The reasons for the increase in algal blooms are unclear, but are believed to include relatively nutrient content in marine waters off the coast of Townsville, and increasing sea surface temperatures.

The TOT development has a high potential for algal blooms to develop, if not adequately flushed. The development of plumes is almost certain to occur in the high temperature, low tidal amplitude (eg: neap tides) months. If this occurs, it can lead to highly unpleasant and / or toxic conditions which will significantly impact on marine life within the development waters, and on human wellbeing among the development's inhabitants. The management plan and monitoring programme must make provisions for the prevention of algal blooms, particularly by ensuring that adequate flushing and regular annual maintenance dredging occurs..

5.7 RISK ASSESSMENT

5.7.1 Extreme Risk

Impacts that pose an extreme risk are those that are almost certain or highly likely to occur, and have major to catastrophic consequences if they do occur. For example, in Cleveland Bay this includes impacts that cause widespread damage to or destruction of habitats such as seagrasses and coral reefs, or injury or death to a whale or dolphin. Impacts are also classed as being of extreme risk if they lead to national media attention, community dissatisfaction and political consequences. The only catastrophic (extreme risk) impact that can occur in the Development is the total degradation of water and sediment quality due to inadequate flushing and dredging. If flushing and annual maintenance dredging occurs, then the chances of a catastrophic event will be minimized. Additionally, the likelihood and consequences of most other environmental impacts are minimized if water and sediment quality are maintained.

In this risk assessment, sand extraction from the Ross River mouth, activities causing noise pollution and the increased potential for boat strikes are classed as extreme risk activities. Sand extraction from the Ross River mouth is likely to destabilise the marine sediments west of Cape Cleveland, due to the prevailing sediment transport mechanisms in the Bay; causing the loss of the most extensive and diverse seagrass beds in Cleveland

Bay. Noise pollution is a highly likely consequence of construction and operation activities of this Development, and can cause injury to dolphins and whales. It will therefore be imperative to explore and implement noise reduction strategies before initiating the construction phase. The Development is also certain to cause an increase in boat traffic, increasing the vulnerability of marine mammals and reptiles that frequent the shallow waters of the Bay to boat strikes. Death and injury of marine mammals and reptiles already attract media attention, and may cause significant controversy if linked to the operation of the Development.

5.7.2 High Risk

High risk activities are those that have impacts of moderate to catastrophic consequences, depending on the likelihood of their occurrence. An impact with minor or moderate consequences can be classed as high risk if it is almost certain to occur. Conversely, an impact with major or catastrophic consequences will be classed as high risk even if it is only moderately likely or even unlikely to occur. Moderate consequences include localised habitat damage, species reduction and ecological community deterioration, and also include the disturbance to a key value of a Commonwealth Reserve (in this case, the Great Barrier Reef Marine Park).

High risk activities in Cleveland Bay are those that adversely affect water quality through increased turbidity, causing light attenuation and sediment deposition to seagrasses and corals. These are the primary impacts leading to the loss of seagrasses and reef-building corals, and because these are key habitats that make a major contribution to the ecological values of Cleveland Bay, their loss is considered a major consequence. Further high risk activities are those that can lead to contamination of seagrasses, corals, benthic communities and water quality from oil, chemical or sewerage spills. The consequences of a spill would be major (eg: off-site effects, significant deterioration of an ecological community), and should therefore be treated as high risk even though the likelihood is only moderate.

5.7.3 Medium Risk

Medium risk activities can occur along a decreasing gradient of likelihood, with a corresponding increasing gradient of consequence. For example, a medium risk activity may almost certainly have an impact with insignificant consequences, or a moderately likely impact of moderate consequences, or an impact of catastrophic consequences that is very unlikely to occur.

Medium risk activities in Cleveland Bay are those that will elevate nutrient contents in water and sediments, endangering seagrasses and corals through the increased growth and shading by macroalgae, and through an increase in contaminants in the sediments and water, which will affect all sessile (attached or non-mobile) organisms. Despite the unlikely even that this might occur, nutrient levels must be monitored and managed, because the impacts of macroalgal overgrowth would have major consequences, and macroalgal blooms would almost certainly attract negative media attention.

5.7.4 Low Risk

Low risk activities are those that are likely to moderately likely to cause adverse impacts with minor or insignificant consequences, or unlikely to very unlikely activities with moderate to major impacts. Minor consequences are those that lead to minor and localised reductions in ecological communities or species, have only on-site effects, and lead to some community dissatisfaction without media attention.

Sediment quality data suggests that there is a low risk of damage to seagrasses and benthic communities through contaminated sediments. The potential burial of benthic organisms through sediment deposition is also considered low risk, because although it is moderately likely to occur, most benthic organisms have the ability to dig through accumulated sediments if necessary.

5.7.5 Minimal Risk

Impacts that are classed as carrying minimal risk are those that are unlikely or very unlikely, and have minor or insignificant consequences. In Cleveland Bay, the only impact falling into this category is the risk of macroalgal overgrowth of benthic organisms as a result of increased nutrients in the water column. It is unlikely that nutrient increases will cause macroalgal blooms in areas of high benthic diversity, because the sediments are too fine for macroalgae to attach.

Table 7. Risk assessment for each type of impact from the Development on Cleveland Bay habitats and species. The degradation of water and sediment quality is considered a threat to almost all key values (see also Nature Conservation Baseline Study).

Habitat/Species	Threat	Likelihood	Consequence	= Risk
Seagrass Beds	Sediment destabilisation through changes in sediment transport regime (eg: sediment removal from adjacent areas)	Likely	Minor, dependent on area/size of disturbance	Medium (eg: World Heritage Values; Dugong Protected Area)
	Decreased Light attenuation through, for example, increased turbidity associated with dredging activities)	Moderately Likely	Minor to Major dependent on area, magnitude and nature of disturbance	Low to High
	Nutrient enrichment leading to increased macroalgal growth (eg: effluent discharge)	Unlikely	Minor to Major dependent on magnitude of input	Minimal to Medium

	Contamination from spill (oil, chemicals)	Moderately likely	Minor to major dependent on nature of contaminant and magnitude of spill.	Minimal to catastrophic dependent on nature of contaminant.
	Contamination from disturbed contaminated sediments	Unlikely to likely dependent on areas of disturbance	Minor to major dependent on area disturbed	Minimal to Medium dependent on area of disturbance and known sediment composition
	Noise pollution (impact on organisms relying on seagrass beds)	Almost certain	Moderate to Major (dependent on distance of organisms from noise source, volume and frequency of noise)	Moderate to Extreme (dependent on species, volume and frequency of the soundwaves)
Coral Reefs	Light attenuation through turbidity	Moderately Likely	Major	High
	Sediment deposition	Moderately Likely	Major	High
	Nutrient enrichment leading to increased macroalgal growth	Unlikely	Major	Medium
	Contamination and mortality from spill (oil, chemicals)	Moderately likely	Major	High
	Contamination from disturbed contaminated sediments	Unlikely	Major	Medium
Benthic Communities	Sediment deposition / burial	Moderately Likely	Minor	Low
	Nutrient enrichment leading to increased macroalgal growth	Unlikely	Minor	Minimal
	Contamination and mortality from spill (oil, chemicals)	Moderately likely	Moderate	Medium
	Contamination from disturbed contaminated sediments	Unlikely	Moderate	Low
	Reduction in predator populations	Unlikely	Moderate	Low
Fishes	Effects of reduction in water quality	Moderately Likely	Moderate	Medium

	Impacts on food resources (eg: benthic communities)	Moderately Likely	Major	High
	Contamination and mortality from spill (oil, chemicals)	Moderately Likely	Major	High
	Noise pollution (impact on organisms relying on seagrass beds)	Almost certain	Minor	High
	Disturbance to breeding and nursery habitats	Likely	Moderate	High
	Increased fishing pressure (operation phase)	Likely	Moderate	
Marine Mammals and Reptiles	Effects of reduction in water quality	Moderately Likely	Moderate	Medium
	Impacts on food resources (eg: seagrass beds)	Moderately Likely	Major	High
	Contamination and mortality from spill (oil, chemicals)	Moderately Likely	Major	High
	Noise pollution	Almost certain	Major	Extreme
	Contamination / reduction in breeding and nursery habitats	Moderately Likely	Major	High
	Increased boat strikes (operation phase)	Likely	Major	Extreme

6 IMPACT REDUCTIONS AND REMEDIATION STRATEGIES

6.1 AIMS AND OBJECTIVES

This baseline study, data evaluation and subsequent risk assessment have established that high ecological values exist in certain parts of the Cleveland Bay system. These areas contain a number of sensitive habitats and dependent species. Many of these areas are under pressure, probably due to their proximity to the coast and the increasing urbanisation and development of the adjacent hinterland. Given current development paradigms, these pressures are likely to increase. The proximity of the Bay to Townsville adds to the value of this ecosystem, due to the ease of access and use for recreation, scientific research and education. However, the ease of access to this resource simultaneously adds to its vulnerability to anthropogenic causes. Consequently, new developments in this area must carefully consider the values of Cleveland Bay, and all possible measures taken not to detract from the quality of this resource. It is the ecological value of this resource that gives the proposed development its economic value. Thus, in order to preserve these values, the overall aims and objectives of the Impact Reduction and Remediation Strategies are to -

- Prevent significant damage to species and ecosystems in Cleveland Bay, consistent with the current biodiversity of the area;
- Mitigate significant impacts of the proposed development activities; and
- Should significant impacts occur, undertake appropriate amelioration and remediation measures as necessary. This may include the cessation of development activities until the impact risk has been fully assessed and appropriate amelioration measures implemented.
- Where appropriate, opportunities should be taken to remedy past negative environmental impacts.

6.2 SPECIFIC PREVENTION, MONITORING AND REMEDIATION OPTIONS

6.2.1 Water Quality:

6.2.1.1 INTRODUCTION

Good water quality is the life support system of all marine environments, and much recent research and management strategies have focused on the measurement and management of water quality. This is especially important in shallow coastal environments such as Cleveland Bay, where the water quality is affected by input from rivers and creeks, coastal erosion and runoff, shipping and Port activities and runoff from the city of Townsville. Any new development must therefore take into consideration the cumulative effects of its expected impacts on water quality (eg: pollution, increased turbidity and sediment load) together with existing pressures. Any exceedance of the trigger levels set by this Baseline Study must be met with immediate cessation of development activities and the implementation of remediation measures.

6.2.1.2 *PREVENTION OF IMPACTS*

Preventing water quality decline will require:

- Ensuring adequate flushing and maintenance dredging occurs;
- Ensuring water quality is maintained by continuous data loggers;
- The prevention of sediment plumes from dredging, by using silt curtains and regulating the timing of dredging activities (see prevention section for Seagrass Beds), and by avoiding the dredging of contaminated sediments;
- The disposal of all dredge spoil to designated terrestrial areas;
- The prevention and containment of accidental spills;
- The setting of conservative water quality investigation and intervention levels to determine when dredging, and all other activities, must cease;
- Initiating a policy of no off-site movement of chemicals, building materials, sewerage, ballast water, etc.; and
- Implementing strictly enforced gardening and household product guidelines for residents of the completed development.

6.2.1.3 *MONITORING OF IMPACTS*

Precise monitoring strategies need to be devised to meet specific investigation and intervention criteria. Generally, water quality must be monitored on an event basis during dredging and other potentially detrimental construction activities. Permanent data loggers placed in strategic positions will provide the most effective means to monitor turbidity. Water quality trigger levels set in this Baseline Study are locally relevant guidelines which must be adhered to; ie: all development activities must cease if trigger levels are exceeded. The monitoring of water quality should take place:

- At predetermined impact and control sites, including those established by this Baseline Study and additional sites if considered necessary; and
- At the top and bottom of the water column.

Note:
Detailed monitoring strategies require acceptance of a specific set of target values and input from -
(a) the Flushing Study,
(b) the Hydrodynamic Study, and
(c) the Stormwater Study
These will be developed upon agreement to comply with the Investigation and Intervention Levels set out in Appendix 1B and in Tables within Section 4.6.

6.2.1.4 *REMEDIATION OF IMPACTS*

If water quality Investigation Levels are reached, further assessment must be immediately undertaken. If Intervention levels are reached, immediate action must be undertaken to assess the source of the contaminant. If necessary, all development activities must cease and reactive monitoring must be initiated.

Remediation of negative impacts on water quality is usually extremely difficult to achieve. Consequently, any negative impacts should be assessed on a case by case basis by appropriately qualified scientists and engineers.

6.2.1.5 SUMMARY

Water quality is one of the most important life-sustaining elements in the marine environment, and is relevant to all species and communities present in Cleveland Bay. The potential for this development to cause water quality decline is of major concern, due to the shallow nature of the Bay and its proximity to a large number of other environmental stresses. Modelling indicates that flushing, coupled with annual maintenance dredging, will ensure water quality is better than the Investigation Levels. However, due to the critical importance of water quality, the development must adopt a policy of 'no tolerance' to water quality decline, both during the construction stage, when dredging is of major concern, and during the operation phase, when maintenance dredging, increased shipping, visitation and pressure from additional human residential areas are likely to affect water quality. The following measures must be taken into account:

- Silt curtains must be employed, and tidal, current and wind considerations must be followed during dredging and other turbidity-causing construction activities;
- No dredge spoil is to be dumped at sea. All material is suitable for land disposal,
- Water quality must be monitored at time intervals appropriate to the nature and extent of detrimental activities being conducted; and
- Consideration of measures to protect water quality must extend into the operation phase of the development by ensuring adequate monitoring.

6.2.2 Sediment Quality:

6.2.2.1 INTRODUCTION

Sediments form the foundation and primary habitat of healthy seagrass beds, benthic communities and intertidal communities. Given the very fine nature of Cleveland Bay sediments, they are easily resuspended through current and wave action, and can either be transported and deposited onto benthic and intertidal communities or influence pelagic organisms in the water column. Both as habitat and as a potential stress factor (eg: for seagrasses and corals), it is important that sediment remain as uncontaminated as possible. The developments must not disturb sediments in areas of significant seagrass growth, and it must not disturb contaminated sediments. Prevention and remediation activities should focus on safeguarding sediments from contamination, and must also identify areas from which sediment removal is likely to be detrimental.

Indications from modeling show that sediment quality, providing annual maintenance dredging occurs, is unlikely to be of concern.

6.2.2.2 PREVENTION OF IMPACTS

The prevention of a decline in sediment quality must focus primarily on avoiding the disturbance of contaminated sediments (and thus the spread of contamination) and avoiding the introduction of contaminants to sediments. Specifically, prevention mechanisms include:

- The production of maps detailing the exact location and extent of areas to be dredged, and to be disturbed during other construction works. This is a requirement for spoil disposal, whether to land or sea.
- Extensive sediment sampling should occur in a manner that adequately covers the areas subject to dredging and construction works;
- Silt curtains should be used during all dredging;

- Dredging should not occur during times of strong wind-driven currents in the direction of seagrass beds and coral reefs;
- Refueling should occur well away from sensitive environments and must be controlled by strict contingency plans; and
- Chemicals that will be detrimental to the environment should be contained, each used and handled according to its MSDS, and appropriate training of all staff must be undertaken before the initiation of construction works.

6.2.2.3 Monitoring of Impacts

The monitoring of sediment quality will take place at designated impact and control sites.

Note:
Detailed monitoring strategies for sediment quality require acceptance of a specific set of target values and will be developed upon agreement to comply with the Investigation and Intervention Levels set out in Section 4.8 and Appendix 1B. The monitoring strategy developed must also consider inputs from:
(a) the Flushing Study,
(b) the Hydrodynamic Study, and
(c) the Stormwater Study

6.2.2.4 Remediation of Impacts

If sediment quality Investigation Levels are reached, further assessment must be immediately undertaken. If Intervention levels are reached, immediate action must be undertaken to assess the source of the contaminant. If necessary, all development activities must cease and reactive monitoring must be initiated.

Remediation of negative impacts on sediment quality is usually extremely difficult to achieve, and removal to land may be the only alternative. Consequently, any negative impacts should be assessed on a case by case basis by appropriately qualified scientists and engineers.

6.2.2.5 Summary

Sediments act as sinks, storing contaminants within their structure predominantly by the process of adsorption. Contaminants (including nutrients) can subsequently be made available, either directly to the marine flora and fauna, or indirectly via the water column, by physical (agitation of the bottom sediments), chemical (pH changes) and biological processes. In coastal environments such as Cleveland Bay, sediment quality decline is of major concern due to the shallow nature of the Bay and proximity to a large number of anthropogenic and natural stress mechanisms. The development must therefore adopt a policy of 'no tolerance' to a decline in sediment quality. The following measures must be taken into account:

- Silt curtains must be employed, and tidal, current and wind direction and strength must be considered during dredging and other turbidity-causing construction activities;

- No dredge spoil is to be dumped at sea. All spoil is suitable for land disposal;
- Sediment quality must be monitored at time intervals appropriate to the nature and extent of detrimental activities being conducted; and
- Consideration of measures to protect water quality must extend into the operation phase of the development.

7 MONITORING PROGRAM

A comprehensive monitoring programme will be essential in protecting the ecology, water quality and sediment quality of Cleveland Bay from the impacts of the proposed Townsville Ocean Terminal. While it will be important to monitor the conditions of seagrass beds, coral reefs and intertidal and benthic communities, the 'early warning system' will be the regular sampling of water and sediment quality in the vicinity of the habitats most susceptible to damage. Rather than monitoring on a seasonal, regular, or calendar-drive basis, we propose the 'event sampling' method, as this is much more meaningful in the seasonally arid tropics. Monitoring all ecological and physical variables would therefore occur at the annual thermal maximum (January-February) and minimum (July-August), at the end of the wet season (eg: March) and after unusual climatic conditions or events (eg: intense rainfall events, extended periods of high turbidity, cyclones, etc.).

7.1 WATER AND SEDIMENT QUALITY

Water and sediment quality will be the first environmental components affected by the development, and any impact on them is almost certain to affect the flora and fauna of Cleveland Bay. Water quality in particular can be used as an 'early warning system' for the protection of marine communities. Different aspects of water quality are likely to affect sensitive communities, such as coral reefs and seagrass beds, at different rates. Turbidity may be the most critical component of water quality for the monitoring program, as the Bay is already highly turbid and even small increases in turbidity may prove detrimental. Turbidity must be monitored continuously (as well as directly after unusual climatic events), particularly during periods of dredging or other construction activity that are likely to increase turbidity. Deploying permanent turbidity, pH and salinity loggers is the most cost-effective way of achieving this. These should be deployed to monitor quality both within and surrounding the Development. A minimum of five should be deployed during construction and three during the operational phase of the project. Water and sediment sampling for other analytes / contaminants should occur quarterly at seagrass, coral reef and benthic sampling sites and should be incorporated into the monitoring strategy of the Port.

Monitoring should include:

- The deployment of permanent data loggers at seagrass and coral reef sites west of the development site, with additional sites placed within the expected dredge plume (obtained through hydrodynamic and dredge plume modelling);
- Event controlled turbidity monitoring at seagrass and coral reef control sites, and other sites closer to the development site but outside the expected dredge plume;
- Immediate cessation of dredging activities if turbidity exceeds 10% of ambient (control site) turbidity at sites downstream from the development site.
- Additional water quality monitoring should include:
  - Water quality samples collected at the annual thermal maximum (January-February) and minimum (July-August), at the end of the wet season (eg: March) and after climatic events, at all seagrass and coral reef impact and control sites. This programme should be incorporated into the monitoring activities of the Port
  - Testing must include copper, lead, zinc, nickel, cobalt, manganese, chromium arsenic, cadmium and all nutrients. This assessment should be incorporated into the monitoring activities of the Port.

- Investigation and intervention levels proposed by this baseline study should be stringently followed.

Sediment quality monitoring should include:

- Sediment quality sampling in July / August, at the end of the wet season, and after climatic events at all seagrass and benthic impact and control sites;
- Testing for copper, lead, zinc, nickel, manganese, and arsenic;
- Investigation and intervention levels proposed by this baseline study to be adhered to.

8 RECOMMENDATIONS

The following recommendations represent a summary of the more specific recommendations presented in Section 9 above, and in other sections of this report. They are relevant to both the EIS and the ongoing monitoring of the environmental values of Cleveland Bay (see also Nature Conservation Baseline Study).

5. During all phases of this development, the highest priority must be placed on protecting water quality, sediment quality, seagrass beds and coral reefs. Cleveland Bay is of high ecological value to species and communities of commercial and conservation significance. Providing adequate flushing and annual maintenance dredging occurs, water and sediment quality will be maintained. The maintenance of current water and sediment quality is critical to the project, both during the construction and operational phases of the Development.

6. The full EIS and subsequent monitoring of Cleveland Bay ecosystems should follow the BACI design set out during this baseline study. Specific monitoring strategies described above should be initiated as soon as possible, so that sufficient data 'Before' the development activities begin is generated to represent the best possible scientific practice for such sampling designs.

7. A number of hydrodynamic and current models should be generated to assist the establishment of sampling sites, for a number of weather and climate patterns. We recommend models for the predominant weather patterns/wind direction and strength, for unusual weather conditions (eg: cyclones, floods, droughts), and for a number of predicted climate change scenarios (particularly sea level rise).

8. We recommend that the EIS discuss all the implications of the most recent climate change predictions. Climate change is highly likely to affect all aspect of the development, given its proximity to sea level susceptibility to sea level rise and extreme storm events.

9. We strongly advise establishing early and efficient communication lines between the developers, government and conservation agencies, scientists, managers and construction staff. This will allow the rapid transmission of information gathered by scientists to decision-makers. The provision should be made for regular briefings from scientists to decision-makers during all stages of the development.

10. Data collected during the EIS and monitoring programme will be important in linking climate, weather and physical / chemical conditions to ecological variables such as coral cover and health, seagrass density and benthic diversity. We suggest that the publication of these data be encouraged and facilitated. It has previously been shown that publication of studies conducted during an EIS process can be valuable information for the public, media and scientific community, and has the added benefit of encouraging and demonstrating that environmental best practice is maintained.

9 CONCLUSIONS

The marine environment in Cleveland Bay harbours a host of valuable and vulnerable ecological communities and species that are easily accessible to residents and visitors of Townsville and Magnetic Island. New developments must be assessed, not as discreet impacts, but together with the cumulative impacts of a large city and a busy port. It is believed that adequate prevention measures and monitoring will prevent impacts from this development from occurring. These prevention measures must include adequate flushing and annual maintenance dredging to ensure all current water and sediment qualities are maintained.

Adequate education and training of construction employees, future staff and residents is recommended during all stages of the Development, and education of visitors and residents will be necessary during the operation of the Townsville Ocean Terminal, the residential area and the marina. It is also recommended that special regulations and restrictions be put in place regarding marina, household and gardening activities as part of the Body Corporate by-laws to maintain the quality of the waters and to avoid pollution of adjacent marine habitats.

It is concluded that if adequate flushing occurs and annual maintenance dredging of the marina bottom sediments is carried out, then:

- Water quality will be better than the ANZECC 2000 95% Species Protection Guidelines, or within ambient ranges currently existing in the Bay close to the Development, or both. and
- Bottom sediment quality will be very similar to that already existing in the Bay, and will meet Queensland HIL-A Soil Guidelines. An implication of this level is that all sediment dredged from the marina must be disposed of to land.

If water and sediment quality are maintained at current conditions, then it is concluded that the project is viable. However, it is stressed that given the high environmental values of the corals, seagrass beds, and other flora and fauna of the Bay, maintenance of this water and sediment quality is vital to the sustainability of these ecosystems and the viability of the project. To this end, a stringent monitoring programme involving:

- Continuous water quality monitoring, quarterly, annual and event monitoring at designated locations, of corals, seagrasses, and their associated ecosystems,
- Quarterly, annual and event monitoring at the same designated locations, of sediments and waters for a comprehensive range of chemical species including heavy metals and nutrients.

If these qualities are maintained, then water and sediment quality concerns do not provide grounds for the Devekionment to be disallowed.

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APPENDIX 1A
WATER & SEDIMENT QUALITY- MEAN VALUES

OCEAN TERMINAL DESCRIPTIVE STATISTICS
ANALYTE MEAN FOR ALL SEDIMENTS

	N	Minimum	Maximum	Mean	Std. Deviation
pH	11	8.2	8.8	8.609	.1921
EC25	11	2170	5130	3680.91	917.327
MC	11	18.9	49.7	31.018	8.9706
Arsenic	11	7	12	8.73	1.679
Barium	11	8	20	9.45	3.588
Beryllium	11	.8	.8	.800	.0000
Cadmium	11	.8	.8	.800	.0000
Chromium	11	6	19	10.55	3.616
Cobalt	11	3	11	6.91	2.548
Copper	11	4	27	7.45	6.593
Lead	11	6	44	17.09	11.777
Manganese	11	261	629	439.00	103.337
Nickel	11	4	14	6.45	2.770
Vanadium	11	15	32	20.45	4.967
Zinc	11	17	75	30.73	17.205
Mercury	11	.08	.08	.0800	.00000
Ammonia	11	16	16	16.00	.000
Nitrite	11	.08	.70	.1364	.18694
Nitrate	11	.08	.80	.1527	.21490
Nitrite_Nitrite	11	.1	.8	.165	.2132
Organic_Nitrogen	11	230	4530	745.45	1259.765
Total_K_Nitrogen	11	230	4530	745.45	1259.765
Total_ Nitrogen	11	230	4530	745.45	1259.765
Total_Phosphorus	11	134	520	277.64	98.584
R_Phosphorus	11	.08	.26	.1200	.05916
Benzene	11	.16	.16	.1600	.00000
Toluene	11	.16	.16	.1600	.00000
Ethylbenzene	11	.16	.16	.1600	.00000
meta_ paraXylene	11	.16	.16	.1600	.00000
orthoXylene	11	.16	.16	.1600	.00000
C6_C9_Fraction	11	1.6	1.6	1.600	.0000
C10_C14 Fraction	11	40	40	40.00	.000
C15_C28_Fraction	11	80	80	80.00	.000
C29_C36_Fraction	11	80	80	80.00	.000
Dichloroethane_D4	11	82.7	104.0	94.645	6.0411
Toluene_D8	11	85.0	100.0	90.127	4.3028
4_Bromo	11	72.8	87.2	80.555	4.8397
Valid N (listwise)	11				

Ocean Terminal Descriptive Statistics
Analyte Means for all Surface Waters

	N	Minimum	Maximum	Mean	Std. Deviation
Mercury	11	.000080	.000080	.00008000	.000000000
Arsenic	11	1.2	2.8	1.891	.5467
Barium	11	6	9	6.55	.934
Beryllium	11	.8	.8	.800	.0000
Cadmium	11	.16	.40	.1818	.07236
Chromium	11	.4	1.8	.545	.4204
Cobalt	11	.2	3.8	.504	1.0941
Copper	11	1	2	1.07	.467
Lead	11	.6	20.6	7.582	6.6421
Manganese	11	7	15	9.54	2.464
Nickel	11	.4	1.2	.536	.2838
Vanadium	11	1.4	2.7	1.936	.3443
Zinc	11	4	7	4.27	.905
Ammonia	11	.030	.381	.08427	.111206
Nitrite	11	.008	.008	.00800	.000000
Nitrate	11	.008	.017	.00982	.003311
Nitrite_ Nitrate	11	.008	.017	.00982	.003311
Organic_Nitrogen	11	.4	.4	.400	.0000
Tot_K_ Nitrogen	11	.4	.7	.427	.0905
Tot_Nitrogen	11	.4	.7	.427	.0905
Tot_Phos	11	.04	19.80	7.7900	8.19722
React_P	11	.008	.008	.00800	.000000
Benzene	11	.8	.8	.800	.0000
Toluene	11	1.6	1.6	1.600	.0000
Ethylbenzene	11	1.6	1.6	1.600	.0000
meta_paraXylene	11	1.6	1.6	1.600	.0000
orthoXylene	11	1.6	1.6	1.600	.0000
C6C9Fraction	11	1.6	1.6	1.600	.0000
C10C14Fract	11	40	40	40.00	.000
C15C28Fract	11	.8	.8	.800	.0000
C29C36Fract	11	40	40	40.00	.000
1.2_DichloroethaneD4	11	96	119	113.83	6.404
TolueneD8	11	103	109	106.36	2.014
4Bromofluorobenzene	11	87.0	94.8	91.309	2.5030
Valid N (listwise)	11				

OCEAN TERMINAL DESCRIPTIVE STATISTICS
ANALYTE MEANS FOR ALL BOTTOM WATERS

	N	Minimum	Maximum	Mean	Std. Deviation
Mercury	11	.00008	.00008	.0000800	.00000000
Arsenic	11	1.4	1.8	1.627	.1272
Barium	11	6	9	6.64	.924
Beryllium	11	.8	.8	.800	.0000
Cadmium	11	.16	.16	.1600	.00000
Chromium	11	.4	.9	.445	.1508
Cobalt	11	.16	.40	.1818	.07236
Copper	11	.8	1.0	.818	.0603
Lead	11	.2	6.8	2.082	1.9954
Manganese	11	6.3	32.9	11.827	7.2093
Nickel	11	.4	.7	.427	.0905
Vanadium	11	1	3	1.97	.476
Zinc	11	4	4	4.00	.000
Ammonia	11	.02	.04	.0246	.00655
Nitrite	11	.008	.008	.00800	.000000
Nitrate	11	.008	.008	.00800	.000000
Nitrite_ Nitrate	11	.008	.008	.00800	.000000
Organic_Nitrogen	11	.4	.6	.418	.0603
Tot_K_ Nitrogen	11	.4	.6	.418	.0603
Tot_Nitrogen	11	.4	.6	.418	.0603
Tot_Phos	11	.0	13.2	3.321	5.6011
React_P	11	.008	.008	.00800	.000000
Benzene	11	.8	.8	.800	.0000
Toluene	11	1.6	1.6	1.600	.0000
Ethylbenzene	11	1.6	1.6	1.600	.0000
meta_paraXylene	11	1.6	1.6	1.600	.0000
orthoXylene	11	1.6	1.6	1.600	.0000
C6C9Fraction	11	2	40	5.09	11.578
C10C14Fract	11	.8	40.0	36.436	11.8192
C15C28Fract	11	1	40	4.36	11.819
C29C36Fract	11	40	118	47.09	23.518
1.2_DichloroethaneD4	11	92	118	111.35	8.499
TolueneD8	11	89.7	108.0	105.336	5.2900
4Bromofluorobenzene	10	89.7	95.7	91.810	1.8193
Valid N (listwise)	10				

OCEAN TERMINAL DESCRIPTIVE STATISTICS
ANALYTE MEANS FOR ALL SURFACE AND BOTTOM WATERS COMBINED

	N	Minimum	Maximum	Mean	Std. Deviation
Mercury	22	.000080	.000080	.00008000	.000000000
Arsenic	22	1.2	2.8	1.759	.4102
Barium	22	6	9	6.59	.908
Beryllium	22	.8	.8	.800	.0000
Cadmium	22	.16	.40	.1709	.05117
Chromium	22	.4	1.8	.495	.3124
Cobalt	22	.2	3.8	.343	.7744
Copper	22	1	2	.95	.350
Lead	22	.2	20.6	4.832	5.5522
Manganese	22	6	33	10.68	5.387
Nickel	22	.4	1.2	.482	.2130
Vanadium	22	1.4	3.2	1.955	.4056
Zinc	22	4	7	4.14	.640
Ammonia	22	.017	.381	.05445	.082709
Nitrite	22	.008	.008	.00800	.000000
Nitrate	22	.008	.017	.00891	.002467
Nitrite_ Nitrate	22	.008	.017	.00891	.002467
Organic_Nitrogen	22	.4	.6	.409	.0426
Tot_K_ Nitrogen	22	.4	.7	.423	.0752
Tot_Nitrogen	22	.4	.7	.423	.0752
Tot_Phos	22	.04	19.80	5.5555	7.22269
React_P	22	.008	.008	.00800	.000000
Benzene	22	.8	.8	.800	.0000
Toluene	22	1.6	1.6	1.600	.0000
Ethylbenzene	22	1.6	1.6	1.600	.0000
meta_paraXylene	22	1.6	1.6	1.600	.0000
orthoXylene	22	1.6	1.6	1.600	.0000
C6C9Fraction	22	1.6	40.0	3.345	8.1869
C10C14Fract	22	1	40	38.22	8.357
C15C28Fract	22	.8	40.0	2.582	8.3575
C29C36Fract	22	40	118	43.55	16.630
1.2_DichloroethaneD4	22	92	119	112.59	7.452
TolueneD8	22	90	109	105.85	3.941
4Bromofluorobenzene	21	87.0	95.7	91.548	2.1651
Valid N (listwise)	21				

OCEAN TERMINAL DESCRIPTIVE STATISTICS
SEDIMENT ANALYSIS – S1, S2, S3 & S4
- ANALYTE MEANS PROXIMAL TO AND WITHIN DEVELOPMENT

	N	Minimum	Maximum	Mean	Std. Deviation
pH	4	8.4	8.8	8.625	.1708
EC25	4	2170	5020	3297.50	1228.885
MC	4	23.8	49.7	31.225	12.4098
Arsenic	4	7	10	8.00	1.414
Barium	4	8	10	9.00	1.155
Beryllium	4	.8	.8	.800	.0000
Cadmium	4	.8	.8	.800	.0000
Chromium	4	8	19	11.50	5.196
Cobalt	4	5	8	6.25	1.500
Copper	4	6	27	11.75	10.210
Lead	4	19	44	28.75	11.177
Manganese	4	261	629	424.25	160.465
Nickel	4	5	14	7.75	4.272
Vanadium	4	17	32	21.50	7.141
Zinc	4	29	75	45.75	21.282
Mercury	4	.08	.08	.0800	.00000
Ammonia	4	16	16	16.00	.000
Nitrite	4	.08	.70	.2350	.31000
Nitrate	4	.08	.80	.2700	.35346
Nitrite_Nitrite	4	.1	.8	.300	.3367
Organic_Nitrogen	4	280	550	402.50	111.168
Total_K_Nitrogen	4	280	550	402.50	111.168
Total_ Nitrogen	4	280	550	402.50	111.168
Total_Phosphorus	4	220	279	253.75	24.798
R_Phosphorus	4	.11	.26	.1750	.06557
Benzene	4	.16	.16	.1600	.00000
Toluene	4	.16	.16	.1600	.00000
Ethylbenzene	4	.16	.16	.1600	.00000
meta_ paraXylene	4	.16	.16	.1600	.00000
orthoXylene	4	.16	.16	.1600	.00000
C6_C9_Fraction	4	1.6	1.6	1.600	.0000
C10_C14 Fraction	4	40	40	40.00	.000
C15_C28_Fraction	4	80	80	80.00	.000
C29_C36_Fraction	4	80	80	80.00	.000
Dichloroethane_D4	4	89.8	104.0	95.725	5.9573
Toluene_D8	4	85.0	91.0	88.075	2.6875
4_Bromo	4	72.8	83.8	77.150	4.8843
Valid N (listwise)	4				

Ocean Terminal Descriptive Statistics
Water Analysis – Surface- S1, S2, S3 & S4
- Analyte Means proximal to and within development

	N	Minimum	Maximum	Mean	Std. Deviation
Mercury	4	.00008	.00008	.0000800	.00000000
Arsenic	4	1.5	1.7	1.625	.0957
Barium	4	6	7	6.25	.500
Beryllium	4	.8	.8	.800	.0000
Cadmium	4	.16	.16	.1600	.00000
Chromium	4	.4	.4	.400	.0000
Cobalt	4	.16	.16	.1600	.00000
Copper	4	.8	.8	.800	.0000
Lead	4	.9	6.8	2.900	2.6994
Manganese	4	9.4	9.9	9.650	.2380
Nickel	4	.4	.4	.400	.0000
Vanadium	4	2	2	1.88	.275
Zinc	4	4	4	4.00	.000
Ammonia	4	.02	.03	.0250	.00141
Nitrite	4	.008	.008	.00800	.000000
Nitrate	4	.008	.008	.00800	.000000
Nitrite_ Nitrate	4	.008	.008	.00800	.000000
Organic_Nitrogen	4	.4	.6	.450	.1000
Tot_K_ Nitrogen	4	.4	.6	.450	.1000
Tot_Nitrogen	4	.4	.6	.450	.1000
Tot_Phos	4	.0	.5	.170	.2045
React_P	4	.008	.008	.00800	.000000
Benzene	4	.8	.8	.800	.0000
Toluene	4	1.6	1.6	1.600	.0000
Ethylbenzene	4	1.6	1.6	1.600	.0000
meta_paraXylene	4	1.6	1.6	1.600	.0000
orthoXylene	4	1.6	1.6	1.600	.0000
C6C9Fraction	4	2	2	1.60	.000
C10C14Fract	4	40.0	40.0	40.000	.0000
C15C28Fract	4	1	1	.80	.000
C29C36Fract	4	40	40	40.00	.000
1.2_DichloroethaneD4	4	92	117	105.95	11.714
TolueneD8	4	106.0	108.0	106.750	.9574
4Bromofluorobenzene	4	91.8	95.7	93.375	1.8062
Valid N (listwise)	4				

OCEAN TERMINAL - DESCRIPTIVE STATISTICS
WATER ANALYSIS – BOTTOM –S1, S2, S3 & S4
- ANALYTE MEANS PROXIMAL TO AND WITHIN DEVELOPMENT

	N	Minimum	Maximum	Mean	Std. Deviation
Mercury	4	.00008	.00008	.0000800	.00000000
Arsenic	4	1.5	1.7	1.625	.0957
Barium	4	6	7	6.25	.500
Beryllium	4	.8	.8	.800	.0000
Cadmium	4	.16	.16	.1600	.00000
Chromium	4	.4	.4	.400	.0000
Cobalt	4	.16	.16	.1600	.00000
Copper	4	.8	.8	.800	.0000
Lead	4	.9	6.8	2.900	2.6994
Manganese	4	9.4	9.9	9.650	.2380
Nickel	4	.4	.4	.400	.0000
Vanadium	4	2	2	1.88	.275
Zinc	4	4	4	4.00	.000
Ammonia	4	.02	.03	.0250	.00141
Nitrite	4	.008	.008	.00800	.000000
Nitrate	4	.008	.008	.00800	.000000
Nitrite_ Nitrate	4	.008	.008	.00800	.000000
Organic_Nitrogen	4	.4	.6	.450	.1000
Tot_K_ Nitrogen	4	.4	.6	.450	.1000
Tot_Nitrogen	4	.4	.6	.450	.1000
Tot_Phos	4	.0	.5	.170	.2045
React_P	4	.008	.008	.00800	.000000
Benzene	4	.8	.8	.800	.0000
Toluene	4	1.6	1.6	1.600	.0000
Ethylbenzene	4	1.6	1.6	1.600	.0000
meta_paraXylene	4	1.6	1.6	1.600	.0000
orthoXylene	4	1.6	1.6	1.600	.0000
C6C9Fraction	4	2	2	1.60	.000
C10C14Fract	4	40.0	40.0	40.000	.0000
C15C28Fract	4	1	1	.80	.000
C29C36Fract	4	40	40	40.00	.000
1.2_DichloroethaneD4	4	92	117	105.95	11.714
TolueneD8	4	106.0	108.0	106.750	.9574
4Bromofluorobenzene	4	91.8	95.7	93.375	1.8062
Valid N (listwise)	4				

OCEAN TERMINAL DESCRIPTIVE STATISTICS
WATER ANALYSIS – BOTTOM AND SURFACE - S1, S2, S3 & S4
- ANALYTE MEANS PROXIMAL TO AND WITHIN DEVELOPMENT

	N	Minimum	Maximum	Mean	Std. Deviation
Mercury	8	.000080	.000080	.00008000	.000000000
Arsenic	8	1.2	1.9	1.600	.2000
Barium	8	6	7	6.13	.354
Beryllium	8	.8	.8	.800	.0000
Cadmium	8	.16	.16	.1600	.00000
Chromium	8	.4	.4	.400	.0000
Cobalt	8	.2	.2	.160	.0000
Copper	8	1	2	.98	.420
Lead	8	.9	9.4	3.750	2.8919
Manganese	8	7	11	9.11	1.252
Nickel	8	.4	.4	.400	.0000
Vanadium	8	1.6	2.2	1.875	.2053
Zinc	8	4	4	4.00	.000
Ammonia	8	.024	.044	.03150	.008142
Nitrite	8	.008	.008	.00800	.000000
Nitrate	8	.008	.015	.00888	.002475
Nitrite_ Nitrate	8	.008	.015	.00888	.002475
Organic_Nitrogen	8	.4	.6	.425	.0707
Tot_K_ Nitrogen	8	.4	.6	.425	.0707
Tot_Nitrogen	8	.4	.6	.425	.0707
Tot_Phos	8	.04	19.80	6.4775	8.68921
React_P	8	.008	.008	.00800	.000000
Benzene	8	.8	.8	.800	.0000
Toluene	8	1.6	1.6	1.600	.0000
Ethylbenzene	8	1.6	1.6	1.600	.0000
meta_paraXylene	8	1.6	1.6	1.600	.0000
orthoXylene	8	1.6	1.6	1.600	.0000
C6C9Fraction	8	1.6	1.6	1.600	.0000
C10C14Fract	8	40	40	40.00	.000
C15C28Fract	8	.8	.8	.800	.0000
C29C36Fract	8	40	40	40.00	.000
1.2_DichloroethaneD4	8	92	118	108.36	10.406
TolueneD8	8	105	109	107.25	1.488
4Bromofluorobenzene	8	91.5	95.7	93.288	1.4808
Valid N (listwise)	8				

Ocean Terminal Descriptive Statistics
Sediment Analysis – S6, S7& S8
- Analyte Levels Removed from Development along Strand

	N	Minimum	Maximum	Mean	Std. Deviation
pH	3	8.7	8.8	8.733	.0577
EC25	3	3170	3640	3423.33	237.136
MC	3	18.9	32.2	25.900	6.6776
Arsenic	3	7	10	8.00	1.732
Barium	3	8	20	12.00	6.928
Beryllium	3	.8	.8	.800	.0000
Cadmium	3	.8	.8	.800	.0000
Chromium	3	6	9	8.00	1.732
Cobalt	3	3	6	5.00	1.732
Copper	3	4	6	5.00	1.000
Lead	3	10	21	14.33	5.859
Manganese	3	328	503	414.67	87.512
Nickel	3	4	5	4.67	.577
Vanadium	3	15	19	17.33	2.082
Zinc	3	19	34	25.00	7.937
Mercury	3	.08	.08	.0800	.00000
Ammonia	3	16	16	16.00	.000
Nitrite	3	.08	.08	.0800	.00000
Nitrate	3	.08	.08	.0800	.00000
Nitrite_Nitrite	3	.1	.1	.087	.0115
Organic_Nitrogen	3	230	4530	1676.67	2471.140
Total_K_Nitrogen	3	230	4530	1676.67	2471.140
Total_ Nitrogen	3	230	4530	1676.67	2471.140
Total_Phosphorus	3	134	520	292.67	201.954
R_Phosphorus	3	.08	.08	.0800	.00000
Benzene	3	.16	.16	.1600	.00000
Toluene	3	.16	.16	.1600	.00000
Ethylbenzene	3	.16	.16	.1600	.00000
meta_ paraXylene	3	.16	.16	.1600	.00000
orthoXylene	3	.16	.16	.1600	.00000
C6_C9_Fraction	3	1.6	1.6	1.600	.0000
C10_C14 Fraction	3	40	40	40.00	.000
C15_C28_Fraction	3	80	80	80.00	.000
C29_C36_Fraction	3	80	80	80.00	.000
Dichloroethane_D4	3	82.7	96.1	89.967	6.7715
Toluene_D8	3	85.1	93.5	89.133	4.2099
4_Bromo	3	84.3	85.7	84.767	.8083
Valid N (listwise)	3				

OCEAN TERMINAL DESCRIPTIVE STATISTICS
WATER ANALYSIS-SURFACE (S6, S7&S8)
- ANALYTE LEVELS REMOVED FROM DEVELOPMENT ALONG STRAND

	N	Minimum	Maximum	Mean	Std. Deviation
Mercury	3	.00008	.00008	.0000800	.00000000
Arsenic	3	1.6	1.7	1.633	.0577
Barium	3	6	7	6.67	.577
Beryllium	3	.8	.8	.800	.0000
Cadmium	3	.16	.16	.1600	.00000
Chromium	3	.4	.4	.400	.0000
Cobalt	3	.16	.16	.1600	.00000
Copper	3	.8	.8	.800	.0000
Lead	3	1.0	1.3	1.200	.1732
Manganese	3	7.6	10.9	9.800	1.9053
Nickel	3	.4	.4	.400	.0000
Vanadium	3	2	2	1.87	.231
Zinc	3	4	4	4.00	.000
Ammonia	3	.02	.02	.0193	.00115
Nitrite	3	.008	.008	.00800	.000000
Nitrate	3	.008	.008	.00800	.000000
Nitrite_ Nitrate	3	.008	.008	.00800	.000000
Organic_Nitrogen	3	.4	.4	.400	.0000
Tot_K_ Nitrogen	3	.4	.4	.400	.0000
Tot_Nitrogen	3	.4	.4	.400	.0000
Tot_Phos	3	9.3	13.2	11.897	2.2574
React_P	3	.008	.008	.00800	.000000
Benzene	3	.8	.8	.800	.0000
Toluene	3	1.6	1.6	1.600	.0000
Ethylbenzene	3	1.6	1.6	1.600	.0000
meta_paraXylene	3	1.6	1.6	1.600	.0000
orthoXylene	3	1.6	1.6	1.600	.0000
C6C9Fraction	3	2	40	14.40	22.170
C10C14Fract	3	.8	40.0	26.933	22.6321
C15C28Fract	3	1	40	13.87	22.632
C29C36Fract	3	40	118	66.00	45.033
1.2_DichloroethaneD4	3	106	118	113.67	6.658
TolueneD8	3	89.7	108.0	101.233	10.0381
4Bromofluorobenzene	2	89.7	90.1	89.900	.2828
Valid N (listwise)	2				

Ocean Terminal Descriptive Statistics
Water Analysis-Bottom (S6, S7&S8)
- Analyte Levels Removed from Development along Strand

	N	Minimum	Maximum	Mean	Std. Deviation
Mercury	3	.00008	.00008	.0000800	.00000000
Arsenic	3	1.6	1.7	1.633	.0577
Barium	3	6	7	6.67	.577
Beryllium	3	.8	.8	.800	.0000
Cadmium	3	.16	.16	.1600	.00000
Chromium	3	.4	.4	.400	.0000
Cobalt	3	.16	.16	.1600	.00000
Copper	3	.8	.8	.800	.0000
Lead	3	1.0	1.3	1.200	.1732
Manganese	3	7.6	10.9	9.800	1.9053
Nickel	3	.4	.4	.400	.0000
Vanadium	3	2	2	1.87	.231
Zinc	3	4	4	4.00	.000
Ammonia	3	.02	.02	.0193	.00115
Nitrite	3	.008	.008	.00800	.000000
Nitrate	3	.008	.008	.00800	.000000
Nitrite_ Nitrate	3	.008	.008	.00800	.000000
Organic_Nitrogen	3	.4	.4	.400	.0000
Tot_K_ Nitrogen	3	.4	.4	.400	.0000
Tot_Nitrogen	3	.4	.4	.400	.0000
Tot_Phos	3	9.3	13.2	11.897	2.2574
React_P	3	.008	.008	.00800	.000000
Benzene	3	.8	.8	.800	.0000
Toluene	3	1.6	1.6	1.600	.0000
Ethylbenzene	3	1.6	1.6	1.600	.0000
meta_paraXylene	3	1.6	1.6	1.600	.0000
orthoXylene	3	1.6	1.6	1.600	.0000
C6C9Fraction	3	2	40	14.40	22.170
C10C14Fract	3	.8	40.0	26.933	22.6321
C15C28Fract	3	1	40	13.87	22.632
C29C36Fract	3	40	118	66.00	45.033
1.2_DichloroethaneD4	3	106	118	113.67	6.658
TolueneD8	3	89.7	108.0	101.233	10.0381
4Bromofluorobenzene	2	89.7	90.1	89.900	.2828
Valid N (listwise)	2				

OCEAN TERMINAL DESCRIPTIVE STATISTICS
WATER ANALYSIS-BOTTOM & SURFACE (S6, S7&S8)
- ANALYTE LEVELS REMOVED FROM DEVELOPMENT ALONG STRAND

	N	Minimum	Maximum	Mean	Std. Deviation
Mercury	6	.000080	.000080	.00008000	.000000000
Arsenic	6	1.6	2.8	1.967	.4844
Barium	6	6	7	6.67	.516
Beryllium	6	.8	.8	.800	.0000
Cadmium	6	.16	.40	.2000	.09798
Chromium	6	.4	1.8	.633	.5715
Cobalt	6	.2	3.8	.767	1.4860
Copper	6	1	2	1.07	.468
Lead	6	1.0	20.6	8.800	9.0189
Manganese	6	7	11	9.07	1.645
Nickel	6	.4	1.2	.650	.3564
Vanadium	6	1.6	2.1	1.883	.2229
Zinc	6	4	7	4.50	1.225
Ammonia	6	.018	.034	.02600	.007403
Nitrite	6	.008	.008	.00800	.000000
Nitrate	6	.008	.017	.01017	.003710
Nitrite_ Nitrate	6	.008	.017	.01017	.003710
Organic_Nitrogen	6	.4	.4	.400	.0000
Tot_K_ Nitrogen	6	.4	.4	.400	.0000
Tot_Nitrogen	6	.4	.4	.400	.0000
Tot_Phos	6	.35	18.00	10.9733	5.92726
React_P	6	.008	.008	.00800	.000000
Benzene	6	.8	.8	.800	.0000
Toluene	6	1.6	1.6	1.600	.0000
Ethylbenzene	6	1.6	1.6	1.600	.0000
meta_paraXylene	6	1.6	1.6	1.600	.0000
orthoXylene	6	1.6	1.6	1.600	.0000
C6C9Fraction	6	1.6	40.0	8.000	15.6767
C10C14Fract	6	1	40	33.47	16.003
C15C28Fract	6	.8	40.0	7.333	16.0033
C29C36Fract	6	40	118	53.00	31.843
1.2_DichloroethaneD4	6	106	119	115.50	4.764
TolueneD8	6	90	108	103.78	7.003
4Bromofluorobenzene	5	88.9	90.8	89.800	.7071
Valid N (listwise)	5				

Ocean Terminal Descriptive Statistics
Sediment Analysis – (C1, C2 & C3)
- Analyte Level Control Sites

	N	Minimum	Maximum	Mean	Std. Deviation
pH	3	8.2	8.5	8.400	.1732
EC25	3	4210	5130	4570.00	491.528
MC	3	31.9	43.6	36.600	6.1798
Arsenic	3	9	12	10.33	1.528
Barium	3	8	8	8.00	.000
Beryllium	3	.8	.8	.800	.0000
Cadmium	3	.8	.8	.800	.0000
Chromium	3	9	14	12.00	2.646
Cobalt	3	5	11	8.67	3.215
Copper	3	4	6	5.33	1.155
Lead	3	7	10	8.00	1.732
Manganese	3	435	473	449.00	20.881
Nickel	3	5	8	6.67	1.528
Vanadium	3	19	26	23.00	3.606
Zinc	3	20	22	21.00	1.000
Mercury	3	.08	.08	.0800	.00000
Ammonia	3	16	16	16.00	.000
Nitrite	3	.08	.08	.0800	.00000
Nitrate	3	.08	.10	.0867	.01155
Nitrite_Nitrite	3	.1	.1	.087	.0115
Organic_Nitrogen	3	260	530	373.33	140.119
Total_K_Nitrogen	3	260	530	373.33	140.119
Total_ Nitrogen	3	260	530	373.33	140.119
Total_Phosphorus	3	272	374	307.33	57.770
R_Phosphorus	3	.08	.14	.1000	.03464
Benzene	3	.16	.16	.1600	.00000
Toluene	3	.16	.16	.1600	.00000
Ethylbenzene	3	.16	.16	.1600	.00000
meta_ paraXylene	3	.16	.16	.1600	.00000
orthoXylene	3	.16	.16	.1600	.00000
C6_C9_Fraction	3	1.6	1.6	1.600	.0000
C10_C14 Fraction	3	40	40	40.00	.000
C15_C28_Fraction	3	80	80	80.00	.000
C29_C36_Fraction	3	80	80	80.00	.000
Dichloroethane_D4	3	93.0	104.0	97.067	6.0343
Toluene_D8	3	88.4	100.0	92.933	6.2011
4_Bromo	3	77.4	87.2	80.800	5.5462
Valid N (listwise)	3				

OCEAN TERMINAL DESCRIPTIVE STATISTICS
WATER ANALYSIS – SURFACE (C1, C2 & C3)
- ANALYTE LEVEL CONTROL SITES

	N	Minimum	Maximum	Mean	Std. Deviation
Mercury	3	.00008	.00008	.0000800	.00000000
Arsenic	3	1.4	1.8	1.567	.2082
Barium	3	6	7	6.33	.577
Beryllium	3	.8	.8	.800	.0000
Cadmium	3	.16	.16	.1600	.00000
Chromium	3	.4	.4	.400	.0000
Cobalt	3	.16	.16	.1600	.00000
Copper	3	.8	.8	.800	.0000
Lead	3	.2	4.9	2.033	2.5146
Manganese	3	6.3	13.2	9.733	3.4501
Nickel	3	.4	.4	.400	.0000
Vanadium	3	1	2	1.80	.361
Zinc	3	4	4	4.00	.000
Ammonia	3	.02	.03	.0243	.00702
Nitrite	3	.008	.008	.00800	.000000
Nitrate	3	.008	.008	.00800	.000000
Nitrite_ Nitrate	3	.008	.008	.00800	.000000
Organic_Nitrogen	3	.4	.4	.400	.0000
Tot_K_ Nitrogen	3	.4	.4	.400	.0000
Tot_Nitrogen	3	.4	.4	.400	.0000
Tot_Phos	3	.0	.0	.040	.0000
React_P	3	.008	.008	.00800	.000000
Benzene	3	.8	.8	.800	.0000
Toluene	3	1.6	1.6	1.600	.0000
Ethylbenzene	3	1.6	1.6	1.600	.0000
meta_paraXylene	3	1.6	1.6	1.600	.0000
orthoXylene	3	1.6	1.6	1.600	.0000
C6C9Fraction	3	2	2	1.60	.000
C10C14Fract	3	40.0	40.0	40.000	.0000
C15C28Fract	3	1	1	.80	.000
C29C36Fract	3	40	40	40.00	.000
1.2_DichloroethaneD4	3	110	118	114.67	4.163
TolueneD8	3	105.0	108.0	106.667	1.5275
4Bromofluorobenzene	3	90.8	92.2	91.300	.7810
Valid N (listwise)	3				

OCEAN TERMINAL DESCRIPTIVE STATISTICS
WATER ANALYSIS – BOTTOM (C1, C2 & C3)
- ANALYTE LEVEL CONTROL SITES

	N	Minimum	Maximum	Mean	Std. Deviation
Mercury	3	.00008	.00008	.0000800	.00000000
Arsenic	3	1.4	1.8	1.567	.2082
Barium	3	6	7	6.33	.577
Beryllium	3	.8	.8	.800	.0000
Cadmium	3	.16	.16	.1600	.00000
Chromium	3	.4	.4	.400	.0000
Cobalt	3	.16	.16	.1600	.00000
Copper	3	.8	.8	.800	.0000
Lead	3	.2	4.9	2.033	2.5146
Manganese	3	6.3	13.2	9.733	3.4501
Nickel	3	.4	.4	.400	.0000
Vanadium	3	1	2	1.80	.361
Zinc	3	4	4	4.00	.000
Ammonia	3	.02	.03	.0243	.00702
Nitrite	3	.008	.008	.00800	.000000
Nitrate	3	.008	.008	.00800	.000000
Nitrite_ Nitrate	3	.008	.008	.00800	.000000
Organic_Nitrogen	3	.4	.4	.400	.0000
Tot_K_ Nitrogen	3	.4	.4	.400	.0000
Tot_Nitrogen	3	.4	.4	.400	.0000
Tot_Phos	3	.0	.0	.040	.0000
React_P	3	.008	.008	.00800	.000000
Benzene	3	.8	.8	.800	.0000
Toluene	3	1.6	1.6	1.600	.0000
Ethylbenzene	3	1.6	1.6	1.600	.0000
meta_paraXylene	3	1.6	1.6	1.600	.0000
orthoXylene	3	1.6	1.6	1.600	.0000
C6C9Fraction	3	2	2	1.60	.000
C10C14Fract	3	40.0	40.0	40.000	.0000
C15C28Fract	3	1	1	.80	.000
C29C36Fract	3	40	40	40.00	.000
1.2_DichloroethaneD4	3	110	118	114.67	4.163
TolueneD8	3	105.0	108.0	106.667	1.5275
4Bromofluorobenzene	3	90.8	92.2	91.300	.7810
Valid N (listwise)	3				

OCEAN TERMINAL DESCRIPTIVE STATISTICS
WATER ANALYSIS – BOTTOM AND SURFACE (C1, C2 & C3)
- ANALYTE LEVEL CONTROL SITES

	N	Minimum	Maximum	Mean	Std. Deviation
Mercury	6	.000080	.000080	.00008000	.000000000
Arsenic	6	1.3	2.7	1.817	.5419
Barium	6	6	7	6.33	.516
Beryllium	6	.8	.8	.800	.0000
Cadmium	6	.16	.16	.1600	.00000
Chromium	6	.4	.4	.400	.0000
Cobalt	6	.2	.2	.160	.0000
Copper	6	1	1	.80	.000
Lead	6	.2	7.8	2.850	2.9757
Manganese	6	6	13	9.93	2.532
Nickel	6	.4	.4	.400	.0000
Vanadium	6	1.4	2.2	1.800	.3406
Zinc	6	4	4	4.00	.000
Ammonia	6	.017	.381	.11683	.148500
Nitrite	6	.008	.008	.00800	.000000
Nitrate	6	.008	.008	.00800	.000000
Nitrite_ Nitrate	6	.008	.008	.00800	.000000
Organic_Nitrogen	6	.4	.4	.400	.0000
Tot_K_ Nitrogen	6	.4	.7	.450	.1225
Tot_Nitrogen	6	.4	.7	.450	.1225
Tot_Phos	6	.04	3.35	.7467	1.32851
React_P	6	.008	.008	.00800	.000000
Benzene	6	.8	.8	.800	.0000
Toluene	6	1.6	1.6	1.600	.0000
Ethylbenzene	6	1.6	1.6	1.600	.0000
meta_paraXylene	6	1.6	1.6	1.600	.0000
orthoXylene	6	1.6	1.6	1.600	.0000
C6C9Fraction	6	1.6	1.6	1.600	.0000
C10C14Fract	6	40	40	40.00	.000
C15C28Fract	6	.8	.8	.800	.0000
C29C36Fract	6	40	40	40.00	.000
1.2_DichloroethaneD4	6	110	119	114.67	3.559
TolueneD8	6	103	108	105.67	1.966
4Bromofluorobenzene	6	89.7	94.8	91.550	1.7785
Valid N (listwise)	6				

Ocean Terminal Descriptive Statistics
Sediment Analysis – C2, C3 & Sun
Analyte Levels Eastern Cleveland Bay

	N	Minimum	Maximum	Mean	Std. Deviation
pH	3	8.2	8.8	8.500	.3000
EC25	3	3320	5130	4220.00	905.041
MC	3	28.8	43.6	35.567	7.4809
Arsenic	3	9	12	10.33	1.528
Barium	3	8	8	8.00	.000
Beryllium	3	.8	.8	.800	.0000
Cadmium	3	.8	.8	.800	.0000
Chromium	3	10	14	12.33	2.082
Cobalt	3	10	11	10.33	.577
Copper	3	4	6	4.67	1.155
Lead	3	6	7	6.67	.577
Manganese	3	435	541	483.00	53.703
Nickel	3	6	8	7.00	1.000
Vanadium	3	18	26	22.67	4.163
Zinc	3	17	22	19.67	2.517
Mercury	3	.08	.08	.0800	.00000
Ammonia	3	16	16	16.00	.000
Nitrite	3	.08	.08	.0800	.00000
Nitrate	3	.08	.10	.0867	.01155
Nitrite_Nitrite	3	.1	.1	.087	.0115
Organic_Nitrogen	3	260	530	410.00	137.477
Total_K_Nitrogen	3	260	530	410.00	137.477
Total_ Nitrogen	3	260	530	410.00	137.477
Total_Phosphorus	3	239	374	296.33	69.759
R_Phosphorus	3	.08	.14	.1000	.03464
Benzene	3	.16	.16	.1600	.00000
Toluene	3	.16	.16	.1600	.00000
Ethylbenzene	3	.16	.16	.1600	.00000
meta_ paraXylene	3	.16	.16	.1600	.00000
orthoXylene	3	.16	.16	.1600	.00000
C6_C9_Fraction	3	1.6	1.6	1.600	.0000
C10_C14 Fraction	3	40	40	40.00	.000
C15_C28_Fraction	3	80	80	80.00	.000
C29_C36_Fraction	3	80	80	80.00	.000
Dichloroethane_D4	3	93.0	97.1	94.767	2.1079
Toluene_D8	3	88.4	92.9	90.567	2.2546
4_Bromo	3	77.4	80.8	78.667	1.8583
Valid N (listwise)	3				

OCEAN TERMINAL DESCRIPTIVE STATISTICS
WATER ANALYSIS – SURFACE (C2, C3 & SUN)
ANALYTE LEVELS EASTERN CLEVELAND BAY

	N	Minimum	Maximum	Mean	Std. Deviation
Mercury	3	.00008	.00008	.0000800	.00000000
Arsenic	3	1.5	1.8	1.700	.1732
Barium	3	6	9	7.33	1.528
Beryllium	3	.8	.8	.800	.0000
Cadmium	3	.16	.16	.1600	.00000
Chromium	3	.4	.9	.567	.2887
Cobalt	3	.16	.40	.2400	.13856
Copper	3	.8	1.0	.867	.1155
Lead	3	.2	4.9	2.233	2.4132
Manganese	3	9.7	32.9	18.600	12.5072
Nickel	3	.4	.7	.500	.1732
Vanadium	3	1	3	2.17	.929
Zinc	3	4	4	4.00	.000
Ammonia	3	.02	.04	.0273	.01168
Nitrite	3	.008	.008	.00800	.000000
Nitrate	3	.008	.008	.00800	.000000
Nitrite_ Nitrate	3	.008	.008	.00800	.000000
Organic_Nitrogen	3	.4	.4	.400	.0000
Tot_K_ Nitrogen	3	.4	.4	.400	.0000
Tot_Nitrogen	3	.4	.4	.400	.0000
Tot_Phos	3	.0	.0	.040	.0000
React_P	3	.008	.008	.00800	.000000
Benzene	3	.8	.8	.800	.0000
Toluene	3	1.6	1.6	1.600	.0000
Ethylbenzene	3	1.6	1.6	1.600	.0000
meta_paraXylene	3	1.6	1.6	1.600	.0000
orthoXylene	3	1.6	1.6	1.600	.0000
C6C9Fraction	3	2	2	1.60	.000
C10C14Fract	3	40.0	40.0	40.000	.0000
C15C28Fract	3	1	1	.80	.000
C29C36Fract	3	40	40	40.00	.000
1.2_DichloroethaneD4	3	116	118	116.67	1.155
TolueneD8	3	107.0	108.0	107.667	.5774
4Bromofluorobenzene	3	90.8	90.9	90.867	.0577
Valid N (listwise)	3				

OCEAN TERMINAL DESCRIPTIVE STATISTICS
WATER ANALYSIS – BOTTOM (C2, C3 & SUN)
ANALYTE LEVELS EASTERN CLEVELAND BAY

	N	Minimum	Maximum	Mean	Std. Deviation
Mercury	3	.00008	.00008	.0000800	.00000000
Arsenic	3	1.5	1.8	1.700	.1732
Barium	3	6	9	7.33	1.528
Beryllium	3	.8	.8	.800	.0000
Cadmium	3	.16	.16	.1600	.00000
Chromium	3	.4	.9	.567	.2887
Cobalt	3	.16	.40	.2400	.13856
Copper	3	.8	1.0	.867	.1155
Lead	3	.2	4.9	2.233	2.4132
Manganese	3	9.7	32.9	18.600	12.5072
Nickel	3	.4	.7	.500	.1732
Vanadium	3	1	3	2.17	.929
Zinc	3	4	4	4.00	.000
Ammonia	3	.02	.04	.0273	.01168
Nitrite	3	.008	.008	.00800	.000000
Nitrate	3	.008	.008	.00800	.000000
Nitrite_ Nitrate	3	.008	.008	.00800	.000000
Organic_Nitrogen	3	.4	.4	.400	.0000
Tot_K_ Nitrogen	3	.4	.4	.400	.0000
Tot_Nitrogen	3	.4	.4	.400	.0000
Tot_Phos	3	.0	.0	.040	.0000
React_P	3	.008	.008	.00800	.000000
Benzene	3	.8	.8	.800	.0000
Toluene	3	1.6	1.6	1.600	.0000
Ethylbenzene	3	1.6	1.6	1.600	.0000
meta_paraXylene	3	1.6	1.6	1.600	.0000
orthoXylene	3	1.6	1.6	1.600	.0000
C6C9Fraction	3	2	2	1.60	.000
C10C14Fract	3	40.0	40.0	40.000	.0000
C15C28Fract	3	1	1	.80	.000
C29C36Fract	3	40	40	40.00	.000
1.2_DichloroethaneD4	3	116	118	116.67	1.155
TolueneD8	3	107.0	108.0	107.667	.5774
4Bromofluorobenzene	3	90.8	90.9	90.867	.0577
Valid N (listwise)	3				

OCEAN TERMINAL DESCRIPTIVE STATISTICS
WATER ANALYSIS – BOTTOM AND SURFACE (C2, C3 & SUN)
ANALYTE LEVELS EASTERN CLEVELAND BAY

	N	Minimum	Maximum	Mean	Std. Deviation
Mercury	6	.000080	.000080	.00008000	.000000000
Arsenic	6	1.3	2.7	1.750	.5089
Barium	6	6	9	7.17	1.472
Beryllium	6	.8	.8	.800	.0000
Cadmium	6	.16	.16	.1600	.00000
Chromium	6	.4	.9	.517	.2041
Cobalt	6	.2	.4	.223	.1031
Copper	6	1	1	.83	.082
Lead	6	.2	7.8	3.317	2.9949
Manganese	6	8	33	14.88	9.191
Nickel	6	.4	.7	.450	.1225
Vanadium	6	1.4	3.2	2.067	.7312
Zinc	6	4	4	4.00	.000
Ammonia	6	.017	.381	.09167	.142199
Nitrite	6	.008	.008	.00800	.000000
Nitrate	6	.008	.008	.00800	.000000
Nitrite_ Nitrate	6	.008	.008	.00800	.000000
Organic_Nitrogen	6	.4	.4	.400	.0000
Tot_K_ Nitrogen	6	.4	.7	.450	.1225
Tot_Nitrogen	6	.4	.7	.450	.1225
Tot_Phos	6	.04	.97	.1950	.37967
React_P	6	.008	.008	.00800	.000000
Benzene	6	.8	.8	.800	.0000
Toluene	6	1.6	1.6	1.600	.0000
Ethylbenzene	6	1.6	1.6	1.600	.0000
meta_paraXylene	6	1.6	1.6	1.600	.0000
orthoXylene	6	1.6	1.6	1.600	.0000
C6C9Fraction	6	1.6	1.6	1.600	.0000
C10C14Fract	6	40	40	40.00	.000
C15C28Fract	6	.8	.8	.800	.0000
C29C36Fract	6	40	40	40.00	.000
1.2_DichloroethaneD4	6	113	119	115.83	2.483
TolueneD8	6	103	108	106.50	1.871
4Bromofluorobenzene	6	87.0	94.8	90.883	2.4669
Valid N (listwise)	6				

APPENDIX 1B – WATER AND SEDIMENT QUALITY

Sediment quality guidelines for specific analytes.

ANALYTE	Guideline	Guideline Level
Arsenic (As)	TPA Background	12 mg/kg
	TPA Screening	24 mg/kg
	ISQG – Low	20 mg/kg
	ISQG – High	70 mg/kg
	Doherty	Not determined
	This study: Control + Sun Metal sample range Sample Zone S6 – S8 range “Project Site”, S1 Sample Zone S2 – S4	 9 – 12 mg/kg 7 – 10 mg/kg 10 mg/kg 7 – 8 mg/kg
	Ocean Terminal Recommended Investigation Level:	12 mg/kg
	Ocean Terminal Recommended Intervention Level:	24 mg/kg
Barium (Ba)	TPA Background	10 mg/kg
	TPA Screening	20 mg/kg
	This study: Control + Sun Metal sample range Sample Zone S6 – S8 range “Project Site”, S1 Sample Zone S2 – S4	 <10 mg/kg <10 – 20 mg/kg 10 mg/kg <10 - 10 mg/kg
	Ocean Terminal Recommended Investigation Level:	10 mg/kg
	Ocean Terminal Recommended Intervention Level:	20 mg/kg
Beryllium (Be)	This study: Control + Sun Metal sample range Sample Zone S6 – S8 range “Project Site”, S1 Sample Zone S2 – S4	 <1 mg/kg <1 mg/kg <1 mg/kg <1 mg/kg
	[1]Ocean Terminal Recommended Investigation Level:	1 – 2 mg/kg
	[1]Ocean Terminal Recommended Intervention Level:	5 mg/kg
	These recommended values based on non-Australian, Marine Guidelines	
Cadmium (Cd)	TPA Background	<5 mg/kg (Below Detection Limits)

[1] These recommended values based on non-Australian, Marine Guidelines

ANALYTE	**Guideline**	**Guideline Level**
	TPA Screening	<5 mg/kg (Below Detection Limits)
	ISQG – Low	1.5 mg/kg
	ISQG – High	10 mg/kg
	Doherty	0 – 0.068 mg/kg Mean: 0.021 ± 0.016 mg/kg
	This study: Control + Sun Metal sample range Sample Zone S6 – S8 range “Project Site”, S1 Sample Zone S2 – S4	 <1 mg/kg <1 mg/kg <1 mg/kg <1 mg/kg
	Ocean Terminal Recommended Investigation Level:	1.5 mg/kg
	[2]Ocean Terminal Recommended Intervention Level:	5 mg/kg
Chromium (Cr)	TPA Background	15 mg/kg
	TPA Screening	30 mg/kg
	ISQG – Low	80 mg/kg
	ISQG – High	370 mg/kg
	Doherty	Not determined
	This study: Control + Sun Metal sample range Sample Zone S6 – S8 range “Project Site”, S1 Sample Zone S2 – S4	 9 – 14 mg/kg 6 – 9 mg/kg 19 mg/kg 8 – 11 mg/kg
	Ocean Terminal Recommended Investigation Level:	8 mg/kg
	Ocean Terminal Recommended Intervention Level:	30 mg/kg
Cobalt (Co)	TPA Background	8 mg/kg
	TPA Screening	15 mg/kg
	ISQG - Low	No Values
	ISQG - High	No values
	Doherty	Not determined
	This study: Control + Sun Metal sample range Sample Zone S6 – S8 range “Project Site”, S1 Sample Zone S2 – S4	 5 – 11 mg/kg 3 – 6 mg/kg 8 mg/kg 5 – 7 mg/kg
	Ocean Terminal Recommended Investigation Level:	8 mg/kg
	Ocean Terminal Recommended Intervention Level:	15 mg/kg
	TPA Background	7 mg/kg

[2] Intervention value based on non-Australian Guideline.

ANALYTE	**Guideline**	**Guideline Level**
	TPA Background	7 mg/kg
Copper ([2]Cu)	TPA Screening ISQG – Low	14 mg/kg 65 mg/kg
	ISQG – High	270 mg/kg
	Doherty (Cleveland Bay Range)	1 – 21 mg/kg
	Doherty (Cleveland Bay Mean)	6 ± 4 mg/kg
	This study: Control + Sun Metal sample range Sample Zone S6 – S8 range “Project Site”, S1 Sample Zone S2 – S4	 <5 – 6 mg/kg <5 – 6 mg/kg 27 mg/kg 6 – 8 mg/kg
	Ocean Terminal Recommended Investigation Level:	7 mg/kg
	Ocean Terminal Recommended Intervention Level:	14 mg/kg
Lead (Pb)	TPA Background	13 mg/kg
	TPA Screening	26 mg/kg
	ISQG – Low	50 mg/kg
	ISQG – High	220 mg/kg
	Doherty (Cleveland Bay Range)	3 – 19 mg/kg
	Doherty (Cleveland Bay Mean)	10 ± 4 mg/kg
	This study: Control + Sun Metal sample range Sample Zone S6 – S8 range “Project Site”, S1 Sample Zone S2 – S4	 6 – 10 mg/kg 10 – 21 mg/kg 44 mg/kg 19 – 32 mg/kg
	Ocean Terminal Recommended Investigation Level:	13 mg/kg
	Ocean Terminal Recommended Intervention Level:	26 mg/kg
Manganese (Mn)	TPA Background	475 mg/kg
	TPA Screening	950 mg/kg
	This study: Control + Sun Metal sample range Sample Zone S6 – S8 range “Project Site”, S1 Sample Zone S2 – S4	 435 - 541 mg/kg 328 - 503 mg/kg 629 mg/kg 261 – 466 mg/kg
	Ocean Terminal Recommended Investigation Level:	475 mg/kg
	Ocean Terminal Recommended Intervention Level:	950 mg/kg
	TPA Background	9 mg/kg
	TPA Screening	18 mg/kg
	ISQG – Low	21 mg/kg
	ISQG – High	52 mg/kg
	Doherty (Cleveland Bay Range)	1 – 24 mg/kg
	Doherty (Cleveland Bay Mean)	9 ± 5 mg/kg

ANALYTE	Guideline	Guideline Level
	This study: Control + Sun Metal sample range Sample Zone S6 – S8 range “Project Site”, S1 Sample Zone S2 – S4	 5 – 8 mg/kg 4 – 5 mg/kg 14 mg/kg 5 – 7 mg/kg
	Ocean Terminal Recommended Investigation Level:	9 mg/kg
	Ocean Terminal Recommended Intervention Level:	18 mg/kg
Vanadium (V)	This study: Control + Sun Metal sample range Sample Zone S6 – S8 range “Project Site”, S1 Sample Zone S2 – S4	 18 - 26 mg/kg 15 – 19 mg/kg 32 mg/kg 17 – 20 mg/kg
	[3]Ocean Terminal Recommended Investigation Level:	25 mg/kg
	[3]Ocean Terminal Recommended Intervention Level:	50 mg/kg
Zinc (Zi)	TPA Background	32 mg/kg
	TPA Screening	64 mg/kg
	ISQG – Low	200 mg/kg
	ISQG – High	410 mg/kg
	Doherty (Cleveland Bay Range)	6 – 67 mg/kg
	Doherty (Cleveland Bay Mean)	26 ± 14 mg/kg
	This study: Control + Sun Metal sample range Sample Zone S6 – S8 range “Project Site”, S1 Sample Zone S2 – S4	 17 – 22 mg/kg 19 - 34 mg/kg 75 mg/kg 29 – 48 mg/kg
	Ocean Terminal Recommended Investigation Level:	32 mg/kg
	Ocean Terminal Recommended Intervention Level:	64 mg/kg
Mercury (Hg)	TPA Background	Not determined
	TPA Screening	Not determined
	ISQG - Low	0.15 mg/kg
	ISQG - High	1 mg/kg
	Doherty	Not determined
	This study: Control + Sun Metal sample range Sample Zone S6 – S8 range “Project Site”, S1 Sample Zone S2 – S4	 <0.1 mg/kg <0.1 mg/kg <0.1 mg/kg <0.1 mg/kg
	Ocean Terminal Recommended Investigation Level:	0.15 mg/kg

[3] Levels based on non-Australian data, apparent effects threshold studies, Professional Judgement relating to local sediments and their sources.

ANALYTE	Guideline	Guideline Level
	Ocean Terminal Recommended Intervention Level:	0.5 mg/kg

NUTRIENT	Guideline	Value
Ammonia (NH_3) as N	This study:	
	Control + Sun Metal sample range	<20 mg/kg
	Sample Zone S6 – S8 range	<20 mg/kg
	"Project Site", S1	<20 mg/kg
	Sample Zone S2 – S4	<20 mg/kg
	Ocean Terminal Recommended Investigation Level:	<20 mg/kg
	Ocean Terminal Recommended Intervention Level:	<30 mg/kg
Nitrite (NO_2^-) as N	This study:	
	Control + Sun Metal sample range	<0.1 mg/kg
	Sample Zone S6 – S8 range	<0.1 mg/kg
	"Project Site", S1	<0.1 mg/kg
	Sample Zone S2 – S4	<0.1 – 0.1 mg/kg
	Ocean Terminal Recommended Investigation Level:	0.2 mg/kg
	Ocean Terminal Recommended Intervention Level:	1.0 mg/kg
Nitrate (NO_3^-) as N	This study:	
	Control + Sun Metal sample range	<0.1 – 0.1 mg/kg
	Sample Zone S6 – S8 range	<0.1 – 0.1 mg/kg
	"Project Site", S1	0.8 mg/kg
	Sample Zone S2 – S4	<0.1 – 0.1 mg/kg
	Ocean Terminal Recommended Investigation Level:	0.2 mg/kg
	Ocean Terminal Recommended Intervention Level:	1.0 mg/kg
Total Kjeldahl Nitrogen (TKN as N), Organic Nitrogen as N, (TKN – Ammonia), Total Nitrogen as N (TKN + NO_x)	This study:	
	Control + Sun Metal sample range	260 - 530 mg/kg
	Sample Zone S6 – S8 range	270 – 4530 mg/kg
	"Project Site", S1	390 mg/kg
	Sample Zone S2 – S4	280 – 660mg/kg
	Ocean Terminal Recommended Investigation Level:	600 mg/kg
	Ocean Terminal Recommended Intervention Level:	1200 mg/kg
Total Phosphorus as P	This study:	
	Control + Sun Metal sample range	239 - 374 mg/kg
	Sample Zone S6 – S8 range	134 – 520 mg/kg
	"Project Site", S1	279 mg/kg
	Sample Zone S2 – S4	220 – 262 mg/kg

Nutrient	**Guideline**	**Value**
	Ocean Terminal Recommended Investigation Level:	400 mg/kg
	Ocean Terminal Recommended Intervention Level:	800 mg/kg
Reactive Phosphorus as P (Dissolved	This study: Control + Sun Metal sample range Sample Zone S6 – S8 range "Project Site", S1 Sample Zone S2 – S4	<0.10 – 0.014 mg/kg <0.10 mg/kg <0.19 mg/kg <0.11 – 0.26 mg/kg
	Ocean Terminal Recommended Investigation Level:	0.15 mg/kg
	Ocean Terminal Recommended Intervention Level:	0.30 mg/kg

Water quality guidelines for specific analytes.

Analyte	**Guideline**	**Guideline Level**
Arsenic (As)	ANZECC (2000) – Marine	Insufficient Data
	ANZECC (2000) – Freshwater - 95% Protection Level - 80% Protection Level	24 μg/L 24 μg/L 360 μg/L
	ANZECC (1992) – Marine	36 – 50 μg/L
	USEPA / NOAA	
	This study Control + Sun Metal sample range - Surface - Bottom Sample Zone S6 – S8 range - Surface - Bottom "Project Site", S1 - Surface - Bottom Sample Zone S2 – S4 - Surface - Bottom	 1.3 – 2.7 μg/L 1.4 – 1.8 μg/L 1.8 – 2.8 μg/L 1.4 – 1.7 μg/L 1.9 μg/L 1.7 μg/L 1.2 – 1.6 μg/L 1.5 – 1.7 μg/L
	Ocean Terminal Recommended Investigation Level:	3.0 μg/L
	Ocean Terminal Recommended Intervention Level:	24 μg/L
Barium (Ba)	This study Control + Sun Metal sample range - Surface - Bottom	 6 – 9 μg/L 6 – 9 μg/L

ANALYTE	Guideline	Guideline Level
	Sample Zone S6 – S8 range - Surface - Bottom "Project Site", S1 - Surface - Bottom Sample Zone S2 – S4 - Surface - Bottom	 6 – 7 µg/L 6 – 7 µg/L 6 µg/L 6 µg/L 6 µg/L 6 – 7 µg/L
	Ocean Terminal Recommended Investigation Level:	10 µg/L
	Ocean Terminal Recommended Intervention Level:	20 µg/L
Beryllium (Be)	USEPA / NOAA	4
	This study Control + Sun Metal sample range - Surface - Bottom Sample Zone S6 – S8 range - Surface - Bottom "Project Site", S1 - Surface - Bottom Sample Zone S2 – S4 - Surface - Bottom	 <0.1 µg/L <0.1 µg/L <0.1 µg/L <0.1 µg/L <0.1 µg/L <0.1 µg/L <0.1 µg/L <0.1 µg/L
	Ocean Terminal Recommended Investigation Level:	<0.1 µg/L
	Ocean Terminal Recommended Intervention Level:	1 µg/L
Cadmium (Cd)	ANZECC (2000) – Marine - 95% Protection Level - 80% Protection Level	 5.5 µg/L 14 µg/L
	ANZECC (1992)	2 µg/L
	USEPA / NOAA	9.3 µg/L
	Local Data (1988)	0.07 µg/L
	This study Control + Sun Metal sample range - Surface - Bottom Sample Zone S6 – S8 range - Surface - Bottom "Project Site", S1 - Surface - Bottom Sample Zone S2 – S4 - Surface - Bottom	 <0.2 µg/L <0.2 µg/L <0.2 – 0.4 µg/L <0.2 µg/L <0.2 µg/L <0.2 µg/L <0.2 µg/L <0.2 µg/L
	Ocean Terminal Recommended Investigation Level: - Better thanANZECC, 2000 95% Species Protection Level	2.0 µg/L

ANALYTE	Guideline	Guideline Level
	Ocean Terminal Recommended Intervention Level:	5.5 µg/L
Chromium (Cr)	ANZECC (2000) – Marine - 95% Protection Level - 80% Protection Level	 27.4 µg/L 90.64 µg/L
	ANZECC (1992) – Total	50 µg/L
	This study Control + Sun Metal sample range - Surface - Bottom Sample Zone S6 – S8 range - Surface - Bottom “Project Site”, S1 - Surface - Bottom Sample Zone S2 – S4 - Surface - Bottom Ocean Terminal Recommended Investigation Level: - Better than ANZECC, 2000 95% Species Protection Level Ocean Terminal Recommended Intervention Level:	 <0.5 – 0.6 µg/L <0.5 – 0.9 µg/L <0.5 – 1.8 µg/L <0.5 µg/L <0.5 µg/L <0.5 µg/L <0.5 µg/L <0.5 µg/L 5.0 µg/L 27.4 µg/L
Cobalt (Co)	ANZECC (2000) – Marine - 95% Protection Level - 80% Protection Level	 1.0 µg/L 150 µg/L
	This study Control + Sun Metal sample range - Surface - Bottom Sample Zone S6 – S8 range - Surface - Bottom “Project Site”, S1 - Surface - Bottom Sample Zone S2 – S4 - Surface - Bottom	 <0.2 – 0.3 µg/L <0.2 – 0.4 µg/L <0.2 – 3.8 µg/L <0.2 µg/L <0.2 µg/L <0.2 µg/L <0.2 µg/L <0.2 µg/L
	Ocean Terminal Recommended Investigation Level:	3.8µg/L
	Ocean Terminal Recommended Intervention Level:	14.0 µg/L
Copper (Cu)	ANZECC (2000) – Marine - 95% Protection Level - 80% Protection Level	 1.3 8
	ANZECC (1992)	5
	USEPA / NOAA	2.9 – 4.8
	Local Data (1988)	0.27 – 0.49
	This study	

ANALYTE	Guideline	Guideline Level
	Control + Sun Metal sample range - Surface - Bottom Sample Zone S6 – S8 range - Surface - Bottom "Project Site", S1 - Surface - Bottom Sample Zone S2 – S4 - Surface - Bottom	 <1.0 <1.0 – 1.0 1.0 - 2.0 µg/L <1.0 µg/L 2.0 µg/L <1.0 µg/L <1.0 µg/L <1.0 µg/L
	Ocean Terminal Recommended Investigation Level:	3.0 µg/L
	Ocean Terminal Recommended Intervention Level:	3.0 µg/L
Lead (Pb)	ANZECC (2000) – Marine - 95% Protection Level - 80% Protection Level	 4.4 12.0
	ANZECC (1992)	5
	USEPA / NOAA	8.5
	Local Data (1988)	0.15
	This study Control + Sun Metal sample range - Surface - Bottom Sample Zone S6 – S8 range - Surface - Bottom "Project Site", S1 - Surface - Bottom Sample Zone S2 – S4 - Surface - Bottom	 0.6 – 7.8 0.2 – 4.9 10.2 – 20.6 0.8 – 1.3 9.4 6.8 2.7 – 3.0 0.9 - 2.6
	Note: Evidence of elevated lead levels already exists in the Bay, especially in surface waters in, and to the west of, the Project Site and towards Rowes Bay. Therefore, ANZECC (2000) levels are used for the recommended Investigation and Intervention Levels.	
	Ocean Terminal Recommended Investigation Level:	10.0
	Ocean Terminal Recommended Intervention Level:	20.0
Manganese (Mn)	ANZECC (2000) – only data	47 µg/L
	USEPA / NOAA	50g/L
	ANZECC (2000) – Freshwater data - 95% Protection Level - 80% Protection Level	 1900 3600
	This study	
	Control + Sun Metal sample range - Surface - Bottom	 8.1 – 15.2 µg/L 6.3 – 32.9 µg/L

ANALYTE	Guideline	Guideline Level
	Sample Zone S6 – S8 range - Surface - Bottom	 7.3 – 9.7 μg/L 7.6 – 10.9 μg/L
	"Project Site", S1 - Surface - Bottom	 8.8 μg/L 9.8 μg/L
	Sample Zone S2 – S4 - Surface - Bottom	 6.5 – 10.6 μg/L 9.4 – 9.9 μg/L
	Ocean Terminal Recommended Investigation Level	50 μg/L
	Ocean Terminal Recommended Intervention Level:	100 μg/L
Nickel (Ni)	ANZECC (2000) – - 95% Protection Level - 80% Protection Level	70 μg/L 550 μg/L
	ANZECC (1992)	1000 μg/L
	USEPA / NOAA	8.3 – 75 μg/L
	Local sources (1988)	0.13 μg/L
	This study: Control + Sun Metal sample range - Surface - Bottom Sample Zone S6 – S8 range - Surface - Bottom "Project Site", S1 - Surface - Bottom Sample Zone S2 – S4 - Surface - Bottom	 <0.5 – 1.2 μg/L <0.5 μg/L <0.5 μg/L <0.5 μg/L <0.5 μg/L <0.5 μg/L 6.5 – 10.6 μg/L 9.4 – 9.9 μg/L
	Ocean Terminal Recommended Investigation Level: - ANZECC (2000) 99% Protection Level	 7 μg/L
	Ocean Terminal Recommended Intervention Level:	70 μg/L
Vanadium (V)	ANZECC (2000): - 95% Protection Level - 80% Protection Level	150 μg/L 280 μg/L
	This study: Control + Sun Metal sample range - Surface - Bottom Sample Zone S6 – S8 range - Surface - Bottom "Project Site", S1 - Surface - Bottom Sample Zone S2 – S4 - Surface - Bottom	 1.4 – 2.7 μg/L 1.4 – 3.2 μg/L 1.6 – 2.1 μg/L 1.6 - 2.0 μg/L 1.8 μg/L 1.6 μg/L 1.7 – 2.0 μg/L 1.7 – 2.2 μg/L

ANALYTE	Guideline	Guideline Level
	Ocean Terminal Recommended Investigation Level: - ANZECC (2000) 99% Protection Level	3.2 µg/L
	Ocean Terminal Recommended Intervention Level:	50 µg/L
Zinc (Zi)	ANZECC (2000): - 95% Protection Level - 80% Protection Level	15 µg/L 43 µg/L
	ANZECC (1992)	50 µg/L
	USEPA / NOAA	81 – 95 µg/L
	Local sources (1988)	1 – 2.13 µg/L
	This study: Control + Sun Metal sample range - Surface - Bottom Sample Zone S6 – S8 range - Surface - Bottom “Project Site”, S1 - Surface - Bottom Sample Zone S2 – S4 - Surface - Bottom	 <5 µg/L <5 µg/L <5 - 7 µg/L <5 µg/L <5 µg/L <5 µg/L <5 µg/L <5 µg/L
	Ocean Terminal Recommended Investigation Level:	7 µg/L
	Ocean Terminal Recommended Intervention Level: - ANZECC (2000) 90% Protection Level	23 µg/ L

ANALYTE	Guidelines	Levels
C6 – C9 (Gasoline)	All levels	<20 µg/L
	Guideline Levels	100 µg/L
	Ocean Terminal Recommended Investigation Level:	20 µg/L
	Ocean Terminal Recommended Intervention Level:	100 µg/L
C10 – C14 (Kerosene)	All levels	50 µg/L
	Guideline Level	100 µg/L
	Ocean Terminal Recommended Investigation Level:	50 µg/L
	Ocean Terminal Recommended Intervention Level:	100 µg/L
C15 – C28 (Diesel)	All levels	100 µg/L
	Guideline Level	1000 µg/L
	Ocean Terminal Recommended Investigation Level:	100 µg/L

ANALYTE	**Guidelines**	**Levels**
	Ocean Terminal Recommended Intervention Level:	500 µg/L
C29 – C36 (Heavy Oils)	All levels	50 µg/L
	Guideline Level	100 µg/L
	Ocean Terminal Recommended Investigation Level:	100 µg/L
	Ocean Terminal Recommended Intervention Level:	500 µg/L
Benzene	All levels	<1.0 µg/L
	ANZECC (2000) Guideline levels ANZECC (2000) 95% Protection level)	700 µg/L
	Ocean Terminal Recommended Investigation Level:	100 µg/L
	Ocean Terminal Recommended Intervention Level: ANZECC (2000) 99% Protection level)	500 µg/L
Toluene	All levels	<2 µg/L
	ANZECC (2000) Guideline Levels	24 µg/L
	Ocean Terminal Recommended Investigation Level:	24 µg/L
	Ocean Terminal Recommended Intervention Level: ANZECC (1992) 95% Protection level)	300 µg/L
Ethyl benzene	All levels	<2 µg/L
	ANZECC (2000) Guideline Levels	2.4 µg/L
	Ocean Terminal Recommended Investigation Level:	2.4 µg/L
	Ocean Terminal Recommended Intervention Level: (ANZECC (1992)	140 µg/L
Meta & Para-Xylenes	All levels	<2 µg/L
	ANZECC (2000) Guideline Levels	200 µg/L
	Ocean Terminal Recommended Investigation Level:	3 µg/L
	Ocean Terminal Recommended Intervention Level:	200 µg/L
Ortho-xylene	All levels	<2 µg/L
	ANZECC (2000) Guideline Levels	200 µg/L
	Ocean Terminal Recommended Investigation Level:	3 µg/L
	Ocean Terminal Recommended Intervention Level:	200 µg/L

NUTRIENT	Guideline	Level
Ammonia as N	ANZECC (2000): - 95% Protection Level - 80% Protection Level ANZECC (2000) – Clear to turbid. Tropical Australia Estuary / Inshore Marine ANZECC (1999) - Estuaries / Coastal Marine Local Sources (1988) This study: Control + Sun Metal sample range - Surface - Bottom Sample Zone S6 – S8 range - Surface - Bottom "Project Site", S1 - Surface - Bottom Sample Zone S2 – S4 - Surface - Bottom Ocean Terminal Recommended Investigation Level: Ocean Terminal Recommended Intervention Level: - ANZECC (2000) 95% Protection Level	 910 1700 1 – 15 20 – 40 12 38 – 381 17 – 40 31 – 34 18 – 28 42 25 30 – 44 24 – 27 60 550
Nitrite (NO_2^-) as N	No specific Guidelines	
	- DEH (2005) NO_X & ANZECC (2000): Tropical Rivers: - Inshore Marine - Estuaries	 2 - 8 µg/L 30 µg/L
	ANZECC (2000) NO_X - Estuaries - Coastal and Marine	 5 µg/L 60 µg/L
	Local Sources: NO_X	12 µg/L
	This Study: All levels found in this study for this analyte (NO_2^-), at all sample locations were below the limit of reporting:	<10µg/L)
	Ocean Terminal Recommended Investigation Level:	15 µg/L
	Ocean Terminal Recommended Intervention Level:	30 µg/L
Nitrate (NO_3^-) as N	No specific Guidelines	
	DEH (2005) NO_X & ANZECC (2000): Tropical Rivers: - Inshore Marine - Estuaries	 2 - 8 µg/L 30 µg/L
	ANZECC (2000) NO_X - Estuaries	 5 µg/L

	- Coastal and Marine	60 µg/L
	ANZECC (2000): NO_3^- Freshwater: - 95% Protection Level - 80% Protection Level	 700 µg/L (= 160 µg/L as N) 17000 µg/L (= 3840 µg/L as N)
	Local Sources: NO_X	12 µg/L
	This study: Control + Sun Metal sample range - Surface - Bottom Sample Zone S6 – S8 range - Surface - Bottom "Project Site", S1 - Surface - Bottom Sample Zone S2 – S4 - Surface - Bottom	 <10 µg/L <10 µg/L <10 – 17 µg/L <10 µg/L <10 µg/L <10 µg/L <10 - 15 µg/L <10 µg/L
	Ocean Terminal Recommended Investigation Level:	100 µg/L
	Ocean Terminal Recommended Intervention Level:	200 µg/L

Nutrient	**Guideline**	**Level**
TKN = TKN-Ammonia = Total Nitrogen as N ($TKN+NO_X$)	DEH (2005): Total N: - Estuarine / Marine	 100 – 250 µg/L
	ANZECC (2000) - Tropical Rivers: Estuarine / Marine	 100 – 250 µg/L
	ANZECC (2000) - Estuarine / Coastal / Marine - Lowland Rivers	 80 – 350 µg/L 1600 µg/L
	Local Sources (1988)	120 µg/L
	This study: Control + Sun Metal sample range - Surface - Bottom Sample Zone S6 – S8 range - Surface - Bottom "Project Site", S1 - Surface - Bottom Sample Zone S2 – S4 - Surface - Bottom	 <500 – 700 µg/L <500 µg/L <500 µg/L <500 µg/L <500 µg/L 600 µg/L <500 µg/L <500 µg/L
	Ocean Terminal Recommended Investigation Level:	600 µg/L
	Ocean Terminal Recommended Intervention Level:	1500 µg/L
	DEH (2005)	

Total Phosphorus as P	DEH (2005)	
	ANZECC (2000) - Total P: Estuarine / Marine - Tropical Rivers: Estuarine / Marine	10 – 20 µg/L 10 – 20 µg/L
	ANZECC (2000) - Estuarine / Coastal / Marine - Lowland Rivers	45 – 55 µg/L 37 µg/L
	This study: Control + Sun Metal sample range - Surface - Bottom Sample Zone S6 – S8 range - Surface - Bottom "Project Site", S1 - Surface - Bottom Sample Zone S2 – S4 - Surface - Bottom	<50 – 3350 µg/L <50 µg/L 350 – 18000 µg/L 9290 – 15100 µg/L 1140 µg/L <50 µg/L 12400 - 19800 µg/L <50 - 470 µg/L
	Ocean Terminal PROVISIONAL Investigation Level:	50 µg/L
	Ocean Terminal PROVISIONAL Intervention Level:	100 µg/L
Reactive Phosphorus as P (Dissolved)	DEH (2005) - Reactive P: Estuarine / Marine	2 – 5 µg/L
	ANZECC (2000) - Tropical Rivers:	2 – 5 µg/L
	ANZECC (2000) - Estuarine / Coastal / Marine	4 – 6 µg/L
	Local sources (1988)	6 µg/L
	This Study:	
	All levels found in this study for this analyte (Reactive P), at all sample locations, were below the limit of reporting	10 µg/L
	Ocean Terminal Recommended Investigation Level:	8 µg/L
	Ocean Terminal Recommended Intervention Level:	20 µg/L

ANALYTE	**Assessment**	**Level**
Chlorophyll-a	Guideline Range	0.3 – 2 µg/L
	Ocean Terminal Suggested Investigation Level:	2 µg/L
	Ocean Terminal Suggested Intervention Level:	4 µg/L
	Guideline Range	7.0 – 8.5 µg/L

	Ocean Terminal Suggested Investigation Level:	<7.5 µg/L >8.6 µg/L
	Ocean Terminal Suggested Intervention Level:	<7.0 µg/L >8.8 µg/L
Dissolved Oxygen (% Saturation)	Guideline Range	Not Applicable
	Ocean Terminal Suggested Investigation Level:	<85% Saturation >110% Saturation
	Ocean Terminal Suggested Intervention Level:	<80% Saturation >120% Saturation
Conductivity / Salinity	Guideline Range	
	Ocean Terminal Suggested Investigation Level: Relative to values as measured at 3 defined monitoring points specific to this development	Below 90% relative value Above 110% relative value
	Ocean Terminal Suggested Intervention Level: Relative to values as measured at 3 defined monitoring points specific to this development	Below 5% relative value Above 115% relative value
Turbidity	More data are currently being collected.	
	Guideline Range	Not applicable
	Ocean Terminal PROVISIONAL Suggested Investigation Level: Relative to values as measured at 3 defined monitoring points specific to this development	Above 110% relative value
	Ocean Terminal Suggested Intervention Level: Relative to values as measured at 3 defined monitoring points specific to this development	Above 120% relative value
Organochlorines & Pesticides	To date sediment and water samples collected from Cleveland Bay and analysed for organochlorins and pesticides (eg: atrazine, diuron, chloropyrifos, heptachlor, endosulfan, lindane, dieldrin, DDT, DDD and DDE, indicate that levels of these analytes are below limits of reporting by usual, commercially available analytical techniques. Trigger levels for most of these analytes are available in the ANZECC (2000) Guidelines. Occasional, routine screening analyses for these species should be undertaken. Should levels found be above the limits of reporting, then further investigations should be undertaken. Should levels found be above the 95% Species Protection Levels of ANZECC (2000), then more direct intervention may be required.	

APPENDIX 2 ALS ANALYTICAL DATA

The full ALS analytical data including Chain of Custody and Quality Assurance Quality Control Material may be obtained from Dr C Cuff, C&R Consulting upon request on CD.

APPENDIX 3 PHREEQC MODELING DATA

PHREEQC modelling output maybe obtained from Dr C Cuff, C&R Consulting upon request on CD.

APPENDIX 4 – RISK ASSESSMENT TABLES

Risk rating table, using both the likelihood and consequence of a potential impact.

Likelihood	Consequences				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	Medium	High	High	Extreme	Extreme
Likely	Low	Medium	High	Extreme	Extreme
Moderately likely	Low	Low	Medium	High	High
Unlikely	Minimal	Minimal	Low	Medium	High
Very unlikely	Minimal	Minimal	Low	Low	Medium

Marine Protected Areas Measures of consequence or impact (source: DEH).

Descriptor	Meaning (one or more of these may apply)
Insignificant	• No injuries, damage to habitat, impact on species, or impacts on achievement of programme objectives • Low financial loss or damage
Minor	• First aid treatment • Minor localised damage to habitat • Minor impact on species • Slight reduction in the abundance of one or more species (non-threatened) • Slight deterioration in ecological communities in a limited area • Medium financial loss • Some community dissatisfaction • Park or programme area is less able to achieve one or more objectives effectively • On-site effects, immediately contained (eg: fire, pollution) • Low likelihood of legal action against Director National Parks
Moderate	• Medical treatment of casualties required • Significant localised habitat or environmental damage • Some reduction of a species (non-threatened) • Some deterioration in ecological communities in a substantial area • High financial loss

	• Park or programme area is unable to achieve one or more objectives effectively • On-site effects, contained with outside assistance • Disturbance of individual members of a species that is a key value of the Commonwealth Reserve • Disturbance of a key value of the Commonwealth Reserve • Frequent repetition of an event that is of 'minor' consequence • Adverse local media attention, significant community dissatisfaction and/or minor damage to Environment Australia's reputation and goodwill • Medium likelihood of legal action against Director National Parks
Major	• Fatalities and extensive injuries • Expansive habitat or environmental damage • Major reduction in abundance of several species (non-threatened) • Significant deterioration in ecological communities in a substantial area • Very high financial loss • Disturbance of an aggregation of a species that is a key value of the Commonwealth Reserve • Unnatural injury or death of a cetacean, a member of a listed threatened species, a member of a listed migratory species, a member of a listed marine species, or a member of a listed protected species (EPBC Act) • Damage to a listed threatened ecological community • Damage to a key value of the Commonwealth Reserve • Repetition of an event that has moderate consequence • The Department of the Environment and Heritage unable to achieve one or several principal objectives • Off-site effects • Adverse national media attention, strong community dissatisfaction and/or significant damage to Environment Australia's reputation and goodwill • Significant political effects • High likelihood of legal action against the Director National Parks
Catastrophic	• Multiple fatalities • Total destruction of habitat or environment • Extreme reduction in abundance (or extinction) of one or more species • Significant reduction in abundance of a threatened species • Loss of ecological communities • Loss of a key value of the Commonwealth Reserve

	• Huge financial loss • The Department of the Environment and Heritage unable to achieve many or all principal objectives • Off-site effects with widespread detriment • Sustained adverse national media coverage, intense community dissatisfaction and major damage to Parks Australia's reputation and goodwill • Major political effects • Very high likelihood of legal action against Director National Parks

Table 13: Marine Protected Areas measures of likelihood

Descriptor	Meaning
Almost certain	The event is expected to occur
Likely	The event will probably occur
Moderately likely	The event may occur in normal circumstances
Unlikely	The event may occur in unusual circumstances
Very unlikely	The event may occur in exceptional circumstances