LAND & WATER CONSERVATION

QUEENSLAND GOVERNMENT
Department of Environment

Tweed River Entrance Sand Bypassing Project

Permanent Bypassing System

Environmental Impact Statement / Impact Assessment Study



Hyder Consulting

Patterson Britton & Partners Pty Ltd

WBM OCEANICS AUSTRALIA





Department
of Environment

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FOR: New South Wales Department of Land and Water Conservation

and

Queensland Department of Environment

BY: Hyder Consulting Pty Ltd, Patterson Britton Partners Pty Ltd and WBM Oceanics Australia Joint Venture

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Submission of Environmental Impact Statement (EIS) prepared under the Environmental Planning and Assessment Act, 1979 (Section 112)

EIS prepared by

Name, qualifications and address of person who prepared Environmental Impact Statement	Hyder Consulting Pty Ltd, Patterson Britton and Partners, and WBM Oceanics Australia Joint Venture c/o Hyder Consulting Level 13, 601 Pacific Highway ST LEONARDS NSW 2065

in respect of

Part 5 activity

Proponent Name	NEW SOUTH WALES MINISTER FOR LAND AND WATER CONSERVATION and QUEENSLAND DEPARTMENT OF ENVIRONMENT
Land on which the activity to be carried out: address.	The activity is to be carried out on the coastal environment at the mouth of the Tweed River and Southern Gold Coast shown in Figures 1.1.1 and 1.1.2 of the EIS

Environmental Impact Statement

An Environmental Impact Statement (EIS) is attached

Certificate

I certify that I have prepared the contents of this Statement and to the best of my knowledge

- it is in accordance with clauses 84 and 85 of the Environmental Planning and Assessment Regulation 1994, and
- it is true in all material particulars and does not, by its presentation or omission of information, materially mislead.

Signature : .....

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Summary

Safe passage into the Tweed River has long been hindered by the periodic formation of sand shoals at the river entrance. River training works and dredging have been undertaken since late last century in an attempt to improve navigability. These works culminated in the extension of the training walls at the river entrance during 1962-65. Although extension of the training walls improved navigation for a period, in recent years the entrance bar has reformed and again created navigation difficulties. As a result of the construction of the entrance training walls, patterns of erosion and accretion have been altered in the region. Accretion has occurred to the south of the southern training wall, resulting in a build up of sand along Letitia Spit and subsequent significant erosion has resulted along the southern Gold Coast beaches. The consequences of not undertaking a sand bypassing project would be a progressive worsening of navigation at the Tweed River entrance and continued erosion of the southern Gold Coast beaches.

The Tweed River Entrance Sand Bypassing Project has been formulated following extensive negotiations between the New South Wales and Queensland state governments. Agreements between the two states were reached to carry out a joint project in order to achieve the project objectives which are to maintain a safe navigable entrance to the Tweed River and to restore and maintain the amenity of the beaches on the southern Gold Coast of Queensland. The project is being administered for NSW by the Department of Land and Water Conservation and for Queensland by the Department of Environment with the support of the Gold Coast City Council. It was proposed that the works be carried out in two stages, namely:

Stage 1: Dredging of a net 2 million m^3 of sand from the Tweed River entrance bar and associated nourishment of southern Gold Coast beaches; and

Stage 2: Construction and operation of a permanent sand bypassing system, in perpetuity.

This document examines the Environmental Impact Statement/Impact Assessment Study (EIS/IAS) requirements relating to Stage 2 of the project. Stage 1 was examined in a separate EIS/IAS (Acer Wargon Chapman, 1994) and most of the Stage 1 works have since been undertaken.

This EIS/IAS assesses the environmental impacts of the project, including construction and operation of the permanent sand bypassing system, pursuant to Part V of the New South Wales *Environmental Planning and Assessment Act 1979* and the Queensland *State Development and Public Works Organisation Act (1971-81).*

Approval Process

The project involves dredging to be carried out in New South Wales (NSW) and beach nourishment in Queensland, and is therefore under the jurisdiction of legislation of both the respective States. In NSW the *Tweed River Entrance Sand Bypassing Act 1995* was enacted to ratify the agreements with Queensland and to facilitate the works.

In New South Wales, under sections 10(2) and (3) of the *Tweed River Entrance Sand Bypassing Act 1995*, the works are subject to Part V of the *Environmental Planning and Assessment Act 1979 (EP&A Act)*. As the works are considered likely to significantly affect the environment, the preparation of an EIS (this document) is required. In NSW, the proponent and nominated Determining Authority is the Minister for Land and Water Conservation. The Department of Urban Affairs and Planning (DUAP) have produced Director's Requirements for the preparation of the EIS.

The nourishment works in Queensland are considered to be "public works" as defined in the *State Development and Public Works Organisation Act 1971-1981 (SD & PWO Act).* The works are therefore covered by the provisions of "Impact Assessment in Queensland: Policies and Administration Arrangements", which outlines the consideration of impact through to the preparation of an IAS. In accordance with the provisions of the *SD & PWO Act*, and associated policies and administrative arrangements, the Queensland Department of Environment (DoE) has assessed that the project is "likely to have major environmental effects", and consequently **requires** an IAS. After consultation with other "Advisory Bodies", DoE produced Terms of Reference/Guidelines for the preparation of the IAS. The final IAS is considered by DoE (the Responsible Authority) and relevant Advisory Bodies, before the activity can be approved, approved with conditions or not approved .

Implementation of the project would involve the cooperation of the relevant local government authorities being, Tweed Shire Council in New South Wales, and Gold Coast City Council in Queensland. In addition, approvals and permits are required from a number of public authorities in each state for various components of the project.

Community Consultation

Comments on the proposed permanent sand bypass system and nourishment operations were initially sought from the local community in June 1996 through local newspaper advertisements and posters at public locations. A public meeting was then held at Tweed Heads Civic and Cultural Centre on 31 July 1996 attended by approximately 40 people including local residents, Councillors, fishermen, surfing community representatives, local media and representatives from local businesses.

The response from the community for both Stage 1 and Stage 2 indicates very strong support for the project with a preference for a permanent structural option and commencement in the shortest feasible time frame. The range of comments expressed were diverse with navigation, quality of surf, impacts on the local fishing industry, and beach amenity seen as major issues of interest.

The Proposal

It is proposed to implement a permanent sand bypassing system at the mouth of the Tweed River. The purpose of this bypassing system is to establish and maintain a defined navigable entrance to the Tweed River and sustain the amenity of the southern Gold Coast beaches. The Deed of Agreement set out in the *Tweed River Entrance Sand Bypassing Act 1995* states that the option chosen must maintain a safe navigation channel and deliver a quantity of sand equal to the net long term average littoral sand transport, currently estimated to be 500 000m^3 per annum to nominated discharge outlets at Duranbah, Snapper Rocks and Kirra Point.

A list of sand retrieval and nourishment systems were assessed for their ability to meet the objectives of the proposal, site conditions, operational requirements and environmental considerations. Alternatives to carrying out the proposal were also assessed.

Existing Environment

The Physical Environment

The study area is located on the NSW/Queensland border in the Tweed Shire in NSW and the City of Gold Coast in Queensland. The Tweed River is part of the major drainage basin in the study area. The structural formation of the basin comprises the remnants of a large caldera formed by the eruption and collapse of the Mount Warning shield volcano 20 million years ago. The basaltic plateau extends north into Queensland bounded by a coastal plain up to 8 km in width comprising alluvial, aeolian and marine deposits.

The local topography of Tweed Heads/Coolangatta is characterised by a low lying coastal plain with significant areas of higher relief formed by volcanic rock outcrops. Prominent rock outcrops include Kirra Point, Greenmount Hill and Point Danger.

The coastal area is highly dynamic. The key natural coastal sedimentary processes in the region are littoral transport averaging a net northerly rate of 500 000 m^3 per year, high beach variability with extensive erosion caused by storm events and gradual beach recovery and strong wind induced dune development (particularly on east facing beaches) and natural dune stabilisation from sand loss by wind erosion provided by vegetation. The area is subject to a moderate to high energy ocean wave climate with significant seasonal variability. On such a littoral coast, a deep entrance and full bypassing cannot coexist naturally.

Sediment samples taken from the proposed dredging and nourishment areas indicate that the sand is very clean and mobile with virtually no heavy metals, pesticides or bacterial contamination.

The oceanic water quality is generally excellent under dry weather conditions. A deterioration in water quality occurs during periods of wet weather, particularly in the lower Tweed estuary, due to increased turbidity caused by suspension of sediments from runoff. Water quality within the Tweed estuary itself can be reduced in periods when tidal flushing is hindered.

The construction of the Tweed River training walls resulted in changes to the natural processes of erosion and accretion. Accretion occurred to the south of the southern training wall along Letitia Spit, and significant erosion occurred along the southern Gold Coast beaches which was offset by a series of artificial beach nourishment works.

Ecological Environment

The study area is situated within a biogeographic zone where plants and animals of both tropical and temperate affinities are well represented. Terrestrial plant formations include littoral rainforest, fringing open forests, shrubland and heathland. Significant areas of saltmarsh, mangroves and seagrass occur in the lower Tweed estuary.

Although the natural environment has been substantially modified since early European settlement, through logging, agriculture and mining, and more recently through urban development, many significant wildlife habitats remain. The lower Tweed estuary provides a habitat for a wide range of avifauna including migratory shorebirds protected by international treaties with China and Japan.

Letitia Spit is an important habitat despite extensive modification resulting from past sand mining activities. South Head beach, located immediately south of the southern breakwater, is an important habitat and roosting site for migratory birds. Bird species utilising the South Head beach roost site include the Little Tern and the Brahminy Kite which are listed as 'threatened' under the NSW *Threatened Species Conservation Act 1995*.

The rocky reefs offshore from Point Danger, Snapper Rocks and Kirra Beach support a rich diversity of marine flora and fauna. The ecology of Kirra Reef, located off Kirra Beach is particularly rich considering its nearshore location surrounded by a highly mobile sandy bed.

A rich and abundant fish fauna occurs along the coast and within the Tweed River estuary. The wetlands within the estuary itself form an important habitat and nursery for many marine species. As well as many species of fish, the study area supports a wide range of other marine and aquatic species including oysters, prawns and beachworms.

Socio-economic Environment

Local council zonings in the study area include open space, residential, business and special use. Open space areas are concentrated around the foreshores and lands adjacent to the Tweed River estuary. Development densities for residential properties are generally higher in Coolangatta than in Tweed Heads reflecting more substantial development of tourist infrastructure. The commercial zone consists of a ribbon type development along the Pacific Highway through both towns.

The region is affected by a strong migration movement to South East Queensland/Northern NSW. Many residents are retirees with people over 60 comprising more than 40% of the population compared to the national average of 15%. Unemployment is substantially higher than the national average possibly reflecting the seasonal influences in the tourism and construction industries and the influence of retirees and unemployed itinerants.

Tourism is one of the most significant industries in the study area. The high scenic quality of the beaches and Tweed River estuary provides a focus for recreational activities including swimming, fishing, surfing, boating, walking and cycling amongst others. Snorkelling and diving are popular off the rocky headlands, Kirra Reef and around Cook Island offshore from Fingal Head. Rainbow Bay, Greenmount and Coolangatta are the most protected ocean beaches on the Gold Coast and are particularly valued by families with children. The beaches in the study area, including Kirra and Duranbah are among the most popular surf breaks in Australia.

The fishing industry based in Tweed Heads is also significant to the local economy. Before the Stage 1 works commenced, the condition of the Tweed River entrance bar had limited fish trawling operations and as a result had affected the viability of the industry.

A number of relic sites of importance to the indigenous community exist in the study area. The sites recorded are mostly middens, with some open artefact scatters, burials, a ceremonial site (bora ring) and a site of significance (cemetery).

Early transportation for European settlers to the Tweed Heads/Coolangatta area was primarily by sea. Several shipwrecks are believed to have occurred off the Tweed entrance bar. In addition the training walls within the estuary, built 1898-1903, are also considered a relic under the NSW *Heritage Act 1977*.

Navigation across the entrance to the Tweed River can be hazardous even in comparatively calm conditions. The complex bar bathymetry and strong ebb tide currents have resulted in complicated and unpredictable wave conditions in the navigation channel. These conditions have made navigation hazardous for many years.

The Environmental Impacts

Physical Environment

The Project will result in greater depths at the Tweed River entrance and significant improvements to the stability of the southern Gold Coast beaches.

The existing drainage and surface topography is not expected to be altered as a result of the permanent sand bypassing system. Acid sulfate soils which exist in the region will not be affected.

Wave patterns will be altered and consequently beach form and wave conditions will change. Duranbah beach is expected to be affected as a result of the implementation of the permanent system. The shape, alignment and surf quality at this beach is expected to alter significantly and reach a new equilibrium. The Project includes provision to preserve amenity of Duranbah beach through beach nourishment. The beach at the northern end of Letitia Spit is expected to retreat to a new dynamic equilibrium state seaward of its position in 1962. The beach at the southern end near Fingal will not be affected.

Beach width is expected to increase at Rainbow Bay, Greenmount and Kirra beaches, buffering the beach and remaining dune systems from erosive storm wave conditions and maintaining more stable beach conditions. Recreational amenity, including surfing, at these beaches is expected to improve.

Depending upon the particular bar bypassing strategy adopted by the successful tenderer, the training walls at the Tweed River entrance may be subject to increased wave height and energy after deepening of the entrance bar.

Changes to tides, floods and storm surge propagation in the Tweed estuary will not be significant if the entrance sand shoals are maintained in accordance with the Tweed Estuary Management Plan. There is expected to be a substantial reduction in the net infeed of marine sand to the estuary and as a consequence the entrance shoals will be slower to recover from flood events. In conjunction with the Tweed Estuary Management Plan, increased tidal flushing and mixing will result in improved water quality within the Tweed estuary.

Ecological Environment

Growth of the lower Tweed estuary shoals would restrict the tidal range resulting in poorer estuarine water quality and damage to ecology including seagrass and mangroves. Permanent sand bypassing will reduce the rate of formation of lower estuary shoals.

Impacts on the ecological environment vary with the system option chosen to achieve the project objectives. Overall, dredging and nourishment patterns are expected to have a minimal impact on the environment.

Potential impacts associated with a jetty mounted system include creation of new reef-type habitat, alteration of the marine species composition and reduction in benthic invertebrates in the immediate proximity of the jetty. The jetty system may cause interference to the migration paths of pelagic fish. Construction and operation of a jetty mounted system have the potential to disturb the roosting sites of several water and shorebird species.

The location of a sand slurry pipeline at the northern end of Letitia Spit has the potential to disturb the roosting sites of several waterbird species and the habitat of the endangered Little Tern. Impacts on wetland ecosystems will only be experienced if the lower Tweed estuary sand shoals were to become eroded as the result of flood events. Mitigative measures that would allow the shoals to be re-established after such events have been detailed in this document.

Cultural and Socio-economic Environment

The proposal is not expected to have any significant impacts on land zoning, landuse or tenure. It is anticipated that the implementation of a permanent sand bypassing system will have substantial benefits for local business, recreation and tourism. Improvement in the safety and navigability of the Tweed River entrance is expected. The benefits associated with improved navigation and beach amenity include increased viability of the Tweed fishing industry, revenue from tourism, benefit to commercial and retail businesses, local employment opportunities and increased recreational potential of the Tweed estuary and southern Gold Coast beaches.

Construction of the permanent bypassing system may cause temporary interruption to beach access during that period. Dredging and nourishment activities associated with mobile systems may result in temporary closure or restricted access to the beaches.

Navigation will be substantially improved with the implementation of the permanent sand bypassing system. Depths will be improved and navigation is expected to be considerably safer in general and possible over a much greater range of weather conditions. Larger craft will be able to safely utilise the channel. Improvements to navigation will have significant positive impacts on local industry, business and tourism. The location of the navigation channel will be changed slightly and some system options will present a navigational hazard which will require management. If dredgers are used as a system option, their periodic presence also present navigational hazards during sand retrieval and nourishment operations similar to those experienced during the recent Stage 1A works.

All system options will have an impact on the existing visual amenity of the region. Noise will be generated by each system option and therefore result in increased noise in the vicinity of plant and equipment which will require careful planning and management. The existing high air quality in the study area may be temporarily affected by emissions associated with fuel powered systems, however climatic conditions will facilitate rapid dispersal and therefore impact will be short term and insignificant. Heavy trucks and equipment associated with construction of some options may have a temporary impact on local traffic. The proposal may result in the need to upgrade the road at Letitia Spit which may encourage further long term increases in traffic in the Fingal Head area.

A potential hazard associated with the project is oil spillage from plant. Management to ensure the impact of such an event is minimised is outlined in this document

Future Management

Current activities associated with the Tweed River Entrance Sand Bypassing Project are being managed by an Environmental Management Plan (EMP). The EMP for the Stage 1A dredging and nourishment works outlined strategies for managing sediment and water quality, noise, stormwater outlets, significant areas such as Kirra Reef, accidents and emergency response, major storms and community consultation. Monitoring and reporting of various aspects of the Stage 1A dredging has also been undertaken.

Management issues relating to Stage 2 works are outlined in this document. Issues include future management of the lower estuary marine shoals, long term water quality, beach system management, Duranbah beach management, navigation channel maintenance, Tweed River entrance training wall stability, maritime heritage, Tweed River ecology, Kirra Reef and noise. Long term environmental monitoring is also outlined.

It is noted that sand bypassing is to occur in perpetuity. Future management of the project will include the maintenance and replacement of particular bypassing systems from time to time.

Conclusion

This study has shown that the project objectives, including maintenance of the navigation channel at the Tweed River entrance and the continuing delivery of sand to Queensland are practical, achievable and sustainable.

Benefits associated with the implementation of the permanent bypassing system are anticipated to include significant improvements for recreational boating, tourism and the fishing industry in the Tweed River. These benefits result from improved navigation, reduction of infilling of the Tweed estuary, and improved water quality within the Tweed estuary as a result of slightly increased tidal flushing. Additional benefits to tourism, recreation and property values arise from the restoration and continuing supply of sand to the southern Gold Coast beaches.

Apart from the improvements to the coastal and estuarine environment, the EIS/IAS has determined some other environmental impacts. These include a small increase in the tidal range in the Tweed estuary, a permanent recession of the northern end of Letitia Spit, and altered beach and wave conditions at Duranbah Beach.

The 'Do Nothing' option would jeopardise the cumulative benefits of Stage 1 and previous beach nourishment campaigns. Doing nothing would raise a plethora of substantial environmental risks including possible damage to entrance navigability and public safety, beach stability and beach amenity, and estuarine habitats, as well as the commercial viability of the many local marine based industries.

This document recommends management and monitoring programmes which should be implemented to ensure that the negative impacts are minimised and that the project objectives are met over both the long and short term.

The conclusion has been reached that the environmental, social and economic benefits of proceeding with the project considerably outweigh any adverse environmental impacts.

Chapter 1

Introduction

Chapter 1

Introduction

This first chapter briefly introduces the proposal, including the New South Wales and Queensland objectives and the Deed of Agreement between the two States. Details of the proponent are outlined. The problems which form the basis of the proposal are described in detail and historical entrance dredging and beach nourishment campaigns are reviewed. An outline of the potential benefits of the proposal is also included.

1.1 The Proposal

It is proposed to implement a permanent sand bypassing system at the mouth of the Tweed River on the far north coast of New South Wales (Figures 1.1.1 and 1.1.2). The purpose of this bypassing system is to restore the amenity of the southern Gold Coast beaches and to establish and maintain a safe navigable entrance to the Tweed River in perpetuity.

The project is being carried out over the state border of New South Wales and Queensland and while the two states acknowledge the mutual benefit of the project, they have expressed their individual objectives as follows:

New South Wales - To establish and maintain a navigable depth of water of at least 3.5m below Indian Springs Low Water (ISLW) in the approach to, and within the channel entrance.

Queensland - To achieve a continuing supply of sand to the southern Gold Coast beaches at a rate consistent with the natural littoral drift rates updrift and downdrift of those beaches, together with the supply of additional sand to restore and maintain the recreational amenity of the beaches.

1.1.1 Heads of Agreement

On 31 March 1994 the Heads of Agreement was signed between the New South Wales (NSW) and Queensland state governments, defining the Tweed River Entrance Sand Bypassing Project (NSW/Queensland Heads of Agreement, 1994). The Agreement commits the governments to undertake cost sharing of the entrance dredging, beach nourishment and construction and operation of a system in perpetuity. It was proposed that works would be carried out in two stages:

Stage 1: Dredging of a net 2 million cubic metres from the Tweed River entrance bar and associated nourishment of southern Gold Coast beaches; and

Stage 2: Establishment and operation of a permanent sand bypassing system in perpetuity.

This document examines the EIS/IAS requirements relating to Stage 2 of the project. Stage 1 was examined in a separate EIS/IAS (Acer Wargon Chapman, 1994) and most of the Stage 1 works have since been undertaken.

1.1.2 Deed of Agreement

The NSW *Tweed River Entrance Sand Bypassing Act, 1995* outlines the Deed of Agreement which has been established to provide for the facilitation of agreements between the two states with regard to improving the navigability of the Tweed River entrance and the bypassing of sand around that entrance to maintain and enhance the attributes of the southern Gold Coast beaches, and for related purposes. The Tweed River Entrance Sand Bypassing Project is the subject of the legally binding Deed of Agreement between both states.

Under the Deed of Agreement, New South Wales and Queensland have agreed to share the final costs of the Project. These costs will be shared as shown in the table below:

Table 1.1.1 State Share of Project Costs

	NSW %	QLD %
Initial dredging and nourishment	75	25
Establishment cost of first bypassing system	75	25
Operating cost (including maintenance, monitoring and replacement systems)	50	50

Separately, the Gold Coast City Council has agreed to pay half the Queensland costs.

The Deed specifies the "Contract Quantity" of sand which needs to be dredged from the Tweed River entrance area and transferred to the southern Gold Coast beaches to meet the objectives of the project. The Contract Quantity is made up of the following amounts:

(a) 2 million cubic metres (representing the required quantity of initial dredging and nourishment assessed in 1990);

(b) 0.55 million cubic metres (representing an allowance for the losses since 1990);

(c) a quantity representing the volume of sand which would have been naturally transported between the completion of the first phase of the initial dredging and nourishment and the commencement of the operation of the permanent bypassing system, calculated at the rate of 500 000 cubic metres per annum; and

(d) the long term average net littoral transport (currently assessed as 500 000 cubic metres per annum) from the commencement of the operation of the permanent bypassing system.

As Joint Principals, the NSW and Queensland Governments acknowledge that the permanent sand bypassing system will need to be replaced at some future time and have agreed to cooperate to ensure that replacement systems will be established and operated in such a way as to fulfil the purpose of the Agreement.

1.2 The Proponent

As outlined in Section 1.1.2 above, the Tweed River Entrance Sand Bypassing Project is being carried out by the New South Wales and Queensland Governments, with the support of the Gold Coast City Council and in conjunction with the Tweed Shire Council. While the project is to be delivered as a joint venture between the two states, for the purpose of management coordination, New South Wales has been assigned the role of 'Coordinating State' and Queensland the complementary role of 'Reviewing State'.

Responsibility for the implementation of the Project rests with the New South Wales Minister for Land and Water Conservation and the Queensland Minister for Environment. Under the Deed of Agreement, NSW

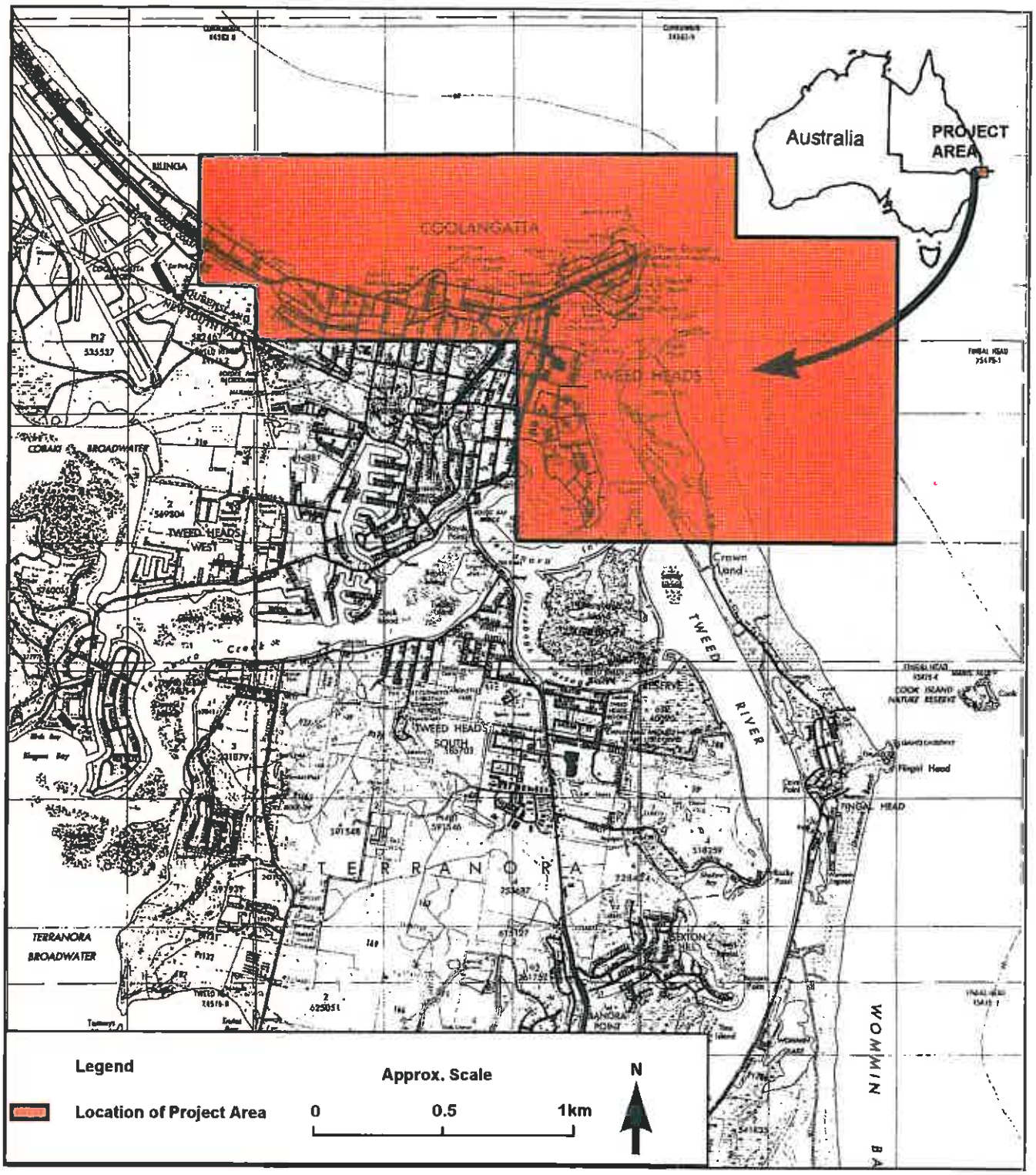


Figure 1.1.1: Project Area

Source: CMA 1985, 1:25 000 Map Series

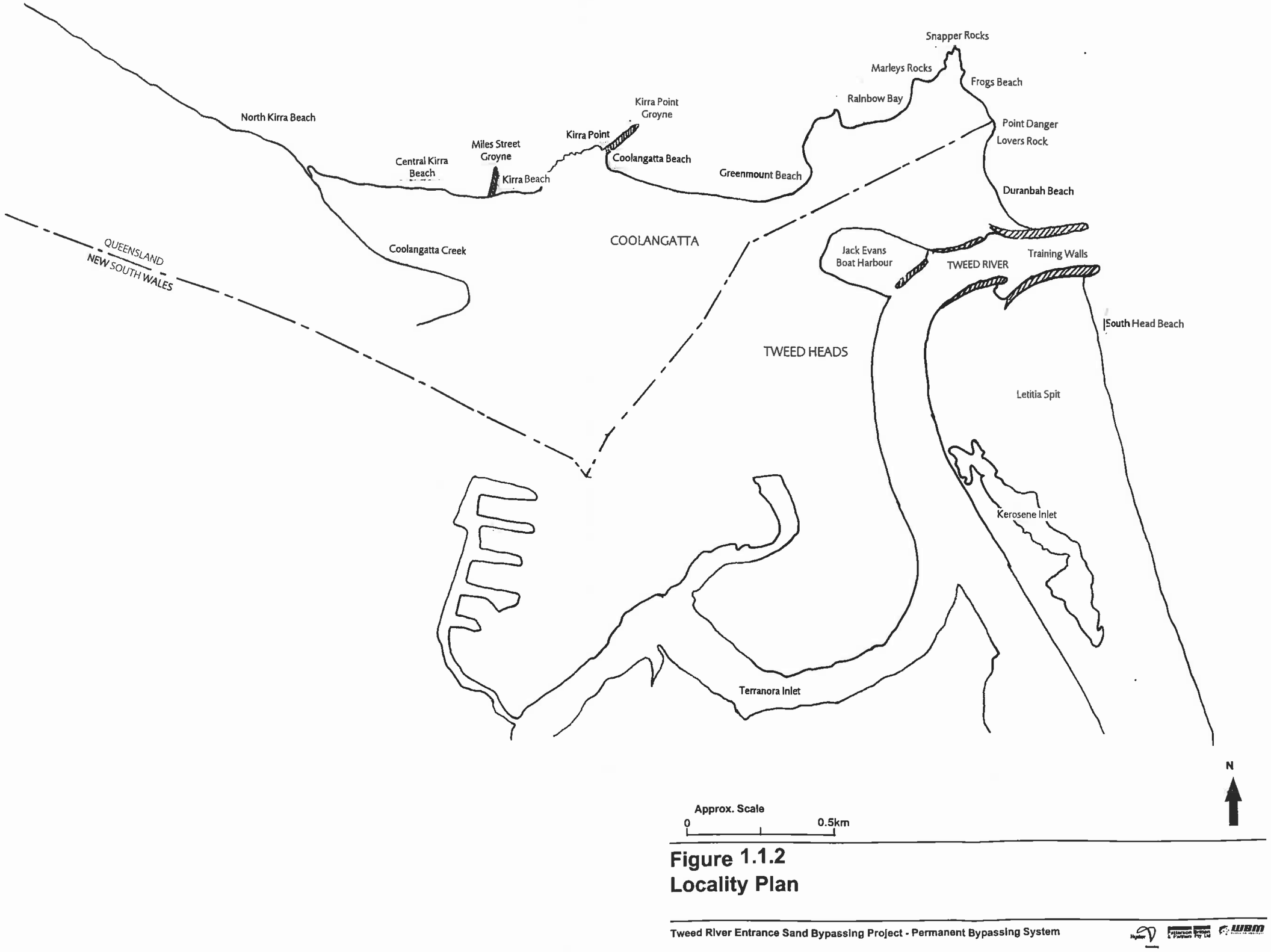


Figure 1.1.2
Locality Plan

as the 'Coordinating State', has the primary responsibility (as the representative of both states) for the implementation of the project. To assist with the implementation, each Minister has established a Project team within their respective Departments. These teams are each led by a Project Director whose primary function is the representation of the respective State's interest.

To ensure a close working liaison and cooperation and the efficient and effective delivery of the Project, a Working Group has been formed. The Working Group is responsible to both Ministers for implementing the project. The Working Group comprises three members from each state nominated by the respective Minister. In addition, the Ministers are advised by an Advisory Committee. This committee comprises four community representatives (two from each state), two officers from each state and one representative from both the Gold Coast City Council and the Tweed Shire Council.

1.3 Background to the Project

1.3.1 General

Prior to the construction of river training works, the mouth of the Tweed River was a typical example of an uncontrolled tidal entrance which captured and then bypassed the natural littoral drift moving northwards up the coast. This process involved large volumes of sand moving in and out of the entrance and resulted in the formation of large sand banks and islands such as Ukerebagh Island and the bar at the entrance to the Tweed River.

On littoral coasts accumulations of marine sediments (bars) are the natural mechanism for sand bypassing of estuaries. Bars progressively build up, fed by sediments transported from adjacent beaches. Eventually the depth of water above the bar becomes shallow enough that the energy of the waves which form on that bar creates sufficient turbulence to move the sand along the bar. This process ultimately results in a state of dynamic equilibrium. On the natural littoral transport coast, full sand bypassing and a deep unbarred entrance are physically incompatible. The project will be implemented in an environment which is naturally changing as a result of the processes which influence it.

The Tweed River Entrance Sand Bypassing Project is a ground breaking project. There are only a few examples in the world where a permanent sand bypassing system comparable with this project has been implemented. Physical bypassing of a river entrance such as the Tweed River is a difficult and complex process due to the dynamic nature of the coastal environment.

This document assesses impacts for several options which have the ability to best achieve the project objectives. However, it does not attempt to limit the options which may be employed to implement the project, nor does it aim to select any one particular option.

1.3.2 Historical Context

Archaeological evidence indicates that Aborigines utilised the Tweed Heads area for at least the last 9000 years (Lilley, 1981). The coastal plains are believed to have been relatively densely populated.

Captain Cook surveyed the eastern coast in 1770, naming Cape Byron, Mount Warning and Point Danger. In 1823, an expedition led by John Oxley explored and surveyed the coast and discovered the Tweed River system. The Tweed River Valley was explored by European settlers in 1828 and settlement soon followed. The early settlement was heavily reliant on coastal shipping for the exchange of trading goods. A significant cedar timber export trade had been established by the mid-nineteenth century. Groceries, clothing and hardware supplies were imported into the valley and agricultural products such as timber and harvested crops exported from the valley to the cities of Sydney and Brisbane.

The influence of natural processes such as tides, floods, waves and wind resulted in continual change in the position and condition of the Tweed River entrance. Steamers and other craft were forced to unload at locations inside and sometimes outside the river entrance as a result of the continual movement of the entrance sand shoals. From these points flat bottom punts would transport cargo to its destination.

Continual development of the region surrounding the river resulted in increased use of the entrance by commercial and recreational craft. Consequently, the number of groundings and fears associated with using the entrance bar which was unsafe to navigate for extended periods of time also increased. As a result, local demand increased for the NSW state government to undertake navigation improvement works at the entrance and within the lower reaches of the Tweed River.

Construction of training walls and dredging works commenced in 1891 at the Tweed River entrance and lower reaches as part of improvement works. This work was essentially completed in 1904. The main training walls in the Tweed Heads town reach were designed to direct the flow and maintain a stable navigable channel through Letitia Spit; the western wall forming a stable bank for Greenbank Island and confining the flow through the Back Channel. Other walls along Ukerebagh Island controlled the flow from Terranora Creek at the junction with the Tweed preventing scour of the island's banks. The resultant channelisation also contributed to maintaining a navigable channel in this reach of the creek. Unfortunately, the benefits of these improvement works were only short lived. Despite these works, the navigation problems at the entrance continued.

The location of training walls in the lower Tweed estuary is shown in Figure 1.3.1.

In 1960 further work was proposed for the entrance training walls (or entrance breakwaters) to improve navigation. Two outer training walls were constructed between 1962 and 1965. The walls have a clear width of 150 metres and extend seaward some 380 metres from the 1960 shoreline position. The extension of the walls into deep water initially achieved the desired effect of increased navigability. However, by the 1970's the sand shoals at the river entrance had grown to an extent where navigation was once again difficult under certain wind, ocean swell and tidal conditions. Since 1960, 1.6 million cubic metres has been dredged from the lower reaches of the Tweed River and Terranora Inlet in an effort to improve the river navigation and to provide material for beach nourishment and land reclamation works. Nearly half of this was dredged in 1974/75 and placed on the southern Gold Coast beaches. Since the late 1970s navigability continued to be reduced due to the build-up of the ebb tide delta (entrance bar), to the extent that navigation over the bar was again a major problem prior to the Stage 1 dredging.

As a result of the construction of the Tweed River training walls, patterns of erosion and accretion have been altered in the region. Accretion has occurred to the south of the southern training wall, resulting in a build up of sand along the updrift beach that runs along Letitia Spit. At the same time there has been a corresponding reduction in the littoral supply of sand north of the training walls which has significantly increased the erosion along the southern Gold Coast beaches. By 1989 an estimated 7 million cubic metres of sand had accumulated on Letitia Spit, within the Tweed River and on the ebb tidal delta. A sand deficit of similar magnitude had developed on the southern Gold Coast beaches. Initially the sand deficit was observed along the subaqueous (nearshore) portions of the active beach profile. However, more visible erosion of the subaerial (onshore) portion of the beach profile became apparent during the series of cyclones that struck in 1967. By 1994, an estimated 4 million cubic metres of sand had accreted on Letitia Spit, immediately south of the southern training wall. In addition, approximately 3 million cubic metres of sand had accumulated within or seawards of the river entrance.

The coastal region of southern Queensland and northern New South Wales is subject to a moderate to high energy wave climate and exposure to infrequent intense storms or cyclones resulting in substantial dynamic changes to the beaches. Large scale erosion of the coastal zone can occur in such events. This is normally followed by a natural process of beach recovery.

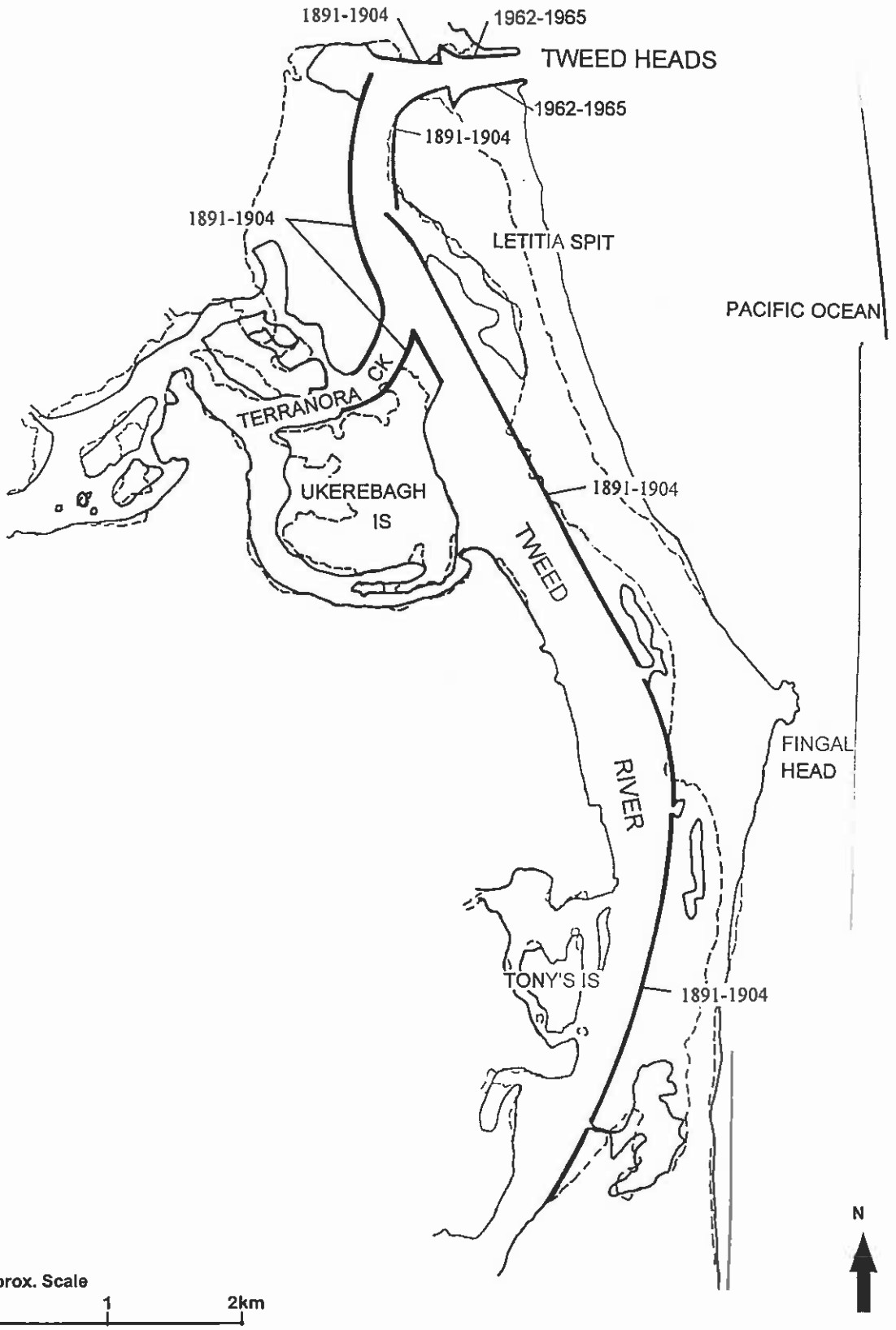


Figure 1.3.1:
Lower Tweed Estuary - Location of Training Walls

Source: Acer Wargon Chapman, 1994

In 1967 and between 1972 and 1976 the southern Gold Coast beaches were struck by a number of cyclones and severe storms in quick succession. The resulting beach degradation exacerbated the erosion problem. At Kirra, the damage was severe and natural recovery did not occur. This prompted the construction of a number of coastal protection structures. In particular, a groyne was built at Kirra Point in 1972 with the intention to trap sand and reform Coolangatta Beach. Despite associated beach nourishment this tended to concentrate erosion further to the north. In an attempt to mitigate this "sand pumping" effect, smaller groynes were then built at Miles Street, Kirra and in front of the North Kirra Clubhouse. Construction of a rock revetment seawall along this section of the coast was also undertaken to protect infrastructure and adjacent property from the continued erosion that tended to be accelerated by the combined effects of the training walls and groyne structures.

Detailed studies of the continued erosion on the southern Gold Coast beaches recognised that the ongoing problem was associated with the reduced sand supply resulting from interruption of the littoral drift through extension of the Tweed River entrance training walls. In an effort to address this shortfall, beach nourishment has been undertaken. To date there has been a total of some 8 million cubic metres of material placed on the southern Gold Coast beaches during nourishment campaigns that have taken place in 1974/75, 1985, 1988 and 1989/90 and 1995/96. In addition, erosion control structures including groynes and revetment walls were constructed. In the late 1980's, the New South Wales and Queensland State Governments commenced negotiations to pursue a permanent solution to the problems.

In 1989, a unit in NSW Public Works, now in the Department of Land and Water Conservation (DLWC) published a feasibility study examining options for improvement of the Tweed River entrance. The study involved a number of major scientific investigations dealing with regional estuarine and coastal processes. The study concluded that dredging and sand bypassing works located at the existing entrance were the preferred options.

The feasibility study recommended the preparation of a River Management Plan (RMP) for the lower Tweed estuary. The plan was completed in 1991 and provided for improvement of the estuary's many facets, including habitat, recreational amenity, fisheries, water quality, navigation and flood mitigation. A programme of dredging was proposed to achieve some of these improvements.

Dredging within the estuary itself (known as Area 5 dredging) has several objectives including removing the shoal below Barney's Point Bridge, creation of a channel adjacent to the entrance training walls and enhancement of fisheries habitats through the creation of deep holes, and shallow banks for seagrass regeneration, and is the subject of a separate EIS (WBM Oceanics, 1993). Although the dredging of the entrance bar is complementary to the estuary dredging operations, the two should be considered as separate operations.

1.3.3 Historical Dredging/Nourishment Campaigns

1.3.3.1 Dredging in the Tweed Estuary

Dredging in the lower Tweed River has been occurring for the last 100 years. Dredging has been carried out for a combination of channel and harbour capital works, channel maintenance, estuary reclamation, beach nourishment and land filling.

Dredging operations carried out include:

- an estimated 380,000 cubic metres from the entrance to Ukerebagh Island between 1915 and 1920;
- a 3 metre wide by 732 metre long channel in Terranora Creek between Ukerebagh Island and Greenbank Island to improve access for the fishing fleet; and

- extensive dredging between 1970 and 1975 to obtain sand for reclamation purposes, such as the Greenbank Island development, and for the nourishment of the southern Gold Coast beaches.

Dredging of up to approximately 920,000 cubic metres in Tony's Island Reach to remove sand shoals from the main channel downstream of Barneys Point Bridge is currently proposed as part of estuary improvement works recommended in the Lower Tweed River Management Plan.

1.3.3.2 Nourishment of the Gold Coast Beaches

A number of beach nourishment campaigns have been undertaken following the seaward extension of the Tweed River training walls and the substantial erosion of the southern Gold Coast beaches in the decade that followed (Section 1.3.2). These works which are described below were completed in an effort to mitigate the problems associated with the significantly reduced supply of sand under littoral drift.

- ***1974/75 Campaign***

The first of these campaigns was undertaken between 1974 and 1975. During this period it was estimated that in excess of 765,000 cubic metres of sand was pumped from the lower reaches of the Tweed River to the beaches at Kirra and North Kirra and updrift of the Kirra Point groyne. This work was undertaken by small cutter suction dredgers pumping with the aid of up to four booster stations via floating, submerged and overland discharge pipelines. Benefit to the downcoast beaches was short term since the sand was removed from the active flood tidal delta of the river and was relatively quickly replaced under natural processes, causing a depletion of sand to the downdrift beaches.

- ***1985 Campaign***

In 1985 a small scale offshore dredging project was implemented at North Kirra beach to restore a small section of beach and to assess the effectiveness of nearshore nourishment. An estimated 315,000 cubic metres of material was removed from compatible offshore sand reserves seaward of the 18.0 m depth contour below Australian Height Datum (AHD). This level was selected as it was considered to be located offshore of the active beach profile within which offshore/onshore movement of beach sediment is understood to occur. This material was placed on the active beach profile, an estimated 215,000 cubic metres being deposited onshore (subaerial) portion of the beach profile by pumping the material ashore and an estimated 100,000 cubic metres being deposited within the nearshore (subaqueous) portion of the beach profile by bottom dumping between the 7.0 and 10.5 m depth contours below ISLW. This work was undertaken by the trailer suction hopper dredger *Vlanderen XX* and this campaign was understood to be the first occasion that this method had been implemented in Australia. Subsequent monitoring established that the material deposited in the nearshore region was reworked onshore under wave action.

- ***1988 Campaign***

Following the successful trial in 1985 a tender was awarded in 1988 for the placement of an estimated 1.5 million cubic metres of material on the nearshore zone of Kirra Beach. Compatible material was sourced by the trailer suction hopper dredger *W H Resolution* from offshore sand reserves lying between the 20.0 and 30.0 m depth contours below ISLW. This material was deposited by bottom dumping within the nearshore zone between the 6.5 and 10.5 m depth contours (ISLW). The work was completed between the months of September to November which were considered to offer a relatively milder wave climate. Subsequent post-nourishment monitoring has established that this campaign was extremely successful. It has been demonstrated that this work served to moderate the wave attack on the onshore beach system and much of the deposited sand had reworked onshore under wave action with visible accretion along the toe of the foreshore rock revetment.

- ***1989 Demonstration***

In April 1989, a beach nourishment demonstration was undertaken at Bilinga Beach using the trailer suction hopper dredger *Sir Thomas Hiley*. An estimated 50,000 cubic metres of material was pumped some 50 m in front of the dredger by bow casting while the vessel held its position in shallow water within the nearshore zone.

- ***1989/1990 - Southern Gold Coast Beach Nourishment Project***

The Southern Gold Coast Beach Nourishment Project was undertaken in late 1989 and early 1990. This was the largest nourishment campaign undertaken to date and involved the removal and placement of an initial 2.4 million cubic metres and a subsequent additional 1.2 million cubic metres of material from compatible offshore sand reserves located between the 20.0 and 30.0 m depth contours. The material was placed over a 5 kilometre stretch of southern Gold Coast beaches on both the nearshore and onshore portions of the beach profile between Kirra Point and Toolona Street, Tugun.

The work was undertaken in two parts using trailer suction hopper dredgers. In November 1989, the *W H Resolution* removed a total of some 400,000 cubic metres of material from the inactive offshore sand sources. This material was subsequently placed on the subaqueous (nearshore) portion of the beach profile in water depths of between 5.0 and 8.0 m depth contours by bottom dumping along a stretch of beach extending from George Street, Bilinga Beach to Toolona Street, Tugun. From January to May 1990 the trailer suction hopper dredger *HAM 310* removed an estimated 3.2 million cubic metres of sandy material from the same offshore sand reserves. This material was placed on the subaerial (onshore) portion of the beach profile using the dredger's pump ashore capability, over the full 5 kilometre stretch of beach indicated above. A detailed monitoring program was set up prior to and following the completion of this project to assess the behaviour and effectiveness of the nourishment works and to provide an improved understanding of the coastal processes in the area. The monitoring program comprised collection of pre and post-nourishment data that incorporated hydrographic and topographic surveys, aerial photography, sediment sampling, wave data (height and period) and nearshore current measurements. The results to date of this monitoring program have indicated that this project has been relatively successful in mitigating the erosion potential of the southern Gold Coast beaches. Monitoring carried out two years after the completion of the nearshore nourishment work demonstrated that almost 90% of the nourished material still remained within the original nourishment region and there was movement of nourishment material both onshore and to the north since placement. However, it was also noted that significant erosion had occurred at the southern section of the nourished area adjacent to the Miles Street groyne on the northern downdrift side of the groyne.

- ***1995/96 Tweed River Entrance Sand Bypassing Project - Stage 1(A)***

Following a program of community consultation and environmental studies in 1994, a contract was awarded as part of Stage 1(A) of the Tweed River Entrance Sand Bypassing Project for conventional dredging of the Tweed River bar and beach nourishment.

The Stage 1(A) dredging and nourishment campaign began on 26 April, 1995 and extended through 20 August, 1996. The purpose of the campaign was initially to remove over 1.7 million cubic metres of sediment from the Tweed River Entrance bar (this amount increased to 2.25 million m^3) and place it nearshore and subaerially along the southern Gold Coast beaches (Figure 1.3.2). The dredging contract was awarded to Dredeco Pty Ltd. Three trailer suction hopper dredges were utilised: the *Pearl River*, *Ngamotu* and *Krankeloon*.

The *Pearl River*, the largest dredge of its kind in the world, dredged the deeper portions of Compartment 3 where its draught of 10.4m would not be a problem. Between 26 April and 2 June 1995, the vessel removed approximately 1.5 million m^3 of sediment from Compartment 3 and deposited it in the Outer Nearshore Deposition Area and along the upper beach areas of the southern Gold Coast beaches. Bottom opening doors allowed placement of material in the Outer Nearshore, while placement along the beaches was accomplished through a 900m long, 1 metre diameter submerged pipeline.

The *Ngamotu*, a much smaller dredge capable of working in the shallower portions of the Entrance Bar and channel (Compartments 1, 2 & 3), began operations on 3 May, 1995. By 16 November the vessel had removed 160 000m^3, clearing a navigation channel 200 m wide to a depth of approximately RL -7m AHD. The dredged material was placed by bottom dumping in the Inner Nearshore Deposition Area.

Between 7 January and 18 February 1996, the *Krankeloon* removed approximately 260 000 m^3 of material from the Entrance Bar (Compartments 1 & 2) which was progressively dumped in both the Outer and Inner Nearshore Deposition Areas. This resulted in entrance bar depths ranging from between RL -7m to RL-15m AHD.

Partially as a response to stormy conditions and rapid infilling of the entrance bar channel during February and May of 1996, further dredging of portions of the entrance bar and channel was undertaken. The *Krankeloon* returned and between 22 July and 20 August, 300 000m^3 was dredged from a newly defined area of the Tweed entrance bar (Figure 1.3.3). This material was placed in the Outer and Inner Nearshore Deposition areas and also at Snapper Rocks.

The work carried out under Stage 1(A) has been successful in temporarily improving navigation at the Tweed River entrance and nourishing the southern Gold Coast beaches. However, the channel may be expected to shoal and the beaches may be expected to erode unless a system of continuous sand bypassing is achieved.

The table below summarises the quantities delivered by the Stage 1A dredging and nourishment works and their relationship to the Deed quantities.

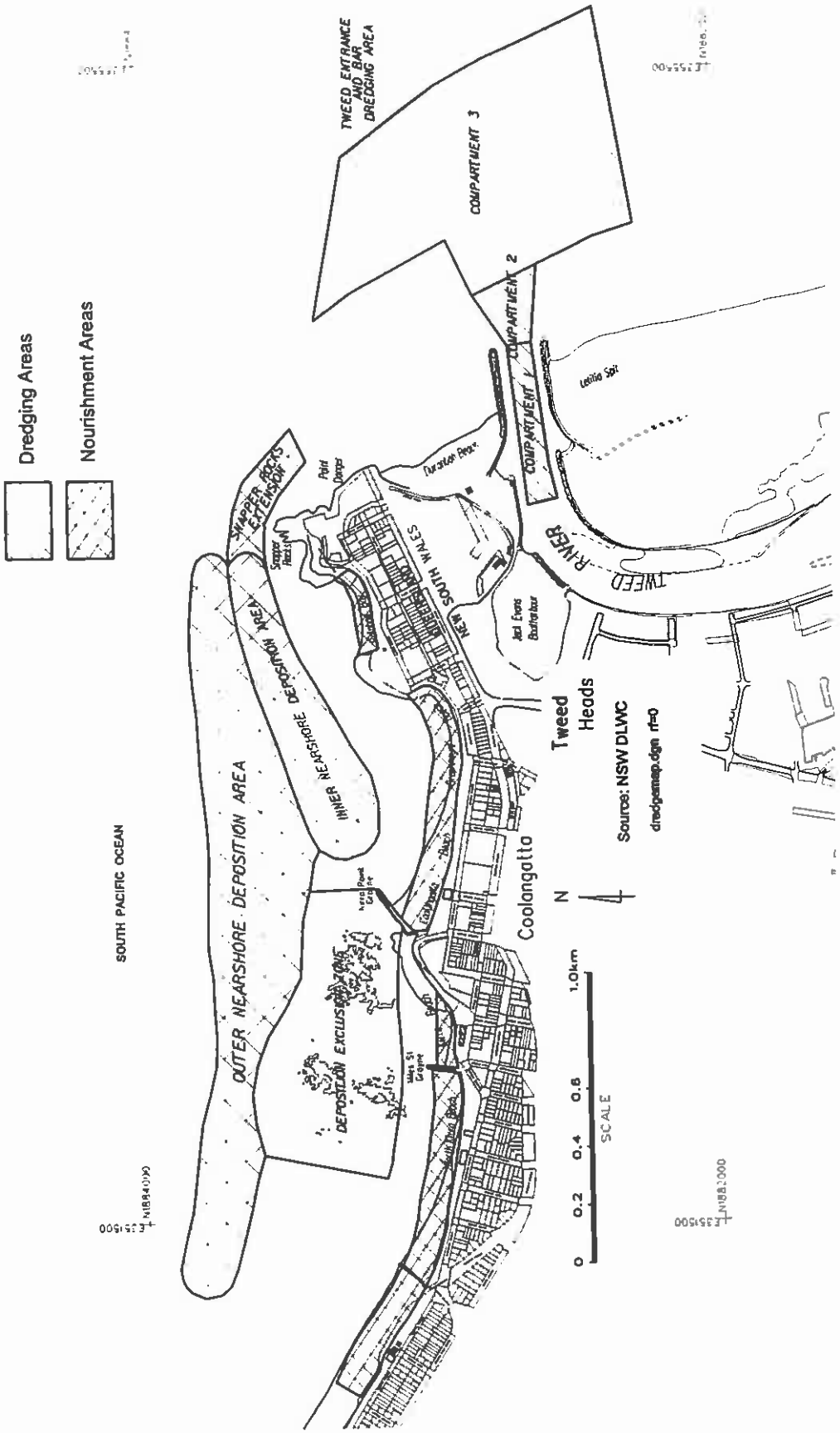


Figure 1.3.2
Stage 1(A) Dredging and Nourishment Layout

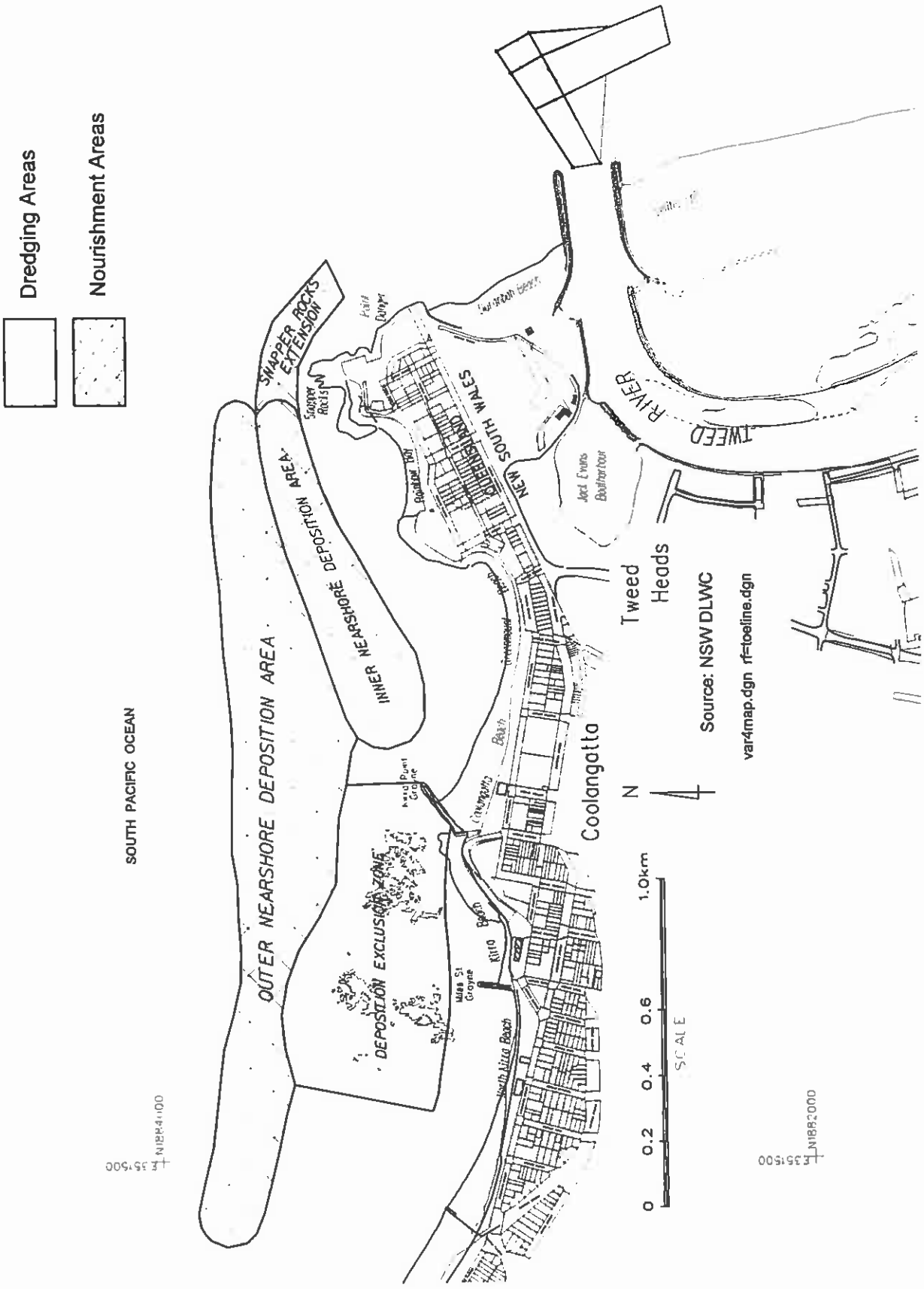


Figure 1.3.3
Stage 1(A) Revised Dredging and Nourishment Layout
(22 July – 20 August, 1996)

Table 1.3.1 Stage 1A Dredging and Nourishment Works

COMPONENT	QUANTITY AS PER DEED AS AT 20/8/96 (cubic metres)	QUANTITY PROVIDED (cubic metres) (based on hopper measurements)	REMAINING QUANTITY AS AT 20/8/96
Initial Dredging Component	2,000,000	1,747,142	252,858
Supplementary Increment Part A	550,000	500,000	50,000
Supplementary Increment Part B	376,454 (Accruing at 500,000 per annum since 19/11/95)	Nil	376,454
Annual Increment	Nil (does not commence until start of Permanent System)	Nil	Nil
Total to 20/8/96	2,926,454	2,247,142	679,720

1.4 Transitional Arrangements Before Construction and Operation of the Permanent Sand Bypassing System

Further supplementary dredging and nourishment may be needed as a transitional arrangement between Stage 1 works before the permanent sand bypassing system (Stage 2) is commissioned. This may be achieved by some of the systems described in this EIS/IAS. The environmental impacts associated with supplementary dredging and nourishment will be similar to those outlined in the Stage 1 EIS/IAS (Acer Wargon Chapman, 1994).

1.5 The Need for Action

Implementation of the proposed permanent sand bypassing and nourishment works is expected to provide a broad range of benefits to the local region.

The continuous removal and bypassing of sand from the Tweed River entrance bar would result in improvement to safety and navigability of the existing entrance. Improved safety would reduce the risk of injury or loss of life to crew and passengers negotiating the entrance bar, and reduce the strain of emergency services. Maintenance of safe access to the river would benefit the local fishing industry and encourage development of other local businesses and the tourist industry. A clear entrance channel may also assist with tidal flushing of the estuary and help maintain good water quality within the estuary.

Nourishment of the southern Gold Coast beaches has provided an increased buffer against storm erosion and substantially improve the existing beach amenity. The proposed works would be aimed at restoring the amenity of the beaches to their condition prior to extension of the Tweed entrance breakwaters. This would assist in improving surfing in an area internationally recognised for the high quality of surf. The nourishment would also improve swimming conditions and beach safety. Improvement of the beach amenity and conditions would also encourage future growth of the local tourist industry.

The local economy of Tweed Heads/Coolangatta would be expected to benefit as a result of the flow-on effect from improvement to the tourist and fishing industries. Benefits could include increased employment, financial and social benefits for the community as a whole.

The consequences of not undertaking the project would be a worsening of the navigation and safety at the Tweed River entrance and loss of the re-established amenity of the southern Gold Coast beaches.

Continual and progressive shoaling at the river entrance would further restrict the operations of the local fishing and tourist industries whose operations are controlled by the condition of the entrance bar. Rescue services would also be placed under additional pressure during periods of bad weather or bar conditions. The reduced tidal flushing of the estuary may be expected to be associated with reduced water quality in the Tweed River.

Deterioration of beach amenity and surf quality would be anticipated with continual erosion of the southern Gold Coast beaches. A flow-on from this may be restricted growth of the local tourist industry as the beaches are a major attraction of the area.

1.6 Structure of this Document

To assist the reader to locate items of interest, the following brief overview of each chapter of the document is provided, indicating its purpose and coverage.

Chapter 2, State Planning and Approval Processes. This chapter outlines the process involved in approving the project in both New South Wales and Queensland. Planning guidelines and approvals are detailed in this section.

Chapter 3, Community Consultation. This chapter discusses the ways in which the public, Authorities and organisations have been informed of the project. Their input has been considered in the definition of the project and the environmental impact assessment.

Chapter 4, Existing Environment. A description of the characteristics of the physical, ecological and social environment which are potentially affected by the proposed works or which may influence the effects of the proposal.

Chapter 5, The Proposal. Details of the proposal are outlined, including the location and extent of works and the location of sand removal and placement areas. Operational details such as efficiency, personnel requirements, maintenance and power supply are also detailed. Alternative plant and equipment options for the permanent sand bypassing system are outlined.

Chapter 6, Alternatives to the Proposal. Alternatives to the permanent bypassing system are presented. These include the "Do Nothing" option and other non-system options.

Chapter 7, The Environmental Impacts. The potential impacts of the proposal on the physical, ecological and socio-economic environment are assessed.

Chapter 8, Environmental Management. Carrying out the project will require provision of a range of environmental safeguards to ensure that the effects on the environment are suitably controlled. In addition, certain aspects will need to be monitored. These provisions, which will form part of the environmental management plan to be prepared, are described in this section.

Chapter 9, Conclusion This chapter summaries the potential impact on the physical ecological and socio-economic environment and the likely benefits of the project. The implications of not proceeding with the project are also examined.

References. A list of the materials referred to in this document is provided. These may be made available for inspection by the reader seeking further information.

Glossary and Abbreviations. A glossary of the terminology and list of abbreviations used specific to the project is provided to assist the reader in understanding the document.

Chapter 2

State Planning & Approval Processes

Chapter 2

State Planning & Approval Processes

This chapter outlines the processes of approval involved in this particular Environmental Impact Statement/Impact Assessment Study and planning guidelines including issues raised in consultation with Authorities.

2.1 Overview

The project involves dredging to be carried out in New South Wales (NSW) and beach nourishment in Queensland, and is therefore under the jurisdiction of legislation of both the respective States.

In terms of the respective legislation, the project activities are classified as "likely to significantly affect the environment" (NSW) and "works likely to have major environmental effects" (Queensland), and therefore an Environmental Impact Statement (EIS) is required in NSW and an Impact Assessment Study (IAS) is required in Queensland.

The procedures for preparation and determination vary between NSW and Queensland, and these are outlined in Sections 2.2 and 2.3, respectively.

The process from identification of need for an EIS through to public display (NSW) and final decision-making is illustrated in Figure 2.1.1. Figure 2.1.1 indicates the differences between the NSW and Queensland planning and approval processes. Planning and approval processes for each state will have to be satisfied before the project can proceed.

This EIS/IAS will be advertised and placed on public display at various centres in the study area. Copies will be available for sale to the public from the NSW Department of Land and Water Conservation and the Queensland Department of Environment. During the display period, written representations can be made to either authority.

2.2 New South Wales

The proposed dredging and nourishment works are covered by sections 10(2) and (3) of the *Tweed River Entrance Sand Bypassing Act 1995,* the works do not require development consent and are subject to Part V of the *Environmental Planning and Assessment Act 1979 (EP&A Act)*. Since the works are considered likely to have a significant effect on the environment, the preparation of an Environmental Impact Statement (EIS) (this document) is required.

In NSW, the proponent and nominated Determining Authority is the Minister for Land and Water Conservation. The Department of Urban Affairs and Planning (DUAP) have produced Director's Requirements for the preparation of the EIS (Appendix A). The Director's Requirements details specific requirements for the EIS and outline Authorities which need to be contacted as part of the EIS process. Comments and requirements which arose as a result of this consultation in relation to the proposed works are summarised in Appendix D.

Section 5A of the NSW *EP&A Act* also defines the process of assessing impact on any threatened species, populations or communities or their habitats as a result of the proposed works in terms of an 'eight point test'. If the works are determined as having a significant effect as a result of this test then a

Species Impact Statement (SIS) must be prepared in accordance with Division 2 of Part 6 of the NSW *Threatened Species Conservation Act 1995*.

2.3 Queensland

The nourishment works in Queensland are considered to be "public works" as defined in the *State Development and Public Works Organisation Act 1971-1981 (SD & PWO Act)*. The works are therefore covered by the provisions of "Impact Assessment in Queensland: Policies and Administration Arrangements", which outlines the consideration of impact through to the process of creating an IAS. In accordance with the provisions of the *SD & PWO Act*, and associated policies and administrative arrangements, the Queensland Department of Environment (DoE) has assessed that the project is "likely to have major environmental effects", and consequently requires an IAS. After consultation with other "Advisory Bodies", DoE produced Terms of Reference/Guidelines (TOR) for the preparation of the IAS (Appendix B). The final IAS is considered by DoE, the Responsible Authority and relevant Advisory Bodies, before the activity can be approved, approved with conditions or disapproved.

Exhibition procedures for Queensland are similar to NSW requirements, as outlined in Section 2.1.

2.4 Statutory Planning, Permits and Guidelines

This project is influenced by statutory planning mechanisms at local, regional and state level, which vary between the states. Table 2.4.1 compares the relevant instruments for NSW and Queensland. Achievement of the project involves the cooperation of the Queensland and NSW State Governments plus the local authorities of Tweed Shire Council and Gold Coast City Council.

Table 2.4.1 Planning Instruments - NSW and Queensland

	NSW	QLD
Level of Instrument	***Planning Instrument/Mechanism***	***Planning Instrument/Mechanism***
STATE	*EP&A Act* (Part V) 1979 *Tweed River Entrance Sand Bypassing Act, 1995* SEPP No. 14 - Coastal Wetlands SEPP No. 26 - Littoral Rainforests	*State Development and Public Works Organisation Act 1971-81* (Subsection 2 of Section 29) *Beach Protection Act* (Section 47) *Harbours Act* (Section 86)
REGIONAL	North Coast Regional Environmental Plan, 1988	SEQ 2001 Regional Framework for Growth Management 1995
LOCAL	Tweed Local Environmental Plan, 1987 Draft Tweed Shire Strategic Plan, 1996	City of Gold Coast Planning Scheme 1994 Coastal Management Plan for the City of Gold Coast

Planning legislation includes State Environmental Planning Policies (SEPPs) which aim to conserve areas of environmental significance in NSW. Within the study area are areas listed under both SEPP 14 - Coastal Wetlands and SEPP 26 - Littoral Rainforests. The requirements of these two SEPPs is that an EIS be prepared to assess any potential disturbance of these areas. In this particular stage of the project which involves construction and operation of a permanent sand bypassing system, SEPP 35 -Maintenance Dredging of Tidal Waterways does not apply since the works are not defined by the proponent as maintenance dredging.

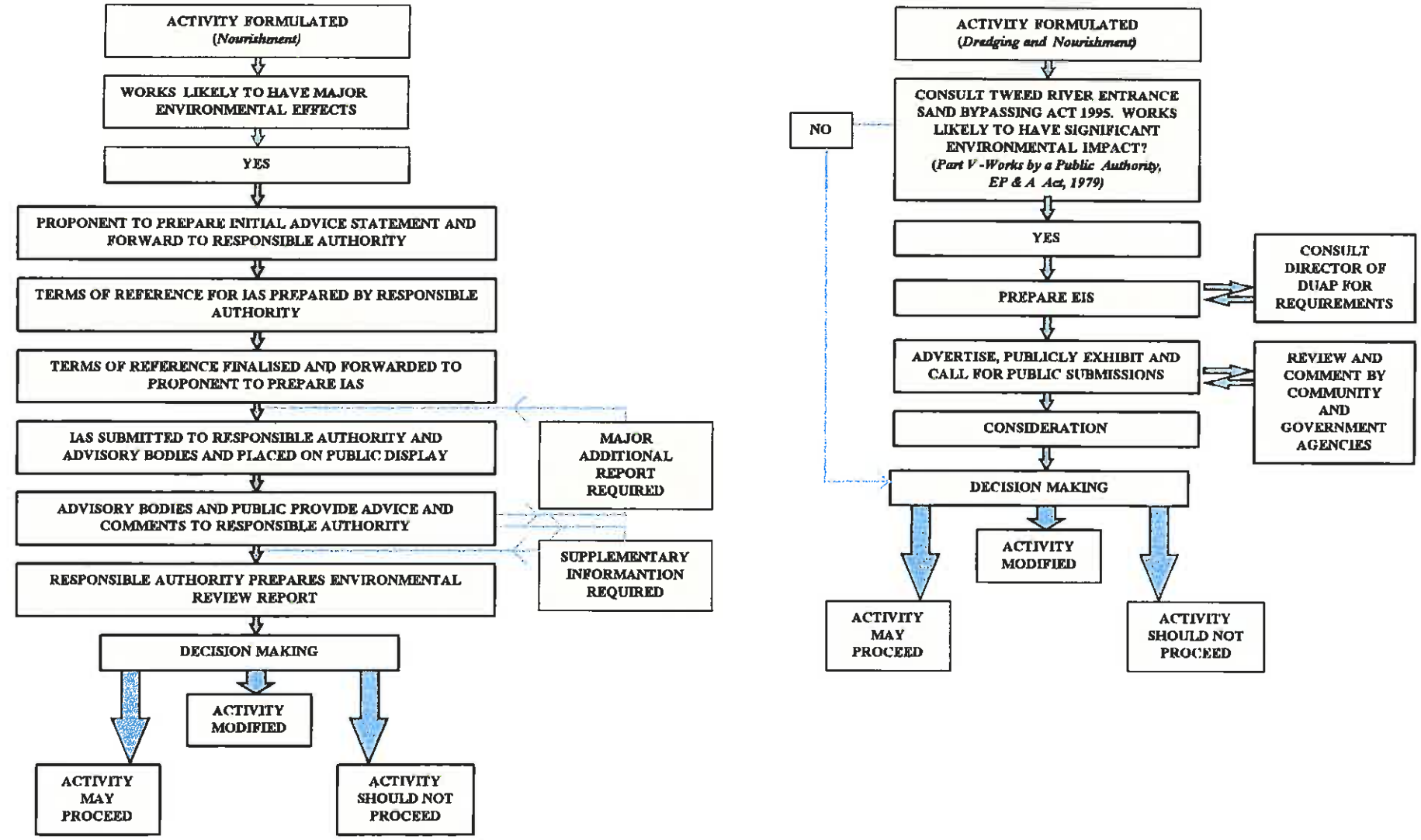


Figure 2.1.1: Statutory Processes in New South Wales and Queensland

The Queensland Beach Protection Authority's Buffer Zone Policy states that 'the provision and proper management of development free and adequately sized buffer zones are the most effective means of protection against the loss of Queensland beaches.' The Authority supports this policy through its educational programme and through its approvals power defined under the *Beach Protection Act.*

At the southern Gold Coast the Authority has declared a Coastal Management Control District No. 11. The Control District includes onshore areas that the Authority considers are vulnerable to erosion from tidal waters within the next fifty years and extends offshore a distance of 80 chains (approximately 1600m) from the low water mark. The Authority's Policy statement on the management of buffer zones recommends the use of beach nourishment as the most effective engineering solution to assist in protecting the buffer zone.

In addition to its general policy the Queensland Beach Protection Authority and the Gold Coast City Council have adopted a Coastal Management Plan for the Gold Coast area. This plan details the proposed scheme of works to support the Authority's general policy. The plan specifically identifies beach nourishment of southern Gold Coast beaches using sand from within the entrance area of the Tweed River.

The intent of the permanent sand bypassing system is therefore totally consistent with both the Authority's general Buffer Zone Policy and the Coastal Management Plan for the Gold Coast.

Several permits may be required from particular public authorities. The following authorities will need to be approached prior to the commencement of works.

(i) NSW Department of Land and Water Conservation (DLWC)

The Department must meet its obligations in accordance with the *EP&A Act 1979* (Clause 91). In addition to being the Determining Authority, the Minister is responsible for administering the *Crown Lands Act 1989*, which requires consent to any proposed occupation of Crown land. However, providing no material is removed from the coastal system and the prior consent of the Minister is obtained, no licence for sand extraction is required.

Should an onshore pipeline be selected as the preferred option, details will need to be submitted to DLWC for consideration of the need to issue a lease licence or easement.

The proposal works may require formal concurrence by the Minister in accordance with the *Coastal Protection Regulation 1979*, under the *Coastal Protection Act 1979.*

A permit may be required for excavation under the *Rivers and Foreshores Improvement Act, 1948.* The Fingal area is the subject of land claims under the *Aboriginal Lands Rights Act 1983* and under the *Commonwealth Native Title Act 1993.*

(ii) NSW Environment Protection Authority (EPA)

The dredging operation may require an approval from the NSW EPA under Section 17 of the NSW *Pollution Control Act 1970.*

An approval under the *Pollution Control Act 1970* will only be required from the EPA if the proposed dredging will involve the installation of ponds or other pollution control equipment for the treatment of wastewater.

A licence may be required under the NSW *Clean Waters Act 1970* for the discharge of dredge wastewaters.

(iii) NSW Fisheries

Under Part 7 of the NSW *Fisheries Management Act 1994,* the consent of the Minister for Natural Resources must be obtained for dredging work and the Tweed Shire Council must be notified.

(iv) Heritage Council of NSW

Under Section 140 of the NSW *Heritage Act 1977,* if any disturbance of archaeological relics, or a site known to or suspected to contain relics protected by the Act is proposed, an excavation permit must be obtained from the Heritage Council.

(v) NSW Department of Urban Affairs and Planning

Under Section 15 of the NSW *Historic Shipwrecks Act 1976,* a permit must be obtained to disturb a protected historic shipwreck from the Director-General of the Department of Urban Affairs and Planning.

(vi) Queensland Beach Protection Authority

The proposed works on the southern Gold Coast occur within Coastal Management Control District No. 11. Pursuant to Section 47(1A) of the Queensland *Beach Protection Act 1968-90* any works which interfere with sand or gravel within the Control District require a permit from the Authority. A permit for beach nourishment works as part of this project has been issued and include conditions relating to the quality and composition of sand and to dune management works which may be required upon completion of the works. Any structures such as pipelines or outlets structures, will also require approval under the Act. Approval for the works would be issued by the Gold Coast City Council in its role as manager of the beach area.

(vii) Queensland Department of Environment (DoE)

Should any area of the site below the mean high water mark (spring tides) be filled and/or any structures into the waterways proposed, an application to the DoE must be made pursuant to the provisions of Section 86 of the Queensland *Harbours Act.* A permit is required under the *Cultural Record (Landscapes & Queensland Estate) Act 1987* to undertake a programme of archaeological monitoring during construction work (Sections 8.3.9 and 8.3.10).

(viii) Queensland Department of Primary Industries - Southern Fisheries Centre

In the event of damage or disturbance of marine plants (ie, Kirra Reef) authorisation would be required in accordance with Section 51 of the Queensland *Fisheries Act 1994.*

(ix) Queensland Department of Mines and Energy

If mineral sand were to be won or processed in the state of Queensland a Mining Lease would be required under the Queensland *Mineral Resources Act 1989.*

(x) Gold Coast City Council

Installation of pipelines, booster stations and outlet structures within the City of Gold Coast boundaries would require specific Town Planning approval and certification of engineering drawings.

Several authorities have outlined guidelines to be followed during and prior to works:

(i) NSW Environment Protection Authority (EPA)

Conditions in relation to water, air and noise pollution control associated with dredging works.

(a) Water pollution control-impact on water quality minimised by detention or treatment of wastewater prior to discharge.

(b) Air pollution control - measures to mitigate dust if stockpiling sand. Impact of construction and operation phases.

(c) Noise pollution control - noise impacts of construction and operation phases.

(ii) Waterways Authority (WA) (NSW), formerly Maritime Services Board.

Requires inspection by a WA officer prior to operation and has set several conditions to be observed during dredging:

(a) day marks and lights to clearly mark dredge and pump lines;

(b) due to the environmental conditions in the area, the operators of the dredge must have oil spill response equipment on site sufficient to cope with the fuel load of the dredge; and

(c) the dredge, markings and oil spill response equipment to be the subject of an on-site inspection by an WA officer prior to operation of the dredge.

(iii) Queensland DoE

(a) *Environment Protection Act* and current drafts of the Noise, Air, Water and Waste Environment Protection Policies;

(b) Preparation of an Environmental Management Plan (EMP) requires long term monitoring of beach profiles, wave action and the entrance of the Tweed River to ensure the objectives of the project are being met; and

(c) Consideration should be given to the possible decommissioning of the system if the system became ineffective and the potential impacts associated with the replacement of the system.

A detailed description of Authority Consultation is outlined in Appendix D.

Chapter 3

Community Consultation

Chapter 3

Community Consultation

This chapter outlines the continual programme of consultation with community organisations and businesses which has occurred in relation to the project. Consultation has involved public advertisement of the proposal, newsletters, public meetings, establishment of a telephone information line and distribution of letters seeking comment from local organisations and community groups.

A wide range of community consultation has been undertaken in relation to the Tweed River Entrance Sand Bypassing Project. In NSW, the long-standing Tweed Entrance Community Liaison Committee has wide community representation including both NSW and Queensland interests. Through an extensive community consultation process the Committee steered the original 'Reviving the Tweed' study (Public Works, 1990) and later the 'River Management Plan' (Public Works, 1991b). This committee was the forerunner for the system of estuary management committees now widely used in NSW for management of its 130 estuaries. The process has been formalised in the 'Estuary Management Manual' (NSW Government, 1992). In Queensland, community consultation occurred during the various beach nourishment projects carried out from 1985 to 1990

Continual community input throughout the various stages of the Tweed River Entrance Sand Bypassing Project is recognised to be important. The Advisory Committee which was formed as part of the Heads of Agreement has been established and comprises of four community representatives, one representative from each local authority, and two officers from each State. This committee was established by the two Ministers in September 1994, and provides and facilitates a two-way dialogue with the community on relevant aspects including environmental impact assessment, monitoring and programming of activities.

The Stage 1 EIS (Acer Wargon Chapman, 1994) involved a programme of community consultation commencing in mid-1994 which was designed to gauge local public opinion and incorporate local concerns into the EIS/IAS. This was followed by a public exhibition of the document in November 1994 and a further public meeting. Additional comments from the community and interested groups were incorporated in the implementation of the works.

During the implementation of Stage 1A, the community was kept informed through information leaflets, media releases and an on-site information office which was visited by over 20,000 people (McGrath and Collins, "Tweed River Entrance Sand Bypassing Project Information Office", NSW Coastal Conference, 1995).

For Stage 2 a similar community consultation program was undertaken. Comments on the proposed permanent sand bypassing system and nourishment operations were initially sought from the local community in June 1996 through local newspaper advertisements and posters at public locations.

A public meeting was held at Tweed Heads Civic and Cultural Centre on 31 July, 1996 attended by approximately 40 people including local residents, Councillors, fishermen, surfing community representatives, local media and representatives from local businesses. At the meeting, members of the Study Team formally introduced the project and answered questions.

A dedicated telephone line at Hyder Consulting's (formerly Acer Wargon Chapman) Gold Coast office was arranged to assist members of the community with comments and queries in relation to the proposal. Comments from each caller were recorded. During the period of the Stage 2, study twelve calls and ten written submissions were received.

Meetings were also held with the Tweed Byron Local Aboriginal Land Council (TBLALC) and Pooningbah Aboriginal Community. The meetings were called to discuss the proposal in relation to issues specific to the local aboriginal community and also to discuss issues relating to the local community in general.

The following community organisations and business associations were contacted during the course of the study:

(i) Queensland Commercial Fishermen's Organisation (QCFO);
(ii) Sunfish - Queensland Sport and Recreational Fishing Council;
(iii) NSW Surf Lifesaving Association;
(iv) Point Danger Surf Life Saving ;
(v) Queensland Surf Lifesaving Association;
(vi) Air Sea Rescue;
(vii) Surfrider Foundation Australia;
(viii) Snapper Rocks Surfriders Club;
(ix) NSW Commercial Fishers Regional Industry Convenor (formerly NSW Commercial Fishing Advisory Council);
(x) Nature Conservation Council of NSW;
(xi) Kirra Boardriders Club;
(xii) Tyalgum Fishing Club;
(xiii) Murwillumbah Services Fishing Club;
(xiv) Coast and Wetlands Society Inc;
(xv) Australian Marine Conservation Foundation (formerly Australian Littoral Society) ;
(xvi) Coastal Solutions;
(xvii) Caldera Environment Centre;
(xviii) Wildlife Preservation Society of Queensland - Gold Coast and Hinterland Branch;
(xix) Gold Coast and Hinterland Environment Council;
(xx) North Coast Environment Council Inc;
(xxi) Tweed Heads Amateur Fishing Club;
(xxii) Tweed Heads - Coolangatta Professional Fishermen's Association;
(xxiii) Ocean Watch Pty Ltd;
(xxiv) Tweed River Management Plan Advisory Committee;
(xxv) Tweed River Entrance Community Liaison Committee;
(xxvi) Southern Gold Coast Chamber of Commerce;
(xxvii) Twin Towns Services Club Fishing Club;
(xxviii) Tweed Dive;
(xxix) FAIRA (Foundation for Aboriginal & Islander Research Action);
(xxx) Gold Coast Environment Centre;
(xxxi) Fingal Community;
(xxxii) Pooningbah Aboriginal Community;
(xxxiii) Tweed Byron Local Aboriginal Land Council;
(xxxiv) Kingscliff Fishing Club; and
(xxxv) Fingal Progress Association.

The response from the community in both the Stage 1 and 2 community consultation programmes indicates very strong support for the project with a preference for a fixed structural option and commencement in the shortest feasible time frame. The range of comments expressed were diverse with quality of surf, impacts on the local fishing industry and beach amenity seen as major issues of interest.

Specific matters raised in the Stage 1 and 2 consultation programmes included:

- The nature of the permanent sand bypass system including aesthetics and safety measures.
- Possible loss of sand offshore near Point Danger and Dreamtime Beach.
- The incorporation of a number of outlets at different beaches in a permanent sand bypass system specifically at Duranbah, Snapper Rocks and Kirra Point.
- Impact on Tweed River ecosystems:
  a. increased movement of seawater upstream may result in the displacement of mangrove populations further upstream;
  b. reduction of seagrasses as a result of unencumbered movement of water;
  c. reduction in the extent of valuable saltmarsh areas as a result of changing tidal regime and consequent mangrove invasion; and
  d. impact on lakes, lagoons and wetlands.
- Build up of debris or coarse grained at the immediate deposition zone.
- Impact on migratory birds which frequent Letitia Spit.
- Inclusion of Indigenous issues.

Specific matters raised in Stage 1 consultation included:

- Details of estuarine and marine processes.
- Seasonal effects on dredging and nourishment operations.
- Results of previous beach nourishment campaigns on the southern Gold Coast beaches.
- Effects on the local fishing industry from possible covering of reefs offshore from the southern Gold Coast beaches.
- Possibility of a new outlet for the Tweed River at Greenmount Beach.
- Effect of dredging on the ecology of Cook Island.
- Effect of dredging at Letitia Spit on beachworms.
- Potential improvement to the local economy from increased use of the Tweed estuary by recreational craft such as ocean going vessels.
- Effect of increased tidal ranges on proposed improvements by Tweed Shire Council on wetland areas in the Tweed Estuary.

Specific matters raised in Stage 2 consultation included:

- Possible traffic congestion and need for traffic calming devices in the Fingal area, and the need for the existing road to be sealed and gazetted.
- The source of electricity for the bypass plant and the suggestion that electricity supply lines be placed underground. The effect on power supply to the existing community at Fingal was also raised.
- Effect of recession of Letitia Spit on the ecology and local community at Fingal.
- Beach stability during cyclone events at Letitia Spit, Duranbah and the southern Gold Coast beaches.
- Effect of possible increased turbidity from dredging on the oyster industry and tourist activities such as diving.
- Direct impacts on fish catches.
- Gaining safe access for all vessels, in particular fishing vessels since many days of fishing are lost as a result of unsafe conditions at the bar. This also affects the operation of commercial activities such as dive tours, etc.
- Navigation conditions at the Tweed River entrance have generally improved access for fishing vessels since Stage 1A works.

- Recreational fishing has improved at the discharge points associated with the Gold Coast Seaway.
- Allowing public access to structures such as jetties for fishing, should this option be implemented. Provision of adequate parking and lighting in these areas.
- Effect on mullet catches and suggestion that works should not take place during the mullet season (May - June annually) since works could impact on this valuable fishery.
- Adequate assessment of the opportunity to improve the local surfing conditions.
- Access to the beaches during construction and operation should not be lost.
- Local employment opportunities should be assessed.

Chapter 4

The Existing Environment

Chapter 4

The Existing Environment

This chapter provides a detailed description of the existing physical , ecological, cultural and socio-economic environment both in the region of the dredging and nourishment works and in the surrounding regions, in order to serve as a baseline against which the impacts of the proposal can be assessed. The physical environment is first addressed in a regional context, followed by a more detailed account of the hydrodynamics and coastal processes along the southern Gold Coast Beaches and the entrance bar of the Tweed River and within the Tweed River Estuary. The existing ecological environment is described in terms of terrestrial, marine and estuarine ecology. The cultural environment is separated into indigenous and non-indigenous heritage and the socio-economic environment which considers business, recreation and tourism in the Tweed and Gold Coast regions.

4.1 Physical Environment

4.1.1 Regional Context

The study area is located on the NSW/Queensland border in the Tweed Shire in NSW and Albert Shire and Gold Coast City in Queensland. Tweed Heads is located on the Pacific Highway 900 km north of Sydney and 105 km south of Brisbane. Tweed Heads is the twin town to Coolangatta. Both towns are popular coastal resorts noted for being at the southern end of over 42 km of popular surfing beaches known as the Gold Coast which stretch up to South Stradbroke Island.

The area is unique from an ecological perspective as it is at the boundary between the temperate and subtropical zones resulting in a diverse terrestrial and marine flora and fauna. The diversity of terrestrial vertebrates is much higher than that found on most of the Australian landmass (Pressey and Griffith, 1992) and there is a relatively high number of rare or threatened species in both a national and state context.

Archaeological evidence indicates that Aboriginal people lived along this coastline possibly dating back as far as 9000 years B.P. Tweed Heads was named in 1823 by John Oxley after the River Tweed in Scotland. Coolangatta was named after a ship wrecked on the coast in the 1840s and is Aboriginal for "beautiful place". The first European settlers harvested timber building up a thriving cedar trade between 1850-1870. As the cedar reserves declined the settlers switched to cash crops such as maize and sugar. From the 1890s dairying became a profitable alternative but by the early twentieth century tropical fruits had emerged as the main cash crop export. All these industries required efficient transport to get raw material to factories or products to market, and in the absence of rail and road transport, sea transport via large steamers and other craft was vital to getting goods to the major coastal cities of Sydney and Brisbane.

As the use of the river by commercial vessels increased, so did local demands for navigational improvement works. Construction of training walls and dredging works at the Tweed Entrance commenced in 1891. These works provided short-term improvement. Groynes were built in the early 1970s at Kirra Point, Miles Street and in front of the North Kirra Clubhouse to try and control serious erosion problems on this section of coast together with a rock revetment seawall to protect property (Section 1.3.2).

Today, the physical environment is dominated by a well established commercial/residential sector which is growing partly from the influx of tourists to the area each year and partly because Tweed Heads has

become a popular retirement spot. There has been continued growth in urban areas and coastal villages, particularly in people aged 65 and over, which comprise the largest group in the Tweed Shire (Tweed Shire Council, 1995). The Tweed River, beaches and climate are major attractions for recreation, tourism and fishing (both commercial and recreational) which together form the dominant part of the economy in the region.

4.1.2 Surface Topography and Drainage

The Tweed River is the main drainage basin in the study area. It is located at the north-eastern corner of the Tweed Shire. The basin was formed 20 million years ago by the eruption and erosion of the Mt Warning shield volcano and comprises the largest caldera (large basin-shaped crater) in the southern hemisphere. The steep rim of the caldera surrounds Mt Warning at a radius of approximately 15 km. The eastern side of the rim has been cut by the Tweed River, whose tributaries have carved out the caldera (Tweed Shire Council, 1995b). The basin is bounded by the McPherson Range to the north, Tweed Range to the west and Nightcap Range to the south.

There are a number of major waterways within the Gold Coast City area, however only Coolangatta Creek lies within the study area. The mouth of Coolangatta Creek is located immediately south of the Surf Club at North Kirra. Coolangatta Creek is categorised somewhere between the 'flooding' and 'stormwater drainage' categories (Gold Coast City Council, 1991). A box culvert is located at the mouth of the creek at Kirra Beach which acts primarily as a stormwater outlet.

The topography of the study area is characterised by a low lying coastal plain with elevation of about 6m AHD. Much of the lower Tweed catchment is relatively flat with slopes of less than 3%, and is subsequently prone to episodes of flooding (Tweed Shire Council, 1987). There are significant localised areas of higher relief formed by outcrops of volcanic rock. The most prominent being Mt Warning at 1156m. Mount Murrabah (81m) and Toongarabah (84m) project from the coastal plain behind the business district of Coolangatta/Tweed Heads.

The Tweed/Gold Coast beaches are part of a broader regional coastal system of beaches, streams and nearshore oceanographic and sedimentation influences. The present coastal sand landforms have evolved over the last 6,500 years of sea level stillstand, following the major post-glacial transgressive sea level rise which occurred over the period 17,000 to 6,500 years before present. Apart from the prominent ocean headlands and associated ridge systems at Coolangatta, the area is generally flat to undulating, consisting of sand dunes and floodplains of streams over ancient ocean beds (Gold Coast City Council, 1991).

Tweed Heads is located at the mouth of the Tweed River. The river forms the southern boundary of the Tweed Heads township and flows to the sea immediately south of Point Danger, close to the NSW/Queensland border.

The main arm of the Tweed River has a length of about 40 km. The total catchment area, together with its various tributary systems, comprises an area of approximately 1100 km^2. Upstream of Murwillumbah the drainage pattern of minor tributaries is generally symmetrical due to the volcanic origin of the valley. Downstream of Murwillumbah the river winds through extensive floodplains (Tweed Shire Council, 1995b).

As outlined in Section 1.3.2, the Tweed River entrance has a clear width of about 150 metres between the training walls. Immediately upstream of the mouth, the river is controlled by revetments and is generally about 200-250 metres wide and up to 8 metres deep. It is somewhat wider near Fingal and Chinderah and becomes progressively narrower with distance further upstream. Near Murwillumbah, it is typically 120-140 metres wide while the depth is generally less than 2-3 metres except in local areas of the town reach where flow and associated flood flow scour has caused deeper water.

Tributaries to the main arm of the Tweed River are the Oxley River which joins at Byangum, about 5 km upstream of Murwillumbah and Dunbible Creek which joins just downstream of the tidal limit near Murwillumbah. The Rous River joins at Tumbulgum and the Terranora and Cobaki systems join the river 2 km upstream of the river mouth at Tweed Heads via Terranora Inlet and Ukerebagh Passage.

The main modifications to drainage in the Tweed River are the Clarrie Hall Dam and The Bray Park Weir. The Clarrie Hall Dam was opened in 1983 and was designed to provide domestic, commercial and industrial water supply to the Lower Tweed Valley. The Bray Park Weir provides water storage and also acts as a tidal barrage (Tweed Shire Council, 1995b).

The ocean tide propagates into the Tweed River system and has an influence beyond Murwillumbah to the barrage in the main arm, a distance of approximately 30 km. Previous studies show that the tide is progressively attenuated with distance upstream, although the most rapid attenuation occurs over the first 2-4 kilometres from the mouth of the river.

The main contributing tidal tributaries are the Terranora and Cobaki Creek systems. These both pass through expansive broadwater areas in their upper reaches. They are connected to the main arm of the Tweed River predominantly via Terranora Inlet which experiences relatively strong tidal flow, and also through Ukerebagh Passage.

4.1.3 Regional Sedimentary Processes

Sand migrating onshore during the sea level rise has been subjected to longshore and cross-shore transport under the influences of the prevailing wind/wave climate. The coastal system is still being reworked by the forces of erosion and deposition over an extensive area from at least as far south as Byron Bay and north to Moreton Bay. Locally, the bedrock outcrops at Fingal Head, Cook Island, Point Danger, Greenmount Hill, Kirra Point and Currumbin all have controlling influences on the shape and relative stability of the beaches in the study area.

Key features of the natural coastal sedimentary processes of the region are:

- strong longshore transport of sand along the beach system, having an average net rate of about 500,000m^3/year in the study area;
- dynamic beach variability, including extensive erosion during cyclone events and subsequent beach recovery; and
- strong wind-induced dune development, particularly on the exposed beaches facing to the east, and natural growth of dune vegetation providing stability against beach sand losses by wind erosion.

Letitia Spit is aligned towards the north-northwest and has formed by accretion of primarily marine sands under the influence of the northward littoral drift along the coast in the region. In the process, the mouth of the Tweed River migrated north until held stable against the bedrock headland of Point Danger.

The form of the Tweed River entrance has been modified by construction around the turn of the century, and extension in 1962-64, of the river training walls. The river mouth area was naturally quite shallow with a strong sand ebb delta. The beneficial effects of the training walls in creating a deeper entrance channel were temporary, and in recent times the entrance bar has been again shallow and dangerous for navigation.

The southern Gold Coast beaches including Rainbow Bay, Coolangatta/Greenmount Beach and Kirra Beach are characterised by a highly mobile beach zone of up to 100m in width. Dunal areas exist behind most of these beaches, however these have been substantially modified by urban development and

removal of sand during the 1930's to fill the hind-dune swale and lagoon areas. Prominent rock outcrops such as Kirra Point (27m), Greenmount Hill (25m) and Point Danger (34m) act as constraints determining the present position of the coastline.

Sediments in the upstream reaches of the Tweed River are primarily of fluvial origin. Downstream from Barney's Point Bridge and in the lower reaches of the Terranora and Cobaki Creek systems, the river channels flow through present day and residual marine sands. The sediments in the lower reaches are quite mobile and the bed topography is continually responding to tidal influences and flood flows, which in turn can influence the controlling hydraulics (WBM Oceanics, 1993).

4.1.4 Coastal Works and Natural Processes Affecting the Beaches

A description of the historical coastal works which have affected the beaches is outlined in Section 1.3.

The earliest works include the original river entrance training walls and revetments constructed early this century. Part of the river training involved confining its course in the lower estuary and dredging to provide sand for reclamation of land, much of which now contains long-established residential and commercial development.

The extension of the training walls resulted in accumulation of sand on Letitia Spit, the entrance bar and eventually Duranbah Beach (Figure 4.1.1).

Until that time, Duranbah contained little sand and had only a minor dune system (Figure 4.1.2). The corresponding erosion on the southern Gold Coast beaches was manifested as obvious beach loss in the cyclones of 1967 and prompted construction of groynes at Kirra Point (1973) and Miles Street (1974) (Figure 4.1.3).

The following extracts 'Kirra' and 'Coolangatta' from "Beach Conservation" issues 11 and 12 (produced by the Queensland Beach Protection Authority) highlight the natural variability of those beaches.

Kirra

" Before 1920, the beach at Kirra consisted of a continuous line of undulating sand dunes extending from the base of Kirra Hill to the mouth of Coolangatta Creek, bounded generally by the route of the present Pacific Highway, but embracing the whole of Pease Park.

The road then followed the contour of Kirra Hill at the base of the present Winders Memorial Park. It is still there and useable.....

A large part of the parking area now on the east end of the surf pavilion, was then occupied by a deeper hollow.....

The flow-off of rainwater from the Winders Memorial Park area and Rutledge Street, ran into this hollow and gradually soaked away. Whatever overflow there was washed off evenly along the entire front of the hollow without damage to the natural sand dunes in front.

Up to this time, Kirra had experienced only that type of intermittent erosion which might be expected as the result of high tides and heavy seas on a completely natural area.

The reclamation of the area extending from the original road west to the Kirra Beach Hotel and its conversion into a carparking area necessitated the construction of a proper drainage system..... One outlet.....flowed directly on to the beach..... In time of heavy rains (which often coincide with heavy

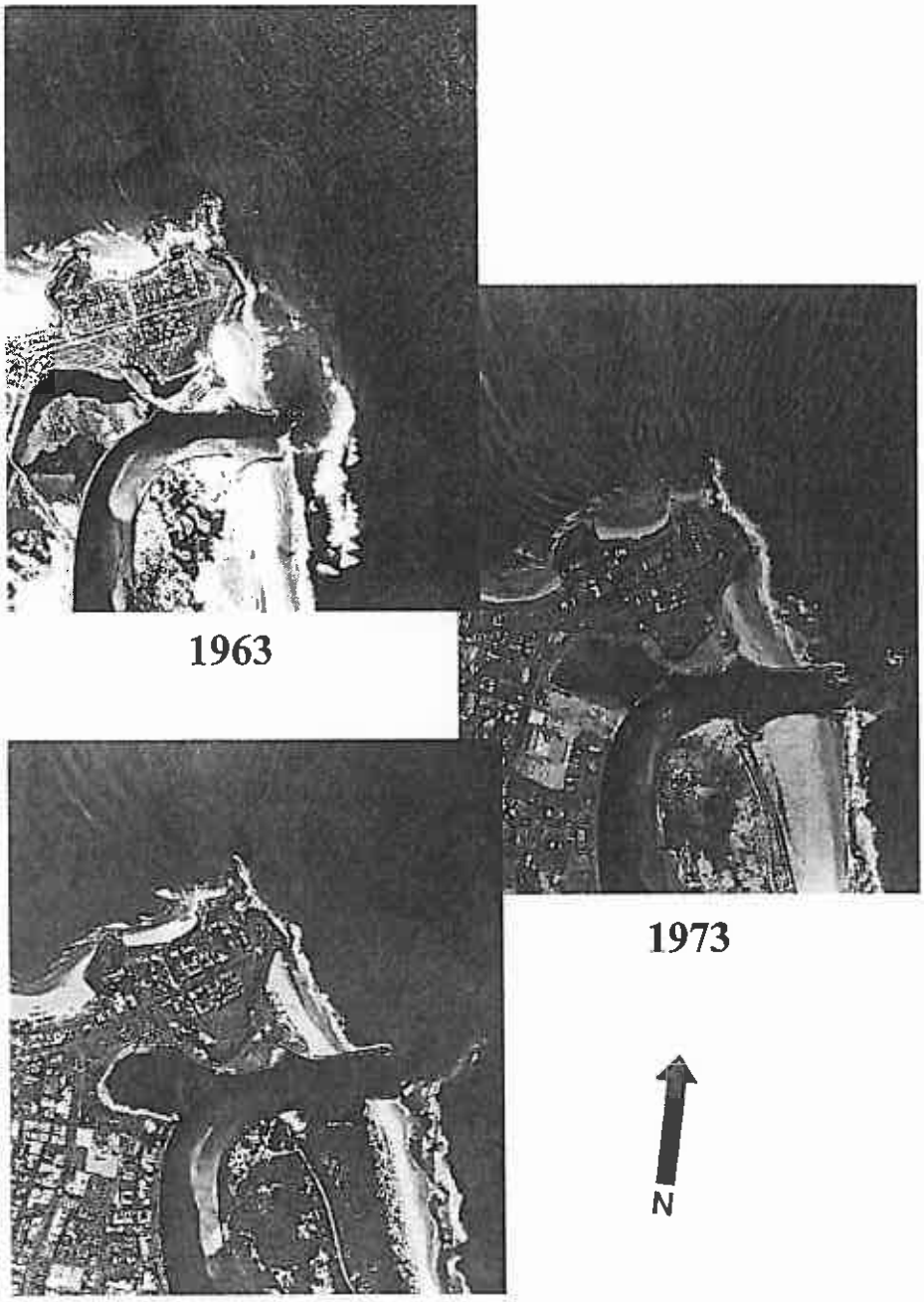


Figure 4.1.1
Tweed River Entrance Area Historical Changes 1963-1995

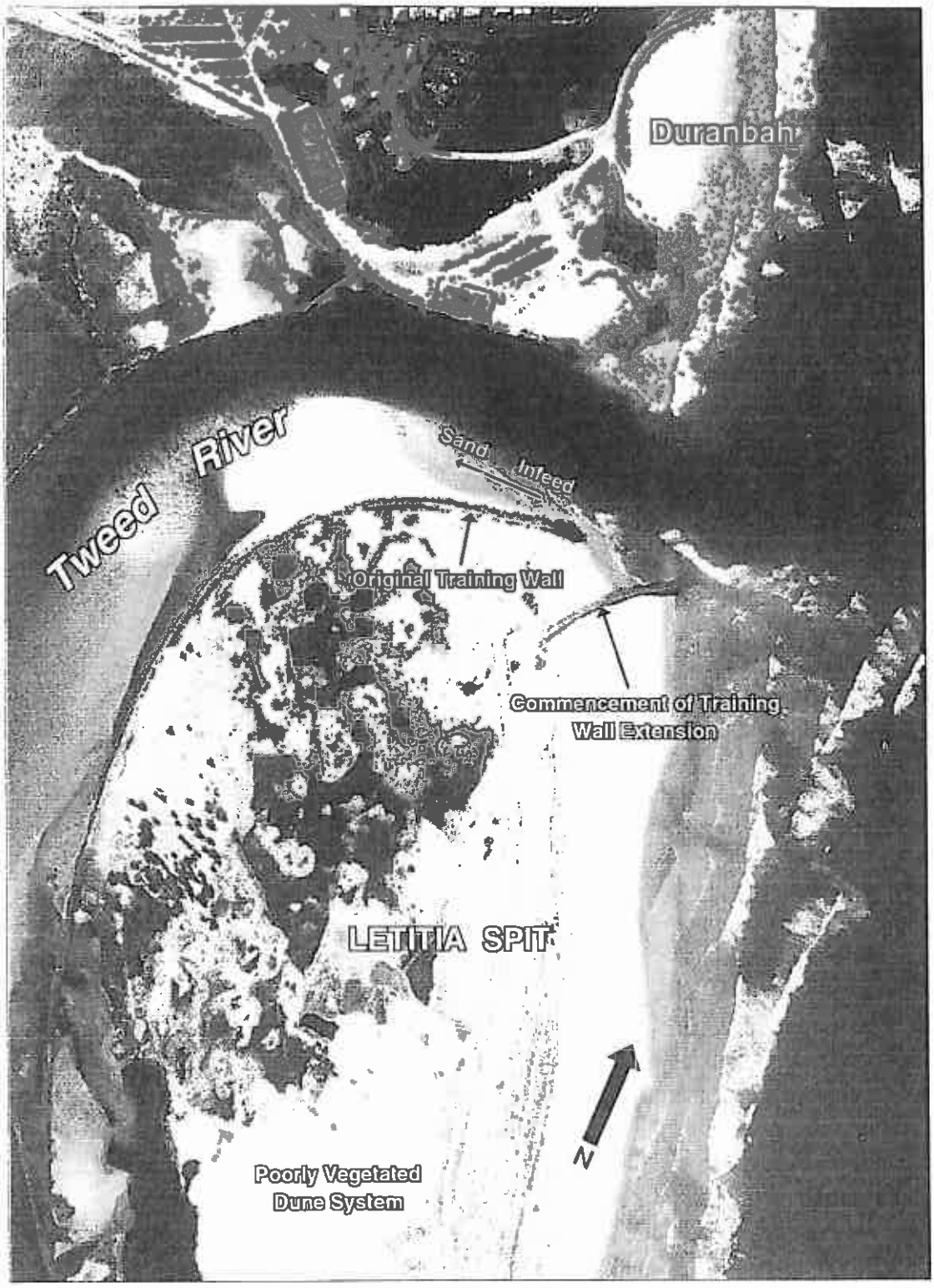


Figure 4.1.2
Duranbah and Northern Letitia Spit - 1962



October 1962



November 1971



February 1974



May 1994

Figure 4.1.3
Greenmount to North Kirra Historical Beach Changes 1962-1994

seas) the flow of stormwater created a deep furrow from the outlet to the water's edge, providing ideal conditions for heavy seas, or even high tides, to erode the area.....

While natural restoration cycles occurred, these became fewer and less effective because it became impossible by natural means to restore the abnormal quantities of sand eroded as a result of the two drainage systems. The first real erosion of the beach occurred, in January 1924, and almost destroyed the Kirra Surf Club building (then situated next to the present public shelter shed)..... In 1936, the sea washed into a corner store which was then on the existing Kirra Hotel site."

Coolangatta

".....around 1880, Coolangatta swamp - now known as Goodwin Park - drained into the sea across Greenmount Beach.

The area between The Grand and Queensland hotels then comprised natural sand dunes behind which extended a large hollow about 16 feet deep.

1920: The hollow in front of the Town Hall was filled with sand from the adjacent dunes to construct Marine Parade. Later reclamation of Coolangatta swamp was undertaken, first by an unsuccessful attempt to pump sand from the beach and later by tramway transport of sand from the dunes.

1930: During the depression years the area between The Grand and Queensland hotels was levelled and made available as building blocks. The vegetation stabilising the dunes disappeared in the process and the natural dunes lost their identity.

1930-1960: Many periods of erosion and natural restoration occurred, the beach width fluctuating greatly. Erosion came close to Marine Parade several times. Accretion always followed, sometimes to such an extent that shallow offshore bars or spits effectively widened the beach to the seaward alignment of Greenmount Hill. At the same time, accretion of Letitia Spit progressed to such an extent that the old Tweed River training walls ceased to be effective.

1962-1964: New training walls were constructed as extensions of the old ones. These walls acting as a groyne trapped a considerable amount of sand that would otherwise have passed to the Gold Coast beaches .....

1967: The Gold Coast experienced a severe cyclone season. An estimated 500,000 cubic yards was removed from Greenmount-Coolangatta beaches and in the following year a boulder wall was constructed to protect Marine Parade. The combined detrimental effects of the boulder wall and the Tweed River training extensions prevented natural restoration of the beach.

1970: The Delft report recommended large-scale beach nourishment to restore the beaches. The logical source was the Tweed River or Letitia Spit.

1972: An experimental groyne was built at Kirra Point.

1973: The Beach Protection Authority advertised a scheme for Beach Erosion Control Districts Nos 2 and 11 which includes restoration by nourishment of over one million cubic metres of sand for Greenmount, Coolangatta and Kirra Beaches."

The Kirra Point groyne was 180 metres long and was constructed with the intention of stabilising the beach at Coolangatta. In 2 years it was estimated that 306,000 m^3 had accreted on Coolangatta Beach and 503,000 m^3 eroded from Kirra beach.

In 1974, a short groyne 60m long was built at Miles Street, Kirra, just west of the Lifesaving building, to preserve a small beach at Kirra.

A detailed discussion of the coastal processes of the study area is presented in Section 4.2.

4.1.5 Sediment Properties

Characteristics of the offshore seabed sediments of the region were investigated in detail based on comprehensive sampling over a large nearshore and offshore region (Hudson, 1989). A brief summary of the findings of that investigation is set out below.

Nearshore Sediments

Inner nearshore sand:

- Generally confined to depths less than 10 metres except at the Tweed River entrance where it extends to 15 metres;
- Pale fawn to fawn-grey, well sorted, fine to medium grained quartzose sand with low to moderate (<30%) shell fragments and minor lithic gravel;
- Quartz sub-angular to rounded; and
- Iron-staining of both the quartz and carbonate grains is low (5-10%).

Outer nearshore sand:

- Extends out to depths of 20-25 metres;
- Olive fawn-grey, well sorted, fine grained quartzose sand with generally low (<10%) shell as abraded fragments;
- Quartz grains are sub-angular to sub-rounded; and
- Iron-staining is low to moderate (15-20%) - definitely higher than the inner nearshore sands.

Inner Shelf Sediments

Inner shelf sands (low carbonate):

- Fawn-brown to orange-brown, well sorted, fine to medium grained quartzose sand;
- Carbonate <30% as abraded fragments;
- Travel gravel;
- Quartz grains are sub-angular to rounded;
- Iron-staining is moderate to high (25-80%);
- Sediment contain minor amounts of well rounded iron-stained quartz grains in the coarse to very coarse sand size range; and
- Trace mud offshore from Tweed entrance.

Inner shelf sand (high carbonate):

- Sediments are coarser, less well sorted and contain more shell (>30%) than their low carbonate counterpart;

- Very coarse sand to granule-sized iron stained quartz and lithic are common; and
- Trace mud in lee of rock reefs.

Considerable sand sampling and analyses have been undertaken over the years to define the size grading characteristics of the active beach system sand. These include investigations for which detailed published reports are available including:

- Delft Hydraulics Laboratory (1970);
- Druery and Curedale (1979);
- Hudson (1989); and
- Jones *et al* (1990).

Further sampling and analyses have been undertaken as part of the Stage 1A dredge monitoring.

These studies show that the beach system is composed of well sorted, clean fine sand of median size typically about 0.20-0.22mm with little or no silt. Local variability is evident, with slightly coarser sand in the higher wave energy swash zone. There is a tendency for somewhat finer sand of median size about 0.18-0.20mm in the outer zone of the active area beyond about 500m from the shore.

AWACS (Australian Water and Coastal Studies, 1996) analysed three sand samples taken from the Tweed River entrance bar area and reported the following sediment quality analysis results.

Table 4.1.1 Tweed River Mouth Sand Size Distribution

Grainsize (microns)	Cumulative % Passing		
	Sample 1	Sample 2	Sample 3
500	97.5	99.8	97.5
300	66.9	91.8	76.8
212	21.5	42.6	34.8
150	1.9	3.5	2.7
106	0.1	0.2	0.1
75	0.0	0.0	0.0
63	0.0	0.0	0.0

(Source: AWACS, 1996)

- Microbiological testing showed that the sediments were essentially unpolluted, with zero E. coli and clostridium perfingens. Only Sample 1 gave a positive count (2 counts/g) for enterococci - the other two gave zero counts.
- The heavy metals Cu, Pb, Zn, Cd, Cr, Ni, Hg and Se were all either below the limit of quantification or well within the sediment background concentration range. Arsenic at about one (1) ppm is also at the lower part of the background range.

  The elements Fe and Mn are not considered to be pollutants as such, but a knowledge of their concentrations is useful when trying to understand trace metal transport or co-precipitation processes in the sediment body. Concentrations of these elements are fairly typical for quartz sands or sediments of coastal Eastern Australia.
- Concentrations of nutrient nitrogen as TKN (Total Kjeldahl Nitrogen - sum of ammonium and biologically derived amino nitrogen) for all three samples were below the limit of quantification. It is well known that Eastern Australian coastal waters are nutrient poor and the quartz sands associated with them will reflect this fact.

- The range of nine herbicides, thirteen organophosphate pesticides and sixteen chlorinated pesticides tested, all were reported at concentrations below the quantification limit (i.e. <0.1mg/kg, <0.01mg/kg and <0.5mg/kg, respectively).
- Analyses for heavy mineral indicator elements Ti, Zr, Cr, Ba, Th, Ce and Fe gave very low concentrations for these analytes. The concentration measured for Fe by total digest is also greater than the analysis for this element by acid digest. This may be interpreted as being due to the dissolution of refractory minerals of iron such as magnetite, ilmenite and chromite.

As all the results for the elements listed above are low it appears that the concentrations of the corresponding minerals giving rise to them are also low. The concentrations of the beach sands mineral zirconia/zircon, rutile/ilmenite, baryte, chromite and monazite are therefore negligibly low ie., less than 0.1% by calculation.

Analyses for TOC (Total Organic Carbon) and TIC (Total Inorganic Carbon - i.e., Carbonates) show, there is very little organic matter or shell material in the three samples tested.

In summary, the marine sediment samples from the Tweed River entrance were unpolluted, both chemically and bacteriologically, with respect to the parameters for which they were tested. Pesticides, both organochlorine and organophosphate, were below the limit of quantification. Pollutant heavy metals including Se, As and Hg were very low or below the limit of detection. Herbicides were not detected in any of the samples. Nutrients were either not detected or of levels below the level of quantification. Micro-organisms were also absent except for one sample with 2 counts/g of enterococci.

Heavy Minerals

Beach sand is made up of three classes of mineral ie., light, intermediate and heavy. The light minerals have specific gravity of about 2.65. The heavy minerals have specific gravity ranging from 4.5 to 5.0, and are significantly finer than the light minerals. On the beaches of the Tweed Coast and Gold Coast, white sands dominate, these being made up of predominantly light minerals (silicates). Zircon, rutile and ilmenite make up 97% of the total heavy minerals. The light white sands are coarse and rougher in nature than the heavier black minerals. When mined, separated from the light minerals and processed into pure forms, these three heavy minerals become a saleable product. In the past, mineral sand mining has occurred extensively on the southern Queensland and northern NSW coasts (Logan, Tomlinson and Robinson, 1995).

Patterson Britton & Partners (1989) completed a comprehensive assessment of the commercial potential of mineral sands in the Tweed littoral system. The study found that the economic mineral sand component of the active marine sands of the lower Tweed and entrance bar varies from 0.07 %wt to 0.52 %wt of the total body, with an average of 0.2 %wt.

4.1.6 Soil Properties

Soil type is determined by local factors including parent material, climatic conditions, topographical and geographical features and vegetation (Gold Coast City Council, 1991). Six soil groups have been identified in the Tweed Shire and include coastal sands, krasnozems, alluvial soils, yellow earths, red podzolics and chocolate soils (Tweed Shire Council, 1995). In the Gold Coast City ten main soil groups have been identified, namely red and yellow podzolics, krazsnozems, red clays, lithosols, alluvia, humic gleys, peaty gleys regosols, meadow podzolics, saline greys and tidal solonchaks (Gold Coast City Council, 1991).

Acid Sulfate Soils

Acid Sulfate Soils (ASS) and Potential Acid Sulfate Soils (PASS) occur in the Tweed Valley area. Acid Sulfate Soils have the potential to impact on aquatic systems, engineering and agricultural systems. These sediments were formed during the last sea level rise in the Holocene, 10 000 years BP and consequently are found in low lying coastal and floodplain areas. Sulfides from the sea water and iron oxides and organic matter from the land chemically reacted to form large quantities of iron sulfides in the water logged sediments. When these sediments are exposed to air they produce sulfuric acid. Unoxidised iron sulfides which are contained in a waterlogged layer are known as PASS. Holocene muds which occur in the lower reaches of the Tweed River are PASS while they remain waterlogged. Organic clay loams (PASS) cover an area of approximately 33km^2 between Murwillumbah and the Tweed Broadwater. The areas now exist as floodplain elevated approximately 0.5 to 2.0m above sea level (Public Works, 1991r).

Activities such as excavation of disturbance of these soils, for example road construction, drainage works, sand extraction, dredging or flood mitigation works, lowering of the watertable or use of these soils requires thorough assessment. The acid produced as a result of the oxidation of ASS affects both the soil and water. Acid movement through the soil strips iron, aluminium and sometimes manganese from the soil. Vegetation may be affected as a result of the acid and toxic conditions of the soil. Acid Sulfate Soils may reduce agricultural productivity as a result of these conditions and reduction in pH which makes vital nutrients less available to plants. Oxidation of ASS also affects water quality and aquatic life. Fish kills may result and have been documented in the Tweed River. Other aquatic organisms such as plants, crustacea and worms may also be affected. Oxidation of ASS has the potential to affect the long term viability of waterways either through killing aquatic species, interruption of the breeding cycle, food chain and species composition. The sulfuric acid produced as a result of the oxidation of ASS corrodes concrete, iron, steel and certain aluminium alloys. Acid Sulfate Soils may cause weakening of concrete structures and corrosion of concrete slabs, steel fence posts, foundations and underground pipes (Sammut and Lines-Kelly, 1996) and therefore structural integrity of buildings and infrastructure may be reduced.

4.1.7 Climate

The study area is located at the boundary of two climatic zones with the tropical zone to the north and temperate to the south. The climate is generally humid, subtropical with moderate temperatures and a concentration of rainfall through summer to late autumn (December to April). During this period over 60% of the total annual rainfall occurs. Rainfall and temperature data from Coolangatta Airport station is summarised in Table 4.1.2 below.

Table 4.1.2 Climate Data - Coolangatta Airport Station

Mean Daily Temperature (°C)	**Maximum**	**Minimum**
February	29.7	20.0
July	20.1	8.7
Mean Annual Rainfall (mm)	1597.6	

(Source: Bureau of Meteorology, 1996)

The study area's proximity to the coast ensures good rainfall. Rainfall is about 10% higher than the average for the Gold Coast due to locally high topographic relief to the west of Coolangatta Airport (Gold Coast City Council, 1991).

Summer months are generally warm to hot and humidity is high. Cyclonic disturbances occasionally occur during summer through to early autumn. On average the area is affected by cyclones once every two years (Gold Coast City Council, 1991). These cyclonic conditions are known to produce very high rainfall over the Tweed catchment and Gold Coast area. Resulting rainfalls of 250 mm in twenty four hours and monthly totals greater than 450 mm have been recorded. Winter months are generally mild and dry with the average temperature around 16°C. Night temperatures may drop to the point that frosts may be experienced in the inland valley lowlands several times a year (Tweed Shire Council, 1987).

From September to March the most frequent wind directions are south to south-east in the morning and north-east to south-east in the afternoon. From April to August the most frequent wind directions are south to south-west in the morning and south-east to west in the afternoon.

Coastal fog is a rare phenomenon, due to the absence of significant temperature inversions. This is generally related to the sub-tropical location and the lack of calm conditions which causes mixing of air masses. Only 3 instances of fog have been recorded at Coolangatta Airport from 1962-1971 (Bureau of Meteorology, 1996).

4.1.8 Wave Conditions

The Tweed/Gold Coast region is subject to a moderate to high energy ocean wave climate with significant seasonal variability. That variability is related strongly to the weather patterns characterised by:

- a well-defined cyclone season from November to April, with cyclones moving southward from the Coral Sea sometimes crossing the coast and sometimes passing well out to sea;
- sequences of high pressure systems off southern Australia in summer, generating persistent southeast to northeast trade winds and swell in offshore areas moderated by early morning land breezes and afternoon sea breezes which affect the locally generated 'sea' waves;
- a northward migration of the high pressure systems in winter, resulting in typically southwest to southeast winds and predominantly south to southeast swells in winter; and
- occurrences of intense low pressure systems off the New South Wales coast in winter, generating moderate to high southerly swells;

An extensive data record of reliable wave information is available for the region. This comprises mainly non-directional recorded data for sites at Gold Coast, Point Lookout (Brisbane), Double Island Point and Byron Bay. Some directional data is available for Letitia Spit (Tweed) and The Spit (Seaway). The recorded data set is one of the most comprehensive available for any site.

4.1.8.1 Average Wave Climate

Previous data collection and hindcasting has shown that 'sea' waves generated by local winds and 'swell' waves propagating from more distant sources commonly coexist in the study region. It is important that they be considered both independently and in combination in assessing sand transport processes because:

- sea and swell often propagate from different directions and have different effects on longshore sand transport; and
- the influence on currents of stronger winds associated with higher sea waves is significant in some areas.

Recorded directional wave data is available for only limited periods at locations relatively nearshore (in 20 to

25 metres water depth) at Gold Coast Seaway and Letitia Spit. A considerably longer directional wave data base is needed to understand the longer term spatial and temporal variability of the sand transport processes. It was therefore necessary to establish additional directional information by hindcasting to augment the recorded wave data for use in the study.

A combination of the recorded non-directional data and hindcast directional information (based on the British Meteorological Office (BMO) hindcast model) was utilised to obtain a composite time series of directional wave data. Considerable effort has been put into determining appropriate deep water wave directions for use with the recorded wave height and period data as input to sediment transport modelling. The non-directional Brisbane wave data was selected as the base time series because of the length of record, depth of water at the waverider site and proximity to the study site. It is also close to a British Meteorological Office hindcasting model grid point. A detailed discussion of the derivation of the final composite time series of directional wave data is provided in Technical Appendix II.

The adopted directional wave climate is detailed in Tables 4.1.3(a) and 4.1.3(b) and more comprehensively in Technical Appendix II in terms of the non-directional height/period probabilities of occurrence for swell, sea and combined waves with peak period respectively. Equivalent directional height/direction probabilities are also presented.

Table 4.1.3(a) Non-Directional Wave Climate - Sea plus Swell (using Peak Wave Train)

Significant Wave Height (m)	Probability of Occurrence for Height and Period Shown								
	Spectral Peak Period (sec)								
	0-2.99	3-4.99	5-6.99	7-8.99	9-10.99	11-12.99	13-14.99	>14.99	TOTAL
0.00-0.50	0.01		0.01	0.01	0.00	0.00	0.00	0.00	0.03
0.51-1.00	0.01	1.37	1.76	2.97	2.94	0.95	0.39	0.08	10.46
1.01-1.50		2.59	5.94	11.65	10.60	3.51	1.07	0.21	35.58
1.51-2.00		0.24	4.59	8.36	8.50	3.08	0.99	0.06	25.87
2.01-2.50			1.22	6.20	4.75	2.16	0.64	0.05	15.00
2.51-3.00			0.14	3.24	2.49	1.20	0.25	0.01	7.33
3.01-3.50			0.02	0.99	1.39	0.76	0.13	0.02	3.32
3.51-4.00				0.21	0.80	0.37	0.07		1.44
4.01-4.50				0.09	0.35	0.17	0.05		0.66
4.51-5.00					0.13	0.07			0.19
5.01-5.50					0.01	0.03			0.05
5.51-6.00					0.01	0.01			0.02
6.01-6.50						0.00			0.00
6.51-7.00						0.02			0.02
7.01-7.50						0.02			0.02
TOTAL	0.02	4.20	13.68	33.72	31.97	12.36	3.58	0.42	99.99

Table 4.1.3(b) **Adopted Directional Wave Climate - Sea plus Swell (Using Peak Wave Train)**

Significant Wave Height (m)	Probability of Occurrence for Height and Period Shown Spectral Peak Period (sec)									
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	TOTAL
0.00-0.50		0.01	0.01							0.03
0.51-1.00	1.11	0.90	0.40	0.52	0.97	0.81	0.95	0.95	1.53	10.46
1.01-1.50	3.16	2.46	1.52	2.81	4.11	3.39	3.83	4.66	5.90	35.58
1.51-2.00	1.26	0.98	0.75	1.06	3.16	3.86	3.77	4.11	5.76	25.87
2.01-2.50	0.43	0.22	0.21	0.35	1.36	2.23	2.83	3.41	3.66	15.00
2.51-3.00	0.18	0.08	0.11	0.14	0.38	0.98	1.64	2.04	1.57	7.33
3.01-3.50	0.05	0.01	0.03	0.01	0.24	0.33	0.59	1.07	0.89	3.32
3.51-4.00	0.07		0.02	0.01	0.06	0.23	0.23	0.48	0.31	1.44
4.01-4.50	0.01			0.02	0.03	0.10	0.18	0.13	0.18	0.66
4.51-5.00					0.02	0.05	0.06	0.03	0.03	0.19
5.01-5.50					0.01	0.01	0.02			0.05
5.51-6.00					0.01	0.00	0.01			0.02
6.01-6.50						0.00	0.00			0.00
6.51-7.00						0.01	0.01			0.02
7.01-7.50							0.02			0.02
TOTAL	6.26	4.67	3.06	4.93	10.35	11.99	14.15	16.88	19.84	99.99

(Offshore Directed Peak Waves : 7.87%)

The average wave climate is characterised by the following key features:

- swell waves of period in the range generally 7 - 15 seconds and predominantly 9-13 seconds, and of height generally less than 3.5 metres and predominantly in the range 0.5-2.0 metres ('modal' conditions);
- swell waves from all seaward directions, but by far most predominantly from the south to southeast sectors;
- sea waves of height most commonly up to about 3.0 metres, but ranging in cyclones and extreme storms to in excess of 7.0 metres; and
- sea waves from all seaward (and offshore) directions, but predominantly from the east to south sectors, and frequently modified in spring and summer by seabreeze effects.

Roelvink and Murray (1992) also utilised the BMO model to assist in enhancing the directional wave database. They concluded that the model produced results in which the swell wave occurrences are biased away from the east sector and towards the south and north sectors.

That pattern is considered to again influence the outcomes of the present studies, despite all efforts to minimise the effects of the geographical limitations inherent in the model. A key feature of this deficiency is an excessive estimate of occurrence of southerly swell and associated upcoast sand transport along the more exposed ocean beaches, and insufficient occurrence of easterly swell and underestimated sand transport along the north-facing beaches around Kirra to Bilinga.

Considerable further directional wave recording with comprehensive analysis of the data in terms of both sea and swell components is needed to improve the presently assessed directional wave climate.

4.1.8.2 Extreme Wave Conditions

Extreme waves in the region are associated with cyclones and severe storms occurring as intense low pressure cells offshore. These are characterised typically with clockwise wind circulation around a central 'eye' which may remain offshore and move along the coast or make landfall at any location. The high to maximum winds are typically limited to the range 20-150 kilometres, and the resulting wave conditions at any particular location are highly dependent on the track pattern of the eye.

Because of the clockwise wind rotation of these events, the dominant directions of the most extreme waves are in the east to southeast sectors. This is illustrated in Table 2.4(b) of Technical Appendix II.

Despite the considerable recorded data for the region, probabilities of occurrence of extreme wave conditions remain uncertain. This is due to the considerable variability of extreme wave occurrences over time frames which are long compared with the length of wave database. The directional characteristics of these waves are even less well defined.

Analyses to date indicate estimated extreme wave conditions as set out in Table 4.1.4. Details of these analyses are provided in Technical Appendix II.

Table 4.1.4 Extreme Wave Conditions

Wave Height Hs (m)	Probability of Exceedence (%)	Average Recurrence Interval (years)
3.0	2.7	0.1
4.0	0.48	0.3
5.0	0.07	1.3-1.7
6.0	0.013	5-7
7.0	0.003	18-22
8.0	0.001	60-70

In the context of the proposed sand bypassing project which would continue in perpetuity, it is of significance for planning and design of the infrastructure and operational procedures to be aware of the probabilities of occurrence of extreme events within the time frame involved. Table 4.1.5 illustrates the probabilities of occurrence of events with various average recurrence intervals over a range of operational design periods.

Table 4.1.5 Probability of Occurrence of Extreme Events

Design Period (years)	Probability of Occurrence during Design Period (%) Average Recurrence Interval (years)						
	10	25	50	75	100	150	200
25	91.8	63.2	39.3	28.3	22.1	15.4	11.8
50	99.3	86.5	63.2	48.7	39.3	28.3	22.1
75	99.9	96.0	77.7	63.2	52.8	39.3	31.3
100	99.99	98.2	86.5	73.6	63.2	48.7	39.3
150	100	99.8	95.0	86.5	77.7	63.2	52.8
200	100	99.9	98.2	93.1	86.5	73.6	63.2

4.1.8.3 Long Term Variability of Wave Conditions

Previous reports, in particular the 1992 Delft Report (Roelvink and Murray, 1992), have identified that the total wave energy can vary significantly from year to year and show long term cyclical trends. The total BMO hindcast directional data period available covers the period January 1989 to June 1996. While this is a significantly long period in terms of data availability, it is relatively short in terms of variability of meteorological patterns, particularly relating to extreme events.

An analysis has been undertaken of the relative significance of the available directional wave data set used in this study in the longer term context. This has involved comparison of the non-directional wave energy

levels against those from the longer recorded data set, and review of weather patterns and cyclone occurrences as noted over many decades. Details of the analysis are provided in Technical Appendix II.

Summary details in the form of plots of wave height occurrence, cyclone frequency and wave energy for an extended historical period are given in Figure 4.1.4. The analysis indicates that:

- the dataset used in this study, the years 1989 to 1996, contains an average wave energy 19% higher than the 19 year average;
- the single year 1989 contains transport capacity some 50% higher than the 19 year average;
- the year 1991 has relatively low wave energy, more or less similar to that for the years 1977 to 1987; and
- the period 1990 to 1995 is more representative of the longer term average, but nevertheless contains about 13% more sand transport capacity than the average.

As well, it is known that long term variations of weather patterns occur in which some years or groups of years contain greater or less extreme events or rainfall. Such variability may be closely linked to the climatic phenomenon known as the El Nino Southern Oscillation (ENSO) which is indicated by the Southern Oscillation Index (SOI). It is considered that strongly positive SOI periods coincide with higher rainfall, greater wave energy and possibly increased cyclone occurrences.

The SOI pattern over the period 1905 to 1995 has been assessed (Technical Appendix II). A pattern of variation in which groups of years exhibit higher or lower values is immediately obvious, indicating some form of irregular cyclic behaviours. Of particular interest are the following features:

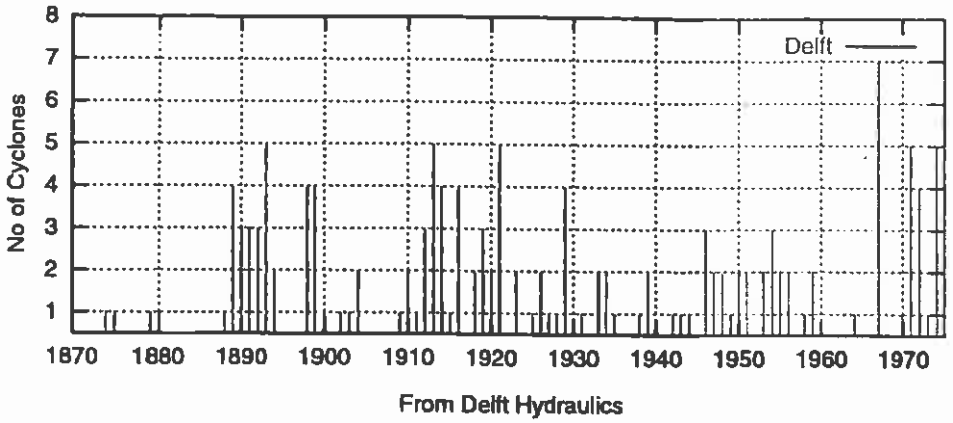
- The period 1954 to 1956 is known to have strong cyclone activity in southern Queensland, and shows high SOI values.
- Similarly, years 1972, 1974 and 1976 were also cyclonically active and had high SOI values.
- The years 1988 and 1989 are indicated with high SOI values and also show relatively high wave energy.
- However, the period 1990 to 1995 show consistently low SOI values but have been assessed as exhibiting somewhat higher wave energy than the longer term (1977-1996) average.

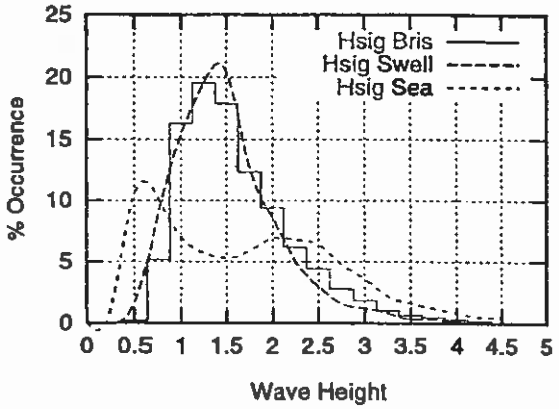
Thus, it remains uncertain how the adopted period 1990 to 1995 fits with the overall long term pattern. Nevertheless, the single year 1989 clearly contains abnormally high wave energy and has been excluded from the assessment of average sand transport rates. The indications are that the adopted period may give somewhat higher than average transport (up to 13% higher). Certainly, it must be recognised that unusually high (1989) and low (1977-86 and 1991) wave energy years occur from time to time and need to be considered in the sand bypassing design and operation.

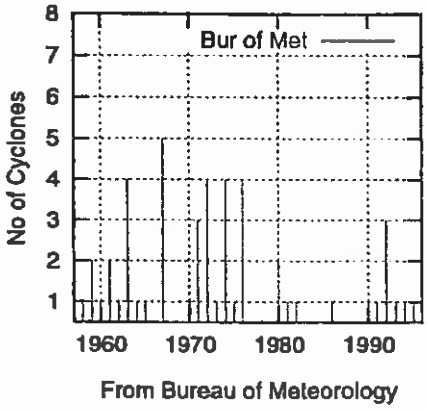
4.1.9 Ocean Water Quality

The nearshore ocean water adjoining the Tweed coast and southern Gold Coast Beaches is typically of very high quality. It is generally characterised by the following range in water quality parameters (on the basis of collated water quality data from the mouth of the Tweed River (PWD, 1992)):

- moderate temperature range (18°- 26°C);
- high (oceanic) salinity range (31-36g/L);
- high dissolved oxygen concentrations (>90% saturation);
- low turbidities (<5 NTU);
- low suspended solids concentrations (<5g/L);
- secchi disc visibility not less than 6m;







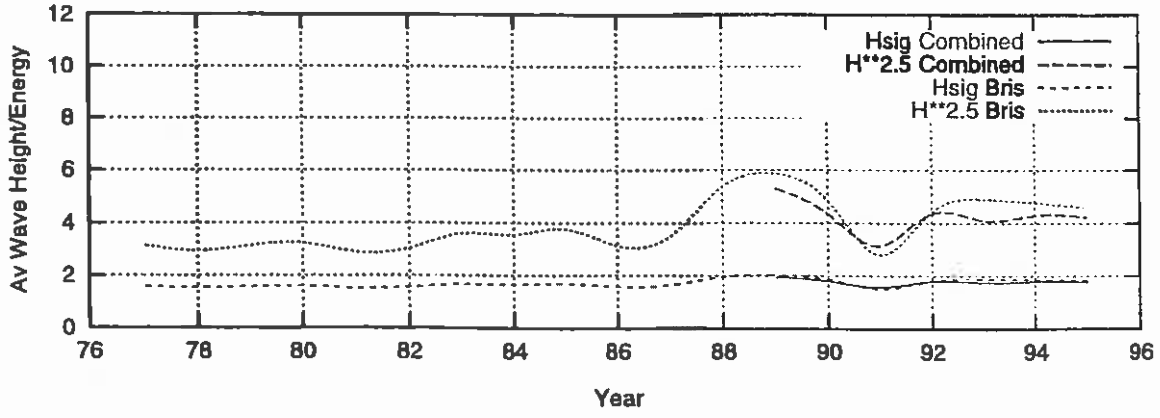


Figure 4.1.4
Long Term Wave Height Occurrence, Cyclone Frequency and Wave Energy Patterns

- nonexistent to very low levels of bacteriological contamination (faecal coliform < 5 orgs/100mL); and
- very low dissolved nutrient levels (Total Nitrogen <0.5mg/L, Total Phosphorus <0.02mg/L).

During periods of flood and/or stormwater runoff, the nearshore ocean waters of the Tweed and southern Gold Coast become a mixing zone for catchment runoff directed from the Tweed River and, to a much smaller extent, Coolangatta Creek. There is at present, little data to quantify the effects or spatial extent of these discharges on the nearshore ocean environment (limited water quality data is collated by Tweed Council at Duranbah Beach following significant rainfall events). The obvious impacts of stormwater runoff from each of these sources are occasionally visible as plumes of turbid and coloured water discharging into the ocean environment during or following periods of prolonged rainfall.

The principle water quality parameters of interest to this study are turbidity and suspended solids, both indicators of water clarity. These are the water quality parameters most likely to be influential in the acceptance of the operation of the planned Tweed River sand bypassing system.

As a consequence, any increases in turbidity of the nearshore ocean water, even small increases, due to sand bypassing, stormwater runoff or flood discharging have the potential to be visible.

4.2 Coastal Processes of the Southern Gold Coast and Tweed Beach System

4.2.1 Overview of Beach Processes

4.2.1.1 General Considerations

Beaches depend on the availability of sand for their sustained existence and recreational amenity. The beach system extends from the dunes across the berm and surfzone areas to deeper water (about 20 - 25 metres water depth). Sand must be available in suitable quantity and profile shape across the entire beach system, and along each coastal unit, for the beaches to sustain their long term dynamic stability.

Net losses of sand from any part of the active beach system will manifest eventually as beach degradation. Similarly, net gains to the beach system, even those made in the nearshore zone, benefit the beaches.

The beaches of northern NSW and the Gold Coast experience substantial movements of sand both in the alongshore and onshore-offshore (cross-shore) directions. During cyclone events, the offshore transport of sand from the (visible) beach and upper profile area into deeper parts of the profile can be massive causing extensive beach erosion. The onshore recovery of the eroded sand and longshore transport of sand along the beaches are somewhat more steady but persistent.

On beaches which have evolved to a condition of natural dynamic equilibrium, the short term erosion is balanced by the longer term onshore recovery. Also, there is long term equality in the longshore sand transport.

Compared with most other beach systems, the beaches of the study area experience moderate to high wave energy and correspondingly high longshore sand transport rates. There are often strong shorter term differentials in longshore transport, leading to significant medium term (months to years) beach variability additional to that caused by storm erosion, with long term net shoreline stability. Thus, shoreline retreat or advance depends on the existence or absence of a long term longshore transport differential. This process is of vital importance in the beach process analysis and consequently to the sand bypassing project.

The movement of sand in the cross-shore direction is generally considered as shorter term transient response to changing wave conditions. This has significant effect on variability of the beach width and nearshore surfing conditions at any particular time.

Sand generally moves offshore to form bars in the early stages of storms when the waves are steep and returns to the beach in calmer weather when swell waves are prevalent. Even though the timescales for cross-shore transport are short in relation to longshore transport and geomorphological changes, they are significant in terms of beach amenity and bypass discharge design.

4.2.1.2 Beach Process Studies

The current knowledge of coastal and estuarine processes of the Tweed and southern Gold Coast region has accrued over many years. The EIS/IAS for the Stage 1 bar dredging and beach nourishment (Acer Wargon Chapman, 1994) was able to draw upon more than two decades of process studies and project investigations carried out by the NSW and Queensland State Governments and Gold Coast City Council. For the purposes of the Stage 1 EIS/IAS, the extensive information base was reviewed and consolidated into conceptual process models (PBP, 1994).

The formulation of Stage 1, however, recognised that in a major coastal project, it is simply not possible to predict the response of the natural system with absolute certainty. Consequently, an environmental monitoring programme was set up to provide feedback about, inter alia, the response of coastal and estuarine processes to the Stage 1A dredging and nourishment works. The data from this programme provides the opportunity to refine process understanding and examine in more detail the long term implications of a permanent entrance bypass system. Analysis of this data is discussed in detail in Technical Appendix I and presented in summary form in Sections 4.2.3.

A key objective of the present studies as part of the environment impact assessment and performance criteria planning for the bypassing design is to quantify both longshore and cross-shore processes and the associated beach responses. This has required special purpose coastal process modelling of a nature never before undertaken for this area. Specifically, the coastal studies available to Stage 1 did not include detailed simulation of sand transport associated with nearshore wave refraction and diffraction and current interaction. Consequently, more detailed coastal and estuary hydrodynamic simulations have been carried out for this Stage 2 EIS/IAS. These new studies provide fine scale resolution of the spatial and temporal variability of longshore transport processes and provide a rigorous basis for examining the long term impacts of a permanent bypass system. Results of that work are discussed in detail in Technical Appendix II and presented in summary form in Section 4.2.4.

4.2.2 Summary of Previous Process Study Results

4.2.2.1 Longshore Sand Transport and Tweed River Training Walls

It has been recognised for many years that there is a general northward longshore transport of sand along the beaches of northern NSW and the Gold Coast. The earliest comprehensive study (Delft Hydraulics Laboratory, 1970) showed that the rate of sand transport along Letitia Spit was about 500,000m^3/year. A similar rate was calculated for The Spit at the northern end of the Gold Coast. However, the rate calculated for the Bilinga area in that study was underestimated at about 200,000m^3/year, implying a net loss of sand to offshore areas near Point Danger. Associated with that result it was deduced that, of the 4.2 million cubic metres of sand estimated at that time to be trapped by the Tweed River training walls, the total quantity of sand loss from the Gold Coast beaches would be about 1.6 million cubic metres over some 20-25 years.

Subsequent studies of longshore transport rates and survey monitoring of accretion and erosion patterns by the Queensland government, including the most recent study by Delft Hydraulics (Roelvink and Murray, 1992), have shown that:

- the transport rate at Bilinga is probably approximately similar to that at Letitia Spit and The Spit, and thus the long term net longshore transport through the beach system is more or less equal throughout the system at about 500,000 cubic metres per year;
- it is likely that any sand losses to offshore at Point Danger are relatively small, certainly substantially less than predicted by Delft (1970);
- the total quantity of sand trapped on Letitia Spit, in the expanded river mouth bar and moving into the lower estuary was 7.6 million cubic metres up to 1989, and prior to the Stage 1A dredging works, an additional deficit of 1.1 million cubic metres was expected for the subsequent 20 years;
- the total loss of sand from Gold Coast beaches due to the training walls was about 7.2 million cubic metres to 1989, with a corresponding additional future deficit of 1.1 million cubic metres expected;
- The extensive shoals which existed offshore of Rainbow Bay, Coolangatta and Kirra beaches before the 1960's and were depleted by the action of the Tweed River training walls, were re-establishing at a rate of approximately 100,000m^3/year, prior to Stage 1A works; and
- without the establishment of a permanent sand bypassing system, it would take at least 20 years to re-establish the equilibrium sediment transport regime.

Erosion of the southern Gold Coast beaches resulting from the effects of the Tweed River training walls continued through the 1970s, 1980s and 1990s. The erosion effects continue at present, although substantial natural bypassing of the river entrance had resumed prior to the Stage 1A works. Considerable effort and expense have been committed by the Gold Coast City Council and the Queensland Government in beach nourishment projects to offset the sand losses. Most recent estimates indicate that the present rate of natural sand bypassing past Point Danger is about 350,000 - 400,000m^3/year, a deficit of about 100,000-150,000m^3/year.

4.2.2.2 Shoreline Dynamics of Nourishment Area: Point Danger to Kirra Beach

The disruption of the longshore transport around Point Danger, because of the Tweed River training walls, caused a littoral deficit to the downdrift beaches. Figures 4.1.1 and 4.1.3. illustrate the substantial changes to the beaches following training wall construction. Tomlinson and Foster (1986) and Foster and Tomlinson (1987) point out that the deficit of sand was responsible for the loss of the extensive sand bars and shoals which used to exist offshore of Point Danger, Coolangatta and Kirra. They estimate the volume of sand in these former bars at 2 million m^3.

Roelvink and Murray (1992) provide a very detailed bathymetric analysis of shoreline change between 1966 and 1989 (i.e., before '89/90' beach nourishment of Kirra to Tugun) along the Coolangatta to Tugun shoreline. Offshore of Coolangatta, their analysis showed that there had been seabed erosion of 0.5 to 2.5 metres. The seabed at Kirra east had experienced even deeper erosion of 1.5 to 3.5 metres. Offshore of Kirra central there was a large area where the seabed had eroded in excess of 4.5 metres. Kirra north showed erosion up to 4.5 metres. These areas of erosion graded from a maximum in the nearshore zone to zero in depths of 15 metres below AHD.

Prior to Stage 1A, the area offshore of Rainbow and the Greenmount Beaches was accreting. Both Tomlinson and Hranisavljevic (1988) and Roelvink and Murray (1992) estimated that the offshore areas of Rainbow to Kirra were accreting in the order of 90,000-120,000 m^3 pa due to the gradually increasing bypassing of Point Danger and Snapper Rocks.

Detailed monitoring of past beach nourishment campaigns has provided a good understanding of the shoreline dynamics in the southern Gold Coast beaches (Chapman, 1980; GCCC, 1990; Roelvink and Murray, 1992; Jackson, 1989; Jackson and Tomlinson, 1980; Murray, Robinson and Soward, 1993; Murray, Robinson and Soward; 1994). The most comprehensive discussion of nearshore morphodynamics is provided by Murray, Robinson and Soward (1993) and Murray *et al* (1994) in respect of the placement of a total of 3.6 million m^3 of sand between Kirra and Tugun.

Figure 4.2.1 shows typical profile adjustments in the area of nourishment. November 1989 is the pre-nourishment profile. By May 1990, 3.6 million m^3 had been placed on the upper beach and nearshore between depths of 6 to 9 metres below AHD.

The June 1990 profile shows up to 3 m of nourishment of the upper beach. Storms in late June 1990 moved sand offshore from the upper beach to form a nearshore bar. The storm bar persisted through two months of stormy weather. Between August 1990 and April 1991, calm weather promoted onshore sand movement. Apparently, the November 1991 profile showed little change whereas the June 1993 profile indicates substantial offshore transport and the formation of a pronounced storm bar, in depths of 3-9 metres below AHD, approximately 300 metres offshore. The 1990 nourished upper beach profile remained in place.

Murray *et al* (1993) carried out sediment budget calculations of detailed nearshore monitoring profile surveys and found that the storm demand in the Kirra area was not matched by a storm bar of similar volume. Over a number of storms, the Kirra area experienced progressive erosion. Murray *et al* (1993) concluded that there was a substantial longshore transport differential in the Kirra area.

In the absence of fully developed nearshore shoals, spits and bars along the beach system, the longshore supply of sand to Kirra is less than that leaving it and nourishment is of short term benefit to the Kirra area (but of long term benefit to beaches further north). This is significant to both short and long term coastal management of this area and was factored into the conceptual design of the nourishment works for Stage 1A (PBP, 1994).

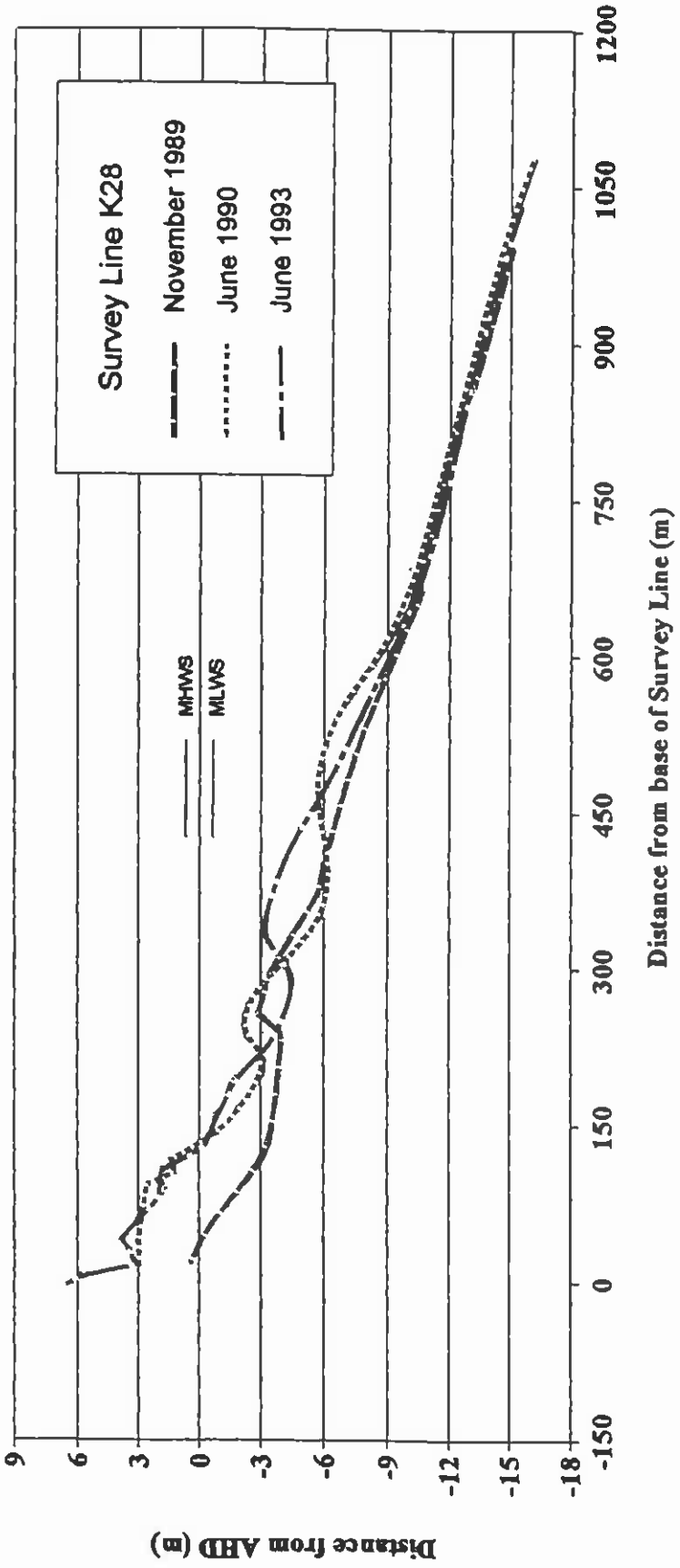
Murray, Robinson and Soward (1993) show that the beaches downdrift of Kirra have remained relatively stable after nourishment, with a slight tendency to accretion. The stability, however, has been maintained at the expense of erosion of the Kirra area. That is, the nourishment to Kirra has acted as an updrift source of littoral sand. An inference can also be drawn that downdrift of Kirra, longshore transport potential may be somewhat less episodic than along the more southern beaches.

The nearshore nourishment, placed initially as a mound in depths of 6-9 metres below AHD, tends to broaden and flatten in a shoreward direction while also being transported slowly alongshore. This is consistent with early observations of Robinson and Patterson (1975) who noted that onshore-offshore storm bar activity in the Kirra area tended to be largely confined to RL -6 m. Hence a disequilibrium bulge placed seawards of RL -6, but still within the actual longshore transfer regime, is likely to move shorewards of the RL -6 m contour until it is "caught up" in the ambient onshore-offshore sediment transport regime of the adjacent beach. This process is referred to in Delft (1986) and WBM (1990).

4.2.3 Analysis of Stage 1(A) Monitoring Data

4.2.3.1 Tweed/Gold Coast Beaches

The NSW Department of Land and Water Conservation (DLWC), Queensland Department of Environment (DoE) and the Gold Coast City Council (GCCC) have monitored the response of the subaerial and subaqueous areas of the southern Gold Coast beaches, Duranbah, Tweed Entrance and Letitia Spit, to Stage 1A dredging and nourishment activities from April, 1995 through October, 1996. Included in this data are aerial photographs, wave climate records, Tweed River tide records and hydrosurveys which cover an area from Letitia Spit to North Kirra.



Source: Murray, Robinson and Soward (1993)

Figure 4.2.1
Nearshore Profile Adjustments after Beach Nourishment - Kirra Area

A brief summary of the key findings of these analyses is presented below. A detailed discussion of the analysis results is presented in Technical Appendix I.

Snapper Rocks

The Snapper Rocks area is very dynamic. Divergence of longshore transport occurs during northerly sea and swell, when sediment is transported concurrently west towards Kirra and South towards Letitia Spit.

- The February and May 1996 storms created a large scour hole just to the North of Snapper Rocks, which had a volume of roughly 110,000m^3.
- Mild wave conditions and nourishment of 55,000m^3, mainly during July and August 1996, reduced the scour hole volume by half,
- Outer contours showed additions due to slugs moving past Snapper Rocks and around to the southern Gold Coast beach area.
- Since the start of monitoring, Snapper Rocks Beach has lost 5,000m^3 of sediment and the 0m contour has receded 22 metres.

Rainbow Bay to Coolangatta Beach

This area is dynamic close to shore, while offshore areas have been relatively slow to change. Storm events are needed to rapidly move and introduce sediment as large slugs. There are no significant reversals in longshore transport in this area i.e., sediment moves to the west from Snapper Rocks at all times.

- Nourishment of approximately 620,000m^3 in the Outer and Inner Nearshore placement areas was reflected in observed volumetric changes of 820,000m^3 between April and October 1995. This suggests that approximately 200,000m^3 of material moved into the area by longshore transport past Snapper Rocks, in that period.
- An observed gain of 60,000m^3 between RL -7m to -5m during October 1995 - January 1996 was partially reflected by deposition of 90,000m^3 in both the Outer and Inner Nearshore deposition areas. The deficit of 30,000m^3 would constitute onshore movement from the Inner Nearshore Deposition area.
- Over the period January to June 1996, there was an increase of 250,000m^3 compared to a nourishment volume of only 70,000m^3. The majority of this addition can be attributed to the ingress of sand, passing Snapper Rocks during the February and May storms.
- Approximately 160,000m^3 was placed subaqueously during June - October 1996, but there was an observed increase of only 30,000 m^3 indicating an overall depletion of approximately 130,000m^3. Hence, despite the relatively calm wave climate over this period, the nearshore nourishment sand and storm slugs were moving longshore at a significant rate.
- Due to the action of storm waves, significant losses occurred to all beaches since October 1995 (subaerial nourishment was in May 1995), resulting in shoreline recession.

Kirra Beach (ie. between Kirra and Miles Street Groynes and immediately North of Miles St Groyne)

Volumetric changes between RL -11m and -6m contours reflected the placement of nourishment material. The subaerial beaches (Kirra/North Kirra) have traditionally had erosion problems due primarily to the episodic nature of the movement of sand slugs through the nearshore area. In recent decades, the Kirra Point and Miles Street groynes have caused the offshore deflection of the beach bar system. This has exacerbated the subaerial erosion problem immediately north of Miles St groyne in particular:

- Addition of nourishment material occurred in the -11m to -7m contours where overall net gains of 600,000m^3 were observed.
- Losses due (primarily) to the May 1996 storm were concentrated in two areas:
  - ⇒ -8m: Nourishment material was the first to trip large waves.
  - ⇒ -4m to -1m: Nearshore material eroded to form a storm bar system
- Subaerially placed material was substantially redistributed to the nearshore bar system, showing an observed net increase in volume of only 45,000m^3. The actual subaerial nourishment was approximately 290,000m^3. This represents an 85% loss of nourishment material from the beachface.
- The sand loss from the beach face was manifested as substantial recession of the nourished beach face.

4.2.3.2 Analysis of Stage 1(A) Monitoring Data - Comparison with 1960 Conditions

As a subset of the monitoring analyses, the present bathymetry of the nourishment area was compared to 1960 conditions, to assess the extent to which the offshore profile has been restored to the natural, pre-Tweed walls profile. The resulting contour comparisons between 1960 and 1996 are quite similar (Figures 4.2.2(a) and 4.2.2(b)). This is especially the case in the Rainbow Bay to Coolangatta Beach section, where storm activity has caused an influx of material and tended to smooth nourishment material alongshore.

The area from Kirra to North Kirra, however, did not have the benefit of nearshore deposition, due to a nearshore exclusion zone designated to protect the Kirra Reef system immediately offshore. This has left a deficit trough landward of the -7m contour (i.e., there is not as much material present in these inner contours as there was in 1960). Surveys show that the current seabed, within this trough, is still up to 2m deeper than the 1960 nearshore profile. The overall deficit, represented by the trough, is approximately 290,000 m^3.

Hydrosurvey data shows that the outer deposition material is moving mostly alongshore and onshore only very slowly. Therefore, this inshore deficit area may remain until storm slugs and nourishment material move into the area from the Coolangatta area. Depending on the occurrence of storms, this process could take many months.

4.2.4 Coastal Process Modelling Investigations

4.2.4.1 General Considerations and Methodology

To determine any impacts of this project on the beaches and to specify the performance criteria for bypassing operations, it is necessary to have a detailed understanding of the spatially and temporally varying sand transport regime of the beach system and to assess the changes due to dredging and sand bypassing. There is considerable natural beach variability and it is expected that any project impacts will be mainly due to restoration of the full sand supply to the Queensland beaches, changes in wave propagation into the surfzone due to bathymetry changes and a reduction in pulsing of longshore transport past Point Danger due to the more consistent mechanical sand bypassing operation.

Waves propagate from deep water to the nearshore areas of Letitia Spit, Point Danger, the southern Gold Coast beaches and the Tweed River through the processes of refraction, diffraction and attenuation due to bed friction.

Wave propagation analyses for the present study have utilised a conventional software system (RCPWAVE) developed for the US Army Corps of Engineers and modified by WBM Oceanics Australia to more adequately cater for the particular requirements of this project. The analyses undertaken cover the full range of prevailing waves from the north-northeast through to the south-southeast. All other waves

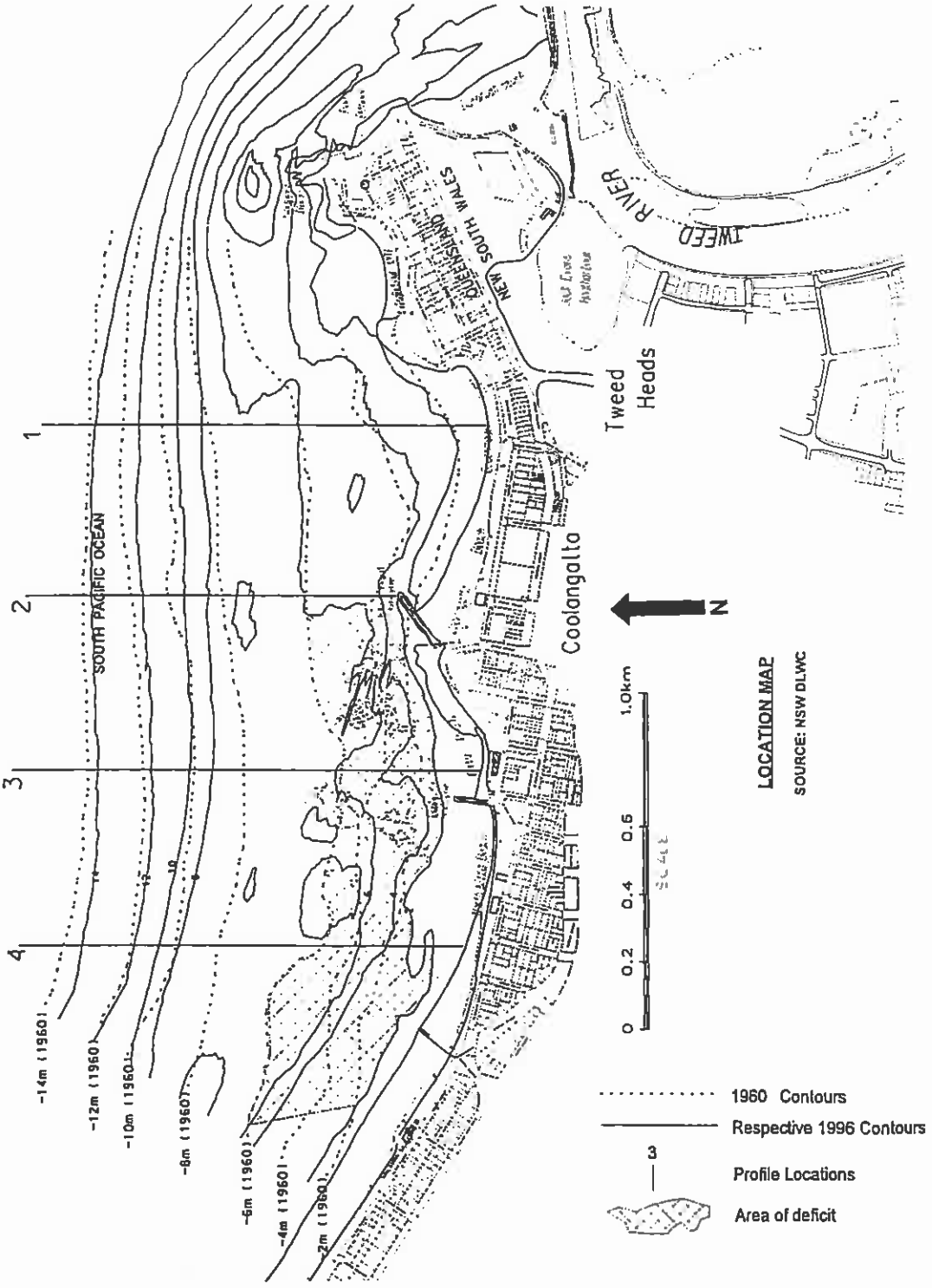


Figure 4.2.2a
Comparison of 1960s and Post Stage 1A Nourishment Contours

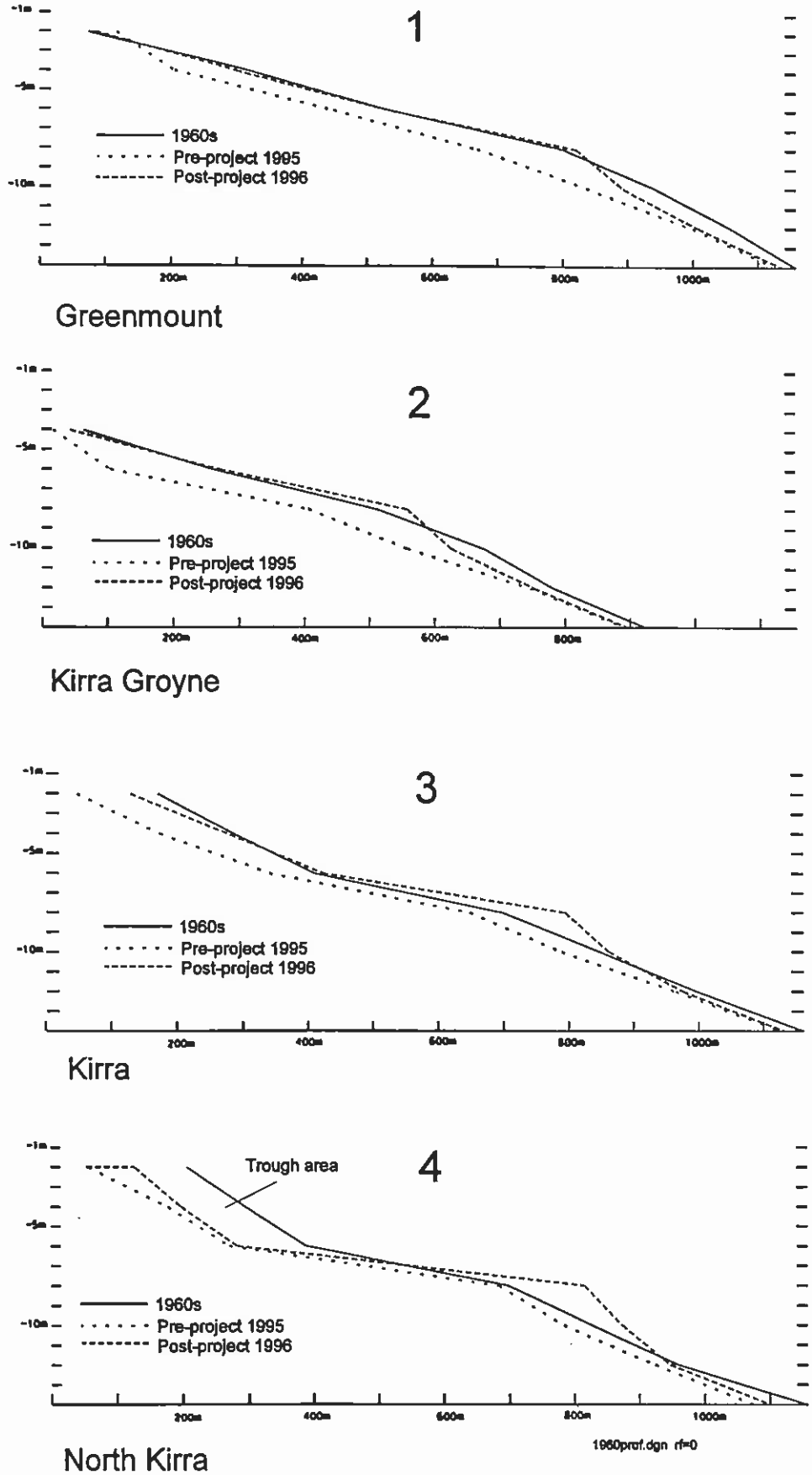


Figure 4.2.2b
1960s, 1995 and 1996 Nourishment Area Profile Comparisons

travelling from more westerly directions are of limited height nearshore and are of no significance to sand transport at the shore. The incident wave time series was determined so that all significant sediment transport conditions are properly accounted for.

Determination of wave propagation and longshore sand transport for each of the beach sites in the study area is extremely complex because of the complex bathymetric character of the nearshore and beach system. It requires analysis procedures at the leading edge of accepted coastal and ocean engineering practice. In particular the coastal process modelling has required comprehensive '2-Dimensional' (in plan) modelling procedures covering the whole study region. Conventional '1-Dimensional' techniques are not appropriate in this area.

The procedure adopted for the present study provides for:

- comprehensive wave propagation from the range of prevailing directions for the range of incident heights and periods incorporating combined refraction, diffraction and bed friction processes;
- generation of nearshore currents generated by the combined action of tidal, wind and wave radiation stress influences and the East Australian Current; and
- calculation of sand transport rates resulting from the combined action of waves and currents within and outside the surfzone areas at each location.

This modelling utilised the WBM Oceanics Australia software packages TWOPRO, TUFLOW and RCPR, incorporating the wave propagation programme RCPWAVE as modified and adopted for the project, and hydrodynamic and sand transport analysis procedures. Full details are provided in Technical Appendix II.

For beach evolution modelling, the US Coastal Engineering Research Centre (CERC) package GENESIS, which utilises the CERC equation for longshore transport, has been used for estimation of beach responses to natural wave variations and the proposed bypassing works. GENESIS is a programme developed by the U.S Corps of Engineers to simulate shoreline change associated with a wide range of coastal processes and works.

A brief description of the coastal and ocean process modelling undertaken for this project is set out in the following sections. Because of the uncertainties inherent in such modelling, key conclusions with respect to impacts on the beach system draw also on practical interpretation of historical and known processes of beach system change. Full details are presented in Technical Appendix II.

4.2.4.2 Wave Data

Necessary input to the modelling is comprehensive wave data. For the present purposes, this takes the form of a time series of height, period and direction for both 'sea' and 'swell' waves. Previous data collection and hindcasting has shown that 'sea' waves generated by local winds and 'swell' waves propagating from more distant sources commonly coexist in the study region. They have been provided for independently and in combination because:

- sea and swell often propagate from different directions and have different effects on longshore sand transport; and
- the influence on currents of stronger winds associated with higher sea waves is significant in some areas.

While an extensive data record of non-directional wave information is available for the region, fully directionally recorded wave data is available for only limited periods at locations relatively nearshore (in 20 to 25 metres water depth) at Gold Coast Seaway and Letitia Spit. A considerably longer directional wave

data base is needed to understand the longer term spatial and temporal variability of the sand transport processes.

It was therefore necessary to establish directional information to augment the recorded wave data for use in the study. This has been achieved using hindcast data from the British Meteorological Office (BMO) for the 7 year period January 1989 to June 1996. A detailed description of the procedure is outlined in Technical Appendix II. Summary results are presented in Section 4.1.8.1 of this report.

4.2.4.3 Wave Propagation

Waves propagate from deep water to the nearshore areas of Letitia Spit, Point Danger, the southern Gold Coast beaches and the Tweed River through the processes of refraction, diffraction and attenuation due to bed friction.

Analysis of wave propagation into the beach areas is fundamental to the determination of the sand transport regime at these areas. The southern Gold Coast beaches are substantially sheltered from the direct incidence of the predominant southeast sector waves. These beaches have a different wave exposure and hence a different sand transport regime from that occurring along the exposed beach and nearshore systems of Letitia Spit, Duranbah and Snapper Rocks.

Wave propagation analyses for the present study are described in Technical Appendix II. Selected wave ray propagation analysis results from Roelvink and Murray (1992) are presented in Figures 4.2.3(a)-(c). The model analyses for this study extended this work to include the combined effects of refraction, diffraction and bed friction.

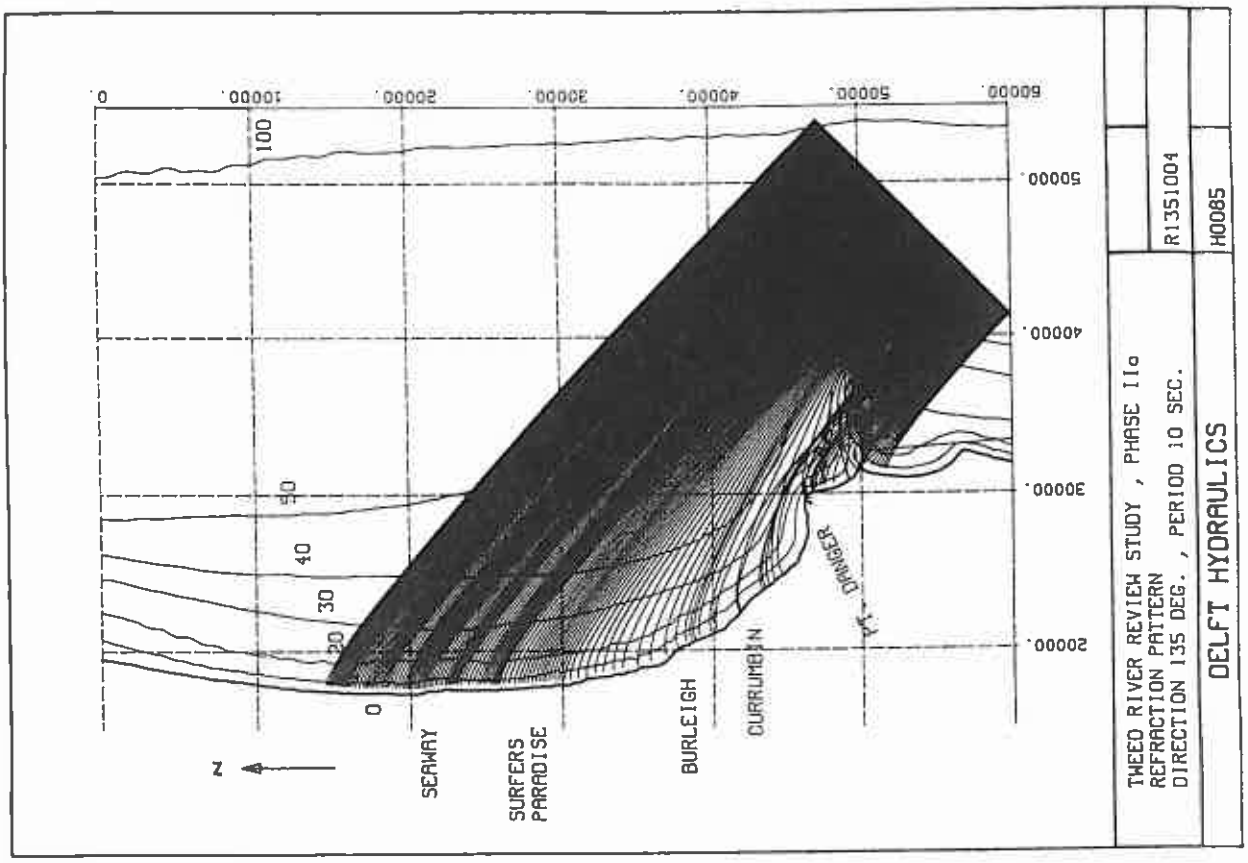
The analyses undertaken cover the full range of prevailing waves from the north (north-northeast) through to the south (south-southeast). All other waves travelling from more westerly directions are of limited height nearshore and are of no significance to sand transport at the shore.

Results of the model analyses of wave propagation from deep water to the Tweed and Kirra Waverider buoys have been compared with the best available assessment of the recorded height data and hindcast direction data as an indicator of model accuracy and any correction factoring which may be required. This validation procedure involved analysis of the deepwater (Brisbane and Byron), Tweed and Kirra recorded wave data to derive wave height factors ($H_{Inshore}/H_{Offshore}$) for recordings dominated by swell (Tp greater than 8 seconds) for the range of incident wave directions and direct comparison with the modelling results. The reliability of this analysis is limited because of the lack of recorded offshore wave directions.

The wave propagation validation results presented in Technical Appendix II show the following:

- good correlation for waves from the east-northeast to east-southeast directions;
- slight over-estimation of wave heights from the northeast; and
- slight under-estimation of wave heights from the southeast to south-southeast.

Hence, it is concluded that the model representation of wave propagation is sufficiently accurate for the present studies. Nevertheless, some corrective factoring may be needed for reliable determination of southeast swell wave conditions around Kirra and North Kirra, where the sand transport analysis results may otherwise be somewhat too low.



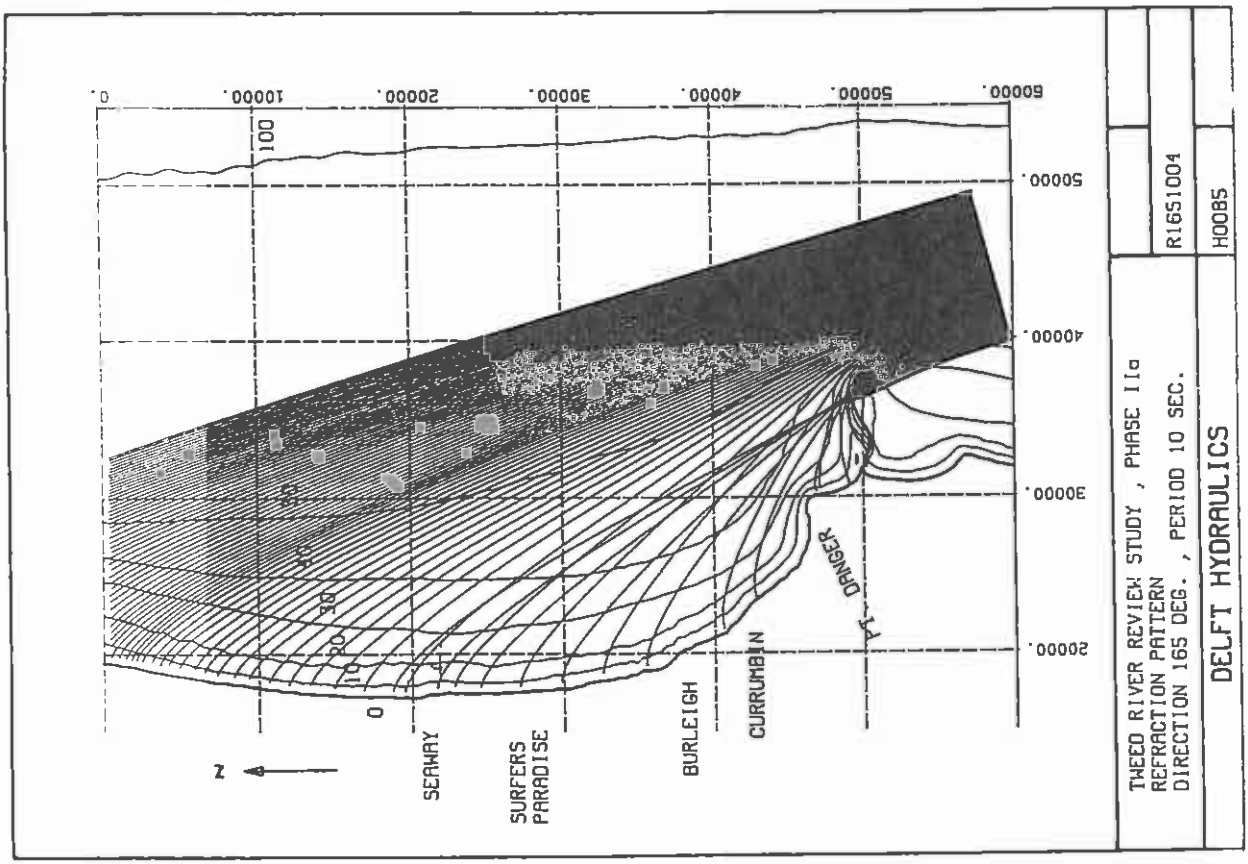
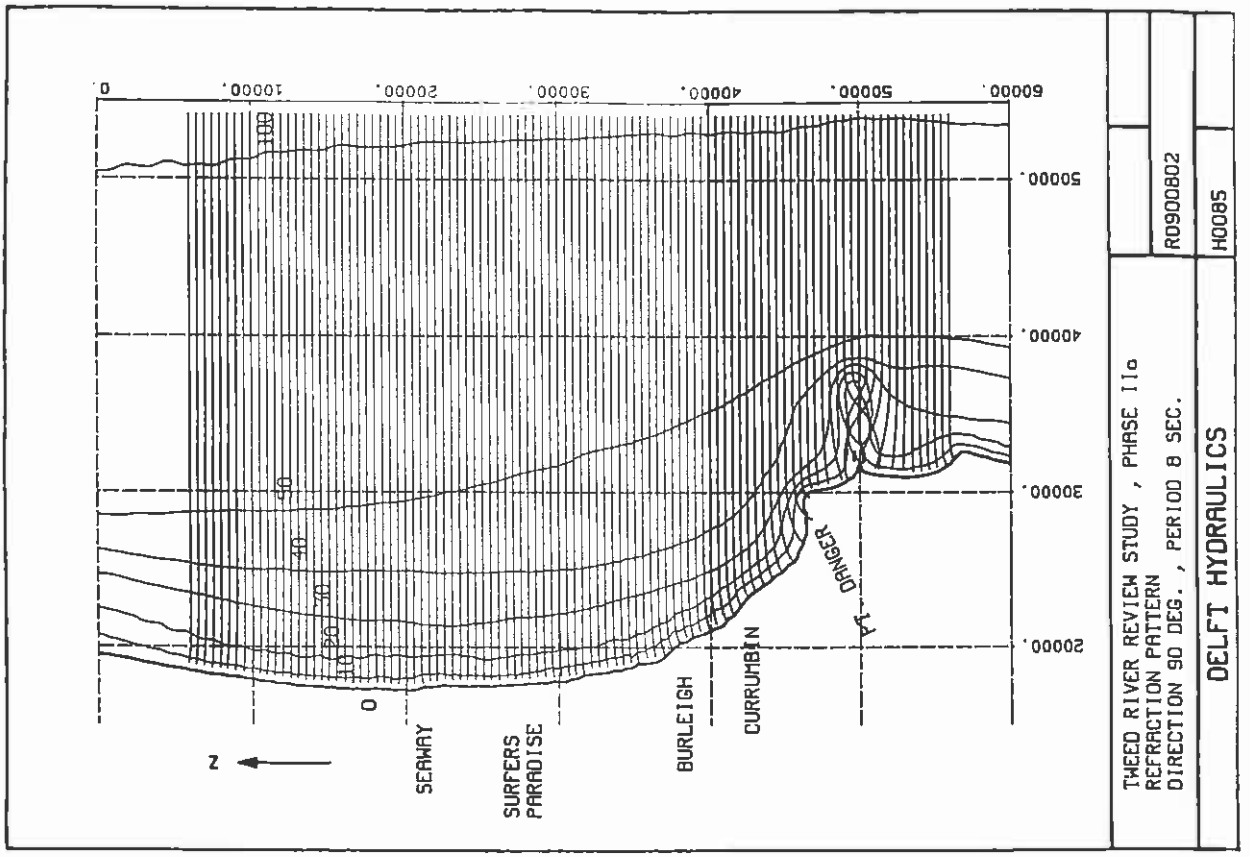


Figure 4.2.3a
Typical Wave Propagation Patterns - SSE and SE



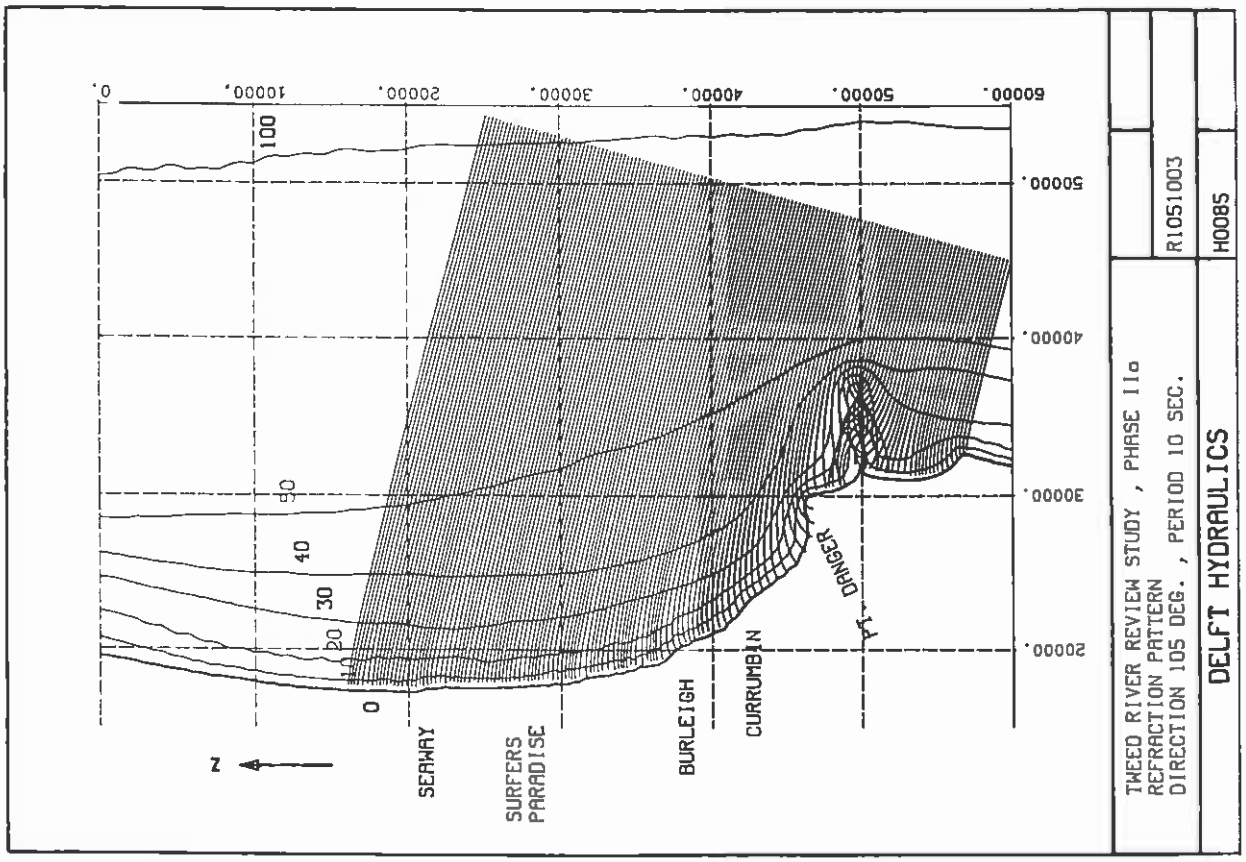
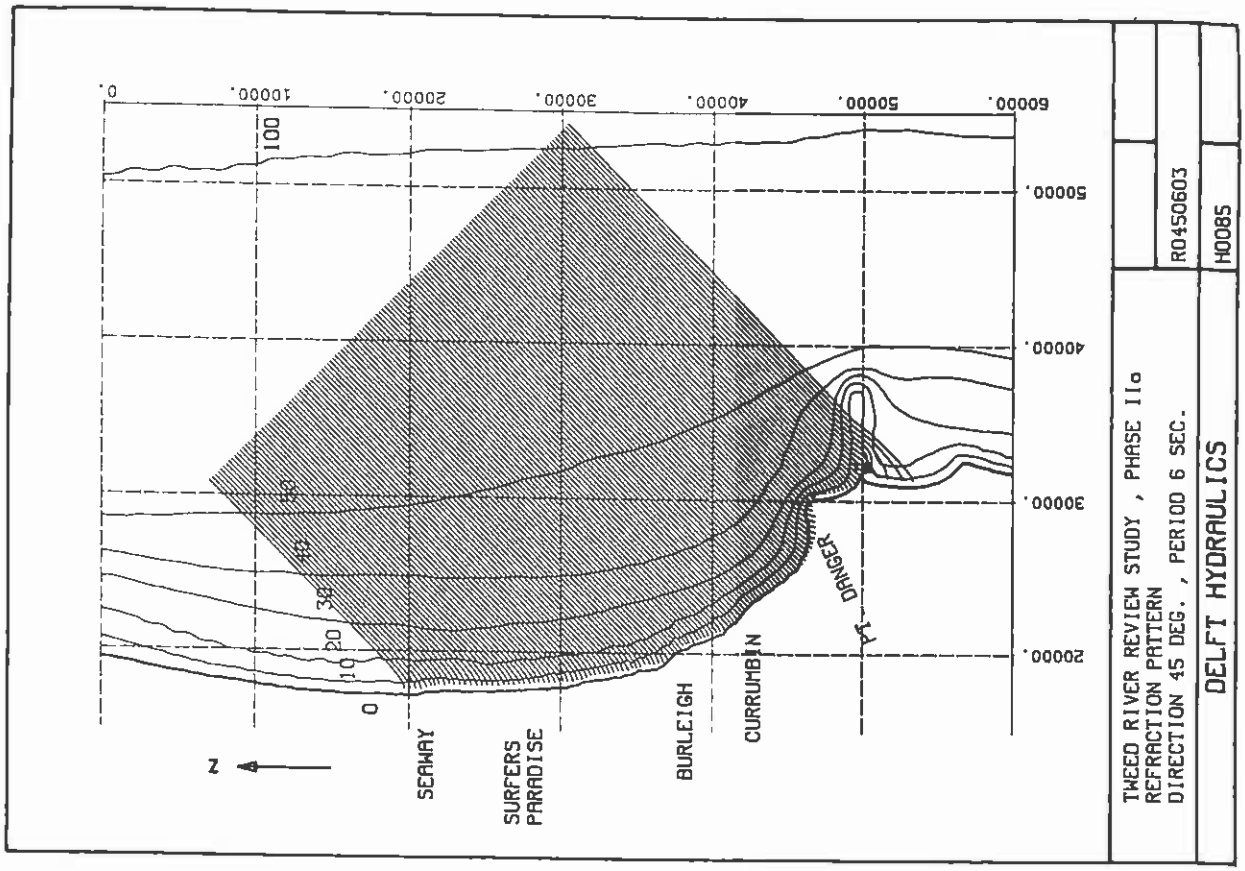


Figure 4.2.3b
Typical Wave Propagation Patterns - ESE and E



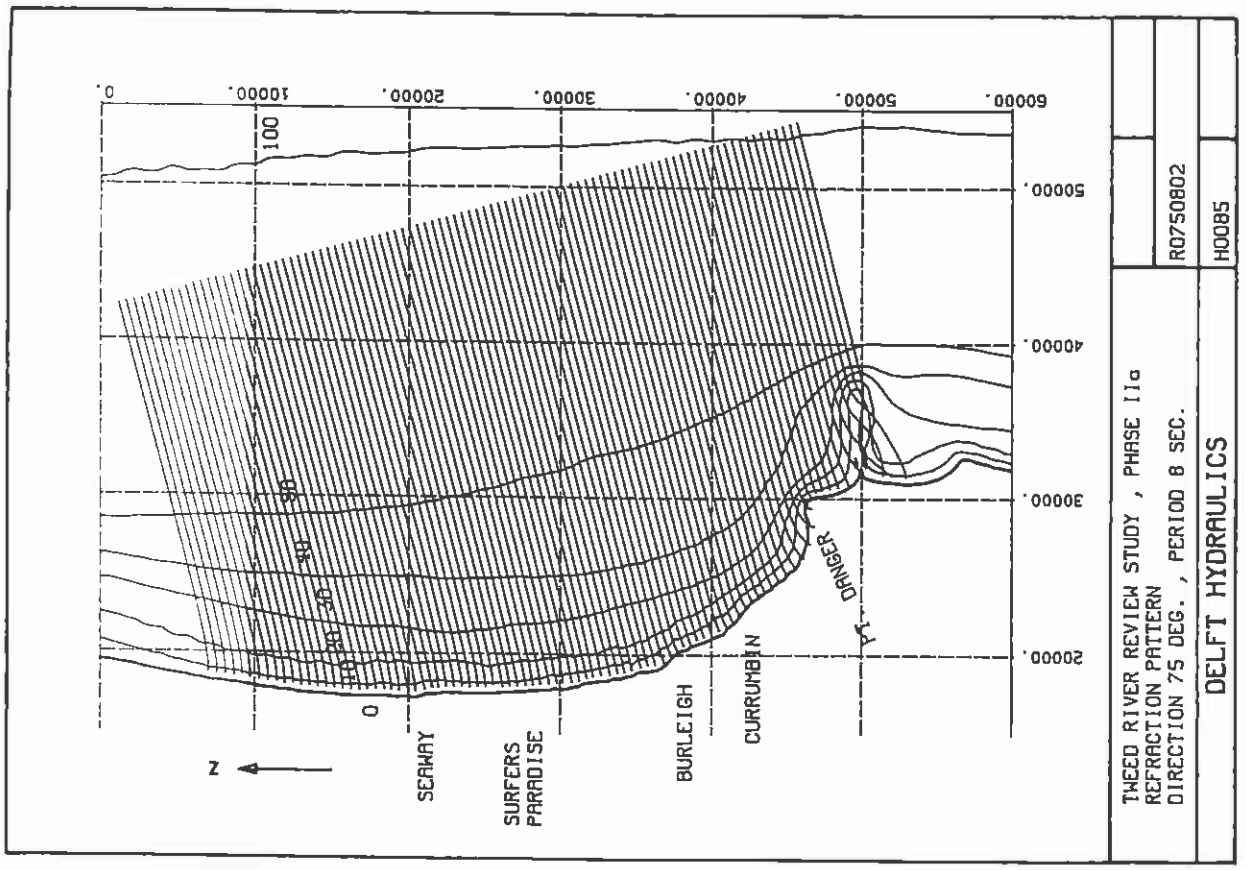


Figure 4.2.3c
Typical Wave Propagation Patterns - ENE and NE

4.2.4.4 Nearshore Currents

Nearshore currents within and outside the surfzone and in the vicinity of the river entrance are important because of their substantial influence on sand transport and their significance for structural and operational design of the bypassing system.

Several factors contribute to generation of the general current patterns in the region, the most significant of which are:

- wave radiation stresses within the surfzone;
- wind stress on the water surface;
- tides; and
- the East Australian Current (EAC).

Wave orbital velocities contribute locally to sand mobility and transport, and also must be considered in the design of structures subject to wave forces.

Each of these is discussed in Technical Appendix II. These factors have been taken into account in the computer modelling of nearshore currents and sand transport regime of the beach system.

4.2.4.5 Longshore Sand Transport Modelling

Sand is transported in the nearshore coastal zone by the complex interaction of waves and currents within the context of the shoreline shape and bathymetry. The prevailing waves may be locally generated sea or swell propagating from distant sources, and different sea and swell wave trains may coexist. The longshore sand transport modelling assessments undertaken for the present study incorporate these influences in a comprehensive manner. However, it must be recognised that this work is at the leading edge of coastal process assessments of its type, applied to a most complex coastal area. Substantial error margins are implicit in the modelling results.

A time series of reliably recorded deep water non-directional wave spectra exists and has been split into component sea and swell wave trains with application of the hindcast sea and swell directions as described in Section 4.2.3. Two-dimensional (in plan) wave height and direction fields have been produced for each of a large range of incident waves. These include sea and swell over a range of heights and periods from seaward directions in 22.5° increments from north-northeast to south-southeast.

The 2-Dimensional modelling of current patterns and sand transport induced by wave radiation stress and wind forces has facilitated the determination of both the spatial and temporal variability of longshore sand transport. For each wave case modelled, the cross-shore distribution of longshore transport rates at each designated calculation site was extracted from the model output. Integration of the transport across each profile yields the total potential transport rate for each wave case. The designated calculation sites are shown in Figure 4.2.4. It should be noted that the modelling is based on a representative fixed nearshore bathymetry. As such, it does not allow for changes in transport potential due to changes in nearshore bed levels. As shown in the analysis of hydro-survey data, the fluctuations of bed levels in some locations can be quite large.

Arrays of sand transport rates for both 'sea' and 'swell' were thus generated, in which the variability of transport as a function of wave height/period for 'sea' and wave period for 'swell' are established. Conventional theoretical relationships for swell-related transport are then applied.

The 6-hourly time series of sea and swell heights, periods and directions have been analysed to produced 6-hourly equivalent transport rates from interpolation and extrapolation of the array values. Daily, weekly,

monthly, annual and seasonal gross and net transport results are then derived from those results.

It has been noted in Section 4.1.6 and in detail in Technical Appendix II that the available non-directional wave time-series for the period 1989 to 1996 may not be representative of the longer term average wave conditions. In particular, wave conditions in 1989 were abnormally (+50%) high in terms of the energy related sand transport capacity. Even ignoring that year of data, the wave energy over the years 1990-1995 appear to be somewhat higher (+13%) but more representative of the longer term average.

Hence, sand transport results presented for the years 1990-1995 are considered to approximately represent the long term average situation, recognising that they may be somewhat higher than the longer term mean depending on the directional representativeness during that period. The results for 1989 are considered as extreme, although within the range of potential transport patterns which may occur during the operation of the bypassing.

The results of the longshore transport modelling are presented in time series form in Technical Appendix II. Tabulated transport results are presented as follows:

- Table 4.2.1 - Annual Average Net and Gross Sand Transport,
- Table 4.2.2 - Annual Average Net Longshore Transport, and
- Table 4.2.3 - Annual Average Gross Longshore Transport.

The results in Tables 4.2.2 and 4.2.3 are presented in terms of both whole profile gross/net results and incremental transport components in the cross-shore depth zones:

0-2m below MSL
2-4m below MSL
4-8m below MSL
8-12m below MSL
>12m below MSL

These results describe the cross-shore variability of the longshore transport and the variability from year to year.

As well, further details of the temporal variability of longshore transport in terms of daily, weekly and monthly transport probabilities are presented in Technical Appendix II. These are to be considered in the performance capacity design of the bypassing system.

Figure 4.2.5 shows the mean seasonal longshore transport rates for Letitia Spit/Snapper Rocks, based on the monthly net and gross results for the six year period. Figure 4.2.6 shows the individual monthly transport rates, illustrating the high degree of variability from year to year. Nevertheless, there is a clear pattern of high net and gross transport in the summer months, and relatively low transport over the period July/August to November.

Table 4.2.1 Annual Average Net and Gross Sand Transport Potential (m^3/year)

Location	Net	Upcoast	Downcoast
North Kirra	434000	434000	0
Kirra	493000	493000	0
Snapper Rocks	601000	614000	-13000
Frog's Beach	495000	575000	-80000
Lovers Rock	600000	676000	-76000
Duranbah	576000	722000	-146000
Letitia Spit	545000	698000	-153000

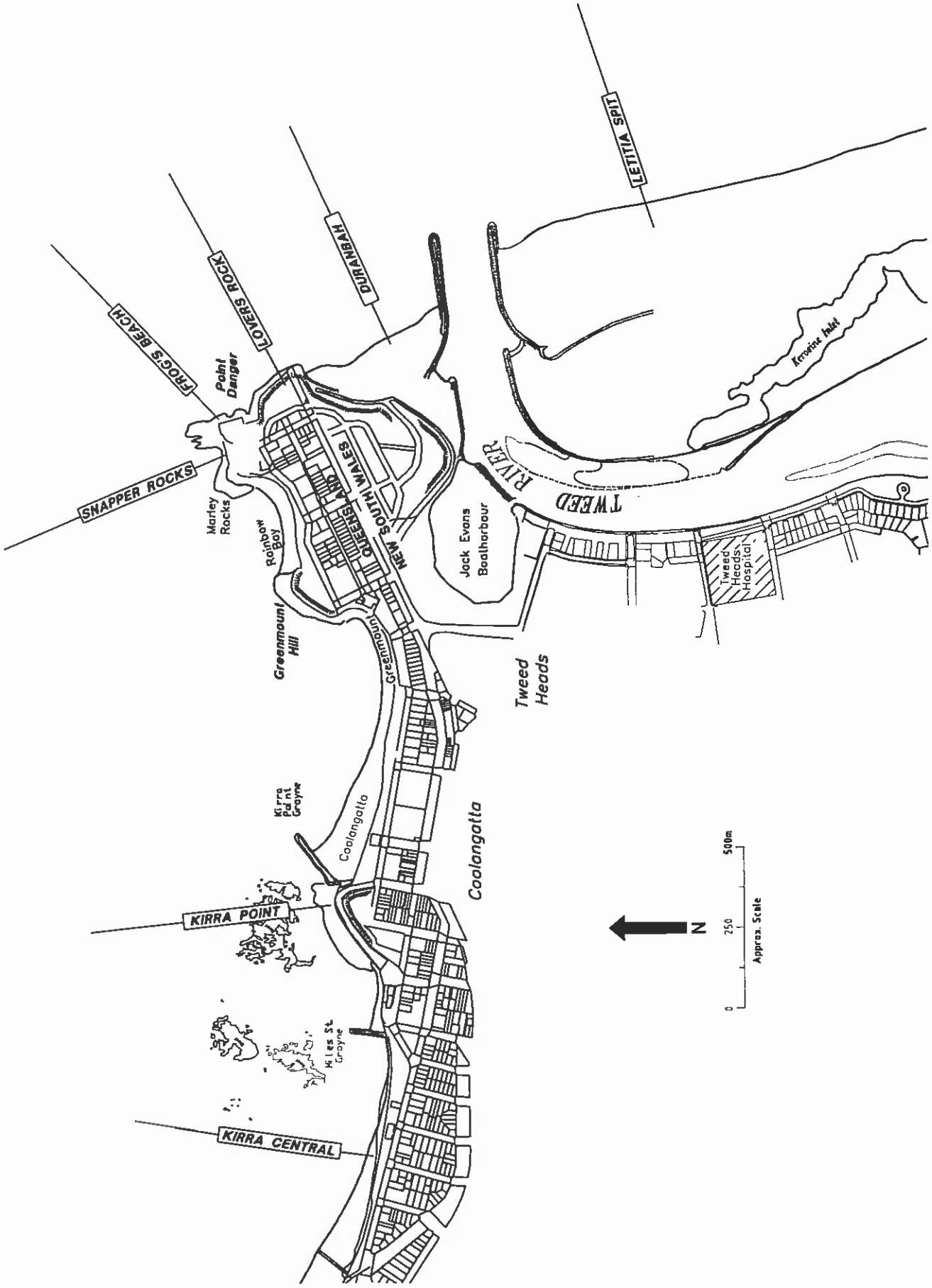
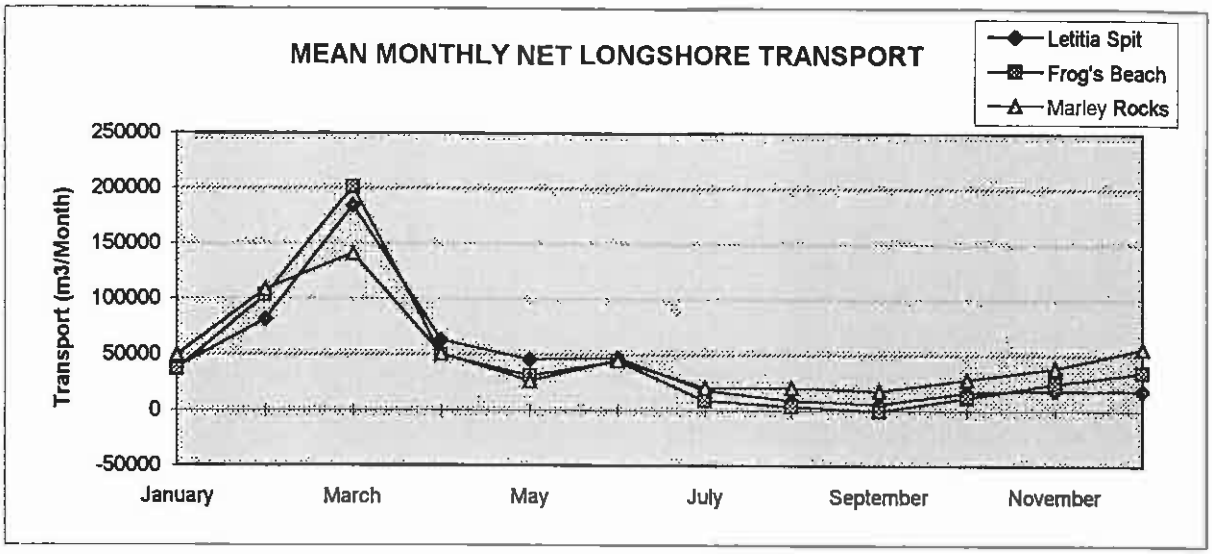


Figure 4.2.4
Longshore Transport Calculation Locations



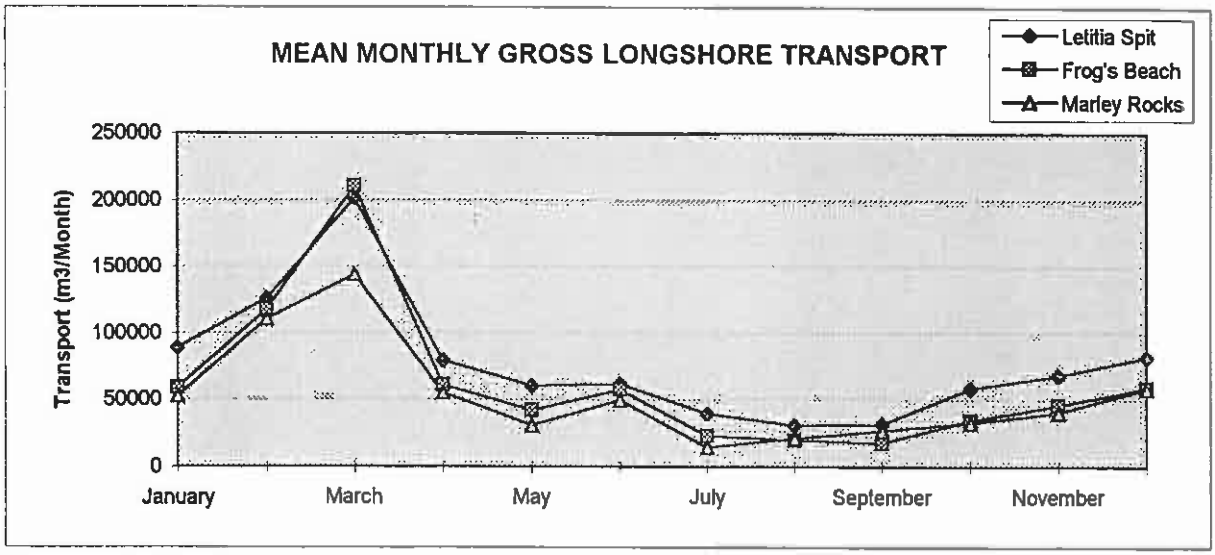
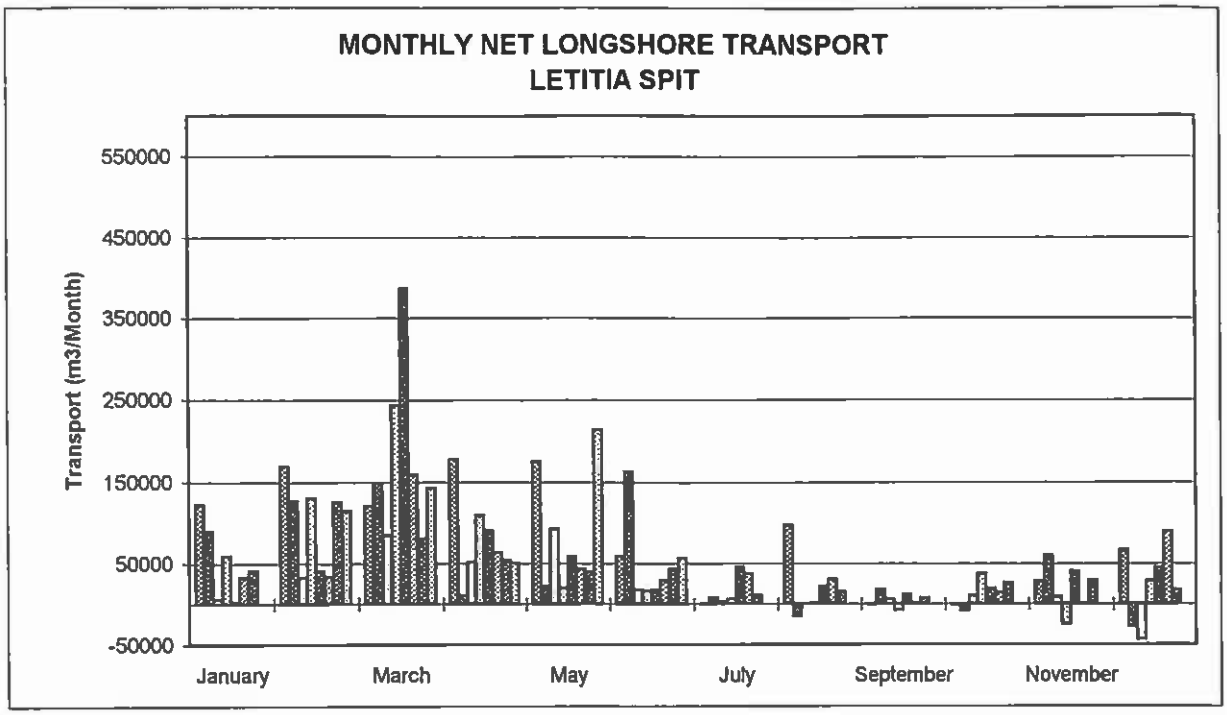


Figure 4.2.5
Mean Monthly Longshore Sand Transport



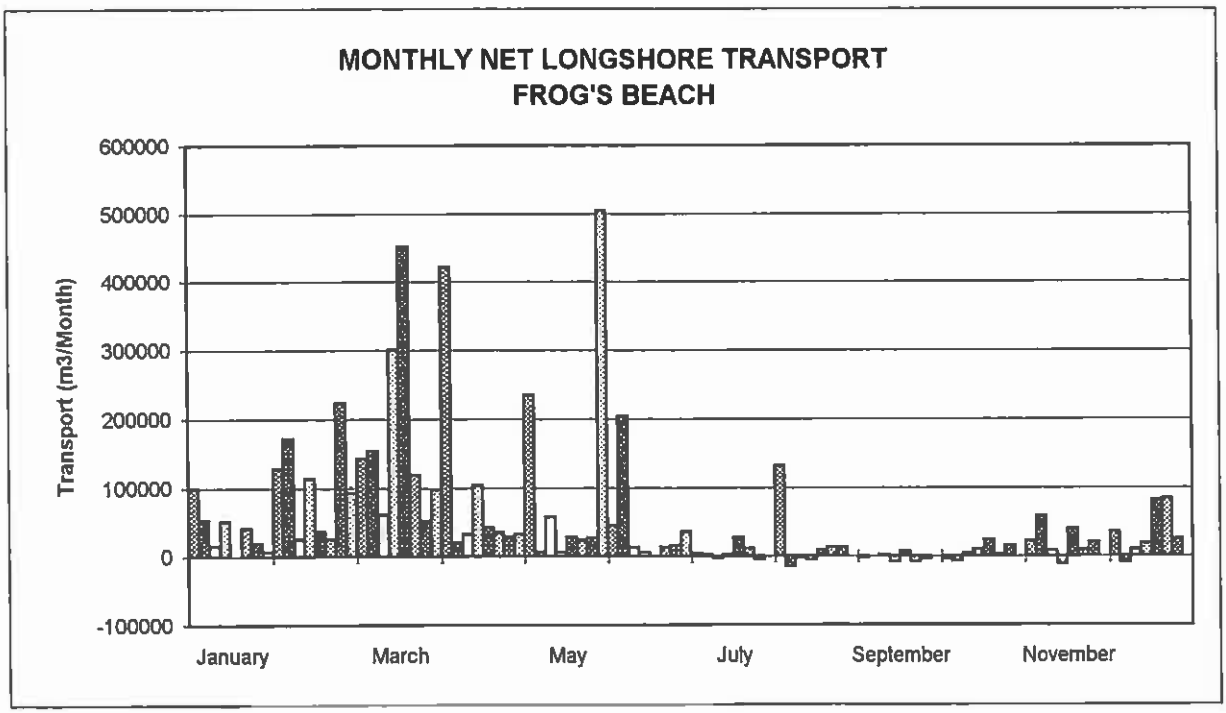


Figure 4.2.6
Monthly Longshore Sand Transport Rates
For the Years 1989 to 1996

Table 4.2.2 Annual Average Net Longshore Transport Potential

Net Transports						
	0 - 2m	2 - 4m	4 - 8m	8 - 12m	>12m	TOTAL
Kirra	68,380	252,240	136,370	27,860	8,140	493,000
Snapper Rocks	188,600	268,260	132,000	10,470	1,230	601,000
Frog's Beach	16,790	316,170	186,850	-16,360	-8,440	495,000
Lovers Rock	72,380	370,770	181,050	-11,090	-13,100	600,000
Duranbah	-11,830	357,950	236,390	8,570	-15,090	576,000
Letitia Spit	145,720	308,930	114,260	2,040	-24,950	545,000

Table 4.2.3 Annual Average Gross Longshore Transport Potential

Gross Transports						
	0 - 2m	2 - 4m	4 - 8m	8 - 12m	>12m	TOTAL
Kirra	68,380	252,240	136,370	27,860	8,140	493,000
Snapper Rocks	188,600	269,500	135,200	31,500	22,200	647,000
Frog's Beach	44,735	317,990	211,790	36,310	44,170	655,000
Lovers Rock	96,030	382,970	194,100	38,630	40,270	752,000
Duranbah	161,950	377,910	238,120	48,080	41,950	868,000
Letitia Spit	213,580	403,650	154,400	30,660	48,690	851,000

Review of the above results indicate the following key conclusions:

(i) The calculated net longshore transport potential throughout the study area is about 500,000 to 600,000m^3 per year at all locations, averaging about 550,000m^3/year. On the basis that the conditions during the period 1990 to 1995 were about 13% higher than the long term average, the previously assessed long term average annual net transport rate of 500,000m^3/year is supported.

(ii) There is substantial variability in the annual net and gross longshore transport rates, calculated to be typically in the range 250,000m^3/year (1991) to 800,000m^3/year (1993). The calculated net rate for Letitia Spit in 1989 is about 1 million m^3/year considered probably at the upper limit likely to occur from time to time.

(iii) Longshore transport rates are highly variable over time, with most transport occurring during the higher swell wave and storm wave periods.

(iv) There is significant spatial variability of longshore transport at different locations along the beach unit at any time. This leads to periods of significant variability of sand volumes at some beaches, most notably:

⇒ Snapper Rocks (Figure 4.2.7), where short term periods of strong southeast sector waves force slugs of surplus sand past Point Danger, followed by prolonged periods (1 to 3 years) of steady movement of the sand away along the beach system.

⇒ River entrance/Duranbah area (Figure 4.2.8), where a relatively steady net surplus supply from Letitia Spit is balanced by periodic short term, moderate net losses of sand past Point Danger.

(v) The vast majority of longshore transport occurs in water depths less than 4 metres, particularly in depths of 2-4 metres. Nevertheless, significant (typically 25-30%) transport occurs in depths of 4-8 metres. Progressively less transport occurs further offshore, with longshore transport at the more exposed beaches increasingly influenced by the EAC which has a low net downcoast effect in the

zone beyond about 10-12 metres depth.

(vi) Gross longshore transport rates are highest at Letitia Spit, where significant downcoast transport occurs from time to time, and least at Kirra Point where transport is always upcoast (that is, the gross and net transport rates are equal).

The most significant short term differentials in longshore sand transport occur between Point Danger and Snapper Rocks. These appear to occur during short term high energy storm events which move slugs of sand into the Snapper Rocks area. This then diminishes gradually over a long period as the sand is moved on along the beaches. This data indicates differential 'slug' quantities of up to about 350,000m^3 which are then depleted over a period of some 1 to 3 years.

These results are the transport potential as calculated for the particular nearshore bathymetries provided for in the two-dimensional model. Thus, they may not properly reflect the actual sand transport rates at locations adjacent to rocky shorelines where the seabed levels vary significantly. Accordingly, the results for the locations at Lovers Rock, Frog's Beach and Snapper Rocks (Marleys) should be regarded as indicative only.

Further, while these results appear to indicate a pattern of lower net transport at Kirra and North Kirra, this may not be the case in the prototype. There are various factors associated with the directional wave climate determination, the wave refraction analysis and the sand transport calculations which would lead to underestimation of the transport in those areas, and overestimation of the transport along the more exposed ocean beaches.

Key factors which contribute to the potential for the present modelling to underestimate the net longshore transport at Kirra, and which would require further data and detailed investigation to assess are as follows:

(i) The adopted BMO model hindcast wave climate, which is considered to underestimate the proportion of swell waves from the easterly sector (refer Section 4.1.8.1).
(ii) The additional influence (not assessed herein) of the component of wave induced mass (cross-shore) sand transport which is directed along the coast in that area. Preliminary estimates suggest that this component could be (order of) 25,000m^3/year or higher (depending on the complex interaction of wind induced currents and the wave orbital velocities).

(iii) Possible limitations of the present model, particularly for North Kirra, with respect to the proximity of the model boundary, wave refraction to that area and proper representation of the nearshore bar/gutter bathymetry.

In the context of these factors, it is considered that the present results are sufficient evidence to conclude that the net transport through the beach system constant at about 500,000m^3/year.

4.2.4.6 Longshore Transport in Storm Events

Storm Wave Conditions

A number of severe storm events in which the significant wave height (Hs) exceeded 5 metres occurred during the period 1989-1996 for which directional wave data has been derived. These are outlined in the following table.

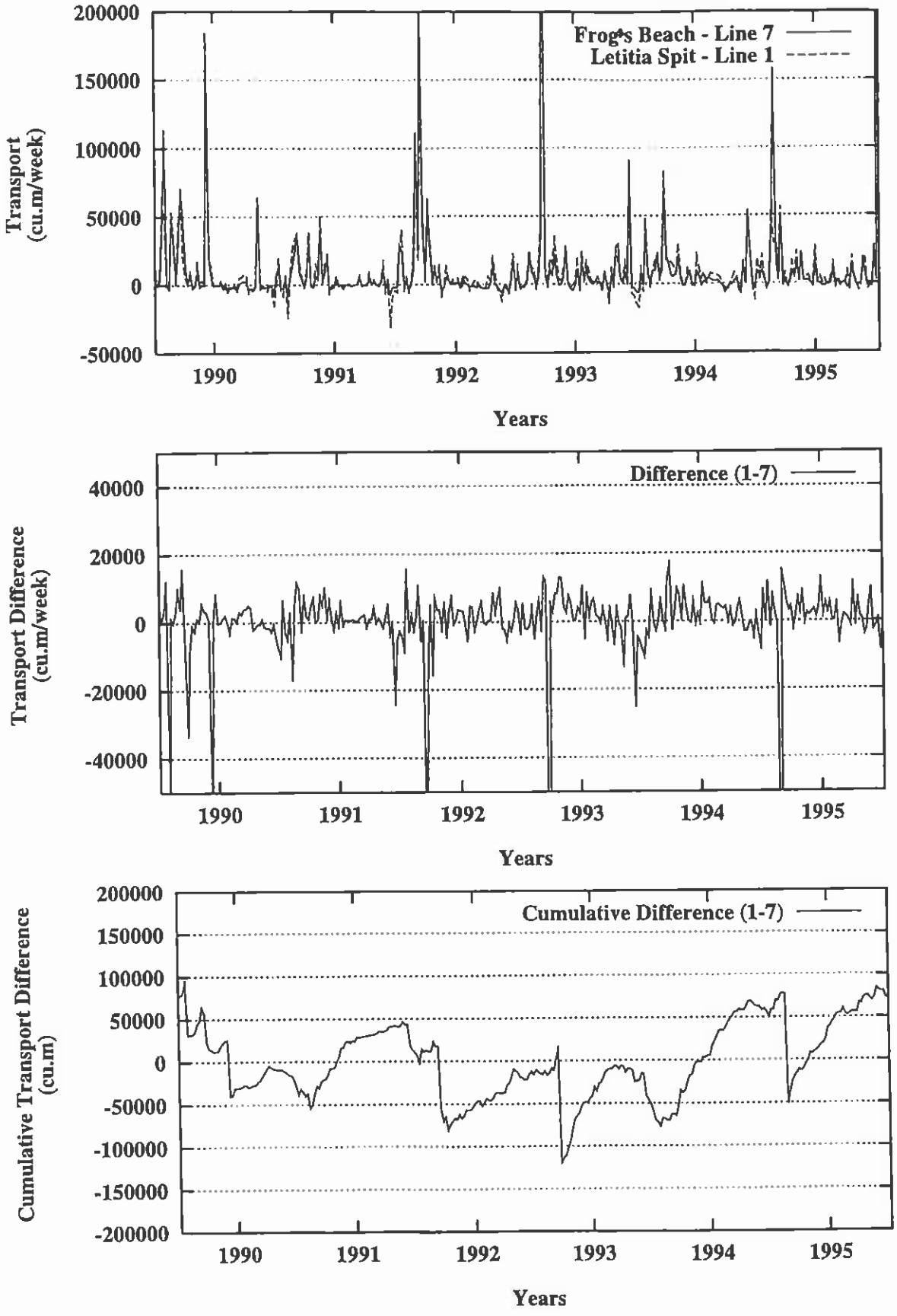


Figure 4.2.7
Longshore Transport Differential
- Letitia Spit to Frogs Beach

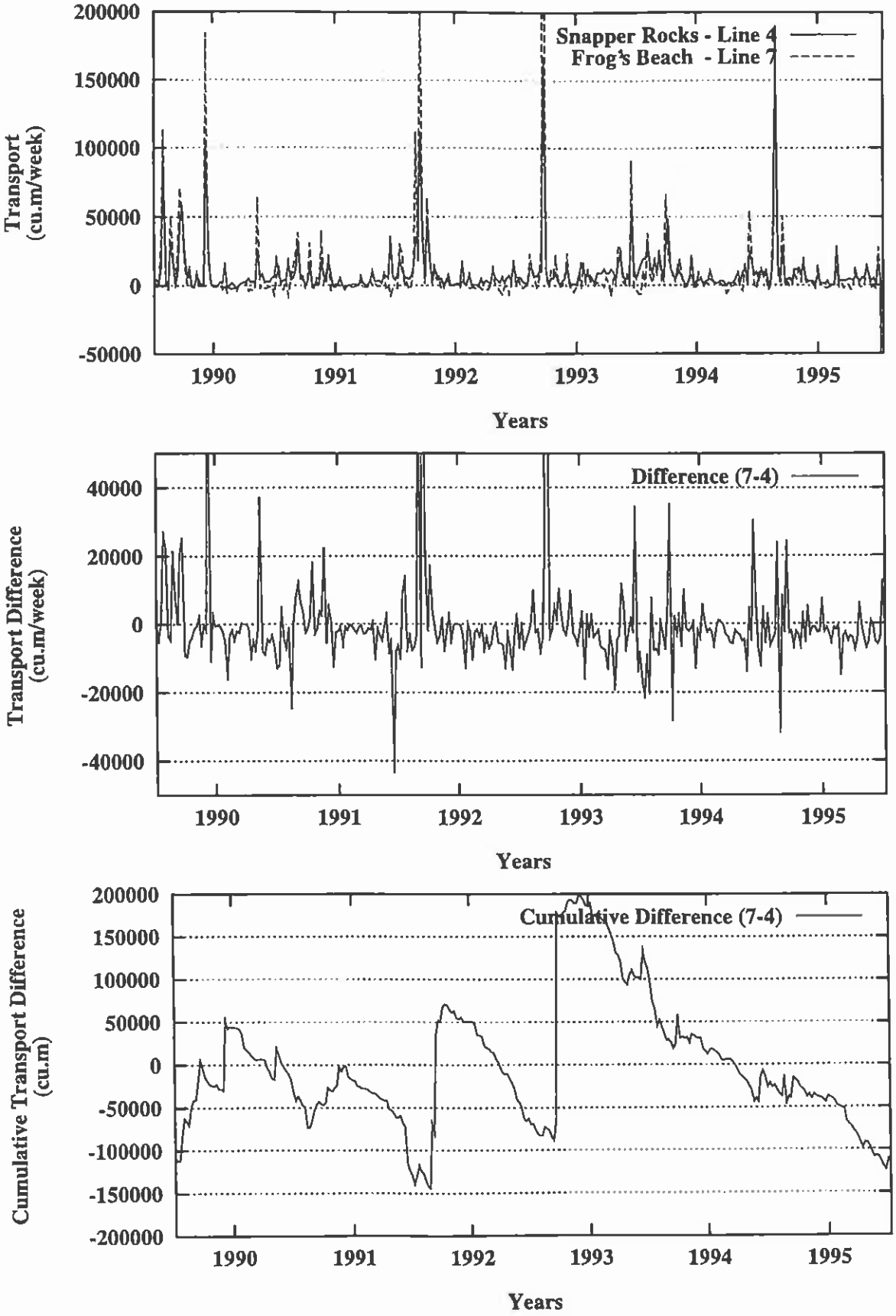


Figure 4.2.8
Longshore Transport Differential
- Frogs Beach to Snapper Rocks

Table 4.2.4 Peak Significant Wave Heights Resulting from Severe Storm Events during 1989 - 1996.

	Peak H_s (m)
April 22-29, 1989	6.1m
February 1-7, 1990	*5.0m
February 25 - March 19, 1992	5.1m
March 11-25, 1993	7.4m
February 12-17, 1995	6.4m
February 13-18, 1996	6.2m
May 1-7, 1996	6.9m

(Note: * indicates that value has been derived from the BMO model results)

Of particular significance in this study are the storms in February and May 1996 which occurred during the river entrance dredging and bathymetric survey monitoring. The available directional wave data for this period are the adopted deep water data combining the recorded Brisbane height/period data with the BMO model hindcast directions, and the nearshore Tweed recorder directional data for about 20 metres water depth offshore from Letitia Spit. The wave height, period and direction data for the more intense May 1996 period, expressed as equivalent deep water values are presented in Figure 4.2.9.

Correlation is good between these data sets for height and period. Substantial differences are evident in the directions. These are affected at the Tweed recorder location by refraction from deep water, and have been converted to deep water equivalent values in the plotted results, based on the refraction model. Wave directions during the first of the storm period was predominantly from east-northeast. Waves during the second, less severe event appear to have been somewhat more from the east to southeast sector. There appears to be a bias in the hindcast directions away from the east sector and towards the south to southeast. That pattern has been noted earlier in this document.

Longshore Transport

Longshore sand transport rates during these events have been derived from the modelling using the recorded wave data with BMO hindcast directions except for the May 1996 storm for which the recorded Tweed data was used. As outlined above, transport rates calculated for such extreme events are likely to contain a potentially high error margin and should be regarded as indicative only.

The net transports rates obtained for each of these storms are summarised in Table 4.2.5. It can be seen that a relatively high proportion of the average annual net longshore transport may occur during these isolated short term events. The total transport in any year may be highly dependent on occurrences of such events. The bypassing system must be designed to cater for the associated high transport rates.

Table 4.2.5 Longshore Transport (m^3/storm)

Storm Event	Net Longshore Transport at Location Shown (m3/storm)				
	Kirra	Snapper Rocks	Point Danger Frog's Beach	Duranbah	Letitia Spit
April, 1989	+225,000	+254,000	+220,000	+155,000	+81,000
March, 1992	+86,000	+173,000	+274,000	+218,000	+206,000
February, 1990	+89,000	+110,000	+113,000	+70,000	+60,000
March, 1993	+120,000	+201,000	>+400,000'	+294,000	+301,000
February, 1995	+270,000	+251,000	+206,000	+154,000	+66,000
February, 1996	+12,000	+28,000	+84,000	+81,000	+97,000
May, 1996	>+400,000'	>+400,000'	+307,000	+193,000	-53,000

(' Estimate - actual result affected by bed scour not modelled.)

4.2.4.7 Shoreline Evolution Modelling

The computer modelling programme "GENESIS" simulates shoreline change produced by spatial and temporal differences in longshore sand transport. These may result from longshore differentials in wave refraction and/or the effects of headlands, groynes, seawalls, breakwaters or other coastal structures.

Shoreline movement such as that produced by beach fills, river sediment discharges and sand extraction can also be represented. The main utility of the modelling system lies in simulating the response of the shoreline to structures and nourishment/extraction sited in the nearshore zone. Shoreline change produced by cross-shore sediment transport as associated with storms and seasonal variations in wave climate cannot be simulated. Such cross-shore processes are assumed to average out over a sufficiently long simulation interval or, in the case of a new project, be dominated by rapid changes in shoreline position from a non-equilibrium to an equilibrium configuration.

Two GENESIS models have been used to simulate shoreline dynamics along the project area, as follows.

Model 1:
- a model facing east incorporating Letitia Spit, the Tweed Entrance and Snapper Rocks with direct wave input from the Tweed wave recorder site; and

Model 2:
- a model facing North incorporating the beaches from Snapper Rocks to North Kirra with wave input in terms of refracted conditions relative to deep water.

The model locations are shown in Figure 4.2.10.

The choice was made to use time series input wave conditions at the seaward boundary in Model 1 and use the internal wave transformation formulations. This was considered acceptable because of the more regular offshore bathymetry.

Because of the formulation GENESIS uses to determine the offshore profile, the models are most suited to simulating the beach changes down to a depth of -6 to -10 metres, however the effects of complex bathymetry further offshore are not properly represented. Therefore the very nearshore and lower beach responses are best represented and any transport by offshore deepwater mechanisms is incorporated as a bypassing component.

For Model 2, RCPWAVE was used to transform the wave condition from deep water to a nearshore location of about 6 metres water depth. The internal transformation formulations are used to take the waves from that location to shore.

Because of the complexity of the entrance bar shoals offshore from Duranbah, the true beach alignment there cannot be simulated accurately in the GENESIS model. Nevertheless, the model is useful as an assessment tool for determining the likely relative change, as discussed in Section 7.2.

Similarly, the GENESIS model does not accurately represent beach alignments at (for example) Greenmount, where sand transport may occur along the nearshore shoals which are detached from the shoreline. Again, the model gives a useful representation of the overall volumetric status of the beach, even though the shoreline position may (in such cases) be over-estimated.

The shoreline evolution modelling showed beach fluctuations through a large range of up to 50 metres in response to the wave time series. These fluctuations were observed to be within the envelope of known historical variations.

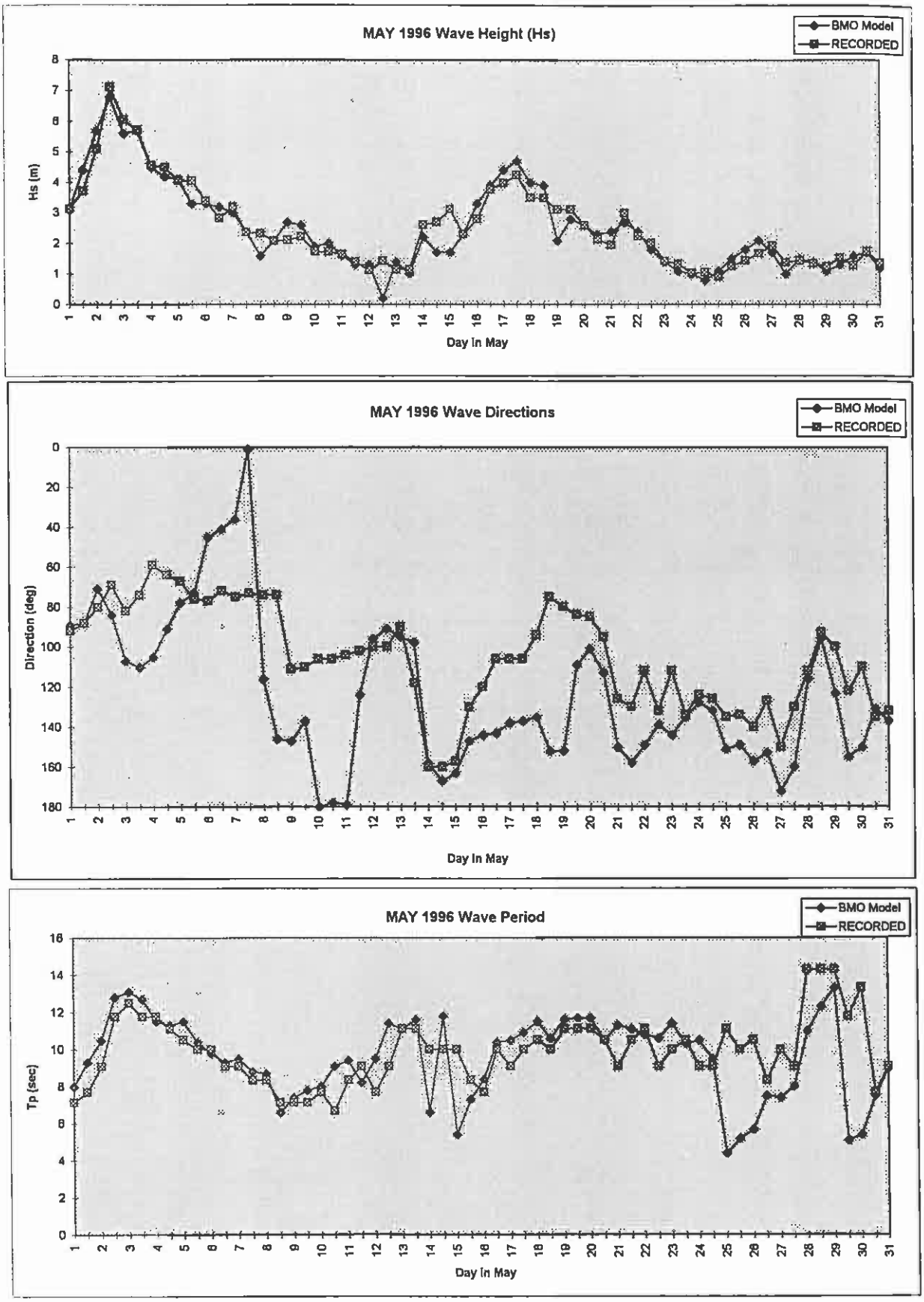


Figure 4.2.9
Wave Data During May 1996

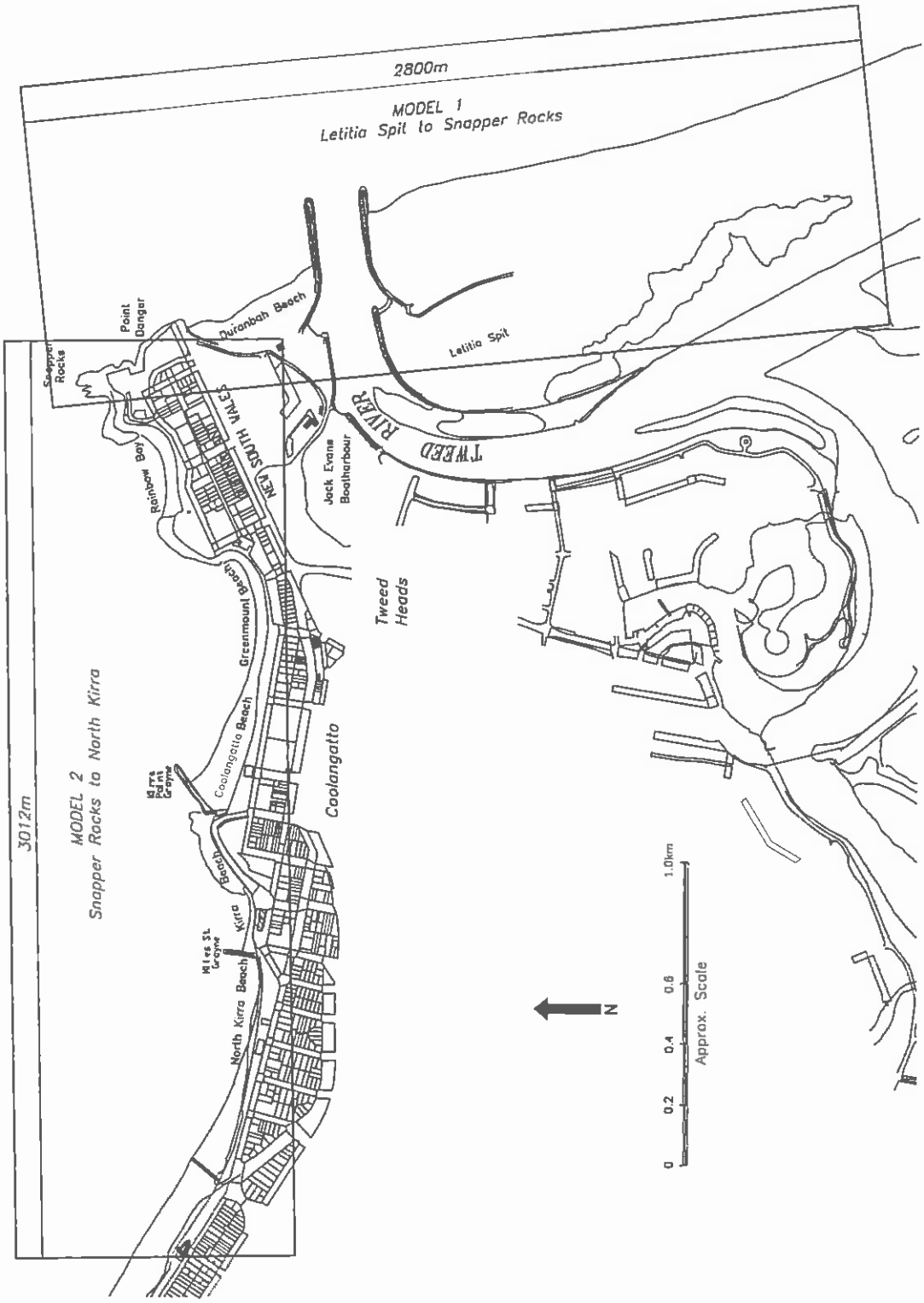


Figure 4.2.10
GENESIS Model Locations

4.2.4.8 Cross-Shore Sand Transport

Sand is transported across the nearshore beach profile by wave action. This cross-shore transport may be in the offshore direction during storm-related erosion events or onshore as the upper profile and beach recovers during normal swell conditions.

Overall, the following general pattern of sediment transport in both the offshore and surfzone regions has been recognised by various researchers:

(a) shorewards outside the breaker zone;

(b) shorewards or seawards inside the breaker zone, depending on the balance between the net orbital velocity influence and the net return flow.

Both wave height and period influence the magnitude of the near bed orbital velocities. Hence, those parameters will determine the scale of the active profile, and the depth to which sand transport may occur.

4.2.4.9 Measured Nearshore Profile Variations

A selection of surveyed profiles have been extracted from the BPA database for further analysis. The location of these survey lines is shown on Figure 4.2.11. The measured survey data are presented and discussed in detail in Technical Appendix II.

- Letitia Spit
  The Letitia Spit profiles show considerable variability in shoreline location, the variability increasing northward towards the Tweed River entrance. There exists an oscillation in the shoreline location in response to storm erosion etc, on top of a general progression of the shoreline seaward. The seaward progression is due in most part to the beach line response to the construction of the entrance walls to the Tweed River. The storm induced variability of the profiles extends to a depth of 12-15 metres with a single offshore bar of crest level at about R.L -2 to -5 metres AHD developing about 200 to 400 metres offshore.

- Duranbah to Point Danger
  Duranbah shows considerable variability. This has occurred as a response to the construction of the Tweed River entrance walls. The deepwater (ETA 12.0) profile has evolved following training wall extension from a slope similar to that south of the Tweed River entrance (1:80) to a much steeper slope similar to those off Snapper Rocks (1:40). Storm related profile variations exist to a depth 10-12 metres. At Point Danger, the nearshore profile has recovered from an eroded depth of about 6 metres to about 3 metres as a result of renewed bypassing. Storm wave activity creates a bar and gutter at chainage 900-1200m (4-10m depth) via cross-shore (offshore) and longshore transport mechanisms.

- Snapper Rocks to Coolangatta
  The profiles become less steep moving from Snapper Rocks (RB 3.0, 1:30) westwards to Coolangatta (CG 3.1, 1:100). Short and longer term variability in the profiles to a depth of 10-12 metres is apparent at RB 3.0 and RB 4.0 while the profiles at GREEN 1.0 and CG 3.1 show little short term variation below a depth of about 5 metres. Also of note is the recent offshore nourishment indicated by the large bars in profiles GREEN 1.0 (chainage 600-800m) and CG 3.1 (chainage 600-1000m).

- Coolangatta to Kirra
  This area shows wide gently sloping (1:100) profiles. Significant longer term variations in the profiles at the shoreline are apparent. This is due to long term erosion caused by the training wall extension and

subsequent benefit from the nourishment exercises at Kirra and offshore in October 1988 and 1989. Recent offshore nourishment can be seen by the presence of bars at CG 6.0 (chainage 600-1000m), K 1.0 (chainage 800m) and K 10.0 (chainage 850m). ETA 14.0 profiles were surveyed from 1966 to 1983 and indicate that profile changes by wave/current action extend out to a depth of 12-15 metres, in this case erosion due largely to the lack of incoming sand as a result of the construction of the Tweed River training walls.

An estimate of cross shore transport rates for beaches in the Tweed and southern Gold Coast regions can be determined from investigation of selected survey profiles. Of interest are profiles where appropriate surveys documenting the following processes have occurred:

- cyclone related beach erosion;
- post storm recovery of offshore bars and deeper parts of the profile; and
- onshore transport of offshore nourishment.

Cyclone Erosion

The data examined shows few occasions where detailed surveys close to a storm event allow determination of cross shore transport rates. Generally the time between the event and survey is too long. Cross shore transport theory indicates that profile change is most rapid when the profile is furthermost from the equilibrium shape. Therefore, to be of greatest benefit in determining the effects of a particular storm, surveys need to be undertaken immediately (1-2 days) following the event.

Considerable data related to extreme erosion was measured along the Gold Coast beaches in 1967. Pre erosion conditions were well documented during 1966. Massive erosion of all beaches occurred during the first part of 1967 due to a series of tropical cyclones and severe storms Comprehensive surveys of the erosion were undertaken in August/September 1967.

These data indicate the following potential offshore transport quantities from the beach, dune and upper nearshore profile, typically out to about the RL-3m(AHD) depth contour.

Table 4.2.6 Beach Erosion During 1967

Location	Erosion Quantity (m^3/m)
Coolangatta	415
Palm Beach	153
Surfers Paradise	387
The Spit	351

The abnormally high erosion quantity at Coolangatta extends out to the RL-6m(AHD) depth contour and reflects the impact of the Tweed River training walls in denuding the nearshore zone, thus causing increased demand of sand from the beach, dune and upper nearshore profile.

There is little more recent data available for specific storm events. It is expected that, given the severity of the 1967 erosion, the above quantities represent an upper limit to design conditions.

Beach widths vary substantially associated with storm and cyclone erosion. Moderate storm events may cause shoreline retreat of 20-40 metres. More extreme erosion may occur less frequently, with shoreline retreat of 50-80 metres and extensive potential dune erosion part of the natural behaviour of these beaches.

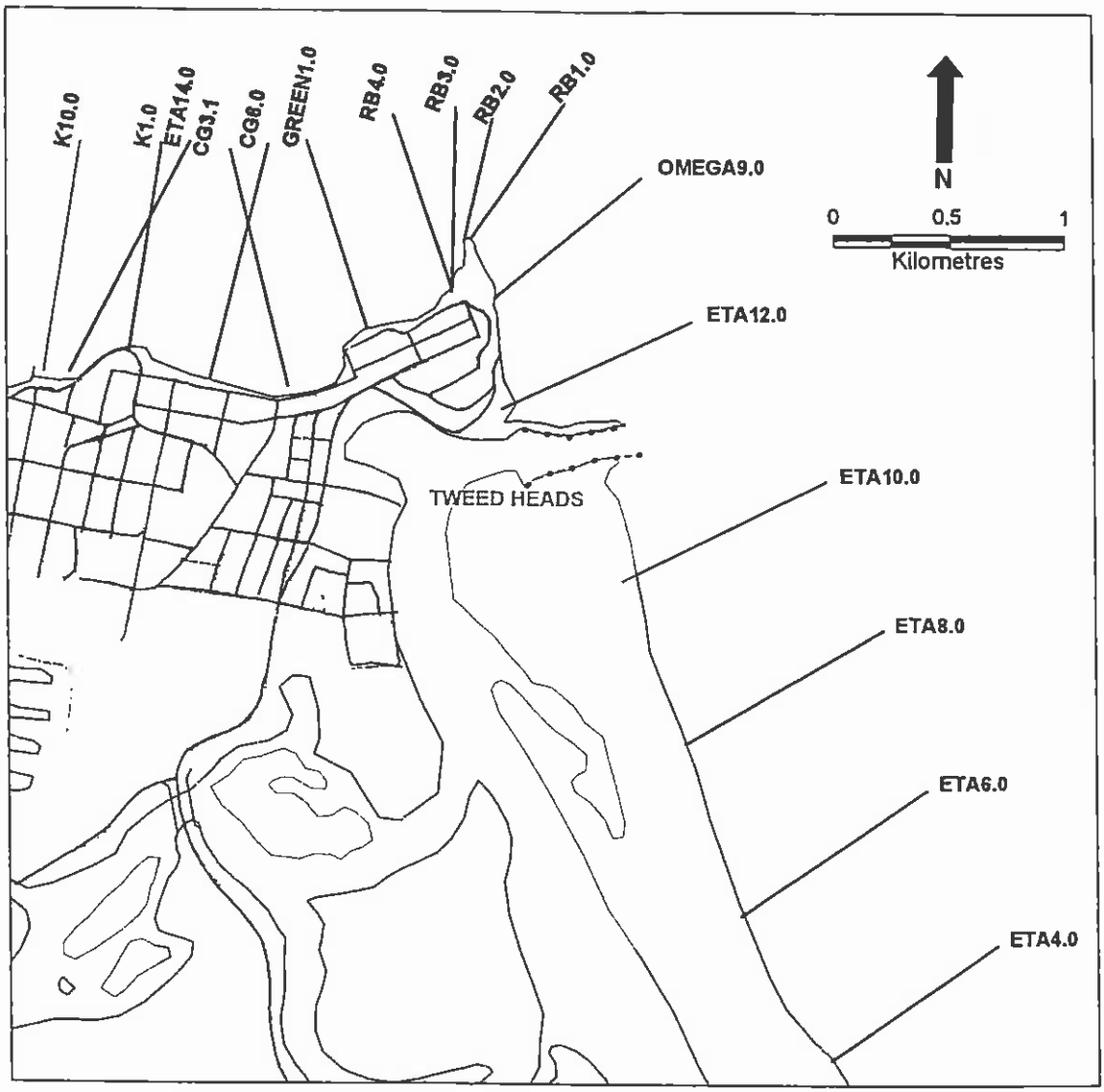


Figure 4.2.11
Location of Profile Survey Lines

Onshore Transport from Offshore

Both profile survey analyses and computer modelling have been used to assess rates of onshore sand transport for various depths across the nearshore profile. Detailed results are presented and discussed in Technical Appendix II. Due to measured survey data being limited, data for other Gold Coast beaches were also referenced.

An assessment of survey line ETA 63.0 at Surfers Paradise has been undertaken as data from numerous survey events are available. The line has similar geographic characteristics to those on Letitia Spit being a relatively long straight eastwards facing beach. Surveys during 1974 and 1988 have been reviewed and selected (Technical Appendix II). All show surveys documenting an onshore transport of sand from a storm bar at a depth of 4-5 metres. The rates of transport for each have been calculated as follows:

- 04/88-05/88 820-1100 m^3/m/yr (nearshore ~ 450 m^3/m/yr)
- 07/88-08/88 240-430 m^3/m/yr
- 08/88-09/88 920-1200 m^3/m/yr (nearshore ~ 310 m^3/m/yr)

Surveys at ETA 75.0 (offshore from The Spit) show the onshore migration of a large-scale offshore bar formed in 1967. The transport has occurred in deeper water (6-8 metres) than at ETA 63.0 and the transport rates are somewhat less as follows:

- 07/67-10/68 165 m^3/m/yr

Modelling software has been developed to simulate cross shore transport taking into consideration processes due to the following:

- wave shoaling;
- wave setup;
- tide;
- wave orbital velocities;
- surfzone bottom return flow; and
- instantaneous sand transport rates.

The method of Bagnold-Bailard 1981 (as presented in Van Rijn 1990) for the calculation of cross shore transport rates has been adopted, with some modifications to facilitate practical representation of the cross-shore transport processes. In this formulation the instantaneous bed load and suspended load transport rates are calculated. Details are presented in Technical Appendix II.

The rates of onshore transport predicted by the model were validated to the limited survey data as mentioned above. Rates of offshore transport within the surfzone as predicted by the model are consistent with the erosion quantities presented above, although at present the model is not yet developed to predict profile evolution with bar formation.

Typical rates of onshore transport as derived from the data analyses and the model are:

- 5-10m^3/m/week at 5 metres depth, balanced from time to time by offshore storm transport;
- about 1m^3/m/week at 10 metres depth
- negligible onshore transport beyond about 15 metres depth.

4.3 Coastal Processes of the Tweed River Entrance

4.3.1 Sediment Transport Pathways

4.3.1.1 Conceptual Model of River Mouth and Adjacent Beach Processes, Pre-Stage 1A

PBP (1994) consolidated the extensive array of coastal and estuarine process studies into a conceptual model of nearshore and lower estuary sediment pathways (Figure 4.3.1). The essential features of the model, working from south to north, can be summarised as follows:

I. The long term average longshore transport, approach the Tweed entrance from Letitia Spit is approximately 500,000 m^3 pa. In any one year, it could range from 250,000 m^3 to 900,000 m^3 pa.

II. Prior to the commencement of Stage 1A works, the marine shoals of the lower Tweed estuary were infilling at a rate of 40,000 m^3 pa, comprising 36,000 m^3 pa from the littoral system and 4,000 m^3 pa average input by freshwater flows.

III. The tidal transport flux through the entrance was about 102,000 m^3 pa, comprising 69,000 m^3 pa by flood tides and 33,000 m^3 pa by ebb tides. The tidal transport flux between the spur wall and the confluence with Terranora Inlet was approximately 38,000 m^3 pa comprising 20,000 m^3 pa transported by flood tides and 18,000 m^3 pa by ebb tides. The entrance shoal (located immediately downstream of spur wall) is a manifestation of a dominant flood tide pathway. Prior to Stage 1A works, approximately 14,000 m^3 pa was "shaved off" the edge of the entrance shoal by ebb tide flows.

IV. Prior to Stage 1A works, of the 500,000 m^3 pa average longshore transport, approximately 14% (ie 69,000 m^3 pa) was conveyed into the estuary by the combined effect of flood tides and wave stirring of the bed. The remainder of the longshore transport (ie 431,000 m^3 pa) together with the ebb tide transport (33,000 m^3 pa) moved directly onto the bar. Significant floods can scour quantities of the order of 200,000 m^3 from the lower estuary and deposit them on the entrance bar.

V. Due to the littoral supply and ebb tide flux, the entrance bar was growing at the rate of 110,000 m^3 pa, immediately prior to Stage 1A works. Floods and major storms cause slugs of sand to move onto and off the entrance bar. Hence bar volume can wax and wane about the average infilling trend.

VI. Prior to stage 1A works, the entrance bar was bypassing at a rate of approximately 350,000 m^3 pa. The longshore transport through Duranbah beach and offshore shoals was 300,000 m^3 pa, leaving about 50,000 m^3 pa accretion of the offshore shoals of the Duranbah coastal compartment. There are no significant losses at Point Danger. Hence, prior to Stage 1A works, Point Danger was bypassing at about 300,000 m^3 pa.

VII. The extensive shoals which used to exist offshore of Rainbow and Coolangatta Beaches, before the 1960's, were re-establishing at a rate of approximately 100,000 m^3 pa, prior to Stage 1A works.

4.3.1.2 Analysis of Stage 1(A) Monitoring Data - Tweed River Entrance Area and Letitia Spit

A detailed discussion of the analysis of the Stage 1A monitoring data is provided in Technical Appendix 1. A brief summary of key findings is presented below.

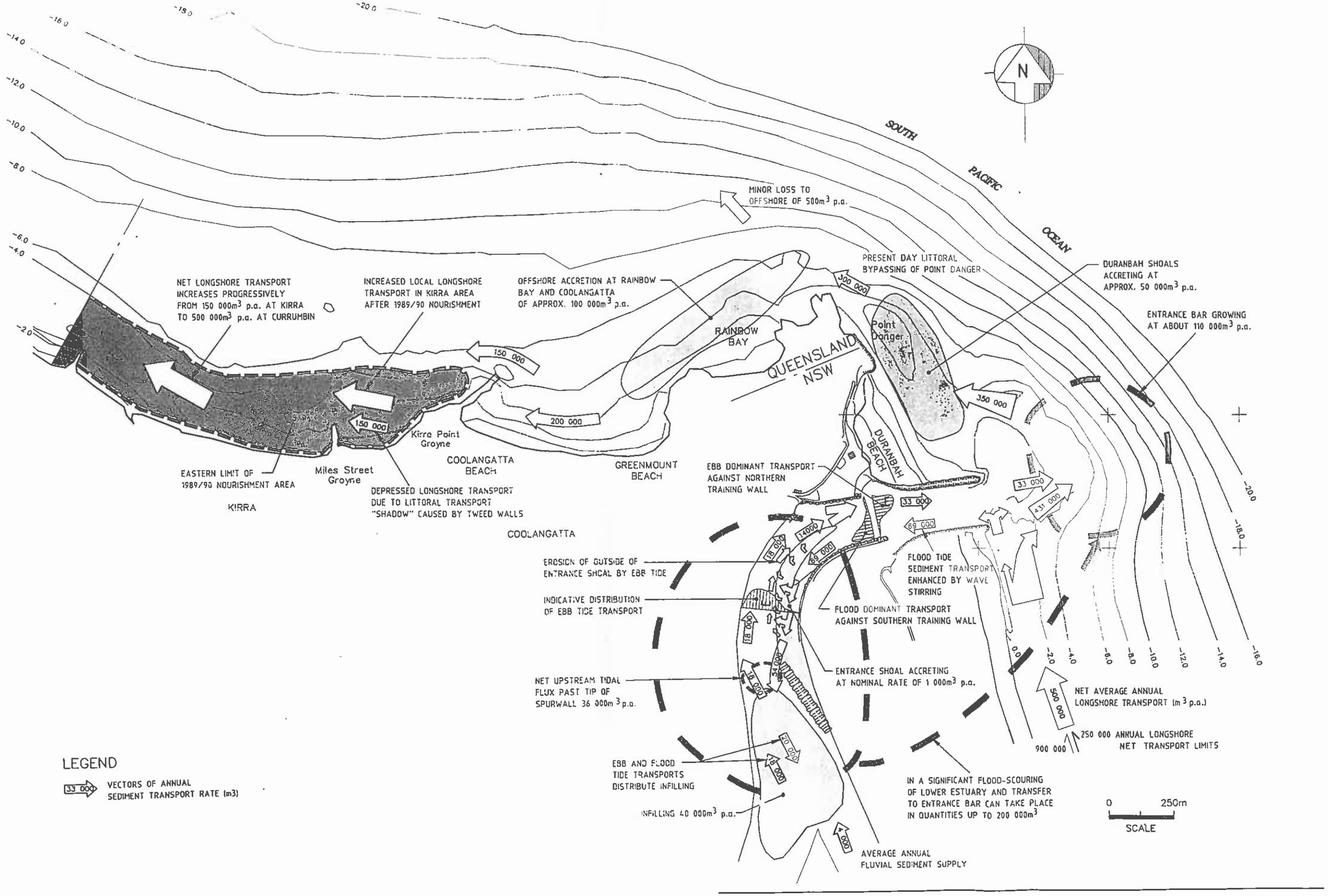


Figure 4.3.1
Conceptual Model of Pre-Stage 1A Coastal and Estuarine Processes

SOURCE: PBP (1994)

South Letitia Spit

Although this area was not greatly affected by the Stage 1A dredging of the entrance channel and bar, some change occurred over the monitoring period which was likely to have been locally influenced by dredging modifications of the nearshore bathymetry to the immediate north. These include:

- accretion of roughly 350,000m^3 between the -15m to -5m contours (due to cross-shore movement of sediment to form a storm bar system along Letitia Spit during the May 1996 storm); and
- loss of 260,000m^3 in the nearshore and subaerial portions of the beach (ie. between -4m to +3m contours) during the February and May storms, resulting in an average shoreline recession of 38 metres.

North Letitia Spit

There appears to have been localised enhanced longshore transport and profile adjustment due to the Stage 1A dredging of the Tweed Entrance bar and channel;

- Longshore transport has differing modal (non-storm) and episodic (storm) pathways
  ⇒ 100m-400m offshore during modal conditions, ie. approx between RL-6m to -2m;
  ⇒ Up to 500m offshore during storm conditions, ie. approx out to RL-9m to -7m;
- The -15 m to -5 m contours show significant accretion (115,000m^3) due to influx of material during storms and the nearshore creation of a well-defined bar system;
- Contours -4m to -1m show losses (105,000m^3) manifested in offshore gains;
- Significant subaerial erosion, primarily as a result of the May 1996 storm, resulted in an overall loss of 200,000m^3; and
- Average shoreline recession of 35-40m, with erosion being fairly uniform along the beach.

South Lobe of the Entrance Bar

The sediment transport pathway commences approximately 200-300m from the tip of the entrance training walls and progresses across the artificially deepened entrance bar channel and gradually widens as bypassing escalates.

Sediment pathway varies according to wave conditions:

⇒ -10 to -7m (300 m - 400 m offshore) during storm conditions; and
⇒ -5m to -3m (100 m - 300 m offshore) during both modal and storm conditions.

The former envelopes the outer edge of the entrance bar, which storm waves encounter initially as they move onshore. The latter (inner) pathway exhibits three separate configurations.

⇒ Storm conditions may cause material to infill the channel directly around the tip of the southern training wall;
⇒ During modal conditions, a sand spit, or tongue, begins to form 200-300m from the tip of the entrance training walls; and
⇒ Also during modal conditions, a portion of the longshore transport is directed between the entrance training walls by the flood tide. This forms a shallow but narrow shoal against the inside of the southern training wall.

Entrance Channel and Bar Crest

There are very few times during the monitoring period that this area was not directly affected by bar dredging. Comparisons of dredging volumes and net volumetric channel changes were used to determine channel infill rates and bar bypassing rates where feasible. The results are summarised in a separate section below.

Total infilling of the channel between June, 1995 and July, 1996 was approximately 250,000m^3. Infill due to storms totalled 120,000m^3 and comprised only 5% of the monitoring time period. 130,000m^3 of infill therefore occurred during modal conditions (95% of time).

Northern Lobe of Entrance Bar and Duranbah

Direct dredging of the outer contours and the subsequent alterations in wave refraction along the Duranbah shoals have significantly impacted both the subaqueous and subaerial portions of this compartment.

- Losses during the monitoring period suggest annual losses of between 100,000m^3 and 200,000m^3;
- These losses occurred primarily during times of greatly interrupted longshore sediment supply (due to entrance channel dredging);
- The implication is that if a deep entrance bar channel is maintained, only minor quantities of sand would be bypassed to Duranbah Shoals, and the above rates of erosion could be expected to continue.
- Duranbah Beach saw a cycle of erosion and accretion during storm and modal conditions respectively. This cycle is a natural characteristic of the area.

River Entrance Channel Infill and Bypassing Rates

Analysis of survey data found that the trapping efficiency of the entrance bar is dependent upon both the channel depth and wave energy intensity. It was found that the trapping efficiency of the channel reduced from 70% to 30% as the average depth of the entrance bar channel reduced from approximately -8m AHD to -4 to -6m AHD, over the three month period December 1995 - February 1996. A detailed discussion is contained in Technical Appendix I. An overview is provided below.

- prior to the December 1995 storm, a deep -7m to -8m channel existed due to dredging;
- trapping efficiency of the channel was quite high (>70%) resulting in infill of the channel by 10,000m^3 and bypassing of less than 4,000m^3;
- prior to the first February storm of 15/02/96, the initial development of a sediment pathway (due to the infilling associated with December storm) lowered the trapping efficiency of the channel;
- the 15 February storm infilled the channel 31,000m^3 and bypassed 18,000m^3, indicating a trapping efficiency of around 60%;
- prior to the 22 February storm the channel was considerably infilled, with -5m to -3m contours extending across much of the channel; and
- consequently, there was a significant reduction in trapping efficiency (to ~25%) during the 22 February storm resulting in infill of 24,000m^3 and bypassing of 72,000m^3.

Based on trapping efficiencies calculated from analysis of hydrosurveys (Technical Appendix I), the bypassing capacity of an artificially dredged bar, for a range of entrance bar channel depths, is summarised in Table 4.3.1.

Table 4.3.1 Trapping Efficiency and Bypassing Capacity of the Entrance Bar and Channel vs Channel Configuration and Wave Climate.

Channel Configuration	Longshore Transport mode	Trapping Efficiency	Bypassing Capacity	Comments
Well-Defined (>-8m AHD)				*Majority of sediment will infill channel area*
	Storm	H = 80%	L = 20%	Possible accretion around tip of southern training wall
	Modal	H = ~100%	L = negligible	Migration of swash bars 200-300m offshore
Partially Infilled (-6m to -8m)				*As infill continues, bypassing begins to increase*
	Storm	M = 40%	M = 60%	Pathway 200-300m offshore starts to take shape
	Modal	H = 70%	L = 30%	Swash bars continue to migrate and infill
Pathway Formed (-4m to -6m)				*Pathway 200-300m offshore increases bypassing rate*
	Storm	L = 20%	H = 80%	Increased flow across -6m "bridge"
	Modal	M = 50%	M = 50%	Swash bars build up pathway further
Infilled (<-4m AHD)	*Storm*	L = <20%	H = >80%	*Extensive bypassing will occur during both storm and modal conditions.*
	Modal	L = <50%	H = >50%	

(NB: L = Low, M = Medium and H = High)

Table 4.3.1 illustrates how the trapping efficiency of the entrance channel varies with channel depth and wave energy intensity. It was found that the trapping efficiency of the channel reduced from approximately 100% to 50% for modal waves over a depth range of 8m (and greater) to 4m below AHD. The greater turbulence associated with storm waves tends to keep sand in suspension and reduces channel trapping efficiency. Consequently, deduced trapping efficiencies reduce from 80% to 20% over the same depth range, for storm waves.

4.3.1.3 Post Stage 1A Conceptual Models

Figure 4.3.1 presents annual sediment transport vectors and rates determined from data covering many years. The short-term fluctuation of sediment movement over the monitoring period of Stage 1(A) (ie from April 1995 to October 1996) makes specific determination of vector rates extremely difficult. Therefore, conceptual diagrams (Figures 4.3.2 - 4.3.4) were prepared to indicate vectors of sediment movement and general rates in the form of arrow direction and relative sizes (ie larger arrows indicate a primary sediment pathway).

Figure 4.3.1 indicates net transport along Letitia Spit of 500,000 m^3 per annum to the North, with accretion

to both the entrance bar and Duranbah shoals. The Stage 1 coastal studies (PBP, 1994) predicted that the entrance bar dredging would affect these processes in three ways:

1. There would be acceleration of erosion along the northern end of Letitia Spit due to a localised increase in longshore transport;
2. Bypassing of the entrance would decrease due to an increase in entrance channel trapping efficiency; and
3. Duranbah Shoals would erode due to lowered sediment supply from the South (ie less bypassing of the entrance).

Monitoring data indicates that the northern end of Letitia Spit has eroded approximately 170,000 m^3, the creation of a well-defined entrance bar channel has increased the trapping efficiency of the entrance bar and the Duranbah area is eroding between 100,000 m^3 and 200,000 m^3 per annum.

Although less sediment reaches Duranbah, the Stage 1 conceptual model (Figure 4.3.1) indicated little change in the littoral transport around Point danger and Snapper Rocks (300,000 m^3 pa) due to the balancing effect of erosion from Duranbah Shoals. Analysis of monitoring data indicates that material accumulates immediately west of Snapper Rocks and moves slowly until significant storm activity mobilises large quantities into the southern Gold Coast Beaches. The wave shadow zone created by Snapper Rocks results in the spreading of material during Southeast conditions (Figures 4.3.2 and 4.3.3), while leaving northeast conditions relatively unaffected (Figure 4.3.4).

The Stage 1 Deposition areas (ie Rainbow Bay to Kirra) have been affected by the placement of over 2 million m^3 of dredged material. In general, however, the processes remain the same:

1. The wave shadow zone results in a significant reduction of longshore transport along the Southern Gold Coast beaches, during modal wave conditions.
2. Large slugs of material are brought into the system by storm activity.

The primary change has been the interaction of these processes with the nearshore and subaerial nourishment, as storms have not only resulted in an influx of sediment, but also a significant redistribution of nourishment material.

The Stage 1 conceptual model indicated relatively slow movement of the Outer Nearshore deposition shoal, with storm activity required for any significant redistribution. The Stage 1A monitoring data indicates that the material is moving slowly alongshore, with little onshore movement.

4.3.2 Wave Propagation to Tweed River Entrance

An important aspect in relation to bank erosion and breakwater stability is the amount of wave penetration to the breakwaters and into the entrance. The factors affecting wave propagation through the entrance are the ebb tide bar and the flood tide shoals. Both of these are being changed in this project and some of these changes, in the form of bar and channel dredging have already occurred.

Public Works (1991j) provide a detailed study of the nearshore wave climate of the Tweed entrance area. Table 4.3.2 summarises the wave climate statistics pertaining to the area immediately offshore of the Tweed entrance. The calculations included allowance for tide, storm surge and wave set up.

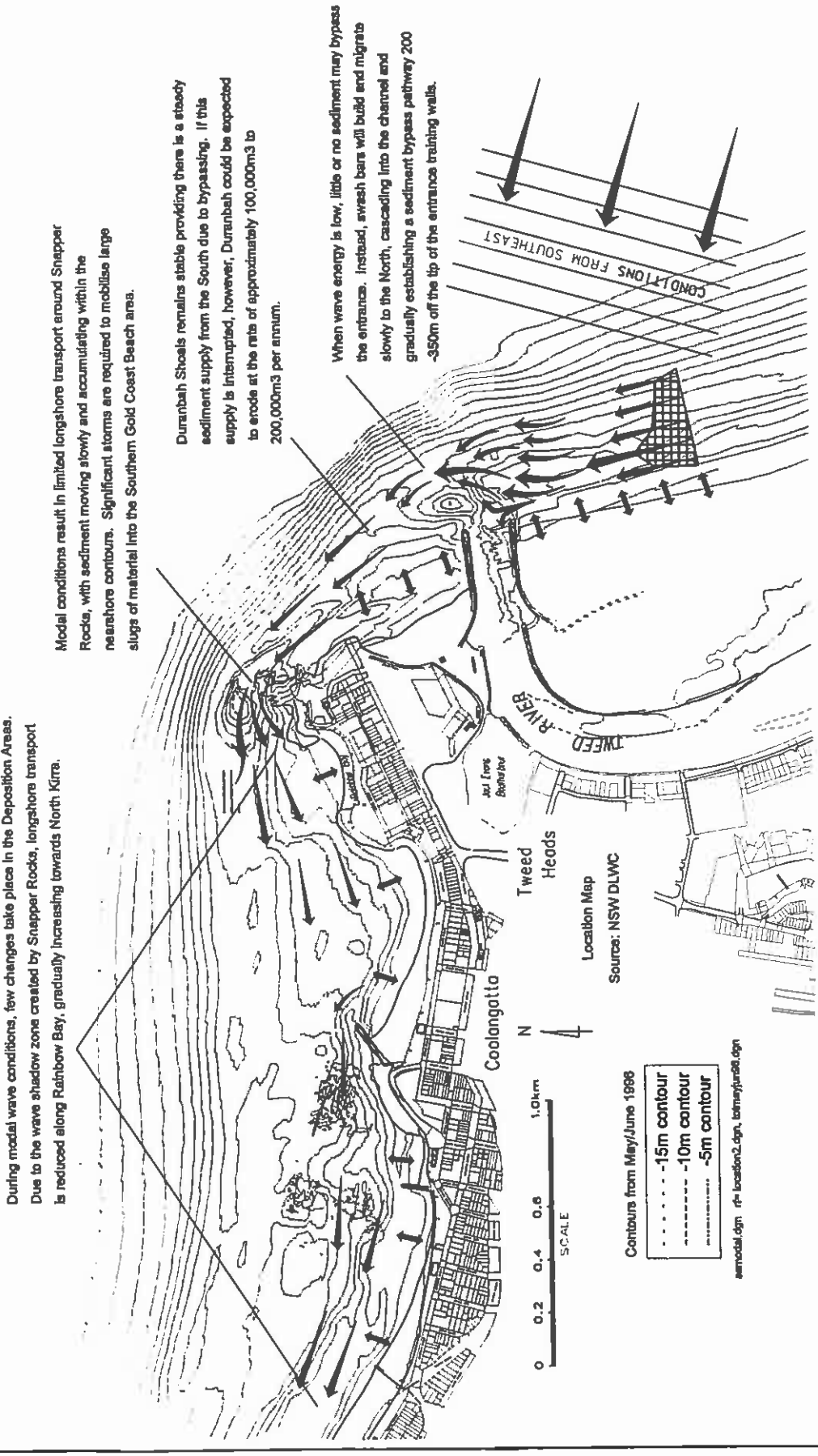


Figure 4.3.2
Coastal Processes During Modal Southeast Wave Conditions

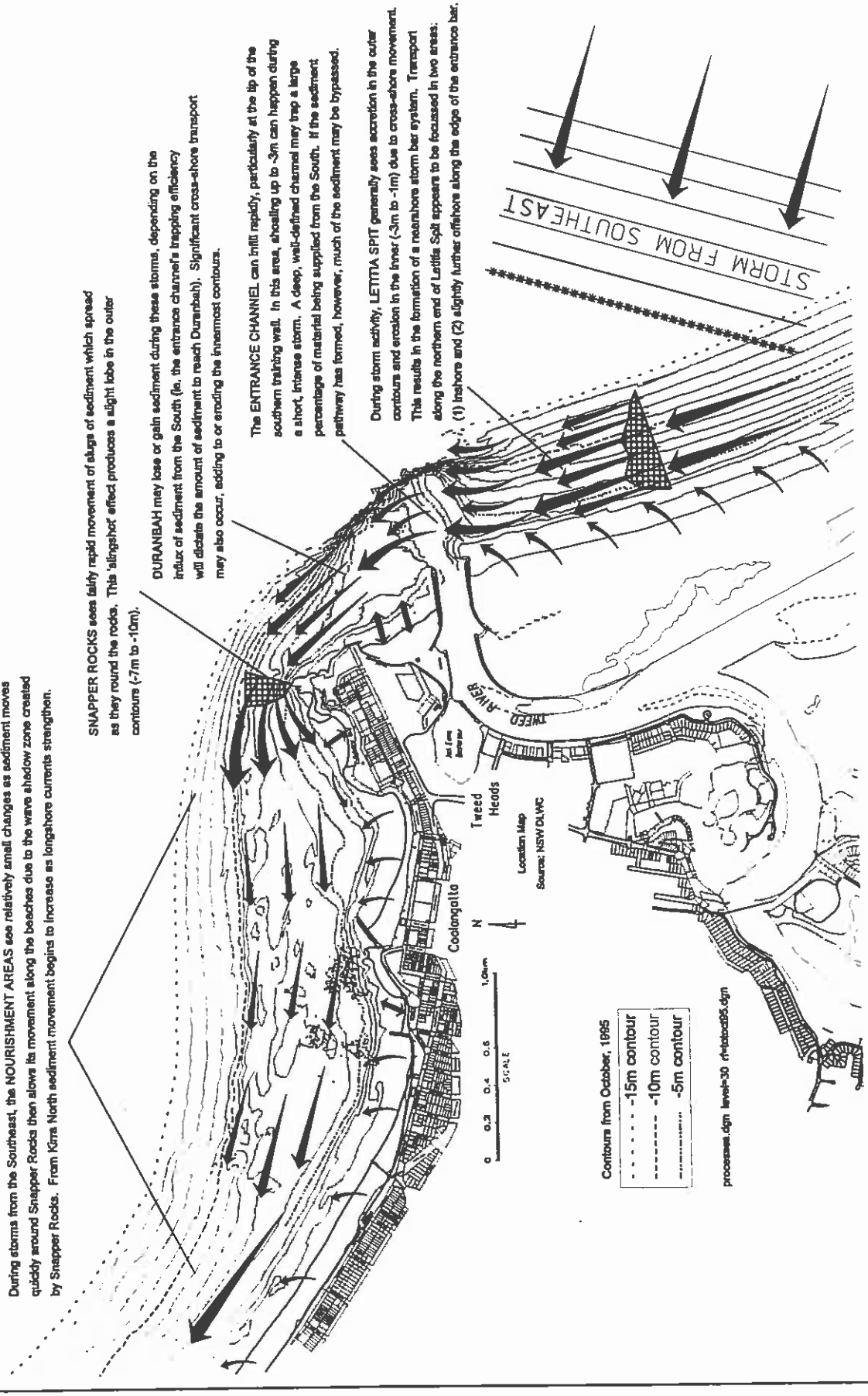


Figure 4.3.3
Coastal Processes During Southeast Storms

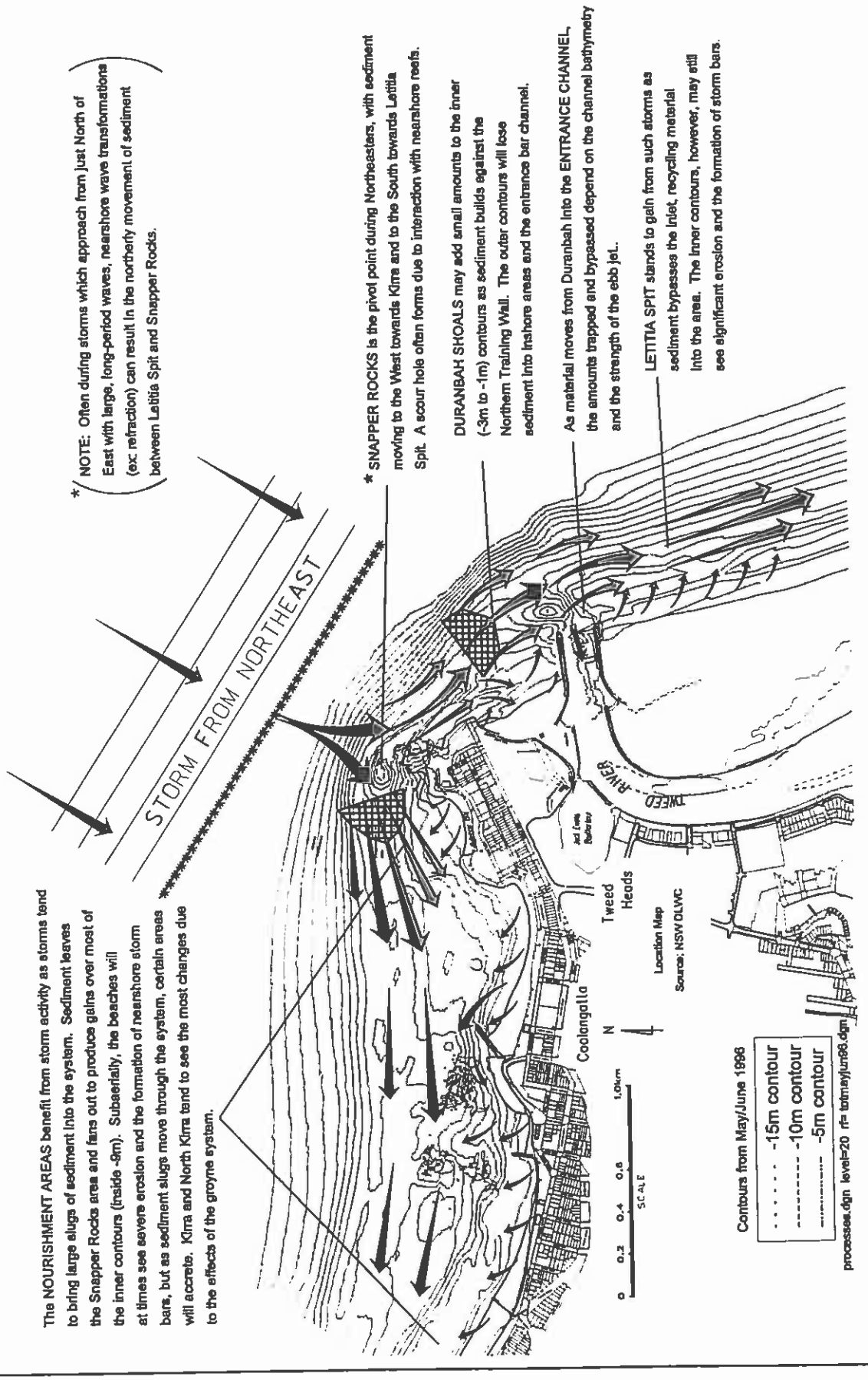


Figure 4.3.4
Coastal Processes During Northeast Storms

Table 4.3.2 Wave Climate Immediately Offshore of Tweed Entrance

Recurrence Interval (yrs)	Depth at MSL (m)	Significant Wave Height Hs (m)	Breaking Wave Height H_b (m)
20	5	5.3	6.4
	10	7.4	9.6
50	5	5.3	6.5
	10	7.6	9.7
100	5	5.4	6.5
	10	7.7	9.7

(Source: PWD, 1991j)

4.3.3 River Mouth Currents

Detailed hydrodynamic simulations (Technical Appendix II) show the pattern of currents at the river mouth due to the combined effects of tidal flow to and from the river and typical modal swell and wind conditions. The results of this modelling for both the peak flood and peak ebb tide conditions are presented in Figures 4.3.5, 4.3.6 and 4.3.7. They indicate:

- the flood tide currents tend to enter the river more or less radially, with a slight offset biasing the inflow to favour the southern side due to wind and wave influences.
- the ebb jet remains quite well defined for a distance of some 400-600 metres offshore from the training walls, with the development of relatively large adjacent eddies which tend to be transient and/or variable depending on the influence of longshore wind/wave forcing.
- the dredging of the entrance to May 1996 had only a slight effect on the currents, with a slight increase on the velocities between the training walls and little effect nearshore where the ebb jet continued to be directed more or less directly seawards over the shallow bar with only slight northward deviation.

Additional modelling with representation of the East Australian Current (EAC) has also been undertaken. The results are presented in Figure 4.3.3c for the existing (1996 dredged) scenario. Key features of these results are as follows:

- During the flooding tide, the EAC runs alongshore quite close to Point Danger and Duranbah and contributes to the radial inflow to the river entrance. The radial inflow from south of the entrance is partially negated. Any upcoast wind/wave current tends to negate or reverse the EAC nearshore.
- During the ebbing tide, the EAC is deflected further offshore by the ebb jet, reducing its nearshore influence at Point Danger and Duranbah. The model shows a large-scale eddy on the southern side of the river, with an upcoast longshore current along the northern end of Letitia Spit.

4.4 Tweed River Estuary Processes

4.4.1 Estuarine Hydrodynamics

4.4.1.1 Background: Historical Perspective

Previous computer modelling studies have indicated that improvement of the river entrance by deepening the entrance channel would change the tidal regime of the Tweed River estuary. Specifically, reducing the frictional resistance of the entrance relative to the quite silted equilibrium condition to which the lower estuary area has been progressively returning over recent decades would lower low tide levels and increase

high tide levels in the river.

During the 1960's, the lower estuary was relatively choked with sand, with highly attenuated tidal ranges in the river (Druery and Curedale, 1979). Extensive sand dredging during the 1970s changed that condition substantially, leading to increased tidal range and increased tidal prism. A by-product of that impact was greater capacity for the ebb jet at the entrance to push the river mouth bar further seaward and maintain somewhat greater depths over the bar.

The lower estuary has been slowly accumulating sand since the 1970s as the lower estuary shoals have progressively reformed with sand primarily from the beach system. This process is continuing and, if left unchecked, would probably re-establish the 1960s conditions again some 20-30 years from now.

If that were to happen, tidal ranges, tidal prism and tidal flushing in the river would once again be attenuated, and the entrance ebb jet would also be reduced. This in turn would allow the river mouth area to become even more silted until dynamic equilibrium is reached.

Hence, the existing situation is not static, but one of progressive change towards more siltation of the lower estuary, smaller tidal ranges, poorer tidal flushing and shallower entrance bar conditions. Approved sand extraction further upstream along the river is also predicted to have additional impacts on these processes.

Computer modelling for this EIS/IAS has been undertaken in order to quantify the present situation in the context of recent past and projected future conditions, stemming from existing river dredging approvals, and to quantify the impacts of the sand bypassing project on those conditions. The studies identify both the cumulative and incremental impacts of the project in the context of historical pattern of change in the estuary.

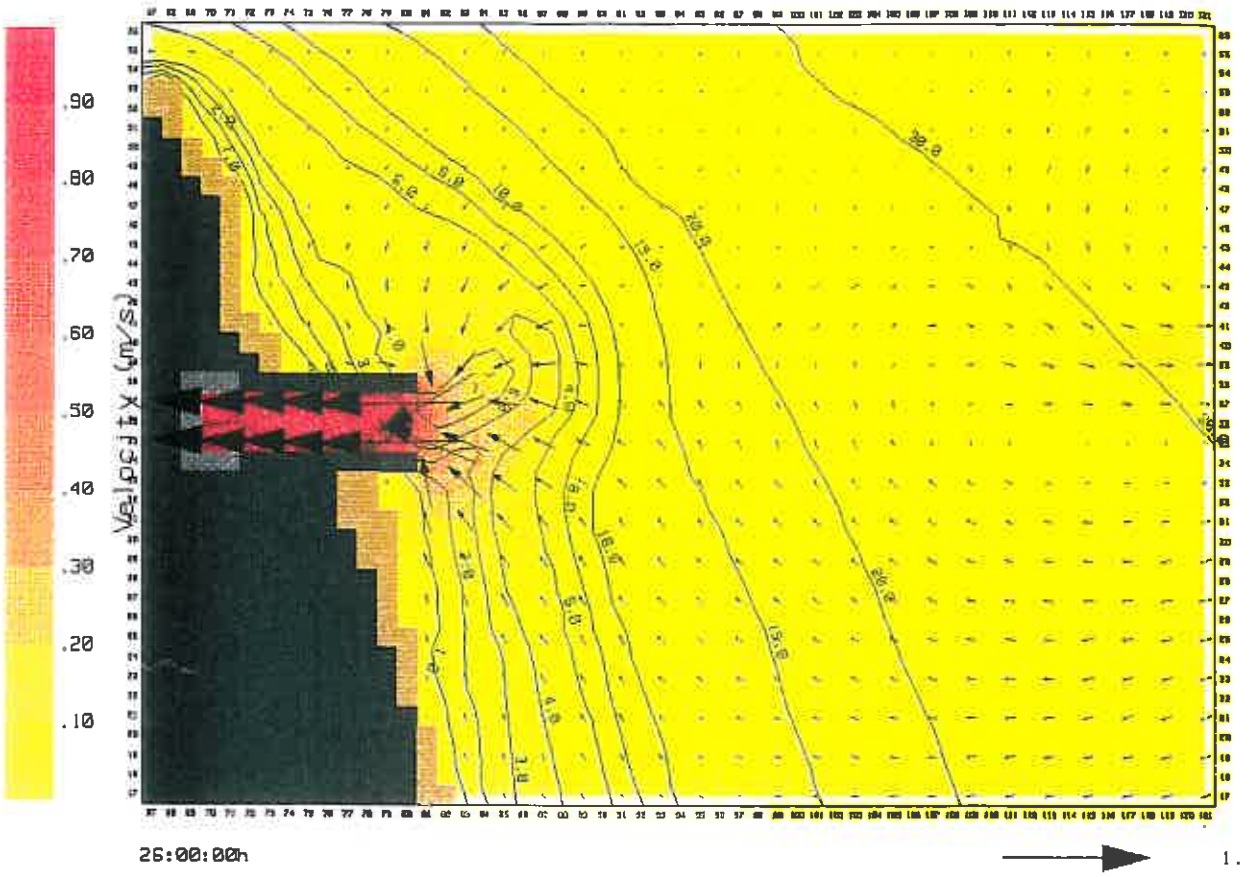
4.4.1.2 Overview of Existing Lower Tweed Estuary Hydrodynamics and Sedimentary Processes

Figure 4.4.1 shows, in broad view, the processes which characterise the Lower Tweed estuary.

The entrance bar is a mound of sand some 200 to 600 metres seawards of the entrance breakwaters. It is formed largely by the substantial amounts of sand which drift onto the bar from Fingal Beach each year. In its natural state, the bar acts as a natural "conveyor belt" for the majority of sand drifting from the south which bypasses the entrance and ends up on the northern side. The bar impedes the movement of the ocean tide into the estuary and approximately 18% of the ocean tidal range is dissipated on the bar and between the entrance training walls (Figure 4.4.1).

A portion of the sand drifting onto the entrance bar is entrained and transported into the estuary each flood tide. There, at the turn of the tide, the sand falls out of suspension in the major flood tide pathways. Successive tides move the sand further upstream where it can build up to form estuarine shoals or move into ebb tide dominant pathways from which it can be transported back to the entrance bar. Hence, there is an area of active or mobile marine sand extending up to the southern end of Ukerebagh Passage in the Main Arm and the northern end of Ukerebagh Passage in the Terranora Arm which is part of a circulation of sand involving the open coast beach system (ie. entrance bar and associated littoral drift) - (Druery and Curedale, 1979). This area is referred to as the marine delta and corresponds to the area of greatest tidal flows and greatest shoal mobility (Figure 4.4.1). The high tidal velocities, flowing across shoal areas, dissipate tidal energy through bed friction. Approximately 13% of the tidal range is dissipated through the marine delta.

In the Main Arm, upstream of the marine delta, moderate tidal flows produce weak sediment movement as far upstream as Barneys Point Bridge. There is a further loss of 12% of the ocean tide to this point. Upstream of Barneys Point Bridge, tidal velocities gradually diminish and bed sediment is no longer moved



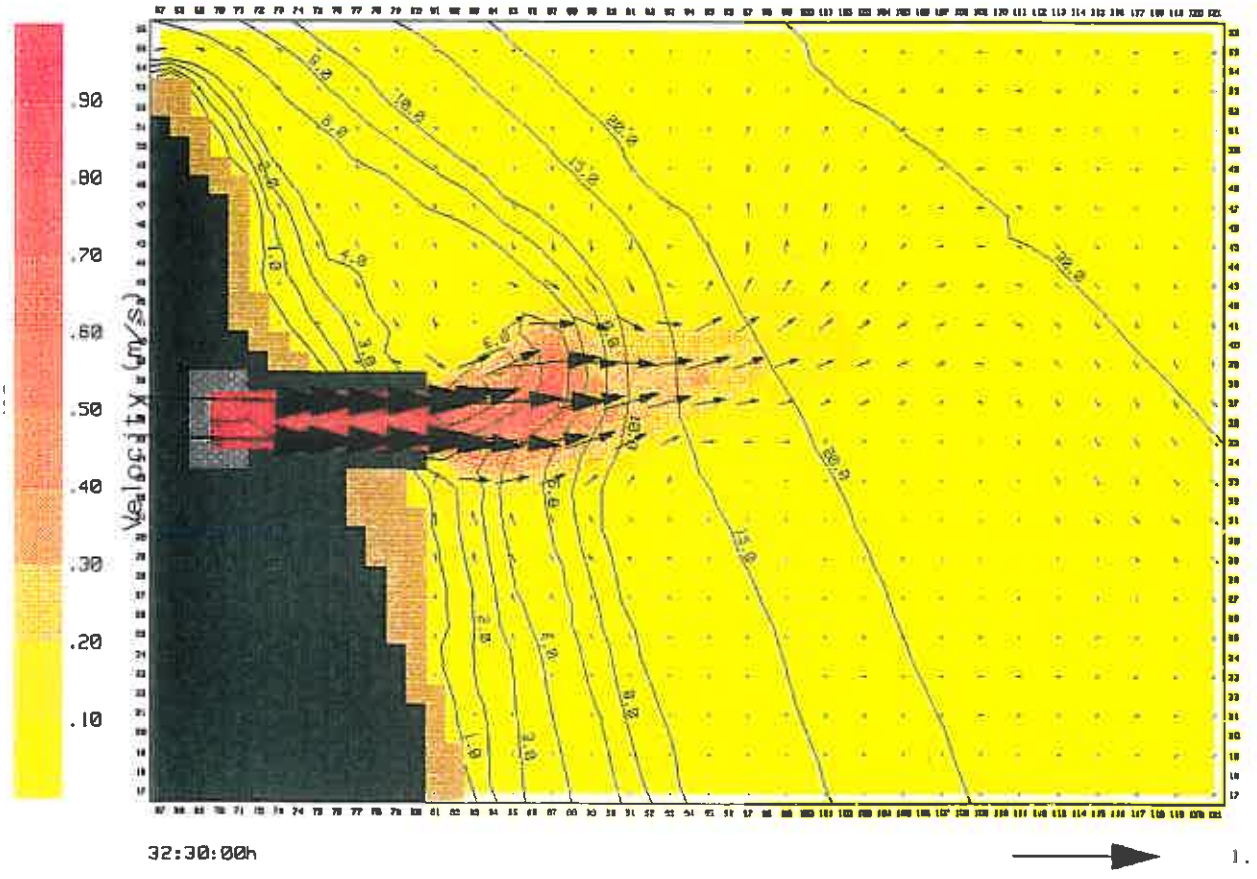
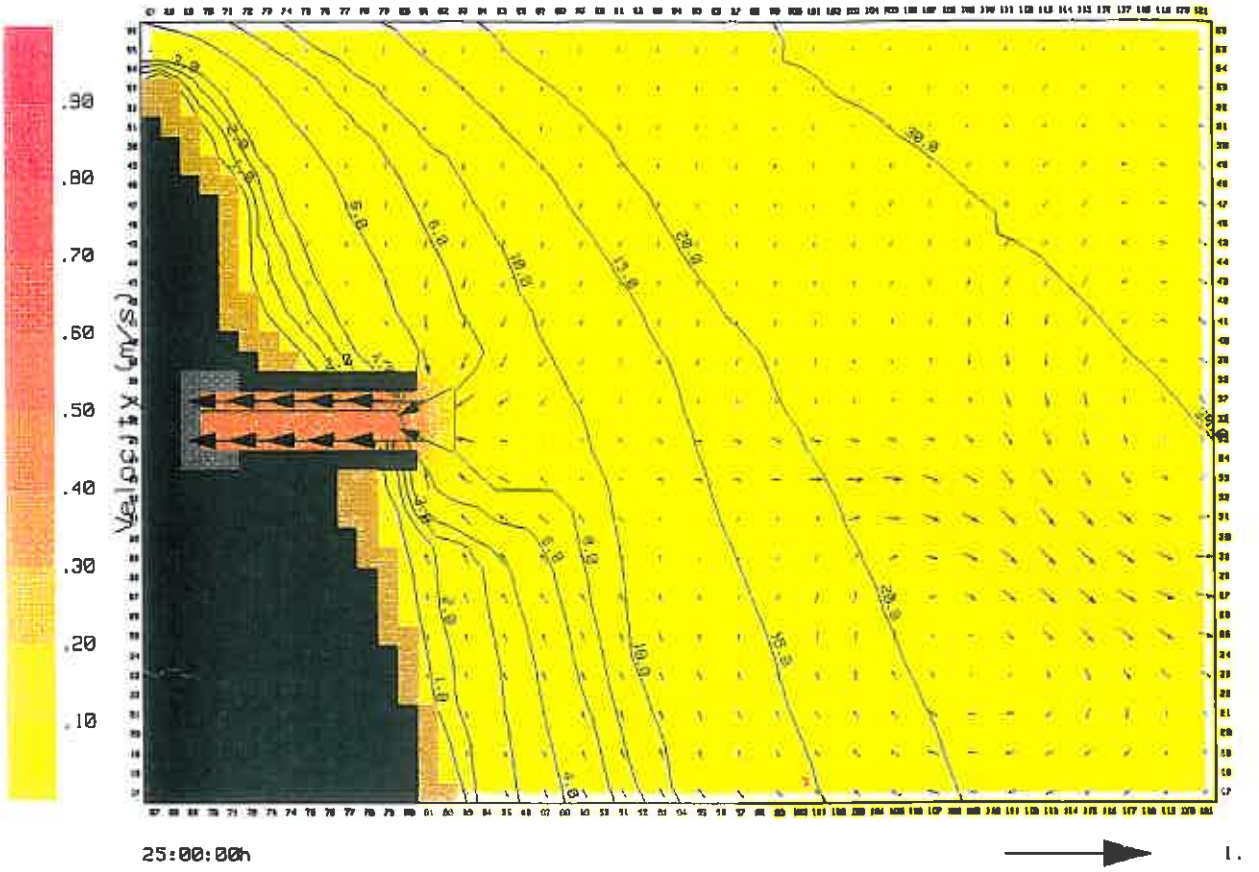


Figure 4.3.5
Tidal Currents at Tweed River Entrance
Pre-Dredging Bathymetry



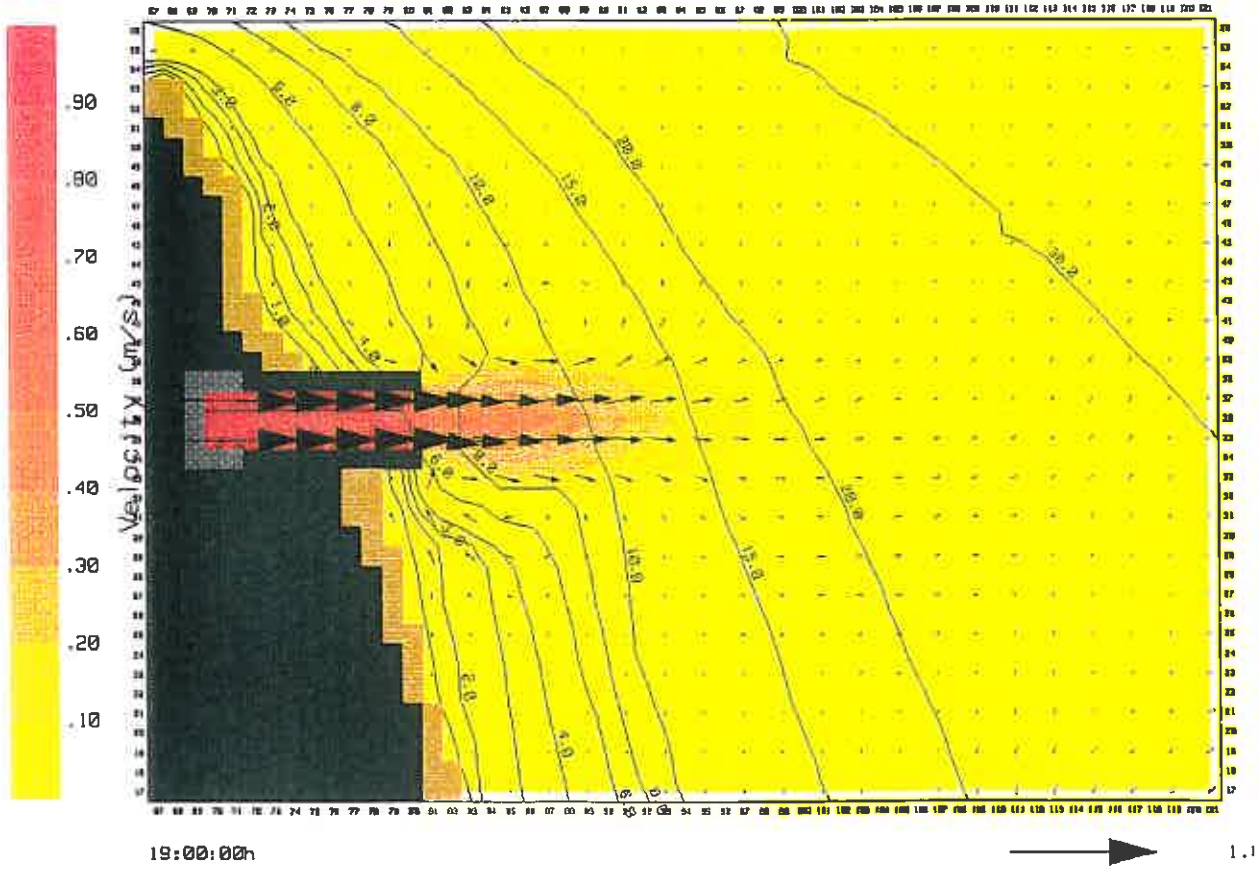


Figure 4.3.6
Tidal Currents at Tweed River Entrance Bypassing Scenario

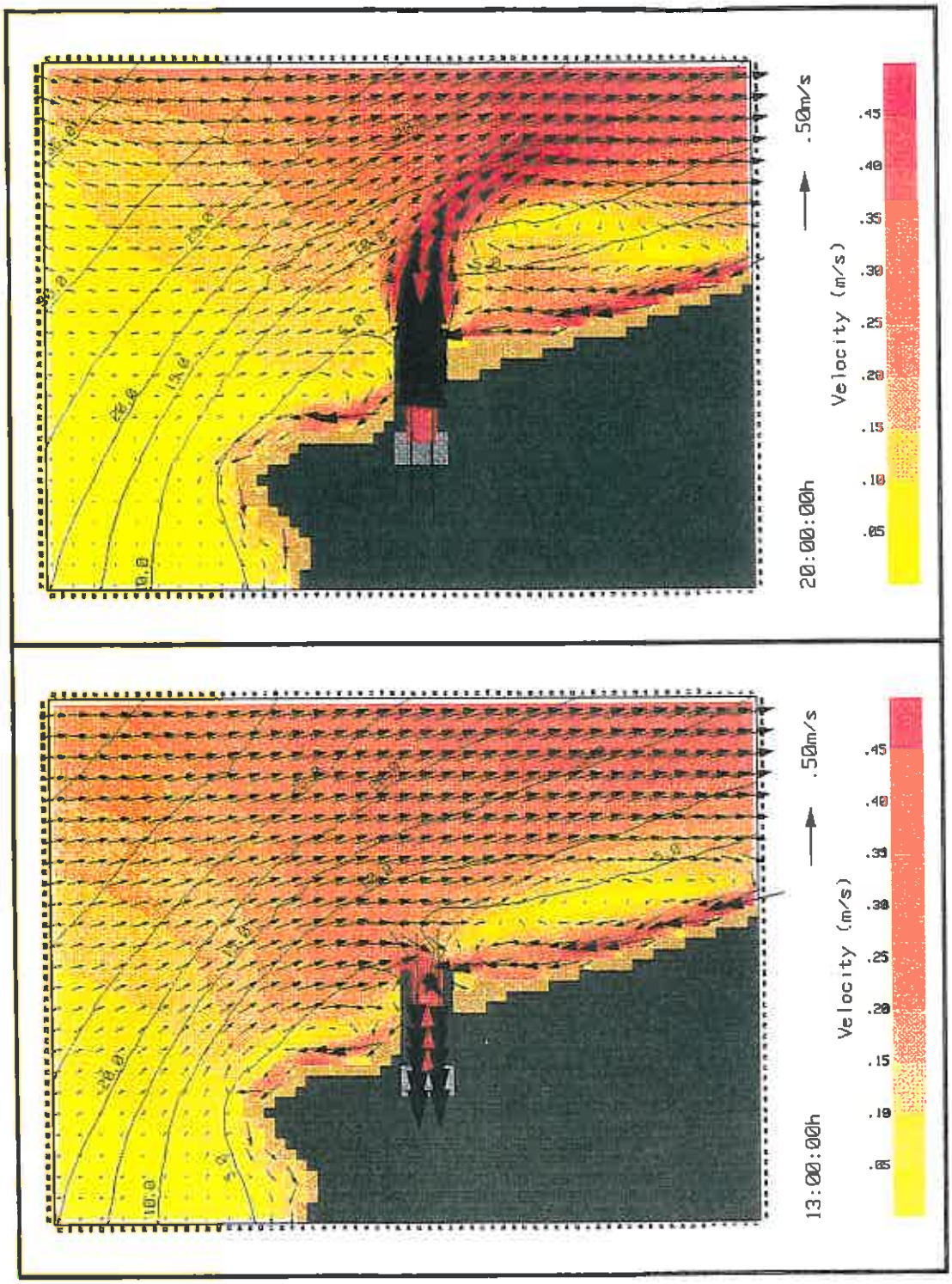
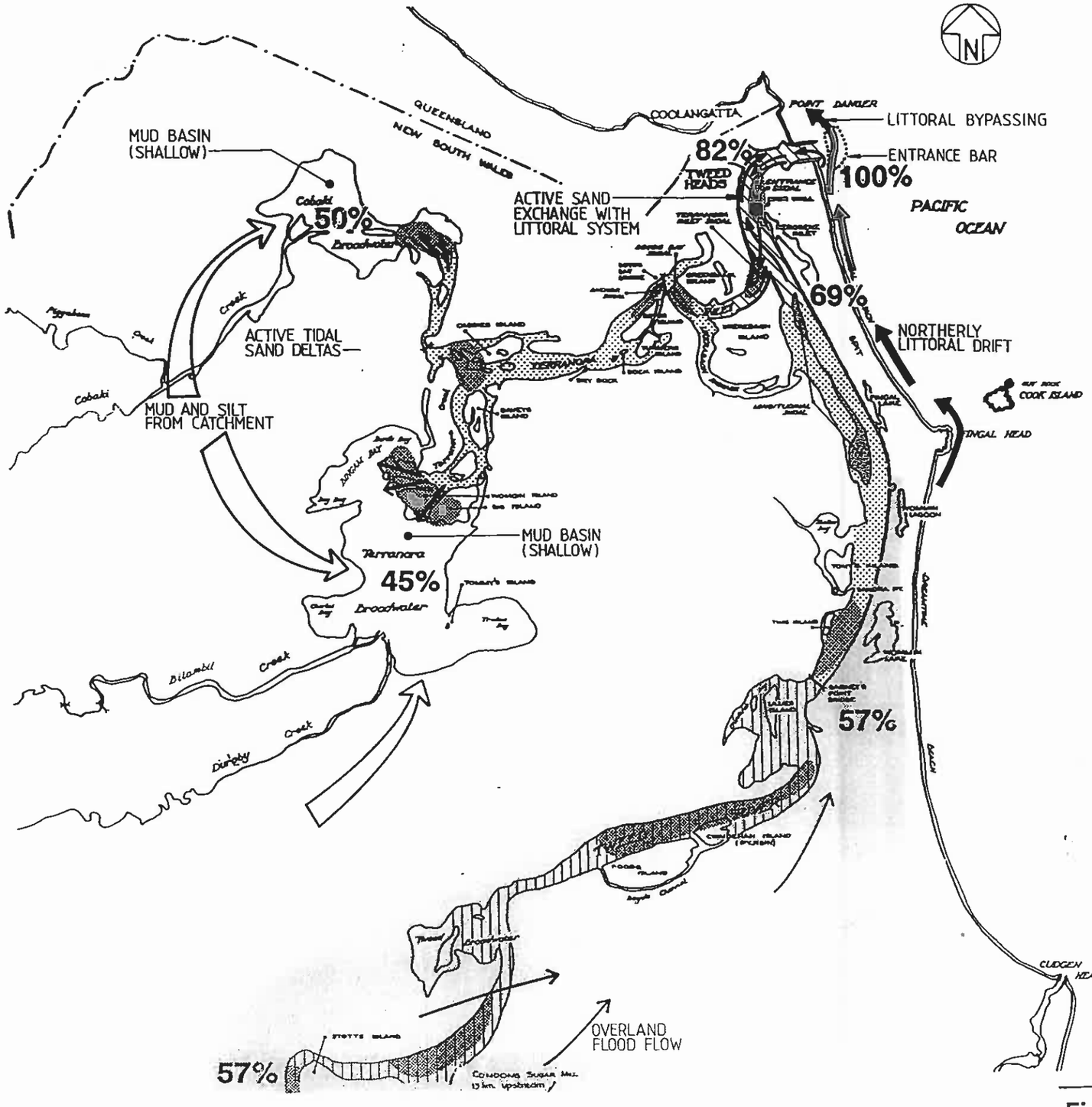


Figure 4.3.7
East Australian Current



LEGEND

- Main floodplain of the Tweed River
- Marine Delta
- Area of competent bed sediment transport by tides
- Area of competent bed sediment transport by floods
- 100% — Local tidal range expressed as % of ocean range
- Areas of significant shoaling

SOURCE: PWD (1991c)

Figure 4.4.1
Lower Tweed Estuary:
Hydrodynamics and Sedimentary Processes Overview

by tidal action. There is little dissipation of tidal energy and the tidal range is largely undiminished between Barneys Point and Murwillumbah, a distance of about 19 km. In fact, the reduced tidal energy dissipation allows some tidal amplification between Barneys Point and Murwillumbah (Section 4.4.1.8).

In the Terranora Arm, tides reduce progressively up to the Terranora and Cobaki Broadwaters where they are approximately 45% and 50% of ocean range, respectively. Under the action of tides, sediment transport occurs throughout Terranora Creek and is continuous into both Broadwaters where active tidal deltas are still growing slowly. The source of this sand is not the downstream marine delta sands but bed sediments contained within the channels. The Broadwaters themselves are gradually shallowing due to the accumulation of catchment derived silts and muds.

Catchment flooding is restricted predominantly to the Main Arm. Stotts Island and the surrounding choked channels act as a large plug in the system, forcing rising flood waters over bank and across the flood plain to rejoin the river in the Chinderah area. Shoaling in the reach from Stotts island to Chinderah is related solely to the action of floods whereas immediately downstream of Barneys Point Bridge shoaling is a mixture of flood deposits and slow upstream reworking by tides (Druery and Curedale, 1979).

Considerable quantities of sand can be scoured from the tidal shoals, in the marine delta, by large floods. This sediment is deposited on the entrance bar.

4.4.1.3 Tidal Propagation into the Tweed Estuary

PWD (1991a, 1991b, 1991c, 1991d) describes the propagation of the ocean tide into the estuary. The style of tidal propagation is best represented by the longitudinal variation in the level of high and low tide. Figure 4.4.2 shows the variation of the level of high and low water throughout the entire estuary for a large ocean tide range of 1.7 metres (cf. Mean Spring Range of 1.32 m).

As noted above, the styles of tidal propagation into the two arms of the estuary are quite different. The Main Arm displays a gradual variation in tidal level which is typical of long, narrow channelised estuaries. Terranora Arm on the other hand, exhibits pronounced attenuation of the tides, a characteristic which typifies the presence of tidal lakes (Druery, Dyson and Greentree, 1983).

The relatively rapid (ie. in a spatial sense) dissipation of tidal energy and the attenuation of tidal range which occurs across the entrance bar and between the entrance training walls is of particular interest to any project which will impact on the bathymetry of the bar and the average depths between the training walls. Table 4.4.1 shows tidal planes for Snapper Rocks (full ocean tide) and the Tweed Regional Tide Gauge (inside estuary at root of entrance breakwaters).

Table 4.4.1 Tidal Planes at Tweed Mouth, Prior to Stage 1A (m AHD)

Standard Tidal Plane	Snapper Rocks	Tweed Regional
MHWS	0.65	0.67
MWL	-0.01	0.10
MLWS	-0.67	-0.47

(Source: PWD, 1991a)

It can be seen that the Tweed River bar and entrance training walls cause considerable energy dissipation of the ebb tide jet with a consequential low tide attenuation of 0.2 m. The flood tide, however, moves into the entrance as an equipotential "sink" flow, often with flood rips at the head of the breakwaters. Consequently, the flood tide does not "feel" the bar as much as the ebb jet and there is very little attenuation of the high tide at the Tweed Regional gauge.

4.4.1.4 Storm Surge Penetration of the Lower Tweed Estuary

Storm surge is an elevation of the still water level due to the following factors associated with major storms, particularly cyclones:

- Barometric Anomaly - each drop of barometric pressure of 10mb produces a rise in sea level of approximately 0.125 metres;
- Wind Stress - interfacial shear between wind and the sea surface produces a water surface current of approximately 2% of the wind speed. Elevation of sea level at the coast is necessary to produce a counter flow and achieve mass balance; and
- Wave Set-up - occurs only in the surf zone where breaking waves produce a forward momentum flux. Mass balance is achieved by an elevation of the still water level against the shoreline which generates rip currents.

The propagation of storm tides (ie., astronomical tide plus storm surge) into estuaries would be similar to normal tides unless the higher water levels involve substantial inundation of overbank areas. Hence the ability of a storm tide to penetrate an estuary is controlled by entrance morphology in precisely the same way as astronomical tides.

Britton (1981) determined non tidal residuals in the Tweed estuary for the period 14-16 February, 1981. A maximum residual of 0.61 metres was determined and this penetrated, undiminished, 7.6 kilometres upstream to Barneys Point. These deviations were associated with cyclone 'Cliff' which crossed the coastline 300 kilometres to the north. As there was no rainfall recorded in the catchment and no unusual low pressure systems over the area during this period, it can be concluded that the deviations were the result of wave set-up alone (Griffin, 1983).

Tomlinson and Foster (1986) concluded that increased water levels in the lower Tweed during storms in 1984 were due to wave set-up resulting from waves breaking across the entrance channel.

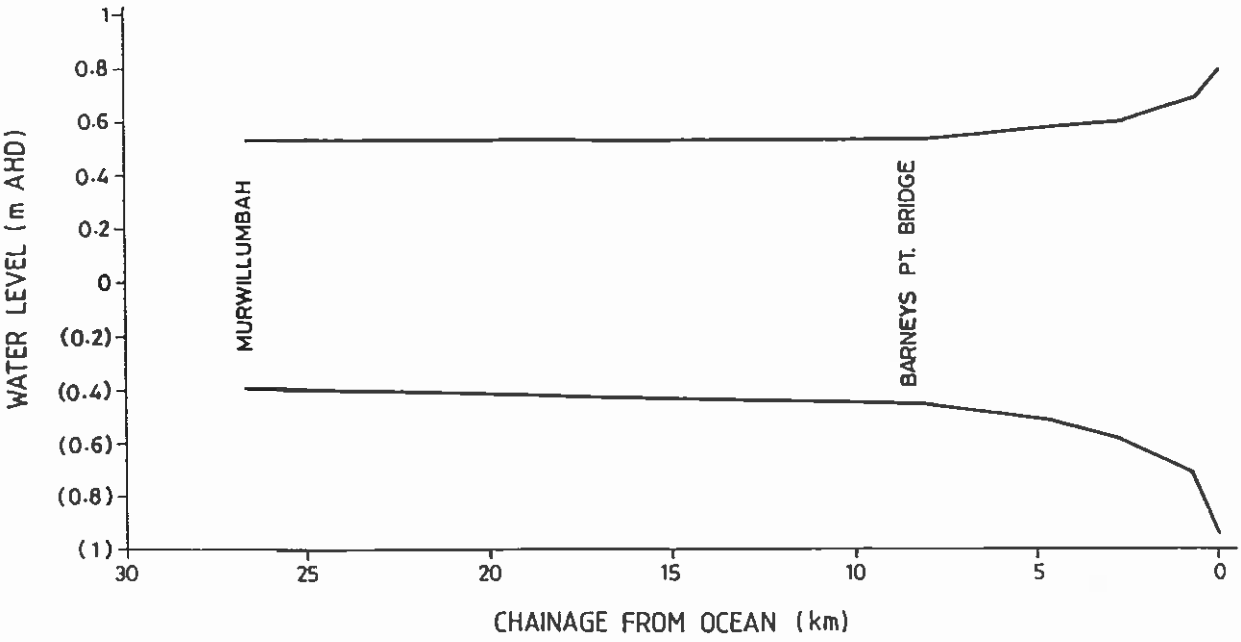
The coincidence of storm surge and catchment runoff aggravates flood levels in the lower reaches of the Tweed River. Oceanics (1983) and PWD (1991m) found that storm surge can elevate flood levels as far upstream as Tumbulgum, a distance of 21 kilometres from the entrance.

4.4.1.5 Tweed River Flooding

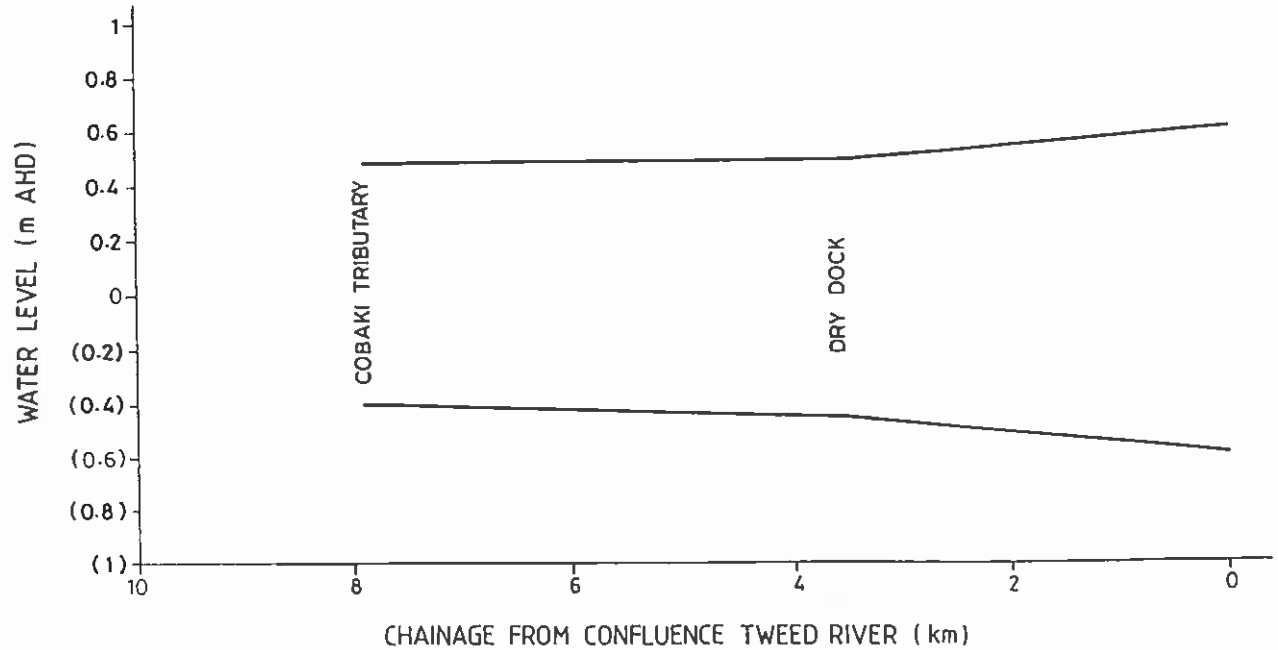
Public Works Department (1991b, 1991k, 1991m) examined the impact of floods of 1% and 5% annual exceedance probability (AEP) on the lower Tweed estuary. Both low and high ocean tailwater conditions were examined. It was found that the head loss through the existing entrance would be approximately 0.2 m for a 1% AEP flood coinciding with a low ocean tailwater of RL 1.0 m AHD. Under higher tailwater conditions (ie., RL 2.6 m AHD) the lower estuary would be "drowned" by the ocean and there would be no appreciable head loss through the entrance.

Flood velocities through the entrance would be 3.6 m/sec and 2.8 m/sec for the 1% and 5% AEP floods, respectively. There is little difference in peak velocity between high and low ocean tailwater conditions because scouring of the entrance bar, allowed for in each flood simulation, tended to produce similar flow areas.

WBM Oceanics (1994) determined that the average annual fluvial supply of the river to the lower reaches is about 4,000-5,000 m^3 pa. Major floods (ie. of the order of 1 to 2% AEP) can scour in excess of 200,000 m^3 from the area of the marine delta (WBM, 1994). The entrance shoal in particular, can be heavily scoured by



MAIN ARM



TERRANORA ARM

Figure 4.4.2
Existing Longitudinal Variation of High and Low Tide (Springs)

SOURCE: PWD (1991c)

floods. The 1954 flood scoured the entrance shoal leaving a pronounced escarpment which persisted for many years after that flood (Druery and Curedale, 1979).

Public Works Department (1991b, 1991k) found that the scouring potential associated with a 5% AEP flood (low tailwater case) was greatest in the channel narrowing, opposite the tip of Ukerebagh Island. The magnitude of the scour potential was estimated to be about 30,000 m^3 and this represents an average scouring over the full area of the channel of approximately 0.4 m. An average scouring potential of this order is not great and is consistent with known flood behaviour in this area (Druery and Curedale, 1979).

PWD (1995) shows that approved river dredging (areas A, B, C and 5 -refer Section 4.4.1.6) will lead to significant lowering of peak flood levels but only in the main arm, upstream of Barneys Point. Peak flood levels below Barneys Point are dominated by storm tide penetration. The approved river dredging will have no impact on peak flood levels in the Terranora arm.

4.4.1.6 Stage 2 Hydrodynamic Simulations

As part of the coastal and estuarine process studies for this EIS/EIA a combined estuary and nearshore hydrodynamic and sediment transport potential model was developed. The model couples existing, and recently updated, one-dimensional models of the estuary (PWD 1991b; PWD 1995), with a two-dimensional hydrodynamic simulation of the nearshore current field generated by the combined effects of tides, winds and the currents induced by breaking waves (ie. wave radiation stresses). The two-dimensional simulation included the area between the entrance training walls. The model provides a more rigorous representation of the hydrodynamic and sediment transport processes operating on the entrance bar.

Full details of the model development are provided in Technical Appendix II.

Tweed Shire Council, through its Tweed River Management Plan Advisory Committee and with the technical and financial assistance of the NSW Government (Department of Land and Water Conservation and other authorities) is implementing a Tweed River Management Plan. The Plan addresses a wide range of environmental issues, such as:

- marine ecology;
- habitat conservation;
- shore birds;
- navigation;
- recreation;
- water quality;
- flooding; and
- sand resources.

A significant component of the Plan is an extractive industry strategy which involves the deepening of the main arm to open the river to navigation and improve water quality, lower flood levels and provide funds for the implementation of habitat enhancement and protection strategies as well as providing enhanced user amenities (PWD, 1991h). In accordance with the Plan, there are three sand extraction areas which have development consent and are in various states of implementation. These areas include:

1. Area A - Comprises the main channel, just upstream of Stotts Island, to just upstream of Tweed Broadwater. A total quantity of approx 800,000 m^3 is earmarked for extraction over a 10 year period. Approval was granted early 1991.

2. Areas B & C - Encompasses the main channel between the upstream end of Dodds Island and Barneys Point Bridge. A total quantity of approx 3M m^3 over an approximate 20 year period is planned. Approval was granted late 1991.

3. Area 5 - Extends from Barneys Point Bridge to Rocky Point. A total of 920,000 m^3 is planned for removal over a period of 10 years. Approval was granted October, 1996. Area 5, may take some time to commence because it was originally conceived to supply sand for the Chinderah Bypass. However, that road bypass has been completed with sand supplied from Areas B & C. Hence the commencement date for Area 5 is unclear.

Generally, the timing of extraction from these areas cannot be determined accurately because it depends, on market demands and opportunities, the timing of regional infrastructure projects and the commercial planning imperatives of each individual operator. For the purposes of this study, however, it is assumed that Areas A, B & C, which have been actively worked for the last 3-4 years, will be fully dredged over the next 10-20 years. For the reason given above, Area 5 is unlikely to commence for some time, however it is assumed that it will be fully extracted over the next 20 years.

This EIS/IAS needs to consider both the cumulative and incremental impacts of a permanent entrance sand bypass system on the fully implemented Tweed Estuary Management Plan. It was not relevant to consider such long term impacts in respect of the Stage 1 EIS/IAS because of its "one-off" nature and its relatively short-lived impacts, compared to the evolving Tweed Estuary Management Plan. For instance, it was estimated that the impacts on the bar would last for a maximum of 3-4 years, in the absence of any follow-on works, such as a permanent bypass system. The cumulative and incremental impact on approved river dredging works is, however, relevant to Stage 2.

4.4.1.7 Discussion of Estuary Hydrodynamic Simulations

Because of the differing time scales and degrees of completion of approved projects, associated with the Tweed Estuary Management Plan, a number of model simulations were carried out to define the immediate and long term hydrodynamic characteristics of the estuary, with and without a permanent entrance bypass system. The following simulations were carried out. Details are provided in Technical Appendix II.

CASE 1 Pre-Stage 1A Base Case, based on a mix of 1989 and 1992 lower estuary bathymetry and 1994 entrance bar and channel conditions (refer Section 4.4.1.8).

CASE 2 Case 1 with extraction Areas A, B, C and Area 5 fully extracted. This represents the long term situation if no permanent entrance bypass works are carried out, all approved dredging components of the Tweed Estuary Management Plan are implemented and the entrance bar reverts to its former, pre-Stage 1A condition. However, it is necessary to take into account that the lower estuary marine shoals are gradually infilling (Section 4.4.2.2). Consequently, the bathymetry of the lower estuary marine shoals will vary in time. If left entirely to the natural infilling process, the marine shoals would increase to their long term regime size. However, this would exacerbate navigation problems and cause a substantial reduction in water quality throughout the estuary. It is most unlikely that this situation would be tolerated and the lower estuary shoals, in all probability, are likely to be maintained in an optimum configuration.

Hence, the long term bathymetry of the lower estuary marine shoals would lie somewhere between existing conditions and a fully infilled regime state. For the purposes of this EIS, the simulation of the long term impact of no entrance bypassing was bracketed by two limit cases, as outlined below:

CASE 2A Areas A, B, C and Area 5 fully extracted, no entrance bypass works and the lower estuary marine shoals maintained at their existing bathymetry.

CASE 2B Case 2A but with the lower estuary marine shoals allowed to undergo substantial infilling of 250,000 m^3. This in filling was distributed as a uniform loss of depth of approximately 1m over the present day shoals, between the entrance and just upstream of the confluence with Terranora Inlet.

CASE 2C Case 2A with 200,000 m^3 removed from the lower estuary marine shoals by a major flood.

CASE 3 Extraction Areas A, B & C fully extracted and the entrance bar and channel schematised to represent the May 1996 survey. This case represents existing conditions, at the completion of Stage 1A. The simulation provides a good indication of the existing hydrodynamics of the lower estuary but it tends to overestimate Stage 1A effects, upstream of Barneys Point, because of the partially completed state of extractive Areas A, B & C.

4.4.1.8 Pre-Stage 1A Base Case

The combined model was run to establish the base case for these studies ie. the tidal regime which existed before the Stage 1A works (CASE 1 in Section 4.4.1.7). The base case adopted the schematisation of the lower estuary shoals used by WBM Oceanics (1993). This schematisation was based on a mix of 1989 and 1992 hydrographic information.

The major river dredging associated with the Tweed Estuary Management Plan (ie Areas A, B, C and Area 5 - Section 4.4.1.6) had not commenced by 1992. Also, there had been little dredging in the River in the late 1980's and early 1990's (PBP, 1989). Hence the pre-Stage 1A base case represents a typical condition of the estuary for the period from late 1980s to early 1990's.

A summary of the results are shown in Table 4.4.2 in respect of an ocean tide with a mean spring range of 1.3 metres. Full results are presented in Technical Appendix II.

Peak ebb and flood discharges are approximately 800 m^3/sec and the peak velocity through the entrance is approximately 0.9 m/sec on both ebb and flood tides.

Table 4.4.2 CASE 1 : Hydrodynamic Response Of Estuary :Pre-Stage 1A Works : Tide Of Mean Spring Range (1.3 m)

Location	Tidal Levels (m) AHD)			Peak Flows (m^3/s)		Peak Velocities (m/s)	
	HW	LW	Range	Ebb	Flood	Ebb	Flood
Entrance (Regional Tide Gauge)	0.60	-0.55	1.15	730	830	0.91	0.90
Letitia 2A	0.50	-0.38	0.88	370	430	0.95	0.87
Letitia 2B	0.49	-0.37	0.86	260	300	0.36	0.38
Barneys Point	0.47	-0.34	0.81	290	350	0.34	0.39
Tumbulgum	0.50	-0.33	0.83	80	98	0.28	0.37
Murwillumbah	0.55	-0.36	0.91	53	51	0.14	0.17
Terranora Inlet	0.51	-0.43	0.94	320	380	0.83	0.79
Dry Dock	0.44	-0.34	0.78	260	310	0.52	0.57
Terranora Broadwater	0.45	-0.30	0.75	140	170	0.41	0.47
Cobaki Broadwater	0.45	-0.31	0.76	68	87	0.27	0.32

(Source: Technical Appendix II)

Peak tidal discharges of the main arm of the Tweed River and Terranora Creek, at their confluence, are approximately 400 m^3/sec and 350 m^3/sec, respectively. Peak tidal discharges diminish in the main arm to a little over 50 m^3/sec at Murwillumbah. Because of the substantial tidal prism of the Broadwaters on the Terranora system, the attenuation of tidal flows is less marked.

As noted in the preceding overview, the tidal range in the Terranora Arm reduces progressively between Terranora Inlet and the Broadwaters. In the main arm, tidal range reduces progressively to Barneys Point but increases progressively from Barneys Point to Murwillumbah. This progressive upstream increase, indicates that the primary ocean tide is amplified in the upper reaches of the main arm due to tidal resonance. Tidal resonance is a macro response of the tide (considered as a long period wave) to the overall length and depth of the estuary (Druery *et al.*, 1983).

4.4.1.9 Tidal Levels, Flows and Velocities: Existing Situation (Post Stage 1A)

The prediction of the hydrodynamic response of Stage 1A (Acer Wargon Chapman, 1994) was revised using the combined model and revised bathymetry from PWD (1995) and the entrance channel and bar survey of 24 May 1996 (Tweed River Entrance Sand Bypassing Project). The latter presents entrance conditions immediately after the May 1996 storm and represents a reasonably average condition for the channel between the training wall, over several months. It presents a channel across the bar which is similar to the 5 metre below ISLW used in the Stage 1A simulation.

Table 4.4.3 summarises the predictions of the post Stage 1A hydrodynamic response of the estuary to a tide of mean Spring range. Detailed model results are contained in Technical Appendix II.

Table 4.4.3 CASE 3: Predicted Tidal Hydrodynamic Response: Existing Conditions *(Post Stage 1A)*: Tide Of Mean Spring Range (1.3 m)

Location	Tidal Levels (m) AHD)			Peak Flows (m^3/s)		Peak Velocities (m/s)	
	HW	LW	Range	Ebb	Flood	Ebb	Flood
Regional Gauge	0.62	-0.58	1.20	760	880	0.96	0.95
Letitia 2A	0.50	-0.38	0.88	400	470	1.02	0.95
Letitia 2B	0.49	-0.37	0.86	280	330	0.38	0.41
Barneys Point	0.49	-0.36	0.85	320	380	0.38	0.44
Tumbulgum	0.53	-0.37	0.90	91	107	0.33	0.39
Murwillumbah	0.58	-0.40	0.98	56	56	0.14	0.17
Terranora Inlet	0.52	-0.44	0.96	330	380	0.83	0.79
Dry Dock	0.45	-0.34	0.79	260	310	0.52	0.57
Terranora Broadwater	0.46	-0.30	0.76	140	170	0.42	0.47
Cobaki Broadwater	0.46	-0.31	0.77	68	87	0.27	0.32

(Source: Technical Appendix -II)

4.4.1.10 Immediate Incremental Impact of Stage 1A Dredging

The immediate incremental impact of Stage 1A is obtained by subtracting Table 4.4.2 (CASE 1) from Table 4.4.3 (CASE 3). The results are set out in Table 4.4.4.

Table 4.4.4 Incremental Impact Of Stage 1A (CASE 3 - CASE 1) : Tide Of Mean Spring Range (1.3 M)

Location	Absolute Change			Percentage Change			
	Tidal Levels (m)			Peak Flows		Peak Velocities	
	HW	LW	Range	Ebb	Flood	Ebb	Flood
Regional Gauge	0.02	-0.03	0.05	4	6	5	5
Letitia 2A	0.0	0.0	0.0	8	9	7	9
Letitia 2B	0.0	0.0	0.0	8	10	6	8
Barneys Point	0.02	-0.02	0.04	10	9	12	3
Tumbulgum	0.03	-0.04	0.07	14	9	18	5
Murwillumbah	0.03	-0.04	0.07	6	10	0.0	0.0
Terranora Inlet	0.01	-0.01	0.02	3	0.0	0.0	0.0
Dry Dock	0.01	0.0	0.01	0.0	0.0	0.0	0.0
Terranora Broadwater	0.01	0.0	0.01	0.0	0.0	3	0.0
Cobaki Broadwater	0.01	0.0	0.01	0.0	0.0	0.0	0.0

The maximum predicted drop in low water, as a result of Stage 1A, is of the order of 3 cm at the regional tide gauge. This compares with the Stage 1A simulation, for a tide with a Spring range of 1.7 m, which predicted a lowering of low water by 0.16 m at the regional tide gauge and 0.12 m at Letitia 2A (PBP, 1994).

Continuous water level records from the Tweed Regional Gauge, for the period 1/1/89 to 31/12/94, were analysed to give reliable tidal constituents which were then used to predict future tides throughout the Stage 1A dredging period. These predicted tides were then compared with recorded tides. It was found that there was no significant difference in the pattern of tidal residuals (ie., differences between predicted and recorded water levels), over six monthly intervals, before, during and after Stage 1A. This

implies that the impact of the Stage 1A dredging was masked by the inherent noise and local variations in the recorded data.

Manly Hydraulic Laboratory (MHL, in prep) carried out a long term harmonic analysis of the tidal records at Letitia 2A, for the period 1980-1996. MHL concluded that the measurements of high and low water and tidal range, after the Stage 1A dredging, showed no discernible departure from the long term envelope of variability.

Both these analyses imply that the actual impact of Stage 1A is much less than the inherent noise in the data. As the tidal residuals had a mean value of approximately 0.1 m, the implication is that the incremental impact of Stage 1A was much less than 0.1 m. Hence a predicted lowering of low water by 3 cm and increase in range of 5 cm, as outlined above, are considered to be of the correct order.

Table 4.4.1.10 shows that because of tidal resonance, the incremental impact of Stage 1A is predicted to increase in the upper Tweed, upstream of Letitia 2B. A significant and discernible increase in peak discharges and velocities is indicated. In complete contrast, the simulations predict no significant impact within the Terranora arm of the estuary.

4.4.1.11 Long Term Cumulative Impact of Tweed Estuary Management Plan

Table 4.4.5 summarises the long term cumulative, hydrodynamic response of the estuary when Areas A, B, C and Area 5 are fully extracted, with no entrance bypass works, and the lower estuary marine shoals are maintained at their existing bathymetry. Detailed results are contained in Technical Appendix II.

Table 4.4.5 CASE 2A : Predicted Long Term Hydrodynamic Response With No Entrance Bypassing Works And Lower Estuary Shoals Unchanged: Tide Of Mean Spring Range (1.3 M)

Location	Tidal Levels (m) AHD)			Peak Flows (m^3/s)		Peak Velocities (m/s)	
	HW	LW	Range	Ebb	Flood	Ebb	Flood
Region Gauge	0.60	-0.55	1.15	770	880	0.95	0.94
Letitia 2A	0.48	-0.37	0.85	400	480	1.01	0.98
Letitia 2B	0.48	-0.37	0.85	290	340	0.38	0.42
Barneys Point	0.49	-0.38	0.87	320	380	0.38	0.44
Tumbulgum	0.54	-0.38	0.92	93	110	0.34	0.40
Murwillumbah	0.59	-0.41	1.00	58	58	0.14	0.18
Terranora Inlet	0.51	-0.42	0.93	320	380	0.82	0.78
Dry Dock	0.44	-0.33	0.77	260	305	0.52	0.57
Terranora Broadwater	0.45	-0.30	0.75	140	170	0.41	0.46
Cobaki Broadwater	0.44	-0.30	0.74	68	86	0.26	0.32

(Source: Technical Appendix II)

Table 4.4.6 summarises the long term cumulative response of the estuary to the Tweed Estuary management Plan, if the lower estuary shoals are allowed to infill substantially.

Table 4.4.6 CASE 2B : Predicted Long Term Hydrodynamic Response With No Entrance Bypassing Works And Lower Estuary Marine Shoals Infilled: Tide Of Mean Spring Range (1.3 m)

Location	Tidal Levels (m) AHD)			Peak Flows (m^3/s)		Peak Velocities (m/s)	
	HW	LW	Range	Ebb	Flood	Ebb	Flood
Region Gauge	0.60	-0.55	1.15	700	800	1.08	1.05
Letitia 2A	0.44	-0.33	0.77	370	440	0.90	0.92
Letitia 2B	0.44	-0.33	0.77	270	310	0.35	0.39
Barneys Point	0.46	-0.33	0.79	300	360	0.35	0.41
Tumbulgum	0.51	-0.36	0.87	87	100	0.32	0.38
Murwillumbah	0.56	-0.37	0.93	55	54	0.14	0.18
Terranora Inlet	0.46	-0.37	0.83	295	350	0.74	0.74
Dry Dock	0.41	-0.29	0.70	230	280	0.48	0.54
Terranora Broadwater	0.43	-0.28	0.71	135	160	0.38	0.42
Cobaki Broadwater	0.42	-0.28	0.70	63	80	0.24	0.30

(Source: Technical Appendix II)

Table 4.4.7 summarises the cumulative impact of the Tweed Estuary Management Plan with no entrance bypass works and the lower estuary marine shoals maintained at their existing bathymetry.

Table 4.4.7 CASE 2A - CASE 1. Long Term Cumulative Impact Of Tweed Estuary Management Plan: Lower Estuary Shoals Unchanged: Tide Of Mean Spring Range (1.3 m)

Location	Absolute Change			Percentage Change			
	Tidal Levels (m)			Peak Flows		Peak Velocities	
	HW	LW	Range	Ebb	Flood	Ebb	Flood
Regional Gauge	0.0	0.0	0.0	5	6	4	4
Letitia 2A	-0.02	0.01	-0.03	8	12	6	13
Letitia 2B	-0.01	0.0	-0.01	12	13	6	11
Barneys Point	0.02	-0.04	0.06	10	9	12	13
Tumbulgum	0.04	-0.05	0.09	16	12	21	8
Murwillumbah	0.04	-0.05	0.09	9	14	0.0	6
Terranora Inlet	0.0	0.01	-0.01	0.0	0.0	-1	-1
Dry Dock	0.0	0.01	-0.01	0.0	-2	0.0	0.0
Terranora Broadwater	0.0	0.0	0.0	0.0	0.0	0.0	-2
Cobaki Broadwater	-0.01	0.01	-0.02	0.0	-1	-4	0.0

Table 4.4.8 summarises the cumulative impact of the Tweed Estuary Management Plan with no entrance bypass works and substantial infilling of the lower estuary marine shoals.

Table 4.4.8 **CASE 2B - CASE 1. Long Term Cumulative Impact Of Tweed Estuary Management Plan: Lower Estuary Shoals Infilled: Tide Of Mean Spring Range (1.3 m)**

Location	Absolute Change			Percentage Change			
	Tidal Levels (m)			Peak Flows		Peak Velocities	
	HW	LW	Range	Ebb	Flood	Ebb	Flood
Regional Gauge	0.0	0.0	0.0	-4	-4	19	17
Letitia 2A	-0.06	0.05	-0.11	-2	2	-5	6
Letitia 2B	-0.05	0.04	-0.09	3	3	-3	3
Barneys Point	-0.01	.01	-0.02	3	3	3	5
Tumbulgum	+0.01	-0.03	+0.04	2	2	14	3
Murwillumbah	0.01	-0.01	0.02	6	6	0.0	6
Terranora Inlet	0.05	0.06	-0.11	-8	8	-10	-6
Dry Dock	-0.03	0.05	-0.08	-11	-10	-8	-5
Terranora Broadwater	0.02	0.02	-0.04	-4	-6	-7	-11
Cobaki Broadwater	-0.03	0.03	-0.06	-7	-8	-11	-6

If the lower estuary marine shoals are maintained at their existing bathymetry, the cumulative impact of all approved river dredging would be a substantial increase in tidal range in the main arm, above Letitia 2A. Peak tidal flows and velocities would be increased 10-15% throughout the main arm and there would be substantial improvements in the tidal mixing and flushing of the main arm. A marked improvement in the water quality of the upper Tweed River could be expected. The Terranora arm, however, would be insensitive to the approved dredging works and there would be little change in the existing tidal regime of the Terranora system.

If the lower estuary marine shoals are allowed to infill, the benefits associated with the dredging components of the Tweed Estuary Management Plan would be largely negated. Tidal ranges would be reduced below Barneys Point and only marginally increased above Barneys Point. The increase in peak flows and velocities would be limited to about 5%. In the Terranora arm, however, there would be a pervasive reduction of tidal range and reduction of tidal flows and velocities of the order of 5-10%. This could be expected to cause a reduction in the tidal mixing and flushing of the Terranora arm with a consequential deterioration of water quality. Hence the future management of the lower estuary marine shoals, under existing conditions and approved river works, will have significant bearing on the long term hydrodynamic regime of the estuary.

4.4.1.12 Impact of Flood Scour on Tidal Hydrodynamics

Incremental Impact

Major floods with an AEP of 1%-2%, can scour in excess of 200,000 m^3 from the lower estuary marine shoals (Section 4.4.1.5). As these shoals are a major control on the propagation of tides (Section 4.4.1.2), a substantial reduction in shoal volume would lead to significant changes in tidal levels and flows throughout the estuary.

The tidal hydrodynamic response of the estuary, to scouring of the lower estuary shoals by a major flood, was simulated by reducing the volume of the existing shoals by 200,000 m^3. Table 4.4.9 summarises the post flood hydrodynamic response of the estuary. Approved river dredging works (ie Areas A, B, C and Area 5) were included to reflect the long term condition. In this regard, upstream fluvial sediment supply rates indicate that all dredged areas would take in excess of 200 years to infill (PWD, 1995).

Table 4.4.9 CASE 2C: Predicted Tidal Response Of Estuary With All Approved River Dredging Completed And 200,000 m^3 Flood Scour: Tide Of Mean Spring Range (1.3 M)

Location	Tidal Levels (m) AHD)			Peak Flows (m^3/s)		Peak Velocities (m/s)	
	HW	LW	Range	Ebb	Flood	Ebb	Flood
Regional Gauge	0.64	-0.60	1.24	860	960	0.96	0.95
Letitia 2A	0.55	-0.48	1.03	470	520	0.95	0.88
Letitia 2B	0.54	-0.46	1.00	330	380	0.46	0.45
Barneys Point	0.54	-0.44	0.98	370	430	0.43	0.48
Tumbulgum	0.58	-0.44	1.02	100	120	0.36	0.44
Murwillumbah	0.64	-0.46	1.10	60	65	0.15	0.18
Terranora Inlet	0.56	-0.50	1.06	350	400	0.92	0.83
Dry Dock	0.48	-0.38	0.86	280	330	0.56	0.62
Terranora Broadwater	0.48	-0.33	0.81	155	190	0.44	0.49
Cobaki Broadwater	0.48	-0.33	0.81	74	94	0.28	0.34

(Source: Technical Appendix II)

Table 4.4.10 summarises the incremental impact of lower estuary scouring by a major flood, compared to the non scoured situation *(ie existing shoal bathymetry, CASE 2A).*

Table 4.4.10 CASE 2C - CASE 2A. Incremental Impact Of Major Flood Scour On Tidal Hydrodynamics: Existing Shoal Conditions With All Approved River Dredging: Tide Of Mean Spring Range (1.3 m)

Location	Absolute Change			Percentage Change			
	Tidal Levels (m) AHD			Peak Flows (m^3/s)		Peak Velocities (m/s)	
	HW	LW	Range	Ebb	Flood	Ebb	Flood
Regional Gauge	0.04	-0.05	0.09	12	9	1	1
Letitia 2A	0.07	-0.11	0.18	18	8	-6	-10
Letitia 2B	0.06	-0.09	0.15	14	12	16	7
Barneys Point	0.05	-0.06	0.11	16	13	13	9
Tumbulgum	0.04	-0.06	0.10	8	9	6	10
Murwillumbah	0.05	-0.05	0.10	3	12	7	0.0
Terranora Inlet	0.05	-0.08	0.13	9	5	12	6
Dry Dock	0.04	-0.05	0.09	8	8	8	9
Terranora Broadwater	0.03	-0.03	0.06	11	12	7	7
Cobaki Broadwater	0.04	-0.03	0.07	9	9	8	6

(Source: Technical Appendix II)

Table 4.4.10 demonstrates that under existing conditions, a major flood, which scours the lower estuary marine shoals, can be expected to have a substantial impact on the propagation of tides into the estuary. In the main arm, low tide levels would be lowered by 10 cm in the lower reaches and by 5-6 cm upstream of Barneys Point. High water would be raised 5-7 cm throughout.

As a consequence, tidal ranges would increase by 18 cm in the vicinity of Letitia 2A and by 10 cm to Murwillumbah. Such a pervasive increase in tidal range would represent a substantial increase in tidal prism and peak tidal flows and velocities could be expected to increase by up to 18% downstream of Barneys Point; the increase varying to about 7% at Murwillumbah.

In the Terranora arm, there would be a 3 cm lowering of low water and a 3-4 cm increase of the level of high water of both Broadwaters. Peak tidal flows and velocities would be generally increased by about 10%.
These hydrodynamic impacts would bring about a substantial improvement in the tidal mixing and flushing of the estuary. The changes in tidal planes could be expected to have a significant impact on the ecology of the estuary and it is emphasised that these impacts relate to existing conditions with all approved river dredging fully implemented.

Post Flood Scour Recovery of Marine Shoals

The hydrodynamic impacts associated with flood scouring of the lower estuary marine shoals would be temporary because the marine shoals would infill again with marine sand transported through the mouth of the estuary. In fact, the increase in tidal flows and velocities, noted above, would rejuvenate the rate of sand infeed.

Stage 1A studies (PBP, 1994) found that as the lower estuary marine shoals infilled over the period 1975 to 1994, the rate of infilling has progressively reduced from 85,000 m^3 pa (1976) through 79,000 m^3 pa (1985) to 36,000 m^3 pa (1994).

Under existing conditions, the scouring of 200,000 m^3 is likely to restore the infeed of marine sand to annual rates which existed in the late 1980's ie of the order of 70,000 m^3 pa. Hence, taking into account that the rate of infilling reduces as the lower estuary marine shoals re-build, it is estimated that the lower estuary shoals would take approximately 3-5 years to revert to their pre-flood condition. Hence under existing conditions, the tidal hydrodynamic impact of major flood scour could be expected to be felt substantially for a period of 2-3 years.

4.4.2 Estuary Shoal Dynamics

4.4.2.1 Existing Estuary Shoal Dynamics

Tidal sediment transport patterns and the consequential shoal dynamics have been investigated by PWD (1991b; 1991d, 1991g). The variations in the predictions of the combined and improved hydrodynamic model in respect of the Stage 1A works (Section 4.4.1.10) are not sufficient to significantly alter predictions concerning estuarine shoaling patterns. Hence, the PWD (1991) studies can be accepted as reasonable estimates of existing sediment transport rates and estuarine shoal dynamics for the purposes of this EIS/IAS. Figure 4.4.3 shows existing shoal dynamics.

Because of the relatively shoaled condition of the lower estuary, existing net transport rates are relatively weak throughout the lower estuary. The Terranora Arm still displays the reversal in sediment transport, downstream of the Dry Dock, which was recognised by Druery and Curedale (1979) as an indication that the estuary is out of regime. Hence the lower estuary has not yet fully recovered from the dredging of the late 60's and early 70's.

Shoaling in Terranora Inlet, in the vicinity of the Boyds Bay Shoal, due to net downstream sediment transport, is relatively weak. There is significant net build-up of sand on the delta leading into Terranora Broadwater.

There is no significant tidal sediment transport upstream of Barneys Point Bridge. Immediately downstream of Barneys Point Bridge, there are areas of accretion at Banora Point and downstream of Tonys Island.

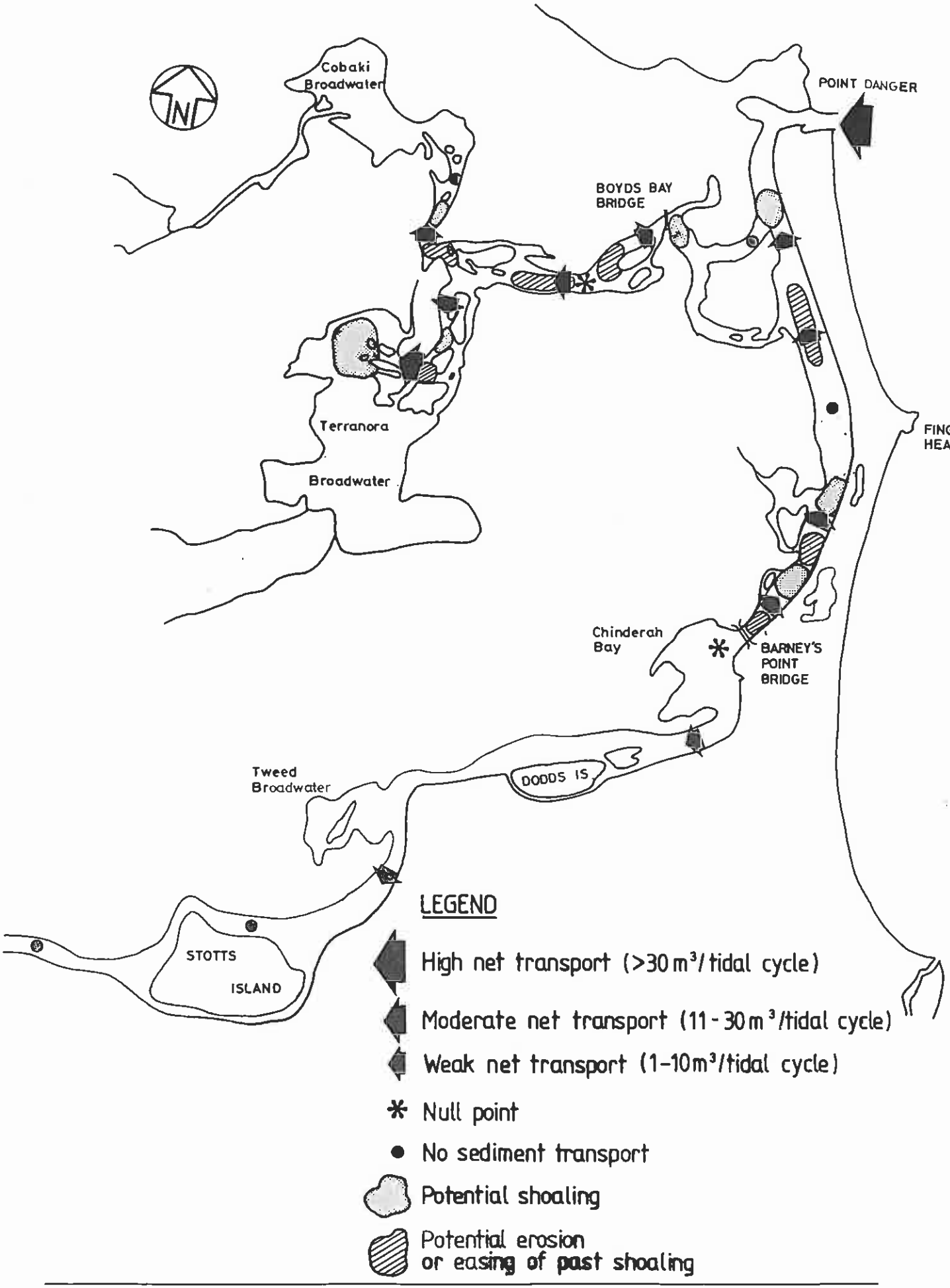


Figure 4.4.3
Existing Shoal Dynamics

SOURCE: PWD (1991b)

The continued build-up of shoals, opposite the entrance to Terranora Inlet, creates persistent navigation difficulties.

4.4.2.2 Long Term Impact of Tweed Estuary Management Plan

Tidal Sediment Transport and Marine Sand Supply

As noted in Section 4.4.1.11, approved river dredging (Areas A, B, C and 5), will have a significant impact on the tidal hydrodynamics of the estuary. The impact will be damped by the gradual infilling of the lower estuary marine shoals. If infilling was to be left unhindered, the estuary would tend towards its regime state, ie a heavily shoaled condition similar to the 1930's and 1960's in which a time averaged balance would exist in the movements of marine sand into and out of the lower reaches of the river.

Studies by WBM (1994) and PWD (1995) have found that the increased hydrodynamics, associated with Areas A, B, C and 5, will increase the rate of marine sand infeed and increase the upstream limit of the lower estuary marine shoals (ie., marine sand will be transported further upstream under the action of tidal flows). However, the increased rate of build-up of the marine shoals, will tend to damp out the hydrodynamic impacts of the dredging. Hence there will be a natural feedback process which will tend to limit the overall build-up.

Using mathematical modelling techniques and empirical extrapolation of hydrosurvey volumes, WBM (1994) and PWD (1995) estimate that the net infill rate of marine sand, through the entrance, is likely to be approx 600,000m^3 over the period 1990 to 2050. There would still be a small infeed after that period, of the order of 1,000m^3/year. After (say) 200 years, the maximum likely cumulative sand infeed quantity would be about 750,000m^3. These predictions, of course, assume that there would be no artificial intervention in the infilling process.

Hence, it will take 50 years or more for the lower estuary marine shoal to approach regime conditions, if the natural infilling process is not altered in any way. Whilst this may appear to be a long time, it reflects the magnitude of the approved works, ie the estuary will take a considerable period to achieve a hydrodynamically steady state after the extraction of a total of almost 4M m^3 of bed sediment. This is consistent with the findings of Druery and Curedale (1979) who determined the estuary would take over 20 years to recover from 1.3M m^3 of dredging of the lower estuary in the late 1960's and 1974/1975.

WBM (1994) demonstrate that the supply of fluvial sand, from upstream, ie 4,000 to 5,000m^3/year (Section 4.4.1.5) would cease because all dredged areas would become effective sand traps. It is predicted that the net tidal transport in the vicinity of Letitia 2A would reverse to a maximum net upstream transport of 4,000 m^3 pa over the period 1990 to 2000 and average approx 2,000 m^3 pa over the next 50 years. This would be the mechanism by which the area of the active marine shoals would increase in plan area.

Long Term Estuary Shoal Dynamics

The long term shoal dynamics associated with a preliminary version of the Tweed Estuary Management Plan has been investigated by PWD (1991a, 1991 c; 1991 d). This, however, was for a much greater area of sand extraction. More recent studies WBM (1994) and PWD (1995) present sediment transport assessments for the current Plan. These study results have been interpreted to provide an indication of the long term shoal dynamics that can be expected over the next 20 years, as the dredging works are fully implemented (Figure 4.4.4).

The approved dredging would not have a significant impact on the hydrodynamics of Terranora Creek (Section 4.4.1.11). Hence the long term shoal dynamics of Terranora Creek would reflect the existing patterns as described in Section 4.4.2.1. Shoaling on the Boyds Bay Shoal, of the order of 2,000 m^3-

4,000 m^3 pa would ensure persistent navigation channel maintenance problems for the fishing fleet in this area. The increased rate of marine sand infeed and the extended limit of effective upstream transport of marine sand, as Area A, B, C and 5 were fully extracted, would be to substantially increase the shoaling at the entrance to Terranora Inlet. The navigation channel in the confluence area, occupies a "crossing" as the main arm ebb channel switches from right bank to left bank, combining with the Terranora Inlet ebb channel in the process. It has been difficult to maintain a navigation channel in this area in recent years. It is considered that under existing conditions, as the impacts of all approved dredging works become manifest, these difficulties would be exacerbated and more regular maintenance dredging would become necessary.

In the main arm, as all approved river dredging is carried out, the lower estuary marine shoals would gradually extend upstream against Ukerebagh Island at a net volumetric rate of approximately 2,000-3,000 m^3 pa. As a consequence, the northern end of the longitudinal shoal would be expected to shoal substantially over the next 20 years. The secondary western channel, against Ukerebagh Island, would be likely to experience some infilling. This is a significant recreational boating area and some maintenance dredging may be necessary if the entrance bypass works are not implemented. The main channel which runs against the right bank, would be likely to be substantially narrowed by any upstream extension of the lower estuary marine shoals. This area has never needed dredging however, and it is considered that any such narrowing would be unlikely to require dredging in the future.

Between Ukerebagh Island and Fingal, there would be a weak, net upstream transport of sand, towards the dredged areas. The rate of transport; however, would be quite low at Fingal (of the order of 500 m^3 pa) because of the natural attenuation of tidal velocities (Section 4.4.1.8). Hence, there would likely be a slow growth of the longitudinal shoal which would be manifest as a progressively greater expanse of shoal exposed at low water. It is unlikely that there would be any significant deterioration of the main navigation channel which bears against the right bank throughout this area.

Throughout the dredged areas, there would be no tidal transport of sand because of the low velocities in the deepened channel. Upstream of the dredged areas, there would be a net downstream transport of sediment. The velocities involved, however, would be only marginally above the threshold of sediment mobility, and the net transport rates would not be significant.

4.4.2.3 Environmental Implications of Tweed Estuary Management Plan

Section 4.4.1.11 demonstrates that the Tweed Estuary Management Plan will lead to a marked improvement in tidal mixing and flushing of the main arm, provided the lower estuary marine shoals are maintained at their existing bathymetry. If the shoals are allowed to infill, these benefits would be largely negated and there would be a marked decline in water quality of the Terranora arm.

Should infilling be allowed to persist until equilibrium is reached (ie. "do nothing" option), there would be a severe deterioration of water quality throughout the estuary (refer Section 6.2). The consequences to the upper Tweed could be disastrous because it is already on the verge of being eutrophic (TSC, 1996b).

Section 4.4.2.2 demonstrates that completion of the approved river dredging will cause the lower estuary marine shoals to extend further upstream. This would exacerbate long standing shoaling and navigation channel maintenance difficulties as well as create new ones ie.:

- the Boyds Bay Shoal would remain a persistent area of build-up;
- channel maintenance is likely to become more difficult in the vicinity of the Terranora Inlet confluence with the main arm;
- the secondary western channel of the main arm against Ukerebagh Island, could infill;

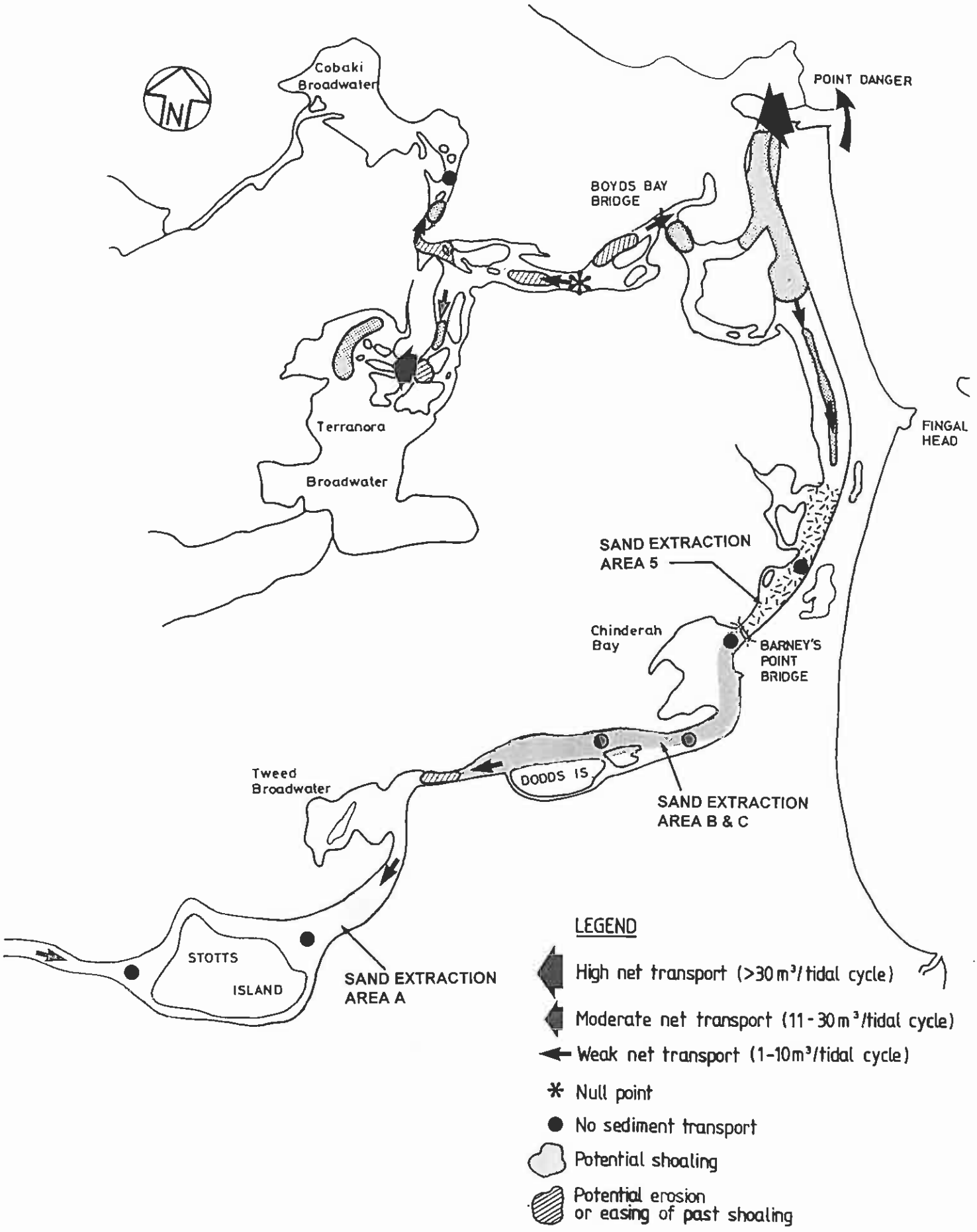


Figure 4.4.4
Existing Environment: Long-term Net Tidal Sediment Transport and Shoal Dynamics with all Approved River Dredging Completed

- the longitudinal shoal, between Ukerebagh and Fingal, would be likely to expand ie. increasing area of drying at low water; and
- the main channel of the main arm, opposite Ukerebagh Island, could be narrowed.

Section 4.4.1.12 demonstrates that, under existing conditions, a major flood is likely to scour the lower estuary marine shoals to such an extent as to cause a marked drop in low tide levels. Without any post-flood corrective measures, the hydrodynamic effects would last for 2-3 years while the natural infilling process restored the shoals.

There is an undeniable need, merely in respect of the existing environment, for the lower estuary marine shoals to be managed. The objective would be to restrain future shoal build-up to acceptable limits, to avoid long term water quality problems, and contain the buildup of sand in sensitive areas.

4.4.2.4 Lower Estuary Marine Shoals Management Strategy

Section 4.4.2.3 demonstrates that in respect of the existing environment, there is a strong need for a Lower Estuary Marine Shoals Management Strategy. The Strategy is needed to maintain the lower estuary shoals in an optimum configuration which would:

- avoid the water quality problems associated with excessive infilling of the shoals; and
- carry out post major flood scour restorative works to avoid a major shift in the tidal planes of the estuary.

Removal of excess sand build-up within the lower estuary, could be easily undertaken by small cutter suction dredge. Because this dredging would not be directly related to this Project, approval of such dredging does not form part of this EIS/IAS. It would be the subject of a separate environmental study, prepared to reflect the prevailing conditions in the estuary and approval process at the time. These studies could examine, inter alia, the suitability of the sand for beach nourishment.

The placement of sand on the lower estuary marine shoals, to restore losses associated with major flood scour, could be achieved by either or combination of:

- nourishment with sand dredging from the maintenance dredging of navigation channels in the lower estuary; and
- sand supplied from the entrance bypass system by means of a temporary delivery line running along the eastern river training wall. An indicative layout, reflecting this possibility, is included in the description of the project footprint (Figure 5.2.2). Any sand supplied for this purpose would be extra to the contract quantity set out in the Deed of Agreement.

Because post flood sand placement is likely to be required irrespective of whether a permanent bypass is constructed or not, the approval of any sand placement on the lower estuary marine shoals, does not form part of this EIS/IAS. Such activity would be the subject of a separate environmental study, reflecting the conditions of the estuary and the approval processes pertaining at the time.

It is considered therefore that the Tweed Estuary Management Plan needs to be extended to include a detailed Lower Estuary Marine Shoals Management Strategy. The Strategy could possibly take the form of a development control plan or other more suitable planning instrument. The Strategy would anticipate and allow for the largely beneficial incremental impacts of a permanent bypass system (refer Section 7.4). It is beyond the scope of this study to develop such a Strategy.

4.5 Ecological Environment

The following sections provide descriptions of the existing environment for those ecological elements that are most likely to be affected by the sand bypassing at the entrance to the Tweed River and associated dredging events further upstream.

Effects are discussed with relevance to marine (external to the river mouth), estuarine (within the river), and terrestrial (land areas above tidal influences). Shorebirds are discussed separately considering the importance of certain areas within the Tweed region as roosting and feeding sites for shorebirds of significance, especially migratory waders and species covered by the *NSW Threatened Species Conservation Act, 1995*.

4.5.1 Marine

This section describes the habitats occurring in the nearshore marine environment which are within the zone of potential impact from the proposal. This zone is defined by the Deed of Agreement as being outside the training walls of the River mouth, and along the coast from about two kilometres south of the Tweed River entrance to approximately North Kirra, and extending offshore in a two kilometre radius from the entrance in NSW and about one kilometre offshore in Queensland to about the -10 m contour. This section focuses specifically on the proposed sand removal areas and the potential disposal areas.

There are two principle substrate habitats within the study area: the dominant substrate is mobile, clean (in the sense of containing little mud), unvegetated sand. The second most common substrate is basaltic rock outcrops, either natural (as submerged reefs) or anthropogenic (in the form of training walls and groynes). The overlying water column is the only other marine habitat within this defined study area. There are no seagrass beds, mangroves, saltmarsh, or hermatypic reefs.

4.5.1.1 Soft Sediment Habitat

The soft, unconsolidated sediment in the nearshore zone consists of clean, mobile, medium to fine sand (grain size varies from 0.1-0.5 mm diameter, with a median size of about 0.2-0.25 mm). The sand contains no silt or clay, little organic material, and very little carbonate (shell material). These characteristics are the same for both the Tweed River entrance and the nourishment area off the southern Gold Coast beaches (Acer Wargon Chapman, 1994).

As a result of the moderate to high wave energy in this nearshore zone, and the corresponding moderate to high mobility of the sand, the benthic infaunal populations are depauperate, as demonstrated by the quantitative sampling carried out for the Stage 1 EIS (Acer Wargon Chapman, 1994). The benthic macro-invertebrate fauna of both the removal area and the nourishment area is summarised in Table 4.5.1. Sampling locations are shown on Figures 4.5.1a and b. It is evident from the data that the most mobile sediment (site 1 in the River entrance, and site 3 on Duranbah shoals) yielded the fewest number of species and individuals. Sites 5, 6 and 9 in the nourishment area had the highest number of individuals and species, indicating greater sediment stability.

Small crustaceans (amphipods, isopods, decapods, and cumaceans) dominate the mobile sand habitat, with 130 individuals from 17 species collected within the eight sites sampled in July, 1994 (Acer Wargon Chapman, 1994). One species of amphipod (*Urohaustorius halei*) was by far the dominant single organism, with 82 individuals distributed fairly evenly over the eight sites.

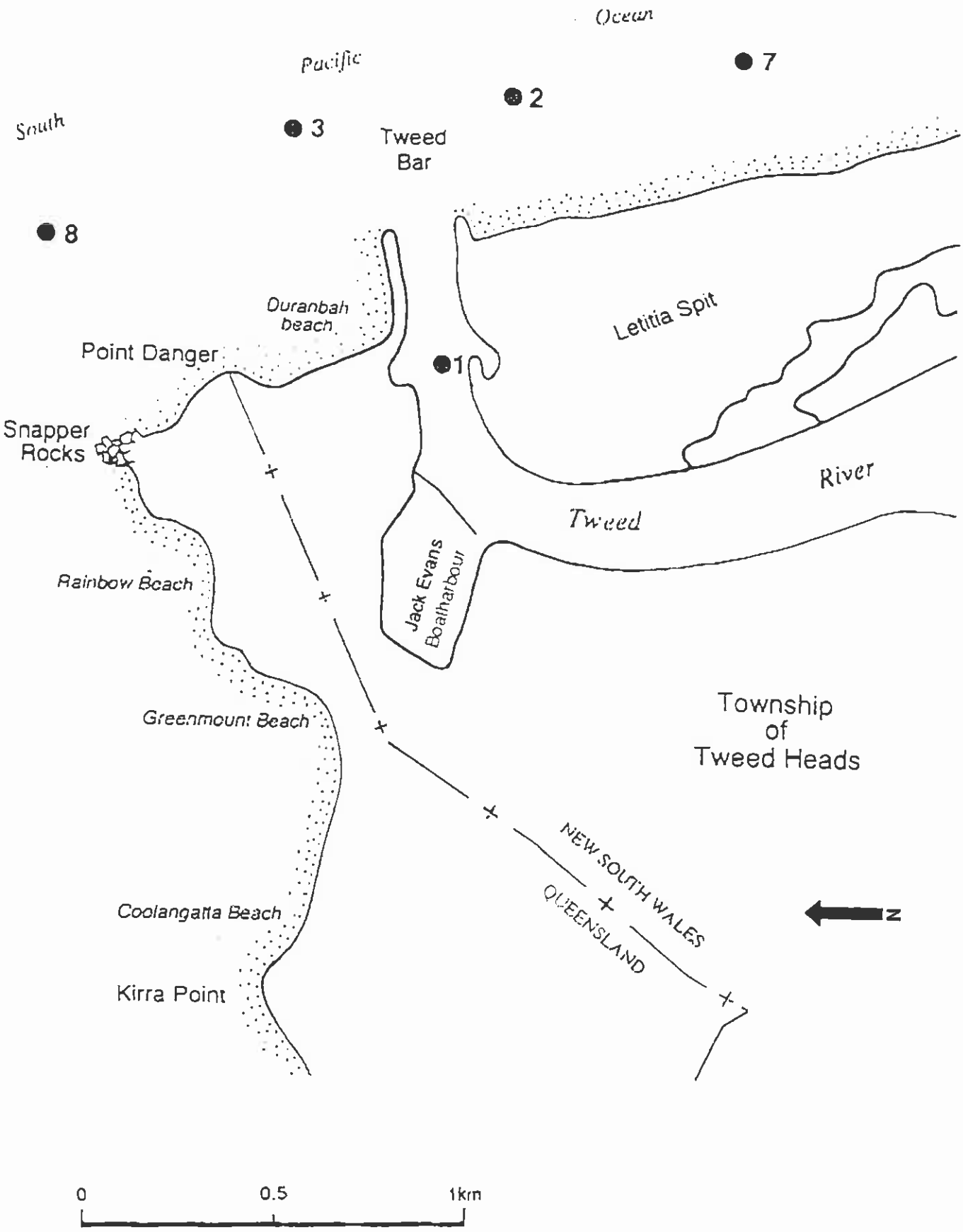


Figure 4.5.1 a
Benthic Invertebrate Sampling Sites (1)

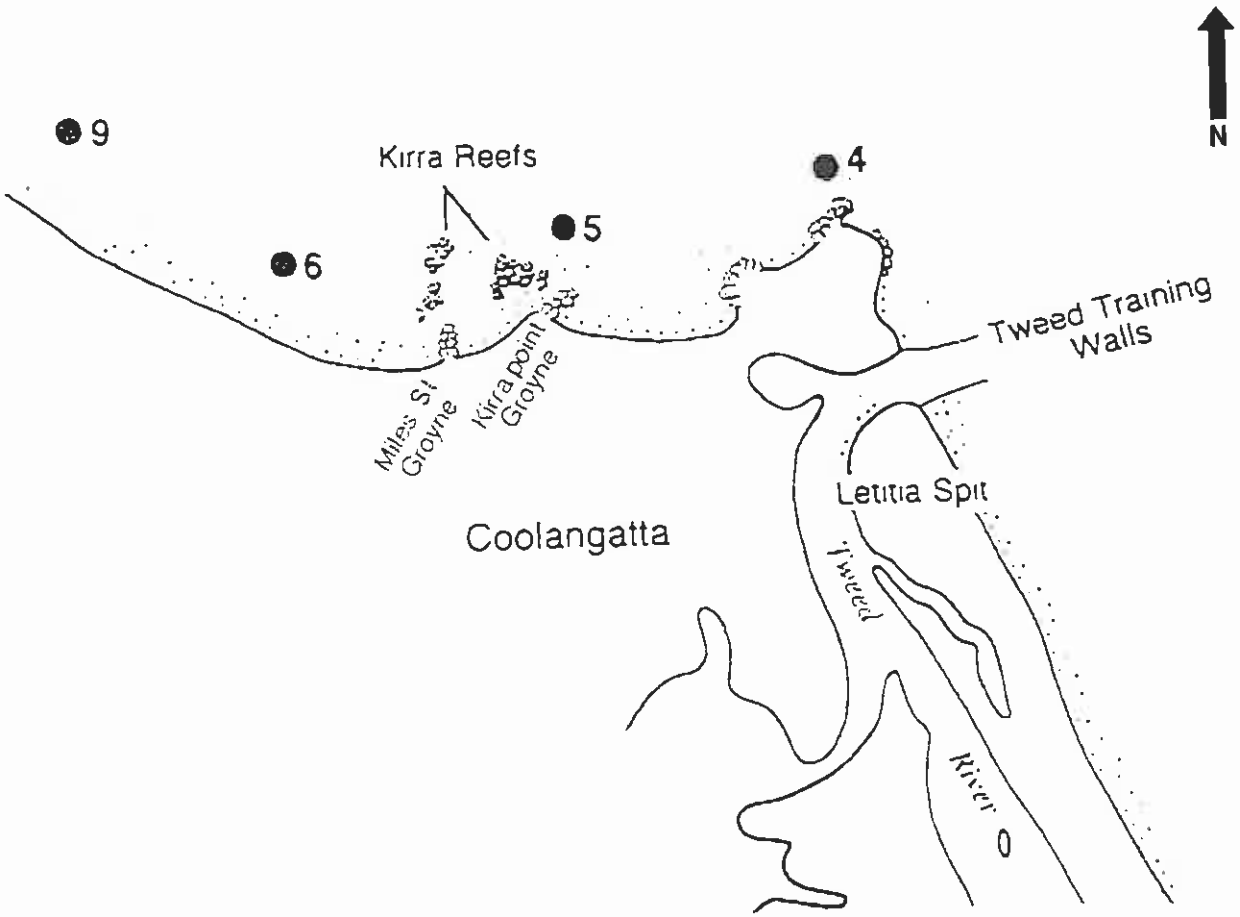


Figure 4.5.1b
Benthic Invertebrate Sampling Sites (2)

Polychaete worms were the second most abundant group, with about 15 species and 60 individuals collected from the eight sites in July, 1994. A Glycerid worm (*Glycera sp.*) was the most dominant species in that group, and was present at 5 out of 8 sites.

Table 4.5.1 Number of Individuals per Species of Benthic Macroinvertebrates collected from the Tweed River Entrance and off Coolangatta Beach, July 1994

Animal Name		Site									
Family	Species	1	2	3	4	5	6	7	8#	9	total indiv.
POLYCHAETE:											
Sigalionidae	*cf. Sigalion oviger*		2		3						5
Sigalionidae	*Euthalanessa sp.*					1*					1
Nephtyidae	*Nephtys longipes*				1	3					4
Glyceridae.	*Glycera sp*		1		2		7	1		8	19
Onuphidae	*Kinbergonuphis sp*		1							2	3
Lumbrineridae	*Lumbrineris latreilli*						3				3
Dorvilleidae	*Schistomeringos filiforma*				1	4					5
Spionidae	*Scolelepis carunculata*	2*	1				1	1			5
Cirratulidae	*Chaetozone platycerca*						3				3
Opheliidae	*Lobochesis bibrancha*			1						5	6
Opheliidae	*Ophelia multibranchia*			1							1
Opheliidae	*Armandia intermedia*				2						2
?	unidentified sp. 1						1*				1
?	unidentified sp. 2						1*				1
?	unidentified sp. 3							1			1
NEMERTEAN MOLLUSCS:		1	1	2	1	1	5	2			13
Bivalvia: Nuculanidae	*Nuculana hanleyi*					1					1
Bivalvia: Tellinidae	*Strigilla euronia*					1					1
Gastropoda: Nassariidae	*Nassarius nigellus*						1				1
CRUSTACEANS:											
Amphipoda:											
Urohaustoriidae	*Urohaustorius halei*	3	37	6	3		12	17		4	82
Corophiidae	*Rhinoecetes robustus*		5								5
Corophiidae.	*Photis sp*						2				2
Platyischnopidae.	*Tittakunara sp*		1				1	2	3		7
Platyischnopidae	*Tomituka doowi*						1				1
Phoxocephalidae	*Uldanamia pillare*				1						1
Phoxocephalidae	*Birubius thalmus*						1				1
Oedicerotidae	*Perioculodes sp.*					1		2			3
Dexaminidae	*Atylus sp.*							1			1
Isopoda:											
Cirolanidae	*Pseudolana elegans*	1	1							1	3
Cirolanidae	*Eurydice binda*									1	1
Paranthuridae (Anthuridea)	*Ulakanthura namoo*				1	3					4
Decapoda:											
Calappidae (Brachyura)	*Matuta planipes*				1						1
Diogenidae (Paguroidea)	*Diogenes sp.*			1		8	2			2	13
Ogyrididae (Caridea)	*Ogyrides delli*						1				1
Mysidae (Mysidacea)	*Australomysis cf. incisa*					1				1	2
Cumacea: Bodotriidae	*Cyclaspis cf. supersculpta*					1		1			2
Echinodermata: Ophiuroidea						1	11				12
TOTAL SPECIES		4	9	5	10	12	15	9	-	10	37
TOTAL INDIVIDUALS		7	50	11	16	26	53	28	-	27	218

(Source: Acer Wargon Chapman, 1994)

* Damaged specimen; uncertain identification. # Samples from Site 8 were lost bringing them to the surface, due to rough weather.

Only three small molluscs were collected. These were of three distinct species. Other species of mollusc, including larger species, were not collected in the July 1994 sampling programme due to the sampling method used.

When the marine macro-invertebrate data is compared to those obtained within the estuaries, which are more protected environments, it is evident that this marine environment is poor in both number of species and number of individuals. For example, examination of the Tweed Entrance Feasibility Study (Environmental Management *et al.*, 1990) demonstrates that the more protected estuarine habitats yielded 100-400 individuals and 15-30 species per site, using the same sample size.

The benthic macroinvertebrate data collected from the Tweed River Entrance and off Coolangatta Beach in July, 1994, and presented in Table 4.5.1, was reviewed by taxonomists at the Australian Museum for the purpose of assessing whether any new or rare species occurrec in these samples. The advice from the Australian Museum indicated that most of the species have been previously recorded, although sometimes only from one other area. That does not necessarily mean they are rare; only that proper lodgement of specimen material has not been documented from other areas.

There is one amphipod that is possibly a new species, since its taxonomy is not a good fit with another similar species: the amphipod *Tittakunara sp.* may be a new species, and in this sense, may be worthy of note. However, it should be pointed out that there are likely to be many new species, or at least undescribed ones, in our coastal marine environment, particularly among the microscopic organisms. The work has simply not been done to collect and describe all of our marine species, and virtually nothing is known about most of them. Therefore, it is not considered exceptional that a new or undescribed species is found. This species was found at sites 2, 6, 7 and 9, and is fairly common in this study area. It occurs within and outside the proposed dredge and disposal area, so the population does not appear to be at risk.

High energy soft sediment environments have the least organisms of any subtidal nearshore soft sediment habitat, and are similar in paucity of animal life to that of an exposed ocean beach (Acer Wargon Chapman, 1994; Environmental Management *et al.*, 1990). It's not the energy level itself which diminishes the diversity and abundance of marine life, but the ephemeral nature of the habitat. Permanent colonisation is not achievable by most species when the substrate is in a continual state of flux.

The shoreward extension of the soft bottom marine environment has the form of sandy beaches both north and south of the Tweed River mouth. To the south, Fingal Beach is good habitat for beach worms. Three commercial beachworm fishermen collect beachworms along Fingal Beach and make their living predominantly from licensed beachworm collecting. Two species of beachworm are captured and sold commercially on Fingal Beach:

- *Australonuphis teres* juveniles (called "stumpies" by the local fishermen) are caught in the upper intertidal zone; and
- *Australonuphis parateres* (called "slimies" by the local fishermen) are caught in the lower intertidal zone.

Occasionally the "king worm" (adult individuals of *Australonuphis teres*) is caught and sold commercially for jewfish. A worm called the "fighter" (*Hirsutonuphis mariahirsuta*) is also caught along the beach, but it is not as abundant, nor as popular with beachworm collectors because it attacks the other beachworms in captivity.

Commercial quantities of worms or other invertebrates are not known from other beaches to the north of the Tweed River mouth and in Coolangatta.

According to the Queensland Commercial Fishermen's Organisation (*pers comm.*), occasional trawling for school prawns occurs within the -10 m contour at the northern end of the proposed nourishment area. Commercial beach netting for mullet and baitfish (garfish and pilchards) occurs within the proposed beach nourishment area.

The annual northerly migration of mullet along the coast occurs in May-June each year. Dredging and/or nourishment activity in the nearshore zone during those months could affect this valuable fishery. Dredging and placement activities may need to consider the migration of other marine species as well. The characteristics of the river entrances along the coast form important linkages between the estuary and the open ocean for species which move in and out of the estuaries. Many species at all trophic levels do so and significant changes to the characteristics of the entrance could have a significant impact (positive or negative) on these onshore/offshore movements. Potential impacts are discussed more fully in Section 7.5.1.

4.5.1.2 Rock Outcrops

Basalt and metamorphic rock outcrops occur naturally at three locations within the study area: Snapper Rocks at Point Danger; the north headland of Rainbow Bay (Marley Rocks); and Kirra Reef offshore of the Miles Street Groyne, with outcrops on Kirra Beach. Kirra Reef is a series of predominantly basaltic rock outcrops extending over a distance of nearly one kilometre along the coast and about 200-400 m offshore from Kirra Beach.

Anthropogenic rock substrate occurs in the form of training walls at the entrance of the Tweed River, and as rock groynes off Kirra Point and at Kirra Beach.

The rock groynes and natural outcrops associated with headlands (Snapper Rocks and Rainbow Bay) are sparsely populated with epifauna.

Snorkel inspection via a series of transects was made of Snapper Rocks by WBM Oceanics Pty Ltd in October, 1996. In general, the rocks were very sparsely colonised and few mature fish were sighted. However, the rocks do appear to be a nursery area for both the Stripey (*Microcanthus strigatus*) and the Silver sweep (*Scorpis linelata*), of which large numbers of juveniles were sighted. The only other fish species observed were a few individuals of Bream (*Acanthopagrus australis*).

There is a zonation of epifauna/epiflora in the immediate subtidal zone: the ascidian *Pyura stolonifera* (cunjevoi) occurs in dense colonies up to 270 individuals/m^2 in the higher subtidal zone. Below the cunjevoi zone is a sparse *Sargassum* zone which is largely bare rock and below that is clean bare sand.

Kirra Reef is a series of scattered rock outcrops which support a surprisingly rich variety of rocky reef organisms, considering its location in very shallow water near the beach and surrounded by mobile sand which is continually being resuspended and settling over the rocky reefs. Natural longshore drift, particularly as a result of storm wave action, brings significant quantities of reworked sand onto Kirra Reef in the form of sand slugs or shoals. The beach erosion and subsequent sediment deficit which has occurred on the southern Gold Coast beaches since construction of the Tweed River training walls has exposed more of Kirra Reef than would normally have been the case prior to construction of these training walls. This has encouraged colonisation of the rocky reef by epifauna and epiflora over the past 20-30 years to an extent probably unique to this habitat. The present extent of the reef (and it associated flora and fauna) probably represents a maximum (or near-maximum) at any time in the geologically recent past, ie. since the last still-stand of sea level. During lengthy intervals between major storms, good cover of soft coral, anemones, ascidians, bryozoans, encrusting sponges, and a variety of red, green and brown algae colonise the rocks. Abundant pencil urchins and crinoids occur in crevices in the rocks, and there is a good variety of the smaller rocky reef fishes and moray eels. Many of the small fishes are very colourful and are popular in the aquarium trade.

The percent cover of the major taxonomic groups occurring at Kirra Reef have been monitored by FRC Coastal Resource & Environmental Consultants prior to, during, and following completion of the Stage 1A dredging and nourishment activity in 1995-96. At each of six locations around Kirra Reef, and at three control sites at Palm Beach Reef several kilometres to the north, they recorded the relative percent cover of benthic macroalgae, turf algae, sponge, ascidian, and coral (both hard and soft). They also recorded at each sampling period the number of species of macroalgae, number of colonies of hard coral, and the number of urchins and crinoids.
The major changes reported since the commencement of the most recent sand nourishment in the area have been an increase in macro-algae cover at all sites; a decrease in ascidian cover at all sites; and an increase in sponge cover at the inshore Kirra sites. It was concluded that the increase in macro-algae and decrease in ascidian cover was unlikely to be related to sand nourishment, since these changes were evident at the control sites at Palm Beach Reef as well as at Kirra Reef. Similarly, they did not attribute the increase in sponge cover at the inshore Kirra sites to sand nourishment.

The ecological monitoring at Kirra Reef also suggests that the number and diversity of fishes at Kirra Reef have not changed significantly during Stage 1A dredging.

4.5.1.3 Water Column

The overlying water column within the study area is subject to continual renewal with fresh seawater and, near the Tweed River entrance, brackish water from the estuary. During dry weather the salinity of water near the Entrance and along the coast to Kirra is within the range of normal marine coastal waters. A slight decrease in salinity (conductivity) is evident directly opposite the Tweed entrance, reflecting a slight dilution of coastal sea water with a small fresh water discharge (Acer Wargon Chapman, 1994).

The species of fish which have been identified at the Tweed entrance and in the nearshore zone were tabulated in the Tweed Entrance Feasibility Study Final Report (Public Works, 1990). A total of 139 fish species have been documented from the Tweed Entrance area (rock walls, sand channels), many of which are of commercial or recreational value. NSW Division of Fisheries catch data for the past 12 years indicates 57 commercial finfish species were caught and submitted for sale at Tweed Heads, with an average annual weight of 124,212 kg for all finfish species.

Records from NSW Department of Agriculture, Division of Fisheries indicate that mullet, and more specifically sea mullet, was by far the dominant finfish species caught at Tweed Heads over the past twelve years, with an average annual weight of 68,355 kg of sea mullet submitted for sale (55% of the ave. annual finfish catch by weight). Total mullet weight (all species) averaged 87,083 kg per annum, which represents 70 percent of the total finfish catch, by weight, in the Tweed River region. Luderick are the second largest catch, comprising just over 10% of the average annual finfish catch by weight. Whiting species are the third most abundant species by weight, comprising 5% of the average annual catch. These three genera of fish (consisting of about 7 species) account for 85% of the Tweed River region catch, using average annual figures.

No studies have been conducted to our knowledge on the plankton dynamics of the study area. This includes the economically important prawn and mud crab larvae which return to the estuary as part of the zooplankton before settling out as juveniles among seagrass beds to mature. Prawn catches averaged 17,467 kg per annum, with school prawns dominating the catch (mean = 16,804 kg). Mud crabs averaged 6,682 kg per annum from the Tweed River.

4.5.2 Estuarine

The Tweed estuary can be divided into two sections, upper and lower. The upper Tweed estuary comprises areas upstream of Barney's Point Bridge and includes the Tweed River north arm (Figure 4.5.2). The lower Tweed Estuary is the region downstream of Barney's Point Bridge to the Tweed River entrance including Terranora Inlet and Cobaki and Terranora Broadwaters (Figure 4.5.2).

4.5.2.1 Historical Changes to the Tweed Estuary

The Tweed Estuary has undergone many changes since settlement of the area last century. Changes have been associated with activities such as :

- dredging activities;
- land clearing for cane/agricultural purposes;
- removal of riparian vegetation and reclamation of river banks;
- construction of canal estates;
- river training works; and
- structural flood mitigation works in the Tweed valley including floodgates on tidal creeks.

Such works/activities have resulted in marked changes to the tidal range of the estuary. In particular, the construction of the Tweed River training walls and repeated dredging exercises within the river (both to mitigate on-going siltation processes resulting from training wall construction and to enhance navigability) has presumably resulted in consequent continual changes to the tidal range, currents and flushing rates in various parts of the river. Additionally, the river course has been altered in many areas. Consequently, the Tweed River can be considered, in an historical sense, as highly modified. Nevertheless, the estuary supports a wide variety of ecologically important habitats as discussed in the following sections.

4.5.2.2 Wetlands

Wetlands associated with the Tweed estuary comprise mangrove forest, saltmarsh and seagrass. Mangroves occur on intertidal land, generally between the Mean Tide Level to Mean High Water Spring Tide Level. Saltmarsh vegetation occurs on intertidal land at the landward side of mangroves (from MHWS level to HAT level), whilst seagrass communities occur on intertidal (generally below MHWS) and subtidal areas, seaward of mangrove forests.

Substantial areas of wetlands in the Tweed estuary are declared under State Environmental Planning Policy No. 14 (Figure 4.5.3). This requires that any disturbance of these areas (eg. clearing, draining) must be preceded by an Environmental Impact Statement.

Mangroves

Mangrove forest covers approximately 309 ha along the Tweed River (West *et al.*, 1985), making it the eleventh largest mangrove estuary in NSW.

The Tweed Estuary contains all 5 species of mangroves known to occur in NSW (Pressey and Griffith, 1992):

- *Aegicerus corniculatum* River Mangrove
- *Avicennia marina* Grey Mangrove

- *Brugiera gymnorhiza* Orange Mangrove
- *Excoecaria agallocha* Milky Mangrove
- *Rhizophora stylosa* Red Mangrove

Only one other estuary in the state (Brunswick River) is known to contain all these species together (West *et al.*, 1984). *Avicennia* extends south to Port Phillip Bay in Victoria, while *Aegicerus* and *Excoecaria* reach the south coast and the mid coast of NSW respectively. The Tweed River is, however, the southern-most limit of *Rhizophora* and *Brugiera* along Australia's east coast (Busby and Bridgewater, 1986).

Local topography and tidal range largely govern the lateral extent of mangrove forest (Hutchings and Saenger, 1987). *Avicennia* occurs across the entire lateral range of the mangrove zone along the lower Tweed River, and is the dominant species at the lower intertidal edge of mangrove forest in upstream areas. *Brugiera* occurs in the midzone while *Excoecaria* grows at the landward edge of the mangrove forest adjacent to saltmarsh.

Mangroves occur throughout the lower Tweed Estuary, mostly in islands within Terranora Inlet and the Cobaki and Terranora Broadwater (eg. Ukerebagh Island, Big Island). Fringing mangroves on the river banks are sparse to absent except around the shores of the Broadwaters, Shallow Bay and Banora Point (Figure 4.5.4a-d). Along the upper Tweed Estuary the largest areas of mangroves occur on the islands and shores of Chinderah Bay, Dodds, Chinderah and Stotts islands and around Tweed Broadwater.

Fish and crustaceans use mangroves as nursery and feeding areas. The richness of the aquatic faunal communities which move into the mangroves on flooding tides reflects the high productivity of such areas (Blaber and Blaber, 1980; Bell *et al.*, 1984; Morton, 1990; Laegdsgaard and Johnson, 1995). Disturbances of these habitats results in losses to fisheries, however, the effects of even large scale disturbances are unclear because few studies provide quantitative information. Additionally, faunal usage of wetlands is highly variable and as a result difficulties arise in distinguishing natural from human-induced changes to fauna communities.

Saltmarsh

Saltmarsh vegetation comprises shrublands, sedge and rush swamps and grasslands (Adam, 1981). Along the Tweed estuary saltmarsh communities are comprised of the following species (Pressey and Griffith, 1987) :

- Saltcouch (*Sporobolus virginicus*)
- Samphire (*Sarcocornia quinqueflora*)
- Seablite (*Suaeda australis*)
- Sea rush (*Juncus krausii*)
- Bare twig rush (*Baumea juncea*)

Saltcouch and samphire generally occur at the mangrove or seaward edge of the saltmarsh and grades into sea rush and finally twig rush at the upper limit of tidal action. Boundaries between species are often difficult and may not always follow this sequence. The dominance of each saltmarsh type varies depending on substrate characteristics (salinity, drainage, etc).

Saltmarsh, comprising the species listed above, occupies approximately 44 ha in the Tweed Shire (Pressey and Griffith, 1987) with 21 ha associated with the Tweed River. Ukerebagh Island, Cobaki Creek and Sponsors Lagoon in the Lower Tweed Estuary support the largest areas of saltmarsh in the Tweed River (PWD, 1990). Numerous other smaller areas occur throughout the estuary but are too small to be mapped.

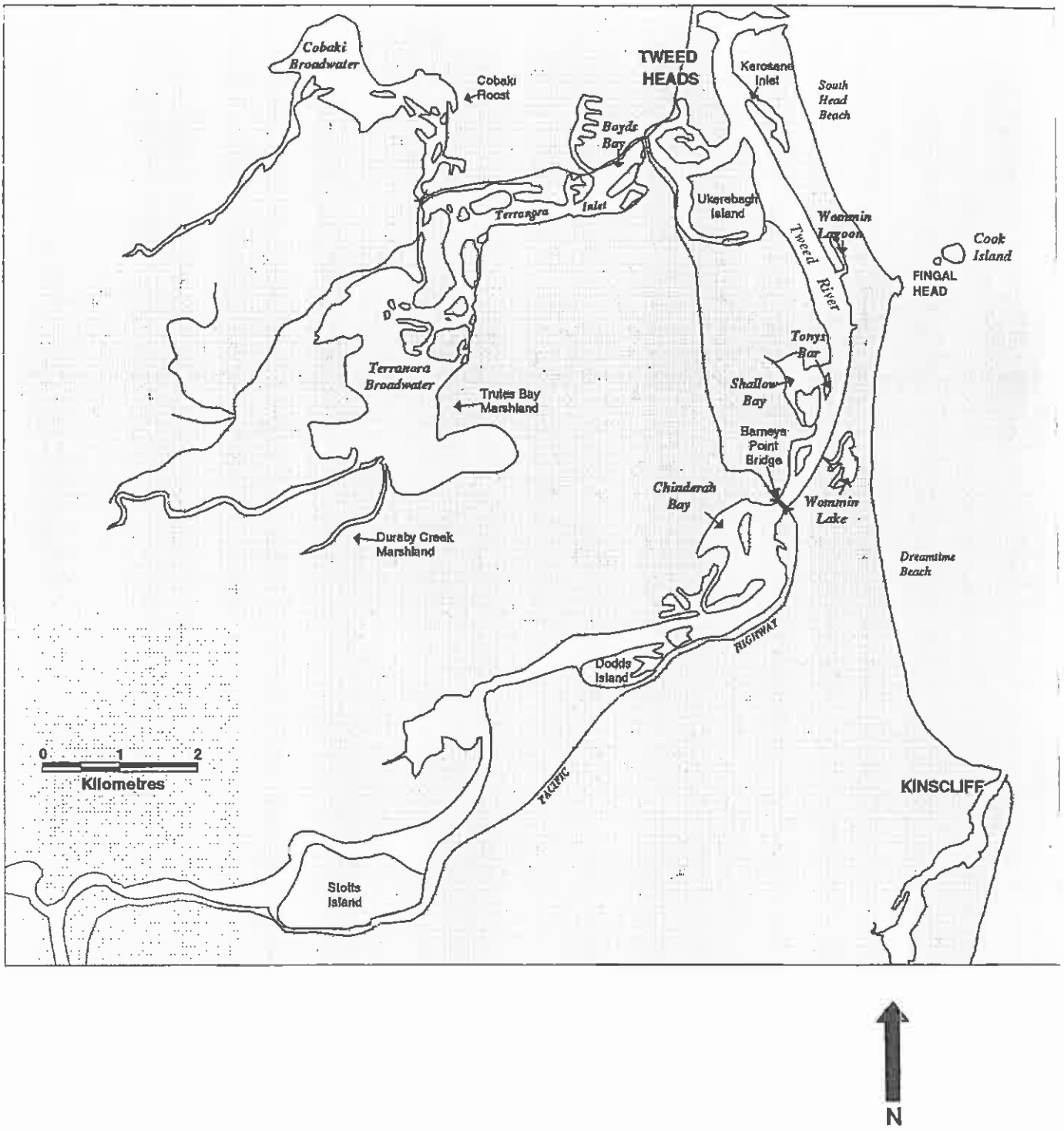


Figure 4.5.2
The Tweed Estuary

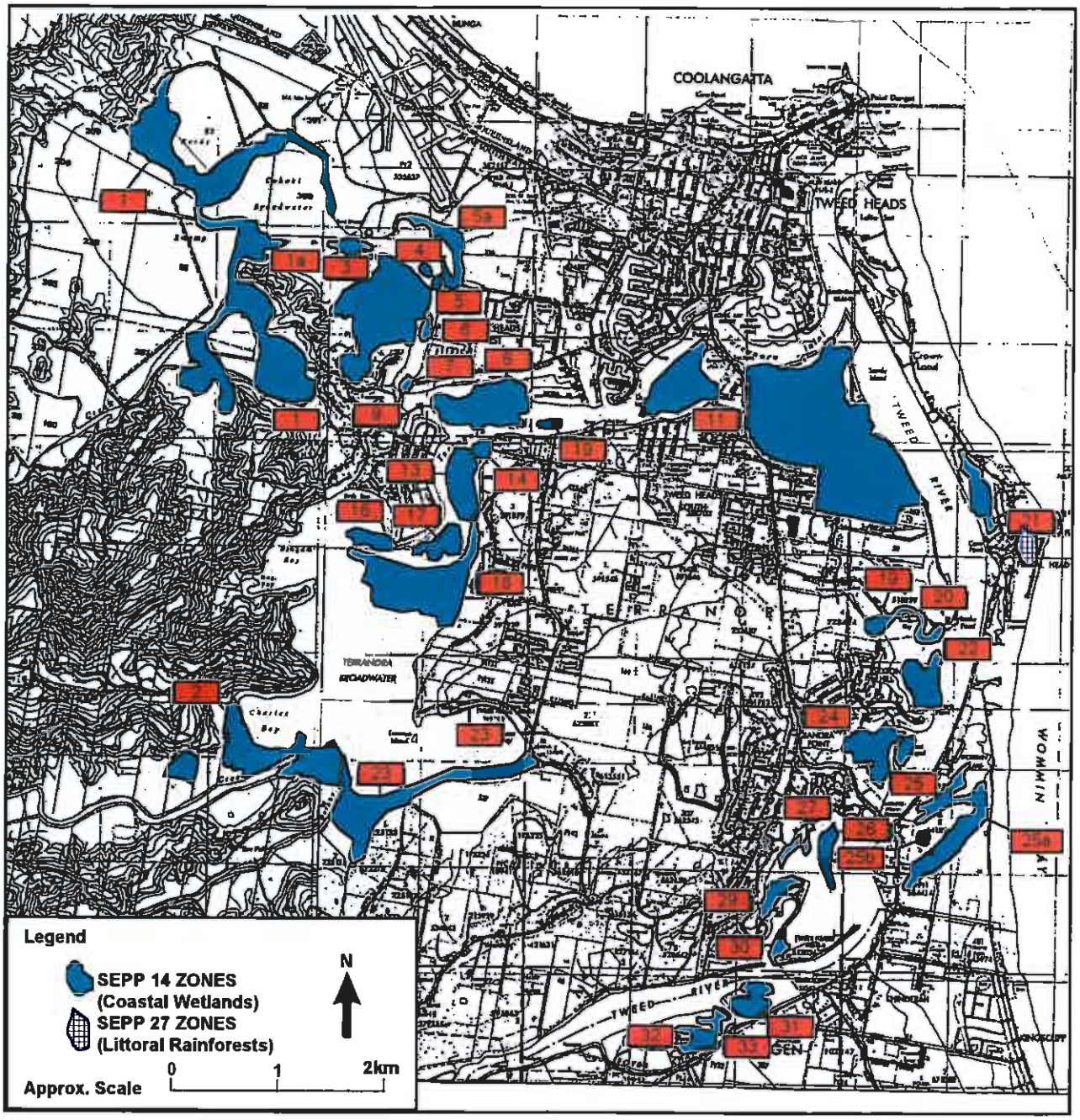
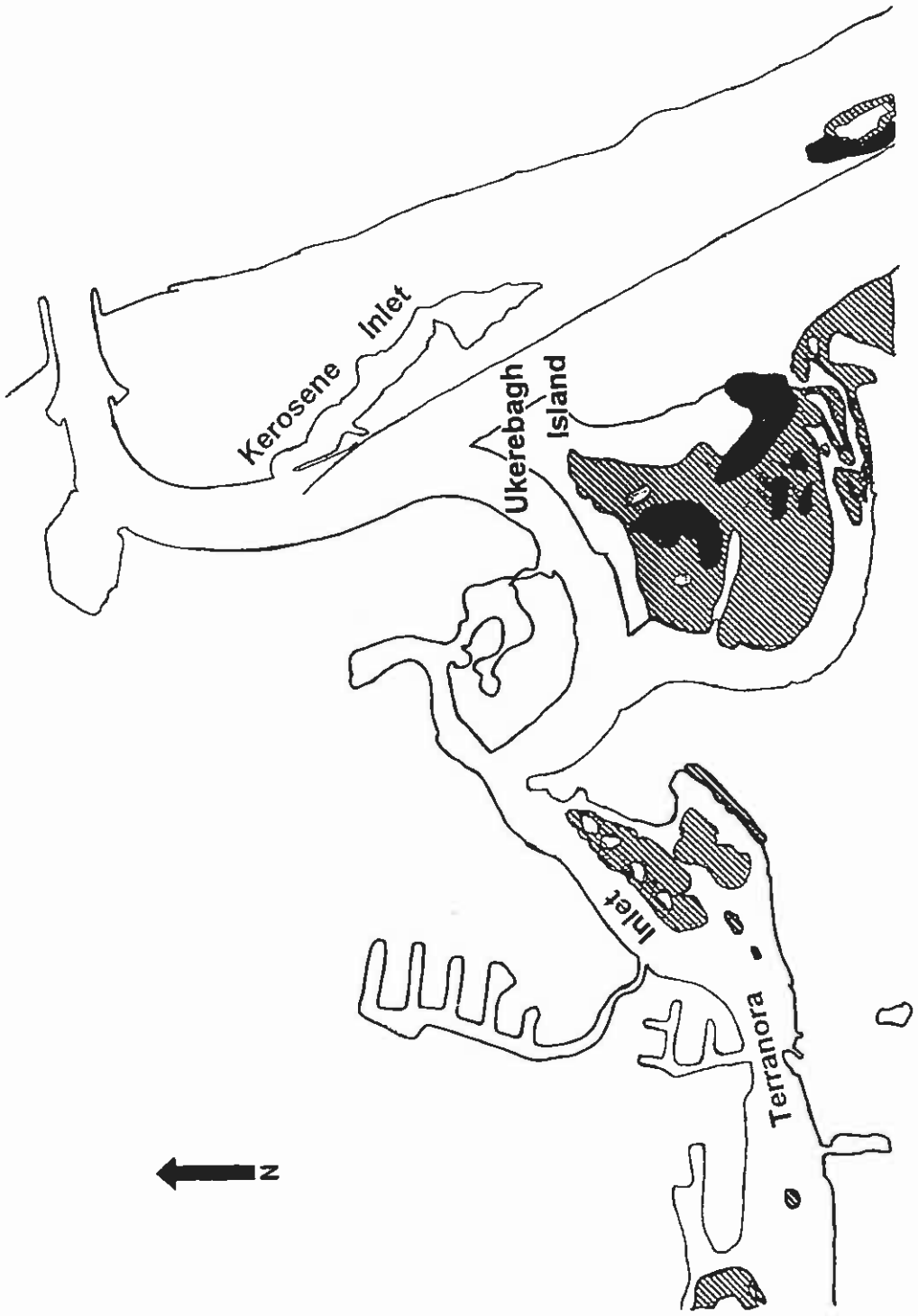


Figure 4.5.3 : Location of SEPP14 and SEPP26 Zones in the Lower Tweed Estuary

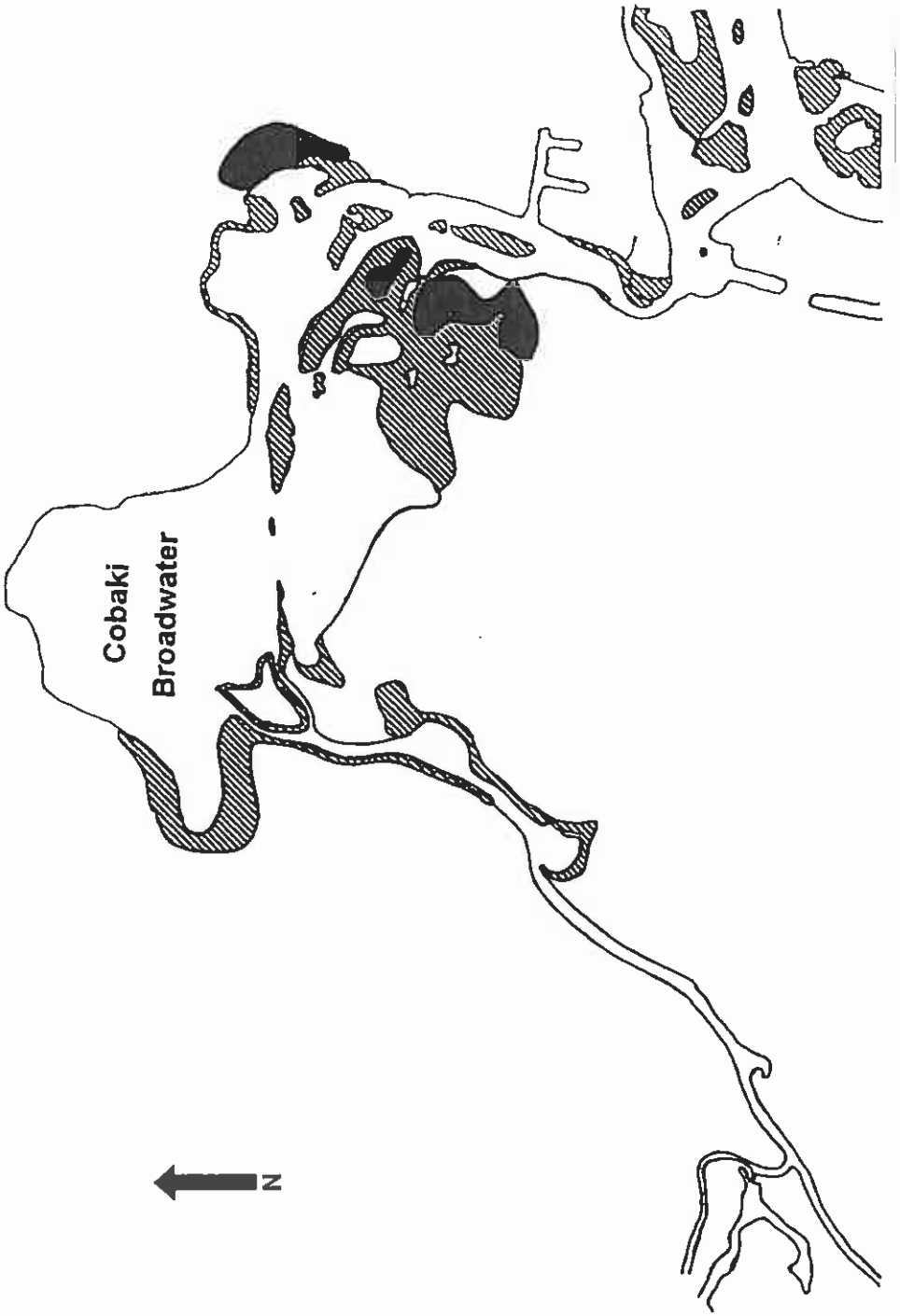
Source: DUAP, 1996, Amendment No.11



Legend
Mangroves
Saltmarsh

Scale
0 0.5 1km

Figure 4.5.4a
Location and Extent of Mangroves and Saltmarsh



Legend
Mangroves
Saltmarsh

Scale
0
0.5
1km

Figure 4.5.4b
Location and Extent of Mangroves and Saltmarsh

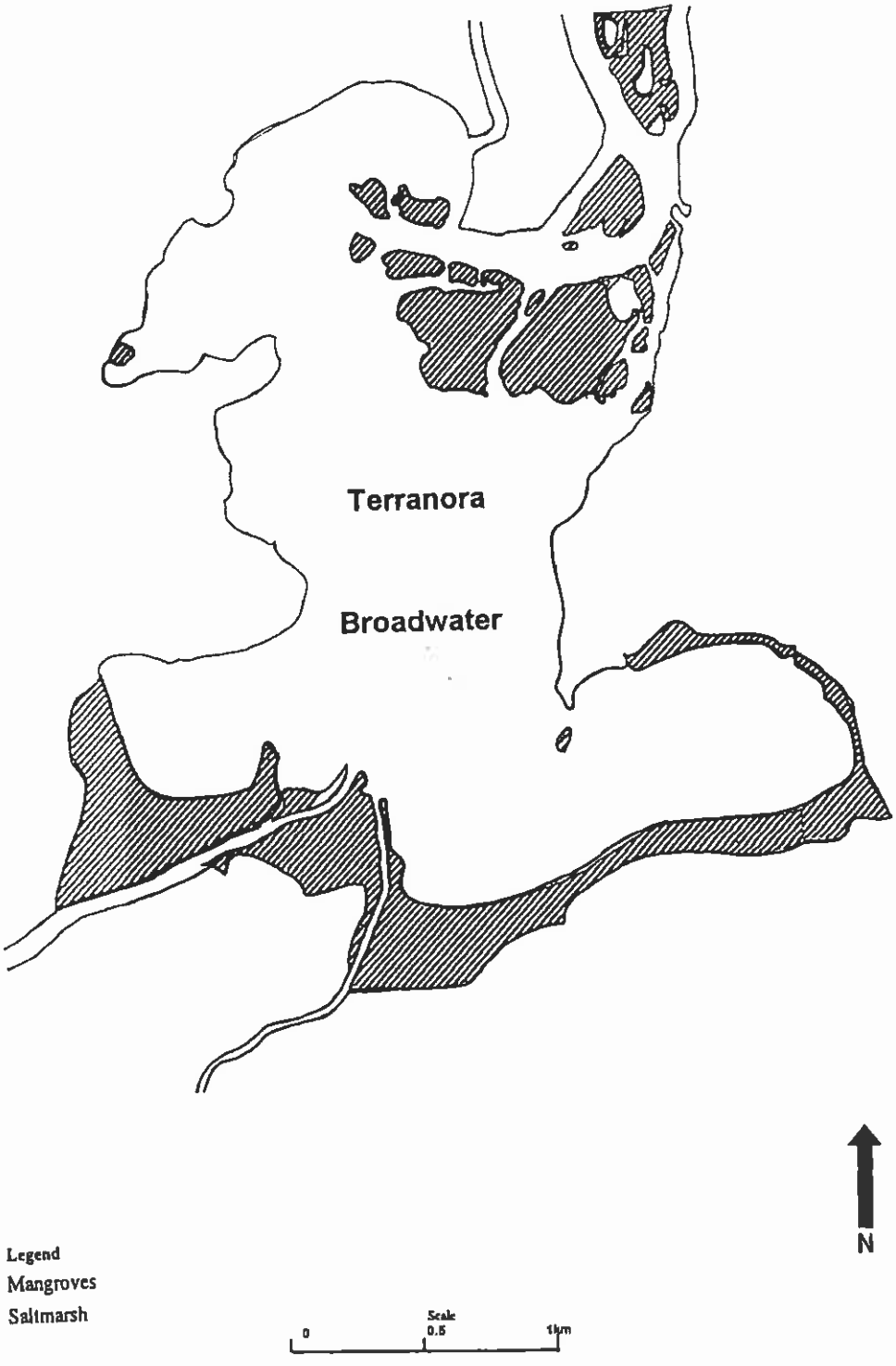


Figure 4.5.4c
Location and Extent of Mangroves and Saltmarsh

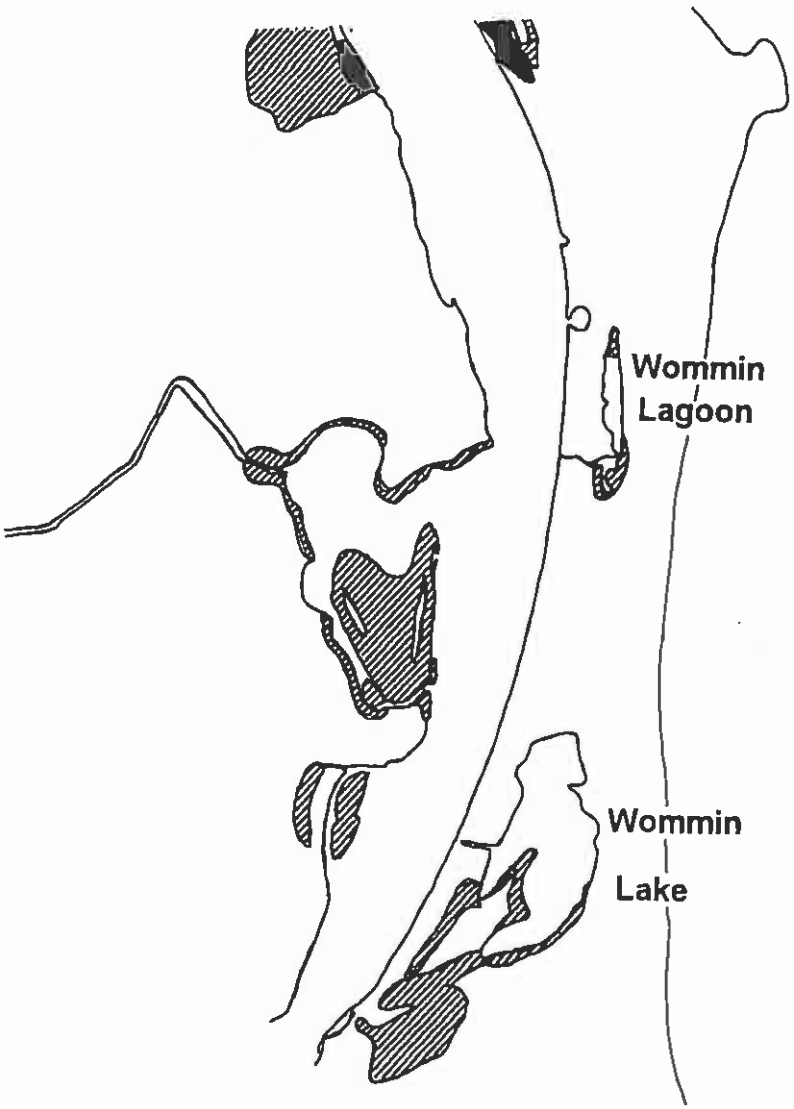


Figure 4.5.4d
Location and Extent of Mangroves and Saltmarsh

Saltmarsh is uncommon in the upper Tweed Estuary, occurring only in small areas (usually <0.5 ha). Saltmarsh species, particularly *Sporobolus virginicus*, sometimes occur in the understorey of Swamp oak forest. Salt couch, samphire, seablite and sea rush (*Juncus krausii*) are the common saltmarsh species of the upper Tweed estuary.

Very little information is available on the utilisation of subtropical Australian saltmarshes by aquatic fauna. However, it has been concluded that tidal inlets to saltmarshes are used as feeding areas by fishes, many of which are of direct fisheries value (Morton, *et al.* 1987; Morton *et al.*, 1988). Upper littoral saltmarsh areas are of little direct value to fisheries but serve as important bird feeding and roosting area.

Seagrass

The most up-to-date information available for the distribution of seagrasses in the Tweed Estuary was collected in 1991 (Figure 4.5.5a-d). Anecdotal evidence suggest that seagrass has expanded its distribution in some areas (eg. Wommin Lake) since that time. In general, however, the areas where seagrass occur is similar, at present, to the 1991 distribution.

The lower estuary contains broad shallow areas with waters that are generally of high clarity (excluding Terranora and Cobaki Broadwaters). These conditions allow development of extensive seagrass areas. Large seagrass beds occur in Ukerebagh Passage, Shallow Bay, Boyds Bay, near Caddys Island, near Daveys island and in Terranora Broadwater. Kerosene Inlet, Sponsors Lagoon, Wommin Lagoon and Wommin Lake all have extensive seagrass areas. Seagrasses also grow in human-made environments including Jack Evans Boat Harbour, the boat ramp area at Fingal, an the Seagulls Estate canals.

Most of the seagrass beds in the Lower Tweed Estuary are composed of *Zostera capricorni*. *Halophila ovalis* was found in association with *Z. capricorni* in Kerosene Inlet, Ukerebagh Passage, Terranora Inlet, Terranora Broadwater and near the eastern entrance to Cobaki Broadwater (WBM Oceanics Australia, 1991), Wommin Lake contains extensive areas of *H. ovalis* and smaller areas of *Z. capricorni*. Wommin Lagoon contains small quantities of *Halophila ovata* and some mixed beds of *H. ovata* and *Z. capricorni*.

Most seagrass in the Upper Tweed Estuary is confined to Cinderah Bay where approximately 8 ha occurs as a large bed along Chinderah Spit. *Zostera capricorni* is the only seagrass species present.

Seagrass beds provide food and shelter for a variety of fish and commercially valuable prawn species, act as substrate stabilisers and support a variety of epibiota (McRoy and Helfferich, 1977). The importance of seagrass beds in the Tweed Estuary as habitat for king prawns (*Penaeus plebejus*), a major commercial species was identified in the Tweed Entrance Feasibility Report (PWD, 1990).

4.5.2.3 Tidal Range Change in the Tweed River and Effects to Wetlands

Effects of Changes in the Tidal Regime to Wetlands

The nature (eg. location, extent, diversity) of the wetland communities (seagrasses, mangroves and saltmarshes) in the river is largely determined by the tidal regime. Therefore, repeated dredging in the estuary over the past 100 years has probably lead to wetland communities being in a state of flux, continually adjusting to artificially altered environmental conditions, particularly changing tidal regime.

Vegetated intertidal habitats such as seagrass, mangroves and saltmarsh provide important habitats for a wide range of aquatic fauna. Additionally they act as effective silt and nutrient traps, helping to maintain water quality within the estuary.

Changes to the tidal range of the river alter the nature and extent of intertidal wetlands and subsequently effect aquatic ecosystems within the estuary. Such effects may be either detrimental and/or beneficial.

Changes in wetland distribution, as a result of decreases in tidal ranges, could result in seaward contraction of landward portions of mangroves and saltmarsh communities and increased aerial exposure of upper littoral seagrass beds. In this way wetland areas are generally reduced with decreased tidal range. Increases in tidal range have an opposite effect and may be considered beneficial in terms of wetland distribution in many areas (depending on topography). Mangroves and saltmarsh will expand in a landward direction where the slope of the land is gentle.

The low tide emergence period is a limiting factor to the upper intertidal distribution of most seagrass communities. Higher high tides results in increased inundation of upper tidal areas leading to shorter aerial exposure periods for seagrass. This would be expected to have a beneficial effect on seagrass communities in upper tidal areas potentially resulting in an increase in seagrass area and possibly longer leaf lengths (therefore enhanced habitat diversity).

Wetland communities can therefore commonly adapt to changes in the tidal regime, either increasing or decreasing in extent, depending upon the nature (eg., magnitude, period of change) of such alterations. Their adaptability is evidenced by the extensive and diverse wetland communities present in the lower reaches of the Tweed River which have experienced a history of tidal range changes due to dredging, entrance works etc and will continue to experience changes as a result of variations in the nature/extent of lower estuary shoals (see below).

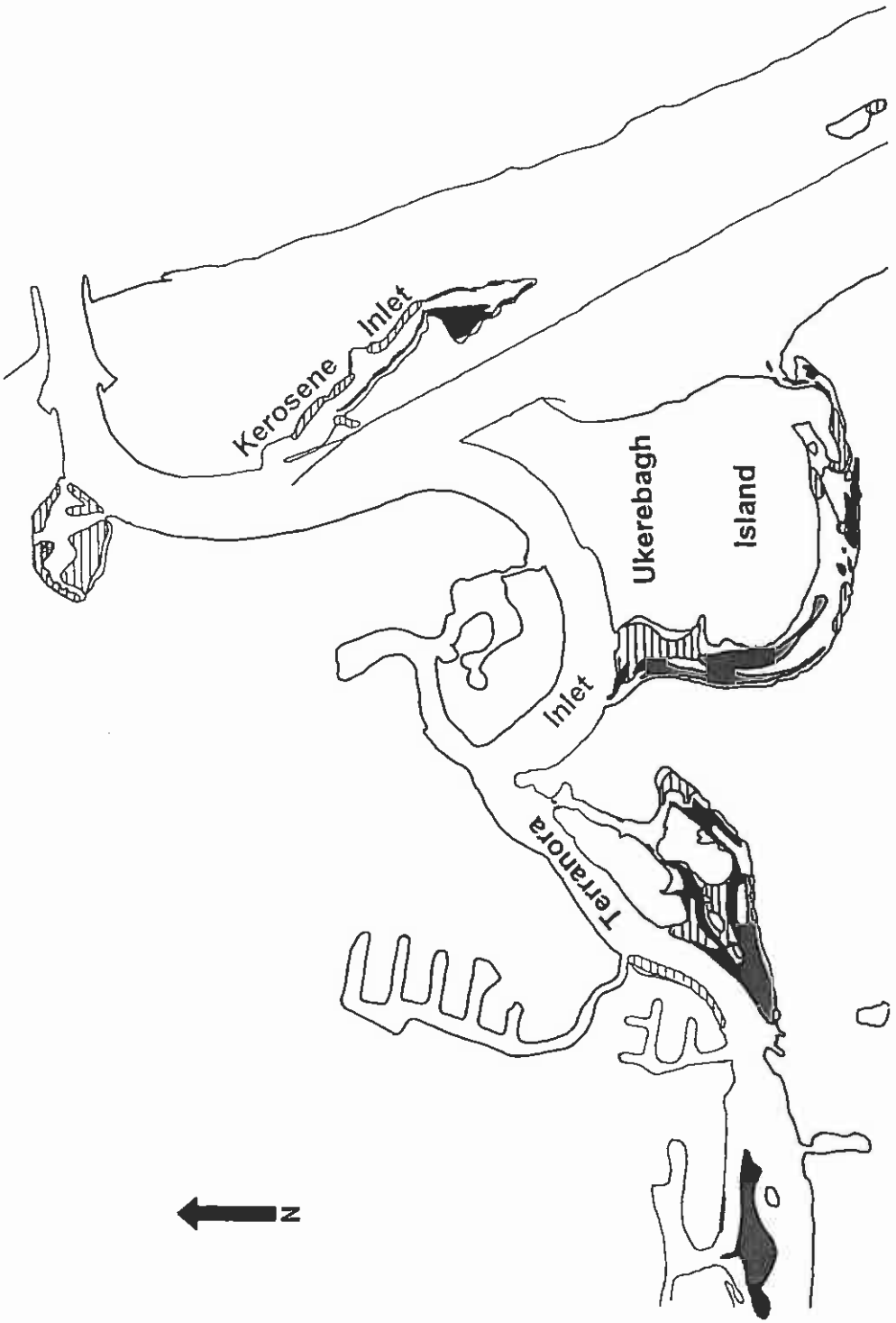
Changes Associated with Lower Estuary Shoals

The main cause of tidal range fluctuations relates to the status of several major shoals that occur near the confluence of Terranora Inlet and the Main Arm of the river, and adjacent to Kerosene Inlet. The shoals are slowly accreting over time, as sand is transported into the estuary, to a maximum regime state (Section 4.4). As a consequence these shoals can obstruct the flow of the tide in through the mouth of the river and effectively decrease the tidal range within the estuary. Decreases in tidal flushing and water quality can be expected with decreases in tidal range within the estuary, especially in upper reaches. This could have adverse effects to intertidal wetlands (a decreased tidal range would result in a decrease in intertidal area, leading to wetland losses), oyster culture operations and recreational activities (as a result of reduced water quality).

Conversely, there is the potential for the shoals to be scoured out during major flood events (eg. 1 in 50 year events, Section 4.4.2.3), periodically increasing the tidal range until they can re-establish naturally. It is estimated that it would take approximately 3-5 years for them to return to their present condition and without bypassing in place (Section 4.4).

Without these shoals in place, there is the potential for slightly greater tidal ranges to be experienced within the estuary. Modelling studies (Section 4.4.1.12) indicate that with the shoals removed by flood and all approved river dredging completed, Mean Spring High Tides would increase by up to 0.07m, whilst Mean Spring Low Tide levels would decrease to a greater extent by 0.11m (Table 4.4.12).

The magnitude of such changes will vary depending upon the location in the estuary, with greatest changes being experienced in the lower reaches of the estuary. More upstream areas such as Terranora Broadwater or Chinderah Bay would experience increased Mean Spring High Tide levels of approximately 0.03m and decreased low tide levels of approximately 0.03m. Such tidal range assessments are maximum-case scenarios and changes of the above magnitude would occur for only two to four days per month and would be lesser on neap tides.



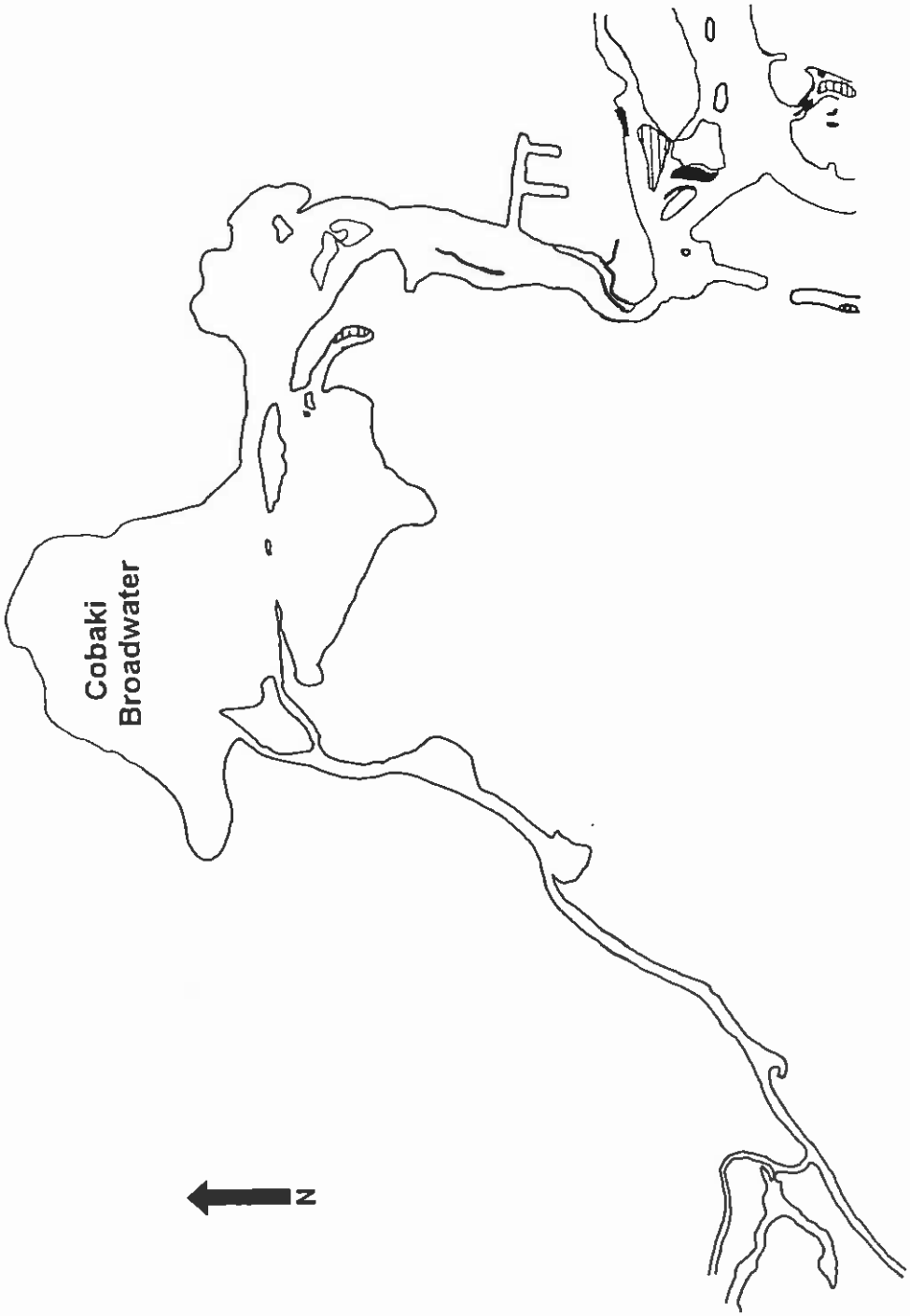
Legend

Patchy Seagrass

Continuous Seagrass

Scale 0 0.5 1km

Figure 4.5.5a
Location and Extent of Seagrass



Legend

Patchy Seagrass

Continuous Seagrass

Scale 0 0.5 1km

Figure 4.5.5b
Location and Extent of Seagrass

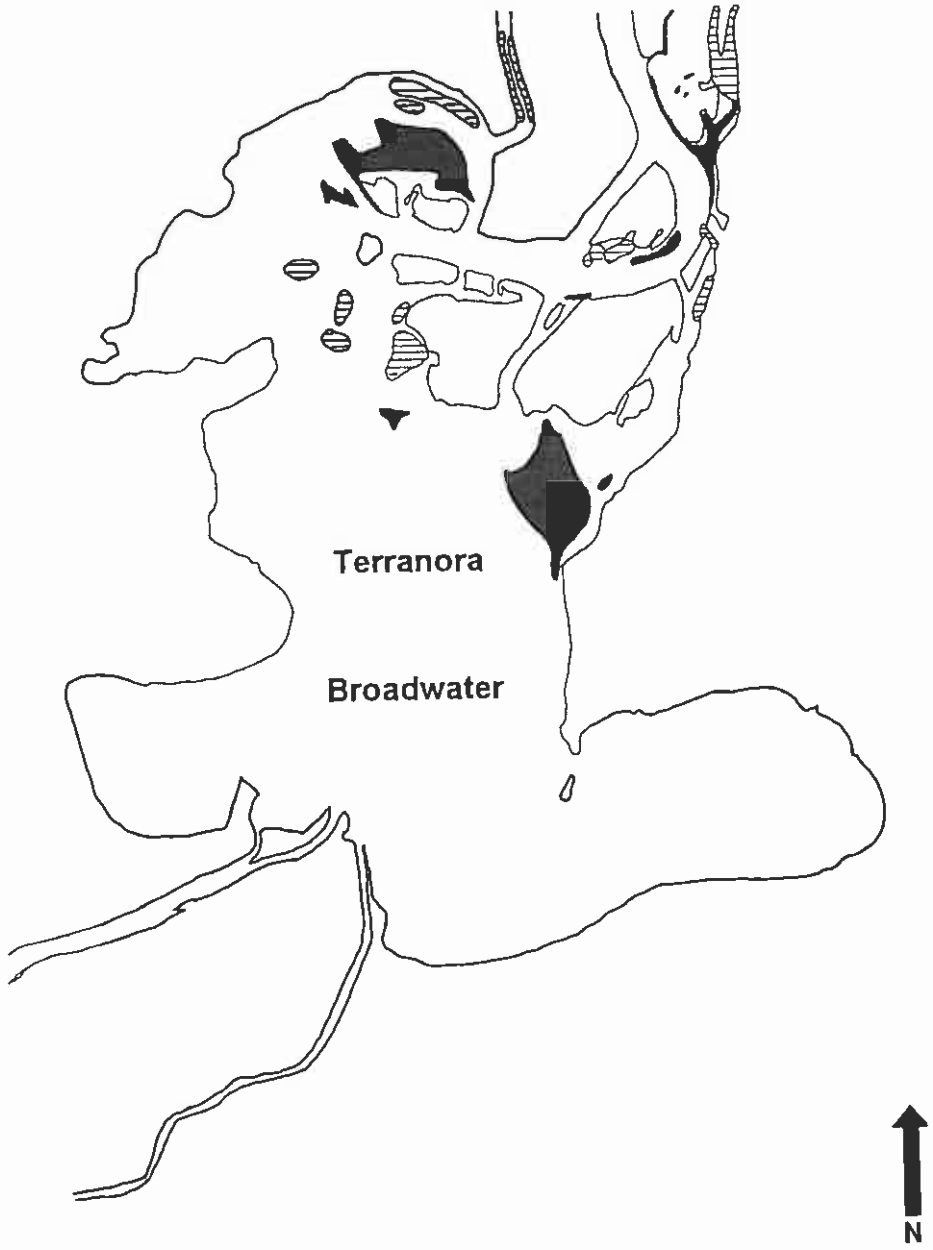
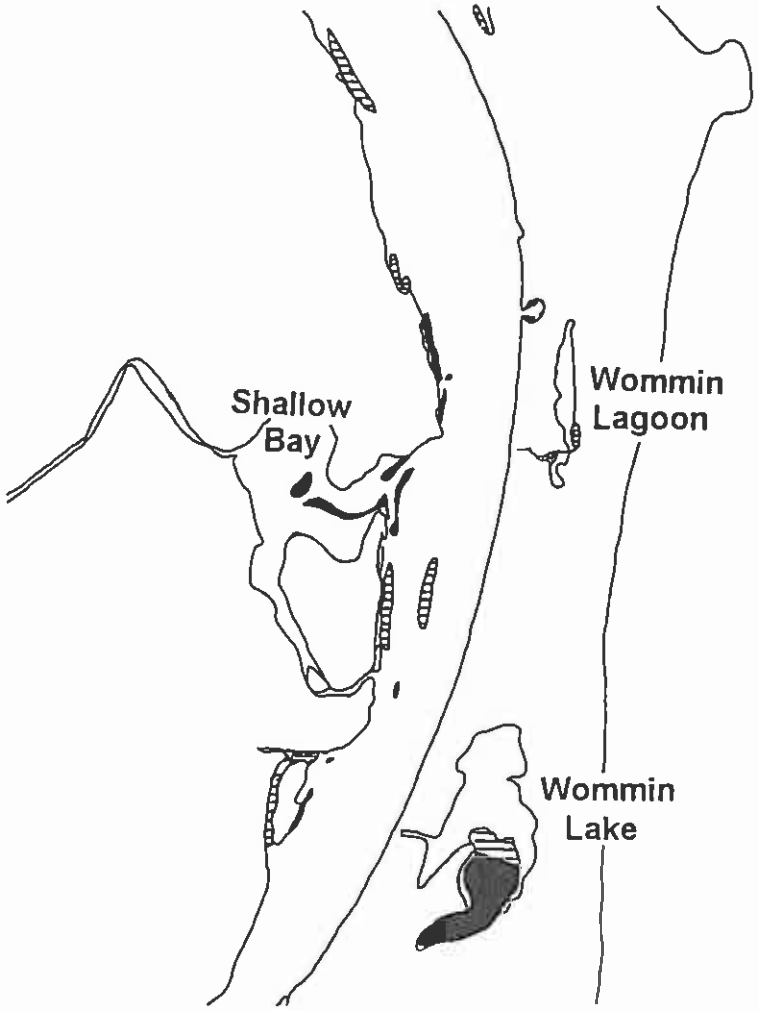


Figure 4.5.5c
Location and Extent of Seagrass



Legend

Patchy Seagrass

Continuous Seagrass

Scale

0 0.5 1km

N

Figure 4.5.5d
Location and Extent of Seagrass

4.5.2.4 Aquatic Fauna

Fish

Studies conducted on the fish fauna of the Tweed estuary have concluded that the fish fauna is a diverse mixture of tropical and temperate marine and estuarine species (Ellway and Hegerl, 1972; WBM Oceanics Australia, 1992).

A comprehensive study of the fish fauna of the entrance to the Tweed River estuary was carried out in 1972 and identified 140 species of fish (Ellway and Hegerl, 1972). The most common and obvious species within the estuary are those that occur throughout the year. These are herring (*Harengula castelnaui*), butter bream (*Monodactylus argenteus*), bream (*Acanthopagrus australis*), stripey (*Microcanthus strigatus*), sweep (*Scorpis lineolatus*), cleaner-fish (*Labroides dimidiatus*), fortescue (*Centropogon australis*) and leather jacket (*Cantherines trachylepis*).

A total of 35 fish species (Table 4.5.2) was recorded in a study of bare sandy substrata of the lower Tweed estuary (WBM Oceanics Australia, 1992). The most abundant species noted within the estuary were Mullet (*Liza argentea, Mugil cephalus, Myxus elongatus*), Toad fish (*Tetractenos hamiltoni*), Whiting (*Sillago ciliata*), Bream (*Acanthopagrus australis*), Herring (*Harengula abbreviata*), Perchlets (*Ambassis marianus*) and Silver biddies (*Gerres subfasciata*). The dominant species (in terms of abundance and frequency of occurrence) recorded in the study were mostly of economic importance. Bream, Whiting and Mullet are of substantial fisheries value and form the basis of commercial net fisheries value and the basis of commercial net fisheries in the Tweed River. It is notable that juveniles of these species were abundant on all shallow sandbanks sampled. Juveniles of these species use shallow sandy areas to feed upon benthos and avoid larger predators which often occur in deeper adjacent channels (Chubb *et al* 1981, Burchmore, *et al* 1988). The shallow sandy areas fringing the channels are thus of considerable importance as nursery areas for species which are mostly of fisheries value.

Mangrove and seagrass areas were not sampled in these studies therefore many more species than those recorded in the above studies are likely to occur within the Tweed estuary. Wetland areas (saltmarshes and mangroves) are known to be important nursery and feeding grounds for most economically important fish occurring in subtropical Australian estuaries (Morton *et al* 1987, 1988: Morton, 1990). Wetlands also provide important nutrient input, in the form of detritus, to estuaries (Odum and Heald 1975). Seagrass beds are used as nursery habitat by the juveniles of many fish species, several of which are of direct fisheries value. Substantial disturbance of these habitats would ultimately influence the commercial and recreational fisheries of the region.

Canal developments in the Tweed support a fish fauna similar to that occurring in the adjacent portion of the river (WBM Oceanics Australia, 1992). Fewer large fish that feed on macrobenthos (most of which are targeted by anglers) were recorded in canals compared to adjacent waterways, presumably because of a lack of suitable macrobenthic prey items in the canals.

Table 4.5.2 Scientific, Common Names, Economic Value and Life History Stage of Fish taken by WBM Oceanics Australia (1992)

SCIENTIFIC NAME	COMMON NAME	ECONOMIC VALUE	LIFE HISTORY STAGE
Acanthopagrus australis	Silver Bream	C/R	J/A
Achlrpa nigra	Black Sole	-	A
Ambassis jacksonensis	Perchlet	-	J/A
Ambassis marianus	Yellow Perchlet	-	J/A
Arothron hispidus	Star & Stripes Toadfish		A
Arrhamphus sclerolepis	Snub-nosed Garfish	C/R	A
Callionymus limeceps	Dragonet	-	J/A
Cymbacephalus nernatophthalmus	Fringe-eyed Flathcad	R	A
Dasyatis fluriorum	Brown Stingray	-	A
Gerres ovatus	Silver Biddy	-	J/A
Girella tricuspidata	Black Bream (Luderick)	C/R	J/A
Harengula abbreviaia	Herring		J/A
Hyporhamphus australis	Sea Garfish	C/R	A
Liza argeniea	Tiger Mullet	C	J/A
Liza dussumeri	Flat-tailed Mullet	C	A
Megalops cyprinoides	Tarpon	R	A
Meuschenia trachylepis	Yellow-finned Leatherjacket	R	A
Monodactylus argentea	Butterfish	-	A
Mugil cephalus	Sea Mullet	C	J/A
Mugil georgii	Fantail Mullct	C	J/A
Myxus elongatus	Sand Mullet	C	J/A
Pelates quadrilineatus	Trumpter	-	A
Platycephalus arenanius	Sand Flathcad	C/R	J/A
Platycephalus fuscus	Dusky Flathcad	C/R	J/A
Plotosus anguillaris	Striped Catfish	-	J
Pomatomus saltatrix	Tailor	C/R	J
Rhabdosargus sarba	Tarwhinc	C/R	J
Scomberoides lysan	Queenfish	R	J
Sillago analis	Golden-line Whiting	C/R	A
Pseudorhombus arsuis	Large-mouth Flounder	C/R	J
Sillago cilùua	Sumnier Whiting	C/R	J/A
Sillago maculata	Wintcr Whiting	C/R	J
Tetractenos pleurogramma	Weeping Toadfish	-	J/A
Tetractenos hamilioni	Common Toadfish	-	J/A
Tylosiurus macleayarus	Stout Long-tom	-	A

(C = Commerical, R = Recreational; - = No Direct Economic Value; J = Juvenile, A = Adult)

Benthos

Estuarine benthos, bottom-dwelling or burrowing animals greater than 1mm in size, perform important ecological functions including nutrient recycline and providing a food resource for fish and crusteaceans. Benthos often characterise an area and thus may be used to monitor the effects of disturbance. Three families of benthos, the Polychaeta, Bivalvia and Crustacea, comprise an integral part of the diet of many species of bottom-feeding fish and invertebrates of fisheries value.

Ecological Consultant Services (1976) examined benthic communities in the Tweed River (specifically the Terranora and Chinderah regions) and concluded that "*the Richmond River (Ballina) and Tweed River*

(Chinderah Bay) estuaries have markedly less diverse and more sparse estuarine benthos than do the coastal lake estuaries of Lake Macquarie and Wallis Lake and the Nerang River estuary. These differences are certainly related to the larger watershed feeding both the Richmond and Tweed Rivers, which in flood would present a very harsh environment for estuarine organisms."

WBM Oceanics Australia (WBM Oceanics Australia, 1991) conducted extensive surveys in the Lower Tweed Estuary. A total of 51 species were recorded from 24 sites. The benthic communities were dominated by polychaetes and, to a lesser extent, bivalves and crustaceans.

Benthic communities within canal developments of the Lower Tweed estuary were numerically dominated by polychaetes and amphipods. Most benthic species that occurred in the river also occurred in the canals but the abundance of benthic organisms in canals was lower than adjacent waterways (WBM Oceanics Australia, 1992).

A total of 66 species of benthic fauna were recorded from 26 sites in the Upper Tweed Estuary (WBM Oceanics Australia, 1992). Polychaetes dominated the benthic fauna both numerically and in terms of species. Other benthic organisms (nemerteans, insects) accounted for approximately 10-18% of the benthic population. Bivalves and crustaceans were equally abundant in the benthos (contributing 11-17% of species numbers), whereas gastropods were very poorly represented in the benthic community (accounting for <5% of the benthos).

The species recorded in previous studies of the Tweed Estuary are to the best of available knowledge, widespread and common in southern Queensland and northern N.S.W. estuaries. Benthic communities in the lower Tweed Estuary are dominated by polychaetes and, to a lesser extent, bivalves and crustaceans.

Major findings resulting from previous studies of benthos occurring within unvegetated substrates of lower Tweed estuary are:

- the number of benthic individuals and species was greatest in shallow banks or bays (eg. Shallow Bay, Ukerebagh Passage, shallow areas surrounding Terranora Inlet islands) and accordingly, these areas have high ecological value. Shallow banks/bays have mostly stable substrates, low current velocities, and accumulate detritus which is a major food source for benthos. Shallow bays act as a "refuge" for benthos during floods, enhancing recolonisation rates in the river (PWD, 1990).
- channels (particularly in downstream areas) generally had coarse sands and surface sediments were often mobile, as a result these areas supported a comparatively poor benthos.
- the abundance and diversity of benthic communities in both shallow and channel sites increased with distance upstream from the river mouth. Terranora/Cobaki Broadwater and Shallow bay have particularly well developed benthic communities. This probably relates to more stable nature of substrates, lesser degree of tidal flushing and the resulting greater accumulation of detritus associated with upstream areas.
- canals supported a benthic fauna similar to shallow upstream river areas although of lesser abundance.
- Letitia Spit waterbodies (eg. Wommin Lake) contained a more abundant and diverse benthic fauna than that occurring in the river. Several species occurred exclusively at Letitia Spit waterbodies. The most similar benthic communities in the river to these associated with Letitia Spit occurred in Ukerebagh Passage although the degree of similarity was relatively low. The distinct nature of the Letita Spit benthic communities probably relates to the restricted degree of tidal flushing, mostly low level stormwater input, and shallow water depth.
- benthic communities in the Tweed River are highly variable and fluctuate with natural variability between years and seasons.
- benthic communities in the lower Tweed River are decimated by substantial floods (PWD, 1990) and are also likely to be altered following minor flooding events.

Marine Turtles

Areas adjacent to the Tweed River entrance are likely to be utilised by Loggerhead (*Caretta caretta*) and Green (*Chelonida mydas*) turtles as feeding areas. Additionally these species may enter the lower portions of the Tweed Estuary, particularly the Green Turtles, to feed. The consultants are unaware of surveys conducted but numbers within the estuary are expressed to be low relative to adjacent areas (Dr C Limpus, *pers. comm.*).

The foreshore areas surrounding the Tweed estuary are not known as nesting sites for marine turtles. Sporodic incidences of nesting have been recorded, but these are likely to be isolated exceptional events (Dr C Limpus, *pers. comm.*).

Marine Mammals

The Tweed Estuary is beyond the generally accepted southern limit of the range of dugongs (*Dugong dugon*). Dolphins, such as the Bottlenose Dolphin (*Tursopis truncatus*) do enter the estuary on occasion to feed on migrating fish schools such as sea Mullet (*Mugil cephalus*). Dolphins would generally be confined to the lower estuary however.

4.5.2.5 Commercial Fisheries

Tweed Heads is a major fishing port. The Tweed River supports a large net fishery and is a major port for prawn trawlers which operate in nearshore coastal waters.

Commercial fisheries operating in the Tweed Estuary involve several elements; trawl fisheries, net (haul and mesh) fisheries, line and trap fisheries and oyster farming. Licensed commercial fishermen are able to participate in several fisheries. For example, a net fisherman may also undertake trapping operations.

(i) Trawl Fisheries

McGowan (1989) reported that 25 otter trawlers operate out of Tweed Heads. The trawlers operate from nearshore coastal areas seaward to the continental shelf. No trawling occurs within the Tweed estuary. The average monthly number of fishing days for each trawler was 10.

King prawns (*Penaeus plebjus*) form the bulk (by weight and value) of catches although school prawns (*Metapenaeus macleayi*) and tiger prawns (*P. esulentus*) are also taken. Marketable by-catch includes shovelnose lobster, sand crabs, fin fish and squid.

(ii) Net Fisheries

Netting operations in the Tweed River involve either hauling (seining) or meshing (gill netting). Haul operations are conducted on beaches, sand banks or spits with gradual slopes. Nets are set from a boat in a semicircle and hauled onto the bank.

Most hauling in the Tweed River occurs in the Upper Estuary (ie., upstream of Barney's Point Bridge). The reach of river between Hindmarsh Weir and a point 200m downstream is closed to commercial fishing. All other regions of the study area are able to be netted legally except Wommin Lagoon and Wommin Lake.

Net fishing operations are subject to a number of Fisheries Regulations. These include weekend closures (no netting between 8am Saturday and 8am Monday), restrictions on netting gear (type, maximum net lengths and minimum mesh sizes) and techniques (monthly changes in time periods

when nets may be set). Some regulations are specific to an area (downstream of Barney's Point Bridge and all of Terranora and Cobaki Broadwaters).

Principal species landed include mullet, jewfish, flathead, black bream (luderick), silver bream, whiting and prawns (school prawns). The abundance of most species fluctuates seasonally. Whiting are commonly taken in summer whilst mullet and silver bream are mostly taken in winter. Net fishermen fish mostly in shallow areas, such as the sand flats near Dodds Island (McAdoo's Flat) and Ukerebagh Passage, although most nets are used in main channels to take Mullet and shark. prawns are often taken from deep "holes" in the river and by hauling techniques. Holes created by dredging are often netted as prawns and some fish (jewfish) reportedly congregate in such areas.

(iii) Line and Trap Fishery

Line and trap fishing is undertaken mostly in nearshore marine waters. Fishing generally does not occur in the Tweed Estuary although jewfish and tailor are targeted on rare occasions. Line fishermen target mainly cod, shark, mackerel, snapper, pearl perch and tuna. Favoured fishing locations are offshore reefs and areas near Cook Island.

Trap fishermen generally target spanner crabs and snapper in coastal waters and mud crabs within the Tweed Estuary. Mud crab fisherman are limited to the use of 10 traps each. Approximately four fisherman trap mud crabs in the study area on a full time basis in summer whilst six fishermen operate of a part time basis in conjunction with netting during winter. Most operators work alone from small outboard powered boats.

Oyster Farming

Oyster farming is an important component of the Tweed fisheries. There are presently ten to twelve oyster farmers (18-20 people employed directly) which operate primarily from the Terranora Broadwater. Oyster farming generally involves rack and tray culture techniques, although some stone walls (northern Ukerebagh Island, main arm of the Tweed River) are also used. A public oyster reserve is situated on the Greenbank training wall, downstream of Terranora Inlet.

Relatively little oyster farming occurs in the upper Tweed estuary in comparison to lower reaches of the river. All oyster leases in the upper estuary are located on Lillies Point at the entrance to Chinderah Bay.

The health and future marketability of oysters from the Tweed depends greatly upon the water quality of the area since oysters are filter feeders and are known to accumulate contaminants. Oyster farmers report that run-off from acid sulphate soils, flood waters, sewage discharges, and perhaps pesticide/herbicide contamination have influenced production rates.

In light of recent incidences of contaminated oysters from the Tweed River, concern about water quality has been raised by oyster farmers. Increasing urbanisation of the region (and associated stormwater runoff) may result in adverse effects to the oyster industry. Oyster farmers would therefore like to see increased flushing of the river in general.

4.5.2.6 Biting Midge and Mosquitos

Three species of biting midge and four ground water breeding of mosquitos cause problems in Tweed Shire :

Biting Midge : *Culicoides longior*
Culicoides molestus

Mosquitoes :
Culicoides submmaculatus
Aedes alternans
Aedes funereus (species complex)
Culex sitiens
Aedes vigilax

The biology of most of these pest species is now reasonably well understood (Debenham, 1982; Marks and Keye, 1982; Easton, 1990). Mosquito and midge problems are often man-induced as a result of poorly planned/implemented development in wetland or other low lying areas (WHO, 1982). Chemical treatment of the problem is often expensive and may have adverse environmental impacts, particularly upon aquatic ecosystems.

The majority of mosquito nuisance in the Tweed estuary results from saltmarsh species. All of the four nuisance species which occur in the estuary except *Ae. funerus*, breed in pools within saltmarsh and mangrove areas created after the highest spring tides. Heavy rain can also fill the same pools and combinations of rain and high tides occasionally create huge areas of suitable breeding habitat.

Aedes funerus is the least understood of the four species as it breeds in temporary pools, in shade, on the landward side of mangroves, in *Melaleuca* or *Casuarina* forest and occasionally shaded pasture near the above (Markes and Reye, 1982).

The other species may fly up to 60km from the breeding site and also bite by day and night whereas *Ae. funerus* tends to be very localised, usually a vicious day-biting pest.

Ae. vigilax and *Cu. sitiens* transmit various diseases including Ross River virus, Murray Valley encephalitis and dog heartworm and are thus of considerable public health importance.

In addition to their naturally occurring breeding sites, the saltmarsh mosquitoes, particularly the most commonly occurring species *Ae. vigilax*, adapt readily to man-made pools such as those resulting from poor agricultural practices, clearing of low lying land, poor agricultural drainage (eg., Bilambil Creek) and other man-made changes to wetland areas.

Biting midge exhibit a very precise choice of breeding site, at distinctive levels on the intertidal continuum. Although midge do not transmit diseases to humans in Australia, their economic impact as pests may be considerable.

Culicoides longior is a problem to humans in those areas of the estuary close to its breeding sites. It breeds under tree cover, usually among heavy fibre impregnated muds often with leaf litter, between mean high water neap and mean high water spring tides (Easton, 1990). The chain of mangrove islands along Terranora Inlet provides the main breeding area.

Culicoides molestus may become a serious pest with a flight range from breeding sites of up to 1.5km. Its breeding sites are most commonly characterised by clear flocculated sand in the open or under light mangrove cover, between mean tide level and mean high water springs (Easton, 1990). This species breeds in beaches, canal developments, on most sandy river foreshores and suitable sandbars. Sandbanks such as Tony's Bay have yielded midge larval densities of up to 30,000 larvae/m^2.

Culicoides subimmaculatus appears to cause a seasonal problem in the Tweed estuary, appearing in large numbers after wet autumn/winter periods (Easton ,1990). *C. subimmaculatus* breeds in clean or muddy sand in the open or under light mangrove cover between mean high water neap and mean high water spring tide levels. Ukerebagh Island is a major breeding area for this species.

4.5.3 Terrestrial

4.5.3.1 Terrestrial Vegetation

Considerable disturbance to terrestrial vegetation communities from sandmining, pastoral, agricultural and forestry activities and urbanisation has occurred in the Tweed River floodplain since European arrival. Some of the earliest settlers of European descent were timber cutters searching for red cedar (*Toona australis*) who arrived in the Tweed Valley in the mid 1840's (Anon 1989).

Settlement of the Tweed valley was largely pioneered by sugarcane farmers who arrived in the 1870's (Anon 1989). Sugar farming rapidly displaced much of the regions lowland rainforest. Condong Sugar Mill was built on the banks of the Tweed River in 1880 by the Colonial Sugar Refining Company (CSR) and is operating today.

Vegetation on high ground (open forest and rainforest), not suitable for sugar cane cultivation, was cleared from the 1890s onward for dairying and banana growing (Anon 1989). Urbanisation of Tweed Heads expanded after development of the Tweed River breakwater and training walls (1892), and a rail link from Queensland (Anon 1989). This would also have put pressure on lowland areas of natural vegetation in the region.

Sand mining, between the 1930's and 1960's (Graham 1990a) resulted in extensive loss of coastal dune vegetation along Letitia Spit, including littoral rainforest, between the river's mouth, and Chinderah along Letitia Spit.

Vegetation of the Tweed Shire has been the subject of many studies as referenced by PWD (1990). Pressey and Griffith (1987) provide descriptive information on the terrestrial plant communities of the Tweed Shire (16 plant associations containing 439 plant species) and their need for protection. Other reports (Murray 1987a), (Murray 1987b, Hunter 1982, Flowers 1988, Floyd 1979, NPWS 1980 cited by PWD 1990) describe the vegetation of selected areas in the Shire. The conservation value of remnant terrestrial vegetation is reviewed by Gilmore (1983) and Hunter (1985 cited by PWD 1990).

Fringing Open (Swamp) Forests

Fringing open (swamp) forests occupy land subject to seasonal, freshwater inundation. They are dominated by swamp she-oak (*Casuarina galuca*) growing at the margins of saltmarsh vegetation, or by the paperbark teatree (*Melaleuca quinquenervia*). Where these two forms abut, there may be a zone of inter-mixing. The structure and species composition of the fringing open (swamp) forests is described by Pressey and Griffith (1987).

Ukerebagh Nature Reserve, Cobaki Broadwater, Wommin Lake and Stotts Island Nature Reserve support the largest areas of fringing open forest along the lower Tweed River.

Rainforests

Rainforest along the Tweed River occurs as littoral rainforest close to the ocean in the shelter of the hind dunes while subtropical rainforest occurs further inland.

Littoral rainforest is restricted to small areas at Fingal Head, Wommin Lagoon, Sponsors (Bonnys) Lagoon and Wommin Lake. These are remnants of a littoral rainforest that once extended from Letitia Spit to Chinderah and possibly beyond (PWD 1990). They are within the National Trust's Fingal Head Coastal Conservation Area and are protected under State Environmental Planning Policy No. 26 (see Figure 4.5.3).

More than 500 specimens of the vulnerable stinking cryptocarya tree (*Cryptocarya foetida*), as well as 120 other tree, shrub, herb, vine, palm and fern species are present in these rainforest remnants (Graham,

1990). Other small areas of littoral rainforest occur in the south east of Ukerebagh Island and south of Tonys Island.

Lowland subtropical rainforest along the lower Tweed River occurs at Stotts Island, Banora Point, Birds Bay, Cobaki Inlet and Cobaki Broadwater. With the exception of Stotts Island, each are only a few hectares in area. Almost 100ha is conserved on the Stotts Island Nature Reserve. Vegetation on the rest of the island is swamp forest and wetland vegetation. The island's rainforest is above 1m elevation and is flooded completely about once every 18 months (Cameron McNarmara 1980, cited by PWD 1990).

Open Forest

Open forest on the lower Tweed River floodplains occurs in small areas on ground of slightly higher elevation than that which supports fringing open (swamp) forests. Floodplain open forest is characterised by two main associations characterised by either forest red gum - bloodwood (*Eucalyptus tereticornis - E. intermedia*) or swamp messmate - paperbark tea tree (*E. robusta - Melaleuca quinquenervia*). Other open forest associations occur on hillsides in the Tweed region and are characterised by blackbutt (*E. pilularis*), the grey gum - white mahogany association (*E. propinqua - E. acmenoides*) or brush box (*Lophostemon confertus*).

Little red gum (*Eucalyptus tereticornis*) open forest remains along the floodplain of the lower Tweed River. Sometimes individual specimens of *E. tereticornis* are all that remains of once larger forest tracts.

A large and relatively undisturbed area of *E. tereticornis* forest occurs on Portion 224, on the mainland adjacent to Ukerebagh Island. Other trees present in this forest are pink bloodwood (*E. intermedia*) and swamp mahogany (*Lophostemon suaveolens*). Less common tree species in the *E. tereticornis* forest include swamp messmate (*E. robusta*), red mahogany (*E. resinifera*), paperbark teatree (*Melaleuca quinquenervia*) and swamp oak (*Casuarina glauca*).

Swamp messmate - paperbark tea tree (*E. robusta - Melaleuca quinquenervia*) open forest occurs on lowland soil with restricted drainage. Only small areas of this forest remain in the study area amongst the heathland and shrubland vegetation west of Coolangatta Airport and fringing parts of the Terranora Broadwater.

Several open forest associations occur on the hillsides along the lower Tweed Rvier. Brushbox (*Lophostemon confertus*) open forest occupies south and east facing lower slopes. Blackbutt (*Eucalyptus pilularis*) open forest occurs on ridges and upper south facing slopes whereas the grey gum-white mahogany association (*E. proprinqua - E. acmenoides*) grows on drier north and west facing slopes (Forster 1978).

Structure and species composition of lowland or floodplain open forest in the Tweed Shire is described in Pressey and Griffith (1987). Hillside open forests in the Tweed Shire are described in further detail by Forster (1978).

Shrublands and Heathlands

Shrublands and heathlands occur on old dune deposits and are characterised by woody and herbaceous plants generally less than 2 or 3m tall. Numerically important plant families of this vegetation are Myrtacea, Proteaceae and the three legume families Mimosaceae, Fabaceae and Caesalpinacea (Coaldrake 1961).

An extensive and well preserved area of shrubland and heathland occurs west of Coolangatta Airport, on the northern margins of Cobaki Broadwater. Pressey and Griffith (1987) provide structural and species composition details on this vegetation. Apart from this relatively undisturbed area, other shrubland and heathland in the study area is fragmentary and disturbed.

Rare or Threatened Plants

The following description of rare or threatened plants utilises terms adopted prior to the introduction of the NSW *Threatened Species Conservation Act, 1995*. While these terms have changed the conservation status of specific plants would remain high.

A national list or rare and threatened plants in Australia reveals that the north coastal region of N.S.W has 26 endangered plant species (Briggs and Leigh, 1988). This is second only to the wheat belt region of south - west Western Australia which has 28.

Within the north coastal region of NSW, the coastal section of the Tweed Shire has 9 endangered, 17 vulnerable, and 13 rare plant species (PWD, 1990).

Eleven of the endangered, vulnerable and rare species of coastal Tweed Shire occur along the Tweed River, mostly in rainforests (PWD, 1990). Table 4.5.3 lists these species in order of conservation priority (PWD, 1990).

Significant Plants

While not being considered rare or threatened on a national basis, there are several plants (Table 4.5.4) of the coastal area of Tweed Shire that are of regional significance (PWD 1990). They are significant because within the Shire they are at the limits of their geographic distribution or they are uncommon in central eastern Australia. Of the 12 significant plants recorded in the Tweed Estuary, eight occur in rainforests and four occur in heathlands (Table 4.5.4).

Table 4.5.3 Rare or Threatened Plants of the Lower Tweed Estuary (after PWD 1990)

Scientific Name	Common Name	Habitat	Distribution	Occurrence	Habitat	Abundance	Conservation Coding*
Diospyros mabacea	red-fruited ebony	tree	Tweed River	Stotts Is	subtropical rainforest	scarce	2ECi
Randia moorei	spiny gardenia	shrub/tree	Lismore to Beenleigh	Stotts Is and Birds Bay Tonys Is	subtropical rainforest littoral rainforest	uncommon scarce	3ECi
Syzygium moorei	durobby	tree	Ballina to Mudgeeraba	Stotts Is Wommin Lake Tonys Is and Birds Bay	subtropical rainforest littoral rainforest littoral rainforest	common scarce	2VCi
Acacia bakeri	marblewood	tree	Federal to Maryborough	Cobaki Bridge & Birds Bay	subtropical rainforest	scarce	3VC-
Bosistoa transversa	three-leaved bosistoa	tree	Mullumbimby to Maryborough	Stotts Is	subtropical rainforest	scarce	3VC-
Cryptocarya foetida	stinking cryptocarya	tree	Wardell to Fraser Is	Birds Bay Fingal Head, Wommin Lake & Wommin Lagoon Ukerebagh Is & Tonys Is	subtropical & littoral rainforest littoral rainforest littoral rainforest	abundant common uncommon	3VC-

(*Briggs & Leight 1988)

LEGEND

2 Geographic Range <100km
3 Geographic Range 100 + km
E Endangered
- Adequately of reservation unknown
R Rare (not threatened)
V Vunerable
C Population reserved
I Inadequately reserved

Table 4.5.3 Rare or Threatened Plants of the Lower Tweed Estuary (after PWD 1990) (Continued)

Scientific Name	Common Name	Habitat	Distribution	Occurrence	Habitat	Abundance	Conservation Coding*
Thozetia racemosa	rusty vine	vine	Iluka to Bundaberg	Birds Bay	littoral rainforest	scarce	3VC-
Cordyline congesta	toothed palm-lily	palm-like shrub	Wardell to Coomera River	Fingal Head, Wommin Lagoon, Barrys Lagoon, Wommin Lake, Ukerebagh Nature Rserve. Tonys Is, Cobaki Inlet, Coolangatta Airport, lower Cobaki Ck, Cobaki Bridge & Birds Bay	littoral and subtropical rainforest and adjacent open forests	uncommon to abundant	2RC-
Endiandra globosa	black walnut	tree	Mullumbimby to Tallebudgera	Lower Cobaki Ck, Cobaki Bridge, Birds Bay	subtropical and adjacent open forest	moderately common	2RC-
Lepiderema pulchella	fine-leaved tuckeroo	tree	Tyalgum to Currumbin	Stotts Is, Cobaki Bridge & Birds Bay	subtropical rainforest	moderately common	2RC-
Cassia marksiana	brush cassia	tree	Crabbes Creek to Beenleigh	Stotts Island	subtropical rainforest	scarce	3Vci

(Briggs & Leight 1988)

LEGEND

2 Geographic Range <100km
3 Geographic Range 100 + km
E Endangered
\- Adequately of reservation unknown
R Rare (not threatened)
V Vunerable
C Population reserved
I Inadequately reserved

Table 4.5.4 Significant Plants of Coastal Tweed Shire Council (PWD 1990)

Scientific Name	Common Name	Habitat	Occurrence	Habitat
Acacia bauerii	Hook-leaf wattle	Shrub	Near Wommin Lagoon and Wommin Lake	Heathland
Banksia robur	Large-leaved banksia	Shrub	Coolangatta Airport	Heathland
Boronia rosmarinifolia	Showy boronia	Shrub	Coolangatta Airport	Heathland
Grevillea hilliana	White Yiel-yiel	Small tree	Tonys Island, Cobaki bridge, Birds Bay	Littoral and subtropical rainforest
Leptospermum whitei	White's teatree	Shrub/small tree	Coolangatta Airport	Heathland
Meicosma cunninghamii	Medicosma	Shrub/small tree	Birds Bay	Subtropical rainforest
Mischocarpus	Veiny pear-fruit	shrub/small tree	Stotts Island	Subtropical rainforest
Palchonella chartacea	Thin-leaved coondoo	Small tree	Fingal Head, Wommin Lagoon, Bonnys Lagoon, Wommin Lake, Ukerebagh Nature Reserve, Tonys Island, Stotts Island, Birds Bay.	Littoral and subtropical rainforest and swamp forest
Planchonella laurifolia	Blush coondoo	Tree	Tonys Island, Stotts Island and Birds Bay	Littoral and subtropical rainforest
Polyalthia nitidisrima	Polyalthia	Small tree	Fingal Head, Wommin Lagoon, Bonnys Lagoon, Wommin Lake, Ukerebagh Island Nature Reserve, Tonys Island	Littoral rainforest
Toechima tenax	Pitted steelwood	Small tree	Stotts Island	Subtropical rainforest

Letitia Spit

Much of the original dunal vegetation on Letitia Spit was replaced during sand mining operations which commenced in the 1930's and finished in the mid to late 1960's (Graham, 1990). The spit was reforested with horsetail oak (*Casuarina equisetifolia*) and the exotic species, bitou bush (*Chrysanthemoides monilifera*).

Dieback is prevalent in the older she-oaks. It is likely that the very competitive bitou bush, which covers the ground, severely impedes regeneration of the she-oaks and other native plants.

Small stands of coast banksia (*Banksia integrifolia*), an element of the original dunal vegetation, also occur amongst the horsetail oak and the bitou bush vegetation on Letitia Spit.

4.5.3.2 Terrestrial Fauna

Terrestrial fauna from several vertebrate groups found in the Tweed region have been classified under the New South Wales National Parks and Wildlife *Threatened Species Conservation Act, 1995*. Within the act, these may be classified as "Vulnerable" or as "Endangered ".

A number of rare/little known butterflies also occur in the region. Among those terrestrial animals which may occur around the lower Tweed estuary the following have been identified (WBM Oceanics Australia, 1991).

Amphibians

Several species of regional significance may occur in the area (eg. *Crinia tinnula*) (WBM-Oceanics 1990a) but none of these are classified under Schedule 2.

Reptiles

Vulnerable

Hoplocephalus stephensi	Stephens Banded Snake

Birds (listing relating to shorebirds are provided in Section 4.5.3.2)

Mammals

Vulnerable

Syconycteris australis	Queensland Blossom Bat
Phascolarctos cinereus	Koala
Potorus tridactylus	Long Nosed Potoroo

Butterflies

A number of rare species of a special interest to NPWS are known to occur in the Tweed valley (Nadolny 1987). These do not have formal protection under the Act at present. PWD (1990) report one species, *Ornithoptera richmondia*, the Richmond Birdwing, from the Coolangatta Pony Club.

In the analysis of the above list it should be noted that many of the species listed above are classified under Schedule 2 as vulnerable within New South Wales simply because they are at, or near the limit of, their natural geographic range. In many cases, the species may be both regionally and locally common within

and beyond New South Wales were habitat is available. For example, Mangrove Honeyeater, Fawn-footed Melomys, *Crinia tinnula*, are all very common in Queensland and much of northern Australia.

In several cases, the animals appear to be mobile but highly secretive, very "patchy" in their natural distribution and consequently poorly understood (eg. *Hoplocephalus stephens*).

Several large, long lived raptors regularly observed around the Tweed estuary such as Osprey and Brahminy Kites, are territorial and consequently require large areas of suitable habitat for breeding/foraging territories.

4.5.3.3 Shorebirds

Those parts of the Tweed Estuary which are significant to waterbirds are the Tweed River below Chinderah Bay, Terranora Creek and associated bays and broadwaters, the mouths of Bilambil and Duraby Creeks and beaches from the Tweed River entrance south to Kingscliff. The upper Tweed Estuary, upstream of Chinderah Bay, does not include any significant sites for waterbirds.

Diversity of Waterbirds

A total of 74 species of waterbirds have been recorded within the Tweed Estuary during surveys between 1987 and 1996. The 74 species are composed of the following groups :

- migratory waders - 23 species;
- resident waders - 9 species;
- terns and gulls - 9 species;
- grebes - 1 species;
- birds of prey - 5 species;
- ducks and magpie goose - 8 species;
- cormorants, darter and pelican - 6 species;
- herons, egrets, spoonbills, ibis, stork - 13 species.

The majority of these species feed on fish and aquatic invertebrates. A wide variety of habitats within the estuary are used by waterbirds including deeper water of rivers, creeks and bays, sandy beaches and spits, intertidal mudflats and sandflats, mangroves, saltmarsh, freshwater marshlands and artificial structures (eg. oyster racks).

Explanation of Terms Used

This document uses common names of birds as given in Christidis and Boles (1994), a well accepted practice amongst ornithologists. Refer to glossary for a description of these terms.

Abundance of Waterbirds

A maximum count of 4,213 waterbirds from 63 species were recorded during the bird monitoring programme during Stage 1A (WBM Oceanics Australia, 1996). This number consisted of 844 migratory waders, 327 resident waders and 3042 individuals belonging to other groups. The maximum count of each species of waterbird is given in Table 4.5.5. The bird monitoring programme was conducted between August 1995 and April 1996 and is the most comprehensive and recent survey of the waterbirds of the Tweed Estuary.

A number of species previously recorded from the estuary were not seen during the bird monitoring programme. These species were black-tailed godwit, wood sandpiper, wandering tattler, sanderling, red-necked stint, broad-billed sandpiper, greater sandplover, glossy ibis, fairy tern, white-fronted tern and swamp harrier. Each of these species is rarely recorded within the estuary, so their absence from the bird monitoring programme does not necessarily indicate a long term decline.

Distribution of Waterbirds

The bird monitoring programme (WBM Oceanics Australia, 1996) confirmed that some sites on the Tweed Estuary are more important to waterbirds than others. Also, the importance of sites can vary depending on the phase of the tide. A total of 15 sites were surveyed during the bird monitoring programme, 14 at high tide and 8 at low tide. The maximum number of waterbirds recorded at high and low tide at each survey site is given in Table 4.5.6. The table shows that large numbers of waterbirds were located at South Head Beach, Kerosene Inlet, Tony's Bar, Trutes Bay and Terranora Broadwater. The first three sites were used mainly as roosting sites at high tide, whereas Trutes Bay and Terranora Broadwater were used for both roosting and feeding.

Table 4.5.5 **The Maximum Number of Each Species of Estuarine Bird Recorded in the Lower Tweed Estuary During the Bird Monitoring Programme**

WADERS		NON-WADERS	
Migratory Species			
Species	Number	Species	Number
Latham's Snipe	4	Magpie Goose	6
Bar-tailed Godwit	289	Black Swan	7
Whimbrel	69	Australian Wood Duck	16
Eastern Curlew	120	Pacific Black Duck	46
Marsh Sandpiper	80	Australasian Shoveller	1
Common Greenshank	44	Grey Teal	14
Terek Sandpiper	2	Chestnut Teal	66
Common Sandpiper	2	Hardhead	4
Grey-tailed Tattler	41	Australasian Grebe	1
Ruddy Turnstone	5	Darter	10
Great Knot	3	Little Pied Cormorant	17
Sharp-tailed Sandpiper	126	Pied Cormorant	229
Curlew Sandpiper	16	Little Black Cormorant	357
Pacific Golden Plover	23	Great Cormorant	8
Double-banded Plover	18	Australian Pelican	193
Lesser Sand Plover	2	White-faced Heron	76
Resident Waders		Little Egret	11
Beach Stone-curlew	1	Great Egret	17
Pied Oystercatcher	8	Intermediate Egret	1
Sooty Oystercatcher	3	Cattle Egret	176
Black-winged Stilt	258	Eastern Reef Egret	1
Red-necked Avocet	33	White-necked Heron	1
Red-capped Dotterel	4	Striated Heron	9
Black-fronted Dotterel	2	Australian White Ibis	91
Red-kneed Dotterel	6	Straw-necked Ibis	11
Masked Lapwing	12	Royal Spoonbill	27
		Black-necked Stork	2
		Osprey	6
		Whistling Kite	6
		Brahminy Kite	4
		White-bellied Sea-eagle	1
		Silver Gull	717
		Crested Tern	637
		Gull-billed Tern	27
		Caspian Tern	4
		Common Tern	190
		Little Tern	49
		White-winged Black Tern	3

Table 4.5.6 The Maximum And Minimum Number Of Estuarine Birds Recorded At High And Low Tide At Each Survey Site During The Lower Tweed Estuary Bird Monitoring Programme, 1995-96

Site	High Tide		Low Tide	
	Maximum	*Minimum*	*Maximum*	*Minimum*
Kerosene Inlet	448	71	445	9
Ukerebagh Passage	240	0	304	37
Tony's Bar	440	75	284	21
Shallow Bay	-	-	131	16
South Head Beach	489	1	-	-
Dreamtime Beach	234	0	-	-
Wommin Lake	10	0	-	-
Chinderah Bay	128	0	308	53
Terranora Creek	184	48	280	89
Cobaki Creek	36	12	-	-
Cobaki Roost	92	8	-	-
Terranora Broadwater	355	24	265	29
Trutes Bay	288	2	385	1
Trutes Bay Marshland	158	0	-	-
Duraby Creek Marshland	217	48	-	-

Among the waterbirds present on the estuary, waders (both migratory and resident) are the group most likely to be adversely impacted on by human disturbance. Waders are vulnerable to disturbance as a result of the sand bypassing project because they forage and roost in intertidal areas, which may be affected by the project. Other waterbirds (eg., cormorants, pelicans) forage in deeper water and have a wider range of roosting sites.

An assessment of the maximum counts of waders at the 15 sites showed the major sites for waders to be :

- South Head Beach - maximum count of 280 waders;
- Trutes Bay - 286;
- Terranora Broadwater - 258; and
- Duraby Creek Marshland - 196.

Conservation Significance of Waterbirds of Tweed Estuary

The Tweed Estuary is a wetland of considerable conservation significance. This has been recognised at the national and state level as detailed below.

The Tweed Estuary supports over 1% of the Australian population of the marsh sandpiper, and in the recent past it has supported over 1% of the Australian population of the whimbrel (WBM Oceanics Australia, 1996). A location which regularly supports 1% or more of the population of a species in a major biogeographical region is recognised as a wetland of international importance under the RAMSAR convention. The RAMSAR convention is an international convention which aims to halt the loss of wetlands worldwide and to promote the wise use and management of the remainder of the world's wetlands.

The Tweed Estuary is considered to be one of the 15 most significant coastal wetland sites for waders in New South Wales (Smith, 1991). In addition, it is ranked as an area of national significance for waders (Watkins, 1993). The estuary supports up to 21 species listed under JAMBA (Japan Australia Migratory Birds Agreement) and 22 Species listed under CAMBA (China Australia Migratory Birds Agreement) (WBM

Oceanics Australia, 1996). These agreements are in place to protect migratory birds which use the flyway between Australia and East Asia.

A number of species present in the estuary are listed in the *Threatened Species Conservation Act 1995* administered by the New South Wales National Parks and Wildlife Service. The species and their listings are given below.

Schedule 1, Endangered Species :

- beach thick-knee; and
- little tern.

Schedule 2, Vulnerable Species :

- black-necked stork;
- osprey;
- magpie goose;
- sanderling;
- great knot;
- greater sand-plover;
- lesser sand-plover;
- sooty oystercatcher;
- pied oystercatcher;
- black-tailed godwit; and
- terek sandpiper.

The NSW *Threatened Species Conservation Act 1995* requires that when a development application is made on land which contains areas declared to be critical habitat or which is likely to significantly affect threatened species, populations or ecological communities or their habitats, the application is to be accompanied by a Species Impact Statement (SIS). Threatened species include both endangered species and vulnerable species. The requirements for an SIS must be obtained from the Director-General of the NSW National Parks and Wildlife Service.

4.6 Cultural and Socio-Economic Environment

The cultural and socio-economic environment of the study area has been shaped by its attractive waterways and sub-tropical climate, and its subsequent evolution as a popular tourist destination. This section provides a description of the physical, social and economic environments surrounding both the southern Gold Coast beaches and the adjoining Tweed Heads area.

4.6.1 Local Zoning, Land Uses and Tenure

One of the unique features of the study area is its inclusion within two separate states and two local authority areas. Consequently, the area is subject to a number of local and state government planning controls and policies. As stated in Section 2.4 of this report, the main planning mechanisms at the local and regional scale are:

- North Coast Regional Environmental Plan 1988;

- Tweed Local Environmental Plan 1987;
- Draft Tweed Shire Strategic Plan 1996;
- Draft Revised Coastal Policy for NSW 1994;
- SEQ 2001 Regional Framework for Growth Management 1995;
- City of Gold Coast Planning Scheme 1994; and
- Gold Coast Coastal Management Plan District No. 11.

At the regional level, the statutory North Coast Regional Environmental Plan 1988 defines the requirements for Local Environmental Plans and does not appear to directly control land uses within the study area. Similarly, the non-statutory SEQ 2001 Regional Framework for Growth Management 1995 sets out a number of broad objectives for the natural, physical and social environments within South East Queensland. It does not have any immediate implications for the study area.

The non-statutory Draft Revised Coastal Policy for NSW lists a number of objectives and actions for implementation by individual government bodies. Whilst the policy does not make any direct reference to sand bypassing or other similar projects, it does include some relevant strategic actions for the:

- monitoring of water quality in rivers and estuaries;
- maintenance of fisheries habitats;
- protection of the aesthetic qualities of the natural and built environs in coastal areas; and
- maintenance of public access to beaches and rivers.

The policy designates responsibility for the implementation of these actions to the New South Wales Department of Urban Affairs and Planning, and the appropriate local Councils. Consequently, these actions should be recognised in the consideration or implementation of the permanent sand bypassing system.

Both Queensland and New South Wales have enforced detailed planning policies which are described below.

Queensland

Within Queensland, there are three (3) State Planning Policies (SPP's) as follows:

- SPP 1/92 - Development and the Conservation of Agricultural Land;
- SPP 2/92 - Planning for Aerodromes and Other Aeronautical Facilities; and
- SPP 1/95 - Conservation of Koalas in the Koala Coast.

As these policies set out guidelines for appropriate forms of urban land development in areas with good quality agricultural land and near airports and koala habitats, they do not apply to this project. There are no other environmental policies or instruments for Queensland.

New South Wales

Many of the mangrove islands and wetlands within the Tweed River are protected under State Environmental Planning Policy (SEPP) No. 14: Coastal Wetlands and as such are subject to specific planning requirements and provisions which have been discussed in Section 2.4.

The littoral rainforest area on Crown Land at Fingal is protected under SEPP No. 26 : Littoral Rainforest and managed by the New South Wales Department of Land and Water Conservation (DLWC).

Specific land uses and zoning patterns within the study area are defined by the Tweed Local Environmental Plan 1987 and the City of Gold Coast Planning Scheme 1994. The combined zoning pattern of the two local authority areas is given in the Study Area Zoning Map (Figure 4.6.1).

There is no apparent conflict between the legislative and policy frameworks of the Tweed Shire Council and the Gold Coast City Council or the New South Wales and Queensland Governments.

4.6.1.1 Land Use and Zoning Pattern

Commercial Land Uses

Commercial centres within the study area focus on the small to medium sized businesses within the neighbourhood shopping centres at Coolangatta and Tweed Heads, and the local scale shops between the Gold Coast Highway and the beachfront at Kirra and Tugun. Whilst there are a variety of retail and professional tenancies within these areas, there are numerous businesses which serve the particular needs of the tourist, surfing and fishing communities. Refer to Section 4.6.6.1 for a detailed discussion of these businesses.

Residential Land Uses

Multi-storey holiday apartments dominate the beach-side esplanades and nearby streets adjacent to Rainbow Bay and the Greenmount, Coolangatta, Kirra, North Kirra and Bilinga beaches. Whilst the majority of these uses are limited to 3 or 4 storeys, some higher set 10-storey apartment buildings are present. These are mostly situated in elevated locations at Greenmount headland, Coolangatta and Tweed Heads to maximise the available views towards the beaches and the Pacific Ocean.

Lower density residential development is located within the southern portion of the Gold Coast area and within the Tweed Shire. The residential areas within proximity to the Tweed River and Ukerebagh Island are occupied by a mixture of lower density unit buildings and single detached dwellings which are intended to accommodate permanent residents.

The village of Fingal Head is occupied by two discrete, low density residential areas which contain some flood prone single detached dwellings.

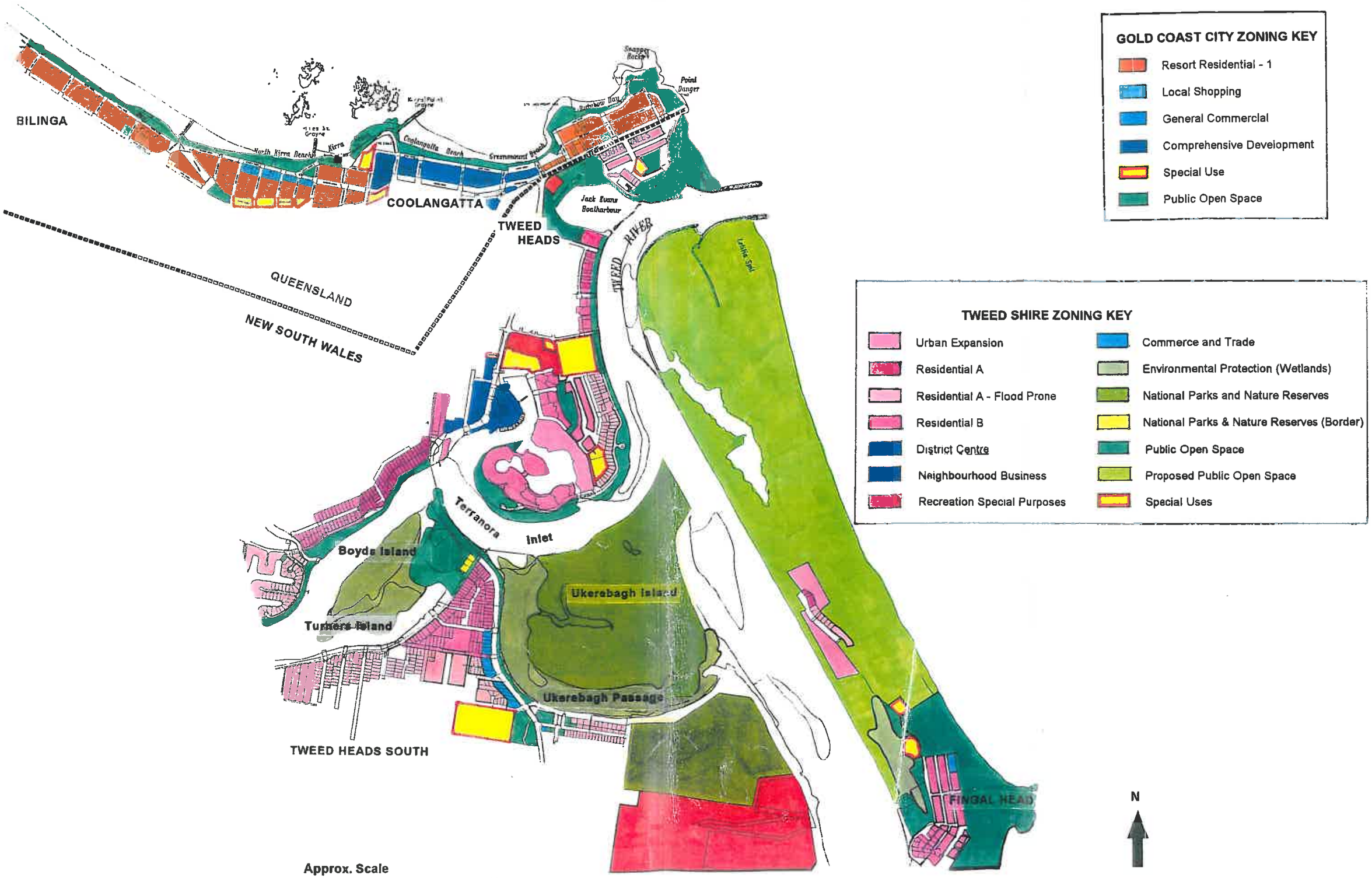
Recreation and Open Space

Duranbah, Coolangatta, Kirra, North Kirra and Bilinga beaches and the Tweed River present a variety of popular recreational opportunities for visitors and residents. These include swimming, surfing, body-boarding, sailboarding, surf-skiing, walking, sun-baking, flying kites, open beach fishing, fishing, diving, recreational boating, etc.

Substantial linear corridors of public open space are located along the coastline adjacent to Duranbah, Coolangatta, Kirra, North Kirra and Bilinga beaches and adjacent to the northern bank of the Tweed River. These offer further beach and river-side recreational activities such as picnicking, playing outdoor sports, fishing and walking.

The isolated, pocket parks adjoining the single detached houses within the southern Gold Coast area and Tweed Heads also provide convenient, recreational facilities for tourists and permanent residents.

The largest portion of environmental open space is situated in the northern portion of Fingal Head in the area zoned "Proposed Open Space" under the Tweed Local Environmental Plan (LEP). Areas to the east



GOLD COAST CITY ZONING KEY

- Resort Residential - 1
- Local Shopping
- General Commercial
- Comprehensive Development
- Special Use
- Public Open Space

TWEED SHIRE ZONING KEY

- Urban Expansion
- Residential A
- Residential A - Flood Prone
- Residential B
- District Centre
- Neighbourhood Business
- Recreation Special Purposes
- Commerce and Trade
- Environmental Protection (Wetlands)
- National Parks and Nature Reserves
- National Parks & Nature Reserves (Border)
- Public Open Space
- Proposed Public Open Space
- Special Uses

Figure 4.6.1
Study Area Zoning Map

and west of the Fingal Head residential area are zoned "Public Open Space" to accommodate the Fingal Head Caravan Park and the historic Fingal Head lighthouse.

There are also a small number of unofficial personal memorial plaques which exist in the vicinity of Snapper Rocks. The plagues are located in a garden to the northern side of the Snapper Rocks u-turn car park.

Natural Environment

The nearshore area within the southern Gold Coast beaches is not affected by any zoning under the City of Gold Coast Planning Scheme. Within the Tweed River, Ukerebagh Island and Stotts Island are protected by their inclusion in the "National Parks and National Reserves Zone" under the Tweed LEP.

The Ukerebagh Passage and several islands within Terranora Creek and the Terranora and Cobaki Broadwaters contain ecologically significant wetland areas. The wetlands immediately to the west of the Fingal Head also have high ecological significance. Land to the south-east of the Fingal headland accommodates a remnant patch of littoral rainforest.

Industrial Uses, Telecommunications and Utilities

A single light industrial precinct is positioned within Gold Coast City and close to the state border. The lack of major industry ensures that there are no adverse impacts upon either the southern Gold Coast beaches or the Tweed River resulting from industrial activities in this part of the study area.

Telecommunications carriers are exempt from the statutory requirements of local and state government bodies. Regardless, the zoning pattern for both the City of Gold Coast and Tweed Shire indicates that there are no significant land holdings by any of the telecommunications carriers.

The Coolangatta Airport to the west of Bilinga Beach represents the largest utility within the study area. Smaller land areas are occupied by SEQEB near the state border and by the Community Health Branch adjacent to Lanham Street within Coolangatta. Other special uses include the Department of Transport's land holdings adjacent to the Gold Coast Highway, the TAFE within Coolangatta and the various schools, hospitals, civic centres, churches and cemeteries within the Gold Coast and Tweed Shire.

4.6.1.2 Tenure

The study area's position across both state and local authority boundaries results in a complex pattern of land ownership and management. The residential and commercial areas identified in Figure 4.6.1 are held in private, freehold ownership. This section discusses land ownership and the stakeholders who have an interest in the lands and waterways surrounding the beaches and the river.

Queensland

Land up to the boulder wall along the coastline consists of privately owned property and land controlled and managed under the Gold Coast City Council. Land and waterways including the Gold Coast beaches to 3 nautical miles to sea is currently controlled by the Crown. The areas to be nourished are therefore Crown Lands which are managed by the Queensland Department of Natural Resources (DNR) and the Queensland Department of Environment (DoE). The relevant legislation and provision for works required have already been noted in Section 2.4.

It is important to note that a number of Native Title Claims have been lodged for areas of land in both Queensland and New South Wales. As these claims have substantial implications for the study area and the project, they will be discussed further in this section.

New South Wales

The bed of the Tweed River up to the Mean High Water Mark is owned by the Crown and administered by the NSW Department of Land and Water Conservation (DLWC).

The majority of the Tweed River is unzoned under the Tweed Local Environmental Plan 1987(LEP) (Jane Lofthouse, Tweed Shire Council, *pers. com.*). However, the areas surrounding the following mangrove islands and associated wetlands are included in the "7(a) - Environmental Protection Wetlands Zone" in the Tweed LEP:

- Ukerebagh Passage;
- Boyds, Turners, Dock, Caddys and Daveys Islands in Terranora Creek;
- Womgin, Big and Tommy's Islands in Terranora Broadwater;
- Mangrove Island in Cobaki Broadwater; and
- Tonys, Tims, Lillies and parts of Chinderah and Dodds Islands in the Tweed River.

These islands are owned by the Crown and managed by the NSW Department of Land and Water Conservation. Accordingly, any developments on this Crown Land require the Crown's consent and Tweed Shire Council is the Determining Authority.

Ukerebagh Island and Stotts Island are zoned "8(a) - National Parks and Nature Reserves Zone" and both are gazetted Nature Reserves under the management of the NSW National Parks and Wildlife Service.

Various allotments within Fingal are owned by the Tweed Byron Local Aboriginal Land Council and occupied by the local Aboriginal community (Jane Lofthouse, Tweed River Shire Council, *pers. com.*) (Figure 4.6.2). These holdings are described as follows:

- two isolated allotments located to the north and west of the Fingal headland; and
- several adjacent residential allotments along Letitia Road included in the "Residential A - Flood Prone", "Residential B" and "Urban Expansion" zones under the Tweed LEP.

Aboriginal Land Claim

The Tweed Byron Aboriginal Land Council has lodged a claim for additional land on Letitia Spit. This matter is currently before the courts.

Native Title

The National Native Title Tribunal has received several Native Title Claims over lands within the study area from various Aboriginal communities. Native Title determinations are currently being sought by these claimants as shown in Table 4.6.1.

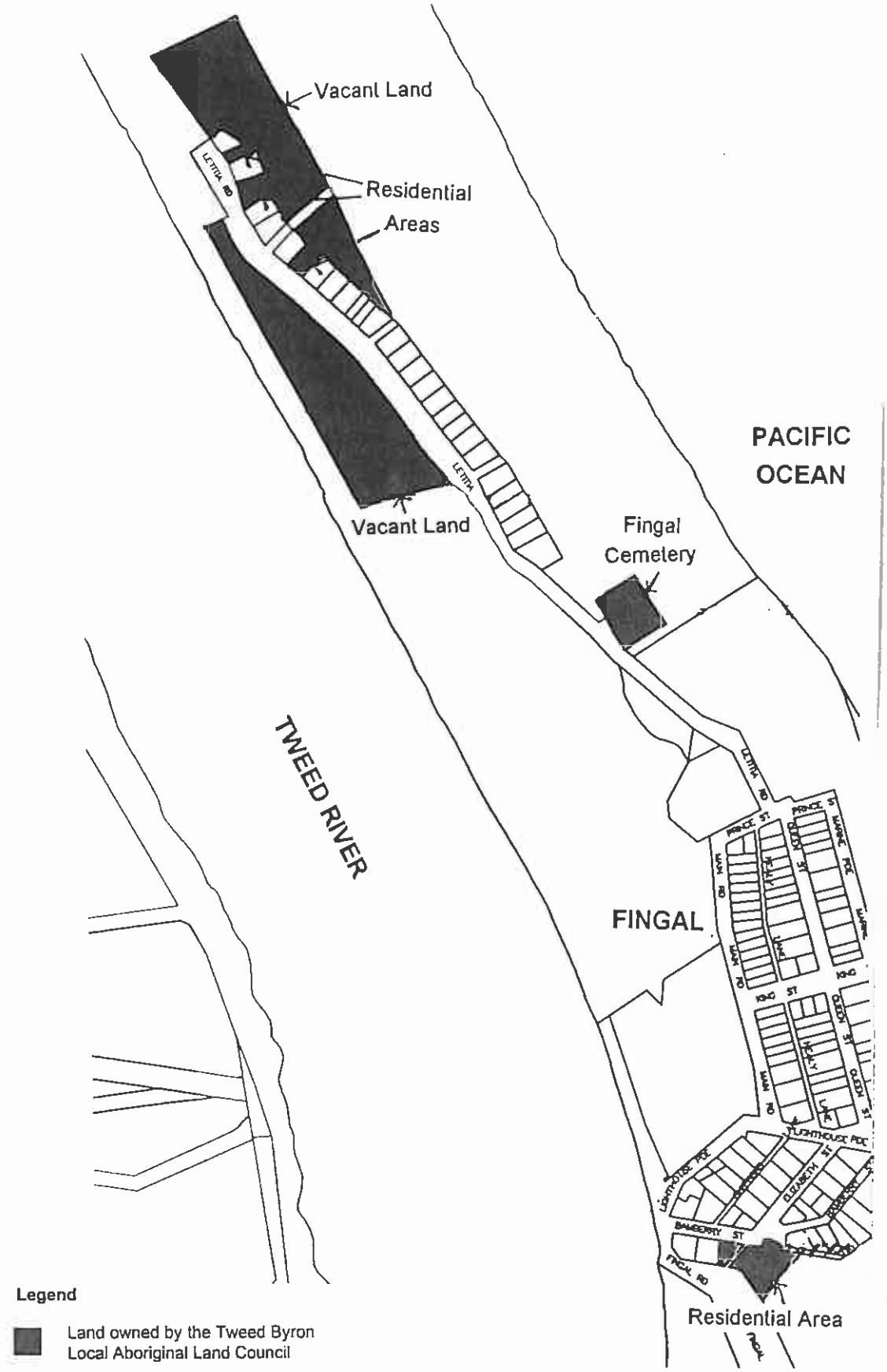


Figure 4.6.2
Aboriginal Land Holdings at Fingal Head

Source: Tweed Shire Council, 1996

Table 4.6.1 Native Title Claims within the Study Area

Claimant/s	Area	Location in Study Area	Description
Pooningbah Aboriginal Community Corporation Ref. No. NC96/3	Tweed Shire Council, NSW	Fingal Peninsula, Kerosene Inlet, Wommin Lagoon and Wommin Lakes.	All lands on the peninsula bounded by the High Water Mark. Extends north of Waugh Street, Fingal Head to the Tweed River and Pacific Ocean. Excludes freehold land, dedicated roads and the Fingal Caravan Park.
Cudgenburra Ref. No. NC96/22	Tweed Shire Council, NSW	Fingal Peninsula, Kerosene Inlet, Wommin Lagoon and Wommin Lakes.	As above.
David Dillon on behalf of the Kombumerri People Ref. No. QC96/69	Gold Coast City Council, Qld; Tweed Shire Council and others, NSW	Land and sea in the area of Southport and Tweed Heads. Includes State Forests in Qld and all other forests in NSW; Terrestrial Conservation Reserves (incl. wetlands) in Qld; National Parks, Recreation Reserves, Environmental Parks, other conservation reserves (incl. wetlands) and Marine Conservation Areas (incl. fish habitat reserves) in NSW. Includes beaches and tidal zones; inland waters and offshore waters. Also all unallocated State land in Qld and NSW.	Defined by the Coomera River to the north, west and south and the Terranora Broadwater and the Tweed River entrance to the east. Also from the mouth of the Coomera River seawards to the continental shelf.

(Source: National Native Title Tribunal (January 1997).)
Note: Detailed and accurate maps of these areas were unavailable from the National Native Title Tribunal at the time of writing. Due to the sensitive and exacting nature of this information, an approximate illustration of these areas has not been included.

It is recognised that the granting of native title cannot remove existing private use rights on freehold lands nor any licenses, permits and leases which have been previously approved. Similarly, it is noted that native title rights may co-exist with other interests or uses.

A decision to uphold native title rights within the study area may have implications for the planning and construction of the permanent sand bypassing system. Whilst ongoing consultation and negotiation would be required with the relevant Aboriginal communities, provisions in the *Tweed River Entrance Sand Bypassing Act 1995* ensure that land will be available for the project if required.

Mining Interests

A Mineral Exploration Permit has previously been issued within the study area by the Department (Don Michael, Queensland Department of Mines and Energy, pers. comm). The Permit was issued in June 1980 to Ocean Resources. The permit covered the areas offshore from the northern tip of Moreton Island to the state border. Extensive investigations were undertaken by Ocean Resources and CRA in a joint venture. The permit overlapped areas under both Commonwealth and State jurisdiction and was ruled invalid in 1983. A subsequent application was lodged by CRA and Ocean Resources for permits covering both Commonwealth and state areas under the respective processes. The applicants did not actively pursue the applications and a permit was not issued (Queensland DoE).

In February 1990 a new application was submitted by CRA and United Mineral Resources NL covering a similar area. To date the application is still outstanding and no permit has been issued (Queensland DoE).

Therefore there are no existing mineral exploration permits which are still current within the Queensland section of the study area.

The New South Wales Department of Mineral Resources confirmed that there were a number of existing mining leases, located within the vicinity of the study area. An application for an Exploration Licence for dredging and underground mining in the area south of Tumbulgum and the Stotts Island Nature Reserve within the Tweed River is also pending (Paul Gorrel, New South Wales Department of Minerals and Energy, *pers. comm.).*

Mining activities in New South Wales are located to the south of the Tweed River entrance and are therefore unlikely to be affected by the permanent sand bypassing system.

Easements

Discussions with the Tweed Shire and the Gold Coast City Councils indicated that there were not likely to be any major easements within the vicinity of the Tweed River entrance which could constrain the project (John McGrath, Gold Coast City Council; Doug Neal and John Henley, Tweed Shire Council, *pers. com.*). These discussions also established that the Tweed Shire Council and Gold Coast City Council would require more detailed information on the likely location of a preferred option/s to conduct a full internal investigation into the nearby easements and services .

Implications of Land Use, Zoning and Tenure

The existing ownership and management of the various lands and waterways within the study area is summarised in Table 4.6.2. The location and zoning of these areas is indicated on the Study Area Zoning Map (Figure 4.6.1).

The implication of this tenure pattern is that various authorities, private companies and community groups must be consulted during the preparation of this EIS/IAS and in relation to any future dredging activities (Section 2.4).

Table 4.6.2 Ownership and Management of the Relevant Lands and Waterways within the NSW Study Area

Land/Waterway	Designation	Ownership	Management
Land up to boulder wall along coastline.	Private properties, Council reserves and parkland included in various zones.	Varies between private property and Gold Coast City Council ownership.	Private/Council gazetted "erosion prone areas" managed by Gold Coast City Council.
Gold Coast beaches to 3 nautical miles to sea.	Unzoned land.	State Government controlled Crown land.	DNR and DoE gazetted "bathing reserves".
Offshore areas, between 3 and 70 nautical miles to sea.	Unzoned areas.	Federal Government controlled Crown land.	
Majority of Tweed River bed	Up to Mean High Water Mark unzoned in Tweed LEP	Crown Land	NSW Department of Land & Water Conservation (DLWC).
Ukerebagh Passage, Tweed River; Boyds, Turner, Dock, Caddys & Daveys Islands, Terranora Ck; Womgin, Big & Tommys Islands, Terranora Broadwater; Mangrove Island, Cobaki Broadwater; Tonys, Tims, Lillies and parts of Chinderah and Dodds Islands, Tweed River.	Zone 7(a) - "Environmental Protection (Wetlands) Zone" under Tweed LEP.	Crown Land	DLWC
Ukerebagh Island and Stotts Island, Tweed River	Zone 8(a) - "National Parks & Nature Reserves Zone" under LEP.	Crown Land; Gazetted "Nature Reserve".	NSW National Parks & Wildlife Service
Dredging and nourishment works, Tweed River	"Designated Development" under *EP & A Act 1979.*	Crown Land	*EP&A Act 1979*
Littoral Rainforest, Fingal Headland	Zone 6(c) - "Recreation (Special Purposes)"	Crown Land	DLWC
Aboriginal land parcels, Fingal	Zone "Residential A - Flood Prone", "Residential B" and "Urban Expansion" under Tweed LEP.	Tweed Byron Local Aboriginal Land Council	Tweed Byron Local Aboriginal Land Council

4.6.2 State Border

4.6.2.1 Description

The eastern most point of the State Border is located between Duranbah Beach and Snapper Rocks at Boundary Street, Tweed Heads and extends seaward three nautical miles. This position is clearly identified by the prominent Captain Cook Memorial atop Point Danger, which also accommodates the headquarters of the Point Danger Air Sea Rescue. The border continues inland along Boundary Street

before veering south along Dixon Street and then north-west along Razorback Road. It bisects the residential areas at Tweed Heads and the Coolangatta Airport before continuing northwards towards Tugun.

4.6.2.2 Implications

The Tweed River entrance and estuaries are located to the south of the border and within the general jurisdiction of the New South Wales Government and Tweed Shire Council. Apart from Duranbah Beach, the nourishment areas are located to the north of the border and consequently are controlled by the Queensland Government and the Gold Coast City Council.

As the state border forms the division between Queensland and New South Wales and between Gold Coast City and Tweed Shire, the area is subject to a number of different government controls and programmes as described in Section 4.6.1.

4.6.3 Aboriginal Heritage

A search of the Aboriginal Sites Register of the National Parks and Wildlife Service (NPWS) was undertaken and no Aboriginal sites were listed as having been recorded from within the study area. A search of the site report collection held by NPWS revealed that no specific survey reports covered the study area.

A detailed investigation and site survey was carried out by Piper (1991) building on the information obtained during an earlier study by Margrit Koettig (1988). The then Chairman of the Tweed-Byron Local Aboriginal Land Council (TBLALC) Mr Franc Krasna assisted in the survey. The locations of sites identified are indicated on Figure 4.6.3. Fourteen sites were located in the archaeological survey. All sites located were shell middens. Of these, nine (Sites 4, 6-13) were considered to be of high scientific significance due to the concentration of deposits thus enhancing their value in a local context. Sites 3 and 5 were considered to be of moderate significance, and Sites 1, 2 and 14 were considered to be of low significance.

It should be noted that the Aboriginal Community may place a greater value on the sites than is indicated by their scientific significance. Piper (1991) concludes that it is important to recognise that the surviving archaeological resource is only a fraction of the original extent and variety.

Three of these sites: Tweed Heads South Bora Ground, Sponsors Lagoon midden and the Ukerebagh midden are listed on the Register of the National Estate held by the Australian Heritage Commission.

Discussions with the Cultural Heritage branch of the Queensland Department of Environment indicated that there were no known Aboriginal cultural sites within the area proposed for beach nourishment works. This is probably due to the extensive urbanisation of the area.

Archaeological evidence indicates that Aboriginal people lived in the Tweed Heads area long before the arrival of Europeans. The earliest base date identified is 655 BP for a midden site on the northern side of the Tweed River opposite Chinderah Island (Barz, 1980), however middens excavated to the south on the Macleay River indicate that Aborigines have lived along the coast for at least the last 9,000 years (Lilley, 1981).

The coastal plains are thought to have been densely populated due to the availability of rich marine, aquatic, and forest food. The original inhabitants may have belonged to the Minjanbal people who are believed to have occupied an area between Byron Bay and Southport. It has also been suggested that these people were part of an even larger group, the Bundajalung, located between the Logan and the

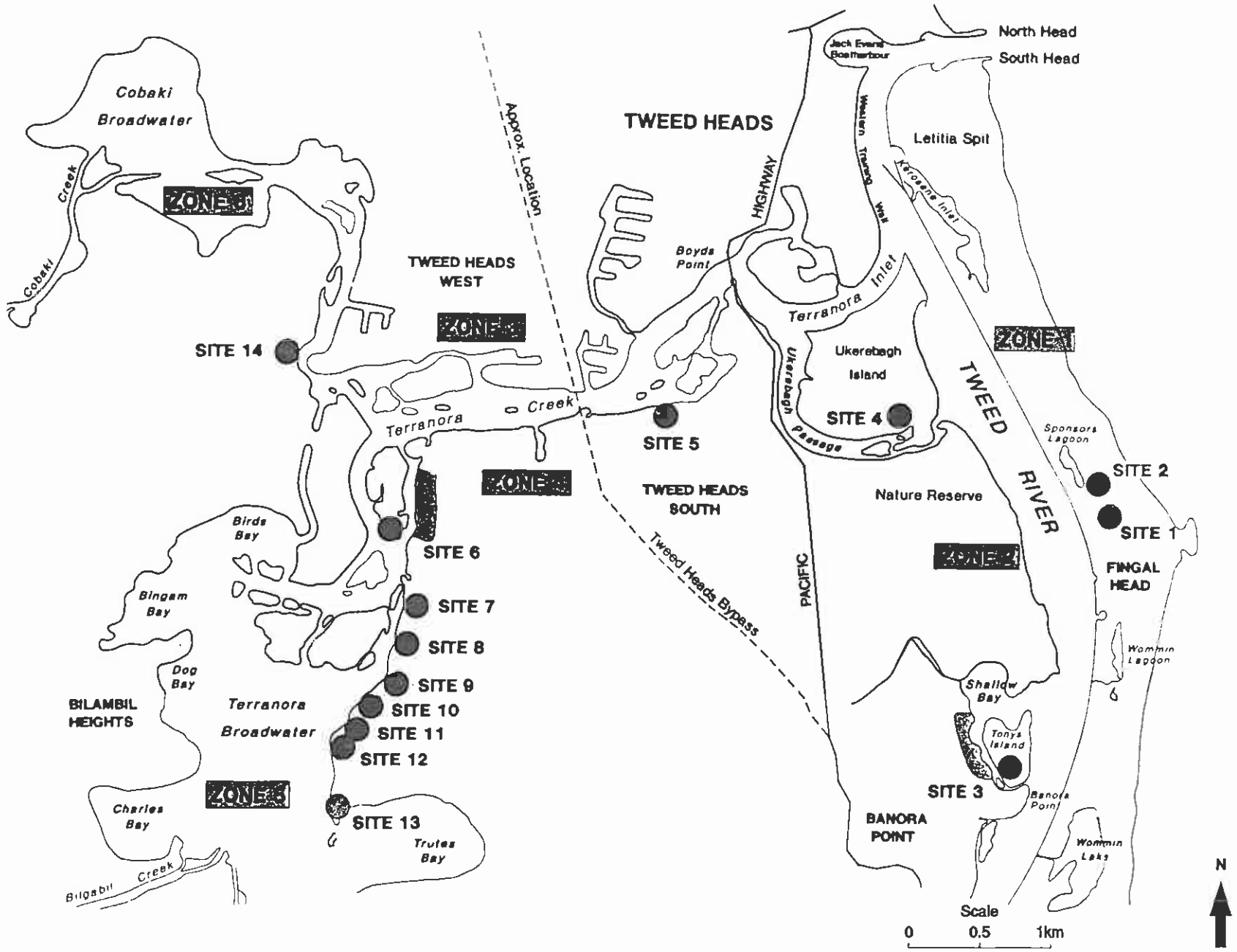


Figure 4.6.3
Archaeological Sites Located in June 1991

Source: Piper, 1991

Clarence Rivers. Such large language associations probably held little significance to Aborigines in an everyday sense, with local clan or land holding groups being more relevant (Piper, 1991).

Aboriginal archaeological sites within the study area are likely to be mainly shell middens. Shell middens are the remains of shellfish eaten by Aborigines. Typically they can come in a variety of shapes and sized depending on the nature of the activities that caused it. In trying to understand shell middens archaeologists have adopted a dichotomy between residential base camps and field camps based on observations of traditional Aboriginal activities. Residential base camps are where a wide variety of activities occur, such as processing of food, maintenance and manufacture of tools and sleeping. These camps are often thought to be specifically located adjacent to several micro-environmental zones (Bonhomme and Ruzer, 1994). Field camps are thought to be transient camps for single purpose activities such a bulk collection of shell fish. Only a limited range of activities occur on these sites.

In considering the study area it should be noted that Letitia Spit has been extensively disturbed due to sand mining and has built up due to the influence of the training walls, It is unlikely to contain Aboriginal sites as much of the spit was formed in the post contact period.

On the northern side of the Tweed River it appears that the terrain is much more stable and therefore it is possible that Aboriginal sites are located in this area. The general area would have offered a diversity of environmental zones to exploit and it seems likely that Aboriginal people would have utilised this area. This area therefore has some potential to contain Aboriginal archaeological sites. The extent to which sites will actually occur depends on how well they survive the intensive urban development in the area. However, it should be noted that archaeological works in the Central Coast of NSW has demonstrated that shell middens can survive amid intensive urban development (for example Hughes' work at Araluen Drive, Hardys Bay, reported by Bonhomme and Buzer, 1994).

In 1770 James Cook observed Aborigines to the south of Tweed Heads and in 1823 John Oxley encountered Aborigines at a camp in the vicinity of Chinderah (Piper, 1980). European settlement of the area commenced in the late 1820s for the exploitation of rich timber reserves, in particular the prized Red Cedar (*Toona Australis*). The following decades were marked by a decline in the Aboriginal population as a result of European diseases and forced removal from traditional lands. Regular skirmishes occurred, including a possible massacre at Fingal Head in the 1850s. South Sea Islanders were brought to the area in the late nineteenth century as a source of labour for the cane fields and eventually became integrated with the local Aborigines (Piper, 1991).

In the Tweed Heads area, Aborigines have lived on Ukerebagh Island, Greenbank Island and Letitia Spit since at least the turn of the century. In Tweed Heads there are at least two communities, an Aboriginal group and an Aboriginal - Islander group. The former is represented by the Tweed-Byron Local Aboriginal Land Council (TBLALC) and the latter by the Midjinbal Trading Company.

The community at Fingal is well established and many residents own their own properties. A land claim for the whole of Letitia Spit was submitted to the Land Claims Unit under the Provisions of the Land Rights Act (1983) in 1985. A small section of this claim was granted and the claim for the spit was resubmitted in early 1988. Another land claim was submitted in late 1987 including Wommin Lake. The 1987 and 1988 claims were rejected and the TBLALC has lodged an appeal. A decision on the appeal is pending.

Site 4-2-13 (Figure 4.6.4) at Fingal is an historical cemetery used by the Aboriginal and Islander community since at least early this century. Twenty marked graves and several unmarked graves of the ancestors of the people in the community at Fingal Head are located at this cemetery. The NPWS have recommended that this location be protected. Site 4-2-9 is a bora ring which is now managed by the Aboriginal community as part of the Minjangbal Resource Museum and Study Centre. Of the 33 sites recorded in this survey 8 were listed as being destroyed since initially recorded generally through agricultural activities or sand mining.

Cane (1989) identified the following areas of special significance on the Fingal Peninsula:

Letitia Spit

i. The Community residential area adjoining Letitia Spit Road.

ii. Baptism sites at Kerosene Bay and Sponsor Lagoon.

iii. The Fingal Head Cemetery.

iv. A massacre site south of Fingal headland.

v. Land claims west and east of the residential area.

Fingal Head

i. A natural cleft in the southern side of the headland, the home of a mythological creature called the Hairy Man.

ii. The Caves areas, destroyed by quarrying for the construction of the entrance training walls last century. The home of a large mythological dog.

iii. Soaks at the base of the quarry, the Council car park to the west and the southern face of Fingal Head.

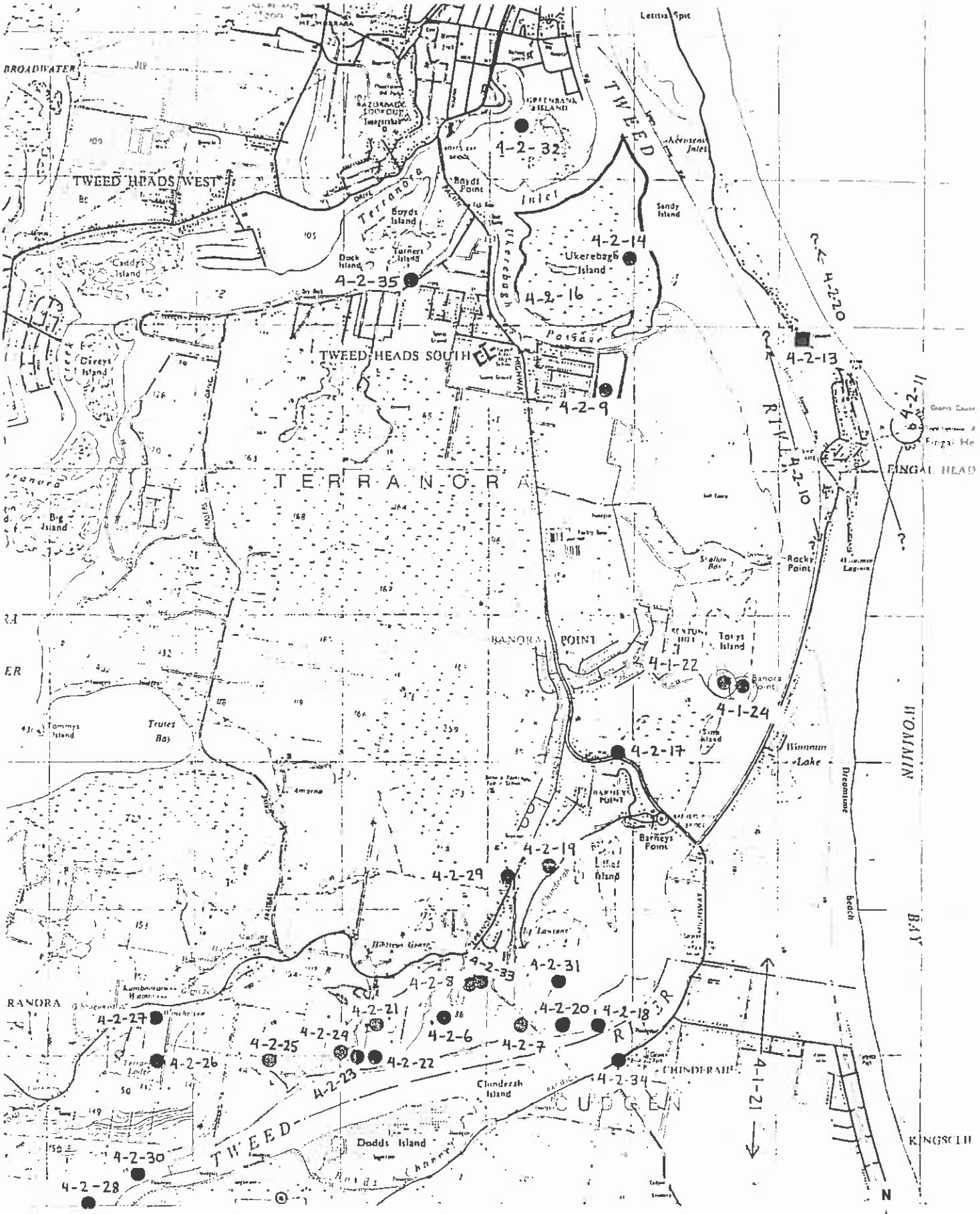
Assessment of Aboriginal Archaeological Potential

Archaeological potential is the likelihood of a study area to contain archaeological sites. To determine archaeological potential, the likelihood that sites occur within the study area needs to be established. For Aboriginal sites, given the length of Aboriginal occupation of the continent, it is likely that Aboriginal sites will occur in almost any locality. Of course some landforms are of a more recent period, such as filled areas, these are unlikely to have Aboriginal sites on them as they were created after traditional Aboriginal society had ceased to operate (they could however, have more recent Aboriginal sites). Other areas are too disturbed by post-contact activities such as urbanisation, land clearing, open cut mining and so on, to contain any evidence of Aboriginal occupation.

Overall, it appears that the study area does not have much potential to contain Aboriginal sites and relics. In the area of Letitia Spit the land was partly created in the post-contact era and then extensively sand mined which is likely to have destroyed all Aboriginal sites. On the northern side of the Tweed the area is so developed that many Aboriginal sites must have been destroyed. However it is possible that some sites remain although obscured by modern construction. This is because the development in this area would have had less impact on Aboriginal sites than sand mining. Nonetheless the area along the coast from Greenmount to Kirra Beach development seems to have been very intensive and likely to have destroyed any Aboriginal sites in this locality. The Point Danger area, and the area between Point Danger and Jack Evans boat harbour seem to be less intensively disturbed, and there remains the possibility that Aboriginal sites might remain in these areas.

4.6.4 Post Contact Heritage

The Heritage Branch, Department of Planning (NSW) has a database of shipwrecks on the coast of N.S.W. This is compiled from primary sources (such as newspapers and official documents) and secondary sources such as Loney (1987; 1991), Parsons (1972) and Richards (1977). It is not a comprehensive listing of all wrecks as it relies on newspaper reports and some wrecks may not be mentioned. Nor does it give exact locations, however, descriptions of locations are given in general



Legend

● Aboriginal Sites

Figure 4.6.4
Aboriginal Archaeological Sites Located in 1988

Source: Koettig, 1988

terms such as "wrecked on the Bar" or "south of XXX rocks". Finally it is difficult to establish the extent of salvage of wrecks. For example, *Atalanta* is listed in the database as being wrecked on the Tweed River bar, yet Keats explains that Peter Scott bought the wreck, repaired it and sold the vessel at a profit (1988:259). This points to the limitations of the data available to predict the location of archaeological sites.

Shipwrecks are shown on the various hydrological charts of the area. The *Panic of 66* is shown on the 1873 chart as being virtually due south of the Signal Station in an area now occupied by the northern breakwater. An unknown wreck is shown on the 1884 chart, again it appears to be located near the northern breakwater. The only wreck reported around this time is the *True Blue* a small ketch wrecked in October 1881. The wreck of the *Chinderah* is shown on the 1896 chart. The site is located in the middle of the channel between what was then the proposed north and south breakwaters this area would have been subject to extensive scouring and dredging over the years (all these charts are reproduced in Smith 1995).

In October 1994, Mapping and Hydrographic Surveys and Seascan Pty. Ltd. undertook bathymetric, Magnetic and Sub-bottom seismic surveys of the Tweed River Bar. The magnetic data was useful in locating possible shipwreck sites. A number of magnetic anomalies were identified, however they were not all specifically interpreted in the report nor did a further report in January 1995 shed much further light. The difficulties lies in the interpretation of the magnetic anomalies recorded based on the nature of the survey that was undertaken (which was not specifically designed for shipwreck identification). Nonetheless it is claimed that one zone (Zone 24) represents a possible shipwreck site, while magnetic anomalies immediately to the south of the southern breakwater were also thought to be the remains of a modern wreck. It should be noted in the context of the magnetometer survey that most of the wrecks were wooden vessels and thus their magnetic signature would be quite faint.

A wreck inspection of part of the study area was undertaken by Tim Smith, Maritime Archaeologist with the Department of Urban Affairs and Planning. The survey was designed to inspect areas where shipwreck material was reported to occur and therefore it did not systematically cover the entirety of the study area. The following sites were inspected: the site of a boiler off the northern breakwater and the *Tyalgum* wreck site on Duranbah Beach.

The boiler was thought to have come from either the steamer *Orana* (1891) or *Friendship* (1912) or the *Terranora* (1933) however given its proximity to the breakwater it could have just as easily been dumped there (Smith *pers. com.*). Projecting the 1884 map onto a modern orthophoto map suggests that the unidentified wreck was recorded in this vicinity. The boiler was relocated by the survey but the archaeological evidence was seen to be "too meagre to identify the origins of the boiler" (1995:26). The site's cultural significance was assessed as follows "the boiler has the potential to be a component of a Tweed Heads Interpretive Wreck Trail, being a readily assessable site for divers and land based visitors" (1995:35).

The *Tyalgum* wreck site was identified by photos of the wreck and by undertaking a magnetometer survey of Duranbah Beach. Two magnetic anomalies were identified. It appears that remains of the wreck were visible for some years before they were covered by sand when the northern breakwater was extended. The statement of significance for this is as follows

"The site tentatively attributed to the *Tyalgum* wreck site has the potential for further archaeological assessment of the surviving remains. Preliminary investigations suggest that a substantial portion of the vessel's lower hull might survive beneath Duranbah Beach which may assist in a positive identification of the site. A shipwreck ideally suited for a shore based Wreck Interpretation Trail, being located adjacent to a popular beach used for public recreation" (Smith 1995:36).

A shipwreck is located in Figure 14 of Druery and Curedale (1979) and identified as "sunken barge". Bruce Druery identified this as the remains of the tug "*Terranora*". The ship is likely to be covered with sand (Druery, *pers com.*).

Eighteen shipwrecks relate to the cedar trade date before 1870 (roughly the end of the trade). They seem to be typical of ships in the cedar trade falling within the specifications given by Keats for ships involved in cedar trading that is they are small vessels mostly under 50 tons. Fourteen are wooden schooners, two are wooden brigantines, one is a sloop and one a cutter.

Based on published dimensions, the smallest vessel in this group would be *Express* of 21 tons 11m long by 3.6m in the beam with a draught of 2m. The largest would be *Koh I Noor* a schooner of 101 tons some 27 m long, 6.3m beam and with a depth of 2.1m.

Nineteen shipwrecks are associated with the coastal trade. These are of a broader range in type of ship with seven screw steamers, two paddle steamers, five wooden schooners, two ketches, two launches and a tug. Generally these vessels are coastal traders but the *Terranora* a tug is more interesting as a representative of an unusual class of vessel for such a small port. There are a few larger vessels of 200 to 300 tons reflecting the improvements to the Tweed entrance.

The largest vessel in this group would be the *Orana* a screw steamer of 298 tons, 41m long, 7.5m in the beam with a depth of 3.3m. The smallest would be one of the launches. Only five of the ships were constructed of iron.

The exact locations of any of these wrecks is hard to pin down. Of the 37 wrecks it is known that one the *Atalanta* was salvaged. The locations of the wrecks of the *Alberta*, *Coolangatta* and *Terranora* are outside the study area (see Shipwreck data base, Druery and Curedale (1979) Fig 14, Keats 1988: 200). It appears that the *Tyalgum* is located on Duranbah Beach. The remaining wrecks occurred on the Tweed Heads bar with the wrecks being described as being either on the south or north entrance or more puzzlingly "off" the bar (presumably at sea in front of the bar). It is not clear how much of the shipwrecks have survived the construction of the breakwaters and the dredging.

It should also be noted that the inner training walls, being more than 50 years old, could also be considered a "relic" under the *Heritage Act 1977*.

The only post-contact heritage site in the vicinity of the study area listed in the Register of National Estate is the Fingal Head Lighthouse. This is quite a significant site and obviously it is related both to the training walls and the shipwrecks as part of the NSW Government's support for improved navigation. The site however is well away from the study area and will not be affected by the development.

Apart from the *Terranora* and the training walls, there are no known post-contact archaeological sites in the general locality of the study area, although from the historical records, 37 wrecks are known to have occurred in the area. This reflects the lack of detailed archaeological investigation in the Tweed Heads area.

Assessment of Maritime Archaeological Potential

Archaeological potential is the likelihood of a study area to contain archaeological sites. To determine archaeological potential the likelihood that sites occur within the study area needs to be established. Despite the vagaries of the historical documentation, it is clear that some ships were wrecked on the bar. Unless the ships were totally removed the remains would have been buried in the mobile sand at the entrance. Any remains buried would be in an anaerobic environment. Under these conditions there is a good chance of archaeological remains surviving. However, it is unlikely that these conditions would have remained stable as; the entrance and bar seem fairly mobile, the entrance has been dredged and the training walls built.

If shipwreck remains were exposed, they run the risk of torero worm (a marine borer) damage (for wooden remains) and corrosion for metal remains. Druery and Curedale (1979) note that extensive dredging in the bar area in January 1933 had lowered the bar but that within 5 months later the bar was at its highest. This suggests that archaeological remains may be exposed for short periods of time.

Construction of the training walls stabilised the position of the entrance and caused a build up of sand behind them. Ships wrecked to the north and to the south would be covered with this sand build up. However, despite indications of a shipwreck on Letitia Spit identified by the land magnetometer survey the extent of sand mining on Letitia Spit is likely to have destroyed any archaeological remains of shipwrecks in this area. Despite this there is some likelihood that archaeological remains of shipwreck will occur within the study area, although the evidence of the changing bar and entrance suggests that these remains may not be intact.

4.6.5 Socio-Economic Profile

The community groups which are most likely to be affected by a permanent dredging system are those communities surrounding the Tweed River entrance at Coolangatta and Tweed Heads. Consequently, this section of the report investigates the characteristics of the communities and businesses within the broad areas of Coolangatta and Tweed Heads based on statistical information from the Australian Bureau of Statistics and from reports by the Gold Coast City Council and Tweed Shire Council.

4.6.5.1 Population

South east Queensland and northern New South Wales are characterised by rapid recent population growth. This is evidenced in the population figures for both Coolangatta and Tweed Heads areas.

The most recent population estimates and projections for the Coolangatta statistical area are illustrated in Figure 4.6.5 below.

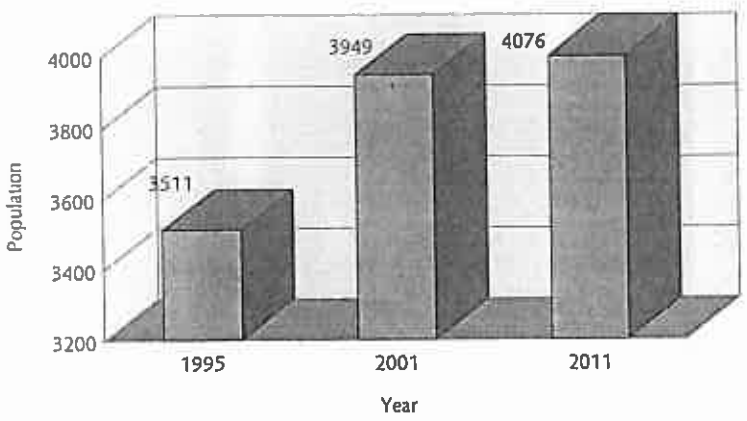


Figure 4.6.5 Population Estimates and Projections for Coolangatta

(Source: Gold Coast City Council Research Unit, 1995)

These projections indicate that population growth within the southern Gold Coast area will be highest over the next 5 years and then slow down after the year 2001. Based on these estimates, it is anticipated that consistent population growth will occur in Coolangatta.

The population estimates and projections for the Tweed Heads statistical subdivision area within Tweed Shire were estimated in the Council's Residential Development Strategy 1991. These figures are illustrated in Figure 4.6.6.

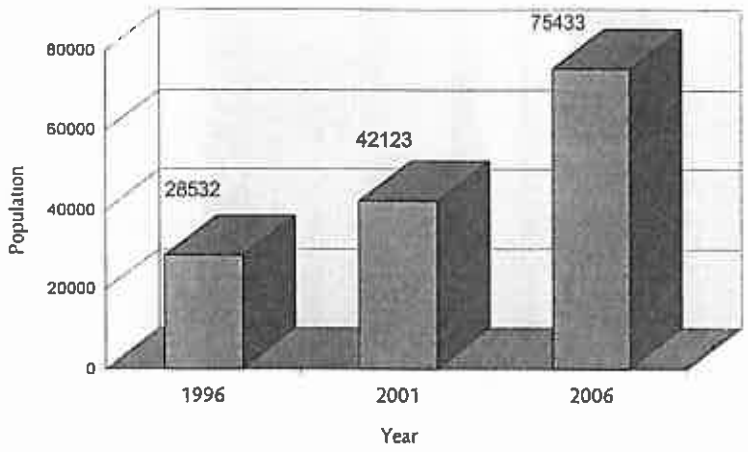


Figure 4.6.6 Population Estimates and Projections for Tweed Heads

(Source: Tweed Shire Council, 1995a and 1991)

Since this time, population growth in Tweed Heads statistical division has far exceeded the original expectations. The figures are based on an assessment of the approved and anticipated future residential development in the Tweed Heads area and the subsequent residential population.

It is noted that high population growth is expected in the currently undeveloped areas within Tweed Heads West, Banora Point and Bilambil Heights (Tweed Shire Council, 1996 and 1991). Tweed Heads South is likely to experience a small decline, followed by a substantial increase in population. Consistent population growth is anticipated for the Tweed Heads and Fingal areas adjacent to the Tweed River.

4.6.5.2 Gender

Coolangatta contains a slightly higher proportion of females (51.06%) than males (48.94%) (ABS, 1996b). Similarly, Tweed contains a population comprised of 51.4% females and 48.6% males (ABS, 1996a). These figures are consistent with the national 1991 Census figures where the proportion of females (50.37%) is slightly higher than males (49.63%) (ABS, 1991).

4.6.5.3 Age Structure

The age structure of the Tweed Heads and Coolangatta areas is characterised by an older population with a large proportion of mature aged citizens. The most recent 1991 Census indicated that the breakdown of the population age structure was as follows:

Table 4.6.3 Comparison of the Age Structure for Coolangatta, Tweed Heads and Australia

Statistical Area	Proportion of Respondents in Age Group (%)					
	0-14	15-29	30-44	45-59	60-74	75-90+
Coolangatta	7.6%	14.5%	13%	15.2%	36.2%	13.5%
Tweed Heads	17.4%	15.6%	19.2%	15.6%	24.9%	7.3%
Australia	16.3%	17.1%	39.5%	11.6%	11.1%	4.4%

(Sources: ABS, 1996a; 1991b and 1991)

From Table 4.6.3, it can be seen that nearly half of Coolangatta's population are over 60 years (49.7%) which is far in excess of the 1991 national figure of 11.3%. As a third of the population of Tweed Heads are also over 60 years (32.2%), the concentration of mature citizens in the study area is significantly higher than the national proportion.

The proportion of children under 15 years of age is much lower in Coolangatta (7.6%) than in Australia (22.4%). Whilst there is a slightly higher proportion of young people in Tweed Heads (17.4%), this proportion is still lower than the national average for people under 15 years. These figures support the dominance of older persons within the population, particularly within Coolangatta.

Similarly, the proportions of young adults (15-29 years) and adults (30-44) in both Coolangatta and Tweed Heads is lower than the national figures. More than one quarter (27.5%) of Coolangatta's population and approximately one third (34.8%) of Tweed Heads' population were aged between 19 and 44 years. The national proportion of persons in this age group was almost two thirds (63.2%). Consequently, the study area contains approximately half the proportion of 19-44 year olds as Australia.

The proportion of mature adults in the study area (45-59 years) is higher than the national figure (11.6%). Approximately 15% of the population in both Coolangatta and Tweed Heads are between 45-59 years.

These findings highlight the area's ageing population and its function as a popular retirement area. The proportion of children, teenagers, young adults and adults who live permanently within the study area is much lower than the national figures. This age structure results in a reduced number of young families and an increased proportion of retirees in the area.

4.6.5.4 Ethnicity

The study area contains a dominant proportion of people from Australia and other English speaking countries as shown in Table 4.6.4.

Table 4.6.4 Comparison of Birthplace (Countries) for Coolangatta, Tweed Heads and Australia

Birthplace	Coolangatta		Tweed Heads		Australia	
	No.	%	No.	%	No.	%
Main English Speaking Countries [1]	5838	92.6%	31206	95%	14.29mill	84.8%
Other Non-English Speaking Countries	271	4.3%	1116	3.4%	2.18mill.	13%
Not Stated	193	3.1%	536	1.6%	368659	2.2%
TOTAL	6302	100.0%	32858	100.0%	16.85mill	100.0%

(Source: Australian Bureau of Statistics, 1991 Census of Population and Housing Table B08 Birthplace Countries by Sex (from CD-ROM CLIB91)).

Note: (1) Includes Australia, Canada, Ireland, New Zealand, South Africa, the United Kingdom and the USA.

Table 4.6.4 indicates that the study area has a significantly lower proportion of people from non-English speaking countries (Coolangatta - 4.3% and Tweed Heads - 3.4%) than Australia (13%). From the people who originated from non-English speaking countries, Table 4.6.5 shows the most common countries of origin for the study area and Australia.

Table 4.6.5 Comparison of Birthplace for Most Frequent Non-English Speaking Countries for Coolangatta, Tweed Heads and Australia

Birthplace (Country) [1]	Coolangatta		Tweed Heads		Australia	
	No.	%	No.	%	No.	%
Germany	33	0.5%	141	0.4%	115223	0.7%
Greece	3	0.0%	28	0.1%	136135	0.8%
Italy	32	0.5%	77	0.2%	254294	1.5%
Netherlands	36	0.6%	177	0.5%	95709	0.6%
Vietnam	3	0.0%	0	0.0%	122304	0.7%
Yugoslavia	10	0.2%	39	0.1%	161138	1.0%
Other [2]	93	1.5%	370	1.1%	718556	4.3%

(Source: Australian Bureau of Statistics, 1991 Census of Population and Housing: Table B08 Birthplace (Countries) By Sex (from CD-ROM CLIB91)).

Note: (1) Most commonly occurring non-English speaking birthplace countries for Coolangatta, Tweed Heads and Australia are shown only. As a result, the total number is not given.

(2) Includes "inadequately described", "at sea" and "not elsewhere classified".

The table indicates that the people who were born in Germany, Italy and the Netherlands are fairly well represented within the study area. This pattern is fairly similar to the national pattern whereby people from Germany (0.7%), Greece (0.8%), Italy (1.5%) and the Netherlands (0.6%) are frequent. However, the study area contrasts with the Australian pattern which contains a larger proportion of citizens from Vietnam (0.7%) and Yugoslavia (1%).

It is recognised that a significant proportion of people across the study area and the nation are included in the "other" countries column and therefore not classified. While it is difficult to draw distinct comparisons between the study area and the nation given the small, relative size of the study area, this analysis has highlighted:

- the large majority of people from Australia and other English speaking countries in the study area; that
- the majority of ethnic people in the study area are from Germany, Italy and the Netherlands; and

- the proportion of ethnic people from particular non-English speaking countries in the study area is relatively similar to the Australian pattern.

4.6.5.5 Aboriginal and Torres Strait Islander Communities

A small number of people of Aboriginal and Torres Strait Islander descent reside within the study area. Coolangatta contains 77 people of Aboriginal descent (1.2% of total population) and 18 people from the Torres Strait Islands (0.3% of total population) (ABS, 1996b).

Tweed Heads contains a similar proportion of Aboriginal or Torres Strait Islander persons with 491 people of Aboriginal descent (1.5% of total population) and 278 people from the Torres Strait Islands (0.8% of total population) (ABS, 1996a).

4.6.5.6 Labour Force Status

The area's role as a retirement community results in a low level of labour force participation. Consequently, more than half the people in Coolangatta (62.3%) and Tweed Heads (52.2%) are not in the labour force (ABS, 1996a and 1996b).

From those people participating in the labour force, approximately one third of people were employed in part-time jobs and two thirds were employed in full time jobs. This indicates a high level of part-time and casual employment within Coolangatta and Tweed Heads, which may be attributable to the area's dominant retail and tourist industry.

Unemployment levels in Coolangatta and Tweed Heads in 1991 were significantly higher than the national average (10.3%) over 1991-92 (ABS ,Oct 1996). In the study area Coolangatta contained the worst unemployment rate at 22.2%, which was slightly higher than the 18% unemployment rate experienced within Tweed Heads (ABS, 1996a and 1996b).

In summary, the study area has been characterised by low labour force participation rates and a dramatically high unemployment rate in 1991.

4.6.5.7 Employment Industry

A large proportion of the local population are employed in commercial, retail, personal services and land development sectors resulting from the substantial tourist industry. Table 4.6.6 presents the most common employment sectors within the study area.

Table 4.6.6 Common Employment Sectors - Tweed Heads /Coolangatta /Australia

Industry Sector	Coolangatta - Employment in Sector (%)	Tweed Heads - Employment in Sector (%)	Australia - Employment in Sector (%)
Agriculture, Forestry, Fishing	1.9%	3.4%	4.5%
Manufacturing	10.1%	6.8%	13.1%
Construction	8.2%	8.9%	5.9%
Wholesale/Retail Trade	17.5%	22.1%	18.8%
Transport/Storage	4.2%	3.9%	4.6%
Finance, property and business services	9.9%	10.4%	11.1%
Public administration, defence	5.5%	2.7%	5.7%
Community Services	13.5%	14%	17.7%
Recreational, personal, other services	18.8%	18.1%	7%

(Sources: ABS, 1991, 1996a and 1996b)

As shown in Table 4.6.6, the largest sources of employment in the study area are the wholesale and retail trades, recreation and personal services, and community services. The construction and property services sectors are also substantial sources of employment.

While most sectors were fairly similar across Coolangatta, Tweed Heads and Australia, there are some notable exceptions:

- the recreational sector is two (2) times the national average indicating the importance of the tourist industry;
- local primary industries generate slightly less employment than Australia;
- local construction industries support more employees than Australia; and
- Tweed Heads employment in retail sector is slightly higher than in Australia.

4.6.5.8 Income

Annual individual incomes in the study area are generally lower than those within Australia, as shown in Table 4.6.7. In 1991, the median annual individual incomes for Coolangatta and Tweed Heads was $8000 - $12000, as compared to $14000 for Australia (ABS, 1996d; 1996e).

Table 4.6.7 Comparison of Annual Individual Income for Coolangatta, Tweed Heads and Australia

Income Group	Coolangatta Prop. (%)	Tweed Heads Prop (%)	Australia Prop. (%)
$0-$12 000	53%	51.3%	41.1%
$12 000 - $20 000	17.8%	19.4%	16.9%
$20 000 - $30 000	11.2%	13.5%	17.3%
$30 000 - $40 000	4.1%	5.2%	8.5%
$40 000 - $50 000	1.6%	1.3%	3.3%
$50 000 - $60 000	0.4%	0.6%	1.5%
$60 000 - $70 000	0.3%	0.2%	0.6%
Over $70 000	0.6%	0.4%	1.2%
Not Stated	11%	8.1%	9.4%
TOTAL	100%	100%	99.8%*

(Source: Australian Bureau of Statistics, 1991 Census of Population and Housing: B27 Annual Individual Income by Sex (from CD-ROM CLIB91)).

Note: * ABS proportions are given to one decimal place which may account for this inconsistency.

More than half of the people within Coolangatta (53%) and Tweed Heads (51.6%) had an annual income in the lowest income group between $0 - $12 000, as compared to a smaller proportion (41.1%) of Australians. Similarly, there was a slightly higher proportion of people in Coolangatta (17.8%) and Tweed Heads (19.4%) with incomes between $12 000 - $20 000 than there were in Australia (16.9%).

In the higher $20 000 - Over $70 000 income groups, there was a consistently higher proportion of Australians than the proportion of people in Coolangatta and Tweed Heads.

Overall, the study area's concentration of people with incomes in the lower income groups may be attributed to the area's role as a retirement destination and its relatively high level of part-time and casual employment (Sections 4.6.5.3 and 4.6.5.6).

4.6.5.9 Household Tenure

Coolangatta is characterised by a high proportion of people renting their dwellings (50.62%), which is approximately twice the proportion of rentals for Tweed Heads (27%) and Australia (25.6%). In contrast, Tweed Heads reflects the Australian trend whereby the large majority of people either own, or are purchasing, their own dwellings. Table 4.6.8 indicates the comparison of household tenure across the study area during 1991 and in Australia during 1990.

Table 4.6.8 Comparison of Household Tenure for Coolangatta, Tweed Heads and Australia

Statistical Area	Owned	Being purchased	Rented	Other
Coolangatta	37.5%	6.3%	50.62%	5.54%
Tweed Heads	49.5%	19%	27%	4.4%
Australia	42.4%	29.2%	25.6%	2.8%

(Sources: ABS, 1996a; 1996b and 1996c)

4.6.5.10 Summary

The socio-economic profile of the study area has been discussed in this section and may be characterised as follows:

- Majority of the population are either mature age adults or senior citizens;
- Substantial urban development and population growth is anticipated in Tweed Heads West, Banora Point, Bilambil Heights and Tweed Heads South;
- Consistent population growth is expected for the areas surrounding the Tweed River entrance at Coolangatta, Tweed Heads and Fingal;
- The majority of the citizens were born in Australia and other English speaking countries;
- Citizens who were born in non-English speaking countries were mostly from Germany, Italy and the Netherlands;
- Aboriginal and Torres Strait Islander communities are present, particularly in the Tweed Heads area;
- Employment sources are concentrated in the wholesale and retail, recreational and personal services, and the community services sectors;
- Incomes in the study area are substantially lower than national incomes; and
- Coolangatta has a high proportion of people in rental dwellings in contrast to Tweed Heads which contains a higher proportion of people in privately owned dwellings.

The demographic characteristics within Coolangatta reflect its role as a high density tourist development area where the population experiences seasonal changes as a result of the tourism industry. In contrast, Tweed Heads contains a more family-based population structure. Large proportions of people over 65 years of age, particularly in Coolangatta, indicate the presence of a large, retired community. These findings highlight the area's role as a significant retirement location and as a tourist resort which experiences substantial, seasonal changes in population and residential accommodation.

4.6.6 Business, Recreation and Tourism

4.6.6.1 Business

The diversity and prosperity of the business activities within the Tweed Heads and Coolangatta regions indicates a thriving tourist and business economy. The majority of the business opportunities and employment sources are contained within the commercial, land development and hospitality related industries. Within Coolangatta alone, the retail trade comprised the largest number of businesses in March 1994 (81 businesses); followed by property and business services (65 businesses) and accommodation, cafes and restaurants (49 businesses) (ABS, 1994).

The major employment sources, as stated in the previous section, support the dominance of commercial and retail services, hospitality services and construction and property services within the local economy.

Retail shops, professional offices and commercial services at Tweed Heads and Coolangatta offer food, surf clothes, surf boards and accessories, banking facilities, real estate services, cafes, personal and other services to both tourists, visitors and permanent residents.

The local shopping centres at Tugun and Kirra provide a range of beach-side convenience facilities such as food stores and cafes, newsagents, convenience stores, bakeries, hairdressers, bars and surf shops. Return Serviceman's League and bowling clubs within the area represent substantial business enterprises which provide food and recreational facilities for visitors and local residents.

A critical factor in the viability and vitality of these businesses is the integrity of the area's natural attractions and the resultant trade from tourists and visitors.

The employment within the agriculture, fishing and forestry sector within Tweed Heads (3.4%) is most likely attributable to the area's role as a major fishing port (section 4.6.5.7).

Commercial fishing activities in and around the Tweed River comprise:

- trawl fishing;
- line and trap fishing;
- ocean and estuary fishing; and
- oyster production from aquaculture.

Trawl fishing operators near Tweed Heads are known to catch mostly ocean king prawns. In November 1996, the Tweed Heads Fisheries Office indicated that four prawn trawlers operated within the Tweed River and a further 12 to 15 licensed prawn trawlers frequently utilised the Tweed Heads port (Andrew Mann, Tweed Heads Fisheries Office, *pers. com.*) The feasibility of their trawl fishing activities is limited by competition from similar operations in Southport and the prevailing difficult climatic and navigation conditions.

The 10 to 15 local trap and line fishing vessels concentrate on catching spanner crabs and snapper as well as shark, cod, pearl perch, mackerel and murwong (Andrew Mann, *pers. com*). Again, it is noted that these activities are severely hindered by the prevailing navigation conditions.

The potential for ocean beach and estuary fishing operations has been diminished by the over exploitation of the resource and reduced water quality in the Tweed River (McGowan International, 1991). However, approximately 10 commercial fishing crews currently mesh fish in the river, catching mostly Mullet, black bream, Flathead, jewfish and prawns (Andrew Mann, *pers. com.*).

A number of oyster farms operate within the western upstream section of the Tweed River in the Terranora Broadwater. It is noted that these oyster farms require efficient flushing of the estuary to ensure a high water quality (McGowan International, 1991). As further urban development is planned for the areas surrounding the Broadwater, it is likely that the levels of pollution and siltation within the Broadwater may increase (Tweed Shire Council, 1996).

Estimates in 1985/1986 placed the value of the commercial fishing industry at $4.2 million which was estimated as adding a further $3.4 million to the Tweed Heads and Coolangatta economy (Griffith University, 1985/86).

Previous constraints on the commercial fishing industry have included:

- declining fish and seafood resources;
- licence restrictions from legislation;
- lack of capital; and the
- shallow entrance at Tweed River. (McGowan International, 1991)

The commercial fishing industry is not controlled by a local fishermen's cooperative. Consequently, fishing operators either hold an Exemption Certificate whereby they sell to seafood wholesalers and retailers or else they may hold a Contents Certificate whereby they can sell their catch themselves (Andrew Mann, *pers. com.*). A number of seafood wholesalers and retailers are established in the area, including:

- Deep Sea Fisheries, Chinderah;
- PKG's market, Tweed Heads;
- G & G Seafoods, Tweed Heads;
- Wharf Seafoods, Tweed Heads;
- Tweed River Seafoods, Chinderah; and
- DeCosti's Seafood, Tweed Heads.

Commercial fishing represents a significant industry in the Tweed Heads area which is responsible for supplying seafood to the main cities. Improvements to the depth and navigability of the Tweed River entrance will have positive financial benefits for both the commercial and recreational fishing sectors. Refer to section 4.6.8 for a detailed description of the existing navigation conditions within the Tweed River.

4.6.6.2 Recreation

The southern Gold Coast beaches and the Tweed River offer a diverse range of water-based recreational opportunities for visitors and residents in the area. Beaches provide opportunities for swimming, surfing, commercial and recreational fishing, walking, jogging and relaxing on the beach. Snorkelling is a popular activity off the rocky headlands and diving cruises operate off-shore around Cook Island and Kirra Reef.

The Tweed River is also used for other recreational pursuits such as fishing, rowing, sailing, canoeing and diving. The following range of recreational activities outlined in Table 4.6.9 have been observed adjacent to the beaches and the river:

Table 4.6.9 Recreational Activities - Tweed Heads/Coolangatta

Bait gathering	Kite Flying	Skateboarding
Beach-combing	Oyster gathering	Snorkelling
Bird watching	Paddleboating	Sunbaking
Boogey-boarding	Parasailing	Surfing
Body-surfing	Picnicking	Surf skiing
Canoeing	Sailboarding	Swimming
Cycling	Power boating	Walking
Dog walking	Rowing	Water skiing
Beach and boat fishing	Dinghy sailing	Houseboating
Diving	River cruising	Rollerblading

(Source: Public Works, 1991q)

Surfing, diving and recreational boating and fishing activities inject a substantial amount of money into the area's economy as well as creating local employment opportunities.

4.6.6.3 Beach Recreation

The southern Gold Coast beaches make up an important part of the world renowned recreational amenity of the Gold Coast region. The area has a considerable attraction for beach users (both tourists and locals) for a wide range of activities such as sunbathing, swimming, body surfing and boardriding. Within the study area Rainbow Bay and Greenmount beaches often provide relatively safe bathing during moderate to high offshore wave conditions due to the protection afforded by Point Danger.

A number of surf lifesaving clubs have been established in the area and provide important services of patrolling and rescue to general beach users, these include:

- Rainbow Bay, established in 1963;
- Tweed Heads and Coolangatta (at Greenmount Beach), established in 1911;
- Coolangatta, established in 1958;
- Kirra, established in 1916; and
- North Kirra, established in 1949.

The Australian Beach Safety and Management Programme is a joint initiative of Surf Life Saving Australia and the University of Sydney Coastal Studies Unit. This Programme provides assessment of beach hazards and general management information for specific beaches throughout Australia and is designed for use by surf life saving clubs in their daily operations. A preliminary draft of the beach hazard assessment for beaches in the southern Gold Coast area has been provided by Surf Life Saving Australia. This information, along with discussions held with officers of Surf Life Saving Queensland (Peter Dawes, *pers. comm.*) provides the basis for the following summary of beach recreation :

- Rainbow Bay and Greenmount beaches offer the most sheltered conditions due to the protection afforded by Point Danger and Greenmount headland. Wave conditions are also controlled by the nearshore sand shoals which often form between Snapper Rocks and Coolangatta and which in turn are affected by the variability in sand supply past Point Danger. Conditions are favourable when the shoals are well formed due to their effect in dissipating wave energy and therefore the tendency of boardriders to avoid the inshore areas;
- Coolangatta beach is generally more exposed than Greenmount however is relatively more sheltered than the open eastward facing Gold Coast beaches. The centre of this beach is generally a transition from the nearshore shoal formation to the typical beach/bar formation. The characteristics can vary greatly depending on the amount of sand in the nearshore areas. Rip currents can occasionally form in this area which cut through the bar system and can tend to progress along the beach. Overall the processes are very dynamic and may cause conditions to change rapidly.
- Due to the relatively 'hard' configuration of groynes in a beach system, a permanent rip current normally forms adjacent to the Kirra Point and Miles Street groynes. These rip currents tend to be a hazard for inexperienced swimmers or boogie board riders as they can be rapidly swept seawards and downdrift of the groyne to deeper water. These problems are exacerbated by the lack of sandy beaches immediately west of the groynes which create additional hazards to a swimmer leaving the water due to the seawalls and the rocky seabed.

Whilst a number of the beaches in the study area are recognised as high quality boardriding sites, certain wave types that may not be ideal for board riders may produce good conditions for other surfing (either boogie board, knee board, surf ski or body surfers). These people often represent a significant proportion of surfers; boogie boards are particularly popular with younger surfers. The ability of these groups to use and enjoy surf conditions is often at conflict with surfboard riders. Hence sub-optimum surfboard riding quality at some parts of the beach system causing boardriders to move elsewhere can be beneficial for this significant group of users.

4.6.6.4 Surfing Sites

Duranbah and Kirra beaches and the adjacent Snapper Rocks area are well recognised as some of the most consistent and popular surf breaks in Australia (Hoskins and Deane, *pers. com.*, Australian Surf Riders Association of Queensland Inc.). It is recognised that the good surfing conditions at Duranbah have resulted largely from the changes caused by the Tweed River training walls.

Ideal surf conditions involve:

- relatively long period easterly to south-easterly swell;
- light off-shore winds; and
- adequate sand supplies from the south being able to move northwards (by littoral drift) towards Snapper Rocks, Rainbow Bay and Greenmount Beach (Bruce Lee, Snapper Rocks Surf Riders Association, *pers. com.*).

During such conditions in October 1996, when there was only a 1m swell, a local surfer estimated that there were approximately 100 surfers at Kirra, 50 surfers at Rainbow Bay and 50 surfers at Coolangatta in addition to a large number of surfers at Duranbah Beach (Bruce Lee, *pers. com.*).

The local popularity of surfing has lead to the establishment of various surfboard, body-boarding, surf clothing and surf accessories stores.

The Snapper Rocks Surf Rider's Association recently estimated, based on these stores, that 1200 people were employed in surfing-related businesses and that the industry was worth in excess of $160 million to the area between Burleigh Heads and Tugun (Bruce Lee, *pers. com.*). These figures support the popularity of the southern Gold Coast beaches as a surfing destination. It is noted that a significant proportion of surfers travel from outside the local area such as Brisbane or further afield. In addition, regular surfing competitions such as the "Iron Man" event are held at the beaches.

The value of the southern Gold Coast beaches as a lucrative economic and recreational resource highlights the importance of maintaining good quality surfing conditions in the future.

Surfing conditions have been assessed for all surf sites within the Project area, from Duranbah Beach in New South Wales through to North Kirra in Queensland. The analysis includes data obtained from meetings with surfers, surfing surveys, hydrosurveys and the Surf Impact Assessment prepared by Moffatt and Nichol Engineers (Technical Appendix III). The area was inspected with representatives of the surfboard riding fraternity, in August 1996, along with Dr James 'Kimo' Walker of Moffatt & Nichol. The overall response of the beaches to the Stage 1A dredging at that time and the generic elements of a permanent bypass system were discussed. Detailed notes of the meeting were circulated for comment.

The following discussions are a qualitative assessment of surfing conditions for the period April 1995 to October 1996. Where possible, links have been established between relevant monitoring data and changes in surfing conditions.

Letitia Spit

Letitia Spit has a persistent, continuous shore-parallel beach bar. Walker (Technical Appendix III) notes that the prevailing SE swell refracts into the beach bar and breaks with a very acute peel angle of approximately 20 degrees. These conditions are not conducive to good surfing.

However, randomly located shore-normal gutters offer transient (ie. vary from day to day) surfing sites with rides less than 100 m.

Letitia Spit is generally not well known as a surf site because of the availability of much better sites with easier access and the tendency for Letitia to have onshore winds during desirable wave conditions (Technical Appendix III). It is not used significantly for general beach use or casual surfing.

Tweed Entrance Bar

The convex shape and wave current interaction effects on the entrance bar provide many surfing opportunities with a wide range of wave peel angles. Southeast waves break on the southeast face, creating a left peel with a 40 degree angle and Walker (Technical Appendix III) classifies the area as having excellent to intermediate surf conditions.

Walker identifies surf sites as south training wall, left bar and right bar. These sites are well offshore, tend to "work" only during large swell and tend to be used by experienced board riders when regular sites are unsuitable.

Duranbah

Historically, the Tweed Entrance training walls are credited with creating rideable surf at Duranbah although this was not exploited until the early 1980s out of previous concerns relating to the possibility of shark attacks near estuary mouths. Ironically, the changes caused by the Tweed training walls have allowed the formation of a new popular surfing location of Duranbah, considered to offer among the best surf for board and boogie-board riders in the region.

Wave refraction patterns caused by the offshore shape of the entrance bar, serve to focus wave energy at Duranbah and create crossing wave trains, referred to by surfers as "A-frames". These factors contribute to the high surf quality of the site. For many years, Duranbah area has been highly valued by the surfing community for its quality of surf characterised by a steep take-off and fast ride. The "A-frame" effect cause wave heights to amplify. Wave transformation modelling (Technical Appendix II) confirms that wave heights can be amplified to be over twice the height of the adjacent beaches at Snapper Rocks and at Letitia Spit, during southeast swell.

Rides can be left or right with a variety of peel angles. Peel angles of 40 degrees on hard plunging waves are common and Walker (Technical Appendix III) classifies surfing conditions as intermediate to expert. Analysis of hydrosurveys, cross-referenced with surfers' comments indicates that, initially, Stage 1A bar dredging reflected wave energy seaward transmitting less energy inshore, creating very poor surf conditions through early 1996, although it is fair to say that much of this was caused by unfavourable wave climate. Another negative impact on surf quality was that wave refraction patterns were changed by the dredging, causing some reduction of the A-frame effect (Technical Appendix III).

The May 1996 storm removed much of the outer portions of the shoals (-9m to -5m RL) and a storm bar was created along the -3m to -4m contours. This caused surf quality to degenerate with waves 'spilling' and 'closing-out' instead of 'plunging' with an A-frame approach. This was due to waves encountering a flatter-edged shoal and shore parallel storm bar system as opposed to the original convex shoal approach. These surf conditions led surfers to believe there was too much sand in the Duranbah system. By October/November 1996, however, the shoals had been reworked and it was reported that they were providing some of the best surfing conditions Duranbah has ever seen (Lee, *pers. comm*).

Snapper Rocks

Surf quality at Snapper Rocks varies in response to wave climate and the presence or absence of sand in the nearshore area. Walker (Technical Appendix III) notes that waves from the southeast and east refract around Snapper Rocks and bend into the beaches, peeling as they move towards shore. The area around Snapper Rocks is generally lean of sand, but when sand is present in sufficient quantities excellent surfing conditions occur. Surfers report that when there is an adequate sand supply, waves peel around Snapper Point and it is not unusual to find a takeoff point near the rocks (when SE swell is operating) from which waves can be ridden almost to and past Greenmount (i.e., up to 1km). Surfers have indicated, however, that the supply of sand has been poor and erratic for decades and these conditions have seldom occurred in recent years.

The lack of sand in the area can be exacerbated by storms (especially from the northeast), which scour the nearshore reef when there is insufficient sediment supply from the south. In the case of the May storm, this scenario created an immense scour hole 11m (RL) deep and over 200m wide just north of Snapper Rocks. This feature had two negative results with respect to surfing conditions:

1. The hole prevented rideable waves from peaking at Snapper Rocks (i.e., too deep for waves to break); and
2. Sediment which eroded from the area moved in a slug to form a large sand bank offshore of Rainbow Bay. This, coupled with the inner nearshore nourishment material, effectively tripped approaching waves, causing them to close out before reaching Rainbow Bay.

At surfers' requests, approximately 55,000m^3 of nourishment material was placed in the vicinity of the scour hole, in an effort to reduce its size and therefore its negative impacts on surfing conditions (Section 4.2.2.3). The nourishment effectively reduced the depth of the hole to -7 m RL, almost returning to its pre-Stage 1A dredging depth of -6m RL. In October 1996, it was reported that Snapper Rocks Point was just beginning to break, with a daily increase in size (Standing, Facsimile 1/11/96). This tends to confirm the need for a strong and reliable northerly sand supply along the eastern (ocean) side of Point Danger and into Snapper Rocks to maintain persistently good surfing conditions in that area.

Snapper Rocks to Coolangatta

Surf sites along this stretch of the coast include Marley Rocks (just west of Snapper Rocks), Rainbow Bay, Greenmount and Coolangatta Beaches. Walker (Technical Appendix III) points out that the key to good surfing conditions in these areas is the availability of sufficient quantities of sand in the nearshore profile to maintain persistent nearshore bars.

When little sand is present and the rock bottom is exposed, the milder bottom slope produces spilling breakers close to shore. However, if a longshore sand bar exists, stretching along the beaches in depths of -2m to -3m, surf quality is at its best. The bar's steeper slope generally produces a stronger break with a rideable peel velocity which can run the full length of the beaches. Walker (Technical Appendix III) points out that because of the angle of approach, shoaling waves feel an effective bar slope which is significantly milder than that felt at Kirra or Duranbah. Surf therefore tends to be smaller producing a milder plunging to spilling wave. Walker classifies surfing conditions as beginner to intermediate. A large number of beginner and intermediate surfers use the area and it is a valuable surfing resource for board riders, body surfers and boogie boarders.

Between April, 1995 and August 1996, approximately 295,000m^3 of nourishment was placed subaerially along the beaches. Eighty five percent of the subaerial nourishment on the beaches of Rainbow, Coolangatta, Kirra and North Kirra was moved under the action of waves to the nearshore zone, forming nearshore bars. Because of these bars, surfers reported excellent surfing conditions during times of swell.

Kirra Point

Prior to 1973, this was a natural rocky headland and one of the world's renowned surf sites, with high quality rides of 200m to 500m in length lasting up to 60 seconds with a peel angle (35 degrees) near the limit of surfability (Technical Appendix III).

In 1973, a groyne was extended from Kirra Point to stabilise Coolangatta Beach. It also had major impacts on the surfing at Kirra associated with initial interruption of sand supply and subsequent ongoing modification of the nature of sand movement through this area. Once the groyne area filled with sediment, it effectively moved the sand bar system at the groyne location seaward by about 100m, lengthening the ride for surfers at Kirra (Walker, Technical Appendix III).

Walker classifies the site as intermediate to expert. A major factor contributing to the excellent surf is the existence of a sand bar system, just offshore, which promotes a smooth, well-formed peel with a hard plunge. This sand bar exists when there is strong natural longshore transport of sand through this beach system.

During the Stage 1A dredging, approximately 630,000m^3 was placed in the Outer Nearshore Deposition Area and 290,000m^3 was placed subaerially along Kirra Beach. The primary influence on surfing conditions resulted from erosion of subaerial sediment from the beachface and influx of sediment around Kirra Point groyne from areas to the east. This sediment formed an extensive bar system stretching along all of Kirra and North Kirra which is reported by surfers to have greatly enhanced the surfing characteristics of the area. The Billabong Pro surfing competition was held at Kirra in February of 1996, with excellent surfing conditions coming in the last few days of competition (Tracks, April 1996).

In June of 1996, 30m of the end of the groyne were removed. It is expected that this will shorten the ride and create a more acute peel angle (Walker, Technical Appendix III). Walker recommends that careful monitoring be undertaken to determine the exact extent of the changes.

4.6.6.5 Diving, Boating and Recreational Fishing

Kirra Reef and Cook Island are popular destinations for a number of diving cruises and charters which operate out of the Tweed River. The success of these diving operators is severely limited by the prevailing weather conditions and the swell at the river entrance. A local dive operator stated that conditions at the bar were dangerous and that this limited the days available for diving cruises (Paul Campbell, Tweed Dive, *pers. com.*). Bookings were often cancelled due to unpredictable bar conditions. It was noted that this makes it difficult for local dive operators to compete with dive operators in more reliable locations. Refer to section 4.6.8 for further details on navigation conditions at the Tweed bar.

Recreational fishing and boating is also a popular activity both within the Tweed River estuaries and beyond the bar. A number of local sporting and recreational clubs offer canoeing, dinghy sailing, rowing, water skiing and other activities. Several companies in the area also offer power boats, surf skis, sailing boats and other watercraft for hire which provide valuable recreational opportunities.

A number of recreational fishing charter companies operate from the Tweed River. As expected, the off-shore activities of these charter companies are also strongly influenced by conditions at the Tweed bar (Paul Campbell, *pers. com.*). Several years ago, the NSW Division of Fisheries estimated that recreational fishing catches were likely to be equal to one third of the recorded catch for commercial fishing (McGowan International, 1991). This supports the role of the Tweed River as a base for various recreational fishing and boating interests.

The Tweed estuary provides many good fishing areas. The lower Tweed River is used by a large number of recreational fishers and has a reputation for being an excellent angling area. Most fishing occurs from the river banks which are generally easily accessible. In contrast, most recreational fishing in the upper Tweed is vessel based as river bank access is limited other than on southern banks between Tumbulgum and South Murwillumbah adjacent to the Pacific Highway.

Principal species targeted by recreational fishers operating within the estuary including whiting, Flathead, black bream, silver bream and mangrove jack. Tailor and other pelagic species are mostly caught from the entrance training walls. Deep holes within the lower estuary (particularly near the river mouth) provide important fishing areas. Yabbies and sand worms (to a lesser extent) are taken for bait from sand banks fringing the main arm (especially Tony's Bar), Caddy, Wommin and Big Islands and from lower sections of Cobaki Broadwater.

4.6.6.6 Tourism

The value of the tourism industry to the study area can not be underestimated. The Queensland Tourist and Travel Corporation (QTTC) recently produced a 1994/95 snapshot which revealed that the largest number of tourists on the Gold Coast were domestic visitors (1.4 million people), mostly from interstate. The area also attracts a high level of international visitors (611,000 people), originating mostly from Japan (44%) and other Asian countries (31%) (Queensland Tourist and Travel Corporation Resource Centre, 1996).
The QTTC's estimates indicate that the 633 000 Queensland, interstate and international visitors who stayed in the southern Gold Coast area spent a total of $432.75 million during 1995/6. As this figure incorporates expenditure on shopping, accommodation, food and beverages, entertainment, transport and other items, it represents a substantial investment in local businesses.

Recent figures from the Australian Bureau of Statistics indicate that the takings from accommodation alone were $3.42 million in Coolangatta and $4.17 million in Tweed Heads over the three months leading up to June 1996 (ABS June Quarter 1996a and b). These hotels, motels and holiday units employed a total of 183 persons in Coolangatta and 376 persons in the Tweed Heads Statistical Subdivision over the same period.

The southern Gold Coast beaches are a critical part of this tourist industry. A survey conducted by the Gold Coast Visitors and Convention Bureau in 1989 revealed that after climate, the beaches were the second most popular tourist attraction for the Gold Coast (Gold Coast City Council, 1991).

The example of erosion of the Gold Coast beaches following a number of tropical cyclones in 1967 indicates the beaches' economic value. In this year, approximately 70m of the beach width and the frontal dune were eroded resulting in the collapse of several beachfront buildings and structures. The widespread media publicity of the beach erosion and the subsequent drop in tourists resulted in an estimated loss of 20-30% in tourism revenue, a local economic depression that lasted 3 years (Smith, 1994).

The southern Gold Coast beaches and the Tweed River are widely used by tourists for a variety of popular recreational activities including swimming, fishing, diving, walking and relaxing. Surfing is particularly popular within the area.

The beaches and the river represent a valuable economic and recreational resource. Maintenance of these natural resources is therefore critical in ensuring that the Gold Coast/Tweed Heads area retains its role as a prime tourist destination and that it is able to effectively compete for tourist revenue against other internationally recognised tourist destinations.

4.6.7 Visual Amenity

A visual field survey was conducted from the waterways in the Tweed Estuary in May 1991 (Public Works, 1991p). This study identified the visual environment of the land/water interface as being critical to assessment of visual impacts associated with activities or developments along the foreshores or within the estuary. The study found that the foreshores of the Lower Tweed Estuary have a diverse, but generally high visual character ranging through dense urban form to open rural scenery and heavily vegetated natural areas. Local views are presented in Figure 4.6.7.

The results of the foreshore survey are summarised in Table 4.6.10 below and the visual units matched to neighbouring areas along the southern Gold Coast beaches within the study area for this document.

As can be seen from Table 4.6.10 the study area presents a wide variety of visual quality and built form ranging from the man-made landscapes that exist within Jack Evans Boatharbour and along the southern

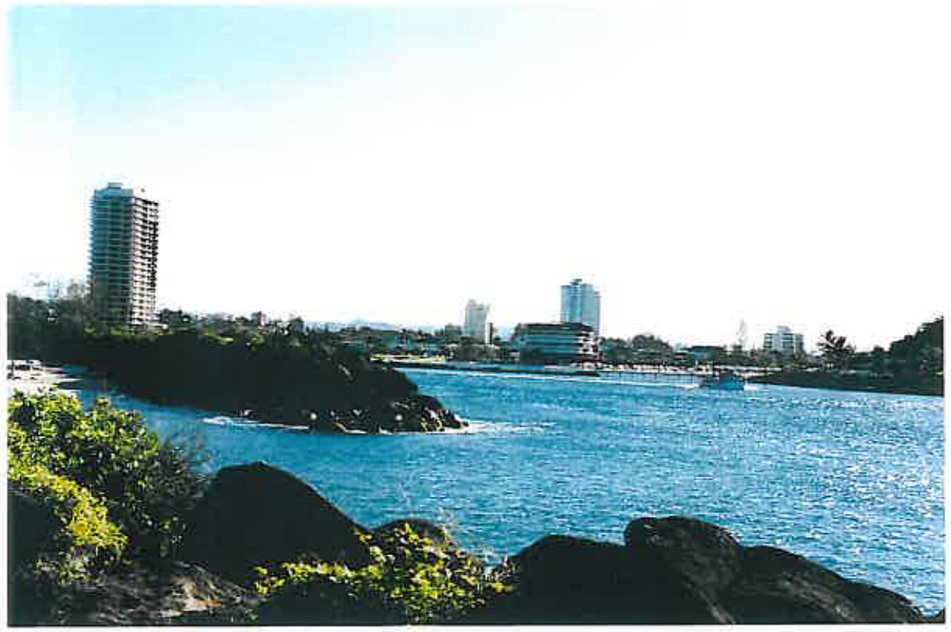


Plate 1 - The Tweed River and Jack Evans Boat Harbour



Plate 2 - The Tweed River entrance breakwaters



Plate 3 - South Head Beach, Letitia Spit



Plate 4 - Kirra Beach

Figure 4.6.7
Local Views

Gold Coast beaches to the undeveloped areas of Letitia Spit. The landscapes are coded A through G in terms of increasing visual quality.

Many parts of the study area are particularly visible, especially those seen from the Pacific Highway, and from lookouts such as the Razorback Lookout and Point Danger in Tweed Heads, and Greenmount Hill in Coolangatta. Such areas include the western shoreline of Letitia Spit, Terranora Inlet, east and west of Ukerebagh Island, and the southern Gold Coast beaches.

In addition views from intensive recreation and shopping/commercial areas are particularly important. Examples are areas visible from Tweed Heads South adjacent to the Pacific Highway, Jack Evans Boatharbour, Twin Towns Services Club, Tweed Heads Rowing and Aquatic Club, Coolangatta-Tweed Heads Golf Course and the surfing beaches.

Table 4.6.10 Summary Of Visual Characteristics

Visual Unit	Visual Characteristics	Location	Visual Quality Class
Aa	Highly developed with an industrial commercial and/or residential backdrop and waterfront structures. Minimal vegetation or landscape treatment.	East of Jack Evans boatharbour. Kirra Beach	Lowest
Ab	As for Aa but with no waterfront structures.	Northern and western foreshores of Jack Evans boatharbour. Southern shore of Terranora Inlet immediately south east of Boyds Bay Bridge	Lowest - Moderate/ Low
Ba	Highly developed with an industrial commercial and/or residential backdrop and waterfront structures. Full or partial landscaping or bushland or mangrove facade.	Rainbow Bay Coolangatta/ Greenmount Beach.	Lowest - Moderate
Bb	As for Ba but with no waterfront structures.	Rocky Point Western shore of Ukerebagh Passage adjacent to Pacific Highway.	Moderate/ Low - High/ Moderate
C	Fully developed residential properties, dominant built form and variable density of waterfront structures. Nil to medium density vegetation along foreshore.	Immediately south of Jack Evans boatharbour.	Moderate/ Low - High/ Moderate
Da	Typically low density residential properties with waterfront structures. Effective screening by high quality landscaped gardens, high amenity bushland and/or high quality foreshore topography.		Moderate - High/ Moderate
Db	As for Da but with no waterfront structures.	Banora Point	High/ Moderate - High
E	Reserves or Government land with high density residential or commercial/industrial backdrop, fronted by high density waterfront development. Nil to sparse vegetation or landscaping.	Western shore, port area of Tweed Heads.	Moderate - High

Table 4.6.10 Summary Of Visual Characteristics (continued)

Visual Unit	Visual Characteristics	Location	Visual Quality Class
F	Typically open space areas and freehold properties in close proximity to reserves or roads mainly fronted by seawalls, rubble or natural banks, or occasional beaches. Minimal waterfront development. Open lawn or sparse vegetation.	Southern foreshore Jack Evans boatharbour. Northern training wall Duranbah beach Western bank Tweed River opposite Kerosene inlet.	High/ Moderate - High
G	Typically open space areas and freehold properties with minimal development on the slopes or hinterland and nil waterfront development. Continuous high quality bushland, landscaped or topographic feature environment on the foreshores and slopes.	Letitia Spit Tonys Island Northern shore Shallow Bay Western shore Tweed River from Rocky Point to Ukerebagh Island. Ukerebagh Island	High

4.6.8 Navigation

Wave propagation processes affecting navigation at the river entrance involve:

- wave shoaling as the waves enter shallower water;
- wave refraction across the entrance bar shoals;
- wave refraction resulting from wave/current interaction associated particularly with the ebb tide discharge from the river; and
- wave/current interaction causing changes in wave steepness, particularly during the peak ebb tide discharge from the river.

To date, the combination of complex nearshore entrance bar bathymetry and strong ebb tide current speeds has caused complex and unpredictable wave conditions in the navigation channel. Spatially non-uniform wave refraction may cause adverse wave/wave interactions, while shallow entrance bar depths cause the high ebb discharge velocities to extend across the bar area.

The processes have caused hazardous navigational conditions for many years. The recent Stage 1A dredging of the bar area has deepened the channel and probably reduced tidal current speeds in the dredged areas, but reports indicate that wave conditions remain unfavourable, at least for some classes of vessel.

Wave propagation modelling undertaken for this study as described in Technical Appendix II indicates:

- wave focussing may occur in the entrance channel or at the southern training wall in instances where natural bar development or channel dredging results in a relatively shallow southern bar lobe protruding seawards more or less in line with the southern training wall; and

- wave propagation through the entrance channel area is considerably more uniform and predictable if the nearshore bar bathymetry is more or less uniform over a wide area.

As well, hydraulic modelling shows that the ebb discharge current speed is reduced significantly over a deeper entrance bar area. Wave shoaling and wave/current interactions will be reduced if the bar area is maintained at a deeper level.

Safe navigation through the Tweed entrance has been one of the driving forces behind the majority of river training works and dredging operations undertaken this century and is one of the primary objectives of the Tweed River Entrance Sand Bypassing Project.

Navigation across the entrance to the Tweed River can be hazardous, even in comparatively calm conditions. Information provided by Point Danger Air Sea Rescue Service indicates that for the period 31 January 1991 to 31 December 1993, 214 rescues were recorded with four deaths. Between September 1994 and September 1996 270 incidents were recorded with 192 people rescued (P. Scott-Glassock, Air Sea Rescue Pt. Danger, fax 8/11/96).

Consultation with members of Point Danger Air Sea Rescue indicated that navigation and manoeuvrability was noticeably improved after the Stage 1A dredging operations were carried out at the Tweed entrance. Prior to dredging, navigation was basically restricted to the northern side of the river entrance close to the northern training wall, immediately after dredging, vessels could navigate straight through the middle of the entrance bar. Since the Stage 1A dredging operations the entrance bar is progressively reforming and navigation conditions are returning to those which existed prior to the Stage 1A dredging with navigation once again restricted to the northern side of the river. (Pt Danger Air Sea Rescue, *pers. comm.*).

Recreational boating is undertaken for a range of purposes such as diving, fishing, rowing, canoeing, water skiing, windsurfing, sailing and cruising/sightseeing. A majority of these activities are undertaken inside the estuary and do not depend on the condition of the bar. However, the activities of recreation cruisers, scuba diving, large sailing boats and fishing charters have all been restricted in the past due to the dangerous navigational conditions of the Tweed River entrance. Cruising yachts and larger recreational vessels do not use the Tweed entrance to any great extent. A possible reason is that the Gold Coast Seaway entrance is close by and is much safer to negotiate than the Tweed entrance.

Data provided by the Waterways Authority indicate that on the 30th October 1996 there were 46 commercial boat licences, 4856 recreational boat licences and 2434 registrations in the Tweed region giving a total of 7336 which is the highest number recorded in the last 6 years.

The commercial fishing fleet has been affected by the hazardous navigation conditions across the bar which has limited the number of achievable fishing days per year for off shore boats and restricted the passage through the entrance. A common complaint from professional fisherman is that when the local fishing fleet is bar bound the Gold Coast fleet which utilises the Gold Coast Seaway is able to put to sea and fish areas traditionally fished by the Tweed River fleet which has produced a concomitant reduction in the earning capacity of the fleet.

The navigability of the Tweed River entrance and bar was examined in 1991 by the Public Works Department (Public Works, 1991j). The study was carried out on the following categories of vessel: yacht; trawler; large cruise and small runabout.

The navigability for each class of vessel was considered based on the parameters which affect each class of vessel, these are:

- wave height;
- wave steepness;

- current velocity;
- wind;
- water depth; and
- channel width.

The study found that the percentage of time which each type of vessel could safely navigate the channel was:

- yacht 1.7% (6 days per year);
- trawler 14% (51 days per year);
- runabout 27% (98 days per year); and
- cruiser 16% (58 days per year).

The bracketed values give a representative number of whole days when navigation is possible. Public Works (1991j) notes that the percentage of time that navigation of the bar is possible does not directly reflect the number of days that navigation is actually possible. The bar may be navigable for certain periods on many days but not the entire day. Therefore the number of days when navigation is possible for only part of the day is higher than the numbers shown in brackets above. Local knowledge of the bar can also increase the time when navigation of the channel is possible.

Hazardous navigation conditions at the Tweed River entrance impacts on the commercial fishing industry (Section 4.6.6.1). Entrance conditions limit the number of achievable fishing days per year for vessels which operate offshore, particularly after heavy storms. The number of estimated fishing days per month in 1991 was 10 for trawlers and 14 for the shallow draft trap and line boats (Public Works, 1991).

Consultation with Paul Campbell of Tweed Dive who uses the entrance frequently stated that Stage 1A dredging of the entrance bar resulted in improved access for vessels, however conditions are deteriorating as the dredged channel progressively reverts to pre-dredged conditions (Campbell, *pers comm.*).

Thus, it is concluded that significantly improved entrance navigation will be achieved if the bypassing operates such that the entrance area bathymetry is deeper and uniform over a wide area. This may have implications for the design, operational, strategy and monitoring requirements for the project.

4.6.9 Background Noise

Investigation of the existing noise climate in the area adjacent to the proposed works has been undertaken. Data from previous studies has been collated and is reviewed below, this data has been supplemented by further monitoring conducted by WBM in the course of this study. Criteria to ensure minimal noise impact from the proposed permanent sand bypass system developed on the basis of this data are described in Section 7.6.8. Associated environmental management requirements are discussed in Section 8.2.15.

In noise assessment it is usual to make use of two descriptors; the background noise level, (denoted $L_{Abg,T}$), which is the average minimum noise level at a site in the absence of the noise under investigation, and the average maximum A-weighted level (denoted $L_{Amax,,T}$). This is a measure of the average of the maximum levels produced by a particular noise source in the time period (T) under consideration.

Particular characteristics of the noise such as tonality (hums, whistles), impulsiveness (bangs, thumps) and modulation (in level or in pitch) which tend to increase the potential for a noise source to be annoying may

be accounted for by adding adjustments to the measured average maximum level $L_{Amax,T}$. For example an adjustment of 5 dB may be added for a readily perceptible tonal or impulsive component. This "adjusted measured level", $L_{Amax,adj,T}$, may then be compared with the background level in order to assess its overall intrusiveness.

In the following discussions, use is made of two statistical noise level descriptors, these are the L_{10} and L_{90}. The L_{10} is the sound level which in a particular measurement period is exceeded 10 percent of the time. It is often used as a measure of the average maximum noise level and is a convenient descriptor of ambient noise level conditions. In noise impact assessment the average maximum level of a particular noise source may in many cases be described by the L_{10}, (adjusted for tonal or impulsive components as described above). The L_{90} is the noise level exceeded 90 percent of the time in a particular time period, and may be used as a descriptor of the background noise level.

The frequency (or pitch) characteristics of a proposed noise source or of an existing ambient or background noise situation is often important to the overall assessment When describing this, it is usual to divide the scale of frequency into "Octave Bands" grouped around the standard octave band centre frequencies 31.5 Hz, 63 Hz, 125 Hz, 250 Hz etcetera to 8000 Hz.

4.6.9.1 Existing Noise Climate

Generally noise levels in the study area are dominated by three major sources. These are wind and wave noise, traffic noise, and particularly in the more central areas of Tweed Heads and Coolangatta, noise from mechanical plant such as air conditioning equipment and cooling towers. Music noise from the various entertainment venues in the area is also of local significance in areas of central Coolangatta and Tweed Heads particularly during the night time periods.

As the majority of through traffic in the area bypasses the central area of Coolangatta and Tweed Heads, there are relatively few traffic movements during the later night time and early morning period, thus traffic noise has much less influence on minimum night time noise levels than it has in comparable urban areas with an appreciable volume of 24 hour through traffic.

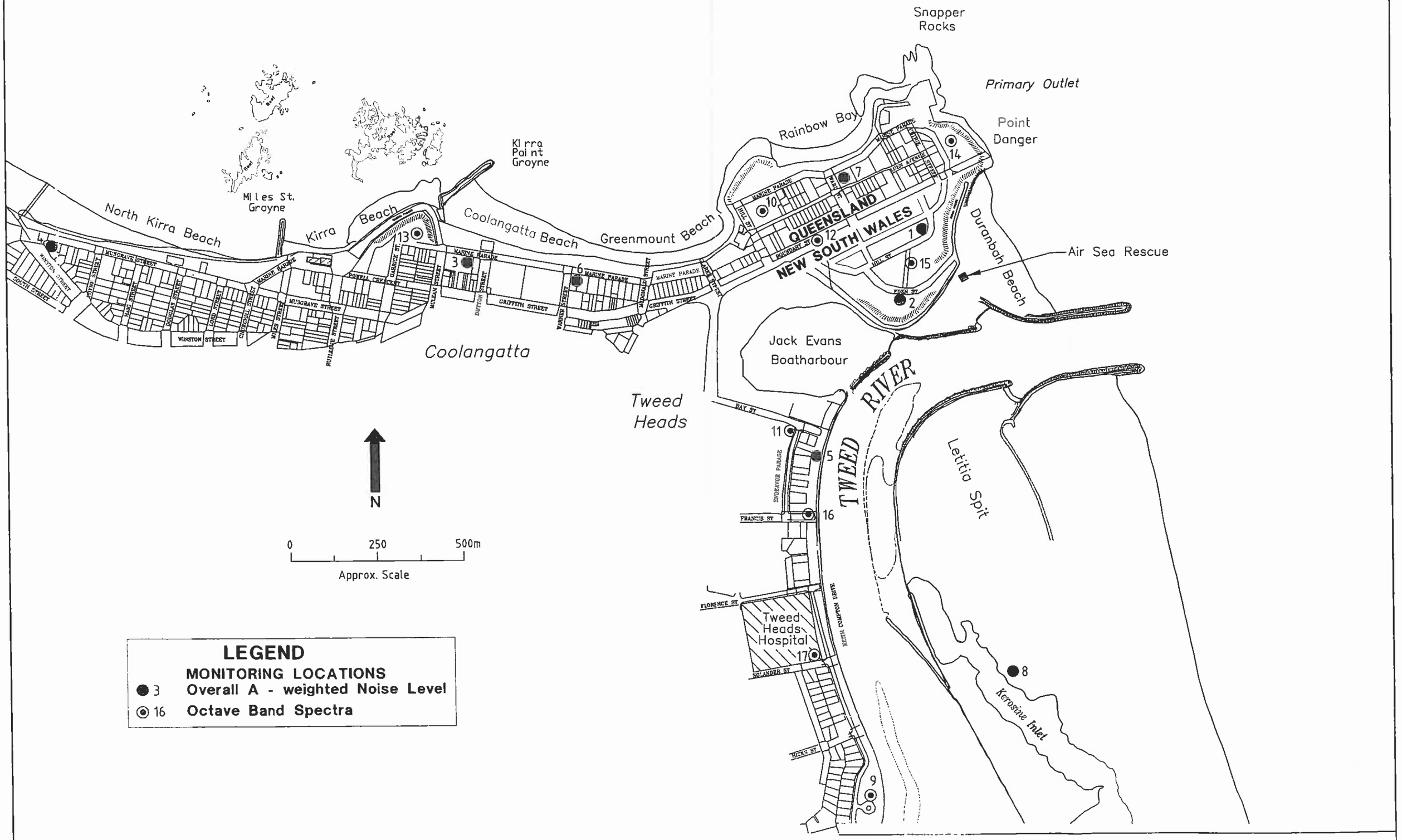
Conversely the influence of wind and wave noise is appreciable throughout the study area at all times of the day and night. Noise measurement positions are shown in Figure 4.6.8; Measurement Positions 1 - 8 relate to data available prior to the current project, and provide information on overall noise levels. Existing data was also available at Measurement Position 9. Measurement Positions 9 - 17 are positions used in the current study.

Noise Measurement Data - Previous Studies

Measurements of ambient and background noise levels have been obtained in previous studies in the Tweed River/Coolangatta area on several occasions over recent years. Data from three such noise surveys are reviewed below. In particular, the following studies are of relevance to the current assessment:

- the Wilkinson Murray Pty Ltd noise study conducted as part of the 1994 Stage 1 Dredging EIS/IAS;
- noise measurements conducted by Gold Coast City Council during May 1995 in the context of beach replenishment operations at Coolangatta; and
- noise measurements conducted by WBM Pty Ltd during 1991 in the context of proposed Tweed River dredging and reported in the River Management Plan, Lower Tweed Estuary EIS "Sand extraction - Area 5", 1995.

Wilkinson Murray conducted noise monitoring at six sites in the study area between 17 June and 21 June 1994. The measurements were carried out utilising noise logging equipment to obtain a continuous record



LEGEND

MONITORING LOCATIONS

- ● 3 Overall A - weighted Noise Level
- ◉ 16 Octave Band Spectra

Figure 4.6.8
Noise Monitoring Locations

of overall noise levels at 15 minute intervals during the measurement period. The measurement sites are detailed below:

1. 5 Hill Street overlooking Duranbah Beach;
2. 13 Eden Street overlooking Tweed River Entrance;
3. Corner of Dutton Street and Marine Parade adjacent Coolangatta Beach;
4. 2 Musgrave Street overlooking North Kirra Beach;
5. 4 Endeavour Parade, Tweed Heads; and
6. 83 Marine Parade Coolangatta overlooking Greenmount Beach.

A Gold Coast City Council Environmental Health Officer conducted noise monitoring at four sites in Coolangatta during May 1995, these were sites 2,4,6 noted above, and:

7. Unit 20 (6 floor) "Rainbow Place", 180 Marine Parade, Coolangatta, (corner of Marine Parade and Ward Street).

The measurements were conducted during the period 8.30pm-12.15am on the nights of 18/5/95 and 25/5/95.

WBM conducted noise measurements during 1991 at several sites adjacent the lower Tweed estuary. Two sites are relevant to this study, these were located at :

8. Kerosene Inlet - waterside, and
9. cul de sac in parkland (Ebenezer Park) adjacent Terranora Inlet, Keith Compton Drive, Tweed Heads.

The measurements at these sites were concerned only with daytime noise levels as 24 hour operation was not proposed for the dredging then under study. Table 4.6.11 summarises the results of these measurements.

Table 4.6.11 Background Noise Level Data - Previous Studies

Location	Background Noise Level, L_{90} dB(A)		Comments
	Day	Night	
1. 5 Hill Street overlooking Duranbah Beach	52	52	Measurement conducted by continuous logging. Background levels are described as 'minimum repeatable background levels' during measurement period . Wind speeds during logging period described as low, wave heights described as in the lowest 10% of typical observations.
2. 13 Eden Street overlooking Tweed River Entrance	43	40	
3. Corner of Dutton Street and Marine Parade adjacent to Coolangatta Beach	52	45	
4. 2 Musgrave Street overlooking North Kirra Beach	46	37	
5. 4 Endeavour Parade, Tweed Heads	38	35	

Table 4.6.11 Background Noise Level Data - Previous Studies (continued)

Location	Background Noise Level, L_{90} dB(A)		Comments
	Day	Night	
6. 83 Marine Parade, Coolangatta overlooking Greenmount Beach	52	47	Gold Coast City Council measurements at sites 2, 4 and 6 indicated comparable or higher noise levels as might be expected for measurement conducted during the earlier part of the night.
7. Unit 20 (6th Floor) 180 Marine Parade Coolangatta	-	45	Measurement conducted 25/5/95: 8.45pm-9.00pm, Calm conditions, wave activity 1-1.5 metre waves
8. Adjacent Kerosene Inlet - waterside	39	-	Winds described as light and variable Measurement conducted mid afternoon – 2.45pm. Noise sources: "unidentifiable distant sources", birds.
9. Waterfront Park along Terranora Inlet, Keith Compton Drive, Tweed Heads	42	-	Measurement conducted mid afternoon – 4.30pm. Noise sources: cars on drive, boating activity

The levels tabulated above indicate a situation in which relatively high noise levels prevail in the more central areas of Coolangatta, and also in the vicinity of Point Danger and Duranbah Beach where respectively, plant noise and surf noise determine the minimum background level throughout the 24 hour period.

Lower background noise levels are encountered in those areas further from the sea beaches and further from the central areas of Tweed Heads/Coolangatta. Thus at the Endeavour Parade site relatively low minimum background levels occur throughout the day and night. This site is well shielded from traffic noise in the Tweed Heads/Coolangatta area by adjacent high buildings. Minimum background level is essentially determined by air conditioning plant noise from nearby apartment blocks and by distant surf.

Noise Measurement Data - 1996 Measurements

The data reviewed above provides information on overall noise levels only; for many purposes, particularly where noise sources may include significant low frequency components (for example, pump noise), octave band noise level information is required. In this regard measurements were undertaken during the early morning period on Friday 29/11/96, Thursday 12/12/96, Sunday 15/12/96 and Wednesday 18/12/96. The measurement sites are detailed below:

10. Balcony of Room 201, 8th Floor, Greenmount Resort Hotel, Coolangatta;
11. Corner of Endeavour Parade and Bay Street, Tweed Heads;
12. Pavement outside 203 Boundary Street, Coolangatta;
13. Kirra Point, southern end of lookout car park, Coolangatta;
14. Point Danger, northern end of car park, area overlooking Snapper Rocks, Coolangatta;
15. Laneway midway between Hill Street and Eden Street, overlooking Duranbah Beach, Tweed Heads;

16. Francis Street Road end, Tweed Heads; and

17. Corner of Solander Street and Keith Compton Drive, Tweed Heads.

Measurements were also obtained at Measurement Position 9. At Measurement Position 10 use was made of a Bruel & Kjaer Type 4426 noise level analyser to conduct continuous logging of overall noise levels during the period 12.00 midnight to 10.30am, Friday 29/11/96.

Octave Band noise level data was obtained at all sites utilising a Rion NA 29 Sound Level Meter and Octave Band Analyser. During measurement the instruments were set to "Fast" time response and "A" frequency weighting. The instruments were calibrated with a Bruel and Kjaer 4230 sound level calibrator. The results of the measurements are summarised below.

Table 4.6.12 gives details of the overall L_{10} and L_{90} noise levels observed during measurement. Details of the octave band measurement results are presented in Appendix G.

Weather conditions on the 28/11/96 were quite unfavourable due to relatively high wind and sea states. However, useable data was obtained by making use of measurement sites in the lee of buildings. On other occasions winds were light and generally sea conditions were quite favourable with low wave conditions prevailing, particularly on the 12/12/96 and 18/12/96. Ebb tide occurred at around 1.30am on the 12/12/96 and measurements at Point Danger and Kirra Point at around this time are expected to be fairly representative of minimum background noise levels at these positions.

Table 4.6.13 presents representative minimum octave band background noise levels derived for each measurement site. The levels quoted are composites of several measurements and for each octave band represent the lowest ($L_{oct,90,12.5minute}$) noise levels recorded at the particular site. This procedure is adopted in order to better estimate the likely minimum overall and octave band background levels which will occur at each site. For example, during certain measurements insect noise was less of a factor than at other times and where this occurs the measurement having the lower noise level is used.

Table 4.6.12 Overall Background & Ambient Noise Levels 1996 Measurements

Date	Measurement Position	Time	Noise Level		Comments
			L_{A10}	L_{A90}	
29/11/96	10	12.00pm - 10.30am	51- 62	47- 55	Measurement on 8th floor balcony Greenmount Resort Hotel -leeward side of building, local wind speed nil. Average maximum level set by surf during early morning, and traffic noise during day. Minimum level of background determined by air conditioning plant and to a lesser extent, surf.
	11	3.20am - 3.33am	52	48	Measurement at Endeavour Place in building lee - very windy night 20 - 25 knots generally. Local wind speed adjacent mic. 2 - 7 knots. Background and ambient noise level determined by wind and surf. Temperature 24°C, Humidity 84%.
	12	3.49am - 4.02am	50	47	In lee of buildings on Boundary Street midway between Hill and Ward Streets. Local wind speed < 2 knots. Background and ambient set by wind and surf, very occasional traffic movements: delivery vans.
	10	10.10am - 10.25am	60	54	8th floor balcony Greenmount Resort Hotel, wind now moderated, local wind speed - nil. Background set by plant noise and surf, L_{10} noise levels controlled by traffic noise. Temperature 29°C, Humidity 60%.

Table 4.6.12 Overall Background & Ambient Noise Levels 1996 Measurements (continued)

Date	Measurement Position	Time	Noise Level		Comments
			L_{A10}	L_{A90}	
12/12/96	14	12.43am - 2.56am	53	51	Car park overlooking Pt Danger and Snapper Rocks, background is surf, some insect noise and bats. Wind <1 knot northerly.
		1.10am - 1.23am	54	51	Temperature 23°C, Humidity 87%. Wind now increased to 2 knots. Ebb tide.
	13	1.25am - 1.38am	51	49	Kirra Point southern end of lookout car park.
		1.41am - 1.54am	49	47	Line of sight to Coolangatta beach. Background and ambient controlled by surf. Infrequent traffic on
		1.57am - 2.10am	50	47	adjacent roads. Minimal insect activity. Wind 0-2 knots.
	11	2.23am - 2.36am	43	39	Corner of Endeavour and Bay Street, very still - nil wind. Some insect noise. Background determined by distant surf, waves breaking on
		2.39am - 2.52am	41	38	Tweed River Bar adjacent Letitia Spit, and by local plant noise. Temperature 22.5°C. Humidity 87%.
	9	3.03am - 3.16am	39	36	Calm conditions, light rain. Main noise source is surf from direction of Fingal Head and occasional distant traffic movements on Pacific Highway. Some fishing boat activity on Tweed River.
	12	3.37am - 3.40am	45	41	Brief measurement outside 203 Boundary Street, light rain, background controlled by plant noise and some crickets.
12/12/96	15	3.49am - 3.52am	48	46	Measurement position overlooking Duranbah Beach. Background is controlled by surf.
		4.11am - 4.24am	49	46	Other noise sources include vehicle movement on Boundary Street. Wind south-westerly 1-3 knots. Temperature 22°C, Humidity 74%.
		4.34am - 4.47am	56	47	Near sun rise. Bird noise dominates L_{10}, 55 dB(A) at 4000 Hz, very quiet. Breaking waves at Duranbah - 1 metre swell.
	14	4.55am - 5.08am	54	51	Background noise dominated by surf. Some vehicles. Wind 2-3 knots, light rain falling.
15/12/96	13	1.05am - 1.18am	54	48	Background and ambient set by surf. Light wind 2-5 knots. Temperature 20°C, Humidity 74%.
	11	1.35am - 1.48am	42	40	Very still conditions. Plant noise and distant surf set background.
	16	2.00am - 2.13am	43	41	Francis Street road end. Main noise source is distant surf. Fingal Head - quite boomy, some insect noise Light breeze from land - 1 knot.
	17	2.20am - 2.33am	41	39	Corner of Solander Street and Keith Compton Drive. Background is set by surf and cooling tower noise from the hospital.
	9	2.40am - 2.53am	41	38	Background is surf, some distant traffic (very intermittent) on Pacific Highway (Boyds Bay Bridge).

Table 4.6.12 Overall Background & Ambient Noise Levels 1996 Measurements (continued)

Date	Measurement Position	Time	Noise Level		Comments
			L_{A10}	L_{A90}	
	17	2.59am - 3.12am	42	40	Background is cooling tower and surf. Some distant traffic including vehicles on bridge.
	9	3.21am - 3.34am	43	41	Distant surf controls background.
	11	3.41am - 3.44am	45	41	Plant noise and surf on sand bar (Letitia Spit) control background. Other sources include sprinkler and truck movements at adjacent Tweed Mall.
	12	4.00am - 4.13am	55	44	Plant noise controls background - Other noise sources - crickets, occasional vehicles.
	15	4.21am - 4.34am	58	47	Strong surf sea breaking between heads. Other sources - boat engines from vessels at mouth. Bird song from early morning flocks controls L_{10} - 56 dB(A) at 4000 Hz.
		4.37am - 4.50am	50	48	Surf noise controls background and ambient.
	14	4.58am - 5.11am	57	52	Surf noise from sea breaking at Snapper Rocks. Wind is 5 knots, gusts 8-10 knots. Temperature 20°C, Humidity 74%.
17/12/96	11	12.55am - 12.38am	50	42	Plant noise controls background. Other sources include wind in trees and insects. Land breeze 5-6 knots. Temperature 24°C, Humidity 77%.
	16	12.44am - 12.37am	41	39	Plant noise from commercial areas to west, local insects. Very little surf noise.
	17	1.07am - 1.20am	-	40	Background is plant noise from hospital. Some insect noise. Measurement of L_{10} disrupted - security guard vehicle.
	9	1.26am - 1.39am	39	37	Background noise includes surf at Fingal Head, some traffic on Pacific Highway and
		1.41am - 1.54am	40	37	insects. Very light land breeze.
	16	2.05am - 2.18am	41	40	Plant noise from commercial areas to west control background and ambient. Wind 0-5 knots. Temperature 24°C, Humidity 77%.

Table 4.6.13 Octave Band Noise Level Spectra - Early Morning Period Minimum Background Noise Levels

	Octave Band Sound Pressure Level (dB(A))										
Location	31.5	63	125	250	500	1000	2000	4000	8000	Overall	Comments
9	≤10	15	24	27	28	28	27	19	15	34	Minimum background levels determined by distant surf in vicinity of Fingal Head.
11	≤10	19	29	32	32	31	28	27	21	38	Minimum background levels determined by distant surf on beaches, breaking waves on bar adjacent Letitia Spit, plant noise from adjacent apartment blocks and Tweed Mall.

Table 4.6.13 Octave Band Noise Level Spectra - Early Morning Period Minimum Background Noise Levels (continued)

Octave Band Sound Pressure Level (dB(A))											
Location	31.5	63	125	250	500	1000	2000	4000	8000	Overall	Comments
12	≤10	22	32	37	38	37	33	27	16	43	Minimum background level set by distant surf and local plant noise from adjacent buildings.
13	≤10	23	32	38	42	42	37	31	19	47	Noise from surf determines background noise levels.
14	≤10	25	37	44	46	45	41	35	23	51	
15	≤10	23	35	40	39	40	38	32	18	46	
16	≤10	13	24	28	33	33	30	30	17	38	Minimum background levels set by distant surf and plant noise from adjacent apartment blocks and more distant commercial buildings.
17	≤10	16	22	28	33	34	28	20	13	38	Minimum background levels determined by distant surf and cooling tower noise from Tweed Heads Hospital.

Note. Lower background levels may occur during winter months, particularly at sites where plant noise is significant.

It should be noted that it is expected that during the cooler months of the year overall background noise levels lower than those measured may be expected, particularly as air conditioning plant and insect noise will be of less significance. However, with respect to the latter source, the noise levels quoted in Table 4.6.13 are likely to be close to minimum expected background noise levels as it has been possible to select measured octave band data with minimal influence of insect noise, (insect noise typically influences the 4000Hz and 8000Hz octave bands).

Air conditioning plant noise typically affects the 125Hz to 1000Hz octave bands and thus, during the winter months, some reduction in background levels in these octave bands may be expected. This would be particularly the case at Sites 11, 12 and 16, (the Endeavour Parade, Boundary Street and Francis Street sites), as at these sites a significant proportion of the plant noise evident was sourced to adjacent residential buildings. At Site 17, noise from cooling towers at the adjacent Tweed Hospital was the dominant feature of the background at low to mid frequencies, thus there may also be some reduction in minimum background noise levels at this site during the winter months.

On the basis of our measurements and of the previous noise logging results obtained by Wilkinson Murray, at Site 5, we would expect a possible reduction in minimum overall background noise level of perhaps 3 dB(A), for a minimum overall background noise level of around 35 dB(A). Greater reductions in noise level may occur in the 125Hz to 500 Hz octave bands.

4.6.10 Traffic

The main arterial routes in the Tweed Heads/Coolangatta region are the Gold Coast Highway and Tweed Heads Bypass. The Gold Coast Highway is the main access road from the north, with the Tweed Heads Bypass diverting traffic from the Chinderah Bypass and the Pacific Highway into Tweed Heads via the Boyds Bay Bridge. Current traffic movements in the region are illustrated in the Average Annual Daily Traffic (AADT) counts in Table 4.6.14.

Table 4.6.14 Average Annual Daily Traffic Counts on the main routes entering the Tweed Heads/Coolangatta Region

Location	State	Average Annual Daily Traffic Count (AADT) 1995
South Tweed Heads (Post Office)	NSW	24, 644
Tweed Heads Bypass-Pacific Highway (Terranora Bridge)	NSW	23,155
Bilinga Border Connection Road	Qld	21,000
Gold Coast Highway (McDonald Street)	Qld	14,560
Gold Coast Highway (Kirra)	Qld	13,000

(Source: Department of Roads, Qld, Nerang and Roads and Traffic Authority, NSW, Grafton Region)

Traffic to the region has been gradually increasing over the last few years with AADT figures being approximately 6% greater in 1996 compared to 1995.

Public transport has been identified as a regional priority. The Better Cities Programme (Tweed Shire Council, 1995) is undertaking a strategic planning study for an extension of the rail from Robina to Coolangatta and a multimodal interchange with Tweed's public transport integrating with the outcomes of this study. The improvements in public transport should help to alleviate the existing traffic congestion.

4.6.11 Air Quality

Air quality monitoring of the area has not been undertaken. However, given the low traffic densities, low level of industrialisation, large expanses of vegetation and the lack of significant temperature inversions (Section 4.1.7) the air quality in the area can be considered to exceed that of more urbanised areas in Australia (Tweed Shire Council, 1995).

Emissions from concrete batch plants (dust), sawmills (smoke, particulates), the Condong Sugar Mill (smoke, particulates) and fuel burning equipment have been licensed in the area by the NSW Environmental Protection Authority (EPA). The impact of burning sugar cane on air quality is not yet established (Tweed Shire Council, 1995).

4.6.12 Site Access

Site access to the nominated nourishment areas or onshore areas adjacent to the removal areas is necessary to enable ancillary equipment to set up onshore pipeline booster stations, materials handling areas and others support activities (ie. repair and maintenance or fuelling of booster stations etc.).

Beach access to the nominated work areas from the main foreshore roads can be obtained from a number of four wheel drive type accessways located within the study area. The main locations for site access are shown on Figure 4.6.9.

Kirra Point

Access to the Kirra Point area is available from a sealed road, Marine Parade, which runs close to the edge of Kirra Point below the headland. Level access to Coolangatta and Greenmount beaches is from Marine Parade.

Kirra Beach may be accessed from Musgrave Street which runs parallel to the beach.

Snapper Rocks/Point Danger

Snapper Rocks Road runs to the end of the point at Snapper Rocks. Point Danger may be accessed by Coral Street. The most westerly area of Point Danger is inaccessible because of steep, rocky cliffs which edge the ocean.

Duranbah Beach

Duranbah Beach is easily accessed from Coral Street. The access is relatively flat with no barriers. Coral Street provides access from Duranbah Beach to Jack Evans Boat Harbour.

Letitia Spit

Access to Letitia Spit is from a sealed road which stops just to the north of Fingal Head. Beyond this point an unsealed road runs nearly to the entrance training walls. The training walls may be accessed from a track. A track also runs along the western side of Letitia Spit to Kerosene Inlet and then rejoins the dirt road.

4.6.13 Services

The appropriate responsible Authorities have been contacted to establish the nature and extent of the services in the vicinity of the site. Services that have been considered comprise:- power supply, water supply, sewerage, gas and telecommunications.

4.6.13.1 Power Supply

Two main alternatives exist for power supply to the alternative plant and equipment systems under consideration; diesel and electricity. Diesel fuel would be supplied by road tanker. The extent of three phase power supply in the vicinity of the nominated work areas is summarised below.

NSW - North Power

An 11,000 volt supply is available in the vicinity of Duranbah Beach and close to Point Danger from substations located in the area. Power supply to Letitia Spit would require the extension of the 11 kV system across the Tweed River. In order to determine the costs and conditions of electricity supply to any of the options the location and size of electrical loading is required.

SEQEB

An 11,000 volt supply is available from the Queensland side of Boundary Street.

4.6.13.2 Water Supply

Water is presently supplied to the northern edge of the residential area on Letitia Spit. Water supply for an operations control facility (ie. domestic type use) would require extension of the service further north after negotiations with Tweed Shire Council. The Duranbah beach area has existing water supply which

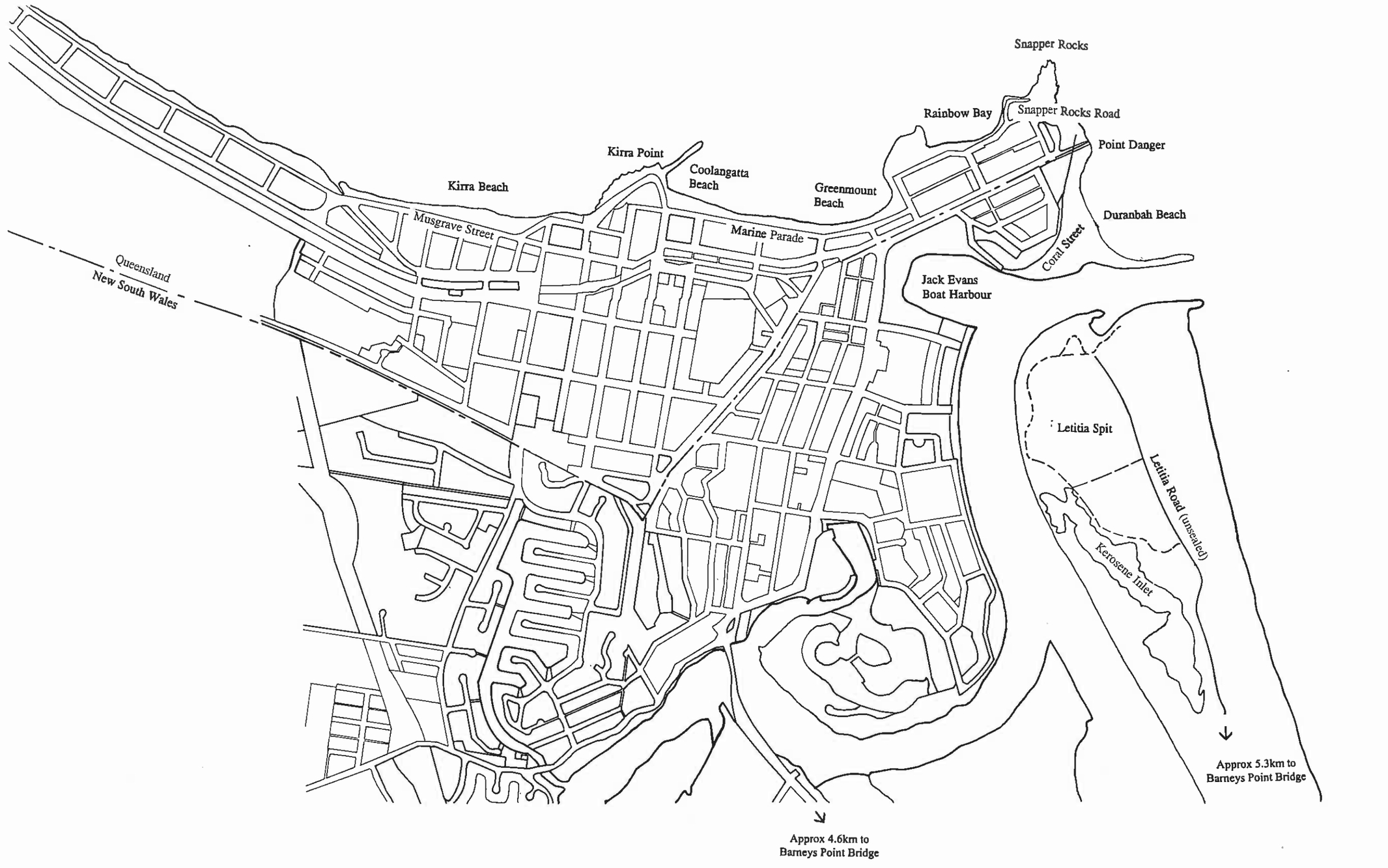


Figure 4.6.9
Site Access

could be used to supply a domestic type water supply to an operations control facility (John Henley, Tweed Shire Council, Engineering Section *per. comm.*).

4.6.13.3 Sewerage

The existing sewerage service stops at the northern edge of the residential area at Fingal Head. There is the potential to extend the existing service northward along Letitia Spit, however if the service were required at the extreme northern end of the spit other onsite treatment and disposal systems should also be considered. Sewage may be beneficially utilised as a resource in close proximity to the operations facility. Sewerage supply currently exists in the Duranbah beach area and could be adapted to supply an operations control facility (John Henley, *pers. comm.*).

4.6.13.4 Gas

Allgas provide the gas supply in the Coolangatta, Tweed Heads area. Presently there is no natural gas supply to Tweed Heads or Fingal, reticulation may be extended into the area in a few years. Allgas can supply LPG through their 45kg exchange service or through a tank fill service, depending on the intended gas consumption. The LPG supply is through local agents located in Byron-Murwillumbah and Kingscliff (Allgas, *pers. comm.*).

4.6.13.5 Telecommunications

Telecom presently has cables which run along Letitia Road to Nos. 28 and 30 on the northern edge of the residential area at Fingal Heads. Construction of an operations control facility at the northern end of Letitia Spit would require extension of this service after negotiations with Telecom. The Duranbah beach area is presently serviced by Telecom. Mobile phones will operate effectively over the study area (Barry Fisher, Telecom, *pers. comm.*).

Chapter 5

Description of the Proposal

Chapter 5

Description of the Proposal

In this chapter the location and extent of works including the location of removal and placement areas, pipelines and outlets, operational details such as efficiency, personnel requirements, maintenance, and power supply are also presented. Alternative plant and equipment options for the permanent sand bypassing system are also outlined.

5.1 Discussion of Generic Approach

A proposal has been prepared for Stage 2 of the Tweed River Entrance Sand Bypassing Project which comprises the design, manufacture, supply, delivery and commissioning of a sand bypassing system, and the continuing operation of that system for a nominal period of 25 years. In an effort to capture and assess the full range of feasible sand bypassing methodologies that are known to be currently available or under development both locally, and around the world, the proposal is generic in nature.

It is not possible within the ambit of a generic assessment of environmental issues and impacts to identify and study every feasible combination of plant types and the various alternatives by which each combination could be set-up and operated. In Sections 5.2 to 5.8, a number of the most likely plant types and possible set-ups (re: ancillary plant and location of possible land based components such as pipeline routes, booster stations, fixed bypass structures etc.) have been selected for detailed environmental assessment. The selection was based on the experience of both Governments and the study team, and it is considered to represent a practical and economic range of generic options.

It is important to emphasise that the range of generic options examined by this EIS/IAS does not preclude any tenderer from proposing specific plant type / combinations and/or modus operandi which may not necessarily be fully addressed by this study. The tender documentation will require the proponent to assess whether a specific proposal raises significant new environmental issues. If new issues are involved, the preferred proponent may be required to carry out supplementary environmental studies.

The generic approach involved the following:

- establishment of the more likely removal, transportation and placement plant that would be utilised by a permanent sand bypassing system within the limits set out in the Deed of Agreement;
- provision of an outline of the particular removal and placement requirements and production rates set out in the Deed of Agreement that must be satisfied in order to achieve the Project objectives;
- establishment of a long list of known sand bypassing systems considered for the Project, which were categorised into one of four main groups comprising:

    1. over-the water mobile systems;
    2. fixed systems located in the nearshore zone;
    3. onshore based mobile systems; and
    4. other systems;

- preliminary assessment of the long list of sand bypassing systems;

- generic discussion of principal plant and associated methodologies for material removal, transportation and placement;
- consideration of activities associated with the construction of the sand bypassing system;
- consideration of the operational requirements associated with the sand bypassing system; and
- preparation of indicative costs for the sand bypassing system.

It is recognised that sand bypassing operations are inherently difficult due to the high-energy, corrosive, abrasive, turbulent littoral environment (indeed in just that part of this environment where those forces and fluctuations are greatest). Operational sand bypassing is successfully implemented in only a few places in the world and there are a number of examples of unsuccessful attempts. The approach of this study is to allow sufficient latitude to implement systems, operations and responses to allow the project to proceed effectively and efficiently.

5.2 Location and Extent of Proposed Works

5.2.1 Limits set out in the Deed of Agreement

The location and extent of the areas proposed for removal and placement activities (Stage 1) are defined by the Deed of Agreement. The limits of placement in Stage 2 are not prescribed by the Deed of Agreement. However, the notional Stage 2 placement area will be considerably less, and is discussed in Section 5.2.2.

5.2.1.1 Removal Areas

The removal area for the Tweed River bar and entrance area is shown in Figure 5.2.1. The extent of this area is set out from a survey control station located midway between the "roundheads" of the entrance breakwaters. The exact positions of these survey control stations are defined by the Integrated Survey Grid (ISG) Control co-ordinates tabulated on Figure 5.2.1. It should be noted that ISG is a rectangular co-ordinate system drawn on a Mercator Projection with zones two (2) degrees wide, designed for integrated surveys in New South Wales.

5.2.1.2 Nourishment Areas

The nourishment area for the southern Gold Coast beaches, for the purpose of the initial stage of the project associated with the maintenance dredging and nourishment works, is also shown in Figure 5.2.1.

5.2.2 Extent of Proposed Works for Permanent Sand Bypassing System

Within the limits set out in the Deed of Agreement, and for the purposes of this EIS/IAS, Figure 5.2.2 indicates the more likely removal, transportation and placement areas that would be utilised by the permanent sand bypassing system during Stage 2 of this project.

The location and extent of these areas have been established on the basis of the project team's understanding and appreciation of the project objectives, and knowledge of recognised sand bypassing technologies. Figure 5.2.2 represents a compilation plan capturing potential work areas required for different types of sand bypassing methodologies and plant and equipment systems in a generic manner.

SURVEY CONTROL

NOURISHMENT AREA OF STAGE 1

Note: A much reduced nourishment area will be involved in Stage 2 – refer Figure 5.2.2

STN.	NORTHING	EASTING
A	1883180	351050
B	1883900	351320
C	1883810	351850
D	1883785	352495
E	1883835	353470
F	1883795	353860
G	1883670	354165
H	1883375	354500
I	1883175	354080

REMOVAL AREA

STN.	NORTHING	EASTING
J	1882665	354530
K	1882510	353995
L	1882550	354145
M	1882360	354335
N	1881375	354610
O	1880700	354875
P	1882675	353970
Q	1882690	354055
R	1882745	354515
S	1883385	354515
T	1884060	355955

NOTES:

1. Hydrographic survey information undertaken by Gold Coast Council in August 1996.
2. All levels are in metres relative to Australian Height Datum (AHD).
3. Co-ordinates are to Integrated Survey Grid (ISG)

LEGEND:

- Survey control station
- Tide guage location
- Wave rider buoy location
- — — Limits setout in the Deed of Agreement

0 200m
15000
Scale

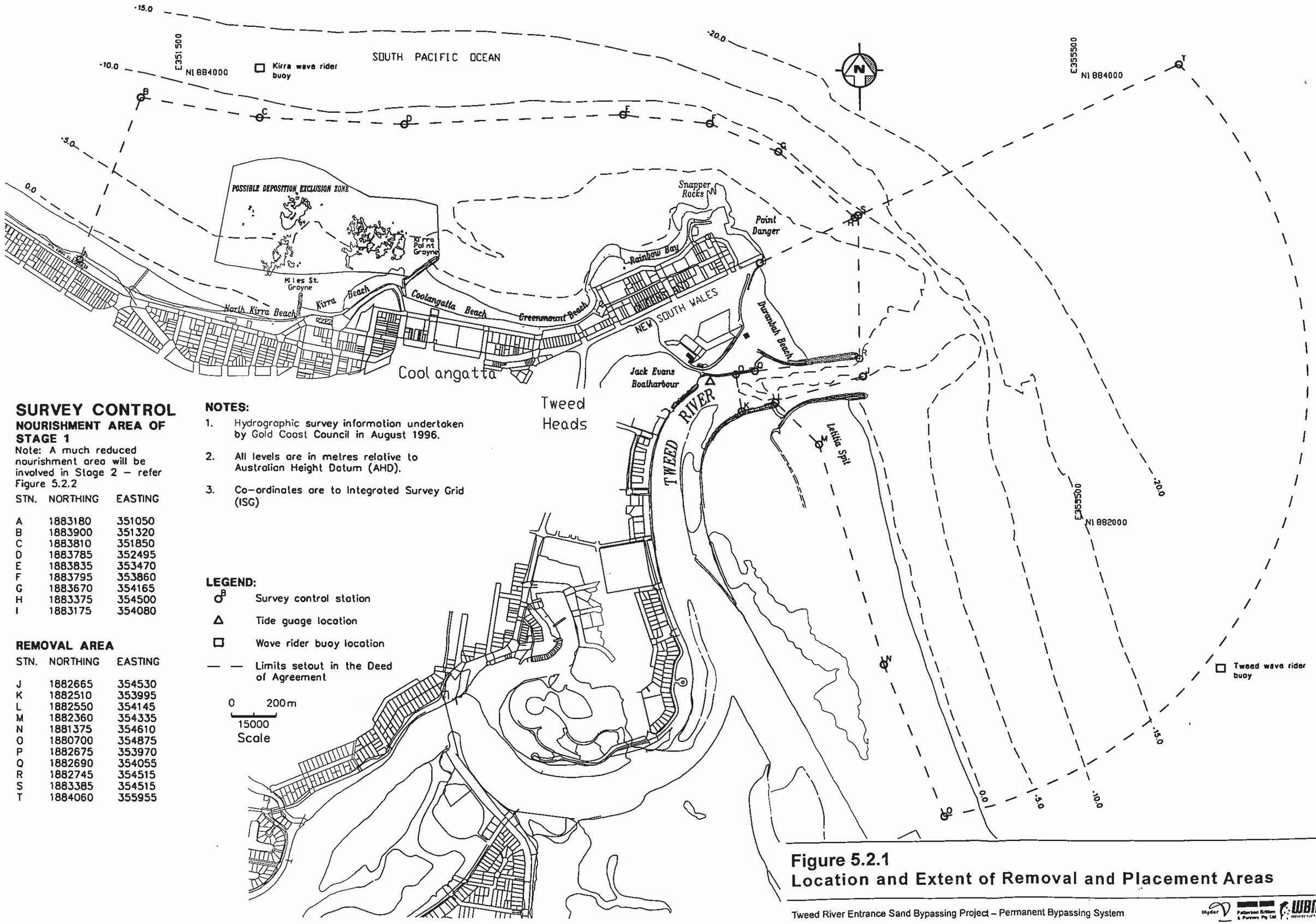


Figure 5.2.1
Location and Extent of Removal and Placement Areas

NOTES:

1. Hydrographic survey information undertaken by Gold Coast City Council in August 1996.
2. All levels are in metres relative to Australian Height Datum (AHD).
3. Co-ordinates are to Integrated Survey Grid (ISG).
4. Locations of buildings, pipelines, booster stations and clear water intakes shown represent potential locations only and are not meant to restrict or limit the proponent.
5. Discharge outlets and beach nourishment areas are indicative only. Actual requirements will depend upon specific nature of selected bypass system.

LEGEND

- Potential buried onshore pipeline (permanent)
- Potential section of directional drilled pipeline (permanent)
- Potential section of submerged pipeline (temporary)
- Potential section of uncovered pipeline
- Limits setout in the Deed of Agreement for sand removal
- Limit of Stage 1 nourishment area – shown merely to identify relationship to potential nearshore nourishment area
- Indication of nourishment areas, North Kirra, Kirra, Coolangatta, Greenmount & Rainbow Bay beaches involve both nearshore subaqueous and subaerial nourishment
- Possible deposition exclusion zone
- Indication of potential pipeline easement
- Indication of most likely removal areas
- Potential booster station location
- Potential discharge outlet location
- Potential intake location
- Potential floating intake location

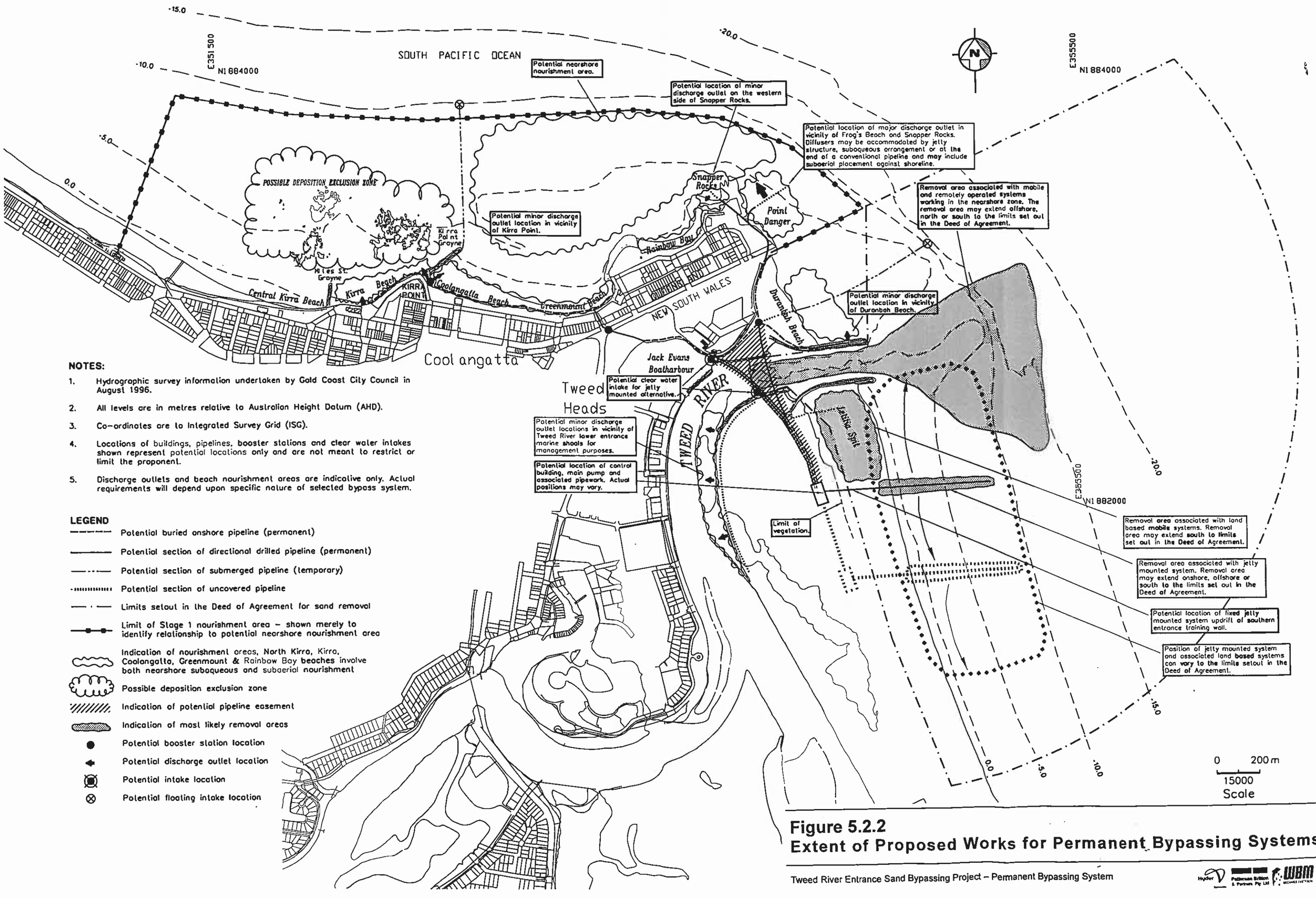


Figure 5.2.2
Extent of Proposed Works for Permanent Bypassing Systems

This has been prepared in order to facilitate environmental assessment and is not meant to restrict or limit a particular proponent from the formulation of a particular project proposal.

5.3 Removal and Placement Requirements

The intent of the removal and placement requirements for this Project are outlined in detail in the Deed of Agreement. The main requirements are summarised below.

In order that the objectives of this Project are satisfied, the nominated permanent sand bypassing system will need to maintain a safe navigation channel, and deliver a quantity of sand equal to the net long term average littoral sand transport (currently estimated at 500,000 m^3 pa) to the nominated discharge outlets (Duranbah, Snapper Rocks and Kirra Point) and beach nourishment areas shown on Figure 5.2.2.

The clear navigation channel shall be maintained such that the bed level is at least 3.5 metres below Indian Spring Low Water (ISLW) over a minimum width of 70 metres between the toes of the channel. The channel shall extend from the upriver limit defined by the upriver boundary of the nominated removal area shown on Figure 5.2.1, to the open sea. In that section of the channel situated between the entrance breakwaters, the channel shall be aligned roughly parallel to the walls. Offshore of the breakwaters the channel shall be maintained in an alignment to ensure safe navigation.

To cater for sand which either outflanks the permanent sand bypassing system (if fixed plant is adopted), or is not intercepted by the system because of practical operating limitations/constraints, and to improve the channel longevity, consideration may need to be given to the creation of appropriately sized and located sediment traps outside the navigation channel. It may even be necessary for such sand "leakages" to be gathered by supplementary plant and equipment (Section 5.7.8) on an 'as-required' basis. However, if supplementary works were required, care would need to be exercised in their implementation to ensure that the integrity of the entrance breakwaters was not compromised and maintenance activities did not interfere with navigation.

The quantity of material to be removed, transported and placed, and the required locations for placement, is discussed below in Section 5.4.

In addition, the permanent bypassing system will need to incorporate flexibility to enable the required quantities of sandy material to be placed where it is most needed on an 'as-required' basis. For instance, placement of quantities of material may need to be placed in the subaerial, or subaqueous, portions of the beach profile, depending on the amenity of the beaches, and also, may need to be placed in a prescribed cross shore pattern to match seasonal considerations.

To summarise, the permanent bypassing system will need to incorporate several factors:

- the system must simultaneously satisfy the dual objectives of improving navigation and beach amenity;
- the chosen system needs to be cost effective and environmentally acceptable. It is possible that a hybrid system may be employed comprising two or more components. For example, the 'modal' sand transport supply may be collected by a fixed system with the remainder collected by a mobile system such as a hopper dredge or a jack up barge working in the channel;
- system operations would be expected to minimise the potential for failure of the navigation channel by recognising the mechanism for infill of the channel (described in section 4.3.1). In general, this would require attention to limiting the growth of the sand shoal on the southern side of the entrance;
- the system would include a strategy for capturing quantities which outflank or 'leak' through and, if necessary, would incorporate a backup plan for major channel infill events; and

- sufficient flexibility would be allowed for in the production rates and the bypassing operations to closely match the natural littoral sand transport of the beaches.

5.4 Production Rate

The production requirements for the project are contained in "Clause 12 Contract Quantity" of the Deed of Agreement and are described below:

The quantity of material to be delivered to the southern Gold Coast beaches will be the long term average annual net longshore sediment transport rate at Letitia Spit. Following the analysis of detailed environmental monitoring data collected during the implementation of the Stage 1A works and process modelling this rate has been confirmed to be around 500,000 m^3 per year (Technical Appendices I and II).

The primary discharge location will be Snapper Rocks. The Deed of Agreement envisages a supply to Duranbah beach of up to 10% of the total and of which 50% (or such other percentage as may be agreed between the States) shall be considered as having been delivered to Queensland. Additionally, the Deed of Agreement provides for a delivery of up to 75,000 m^3 of sand per year to Kirra Point on a long term average.

The results of this analysis and modelling also suggest that the net longshore transport rate can vary between 250,000 m^3 (in a calm year) to 1,000,000 m^3 (in a stormy year) in any single year. The delivery of sand by the proposed permanent sand bypassing system will match the long term average longshore transport rate, but will take account of the natural variations in the net longshore transport rate and the specific objectives of the project. These specifically include coastal process issues associated with the beaches and the entrance, beach usage and navigation.

If the long term average net longshore transport rate changes, the rate of delivery will be changed accordingly. The revision of the long term average net longshore sediment transport rate will take into account the quantity of sand which bypasses the Tweed River entrance and is transported to the southern Gold Coast beaches by natural processes.

Depending upon the specific bypass system design, it may be necessary for the nominated system to remove, transport, and deliver material at production rates, for short periods, that greatly exceed the annual rates. This may be required to ensure that the navigation objective of the Project is not compromised. In particular, the specific system design may require the peak transport rate associated with storms, to be intercepted and bypassed. Results of the analysis and modelling have found that storms (approx. 1 in 20 year return interval) can move around 200,000 m^3 of sediment in a week.

An additional quantity of material will be delivered over the first six years of operation. This additional quantity, corresponding to the Supplementary Increment detailed in Table 1.3.1, is required to compensate for the continuing accretion of sand over the period from the completion of the initial dredging, to the commencement of the permanent sand bypassing system. The actual additional quantity depends on a number of factors and is not known accurately at present, however, it may be of the order of 1.5 million m^3.

5.5 Alternative Plant and Equipment Systems

5.5.1 General

In establishing the alternative plant and equipment systems for the removal, transportation, and placement of material, the full range of alternative sand bypassing methodologies that are known to be currently available both locally, and around the world, were identified, and assessed.

A long list of possible sand bypassing systems was prepared (Section 5.5.2) including each of the alternatives identified for Stage 1 of this project (Acer Wargon Chapman, 1994). This comprised some 14 systems which had been used at various locations around the world over the last forty or so years, and a proprietary system which induces and transfers sand by fluidisation which is deployed in a maintenance contract for the port of Portland, Victoria.

In addition, a number of new and innovative sand bypassing systems, which have surfaced in the last few years, were captured through the Notice to Contractors document distributed both locally and around the world to potential proponents (expressing interest or specialist expertise in sand bypassing technology) as part of the environmental assessment phase of this Project. In particular, these have comprised:- a remotely operated submersible dredger, which has been recently developed and commissioned that supports water jetting devices; slurry dredge pumps, which are connected to a mobile shore station by an umbilical chord and cable system forming part of the discharge pipeline; and recent advances in agitation dredging.

The long list of sand bypassing systems was assessed in a qualitative manner in terms of physical site conditions; operational requirements; and environmental, social and economic criteria applicable to the Project. A total of six of these systems were considered to be unsuitable, as they could not meet basic Project objectives (Section 5.5.3), and were subsequently eliminated from detailed environmental assessment for this Project.

For the remaining systems, it was recognised that a number of major components were common to more than one type of system (ie. different method of sediment removal but same method of sediment transportation and placement; or, similar method of removal but different method of transportation and placement). It was also recognised that some particular plant and equipment, although unable to achieve the Project objectives as a stand alone system (eg. onshore based mobile systems and breakwater mounted systems), could be combined to supplement part of another system (eg. jetty mounted systems) to form a hybrid system that may be capable of achieving the Project objectives.

In order to assess such a large number of potential systems in an efficient manner, a generic approach has been adopted to assist in the environmental assessment of the alternative plant and equipment that comprises the sand bypassing systems. This approach has involved the breaking down of each system into convenient generic components for which the main elements of plant and equipment and/or methodologies have been described and subsequently assessed. This approach is easier to follow, minimises duplication of work, and ensures that all combinations of hybrid systems are in fact captured by the environmental assessment process. The main activities/elements considered in this generic approach comprise the removal, transportation and placement of material.

5.5.2 Long List of Sand Bypassing Systems

The long list of sand bypassing systems have been categorised into one of four main groups according to the nature of principal plant by which the system can be recognised. These comprise:-

- over-the water mobile systems,
- fixed systems located in the nearshore zone,
- onshore based mobile systems, and
- other systems.

5.5.2.1 Over-the-water Mobile Systems (both sheltered and exposed)

Ov-1. trailing suction hopper dredger working in the river entrance and nearshore zone. This system incorporates removal (by draghead and slurry pump) and loading of vessel hopper with sediment; transportation of removed material by vessel steaming to the nourishment area; and

placement of removed material by either bottom dumping, bow or side casting and pumping ashore methods;

Ov-2. cutter suction or suction dredger working in the river entrance and nearshore zone. This system incorporates removal (by cutter and/or slurry pump or jet pump) and hydraulic pumping of sediment to shore via discharge pipeline; transportation of material in a hydraulic slurry to nourishment areas by onshore discharge pipeline; and placement of removed material by either onshore (utilising land based equipment such as bulldozers and front end loaders) or nearshore discharge methods (utilising spreader barge, jetty or subaqueous structures). Variations of this system comprise: the cutter suction dredger working in conjunction with hopper barges into which sediment is loaded; a bucket dredger loading into hopper barges; and, trailing suction hopper dredger which could rehandle material previously sidecast by the cutter;

Ov-3. cutter suction or suction dredger working in the river entrance and nearshore zone in conjunction with an entrance weir. This system incorporates removal, transportation and placement methodologies similar to that described for the cutter only system, however, a higher operational efficiency would be achieved due to the protection offered by the entrance weir;

Ov-4. cutter suction or suction dredger working in the river entrance and nearshore zone in conjunction with an offshore breakwater. This system incorporates removal, transportation and placement methodologies similar to that described for the cutter only system, however, a significantly higher operational efficiency would be achieved by the protection offered due to the offshore breakwater; and

Ov-5. jack-up dredge working in the river entrance and nearshore zone. This system incorporates removal, transportation, and placement methodologies, which would similar to that described for the cutter dredger system.

5.5.2.2 Fixed Systems Located in the Nearshore Zone (both breakwater and jetty mounted)

Fx-1. fixed element of plant (such as a dragline, crane or excavator with restricted/limited ability to move along the structure) **mounted on the 'roundhead' of the southern breakwater.** This system incorporates removal (by submersible pump or jet pump) and hydraulic pumping of sediment to shore via discharge pipeline; transportation of material in a hydraulic slurry to nourishment areas by onshore discharge pipeline; and placement of removed material by either onshore (utilising land based equipment such as bulldozers and front end loaders) or nearshore discharge methods (utilising spreader barge, jetty or subaqueous structures). Variations of this system may incorporate less efficient, mechanical grab/clamshell, removing and placing of material into a constant density tank either directly or via trucks prior to hydraulic pumping. Some minor works may be required to the breakwater structure as part of this option. These works may include strengthening and/or some widening of the roundhead;

Fx-2. mobile element of plant (such as a dragline, crane or excavator with unrestricted/unlimited ability to move along the structure) **mounted on the southern breakwater.** This system incorporates removal, transportation, placement methodologies and breakwater modifications that would be similar to that described for the fixed element of plant;

Fx-3. jetty mounted system comprised of fixed plant, such as sand fluidising and/or slurry transportation devices. This system involves the construction of a jetty structure through the nearshore zone (it may extend from the southern breakwater). This system incorporates removal of sediment by an array of jet pumps and/or submersible pumps arranged in series at an appropriate

spacing and depth along the structure. Transportation and placement methodologies would be similar to that described for the breakwater mounted systems;

Fx-4. **jetty mounted system comprised of mobile plant** with the ability to track along structure. This system also involves the construction of a jetty structure through the nearshore zone. This system incorporates removal, transportation and placement methodologies that would be similar to that described for the mobile breakwater mounted system; and

Fx-5. **fixed scraper supported from towers and cables**. This system involves the construction of towers and cables through the nearshore zone. This system incorporates removal of sediment by a large dragline type bucket. Material is temporarily stockpiled onshore prior to being rehandled by land based equipment such as bulldozers and front end loaders and placement into a constant density tank either directly or via trucks prior to hydraulic pumping. Subsequent transportation and placement methodologies would be similar to that described for the breakwater mounted systems.

5.5.2.3 Onshore Based Mobile Systems

Os-1. **scraping of material using land based plant and equipment**. This system incorporates removal of sediment by equipment such as tractor scrapers, bulldozers and front end loaders and its placement into a constant density tank either directly or via trucks prior to hydraulic pumping. Subsequent transportation and placement methodologies would be similar to that described for the breakwater mounted systems. A variation of this system could comprise the transportation of material in trucks by road;

Os-2. **mobile land based system working within the upper portion of the beach profile**. This system incorporates removal, transportation, and placement methodologies, which would be similar to that described for the mobile breakwater mounted system; and

Os-3. **cutter suction dredger working within the upper portion of the beach profile**. This system incorporates removal, transportation, and placement methodologies, which would be similar to that described for the cutter system working in the river entrance and nearshore zone.

5.5.2.4 Other systems

Ot-1. **remote system comprised of sand fluidising and slurry transportation devices**. This system involves the installation of fluidising conduits and cables in an appropriate arrangement through the nearshore zone (radiating seawards from the breakwaters, a jetty structure or piles). This system facilitates removal of sediment by collection at sumps from which it is transferred via an array of jet pumps and/or submersible pumps in a hydraulic slurry. Transportation and placement methodologies would be similar to that described for the breakwater mounted systems;

Ot-2. **remote system combining directional drilling with sand fluidising and slurry transportation devices**. This system involves the installation of a directionally drilled hole subsequently sleeved with conduit. This system facilitates removal of sediment by fluidisation of sediment at mouth of conduit. The hydraulic slurry is sucked into, and transported along, the conduit by an array of jet pumps and/or submersible pumps. Transportation and placement methodologies would be similar to that described for the breakwater mounted systems;

Ot-3. **remote system comprising submersible dredger that** supports **water jetting devices and slurry dredge pumps**. This system incorporates agitation of sediment by water jets, removal by slurry pump, and hydraulic pumping of sediment to shore via discharge pipeline. This system

incorporates transportation and placement methodologies that would be similar to that described for the cutter dredger system; and

Ot-4. agitation dredging. This system incorporates agitation of sediment by devices such as underwater ploughs, water jets, air lifting equipment and propellers on the ebb tide either dragged, suspended or supported from work vessels. Suspended material is then moved by natural processes out of the removal area.

A conceptual arrangement has been prepared for each of these sand bypassing systems. These arrangements are shown on Figures 5.5.1a to 5.5.1e inclusive. A summary of the main features of each of these alternative systems has been prepared and is summarised in Table 5.5.1 (located at the end of the chapter). This table provides a brief description and lists some of the advantages, disadvantages, and general comments that relate to each sand bypassing system.

5.5.3 Preliminary Assessment of the Long List of Sand Bypassing Systems

A qualitative assessment of the long list of alternative plant and equipment systems for the removal and placement of material identified above, and described in Table 5.5.1, has been undertaken in terms of Project objectives, and selected criteria that summarise the site conditions; operational requirements; environmental, and social and economic considerations applicable to the Project.

Following the assessment of the long list of plant and equipment systems against each of the selected criteria it was established that a number of the systems would not be appropriate to the achievement of the Project objectives in an environmentally sensitive and cost effective manner, and as such were excluded from further consideration.

The systems eliminated comprised:

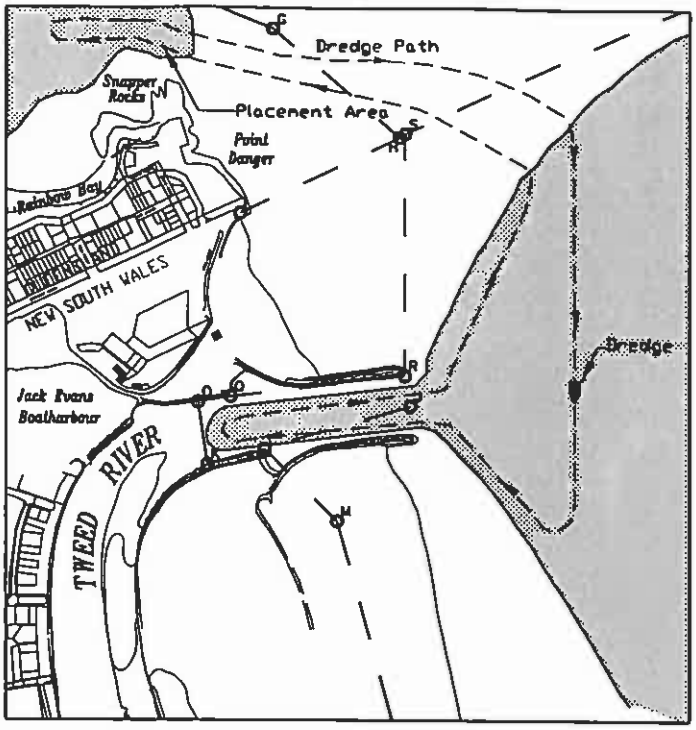
Ov-2. cutter suction dredger working in the river entrance and nearshore zone;
Ov-3. cutter suction dredger working in the river entrance and nearshore zone in conjunction with an entrance weir;
Ov-4. cutter suction dredger working in the river entrance and nearshore zone in conjunction with an offshore breakwater;
Fx-5. fixed scraper supported from cables and towers constructed through the nearshore zone;
Os-1. onshore scraping of material using conventional land based plant and equipment; and
Ot-4. agitation dredging in isolation.

The main reasons for the elimination of certain systems are summarised below.

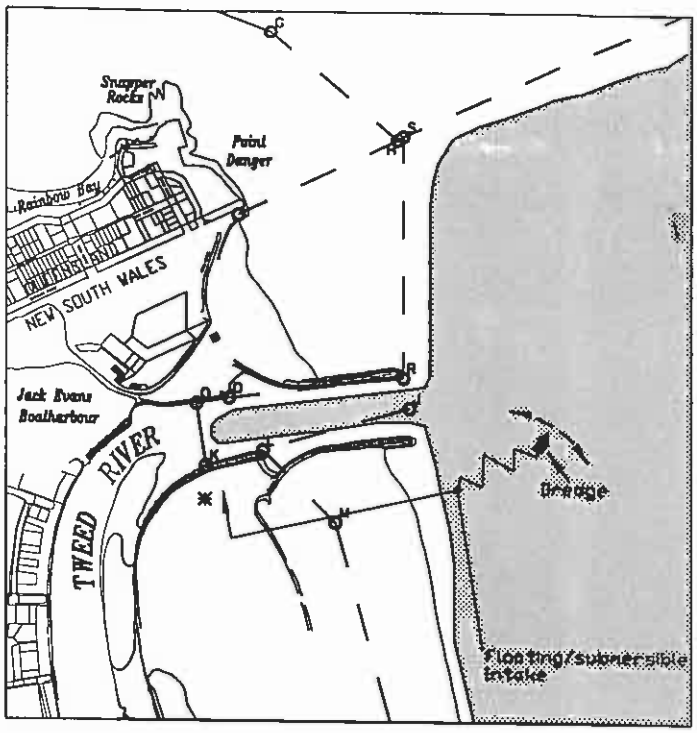
Ov-2. cutter suction dredger working in the river entrance and nearshore zone

The river entrance and nearshore zone can be a particularly hostile environment for systems incorporating floating plant and equipment. In particular, site conditions comprise relatively long period (6 to 12 seconds) waves with an offshore significant wave height of 1.5 m occurring around 50% of the time. In addition, relatively strong currents of around 1.0 m/s (associated with freshwater events and tides in the vicinity of the river entrance and wave induced in the nearshore zone) can occur regularly.

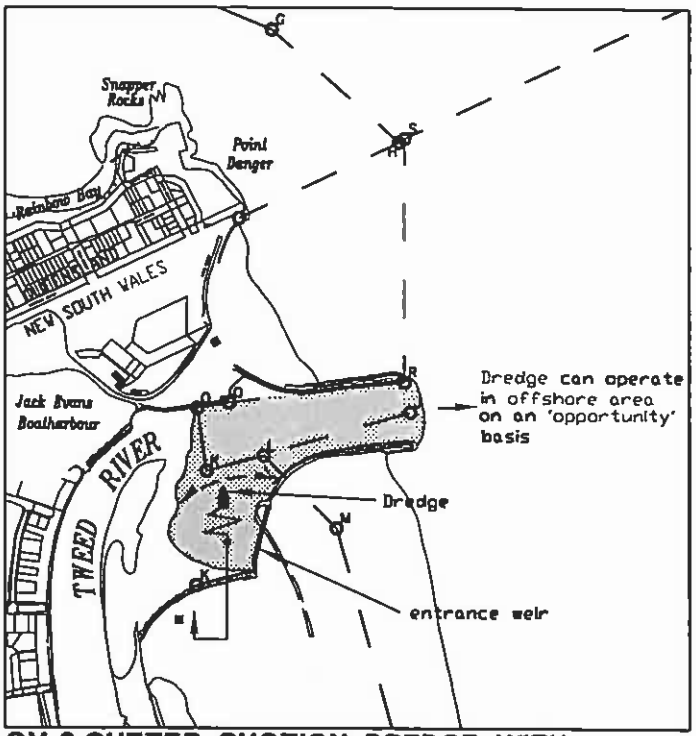
Such an environment is not suited to the operation of a system utilising an unprotected cutter suction dredger which can experience substantial damage to elements such as the cutter, ladder, spuds and anchoring system, when exposed to excessive movement. As a consequence, a high downtime and low operational efficiency would be expected with this system, which may significantly compromise the ability



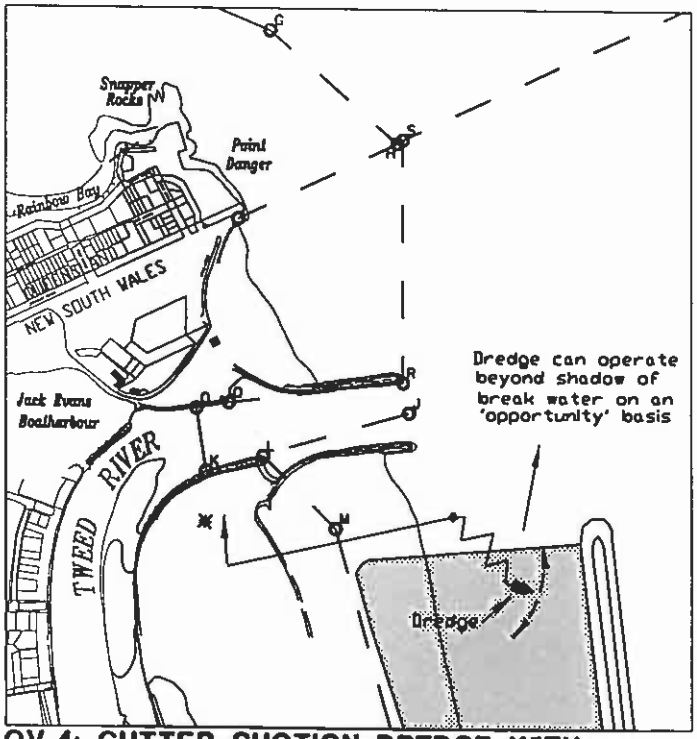
OV- 1: TRAILING SUCTION HOPPER DREDGE



OV-2: CUTTER SUCTION DREDGE



OV-3:CUTTER SUCTION DREDGE WITH AN ENTRANCE WEIR

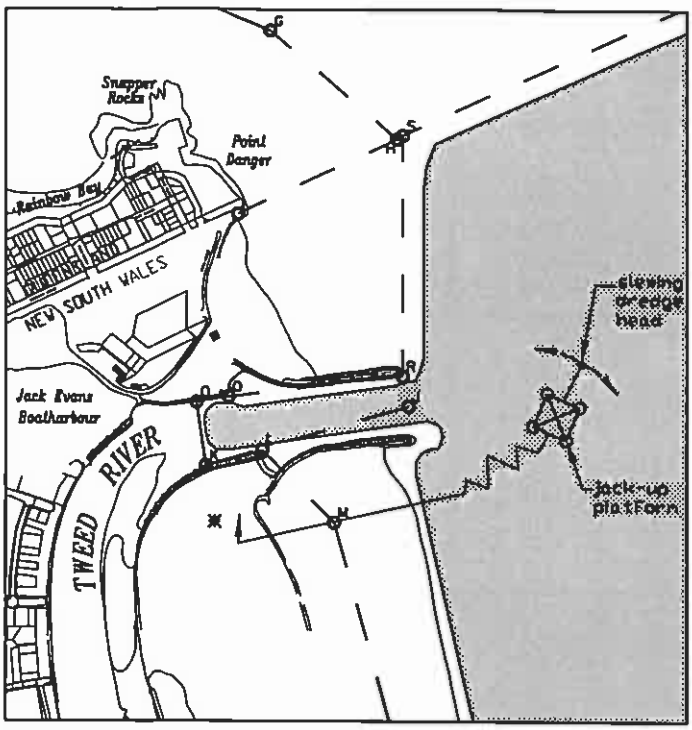


OV-4: CUTTER SUCTION DREDGE WITH AN OFFSHORE BREAKWATER

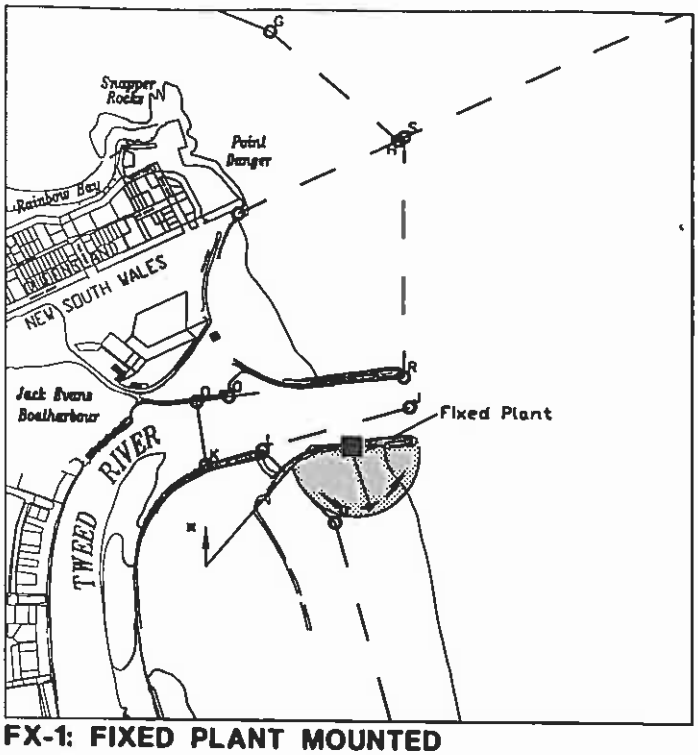
LEGEND
- Potential primary removal area
- Flexible floating pipline
- Submerged pipeline
- × Transportation to placement area (details not shown)

0 400m
Scale

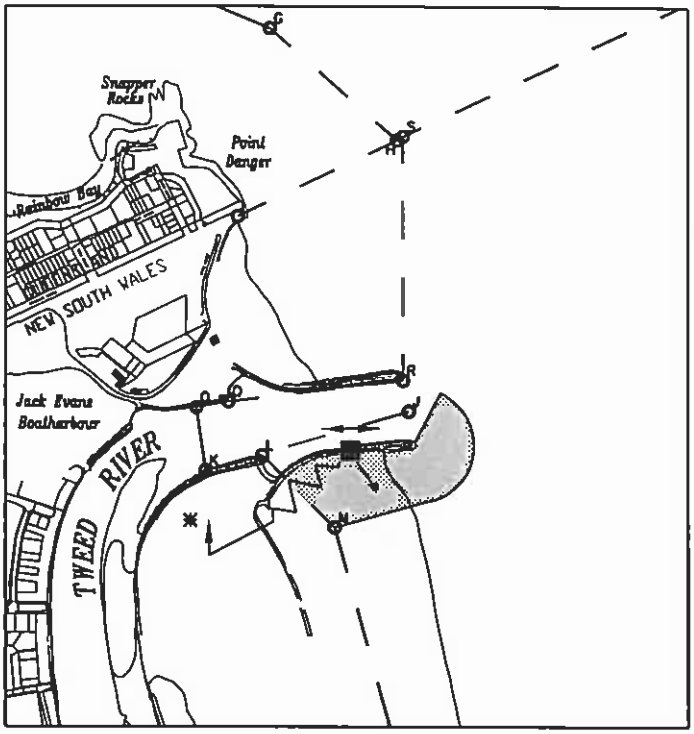
Figure 5.5.1(a)
Conceptual Arrangements for the Long List of Alternative Removal Systems – Sheet 1 of 5



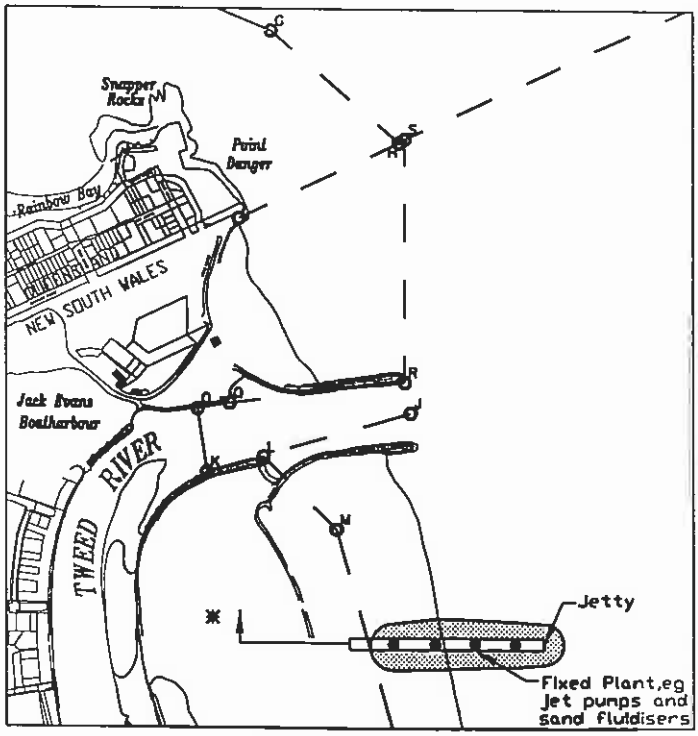
OV-5: JACK-UP DREDGE



FX-1: FIXED PLANT MOUNTED ON SOUTHERN BREAKWATER



FX-2: MOBILE PLANT MOUNTED ON SOUTHERN BREAKWATER

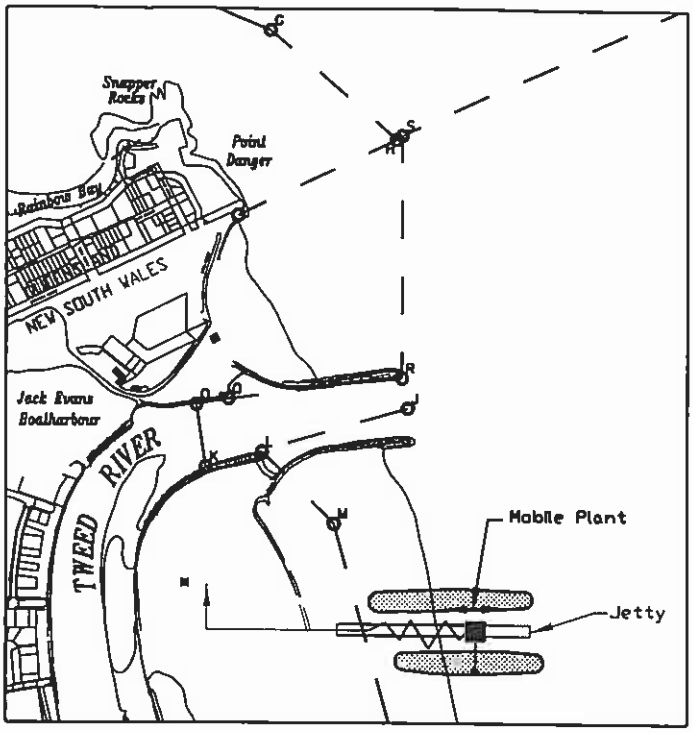


FX-3: FIXED PLANT ON JETTY

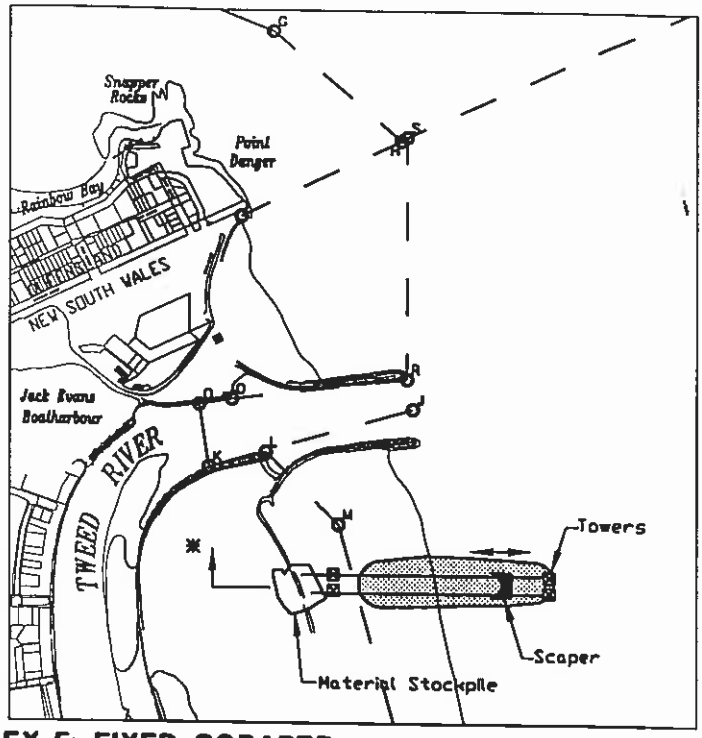
LEGEND
- Potential primary removal area
- Flexible floating pipline
- Submerged pipeline
- × Transportation to placement area (details not shown)

0 400m
Scale

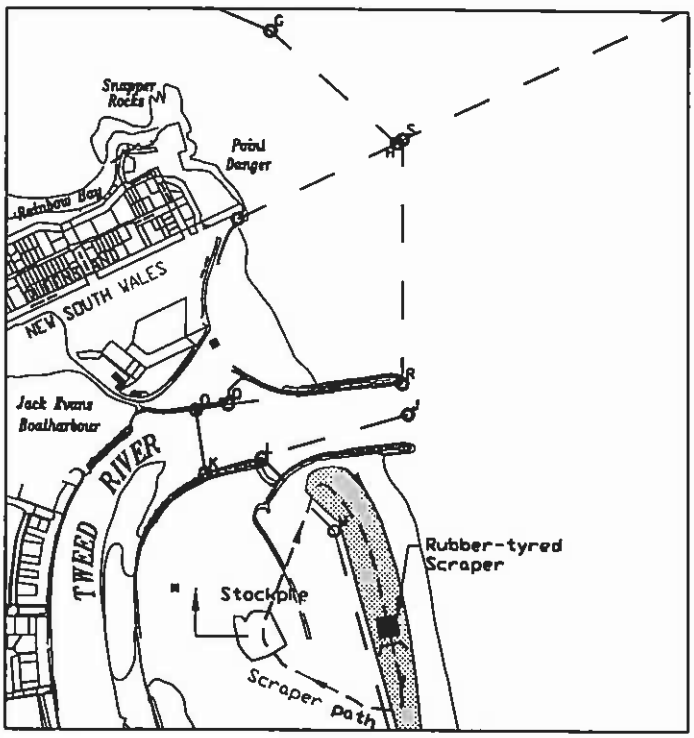
Figure 5.5.1(b)
Conceptual Arrangements for the Long List of Alternative Removal Systems – Sheet 2 of 5



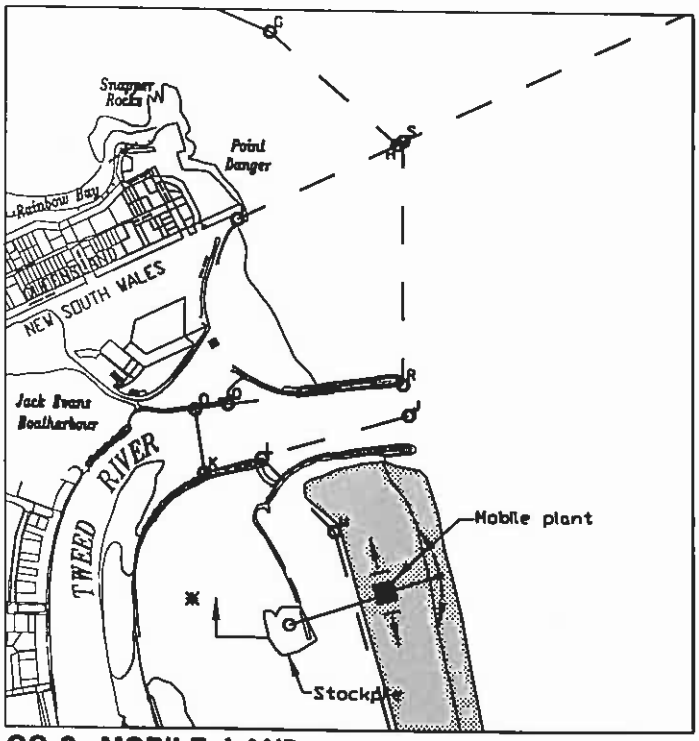
FX-4: MOBILE PLANT ON JETTY



FX-5: FIXED SCRAPER SUPPORTED BY TOWERS AND CABLE (Sauerman scraper)



OS-1: SCRAPING USING LAND-BASED PLANT AND EQUIPMENT

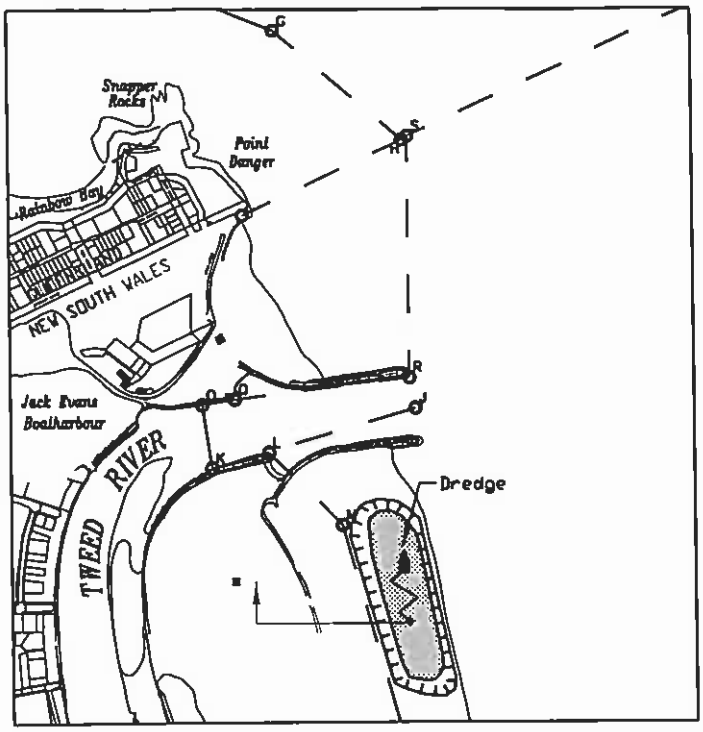


OS-2: MOBILE LAND BASED PLANT AND EQUIPMENT

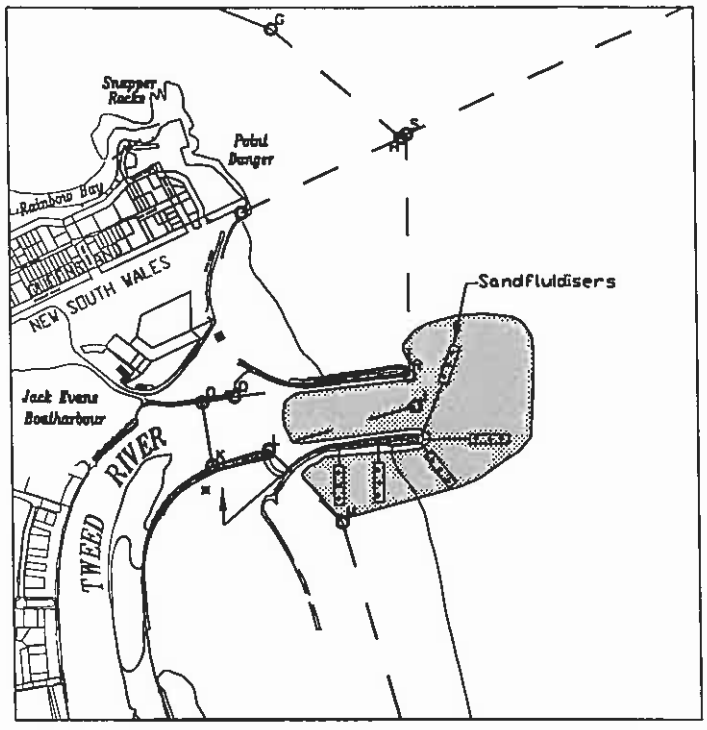
LEGEND
- Potential primary removal area
- Flexible floating pipline
- Submerged pipeline
- × Transportation to placement area (details not shown)

0 400m
Scale

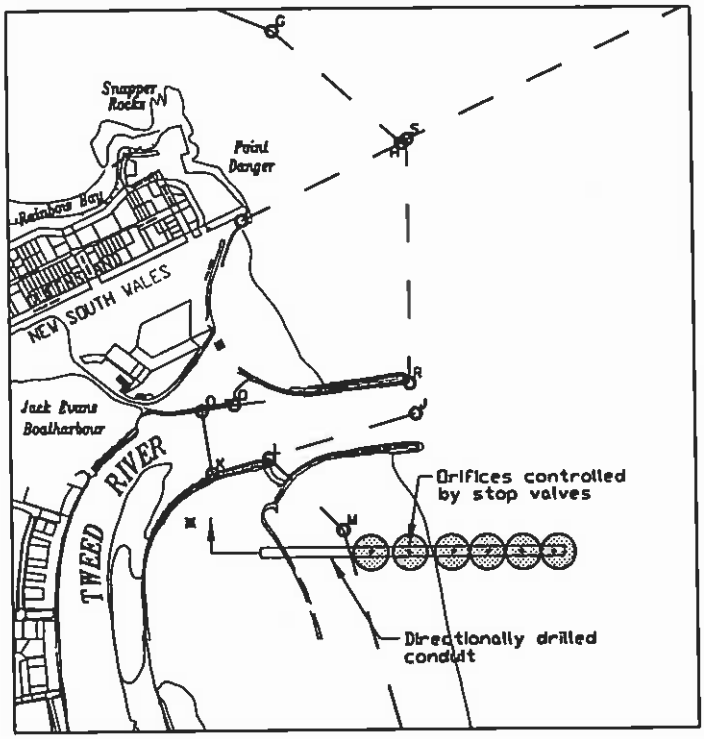
Figure 5.5.1(c)
Conceptual Arrangements for the Long List of Alternative Removal Systems – Sheet 3 of 5



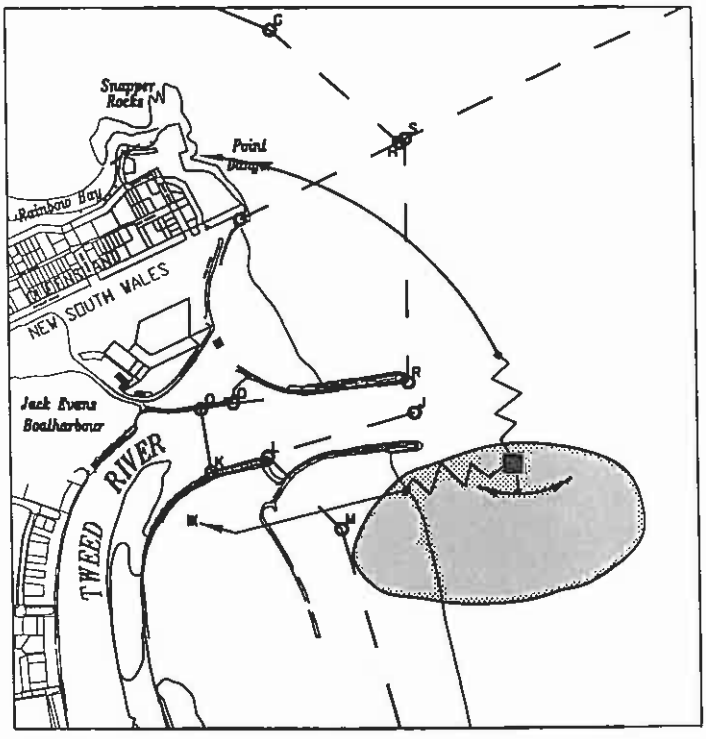
OS-3: CUTTER SUCTION DREDGER IN UPPER PORTION OF BEACH PROFILE



OT-1: REMOTE SAND FLUIDISATION AND SLURRY TRANSPORTION



OT-2:REMOTE DIRECTIONAL DRILLING AND SAND FLUIDISATION

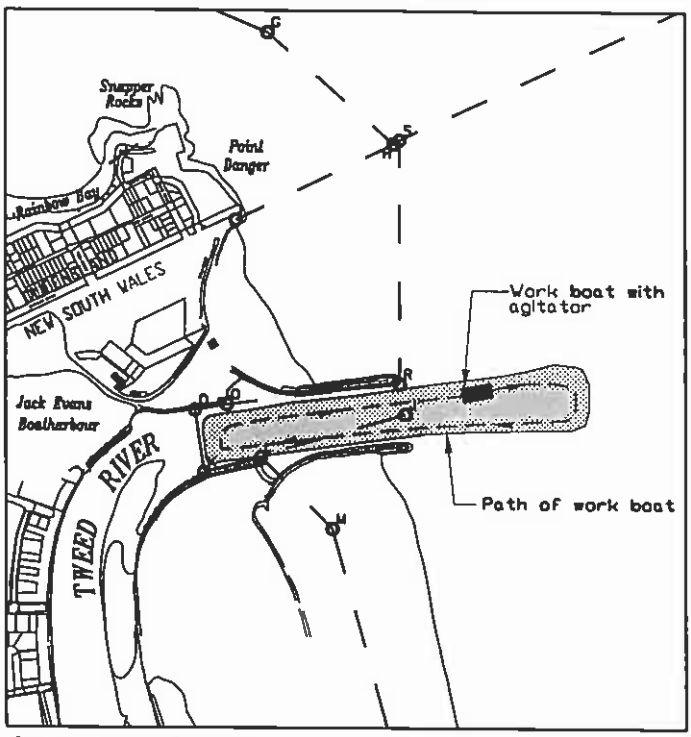


OT-3: REMOTE SUBMERSIBLE DREDGER WITH WATER JETTING AND SLURRY PUMPS

LEGEND
- Potential primary removal area
- Flexible floating pipline
- Submerged pipeline
- × Transportation to placement area (details not shown)

0 400m
Scale

Figure 5.5.1(d)
Conceptual Arrangements for the Long List of Alternative Removal Systems – Sheet 4 of 5



OT-4 AGITATION DREDGING

LEGEND
- **Potential primary removal area**
- **Flexible floating pipline**
- **Submerged pipeline**
- **× Transportation to placement area (details not shown)**

0 400m
Scale

Figure 5.5.1(e)
Conceptual Arrangements for the Long List of Alternative Removal Systems – Sheet 5 of 5

of this system to achieve the objectives of the Project. Therefore, option Ov-2 has been eliminated from further consideration.

Ov-3. cutter suction dredger working in the river entrance and nearshore zone in conjunction with an entrance weir

The provision of an entrance weir would offer protection to the cutter suction dredger in the vicinity of the river entrance.

To construct the entrance weir a significant alterations to the existing configuration of the entrance would be required. These alterations would come at an environmental and economic cost. In particular, a large section of Letitia Spit landward and immediately to the south of the existing breakwater would need to be removed to enlarge the entrance. In addition, significant quantity of rock, estimated at around 10,000 tonnes, would need to be sourced, imported, stockpiled, and placed, to create a weir with a length of around 200 metres. The capital cost of these works, assuming that a suitable quarry is located within a 60 kilometre radius of the site, could be of the order of $2.0 million.

The nature of these alterations may result in a number of adverse environmental impacts during construction, and in the long term. These impacts could comprise the removal and/or damage to existing foreshore habitat, noise, traffic, conflicts with beach users, safety, and affect the terrestrial ecology and visual amenity of the river entrance. In addition, the dredger would still only be able to venture into the nearshore zone on an opportunity basis during favourable conditions. Although the operational efficiency would be marginally higher than without an entrance weir, the dredger would not be able to work in the nearshore zone for long enough periods to effectively manage the entrance bar. As only a small proportion of material is brought into the entrance compartment by the flood tide, this system would have difficulty in achieving the objectives of the Project. Therefore, option Ov-3 has been eliminated from further consideration.

Ov-4. cutter suction dredger working in the river entrance and nearshore zone in conjunction with an offshore breakwater

The provision of a detached/offshore breakwater, located within the nearshore zone, and to the south of the entrance, would largely improve the wave climate and enable a significantly higher operational efficiency for the cutter suction dredger. However, the improvements to this system would come at a significant environmental and economic cost.

For such a structure to be effective, it would need to be located offshore between the 5.0 to 10.0 m below AHD contours (located some 250 to 500 m offshore of the mean sea level mark, respectively). Based on overseas experience the rule of thumb dimensions to ensure attachment of a sand tombolo is a ratio of breakwater length to distance offshore of around 2.0. Hence, this structure would need to be between 500 and 1000 metres in length to be effective. In addition, the crest level and width of the structure and heavy armouring would need to be selected to ensure that wave breaking and overtopping did not result in unacceptable damage levels to the structure.

To construct this structure could require some significant quantities of rock and precast concrete armour. Rock of appropriate size and quality would need to be located, won, sorted, and transported to an appropriate stockpile location on site. Concrete armour units would need to be cast in a suitable nearby yard. Material would need to be loaded into floating barges from a purpose built heavy duty wharf and steamed to the required location for placement in a particularly hostile environment.

The construction of this structure may introduce significant short term environmental impacts during construction at the quarry, along the proposed road transportation route, at the stockpile location, which

would probably be in the vicinity of the southern breakwater, within the river entrance associated with barging movements, and at the proposed construction site. In addition, the construction of this structure may introduce significant long term environmental impacts on the coastal processes, marine ecology and visual amenity. These impacts, if adverse, could have the potential to handicap the Project on environmental grounds. The capital cost of such a structure could be of the order of $10 to $20 million. This is a significant cost penalty when compared to other systems. Clearly, this system is out of scale with the Project and it would be unable to achieve the Project objectives in an environmentally sensitive and cost effective manner. This scheme was eliminated from further consideration.

Fx-5. fixed scraper supported from cables and towers constructed through the nearshore zone; and Os-1. onshore scraping of material using conventional land based plant and equipment

The fixed scraper supported from towers and cables, and the scraping of material using conventional land based plant and equipment, are both systems that would incorporate intensive usage of Letitia Spit by land based equipment, such as tractor scrapers, bulldozers, and front end loaders. Both systems could create significant adverse environmental impacts on the existing environment associated with noise, visual amenity, conflict with other beach users, and safety. In addition, both systems are comparatively ineffective and inefficient at removing material, and would have difficulty meeting the removal, placement, and production rate requirements of the Project. Both of these systems have therefore been excluded from further consideration.

Ot-4. agitation dredging

Agitation dredging relies on natural processes to transport sediment from the nominated removal areas to the designated placement areas. Favourable conditions at the site may only exist for relatively short periods of time (ie. ebb tide combined with strong northerly longshore currents) with little or no control over where the material will be deposited. As such, this method, in isolation, would have difficulty meeting the removal, placement, and production rate requirements of the Project. This method, as a primary component of the bypassing system, would be unable to achieve the Project objectives however, it should be noted that this methodology may be considered as part of a hybrid system.

5.5.4 Principal Plant and Associated Methodologies for Material Removal

The principal plant by which a particular long listed sand bypassing system can be recognised, and the associated methodology for which the removal of material can be described, are listed below:-

- trailing suction hopper dredger;
- cutter suction dredger;
- jack-up dredger;
- land based plant customised for dredging;
- jetty mounted system;
- sand fluidisation and transportation technology; and
- other removal methodologies.

A generic description for each of these methodologies customised to this Project has been prepared and is set out below. An indication of the likely removal areas for each of these principal items of plant is shown on Figure 5.2.2.

Trailing suction hopper dredger

A trailing suction hopper dredger is usually a self propelled, ocean going vessel with its own onboard hopper for carrying sand or other materials. An example of a typical smaller trailer dredger which would be suited to this Project is shown on Figure 5.5.2.

During dredging operations, materials would be removed off the seabed by trailing a draghead lowered to the seabed. The draghead agitates the seabed material as it is pulled along by the motion of the dredger. Agitated material is transported up the suction pipes (the drag arms) in the form of a hydraulic slurry (mixture of removed material and seawater) into the hopper by large onboard pumps. Trailer dredgers may be fitted with one or two suction pipes, depending upon the size of the vessel.

In the hopper of the dredger, the sand (or coarser grained) particles settle out and the excess water and fine fractions pass through a hopper overflow system back into the sea, via a discharge outlet normally located at the keel level of the vessel.

Trailer dredgers are designed to work in open sea conditions. Typically, a small trailer dredger, if fitted with swell compensation equipment, would be capable of working in swell up to 1.5 m.

Once the dredger has loaded its hopper, it would cease dredging operations by raising its dragheads off the seabed, and steam to the nominated nourishment area. Electronic position fixing systems enable accurate location of the vessel during dredging and discharge activities. Within the nourishment area, the dredger would discharge its load by either bottom dumping, pumping ashore or bow casting.

In addition to the above methods, if there is no pump ashore capability, or if water depths preclude safe navigation, the trailer dredger can discharge its load by bottom dumping in a designated area and from here it can be rehandled and pumped ashore by a suction dredger or cutter suction dredger.

Alternately, a scheme may be employed that includes material rehandling close to the Tweed River entrance area. This would allow a small trailer dredger to work efficiently within the navigation channel and deposit material to a spoil rehandling area close by. The sand may then be picked up by other plant such as a larger trailer dredger or a submersible dredge and transported to the designated nourishment areas possibly at a later time. This type of scheme could be employed during periods when the channel must be cleared (to meet the navigation performance criteria) but sand cannot be delivered to the designated discharge locations because the Contract Quantity would be exceeded. The rehandling area used for a scheme of this type would need to be designed and managed to minimise effects on coastal processes.

Although taking longer than anticipated, plant of this type was eventually successful in the completion of Stage 1A of this project.

Cutter-suction dredger

Although bypassing systems using cutter-suction dredgers as the primary component have been eliminated from the long list, cutter-suction dredgers may be utilised in hybrid schemes as a principal piece of plant, depending on the system proposed by the Contractor. Such could be the case if the dredger worked within a protected environment, such as the upper portion of the beach profile.

A cutter suction dredger is generally a floating barge type vessel, comprised of a number of major elements that include a cutter, ladder, onboard pipework and pumps, an onboard power plant, control room and anchoring system (comprising spuds, swing wires and anchors). An example of a small to medium size cutter suction dredger is shown on Figure 5.5.3.

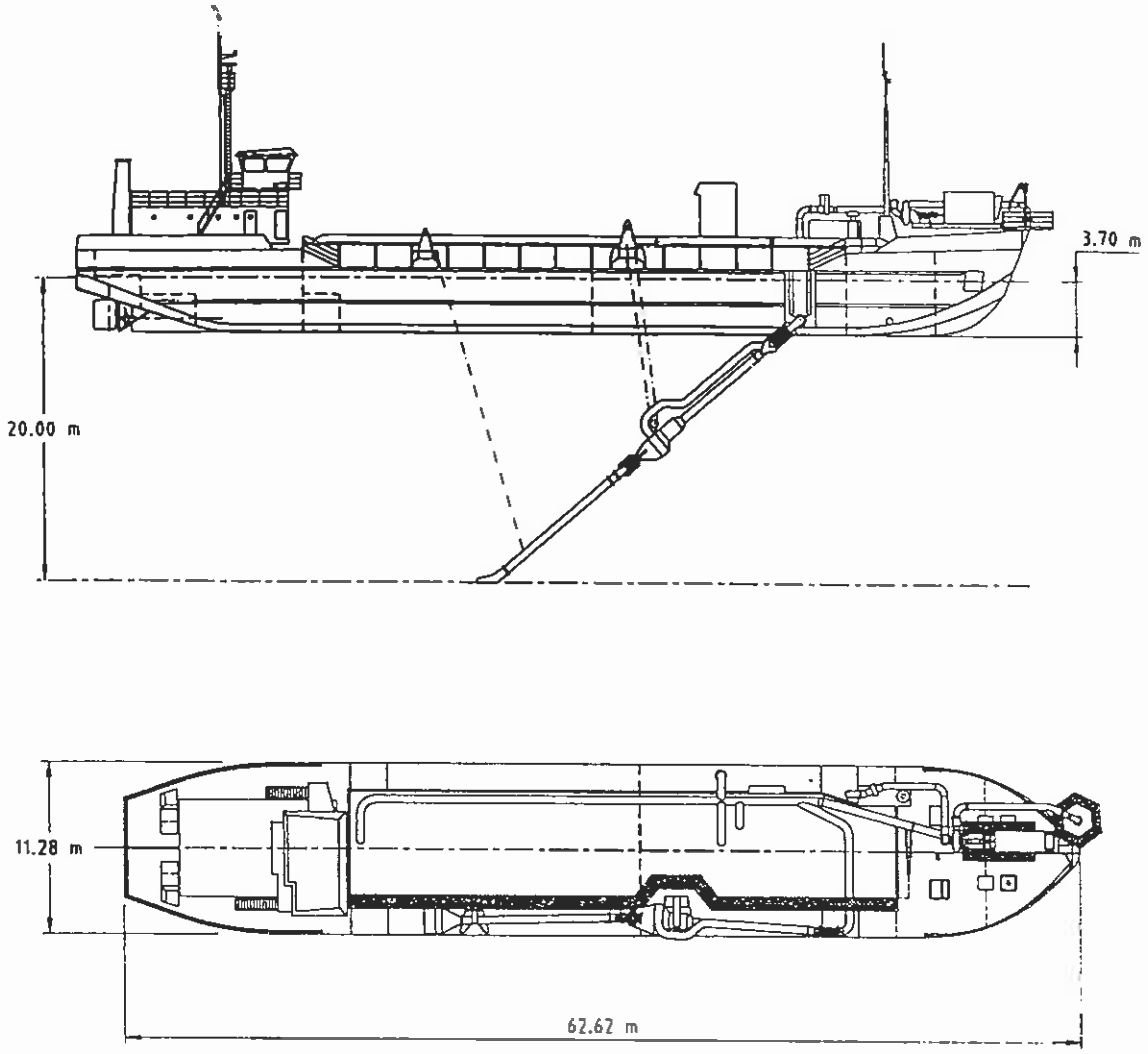
During dredging operations, the cutter which is located at the end of the ladder, is lowered to the seabed. The cutter revolves through the bed material and in so doing loosens material. Agitated material is sucked up into the pipe intake located behind the cutter and onboard pipework by the onboard pumps in the form of a hydraulic slurry (typically the solids concentration of the hydraulic slurry would be in the order of 20% to 35% by weight). The hydraulic slurry would then be pumped through a discharge pipeline (which may be a combination of floating, submerged and onshore sections) to the nominated disposal area.

This type of dredger works in a controlled manner with the vessel's pontoon normally held in position at the stern by a "spud" which is dropped into the seabed. The cutting action is then facilitated by swinging the forward end of the pontoon in an arc across the seabed between two anchors set out in front and to the side of the dredger. The dredger works along a fixed centreline and the cutterhead is lowered below water to the required dredging depth. Once the dredge face is cut down to the required depth, the dredge (and hence the cutterhead) is advanced along the centreline by means of moving the spud carriage in which the working spud is mounted. To move ahead, the dredger is pushed forward against the spud by a hydraulic ram at a predetermined step size. At the completion of a spud ram, an auxiliary spud is lowered and the main spud raised and returned to its starting position. The main spud is dropped and the auxiliary spud is raised prior to the recommencement of dredging operations. Small cutter dredgers may not be fitted with a spud carriage and often advance by "stepping" through the alternative use of the main working spud and the auxiliary spud.

Cutter dredgers are designed to dredge material ranging from silt to hard clays and soft rock. The ability to dredge harder materials is a function of the power on the cutterhead, the power on the side winches, and the physical construction of the dredger. For the production rates and duty required, a small to medium size dredger would be suitable. As such, it is envisaged that it would be limited to dredging sands, silts and very soft clays due to its size. The distance over which it could pump the material is governed by the pump power installed in the dredger. This can be supplemented by placing booster pumps at predetermined locations along the discharge line to increase the pumping distance. For small to medium sized dredgers, the use of lightweight sections of high density polyethylene (HDPE) pipes incorporating quick release victaulic couplings are preferred for the onshore pipeline as they can be readily man handled, assembled and disassembled.

Cutter dredgers are limited in their capability to work in rough seastate conditions, depending upon the approach direction and characteristics of the incoming waves, the nature of material being dredged, and the particular requirements within the nominated removal area (ie. navigation channel requiring tighter control of as-constructed dredge levels compared to a borrow area where such tolerances are not applicable). A small to medium cutter dredger would generally be limited to working effectively in waves with a maximum wave height of approximately 0.5 metres, and a wave period in the order of 2 to 4 seconds (depending on water depth and wave length). Due to the tendency of floating vessels to ride the longer period swell waves, they become more sensitive to movement in this type of wave, and as such, their operational effectiveness is significantly reduced. It is considered that effective operation would be limited to a maximum wave height of around 0.3 metres in the longer period swell waves. A cutter dredger may also be fitted with a "Christmas tree" anchoring system instead of spuds. This system is comprised of three anchors deployed from cables attached to winches located on the stern of the vessel (along the centreline, off the starboard and port quarters). As the Christmas tree system is more flexible, it may allow some nominal increase in the seastate workability of the dredger, but at the expense of production rate and accurate positioning.

This type of plant is currently operating successfully at the entrance to Tuggerah Lakes on the Central Coast of New South Wales.



Year of construction	1984
Yard	Stapel, The Netherlands
Classification	Bureau Veritas I 3/3 E coastal waters/suction dredger-dredging within 15 miles offshore
Length overall	62.62m
Beam	11 28m
Depth	4.27m
Draught at dredging mark	3.70m
Hopper capacity	965m3
Propulsive power	2 x 325kW
Dredge pump power	294kW
Generator/discharge pump power	375kW
Jet pump/bow thruster motor	299kW
Total machinery output	'.504kW
Laden speed	9 knots
Suction pipe diameter	450mm
Discharge system	split-hopper or discharge pump system
Pump ashore connection	optional side/bow coupling
Max. dredging depth	20.00m
Gross Registered tonnage	2340t
Nett Registered tonnage	1350t

Figure 5.5.2
Small Trailer Suction Hopper Dredger

SOURCE: WESTHAM DREDGING

DREDGE NO. 8

CUTTER SUCTION

REBUILT	1987
LENGTH	32 METRES
WIDTH	5.6 METRES
DRAUGHT	1.0 METRES
GROSS WEIGHT	70 TONNE
DREDGING DEPTH	13 METRES
ENGINE	ROLLS ROYCE – 350HP
AUXILIARY ENGINE	ROLLS ROYCE – 200HP
SAND PUMP	WARMAN 12/10
WINCHES	HYDRAULIC
MOVEMENT	FITTED WITH TILTING SPUD AND/OR XMAS TREE
CUTTER	150HP

Note: Due to the modular designs of our dredges, this specification indicates the normal configuration of this dredge.

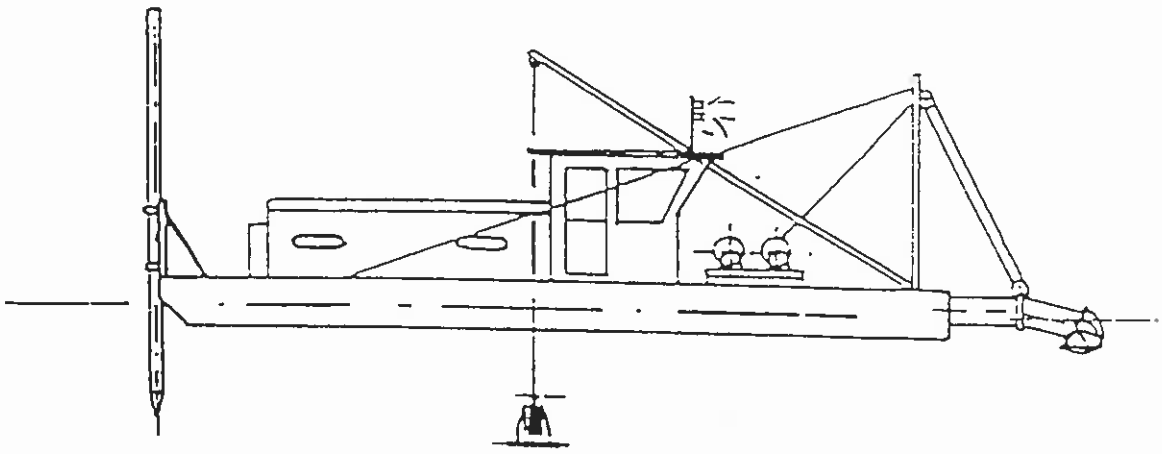


Figure 5.5.3
Small to Medium Cutter Suction Dredger

SOURCE: WESTHAM DREDGING

Jack-up dredger

A jack-up, or self elevating, dredge is a floating barge (or platform) which is capable of elevating itself out of the water to a predetermined operating level above the anticipated maximum wave height. This type of dredger is comprised of a floating barge and at least three legs (or spuds). When in position, the legs are lowered to the seabed and the platform/barge is lifted (jacked-up) out of the water to the required operating level. Onboard, the platform would contain the plant and equipment (eg. cutter, ladder, pumps, pipework, power plant and control room etc) necessary to enable the structure to operate as a dredging system.

An example of a jack-up dredge in conceptual form is shown on Figure 5.5.4a. The operation of this system, pumping ashore, would be similar to the cutter suction dredger described previously. The plant shown comprises a cutter, pump and pipework supported from a ladder arrangement that can be lowered or raised and swung from side to side in an arc. Forward movement of the dredge could be provided through a hydraulic ram that pushed the boom arrangement forward at a predetermined step size. At the limit of the boom carriage, the platform would be lowered and pulled forward in floating mode by its anchor winches. Dredging would recommence when the system had elevated itself out of the water once again. Alternative movement could comprise an extendable boom or auxiliary legs that could facilitate movement in an elevated mode.

Other variants of this type of dredger include one of a number of devices that can be connected to the self elevating platform by an umbilical chord. Such devices could comprise a simple jet pump or submersible pump arrangement that is supported from the platform. Once lowered to the bed a deep cone is created as material is removed. The extent of a particular cone being largely a function of the stable side-slope created in the sand, location of bedrock/indurated sand beneath the bed level, and the potential to undermine the legs of the supporting platform. More sophisticated devices, such as submersible dredgers, could be remotely operated from the platform. Alternative dredge heads comprise a cutter and pump arrangement housed within a tracked vehicle. Material removed off the seabed would be pumped to the surface via the supporting platform.

The discharge outlet for the onboard pipework could be coupled to a discharge pipeline through which the dredged material would be pumped ashore to the onshore discharge pipeline. Alternatively, a discharge outlet for the onboard pipework could be coupled to a short section of pipeline through which the dredged material would be sidecast into self propelled hopper barges that were moored alongside the self elevating platform, or onto the sea bed for rehandling by a trailing suction hopper dredger.

This type of plant has operated successfully in the Middle East where two jack-up dredgers were in operation in the seventies and early eighties.

For smaller jack-up dredges, the pontoon can be designed to be raised whilst in the water, whereby reducing its buoyancy and increasing its seastate availability. An example of this system is shown in Figure 5.5.4b. It comprises a steel pontoon of very rigid construction, with four hydraulically operated spuds at each corner. For this example, the dimensions of the hull are approximately 13 m long by 3.5 m wide. The spuds each have a crawler track fitted at their lower ends, driven by a hydraulic motor which enables it to be moved whilst dredging.

A swinging cutter ladder is mounted on a pivot amidships forward and is articulated by hydraulic rams to facilitate the cutting process as for a conventional cutter dredger. All movements of the dredger and the cutter system are controlled by one man in the cabin, with hand operated hydraulic valves. Potential concerns have been identified with this type of dredger regarding its utilisation in the nearshore zone, particularly with respect to footing stability and stability against overturning due to current and wave loads on the discharge pipeline.

A number of these smaller jack-up type dredgers have been deployed for use in India (associated with improvements of internal waterways) and one is known to exist in the Pilbara region of Western Australia (associated with salt mining).

Land based plant customised for dredging

This alternative is comprised of conventional land based plant with long reach capability such as draglines, crawl cranes, or excavators that have been customised for dredging through the incorporation of an appropriate removal device (such as jet pump or submersible pump) attached to the boom. This type of dredger would be capable of operating from the southern breakwater, a jetty structure constructed through the nearshore zone, or onshore within the upper portion of the beach profile (ie. above low water). In addition it could operate over the water from floating barges or a large self elevating platform. This type of dredger could be effectively utilised to source the large quantities of sand that are contained in the accretion fillet located behind the southern entrance breakwater.

An example of this alternative would comprise a hydraulic excavator fitted with a submersible pump attachment on the end of the boom. This unit would be a customised attachment much the same as a bucket or rock hammer, sized to meet the lifting capacity, and coupled to match the hydraulic limitations of the excavator's power plant (or provided with separate power plant) without compromising other requirements, such as mobility of the system. An example of an excavator with a submersible pump attachment is shown on Figure 5.5.5.

The pump shown in Figure 5.5.5 has a heavy duty agitator fitted at its base which is housed inside an open frame which provides protection. During operations the agitator acts in much the same way as a cutter on a dredger to loosen the material on which it sits. This material can be sucked up by the pump unit in a hydraulic slurry at high concentrations. The hydraulic slurry is then passed through a section of flexible discharge line (that will not inhibit movement of the excavator) which is connected to the outlet of the submersible pump. This section of line would then be connected to an onshore discharge pipeline. The material can then be pumped directly to the nourishment site with the use of the onshore pipeline and additional booster pumps as described for the cutter suction dredger alternative. The placement of material from the discharge pipe on to the nominated nourishment area would be similar to that described for the cutter suction dredger.

Although relatively mobile the excavator requires stable ground to work from, and its capabilities are governed by its reach and the power of the submersible pump. This system alone is limited to working in relatively shallow water depths not exceeding 1.0 m for risk of flooding and damage to critical elements of the excavator (ie. the engine).

A recent example of the use of land based plant customised for dredging is at the entrance to the Indian River, Delaware where a jet pump is supported from a crawler crane.

Jetty mounted system

This alternative is comprised of a fixed jetty arrangement constructed through the nearshore portion of the beach profile. The jetty provides a working platform located above water level from which sand fluidisation and/or slurry transportation devices can be supported. Material agitated and fluidised off the seabed is subsequently pumped along a discharge pipeline to the nominated placement location. The sand agitation and fluidisation devices are strategically located and spaced across the active beach profile to create an effective trap to intercept sediment material being moved by natural coastal processes. An example of this type of system is shown on Figure 5.5.6, where it has been successfully deployed at the entrance to the Nerang River, which is located at the northern limit of the Gold Coast some 30 kilometres north of the Tweed River entrance.

At the Nerang River entrance, the system is comprised of a jetty that extends some 490 metres offshore across the beach profile to intercept the 6.0 m below AHD contour. The jetty is some 5.0 m wide and incorporates a vehicular access way. The deck level of the structure is at 6.0 m above AHD. The main structural elements comprising piling, headstocks, and girders, are of all steel construction. Piles are tubular steel (diameter of approx. 650 mm) and each bent is comprised of a vertical (southern pile) and a raker. The pile bent spacing is around 10.0 m. A timber deck overlying the girders provides the trafficable surface for pedestrians and vehicles.

Along the southern side of the structure, ten jet pumps are attached to the jetty piles. The jet pumps are at 30 m centres along the structure and together provide a trap length of some 270 m between the -2.0 m and -6.0 m AHD contours. The jet pumps have been located at a level of -11.0 m AHD to ensure an effective and efficient removal operation, and that the resulting cones of removed material (which form at the natural angle of repose of the sand) have sufficient overlap to create an effective sand trap.

The jet pumps are driven by clean water sourced from the Broadwater by means of twin pumps installed in a low pressure pump station, constructed in the vicinity of the intake. This pump station feeds water to twin high pressure jet supply pumps mounted in the control building, located adjacent to the shoreward end of the jetty structure. This high water pressure supply provides the motive water which drives the jet pumps. The motive water pipeline runs along the length of the jetty and is supported on cradles attached to the headstocks of the jetty structure. Agitated material is subsequently entrained by the high pressure motive water jet that passes across the narrow gap between the discharging and receiving nozzles. The resulting hydraulic slurry is subsequently discharged from each jet pump to a discharge pipe flume that runs along the length of the jetty and is supported on cradles on top of a frame arrangement which is also attached to the headstocks of the jetty structure. This pipe flume feeds slurry into a constant density tank to optimise a steady slurry density concentration and facilitate removal of rubbish and debris. A conventional centrifugal pump is then used to transfer the slurry along the discharge pipeline to the placement location on the northern side of the entrance. The discharge pipeline is essentially buried over its entire length (including onshore and submerged portions). To ensure a long operational life in terms of wear and tear, the steel discharge pipeline is lined with polyurethane.

The system is electrically powered and controlled by a programmable logic controller to enable unattended night time operation (to take advantage of the cheaper off-peak electricity) to pre-set pump selection and times. The plant capacities are set such that the system can operate with any combination of four to seven jet pumps at any one time. The system has been designed to handle an average northward longshore sand transport of 500,000 m^3 annually under normal operation (four pumps running at once), although it incorporates reserve capacity to handle higher peak transport rates that may occur during significant storm events (seven pumps running at once).

Sand fluidisation and slurry transportation technology

These alternatives utilise sand fluidisation and slurry transportation technology developed in the mining industry. Sand fluidising conduits can be placed and remotely operated within the removal area and used to collect and transport agitated material to an appropriately located sump, from where it can be transferred using jet pumps, a pipe flume, constant density tank, slurry pumps and slurry discharge pipeline.

An example of this type of system has recently been deployed in a maintenance dredging contract for the port of Portland, Victoria. The concepts of this system are shown on Figure 5.5.7.

The basic units are comprised of diffuser pipes, with appropriately spaced water jets, and a sump. The units are arranged on the seabed in a predetermined pattern. One end of the unit is free and the other end leads to a sump. On provision of motive water, sand is fluidised through the water jets. A net pressure head differential is established that serves to drive the fluidised material from the open end to the sump. At the sump, a jet pump recovers the discharged sand and transfers material to a direct-coupled centrifugal slurry

pump for bypassing via a discharge pipeline. The units may be manipulated with a system of cables attached to piles in the nearshore area. The location and stability of any such piles and cables would be designed in such a way as to avoid compromising navigation.

In addition to fixed sand fluidisers, mobile floating sand recovery units could be utilised to supplement the operation. These units would comprise a jet pump and power plant supported on a floating platform that could be relocated on an as required or opportunity basis. The mobile system could capture material that had outflanked the fixed installations.

Fixed pump systems, fluidisation systems and sand collection plant, which are restricted to a very localised area of operation, may need to create very deep but localised holes in the entrance bar area, depending upon the specific operating characteristics of the particular bypass system. From a hydrodynamics and coastal processes viewpoint, such very local deep holes would not present any process impacts additional to those associated with the overall deepening of the bar surface. The specific location and depth of any such localised holes, however, would be determined as part of the project detailed design, so that they would not compromise the stability of the training walls.

Other removal technologies

In addition to the recognised principal plant and associated methodologies which have been utilised in the past at known locations, there exist a number of new sand removal technologies that are currently under development, or have only recently been on trial. One such technology is remotely operated, and combines directional drilling technology with sand fluidising and slurry transportation devices discussed above. Another technology, which is also remotely operated, comprises the use of a submersible dredger in combination with a over water platform or land based mobile station.

In the case of the former technology, a hole is drilled along a predetermined route to the identified removal area. This hole is subsequently sleeved with a conduit that incorporates nozzles around its annulus. Motive water would be pumped through the annulus for agitation and liquification of cohesionless sediment. Agitated material would then be sucked into the inner core of the conduit where an array of jet pumps would be appropriately positioned. A hydraulic slurry would then be subsequently discharged via a pipe flume, constant density tank, slurry pumps and slurry discharge pipeline in a similar manner to that described for other principal plant and associated methodologies.

In the case of the latter technology, a submersible dredge head is utilised, which incorporates water jets and slurry pumps for removal of material, flotation tanks and ballast control. The submersible dredge head is positioned by a dedicated work vessel. The submersible dredge head is connected to a platform or shore facility by an umbilical chord (containing telecommunications, power and pneumatic supply lines) and cable arrangement that forms part of the flexible discharge pipeline. This technology may need to create very deep but localised holes in the entrance bar area, depending upon the specific operating characteristics of the particular bypass system. From a hydrodynamics and coastal processes viewpoint, such very local deep holes would not present any process impacts additional to those associated with the overall deepening of the bar surface. The specific location and depth of any such localised holes, however, would be determined as part of the project detailed design, so that they would not compromise the stability of the training walls.

As noted in Section 5.5.3, agitation dredging could form a component of a hybrid system. In such a scheme, agitation dredging is most likely to be used in areas where conventional plant would have difficulty accessing, such as shallow areas of the entrance bar which are dominated by wave action. These are areas where the sand is continually agitated and the introduction of artificial agitation dredging would not be expected to have any significant impact.

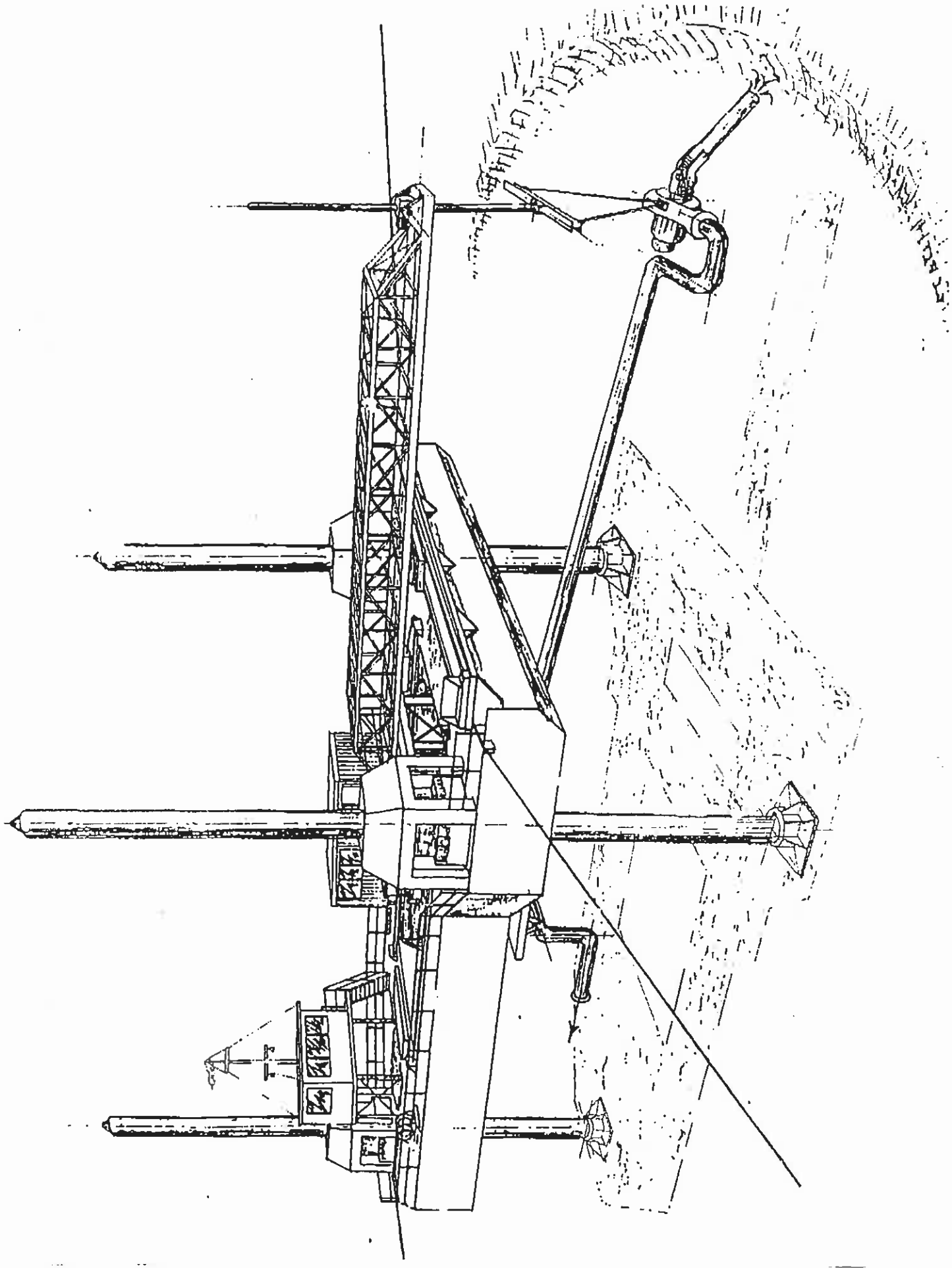
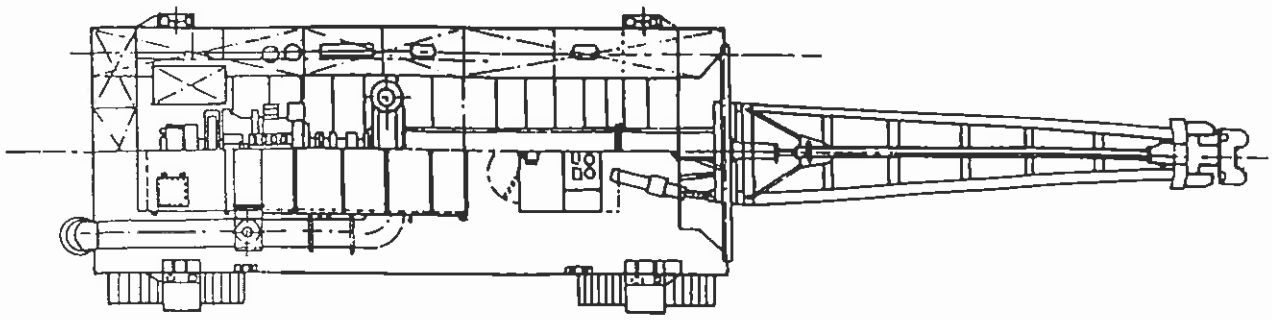
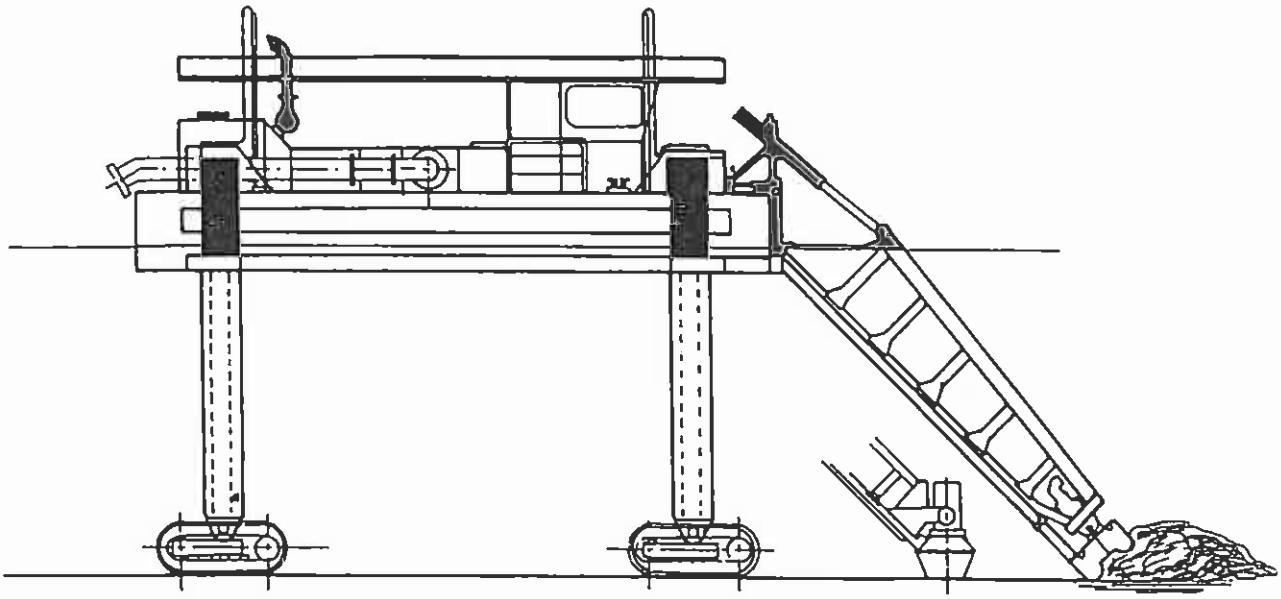


Figure 5.5.4(a)
Jack-Up Dredger

SOURCE: WESTHAM DREDGING





TECHNICAL DATA	cc 200	cc 250	cc 300
Dimensions	9 x 3.5 x 1.5 mtr	11.6 x 3.5 x 1.75	11.6 x 3.5 x 1.75
Dredging Depth	- 5 mtrs	- 5 & - 6 mtrs	- 6 mtrs
Dredge Pump	130 L/Sec	240 L/Sec	320 L/Sec
Main Engine	200 kw	300 kw	350 kw
Cutter Swing	8 mtrs	8/10 mtrs	10 mtrs
Bottom Pressure	0 - 1 kg/cm²	0 - 1 kg/cm²	0 - 1 kg/cm²
Assembled Dry Weight	43 T	50 T	55 T
Speed Max.	15 m/min	15 m/min	15 m/min
Mean Draft	1.25 mtrs	1.4 mtrs	1.4 mtrs

Figure 5.5.4(b)
Small Jack-Up Dredger

SOURCE: BECFAB EQUIPMENT PTY. LTD

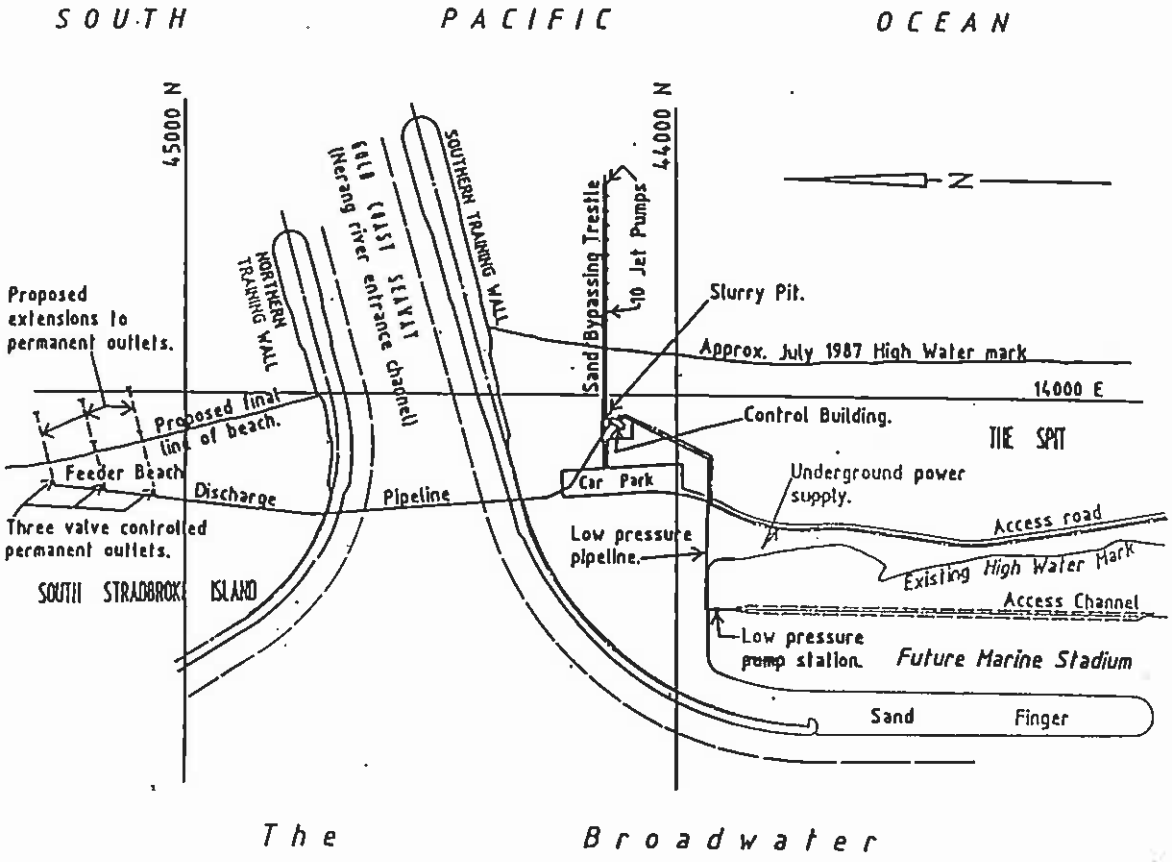


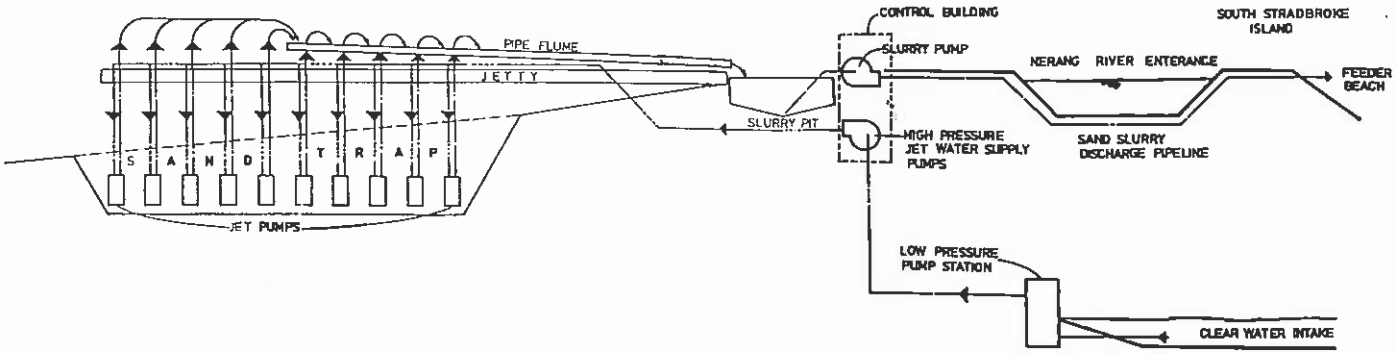




Figure 5.5.5
Land Based Plant Customised for Dredging

SOURCE: TOYO PUMPS AUSTRALIA



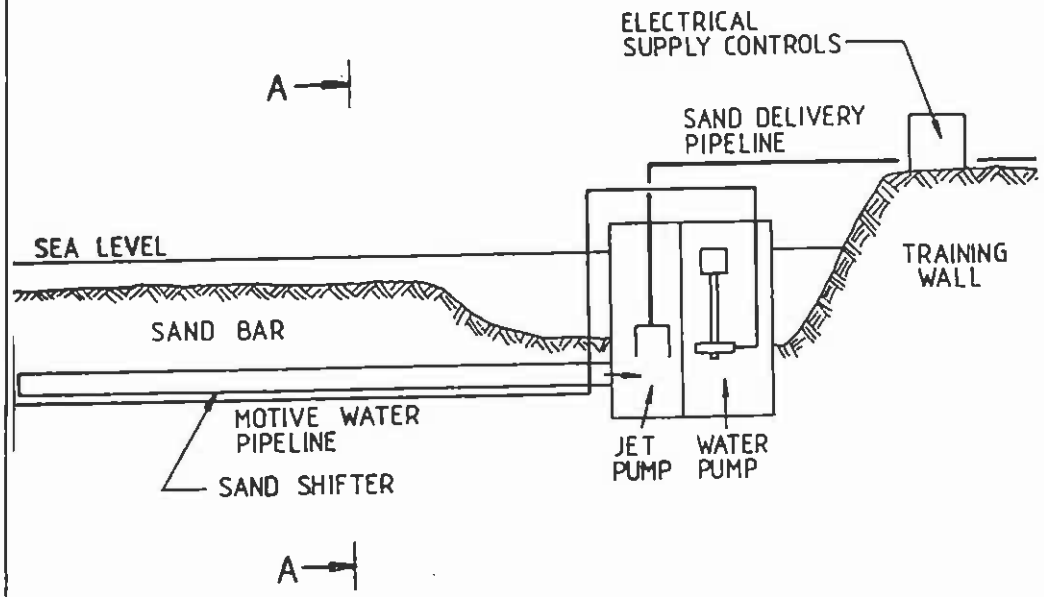


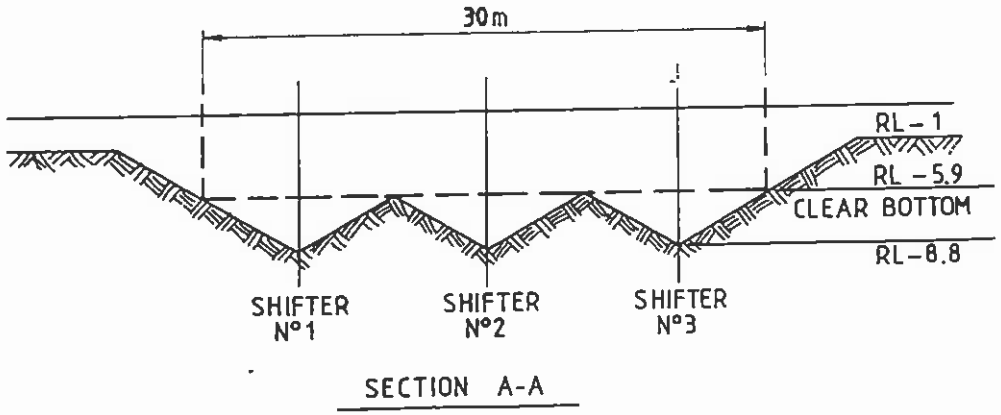
SOURCE: NERANG RIVER ENTRANCE STABILISATION
BEACH PROTECTION AUTHORITY BROCHURE
(JANUARY 1986)

Figure 5.5.6
Jetty Mounted System

Figure 5.5.7
Concepts Describing Sand Shifter System

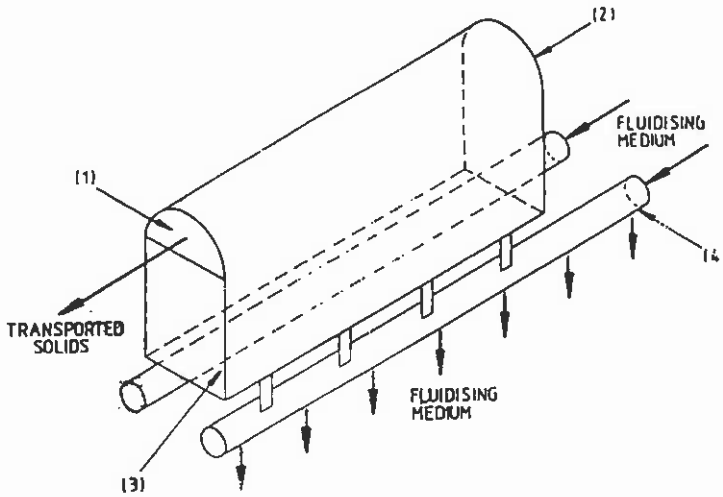
SOURCE: SLURRY SYSTEMS



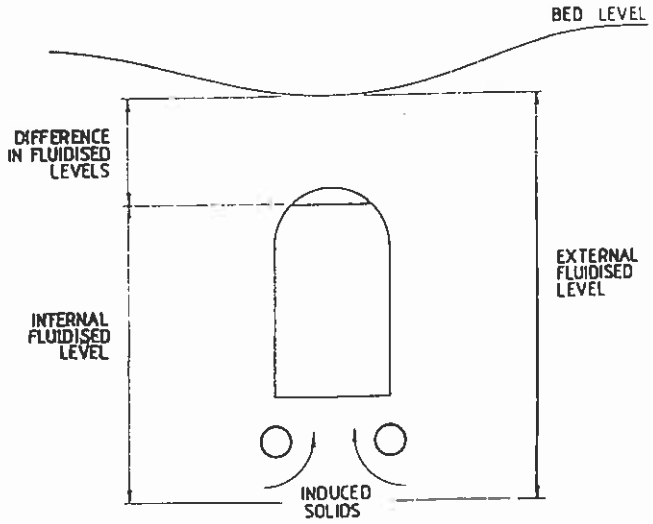


SECTION A-A

CONCEPTUAL SAND SHIFTER



STRUCTURAL DETAILS



TYPICAL CROSS-SECTION

5.5.5 Principal Plant and Associated Methodologies for Material Transportation

The principal plant and equipment by which a particular long listed sand bypassing system can be recognised, and the associated methodology for which the transportation of material can be described, are listed below:

- pipeline and associated ancillary equipment;
- floating vessel;
- trucking; and
- natural processes.

To transport the average yearly production rate of 500,000 m^3 per year via trucking would require an estimated 100,000 truck movements (utilising 10 m^3 trucks). Potential adverse environmental impacts associated with this alternative could comprise noise, traffic, conflicts with beach users and safety which could significantly affect the amenity of the local area. As such, this alternative was not considered to be environmentally sustainable and has not been included in the subsequent discussion. A generic description for each of the remaining methodologies customised to this Project has been prepared and is set out below.

Pipeline and associated ancillary equipment

An indication of the likely location of the pipeline routes and associated ancillary equipment (such as the main pump stations and booster stations) used by the sand bypassing systems is shown on Figure 5.2.2. In particular, potential locations for nearshore floating discharge intakes, floating, submerged and onshore discharge pipelines (buried and uncovered); clear motive water intakes and water supply pipeline; pump station and pump booster stations are indicated on Figure 5.2.2. Generally, the locations indicated for the pipeline routes and ancillary equipment have been carefully selected such that although accessible where practicable, they are situated in areas of low social and environmental significance. The main pump station may be located on the northern end of Letitia Spit or adjacent to Duranbah Beach in the location of the booster pump station shown in Figure 5.2.2. Also a submerged pipeline laid directly from the entrance area to Snapper Rocks may be used. As noted in Section 5.1, other specific routes may be utilised and would be assessed against local government requirements.

Nearshore floating discharge points will be required to enable principal dredging plant (such as a trailing hopper dredger and hopper barges with pump ashore capability or a cutter suction dredger) to pump material ashore from the nominated nearshore removal areas. The discharge points generally comprise a floating buoy or pontoon attached to one end of a submerged discharge pipeline. Convenient locations are generally selected to facilitate safe, deep water access, while at the same time minimising pipeline lengths. Potential locations identified for these intakes are offshore of Letitia Spit, Duranbah and Kirra Point.

Connection of the dredge discharge line to the main onshore pipeline would be via sections of floating pipeline, the nearshore floating intake, and submerged discharge pipeline. A section of floating line would normally be deployed to enable the dredge system a certain amount of flexibility and mobility. However, as this type of pipeline is significantly more expensive (by virtue of its flotation devices and high wear and tear at joints associated with wave activity. Its length would normally be kept to a minimum. Sections of submerged line would normally be assembled and strategically placed along the seabed, and run across the beach profile (at right angles to the sea bed contours) to the onshore pipeline. Sections of permanent submerged pipeline may need to be buried in a trench across those sections of the beach profile subject to storm activity. However, relocation, along with difficulties associated with ongoing repair, may be relatively expensive with a permanently installed line, and it may be more appropriate in the event of a storm to decommission it, tow it offshore, and leave it on the seabed, provided sufficient lead time is available. Issues that would need consideration relating to the operation of a submerged pipeline include:

- incorporation of a snifter (air purge) valve behind the dredger to enable air within the discharge line to be carefully purged. Slugs of air can cause sections of the submerged pipeline to rise above the seabed and damage the pipeline. This device would normally be located on a barge attached to the floating line in the vicinity of the floating/submerged intake;
- locating and marking of the position of the submerged line in a manner to prevent it being a navigation hazard; and
- completion of routine inspections to ensure its integrity to avoid leakage and the creation of underwater islands during removal and placement operations.

Although leaving the submerged pipeline in place between campaigns may be preferable, it may be difficult to achieve (ie. safety from storm damage, infilling with sand or weed, hazard to navigation or beach users and the risks associated with it floating to surface). In a similar manner to that discussed above, it may be more appropriate to remove the pipe, store it underwater in a safe location, and replace this type of pipeline, following each campaign.

The proposed route of the onshore discharge pipeline has been selected to minimise environmental disruption and pumping distance. Along Letitia Spit, the pipeline is most likely to be located within an easement that follows the existing access road. In the vicinity of the southern training wall, the pipeline would diverge and follow two possible routes to Snapper Rocks via Duranbah, and to Kirra Beach via Jack Evans Boatharbour and Greenmount Beach. This pipeline would typically be buried and sections (across the River, between Jack Evans Boatharbour and Greenmount Beach and through the headland at Point Danger) may need to be installed by techniques such as directional drilling although some sections in the vicinity of Point Danger may be exposed. An alternative route to that shown in Figure 5.2.2 would be from Jack Evans Boatharbour to Snapper Rocks via Rainbow Bay. Along the southern Gold Coast beaches, the onshore pipeline would run behind the beach. The material and size for the pipeline would be selected by the successful Contractor to match the nominated bypassing system and methodology. However, based on the Gold Coast Seaway experience, the discharge pipeline may be polyurethane lined steel (for superior wear and tear performance) of approx. 400 millimetres diameter.

Due to the pumping distances, and the required pumping duty, it is likely that pump booster stations will be required at a number of locations along the pipeline route. The spacing of booster stations would be a function of the size of plant selected. For a high performance small to medium cutter suction dredge, for instance, booster stations would need to be spaced at around 2.0 km intervals to ensure optimal performance. The booster station locations indicated on Figure 5.2.2 are in the foreshore reserve behind Duranbah Beach, a halfway point on Boundary Street and at Kirra Point (for additional flexibility for the subaerial nourishment at Coolangatta, Greenmount and Kirra beaches).

In addition to transportation of the hydraulic slurry along a discharge pipeline, bypassing systems incorporating sand fluidisation technologies will require a supply of motive water. As this water is pumped under high pressure, clear water is required to minimise wear and tear on system components. Potential clear water intakes should be located where river flows are slowest, and suspended sediments levels are lowest. Potential intake locations are situated adjacent to the southern training and within the Jack Evans Boatharbour, as indicated on Figure 5.2.2. The pipeline route for the supply of clear water would be within the easement indicated for the discharge pipelines.

Floating Vessel

As indicated in Section 5.5.4, material removed can be loaded into hoppers contained within trailing suction hopper dredgers and hopper barges. Once full the vessel steams to the nourishment area for placement by either bottom dump, side cast/bow cast, or pump ashore methodologies. An example of a self propelled hopper barge is shown on Figure 5.5.8.

Natural Processes

Natural coastal and estuarine processes that occur within the river entrance and nearshore regions can be utilised to assist in the movement of sediment from the nominated removal areas to the designated nourishment areas. Favourable site conditions that will assist in transporting material in the right direction would comprise an ebbing tidal current in conjunction with a strong northerly wave induced current.

Natural processes would be unsuitable as the primary transportation system, as favourable meteorological conditions would not occur for long enough periods, and hence, Project objectives could be compromised. However, it is envisaged that natural processes could be used in some regard to transport smaller quantities of sand over shorter distances.

5.5.6 Principal Plant and Associated Methodologies for Material Placement

The principal plant and equipment by which a particular long listed sand bypassing system can be recognised, and the associated methodology for which the placement of material can be described, are listed below:-

- bottom dumping;
- pumping ashore;
- bow or side casting; and
- discharge outlets.

A generic description for each of these methodologies, customised to this Project, has been prepared and is set out below.

Bottom dumping

Bottom dumping involves either a trailing suction hopper dredger or a hopper barge approaching the subaqueous (nearshore) portion of the active beach profile to within the safe operational limits of its navigable depth. The doors or valves constructed on the bottom of the hull of the vessel are opened and the load is dumped on to the beach profile. During this process, because the vessel actually rises out of the water as the load is dumped, the navigable depth is maintained. Electronic position fixing systems enable accurate location of vessel prior to bottom dumping material.

As demonstrated in Stage 1A of this Project, this method of placement is very cost effective in placing material within the designated nearshore beach nourishment area.

Pump ashore

Pumping ashore is a method developed with plant such as a trailing suction hopper dredger or a hopper barge specifically for beach nourishment works. This method involves the fluidising of material in the hopper and the pumping of this material from the hopper to the subaerial (onshore) portion of the beach profile via a discharge pump, outlet, and pipeline. This method, when used in conjunction with other placement methods, facilitates complete nourishment of the beach profile.

Typically, the solids concentration of the slurry would be in the order of 20% solids by weight. This would normally involve the vessel anchoring in a mooring area that is located within the safe operational limits of its navigable depth, and the coupling of its pump ashore discharge outlet to the discharge pipeline intake that

is attached to a floating nearshore intake anchored to the seabed. The discharge pipeline would typically comprise sections that are floating, submerged and onshore. A discharge outlet would be located onshore from which deposited material would be reworked by an onshore crew using land based plant and equipment such as bulldozers and front end loaders. The onshore outlet can be moved by extending sections of pipeline. The "pancake" method of construction would normally be adopted to progress the onshore beach nourishment area.

As demonstrated in Stage 1A of this Project, this method of placement was effective in placing material within the designated onshore beach nourishment area.

Variations to this method could incorporate the utilisation of a spreader barge for underwater placement of material in the subaqueous portion of the beach profile. The spreader barge would comprise a diffuser placed on the end of the discharge pipeline which is supported from a floating, or over the water, working platform. The diffuser and the supporting platform can be moved to ensure an even spread of material on to the sea bed. This variation has a lower operational efficiency and is correspondingly more costly.

Bow or side casting

Bow or side casting is a method developed with plant such as a trailing suction hopper dredger or a hopper barge, specifically for beach nourishment works. This method involves the fluidising of material in the hopper and the pumping of this material in a similar manner to the pump ashore method of discharge, except that rather than coupling the pump ashore discharge outlet to the discharge pipeline, material is simply pumped out of the pump ashore outlet and cast some 50 metres or so in front of the bow or to the side of the vessel.

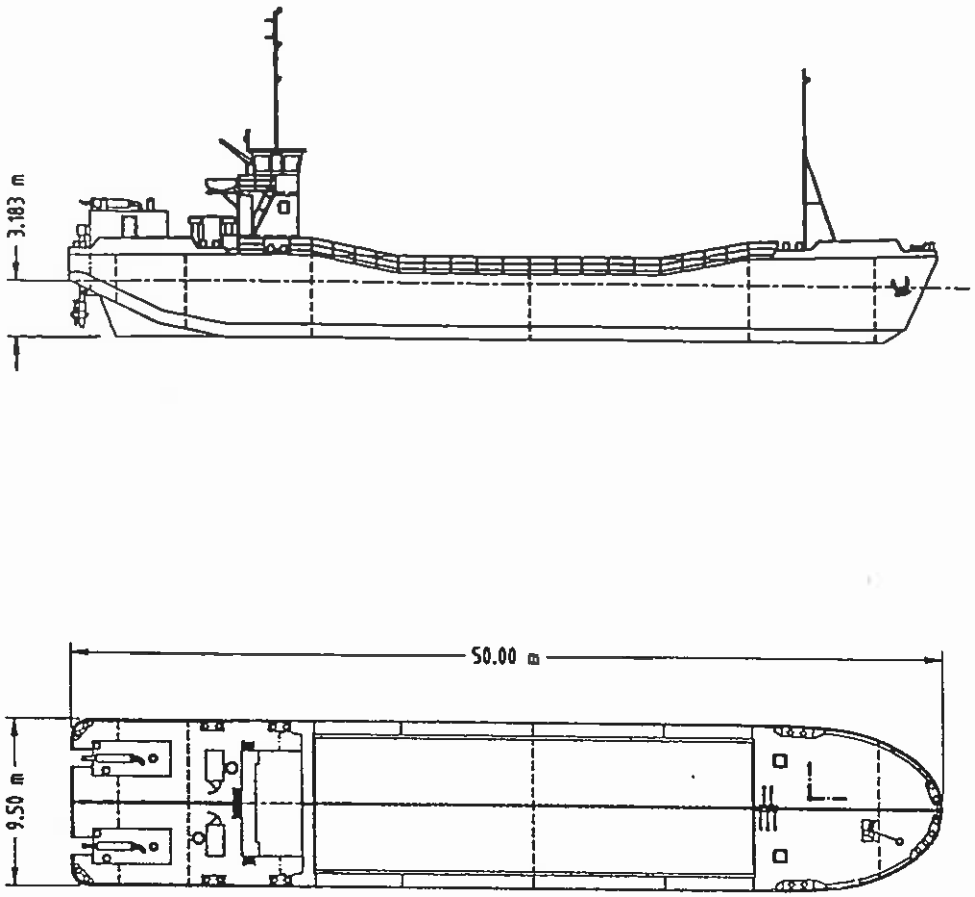
This technique is used for profile nourishment within the subaqueous portion of the beach profile and enables placement of material closer to the shoreline than that achieved through bottom dumping.

As demonstrated in Stage 1A of this Project, this method of placement was very effective in placing material within the designated nearshore beach nourishment area and in that rocky section of coastline between Lovers Rocks and Snapper Rocks under favourable offshore conditions.

Discharge outlets

Conventional placement of material from the discharge pipe on to the nominated onshore nourishment area is typically managed by controlling the direction of flow of the discharge water with conventional land based plant and equipment such as bulldozers and front end loaders. A diffuser is often placed on the end of the discharge pipeline to assist in spreading material over a greater area.

The secondary discharge locations at Duranbah, west of Snapper Rocks and Kirra Point would be used on an as-needed basis and for relatively short periods. A likely configuration for these outlets would involve the installation of a permanent pipeline in a service trench behind the beach which is covered over for the majority of the time. When required, a temporary length of pipe (probably polythene pipe of around 300 mm diameter) would be attached to a take-off point on the permanent line to allow discharge directly on the upper beach or the nearshore. Within the onshore nourishment area, the discharge distribution pipeline may have a series of take-off points along its length in order to progress the deposition face in an even manner. Once the required level of nourishment has been achieved at one location, the discharge is redirected to another outlet and so on. This also facilitates the efficient use of the land based plant and equipment, which can be kept working continually (ie. from one outlet to the next) for the majority of time. When the required profile height has been achieved in front of, and around a particular outlet, a new section of pipeline is added, and the deposition face progresses. This technique lends itself to both subaerial and subaqueous discharge.



Year of construction		1978
Yard		Whyalla, S.A.
Type		I.H.C. Split Hopper Barge
Classification		Lloyd's 100A1 LMC Hopper barge for extended protected waters service
Dimensions	Length o.a.	50m
	Breadth	9.5m
	Hopper Length	25m
	Hopper Width	7.5m at deck
Light service draft (with 20t fuel & 10t water)		0.15m fwd 2.17m aft 1.14m @ LCF
Loaded draft		2.96m fwd 3.38m aft 3.18m @ LCF
Hopper capacity		500m3
Tonnage	Registered Nett	561t
	Lightship	383t
	Light service	411t
	Deadweight(loading capacity)	900t
Propulsion		2 x Schottel Rudder Propellers
Main engines		2 x 365 HP Caterpillar Diesels Model 3408
Fuel		Distillate
Accommodation		Mess room, crew and officer's change rooms, showers, toilets

Figure 5.5.8
Self Propelled Hopper Barge

SOURCE: WESTHAM DREDGING

A possible discharge strategy for the major Snapper Rocks discharge involves creation of a temporary beach against the shoreline which would then be reworked by natural wave action (Section 7.2.2 and Technical Appendix II). This would involve one or more discharge points near the mean waterline, similar to the Gold Coast Seaway bypassing system outlet on South Stradbroke Island. Alternatively, material can be placed from a series of diffusers attached to either a jetty structure or risers forming part of a subaqueous structure. These structures may extend some 100 m offshore into the nearshore zone and be comprised of up to eight equally spaced diffusers incorporating vertical risers above the seabed. Such discharge outlet structures would enable material to be spread in a prescribed cross shore pattern that can replicate natural processes and can be adjusted to match seasonal considerations.

5.5.7 Miscellaneous Infrastructure

In addition to the principal plant associated with the removal, transportation, and placement of material, there exists some important miscellaneous infrastructure that may be required to support the permanent sand bypassing system. Although the nature of the support infrastructure will vary from system to system the full range of infrastructure is likely to include buildings, carparks, security fencing, materials handling areas, specialised plant and equipment for heavy mineral sand extraction, access roads and services.

During the construction phase of the Project, all systems would need a suitable land base containing some miscellaneous infrastructure, such as temporary buildings, carparks, access roads, and services. However, during primary operation, it is mainly the land-based systems that will need to maintain this land base. Over-the-water based systems, once operational, would have minimal land requirements, and as such, would have minimal land-related infrastructure.

The most suitable location for this land-related infrastructure would be on the northern end of Letitia Spit. A potential location is indicated on Figure 5.2.2.

This full range of miscellaneous infrastructure is described below.

5.5.7.1 Buildings, Carparks and Security Fencing

The operations building, if required, would accommodate important electronic equipment necessary for control and accommodation for personnel involved in the operation of the sand bypassing system. Particular equipment may comprise instrumentation, controls, communications, and services. The building would probably have dimensions of around 20 m by 10 m and would be designed to be unobtrusive in appearance and constructed of natural materials to fit sensitively into the existing environment. Facilities offered to the building would include a reception/secretarial area, an office, common/meal room, kitchen, and male/female toilets.

Other facilities that may be required could include a building to house a pump station and outside lighting.

A workers/visitors carpark would be located adjacent to the control building, if required. The carpark would probably be some 50 m long and around 15 m wide in order to accommodate around 20 car parking spaces with appropriate access ways. In order to match the existing environment, the carpark area would be constructed as an informal area paved with gravel.

The location of the operations building is likely to be on the northern end of Letitia Spit although it could be situated adjacent to Duranbah Beach near the booster station location shown in Figure 5.2.2 or adjacent to Lovers Rock. As with the Nerang bypassing system, a fixed system could become a local tourist destination. It may therefore be necessary to isolate the operations control building and plant and equipment associated with the operation of the system from access by the public or native fauna. If required, security fencing

would comprise cyclone type wire fencing with a height of around 2.1 m posts with a spacing not exceeding 3.0 m and a layer of high tensile barb wire fastened to the top of the posts.

5.5.7.2 Materials Handling Areas

An area depending upon the particular system, may need to be incorporated to handle material during construction of the system and for storage of spare parts and the like during operations. This area would be located to meet the requirements of a particular system and could be of the order of 500 m^2 in area.

5.5.7.3 Access Roads

An existing gravel access road runs along Letitia Spit and connects the southern breakwater with the township of Fingal (Section 4.6.12). In order to facilitate construction and operation activities to it may be necessary to upgrade this road. This road would be sufficiently wide to enable two way truck access.

5.5.7.4 Services

Services to be provided to the site would comprise water, sewerage, power and telecommunications (Section 4.6.13). It is likely that these services would be brought into the site within the easement nominated for the discharge and motive water pipelines. Alternatively, they could be brought to the site from the township of Fingal.

5.6 Activities Associated with Capital Works

5.6.1 Construction Activities

Construction activities would vary significantly depending on the permanent bypassing system adopted. Some systems, such as the water-based dredgers, would require minimal land-based construction activities, whereas onshore-based, and fixed systems would involve substantial construction activities.

The construction activities would encompass all activities required to construct the permanent sand bypassing, which may include pile driving, trenching (including minor blasting works), assembling of pipelines on beaches and launching them, storage of equipment and materials for construction of any structures (eg trestles) and storage of fuel and chemicals in accordance with accepted construction good practice. The construction site would contain temporary buildings for site administration employee amenities and storage of supplies. Temporary parking areas would be required for employee vehicles and deliveries.

5.6.2 Duration of Works

The duration of construction works will vary depending upon the nature of the successful tender. Schemes based on dredging would involve the least construction time; of the order of two to three months for dredge mobilisation and laying of pipelines. Remote systems involving the installation of fluidising pipes and slurry transportation systems would probably take in excess of six months to construct.

A system based on an offshore jetty would be likely to require the longest construction time; of the order of 18 months to two years.

5.6.3 Land Area Requirements

The land area requirements will also vary depending upon the nature of the proposal of the successful tender. Some systems, such as water based dredgers, would require minimal land area, whereas onshore based and fixed systems would involve a need for plant equipment and associated facilities to be accommodated.

The water based systems would require a small compound typically 20 m by 30 m for storage of pipes, pumps and miscellaneous equipment.

The onshore based and fixed systems would require a significantly larger land area. As a guide, based on the Gold Coast Seaway experience, the main compound would occupy an area at least 30 m by 60 m and incorporate a pump station building with an area of 2,500 m^2, hardstand carparking and access way. In addition, smaller compounds of the order of 10 m by 10 m would be required to accommodate/house booster stations.

5.7 Operational Considerations

5.7.1 Maintenance

Each of the nominated plant and equipment systems would require inspection, repair and maintenance during the completion of the nominated works.

In order to minimise downtime and therefore costs associated with the completion of the nominated works, the preferred plant and equipment systems should be manufactured using proven technology and readily available (off the shelf) components, and should involve straightforward maintenance.

Nominated rates of wear and tear on key parts and elements in achieving the production rates required, and an appropriate on going maintenance program during the operational life of the permanent sand bypassing system would need to be specified by the Contractor.

5.7.2 Personnel Requirements

The personnel requirements to implement the Project may vary significantly between each of the different sand bypassing systems depending on the plant and equipment nominated. Personnel could be expected to range from 2-4 operators (fixed system) through to 20-25 on a dredge.

An increase in the number of personnel required would generally result in a corresponding increase in operational logistics (and therefore costs) and influence the strategy by which the works might be most efficiently undertaken.

For a system which utilises floating plant and equipment for the delivery of the sand, all floating vessels would have to meet relevant maritime codes and be manned by competent maritime personnel. This requirement would vary depending on whether the floating vessels were self propelled or towed by work boats.

Personnel requirements necessary for the efficient and safe implementation and ongoing maintenance of the nominated permanent system, including ancillary plant and equipment requirements would need to be specified by the Contractor.

5.7.3 Construction and Operating Hours

To minimise the effects of the permanent bypassing system on the existing environment (ie. effects associated with noise generation, traffic and potential conflicts with beach users), it would be preferable to restrict the times during which operational activities were undertaken. Construction hours, however, would need to be flexible in recognition of the hostile marine environment. Construction would need to optimised during periods of favourable weather. The following times are suggested for the construction and operation phases:

Construction

To facilitate construction and to take advantage of good weather, construction could take place 7 days a week although most work would be likely to be between the hours of 7 am to 7 pm, 6 days per week. .

Operation

The operating hours during the operation of the permanent sand bypassing system will largely be dependent on the nature and location of the plant and equipment nominated and the down drift sand requirements at a particular time. However, fixed systems would need to operate virtually continuously, or a least daily, to maintain efficiency and effectiveness. Fixed systems could particularly target evening operation to take advantage of off peak electricity rates 9 pm - 6 am.

Operational times for the system nominated would be established by the Contractor to minimise the effects on the existing environment and to allow optimisation of the plant and equipment capabilities.

5.7.4 Management and Logistics

To ensure that each of the plant and equipment systems effectively execute the project proposal in a well coordinated, efficient and environmentally sensitive manner, a certain level of management and logistical support would be required.

The personnel requirements necessary for management of the project would typically comprise a project manager (responsible for planning and operations), technical superintendent, hydrographic survey team, dedicated work boat or support vessel crew, and onshore reclamation crew.

Logistics support necessary to ensure each of the plant and equipment systems operate properly would include the transportation and supply of items (such as personnel, fuel, ancillary plant and equipment, spares and stores) and the facilitation of repair and maintenance activities on an 'as-required' basis.

5.7.5 Ancillary Plant and Equipment

Ancillary plant and equipment is often necessary to support the primary plant and equipment systems during the construction, operation and maintenance phases of the project.

Such plant and equipment could include a dedicated work boat or support vessel, a hydrographic survey vessel, a self propelled or dumb barge incorporating storage and lifting capacity (to handle and deploy anchors, pipelines, deliver fuel, spare parts and small stores), spreader barge (to assist in underwater placement of material), snifter barge (in the case of submerged pipelines to purge slugs of air) and land

based plant and equipment (such as four wheel drive vehicles, excavator and bulldozer) to provide support to the onshore placement areas.

5.7.6 Replacement of the Permanent Sand Bypassing System

It should be noted that the permanent sand bypassing system will be designed and constructed to operate effectively and efficiently for a period of the order of 25 years. At the completion of its operational life, the system will be replaced. Activities which may be required at this time could include removal of existing plant and equipment and the construction and commissioning of a replacement system. These activities would be similar to the initial construction activities identified in this document.

5.7.7 Risk of Failure

During the operation of the system, a mechanical breakdown or blockage may occur. A significant cessation to operations may result in the outflanking of the permanent sand bypassing system by the movement of quantities of material under modal, or episodic, longshore transport processes. The movement of large quantities of material past the permanent system may compromise the objectives of the Project, and thereby constitute a failure of the sand bypassing system.

The successful proponent will be required to identify the potential problem sources that may have the potential to result in the failure of system, provide an indication of an appropriate course of action emergency procedure for implementation, provide an indication of the time that may be required to repair/rectify the problem, and nomination of appropriate plant and methodology that would supplement the permanent sand bypassing system in the event of failure of the primary system.

Adequate mechanisms, to minimise the risk of failure, would be required as part of the total bypassing system. It is possible that, from time to time, additional construction activities could be required to modify or repair the plant and equipment following a system failure. These activities would be similar to the initial construction activities identified in this document.

5.7.8 Occasional Supplementary Dredging and Nourishment

It is recognised that no single system (by itself) is likely to be able to capture all material during its operational lifetime.

Outflanking of a fixed system may occur due to large episodic movements of material (in the form of sand slugs associated with significant storm events), deposition of material at the mouth of the river entrance following a significant fresh event, and modal transport of material past the system resulting from a temporary cessation of the system (due to blockage or maintenance works). To ensure that the objectives of the Project are not compromised, it may be necessary, on occasions, to undertake supplementary dredging and nourishment operations.

Outflanking of a mobile system is less likely due to the flexibility of the system to capture sediment over a larger area. Nevertheless, supplementary dredging and nourishment may still be required to combat the transport of large sediment 'slugs'.

If supplementary dredging is required, such operations would be undertaken utilising appropriate plant and methodologies discussed in this document.

5.7.9 Disposal of Waste Material

Waste material can be generated during dredging / nourishment type projects by the wearing out of parts and components of machinery and refuse created by the workshop employed on the project.

Over the duration of the project, the contractor would be responsible for the appropriate disposal of this material. In particular, waste materials would be removed from plant and equipment involved in the project as part of the routine maintenance servicing activities. Maintenance waste, such as scrap metals, would normally be collected by a waste contractor. Waste lubricants would be collected by a licensed liquid waste recycling company.

Site office waste would include paper, plastic and other items of domestic waste, which would either be collected by a waste contractor or disposed of through the community recycling system.

Table 5.5.1 Alternative Sand Bypassing Systems

	Alternative	Description	Advantages	Disadvantages	Comments
	Over-The-Water Mobile Systems				
Ov-1	*Trailing suction hopper dredger in river entrance and nearshore zone*	Trailing suction hopper dredge removes material from the entrance bar and updrift nearshore zone. Dredge moves under own power to nourishment area where material is then either pumped ashore, bow cast or bottom dumped	• Can dredge directly on the entrance bar or within the navigation channel. • Relatively inexpensive. • Easy to maintain. • Contractually suitable for 'opportunity' type operation. • Dredge can be utilised elsewhere when not required for bypassing. • Not susceptible to debris problems. • Nourishment of both sub-aerial and sub-aqueous portions of the beach profile can be achieved • High flexibility to modify / optimise operation procedure. • No fixed structures required. • No ancillary plant necessary. • Relatively low noise and visual profile.	• Assumes availability of ocean going trailing suction dredge, as required to satisfy bypass operations. • Dredge operations can be limited by storm conditions. • Bottom dump option requires natural nearshore processes to rework material onshore and perceived benefits not immediate. • Potential navigational hazard whilst dredging is in progress on bar	Cost effective short term solution providing adequate weather window exists. Intermittent nature of operation and of practicality of having an ocean-going dredge 'on-call' may result in difficulties in achieving a reliable solution. Minimal initial capitalisation. Project may require a dedicated dredge.
Ov-2	*Cutter suction or suction dredger in river entrance and nearshore zone*	Conventional cutter suction dredge removes and pumps material in a hydraulic slurry via sections of floating, submerged and onshore delivery lines to discharge outlets.	• Relatively inexpensive. • Easily maintained. • Direct dredging within navigation channel. • Not susceptible to debris build up. • Contractually suitable for "opportunity" type operation. • Relatively low noise and visual profile. • Plant can be utilised elso-where when not required for bypassing	• Cannot dredge directly on the entrance bar. • Will intercept a relatively small proportion of the total littoral drift. • Limited effectiveness in long period nearshore wave climate.	Low operational efficiency due to nearshore wave climate will severely limit effectiveness of this system, particularly on a moderate to high littoral drift coast. Best used in conjunction with one of the other alternatives. Is best suited to role of ancillary plant.
Ov-3	*Cutter suction or suction dredger in river entrance and nearshore zone in conjunction with an entrance weir*	A low weir section in the updrift training wall allows sand to be washed/blown into a trap inside the entrance. A normal cutter suction dredge operates in the sheltered waters of the trap transferring sand via a submerged discharge pipeline to the discharge outlet.	• Relatively inexpensive bypass plant. • Easily maintained. • Debris build up controllable. • Contractually suitable for 'opportunity' type operation. • Will capture a more significant proportion of the littoral drift than without an entrance weir (option Ov-2) provided updrift training walls is an adequate length. • Relatively low noise and visual profile. • Dredge can be utilised elsewhere when not required for bypassing	• Cannot dredge directly on the entrance bar. • Requires an expensive updrift training wall with a long weir section and a head which is remote from the land. • Difficult to maintain updrift training wall due to access problems. • Precludes recreational usage of updrift training wall unless a bridge is installed along the weir. • Requires a large trap area inside the entrance if full benefits are to be gained	A high initial capital cost solution. Updrift training wall would need to be sufficiently long and robust to cope with the associated shoreline fluctuations. Would require a substantial area within the entrance to accommodate the required sand trap. Would raise considerable new environmental issues.
Ov-4	*Cutter suction or suction dredger in river entrance and nearshore zone in conjunction with an offshore breakwater*	An offshore breakwater is constructed parallel to the coastline, outside the 'normal surf zone'. The breakwater is located updrift the river entrance. A depositional trap is formed in the sheltered region of the updrift extension. A conventional cutter suction dredge would be deployed periodically to work in the sheltered waters behind the training wall to clear the trap. The dredged sand is pumped via a submerged discharge line to the discharge outlet.	• A proven, very successful, method for moderate to high littoral drift coasts. • Dredges can be used on an 'opportunity' basis. • Downdrift training wall can be relatively short. • Offshore breakwater provides some additional protection to entrance. • Maintenance of training wall is reduced as a function of modified wave climate. • Low noise level. • Dredge can be utilised else where when not required for bypassing.	• Probably the most expensive capital cost solution reflecting offshore breakwater construction. • Dredging can only be undertaken in the area where sheltering effect of training wall is adequate. • Maintenance of the offshore training wall is difficult and expensive. • Visually intrusive. • Potential navigation hazard if not appropriately marked or illuminated	The capital and/or maintenance costs of the offshore breakwater would be prohibitive. It is, however, a proven method for successfully trapping and transfer of sand across a river entrance. Construction impacts would be significant.
Ov-5	*Jack-up dredge in river entrance and nearshore zone*	A floatable self elevating platform is used as an offshore base for a suction dredge. The dredge head can be mounted on a slewing arm or housed in a remotely operated vehicle connected to the platform by an umbilical cord. Material is delivered via a submerged pipeline to the required discharge point. Material can be removed in a pre-determined pattern. Platform can be relocated as required by jacking-down and floating to a new location.	• Can dredge directly on the entrance bar or within the navigation channel. • Very flexible solution which is relocateable, re easy to modify / optimise operation procedure. • Not affected by fluctuation in surf zone width. • Can be utilised elsewhere when not required for bypassing. • Low noise and visual profile. • Can be moved or jacked-up to a survival condition if severe weather occurs. • Can operate in all but most severe weather	• Relatively expensive capital and maintenance costs. • Requires permanent crew with associated costly crew transfer. • Potential navigation hazard when working in the entrance channel or on the bar	Well suited to moderate to high littoral drift coasts. Although expensive capital and maintenance costs this alternative has the ability to hunt for material in the entrance and nearshore compartments, making it an attractive alternative.
	Fixed Systems Located In The Nearshore Zone				
Fx-1	*Fixed element of plant mounted on the southern breakwater*	System comprising fixed plant, such as pump and slewing dredge head, mounted on the updrift southern training wall. Material pumped via a submerged discharge pipeline located under entrance channel to a discharge outlet. Dredge head could comprise • jet pump, • submersible pump, and • grab	• Relatively inexpensive to construct, maintain and operate. • Operational in all but most severe conditions. • Can be connected to shore based power. • Can be automated	• Susceptible to littoral outflanking, re will not maintain entrance bar channel • Cannot accommodate local shoreline fluctuations. • Potentially ineffective in a wide surf zone. • Cannot be relocated to dredge sand build up on entrance bar or the navigation channel. • Must be capable of handling peak transport as there is no facility for updrift storage. • Potential for problems with debris build up. • Potentially a safety hazard to swimmers or person using the training wall for recreation purposes. • Potential to be an unsightly piece of plant, due to bulk required to resist wave forces. Potential to undermine host training wall structure. • Dedicated plant. • Inflexible operation	Only suitable for small inlet on low littoral drift coasts where short term shoreline fluctuations are small. May have possible application as ancillary plant as part of a hybrid scheme.
Fx-2	*Mobile element of plant mounted on the southern breakwater*	Side cast dredge or dredge head mounted on vehicle which moves along training wall similar to that described for option Fx-1.	• Can operate over a wider area of the surf zone than the alternative (Fx-1). • Can accommodate some shoreline fluctuation. • Can be used to clear the entrance channel inside the training wall. • Relatively inexpensive to install, maintain and operate. • Can be connected to shore based power.	• Likely to require manning during operations. • Cannot dredge directly on entrance bar or within the navigation channel. No facility for updrift storage. • Potentially a safety hazard to swimmers and persons using training wall for recreation purposes. • Potential to be an unsightly piece of plant due to bulk required to resist wave forces. • Potential to undermine host training wall. • Dedicated plant • Will not maintain entrance bar channel	Suitable for low to moderate littoral drift coasts where navigation is not a major issue and where the lack of an updrift storage area is not critical to effective and efficient operation. The recreational amenity of the training wall can be significantly reduced by the plant operation. May have possible application as ancillary plant as part of a hybrid scheme.
Fx-3	*Jetty mounted system comprising of fixed plant*	Jet pumps or slurry pumps located at fixed points along a jetty. Dredged material would be pumped through a discharge pipeline that runs along the jetty under the foredunes and beneath the entrance channel to the discharge outlet. The jetty would be located an appropriate design distance updrift of the walls.	• May operate in all but most severe wave conditions. • Can be automated. • Creates storage cones which buffer the fluctuations resulting from the natural coastal processes. • Can be connected to shore based power. • Jetty can be utilised as a recreational facility. • Offers some flexibility to optimise removal effort, spatially	• Cannot dredge directly on the entrance bar or within the navigation channel • High capital investment on jetty structure. • Can only operate on material in immediate vicinity of jetty. • Depends on natural processes to maintain delivery of sand to cones at dredge heads. • Potential problem with debris build up at fixed head locations. • Visually intrusive. • Significant maintenance of structure and pumps required *(multiple pumps)* • Dedicated plant. • Likely to need ancillary plant to maintain channel from time to time.	Such a system is currently operating at Southport on the mouth of the Nerang River. Capital cost, lack of flexibility and maintenance problems are the major drawbacks to this system. Can be used on high littoral drift coastlines and has the advantage of a high level of automation thus allowing optimal use of low cost power and low labour costs. Requires multiple pumps to adequately intercept littoral drift and hence additional maintenance costs due to pump numbers.

TABLE 5.5.1 Alternative Sand Bypassing Systems (continued)

	Alternative	Description	Advantages	Disadvantages	Comments
	Fixed Systems Located In The Nearshore Zone (Continued)				
Fx-4	*Jetty mounted system comprising of mobile plant*	Jet pumps or slurry pumps, mounted on a moving platform which can traverse along a jetty located at an appropriate distance updrift of the entrance. Sand would then be pumped to the discharge point via a discharge pipeline located under the entrance channel.	• May operate in moderate to high wave conditions, • Accessible for maintenance, • Creates a storage trench which buffers the natural fluctuation resulting from the natural coastal processes. • Can be connected to shore based power. • Single pump head • Greater flexibility than option Fx-3 to optimise removal effort, spatially.	• Cannot dredge directly on the entrance bar or within the navigation channel, • High capital investment in jetty and system, • Can only operate on material in vicinity of jetty. • Depends on natural processes to deliver sand to trench. • Jetty cannot be utilised for recreational purposes • Visually intrusive, • Significant maintenance of structure and system required. • Dedicated plant • Likely to need ancillary plant to maintain channel from time to time.	Moving head produces a trench rather than the fixed head cones When compared to the fixed system (Fx-3) this has the advantages of reduced debris build up and improved ability to dredge from optimum location, but the disadvantage is a jetty which has single purpose and cannot be automated to the same degree as fixed system
Fx-5	*Fixed scraper supported from towers and cables (Sauerman Scraper)*	A dragline type bucket which runs along a flying fox to a tower located in the surf zone As bucket is dragged ashore it scrapes sand from surf zone to form a trench *(sand crap)*. Sand collected onshore can be trucked or pumped across channel to discharge point	• Relatively expensive to operate and maintain, • Can accommodate shoreline fluctuations, • Creates a storage area in the form of a trench which buffers the fluctuations in the natural surf zone processes. • Can be connected to a shore based power.	• Cannot dredge directly on entrance bar or within the navigation channel, • Has a fixed capacity depending on cycle times and practical bucket size. • Visually intrusive and noisy. • Cuts beach access at working point, • Safety hazard to beach users, • Cannot be readily relocated, • Only operates over limited area, • Cannot work in moderate to high wave conditions, • Dedicated plant	Apart from the major loss of recreational amenity and access because bucket regularly traverses the surf zone and beach, there is a practical upper limit to the peak sand transfer capacity Unsuited to the local environment
	Onshore Based Mobile Systems				
Os-1	*Scraping of material using land based plant and equipment*	Rubber tyred, self elevating scrapers loading sand from beach then transferring to slurry pit and pump system for delivery under entrance channel through discharge pipeline.	• Maximum flexibility with respect to cost effectiveness, • Low maintenance, • Very adaptable to 'as required' contractual 'opportunity' arrangements, • No permanent structure on shoreline, • No dedicated plant	• Cannot dredge directly on entrance bar or within the navigation channel. • Only removes sand from beach, • After a storm event much of the sand may be offshore and therefore inaccessible • Requires 'over dredging' of beach to form a trap • Totally alienates a stretch of beach whilst operation in progress. • Safety hazard on beach, • Noisy and visually intrusive on natural environment	This method is too reliant on natural processes to provide material Pumping option would need to be utilised to transfer the sand across the entrance The need to operate large vehicles on the beach and/or roadways would be undesirable in a region where tourism is a major industry. Only suitable as ancillary plant as part of a hybrid scheme
Os-2	*Mobile land-based system in upper portion of beach profile*	Involves removal of material from the upper beach profile using conventional land based plant with long reach capability such as draglines, crawl cranes, or excavators that have been customised for dredging through the incorporation of an appropriate removal device *(such as grabs, jet pump or submersible pump)* attached to the boom.	• Relatively inexpensive to construct, maintain and operate, • Low maintenance, • Very adaptable to 'as required' contractual 'opportunity' arrangements, • No permanent structure on shoreline, • No dedicated plant.	• Cannot dredge directly on the entrance bar or within the navigation channel, • Only removes sand from beach, • After a storm event, much of the sand may be offshore and therefore inaccessible, • Safety hazard on beach, • Visually intrusive on natural environment, • Susceptible to outflanking,	This method is limited in area of removal, ie up to 30 metres from LW only Also, there is a major loss of recreational amenity and access because equipment, such as dragline bucket, regularly traverses the surf zone and beach. There is a practical upper limit to the peak sand transfer capacity Only suitable as ancillary plant as part of a hybrid scheme
Os-3	*Cutter suction dredger in upper portion of beach profile*	A large trench is periodically created along the back beach region parallel to the shoreline using conventional cutter suction dredges. Sand is transferred to downdrift beaches by discharge pipeline located under entrance channel. After trench has been completed, it is opened up to the ocean to allow infilling by natural processes	• Relatively inexpensive. • Can be effective in trapping a significant proportion of the littoral drift. • Contractually suitable for 'opportunity' type operation. • Can have low noise and visual intrusion if buffer zone established around the disturbed area, • Plant can be utilised else where when not required for bypassing	• Cannot dredge directly on the entrance bar or within the navigation channel, • Alienates a significant portion of the coastline updrift of the training wall. • Can result in large fluctuation in coastal alignment. • Highly dependent on prevailing natural processes for its success, • Major public safety hazards during dredging and natural infilling • Intercept only minor proportion of total longshore transport	A relatively inexpensive solution even on high littoral drift coasts provided that the updrift training wall is sufficiently long and robust to cope with the associated shoreline fluctuations However, this alternative may not be acceptable on social and environmental grounds as it would require isolation of a significant length of coastline updrift of training wall Only suitable as ancillary plant as part of a hybrid scheme
	Other Systems				
Ot-1	*Remote system comprising sand fluidising and slurry transport*	Sand fluidising conduits are placed and remotely operated within the removal area and used to collect and transport agitated material to an appropriately located sump, from where it can be transferred using jet pumps, a pipe flume, constant density tank, slurry pumps and slurry discharge pipeline	• Can accommodate some shoreline fluctuation, • Relatively inexpensive to install, maintain and operate, • Can be connected to shore based power, • Very adaptable to 'as required' contractual 'opportunity arrangements, • Minimum visual and noise impacts	• Cannot operate during high and severe wave conditions. • Significant maintenance of pumps required. • Susceptible to blockage. • Likely to have high running costs	Remote nature of system enables material to be won from a large are on an 'as required' basis not relying on natural process to transport material to the dredger
Ot-2	*Remote system with directional drilling, sand fluidising and slurry transport*	A hole is drilled to the identified removal area This hole is sleeved with a conduit that incorporates nozzles around its annulus. Motive water is pumped through the annulus for agitation and liquification of cohesionless sediment Agitated material is then sucked into the inner core of the conduit where an array of jet pumps generated a hydraulic slurry, which is then discharged via a pipe flume, constant density tank, slurry pumps and slurry discharge pipeline	• Minimum visual and noise impacts. • Can be connected to shore power. • Not subject to shoreline fluctuations, • May operate in all but severe wave conditions. • Can be automated, • Creates storage cones which buffer fluctuations resulting from natural coastal processes	• Limited mobility, • Depends on natural processes to deliver sand to storage cones. • Potential problem with debris build-up at annulus locations. • Significant maintenance of pumps required.	System is reliant on natural processes to deliver material to dredger, however, a series of annuluses could be adopted to cover a wider area of removal Relatively new technology for this type of application / environment
Ot-3	*Remote system with submersible dredger supporting water jets and slurry pumps*	A submersible dredge head is utilised, which incorporates water jets and slurry pumps for removal of material, flotation tanks and ballast control, and an independent propulsion system. The submersible dredge head is connected to a platform by an umbilical chord *(containing telecommunications, power and pneumatic supply lines)* and cable arrangement that forms part of the flexible discharge pipeline.	• Can accommodate some shoreline fluctuation, • Relatively inexpensive to install, maintain and operate, • Can be connected to shore based power, • Very adaptable to 'as required' contractual 'opportunity arrangements, • Minimum visual and noise impacts, • High flexibility to modify / optimise operation procedure	• Cannot operate during high and severe wave conditions. • Significant maintenance of pumps required. • Requires deep cone to be created to increase effectiveness.	Remote nature of system enables material to be won from a large are on an 'as required' basis, not relying on natural process to transport material to the dredger Relatively new technology for this type of application / environment
Ot-4	*Agitation dredging*	Agitation of sediment by devices such as underwater ploughs, water jets, air lifting equipment and propellers on the ebb tide either dragged, suspended or supported from work vessels. Suspended material is then moved by natural processes out of the removal area	• Low capital and maintenance costs, • No dedicated plant, • No permanent structures on shoreline, • Very adaptable to 'as required' contractual 'opportunity arrangements,	• Relies on natural processes to transport sediment from the nominated removal area, • Favourable conditions may only exist for short periods of time, • Little or no control over where material will be deposited. • Difficulty meeting production rate requirements. • Could create unacceptable environmental impacts	Potentially suitable as ancillary plant as part of a hybrid scheme. Environmental issues concerning turbidity and water quality may need to be examined

Chapter 6

Alternatives to the Proposal

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Alternatives to the Proposal

This chapter presents the alternatives to the planned permanent sand bypassing system. Alternatives include the "Do Nothing" option and other non-system options are outlined.

6.1 Construct a New and Improved Tweed Entrance

As part of the 1989 Tweed Entrance Feasibility Study a wide range of strategies were examined aimed at achieving, *inter alia*, a minimum navigation depth over the entrance bar of 3.5 m below ISLW and maintenance of the net longshore transport towards Point Danger. The strategies considered were of two basic types:

(i) rectifying the deficiencies of the existing entrance, whether by dredging, installing a bypass and/or modifications to the training walls; and

(ii) taking advantage of potential hydraulic efficiencies, tidal gradients and natural wave shelter to create a better entrance at one of several possible locations.

The studies were very extensive, covering two years. The preferred strategy, arising from the studies, was to install a permanent bypass system at the existing entrance and dredge the river. This outcome set in motion the various committees, community consultation and intergovernmental negotiations which have culminated in the Tweed Estuary Management Plan (TSC, 1996) and the Deed of Agreement for this Project. Hence the option of creating an alternative entrance has been thoroughly "laid to rest".

6.2 The "Do-Nothing" Alternative

The Project has been designed to overcome the historical problems of hazardous navigation at the entrance to the Tweed River and erosion and sand depletion on the southern Gold Coast beaches. The planned Project has been developed following intensive negotiations between the Governments of New South Wales and Queensland with input from Gold Coast City Council and other stakeholders (Section 1.1). A Deed of Agreement between the two State Governments underpins the joint commitment to the Project (Section 1.1.2). The initial component of Stage 1 of the Project has been successfully completed and involved removal by dredging, and associated nourishment of the southern Gold Coast beaches, of approximately 2.3 million cubic metres of material.

In the face of such substantial lead-up work, the "Do-Nothing" option would have a number of major environmental drawbacks:

- All areas dredged during Stage 1A would infill over a period of approx 5 years and the entrance bar channel would revert to the shallow dangerous navigation conditions which existed immediately before Stage 1A ie. a ruling bar depth of approx 2 metres below low water would re-establish and waves would once again break frequently across the bar and create unpredictable, dangerous water surface motions in the vicinity of the channel.

- Apart from the issue of safety to the overall seafaring community, a return to the dangerous bar conditions of the past would reduce the effectiveness of the local trawler fleet and adversely impact

upon other maritime based industries. This would adversely affect the local economy and employment opportunities.

- In the long term, the entrance bar would continue to grow until its equilibrium volume was achieved. Roelvink and Murray (1992) estimated that this would involve an additional 1.1 million m^3 over the next 20 years. Such additional bar infilling would cause navigation conditions to become worse than they were in the recent past. (Note. This estimate was made before the recent Stage 1A dredging works)

- Infilling of the lower Tweed estuary would continue unbridled and the lower estuary marine shoals would return to the conditions which existed in the 1930's and early 1960's. In Section 4.4.2.2 it is estimated that this would occur over a period of approximately 50 years and would result in a loss of approximately 600,000 m^3 of sand from the littoral system.

Druery and Curedale (1979) simulated the hydrodynamic conditions of the 1960's. Table 6.2.1 summarises their results.

Table 6.2.1 Simulated 1960 Regime Conditions : Tide Of Spring Range Of 1.7 m

Location	Tidal Range m TRHD*			Peak Discharge
	HW	LW	Range	m^3/sec
Entrance	1.78	0.15	1.63	350
Letitia 2A	1.51	0.66	0.85	220
Letitia 2B	1.44	0.74	0.70	190
Banora Point	1.29	0.92	0.37	160
Terranora Inlet	1.34	0.85	0.49	115
Dry Dock	1.27	0.92	0.35	100
Terranora Breakwater	1.27	0.94	0.33	55
Cobaki Broadwater	1.26	0.94	0.32	25

* TRHD - Tweed River Hydrographic Datum

(Source : Druery and Curedale, 1979)

Hence under the "Do Nothing" option, tidal ranges and discharges would be more than halved, over the next 50 years.

Whilst such heavily restricted tidal flows may have been "accepted" in 1960, they could not be countenanced today. The urbanisation of the catchment over the last 40 years has built up a large pollution loading. The Upper Tweed Estuary Management Plan (TSC, 1996), highlights that the estuary is having difficulty assimilating the present pollution loading. The foregoing reduction in tidal flows and ranges would cause a severe deterioration of water quality and loss of habitat. The public health, ecology, fishing industry and recreation amenity ramifications would be intolerable. It should be noted however that these issues are addressed by the Tweed Estuary Management Plan and are not directly related to the Project.

- The nourishment of the southern Gold Coast beaches, carried out as part of Stage 1A, would not be sustainable because of the deficit in the net longshore transport between Letitia Spit and Snapper Rocks. Hence the nourishment sand would be eroded and the southern Gold Coast beaches would return to the sand depleted nearshore profiles which existed prior to Stage 1A. The nearshore bar regime of these beaches would once again become very ephemeral and the consistency and quality of surfing conditions, and general beach amenity, would deteriorate.

Taking into account both the build up of the entrance bar and losses to the lower Tweed which would occur under a "Do Nothing" option, the southern Gold Coast beaches could be expected to lose about 3.5 million m^3 over the next 20 years or so.

- The erosion of the southern Gold Coast beaches would cause an "erosion shadow" to progress downdrift towards the northern beaches of Bilinga, Tugun and Currumbin etc. This would undo the beach nourishment gains achieved by the Southern Gold Coast Nourishment Project during the 1980's and early 1990's (Section 1.3.3.2). Ultimately the erosion could re-establish threats to foreshore property.

- The sustained loss of surfing and general beach amenity would adversely impact upon the local surfing, tourism and beach dependent industries.

The "Do Nothing" option would jeopardise the cumulative benefits of Stage 1 and previous beach nourishment campaigns. Doing nothing would raise a plethora of substantial environmental risks including possible long term alteration to estuarine habitats, entrance navigability and public safety, beach stability and beach amenity as well as the commercial viability of the many local marine - based industries. Clearly, doing nothing would not be acceptable.

6.3 Unilateral State Government Action

The NSW and Queensland Governments could take unilateral action to achieve the basic project objectives relevant to their specific constituencies. These activities could, for instance, take the following forms:

Possible Unilateral Action by NSW Government

If the navigation objective of the Project was considered in isolation, the NSW Government could improve the navigability of the bar by intercepting longshore transport from Letitia Spit with any combination of fixed or mobile plant. The sand would not necessarily be delivered to the southern Gold Coast beaches. For instance, the sand could be transferred to Duranbah shoals only or sold to defray costs. Alternatively, both training walls could be extended into deep water to re-establish improved navigation conditions.

Such unilateral action by the NSW Government would either deprive the southern Gold Coast beaches of supply of sand or substantially alter the annual pattern of longshore transport past Snapper Rocks. The southern Gold Coast beaches would become depleted of sand and the natural beach bar regime would be substantially altered. The Queensland Government would find such unilateral action as extremely provocative and legal action to prevent the action or extract restitution for damages to the beaches, would be likely.

The wall extensions would not satisfy the objective of the project "in perpetuity" because past experience in respect of the current entrance walls shows that navigation improvements would be relatively short-lived.

Possible Unilateral Action by Queensland Government

The Queensland Government could take unilateral action, to restore and maintain the recreational amenity of the beaches through resurrection of the Southern Gold Coast Nourishment Project (SGCNP). Such action, however, would not satisfy the objectives of the Project because there would not be a facility "to achieve a continuing supply of sand to the southern Gold Coast beaches at a rate consistent with the natural littoral drift rates updrift and downdrift ....." (Deed of Agreement).

The SGCNP accessed offshore relict marine sand by large trailing suction hopper dredges. As such, large quantities of sand are placed in the nearshore in a relatively short space of time. This approach does not lend itself to placing sand on a regular basis to approximate the natural longshore transport regime.

Unilateral action by the Governments would not achieve the objectives of the Project and would be likely to give rise to litigation between the two. The negotiations between the two Governments, which lead to the Heads of Agreement and the Deed of Agreement recognised that the project objectives could only be achieved economically and equitably by a joint project.

6.4 Dismantle Tweed Training Walls

The need for the Project arose in part from the interception of longshore transport from Letitia Spit by the construction of the Tweed entrance training walls, in the early 1960's.

Roelvink and Murray (1992) estimate that it will be at least another 20 years before the storage of littoral sand on the southern side of the Tweed entrance reaches equilibrium. Hence an option would be to substantially remove the entrance training walls such that an equilibrium, full bypassing bar volume would establish straight away.

The sand in excess of the equilibrium volume would tend to be transported relatively quickly northwards in large slugs. Longshore transport to the Queensland beaches would be re-established. However, the depth of the entrance bar channel would not be improved; it would most probably worsen as slugs of sand moved across the entrance. With shortened training walls, there would be an increase in the rate of sand supply to the estuary which would bring forward the water quality and ecological problems noted above in respect of the "Do Nothing" option. Hence ancillary river dredging would be required to avoid long term problems.

Dismantling the walls would lead to considerable erosion of Letitia Spit. Whilst it could be argued that such erosion would merely involve sand which had built up behind the training walls, it would be nonetheless valuable land with ecological attributes and its possible loss is not recognised as an agreed outcome by the Deed of Agreement.

Although longshore transport to the southern Gold Coast beaches would be re-established, the supply would reflect the natural variability of nearshore transport processes between the entrance and Snapper Rocks. This would be less optimal than the Project which allows a more continuous supply to the beaches to be obtained plus the ability to carry out specific beach enhancements.

Hence, dismantling the entrance training walls would not satisfy the objectives of the project. In addition, it would have significant environmental disadvantages associated with infilling of the estuary, a significant loss of land from Letitia Spit, and no ability to manage and optimise the supply of sand to the southern Gold Coast beaches.

6.5 Dismantle Tweed Training Walls and Install a Permanent Bypass Plant

Most of the short-comings of dismantling the training walls, could be overcome by installing a bypass system. This would achieve the same outcomes as the Project but with a substantial additional cost and still with the loss of a portion of Letitia Spit and still with a residual risk of enhanced feed of marine sand into the entrance. Hence, there would be no advantage with this option over the planned Project.

6.6 Major Extension of Entrance Training Walls

The entrance training walls could be extended seawards substantially to trap longshore transport. As noted above, this would not satisfy the navigation objective of the Project in perpetuity because the navigation benefits would be short-lived (or at least finite) and the disruption to longshore transport would be deleterious for the southern Gold Coast beaches.

In addition, an extension of the walls of sufficient length to effectively trap all the longshore transport from Letitia Spit could cost in the order of $5 -10 million per wall, not including maintenance costs. Any major wall extension would be costly to maintain and maintenance costs would be substantial over the life of the Project.

Very heavy armour stone and/or concrete armour units would be required for construction of any extension. The trucking of concrete units and stone and/or fabrication of concrete units on site as well as overall establishment of a construction site, would raise significant additional environmental impacts concerning habitat, wildlife, road infrastructure and the residential community of the Fingal Peninsula and the commercial/residential areas of Tweed Heads/Coolangatta.

Hence major extensions of the entrance training walls can be ruled out as unacceptable because they would not satisfy the objectives of the project. They would be unacceptable also from the viewpoint of both cost and construction impacts.

6.7 Major Extension of Entrance Training Walls in Conjunction with Bypassing

This option would involve the use of major wall extensions to improve the trapping efficiency of bypassing plant associated with the Project. It could also extend to the construction of an offshore breakwater immediately to the south of the entrance to create an effective sand trap and protected area for a cutter suction dredge to operate. Sand placement could be the same as the Project ie., Snapper Rocks could still be the major discharge location.

In conjunction with a bypassing system, a major wall extension may not necessarily be as long as that required for the extension only option (Section 6.6). However, a major wall extension would still involve a substantial cost in the order of $2-5 million per wall extension, not including maintenance costs, depending upon the length involved. An offshore breakwater would involve considerably more cost (of the order of $10 to 20 million, not including maintenance costs) because of the need to construct in deepwater to avoid seaward outflanking. Any major wall extension, and particularly an offshore breakwater, would introduce significant additional environmental impacts, as noted above.

C.D. Floyd (1968) examined the trained river entrances of NSW and found that navigation conditions are generally worse at those entrances which have unequal lengths of north or south entrance training walls. A major extension of the southern training wall would have a substantial impact on the coastal processes of the entrance. Alteration of the expansion of the ebb jet and local sand movement patterns could work

against the navigation benefits of the potential bypassing scheme. Hence, despite the substantial additional cost involved there would be a residual risk that the option would not fully satisfy the Project objectives.

A major wall extension would present the same shortcomings as option 6.6, if the bypassing scheme ceased to function ie. the option would not be "fail safe".

Hence, major extension of the entrance training walls including offshore breakwaters, can be ruled out because the cost and environmental implications associated with construction would be out of scale with the Project, they would compromise the economic viability of the Project.

6.8 Duranbah as Major Sand Discharge Location

An alternative to the planned Project could be to establish Duranbah shoals/beach as the major discharge location. This would retain the nearshore shoals at Duranbah (NB - one of the few adverse impacts of the Project will be the loss of Duranbah shoals, refer Section 7.2.3.2). On face value, it would appear that this option would have some economic advantage because of the smaller discharge distance involved.

A major difficulty with this concept concerns its performance under northerly swell which would redirect substantial quantities of sand back onto the entrance bar and into the estuary. Such reversal of sand transport would compromise the navigation objective and require costly double handling of the sand, to keep the channel clear. The scheme would promote rapid infilling of the estuary with the consequential environmental problems noted above (Section 6.2).

Because of the inherent lag between the transport of storm slugs from a major discharge site at Duranbah to Snapper Rocks, it would not be possible to provide an improved, relatively uniform supply to Snapper Rocks. Consequently, the nearshore bar regime of the southern Gold Coast beaches would continue to be variable and the surfing and beach amenity benefits of the Project would not be realised in full measure.

There would also be the risk that a major discharge at Duranbah would lead to sand being placed in areas much further offshore of Duranbah than has been the case in the past. This could lead to potential offshore losses of sand through greater interaction with the East Australian Current.

It would be possible to contain the sand reversal by including a major extension of the northern entrance training wall. As noted in Section 6.7, however, this would be costly and it would create a wave shadow immediately north of the wall with a consequential tendency for the overall size of Duranbah shoals to increase. This would further compromise sand supply to the southern Gold Coast beaches.

Hence it is concluded that this option would not be economically justifiable because of the cost associated with double handling and/or northern wall extension and the unacceptable risk it would pose to loss of sand supply to Snapper Rocks through potential nearshore accumulation of sand and potential offshore losses.

Chapter 7

The Environmental Impacts

Chapter 7

The Environmental Impacts

The potential environmental impacts of the implementation and operation of a permanent bypass system are outlined for the short-listed system options. Potential impacts on the ecological, social and economic environments are presented and measures to mitigate these impacts given. Cumulative impacts of the project are also considered. Application of the principles of Ecologically Sustainable Development to the project is detailed at the end of this chapter.

7.1 Physical Environment

7.1.1 Surface Topography and Drainage

No changes to surface topography are expected in the upper reaches of the Tweed Estuary for all sand retrieval options. The sand removal and placement options are unlikely to affect terrestrial surface topography and existing patterns of drainage within the entire study area are unlikely to change.

The project is designed to maintain the existing sand shoals and equilibrium within the estuary. Consequently, the impact on shoals within the estuary and alteration to tidal levels within the estuary will be minimal. Similarly the distance of tidal influence is not expected to change.

Minor changes in the size of some beach areas are expected to result adjacent to the dredging and nourishment zones. This is detailed in Section 7.2.

Within the Tweed estuary the existing river training works would be expected to ensure the stability of foreshore areas and prevent changes to river width. Some erosion of the shoal on the first bend of the river, opposite Jack Evans Boatharbour is expected to result from increased tidal energy directly at the river entrance. This is discussed in detail in Section 7.3.

All options will result in gradual localised retreat of the northern end of the beach at Letitia Spit and development of a new equilibrium state. The associated dune system would be modified until a new equilibrium is achieved.

For all sand transportation and placement options nourishment works proposed include the establishment of substantial offshore sand shoals which will effectively protect the southern Gold Coast beaches and enhance the stability of dune systems particularly during bad weather, decreasing the risk of erosion.

7.1.2 Soils

The proposed works are not expected to have any impact on the soils that occur within the study area.

7.1.2.1 Acid Sulphate Soils

The proposed entrance dredging works are not expected to impact on Acid Sulphate Soils (ASS) or Potential Acid Sulphate Soils (PASS) in the lower Tweed estuary. The sediments do not occur in the area to be directly affected by construction activities. No wetland or floodplain areas further upstream will be

drained, therefore no new areas of ASS will be formed. In addition, no land-based dewatering of dredging sediment is proposed, therefore the potential for increased surface runoff from areas of ASS is negligible.

Changes to tidal range is not expected to be significant and therefore ASS and PASS will not be oxidised as a result of tidal level decreases, ie. the sediments will remain waterlogged.

7.1.3 Wave Propagation to the Beaches

Wave propagation to the beaches adjacent to the Tweed River entrance will be affected by reduction of the entrance bar and the nearshore bathymetry offshore from Duranbah and the northern end of Letitia Spit. The extent of modification of the bathymetry and wave patterns will in turn, affect the sand transport patterns in the area.

For the predominant prevailing southeast sector swell waves, the major impacts of the project will be as follows:

(i) Reduced effect of the entrance bar in refracting and focussing the waves at Duranbah. Southeast sector swell is expected to approach the beach more uniformly and with a somewhat greater angle (refer Figure 7.1.1).

(ii) Reduced refraction of the more southerly waves, allowing more of the wave energy from those directions to impinge on the shoreline between Duranbah and Snapper Rocks and at greater incident wave angle.

(iii) Reduced effect of the tidal ebb jet and entrance bar in causing confused wave condition in the entrance channel immediately seaward of the training walls.

(iv) Reduced wave breaking in and near the entrance channel.

(v) Slightly increased wave heights in the entrance channel between the training walls.

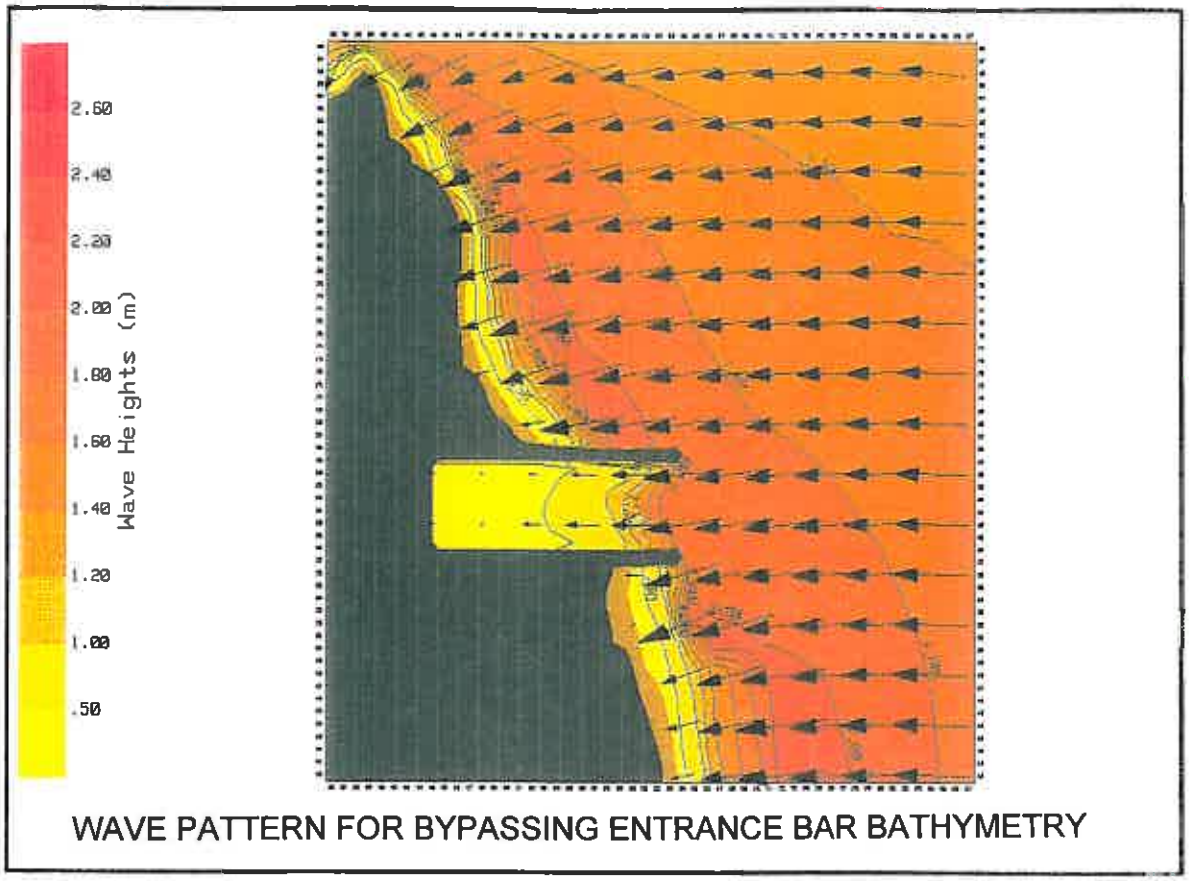
For the smaller, shorter period sea waves, the effects will be less significant because of the lower potential for refraction. These waves will continue to propagate directly to the nearshore zone.

The larger cyclone and storm waves will be less attenuated by breaking over the deeper entrance area. Thus, these waves will propagate further inshore before breaking. Depending on the prevailing entrance area depth, larger waves may impinge on the training walls as discussed further in Section 7.3.5.

Wave propagation to the southern Gold Coast beaches west of Snapper Rocks will be affected only slightly There will be some further changes to refraction patterns there as the nearshore bathymetry readjusts to natural equilibrium conditions following the Stage 1A dredging. This will be beneficial in terms of restoring the natural beach sand transport processes.

7.1.4 Water Quality Impacts

Sand retrieval is not expected to cause any change to the existing water quality at the Tweed River entrance due to resuspension of pollutants or mobilisation of toxicants in the sediments. No bacterial contamination was measured in the sediment, so there is not likely to be any health risk from spoil disposal along the southern Gold Coast beaches (Acer Wargon Chapman, 1994). There are no heavy metals or pesticides which could be mobilised during the resuspension of dredged sediment.



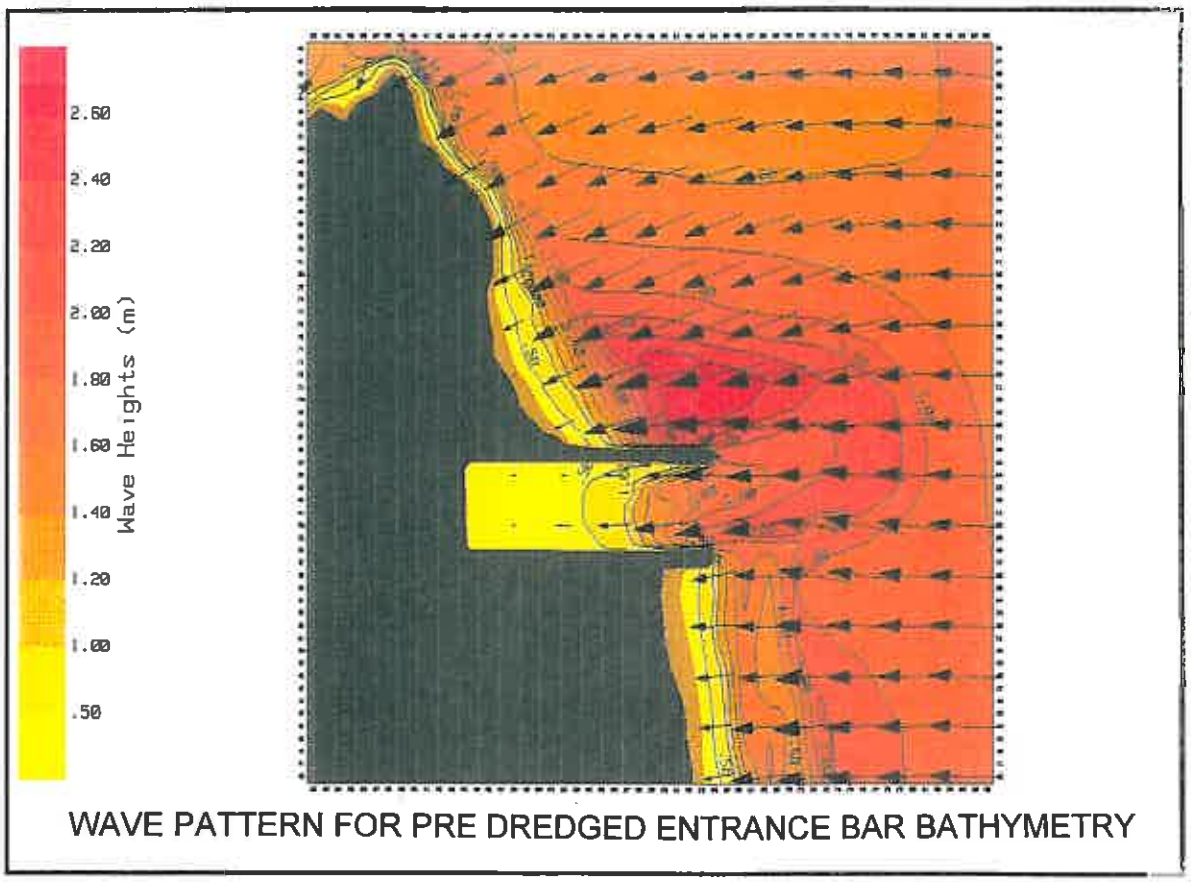


Figure 7.1.1
Impact on Wave Refraction Near Tweed River Entrance

The almost total absence of fines (0-0.06%) observed in the clean marine sand forming the Tweed bar indicates that turbidity effects from dredging and nourishment works will be of short duration.

Opening-up the Tweed River entrance will improve flushing in the lower estuary, which is expected to result in improvement in water quality in the lower estuary, particularly water clarity, nutrients, and bacterial loads.

The proposed nourishment of the southern Gold Coast beaches is not expected to diminish water quality in the area because of the very clean nature of the borrow material from the Tweed entrance. Turbidity will not be a problem because there is no silt or clay in the sediment to be dredged. There are no measurable bacteria, heavy metals or pesticides in the material to be dredged. The characteristics of the sand from the Tweed entrance are the same as those from the nourishment area (ie medium to fine quartz sand, with no silt or clay, no organic material, and very little carbonate material), so the appearance and performance of the material will be the same.

7.1.5 Sediment Quality Impacts

Concern has been expressed that sand dredged from offshore areas for previous nourishment campaigns was coarse and contained a high shell content thus leading to a detrimental effect on beach amenity. The sieve analyses carried out as part of this study indicated that the sand to be dredged is a fine to medium grain clean marine sand with a typical grain size of 0.1 mm - 0.5 mm with minimal shell content. It is considered that this material would be similar to naturally deposited beach sand and would therefore have a similar texture more so than the shelly outer nearshore sand and inner nearshore sand previously used for nourishment.

7.2 Coastal Processes of the Southern Gold Coast - Tweed Beach System

7.2.1 Overview of Impacts on Beach System

One of the two primary objectives of the proposed sand bypassing project is improvement of the southern Gold Coast beaches. Thus, effective operation of a properly designed bypassing system will result in a significant beneficial impact to those beaches, particularly at Rainbow Bay, Greenmount and Kirra.

The benefits derived will take the form of :

- restoration of the full littoral sand supply to the Gold Coast beaches;
- prevention of further deterioration of the beach system by up to 3.5 million cubic metres of sand over the next 20 years;
- opportunity for more regular supply of sand along the nearshore beach system;
- increased beach widths and recreational amenity; and
- enhanced surfing conditions.

At the same time, there will be removal of sand from the northern Letitia Spit and Tweed River entrance nearshore area. This will have effects on the beach system and bar processes there, and will significantly reduce the sand supply to Duranbah which will respond to this reduction by realigning and retreating to establish a new equilibrium with the sand supply rate.

The Deed of Agreement offers the opportunity to place up to an average of 50,000 cubic metres of sand per year at Duranbah and 75,000 cubic metres at Kirra. Options are considered to maximise the benefit of these supplies.

Further discussion of these impacts is set out below. These impacts are illustrated in Figure 7.2.1 which represents a conceptual model of the long term processes with the sand bypassing system in operation.

7.2.2 Sand Discharge at Snapper Rocks

Snapper Rocks (or a location in the vicinity) is designated in the Deed of Agreement as the primary discharge site. There is some flexibility in the precise location of the discharge at any time, both along a zone in the general vicinity of Frogs Beach, Point Danger, on the eastern (ocean) shoreline and at Marleys Rocks immediately west of Snapper Rocks .

The sand transport modelling undertaken for this study supports this discharge strategy as being the most suitable for introducing the sand into the longshore transport system of the Gold Coast beaches. A minimum of 75% of the discharged sand would be placed directly in this area.

The response of the nearshore bathymetry and sand transport patterns in this region will be dependent on both the discharge strategy and the action of the waves in redistributing the placed sand across the active profile.

The computer modelling of longshore transport processes has shown that essentially all of the longshore sand supply to the Queensland beaches occurs at Point Danger in a relatively narrow band within the -8 metre (AHD) contour and the shoreline. Upcoast transport occurs seaward of that depth during the larger storm events, but this tends to be balanced by the persistent downcoast transport influence of the East Australian Current. The zone of predominant longshore transport is somewhat wider in the area north of Snapper Rocks, extending out to about the 10 metre contour.

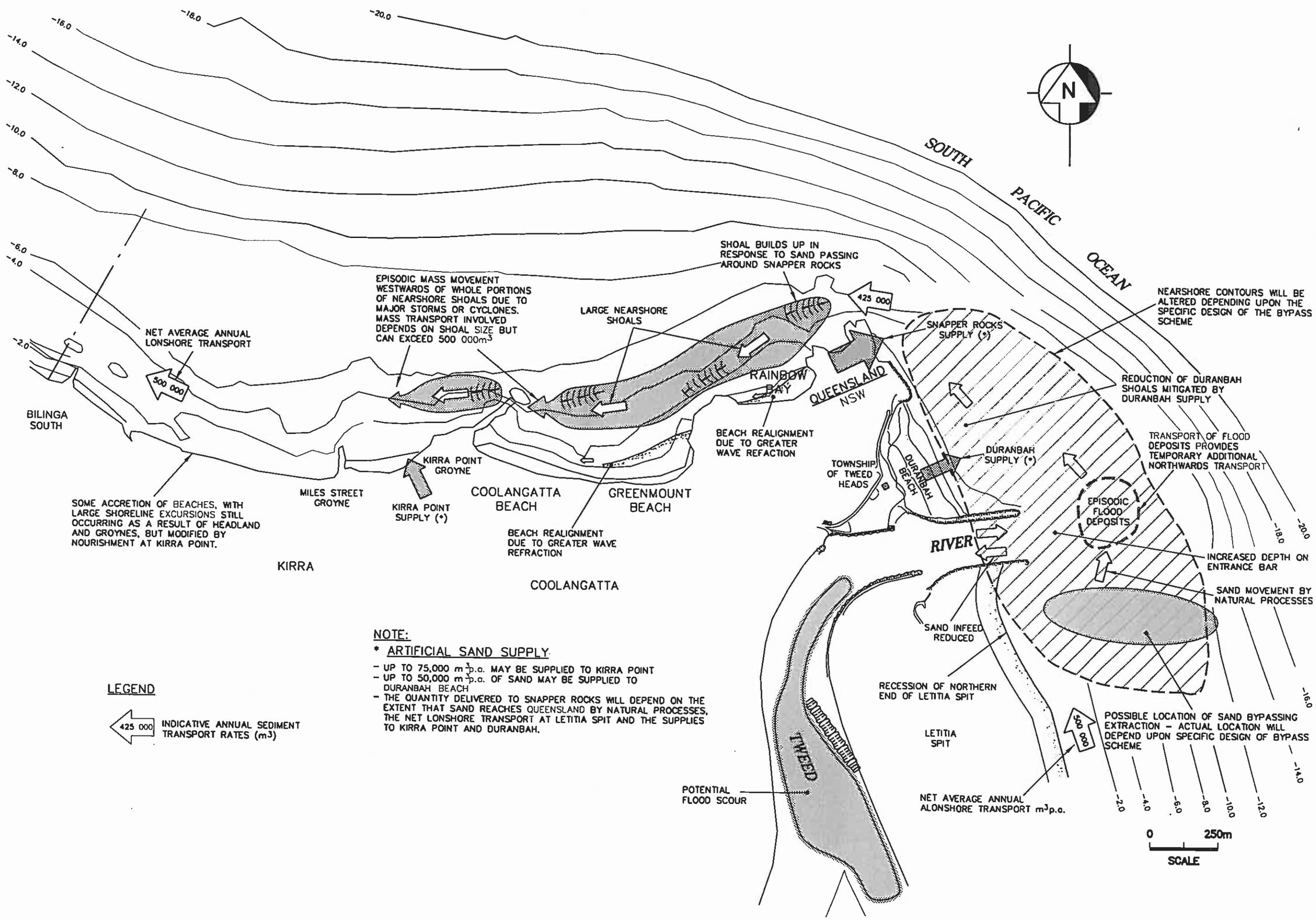
Thus, it is concluded that all of the bypassed sand placed such that it is confined within the 8 metre contour in the Frog's Beach area would be transported by the natural wave/current processes to the Gold Coast beach system. This is illustrated in Figures 7.2.2 and 7.2.3.

Placement of the sand in that area to achieve a suitable distribution into the sand transport system of the Gold Coast beaches could thus be achieved by one or more of the following procedures:

- discharge directly from the shore, allowing the waves and currents to redistribute the sand both alongshore and seaward;
- discharge from a trestle structure or detailed platform within (about) the 6 metre contour; or
- bottom dumping from mobile hopper dredgers within (about) the 6 metre contour.

The placement of sand at Point Danger will lead to a number of beneficial impacts including:

- potential development of a sandy beach there, at least from time to time;
- inducement of a more persistent sand supply north from the discharge area past Point Danger to Snapper Rocks, Rainbow Bay and beaches further downdrift;
- the opportunity to achieve cost-effective placement of sand into the beach system in a manner which closely mirrors that of the natural sand transport system (with operational variability to enhance beach condition), thereby ensuring redistribution to the southern Gold Coast beaches and nearshore shoals appropriately; and
- there will be natural wave-induced redistribution of sand placed in the upper profile area to somewhat



NOTE:

* ARTIFICIAL SAND SUPPLY

- UP TO 75,000 m^3p.a. MAY BE SUPPLIED TO KIRRA POINT
- UP TO 50,000 m^3p.a. OF SAND MAY BE SUPPLIED TO DURANBAH BEACH
- THE QUANTITY DELIVERED TO SNAPPER ROCKS WILL DEPEND ON THE EXTENT THAT SAND REACHES QUEENSLAND BY NATURAL PROCESSES, THE NET LONSHORE TRANSPORT AT LETITIA SPIT AND THE SUPPLIES TO KIRRA POINT AND DURANBAH.

LEGEND

425 000 — INDICATIVE ANNUAL SEDIMENT TRANSPORT RATES (m^3)

Figure 7.2.1
Conceptual Model of Long Term Coastal and Estuarine Processes with Permanent Sand Bypassing System

deeper water, both at the discharge site and as the sand moves away to the north.

In order to avoid sand moving southward to the Tweed River entrance during northeast wave conditions (predominantly during the period September to December), as an additional or alternate strategy, sand placement could be redirected to the west of Snapper Rocks. This would assure continued persistent supply to the Gold Coast beaches at times when the net transport capacity at Point Danger is such that little or no supply would otherwise occur.

A predominance of sand discharge directly to the beaches west of Snapper Rocks would also ensure effective delivery of all of the bypassed sand to the Gold Coast beaches. However, in such cases, care would need to be taken to distribute the sand over a somewhat wider area north of Snapper Rocks across the whole active transport zone. This would be needed to prevent excessive supply immediately downdrift of Snapper Rocks and to prevent longer term denudation of the deeper water bathymetry which controls wave refraction to the adjacent beaches.

Placement of sand in this area could be achieved by direct discharge from the shoreline or as bottom dumping from hopper dredgers. The majority (about 75%) of the placement should occur within the 6 metre contour, with the remainder acceptably placed out to (about) 8 metres, to ensure that all sand is contained within about the 10 metre contour.

However, placement in this area could present adverse impacts with respect to:

- direct physical interference with recreational surfing activities and beach amenity; and
- excessive turbidity plumes in the areas widely used for surfing.

Thus discharge predominantly to the Frogs Beach area is recommended as the preferred option, with discharges to west of Snapper Rocks taking place only when specifically needed and planned to minimise such adverse impacts.

Options are included in the identified scope of bypassing systems for a flexible discharge strategy at Snapper Rocks.

7.2.3 Specific Beach Impacts

7.2.3.1 Letitia Spit

The Stage 1 EIS studies predicted that the bar dredging would modify the local wave refraction patterns in such a way that wave energy would be increased along about 700 metres of the northern end of Letitia Spit. This was expected to result in erosion of 200,000m^3 with accompanying retreat of 20-75 metres, occurring primarily by storm demand.

Monitoring of the Stage 1A dredging confirmed that processes of this nature did occur as a result of those works (Technical Appendix I).

The longer term impacts of the bypassing project on Letitia Spit will depend substantially on the design option and operational procedures adopted.

Extraction of sand from the beach and nearshore profile south from the existing river entrance will directly change the nearshore bathymetry and beach shape. This would occur with, for example, a fixed trestle-mounted pumping system equivalent to that at the Gold Coast Seaway or dredging by mobile plant in that area. In that case, the following impacts would result:

(i) there would be a localised retreat of the beach itself and development of a new equilibrium beach shape; and

(ii) associated with the above, the dune system would become modified including some erosion until new equilibrium is achieved

It is recognised that the existing Letitia Spit beach and dune system is largely artificial, having developed as a response to the training wall extension in 1962. The dune system is now considerably wider than would be required for beach stability, and could accommodate some retreat without adverse impact. Similarly, the beach itself would adapt to the new situation, and retain its character and amenity despite any shoreline retreat which may take place.

The nature and extent of shoreline retreat will depend on the particular bypass system adopted and its operational design. Specifically, should the sand extraction occur in the form of regular dredging of the river entrance channel, as was undertaken in the Stage 1A dredging, then there will be little associated impact on Letitia Spit, consistent with the present situation. Should the zone of sand extraction extend south of the river entrance, and should it occur at a localised nearshore area (eg. a trestle system as at the Gold Coast Seaway), then the impact on Letitia Spit would tend to be more extensive at and near the extraction location.

Shoreline response modelling has been undertaken for two sand extraction scenarios to augment the knowledge gained in monitoring the effects of the Stage 1A works. These are:

- localised extraction along the approximate alignment of the southern training wall, and
- localised extraction (eg. trestle system) at a location about 250 metres south of the training wall.

The results are illustrated in Figure 7.2.4. In the former case, the maximum impact on the Letitia Spit shoreline is immediately adjacent to the training wall, where a retreat of 30-40 metres is predicted. In the latter case, a maximum shoreline retreat of about 90 metres is predicted at the extraction location. Retreat would occur along about 1000-1500 metres of the northern end of Letitia Spit, decreasing in extent with distance away from the extraction location.

Clearly, for each scenario, normal beach fluctuations due to cross-shore transport associated with variations in wave conditions and in longshore supply of sand would continue.

Accordingly, immediate localised impacts on Letitia Spit may be quite minor and of little consequence in terms of beach and dune impacts, or may involve shoreline retreat by up to about 90 metres, depending on which bypassing option is adopted. There may be other processes, such as long term slow leakages of sand to the Tweed River or other areas, which may cause slow long term retreat of parts of Letitia Spit. Such changes are likely to be imperceptible in the context of the short term beach variability.

In all of the above scenarios, the beach/dune system would adapt to a new dynamic equilibrium situation such that there will be no loss of beach width or capacity to accommodate storm erosion.

It may be feasible to implement a bypass scheme which incorporates excavation of a sand trap area within the present shoreline of Letitia Spit. Any such option would require specific design and management controls to ensure protection and preservation of the dune system and its habitat.

The bypassing project will have no effect on the shoreline or beach processes at southern Letitia Spit in the vicinity of Fingal. The beach and dune there will continue to fluctuate naturally as at present in response to the changing wave conditions and storms.

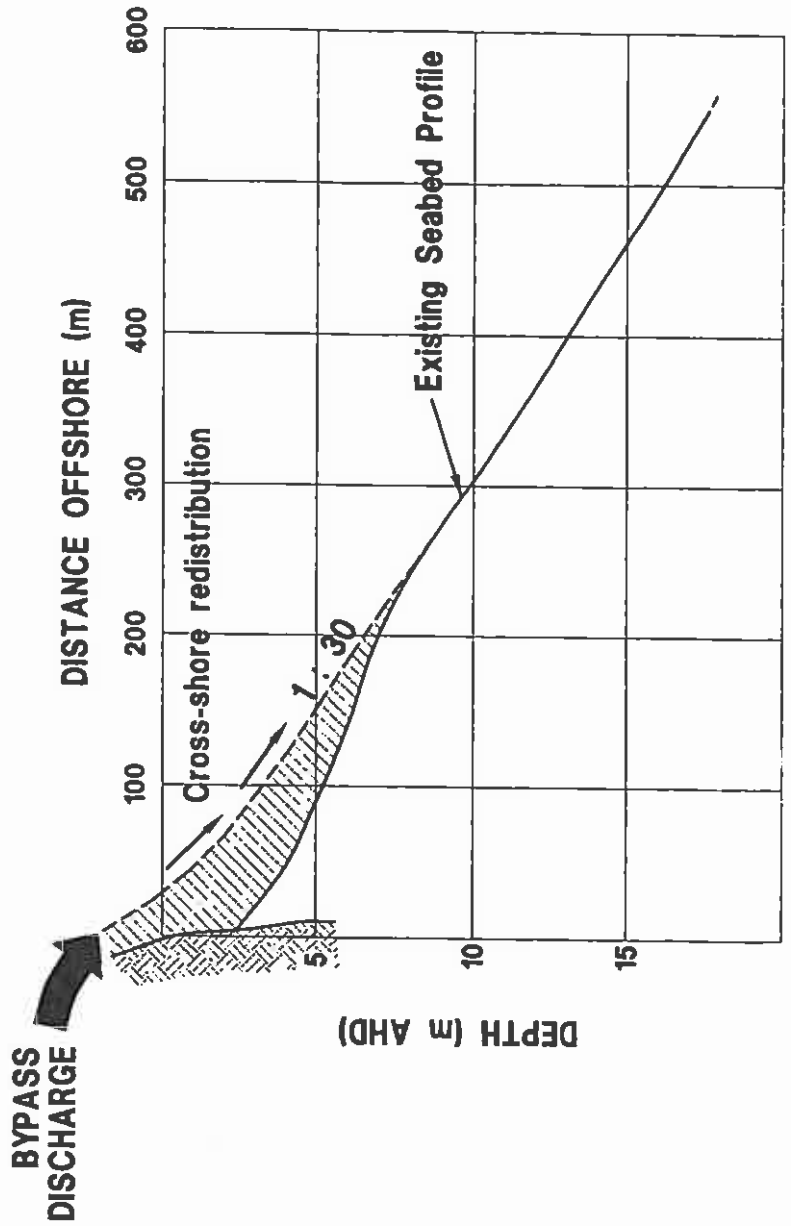


Figure 7.2.2
Cross-shore Re-Distribution of Sand Placed at Frogs Beach

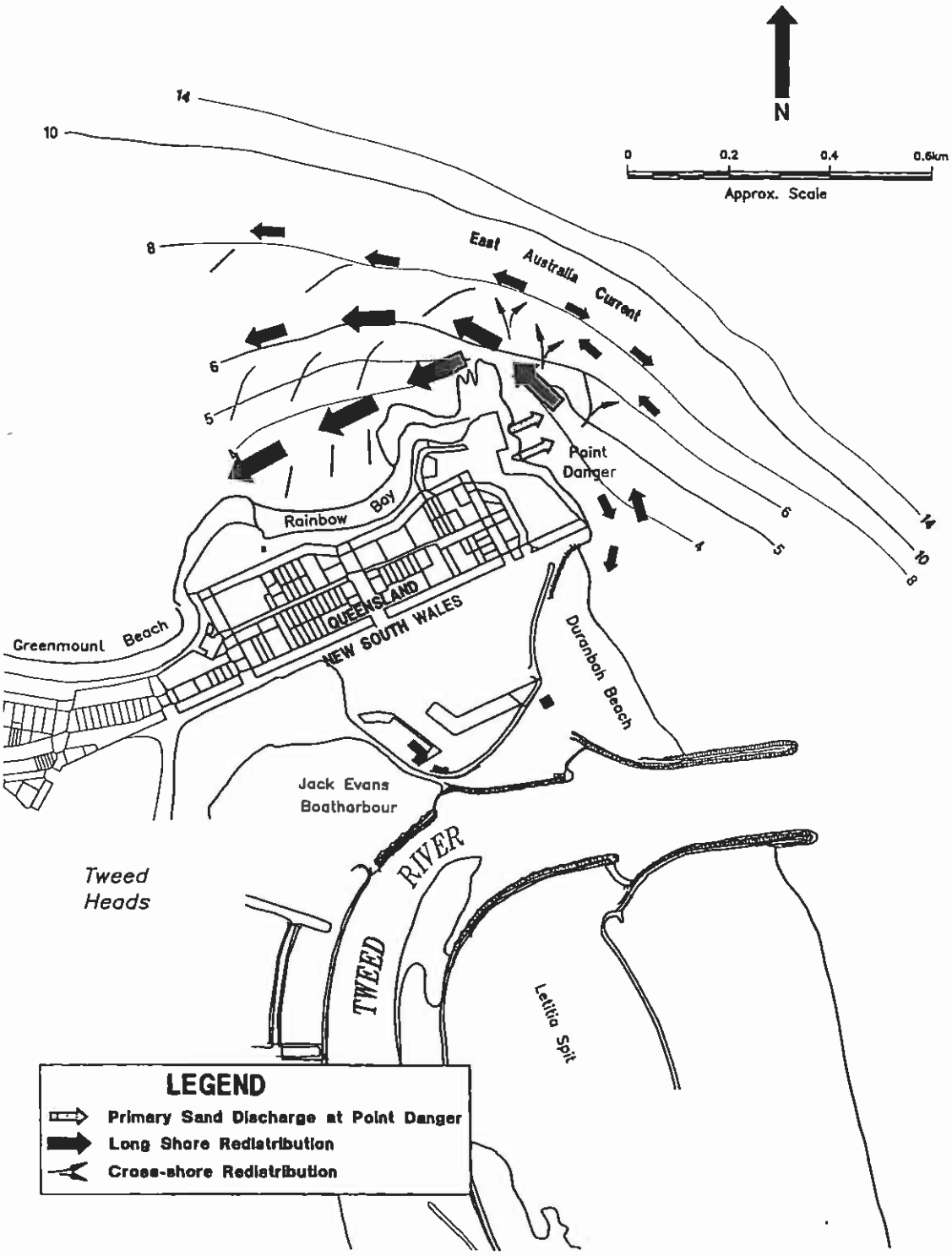


Figure 7.2.3
Spatial Re-Distribution of Sand Placed at Frogs Beach



Figure 7.2.4
Bypassing Impact on Letitia Spit and Duranbah

7.2.3.2 Duranbah

Prior to the Stage 1A dredging, the offshore shoals of Duranbah Beach were accreting at an estimated 50,000 m^3 pa (Section 4.3.1). It was predicted that the bar dredging would decrease the rate of bypassing, and therefore reduce the net sediment supply to Duranbah. Erosion of the nearshore shoals was predicted at approximately 200,000 m^3 pa (PBP, 1994).

Analysis of Stage 1A monitoring data (Section 4.3.2) indicates that Duranbah has incurred net losses at a rate of 120,000 m^3 to 130,000 m^3 pa, not including the impact of the May 1996 storm. The latter was a particularly severe storm and resulted in net erosion of the offshore shoals by 200,000 m^3,

The monitoring data indicates that if a relatively deep entrance bar channel is maintained, the offshore shoals will continue to erode at a rate of approx 130,000 m^3 pa, decreasing over the longer term. Section 7.3.2 demonstrates that the current bypassing is probably of the order of 200,000 m^3 pa, implying that the net longshore transport is of the order of 330,000 m^3 pa. This is similar to that estimated in Stage 1 (PBP, 1994).

The existing sand transport pattern at Duranbah will be altered significantly by the bypassing project. The shallower river entrance bar system located about 300-400 metres offshore from the tip of the breakwaters will be depleted, reducing or preventing sand transport northward in that area.

The sand supply to the profile offshore from Duranbah will be reduced. Thus the profile there will tend to be depleted. Longshore sand transport will increasingly shift to the zone nearer the beach.

The particular response of Duranbah Beach to the sand bypassing will depend on a range of factors which, at this stage, cannot be predicted. These will be determined by the type and operational procedures of the bypassing system adopted.

The beach response will be determined by two principal factors, namely:

- reduction of the longshore sand supply, and
- changes to incident wave directions associated with changes to refraction patterns over the entrance bar and nearshore shoals.

With respect to the former of these, the beach condition soon after training wall construction provides a good indicator of the equilibrium beach position and alignment. Aerial photography (Figure 7.2.4) and particularly that taken in 1965 has been used, together with the GENESIS modelling to quantify the likely shoreline response. These indicate a shoreline retreat of about 50 metres from the present position, more or less uniform along the beach (Figure 7.2.6).

Changes to wave patterns cannot be predicted, as they depend intimately on the bypassing system, operational procedures and the extent of natural leakage of sand across the entrance channel to Duranbah. In the event of high leakage, the bar and shoals will continue to exist, albeit in reduced size and form, and the 1965 situation is probably a good indicator of the future beach alignment.

In the event that there is little sand leakage to Duranbah and the Duranbah Discharge Quantity (50,000m^3/year) is the only supply, then it is likely that the entrance bar and nearshore shoals will be largely removed. In that case, the waves will approach the beach more from the southeast and the beach alignment will tend to rotate clockwise. There could thus be greater shoreline retreat near the southern end, estimated to be up to about 80-90 metres from the existing position in the worst case scenario as illustrated in Figure 7.2.4.

In the process of shoreline retreat, the existing dune system will be subject to increased erosion, manifesting predominantly during storms. The dune system will reform by wind transport during recovery following each storm erosion event further inland than at present. Care must be taken to protect the foredune from vegetative damage during this process to prevent sand losses by wind erosion. Monitoring and appropriate control fencing are recommended to allow the beach system to develop a new dynamic equilibrium configuration (Chapter 8).

7.2.3.3 Southern Gold Coast Beaches

Long term dynamic stability of the southern Gold Coast beaches requires:

(i) initial restoration of the beaches and the natural nearshore bathymetry, being the objective of past beach replenishment works and the recent Stage 1A dredging; and

(ii) ongoing supply of sand past Point Danger to the beach system at a rate matching the natural net longshore transport capacity for the area, presently estimated at an average annual rate of 500,000m^3/year, being the objective of the sand bypassing works.

The aim of the Stage 1 nourishment campaign was to re-establish the offshore shoal regime of the early 1960's. The total volume of sand required to restore these conditions was 2 million m^3. As indicated in Section 4.2.3, the nourishment has performed close to expectation but it will still be some time before the nearshore profiles fully establish their historical bathymetry particularly in the vicinity of the Kirra Reef exclusion zone. The outer deposition area in particular has been less mobile than expected and tending to move mainly alongshore. Consequently it is not nourishing the nearshore profile as quickly as anticipated.

The fundamental beneficial impact of the proposed bypassing works for the southern Gold Coast beaches is the restoration of the full littoral sand supply at Snapper Rocks. This will ensure that the beaches are maintained in long term dynamic equilibrium, although they will experience substantial natural variability.

The present status of sand supply at Snapper Rocks is uncertain. Recent estimates (Roelvink and Murray, 1992) show that the supply rate is recovering steadily but slowly after being negligible directly after training wall extension in the 1960's.

Complexities and uncertainties in determining the present sand supply rate and the ultimate further sand loss from the beaches if no works are done include:

- sand infeed to the Tweed River;
- interpretation of the measured survey data in the context of variability of the net longshore transport rates at Fingal;
- the ultimate equilibrium Tweed River bar size; and
- accuracy limitations on the survey data.

The best available estimate is that the present sand supply rate is about 350,000 m^3/year, and that the probable further sand loss to the Gold Coast beaches if the bypassing does not proceed could be about 3.5 million cubic metres. Thus, the fundamental beneficial impacts of the project on the southern Gold Coast beaches are:

- the incremental increase of the littoral supply of sand by some 150,000m^3/year, decreasing over time;
- prevention of loss of the benefits derived from placement of the 2.3 million cubic metres in Stage 1 dredging; and

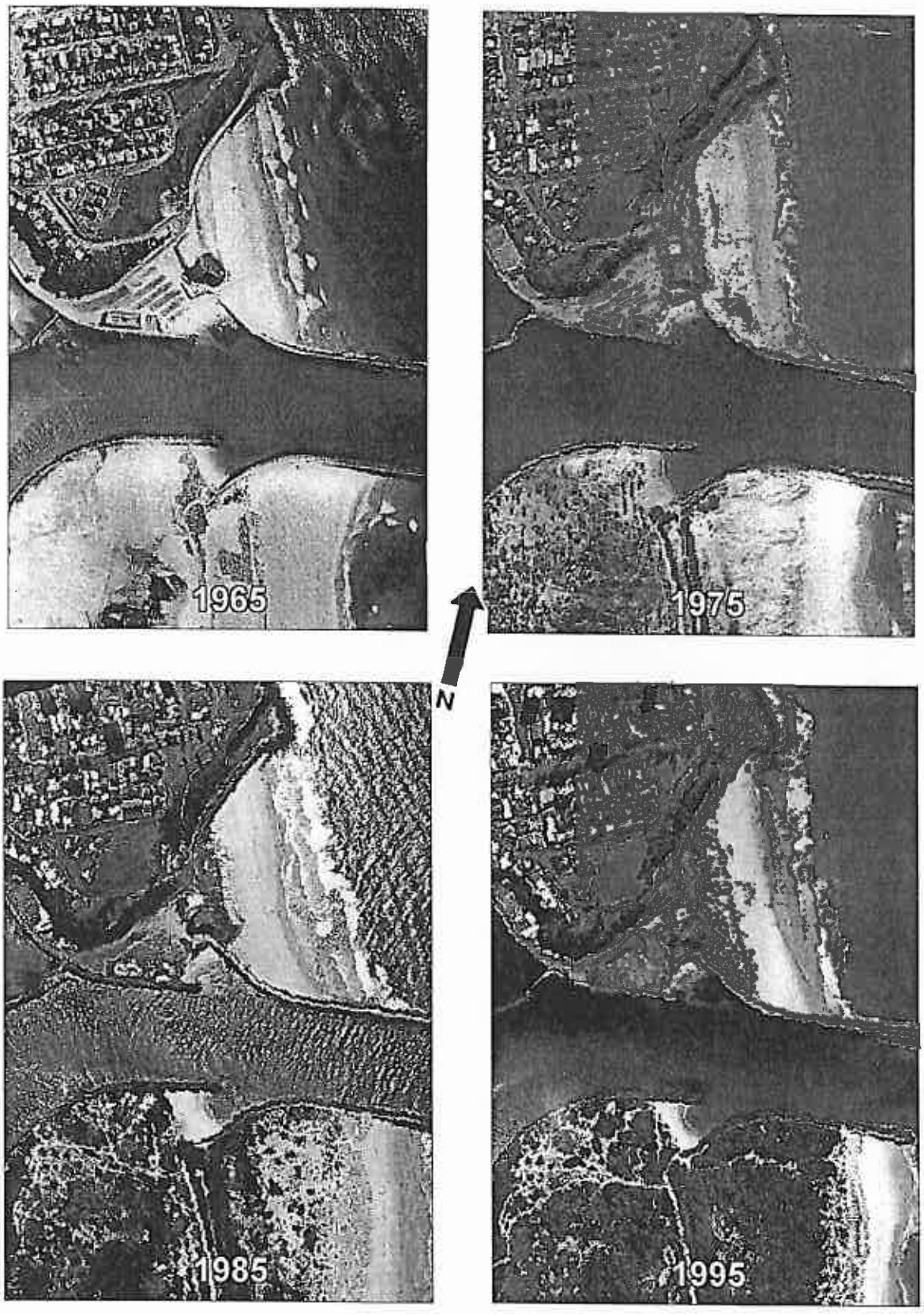


Figure 7.2.5
Historical Aerial Photographs - Duranbah

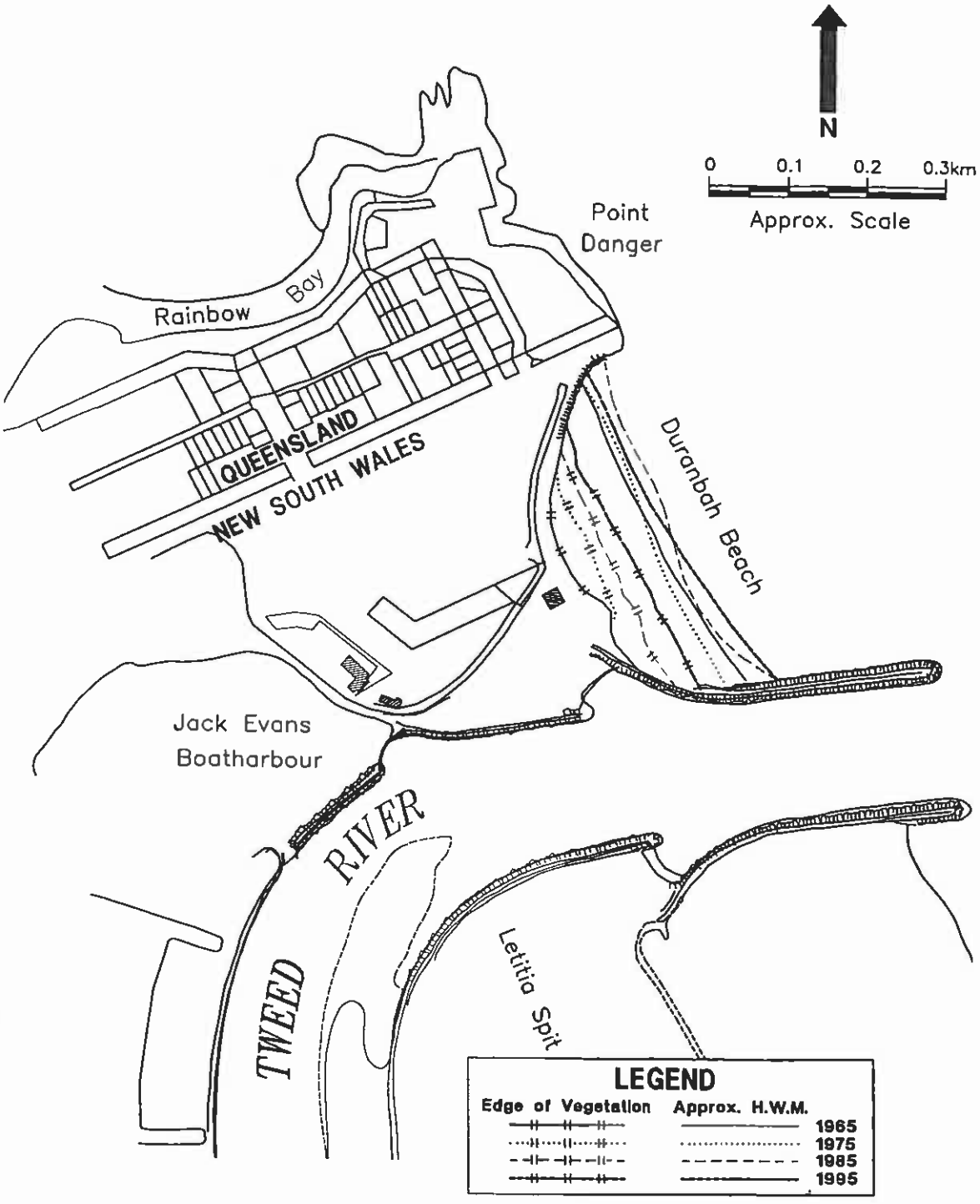


Figure 7.2.6
Historical Shorelines and Dune Locations - Duranbah

- prevention of further deterioration of the beaches associated with potential erosion by about 3.5 million cubic metres of sand.

Impacts with respect to beach system processes at each specific beach are discussed below.

Rainbow Bay

The shape and condition of the beach at Rainbow Bay is largely dependent on the condition of the offshore shoals around Snapper Rocks. With the bypassing plant operational, it is likely that the offshore shoals around Snapper and Marley Rocks will be consistently full, ensuring a strong persistent sand supply to this area.

This will represent a return to the natural condition existing prior to training wall extension, characterised by:

- strong and persistent development of the nearshore shoal extending directly past Rainbow Bay from Marley Rocks to Greenmount Hill;
- strong and persistent longshore sand transport along this shoal to Greenmount;
- the common occurrence of a nearshore lagoon between the shoal and the main public beach, in which wave action and currents are relatively calm;
- increased occurrence of a wider recreational beach;
- separation of areas of general beach and surf use from areas used by surfboard riders; and
- increased nearshore sand buffer against excessive beach erosion during storm events;

Despite this, the beach will behave dynamically, with beach width and nearshore shoal bathymetry varying considerably over the short to medium term associated with natural variability of wave conditions and storm erosion events.

Greenmount

The condition of the beach at Greenmount is largely dependent on the flow of sand around Greenmount Hill and the transport away from the beach past Kirra Point. The supply of sand to this area will be improved as a consequence of the improved supply to and past Rainbow Bay and the effects of the Stage 1 dredging in restoring the nearshore profile bathymetry.

As at Rainbow Bay, the behaviour of Greenmount Beach will return to that which characterised the area prior to training wall extension. This includes persistent occurrence of a wide recreational beach and frequent strong sand supply in the form of a spit-like shoal extending past Greenmount Hill. This shoal may or may not be attached to the beach in the area towards Coolangatta, but typically will create a lagoon between it and the main recreational beach.

The shoal bathymetry will be highly variable in response to varying wave conditions. It will provide a sand buffer which will help to minimise storm erosion of the recreational beach. Nevertheless, the beach width will vary significantly in the short to medium term, and storm erosion will continue to occur from time to time.

Similarly, Coolangatta will receive a more persistent littoral sand supply which will move past Kirra Point under the natural wave/current action. The Kirra Groyne Point creates a different beach and sand transport pattern from that existing prior to the training wall extensions. It has the effect of stabilising Coolangatta Beach with greater width than before, and may alter the beach/bar alignment in such a way that the sand supply past Kirra Point is somewhat more variable than was originally the case.

Kirra

The condition of the beach at Kirra is dependent on the nearshore profile bathymetry, the associated wave refraction patterns, and the transport of sand past Kirra Point. The Kirra Point and Miles Street groynes influence the sand transport patterns and beach conditions.

As described in Section 4.2, the Stage 1A dredging has not yet restored the natural nearshore profile bathymetry in this area. Sand deposited in the deeper water and outside the Kirra Reef Exclusion Zone has not yet been redistributed by the waves and currents to the longer term equilibrium condition. Such condition is characterised by greater sand volume in the area out to about the 6 metre contour than presently exists and correspondingly less in the sand deposition area further offshore.

A consequence of the recovery of the bathymetry offshore from Kirra back to the pre 1960s situation will be a reduction in the presently exposed extent of Kirra Reef. This would occur by sand transport along the bed rather than by depositional smothering.

Kirra Beach and the beaches further north are fed by sand moving along the shoreline and sand moving through the reef area in longshore and cross-shore directions. Essentially, the area in the vicinity of the reefs is a rocky substrate of which most is covered by sand, with that part not covered by and constituting the reef. Historically, Kirra and Kirra Central beaches have fluctuated about their mean position and, for Kirra Central the landward extent of fluctuation has been seaward of its recent position.

A preliminary analysis of past extent of reef and Kirra and Kirra Central beaches show:

- reef area has been historically small;
- reef area enlarged due to erosion in the 1960s;
- upper beaches also eroded;
- reef area is largest in the late 1980s and early 1990s;
- upper beach erosion worst in late 1980s; and
- there is strong correlation between good beach width and smaller reef size associated with the amount of sand in the beach system in that area.

Thus reduction in the exposed extent of the reef will be an inherent consequence of the restoration of sand supply and improvement of Kirra Central beach resulting from the project.

Thus nearshore depths and wave propagation patterns are not expected to be yet as they are needed for beach recovery or medium term stability. It may take some years before equilibrium is restored.

The beneficial impact of the bypassing project at Kirra will be the restoration of the full littoral sand supply. This is of importance for Kirra (Central) which is located at the downdrift end of the series of natural headlands and artificial groyne structures. These controlling features help stabilise the beaches immediately updrift and, in so doing, tend to focus the erosion effect of any sand supply deficient in the area west of the Miles Street groyne.

Nevertheless, despite restoration of the long term average sand supply to the required 500,000m^3/year along all these beaches, Kirra beach will continue to be subject to sand supply variability caused by those features. Resulting beach width variability can be moderated within the Deed of Agreement provisions by direct placement of (average) 75,000m^3/year of sand as required.

Thus, it is considered most likely that, over time, Kirra Beach and Kirra Central west of the Miles Street groyne will be restored to conditions with the general shoreline position seaward of that presently existing.

similar to that which existed prior to training wall extension (refer to Figure 7.2.7), subject to the additional influences of:

- the Kirra Point and Miles Street groynes, which tend to create increased beach variability,
- frequency of discharge relating to the bypassing system's operational strategy ; and
- direct placement of sand from time to time, which will tend to moderate beach variability.

With effective delivery of the full littoral sand supply and management of the sand placement strategy, a useable beach will be restored west of the Miles Street groyne; with infrequent storm erosion extending back to the rock seawall.

Coolangatta Creek/North Kirra

The beach at Coolangatta Creek and past North Kirra is presently relatively wide as a result of the past beach replenishment works. The beach and nearshore system in this area is continuing to adjust slowly to those works under the influence of the prevailing wave, current and wind conditions.

The precise nature of the final equilibrium state of this beach area is uncertain, but is likely to eventually replicate that of the early 1960's. Thus, continuing evolution of the beach there is likely to include:

- little change in the location of high water mark from the present location, and
- development of a wind formed dune system at the back of the beach.

The stormwater outlet to Coolangatta Creek will be largely contained within the beach berm except following storm erosion. However, it is expected that the discharge should continue to be clear of sand and function effectively. This should be monitored to assess any need for remedial action over time.

There will be a need for dune management in the form of vegetation protection and control fencing as the dune develops and extends east along the back of the beach towards Kirra.

7.2.4 Implications of Long Term Leakages of Sand from the Bypass Area

There is a possibility that the sand bypassing system as designed and implemented to satisfy the Deed of Agreement criteria on quantities of sand delivered in the long term may not prevent leakages of sand to areas beyond that of its normal operations. The degree of risk of that occurring and the nature and quantities of leakage which may be involved depend intimately on the type and operational procedure of the system adopted.

Potential leakages of sand could occur as:

- sand passing to and across the entrance channel area to deposit in regrowth of the entrance bar or nearshore Duranbah shoals;
- sand placed at Duranbah moving offshore to deposit in regrowth of the entrance bar or nearshore Duranbah shoals;
- sand entering the river estuary as infeed through the entrance channel; and
- any incremental sand loss to offshore deeper water.

The consequences of each of these possibilities is discussed below.

Sand Leakage to and Across Entrance

If the system is operated achieving the required bypassing quantities, but with a continued (though reduced) net transport of sand to and across the river entrance, the likely consequences are as follows:

(i) The water depth in the entrance channel will be shallower than for minimal natural bypassing. The implications of that are:

- a benefit for training wall stability by restriction of the maximum height of waves which could impinge on the walls;
- a disadvantage in allowing conditions which would allow significant net infeed of beach sand into the river;
- a disadvantage for navigation in allowing shallower depths and probable entrance shoal development which would exacerbate ebb tide current speeds and complex wave interaction; and
- a disadvantage for channel depth maintenance by allowing a reduced siltation buffer.

(ii) The sand which enters the entrance area will tend to be redistributed by the tidal ebb jet out to reform the entrance bar, or by waves/current interactions to reform shoals offshore from Duranbah. The implications of that are as follows:

- a substantial proportion of the leaked sand will not be delivered to the Queensland beaches, but will (as has occurred previously) contribute to regrowth of the bar area;
- if the bypass system design incorporates mobile plant, then removal of these shoals and discharge to the beaches may occur from time to time as an integral part of the bypassing at normal cost, and be accounted for in the bypassed quantity;
- if the bypass system design does not incorporate mobile plant, then the sand may be retrieved only by special-purpose remedial maintenance action, at potentially higher cost;
- if this leakage of sand relocated to the bar area is not retrieved, then the bypass sand collection area and eventually Letitia Spit will experience an equivalent net loss of sand, manifesting as shoreline retreat on Letitia Spit. Such retreat may eventually cause reduction in the leakage amount; and
- survey monitoring is recommended to quantify any net sand accumulation in the nearshore shoals/entrance bar area and to allow appropriate maintenance action to be taken.

Redistribution of Discharged Duranbah Sand

The Deed of Agreement provides for the delivery to Queensland beaches of the Long Term Average longshore sand transport rate , presently agreed to be 500,000m^3/year. Studies undertaken as part of this EIS/IAS have confirmed that quantity as the best available estimate at this stage. Provision is made in the Deed of Agreement to review that quantity from time to time.

The Deed of Agreement provides for up to 10% of the amount bypassed (that is approximately 50,000m^3/year on average) to be placed at Duranbah. Of that quantity, 50% (that is 25,000m^3/year) would be deemed to have contributed to the Contract Quantity.

The other 50% may be redistributed by the waves and currents away from Duranbah Beach to other areas such as:

- southward across the entrance to the intake area;
- to the entrance bar or nearshore Duranbah shoals;

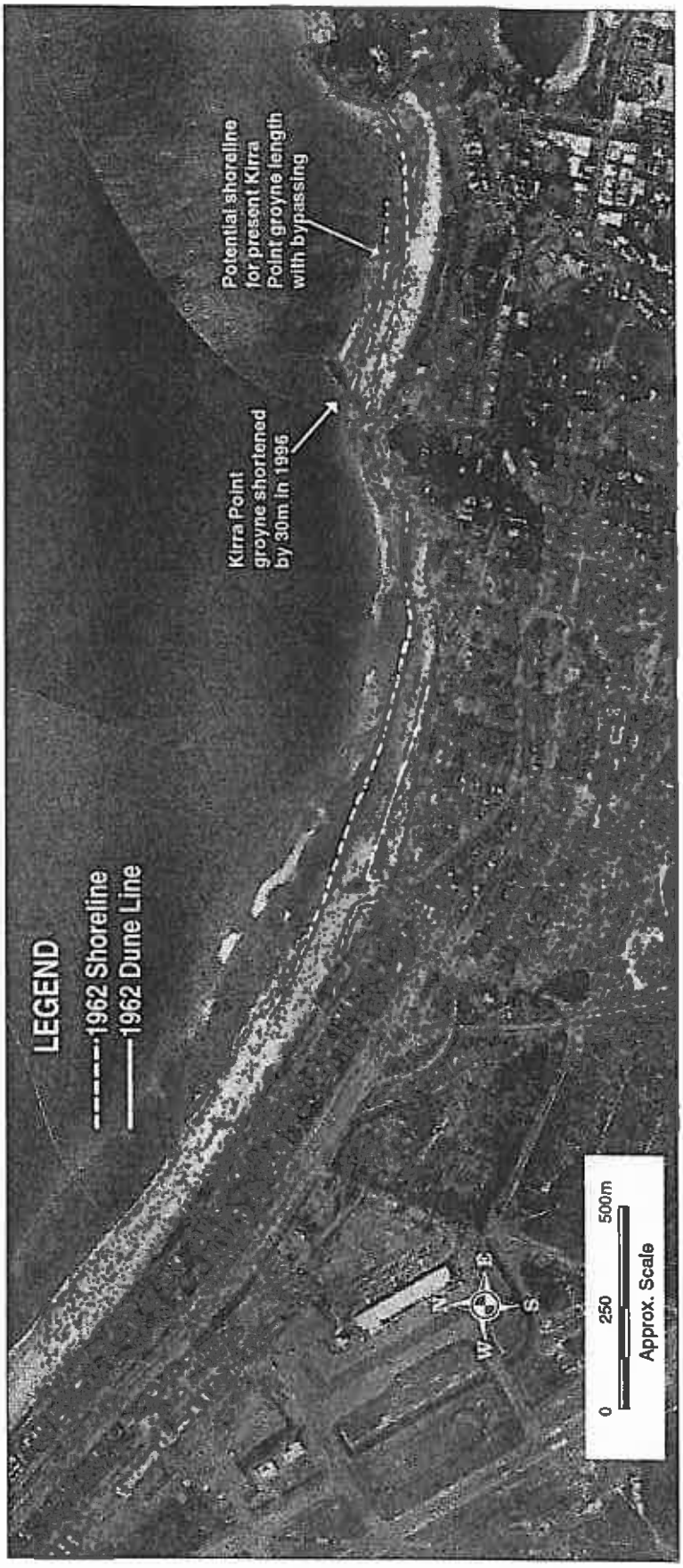


Photo: 25 May 1994

Figure 7.2.7
Historical and Projected Shorelines
- Greenmount and Kirra

- infeed to the Tweed River Lower Estuary; and
- northward to the Gold Coast beaches.

Thus, at least for the initial period until the Long Term Average and/or Duranbah Supply is formally varied, an average quantity of up to 525,000m^3/year would be taken from the bypass intake area to satisfy the Deed of Agreement provisions. This may potentially lead to some retreat of Letitia Spit, matched by a net gain of sand elsewhere.

In the longer term (order of decades), survey monitoring would identify any significant net gain or loss from the Gold Coast beaches. This information may then be used to assist in reviewing the Contract Quantity of sand delivered to those beaches.

Similarly, survey monitoring would assist in quantifying any significant progressive accumulation of the entrance bar or nearshore shoals at Duranbah, allowing appropriate remedial action to be taken under the Deed of Agreement provisions.

A bypassing system consisting of mobile plant could readily retrieve this sand as part of normal operations, otherwise remedial maintenance action may be needed from time to time.

Comprehensive beach and nearshore surveys along the area from the river entrance to around Bilinga are recommended to monitor these processes and provide a reliable basis for review of the Contract Quantity. Survey detail should be sufficient to give a high degree of confidence in the overall quantities of sand in the beach system derived. However, because of the slow, long term (decades) nature of the changes under review, these surveys may be undertaken infrequently (say each two years) to provide both reliable and cost-effective outcomes.

Sand Infeed to Tweed River Lower Estuary

As outlined in Section 4.4.2.2, the long term impact of the Tweed Estuary Management Plans in the absence of any further works would be an infeed to the lower estuary of approximately 600,000 m^3 of sand from the beach system over the period 1990 to 2050.

The bypassing operation is likely to reduce the net infeed rate and could reverse it (Section 7.4.3 and 7.4.4). Such reduction will depend on the extent to which the sand availability at the mouth is reduced. This in turn will depend on the type of system and operational depths in the entrance channel area.
The implications of the sand infeed to the river in conjunction with the sand bypassing system are as follows:

- there will be a net depletion of the entrance bar and, depending on the nature and location of the bypass sand collection, Letitia Spit by a quantity equal to that of the infeed, manifesting potentially as shoreline retreat on Letitia Spit;
- the total quantity of infeed over the long term may be substantial, but remains relatively much smaller than the quantity of sand accumulated on the bar and Letitia Spit since 1962, and hence may be readily accommodated;
- should future considerations be given to replacement of the sand back to the beach system, then a range of environmental issues including quality of the sand (silt content) and approval procedures would need to be addressed; and
- survey monitoring is recommended to assist in quantifying any net infeed of sand to the Tweed River Lower Estuary.

Incremental Sand Losses to Deeper Water

To date, it has not been feasible to identify or quantify any permanent losses of beach system sand to deep water offshore from Point Danger or the Tweed River bar. The available evidence suggests that any such losses are relatively small.

It is expected that the Stage 1A dredging and ongoing bypassing would tend to reduce any potential for offshore losses at the river entrance because of the bar deepening involved.

Further, performance criteria for the sand discharge at Snapper Rocks should be set to ensure that excessive deposition in that area does not occur. This will prevent induced leakage of the sand to deeper water (beyond 8m) where it may be transported by the East Australian Current or other wave/current action away from the Gold Coast beach system transport zone.

7.2.5 Turbidity Plume Impact

To gain an understanding of the nature of turbidity plumes likely to be generated by sand bypassing operations for the Tweed River entrance, the characteristics of the sand discharge turbidity plumes were measured at the Gold Coast Seaway (30km north of the Tweed River) (Technical Appendix IV). The characteristics of the sand to be pumped at the Tweed are essentially the same as at the Seaway.

Measurements conducted at the Gold Coast Seaway focussed on the discharge of sand under two scenarios:

- surface discharge near the mean high water contour, and
- surface discharge to deeper sub-tidal water depths.

Although, the two scenarios investigated had quite different discharge rates, varying between 30 and 200kg/s of bulk sand, the visible and measured distance of effect of the turbid plume was somewhat independent of the bulk sand discharge rate.

The results of this investigation indicated the following:

- the visible and measurable limit of the turbidity plume resulting from the surface discharge of 200kg/s of bulk sand to the beach at mean high water was approximately 50m from the discharge location. The turbidity of the plume generated by sand by-passing was frequently overwhelmed by the turbidity generated by breaking waves and surf in the nearshore zone;
- the visible and measured limit of the turbidity plume resulting from the surface discharge of 30kg/s to comparatively deep water with unbroken waves some 90m from shore was approximately 50m from the discharge;
- for each scenario, the bulk of the turbidity associated with the discharge was contained within the first 10-20m of the plume, regardless of the discharge rate; and
- the residual turbidity plume associated with either scenario was visible only for a period of between 2 and 3 minutes after the cessation of the sand pumping discharges.

Application of these results to the Tweed River entrance project, which involves transfer of clean beach sand from the entrance area to the discharge locations, indicate that the visibility of turbidity plumes associated with the surface discharge of bulk sand will be contained within an approximate distance of 50m from the point of discharge. It is anticipated that the residual turbidity plume will be short-lived, and last some 2-3 minutes after the cessation of sand pumping activities.

It is concluded that, for the normal sand bypassing operations, there will be no significant adverse impact to recreational use of the beaches or surfing associated with turbidity at any sand discharge locations more than 50 metres away from user areas. However, discharges to Duranbah, Snapper Rocks and Kirra may take place within areas commonly used for recreation. Hence, a management strategy for discharge at those locations is needed to minimise such impacts. This could include:

- restriction of discharge locations to areas of least impact; and
- restriction of discharge times such that minimal disturbance to recreational activities results (eg. night time, winter, non-holiday periods, etc).

There may be some circumstances in which a component of silt is combined within the bypassed sand. These could include:

- following flood events when silts are discharged from the river and deposit in the entrance area; and
- instances when sand infeed to the Tweed River Lower Estuary is utilised for placement on the beaches.

In the former case, turbidity at the discharge location may be temporarily increased until the supply of clean sand resumes. As such time, discharge at the more remote location at Frogs Beach (rather than the recreational beach areas) should be utilised. The turbidity generated will be part of that caused by the flood event and will be of limited duration.

In the latter case, the placement of any lower estuary sands on the beaches would be the subject of special approval procedures. The silt content and appropriate placement strategies would need to be assessed at that time.

7.2.6 Impact of Heavy Mineral Sand Extraction on Beach Processes

Mineral sand mining has occurred extensively on the southern Queensland and northern NSW coasts. The economic mineral sand component of the active mineral sands of the Lower Tweed and entrance bar varies from 0.07% to 0.52% by weight of the sand body, used on average at 0.2% by weight (PBP, 1989).

Although heavy mineral extraction does not form part of this project, the potential impact of such mining on coastal processes has been assessed. The full assessment is provided in Technical Appendix II. This report concludes that the removal of heavy minerals would have no impact on the sand transport regime of the beaches in the study area. However, the volume of sand involved in such removal would be finite (ie. of the order of 1,000-1500m^3 per year) and it would be necessary to replace the removed sand with an equivalent volume of silica sand, of appropriate grain size to maintain the long term average net supply of sand to the southern Gold Coast Beaches.

7.3 Impacts on Coastal Processes at Tweed River Entrance Area

7.3.1 Littoral Bypassing Across the Tweed Bar

A dredged entrance bar channel is subject to progressive inflow of sand as part of the natural process of longshore transport. A channel which forms a 'slot' within adjacent shallow areas receives inflow from both the south and the north, being the gross longshore transport. Over time, the northern (Duranbah) side would become depleted and transport to the entrance bar channel would reduce and the inflow to the channel would approach the net longshore transport.

The proportion of the inflowing sand which remains as siltation in the entrance channel (the so-called "trapping efficiency") is the difference between that transported into, and that transported out from within

the channel. This is a function predominantly of the relative depth of the channel and the inflowing transport rate. The situation is more complex for a wide channel, in which sand may be deposited near one side while substantial erosion occurs at the other side.

Detailed analysis of Stage 1A monitoring data (Section 4.2.3) confirms that the trapping efficiency of the entrance bar channel is dependent upon both channel depth and wave energy intensity. It was found that the trapping efficiency of the channel reduced from 70% to 30% as the average depth of the entrance bar channel reduced from approximately -8 m AHD to -4 to -6 m AHD, over the three month period December 1995 - February 1996. Also, the entrance channel trapping efficiency can vary from 100% to less than 20% under low energy modal conditions and high energy storms, respectively. The turbulence associated with the larger storms helps to maintain sand in suspension and enhance bypassing.

A computational approach was used as an independent check on the likely trapping efficiencies for various depths of channel and wave heights. A simplified approach was used on the relatively narrow channel assumption in which the longshore current speed in the channel is calculated from continuity, being more or less in inverse proportion to the depths. Details are provided in Technical Appendix II.

The computation was based on the full range of prevailing deepwater wave heights in the region. No attempt, however, was made to incorporate comprehensive wave refraction or two-dimensional effects or the impact of turbulence due to breaking waves and tidal currents. It is considered that the computation approach tends to overestimate the trapping efficiency but the intention was to indicate the relative trapping efficiencies for various channel depths.

The computational results were consistent with the analysis of Stage 1A monitoring data, tending to be on the high side. The computed trapping efficiencies varied from 80% to 100% for modal waves over a depth range of -4.5 m AHD to -8 m AHD and 30% to 76% for storm waves and the same depth range.

Channel trapping efficiencies determined from hydrosurvey and wave data analysis, were applied to the predicted pattern of longshore transport to assess bar bypassing rates for different entrance bar channel depths. Longshore transport simulations (Technical Appendix II) indicate that the annual longshore transport can be apportioned approximately 70-% to modal wave conditions (up to 2.5 metres) and 30% to storm waves. Hence, the average net annual longshore transport occurs as 350,000 m^3 pa due to modal waves and 150,000 m^3 pa due to storm waves. The application of channel trapping efficiencies to these longshore transport components is shown in Table 7.3.1.

Table 7.3.1 Estimates Of Annual Bar Bypassing Rates Versus Entrance Bar Channel Depth

Annual Net	**Indicative Entrance Bar Channel Depth**					
Longshore	**-8 m AHD and greater**		**-6 to -8 m AHD**		**-6 to -4 m AHD**	
Transport Letitia Spit	**Trapping Efficiency (%)**	**Bypass Quantity (m^3pa)**	**Trapping Efficiency (%)**	**Bypass Quantity (m^3 pa)**	**Trapping Efficiency (%)**	**Bypass Quantity (m^3 pa)**
Modal Transport 350,000 m3 pa	100	Nil	70	105,000	50	175,000
Storm Transport 150,000 m3 pa	80	30,000	40	90,000	20	120,000
TOTALS		30,000		195,000		295,000

The total by-passing rates of Table 7.3.1, are an indication of the bypassing that would be expected if the channel across the bar was maintained at the various depths indicated and to relatively narrow dimensions

ie. similar to Stage 1A. A total bypassing rate of approximately 300,000 m^3 pa in respect of a depth of -6 m to -4 m AHD (ie. about -5 m to -3 m below ISLW) would appear to be on the high side when compared to the 128,000 m^3 pa determined by Roelvink and Murray (1992). It is consistent, however, with the pre-Stage 1A rate of 350,000 m^3 pa, given that bar depth was varying between -2.5 m to 3 m below ISLW at that time (PBP, 1994).

As the Roelvink and Murray (1992) estimate represents an average bypass rate over the period 1966-1972 (ie. immediately after wall construction), it represents a disequilibrium bypass rate and, therefore, could be on the low side. On balance, the bypass values in Table 7.3.1 accord well with the available data and provide confidence that the trapping efficiencies are of appropriate order.

A permanent bypass system with large sand traps (ie. much wider area of deepening than a "slot") would improve trapping efficiency in respect of modal longshore transport. A bypass system with updrift interception of longshore transport would reduce the effective longshore transport reaching the channel. Highly efficient systems would be able to intercept or trap most of the modal transport. They would be unlikely to have a major impact on storm transport though. Assuming a minimum bypass system interception/trapping efficiency of 90% in respect of modal longshore transport, it is concluded that the net bar bypassing rates, under a permanent bypassing system, would range from 30,000 m^3 pa to 160,000 m^3 pa, depending upon the design depth of the bar channel and sand trap areas.

7.3.2 Entrance Bar and Channel Infilling Rate

The analytical approach of Section 7.3.1 can be used to estimate maximum potential infilling rates. The gross longshore transport must be used because the entrance bar channel will capture sand equally as well as when there is a southerly reversal in the direction of longshore transport as when the dominant northerly transport is operating. Hindcast longshore transport simulations (Section 4.2.4.5) indicate that the gross longshore transport across the entrance has, in recent years, been of the order of 800,000 m^3 pa. The simulations indicate that approximately 70% of the flux can be attributed to modal waves and the remainder to storm waves. The initial bar and channel infilling rates are summarised in Table 7.3.2.

Table 7.3.2 Estimates Of Annual Bar And Channel Infilling Rates Versus Entrance Bar Channel Depth

Annual Gross Longshore Transport Across Entrance	Indicative Entrance Bar Channel Depth					
	-8 m AHD and greater		-6 to -8 m AHD		-6 to -4 m AHD	
	Trapping Efficiency (%)	Infilling Rate (m3pa)	Trapping Efficiency (%)	Infilling Rate (m3 pa)	Trapping Efficiency (%)	Infilling Rate (m3 pa)
Modal Transport 560,000 m3 pa	100	560,000	90*	504,000	90*	504,000
Storm Transport 240,000 m3 pa	80	192,000	40	96,000	20	48,000
TOTALS		752,000		600,000		552,000

* Adopted minimum efficiency - refer Section 7.3.1

Because of the high longshore transport flux in the vicinity of the entrance bar, the infilling of the bar and channel would range from 750,000 m^3 pa to 550,000 m^3 pa depending upon the depth being maintained on the bar. The deeper the bar, the greater the trapping efficiency and the consequential potential for annual

infilling.

These are the quantities of sand that would need to be shifted, during the initial period of operation of a permanent bypass system, to maintain the navigation channel through the bar, and any associated sand traps. These quantities would not be sustainable in the long term because they exceed the net longshore transport and some natural bypassing would be occurring, as determined in the previous section

Over time, the northern delta lobe and Duranbah shoals would become depleted and the total sand flux across the bar would approach the net longshore transport (Section 7.2.3.2). Hence, in the longer term, channel infilling due to longshore transport, would vary from 470,000 m^3 pa to 340,000 m^3 pa depending upon the depth being maintained on the bar. The occurrence of a major flood, in any one year, would add up to 200,000 m^3 to these values.

7.3.3 Entrance Bar Bathymetry

The long term, average bathymetry of the bar will depend on the type/capacity of the specific bypass system which is installed by the successful tenderer. It will be very difficult for any system to intercept all longshore transport (ie. both northerly and southerly components) before it reaches the entrance bar channel ie. some outflanking is inevitable, storm rates will be too high and reversal of longshore transport will be problematical. In other words, there is likely to be considerable leakage of longshore transport no matter what bypass system is employed. To keep the risk of infilling of the navigation channel acceptably low, it is considered that a bypass scheme will probably need to have a built-in buffering capacity (ie. sand trap) which can capture such sand leakage and provide the time necessary for the trapped sand to be picked up by the bypass system before the navigation channel is compromised.

From a generic viewpoint, there are numerous factors which will need to be taken into account in sizing and locating appropriate sand traps viz:

1. Bypass systems with high updrift interception capacity would require the smallest sand trap size. Most fixed systems are likely to aim for this strategy.

2. Bypass systems with low interception capacity would require the greatest sand trap size. Mobile systems would tend to epitomise this strategy.

3. As a variant on both 1 and 2, continuous versus intermittent operation would affect sand trap size. Intermittent operation would require a greater sand trap as compared to the same operation running continuously. Mobile systems are unlikely to be truly continuous because of the difficulty of operating during storms and fixed systems are unlikely to be 100% continuous because of mechanical failure and maintenance downtime.

4. Any bypass system will represent an optimisation of bypass plant and system capacities, sand trap volumes and the longshore transport regime of the bar. Analysis of survey monitoring data (Technical Appendix I) indicates longshore transport regimes of:

   - modal transport (Hsig up to 1.5 m) - up to 5,000 m^3/day
   - annual storm transport *(Hsig ~2 m)* - 16,000 m^3/day
     total sand volume over 5 day storm
     80,000 m^3
   - large storm transport *(Hsig > 4m)* - 35,000 m^3/day
     total sand volume over 6 day storm
     200,000 m^3

   Hence, quite a range of sand trap sizes is possible depending upon the specific design capacities

of the primary and any ancillary bypass plant/systems.

5. Section 7.3.1 demonstrates that sand trap efficiency, during modal waves, increases from approx 50% in respect of channel depths of 4m to 6m below AHD and to 100% for depth in excess of approx 8m. The greater the efficiency of any sand trap, the lesser the risk of infilling of the navigation channel.

6. It is likely to be impractical to attempt to trap the longshore transport associated with large storms because the trap volume would be too large and the high current regime associated with large storms is likely to substantially reduce effective sand settling. As a consequence, sediment infilling is likely to be well disseminated and occur as a uniform layer over the bed of both the sand trap and the entrance bar channel. Analysis of monitoring surveys confirms that the trapping efficiency during large storms could be as low as 20%.

7. It would be feasible for the leakage associated with annual storms to be intercepted before reaching the navigation channel. Assuming 50%-100% trapping efficiency , and depending upon the degree of updrift interception, above transport rates indicate a trap volume of the order of 100,000 m^3. This would be required both sides of the navigation channel, recognising that the need for the north side sand trap may decrease in time, as the northern lobe of the bar gradually reduces in size.

8. It is envisaged that the sand trap would need to be maintained at a minimum rate of twice the modal longshore transport rate (ie. to get "ahead" of modal infilling) ie. approx 10,000 m^3/day. This rate is well within the capabilities of likely plant.

9. The overall plan area of a sand trap would depend upon bar depth and desired trap volume.

10. The shape of the sand trap would need to be compatible with the dimensions of the major sand pathway onto the bar and the natural tendency of the entrance bar channel to shoal by a prograding sandspit from the southern lobe of the bar, commencing some 200 m or more from the tip of the training wall ie. the trap could extend from say 150 m from the tip of the training wall to the -6 m to -5 m contour; the latter being indicative of the outer limit of the major sand transport pathway. This would involve a typical sand trap length (ie. parallel to channel) of the order of 300 m. The width of the trap would then depend upon the desired plan area.

11. The depth of the sand trap, in the vicinity of the training walls, would need to be designed to avoid loss of training wall support. Actual depths and bed slopes would need to be established by detailed geotechnical and coastal engineering analysis. Sand removal in this area could involve ancillary plant operating from the walls.

12. If the traps were created and maintained by trailing suction hopper dredge, it would be necessary to define straight dredging limit lines, to allow the dredge to operate effectively. This was essentially the method of operation of the dredge "Krankeloon" during the later stages of Stage 1A bar dredging.

13. The location of any northern sand trap is most likely to be adjacent to the navigation channel. A northern sand trap may not be necessary in the long term if the permanent bypass system has a high trapping efficiency and the northern lobe of the entrance bar and Duranbah Shoals become substantially depleted.

14. The southern sand trap could be located adjacent to the navigation channel or updrift possibly integrated with a fixed system (refer Figure 5.2.2). An effective updrift sand trap would gradually expand in area and eventually extend to the entrance bar channel because any relict shallow area, between the initial trap and the channel, would be unstable. Hence any updrift sand trap depending upon its effectiveness, would most probably cover a large plan area, over time.

Figure 7.3.1 illustrates these generic factors and provides an indicative reconfiguration of the bar. Because of the many interacting factors, the actual bar bathymetry will depend upon the design philosophy and specific optimisation, of bypass components, adopted by the successful tenderer. The most likely major variation to this generic bar configuration would be the partial re-accumulation of the sand shoals south of the entrance. As discussed in section 4.3.1 the accretion of these shoals is the key mechanism for infill of the navigation channel and natural bypassing of the entrance. The complex wave refraction and breaking patterns on these shoals is a major cause of the navigation difficulties experienced in the entrance. The extent of these shoals is therefore of major importance to the project because of the implications to the navigation objective and the efficiency of the overall scheme.

Operational considerations of various plant and equipment options which may result in the partial re accumulation of the entrance shoals are as follows:

- a fixed system constructed south of the entrance will not be able to capture 100% of the littoral drift. During times of high transport or during downtime, quantities of sand would 'leak' past the system resulting in a growth of the entrance shoals (section 4.2.4 shows that quantities of up to 200,000 m^3 may be transported to the entrance area within a single event);
- a mobile system such as a jack-up barge or a submersible dredge would be able to work directly in the area south of the entrance channel. However to control operating costs, these systems would tend to minimise their requirements for repositioning as much as possible. This operating characteristic, along with downtime and the effects of high longshore transport rates caused by storm events, would inevitably result in some temporary accretion of the sand shoals;
- a trailer suction hopper dredge operating regularly to maintain the navigation channel would often be unable to work directly in the area of shoals south of the entrance. Similar to the Stage 1A campaign, it is likely that the dredge would target the channel and the seaward edge of the bar in order to minimise downtime and risk of grounding. Additionally, it is likely that the dredge would not be permanently stationed on site thus resulting in extended periods of no dredging and accretion of the entrance shoals; and
- shore based mobile systems operating on their own would certainly have no mechanism to directly control the nearshore shoals.

7.3.4 Tweed Entrance Channel

Stage 1A monitoring surveys included an 87 m wide central portion of the entrance channel, between the training walls. The surveys cover only the centre portion of the channel and volumetric analyses can be used to assess the stability of the navigation channel between the entrance training walls. Detailed volumetric data is presented in Technical Appendix I.

Volumetric analyses indicate that volume fluctuations over both the short and long term can be quite significant. The greatest change during Stage 1(A), took place between 6 and 18 February 1996. The Krankeloon dredged 725 m^3 between the training walls during this period but, because of storm activity, the channel infilled approximately 25,225 m^3 in just 12 days.

Erosion of the channel occurs in response to floods and readjustment due to bar deepening. The most significant change occurred during the May storm when floods scoured 13,500 m^3 from the channel.

Overall, there was a net infill of approximately 35,000 m^3 between April 1995 and November 1996. The channel has consistently maintained better than 4.5 m below AHD and it is considered that with a permanent bypassing system, the navigation objective of the project should be easily achieved.

Hydrosurveys indicate that a shallow, narrow shoal has been present along the inside of the southern

Figure 7.3.1
Stylised Reconfiguration of Bar Bathymetry Under a Permanent Bypass System

training wall. It was considered that the Stage 1A dredging of the entrance bar would have no significant impact on the flood tide supply of sediment which creates this shoal (PBP, 1994). Over the longer term, as permanent bypassing reduces the net infeed of marine sand, this narrow shoal is expected to decrease in size. There will still be occasions, such as the February 1996 storms, which will cause slugs of sand to move into the area and temporarily increase the size of the shoal. The presence of this shoal is unlikely to compromise navigation between the training walls.

7.3.5 Wave Impacts on Tweed River Entrance and Training Walls

Deepening of the bar will mean that significantly fewer waves will break in the deepened areas and therefore the waves approaching the entrance and training walls will contain more energy. Wave propagation into the entrance will increase as the wave condition at the entrance will be increased and the channel between the breakwaters and the training walls will be deepened by dredging.

As discussed in Section 7.3.3, the bathymetry of the bar will depend upon the specific bypass system and bypass strategy of the successful tender. Depending upon these, the bathymetry of the bar will vary from a maximum depth scenario, in which the bar would be largely removed, to a relatively shallow scenario with depths of the order of 5m to 6m below AHD. Furthermore, bar bathymetry will vary depending upon the location, size and shape of any northern and southern sand traps which may be incorporated as part of the bypass system.

For the maximum depth scenario, the maximum wave condition likely to impinge on the walls would be controlled by both:

- total water depth resulting from the bar deepening plus tide, storm surge and setup; and
- nearshore wave refraction which may focus or diminish the wave energy at a particular location.

Where reconfiguration of the bar forms a wide, relatively flat nearshore seabed, focussing by refraction would be negligible. If shallow nearshore shoals persist, then they could focus the waves onto the training walls, although they would also limit the height of the transmitted waves.

Wave transmission across the entrance bar would be further complicated by any general build-up of sand, from time to time, due to storm slugs which may invade the system. Such buildup and localised shoaling could cause large waves to break before they impinge on the walls. Clearly, comprehensive coastal engineering investigations will be needed to assess wave transmission and entrance training wall stability associated with the specific characteristics of the selected bypass system.

PWD (1991j) surveyed the rock armour of the training walls and found that the size, distribution and slope of the armour surface was slightly undersized in respect of the existing wave climate, at the walls. The Stage 1 study (PBP, 1994) concluded that under existing conditions, the training walls could sustain up to 5% damage ie. up to 5% of the armour stone could be dislodged over the outer quarter or so of the walls, during a severe storm.

A desk top assessment of wave breaker indices was carried out to assess design wave heights for various bar depths (refer Technical Appendix II for details). It was found that design breaking wave conditions (H_s) could vary from 6.5m to 8.0m in respect of the shallow bar scenario and maximum depth scenario, respectively.

The magnitude of the expected damage in a major storm, with a permanent bypass system in place, is estimated to vary between 5% (ie. similar to existing conditions) and over 30% for the shallow and maximum depth scenarios, respectively. It is generally accepted that a rubble mound breakwater could not survive loss of primary armour of more than 20-30%. Hence, it is concluded that a permanent bypass system, based on a deep bar scenario, could expose the existing training walls to risk of sudden and severe failure during a

major storm. In contrast, a shallow bar scenario may not significantly increase the risk of storm damage to the walls, although the risk would need to be confirmed by physical modelling as part of the detailed design of the successful tender.

Recent detailed design and physical model testing for the reinforcement of the primary armour of the southern Richmond River training wall determined that the most cost effective solution was the use of concrete armour units in the most heavily exposed sections of the wall and heavy armour stone for the remainder.

Based on the detailed cost estimates prepared for the Richmond River, and taking into account the significantly greater design wave height associated with the deep bar scenario, the estimated cost of strengthening both the northern and southern Tweed training walls, as part of a deep bar scenario, is of the order of $5-10M. Depending upon the outcome of detailed investigations, it is possible that a shallow bar scenario may not require any wall strengthening.

The foregoing assessment is consistent with the design of the Gold Coast Seaway (BPA, 1986) which was designed for minimal storm damage potential and a design wave height of 7 m. It comprises 25 tonne concrete cubes on a relatively flat 1 in 2 slope and incorporates a 10 metre toe berm. The latter improves wall stability greatly.

It is important to appreciate that whilst the May 1996 storm was of the order of a 5% AEP storm (with H_s up to 7m recorded offshore) it caused no damage to the Tweed training walls because the shallow mass of shoals, on the southern and northern lobes of the bar, protected the walls. Photographs taken during the storm, show large waves breaking on the outer edge of the bar with only relatively minor wave action against the walls themselves.

7.3.6 Wave Penetration to Entrance Channel

Recorded wave data from the Tweed Regional tide gauge site indicates increased wave action at this site during the initial Stage 1(A) dredging programme. This recorder site is not representative of other more exposed areas within the entrance. Hence, the absolute wave height values recorded are of limited significance. Nevertheless, these data indicate that there has been a significant and persistent increase in the height of waves propagating into the river entrance associated with the entrance dredging. The typical pre-dredging wave heights in the range 0.1-0.3m have clearly increased to 0.3m-0.6m.

It is likely that these increases will continue when the offshore area is dredged to its final shape. Numerical modelling of wave penetration into the entrance channel (refer Technical Appendix II) indicates that wave conditions between the training walls will depend on the specific nature of the bypassing and resultant nearhsore bathymetry.

It is considered that this increase in wave height within the entrance reaches of the estuary will not pose any threat to bank stability (Section 7.4.6).

7.3.7 River Mouth Currents

The impact of deepening the entrance bar on the pattern of currents at the river mouth, due to the combined effects of tides, swell and wind, is shown in Figures 7.1 a-c of Technical Appendix II.

Improvement of the bar will simplify the ebb jet pattern and reduce its intensity outside the training walls, where the water depths are expected to be increased.

7.4 Impacts on Tweed River Estuary Processes

7.4.1 Impacts on Tweed River Estuary Tidal Hydrodynamics

Model simulations were carried out to differentiate between the impact of a permanent bypass scheme immediately after commissioning and in the long term when all approved river dredging would be complete. Because of the uncertainty about the future bathymetry of the lower estuary marine shoals, the simulations take into account what are considered to be the likely limits of the lower estuary marine shoals. The following simulations were carried out and compared with results presented in Section 4.4:

CASE 4 Extraction areas A, B & C fully extracted and the entrance bar and channel schematised to represent the long term average entrance condition, under a permanent entrance bypass system (refer Technical Appendix II for details). The lower estuary shoals are maintained at their existing condition ie. this case represents the situation just after commissioning of a permanent bypass system.

CASE 5 Case 4 with Areas A, B, C and Area 5 fully extracted ie. after long term operation of a permanent bypass system. The long term case needs to be defined by two limit cases:

CASE 5A Case 4 with Areas A, B, C and Area 5 fully extracted and lower estuary, marine shoals maintained at existing conditions.

CASE 5B Case 5A with lower estuary marine shoals allowed to infill substantially.

7.4.1.1 Immediate Incremental Impact

Simulation Case 4 represents the estuary immediately after commissioning of a permanent bypass system. Notwithstanding their lease expiry limits, extraction areas A, B and C are likely to be substantially extracted by the time of commissioning of a permanent bypass system (J Henley, TSC, *pers. comm*). Consequently, the extraction of these areas was included in the simulation.

Table 7.4.1. summarises the predicted hydrodynamic response of the estuary to a tide of mean spring range (1.3 m), immediately after commissioning of a permanent bypass system. Detailed results are provided in Technical Appendix II.

Table 7.4.1 CASE 4: Predicted Tidal Hydrodynamic Response: Immediately After Commission Of Bypass System: Tide Of Mean Spring Range (1.3 m)

Location	Tidal Levels (m) AHD)			Peak Flows (m^3/s)		Peak Velocities (m/s)	
	HW	LW	Range	Ebb	Flood	Ebb	Flood
Regional Gauge	0.63	-0.60	1.23	780	890	0.98	0.96
Letitia 2A	0.51	-0.39	0.90	410	480	1.05	0.95
Letitia 2B	0.50	-0.38	0.81	290	340	0.39	0.42
Barneys Point	0.49	-0.38	0.87	330	390	0.38	0.45
Tumbulgum	0.55	-0.38	0.93	93	110	0.33	0.40
Murwillumbah	0.59	-0.41	1.00	58	58	0.14	0.17
Terranora Inlet	0.53	-0.46	0.99	340	390	0.88	0.80
Dry Dock	0.45	-0.35	0.80	270	320	0.54	0.59
Terranora Broadwater	0.47	-0.31	0.78	145	175	0.43	0.48
Cobaki Broadwater	0.46	-0.32	0.78	70	90	0.28	0.33

(Source: Technical Appendix -II)

Table 7.4.2 summarises the incremental hydrodynamic impact of a bypass scheme, immediately upon commissioning (ie. CASE 4 - CASE 3), as compared to existing condition (ie. Post Stage 1A).

Table 7.4.2 Immediate Incremental Impact Of Permanent Bypass Scheme (CASE 4 - CASE 3) : Tide Of Mean Spring Range (1.3 m)

Location	Absolute Change Tidal Levels (m)			Percentage Change			
				Peak Flows		Peak Velocities	
	HW	LW	Range	Ebb	Flood	Ebb	Flood
Regional Gauge	0.01	-0.02	0.03	3	1	2	1
Letitia 2A	0.01	-0.01	0.02	3	2	3	0.0
Letitia 2B	0.01	-0.01	0.02	4	3	3	2
Barneys Point	0.0	-0.02	0.02	3	3	0.0	2
Tumbulgum	0.02	-0.01	0.03	2	3	0.0	2
Murwillumbah	0.01	-0.01	0.02	4	4	0.0	0.0
Terranora Inlet	0.01	-0.02	0.03	3	3	6	1
Dry Dock	0.01	-0.01	0.01	4	4	4	4
Terranora Broadwater	0.01	-0.01	0.02	4	4	2	2
Cobaki Broadwater	0.0	-0.01	0.01	3	3	3	3

The predicted immediate incremental impact of a permanent bypass scheme is relatively insignificant. The maximum predicted drop in low water is only of the order of 2 cms below existing conditions (ie. post Stage 1A).

A consistent but minor, increase in peak flows throughout the estuary is predicted. The increase, however, is considered to be insufficient to generate any discernible improvement in water quality. Hence it is concluded that the immediate incremental impact of a permanent entrance bypass scheme on the hydrodynamic regime of the estuary, will not be significant.

7.4.1.2 Long Term Incremental Impact

The long term incremental impact of a permanent bypass system needs to be considered in the context of the likely range in conditions of the lower estuary marine shoals. Simulation Cases 5A and 5B represent the long term cumulative impact of a permanent entrance bypass system and the Tweed Estuary Management Plan with the marine shoals remaining unchanged or substantially infilled,

respectively.

The difference between these two cases identifies the long term incremental impact of a permanent entrance bypass system.

Existing Lower Estuary Marine Shoals

Table 7.4.3 summarises the long term incremental impact of a permanent bypass system on the hydrodynamic regime of the estuary, with dredging components of the Tweed Estuary Management Plan fully implemented and the lower estuary marine shoals maintained in their existing condition.

Table 7.4.3 (CASE 5A-CASE 2A) Long Term Incremental Impact Of A Permanent Bypass Scheme With All River Dredging Completed And Lower Estuary Shoals Maintained In Existing Condition: Tide Of Mean Spring Range (1.3 m)

Location	Absolute Change Tidal Levels (m)			Percentage Change Peak Flows (%)		Peak Velocities (%)	
	HW	LW	Range	Ebb	Flood	Ebb	Flood
Regional Gauge	0.03	-0.05	0.08	4	2	5	4
Letitia 2A	0.03	-0.02	0.05	5	3	7	2
Letitia 2B	0.02	-0.02	0.04	3	3	5	2
Barneys Point	0.02	-0.01	0.03	6	5	5	6
Tumbulgum	0.02	-0.02	0.04	3	3	3	5
Murwillumbah	0.02	-0.01	0.03	2	3	7	1
Terranora Inlet	0.02	-0.04	0.06	6	3	5	3
Dry Dock	0.01	-0.02	0.03	4	5	4	3
Terranora Broadwater	0.02	-0.01	0.03	4	3	2	4
Cobaki Broadwater	0.02	-0.02	0.04	3	5	7	3

(Source: Technical Appendix II)

The long term incremental impact of a permanent bypass scheme would be a slight increase in tidal range and peak discharges and velocities. Apart from the entrance reach, the incremental impact of a bypass scheme would be to lower low water and raise high water by 1-2 cms, throughout both arms of the estuary. Below Letitia 2B, the change in tide levels would increase to 3-5 cms.

The incremental impact on peak tidal discharges and velocities would be a relatively uniform increase throughout, of 3-5%.

Possible Shoaling of Lower Estuary Marine Shoals

Table 7.4.4 summarises the long term incremental impact of a permanent bypass system on the tidal hydrodynamics of the estuary, with dredging components of the Tweed Estuary Management Plan fully implemented, and the lower estuary marine shoals allowed to substantially infill.

Table 7.4.4 (CASE 5B-CASE 2B) Long Term Incremental Impact Of A Permanent Bypass Scheme With All River Dredging Completed And Lower Estuary Shoals Infilled: Tide Of Mean Spring Range (1.3 m)

Location	Absolute Change Tidal Levels (m)			Percentage Change Peak Flows (%)		Peak Velocities (%)	
	HW	LW	Range	Ebb	Flood	Ebb	Flood
Regional Gauge	0.03	-0.05	0.08	6	5	3	2
Letitia 2A	0.02	-0.02	0.04	3	5	7	3
Letitia 2B	0.02	-0.02	0.04	4	3	6	3
Barneys Point	0.02	-0.03	0.05	3	3	6	5
Tumbulgum	0.01	-0.01	0.02	7	5	3	0.0
Murwillumbah	0.00	-0.02	0.02	2	2	0.0	-6
Terranora Inlet	0.02	-0.02	0.04	5	3	4	3
Dry Dock	0.02	-0.02	0.04	4	0.0	2	2
Terranora Broadwater	0.01	0.00	0.01	0.0	3	0.0	5
Cobaki Broadwater	0.01	-0.00	0.0	3	6	7	3

(Source: Technical Appendix II)

Even with the lower estuary marine shoals substantially infilled, the incremental impact of a permanent bypass scheme would still be a pervasive increase in tidal range and peak discharges and velocities. Furthermore, the impacts would be generally of the same order as those predicted in respect of the lower estuary shoals in their existing condition.

Summary of Incremental Impacts

The long term incremental impact of a permanent entrance bypass scheme is a pervasive increase in tidal range and peak discharges throughout both arms of the estuary. The impacts would be reduced only slightly by infilling of the lower estuary marine shoals.

The increase in tidal flows and velocities would be generally of the order of 5% which would bring about a minor improvement in tidal mixing and flushing, throughout the estuary. It is significant, however, that the hydrodynamic impacts of a permanent bypass scheme would work to ameliorate the tidal damping effect of any future infilling of the lower estuary marine shoals.

Overall, it is concluded that a permanent entrance bypass scheme will have a minor, beneficial impact on the long term hydrodynamics of the estuary. If the lower estuary marine shoals are maintained in their existing configuration, entrance bypassing would enhance the tidal mixing and flushing benefits already planned in respect of the Tweed Estuary Management Plan (PWD, 1995). On the other hand, if the lower estuary marine shoals are allowed to continue infilling, water quality, mainly in the Terranora Arm, would deteriorate but the impact of entrance bypassing would be to reduce the magnitude of the deterioration. Hence by acting to increase tidal exchange, a permanent bypass system would lessen the impact of infilling.

7.4.2 Impacts On Lower Estuary Shoal Dynamics

7.4.2.1 Impact on Marine Sand Infeed Rate

Existing Shoal Dynamics - Post Stage 1A

The Stage 1 EIS predicted that Stage 1A would reduce the infeed of marine sand (PBP, 1994). Post Stage 1A monitoring however, has shown that the hydrodynamic impact of Stage 1A has been much less than anticipated, with increases in tidal flows and velocities, through the entrance, being limited to 5%

(Section 4.4.1.10). Also, the hydrodynamic impact has been largely symmetrical, ie no pronounced ebb tide bias. Hence, it is concluded that the net rate of infeed of marine sand has not been affected by the Stage 1A works.

The present estuarine shoal dynamics is represented by Figure 4.4.3.

Permanent Entrance Bypass System

WBM (1994) and PWD (1995) conclude that a permanent entrance bypass system should result in no net infeed of marine sand to the estuary. This conclusion was predicated on the assumption that a bypass system would intercept all the longshore transport, ie there would be negligible longshore transport reaching the entrance.

Analysis of Stage 1A survey data, however, indicates that the trapping efficiency of a permanent bypass system is likely to be of the order of 50% to 100% during modal longshore transport conditions and only 20% to 70% during storms, depending upon the actual bar and sand trap configuration developed and maintained by the system (Section 4.3.1). Hence there is always likely to be significant quantities of sand leaking through any permanent bypassing system, portion of which could feed into the estuary.

The infeed of marine sand, through the entrance, will be dictated by the availability of sediment. Whilst littoral leakage associated with a permanent bypass system would mean that some quantities of sand would always be available, such quantities would be considerably less than those associated with current bar conditions. Also, there would be a substantial reduction in the ability of flood tide currents and wave radiation stresses, to convey sand to the river mouth, across the deepened entrance bar surface.

It is not possible to quantify the outcome accurately because the processes involved are too complex and the outcome will depend, to a fair degree, on the operating characteristics of actual bypass system. It can be concluded, however, that the net impact of a permanent entrance bypass system would be to substantially reduce the net infeed of marine sand to the estuary.

7.4.3 Impact on Infilling of Lower Estuary Marine Shoals

Without entrance bypassing, or other new river works, infilling would continue for at least 50 years until regime conditions were achieved (Section 4.4.2.2). A permanent bypass system, however, would reduce the net infeed of marine sand and therefore slow down the growth of the marine shoals.

The magnitude of the reduced infeed cannot be calculated accurately. However, two outcomes are feasible:

- *flood tide infeed > ebb tide transport* - if the reduced flood tide infeed of sand is still greater than that carried by the ebb tide discharge, the lower estuary marine shoals would continue to grow in the long term but at a much slower rate, ie it would take considerably longer than 50 years to achieve regime conditions; and
- *flood tide infeed < ebb tide transport* - if the reduced flood tide infeed of sand is less than that carried by the ebb tide discharge, the lower estuary marine shoals would slowly erode. A net "export" of sediment has occurred on other NSW river systems eg Forster (Gordon & Nielsen, 1980).

The implications of these two outcomes to the long term management of the shoals are discussed below.

7.4.4 Impact on Long Term Shoal Dynamics

The hydrodynamic impact of a permanent entrance bypass system would be a uniform increase of peak tidal discharges and velocities of the order of 3-5%, irrespective of whether the lower estuary marine shoals are infilled or not (Section 7.4.1.3).

The long term shoal dynamics would depend largely on the direction of net marine sand infeed.

Reduced Net marine Sand Infeed

If the impact of a permanent bypass system, would be to merely reduce the long term infeed of marine sand, the long term impact on shoal dynamics would be no different to that described in respect of the existing environment (Section 4.4.2.2), except that the time for the estuary to reach equilibrium conditions would be much longer than 50 years.

The relatively minor increase in flows and velocities, of 5%, would not alter the impacts discussed in Section 4.4.2.2 such as:

- the lower estuary marine shoals would be expected to extend upstream with consequential shoaling of the northern end of the longitudinal shoal;
- the secondary western channel, against Ukerebagh Island, would be likely to infill and could require maintenance dredging;
- the main ebb channel against the right bank, in the vicinity of Ukerebagh Island, would be likely to experience some narrowing;
- minor build-up of the longitudinal shoal, between Ukerebagh and Fingal, would cause a gradual increase in the low water expanse of shoal;
- the present tendency for shoaling of the Boyds Bay Shoal would be a persistent, long term issue, requiring regular navigation channel maintenance; and
- navigation channel infilling in the vicinity of the confluence with Terranora Inlet would be exacerbated. Maintenance dredging could be needed more frequently in this area, than in the past.

Reversal of Marine Sand Infeed

If the impact of a permanent bypass system, would be to cause a net loss of sand from the lower estuary marine shoals, the hydrodynamic impacts would tend towards the flood scour scenario discussed in Section 4.4.1.12. The net annual erosion, however, would be small and it would take more than a decade to cause erosion equivalent to flood scour. In the absence of any corrective measures, however, there would be no shoal recovery.

7.4.5 Fluvial Impacts

Section 4.4.1.5 concludes that the entrance bar has no significant impact on flood behaviour. There is, therefore, no scope for significant improvement of flood levels due to a permanent entrance bypass system (PWD 1991m, 1995).

Similarly a bypass system will have no direct impact on the pattern of shoaling and erosion within the estuary caused by floods. It could have an indirect impact by reducing the size of the lower estuary marine shoals, through reduced tidal infilling rate over time (Section 7.4.2.1).

Major floods would still deposit the sand scoured from the lower estuary, onto the bar. The natural ruling depth of the entrance bar (with existing estuary flows) is about -3 m to -3.5 m AHD. In this state, the natural action of a flood is to scour the entrance bar channel and deposit all its sand load as a disequilibrium bulge on the seaward face of the bar (PBP, 1994).

As part of a permanent bypassing scheme, however, the entrance bar would be maintained deeper than its natural regime, over a substantial area. This would lead to a reduction in flood velocities, as the flood discharge expands across the deepened bar surface. Significant deposition in the bar entrance channel and areas of the bar would be likely.

The discharges of significant floods, are much greater than tidal discharges. Hence it would be expected that the minimum depth, over flood deposits on the bar, would be much greater than the natural regime depth. It is estimated that a 5% AEP flood would be unlikely to deposit sand above a level of approx -5 m AHD. Hence, flood deposits are unlikely to compromise bar depth directly but they could infill sand trap areas and leave the entrance bar channel prone to rapid infilling by post-flood longshore transport and/or local reworking of the bar crest by wave action.

It is considered that the bar could need maintenance dredging immediately after each significant flood (ie. 20% AEP flood or lower), to maintain the buffer capacity of sand trap areas. The portion of flood sand load which is transported across the surface of the entrance bar by the flood and deposited on the seaward face, is most likely to be reworked and slowly transported north.

It is concluded that a permanent entrance bypass system will not have a significant impact on fluvial processes. The design and operation of the system, however, would need to take into account that floods could deposit up to 200,000 m^3 of sand on the central bar area.

7.4.6 Impact On Wave Penetration Into The Lower Tweed Estuary

The impacts of the bypassing works on propagation of the ocean waves to the river mouth and implications for training wall stability are presented in Section 7.3.5. The works will allow larger waves to impinge directly on the training walls and enter the river entrance channel to the lower estuary.

Current refraction and the complex bed topography of the estuary would tend to cause large waves to be directed onto the breakwaters. However, whilst the larger waves would not penetrate into the estuary, there would be an increase in the height of storm waves penetrating the Tweed channel. Measurements of wave heights at the Tweed Regional Tide Gauge confirm that there is substantial attenuation of the height of waves as they move into the estuary. The Stage 1A dredging has caused waves penetrating the estuary to increase from a maximum of 0.3 m to 0.6 m (Section 7.3.6). These measurements include the May 1996 storm. It is concluded that there is no potential for large waves to penetrate the lower Tweed estuary.

The area of increased storm wave height would be largely confined by the bend in the Tweed River and the Entrance Shoal. Reflection of storm waves along the western training wall would be likely to occur which would have the effect of transmitting storm waves further upstream than may be initially thought. The area likely to be affected by increased storm wave height comprises Jack Evans Boatharbour and the western training wall extending to where there is pronounced shoaling against the wall, opposite Solander Street.

The impact of increased storm waves in the lower Tweed, of the magnitude noted above, would not be significant because the western training wall is substantial and has been in place for almost 100 years. It is founded on very strong indurated sand (Druery and Curedale, 1979) which is scour resistant. There have been occasions when the bar conditions would have been similar to the bar dredging configuration likely to accompany a permanent bypass system, because of major flood scour (eg. 1954). Hence the lower Tweed has experienced increased storm waves, due to entrance bar modifications, in the past. It is considered, therefore, that there would be no threat to the stability of the existing internal training wall or the safety of foreshore parkland immediately behind it.

7.4.7 Impact On Storm Surge Penetration

A permanent bypass facility would have no impact on that component of a storm surge associated with barometric and regional wind stress effects. However, a deepened bar surface would reduce wave breaking across the bar, for any particular storm. Higgs and Cox (1984) and Griffin (1983) have shown that storm surges in the Tweed Estuary can, at times, be attributed solely to wave set up on the bar.

PWD (1991j) considered that the impact of permanent deepening of the bar would not be significant in terms of reducing storm surge.

On balance, it is concluded that the impact of bar dredging would be to reduce storm surge. However, the reduction would not be great and undiminished penetration of storm surge into the lower estuary is adopted for the purposes of this environmental study.

7.4.8 Impacts On Bank Erosion

Bank erosion in the estuary is largely limited in the main arm, to areas upstream of Barneys Point and to Ukerebagh Island, in Terranora Inlet. PWD (1995) and TSC (1996) show that the erosion in the main arm is mostly related to wave action and river thalweg adjustment. Apart from the southern bank at Chinderah and the northern bank of Ukerebagh Island, tides have little bearing on the erosion.

In Sections 7.4.1 and 7.4.5, it is demonstrated that a permanent bypass system will have only a minor impact on tidal flows and no impact on flood flows. Hence it can be concluded that a permanent bypass system will not exacerbate existing bank erosion or initiate any new erosion sites. As discussed in Section 7.4.6, the increased height of waves penetrating the entrance will not cause bank erosion in the lower Tweed Estuary.

7.5 Ecological Environment

This Section describes impacts to the ecological environment which will mainly relate to the marine and estuarine environments. Terrestrial areas are likely to be subject only to minor disturbances associated with placement of infrastructure for some by-passing options.

7.5.1 Marine

The permanent bypass options will have varying degrees of impact in the removal zone off the Tweed River entrance, depending on the depth and extent of permanent sediment removal, and the amount of infrastructure installed in the marine environment.

The impacts within the nourishment area are similar from one option to the other because the nourishment areas and the methods of sand placement will be much the same for all the options.

A permanent jetty-mounted system would appear to have the greatest impact on marine ecology. Not all impacts would be negative. Design and operation would be similar to the Gold Coast Seaway Bypassing Scheme at the mouth of the Nerang River. Localised impacts would arise from this alternative due to the deep sand trap (-11.0 m AHD at the Gold Coast Seaway) which would be created, inhibiting benthic invertebrate recolonisation over the length of the removal zone due to the difference in substrate depth, the continual removal of accumulating sand, and the fixed and permanent nature of the system. A new and different habitat would be created in the nearshore zone consisting of the deeper zone of removal, the hard substrate provided by steel jetty piles, and a permanently shaded substrate and water column due to the

jetty deck. This would attract a different complement of fish species to the area, which would feed on growths of animals and plants attached to the piles, since the soft substrate would continually be agitated and removed by the jet pumps.

The steel piles, and associated attached animals/plants, would attract rocky-reef-type fishes, probably similar to the larger species which inhabit Kirra Reef. The smaller species of rocky reef fish may not find suitable protection such as that found in small crevices of Kirra Reef. The larger fish which are attracted to the structure are likely to provide improved recreational fishing which has been the experience at the Gold Coast Seaway. Discussions with the Queensland Department of Transport and local commercial fishermen suggest that the Gold Coast Seaway breakwater and trestle have become popular recreational fishing spots as a result of the fish attracted to the artificial reef-type structure created at the seaway mouth. According to local fishers, species commonly caught off the breakwater include trevally, tailor, mackerel, red bream, and whiting.

There is no quantitative information to assess whether there has been an alteration of the commercial fishery at Nerang or in the adjacent Southport Broadwater. However, long-time mullet fisher and Chairman of the Jumpin Pin Branch of the Queensland Commercial Fisherman's Organisation (QCFO), Mr. Lindsay Zink, considers that there has been a decrease in the mullet fishery within the Broadwater from the Southport area north to Paradise Point since the construction of the bypassing system at the Gold Coast Seaway. He is of the opinion that some northward-travelling schools of mullet are swinging wide of the structure at the Seaway and not returning to the beach for up to several kilometres further up the coast. He concedes that some schools are coming in the Gold Coast Seaway entrance, but a significant quantity are now by-passing the entrance, whereas they didn't prior to the construction of the breakwater.

A local Southport mullet fisher and State Chairman of the QCFO, Mr. Dennis O'Connell, advises that there has been no detrimental effect of the Gold Coast Seaway on the mullet fishery. However, he advises that since the construction of the breakwater and associated dredging works inside the Broadwater, the whiting catches have decreased dramatically. This is attributed to a combination of the effects of the breakwater itself and a reduction in preferred habitat inside the Broadwater due to navigation channel dredging. Whiting are now apparently schooling around the breakwater and not entering the channel into the Broadwater, where sand bars have been removed by dredging. These sand bars are a preferred foraging area for whiting, and convenient hauling areas for seine net fishers. This opinion regarding the mullet fishery is supported by a long-time commercial prawn and long-line fisher, Mr. Alf Ness, who has commercially fished for 35 years, although he is now retired and has not actually fished for mullet or whiting on the Gold Coast. His opinion is based on conversations with other local fishers in the area.

Economically, whiting are a relatively important component of the commercial fishery in the Tweed River: catch figures from NSW Fisheries show that sand and trumpeter whiting species have averaged 6016 kg per annum from 1984-1996. Whiting do not migrate long distances along the coast like mullet, however, they shoal in large schools and move from the estuaries into nearshore coastal waters as they mature. Although whiting represent only about five percent by weight of the reported commercial finfish catch from the Tweed River, they are the third most abundant commercial finfish species after mullet and luderick. The low percentage is due to the fact that mullet catch figures completely swamp all other finfish species, representing 70 percent of the commercial catch, by weight, in the estuary. The sum of mullet and luderick amount to over 80 percent of the finfish catch in the Tweed River. Dollar value figures for the catch have been requested but had not been received at the time of writing this report. Furthermore, from anecdotal information, whiting is a significant component of the recreational catch.

The anecdotal information and opinion from local experienced fishers on the impacts of the Gold Coast Seaway Bypass Scheme is inconclusive, but there is a body of opinion which suggests that the mullet fishery in the Broadwater has not suffered as a result of the Bypass Scheme. However, scientific and some commercial fishers opinion would suggest that there may be a risk that the jetty structure, the shade that it provides, and the submarine noise of the jet pumps may inhibit migrating schools of fish, such as the annual mullet run, from passing close to shore in this area. The structure could also encourage whiting to remain

outside the entrance and school around the breakwater and trestle structure. However, it must be noted that the perceived decrease in whiting catches within the Broadwater was attributed by local fishers to be a combination of the breakwater construction and a reduction of preferred habitat inside the Broadwater. In the case of the Tweed River, the breakwater is already in place and has been for several decades; with the proposed management of the lower estuary, no significant changes to the extent or location of the sand shoals are expected in the lower estuary as a result of the bypass scheme. Therefore, the perceived causes of decreased whiting catches in the Broadwater should not apply in the Tweed River. Despite this observation about whiting, there is still considered to be a moderate risk that some of the migrating finfish (most notably the annual mullet run) could be discouraged from entering the Tweed Estuary, and a slight risk that immature whiting could remain outside the estuary, seeking the apparent protection of a permanent trestle. This could result in some of the finfish species bypassing the entrance to the Tweed River, where they are safely fished commercially. This would adversely impact on commercial fishing in the Tweed River. The further south from the mouth the structure were constructed, the less the risk of migrating fish bypassing the Tweed River Entrance. Figure 5.2.2 suggests that the permanent jetty structure could be as much as 400-500 m south of the southern training wall. This is considered far enough away from the mouth to mitigate the potential adverse impact discussed above.

The jetty structure would have a perceived positive impact of attracting a greater variety of fish species to the immediate area than presently occur, and the structure itself could provide convenient access for recreational anglers to fish for these newly attracted species.

Anecdotal evidence from the Queensland Department of Transport (DoT) and the QCFO suggests that noise generated by the bypassing system to the Gold Coast Seaway does not inhibit fish, and, in fact, may attract them. The noise levels observed above water on the trestle and breakwater are reported by DoT to be low. This evidence provides some basis on which to conclude that there is not likely to be an adverse impact due to noise from the jet-pump system. It is considered that if the noise were more like a continuous low frequency sound, the fish may indeed acclimatise to it, as opposed to short, sharp, high frequency sounds which would tend to startle them. It is more likely that the submarine noise would be like the former, rather than the latter.

Prawns and mud crabs spawn at sea, and the larvae return to the estuary to mature. Since the larvae (called zoea) are planktonic at this stage of their life cycle, they should not be affected by sediment removal from any of the bypass options.

The mullet catch figures from the Tweed River could be reduced if the bypass scheme inhibits this species from entering the estuary. It is considered that the trestle-mounted fixed sand-fluidising and slurry system has the greatest potential to inhibit migratory species, but much of the anecdotal evidence available from the similar system operating at Gold Coast Seaway suggests that this has not occurred there.

Relocation of bypassed sand would not create significant environmental problems provided large volumes of sand were not placed in one spot, causing smothering of the existing *in situ* invertebrate population as well as those animals which survive removal and transport via the slurry pipeline. The solids concentration of a pumped slurry is typically 20-30 percent solids by volume (Section 5.5.4) which is dilute enough to allow organisms to rise to the surface of the settling plume.

Recolonisation of the soft sediment habitat in the nourishment area would occur within weeks to months after nourishment. The potential for complete recovery of benthic infauna is high, given that the surrounding area will be available for recolonisation.

The jack-up dredger alternative is considered to have less ecological impact than the fixed jet-pump system because it is semi-mobile and would generally not remove sand to as great a depth as the fixed jet-pump system. There would be minor impacts within a defined zone of activity since the dredger itself would maintain an arc of deeper substrate which would be devoid of invertebrate life. The substrate under the dredger would be a few metres deeper than the surrounding substrate, and would be continually

redredged, thereby keeping it virtually devoid of fauna. However, the mobile sands off the entrance are naturally very depauperate in fauna (Section 4.5.1).

The system is not as permanent as the jetty concept, and the barge would move around as required, thereby discouraging a different faunal assemblage from becoming established, as would be the case with the permanent jetty. The potential for recolonisation of benthic macroinvertebrates in the removal area is low while the dredger remains in one position. However once the dredger moves to a new area the opportunity for recolonisation is significantly greater.

Submarine noise levels would probably be similar to the fixed jet-pump system.

The impacts at the nourishment area (ie., smothering, burial and recolonisation potential) would be the same as with the fixed jet-pump system, since a slurry pipeline would be used to carry the spoil to the nourishment area.

The remote sand fluidising system is free of any jetty or platforms, and would have less impact than the permanent or semi-permanent structures which have considerable infrastructure associated with them. However, this alternative is semi-permanent and would create a large zone devoid of infauna within its sand trap with poor potential for recolonisation. The conceptual layout of the system would have a disturbed zone of sand collection approximately 30 m wide by 100 m long for each unit. There may be several units arranged in a set, and up to three sets placed within the removal zone. Thus, it can be seen that there would be relatively large areas of sea floor surrounding the Tweed Entrance which would be virtually devoid of marine life. It appears conceivable that the area of continual disturbance could be on the order of 2-3 hectares.

Agitation dredging is most likely to be used in shallow areas dominated by wave action. These areas are naturally devoid of fauna therefore this method of dredging should not have significant ecological impact.

The trailing suction hopper dredger would have the least ecological impact since the width of the dredged path created by the dredgehead would be narrow (on the order of a metre or two). It would be a somewhat random and meandering track in the substrate, the dredge path would not be very deep, and the inter-dredge area would be very large in comparison with the dredge path. Therefore, recolonisation by nearby immigrant organisms would be rapid, and the process would not be excessively disruptive. No potentially new habitat would be created.

Disturbance impacts would only be slight since the dredger will be moving all over the removal area and would operate intermittently. Although a large area would eventually be dredged, the random, narrow, shallow nature of the dredge path allows for rapid recolonisation from contiguous areas at any given time, thus minimising impacts.

The migration of fish into and out of the Tweed River estuary should not be significantly adversely affected by this method.

A potentially measurable short-term impact could occur in the nourishment area if the sand is placed in bulk out of the hopper or bow-cast in one spot. These methods of disposal would cause smothering of *in situ* organisms as well as those which survive dredging and transport in the hopper. If the sand were disposed via a slurry pipeline whose outlet can be moved around or released from the hopper gradually while the vessel was underway, the impact could be ameliorated considerably. In both cases the potential for complete recolonisation is high.

An excavator or cutter-suction dredger working in the upper beach zone would not have significant impacts on the subtidal zone, but would temporarily destroy the beach worm habitat at the north end of Letitia Spit. Once the new beach profile was established, the beach worms would migrate back into the area from the south. The other submarine dredging systems would cause a gradual reduction in the width of the spit

through natural winnowing, allowing the worms to migrate up the beach to new habitat in a natural fashion, thereby maintaining the population.

Summary

From the above discussion, it becomes evident that the permanent structures, with large and/or deep zones of removal, are assessed as having the greatest marine ecological impact. The impacts identified are:

- the addition of new reef-type habitat where none was there before. This will attract a different complement of invertebrates and fish, which may be seen as a benefit by those interested in fishing. But environmentally, such changes are not necessarily positive in the long term;
- the creation of zones devoid of benthic invertebrates within the sand trap of the collection system; and
- characteristics of the structure (ie., physical barrier, shading, deeper holes, dipauperate invertebrate fauna in the trap) and operation of the system may inhibit migrating schools of mullet and/or shoaling schools of whiting from entering the Tweed River to feed.

The option with the least marine impact is the mobile trailer suction dredger which operates on an as-needed, where-needed basis. The dredge path at any instant of time is small compared to undredged areas, the depth of removal is relatively shallow compared to the fixed systems, and the submarine noise would be intermittent. These characteristics would allow mobile marine species unimpeded access to the mouth of the estuary during the night, rough weather and the time taken to discharge its load.

The magnitude of dredging impacts can be put into perspective by considering the habitat in which the impacts will occur. The removal zone consists of actively mobile sand, with a naturally depauperate and mobile infauna. The offshore nourishment area is slightly richer in faunal species because the sediment is slightly less mobile. The on-shore beach nourishment areas are even more devoid of marine life than the removal area. Nourishment configuration will avoid Kirra Reef. It will be kept at least 50m away from any portion of the outcrops, and sediment will slowly accrete around the base of the outcrops as it had always done in the past.

7.5.2 Estuarine

Several options have been developed for the sand by-passing system at the Tweed River entrance (see Section 5.5). None will impact directly upon estuarine systems, other than for the installation of an intake pipe (Section 5.5.4). The majority of impacts associated with sand by-passing the entrance will be indirect and relate to minor tidal range changes associated with :

- maintaining the river mouth in an "open" condition (as opposed to the existing situation where the mouth has a sand bar offshore from the training walls). Each of the by-pass options being considered will change the entrance morphology in the same way, hence the indirect impacts to the tidal regime of the estuary are identical for each option; and
- the rate of infill of the shoals near the confluence of Terranora Inlet and the Tweed River Main Arm. Rates of infill are likely to be slower with the sand bypassing system in place with rates being dependent upon the bypassing system adopted.

No tidal range changes are expected to occur as a result of the above processes to estuarine waterbodies located along Fingal Peninsula/Letitia Spit all of which are of significant ecological value. Wommin Lake and Wommin Lagoon are tidally connected to the Tweed River by culverts whilst Kerosene Inlet has a rock bar at its entrance. These structures ensure that low tide levels are higher than in the river and that the waterbodies are essentially "perched " (WBM Oceanics, 1996). Similarly these structures prevent the full

high tide level being experienced, thus a slightly increased high tide in the river would be unlikely to result in an equivalent increase in high tide levels of the waterbody.

The impacts to estuarine flora/fauna differ depending upon the process, entrance condition or lower entrance shoal infill rates. Hence, impacts are discussed below in relation to each process separately.

7.5.2.1 Potential Impacts on Wetlands

River Mouth Condition

Maintaining the mouth of the Tweed River in an "open" condition will increase tidal ranges and flows within the river from those occurring presently. This increase, however, is anticipated to be negligible with Mean High Water Spring Tide Levels to increase by 0.01m and Mean Low Water Spring Tide Levels to decrease by 0.02m (Table 7.4.2).

Even when all approved dredging works within the estuary have been completed (ie. Areas A, B, C and 5), Mean Spring High Tide levels are anticipated to increase by less than 3 cm and Mean Spring Tide Low levels will decrease by less than 2 cm (Section 7.4.1.2).

Since the above changes refer to spring tides they would occur for a few days per month and for all other tidal phases (eg. neap tides), differences can be expected to be less. The alterations to the tidal regime will be evident in the Lower Estuary due to the increased tidal flushing levels experienced, while in the Upper Estuary (above Barney's Point Bridge) where tidal penetration is less they would be almost immeasurable.

Such small increases/decreases are unlikely to result in significant ecological impacts. They would presumably be well within the existing tidal range variations occurring as a result of fluctuations in the entrance sand bar location and scouring associated with flood events. Tidal ranges are likely to vary not only due to entrance condition, but also depending upon winds, waves, coastal trapped waves, low pressure systems and storms.

Rate of Infill of Lower Entrance Shoals

The lower entrance shoals are exhibiting a trend of accretion and consequently reducing the tidal range in the estuary. However, within this trend, the tidal range of the Tweed River periodically increases when the lower entrance shoals are removed as a result of large floods. A reduced infill rate for the lower estuary shoals as a result of bypassing will therefore:

- slow the rate at which the tidal range of the estuary is reduced. This would be beneficial to estuarine communities as a reduced tidal range (eg. reduced high tide levels of 0.04m and increased low tide levels of 0.03m) would lead to potentially poorer water quality and a narrower intertidal zone; and
- reduce the rate at which lower estuary shoals (hence estuary tidal ranges) recover to pre-flood conditions. This will lead to estuarine wetlands experiencing a more stable tidal regime between major flood events. Flood related changes to tidal ranges presently may be significant (eg. increased high tide levels of 0.07m and decreased low tide levels of 0.11m) and restoration of levels to pre-flood conditions may occur rapidly (say within 2-3 years - see section 7.4). These changes would also occur following bypassing but the reduced rate of infilling would ensure the period of recovery would be longer (say 10 years or more). Therefore bypassing will result in wetlands experiencing less rapid changes in tidal range which is likely to be beneficial. Tidal range stabilisation may be beneficial to wetlands in that the margins of intertidal wetlands would be subject to lesser change and have greater opportunity to become more mature and diverse.

Overall, bypassing is likely to be beneficial to wetlands in that it will reduce the on-going trend of tidal range

constriction due to lower entrance shoal accretion and stabilise interannual tidal range variation within the river.

7.5.2.2 Effect on Aquatic Fauna and Fisheries

River Mouth Condition

Changes to estuarine wetlands (which function as nursery and feeding habitats) are anticipated to be negligible due to entrance bypassing in isolation (Section 7.5.2.1).

With the river entrance being maintained in an "open" condition there may be an increase in the abundance/occurrence of oceanic species of fish within the estuary as a consequence of improved access through the river mouth although the extent to which this would occur cannot be quantified.

Recreational fishermen on the Gold Coast (Queensland) verbally report increased catches of pelagic species (eg. trevally, mackerel) in the Southport Broadwater since the entrance was dredged and trained in the 1980's. Conversely, anecdotal evidence from some anglers suggests that catches of estuarine species such as whiting have decreased (Section 7.5.1). However, it needs to be recognised that the magnitude of river mouth changes associated with the Gold Coast Seaway work, were much greater than proposed for the present bypassing works.

Additionally, a more "open" entrance may influence movement of juvenile fauna into the estuary. Unfortunately little scientific research has been conducted in regard to this issue. Many prawn and fish species of fisheries importance present within the river spawn in coastal waters and would migrate from the river for this purpose. The extent to which the entrance is "open" would probably have little influence on this movement from the estuary (prawns and fish often traverse very shallow water as part of such migrations). However, the extent of entrance opening may influence aquatic fauna movement into the river. Eggs, larvae and juveniles resulting from prawn and fish spawning in coastal waters drift into estuaries, such as the Tweed River, where they grow and mature (Pollard, 1976). To a large degree, this movement is passive with eggs and larvae (as part of the plankton) being transported into the estuary by tidal currents (some juveniles may exhibit an active movement).

It would therefore seem that, at least for planktonic eggs and larvae, a greater volume of water entering an estuary could result in a greater potential for such organisms to be transported into the estuary.

Navigation of the Tweed River entrance is often dangerous and this has reduced available fishing time (section 4.6.8). Sand bypassing is likely to result in safer navigation of the river entrance and is likely to be benefit to commercial fishing in the area.

Rate of Infill of Lower Entrance Shoals

The reduced rate of infill is likely to lead to a slowing of the lower entrance shoaling process which constrains estuary tidal range which in turn may adversely affect water quality/wetland extent. Ultimately a reduced rate of infill will lead to more "stable" estuarine wetlands. Prediction of whether such changes (eg. slightly less variation in wetland communities at their margins in specific areas) would lead to alterations in the abundance and diversity of aquatic fauna communities is difficult considering :

- the "carrying capacity" of estuarine wetlands/seagrass beds and fish/prawn recruitment levels to areas such as seagrass beds is likely to vary annually and between sites (Bell and Westby, 1986);
- relatively little is known about the ecology of subtropical wetland/seagrass areas in Australia; and

- wetlands (seagrass beds, in particular) naturally vary annually in terms of distribution and density of substratum cover.

However, it is considered that changes to aquatic fauna communities would be relatively minor considering the level of change expected to aquatic habitats and existing variability of such habitats.

Commercial and recreational fisheries within the region are unlikely to be adversely affected by a slower rate of shoal infilling as fish and crustacean communities within the river will not be substantially altered or disturbed. That is, the overall fisheries value of the region should not be affected.

The oyster culture industry is restricted to upstream areas (Chinderah Bay and Terranora Broadwater). Increased tidal flushing of the river, however slight, has the potential to improve river water which would benefit the oyster growing industry. Oysters are filter feeders and thus accumulate pollutants from the water column. In light of recent events involving suspected contamination of oysters grown in the Tweed River, improved water quality would aid oyster farmers in producing a healthy uncontaminated product.

7.5.2.3 Effects to Mosquito/Midge Breeding

River Mouth Condition

Installation of the bypass system would have negligible effects to the river tidal range and would not influence mosquito/midge breeding grounds.

Rate of Infill of Lower Entrance Shoals

Tidal ranges in the Tweed River presently increase when flood events scour out the lower entrance shoals. The consequent tidal range increase leads to additional intertidal areas in upper littoral regions which may provide suitable conditions for biting midge/mosquito breeding. The newly available area slowly decreases as the lower entrance shoals infill and tidal ranges return to pre-flood conditions. Whilst this process will still occur following bypassing works, the reduced rate of shoal infilling will lead to these areas being available for a longer period potentially resulting in a greater area of breeding habitat being available over time.

The species that are likely to be of most concern are *Culicoides molestus* and *Culicoides subimmaculatus*. *C. molestus* is a highly mobile, aggressive species of biting midge that breeds prolifically along suitable upper intertidal foreshores. Gradually sloping shores that are covered by the tide are particularly susceptible as breeding sites for this species. Increased tidal heights on these type of shores within the Tweed estuary may increase the area available for *C. molestus* to breed (Easton, 1996).

C. subimmaculatus breeds extensively in the muddy sands just above the tide level where dense stands of mangroves begin to thin out and form a transition zone into saltmarsh areas. They bite actively around early morning and late afternoon (Easton 1996). Extensions of the foreshore area around the upper tidal plane are likely to occur as a result of alterations in tidal range. With the displacement of saltmarsh communities and expected sparse mangrove growth in these upper tidal areas, these areas can be expected to breed *C. subimmaculatus*.

7.5.3 Terrestrial

It is considered that terrestrial habitats within the estuary area will not be influenced by the potential slight increase in tidal ranges either as a result of bypassing options or the reduced rate of infill for lower entrance shoals. Tidal range increases from the existing situation would be minor and the upper tidal level (ie. location of Highest Astronomical Tide contour) would not differ from that experienced in the past 10 to 20

years. On this basis , no adverse impacts would occur to terrestrial flora/fauna (including the species listed in Tables 4.5.3, 4.5.4, and Section 4.5.3.1) associated with the Tweed River.

Terrestrial areas on northern portions of Letitia Spit however may be influenced by:

- provision of infrastructure associated with the fixed jetty mounted system (eg. pumping facilities, the jetty and vehicular access routes); and
- retreat of the foreshore by as much as 90m.

This could occur as a result of most of the bypassing options being considered. For example, a mobile land based system would directly excavate the foreshore whilst some of the dredging options could indirectly result in a retreat of the foreshore. The area influenced would depend upon the option and specific implementation strategy adopted for that option. Foreshore retreat could also be minimal and/or a slow process developing a new equilibrium situation over many years.

These influences are likely to affect terrestrial vegetation/habitats on Letitia Spit and shorebird roosting areas on South Head beach. Effects to the roosting areas are described under Section 7.5.4. Provision for infrastructure and/or foreshore retreat would involve vegetation disturbance, although as noted in Section 4.5.3, the majority of vegetation in potentially affected areas is of relatively low conservation/ecological value comprising species planted following sand mining in the area (mainly horsetail oak, *Casurina equisetfolia*) and numerous weed species (mainly bitou bush, *Chrysanthemoides monilifera*). Whilst no detailed fauna surveys (eg. trapping) have been undertaken, it is unlikely considering the vegetation types present in potentially affected areas, that any habitats of significant conservation value to fauna (hence associated faunal species) would be disturbed. However, the vegetation performs a valuable role of stabilising the dunes against wind erosion. In this regard, a Dune Management Plan will be prepared when the adopted option has been identified to ensure appropriate management actions are implemented.

7.5.4 Shorebirds

Impacts to shorebirds from the Sand Bypassing Project relate to those experienced in areas near South Head beach where infrastructure is located and foreshore retreat is anticipated.

The impacts to waterbirds from the proposed bypassing system are considered to relate to the Tweed River and northern New South Wales beaches only. The southern Gold Coast beaches are not of relevance, as they are not regularly used by waterbirds.

Removal of the bar at the mouth of the Tweed River and the associated reduced rate of estuary infilling will result in a minimal increase the tidal range within the Tweed estuary. Since changes in tidal range are expected to have minimal impact on the extent or nature of intertidal areas (eg., major feeding areas for birds, see Section 7.5.2.2), the availability of food and roost sites in the area for waterbirds will not change.

Impacts will however be experienced during the construction and operation phase of the Bypassing System on northern portions of Letitia Spit as a result of provision of infrastructure or foreshore retreat.

Based on the current plan for the proposed works, use of land based systems would require the placement of infrastructure and perhaps removal of a considerable area of sand from the northern section of Fingal Peninsula. An uncovered pipeline would run from the system across the dunes to a section of submerged pipeline connected to a booster platform. In addition to effects associated with infrastructure provisions, the existing foreshore could retreat by as much as 90m depending upon the bypassing option selected (ie. land or water based).

The area likely to be disturbed could include a large portion of the waterbird roost at South Head beach at the northern end of Letitia Spit. This location is one of the major waterbird roosts on the Tweed Estuary, and it had the highest count for any site during the bird monitoring programme of 489 birds (Table 4.2.3). The roost is also the most important roost for migratory waders, in terms of numbers, on the estuary. The maximum count of waders at a high tide roost during the bird monitoring programme was 280 birds at South Head beach. The roost is used almost exclusively by three species of waders, bar-tailed godwit, eastern curlew and whimbrel. These three species are among the most common migratory waders present on the Tweed estuary (Table 4.2.2). The entire population of eastern curlew and bar-tailed godwit often roost at South Head beach when human disturbance is low (ie. no vehicles on beach).

South Head beach is also used at times by large numbers of terns and gulls, including the little tern which is listed as endangered under the NSW *Threatened Species Conservation Act 1995*. Up to 50 little terns have been recorded roosting at South Head beach at any one time. The roost may also be a potential breeding area for this species.

The mobile land based system could not be constructed and operated without having a significant impact on the use of the roost by waders and terns. Some of the present roost would be lost and disturbance on the beach would increase.

The infrastructure associated with the jetty mounted system will cause less disturbance than the land based mobile system because it will not involve removal of sand from the intertidal area of the beach.

Foreshore retreat, by up to 90m, is likely with most of the bypassing options being evaluated although the extent and rate of the retreat cannot be quantified at this stage.

The largest concentrations of roosting birds at South Head beach are usually close to the southern breakwater, so less disturbance will result if manageable impacts (eg. provision of infrastructure) are focussed further south of this point. The amount of disturbance and the extent/rate of foreshore retreat will depend on the bypassing option selected which has not yet been determined.

Quantification of potential impacts to shorebirds is therefore difficult at this stage although it is recognised that potential impacts are probable. However, general mitigating options can be defined recognising these will need to be refined once a bypassing option has been selected and detailed design (for construction and operation) is undertaken as part of the works tendering process. Mitigating options include:

- plan the project to undertake the more disruptive construction works during winter, specifically between late April and early August when the majority of waders have returned to Northern Hemisphere breeding grounds;
- effective management of alternative roosts in the Tweed estuary. For example, bird monitoring studies (WBM Oceanics Australia, 1996) have indicated many of the roosts used by birds present at South Head beach (eg. Kerosene Inlet, Tonys Bar, Terranora Broadwater) have lower numbers of birds than expected (ie. they have a higher carrying capacity). The most likely explanation is the high levels of disturbance that these sites experience (eg. Kerosene Inlet birds are disturbed by people fishing from land and by boat and by people walking across the inlet, sometimes with dogs, after having driven there in 4WDs whilst at Tonys Bar anglers gathering bait frequently disturb birds). It would appear that these sites would be able to regularly hold larger numbers of shorebirds, terns and gulls provided steps are taken to reduce disturbance; and
- provision of a fenced area at South Head beach during construction specifically for roosting birds. Birds at South Head beach are presently frequently disturbed by people/dogs etc and therefore the fencing would need to be sufficient to exclude dogs (and other feral/domestic animals, people and vehicles). A public education program would also be beneficial to maximise the success of this option and should include media releases, distribution of pamphlets, signposting at and near the fenced area etc. The location of the fenced area (both within the South Head beach area and in terms of proximity

to any infrastructure) would need to be assessed once a bypassing option and implementation strategy is determined. The success of this mitigating option and design attributes (eg. in terms of fence and substrate type) is discussed in further detail within Smith (1990). Adoption of this option could have long term benefits to the management of shorebirds in the Tweed estuary, particularly considering that the potential for human disturbance of bird roosts throughout the estuary is likely to increase in the future in conjunction with population growth.

The Little Tern which utilises South Head beach for roosting is listed as endangered under the *Threatened Species Conservation Act 1995*. Section 5A of the *Environment Planning and Assessment Act* sets out the factors to be considered in deciding whether there is likely to be a significant effect on threatened species, populations or ecological communities, or their habitats and hence, if a Species Impact Statement is required. Those factors within Section 5A are commonly referred to as the eight point test of significance. This test is provided below:

(a) *In the case of a threatened species, whether the life cycle of the species is likely to be disrupted such that a viable local population of the species is likely to be placed at the risk of extinction;*

This bird is a summer visitor to most Australian coasts with very few known Australian breeding localities. It is recorded from Shark Bay in the north-west of Australia, around the north and east coasts to Tasmania and the Gulf of St Vincent in South Australia. Known breeding sites are generally confined to the Gulf of Carpentaria and to eastern and south-eastern Australia (Garnett, 1993). However, over-wintering has been recorded recently in Australia, and there may well be a resident population (Garnett, 1993).

A census in 1989 indicated a population of about 5,000 birds in New South Wales, Victoria and Queensland, but continuing decline has been noted (Garnett, 1993). South Head beach is used as a roosting site (amongst several others in the Tweed River region) with birds dispersing on low tide to forage elsewhere (WBM Oceanics Australia, 1996). Smith (1990) noted that nesting was recorded in the Tweed Heads region (<10 pairs) prior to 1976 but not between 1976 to 1990. Nesting sites since 1976 have been recorded on adjacent beaches to the south (Hastings Point, Pottsville and Brunswick Heads) with most breeding occurring in central and southern NSW coastal areas.

The proposed bypassing works are therefore considered unlikely to impact on the life cycle of the species.

(b) *In the case of an endangered population, whether the life cycle of the species that constitutes the endangered population is likely to be disrupted such that the viability of the population is likely to be significantly compromised;*

As per, Part 2, Schedule 1 of the *TSC Act*, endangered populations are yet to be defined by the Scientific Committee and therefore this aspect cannot be addressed at this time.

(c) *In relation to the regional distribution of the habitat of a threatened species, population or ecological community, whether a significant area of known habitat is to be modified or removed;*

South Head beach is recognised as an important roost site for Little Terns within the Tweed region (WBM Oceanics Australia, 1996) particularly in February and March when large numbers of birds migrate along the coast. It is subject to comparatively less disturbance by humans, dogs, etc than other similar habitats used as roosts in the region.

The proposed bypassing works may impact upon all or some of the roost area by removing habitat and/or creating high levels of disturbance associated with construction works. The level of impact will depend upon the bypassing option and implementation strategy selected. There is however potential for the impact to involve a significant area of habitat.

(d) *Whether an area of known habitat is likely to become isolated from currently interconnecting or proximate areas of habitat for a threatened species, population or ecological community;*

There is some potential for land based options to bisect or isolate the current roost site .

(e) *Whether critical habitat will be affected;*

Section 37, Part 3, Division 1 of the *TSC Act*, provides for the identification and declaration of critical habitat, which are yet to be identified and consequently this point cannot be addressed.

(f) *Whether a threatened species, population or ecological community, or their habitats, are adequately represented in conservation reserves (or other similar protected areas) in the region;*

Little Tern roosts in the region are known to occur at Dreamtime beach (approximately 10 km to the south) and Tonys Bar (WBM Oceanics Australia, 1996). These are apparently utilised to a lesser degree than that at South Head beach. Roosting has also been reported at Kingscliffe, Hastings Point, and Brunswick Heads but these apparently are subject to higher levels of disturbance than South Head beach.

(g) *Whether the development or activity proposed is of a class of development or activity that is recognised as a threatening process;*

"Threatened processes" (Schedule 3 or *TSC Act*), are yet to be identified and hence, cannot be discussed further at this time.

(h) *Whether any threatened species, population or ecological community is at the limit of its known distribution.*

Little Tern has a wide distribution through Asia and Australia and is not at its limit of distribution at Tweed Heads.

Overall, the above eight point test indicates that a Species Impact Statement (SIS) may be necessary for the proposed works although this would depend on the option adopted and the associated potential (extent and rate) for retreat of South Head beach.

The need for an SIS is strengthened by:

- importance of the roost at South Head Beach to migratory waders (eg. bar-tailed godwits, eastern curlews) which are included in international agreements on protecting habitat important to migratory species (JAMBA and CAMBA); and
- other works proposed for bird roosting areas in the Lower Tweed River (eg. reduction of biting midge breeding areas by dredging of Tonys Bar which is likely to be subject to a specific EIS) and the potential for cumulative effects.

The nature of the SIS should be confirmed with the Director-General NSW NPWS once the bypassing option and potential effects are determined.

7.6 Cultural and Socio-economic Environment

The implementation of the permanent sand bypassing system will have substantial, positive impacts on the recreational and economic environments within the region. Some minor, adverse impacts are expected

with regard to the current levels of physical and visual amenity in the areas immediately adjacent to the Tweed River and the southern Gold Coast beaches. This section investigates the potential impacts of the permanent sand bypassing system upon the land use patterns, human environment and the physical and visual character of the study area.

7.6.1 Local Zoning, Landuses and Tenure

Land use patterns within the vicinity of the southern Gold Coast beaches and the Tweed River will ensure that the proposal does not have a significant impact on the existing zonings or amenity of private land holdings. The majority of the commercial and residential uses will be effectively buffered from the proposal by the existing open spaces adjacent to the waterways.

Privately owned lands and residential canal estates adjoin the Terranora Broadwater, Terranora Inlet and Cobaki Creek within the Tweed River estuary. The boundaries of these allotments will not be adjusted as they are already determined by the Mean High Tide level at the original survey and any changes to the tidal levels will be human-made. As the residential buildings are well above the high tide level and the tidal range increases in the river are minor, these buildings will not be inundated as a result of the bypassing system

The publicly owned lands within the waterways and adjacent to the beaches may be utilised for the sand bypassing system without being formally acquired. The options avoid direct interference with the wetlands and nature reserves which are included in specific environmental zones and protected under both Local and State Government legislation.

Pipeline route(s) and booster station locations are to be decided in conjunction with Gold Coast City Council and Tweed Shire Council and pipelines are likely to be buried in existing service trenches. Gold Coast City Council and Tweed Shire Council advise that all pipelines shall:

- be buried, with a minimum 600 mm cover;
- be located clear of private property;
- be located clear of existing and future services;
- at the discharge outlets be designed to minimise visual impacts; and
- require engineering drawings to be submitted for approval, for that section of pipeline located within the Gold Coast City/Tweed Shire Councils boundaries.

In addition, Gold Coast City Council and Tweed Shire Council advise that all booster stations shall:

- be located on Crown land (GCCC/TSC) or public land (TSC);
- be located underground or if above ground, be adequately sound proofed and be designed to match the amenity of the area;
- require Town Planning approval (GCCC); and
- require engineering drawings for approval.

Crown land at Letitia Spit is currently subject to an Aboriginal land claim under the responsibility of the Tweed Byron Local Aboriginal Land Council (TBLALC). Whilst the proposal may result in some readjustment of the coastline at the northern end of Letitia Spit, discussions indicate that the TBLALC are not unduly concerned about this erosion as it is likely to be comparatively minor and would only affect land on the northern end of Letitia Spit that has accreted since the construction of the breakwaters.

Native Title Implications

As stated in section 4.6.1.2 determinations are currently being sought on three (3) Native Title claims over both the lands and waterways within the study area. It is noted that native rights may co-exist with other interests over land and water (National Native Title Tribunal, Native Title - A Simple Explanation, facsimile, 1997). However, a decision to uphold local native title rights under the *Native Title Act 1993* may have implications for the acquisition of land for the construction of the permanent sand bypassing system.

Consequently, it is recommended that consultation be maintained between the relevant native title claimants during the preparation and evaluation of the sand bypassing options. In the situation where native title rights are upheld, ongoing consultation and/or negotiation with the relevant Aboriginal community/s will be necessary to facilitate implementation of the proposal.

Mining Interests

As discussed in section 4.6.1.2 a Mineral Exploration Permit had previously been issued in Queensland in the offshore areas between the Gold Coast and the southern foreshore of the Tweed River entrance. The permit was ruled invalid in 1983. Therefore there are no existing mining leases within the study area to limit the implementation of the project.

Summary

The short list of plant and equipment systems described in Chapter 5 include a range of mobile dredgers, a jetty mounted system, mobile land based systems or remote systems.

The majority of these options rely on the installation of submerged or uncovered pipelines as shown in Figure 5.2.2. Such pipelines could be installed within the bed of the Tweed River and along the coastline on Crown Lands without impacting upon privately owned lands or existing zoning patterns. However, the installation of submerged and covered pipelines is preferable to uncovered pipelines given the visual impact and public safety considerations.

The construction of major and minor sand outlets at Snapper Rocks and near Duranbah Beach, and at Kirra Point and in the lower entrance of the Tweed River will not significantly impact on existing land use patterns. The unofficial memorial plaques which exist in the vicinity of Snapper Rocks may be affected by the placement of the sand pipelines. While all attempts should be made to maintain these unofficial personal plaques, they were placed in the area without council authority and should not represent a constraint on placement of the pipelines. Management of these plaques if encountered in construction may involve relocation to a more suitable site.

Maintenance and servicing of the plant and equipment will require the use of a construction compound within the vicinity of the Tweed River entrance. It is anticipated that the permanent, fixed bypassing options will require the establishment of a substantial construction compound either near the southern entrance training wall at Letitia Spit or adjacent to Duranbah beach or Lovers Rock and the installation of an electricity line along the Fingal peninsula or under the Tweed River. Whilst the compound and electricity line will be located on Crown Land, their installation at Letitia Spit may have implications for the Aboriginal land claim currently being undertaken by the Tweed-Byron Local Aboriginal Land Council (TBLALC) and the Native Title claims.

The possible establishment of the compound near the southern entrance breakwater may necessitate the upgrading of Letitia Spit Road. It is noted that the jetty mounted bypassing option, if chosen, will attract a larger surfing and recreational fishing community to Letitia Spit and require substantial car parking facilities such as those at the Gold Coast Seaway (Turner, *pers. comm.).* The jetty mounted option will also require the installation of a pipeline from the jetty to Tweed River and have further

implications for the TBLALC's land claim.

Nourishment of the beach profile will require beach closures and public access restrictions on the southern Gold Coast beaches. The use of bull-dozers, front end loaders and/or spreader barges, associated with some of the bypassing options, will further restrict public beach access along the beach face and in the nearshore area.

The main findings with regard to zoning, land uses and tenure can be summarised as follows:

- no significant impact upon private land holdings or zonings;
- no changes to private property boundaries;
- no need to formally acquire lands; and
- an Aboriginal Land Claim and Native Title Claims have been lodged.

The proposal will not have a significant impact upon the existing land uses and tenure patterns within the study area. The permanent bypassing system may be installed without substantial disturbance to either public or private land holdings.

7.6.2 Aboriginal and Post-Contact Heritage

Sand Extraction

For the trailing suction hopper dredger, jackup dredge, cutter suction dredge and two remote systems sand extraction will occur at the Tweed River entrance. The mouth of the Tweed River, being a series of underwater sand deposits is considered to have the potential to contain shipwreck sites. Given that there are no known historical wrecks in this area and that there is no clear evidence of historical wrecks occurring, there is no archaeological reason why dredging should not proceed.

In the event that dredging does uncover remains of a shipwreck, these remains would be considered to have a high archaeological significance and require further assessment. On land, a management programme would be recommended in similar circumstances. In this instance, remote sensing techniques during the dredging process should be considered, however, such techniques are expensive, will not definitely locate shipwrecks and are limited in their ability to reliably locate deeply buried sites or substantially non-magnetic sites. Remote sensing techniques are most useful for any sand bypassing system implemented to further interrogate areas already identified as potential shipwrecks, namely the area identified as Zone 24 and associated anomalies (Seascan letter 5/01/95). It is recommended that further remote sensing occur in this area for all sand extraction options only if disturbance due to the system is likely in order to attempt to define the nature of the target and outline options of management if further investigations identify these areas as containing a shipwreck.

The sand retrieval area for the jetty mounted system will have no effect on any known shipwrecks. There is a possibility that unknown shipwreck material could be located in this area. Considering that for the jetty mounted system the sand retrieval area is fixed, it is recommended that a programme of remote sensing be undertaken to locate any evidence of wreck material.

The mobile land based option will retrieve sand by excavating from the area immediately to the south of the southern breakwater. This area is comprised of sand which has accumulated since the breakwater was constructed in the 1960s and therefore should not contain any Aboriginal archaeological sites. A recently wrecked trawler was found and inspected in this area however it is not of historical significance. It is recommended that remote sensing (magnetometer) be carried out in the area to locate evidence of other possible shipwreck material. If evidence is located then it is recommended that this be explored by

probing. Depending on the results of the remote sensing and probing it is recommended that limited test excavation occur to determine what exactly has been located. Cultural significance must be assessed according to the ICOMOS (Aust.) *Charter for the Conservation of Places of Cultural Significance* (the Burra Charter) as adapted in Draft Manual for the use of Historic Themes and Evaluation Criteria issued by the Heritage Council and the Department of Planning (NSW). The test excavation programme will require a permit under Section 140 of the *Heritage Act 1977*.

Following the results of the test excavation, several options will remain. If nothing of significance is located sand retrieval can proceed. If a significant site is located then management options will be developed taking into account the sites cultural significance. Management procedures range from avoidance to salvage archaeological excavation and recording.

Sand Transport

Sand transport associated with the jackup dredge, cutter suction dredge and remote system options require sand to be pumped to shore and then through an onshore distribution system. The pipeline may run from the northern breakwater or via Jack Evans Boatharbour to distribution points as outlined in Figure 5.2.2.

The degree of disturbance along the proposed route has not been assessed. However based on the archaeological potential assessment, the potential route of the pipeline around the northern edge of Jack Evans Boatharbour will traverse an area which has the potential to contain Aboriginal sites, notably shell middens. The degree of ground disturbance has not been assessed and therefore the conditions of site preservation are unclear.

An archaeological survey is recommended along the pipeline route to determine whether there are any visible signs of Aboriginal sites and to evaluate the level of disturbance along the route. This is described further in Section 8.3.9.

Sand retrieval associated with a mobile landbased system option would require sand to be pumped into the distribution system. The first stage of this system would be located on Letitia Spit. As outlined earlier, it is unlikely that any significant Aboriginal sites are located on Letitia Spit. In addition, a recently wrecked trawler has been inspected in this area and was found not to be of historical significance. It is recommended that remote sensing (magnetometer) occur in this area to locate evidence of other possible shipwreck material as outlined for sand transport associated with the jetty mounted system.

Sand Deposition

For all options sand will be deposited in the nourishment compartments along the southern Gold Coast beaches. The sand deposition will have no negative impact on Aboriginal or post-contact archaeology. Indeed the build up of sand will reduce potential damage to sites by erosion and for shipwreck sites the addition of sand will improve the anaerobic conditions which aids their preservation.

7.6.3 Socio-economic Profile

The socio-economic profile in Section 4.6 highlighted the temporary and transient nature of the local community, particularly within the Coolangatta area. This transient population and the permanent, residential community are likely to experience substantial recreational and economic benefits as a result of the permanent sand bypassing system. Direct, adverse impacts from the proposal will be limited by the buildings' setback from beaches and the waterways and the transient nature of a large proportion of the population.

The direct negative impacts of the proposal may include an increase in noise levels emitted from plant and machinery and increased traffic along Letitia Spit if the fixed jetty mounted system is realised

(Section 7.6.7). Public beach access on the southern Gold Coast beaches may also be limited during construction and periods of beach nourishment for public safety reasons. These adverse impacts are likely to be off-set by significant improvement in recreational opportunities offered by the beach nourishment and the improved navigation conditions at the Tweed bar.

There is not expected to be any significant direct employment benefits as a result of the construction and implementation of the permanent sand bypassing system. However, indirect impacts of the proposal will include greater employment opportunities owing to the continuing development of local industry.

It is expected that the sustained revenues from tourist expenditure will continue to support local businesses and services.

The proposal is not anticipated to have any significant impact upon the study area's demographic profile (ie. age structure, population growth, income). The characteristics of the various socio-economic groups and employment sectors will remain relatively constant.

7.6.4 Business, Recreation and Tourism

In 1991, ACIL (1991) estimated that implementation of the permanent sand bypassing system and the lower estuary improvements would result in $115 million worth of benefits, representing $63 million benefits for New South Wales and $52 million for Queensland.

Business

New South Wales' potential benefits include safer navigation and improved water quality leading to:

- improved viability of the Tweed fishing industry;
- increases in ocean going yachts and recreational boating within the Tweed estuary;
- increase in tourism revenues from the improved amenity of the Tweed waterways; and
- flow-on effects to local commercial and retail businesses.

Queenslands' potential benefits include increased protection against storm erosion on the beaches and improved recreational amenity on the southern Gold Coast beaches leading to:

- consistent surf conditions and maintenance of the famous point breaks;
- further development of the tourist industry;
- flow-on effects to local commercial and retail businesses; and
- avoidance of further beach nourishment costs.

Improvements to the existing navigation conditions and recreational amenity following the establishment of the permanent sand bypassing system will greatly improve the opportunities for the fishing and tourism industries. It is expected that these improvements will have substantial long term flow-on effects to enhance the local commercial and retail economy.

It is expected that the proposal will support the continued viability and vitality of the local businesses, particularly those involved in:

- Surf boards, surf clothing and accessories;

- Tourist and holiday accommodation;
- Land development and investment;
- Retail and personal services;
- Cafes, restaurants and nightclubs;
- Public and private transport;
- Sporting and entertainment venues;
- Commercial and recreational fishing;
- Seafood sales and export; and
- Diving charters and boat hire.

While these direct flow-on effects have not been estimated, the annual tourist expenditure of $432.75 million represents a huge injection into these businesses (Queensland Tourist and Travel Corporation Resource Centre, 1996). It is recognised that a critical factor in the development of these businesses is the picturesque natural environment and the tourists that it attracts. The maintenance of the southern Gold Coast beaches is therefore essential in ensuring the ongoing success of such retail and commercial enterprises.

Implementation of the proposal will boost the commercial fishing industry in Tweed Heads by improving navigation within the Tweed River and allowing commercial fishing boats and trawlers to cross the bar more safely. It is expected that the trawlers and the trap and line fishing operators will be less constrained by the bar conditions and will be able to operate more frequently resulting in:

- improved fish and seafood catches;
- greater personal safety for fishing operators;
- reduced risk and maintenance of boats and equipment;
- sustained local employment opportunities;
- greater revenues and capital availability for operators; and
- further investment and development within the local fishing industry.

Existing oyster farming operations will benefit marginally due to improved water quality since slight tidal increases are predicted within the Terranora Broadwater. The proposed urban development threatens to increase pollution levels within the Broadwater. Consequently, the proposal will aid in ensuring acceptable water quality levels and therefore promote the continuation of local oyster farming enterprises.

Improvements in the local fishing industry will also support the activities of the local seafood wholesalers and retailers stated in section 4.5.2.5. Improved production catches will allow these retailers to continue exporting fish and other seafoods to supply the major cities along Australia's eastern coast.

Installation of the permanent bypassing system may result in construction works at the mouth of the Tweed River and some temporary disturbance to navigation conditions. However, it is expected that this short term interference will be offset by the potential long term financial gains accruing to the commercial fishing industry.

Recreation

Existing recreational opportunities will be enhanced by improving navigation conditions at the Tweed bar

and by maintaining the sand supply on the southern Gold Coast beaches. It is anticipated that the existing recreational activities, as stated in section 4.6.1.1, will continue largely unaffected and that surfing, recreational fishing and diving conditions will improve.

Beach Recreation

The proposal is expected to result in some changes to surfing conditions at the internationally famous Kirra, Greenmount and the other southern Gold Coast beaches.

As discussed in Section 4.6.6.3, the beaches in the study area offer a wide range of conditions and relative protection for general beach users. The effects of the permanent sand bypassing system on the relative beach hazards and the operations of local surf life saving clubs would relate mainly to the enhanced supply of sand available to the beaches. Re-establishing the full sand bypassing quantities to Snapper Rocks on a more continuous basis will provide an effective feed to the nearshore shoal system which forms offshore of Rainbow Bay and Greenmount and will tend to smooth out the fluctuations in its characteristics. This would provide the following benefits:

- the bathing conditions at Rainbow Bay and Greenmount beaches would be generally safer due to the more persistent protection from the nearshore shoals;
- the potential for conflict between boardriders and general beach users at Rainbow Bay and Greenmount is reduced as the shoals tend to separate the two activities; and
- the beach hazard characteristics of Coolangatta beach may become more predictable and hence more manageable for surf lifesaving operations;

The operation of a permanent sand bypassing system which involves regular nearshore nourishment campaigns using a trailer hopper dredger would partially reduce these benefits. This type of scheme would tend to deposit sand in large discrete 'lumps' and over a much larger region than a pipeline delivery system. This would result in more variability in the characteristics of the beach system including the volume and extent of the nearshore shoal system.

The existing hazards at the Kirra Point and Miles Street groynes caused by the permanent rip currents (discussed in 4.6.6.3) would still remain following the installation of the bypassing system. However the more persistent presence of sandy beaches directly west of these groynes would lessen the hazards caused by rocks and seawalls for swimmers who are carried there unintentionally.

It is recognised that the initial installation of the permanent bypassing system, including pipelines and equipment, may cause short term disturbance to the beaches and local bathing and surfing conditions. In addition, the temporary closure of beaches during nourishment programmes will limit access and use of the beaches for short periods of time. Closure of beaches should be avoided during holiday and summer periods to minimise loss of beach amenity for tourism and the local community in general. Some of the options may have long term impacts upon the nearshore zones adjacent to Letitia Spit, Duranbah Beach, Point Danger, Kirra Point and Kirra Beach resulting from the potential installation of pipes, booster stations and outlets. However, it is expected that these minor, adverse impacts are justified by the potential, positive impacts on beach use and the local community.

Diving, Boating and Recreational Fishing

Recreational fishing and boating activities are expected to gain from the improved navigation conditions at the Tweed bar and the maintenance of the Tweed River's lower estuary. Such improvements will encourage greater recreational opportunities and revenues for the diving and charter boat companies mentioned in Section 4.6.8.

The potential installation of the jetty-mounted bypassing system at Letitia Spit is likely to raise considerable interest in its use for recreational fishing (eg. Gold Coast Seaway). It is recognised that

public access to the jetty, if allowed, will result in greater use of the area and require the installation of car parking, lighting and other facilities at Letitia Spit.

Anecdotal evidence suggests that recreational fishing has been improved at the sand discharge points associated with the Gold Coast Seaway (Pooningbah Aboriginal Corporation, *pers. comm.*, 1997). Therefore there is the potential that a similar improvement may occur at the sand discharge points associated with the sand bypassing system chosen.

Overall, the proposal promises to deliver improved recreational opportunities for both tourists and permanent residents. Activities associated with the initial installation of the bypassing system and the regular nourishment of the southern Gold Coast beach profiles are, however, likely to limit beach access for certain periods. It is believed that these minor inconveniences are justified by the potential increase in recreational opportunities offered by the proposal.

Tourism

The proposal's implementation will assist in securing the substantial $432.75 million annual revenues from tourism expenditure in the Gold Coast area. Nourishment of Rainbow Bay and the Duranbah, Greenmount, Coolangatta and Kirra beaches will ensure consistent sand supplies and promote the popular "surf, sand and sun" tourist image of the Gold Coast. The improved recreational amenity of the Tweed River may also attract further visitors to the Tweed Heads area. Substantial flow-on effects are expected to the tourist industry, such as:

- promoting the beach as a substantial tourist attraction;
- retaining the $432.75 million annual tourist revenues;
- supporting further development of the tourist industry; and
- generating local employment.

The temporary disturbances created by the installation of the bypassing system and beach nourishment activities are not expected to significantly disturb the existing tourist industry. The long term benefits accruing to tourist-related businesses, as stated above, are likely to far outweigh the short term impacts.

Surfing Sites

The permanent sand bypassing options are consistent with the surfing community's preference to have the primary sand outlet near the Point Danger/Snapper Rocks area so that sand can move northwards via the natural littoral drift (Turner and Lee, *pers. comm.*).

Enhancement to the high quality surfing conditions will continue to attract surfers and result in substantial flow-on effects which are likely to assist in:

- supporting the surfing-related businesses valued at $160 million;
- creating local employment opportunities in surfing-related businesses;
- encouraging further investment in surfing-related businesses;
- maintaining a valuable tourist attraction; and
- maintaining an enjoyable and popular recreational activity.

Impacts on surfing conditions in particular beach locations are described below.

Letitia Spit

As noted in Section 4.6.6.4, Letitia Spit does not have good quality surf because breaking waves have very acute peel angles along the beach bar. A permanent bypass system will not alter this condition, except near the Tweed entrance.

Section 7.2.3.1 notes that there may be some localised retreat of the northern extremity of Letitia Spit, to a new equilibrium shape, depending upon the nature of the actual bypass system. Any variation in beach shape is likely to increase the peel angle of the local waves, thereby improving the ability to ride those waves.

Tweed Entrance Bar

The Stage 1 A dredging has altered the surf sites seaward of the entrance (Walker, Technical Appendix III). Process modelling (Technical Appendix II) indicates that sand presently in the northern lobe of the entrance bar would move both onshore and northwards, under the influence of a bypassing system. Hence the right bar surf site referred to by Walker, would disappear.

Walker indicates that refraction pattern changes due to deepening and widening of the bar (ie. sand traps) could create an enhanced channel surf site, on the southern edge of the deepened area. Depending upon whether fixed structures would be involved or not, the left bar surf site would continue to provide rideable waves for experienced surfboard riders.

Duranbah

The convex entrance bar shape and size have been reduced by the Stage 1A dredging to the extent that surfing characteristics have altered at Duranbah for east and southeast waves. Walker (Technical Appendix III) and process modelling (Technical Appendix II) indicate that that the A-frame effect has been diminished, ie. the tendency for crossing wave patterns and wave height amplification has been reduced.

Section 7.2.3.2 concludes that in the long term, under the influence of a permanent bypassing system, the offshore profile at Duranbah will tend to be depleted and the beach will tend to realign to become more normal to the prevailing waves. The extent of change will depend upon the trapping efficiency of the bypass scheme. A leaky scheme could allow significant quantities of sand to feed the Duranbah shoals. This would lessen the overall impact on Duranbah and its surfing conditions. As a worse case scenario, in which very little sand reaches Duranbah, Walker indicates that such re-alignment could cause Duranbah surfing conditions to deteriorate and become similar to those at Letitia Spit.

Walker examined the possible use of the annual Duranbah discharge to enhance surf conditions of Duranbah. It was considered that it would be feasible to use the discharge to create a temporary nearshore mound of sand of sufficient size and shape that would cause waves to shoal into left and right breaks with a peel angle conducive to good surfing conditions. Details are provided in Technical Appendix II.

The long term surf quality at Duranbah will depend to a large degree on how the Tweed entrance bar is managed and the strategy adopted for the Duranbah discharge. It is considered that a Duranbah Surf Quality Management Plan is required and this is discussed in Chapter 8.

Snapper Rocks to Kirra

Good surf conditions require a beach bar to cause wave shoaling (height amplification) and oblique wave approach so that a long, smooth peel is formed (Walker, Technical Appendix III). However, waves approaching at an angle to the beach bar create a high rate of longshore transport. Therefore a consistent and high rate of supply of updrift beach sand is required to maintain the beach bar and the good surfing conditions that depend on it.

The Stage 1A nourishment programme demonstrated that surfing sites between Snapper Rocks and Kirra can be preserved and perhaps enhanced with careful beach bar management. 85% of the 290,000 m^3 of sand placed as subaerial nourishment on the beaches was reworked by storms to form nearshore bars and surfers reported excellent surfing conditions during times of swell.

Walker (Technical Appendix III) concludes that the steady placement of sand in the nearshore zone south of Snapper Rocks, on a reasonably continuous basis, as opposed to large instantaneous depositions, would be the most beneficial practice for maintaining a longshore beach bar from Snapper Rocks to Kirra Point. This would make the area's surf sites and beaches have higher quality surfing conditions more of the time.

7.6.5 Visual Amenity

The permanent sand bypassing system options have been assessed based on relevant criteria needed to distinguish the visual qualities and impact of each system in terms of the visual sensitivity at the site, and the nature of view catchments throughout the study area.

Table 7.6.1 and 7.6.2 identify the criteria and allocate a value to each plant and systems option. The options are coded 0 to 10 in terms of increasing visual impact. The criteria are all of equal weights. The highest total visual impact rating is 80 and the lowest total impact rating is 0.

7.6.5.1 Sand Retrieval

Trailing Suction Hopper Dredger

The dredger would be active in the nearshore zone primarily between Letitia Spit and Duranbah beach, extending into the Tweed River entrance between the training walls.

The extent of view catchment is limited to the Letitia Spit, Duranbah beach, Point Danger headland and adjacent ridge parks, and will vary as determined by the operational location of the dredger. The key view receptors would include Duranbah and Letitia Spit beach users, visitors to Point Danger headland, residents of high-rise apartment buildings adjacent to the Jack Evans Boatharbour, and users of park land adjacent to the northern training wall.

As a mobile unit with varying and intermediate patterns of use the period of visual impact from any given view point will vary. The visual sensitivity of the view catchments ranges from moderate to high with the highest visual sensitivity being the vista from Point Danger Headland and the lowest being from the river bank park land immediately south of Jack Evans Boatharbour. In terms of scale the dredger is comparatively larger than sea-going vessels which utilise the river, however its form is related to the recreational imagery and context of the site.

The visual form is predominantly that of a marine vessel and is the most readily expected and accepted of human forms within the ocean site. The Trailing Suction Hopper Dredger has the lowest visual impact of all the options.

Jack Up Dredger

The Jack Up Dredger would be active primarily within the vicinity of Letitia Spit and Duranbah Beach. Its view catchment would extend from Letitia Spit to Duranbah Beach and Point Danger Headland.

The view receptors would include the beach users and visitors to the Point Danger Headland, Jack Evans Boatharbour and adjoining ridge park lands to the south and north. The view catchment from these

locations is one of high visual sensitivity due to its naturalism, range of view and level of passive recreational use.

In terms of scale and form the Jack Up Dredger has a high visual impact due to its size and the predominantly industrial nature of its form when operating. In these terms it is in conflict with the recreational context of the site and is unrelated to the expectations of views to the area (Figure 7.6.1).

The visual impact of the agitation dredger would be similar to the impacts described for the Jack-up Dredger option above.

Table 7.6.1 Visual Impact of Sand Retrieval Options

	SAND RETRIEVAL						
ASSESSMENT CRITERIA	**Trailing suction hopper**	**Jackup dredge**	**Jetty mounted**	**Mobile land based in upper beach profile**	**Dredger in upper beach profile**	**Remote system of sand fluidising & slurry transportation**	**Remote System of Directional drilling, sand fluidising and slurry transportation**
Visibility from major vista points	10	10	10	9	8	7	7
Impact on naturalism of views	5	10	10	10	8	7	7
Relative scale of structure	5	9	9	9	8	6	6
Context to recreational setting	3	9	9	10	9	8	8
Visual appearance and outputs during operation	6	9	8	9	8	6	6
Perceived impact on residents expectations of views	3	8	7	7	6	5	5
Perceived impact on tourist expectations of views	5	9	8	9	8	7	7
Period of visual impact	5	7	10	8	8	10	10
TOTAL (OUT OF 80)	**42**	**71**	**71**	**71**	**63**	**56**	**56**

Table 7.6.2 Visual Impacts of Sand Transport and Placement Options

	SAND TRANSPORT AND PLACEMENT OPTIONS							
ASSESSMENT CRITERIA	**Buried pipeline and booster stations**	**Pumping to beach combined with dozer machinery**	**Spraying to beach combined with dozer machinery**	**Jetty mounted discharge**	**Dumping in water from hopper**	**Major outlet subaqueous**	**Minor outlets exposed**	**Minor outlets submerged**
Visibility from major vista points	5	9	10	10	10	0	5	0
Impact on naturalism of views	5	10	10	10	5	0	5	0
Relative scale of structure	3	8	8	9	9	0	3	0
Context to recreational setting	5	9	9	9	3	0	3	0
Visual appearance and outputs during operation	3	10	10	8	6	2	8	1
Perceived impact on residents expectations of views	5	8	9	8	1	0	4	0
Perceived impact on tourist expectations of views	5	10	10	9	2	0	8	0
Period of visual impact	10	6	6	10	5	0	10	0
TOTAL (OUT OF 80)	**41**	**70**	**72**	**73**	**36**	**2**	**44**	**1**

Jetty Mounted System

There is some flexibility as to the location of the Jetty Mounted System although it is anticipated to be within proximity to the southern breakwater at the Tweed Entrance and thus its view catchment would extend from Letitia Spit to Duranbah Beach, the Point Danger Headland lookout and adjoining ridge park lands to the south.

The view receptors would include beachgoers, and visitors to the Point Danger Headland and high-rise residents adjacent to the Tweed River lower entrance. The view catchment from these locations is one of high visual sensitivity due to its relative naturalism, range of view and level of passive recreational use which is focused primarily on experiencing the view of the ocean and headland interface and the form of Letitia Spit Beach extending down to Fingal. It is noted that this view also includes the Tweed River training walls which tend to dominate the foreground (Figures 7.6.2 and 7.6.3).

In terms of scale the Jetty Mounted System would have high visual impact due to the size of the structure (up to 500 metres in length) and the industrial character of its associated discharge pipeline and appurtenances. A jetty form can relate to water/shoreline landscapes in wharf/port activity areas and in still water zones, however within the open headland and surf beach environs the jetty structure is viewed to be in conflict with the context of the site. Visual impact may be reduced by painting the structure with colours that will blend into the surrounding marine environment and by providing human scale / recreational use elements in the structure form eg. timber boardwalk to top of structure, however it will continue to have a high visual impact.

It should be noted that associated built infrastructure would also have high visual impact within the landform of Letitia Spit, which is valued for its naturalism, flatness and undeveloped expanse of coastal vegetation. The visual impact of the infrastructure may be reduced to some extent by the use of colour and architectural treatment.

Mobile Land Based Systems

This system, based on the use of conventional land based plant such as crawl cranes and excavators, would be active within the accretion fillet zone located behind the southern entrance Breakwater wall.

The view catchment of this area extends from Letitia Spit to the Point Danger Headland. This is a catchment of high visual sensitivity particularly within Letitia Spit, which is valued for its undeveloped flat landform and coastal vegetation.

View receptors would include beachgoers, visitors to the Point Danger Headland, and residents of the high-rise towers adjacent to the Tweed River entrance.

The visual impact of the operational site is diminished to some extent from low elevation viewpoints by the Letitia Spit vegetation and the southern Breakwater wall, however the form and scale of the operating plant is in conflict with the context of the site and it is unrelated to the expectations of viewers to the area, and as such this option is viewed to have a high visual impact.

Visual impact of the land based plant equipment may be reduced through the use of mitigative measures such as colour painting equipment to blend into the surrounding beach spit environment .

Dredger In Upper Beach Profile

This system would be active within the accretion fillet zone located behind the southern training wall.

The view catchment of this area extends from Letitia Spit to the Point Danger Headland, with view

receptors and sensitivity being the same as for the previous mobile land based system.

Work would be carried out by a cutter-suction dredger. The scale and form of the dredger is relative to the context of the site however the work environment it creates is extractive in its nature and requires the use of other land based industrial machinery plant. This option has a high visual impact. Visual impact mitigative measures would be the same as for the Mobile Land Based System in the Upper Beach Profile.

Remote System of Sand Fluidising and Slurry Transportation

The location of the systems components and associated transfer station is likely to occur near to and on the head of the southern entrance breakwater.

The view catchment of this area extends from Letitia Spit to the Point Danger Headland, with key view receptors being beach users and visitors to the Point Danger Headland. This is a catchment of high visual sensitivity, particularly at Letitia Spit, which is valued for its natural, flat, vegetated landscape, uninterrupted by built forms.

The visible components of the 'sand shifter' system are predominantly industrial in form with jet pumps partly submerged at the northern side of the southern Breakwater wall, feeding pipe work to the Transfer Station. Housing the Transfer Station infrastructure would require a built form approximately 3 to 4 metres high by 3 metres by 3 metres. The sand shifter components would be in conflict within the Letitia Spit catchment and would have moderate to high visual impact.

The basic units of this technology may be attached to piles in the nearshore zone. These units would be predominantly industrial in form and would have moderate to high visual impact.

Mitigative treatment such as an alternative location of the Transfer Station closer to the natural vegetation may be possible and would enable some screening measures to be engaged. Also the use of colour and architectural treatment to the structure may reduce the visual impact to some extent, however the structure would continue to have moderate visual impact within the site.

Remote System of Directional Drilling, Sand Fluidising and Slurry Transportation

The location of this system, the view catchment, view receptors, visual sensitivity of the site and form and scale of the system components are similar to those of the previous remote system.

For this system the Transfer Station may also be able to be located closer to the spit vegetation thus enabling some screening measures to be engaged. Also the use of colour and architectural treatment to the structure may reduce the visual impact to some extent, however the structure would continue to have a moderate visual impact within the site.

7.6.5.2 Sand Transport and Placement

Trailing Suction Hopper Dredger

The Trailing Suction Hopper dredger would be active in the inner and outer shore zone, primarily from Duranbah Beach, extending to the northern end of Kirra Beach as required.

Its view catchment would extend from Letitia Spit to Duranbah Beach, Point Danger Headland, Snapper Rocks, Rainbow Bay, Greenmount, Coolangatta Beach, Kirra and North Kirra Beach, and associated esplanade road systems adjacent to these zones. The extent of view catchment will vary determined by the operational location of the dredger, and the elevation of the viewpoint. Views from beaches and low



Figure 7.6.1:
Schematised View of Jack-Up Dredger Looking South from Point Danger



Figure 7.6.2:
Schematised View of Trestle Mounted System Looking South from Point Danger
Source: Kinhill Engineers (1997)



Figure 7.6.3:
Schematised View of Trestle Mounted System Looking Northeast along Letitia Spit
Source: Kinhill Engineers (1997)

points of headlands will have catchments contained by adjoining landforms. Views from Snapper Rocks, Greenmount, Point Danger Headland and ridge park lands will have a large view catchment. As a mobile unit with varying and intermediate periods of use, the period of visual impact from any one view point will vary and thus the potential of visual impact is reduced.

The key view receptors would include beachgoers, visitors to the headlands and ridge parks, and some high-rise apartment residences adjacent to beach esplanades and the Tweed River lower entrance. Visual sensitivity of the view catchments range from low to high with the highest visual sensitivity being the vista from Point Danger Headland and the lowest being those beach environs with the most excessive urban development fringe, eg. Coolangatta, Kirra.

In terms of scale the dredger is comparatively larger than sea-going vessels which utilise the entrance, however its form is related to the recreational imagery and context of the site. The visual form is predominantly that of a marine vessel and is the most readily expected and accepted of man-made forms within the ocean site. During the dumping process sand is released from the hopper subaqueously and therefore minimal visual impact occurs. The Trailing Suction Hopper Dredger has the lowest visual impact of all the options.

Pumping To Beach Combined With Dozer Machinery

Beach nourishment operations may be carried out on Duranbah Beach, Snapper Rocks Beach, Rainbow Bay, Greenmount Beach and Kirra Beach.

Within the beach zones north of Point Danger, views from low areas are contained within the headlands and areas that frame each beach. As an elevated site, Greenmount Hill offers views of the beach environs, as well as the backdrop of urban infrastructure. The key view receptors of these areas would be beachgoers, residents and visitors of high-rise apartment buildings and to some extent users of the esplanade road adjacent to the sites. The view catchment within these areas are of low to moderate/low visual sensitivity due to the close proximity and visual accessibility of the adjacent urban infrastructure.

This beach nourishment process requires the use of heavy earthworks machinery combined with temporary pipe outlets spraying sand slurry onto the beach. In terms of scale and form this process would have high visual impact while in operation. The process would however be carried out with intermediate patterns of use therefore the period of visual impact would be temporary rather than permanent. Visual impact may be reduced by designing discharge outlets and booster stations to match the amenity of the area. This option would have moderate to high visual impact.

The option in operation at Duranbah Beach would have a higher visual impact due to the high sensitivity of the view catchment as viewed from Point Danger Lookout and adjoining ridge park land.

Bow-casting to Nearshore

The view catchment, sensitivity and view receptors of this system are similar to those of the Pumping To Beach Combined With Dozer Machinery.

In terms of scale and form, the visual impact of this system is slightly higher than the previous system, due to the need to cast/pump sand slurry from the bow of the dredge into nearshore areas, operating within several hundred metres of the shore. This system creates high visual impact whilst in operation, however being a system with intermediate patterns of use, the period of visual impact would be of a temporary nature rather than permanent.

Jetty Mounted Discharge Outlet

There is some flexibility as to the location of the Jetty Mounted Discharge Outlet, although it is anticipated to be located near Snapper Rocks in the vicinity of Frog's Beach.

The view catchment would be limited to the local Snapper Rocks area with elevated views directly down onto it from the extreme eastern boundaries of Point Danger Lookout and associated ridge park lands. The view receptors would include Duranbah and Snapper Rocks Beach beachgoers, and visitors to the Point Danger Headland.

The view catchment from Point Danger Headland is one of high visual sensitivity and is valued for its naturalism, range of views and level of passive recreational use which is focused primarily on experiencing the view of the ocean/headland interface.

In terms of scale and form the Jetty Mounted Outlet would have high visual impact due to its size (up to 250 metres) and industrial character. A jetty form can relate to water/shoreline landscapes in wharf/port activity areas and in still water zones however within the open headland and surf beach environs the jetty structure is viewed to be in conflict with the context of the site.

Visual impact may be reduced by painting the structure with colours that will blend into the surrounding marine environment and by providing Human Scale / Recreational Use elements in the structure form eg. timber boardwalk to top of structure, however the option will continue to have a high visual impact.

Major Outlet Subaqueous

This system would occur in the same location as the Jetty Mounted Discharge system near Snapper Rocks in the vicinity of Frog's Beach.

The discharge system would be located on/under the seabed up to 250 metres out to sea and would provide no visual impact when not in operation. Water discolour may be evident during operation due to sand movement in the water however this is viewed as consistent with the visual environs of the headland, emulating the existing naturally-occurring littoral sand drift that can be observed.

When not in operation this form of sand discharge would have very low visual impact.

Buried Pipeline and Booster Stations

As a buried element the pipeline will provide no visual impact once installed. Associated infrastructure in the form of Booster Stations will have a predominantly built form. Booster stations may be located at Kirra Point near Kirra groyne, at a halfway point on Boundary street or in park land adjacent to Duranbah beach. The operations building will also have a predominantly built form and may be located either on the northern end of Letitia Spit, adjacent to Duranbah beach or Lovers Rock.

The view catchments within these areas are contained within the immediate site and there is opportunity for effective architectural treatment of housing and screening of the unit with landscaping to minimise the visual impact. The location of these units within the vicinity of other built forms and manipulated landscapes further reduces the extent of visual impact.

The buried pipeline and booster stations have a low visual impact. The system must be considered in conjunction with its associated methods of sand retrieval.

Minor Outlets

Minor sand outlets would be located on or near existing groyne and walls . These would occur in the vicinity of Miles Street groyne, Kirra Point and Duranbah Beach.

The view catchment for the groyne and breakwater related outlets are generally contained within the immediate site, where beachgoers would be the key view receptors. The view from these areas has low to moderate visual sensitivity due to surrounding urban infrastructure.

The minor outlets may be provided in three (3) forms: Exposed (on top of groyne), Buried (within groyne but with outlet above surface) or Subaqueous, (pipe and outlet under water).

Exposed minor outlets are of a predominantly industrial form. These elements have a high visual impact (Figures 7.6.4, 7.6.5 and 7.6.6). The visual impact of the pipes may be reduced by painting them in colours which blend into the rock groyne structure on which they are placed, however this option will continue to have a high visual impact.

Buried minor outlets provide minimal visual impact when not in operation. The outlet head treatment is of Man Made/Natural form, moulded to the groin rock material. During operation the outlet would provide moderate visual impact as sand slurry discharges from the outlet into the water.

Subaqueous minor outlets are located on the sea bed and provide no visual impact when not in operation. Water discolour may be evident during operation due to sand movement in the water however this is viewed as relevant to the visual environs of the surf beach zone.

7.6.6 Navigation

Navigation will be significantly improved by the implementation of a permanent sand bypassing system, since a permanent system will maintain a deeper and more stable navigable entrance in most weather conditions.

Improvement in navigational conditions will lead to improved safety for vessels traversing the entrance bar, resulting in fewer rescues and fatalities as a result of channel conditions. However, it is possible that the number of inexperienced sailors attempting to navigate the bar may increase therefore the number of vessels requiring assistance may not alter significantly.

Wave propagation processes affecting navigation at the river entrance involve:

- wave shoaling as the waves enter shallower water;
- wave refraction across the entrance bar shoals;
- wave refraction resulting from wave/current interaction associated particularly with the ebb tide discharge from the river; and
- wave/current interaction causing changes in wave steepness, particularly during the peak ebb tide discharge from the river.

Wave propagation modelling undertaken for this study as described in Technical Appendix II indicates:

- wave focusing may occur in the entrance channel or at the southern training wall in instances where natural bar development or channel dredging results in a relatively shallow southern bar lobe protruding seawards more or less in line with the southern training wall; and

- wave propagation through the entrance channel area is considerably more uniform and predictable if the nearshore bar bathymetry is more or less uniform over a wide area.

As well, hydraulic modelling shows that the ebb discharge current speed is reduced significantly over a deeper entrance bar area. Wave shoaling and wave/current interactions will be reduced if the bar area is maintained at a deeper level.

To date, the combination of complex nearshore entrance bar bathymetry and strong ebb tide current speeds has caused complex and unpredictable wave conditions in the navigation channel. Spatially non-uniform wave refraction may cause adverse wave/wave interactions, while shallow entrance bar depths cause the high ebb discharge velocities to extend across the bar area.

These processes have caused hazardous navigational conditions for many years. The recent Stage 1A dredging of the bar area has deepened the channel and probably reduced tidal current speeds in the dredged areas, but reports indicate the wave conditions remain unfavourable, at least for some classes of vessel.

Recreational boat movement data from October 1993 to August 1995, including number of small, cruiser, charter and dive craft utilising the Tweed entrance, were obtained from NSW Fisheries. Analysis of the total boat movement data indicates that there has been an increasing trend of movement across the river entrance during the period (Figure 7.6.7).

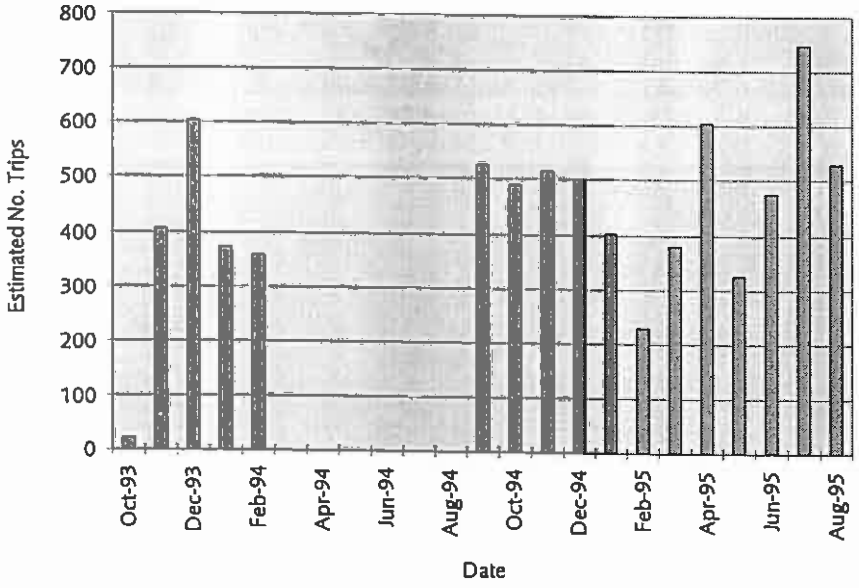


Figure 7.6.7 Total Recreational Boat Movements at Tweed Heads October 1993 - August 1995

(Source: NSW Fisheries)

The above graph indicates a general trend of increasing boat movement from pre- to post-Stage 1A dredging. While the data suggests such a trend, it should be noted that many factors aside from the condition of the channel may govern the number of boats which utilise the Tweed River entrance eg., weather and season variation.

Channel dredging can be expected to enable significantly larger vessels to utilise the entrance than prior to dredging. In October, 1995 *HMAS Tarakan* with a draft of approximately 2.2m safely navigated the channel. This vessel is the first vessel of its size to enter and anchor in the river and was



Figure 7.6.4:
Schematised View of Outlet Structure near Frogs Beach



Figure 7.6.5:
Schematised View of Outlet Structure at Snapper Rocks looking North from Point Danger
Source: Kinhill Engineers (1997)



Figure 7.6.6:
Schematised View of Outlet Structure at Snapper Rocks
Source: Kinhill Engineers (1997)

able to do so as a result of the Stage 1A dredging operations which have deepened the entrance bar (*Tweed Heads Daily News*, 4/10/95). In addition, various other sizes of vessels have been able to negotiate the bar safely since Stage 1A dredging (Betty Dunn, Gold Coast Cruising Yacht Club *pers. comm.*).

Consultation with members of the fishing community who utilise the Tweed River entrance have commented that navigability has improved since the Stage 1A dredging. In general, larger vessels are able to negotiate the bar in all but extreme weather conditions during both ebb and flood tides. During flood tides the navigation conditions are greatly improved, however, due to sand infilling of the channel navigation during the ebb tide is less predictable than before Stage 1A dredging. Smaller vessels are more disadvantaged by the poor navigation conditions during the ebb tide (Alf Ness, Commercial Fishers Association, 1997, *pers comm.*).

Consultation with Paul Campbell of Tweed Dive who uses the entrance frequently stated that Stage 1A dredging of the entrance bar resulted in improved access for vessels directly after the *Ngamotu* cut an initial narrow channel in the bar. Paul stated however that after Stage 1A dredging navigation during flood tides caused no problems (Paul Campbell, Tweed Dive, 1996, *pers comm.*).

The general improvement in navigation conditions immediately after dredging progressively deteriorate as the channel reverts to pre-dredged conditions as sediments are reworked by natural processes. The result of implementation of a permanent system would be to achieve more stable entrance conditions and safer navigation to ensure long term improvement of the Tweed River entrance.

Results of the Public Works study (1991j) suggest that the amount of time when the Tweed River entrance would be navigable for each class of vessel after dredging the channel would increase (Table 7.6.3).

Table 7.6.3 Estimated Impact on Navigation Conditions

Vessel	Existing Bar	Dredged Bar
Yacht	1.7% (6 days per year)	6.4% (23 days per year)
Trawler	14% (51 days per year)	28% (102 days per year)
Runabout	27% (98 days per year)	35% (128 days per year)
Cruiser	16% (58 days per year)	38% (139 days per year)

(Source: PWD, 1991j)

Bracketed values give a representative number of whole days when navigation is possible. The number of days when navigation is possible for part of the day is much greater. Local knowledge of the bar and an understanding of the effects of tides can also increase the time when navigation of the channel is possible.

Improved navigational conditions at the entrance would be expected to have significant flow on effects to local business. Improved safety at the bar would be expected to increase opportunities for business such as commercial fishers and charter operators.

The waiting period (currently 3-4 days) for vessels to return to sea after heavy storms would be expected to decrease resulting in increased competitive advantage with fishermen based at Southport who use the same fishing grounds (Public Works, 1991). This will maintain the number of viable fishing days at approximately 180 days per annum which may encourage trawlers operating from the overcrowded Southport (particularly those who were originally located in the Tweed) to relocate to the port at Boyds Bay.

Alf Ness (Commercial Fishers Association) stated that in 59 years he had never seen so many pleasure craft (yacht and powered vessels) utilising the Tweed River. This observation is supported by the NSW Fisheries data (Figure 7.6.7)which shows a general increase in the number of recreational craft utilising the entrance. Alf Ness believes this is attributed to the improvements of the entrance due to dredging activities. He has also noticed that 15-18m vessels are moving from the Clarence River to the Tweed River as a result of the improved conditions since Stage 1A dredging (A. Ness, *pers comm.*).

Direct navigational impacts include the effect of altered bar and channel conditions, currents, wave hydrodynamics and shoal location. Hazard could be reduced by publicising the changes and potential danger areas to all utilising the area. The navigation channel should be well defined with provision of navigation lights and other hazard reduction measures.

The trailing suction hopper dredger and jackup dredger systems would create a navigational obstacle for craft utilising the Tweed River entrance and channel over the period when sand is being retrieved. The basic units of the sand fluidisation and slurry transportation technology may be attached to piles in the nearshore area. These may also create a navigational hazard for vessels utilising the coastline. A fixed jetty system could create a permanent navigational hazard for vessels utilising the coastline along Letitia Spit. Navigation during the construction period may be disrupted at the jetty location and in the estuary, however this impact would be temporary.

Sand retrieval using a dredger in the nearshore profile, remote systems and mobile land based system will temporarily impact on navigation in the nearshore zone at Letitia Spit during sand retrieval. The mobile land based system requires use of a pipeline which would stretch from land based plant with a submersible pump attachment. This equipment could temporarily disrupt boating activities along Letitia Spit when sand retrieval operations are taking place.

The trailing suction hopper dredger would periodically be active in the inner and outer nearshore zones from Duranbah to the northern end of Kirra Beach. This option could provide a problem for the safety of small recreational craft over the period when sand is being deposited in these areas.

Beach nourishment operations involving pumping to the beach combined with dozer machinery may occur on Duranbah, Snapper Rocks, Rainbow Bay, Greenmount and Kirra Beaches. Nourishment involves the use of heavy machinery on the land and a temporary pipe outlet transferring sand slurry onto the beach from a mobile dredger. Navigation would be periodically interrupted in the sand placement areas when these systems are being employed.

Outlets associated with beach nourishment could incorporate a major discharge outlet located in the proximity of Snapper Rocks. Diffusers may be accommodated by a jetty structure which would create a navigational hazard and require adequate lighting and other hazard mitigation measures to ensure navigation safety during both construction and operational phases. Alternatively this outlet could involve a subaqueous discharge pipeline which would essentially be buried over its entire submerged length and should not present a navigational problem to vessels.

Minor discharge outlets could be located in the vicinity of Duranbah Beach on the western side of Snapper Rocks, and in the vicinity of Kirra Point. The outlets could be exposed (on top of groyne), buried (within groyne, but with exposed outlet) or subaqueous (pipe and outlet buried under water). Navigation would not expected to be affected by these option since the outlets would be located on the existing groynes or would be buried under water. Navigation may be interrupted during construction if vessels or platforms are required.

It is concluded that significantly improved entrance navigation will be achieved if bypassing operates such that the entrance area bathymetry is deeper and uniform over a wide area. This may have implications for the design, operational, strategy and monitoring requirements for the project.

7.6.7 Noise

Potential noise sources associated with the proposed sand bypass system include:

- noise from the primary dredging system, (both intake and deposition processes);
- noise from secondary land based systems such as booster pumps and intake systems;
- noise from construction activity associated with any land based infra-structure;
- noise from occasional land based maintenance type activity such as beach sand redistribution works; and
- noise from marine maintenance activity such as relaying of "pump ashore" pipelines or anchors of dredge platforms.

7.6.7.1 Adjacent Noise Sensitive Areas

The major plant associated with the proposed permanent bypass, whether primarily land or marine based, would be located on or adjacent to the northern end of Letitia Spit and would discharge sand primarily in the vicinity of Snapper Rocks.

In a marine based system the majority of the activity would take place off-shore of the Tweed River breakwaters, Duranbah Beach and Point Danger.

Pipeline systems may include a major booster pump station at the base of the cliffs adjacent to Duranbah Beach. Intake plant may be located in the vicinity of the south-western end of Jack Evans Boatharbour. A booster pump station may be located on Boundary Street servicing the secondary deposition zone between the Kirra Point groyne and the Miles Street groyne.

Figure 7.6.8 identifies the adjacent noise sensitive localities, and includes schematic details of some of the proposed systems. Reference may also be made to Figure 5.2.2 which includes fuller details of the systems under consideration.

Three basic areas or groupings of noise sensitive land use can be identified, and are denoted in Figure 7.6.8 as areas "A", "B" and "C".

"Area A" consists of the land adjacent to the Tweed River foreshore between Jack Evans Boatharbour and Terranora Inlet. Much of the land in this area was reclaimed and it is generally low lying.

This area comprises the most noise sensitive of the three groupings and is characterised by the lowest background noise levels, particularly for the late night/early morning period, where overall minimum background noise levels between 34 dB(A) - 39 dB(A), are expected. Ambient and background levels in this area are largely determined by distant surf noise, and in the areas adjacent to and north of Solander Street, by plant noise. Those sites immediately adjacent to the Tweed River frontage benefit also from a reduction in plant and traffic noise levels from commercial areas to the west as a result of the shielding effect of intervening buildings.

With the exception of the extensive area of the Tweed Heads Hospital, land use is almost entirely residential, with low set detached housing predominating at the southern end of the area and large blocks of residential units predominating at the northern end. Some of the latter are of very significant height, with a residential tower development of over 20 stories at the northern end and other apartment blocks of between 6 and 8 stories. Residents in these units have views which overlook Letitia Spit, potential plant

locations adjacent to Jack Evans Boatharbour and Duranbah Beach and the likely dredge areas.

"Area B" consists of those areas of land in the vicinity of Snapper Rocks, Point Danger and Duranbah Beach.

This area is characterised by higher background and ambient noise levels with minimum overall background noise levels between 40 dB(A), (13 Eden Street), and 51 - 52 dB(A), (sites overlooking Duranbah Beach and/or Point Danger, Snapper Rocks). Ambient and background levels in this area are largely determined by surf noise, particularly from waves breaking adjacent to Duranbah Beach and Snapper Rocks and in this regard it should be noted that the higher minimum overall background noise levels of 51 - 52 dB(A) are probably more typical of the area as a whole.

Land use in this area is residential with a predominance of multiple level apartment blocks and a few lowset detached dwellings on Hill and Eden Streets. The land is quite elevated and the majority of residential sites having seaward frontage will have good views both to the west and south. In particular, the majority of residential sites at the southern end of Area B have views over Letitia Spit, the Tweed Heads breakwaters and the likely dredge areas. Residents at the northern end of Area B overlook the primary deposition zone between Snapper Rocks and Point Danger.

Residents on Eden Street may overlook the clean water intake system incorporating fluidiser pumps. Tweed Heads Rowing and Aquatic Club and the Fisherman's Cove Restaurant which are located at the south-eastern corner of Jack Evans Boatharbour at the base of the cliff and adjacent the proposed intake are also of note.

Attention should also be drawn to the Air Sea Rescue Clubhouse at Duranbah Beach (as may be seen from Figures 4.6.8 and 7.6.8) as a possible site for a booster pump station is located immediately to the west of this facility.

"Area C" consists of those areas of land between Rainbow Bay and Winston Street, North Kirra.

This area is also characterised by background and ambient noise levels which are largely determined by noise from the surf, with however areas where plant noise is also very significant. Minimum background levels vary between 37 dB(A) and 47 dB(A), with those sites which are elevated, and therefore "see" more of the adjacent surf, (eg dwellings at Kirra Point, high rise buildings on Marine Parade) having higher minimum background levels. High rise developments adjacent the Coolangatta and Kirra Beaches and in the Greenmount/Rainbow Bay area also tend to "see" more noise from rooftop mechanical plant.

Land use in this area is substantially residential with a predominance of resort and guest house accommodation. There is significant commercial development on Musgrave Street, adjacent Kirra Beach and on Marine Parade adjacent Coolangatta Beach. Residential tower blocks predominate in the Greenmount/Rainbow Bay area and also adjacent Coolangatta Beach. Two and three storey developments predominate adjacent Greenmount Beach and the Kirra beaches.

Low rise guest house and high rise residential unit style accommodation in the vicinity of the western end of Boundary Street may overlook a possible secondary booster pump station located in the Boundary Street median strip.

7.6.7.2 Noise Criteria

Based on the background and ambient noise levels reported in Section 4.6.9 it is possible to develop noise criteria for the proposed permanent bypass in order that the system selected can be designed to ensure minimum impact.

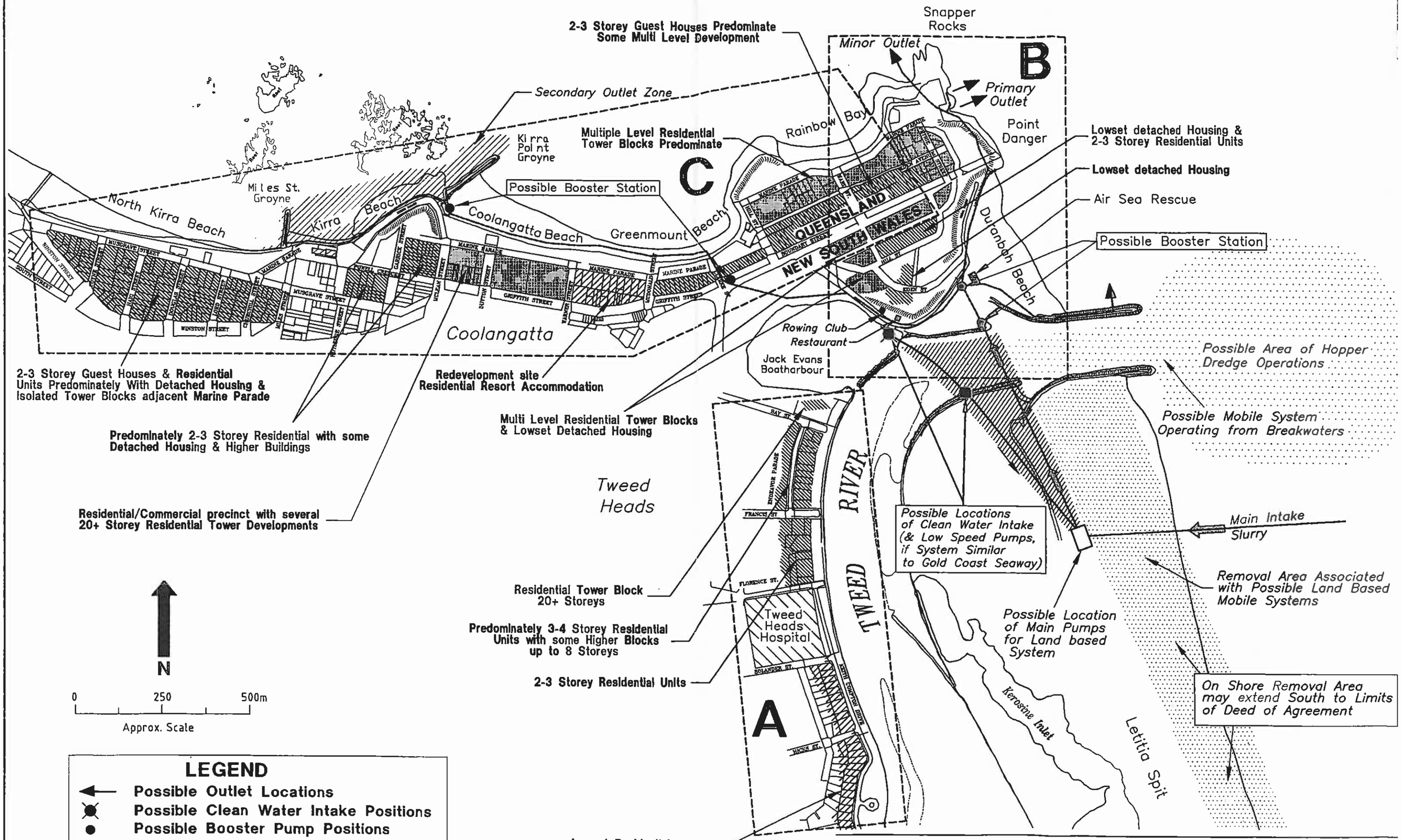


Figure 7.6.8
Adjacent Noise Sensitive Localities

Criteria applying during the construction phase of the project and to maintenance type activities during the operational phase are less stringent than those which would apply to the general plant operations during the operational phase of the project. Both sets of criteria are presented below.

7.6.7.3 Construction and Maintenance

Guidelines for noise from construction and maintenance activity applying in New South Wales and Queensland differ. Specifically, the Queensland guidelines do not set noise limits for operations within recommended hours. For operations outside recommended hours noise limits are applied. New South Wales applies specific noise limits based both on the duration of the construction activity and on the hours of operation.

New South Wales Construction Noise Guidelines

The New South Wales Construction Noise Guidelines may be summarised as follows:

1. For construction periods of 4 weeks or less.
   Noise limit L_{10} (15 minutes) $\leq L_{Abg}$ + 20 dB(A)

2. For construction periods longer than 4 weeks and not exceeding 26 weeks.
   Noise limit L_{10} (15 minutes) $\leq L_{Abg}$ + 10 dB(A)

These limits apply in the hours Monday to Friday 7.00 am to 6.00 pm and Saturday 8.00 am to 1.00 pm. For Saturday operations the hours 7.00 am to 1.00 pm may be applicable if the operation is inaudible at the affected residence. Operation outside these hours is not recommended.

However, where operation outside these hours is to occur, we understand the daytime usual noise limit criterion would be that the L_{10} (15 minutes) of the construction noise not exceed L_{Abg} + 5 dB(A). For periods of time when residents may be asleep (i.e. 10.00 pm to 7.00 am) a sleep interference criteria may also be applied.

This would usually take the form: L_1 (60 seconds) $\leq L_{Abg}$ + 15 dB(A)

That is, that the noise level from the construction activity not exceed the background noise level by more than 15 dB(A) more than 1% of the time in any 60 second period.

For construction activity extending beyond 26 weeks a noise limit based on L_{Abg} +5 would usually apply within the recommended hours of operations.

While these guidelines do not specifically refer to noise from maintenance activity it is believed that in the current situation it would be appropriate to apply similar guidelines to such activities in order to minimise noise nuisance.

Queensland Construction and Maintenance Noise Guidelines

The Queensland construction noise guidelines are embodied in the Queensland Department of Environment document Environmental Guideline E1: "Noise from construction, renovation, maintenance and demolition sites". This document provides for recommended hours of operation and requirements that all mechanically driven equipment be fitted with efficient exhaust mufflers. In the event that appropriate noise control measures are not being applied, an authorised officer can apply site specific limits.

These guidelines are summarised in Table 7.6.4.

Table 7.6.4 Queensland Guidelines for Noise from Construction and Maintenance Activities at Sites Affecting Residencies

A. WORK WITHIN RECOMMENDED HOURS OF OPERATION		
Location	**Noise Limit**	**Recommended Hours of Operation**
Central traffic area or adjacent major thoroughfare	not applicable	6.00am - 6.00 pm Monday to Saturday
Other areas	not applicable	7.00 am - 6.00 pm Monday to Friday 7.00 am - 12.00 noon Saturday
B. WORK OUTSIDE RECOMMENDED HOURS OF OPERATION		
Location	**Noise Limit**	**All Other Hours of Operation**
All areas	L_{Abg} +10 dB(A)	6.00 pm - 10.00 pm Monday to Saturday Noon - 10.00 pm Saturday 7.00 am - 10.00 pm Sunday and Public Holidays
Central traffic area or adjacent major thoroughfare	site noise should be inaudible within any habitable room of any residential premises.	10.00 pm - 6.00 pm
Other areas	site noise should be inaudible within any habitable room of any residential premises.	10.00 pm - 7.00 am

7.6.7.4 Operational Phase - General Plant Operations

As the system is to be a permanent operation the construction noise criteria which applied in respect of the maintenance dredging program previously conducted will not apply to the general plant noise associated with the permanent bypass. General aspects of the noise policies applying in New South Wales and Queensland are reviewed below.

New South Wales Noise Policy for Residential Receivers

New South Wales noise policy would generally apply a limit ($L_{Amax,adj,T}$ or $L_{A10,adj,T}$) of "background noise level + 5 dB(A)" to the noise from new plant. This limit, the "recommended planning level" is modified by a concern to ensure that addition of a new noise source to an area does not increase the underlying background noise level significantly, ("background creep"). In certain circumstances this may take the form of applying a design limit to the new noise source of "background noise level - 10 dB(A)" with the intention of maintaining the existing ambient noise environment effectively as it was and avoiding "background creep".

The extent to which the planning noise limit varies within the range "background + 5" to "background - 10" is dependent on a comparison of the actual background level at an assessment site with deemed "acceptable" background noise levels for day and night time periods.

For a rural situation or a R1 urban residential situation the acceptable background levels are 45 dB(A) and 35 dB(A) respectively.

Generally the minimum planning noise limit for a noise source, $L_{A10,adj,T}$, would be 30 dB(A).

Queensland Noise Policy for Residential Receivers

Whilst Queensland noise policy is currently under review the most usual approach in the situation of new plant would be to apply a limit, $L_{Amax,adj,T}$, of "background + 5" for operation in the period 7.00 am - 10.00 pm and "background + 3" for operation in the period 10.00 pm - 7.00 am. These limits apply to the measured noise level. For situations in which backgrounds below 30 dB(A) may apply the background noise level may be deemed to be 30 dB(A). Higher deemed background levels of 35 and 45 dB(A) may be applied in certain limited situations.

Criteria for Noise from the Permanent Sand Bypassing System

It is apparent that whilst noise policies in New South Wales and Queensland differ somewhat in detail a uniform noise design approach to the overall project will provide the best outcome.

Late Night/Early Morning Period

As the permanent bypass will require the flexibility to operate throughout the 24 hour period the noise emission during the late night/early morning period (10.00 pm - 7.00 am) will be crucial to the overall impact of the system. It is apparent that for long term acceptability of the system plant should be effectively inaudible at adjacent residential sites. This is particularly the case as many of the noise sources likely to be involved (for example, pumps, marine diesels) emit low frequency sound which would be quite intrusive against a prevailing background in which such strong low frequency components are virtually absent.

In order to achieve such an outcome design criteria for the noise emission from the bypass will need to be matched to the octave band data for the late night/early morning background noise level.

Review of the existing octave band data suggests that a two part criterion should be utilised the first part of the criterion would be an overall noise limit selected on the basis of the overall background noise level at the site. The second part of the criterion would be related to the octave band background level, $L_{A\,oct,bg}$, as follows:

$$L_{A\,oct,10} \leq L_{A\,oct,bg} + 3 \text{ dB(A)}$$

For example, for residential sites adjacent to the Tweed Estuary, (Area A and those sites at the south western end of Area B overlooking Jack Evans Boatharbour), the overall noise limit would be the New South Wales minimum planning level, $L_{A10,adj,T}$ of 30 dB(A). In practice the requirement to meet an overall level of 30 dB(A) will limit the mid frequencies to levels well below the existing octave band background levels, $L_{A\,oct,bg}$, and the low frequencies will be controlled to a level at which they would generally be masked by the ambient variation in wave activity.

Table 7.6.5 tabulates design noise level criteria for bypass plant operating overnight on a permanent basis within the study area.

Table 7.6.5 Design Noise Limits at Residential Sites for Noise from Permanent Bypass Plant Operating Overnight

Description of Area	Noise Level dB(A)		
	Minimum Overall Background Noise Level $L_{Abg,T}$	Overall Noise Limit $L_{A10,adj,T}$	Octave Band Noise Limit $L_{Aoct,10,T}$
Area A and south western end Area B - adjacent Eden Street and overlooking Jack Evans Boatharbour	34 - 40	30	$L_{A\,oct,10} \leq L_{A\,oct,bg} + 3$
Area B - south eastern end overlooking Duranbah Beach	46	36	
Area B - overlooking Point Danger	51	41	
Area C - Rainbow Bay	45	35	
Area C - Greenmount to Kirra Beach	47-52	37	
Area C - Boundary Street Precinct	43	33	
Area C - North Kirra	37	30	

These noise limits would apply to noise from permanent shore installations and long term marine operations at adjacent residential areas. For example they would apply to onshore pump systems and to marine platforms (dredge vessel, hopper barge or jack-up platform) operating in the vicinity of the dredging and main deposition zones.

Such criteria would also be appropriately applied to situations such as noise from clean water intake pumps and booster pump plant at adjacent non-residential noise sensitive sites such as the Club Houses and Restaurant at Jack Evans Boatharbour and Duranbah Beach.

For occasional relatively short term activities such as hopper barge activity shuttling between the dredge area and a deposition area off-shore of the Coolangatta/Kirra Beaches less stringent limits based on "overall background + 3 dB(A)" could be used. An appropriate design criteria for such an activity would be based on the minimum overall background noise level applying at residential sites adjacent the deposition zone. The criterion used may also need to specify a minimum closest approach to shore for the vessel whilst on passage between the dredge and deposition zones.

Daytime and Evening Periods

For permanent plant which would only operate during the daytime and evening periods 7.00 am - 10.00 pm it would be possible to specify noise limits based on "background + 5 dB(A)" for individual sites.

From consideration of the data on existing daytime background noise levels (see Table 4.6.12) it can be seen that the daytime background noise levels in the area fall into two groupings around average levels of 50 dB(A) and 40 dB(A). To simplify the noise management task it would be possible to specify noise limits based on these "area average" background levels of 55 dB(A) and 45 dB(A) respectively.

The 55 dB(A) noise limit would apply to plant noise at those residential areas adjacent to the Queensland Beaches, Point Danger and those areas adjacent to Hill Street overlooking Duranbah Beach.

The 45 dB(A) noise limit would apply to plant noise at those residential areas adjacent Eden Street and overlooking Jack Evans Boatharbour and those areas adjoining the Tweed River Estuary south to Terranora Inlet.

These noise limits would apply to the adjusted measured noise level, $L_{Amax,adj,T}$, that is, to the noise from the noise source plus the contribution from the existing background.

7.6.7.5 Noise Issues Relating to Proposed Dredge Systems

At this juncture a large number of different dredging systems are under consideration for possible selection as part of the final bypass system. In the sections following the potential impacts involved (in the absence of specific acoustic treatments) are reviewed. As the specific plant selection is not yet known, the likely impacts cannot be determined other than indicatively. Specific measurements, however, were carried out for the Gold Coast Seaway Sand Bypass. The situation of a bypass plant of similar design to the Gold Coast Seaway is considered in some detail as there are a number of features of this plant which are generic to the overall proposal.

7.6.7.6 Indicative Noise Impacts - System based on the Gold Coast Seaway

The Gold Coast Seaway has been in operation since the late 80's and shifts around 500, 000 m^3 of sand per year. The pump capacities used are therefore representative of the likely requirement for any system utilised at the Tweed mouth. The Gold Coast system involves five major pumps and their drive motors. Three of these pumps are located in the main plant building. These are the two high speed pumps which provide high pressure water to the jetty mounted jet pumps, and a large slurry pump which is utilised to pump the sand slurry from the dredge area to the other side of the Seaway. The other two pumps, known as low speed intake pumps, are located on the Nerang Broadwater some distance from the main plant and directly above the clean water intakes. All plant is electrically driven and typically the system is operated at night only in order to take advantage of the favourable electricity tariff.

Both major groupings of plant are housed in buildings of standard besser block and concrete construction with sheet metal (kliplok) roofing.

The plant is located at a relatively isolated position; the nearest residential areas are located at the other side of the Broadwater approximately 3 kilometres distant.

Measurements have been undertaken of noise from both the low speed plant house and the main plant house.

Table 7.6.6 provides details of the measured noise level spectra. For convenience of comparison with other data noise levels have been equated to a standard distance of 30 metres.

Table 7.6.6 Octave Band, A-weighted, Noise Levels Pump Systems Gold Coast Seaway - 30 metres

Plant Description	Octave Band Centre Frequency (Hz) Noise Level dB(A)									
	31.5	63	125	250	500	1000	2000	4000	8000	Over all
Main Pump System	30	40	53	62	71	68	61	63	63	74
Low Speed Pumps	49	57	58	53	51	49	44	43	40	62

As may be seen from this table the main pump system is in overall terms considerably noisier than the low speed pumps, however it may be noted that the low speed pumps produce much more noise at low frequencies (31.5 Hz - 125 Hz) than the main plant. In this regard it is notable that significant levels of ground vibration were noted in the vicinity of the intake plant house.

This data has been utilised in a noise model to predict the likely emission from a similar system in use at the Tweed. The model is based on the well known method of "Concawe" and predicts noise levels at receptor positions taking into account the effect of attenuation due to distance, barriers, ground absorption and atmospheric absorption, and incorporates features which enable the influence of varying meteorological conditions to be assessed.

For purposes of assessment the following arrangement is considered:

1. Intake plant located at the south eastern end of Jack Evans Boatharbour.

2. Main plant located at a position approximately 500 metres south of the Southern Breakwater (see Figure 7.6.8).

It is assumed that both plant houses are of similar construction to those used at the Gold Coast Seaway.

In this scenario the nearest noise sensitive site to the intake plant would be the adjacent Restaurant and Club House around 30 to 40 metres away. Based on the measured noise levels an overall level of around 59 - 62 dB(A) would be expected. As noted in Section 7.6.8.2, to ensure a situation of minimal impact, an overall noise level from the plant of 30 dB(A) would need to be achieved. Thus around 30 dB(A) reduction in noise level would be required in overall terms. As the majority of the emission from this plant occurs in the 63 Hz and 125 Hz octave bands - this would be very difficult to achieve; detailed acoustic design and a substantial structure would be needed to achieve these criteria.. It should further be noted that the plant house would need to be isolated in some way so that vibration from the pumps did not cause nuisance at adjacent buildings. These treatments would significantly add to the cost of the structure.

Other noise sensitive sites are located at Eden Street approximately 100 metres distant and across Jack Evans Boatharbour at Bay Street approximately 320 metres distant. Calculations indicate that under reasonable worst case weather conditions (a light breeze from source to receiver) overall noise levels of 51 dB(A) and 44 dB(A) respectively would be likely. Thus to achieve an overall noise limit of 30dB(A) reductions in overall noise level of 21 dB(A) and 14 dB(A) would be required. Larger reductions would be required at low frequencies.

Table 7.6.7 compares the calculated noise level for a receiver at Bay Street with the measured octave band background noise level spectra for Measurement Position 11. As may be seen from this Table in overall terms the noise from the intake pumps would be around 6 dB(A) above the background noise level. At low frequencies, however, much higher exceedances would occur - in this case the exceedance in the 63 Hz octave band would be 18 dB(A) and the noise emission from intake pumps would in consequence be very intrusive.

If the "background + 3" octave band criteria is applied the intake pump noise emission in the 63 Hz octave band would need to be reduced to 21 dB(A) or below. At that level the noise would be just noticeable and in practice masked by the normal variation in ambient noise levels.

Table 7.6.7 Comparison of Predicted level from Intake Pumps with Background Noise Level: Residential site southern side of Jack Evans Boatharbour

Description	Octave Band Centre Frequency (Hz) Noise Level dB(A)									
	31.5	63	125	250	500	1000	2000	4000	8000	Overall
Predicted noise level from Intake Pump House	18	37	40	37	34	30	23	19	-	44
Background Noise Level Measurement Position 11 (late night/early morning)	≤10	19	29	32	32	31	28	27	21	38

For convenience of discussion we have not considered the influence of the noise emission from the main plant house at this site. In the scenario under consideration the main plant would be located around 800 metres distant (see Figure 7.6.8).

Calculations indicate that with a main plant house constructed as per the Gold Coast Seaway arrangement the overall noise level from the main plant under reasonable worst case weather conditions would be around 39 dB(A). This would be mainly mid frequency noise with the predominant component in the 500 Hz octave band (37 dB(A) at 500 Hz). The contribution from the main plant would increase the overall noise level from the Bypass system to 45 dB(A).

Depending on the installation, noise from booster plant at Duranbah may also contribute to the overall noise level at this site. However, any contribution from such plant at this site is likely to be much less significant than either of the above components. Nevertheless it would need to be considered in designing the overall system to minimise impact.

From the above review it is apparent that significant noise control measures will be needed to achieve a noise emission from the Bypass which would result in minimal impact at adjacent residential sites.

This assessment would also apply to the other potential bypass systems, indeed because the Gold Coast System is a fixed land based system it has advantages over several of the other systems under consideration in terms of noise control. Nevertheless an intake system at Jack Evans Boatharbour is probably too close to adjacent noise sensitive areas, and the impact of noise would be reduced if another location was used. In this regard, the possible intake location on Letitia Spit is preferable from a noise standpoint.

7.6.7.7 Review of Proposed Systems

In the following sections the noise issues which will need to be considered for each of the various systems are discussed.

Marine Based Systems

- Trailing Suction Hopper Dredge

  Noise Sources:

  - Slurry pump system and pump motors.

- Propulsion motors.
- Ventilation plant.
- Ancillary pumps.
- Possible pump ashore system.

Land based booster pump plant may be required in certain pump ashore scenarios.

Comments:

This option benefits from maximisation of distance between the main dredge plant and nearest noise sensitive receptors (Area B), except when working in the Tweed River Channel. Noise sensitive receptors in Area A are relatively remote, however, as against this there is probably a distinct limit to the degree of noise amelioration which can be achieved with marine systems due to structural considerations. If based at Tweed Heads the dredge would also have to access facilities in the estuary for maintenance purposes with potential noise impacts while underway in the estuary.

Overall the system would benefit if dredge requirements in the estuary could be limited to a daylight operation only.

- Jack-up Dredge

Noise Sources:

- Slurry pump system.
- Pump ashore system.
- Ventilation plant.
- Associated booster pump systems at Duranbah and Boundary Street.

May include deposition by bottom dumping from spreader barge in certain scenarios. Noise from barge engines should be considered Depending on which system for bottom dumping is used may be associated with impulsive noise.

Comments:

As with other marine systems this option benefits from maximisation of distance between primary dredge plant and the nearest noise sensitive receptors (except when working in Tweed River Channel). The option would probably be limited in the degree of noise amelioration which could be achieved due to structural considerations. The platform is likely to require berthing facilities in the Tweed River Estuary with potential impacts whilst on passage between dredge zone and berthing facility. The platform may require a tug vessel to assist. Relative to a conventional dredge vessel this system would require much higher levels of shore infrastructure with associated noise impacts.

Overall, the impact of noise would be reduced if service requirements were limited to daylight operations.

Fixed Systems Located in Near Shore Zone

- Fixed plant mounted on Roundhead of Southern Breakwater

a) Pump based dredge systems

Noise Sources:

- Main slurry pump.
- Jet pump motive water pumps.
- Possible clean water intake pumps, e.g. at Jack Evans Boatharbour.
- Possible booster pump systems at Duranbah and Boundary Street.

Comments:

Main plant area is located at furthest distance from adjacent noise sensitive areas of all land based systems. Plant will require relatively substantial concrete housing to provide adequate levels of protection from wave action. Such a housing would provide a good opportunity for relatively high levels of noise amelioration to be provided about the noise producing equipment.

b) Mechanical Dredge Systems

Noise Sources:

- Main slurry pump,
- Booster pumps at Duranbah and Boundary Street
- depending on system, may require other elements of a slurry pump system
- potential impulsive noise sources - grab bucket, rope slap, sheave noise
- motor noise, such as hoist and drag motors, or hydraulic motors

Comments:

This operation is inherently less amenable to noise amelioration than pump based systems. This may limit the ability to conduct 24 hour operations. If substantial superstructure is required, this may be associated with whistling or other tonal noise sources due to wind interaction with the structure.

- Mobile dredge plant with unrestricted ability to move along the Breakwater.

Noise Sources:

Noise sources as for above fixed plant, depending on system, may include significant contribution from system used to traverse breakwater.

Comments:

Relative to fixed plant it is anticipated there would be relatively much greater difficulty in providing noise amelioration, primarily due to structural constraints. As the system would have the ability to move over the length of the dredge channel, distance to residents is reduced.

- Jetty mounted system with fixed sand fluidising and/or slurry transportation devices.

Noise Sources:
- Main slurry pump.
- High pressure motive water pumps supplying jet pumps.
- Cleanwater intake pumps.
- Booster pumps at Duranbah and Boundary Street.

Systems involving submersible pumps would not require (i), (ii), or (iii) but may include shore jetty mounted hydraulic motor and associated driver.

Comments:

The main noise producing plant involved in this system would be similar to that currently operating at the Gold Coast. Likely impacts in the absence of specific noise amelioration are reviewed in Section 7.6.7.1.

In this option the main noise producing plant is relatively remote from adjacent residential areas and could be housed in a building of substantial construction with good noise amelioration. The main plant house would also be somewhat shielded from noise sensitive areas to the west by intervening dunes. However the upper floors of high rise buildings in Area A and Area B at adjacent Duranbah will overlook the main plant house.

The clean water intake plant house, would be located in much closer proximity to residential areas. Based on levels measured for the Gold Coast Seaway it is expected that very significant levels of attenuation would need to be provided particularly for the low frequency emission from this plant.

If the intake is located on Jack Evans Boatharbour there may also be a need to provide efficient structural isolation to prevent ground vibrations induced by the pump station impacting on the adjacent restaurant and club house.

- Jetty mounted system with mobile plant similar to breakwater systems with mobile plant.

  Noise Sources:

  As per mobile breakwater system.

  Comments:

  Relative to a breakwater mounted system, the main plant will be located at a much greater distance from Area B.

Systems Working in the Upper Portion of the Beach Profile

- Mobile land based systems - similar to plant proposed for mobile breakwater mounted system.

  Noise Sources:

  Noise sources would be as described for mobile breakwater mounted systems. Dependent on area to be dredged and the length of the dredge basin these systems may require several additional mobile booster stations.

  Other systems include booster plant at Duranbah Beach and Boundary Street.

  Comments:

  As systems are mobile any ability to provide noise amelioration is limited. Fixed elements such as major slurry pumps may of course be provided with substantial housings to ameliorate their noise emission.

  With the exception of those residents in the high rise developments on Endeavour and Bay Streets the frontal dune may provide some shielding for plant for noise sensitive areas to the west.

  In the event that the dredge zone is extended south towards the Limits of the Deed of Agreement it

is apparent that potential noise impacts at Fingal village will need to be considered and relevant noise limit criteria met.

In this regard, while the range of possible options covered in this EIS/IAS includes the possibility of dredging plant operating within the beach zone near the southern limits of the Deed of Agreement area, the probability and duration of and such activity will be extremely low. Practical and economic constraints relating to pumping distances and energy consumption would ensure that any operations of this type are confined primarily to the area mediately south of the Tweed River training walls.

In the event of such dredging occurring within around 500m of Fingal Village, noise considerations relating to this residential area would need to be addressed. It is apparent that significant noise control would be needed particularly for plant working overnight. It is noted that in this case the level of amelioration required to meet noise criteria may not be practically feasible with typical mobile equipment.

- Cutter Suction Dredger

Noise Sources:

Noise sources include slurry pump and drive motor (diesel), and dependent on dredge area, additional (mobile) booster pump stations.

Other systems include booster plant at Duranbah Beach and Kirra Point.

Comments:

As systems are mobile amelioration potential is limited, additionally main noise source is mounted on a floating platform which may further affect level of amelioration achievable.

As with the land based mobile systems, some shielding may be provided by Letitia Spit dunes for low set residential receivers to the west.

In the event that the dredging area is extended south towards the Limits of the Deed of Agreement it apparent that consideration will need to be given to potential noise impacts at Fingal and relevant noise limit criteria met.

As was noted with respect to mobile land based systems, in the event of the dredger working within around 500m of Fingal Village significant noise controls will be required to achieve noise criteria levels. This would require levels of noise amelioration which may not be practicably feasible with standard equipment. In this regard it is noted that with respect to the Area 5 dredging operation, which was conducted with similar equipment, overnight operations were not permitted.

Particular Noise Issues Relating to Materials Transport

- Pipelines

Noise issues which may arise from pipelines are usually due to noise from major sources (pumps or valves) being transmitted along the pipe either by vibrational excitation of the pipe wall or as pressure fluctuations in the fluid being pumped.

In particular circumstances these can give rise to nuisance noise or vibration adjacent to the pipe route at significant distances from the source.

Potential noise issues can be avoided by:

a) utilising buried pipeline;
b) using a steel pipeline. This can be lined with plastic (e.g. polyurethane) for wear resistance;
c) providing flexible pipe connectors adjacent major sources such as booster pump installations to provide structural isolation;
d) ensuring that the pipe route avoids existing habitable buildings and that a reasonable separation is maintained between the buried line and adjacent structures.

In this case the proposed route is generally well separated from existing buildings over most of its route. There are three locations, however, where the pipeline may come close to existing buildings. These are at:

- the eastern end of Jack Evans Boatharbour - commercial properties;
- Clarke Street - commercial and residential properties;
- Kirra Surf Club.

It is recommended that a minimum separation of 10 m between pipeline and buildings be maintained. Care should be taken to ensure the pipe is isolated from any underground structures which may be contiguous with building foundations.

- Self Propelled Barge

Noise issues relating to barge transport have been discussed in relation to a number of the primary dredge systems. Particular considerations are reviewed below.

Noise Sources:

- engine noise (diesel)
- noise from ventilation plant
- noise from bottom dumping system
- pump ashore plant

Comments:

As with other marine systems the distance of the noise source from adjacent noise sensitive areas is maximised, however, noise impacts would generally be more difficult to ameliorate than with a shore based system. Impulsive noise sources may be an issue particularly with bottom dumping.

While in the short to medium term noise impacts from barge transport may be well accepted, in the longer term such impacts may be considered a nuisance. This would be particularly the case where relatively high rates of barge movement are likely, for example in the situation of a barge shuttling between the dredge zone and the Snapper Rocks deposition area. Similar comments would apply to a regular long term "pump ashore" scenario.

- Permanent Booster Pump Stations

Permanent booster pump stations at Duranbah Beach and Boundary Street have been nominated. Particular issues which may be associated with these stations are discussed below.

Booster Station - Duranbah Beach

This station would be located in the area between the northern sea wall of the Tweed River Estuary and the base of the cliffs adjacent Duranbah Beach (see Figure 7.6.8). The pump installation would be sized to take the full throughput of the main dredging plant. The pump and its drive motor is thus likely to be a significant noise source.

The nearest noise sensitive building to this booster pump location is the Air-Sea Rescue Club house at Duranbah Beach. As may be seen from Figure 7.6.8 the pump location may be within 20 to 120 metres of the Clubhouse.

At the closer distance both noise and vibration impacts are likely to be issues which would need to be addressed in the design stage. At the greater distance it is likely that noise only would need to be ameliorated. In both situations a relatively substantial housing, (perhaps partially buried), will be required in order to minimise impacts.

Other noise sensitive land use is located at Hill and Eden Streets and adjoining the base of the cliffs adjacent to Jack Evans Boatharbour. As with the situation of the Air Sea Rescue Club it is apparent that the distance to these areas should be maximised. In the situation that the plant is located to maximise the distance to the Clubhouse, potential impacts at the Eden Street residencies and the commercial premises adjacent to Jack Evans Boatharbour may be the controlling factor in noise design.

Booster Station -Boundary Street

This station would be located at the western end of Boundary Street, adjacent to the Clarke Street intersection, as such the nearest residential land use is located in adjacent low rise guest houses and in a high rise apartment block, between Marine Parade and Boundary Streets at distances of approximately 50 metres. Commercial premises may be located in closer proximity.

The Heads of Agreement allow for direct deposition of 75,000 tonnes of sand or 15% of the total bypass in the area adjacent to Kirra Point. Assuming that this total was shifted at approximately the same rate as the main system this could be done in approximately 1.5 months. Alternatively smaller quantities may be pumped over a longer period. Pump size and therefore noise produced will vary depending on the duty needed. In any case it is apparent that the pump will need to be housed in a acoustically suitable building to ensure noise impacts are controlled. It is likely that noise criteria based on the late night background at the adjacent residential sites will control this design, however, daytime impacts at the closer recreational facilities may also need to be considered.

Careful attention will need to be paid to vibration isolation of the booster pump in order to avoid potential pipe borne vibration and noise impact to adjacent buildings. This is particularly the case as the proposed pipe route passes in relatively close proximity to buildings in Clarke Street.

- Discharge Outlets

Potentially sand discharge outlets will be located at the eastern end of the North Head Breakwater, at Snapper Rocks, to the west of Snapper Rocks and between the Kirra Point Groyne and the Miles Street Groyne. All outlet zones are characterised by relatively high ambient noise levels due to breaking surf. This ambient noise will tend to mask any noise produced by a slurry outfall. The outlet zones are also relatively remote from adjacent residential premises. Indeed, with the possible exception of the North Head outlet, it should be relatively easy to ensure that there is no direct line of sight to the outlets from adjacent residential areas.

Thus it is considered that noise from the outlets is unlikely to be audible at adjacent residential sites and no appreciable impact is expected.

7.6.8 Air Quality

Some localised minor effects would be expected to result during works from exhaust fumes if an over-the-water mobile system or onshore based mobile system were selected. The majority of plant and equipment available for these options are diesel powered and therefore produce exhaust gases such as carbon monoxide (CO), nitrogen oxides (NO_x) and small quantities of uncombusted hydrocarbons and particulates. Given the existing high air quality in the area and the absence of significant temperature inversions (Section 4.1.7) exhaust products are expected to be rapidly dispersed and not lead to any noticeable temporary decline in existing air quality.

Fixed systems would be powered by electricity and do not produce exhaust fumes, therefore the impact on air quality as a result of power supply is insignificant. If the jetty mounted system is implemented access will be via Letitia Road which is an unsealed dirt road. Therefore the local air quality will be affected as a result of dust generation if the road is not sealed and due to the increased traffic movement in the area.

During the construction process some dust generation would be expected from excavation and stockpiling of materials. With the adoption of appropriate mitigative measures the impact of these activities on air quality would be expected to be minimal and short term.

7.6.9 Traffic

The traffic flow through the Tweed Heads/Coolangatta region is unlikely to be significantly impacted during the construction and operational phases, although there may be some temporary congestion experienced along the Tweed Bypass and crossing the Boyds Bay Bridge.

The improved access to the Tweed River entrance and the potential improvements in the surf and beach amenity may increase tourist influx to the area which will have a concomitant impact on traffic levels. The Tweed 2000 project being undertaken by Tweed Shire Council is addressing future traffic access to the region (John Henley, Tweed Shire Council, *pers. comm.*).

Fixed Options

The traffic flow through Fingal Heads is likely to be negatively impacted by the installation of a jetty system as there is only one route for heavy vehicles through the town to the construction site but this will only be short term. At present, access to the end of Letitia Spit is via a loose unsealed dirt road. Dust generation as a result of more frequent use by a greater number of vehicles could have a significant impact on vegetation communities on Letitia Spit due to smothering. Dust generation also has the potential to cause significant human health problems in the local community. Therefore Letitia Spit road may need to be sealed and possibly widened initially for construction vehicles and subsequently service and maintenance vehicles.

The sealed road will provide an amenity for local residents who use the spit. Presently Letitia Spit road is ungazetted. Members of the Pooningbah Aboriginal Community have suggested that the road should be gazetted. In doing so there is greater opportunity for the road to be maintained and to discourage undesirable activities such as the dumping of car bodies and uncontrolled 4WD access. A construction depot/office may also need to be located in the vicinity which could be turned into a car park on completion of the project.

Access to the proposed pipelines and discharge outlets is available from Marine Parade which may cause some minor disruptions to traffic flow during construction but this will only be temporary.

Duranbah Beach is easily accessed from Coral Street and should not significantly influence traffic flow through the region.

Installation of traffic calming measures should be considered to slow the movement of traffic through the Fingal Heads township and along Letitia Spit road if the road is sealed.

7.6.10 Energy Statement

Energy Consumption During Construction and Operation Phases

The predominant energy source used during construction would be fuel for construction vehicles. This will be primarily in the form of distillate and petrol. While for operation, the predominate energy source will be distillate and electricity. Estimated energy consumption during construction and operation for each of the sand removal, pipeline and placement options are shown in Tables 7.6.8, 7.6.9 and 7.6.10. Exact energy consumption would depend on the equipment used, conditions encountered and the operation and management practices employed by the contractor during the construction phase and ultimately, the final system selected for implementation.

Table 7.6.8 Energy Consumption for Sand Removal Options

METHOD OF SAND REMOVAL	METHOD OF SAND TRANSPORTATION	METHOD OF SAND PLACEMENT	ENERGY CONSUMPTION	
			CONSTRUCTION PHASE	OPERATIONAL PHASE
Trailer Suction Hopper Dredger	Trailer Suction Hopper Dredger	Bottom Dumping / Bow or Side Casting	Nil	1.25×10^6 kWh
	Pumping via Discharge Pipeline	Spreader Barge / and or Land-Based Machinery	(See Pipeline Installation Energy requirements)	2.17×10^6 kWh
Cutter Suction Dredger	Pumping via Discharge Pipeline	Spreader Barge / and or Land-Based Machinery	2.6×10^3 kWh + Pipeline Installation Energy requirements	1.4×10^6 kWh
Jack-Up Dredger	Pumping via Discharge Pipeline	Spreader Barge / and or Land-Based Machinery	2.6×10^3 kWh + Pipeline Installation Energy requirements	1.5×10^6 kWh
	Self-Propelled Hopper Barge	Bottom Dumping / Bow or Side Casting	2.6×10^3 kWh + Pipeline Installation Energy requirements	2.0×10^6 kWh
Land-Based Plant Customised for Dredging	Pumping via Discharge Pipeline	Spreader Barge / and or Land-Based Machinery	2.6×10^3 kWh + Pipeline Installation Energy requirements	1.2×10^6 kWh
Jetty-Mounted Dredging System	Pumping via Discharge Pipeline	Spreader Barge / and or Land-Based Machinery	1.9×10^6 kWh + Pipeline Installation Energy requirements	2.2×10^6 kWh
Sand Fluidisation and Slurry Transportation System	Pumping via Discharge Pipeline	Spreader Barge / and or Land-Based Machinery	Unknown	2.9×10^6 kWh
Submerged Dredger and Overwater Platform	Pumping via Discharge Pipeline	Spreader Barge / and or Land-Based Machinery	2.6×10^3 kWh + Pipeline Installation Energy requirements	1.2×10^6 kWh

Notes:

1. Operational Phase energy consumptions are based on the removal and discharge of 500,000 m^3 of sand per year.
2. Spreader Barge and Land-Based Machinery energy consumptions have not been included, as this equipment has variable yearly usage.
3. Pipeline Installation energy consumptions are detailed in a separate table following.

Table 7.6.9 Energy Consumption for Sand Placement Options

Sand Placement Plant Item	Energy Consumption Per Hour Usage
Bulldozer	110 kWh
Front-End-Loader	140 kWh
Spreader Barge	80 kWh

Table 7.6.10 Energy Consumption for Sand Delivery Options

Pipeline Type	Pipeline Length (Assumed)	Installation Energy Consumption
Buried On-Shore Pipeline	3000m	1.29×10^5 kWh
Directional Drilled Pipeline	2500m	1.68×10^5 kWh
Submerged Off-Shore Pipeline	1200m	4.8×10^3 kWh
Uncovered On-Shore Pipeline	1800m	1.62×10^4 kWh

7.6.11 Hazard Assessment

Dredging of the Tweed entrance bar would be expected to substantially improve navigation safety and reduce the risk of boating accidents for both the commercial and recreational craft. This would have the benefit of reducing loss of life and injury, and also place less strain on the local emergency services.

However, the predicted increase in usage of the Tweed estuary by recreational and commercial vessels may partially negate the benefits of improved navigation. In particular, inexperienced recreational sailors inexperienced with local conditions may be at risk. It is therefore recommended that navigation information and literature be made readily available for both recreational and commercial sailors and that day marks and lights clearly mark the dredge and pump lines to advise of any hazards.

There is some potential hazard associated with the subaerial discharge points. The discharge occurs directly onto the beaches from the bypassing system. These discharge points will require management to ensure that public safety is not jeopardised. It is recommended that access to beaches with subaerial discharge points be restricted during periods of nourishment to ensure public safety. During previous similar beach nourishment activities where proper management procedures have been adopted public safety has not been reduced. Offshore and nearshore subaqueous discharge outlets pose no threat to public safety.

There is a risk of fuel spillage from equipment being used in offshore and onshore areas. To reduce the risk of spillage during equipment operation and nourishment works will have adequate oil spill response equipment on site to cope with the fuel load of the sand bypassing system. In addition, oil spill response equipment would be available at the construction compound for rapid deployment during the construction phase.

Within the area of potential nourishment as defined in Figure 5.2.2, the Queensland Department of Primary Industries (DPI) has two shark nets (of approximately 100m length each) and up to 10 baited drum lines. These nets and lines are checked and maintained by a contractor every second day. The location of this equipment places operational restrictions on potential nearshore sand deposition by dredgers or barges.

During the Stage 1A dredging and nourishment works, shark meshing equipment was relocated from the deposition area. During nourishment DPI requested additional surveillance or equivalent protection while nets and drum lines were temporarily relocated. The DPI Shark Meshing Liaison Group recommended a revised programme be put in place to provide at least as great a level of protection. This included a Life

Guard at Greenmount, increased frequency of checking of nets from every two days to daily, and increased vigilance and overflights by Surf Lifesaving Aerial Patrols. These amendments resulted in a significant extra cost. There were no shark attacks reported during the works.

During previous nourishment operations in 1988 and 1989/90 equipment was relocated or removed during the works and no adverse impacts resulted. Furthermore, there has never been any shark protection for Duranbah or Letitia Spit and there have been no reported shark attacks on these beaches for many years.

If the successful tenderer for the permanent system proposes nourishment utilising trailer dredgers or barges, the existing shark control programme may constrain operations. Access for nourishment by bottom dumping, pump ashore or bow casting may be constrained by the current location of shark meshing equipment. The timing and frequency of these operations will depend on the size and method of operation of the vessels. To overcome these operational constraints, a strategy will need to be developed which considers the timing and nature of amendments to the existing control programme and is likely to require that an equivalent level of protection is provided on an ongoing basis. This strategy will need to be prepared with consultation and approval of the Shark Meshing Liaison Group. The development of this strategy is likely to require that the nourishment activities of the project do not adversely affect the level of shark risk.

7.7 Environmentally Sensitive Areas

Environmentally sensitive areas which could be impacted by the proposed permanent sand bypass system occur at Kerosene Inlet, Letitia Spit, South Head Beach and at Kirra Reef. These sites encompass a diverse range of habitats supporting commercially viable or species rich communities and include beachworm habitat, waterbird roosting sites, and rich reef habitat.

Letitia Spit provides an important roosting habitat to shorebirds, particularly waders and terns and acts as a habitat for the commercially viable beachworm population. Land-based bypass systems would temporarily destroy the beach worm habitat at the northern end of Letitia Spit (Section 4.5). However, once the new beach profile was established, the worms would migrate back into the area from the south and any reduction in the width of the spit through natural winnowing would allow worms to migrate up the beach. Therefore the impact on the commercial beachworm fishery is not expected to be significant.

South Head beach contains one of the largest concentrations of roosting birds on the Tweed Estuary with the highest count of 489 birds for any site during the bird monitoring programme (refer Section 4.5.3.2 and 7.5.4). Kerosene Inlet is also a major roost within the study area. Construction and operation of the fixed jetty system and the mobile land based system may impact roosting sites and potential breeding areas for shorebirds. This is detailed in Section 7.5.4.

Kirra Reef consists of scattered rock outcrops supporting a diverse and rich variety of rocky reef organisms which is unusual considering it is located in very shallow water near the beach and is surrounded by mobile sand which is continually being resuspended and settling over the reef. Fauna attached to the reef range from soft coral, anemones, ascidians, bryozoans, encrusting sponges while flora assemblages largely consist of a variety of red, green and brown algae which colonise the rocks. Abundant pencil urchins and crinoids occur in crevices in the rocks, and there is a good variety of the smaller rocky reef fishes and moray eels attracted to this habitat (Section 4.5.1). Nourishment configuration will avoid Kirra Reef, therefore, significant direct impacts from the sand deposition process are not expected (Section 7.5.1).

7.8 Cumulative Impacts

The permanent nature of the sand bypass system means that there are likely to be cumulative impacts on the physical, ecological and socio-economic environments in the long term, as illustrated in the following section.

Physical Environment

The maintenance of long term beach stability along the southern Gold Coast and increased amenity through persistent supply of sand along the nearshore beach system, increased beach widths and enhanced surfing conditions will be key cumulative impacts to arise from the permanent bypass system. Dredging from the northern Letitia Spit and Tweed River entrance nearshore spit will significantly reduce the sand supply to Duranbah which will result in the beach realigning and retreating until a new equilibrium is established.

Various scenarios and model simulations have been developed to endeavour to predict the incremental impacts on the hydrodynamics and estuarine shoal dynamics of the bypassing system over the next 20 years (Section 4.2.4 and 7.2.1). The long term cumulative impact of the permanent bypass system in conjunction with implementation of the Tweed Estuary Management Plan is likely to be an improvement in the tidal mixing and flushing of the main arm of the estuary, irrespective of whether the lower estuary shoals are maintained in their existing condition or are allowed to infill. However, the cumulative hydrodynamic impact on the Terranora Inlet will be dictated by future management of the lower estuary marine shoals ie. a minor increase in tidal flushing, if the lower estuary shoals are kept in their existing configuration, and a minor decrease in tidal flushing if the shoals are allowed to infill. Overall, it is concluded that a permanent bypass scheme will have a minor beneficial impact on the long term hydrodynamics of the estuary. Long term cumulative hydrodynamic impacts are discussed in detail in Section 7.4.1.3.

The cumulative impacts of the proposal in relation to climate change remain uncertain due to the complexity of the natural feedback mechanisms in the atmosphere. A significant potential impact of the Greenhouse Effect is a predicted rise in sea level and an increase in cyclonic events (Section 7.12.1). The nourishment strategy should help to protect southern Gold Coast beaches from Greenhouse induced shoreline recession over the next 25-50 years (refer Section 4.3.4.8).

Ecological Environment

The cumulative impacts on the marine ecology will vary according to the type of permanent bypass system used. The fixed jetty system and/or Breakwater-Mounted Fixed Sand-Fluidising and Slurry Systems will cause the greatest long term impact leading to permanent alteration of the habitat in the nearshore zone. The addition of steel jetty piles (fixed into artificial hard substrate), the deeper zone of sand removal and the permanently shaded substrate and water column will act together to create a different habitat leading to a concomitant shift in species composition. The bottom substrate would be devoid of benthic invertebrates in the removal zone and the steel pylons will represent an artificial reef structure, encouraging larger finfish to the area which will benefit recreational fishermen. However, it is possible that the characteristics of the structure and the operation of the system will adversely impact the commercial fishermen by inhibiting migrating schools of mullet and/or whiting from entering the Tweed River to spawn and feed. Conversely, the mobile trailer suction dredger will have the least cumulative impact as it operates on an as-needed, where-needed basis, with a relatively shallow and narrow dredging path. No new habitat would be created as rapid recolonisation from the surrounding benthos would occur and migratory finfish would be unimpeded from passing into and out of the estuary (Section 7.5.1).

The slower rate of recovery of the lower entrance shoals following a flood due to bypassing could result in a higher tidal range being experienced over a longer time period than presently occurs which will increase the "stability" of the estuarine wetlands. This may result in a reduced variation of wetland margins in

specific areas (Section 7.5.2.1). Changes to wetlands will only be able to be quantified through a detailed monitoring programme after the permanent sand bypass is operational (Section 8.1.2).

The oyster industry is unlikely to experience any direct impact from tidal level changes as it is restricted to upstream areas. However marginal, increased tidal flushing should help to maintain a healthy oyster industry by diluting these pollution sources (Section 4.5.2.5 and 7.5.2).

Cumulative impacts to shorebirds could be experienced in areas where infrastructure is located. A mobile land based system will have a significant impact on waders and terns as it would require removal of a substantial area of sand from the northern section of Fingal Peninsula, which includes one of the major water bird roosts on the Tweed Estuary. The disturbance of the little Tern is particularly significant as it is listed as endangered under the NSW *Threatened Species Conservation Act 1995.*

Cultural & Socio-Economic

The implementation of a permanent sand bypass system will have substantial positive impacts on the recreational and economic environments within the region through improved beach amenity on the south Gold Coast beaches from the nourishment campaigns and improved navigation conditions at the Tweed bar. These will more than offset any minor adverse impacts of the options from increased noise, reduced air quality or increased traffic along Letitia Spit, if the jetty mounted system is used. A key cumulative impact will be greater employment opportunities from continued development of the local tourist industry. The sustained revenues from tourist expenditure are expected to have substantial flow on effects in local business and service sectors (refer Section 7.6.1).

Improved navigation will boost the commercial fishing industry by increasing the duration over which trawlers can safely cross the bar. This will improve catches and reduce risk to equipment, boats and personal safety, creating greater revenue and capital for investment. Improvements in the local fishing industry will also support the activities of the local seafood wholesalers and retailers (Section 7.5.2). All retrieval, transport and placement options would create a navigational obstacle whether fixed or mobile, permanent or short term but this is unlikely to result in any significant cumulative impacts if precautionary measures are taken (Chapter 8).

The improved beach amenity will attract larger numbers of tourists to the region. The continuing nourishment is expected to maintain high quality surfing conditions which will attract surfers and result in flow-on effects to surf-related businesses and other recreational activities. Recreational boating including fishing charters and diving are also expected to benefit from improved navigational safety. Minor adverse impacts will occur during infrastructure installation and the regular nourishment operations but this can be justified by the potential increase in recreational and economic opportunities (Section 7.6.4).

7.8.1 Impacts And Interactions Associated With Climate Change (Greenhouse Effect)

7.8.1.1 Present Position

The Greenhouse Effect is a predicted global climate change associated with a build up of certain gases in the earth's atmosphere. The gases, which include carbon dioxide, nitrous oxide, methane, and chlorofluoro-carbons, are partially opaque to heat radiation emitted from the earth's surface. There is evidence to suggest that these gases are building up in the atmosphere mainly as a by-product of industrialisation. The buildup will cause heat to be trapped in the lower layers of the atmosphere, thus producing an increase in the temperature of the earth.

Over the last 100 years the earth's temperature has risen by about 0.5°C. Numerical models of global atmospheric circulation indicate temperature rises of between 1°C and 5°C in the next 50 years depending on geographic location and the amount of greenhouse gas emissions.

The effect of this possible change in temperature on climate is, as yet, poorly defined due to the complexity of the natural system and in particular the role of water vapour, snow, ice and clouds in producing either net positive or negative feed-back. Considerable uncertainty also exists with regard to future emissions of trace gases and the impact of these gases on atmospheric ozone depletion. Combined with the imperfections of the existing predictive models, this means that the present understanding is based on best estimates rather than firm predictions.

A significant potential impact of the Greenhouse Effect is a predicted rise in mean sea level. This rise would be due to both the thermal expansion of the upper layers of the world's oceans and the melting of the ice sheet. However, only the former is likely to contribute significantly to the effect within the next 30 to 50 year period. A number of other factors may also be affected by a climatic change. These include the severity and frequency of storms which may increase, rainfall intensity which similarly may increase in some areas, and the principal direction of wave attack on the coast which could alter in response to changed patterns of storm generation. These factors are, however, extremely difficult to quantify.

The Intergovernmental Panel on Climatic Change (IPCC) has outlined low, "best estimate" and high estimates for sea level rise to the year 2100 corresponding to various scenarios for sea level rise (IPCC, 1996). So called "Scenario A" which is based on no limitation of greenhouse gas production is considered by the NSW Government (1990) to be the most realistic option to choose for planning purposes at this time. The magnitudes of the postulated sea level rise to the year 2100 associated with "Scenario A" are set out in Table 7.8.1.

Table 7.8.1 Estimates Of Mean Sea Level Rises Associated With The Greenhouse Effect

	Sea Level Rise (m) (Relative to 1990)		
	Year 2030	**Year 2050**	**Year 2100**
Low	0.04	0.10	0.23
"Best Estimate"	0.13	0.24	0.55
High	0.25	0.44	0.96

(Source: IPCC, 1996)

Impact on Wave Climate

Predictions of climate change are not sufficiently advanced to indicate the likely scale of future changes in local wave climate. In broad terms, it is generally accepted that wind patterns will change and that there will be more common and more powerful storms including tropical cyclones. The tropical cyclones could extend to higher latitudes than in the past.

It is considered that apart from possible subtle shifts in wave direction spectra, there is unlikely to be a significant change in the modal wave climate.

In respect of extreme events, however, there could be a more marked change. Based on present scenarios, the frequency of cyclones is likely to increase. The implications to wave heights and directions associated with swell is unknown. On balance, it would appear, that the percentage exceedance of large waves is likely to increase.

Impact on Longshore Transport

Longshore transport is driven by the wave energy flux at the coastline which in turn depends upon the offshore wave height and direction spectra. A substantial proportion of longshore transport occurs in discrete slugs. Slug transport along the southern Gold Coast beaches is a characteristic feature of the area.

The net impact of wave climate change on longshore transport will depend on the natural integration of many features such as:

- changes in deepwater wave height exceedance and direction spectra;
- changes in the episodic nature of longshore transport;
- net effect of wave refraction as waves travel to the shoreline, taking into account the expected rise in sea level; and
- changes in plan shape of the shoreline due to coastal recession or sediment budget impacts associated with a rising sea level;

Until more is known about the implications of the Greenhouse Effect on wave climate, it is not possible to draw any inferences on possible changes to the net longshore transport rate.

Impact on Tweed Training Walls

The maximum height of wave that can impact on the Tweed training walls is limited by the depth of water over the bar. A rise in sea level would therefore have the capacity to lead to a direct increase in the maximum wave height that can reach the training walls. However the average depth of water over the bar would be maintained at a design level, relative to sea level. Hence as sea level rises, the surface of the bar would be allowed to rise an identical amount. Consequently, maximum wave height reaching the walls would not change.

Impact on Estuary Tidal Hydrodynamics

The most significant impact of sea level rise would be a quid-pro-quo increase in half-tide levels throughout the estuary. The natural oscillation of the tide about these elevated half-tide levels, however, varies throughout the estuary. As a general tendency, a rise in half-tide level could be expected to dampen shallow water effects at low tide, leading to relative lowering of the level of low tide and an increase the range of the tide.

PWD (1990) found that a sea level rise of the order of 0.2 m would not produce any significant change in tidal ranges throughout the estuary, irrespective of whether an entrance bypass system is emplaced or not. In other words, a rise in sea level of the order of 0.2 m would lead to local high and low water levels which would be 0.2 m above those which occur under present mean sea level and these changes would occur irrespective of entrance improvements.

Impact on Beaches

A rise in sea level has the potential to cause beach recession because the beach profile would adjust to a new, higher mean position in sea level. Beaches such as Frog Beach and Marley Beach, which are pocketed by bedrock, would not suffer recession, although the average area of subaerial beach would diminish. Kirra Beach will always exhibit fluctuations in beach alignment due to the movement of sand slugs through the area. The Bypassing Project, however, would reduce the fluctuations through direct beach nourishment. A rise in sea level would work against beach nourishment and it will become increasingly difficult to maintain a subaerial beach at Kirra, in the face of a rising sea level.

The remaining, largely unconstrained beaches such as Letitia, Duranbah, Rainbow, Greenmount and Coolangatta would be expected to recede as sea level rises. PWD (1991) estimates that a rise in sea level of the order of 0.1/0.2 m has the potential to cause a recession of the erosion escarpment of Letitia Spit, of approximately 5-10 metres. The nearshore profiles of the southern Gold Coast Beaches are much flatter than those of Letitia Spit. Consequently there would be a trend for greater recession of these beaches possibly up to 150% of that of Letitia Spit.

The plan shape of all beaches in the study area will react to any "Greenhouse" induced change in the net longshore transport. If the long term average net northerly longshore transport (viz: estimated at 500,000 m^3 pa) were to reduce, the alignment of the beaches would be expected to rotate clockwise a slight amount. The converse would hold if there was to be an increase in the long term average net northerly longshore transport.

Until more is known about the impacts of climate change on the local wave climate, it is not possible to indicate the full extent of impact on the beaches, due to climate change. It would appear however, from the foregoing discussion that there is unlikely to be any substantial adverse effects which could threaten coastal assets or beach amenity.

7.8.1.2 Management of Climate Change with a Permanent Bypass System

There is still scientific uncertainty about the magnitude and scope of future climate change due to the Greenhouse Effect. It is generally accepted that the various manifestations of change are gradual. Indeed, this is part of the problem of demonstrating climate change from one contemporary period to the next. Within this context it is appropriate to plan for climate change in an evolving manner as impacts become manifest and predictions of the impacts of climate change to coastal processes become more confident and more specific.

The NSW Government's discussion paper on strategies for living with the Greenhouse Effect (June 1990) highlights the need for adaptive responses so that communities and lifestyles can be adjusted to suit changing climatic conditions and associated effects caused by the Greenhouse Effect. The Government's strategies acknowledge that early planning is essential if the community is to adapt to the exigencies of changed environment. In respect of management of the coastal zone, adaptive responses would include:

- identifying the most sensitive/high risk areas to sea level rise and changes in patterns for climate hazards such as floods and cyclones;
- developing environmental strategies and planning controls to guide development in coastal areas;
- reviewing flood policies and floodplain development codes;
- reviewing building standards in areas where increased cyclonic activity may occur;
- reviewing coastal safety standards and guidelines; and
- reviewing and improving storm and flood forecasting systems.

The underlying performance criteria for a permanent bypassing system at the entrance to the Tweed River, as outlined in the Deed of Agreement represent a blueprint for adaptive response. Because of the very dynamic nature of the coastal environment, a bypassing system designed to cope with the inherent variability of coastal processes, as they are currently understood, will adapt to any shift in these processes due to climate change. There will be opportunities for the bypass system to offset some of the deleterious impacts of climate change.

The adaptive response capability of a permanent bypass system can be summarised as follows:

Change in Wave Climate

The aim of a permanent bypass system is to intercept the longshore transport on an annual basis and deliver it to the various outlet locations. To do this, the system will have the capacity to cope with the peak longshore transport rates associated with annual storms ie storms which can be expected to occur several times a year. A fixed bypass system would probably need to cope with the peak daily longshore transport rate, whilst a mobile system would probably target the weekly/monthly rate. Climate change may increase the frequency of these storms, but their associated peak transport rates would remain within the capacity of the system.

Climate change is most likely to affect extreme wave events such as those associated with cyclones. It is unlikely, however, that any bypass system could be designed to cope with the peak longshore transport rate associated with extreme events. Furthermore, the Stage 1A monitoring data (Section 4.3.2) indicates that the majority of sand mobilised during major storms, is transported across the entrance bar channel.

Longshore Transport Processes

The permanent bypassing system will aim to artificially intercept and deliver to the output locations, the average annual net longshore transport. Various studies have concluded that the current rate is approximately 500,000 m^3 pa. The project performance criteria in the Deed of Agreement, recognise the need to review the net longshore transport rate periodically. Hence the operation of the system would have the flexibility to respond to any shift in the average annual net longshore transport rate or natural bypassing of the bar, due to climate change.

Tweed Training Walls

As discussed above, a permanent bypassing system can be operated to ensure that there would be no change in height of waves impacting upon the Tweed training walls, due to climate change.

Estuary Tidal Hydrodynamics

As discussed above, the likely increase in sea level over the next 25-50 years or so, and the reduction in size of the Tweed entrance bar, as a result of the permanent bypass strategy would not lead to a significant change in tidal ranges throughout the estuary. Both local high and low water would increase by an amount equal to the rise in sea level, irrespective of the condition of the Bar.

Letitia Spit - Beach Recession

As the permanent bypass system will be located at the downdrift end of Letitia Spit, it will not impact on the majority of Letitia Spit.

Process modelling indicates a maximum shoreline retreat of 90m plus the normal variability due to storm erosion and accretion (Section 7.2.3). The recession will depend upon the nature of the successful tender but is likely to be confined to about 1,000 metres of the northern end of Letitia Spit.

It is concluded that the potential recession associated with a rise in sea level over the next 25-50 years, would be totally overshadowed by these project specific impacts.

Duranbah

It is expected that Duranbah Shoals would erode as a result of the bypassing of the majority of longshore transport. Analysis of Stage 1A monitoring data (Section 4.3.2) indicates that the offshore shoals are currently eroding at 100,000 m^3 to 200,000 m^3 pa. The actual long term impact, under a permanent bypass system, will depend upon the trapping efficiency of the system. A system which allows significant quantities of sand to "leak" through the entrance and feed Duranbah shoals (ie. in addition to the Duranbah discharge) would have less impact on Duranbah shoals.

Sustained erosion of the offshore profile can be expected to lead to beach recession. Shoreline modelling (Section 7.2.3.2) indicates that under the worst case scenario of little sand leakage to Duranbah, Duranbah Beach can be expected to undergo 80-90m of recession, as the beach adopts a stable, more southeast orientation. This would be in addition to a 5-10 m recession due to the possible rise in sea level over the next 25 to 50 years.

Hence shoreline recession due to rise in sea level is likely to be overshadowed by project specific impacts. As such they would be readily embraced by beach monitoring and management measures developed to cater for project specific impacts.

Southern Gold Coast Beaches

A rise in sea level can be expected to cause recession of the southern Gold Coast Beaches. A permanent bypass system will offset some of this to an extent by re-establishing the much fuller nearshore profiles of the 60's. However, sustained long term recession would be caused by a rising sea level irrespective of a permanent bypass system. Specific beach management plans and policies will be needed to maintain beach amenity. The presence of a permanent bypassing system may provide the opportunity to modify nourishment quantities and placement to compensate for long term, adverse impacts associated with rising sea levels.

7.8.2 Principles and Application of Ecologically Sustainable Development

The Commonwealth Government in its document "Ecologically Sustainable Development: A Commonwealth Discussion Paper" (1990) defined ecologically sustainable development as:

"using, conserving and enhancing the community's resources so that ecological process, on which life depends, are maintained and the total quality of life, now and in the future can be increased".

Generally, ecologically sustainable development (ESD) aims to address the wise use or reuse of resources.

Legal definition to the concept of sustainable development is provided by the NSW *Protection of the Environment Administration Act 1991* which established the NSW Environment Protection Authority. Section 6 (1) (a) of the Act requires the Authority to:

"have regard to the need to maintain ecologically sustainable development ..... through ..... the effective integration of economic and environmental considerations in the decision making processes".

Core principles aimed at assisting in the achievement of ecologically sustainable development are incorporated into the environmental impact assessment process by Schedule 2 of the NSW *Environmental Planning and Assessment Regulation 1994* as follows:

i. The precautionary principle - namely, that if there are threats of serious or irreversible

environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

ii. Inter-generational equity - namely, that the present generation should ensure that the health, diversity and productivity of the environmental are maintained or enhanced for the benefit of future generations.

iii. Conservation of biological diversity and ecological integrity - namely, that measures which halt the non-evolutionary loss of species and genetic diversity should be pursued.

iv. Improved valuation and pricing of environmental issues -namely, that while prices for natural resources should be set to recover the full social and environmental costs for their use and extraction, many environmental values cannot be priced in monetary terms.

NSW Department of Land and Water Conservation and Queensland Department of Environment as the proponents for this project must have regard for the principles of ESD.

The basis of the Tweed River Entrance Sand Bypassing Project is to reinstate the natural coastal processes which have been interrupted as a result of the extension of the Tweed River training walls. The project entails the core principles of ESD. Further environmental degradation of the southern Gold Coast beaches will be minimised since the natural northward movement of sand along the coast will not be impeded as a result of obstruction by the training walls. The re-establishment of sand bypassing will ensure that the health and diversity of the environment both at the Tweed River and southern Gold Coast will be maintained for future generations. Through reinstatement of the natural sand bypassing regime existing ecosystems will reach an equilibrium state similar to that which existed prior to the extension of the training walls, but with the added benefit of safe navigation of the Tweed River entrance.

Specific examples of how the core principles which have been considered in light of this proposal to implement a permanent sand bypassing system at the Tweed River entrance are discussed below:

i) Precautionary Principle

The formulation of Stage 1 of the Project recognised that in a major coastal project, it is simply not possible to predict the response of the natural system with absolute certainty. Consequently, an environmental monitoring programme was set up to provide feedback about the response of the coastal and estuarine processes to the Stage 1A dredging and nourishment works. The data has provided the opportunity to refine process understanding and examine in more detail the long term implications of a permanent sand bypass system. The long term impacts of this project on the environment are subsequently predicted to be within the natural range of fluctuations experienced within the system.

Achievement of improved navigation at the Tweed entrance and nourishment of the southern Gold Coast beaches must be considered with regard to any potential environmental impacts even where complete understanding of such impacts does not yet exist. Subsequently, the precautionary approach is further adopted throughout the project because although monitoring is a useful guide to predict the potential impacts of this project, it was recognised that further monitoring will be required to refine understanding of the natural system. Therefore the proposed location of the sand retrieval and placement options will be designed to avoid areas of high ecological value or high sensitivity where risk of potential impact may exist. In addition, mitigative measures have been outlined throughout this chapter and specific management and further monitoring is outlined in Chapter 8 to further improve understanding of the process and associated impacts of the project. For example, the placement of sand near Kirra Reef has the potential to smother marine organisms. An exclusion zone around Kirra Reef has therefore been incorporated into the nourishment configurations to ensure that the reef is not

affected by nourishment activities. Where possible, construction activities will be timed to ensure that migratory shorebirds are unaffected. Lack of complete knowledge of the presence of shipwrecks within the sand retrieval compartments means that the precautionary approach will be employed when sand retrieval occurs such that if materials which have the potential to be a wreck are encountered, operations will be stopped until the object has been identified.

ii) Inter-generational Equity

On the natural littoral transport coast, full sand bypassing and deep unbarred entrance are physically incompatible. As noted throughout this document, the construction of the Tweed River training walls to maintain a stable navigation channel has disrupted the natural littoral transport processes and has resulted both in accretion of sand at Letitia Spit and subsequent erosion along the southern Gold Coast beaches. The Permanent Sand Bypassing System endeavours to reinstate longshore transport around Point Danger in conjunction with improving the navigability of the Tweed River entrance. Removal of the sand bar at the entrance will ultimately improve safety and reduce the risk of injury or loss of life to crew and passengers of vessels negotiating the entrance. In addition, removal of the sand bar at the entrance will assist with tidal flushing, decrease sand infilling and help maintain good water quality within the estuary. Nourishment of the southern Gold Coast beaches will ensure the sustainability of sand to provide increased buffer against storm erosion and improve beach amenity. Overall, the Tweed River Sand Bypassing Project has arisen as a result of the need to enhance the Tweed Heads - Gold Coast area for present and future generations.

iii) Conservation of Biological Diversity and Ecological Integrity

This EIS/IAS has assessed the project with regards to the maintenance of habitat and ecosystem diversity and ecological integrity. The impact of sand retrieval and placement operations will be minimised through a good understanding of the existing environment and adopting the "precautionary principle" as stated above where such understanding is not yet available. The study area has been identified as having many areas of high ecological value and biological diversity (for example significant wetlands, shorebird roosts and marine habitats). The 'Do Nothing' alternative discussed in Chapter 6 has described infilling of the lower Tweed estuary will continue such that the tidal ranges and discharges will be more than halved over the next 50 years. This would cause severe deterioration of water quality and loss of habitat in the Tweed estuary. This would also have flow on ramifications to public health, ecology, fishing industry and recreational amenity. Consequently, sand retrieval to improve navigation at the Tweed River entrance and nourishment activities to maintain the southern Gold Coast beaches will assist in the conservation of biological diversity and ecological integrity and the Project will be designed to ensure that potential impacts of construction and operation activities are minimised. Effective management techniques will ensure that areas such as wetlands will not be significantly affected by the project. Migratory bird and shorebird habitats will also be effectively managed to ensure that the areas are unaffected by this project.

iv) Improved Valuation and Pricing of Environmental Resources

The principle of improved valuation and pricing of environmental resources is a key component of inter-generational equity. Aside from the intrinsic value of conserving the biological diversity and ecological integrity of the region for future generations, it is estimated that potential benefits of improved navigation and maintaining the southern Gold Coast beaches will benefit local business and tourism ensuring that quality of life in the region is further enhanced. Through improvement of the natural environment economic and social benefits will accrue, for example improving navigation at the Tweed River entrance, water quality within the estuary will improve due to greater tidal flushing. This will in turn benefit local business such as the oyster farming industry.

7.9 Summary of Impacts

Tables 7.9.1 and 7.9.2 outline a summary of the benefits and impacts associated with the options associated with the permanent sand bypassing project.

Table 7.9.1 Sand Retrieval Options Impacts Matrix

Environmental Criteria	Impacts	Sand Retrieval Options Do Nothing Option	Trailing Suction Hopper Dredger	Cutter Suction Dredger	Jack-up Dredger	Land Based System	Jetty Mounted System	Agitation Dredging	Sand Fluidisation and Slurry Transport
Surface Topography and Drainage	**Positive**	No changes to surface topography in upper reaches of estuary. Existing drainage patterns unaltered. Tidal levels and influence unaltered. No impact on Acid Sulfate Soils. Sand supply to Letitia Spit will continue and consequently maintain the existing beach width.	No changes to surface topography in upper reaches of estuary. Existing drainage patterns unaltered. Tidal levels and influence unaltered. No impact on Acid Sulfate Soils.	-No changes to surface topography in upper reaches of estuary. -Existing drainage patterns unaltered. -Tidal levels and influence unaltered. -No impact on Acid Sulfate Soils.	No changes to surface topography in upper reaches of estuary. Existing drainage patterns unaltered. Tidal levels and influence unaltered. No impact on Acid Sulfate Soils.	No changes to surface topography in upper reaches of estuary. Existing drainage patterns unaltered. Tidal levels and influence unaltered. No impact on Acid Sulfate Soils.	No changes to surface topography in upper reaches of estuary. Existing drainage patterns unaltered. Tidal levels and influence unaltered. No impact on Acid Sulfate Soils.	No changes to surface topography in upper reaches of estuary. Existing drainage patterns unaltered. Tidal levels and influence unaltered. No impact on Acid Sulfate Soils.	No changes to surface topography in upper reaches of estuary. Existing drainage patterns unaltered. Tidal levels and influence unaltered. No impact on Acid Sulfate Soils.
	Negative		Reduction in beach width and modification of dune system at northern extremity of Letitia Spit and Duranbah Beach.	Reduction in beach width and modification of dune system at northern extremity of Letitia Spit and Duranbah Beach.	Reduction in beach width and modification of dune system at northern extremity of Letitia Spit and Duranbah Beach.	Modification to upper beach on Letitia Spit.	More recession of coastline at Letitia Spit.	Reduction in beach width and modification of dune system at northern extremity of Letitia Spit and Duranbah Beach.	Reduction in beach width and modification of dune system at northern extremity of Letitia Spit and Duranbah Beach.
Wave Propagation	**Positive**	Surf quality at Duranbah will be unaltered. Training walls will be unaffected since sand shoals at the river entrance will dissipate wave energy. No alteration to wave penetration into the estuary.	Wave steepening and shoaling will be reduced in entrance bar channel.	Wave steepening and shoaling will be reduced in entrance bar channel.	Wave steepening and shoaling will be reduced in entrance bar channel.	Wave steepening and shoaling will be reduced in entrance bar channel.	Wave steepening and shoaling will be reduced in entrance bar channel.	Wave steepening and shoaling will be reduced in entrance bar channel. Likely to have minimal adverse impact compared to other systems due to dredging not likely to be involved with deep dredging.	Wave steepening and shoaling will be reduced in entrance bar channel.
	Negative	Wave steepening and shoaling on bar will return.	Altered wave refraction may affect surfing quality at Duranbah Beach . Increased exposure of training walls to storm waves. Increase of wave penetration into estuary but no significant impacts.	Altered wave refraction may affect surfing quality at Duranbah Beach . Increased exposure of training walls to storm waves. Increase of wave penetration into estuary but no significant impacts.	Altered wave refraction may affect surfing quality at Duranbah Beach . Increased exposure of training walls to storm waves. Increase of wave penetration into estuary but no significant impacts.	Altered wave refraction may affect surfing quality at Duranbah Beach . Increased exposure of training walls to storm waves. Increase of wave penetration into estuary but no significant impacts.	Altered wave refraction may affect surfing quality at Duranbah Beach . Increased exposure of training walls to storm waves. Increase of wave penetration into estuary but no significant impacts.	No system specific impacts.	Altered wave refraction may affect surfing quality at Duranbah Beach . Increased exposure of training walls to storm waves. Increase of wave penetration into estuary but no significant impacts.
Turbidity	**Positive**	No changes to low turbidity of ocean water quality.	No significant increases in background turbidity levels.	No significant increases in background turbidity levels.	No significant increases in background turbidity levels.	No system specific impacts.	No significant increases in background turbidity levels.	No system specific impacts.	No significant increases in background turbidity levels.
	Negative		No system specific impacts.	No system specific impacts.	No system specific impacts.	No system specific impacts.	No system specific impacts.	Generation of highest turbidity but system is likely to be restricted to areas of high wave energy where natural turbidity levels are higher.	No system specific impacts.
Water Quality	**Positive**	No changes to high ocean water quality.	No system specific impacts.	No system specific impacts.	No system specific impacts.	No system specific impacts.	No system specific impacts.	No system specific impacts.	No system specific impacts.
	Negative		No system specific impacts.	No system specific impacts.	No system specific impacts.	No system specific impacts.	No system specific impacts.	No system specific impacts.	No system specific impacts.
Sediment Quality	**Positive**	No changes to clean fine sand quality of marine sediment.	Sand on the bar is part of the longshore continuum between Letitia Spit and Gold Coast beaches hence no adverse impact on sediment quality.	Sand on the bar is part of the longshore continuum between Letitia Spit and Gold Coast beaches hence no adverse impact on sediment quality.	Sand on the bar is part of the longshore continuum between Letitia Spit and Gold Coast beaches hence no adverse impact on sediment quality.	Sand on the bar is part of the longshore continuum between Letitia Spit and Gold Coast beaches hence no adverse impact on sediment quality.	Sand on the bar is part of the longshore continuum between Letitia Spit and Gold Coast beaches hence no adverse impact on sediment quality.	Sand on the bar is part of the longshore continuum between Letitia Spit and Gold Coast beaches hence no adverse impact on sediment quality.	Sand on the bar is part of the longshore continuum between Letitia Spit and Gold Coast beaches hence no adverse impact on sediment quality.
	Negative		No system specific impacts.	No system specific impacts.	No system specific impacts.	No system specific impacts.	No system specific impacts.	No system specific impacts.	No system specific impacts.
Beach Systems	**Positive**	Beach and dune system at Letitia Spit will be unaffected. Beach and surf conditions at	Improved coastal protection and beach amenity of southern Gold Coast.	Improved coastal protection and beach amenity of southern Gold Coast.	Improved coastal protection and beach amenity of southern Gold Coast.	Improved coastal protection and beach amenity of southern Gold Coast.	Improved coastal protection and beach amenity of southern Gold Coast.	Improved coastal protection and beach amenity of southern Gold Coast.	Improved coastal protection and beach amenity of southern Gold Coast.

		Sand Retrieval Options							
Environmental Criteria	**Impacts**	**Do Nothing Option**	**Trailing Suction Hopper Dredger**	**Cutter Suction Dredger**	**Jack-up Dredger**	**Land Based System**	**Jetty Mounted System**	**Agitation Dredging**	**Sand Fluidisation and Slurry Transport**
		Duranbah will not be affected.							
	Negative	Loss of 3.5 million cu. m. of sand to southern Gold Coast beaches.	Alteration of beach system and modification of dune system at Letitia Spit however present beach and dune system are largely artificial due to construction of training walls. The net sand supply to Duranbah will be reduced and nearshore shoals will erode depending upon trapping efficiency of system. Retreat and realignment of Duranbah to a southeast facing shape depending upon trapping efficiency of system.	Alteration of beach system and modification of dune system at Letitia Spit however present beach and dune system are largely artificial due to construction of training walls. The net sand supply to Duranbah will be reduced and nearshore shoals will erode depending upon trapping efficiency of system. Retreat and realignment of Duranbah to a southeast facing shape depending upon trapping efficiency of system.	Alteration of beach system and modification of dune system at Letitia Spit however present beach and dune system are largely artificial due to construction of training walls. The net sand supply to Duranbah will be reduced and nearshore shoals will erode depending upon trapping efficiency of system. Retreat and realignment of Duranbah to a southeast facing shape depending upon trapping efficiency of system.	Modification of upper beach on Letitia Spit. Modification of dune system at Letitia Spit however present beach and dune system are largely artificial due to construction of training walls. The net sand supply to Duranbah will be reduced and nearshore shoals will erode depending upon trapping efficiency of system. Retreat and realignment of Duranbah to a southeast facing shape depending upon trapping efficiency of system.	Localised retreat of beach south of Tweed River entrance. Modification of dune system at Letitia Spit however present beach and dune system are largely artificial due to construction of training walls. The net sand supply to Duranbah will be reduced and nearshore shoals will erode depending upon trapping efficiency of system. Retreat and realignment of Duranbah to a southeast facing shape depending upon trapping efficiency of system.	Alteration of beach system and modification of dune system at Letitia Spit however present beach and dune system are largely artificial due to construction of training walls. The net sand supply to Duranbah will be reduced and nearshore shoals will erode depending upon trapping efficiency of system. Retreat and realignment of Duranbah to a southeast facing shape depending upon trapping efficiency of system.	Alteration of beach system and modification of dune system at Letitia Spit however present beach and dune system are largely artificial due to construction of training walls. The net sand supply to Duranbah will be reduced and nearshore shoals will erode depending upon trapping efficiency of system. -Retreat and realignment of Duranbah to a southeast facing shape depending upon trapping efficiency of system.
Tweed River Entrance	**Positive**	Training walls will not be threatened by increased waves at walls. Training walls will not need strengthening.	Entrance bar channel depth maintained.	Entrance bar channel depth maintained.	Entrance bar channel depth maintained.	Entrance bar channel depth maintained.	Entrance bar channel depth maintained. System will require relatively smaller sand trap size.	Entrance bar channel depth maintained.	Entrance bar channel depth maintained.
	Negative	Entrance channel will continue to infill. Bar infilling until equilibrium in about 20 years. Bar depths and navigation will worsen.	Depending on the bar depth the height of waves during severe storms may be increased leading to possible damage or failure of training walls. Bar configuration will have impact on height of waves breaking against walls. Depending on bar depth, Strengthening of training walls could occur with a cost up to $5-10 M depending on bar configuration. System could require larger sand trap size depending upon frequency of dredging.	Depending on the bar depth the height of waves during severe storms may be increased leading to possible damage or failure of training walls. Bar configuration will have impact on height of waves breaking against walls. Depending on bar depth, Strengthening of training walls could occur with a cost up to $5-10 M depending on bar configuration. System could require largest sand trap size because of difficulty of working in waves.	Depending on the bar depth the height of waves during severe storms may be increased leading to possible damage or failure of training walls. Bar configuration will have impact on height of waves breaking against walls. Depending on bar depth, Strengthening of training walls could occur with a cost up to $5-10 M depending on bar configuration. System will require modest sand trap size depending on actual operation mode.	Depending on the bar depth the height of waves during severe storms may be increased leading to possible damage or failure of training walls. Bar configuration will have impact on height of waves breaking against walls. Depending on bar depth, Strengthening of training walls could occur with a cost up to $5-10 M depending on bar configuration. System will require large sand trap provisions.	Depending on the bar depth the height of waves during severe storms may be increased leading to possible damage or failure of training walls. Bar configuration will have impact on height of waves breaking against walls. Depending on bar depth, Strengthening of training walls could occur with a cost up to $5-10 M depending on bar configuration.	Depending on the bar depth the height of waves during severe storms may be increased leading to possible damage or failure of training walls. Bar configuration will have impact on height of waves breaking against walls. -Depending on bar depth, -Strengthening of training walls could occur with a cost up to $5-10 M depending on bar configuration.	Depending on the bar depth the height of waves during severe storms may be increased leading to possible damage or failure of training walls. Bar configuration will have impact on height of waves breaking against walls. Depending on bar depth, Strengthening of training walls could occur with a cost up to $5-10 M depending on bar configuration.
Tweed River Estuary	**Positive**	Estuarine ecosystems will be maintained. Lower estuary marine shoals will recover from flood events in 2-3 years.	Change in tidal levels will not be significant. In conjunction with the Tweed Estuary Management Plan, improvement of tidal mixing and flushing (improved water quality) of main arm . Substantial reduction of net infeed of marine sand into estuary. No impact on flood flows. No threat to existing internal training wall or parkland behind from wave penetration. No significant impact on storm surge into the estuary.	Change in tidal levels will not be significant. In conjunction with the Tweed Estuary Management Plan, improvement of tidal mixing and flushing (improved water quality) of main arm . Substantial reduction of net infeed of marine sand into estuary. No impact on flood flows. No threat to existing internal training wall or parkland behind from wave penetration. No significant impact on storm surge into the estuary.	Change in tidal levels will not be significant. In conjunction with the Tweed Estuary Management Plan, improvement of tidal mixing and flushing (improved water quality) of main arm . Substantial reduction of net infeed of marine sand into estuary. No impact on flood flows. No threat to existing internal training wall or parkland behind from wave penetration. No significant impact on storm surge into the estuary.	Change in tidal levels will not be significant. In conjunction with the Tweed Estuary Management Plan, improvement of tidal mixing and flushing (improved water quality) of main arm . Substantial reduction of net infeed of marine sand into estuary. No impact on flood flows. No threat to existing internal training wall or parkland behind from wave penetration. No significant impact on storm surge into the estuary.	Change in tidal levels will not be significant. In conjunction with the Tweed Estuary Management Plan, improvement of tidal mixing and flushing (improved water quality) of main arm . Substantial reduction of net infeed of marine sand into estuary. No impact on flood flows. No threat to existing internal training wall or parkland behind from wave penetration. No significant impact on storm surge into the estuary.	Change in tidal levels will not be significant. In conjunction with the Tweed Estuary Management Plan, improvement of tidal mixing and flushing (improved water quality) of main arm . Substantial reduction of net infeed of marine sand into estuary. No impact on flood flows. No threat to existing internal training wall or parkland behind from wave penetration. No significant impact on storm surge into the estuary.	Change in tidal levels will not be significant. In conjunction with the Tweed Estuary Management Plan, improvement of tidal mixing and flushing (improved water quality) of main arm . Substantial reduction of net infeed of marine sand into estuary. No impact on flood flows. No threat to existing internal training wall or parkland behind from wave penetration. No significant impact on storm surge into the lower estuary.
	Negative	If no works to curb marine infill major water quality	Lower estuary marine shoals will be slower to recover	Lower estuary marine shoals will be slower to recover from	Lower estuary marine shoals will be slower to recover from	Lower estuary marine shoals will be slower to recover from	Lower estuary marine shoals will be slower to recover from	Lower estuary marine shoals will be slower to recover from	Lower estuary marine shoals will be slower to recover from

		Sand Retrieval Options							
Environmental Criteria	**Impacts**	**Do Nothing Option**	**Trailing Suction Hopper Dredger**	**Cutter Suction Dredger**	**Jack-up Dredger**	**Land Based System**	**Jetty Mounted System**	**Agitation Dredging**	**Sand Fluidisation and Slurry Transport**
		problem will arise. Improved tidal mixing and flushing objectives of the Tweed Estuary Management Plan not achievable. Maintenance of lower estuary marine shoals required frequently.	from flood events.	flood events.	flood events.	flood events.	flood events.	flood events.	flood events.
Marine Ecology	**Positive**	Existing environment and species composition will be maintained. Areas of significant ecological value unaltered. Path of migrating finfish will be unaffected. No impact on benthos.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	The jetty mounted system may create new reef type habitat.	Minimal system specific impacts due to dredging occurring in areas of high energy which are often devoid of benthos.	No system specific Impacts.
	Negative		Short term impact on benthos. Minimal interruption to organisms and recolonisation possible due to shallow, intermittent dredging pattern.	Short term impact on benthos. Minimal interruption to organisms and recolonisation possible due to shallow, intermittent dredging pattern.	Short term impact on benthos. Minimal interruption to organisms and recolonisation possible due to shallow, intermittent dredging pattern.	Short term impact on beach worm habitat.	The jetty mounted system may cause alteration of species composition. The jetty mounted system may create zones devoid of benthic invertebrates. Potential alteration of the path of migrating fin fish.	No system specific Impacts.	Short term impact on benthos Semipermanent nature results in creation of zones devoid of fauna in sand trap areas
Estuarine Ecology	**Positive**	Entrance shoals will recover from flood events as in the past and therefore maintain estuary environment and ecology. Movement of migratory fish species into estuary unaltered.	Negligible impact in tidal ranges. Insignificant direct ecological impacts. Permanent system will result in stabilisation of intertidal wetlands. Mitigating measures available to maintain the tidal range at pre-flood conditions such as installation of temporary sand pumping pipeline from the permanent bypassing system. Improved tidal flushing will improve water quality.	Negligible impact in tidal ranges. Insignificant direct ecological impacts. Permanent system will result in stabilisation of intertidal wetlands. Mitigating measures available to maintain the tidal range at pre-flood conditions such as installation of temporary sand pumping pipeline from the permanent bypassing system. Improved tidal flushing will improve water quality.	Negligible impact in tidal ranges. Insignificant direct ecological impacts. Permanent system will result in stabilisation of intertidal wetlands. Mitigating measures available to maintain the tidal range at pre-flood conditions such as installation of temporary sand pumping pipeline from the permanent bypassing system. Improved tidal flushing will improve water quality.	Negligible impact in tidal ranges. Insignificant direct ecological impacts. Permanent system will result in stabilisation of intertidal wetlands. Mitigating measures available to maintain the tidal range at pre-flood conditions such as installation of temporary sand pumping pipeline from the permanent bypassing system. Improved tidal flushing will improve water quality.	Negligible impact in tidal ranges. Insignificant direct ecological impacts. Permanent system will result in stabilisation of intertidal wetlands. Mitigating measures available to maintain the tidal range at pre-flood conditions such as installation of temporary sand pumping pipeline from the permanent bypassing system. Improved tidal flushing will improve water quality.	Negligible impact in tidal ranges. Insignificant direct ecological impacts. Permanent system will result in stabilisation of intertidal wetlands. Mitigating measures available to maintain the tidal range at pre-flood conditions such as installation of temporary sand pumping pipeline from the permanent bypassing system. Improved tidal flushing will improve water quality.	Negligible impact in tidal ranges. Insignificant direct ecological impacts. Permanent system will result in stabilisation of intertidal wetlands. Mitigating measures available to maintain the tidal range at pre-flood conditions such as installation of temporary sand pumping pipeline from the permanent bypassing system. Improved tidal flushing will improve water quality.
	Negative	If no works to curb marine infill major water quality problem will arise.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	Potential to inhibit migratory fish species from entering Tweed River estuary	No system specific Impacts.	No system specific Impacts.

Environmental Criteria	Impacts	Sand Retrieval Options Do Nothing Option	Trailing Suction Hopper Dredger	Cutter Suction Dredger	Jack-up Dredger	Land Based System	Jetty Mounted System	Agitation Dredging	Sand Fluidisation and Slurry Transport
Shorebirds	**Positive**	Waterbird and endangered Little Tern roosting sites unaffected.	No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts
	Negative	Disturbance of waterbirds at roosts on Tweed estuary is increasing as a consequence of increased recreational use of the estuary.	Disruption of shorebird habitat on northern end of Letitia Spit as a result of infrastructure or foreshore retreat. Shorebird habitat will require management.	Disruption of shorebird habitat on northern end of Letitia Spit as a result of infrastructure or foreshore retreat. Shorebird habitat will require management.	Disruption of shorebird habitat on northern end of Letitia Spit as a result of infrastructure or foreshore retreat. Shorebird habitat will require management.	-Location of pipeline and sand removal from intertidal area associated with mobile land based systems at Fingal Peninsula will disturb large waterbird roosting site and endangered little tern roosting and breeding areas at South Head beach.	Construction and operation of the fixed jetty mounted system will disturb waterbird roosts at South Head beach and Kerosene Inlet. Clear water intake may disturb major roosts in Tweed River estuary.	Disruption of shorebird habitat on northern end of Letitia Spit as a result of infrastructure or foreshore retreat. Shorebird habitat will require management.	Disruption of shorebird habitat on northern end of Letitia Spit as a result of infrastructure or foreshore retreat. Shorebird habitat will require management.
Landuse, Zoning and Tenure	**Positive**		No significant impact on private land holdings or zoning. No changes to private property boundaries. No need to formally acquire lands.	No significant impact on private land holdings or zoning. No changes to private property boundaries. No need to formally acquire lands.	No significant impact on private land holdings or zoning. No changes to private property boundaries. No need to formally acquire lands.	No significant impact on private land holdings or zoning. No changes to private property boundaries. No need to formally acquire lands.	No significant impact on private land holdings or zoning. No changes to private property boundaries. No need to formally acquire lands.	No significant impact on private land holdings or zoning. No changes to private property boundaries. No need to formally acquire lands.	No significant impact on private land holdings or zoning. No changes to private property boundaries. No need to formally acquire lands.
	Negative		No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.
Aboriginal and Post Contact Heritage	**Positive**	No known significant aboriginal sites and historical shipwrecks in area to be dredged.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.
	Negative	Potential shipwrecks or aboriginal sites at Letitia Spit. Possible wrecked trawler south of the southern breakwater.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.
Socio-economic Profile	**Positive**	Public access to beaches will not be affected.	Substantial recreational and economic impacts.	Substantial recreational and economic impacts.	Substantial recreational and economic impacts.	Substantial recreational and economic impacts.	Substantial recreational and economic impacts.	Substantial recreational and economic impacts.	Substantial recreational and economic impacts.
	Negative	Continual risk to life of mariners. Decline of local business associated with safe navigation of the Tweed River entrance. Loss of benefits to other business in the regions.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	Public beach access and public safety on beaches may be limited during operation.	Public beach access and public safety on beaches may be limited during construction.	No system specific Impacts.	No system specific Impacts.
Business, recreation and Tourism	**Positive**	Beach access and surfing will not be interrupted.	Improved viability of the Tweed fishing industry. Increased boating (including ocean going vessels) within Tweed estuary. Establish consistent, good surfing and beach amenity in all seasons. Revenue from tourism likely to increase. Benefit to local commercial and retail businesses. Oyster fisheries will benefit from improved tidal flushing of estuary. Possibility of local employment Benefits.	Improved viability of the Tweed fishing industry. Increased boating (including ocean going vessels) within Tweed estuary. Establish consistent, good surfing and beach amenity in all seasons. Revenue from tourism likely to increase. Benefit to local commercial and retail businesses. Oyster fisheries will benefit from improved tidal flushing of estuary. Possibility of local employment Benefits.	Improved viability of the Tweed fishing industry. Increased boating (including ocean going vessels) within Tweed estuary. Establish consistent, good surfing and beach amenity in all seasons. Revenue from tourism likely to increase. Benefit to local commercial and retail businesses. Oyster fisheries will benefit from improved tidal flushing of estuary. Possibility of local employment Benefits.	Improved viability of the Tweed fishing industry. Increased boating (including ocean going vessels) within Tweed estuary. Establish consistent, good surfing and beach amenity in all seasons. Revenue from tourism likely to increase. Benefit to local commercial and retail businesses. Oyster fisheries will benefit from improved tidal flushing of estuary. Possibility of local employment Benefits.	Recreational fishing may be improved due to creation of a reef-like habitat and provision of public access to a jetty structure. Improved viability of the Tweed fishing industry. Increased boating (including ocean going vessels) within Tweed estuary. Establish consistent, good surfing and beach amenity in all seasons. Revenue from tourism likely to increase. Benefit to local commercial and retail businesses. Oyster fisheries will benefit from improved tidal flushing of estuary.	Improved viability of the Tweed fishing industry. -Increased boating (including ocean going vessels) within Tweed estuary. Establish consistent, good surfing and beach amenity in all seasons. Revenue from tourism likely to increase. Benefit to local commercial and retail businesses. Oyster fisheries will benefit from improved tidal flushing of estuary. Possibility of local employment Benefits.	Improved viability of the Tweed fishing industry. Increased boating (including ocean going vessels) within Tweed estuary. Establish consistent, good surfing and beach amenity in all seasons. Revenue from tourism likely to increase. Benefit to local commercial and retail businesses. Oyster fisheries will benefit from improved tidal flushing of estuary. Possibility of local employment Benefits.

Environmental Criteria	Impacts	Sand Retrieval Options Do Nothing Option	Trailing Suction Hopper Dredger	Cutter Suction Dredger	Jack-up Dredger	Land Based System	Jetty Mounted System	Agitation Dredging	Sand Fluidisation and Slurry Transport
							Possibility of local employment Benefits.		
	Negative	Decline of local fishing industry. Limited boating within Tweed River estuary. Limited growth in commercial and retail business. Oyster fisheries will not benefit from improved water quality in estuary. Reduction in growth of local business. Reduced possibility of local employment benefits. Recreational fishers will not benefit from possible installation of jetty.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	No system specific Impacts.	Construction may cause temporary disturbance of beach access and surfing conditions.	No system specific Impacts.	No system specific Impacts.
Visual Amenity	**Positive**	Existing high visual amenity will not be reduced due to construction and operation of system.	Lowest visual impacts of all options. Period of impact relatively short. Visually related to the imagery and context of the area.	Semi permanent impact.	Semi permanent impact.	Semi permanent impact.	No system specific Impacts	-Semi permanent impact.	No system specific Impacts
	Negative	Visual amenity of the southern Gold Coast beaches could decline with continual beach erosion.	High but intermittent visual impacts from major vista points (may not be on site for many weeks at a time).	Generally visible from major vista points. High impact on naturalism of views.	Highly visible from major vista points. High impact on naturalism of views. Large, industrial appearance.	Generally visible from major vista points. High impact on naturalism of views.	Highly visible from major vista points Permanent therefore long term visual impact High existing visual sensitivity of Letitia Spit Large size and industrial appearance.	Generally visible from major vista points.	Visible from major vista points. Industrial form. Permanent therefore long term visual impact.
Navigation	**Positive**		Increased safety of navigation of entrance, particularly during incoming tide. Infilling of navigation channels within the estuary reduced. Potential infilling of secondary channel of main arm reduced. Larger vessels will be able to more safely navigate the entrance	Increased safety of navigation of entrance, particularly during incoming tide. Infilling of navigation channels within the estuary reduced. Potential infilling of secondary channel of main arm reduced. Larger vessels will be able to more safely navigate the entrance	Increased safety of navigation of entrance, particularly during incoming tide. Infilling of navigation channels within the estuary reduced. Potential infilling of secondary channel of main arm reduced. Larger vessels will be able to more safely navigate the entrance.	Increased safety of navigation of entrance, particularly during incoming tide. Infilling of navigation channels within the estuary reduced. Potential infilling of secondary channel of main arm reduced. Larger vessels will be able to more safely navigate the entrance.	Increased safety of navigation of entrance, particularly during incoming tide. Infilling of navigation channels within the estuary reduced. Potential infilling of secondary channel of main arm reduced. Larger vessels will be able to more safely navigate the entrance.	Increased safety of navigation of entrance, particularly during incoming tide. Infilling of navigation channels within the estuary reduced. Potential infilling of secondary channel of main arm reduced. Larger vessels will be able to more safely navigate the entrance.	Increased safety of navigation of entrance, particularly during incoming tide. Infilling of navigation channels within the estuary reduced. Potential infilling of secondary channel of main arm reduced. Larger vessels will be able to more safely navigate the entrance.
	Negative	- Continual infilling of estuary resulting in navigation problems at Boyds Bay, Terranora Inlet and new area at downstream end of secondary channel of main arm. - Navigational safety will decline on entrance bar. - Large vessels in particular will be unable to safely navigate the Tweed River entrance	Operation may result in occasional obstruction of channel for short periods.	Operation may result in occasional obstruction of channel for short periods.	Operation may result in occasional obstruction of channel for short periods.	Will not achieve navigation objectives on its own - only used as part of a hybrid system.	Due to natural bypass of longshore transport occasional bar dredging will be required. Public safety may be limited during construction of bypass system.	Will not achieve navigation objectives on its own - only used as part of a hybrid system.	No system specific Impacts.

Environmental Criteria	Impacts	Sand Retrieval Options Do Nothing Option	Trailing Suction Hopper Dredger	Cutter Suction Dredger	Jack-up Dredger	Land Based System	Jetty Mounted System	Agitation Dredging	Sand Fluidisation and Slurry Transport
		- Estuary navigation channels maintenance strategy required as part of Lower Estuary Marine Shoals Management Strategy.							
Noise	**Positive**	Existing noise conditions will be maintained.	Noise sensitive receptors relatively remote.	Frontal dune may act to buffer noise impact on low rise developments.	Noise sensitive receptors relatively remote.	Frontal dune may act to buffer noise impact on low rise developments.	Potential to ameliorate noise generated.	Noise sensitive receptors relatively remote.	Noise sensitive receptors relatively remote. Noise amelioration possible
	Negative		Noise impacts if used within estuary. Noise impacts on ecology. Tweed River foreshore between Jack Evans Boatharbour and Terranora Inlet areas have high noise sensitivity.	Noise amelioration difficult. Noise impacts on ecology. Tweed River foreshore between Jack Evans Boatharbour and Terranora Inlet areas have high noise sensitivity.	Noise impacts if used within estuary. Requires a large level of shore infrastructure relative to other options with associated noise impacts. Noise impacts on ecology. Tweed River foreshore between Jack Evans Boatharbour and Terranora Inlet areas have high noise sensitivity.	Noise amelioration difficult. Noise impacts on ecology. Tweed River foreshore between Jack Evans Boatharbour and Terranora Inlet areas have high noise sensitivity.	Increased noise resulting from plant at the restaurant and Clubhouse at Jack Evans Boatharbour. Increased noise at Eden and Bay Streets. Noise impacts on ecology. Tweed River foreshore between Jack Evans Boatharbour and Terranora Inlet areas have high noise sensitivity.	Noise impacts on ecology. Tweed River foreshore between Jack Evans Boatharbour and Terranora Inlet areas have high noise sensitivity.	Clean water intake will increase noise levels in adjacent areas.
Air Quality	**Positive**	Existing high air quality will be maintained.	No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts	System electricity powered therefore no emissions in local area.	No system specific Impacts	System electricity powered therefore no emissions in local area.
	Negative		Fuel powered therefore production of emissions	Fuel powered therefore production of emissions	Fuel powered therefore production of emissions	Fuel powered therefore production of emissions	No system specific Impacts	Fuel powered therefore production of emissions	No system specific Impacts
Traffic	**Positive**	Existing traffic movements would continue.	No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts
	Negative		No system specific Impacts	No system specific Impacts	No system specific Impacts	May need construction of a sealed road along Letitia Spit.	May need construction of a sealed road along Letitia Spit.	No system specific Impacts	No system specific Impacts
Hazard	**Positive**	No potential fuel spillage. No navigation hazard during construction and operation.	Reduction in hazard by improved navigation.	Reduction in hazard by improved navigation.	Reduction in hazard by improved navigation.	Reduction in hazard by improved navigation.	Reduction in hazard by improved navigation.	Reduction in hazard by improved navigation.	Reduction in hazard by improved navigation.
	Negative	Hazard associated with navigating the entrance channel will increase.	Potential fuel spillage from plant. Use of entrance by increased number of vessels and inexperienced sailors. Potential navigational hazard during operation. Operational restrictions due to shark meshing equipment.	Potential fuel spillage from plant. Use of entrance by increased number of vessels and inexperienced sailors. Potential navigational hazard during operation. Operational restrictions due to shark meshing equipment.	Potential fuel spillage from plant. Use of entrance by increased number of vessels and inexperienced sailors. Potential navigational hazard during operation. Operational restrictions due to shark meshing equipment.	Potential fuel spillage from plant. Use of entrance by increased number of vessels and inexperienced sailors.	Use of entrance by increased number of vessels and inexperienced sailors. Potential navigational hazard during construction and operation.	Use of entrance by increased number of vessels and inexperienced sailors. Potential navigational hazard during operation.	Use of entrance by increased number of vessels and inexperienced sailors. Potential navigational hazard during construction and operation. Operational restrictions due to shark meshing equipment.

Table 7.9.2 Sand Transport and Placement Options Impacts Matrix

		Sand Transport and Placement Options				
Environmental Criteria	**Impacts**	**Do Nothing Option**	**Pipeline and Ancillary Equipment**	**Bottom Dumping**	**Pumping Ashore**	**Discharge Outlets**
Surface Topography and Drainage	**Positive**	Existing terrestrial drainage patterns unaltered. No impact on ASS.	Existing terrestrial drainage patterns unaltered. No land based dewatering of dredged sediments and therefore no impact on Acid Sulfate Soils. Protection and enhancement of beach and dune systems in the nourishment areas.	Existing terrestrial drainage patterns unaltered. No land based dewatering of dredged sediments and therefore no impact on Acid Sulfate Soils. Protection and enhancement of beach and dune systems in the nourishment areas.	Existing terrestrial drainage patterns unaltered. No land based dewatering of dredged sediments and therefore no impact on Acid Sulfate Soils. Protection and enhancement of beach and dune systems in the nourishment areas.	Existing terrestrial drainage patterns unaltered. No land based dewatering of dredged sediments and therefore no impact on Acid Sulfate Soils. Protection and enhancement of beach and dune systems in the nourishment areas.
	Negative	Existing dune and beach systems will continue to be eroded.	No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts
Turbidity	**Positive**	No changes to low turbidity of ocean water quality.	No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts
	Negative		No system specific Impacts	Turbidity plumes will be contained within an approx. distance of 50m from the point of discharge. However, plume will be short lived and last some 2-3 minutes after cessation of sand pumping activities.	No system specific Impacts	Turbidity plumes will be contained within an approx. distance of 50m from the point of discharge. However, plume will be short lived and last some 2-3 minutes after cessation of sand pumping activities.
Water Quality	**Positive**	No changes to high ocean water quality.	No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts
	Negative		No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts
Sediment Quality	**Positive**	No changes to clean fine sand quality of marine sediment.	Sand on the bar is part of the longshore continuum between Letitia Spit and Gold Coast beaches hence no adverse impact on sediment quality.	Sand on the bar is part of the longshore continuum between Letitia Spit and Gold Coast beaches hence no adverse impact on sediment quality.	Sand on the bar is part of the longshore continuum between Letitia Spit and Gold Coast beaches hence no adverse impact on sediment quality.	Sand on the bar is part of the longshore continuum between Letitia Spit and Gold Coast beaches hence no adverse impact on sediment quality.
	Negative		No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts
Beach Systems	**Positive**		Beach width increased at Rainbow Bay, Greenmount and Kirra. Enhanced surfing conditions at Rainbow Bay, Greenmount and Kirra. Potential periodic development of beach at Marleys and Frogs Beach. Cost-effective method of sand placement. Beach conditions at Rainbow Bay will be maintained. Storm erosion will have less impact on beach amenity. Reduction in variability of Kirra Beach.	Allows nourishment of offshore profile ie., re-establishment of long term bathymetry. Provides opportunity to quickly create initial bar systems which will be reworked by waves and create enhanced surfing conditions.	Allows nourishment of offshore profile ie., re-establishment of long term bathymetry.	Allows nourishment of offshore profile ie., re-establishment of long term bathymetry.
	Negative	- Southern Gold Coast beaches will continue to erode. - Enhancement of surf conditions will not be feasible. - Impact of storm erosion on Gold Coast beaches will be more significant.	Requires ancillary beach spreading plant if discharge is subaerial.	No immediate benefit to subaerial beach.	No system specific Impacts.	No system specific Impacts.
Marine Ecological	**Positive**		Less impact on marine	No system specific Impacts	No system specific Impacts	Re-establishment of new

		Sand Transport and Placement Options				
Environmental Criteria	**Impacts**	**Do Nothing Option**	**Pipeline and Ancillary Equipment**	**Bottom Dumping**	**Pumping Ashore**	**Discharge Outlets**
Environment			organisms through smothering. Re-establishment of new reef habitats on any trestle structure.			reef habitats on any trestle structure.
	Negative		Potential alteration of the path of migrating fin fish for trestle structure. Short term impact on benthic habitat. Potential sand migration onto Kirra Reef however any such movement would replicate historical natural sand transport patterns.	Short term impact on benthic habitat. Potential sand migration onto Kirra Reef however any such movement would replicate historical natural sand transport patterns.	Short term impact beach worm habitat.	Potential alteration of the path of migrating fin fish for trestle structure. Short term impact on benthic habitat. Potential sand migration onto Kirra Reef however any such movement would replicate historical natural sand transport patterns.
Estuarine Ecological Environment	**Positive**		Insignificant direct ecological impacts.	Insignificant direct ecological impacts.	Insignificant direct ecological impacts.	Insignificant direct ecological impacts.
	Negative		No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts
Shorebirds	**Positive**		No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts
	Negative		Location of pipeline associated with mobile land based systems at Fingal Peninsula will disturb large waterbird roosting site and endangered little tern roosting and breeding areas at South Head beach.	No system specific Impacts	No system specific Impacts	No system specific Impacts
Landuse, Zoning and Tenure	**Positive**		No significant impact on private land holdings or zoning. No changes to private property boundaries. No need to formally acquire lands.	No significant impact on private land holdings or zoning. No changes to private property boundaries. No need to formally acquire lands.	No significant impact on private land holdings or zoning. No changes to private property boundaries. No need to formally acquire lands.	No significant impact on private land holdings or zoning. No changes to private property boundaries. No need to formally acquire lands.
	Negative		No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts
Aboriginal and Post Contact Heritage	**Positive**		No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts
	Negative		Pipeline associated with jack-up dredging has the potential to impact on Aboriginal midden sites located at the northern edge of Jack Evans Boatharbour.	No system specific Impacts	No system specific Impacts	No system specific Impacts
Socio-economic Profile	**Positive**		No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts
	Negative		Public beach access and public safety on beaches may be limited during construction.	No system specific Impacts	Public beach access and public safety on beaches may be limited during periods of nourishment.	Public beach access and public safety on beaches may be limited during construction.
Business, Recreation and Tourism	**Positive**		No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts
	Negative		Construction may cause temporary disturbance of beach use.	Can effect nearshore wave shoaling and surfing conditions.	Operation may cause temporary disturbance of beach use.	Construction may cause temporary disturbance of beach use.
Visual Amenity	**Positive**	Existing visual amenity will not be altered.	Relatively non-intrusive visually.	In context with regional setting. Minimal impact on expectation of views.	Impact periodic, not continuous.	Submerged outlets not visible.
	Negative	Visual amenity of southern Gold Coast beaches will be degraded if beaches	Permanent visual impact for trestle system.	Highly visible from major vista points however impact intermittent and short term.	Temporary impact while sand spreading plant operating.	Exposed outlets are permanent and partially visible from major vista

Environmental Criteria	Impacts	Sand Transport and Placement Options				
		Do Nothing Option	Pipeline and Ancillary Equipment	Bottom Dumping	Pumping Ashore	Discharge Outlets
		become further eroded.				points.
Navigation	Positive	No impact on public safety as a result of construction or operation.	No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts
	Negative		Public safety may be limited due to construction and operation of bypass system.	Public safety may be limited due to operation of bypass system.	Public safety may be limited due to operation of bypass system.	Public safety may be limited due to construction and operation of bypass system.
Noise	Positive	No impact on existing noise conditions.	Pipelines may be designed and buried to reduce impact.	No system specific Impacts	No system specific Impacts	No system specific Impacts
	Negative		Noise and vibration impacts associated with pumps, valves and booster stations.	Noise and vibration impacts associated with pumps, valves, dredger and booster stations.	Noise and vibration impacts associated with pumps, valves, dredger and booster stations.	Noise and vibration impacts associated with pumps, valves and booster stations.
Air Quality	Positive	No impact on existing high air quality.	No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts
	Negative		No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts
Traffic	Positive	No impact on existing traffic conditions.	No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts
	Negative		May require construction of a sealed road along Letitia Spit.	No system specific Impacts	No system specific Impacts	May require construction of a sealed road along Letitia Spit.
Hazard	Positive	No additional hazards.	No system specific Impacts	No system specific Impacts	No system specific Impacts	No system specific Impacts
	Negative		Navigation hazard associated with the construction and operation of permanent system. Operational restrictions due to shark meshing equipment.	Potential fuel spillage from equipment. Operational restrictions due to shark meshing equipment.	Potential fuel spillage from equipment. Management of public safety required.	No system specific Impacts

Chapter 8

Environmental Management

Chapter 8

Environmental Management

Chapters 4 and 7 describe the existing physical environment and impacts of the planned permanent sand bypassing project. A number of specific impacts have been identified which would require management initiatives to avoid adverse impacts. Appropriate environmental management measures are discussed in this section. In addition, an environmental monitoring program is described to provide feedback on the physical and biological processes and to update environmental management measures.

8.1. Introduction

Assessment of the short listed options for the planned Permanent Sand Bypassing System outlined in Chapter 5 has enabled development of overall environmental measures to ensure that environmental impacts will be minimal and acceptable. Due to the generic nature of this EIS/IAS, a detailed Environmental Management Plan will need to be formulated once the system to be implemented is selected. The Environmental Management Plan (EMP) prepared for Stage 1 works can be used as a template for the Stage 2 works, however, the detailed EMP for Stage 2 works would incorporate the management measures outlined in this Chapter, as required.

8.2. Management Activities Being Undertaken for Stage 1

The Environmental Management Plan (EMP) prepared for Stage 1 was aimed at ensuring that all activities associated with the works were undertaken in such a manner that there is not significant environmental degradation in and around the area of works. The management process was also aimed at capturing sufficient information on the effects of the works to ensure adequate design of a permanent sand bypassing system (Kinhill *et al.*, 1995). As a result, monitoring of the Stage 1 works is very comprehensive and geared mainly towards examining short term responses rather than the more long term approach needed for the permanent system.

A number of environmental management objectives and strategies are outlined in the EMP, as listed below.

- Sediment and water quality around southern Gold Coast beaches.

  To ensure that the quality of sand used for nourishment does not present a hazard for the community or marine habitat, dredged material has been tested and visually inspected to ensure compliance with the relevant standards and turbidity in nearshore areas measured.

- Noise

  In order to minimise noise disturbance to the community, night time work has been minimised and every attempt made to complete work activities in the least time possible. Information bulletins informing the community of periods of high noise levels have been prepared and facilities have been implemented for day and night telephone access for complainants.

- Stormwater Outlets

  Placement of sand on the southern Gold Coast beaches is being managed to ensure that blockage of stormwater outlets does not occur.

- Kirra Reef - Marine Ecology

  In order to mitigate adverse impacts on Kirra Reef sand placement was designed with an exclusion zone which surrounds the reef.

- Accident and Emergency Response

  To prevent the coastline from accidental pollution response mechanisms were formulated and discussed with Contractors.

- Major Storm Contingency Plan

  To manage the erosion caused by a major storm or a series of storms, a major storm contingency plan was developed to ensure that the objectives of the project are met at the end of Stage 1 dredging. The plan involves the implementation of "Optional Extra Dredging" if necessary and practicable.

- Community Liaison

  A regular and open dialogue has been established with the community and community groups regarding the project. This has involved media releases, media bulletins, open contact lines and community group feedback mechanisms.

Site monitoring has been undertaken in accordance with the Stage 1 EMP prior to, during and subsequent to the works. These are outlined below.

- Sediment and water quality around southern Gold Coast beaches.

  Sediment and water samples have been monitored throughout Stage 1.

- Noise

  Background noise levels have been monitored and levels at night are maintained lower than background noise levels. Some minor complaints were investigated relating to noise and vibration associated with earthmoving equipment on the upper beaches at Kirra and Rainbow Bay.

- Stormwater Outlets

  Compliance to sand placement design profiles was verified.

- Kirra Reef - Marine Ecology

  Sea bed level changes were monitored to assess impact on the Reef. Marine ecology of the Reef was also monitored to ensure that no significant changes or impacts occur.

- Accident and Emergency Response

  Response plan and field facilities were verified prior to activities commencing.

- Major Storm Contingency Plan

  Bathymetric surveys are being conducted to monitor the effects of major storms.

- Community Liaison

  Monitoring has occurred by recording the number of inputs from community groups, media releases, complaints and the number and general response of visitors to the information centre.

In addition to the above, further reporting has occurred on items such as:-

- avifauna;
- ongoing aerial photography to establish a baseline and determine shoreline changes, breakwater stability and effect on wetlands;
- photogrammetry to establish shoreline changes;
- monitoring of surfing conditions;
- monitoring estuary water levels by the use of monitoring equipment;
- installation of Tweed Waverider buoy to monitor offshore directional wave conditions;
- upgrade of water level recorder (Zwarts Pole) to assess wave penetration in the Tweed estuary;
- beach survey data;
- hydrodynamic surveys have been undertaken to determine beach profiles from Fingal to North Kirra; and
- an overall photographic monitoring of Stage 1(A) works was completed.

8.3. Specific Management Issues for Stage 2

8.3.1. Navigation of the Tweed River Entrance

To ensure that the sand bypassing system has a positive impact on navigational conditions at the Tweed River Entrance, monitoring of the entrance conditions should be carried out. Monitoring results can be used to measure the actual changes in the channel compared to the predicted changes.

Monitoring of the channel bathymetry would be an effective method of monitoring navigational conditions at the Tweed River entrance. This is required to monitor the performance of the permanent bypassing system in meeting the project objective of maintaining a clear navigation channel.

Monitoring could involve observations of navigational conditions on a daily basis by the Point Danger Air Sea Rescue. Conditions which could be recorded include the location, depth and width of the navigational channel and distribution of sand shoals.

Anecdotal evidence from regular users of the channel is also a valuable source of information regarding navigation conditions. The community consultation process carried out for this project has established a means for open communication with members of the local fishing community, local business and Air Sea Rescue. In this regard, it is considered important that consultation be continued through the Community Advisory Committee which has been set up under the Deed of Agreement.

8.3.2. Beach System Management

8.3.2.1. General Considerations

A number of factors need to be considered and incorporated into design criteria and operational management in order to maximise the effectiveness of the bypass system and the benefits to the beach system. Broadly, bypass system strategies for effective operation and beach management relate to:

- sand dredging at the bypass intake area, and
- sand discharge to the beach system.

Ideally, bypassing operations of dredging and discharge seek to parallel the natural longshore transport patterns as much as practicable. These activities are inextricably linked, and yet conditions at the dredging area may not always match those at the discharge point, and discontinuities in sand supply and demand will occur from time to time.

Thus operational and monitoring strategies need to be put in place to ensure effective bypassing over the longer term.

8.3.2.2. Sand Dredging and Snapper Rocks Discharge Strategy

The strategy adopted at the intake area will depend intimately on the type of system adopted. Specifically, a fixed trestle system depends on sand being brought to the intakes by the prevailing waves and currents. Thus, in times of low waves, little sand will feed to the system and only small quantities may be bypassed. Alternatively, a mobile intake system (hopper dredge or jack-up platform) may be moved over a wide area and collect sand regardless of the prevailing transport conditions.

In the case of the fixed intake system, low waves and supply at the intake would coincide with low waves and demand at the discharge. However, there would be a corresponding requirement to match the transports during high energy waves if no reserve of sand is built up at the discharge point during calmer weather. This has proven to be difficult at other bypass plants, where system shutdown usually occurs in storm conditions.

Thus, it is desirable that the bypassing seeks to dredge and bypass more sand in calmer 'modal' conditions to build a discharge reserve at Snapper Rocks to cater for the storm periods. This can be achieved readily for mobile dredging plant.

A key issue in regard to the fixed trestle option is that the sand transported to the intakes is the gross (upcoast and downcoast) transport, which exceeds the net rate of 500,000m^3. This is more so at Letitia Spit than at any other location along this beach system.

The modelling indicates an existing typical gross transport of 750,000-1,000,000m^3/year at Letitia Spit. This can be expected to decrease somewhat as the system changes the sand transport regime by depletion of the bathymetry in the entrance channel area. Nevertheless, even for fixed trestle system, if properly designed and operated, the opportunity would be there to dredge the full quantity to build and maintain the discharge reserve at Snapper Rocks.

It is important to note that the experience at the Gold Coast Seaway cannot be applied directly to the Tweed in this regard. At the Seaway, the southern training wall acts as a partial sand trap for sand leaking past the system, providing a mechanism for return of the sand in northeast waves. This will not be the case at the Tweed. Hence, any fixed trestle system at Tweed would need to be designed and operated to collect

upcoast transport more efficiently, when it occurs, to minimise leakage into the entrance channel.

Performance criteria should be set to control both sand intake/entrance channel maintenance and the discharge strategy for Snapper Rocks. The objective of the discharge strategy would be to ensure that the sand is contained within the active zone of longshore transport to the beaches, with no leakages of sand to deep water or other areas. These will specify circumstances under which the sand discharge location may be changed to Kirra, west of Snapper Rocks (Marleys) or Duranbah.

8.3.2.3. Sand Discharge in Northeast Waves

The downcoast (northeast wave) component of the gross transport at Letitia Spit coincides with downcoast transport at Point Danger, but upcoast transport west of Snapper Rocks and at Kirra. Thus a choice will need to be made about the discharge during such conditions.

Periods of local northeast sea waves tend to occur predominantly in spring (September through December). Usually, there is an underlying southeast swell occurring at the same time. This period in particular will need monitoring of the Snapper Rocks sand reserve and adjacent beach conditions to determine the most appropriate discharge location(s).

At this stage, it is sufficient to ensure that provision be included in the bypass system design for direct discharge to both west of Snapper Rocks and Kirra as alternatives to the primary discharge at Snapper Rocks (Frogs Beach), and that sufficient monitoring of the discharge and beach conditions is in place to direct the discharge most effectively.

Monitoring for this purpose may take the form of continuous directional wave data from the existing Tweed wave recording station along with daily observations of beach, shoal and surf conditions, assessed in terms of medium term trends and anticipated seasonal weather patterns.

8.3.2.4. Intermittent Sand Discharge Scheme

It is recognised that a possible option which may be offered as the permanent bypassing system is an ongoing programme of regular dredging and nourishment by a conventional trailer suction dredger. This type of scheme has implications for the deposition strategy as it becomes impractical to place the full quantity of sand in the vicinity of Snapper Rocks over relatively short campaigns. As discussed in Section 7.2.2 it is envisaged that the primary deposition area would be the inner nearshore nourishment zone as shown in Figure 5.2.2

It will be necessary to place a limit on the quantity of sand placed in the inner nearshore nourishment zone, so as not to exceed the natural variability of the sand shoals in the area. In Section 4.2, it was found that the natural variability of shoals in the vicinity of Snapper Rocks is up to 350,000 m^3 . This stems from the natural longshore movement of sand slugs. Hence, any quantities of sand discharged in the nearshore nourishment zone, in areas outside of the primary discharge area, should not exceed about 300,000 m^3.

The natural variability of the nearshore shoals, in the vicinity of Snapper Rocks, should be monitored with periodic hydrographic surveys and aerial photographs. Performance criteria should be set to control the quantities of sand discharged to the nearshore nourishment zone. The objective would be to control sand discharges so that they do not exceed the natural variability of shoals in the area. This will involve a process of trial and error, based on the results of monitoring, as part of the "fine tuning" of the sand bypass system in its initial years of operation.

8.3.2.5. Storm Period Operation

It is recognised that operations during storms will be difficult. This is because of adverse wave and weather together with the prevalence of debris in the sand which can cause problems with the bypass pumping.

Nevertheless, the objective of the system should be to mimic the natural sand transport regime as far as practicable. The extent to which operation is necessary during storms will depend on a number of factors, predominantly:

- the ability to maintain a reserve of sand at Snapper Rocks during normal wave conditions to act as a supply for the beach during storm periods;
- the degree of acceptance of beach variability associated with short to medium term deficits of supply at Snapper Rocks;
- the size and efficiency of the dredged sand buffer at the entrance channel area, and its capacity to accommodate siltation without causing navigation problems; and
- the extent of overall 'leakage' of sand through the system, which will tend to occur during storm periods.

The design and operation of the system must recognise that beach and nearshore sand is moved offshore to form longitudinal bars in deeper water during major storm events. The zone of predominant transport correspondingly moves further offshore. One or two nearshore bars may form. The historical survey evidence suggests that these bars may extend out to existing water depths of 7-10 metres, some 500 metres offshore from the existing beach.

For a fixed trestle system, consideration will need to be given to the most cost-effective means of collecting this longshore transport occurring such distances offshore. Extension of the trestle to such lengths would be costly and of little benefit in normal waves. Accompanying dredging by mobile plant (hopper dredge) immediately following storm events may be feasible.

8.3.2.6. Day/Night Operations

The design of the Seaway bypass system, particularly with regard to its remote location and the updrift beach alignment relative to the extent of the training walls, is such that the option is available to concentrate the bypass dredging during night hours to minimise power costs. This may not be the case at the Tweed for the following reasons:

(i) The Tweed training walls will not act as a downdrift sand trap to minimise leakage of sand through the system. Thus, for a jetty based option, sand dredging may need to be more continuous.

(ii) The Letitia Spit alignment is such that upcoast transport occurs for east waves, more so than at the Seaway.

(iii) The Tweed site is relatively close to residential areas and noise nuisance will need to be avoided, as discussed in section 7.6.7.

Noise management issues are discussed in Section 8.4. It is recommended that specific design criteria are specified for the on-land pump station to attenuate the noise if night time operations are to be undertaken.

To ensure effective operational efficiency, it is recommended that provision be made in the initial system design and costing for flexibility in the operations to include both night and day time bypassing as required.

8.3.2.7. Kirra Discharge

The project provides for an average of up to 75,000m^3/year (15%) to be placed directly at Kirra. This is intended primarily to restore short term erosion of the beach there to maintain its recreational amenity. As such, direct placement to the subaerial beach may be considered.

Alternatively, the sand could be placed into the nearshore longshore transport system. This could provide benefit to the surf break along Kirra Point, while also providing a less direct and immediate sand supply to the beach itself. It should be noted however, that such nearshore placement may not result in significant benefit to the beach if it remains within the nearshore bar system.

Clearly, monitoring and flexibility are needed to optimise this activity in the longer term.

8.3.2.8. Letitia Spit

Section 7.2.3.1 discusses the potential for permanent shoreline recession along the northern end of Letitia Spit in the vicinity of the sand extraction zone. The extent of recession will depend on the particular bypass system adopted and its operational design. A maximum shoreline retreat of the order of 90 metres plus the normal fluctuations in high water mark of up to 50-80 metres due to storm erosion and accretion is anticipated.

This permanent recession of the shoreline would result in a corresponding localised loss to the dune system and the foreshore area. A managed response to this recession is recommended which would provide for removal of trees if required.

A sand retrieval scheme which incorporates excavation of a sand trap area within the present shoreline of Letitia Spit would have the potential to create localised shoreline recession greater than 90 metres. Any such option would require specific management controls to limit any adverse effects on the dune system and its habitat.

8.3.2.9. Duranbah Discharge

As for the Kirra discharge, provision exists for direct discharge of sand to Duranbah. Up to 10 % of the total quantity delivered by the system (approximately 50,000m^3/year) may be placed there as the long term average.

It has been noted that Duranbah will be altered by the bypassing project, with shoreline retreat and depletion of the nearshore shoals. The beach will tend to develop 'pocket' beach characteristics, but should retain good recreational amenity. Surfing conditions are predicted to change significantly.

Sand discharge to Duranbah may be utilised to either:

- influence the alignment and shape of the beach itself, or
- assist in providing good surfing conditions.

In both instances, the beach would benefit from the placement of sand. However, the discharge strategy will be different if the focus of the discharge relates to surfing and not beach maintenance.

Walker (Technical Appendix III) has identified two discharge options for surf amenity enhancement. These are:

- discharge off the northern training wall to provide an alongshore bar aligned suitably for good surf, or
- discharge to a location in about 5 metres water depth about mid-beach to create a shoal suitable for surf wave formation.

Discharge off the training wall would be the less expensive of these options for a pipe delivery system. Creation of an isolated mid-beach shoal would require special design and operational action and probably an increased cost.

Walker estimates these options would have limited duration (up to several months), although it is not feasible to predict the behaviour of such shoals or bars with any reliability. Hence, a trial and error based strategy may be needed.

A first step in the Duranbah sand discharge strategy is to identify the primary objective and to decide on priorities for action based on likely costs and benefits.

8.3.3. Future Management of the Lower Estuary Marine Shoals

In Section 7.4.5, it is concluded that a bypass system will have no incremental impact on flood behaviour and, therefore, scouring of the lower estuary. However, Section 7.4.3 concludes that a permanent entrance bypass system would substantially reduce the rate of marine sand infilling; it could even reverse the process. Because the post-flood recovery of the lower estuary marine shoals would be much slower, the tidal hydrodynamic impacts and the consequential ecological stress on the estuary would last much longer than the 2-3 years under existing conditions (Section 4.4.1.12). It therefore may be necessary to restore the shoals to an optimum volume, as soon as practicable after a major flood. In contrast to the existing environment, a bypass system would have the capacity to reinstate the scoured shoals at a greater rate than natural infilling processes (2-3 years under existing conditions).

Section 4.4.2.4 demonstrates that in respect of the existing environment, there is a strong need for the Tweed Estuary Management Plan to include a Lower Estuary Marine Shoals Management Strategy. The introduction of a permanent entrance bypass system would not eliminate this need. It would merely place greater emphasis on the need for post major flood scour restorative works, because of the extended time for natural recovery otherwise. It would also introduce the need for periodic restoration of the shoals, if the bypassing leads to a net loss of marine sand through the entrance.

It is considered that the post major flood restorative works would involve the addition of 200,000 m^3 once every 50 years, on average. It is difficult to indicate a likely frequency for restoration of the shoals if there is a net tidal export of marine sand from the lower estuary. Such a net loss (if it eventuates) is likely to be very slow and the frequency of restorative works is more likely to reflect the cumulative scour impacts of small floods. Hence, an indicative frequency of once every 10 years is considered of an appropriate order.

If a bypass system does not cause a reversal of marine sand infeed, but merely a reduction in the rate of infeed, corrective dredging to remove excessive build-up of the lower estuary marine shoals is likely to be needed less than every 10 years or so.

Hence for the purposes of this EIS/IAS, it has been demonstrated that a permanent entrance by-pass system would not require environmental management provisions for the lower estuary marine shoals, which would be additional to that which has been recognised in respect of the existing conditions under the Tweed Estuary Management Plan.

8.3.4. Long Term Water Quality Management

Section 7.4.1.2 shows that a permanent entrance bypass system would add to the tidal flushing and water quality benefits of the Tweed Estuary Management Plan, particularly the Terranora arm. Bypassing would prolong these benefits by slowing down the rate of marine sand infeed. It could even "preserve" them if bypassing were to lead to a reversal in the net marine sand infeed (eg. net sand export). In this eventuality, it would be necessary to periodically restore the lower estuary shoals to an optimum volume.

The rate of growth of the lower estuary shoals needs to be monitored and the shoals need to be managed to maintain the water quality benefits of the Tweed Estuary Management Plan. As discussed in Sections 4.4.2.3 and 4.4.2.4, this is not an obligation that arises out of the Bypassing Project; it falls fully within the responsibilities and objectives of the Tweed Estuary Management Plan.

8.3.5. Duranbah Surf Quality Management

Depending upon the extent to which the permanent bypass scheme fully captures the net longshore transport from Letitia Spit, surf quality at Duranbah is likely to be adversely affected. A leaky bypass scheme, in conjunction with the Duranbah discharge, could retain much of the valued surfing traits of the site. The actual outcome will depend upon the nature of the successful scheme and there will be a need to monitor surfing conditions and manage the Duranbah discharge to achieve optimum surf quality. Experience with the Stage 1A nourishment of the southern Gold Coast beaches has shown that surf sites can be maintained and perhaps enhanced with careful management of beach bars.

This study has shown that it would be feasible to develop a beach and shoal nourishment strategy for dredging and placement of the Duranbah discharge in a manner that maintains surfing opportunities. The strategy would need to embrace the Tweed entrance bar bypassing configurations, including any sand traps that may be created as part of a sand bypassing system, to the most practicable extent, to create conditions favourable to surfing.

The implementation of the strategy would depend upon nourishment objectives for Duranbah (section 8.3.2.9). This study has identified two examples of how the Duranbah discharge could be used to create temporary nearshore shoals of a particular size and shape to enhance surf quality. The development of a detailed strategy would have to consider the practicality and cost implications of any such nourishment in the context of the specific capabilities of the successful bypass scheme.

Detailed numerical process modelling could be used to develop a strategy suited to the adopted bypassing system. There would be a need to closely monitor the system and develop/refine the strategy through feed back. In this regard, it is considered important that the development/refinement be done through the Community Advisory Committee which has been set up under the Deed of Agreement. This will ensure that representatives of the local surfing community are involved in the development of the strategy.

Collaboration with the local surfing community may identify possibilities for nourishment to be timed to suit surfing contests and/or periods of the year when there is the highest probability of good swell.

8.3.6. Estuary Navigation Channel Maintenance

Section 4.4.2.2 concludes that the long term implications of the Tweed Estuary Management Plan, over the next 20 years, are that shoaling of the Boyds Bay Shoal will persist and the infilling of navigation channels in the confluence of Terranora Creek and the main arm will worsen. Also, a new area of

channel infilling could develop at the northern end of the western secondary channel of the main arm, against Ukerebagh Island.

Hence, irrespective of whether a permanent bypass system is implemented or not, more regular maintenance dredging will be required in the established commercial channels at Boyds Bay Shoal and Terranora Inlet at the northern end of the western secondary channel.

Section 7.4.4 shows that the impact of a permanent bypass system would be beneficial. Bypassing would slow down or eliminate the infeed of marine sand thereby reducing the channel infilling rates. Hence no specific management measures are necessary.

8.3.7. Tweed Entrance Training Wall Stability

In Section 7.3.5 it is concluded that deepening the bar could increase the risk of storm damage to the entrance training walls. The actual risk would depend upon the adopted bypass system and the associated long term entrance bar configuration and the actual wave transformations in the very complex area near to the walls. Works to increase the strength of the protective armour layers, would range from minimal cost, for shallow bar scenarios, up to $5 million - $10 million, for deep bar scenarios.

Rubble mound training walls like those at the entrance to the Tweed River would be able to sustain up to 20% storm damage ie. the damage should not lead to a catastrophic failure. The damaged walls would still train the river flows and continue to protect the navigation channel between them. However, a notional damage level in excess of 30% could lead to total collapse of sections of walls. Even damage levels less than 20% would be hazardous to the general public using the walls for fishing, sightseeing, etc. The cost of reinstating severely damaged walls would be greater than the cost of pre-emptive wall strengthening.

It is estimated that storms which would produce this type of wave, for a significant duration, would have a return interval of approximately 20 years or more (Section 4.3.2). The probability or chance of such a storm or larger occurring in any one year is 0.05. Hence a risk management decision would need to be made by the NSW Government.

If the successful tender is based on a relatively shallow bar scenario, the potential for wall damage would be relatively low and the NSW Government could decide to accept the risk and repair the walls after any damage occurs, to a standard considered appropriate at the time. Even if the successful tender is based on a deep bar scenario, with its perceived risk of sudden and severe failure of the walls during a major storm, the Government could choose to delay strengthening of the walls pending monitoring of the initial years of the project so as to better define the risk involved. Hence it is not possible to specify the timing and extent of wall strengthening that may be required.

Any major strengthening of the training walls would most likely involve the use of precast concrete armour units and very heavy armour stone. The trucking of concrete units and stone and/or fabrication of concrete units on site, as well as overall establishment of a construction site, would have environmental impacts on the habitats, wildlife, road infrastructure and residential community of the Fingal Peninsula and the commercial/residential areas of Tweed Heads/Coolangatta. Because of the uncertainty of when and to what extent strengthening or wall repairs may be needed, approval of such strengthening or wall repairs does not form part of this EIS/IAS. They would be the subject of a separate environmental assessment to suite the approval process at the time.

8.3.8. Aboriginal Heritage

An archaeological survey is recommended along the pipeline route to determine whether there are any visible signs of Aboriginal sites and to evaluate the level of disturbance along the route. This survey should be undertaken in consultation with the Tweed Byron Local Aboriginal Lands Council and relevant authorities.

If the survey recommends further archaeological work a Preliminary Research Permit must be obtained under the provisions of the NSW *National Parks and Wildlife Act 1974* to undertake sub-surface testing. Following the results of this work further permits, salvage archaeological excavation or re-routing of the pipeline may be necessary.

The potential route of the pipeline along the southern Gold Coast is heavily disturbed and unlikely to contain Aboriginal sites. Sub-surface testing to confirm this would be difficult to implement. It is recommended that an inspection similar to that outlined above be undertaken along the pipeline route to evaluate the level of disturbance and to propose a management programme to mitigate the impact of the pipeline. If further archaeological work is recommended a permit must be obtained from the Queensland Department of Environment (DoE) under the provisions of the *Cultural Record (Landscapes Queensland and Queensland Estate) Act 1987* to undertake a programme of archaeological monitoring during construction work.

8.3.9. Maritime Heritage

Shipwrecks and historic relics over 75 years old are protected under the provisions of the Commonwealth *Historic Shipwrecks Act 1976.* The provisions of the Act apply to Commonwealth waters and to State waters where the Commonwealths powers extend and the relevant State government has allowed the act to be proclaimed. As both NSW and Queensland have done this, the act partially covers shipwrecks in state waters. However there are some constitutional limits to the Commonwealths powers and it seems that Commonwealth power does not extend into the Tweed River and of course does not extend onto land.

Shipwrecks and associated material on land in NSW or in the Tweed river proper that are more than 50 years old would be protected by the relics provisions of the *Heritage Act* (1977). If such material is discovered it must be reported to the Heritage Office Maritime archaeologists and they will advise on further action.

In Queensland shipwreck material found on land or in State waters would be protected by the *Queensland Heritage Act* (1992). If shipwreck material is discovered it must be reported to the Minister.

If substantial archaeological remains are located within the study area it is likely that the dredge will run into timbers or metal frames causing a blockage. If a series of blockages occur in a constrained area then it is likely that a shipwreck (or something else of that size) has been encountered. Wooden schooners ranged from the *Express* of 21 tons 11m long by 3.6m in the beam with a draught of 2m to the *Koh I Noor* a schooner of 101 tons some 27 m long, 6.3m beam and with a depth of 2.1m. The largest coastal vessel would be the *Orana* a screw steamer of 298 tons 41m long, 7.5m in the beam with a depth of 3.3m. The smallest would be one of the launches.

If targets of these sizes are encountered then it is recommended that, if feasible, the dredging operations be moved elsewhere in the study area and the location of the target be accurately recorded for future inspections.

It is possible that during the bypassing operations more tangible evidence of a shipwreck is located such as an anchor. On no account is evidence of a shipwreck to be moved without the appropriate permissions under the relevant Commonwealth or State legislation.

As the majority of known shipwrecks occurred earlier than 1922 (for Commonwealth waters) or 1947 (for State waters) all such occurrences of shipwreck or relics from shipwrecks are protected under law. In addition all occurrences of wreck must under the *Navigation Act 1912* (as amended) be reported to the Receiver of Wreck for NSW. The location of a large obstruction, possibly a shipwreck, must be reported to the Maritime Archaeologists in the Heritage Branch Department of Planning. They will be able to recommend further action.

It is recommended that the bypassing operators be fully briefed on the nature of the shipwrecks in the area and the procedure to be followed should one or a suspicious target, be located. Copies of the relevant brochures and details of contact numbers for the Heritage Branch Archaeologists are to be issued and displayed.

8.3.10. Ecology of the Tweed River Estuary

Section 7.5.2 discusses impacts to aquatic flora/fauna and fisheries resulting from entrance bypassing works and an associated slower rate of infill of lower estuary shoals. Such impacts relate almost exclusively to alterations to the tidal regime.

It needs to be recognised that with loss of the entrance bar, and associated reduced infill rates, there would be improved tidal flushing of the estuary. Increased tidal flushing may be expected to lead to slightly improved water quality within the estuary, particularly for upstream areas. Many upstream areas are poorly flushed, and water quality may deteriorate at times (eg. as a result of stormwater input) to the detriment of some commercial and recreational activities (eg. oyster growers in Terranora Broadwater would be likely to support options which improve tidal flushing).

As discussed in Section 7.5.2.1, as a consequence of the reduced rate of estuary infill, there will be a more "stable" tidal regime within the river and a more prolonged period of increased tidal ranges following loss of the lower estuary shoals from major floods (although the magnitude of tidal range change would not differ from that which can presently occur due to floods). This may result in wetland margins becoming less variable and a slightly increased area of mosquito/biting midge habitat being available for a longer period than presently occurs. These factors need to be considered in assessing and need for mitigating measures if the lower entrance shoals were lost during major flood events.

8.3.11. Ecology of the Tweed River Entrance

Shorebirds

The impact of disturbance at the South Head beach roost (see Section 7.5.4) has been examined within a wider perspective that includes all waterbird roosts within the Tweed Estuary. Environmental management needs to consider impacts at roosts throughout the estuary, and to base management objectives at this larger scale.

Specifically, Tweed Shire Council is evaluating options for partial removal of another major waterbird roost at Tony's Bay which supports major midge breeding areas. This could occur at a similar time to disturbance at South Head beach and Kerosene Inlet. Results of the bird monitoring program suggest that South Head beach, Kerosene Inlet and Tony's Bay are the three most important roosts in the estuary (Table 4.5.3). Effective planning should ensure that simultaneous disturbance at two of these three roosts is avoided. The

removal of Tony's Bar should either precede or follow the construction of the Permanent Bypassing System by a period of about 12 months. This time lag will enable waterbirds to adjust behaviourally to the loss or relocation of roosts.

The impacts to birds at the South Head beach roost from disturbance associated with the initial construction of a jetty -based bypassing system or operations of a land based system could be offset by fencing off a large section of beach around the infrastructure. It is recommended that signs be erected notifying people of the significance of the roost. Exclusion of people from this area would encourage its use by little terns and waders thus contributing to the value of the area to shorebirds.

A large amount of disturbance at all three roosts could be avoided by scheduling the more disruptive works during the winter months, specifically between late April and early August. The majority of waders are at their Northern Hemisphere breeding grounds at this time, although small numbers remain on the estuary. It is recommended that, where possible, placement of infrastructure, construction of pipelines and associated fencing in these areas should take place during this period.

The disturbance experienced by waterbirds at roosts on the Tweed estuary is increasing, as a consequence of increasing recreational use of the estuary as well as from specific development projects. Other roosts which experience disturbance include those at Terranora Broadwater and Duraby Creek Marshland. The Terranora Broadwater Management Plan has suggested the construction of artificial roosts at Trutes Bay, Charles Bay and Terranora Broadwater. The construction of these roosts is highly desirable as it will reduce the pressure on roosts at the mouth of the Tweed River. Waterbirds move freely within the Tweed estuary, therefore, roosts constructed in the broadwaters and bays should be readily used by these birds.

8.3.12. Kirra Reef

It is recommended that the disposal of sand be excluded from a defined area around the rock outcrops known as Kirra Reef because of the diversity and abundance of marine life on and within the rocks. The defined exclusion zone should be of the order of 50m from any portion of the outcrops.

8.4. Noise

8.4.1. Construction Phase - Noise Management

Construction noise criteria are detailed in Section 7.6.8.2. As far as possible construction activities should be managed to occur within *recommended hours* as detailed.

To minimise transport noise impacts at residential sites, truck movements should be managed so that trucks do not pass through residential areas outside of recommended hours. This applies to truck movements in residential areas not adjacent to major thoroughfares and particularly to those residential areas on Letitia Spit. Access roads to construction sites should be maintained in good condition and trucks should be fitted with efficient mufflers.

All mechanically driven plant used in construction activities should be fitted with efficient exhaust mufflers.

As particular limits apply to noise from construction operations in New South Wales, (and in Queensland outside recommended hours), monitoring of noise levels from these activities may be required in order to ensure the relevant Guideline noise levels are complied with. This will particularly apply where construction activity will occur in areas closely adjacent to residents in Tweed Heads and Coolangatta, for example in pipe laying activities and in the construction of booster pump facilities.

8.4.2. Operational Phase - Noise Management

8.4.2.1. Maintenance Activities

Major maintenance activities which may result in noise impacts would include marine operations such as anchor laying and movement of pump ashore pipelines and operations such as relocation of a jack-up platform. Land based operations in this category would include short term activities such as beach sand redistribution using conventional earth moving equipment, (but not including primary dredging activities on Letitia Spit).

As with operations in the construction phase, such activities should be managed to occur where possible within *recommended hours* and should comply in other respects with the relevant State Guidelines.

All mechanically driven plant should be fitted with efficient exhaust mufflers and all vehicles and access roads should be maintained in good condition. Trucks should be fitted with efficient exhaust mufflers and truck movements should be managed to occur within recommended hours.

8.4.2.2. Permanent Operations

To minimise noise impacts all plant and equipment which would be utilised on a permanent basis should be designed to meet noise criteria as described in Section 7.6.8.2. In order to ensure that appropriate design standards are utilised, further octave band noise measurement will be required to confirm background noise levels at adjacent noise sensitive sites.

Permanent plant (pumps and pipelines) located in close proximity to residents or noise sensitive commercial sites should be designed and installed so that vibration levels from activities associated with the bypass are essentially imperceptible within adjacent habitable areas, (this would include adjacent outdoor dining areas).

Subsequent to installation of bypassing plant, noise measurements should be undertaken under normal operational conditions to ensure that specified noise limit criteria are being met.

8.5. Environmental Monitoring Programme

8.5.1. Monitoring Programme for Coastal and Estuary Processes

8.5.1.1. Tweed River Entrance

Monitoring of the bathymetry of both the entrance channel and entrance bar is required to ensure that the navigation objectives of the Project are achieved. This would involve regular hydrographic surveys on an ongoing basis. The surveys are likely to be required as part of the operational obligations of the by-pass operator.

The condition of the walls, deepwater wave heights and bar bathymetry need to be monitored during the first few years of operation of the system to assess the possible risk to the training wall structures and the need for additional investigations. Ongoing monitoring, at lesser frequency and detail could then be continued to confirm the adequacy of any protective measures and/or to improve understanding/confidence in the damage risk.

8.5.1.2. Beach Management and Nourishment Strategies

Monitoring of the southern Gold Coast beaches is needed to provide data about the response of each beach to nourishment discharge strategies. Analysis of monitoring data will allow both natural and artificially induced changes to be quantified over the medium to longer term. Through continual refinement, optimised nourishment strategies would evolve which would achieve the best possible result in respect of beach amenity, surfing conditions and general public expectations.

It would be neither feasible nor cost-effective to undertake reactive works in response to short term variations in the beach system. Substantial variability of beach widths and surfing conditions will always be an inherent natural feature of these beaches. The monitoring programme would ensure that nourishment activities are not over-reactive but rather, planned in the context of the longer operation of the system.

Similarly, any special maintenance activity such as placement of a quantity of sand in deeper water off Snapper Rocks to maintain the desired bathymetric profile need not occur as a short term emergency work. A monitoring programme will allow such need to be identified early and corrective measures to be planned as an integral component of the longer term operation of the system.

The key objectives of the monitoring should include:

(i) verification of sand quantities bypassed
(ii) identification of sand discharge requirements in terms of locations and quantities to maintain beach/surf amenity
(iii) correlation of sand dredging and discharge with longshore transport rates to progressively optimise the operation procedures.

Monitoring could include:

- sand bypass quantity and performance;
- simple beach and surf condition observation
- detailed beach and bathymetric surveys
- directional wave recording
- continued assessment of longshore transport regime
- regular aerial photography
- community feedback

Sand Bypass Quantity and Performance

Monitoring of the quantities of sand bypassed is required for two purposes, namely:

- for operational management and payment, and
- for assessment and review of the Contract Quantity, the Duranbah Contract Quantity and the bypass performance in terms of beach maintenance.

Determination of operation management and payment criteria are contractual matters which will be dealt with in the setting of performance criteria and the design/construct phase of the project.

Assessments of bypass performance and review of the quantities of sand bypassed will require regular detailed survey monitoring. In principle, design of such a monitoring program should provide for:

- acceptance that the beach system evolves relatively slowly, despite the occurrence of short term erosion from time to time;
- acceptance that hydrographic surveys contain significant error margins, mainly due to wave action and particularly in the surf zone;
- a high degree of spatial survey resolution to ensure that derived sand quantities are determined as accurately as practicable, suitable as a basis for reviewing the Contract quantities.

Thus, comprehensive surveys of the whole beach system should cover the area from around Fingal to Currumbin. A systematic common survey grid or profile system should be used. Such surveys are not required at short time intervals, but could be for example:

- annually for the first 5 years;
- bi-annually over the next 10 years, and
- reviewed thereafter.

Beach and Surf Observations

Changes to sand discharge rates or locations should not be required as a response to short term local beach variations. It is accepted that beaches change significantly in response to changing wave conditions. However, sand discharge changes may be carried out in response to sustained need.

Monitoring of the beaches is needed to define both the natural dynamic variability of (say) the High Water Mark location and to identify when a sand discharge response is needed. This can be achieved by simple, low cost observation procedures similar to those used in the Queensland COPE program. Sites for such monitoring should include:

- Letitia Spit
- Duranbah
- Snapper Rocks/Rainbow Bay
- Greenmount
- Kirra
- Kirra Central
- North Kirra

Directional Wave Recording/Longshore Transport Assessment

Effective operation of the bypass system, particularly with regard to understanding and matching the longshore transport capacities and the bypassing quantities, will require a method for indicating short and long term longshore transport behaviour. As well, the effects of storms on beach and transport conditions will need to be understood to assess system performance.

Longshore transport indicators can be developed based on reliable directional wave data. It is recommended that the Tweed directional wave recorder be kept in place for that purpose.

Community Feedback

The opportunity exists for ongoing feedback on system performance from the community. This would assist in refining the discharge strategy.

It is recommended that a program of community feedback be implemented through the local surf lifesaving clubs and local surfing representatives

8.5.1.3. Duranbah Surf Quality Monitoring

Monitoring of the surf conditions at Duranbah and the entrance bar configurations would be beneficial toward optimising the placement of sand for surf quality.

Over the first years of operation of the system a strategy based on trial and error is recommended. If required, a detailed numerical model of the Duranbah Shoals and entrance bar, to predict wave transformation and sediment transport, could be developed and used as an aid in optimising the placement of sand and understanding how sand is transported over the nearshore profile of Duranbah to create surfing opportunities. The model needs to predict both sediment transport and surf conditions to help devise an optimum program for dredging as well as beach and surf enhancement. Basic wave transformation models can be used to generally predict the waves approaching the site and to make relative assessments of wave transformations over the shoal. A model that incorporates wave breaking, nonlinear wave shoaling and finite-heights effects on wave velocity near the surf zone is required to reasonably predict wave breaking over a surf site.

A comprehensive monitoring programme for Duranbah would be incorporated into the overall beach and entrance monitoring programme and would comprise:

Offshore wave measurement

- Regular surf quality assessments
- Regular hydrosurveys of nearshore shoals
- Regular hydrosurveys of entrance bar bathymetry
- Regular aerial photography

8.5.1.4. Lower Estuary Marine Shoals Monitoring

Monitoring of the lower estuary marine shoals is needed because their maintenance is crucial to achieving the long term water quality benefits of the Tweed Estuary Management Plan. Analysis of monitoring data should establish the optimum bathymetry for the shoals within the context of water quality and ecological goals. This will necessarily embrace ecological considerations.

A channel maintenance strategy is required in respect of the main navigation channels located in the marine shoals ie. Boyds Bay, Terranora Inlet and the northern end of the western secondary channel *(against Ukerebagh island)*. The emphasis of the strategy should be on the disposal of dredgings in the context of the overall management of the lower estuary marine shoals.

A comprehensive monitoring programme would comprise:

- regular hydrosurveys of lower estuary;
- ongoing water level recording in the estuary; and
- aerial photographs.

8.5.1.5. Wetland Distribution

An environmental monitoring program may be beneficial to quantify the extent and nature of any changes to wetlands attributable to the slower rate of lower entrance shoal recovery.

It will be important for the monitoring program to incorporate a baseline data collection phase to provide a set of background data to assess wetlands prior to loss of the lower entrance shoals as a result of a flood event. It is anticipated that baseline data collection would begin upon approval of the sand bypassing operation and continue until the operation commences.

A wetland monitoring program could include seagrass, mangrove and saltmarsh communities using aerial photography undertaken for other monitoring programs

8.5.1.6. Monitoring Costs

The cost of monitoring would depend upon the adopted bypass system and the outcomes of initial monitoring which would redirect the monitoring as necessary. An approximate schedule of costs is provided in Table 8.5.1

Table 8.5.1 Indicative Environmental Monitoring Schedule and Costs

Monitoring Activity	Pre-Construction Activity and Indicative Frequency	Post-Construction Activity and Indicative Frequency	Indicative Unit Cost	Indicative Cost over first 10 yrs* of Operation
Beach Management Nourishment Strategy				
• surf surveys	yes - monthly during season	yes - monthly during season	$1,000/month	$84,000
• sand bypass quantity measurement	N.A.	yes - bypass operator requirement	-	-
• beach and offshore surveys	yes -once off	yes - annually for 5 years then bi-annually	$50,000/survey	$400,000
• directional wave measurement	yes - continuous	yes - continuous	$50,000/yr	$600,000
• longshore transport assessment	yes - annually	yes - annually	$10,000/yr (decreasing)	$50,000
• aerial photography	yes - 6 monthly	yes - 6 monthly first 5 yrs then annually	$5,000	$95,000
• community feedback	yes - ongoing via Advisory C'ttee	yes - ongoing via Advisory C'ttee and occasional user surveys	$500/yr	$6,000

Table 8.5.1 Indicative Environmental Monitoring Schedule and Costs (Continued)

Duranbah Surf Quality Management				
• directional wave measurements	included in above	-	-	
• regular surf quality assessment	included in above	-	-	
• beach and offshore survey	included in above	-	-	
• entrance bar surveys including entrance channel	included in above	yes - 3 monthly first 6 years then 6 monthly	$7,000	$224,000
• aerial photography	included in above			
Lower Estuary Marine Shoals Management				
• estuary hydrosurveys	yes - 6 monthly	yes - 6 monthly first 5 years then annually	$20,000	$380,000
• aerial photographs	included in above		-	-
Training Walls Stability				
• storm damage surveys	yes - annual	yes - annual	$5,000	$60,000
• wave measurements	included in above		-	-
• entrance bar surveys	included in above		-	-
Wetland Distribution				
• wetland extent	yes - 6 monthly first 5 years then annually		$5,000	$95,000

*monitoring programme is likely to be scaled down considerably after about 10 years due to experience obtained from operation of system.

Hence average annual cost of environmental modelling, is approximately $165,000 per year, in the first 12 years of the project assuming two years before commencement of bypassing.

Chapter 9

Conclusion

Chapter 9

Conclusion

Conclusions regarding the environmental impacts of the project are made with reference to the project objectives.

This EIS/IAS addresses the relevant environmental issues related to the construction and operation of Stage 2 of the Tweed River Entrance Sand Bypassing Project which involves the implementation of a permanent artificial system to remove sand from the entrance of the Tweed River and use it to re-establish and maintain the eroded southern Gold Coast beaches.

The project is being carried out across the state border between New South Wales and Queensland. The New South Wales objective is to establish and maintain a navigable channel 70 m wide and at least 3.5m below Indian Springs Low Water in the entrance to the Tweed River. The Queensland objective is to achieve a continuing supply of sand to the southern Gold Coast beaches at a rate consistent with the natural littoral drift rates updrift and downdrift of those beaches, together with the supply of additional sand to restore and maintain the recreational amenity of those beaches.

As a result of improved navigation in the Tweed River with the implementation of the permanent bypassing system, associated benefits are anticipated to commercial and recreational boating. Industries likely to be positively affected by the improved navigation conditions include local fishing and dive operators. Other associated benefits include improved viability of the tourist industry, in particular related to the nourishment and restoration of the southern Gold Coast beaches. Consequently property values would also be expected to increase. The implementation of the permanent sand bypassing system would result in a reduction in the rate of infilling of marine sediments in the Tweed estuary and slightly improved water quality within the estuary as a result of increased tidal flushing.

This document assesses the relative impacts of a range of system options including a combination of options which could satisfy the objectives of the project. Assessment of these options has been on the basis of their ability to achieve both the New South Wales and Queensland objectives and also on the basis of the short and long term impacts on the physical, social and economic environments of the surrounding area. The EIS/IAS does not select any one option or preclude other options from the process of selecting the best option available at the time to implement this project.

A range of alternatives to the project were also assessed. The 'Do Nothing' option would jeopardise the cumulative benefits of Stage 1 and previous beach nourishment campaigns resulting in a worsening of navigation at the Tweed River entrance and continued erosion of the southern Gold Coast beaches. Doing nothing would raise a plethora of environmental risks including entrance navigability and public safety, beach stability and beach amenity and alteration to estuarine habitats as well as the commercial viability of the many local marine based industries.

This study has shown that the project objectives are practical, achievable and sustainable while recognising that the selected system will require careful design and consideration of its exposure to the complex and often difficult environmental forces.. The short-listed options which were assessed satisfy the objectives of the project. Many of the impacts associated with the project are common between the options assessed, some impacts are however associated with specific options. The major impacts on the existing environment are positive. The negative impacts associated with the project can be limited by

effective management which is outlined in this EIS/IAS. It is concluded that the the significant positive impacts considerably outweigh the negative impacts which would be limited by effective management.

This document also recommends monitoring programmes to ensure both that negative impacts are limited and that the project objectives are met over both the long and short term.

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Glossary and Abbreviations

Glossary

Accretion	Accumulation of sand on a beach or shoal: opposite to erosion.
Australian Height Datum (AHD)	Survey datum adopted by National Mapping Council as the datum to which all vertical control for mapping is to be referred (roughly approximates to Mean Sea Level).
Avifauna	Bird life.
Attenuation	Reduction in force or intensity.
Bar	An accumulation of marine sediment.
Bathymetry	The measurement of depths in oceans, seas and estuaries and the information derived from this measurement. Commonly used as a term for the topography of the ocean bed.
Beach Berm	The area of shoreline lying between the swash zone and the dune system; the berm typically has a gentle slope.
Beach Erosion	The offshore movement of sand from the beach during storms.
Beach Nourishment	The placement of sediment by mechanical means to supplement the sand reserve on an existing beach or to build up an eroded beach.
Before Present	Years before 1950, being the accepted radiocarbon dating reference year.
Benefit/Cost Ratio	The ratio of the benefits derived from a project to the costs of construction and operating the project.
Benthic	Relating to animals and plants that exist on or beneath ocean or estuary floors.
Bio-available	Able to be ingested by living organisms.
Bottom Dumping	Method of subaqueous beach nourishment where dredged sand is discharged from beneath the dredging vessel.
Breakwater	Structure protecting a shoreline, harbour, anchorage or basin from ocean waves.
Caldera	Large basin-shaped crater formed by the collapse of the top of a volcano.
Crustacea	Animal family commonly having a body covered by a hard shell or crust eg lobsters, prawns, barnacles, woodlice.

Compartment	Geographic unit in a coastal region distinguished by specific coastal processes and sediment transport patterns.
Cusp	Small arc-like depression in the shoreline of a beach.
Depauperate	Small populations of fauna species present.
Desiccation	Drying out or dehydration.
Detritus	Fragments of material removed by the erosion of the surfaces of rocks.
Diffraction	The process by which energy is transmitted laterally along a wave crest. When a part of a wave is interrupted by a barrier, diffraction causes the "curving" of waves into the sheltered region on the lee of the barrier. Diffracted waves are lower in height than the incident waves.
Downdrift	The direction of predominant movement of littoral sediments along the coast in reference to the direction of net longshore transport; ie the direction along a shoreline to which most of the sediment moves from a particular location, opposite to updrift.
Dump Line	Surf wave breaking along a single line, generally oriented parallel to the shore.
Ecologically Sustainable Development	Using, conserving and enhancing the community's resources so that ecological processes on which life depends, are maintained and the total quality of life now and in the future can be increased.
Ebb Tide	The outflow of coastal waters from bays and estuaries caused by the falling tide.
Entrance Bar	Accumulation of sand in a mound formation at the mouth of a river.
Environmental Impact Statement	A formal description of a project and an assessment of its likely impact on the environment. It includes an evaluation of alternatives and an economic justification of the project. The EIS is used as a vehicle to facilitate public comment and as the basis for analysing the project with respect to granting approval under relevant legislation. In NSW carried out under the Environmental Planning and Assessment Act 1979.
Epibenthic	Organisms living on the surface of the ocean floor or bed of river estuaries.
Epilithic	Organisms attached to or living on the surface of rock.
Equipotential Sink Flow	Flow directed radially to a point.

Flux	Quantity of flow per unit area.
Frontal Dune	Continuous sand dune at front of dune zone behind an ocean beach.
Flood Tide	The inflow of coastal waters into bays and estuaries caused by the rising tide.
Fluvial	Relating to rivers or streams.
Gross Longshore Transport	The total movement of beach material along the shoreline past a particular point regardless of direction, due to the effect of waves breaking obliquely on the beach. Longshore currents move the sediment stirred up by the waves. The movement is typically expressed as an annual rate.
Groyne	A shore protection structure built (usually perpendicular to the shoreline) to trap littoral drift or prevent erosion of the shore.
Impact Assessment Study	A study similar in format to an EIS (see above) carried out under the Queensland *State Development and Public Works Organisation Act 1971*.
Indian Spring Low Water (ISLW)	The approximate level of the mean of lower low waters during spring tides at a given location. ISLW is usually the level adopted for a port Chart Datum. Australian Height Datum (& MSL) is approximately 0.9m above ISLW, at the Tweed entrance.
Invertebrate	Animal species not possessing a backbone.
Isopach	A line drawn on a map joining points of equal height following comparison of topographic conditions measured at two different sites.
Littoral Rainforest	A type of rainforest adapted to grow in harsh conditions next to the sea. It is found on headlands, generally with fertile soils derived from slates or basalts, or behind beaches on nutrient-enriched deep soils.
Littoral Drift	The sedimentary material moved in the littoral zone under the influence of waves and currents.
Littoral Transport	The movement of littoral drift in the littoral zone by waves and currents. Includes movement parallel (longshore transport) and perpendicular (onshore/offshore transport) to the shore.
Local Environmental Plan	Environmental planning instrument (or zoning plan) for part or the whole of a local government area.

Lower Tweed Estuary	The Lower Tweed estuary is taken to include all of the Tweed River below Chinderah Island, all of Terranora Creek and associated bays and broadwaters (including Cobaki Broadwater) and the mouths of Bilambil and Duraby Creeks.
Macroinvertebrate	Larger invertebrate (see above) species
Manipulated Landscapes	Open space areas which are human-made and contain human-made structures/elements eg., parks with shelter sheds on reclaimed or releveled land.
Mean Low Water Springs	Long term average of the heights of two successive low waters during those periods of 24 hours (approx once a fortnight) when the range of tide is greatest, ie at full and new moon.
Mean High Water Springs	Long term average of the heights of two successive high waters over the same periods as defined for Mean Low Water Springs.
Mean Sea Level (MSL)	The average height of the surface of the sea for all stages of the tide over an extended period, typically about 19 years. Usually determined from hourly tide readings. MSL is approximately equivalent to AHD.
Midden	Mound consisting mainly of shell fragments marking a site of Aboriginal habitation.
Migratory Wader	A species of wader the majority of individuals of which are present in Australia for only a certain time of the year. Migratory waders do not breed in Australia. There are two types of migratory wader; summer migrants which are present from about late August to early April (some individuals do stay all year) and winter migrants which are present from late March to early September. The double-banded dotterel is the only species of wader that is a winter migrant to Australia. This species breeds in New Zealand in summer. All other species of migratory waders breed in the northern hemisphere and migrate south to spend the southern summer in Australia.
Mitigative measures	Management strategies which can be implemented to alleviate or moderate impacts.
Morphology	Relating to the form and structure of landforms.
Naturalism	Quality of the site pertaining to its natural, unspoilt state.
Nearshore Zone	Coastal waters between the offshore bar and the 60 m depth contour. Swell waves in the nearshore zone are unbroken, but their behaviour is influenced by the presence of the seabed.

Net Longshore Transport	Net amount of beach material moving alongshore past a particular point on a shoreline in the predominant direction of transport. Typically expressed as an annual rate.
Net Present Value	An economic index of the value of a project, calculated by subtracting the present value (see below) of the costs of the project from the present value of the benefits.
Obliquity	Relating to waves breaking at an angle to the shoreline.
Particulates	Fine solid particles carried in suspension in either water or the atmosphere.
Phytoplankton	Small plant species that float or drift in the ocean.
Point Break	Long rolling surf wave oriented at an angle to the shoreline.
Present Value	The value of an amount of money at some time in the future (or the past) if available today. It is calculated using an assumed discount rate. For example, with a discount rate of 10%, $100 today is the present value of $121 in two years time.
Progradation	The process in which a shoreline advances seaward owing to the inshore deposition of sediments accumulating at a faster rate than that of sediment removal. The sediment can accumulate from both the onshore and longshore sediment movement.
Recession	A long-term landward movement of the shoreline caused by a net loss in the sediment budget; opposite to progradation.
Recreational Imagery	Images, activities and views which reinforce the recreational atmosphere, character and use of the site as anticipated by residents and visitors to the area.
Reduced Level (RL)	Level or height specified in relation to a known datum.
Regime	The stable or balanced state of a natural system.
Regional Environmental Plan	NSW environmental planning document which examines a region of the State eg North Coast.
Replicate	Sample taken for scientific analysis to be used as a basis for comparing sites or properties.
Resident Wader	A species of wader that is present in Australia all year and which breeds here.

Sand Bypassing	Hydraulic or mechanical movement of sand from the accreting updrift side to the eroding downdrift side of an inlet or harbour entrance.
Sand Bypass System	Permanent system (usually mechanical) used to transfer sand transported in the littoral drift (see above) across the river entrances eg Nerang Sand Bypass.
Sand Slug	Mound-shaped sand deposit in nearshore area which tends to move as a single unit during storm events.
Sediment Budget	An accounting of the rate of sediment supply from all sources and the rate of sediment losses to all sinks from an area of coastline to obtain the net sediment supply/loss.
Sessile	Permanently attached at the base.
Shield Volcano	A volcano with an extremely broad base and gentle slope, characterised by basaltic rock formation.
Shorebirds	All species of waders and all species of terns and gulls are considered to be shorebirds. The term describes the habits of these species in usually being found close to or on the shore.
Species Diversity	The number of species present in an area.
State Environmental Planning Policy	NSW planning policy which considers matters of environmental significance for the whole State.
Storm Bar	An offshore bar, usually parallel to the coast, formed during storm conditions through deposition of sand which has been eroded from the beach berm.
Storm Surge	Temporary localised increase in sea level associated with intense storm events.
Subaerial	Onshore portion of active beach profile.
Subaqueous	Nearshore portion of active beach profile.
Surf Zone	Coastal waters between the breaker zone and the swash zone characterised by broken swell waves moving shoreward in the form of bores.
Temperature Inversion	An increase of temperature with height commonly experienced on cool calm clear mornings. Usually associated with the formation of fog.
Tidal Delta	Area of active or mobile marine sand within a river estuary.

Tidal Prism	The total volume of water that flows into an estuary or out again with the movement of the tide, excluding any freshwater flow.
Tides	The regular rise and fall of sea level in response to the gravitational attraction of the sun, moon and planets. Tides in the Tweed/Coolangatta region are semi-diurnal in nature, ie they have a period of about 12.5 hours.
Training Walls	Walls constructed at the entrances of estuaries and rivers to improve navigability. Typically constructed as rock or concrete armour revetments.
Tweed River Hydrodatum (TRHD)	Hydrosurvey chart datum for the Tweed River approximates ISLW. Australian Height Datum is about 0.9 m above Tweed River Hydrodatum.
Updrift	The opposing direction to the predominant direction of movement of littoral sediments along a shoreline; ie the direction along a shoreline from which most of the sediment arrives at a particular location, opposite to downdrift.
View Receptors	People who will be exposed to views of sand bypass options infrastructure and activities.
Vertebrate	Animal species possessing a backbone.
Waders	A grouping that includes all species of snipe, sandpiper, oystercatcher, stone-curlew, stilt, avocet, plover and related birds. These species typically feed on invertebrates along beaches, in estuaries and in marshlands. In Australia waders are the most characteristic group of birds associated with estuaries.
Wader Season	The time when summer migrant waders are present in Australia, which commences in late August and finishes in early April.
Wave Attack	Action of waves breaking on a beach or frontal dune which can result in erosion.
Wave Climate	The range of wave conditions experienced at a particular location.
Wave Transmission Coefficient	Ratio of the height of a wave inside a river entrance to the height it reached immediately seaward of the entrance.

Abbreviations

AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ANZECC	Australia and New Zealand Environment and Conservation Council
BP	Before Present
C	carbon
CAMBA	China-Australia Migratory Bird Agreement
CO_2	carbon dioxide
dBA	Decibels using the 'A' weighted scale, measured according to the frequency of the human ear.
DoE	Queensland Department of Environment
DIN	dissolved inorganic nitrogen
DLWC	New South Wales Department of Land and Water Conservation
DOC	dissolved organic carbon
DON	dissolved organic nitrogen
EDTA	ethylenediaminetriacetic acid - Dilute organic acid used to leach heavy metals which are bio-available.
EIS	Environmental Impact Statement
EPA	Environment Protection Authority
EP & A Act	NSW *Environmental Planning and Assessment Act 1979*
ESD	Ecologically Sustainable Development
g	gram
GCCC	Gold Coast City Council
IAS	Impact Assessment Study
ISLW	Indian Springs Low Water
HCO_3^-	bicarbonate ion, a product of the solution of carbon dioxide in water
HW	High Water

JAMBA	Japan-Australia Migratory Bird Agreement
km	kilometre
km^2	square kilometre
L_{A90}	The noise level which is exceeded for 90% of the time.
L_{Aeq}	The average noise level perceived by the human ear.
LEP	Local Environment Plan
LGA	Local Government Area
LW	Low Water
m	metre
m/s	metres per second
m^3	cubic metre
m^3/s	cubic metres per second
MHWS	Mean High Water Springs
mg/L	milligrams per litre
MLWS	Mean Low Water Springs
MWL	Mean Water Level
N	nitrogen
NO_x	nitrogen oxides
NPWS	NSW National Parks and Wildlife Service
OC/OP	ratio of organic carbon to organic phosphorus
P	phosphorus
pH	An index used to describe level of acidity ($-\log_{10}[H^+]$). A pH of 7 is neutral, ph less than 7 acidic, and a pH greater than 7 alkaline.
PW	NSW Public Works
REP	Regional Environmental Plan
SD & PWO Act	Queensland *State Development and Public Works Organisation Act 1971*
SEPP	NSW State Environmental Planning Policy

SLSANSW	Surf Lifesaving Association of NSW
TBLALC	Tweed Byron Local Aboriginal Land Council
TECLC	Tweed Entrance Community Liaison Committee
TRESBP	Tweed River Entrance Sand Bypassing Project
TFN	total filtrable nitrogen
TN	total concentration of nitrogen
TP	total concentration of phosphorus
WA	Waterways Authority

Appendix A

THE REQUIREMENTS OF THE DIRECTOR OF THE DEPARTMENT OF PLANNING (NSW) "THE DIRECTOR'S REQUIREMENTS"

New South Wales Government

Department of Planning

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Telephone :(02) 391 2000 Ext: 2026

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Contact : Chris Masters

Our Reference : G94/00236/001

Your Reference :

Mr M.F. Porter
Manager, Estuaries and Environment Policy
Dept. of Public Works
Box 5280 GPO
SYDNEY, NSW 2001

NSW PUBLIC WORKS
30 SEP 1994
ESTUARIES & ENVIRONMENTAL POLICY BRANCH

Dear Sir

Tweed Heads Sand Bypassing Project

Thank you for your letter of 4 August, 1994 indicating that you are consulting with the Director regarding the preparation of an environmental impact statement (EIS) for the above activity.

2. General requirements for the form and content of an EIS together with requirements for public exhibition and seeking approval are outlined in Attachment 1. It is noted however, that the approval process for some components of the project will require clarification prior to exhibition of the EIS.

3. Attachment No. 2 contains advice on the type of information most likely to be relevant to the activity you propose. Not all of the matters raised may be appropriate for consideration in the EIS for the proposal; equally, it is not exhaustive.

4. In addition, pursuant to clause 85 of the *Environmental Planning and Assessment Regulation* 1994, the Director requires that the following matters be specifically addressed in the EIS:

Key Issues

- Interaction and linkages between the NSW and Queensland objectives.
- Alternative proposals that satisfy the objectives of the proposal and the reasons for their rejection.
- Description of the hydrodynamics of the lower estuary and the nearshore zone affected by the proposal. This should include an assessment of the effect of the

training walls on nearshore and estuarine currents and likely changes brought about by the removal of sediment from Letitia Spit and other areas deemed necessary. The likely impact of any hydrodynamic changes on coastal and estuarine habitats should also be assessed.

- Description of the sediment budget. This should include identification of the various sources of sediment and an indication of their relative contributions. A description of the nature of sediment transport (in terms of both magnitude and frequency) within the area affected by the proposal and in areas outside of it subject to indirect impacts should be provided. Likely changes in transport rates due to hydrodynamic changes should be described. The accuracy of all estimates of sediment transport rates and volumes should also be indicated.

- Description of the operation of the sand bypassing facility. Particular attention is to be given to the manner in which this accords with natural patterns of sediment movement. The relative significance of remedial dredging and the manner in which it fits into the overall operational strategy of the sand bypass system should also be fully described.

- With respect to the pipeline option, a full description of the route (both on land and under water) should be provided. This is to include construction and operation details and the associated impacts on all existing land (and water) uses, in particular noise and vibration impacts, impacts on pelagic and benthic marine life along the pipeline route (from placement and burial if pertinent), at sediment collection locations and at delivery locations. Impacts on flora and fauna assemblages and recreational and commercial fishing should also be included.

- Impacts on water quality associated with all aspects of the proposal including those due to increased turbidity and sediment quality with particular consideration given to acid sulphate potential. The significance of pelagic and benthic marine life in localities likely to be affected by increased silt loads is to be assessed. Mitigation measures and strategies to guard against any deleterious impacts should be proposed and discussed.

Other Specific Issues

- The manner in which the proposal accords with the Tweed River Management Plan and with existing dredging operations.

- Disposal of material not required for beach nourishment.

- Consideration of maritime archaeology including identification of any submerged archaeological sites likely to occur within the study area and a description and assessment of the significance of any identified sites, relics or places. In this regard you are advised to contact the Department's Heritage Branch for advice.

- Consideration of issues affecting local amenity including noise, visual, air quality, water quality (particularly in regard to silt loads) and traffic (land and water) impacts. Mitigation measures should be identified.

- Potential impacts on any SEPP 14 wetlands in the lower Tweed estuary.

- Outline of an environmental and operational management plan (including ongoing maintenance dredging) for the proposal. This should include a description of any proposed measures intended to guard against actual and potential disturbances to vegetation, fauna, water quality and the hydrological regime during the construction and operation of the proposal.

- Results of consultations with:
  - Environment Protection Authority;
  - Department of Conservation and Land Management;
  - NSW Fisheries;
  - Maritime Services Board;
  - National Parks and Wildlife Service;
  - Heritage Council of NSW;
  - Tweed Council;
  - Queensland Dept. of Environment and Heritage;
  - any servicing authorities which may be affected.

Should you require further information regarding this matter please contact Chris Masters on 02 - 391 2026.

Yours faithfully,

29/6/94

Ken Sullivan
Manager
Government Infrastructure Assessments Branch
As Delegate for the Director

ATTACHMENT No.1

STATUTORY REQUIREMENTS FOR ENVIRONMENTAL IMPACT STATEMENTS PREPARED UNDER PARTS 4 & 5 OF THE ENVIRONMENTAL PLANNING AND ASSESSMENT ACT

In accordance with the *Environmental Planning and Assessment Act* 1979 (the Act), an environmental impact statement (EIS) must meet the following requirements.

Content of EIS

Pursuant to clauses 51 and 84 of the *Environmental Planning and Assessment Regulation* 1994 (the Regulation), an EIS must include:

1. A summary of the environmental impact statement.
2. A statement of the objectives of the development or activity.
3. An analysis of any feasible alternatives to the carrying out of the development or activity, having regard to its objectives, including:
   (a) the consequences of not carrying out the development or activity; and
   (b) the reasons justifying the carrying out of the development or activity.
4. An analysis of the development or activity, including:
   (a) a full description of the development or activity; and
   (b) a general description of the environment likely to be affected by the development or activity, together with a detailed description of those aspects of the environment that are likely to be significantly affected; and
   (c) the likely impact on the environment of the development or activity, having regard to:
      (i) the nature and extent of the development or activity; and
      (ii) the nature and extent of any building or work associated with the development or activity; and
      (iii) the way in which any such building or work is to be designed, constructed and operated; and
      (iv) any rehabilitation measures to be undertaken in connection with the development or activity; and
   (d) a full description of the measures proposed to mitigate any adverse effects of the development or activity on the environment.
5. The reasons justifying the carrying out of the development or activity in the manner proposed, having regard to biophysical, economic and social considerations and the principles of ecologically sustainable development or activity in the manner proposed, having regard to biophysical, economic and social considerations and the principles of ecologically sustainable development.
6. Compilation, (in a single section of the environmental impact statement) of the measures referred to in item 4 (d).
7. A list of any approvals that must be obtained under any other Act or law before the development or activity may lawfully be carried out.
8. For the purposes of this Schedule, **'the principles of ecologically sustainable development'** are as follows:
   (a) The precautionary principle - namely, that if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

(b) Inter-generational equity - namely, that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.
(c) Conservation of biological diversity and ecological integrity.
(d) Improved valuation and pricing of environmental resources.

Note: The matters to be included in item (4) (c) might include such of the following as are relevant to the development or activity:

(a) the likelihood of soil contamination arising from the development or activity;
(b) the impact of the development or activity on flora and fauna;
(c) the likelihood of air, noise or water pollution arising from the development or activity;
(d) the impact of the development or activity on the health of people in the neighbourhood of the development or activity;
(e) any hazards arising from the development or activity;
(f) the impact of the development or activity on traffic in the neighbourhood of the development or activity;
(g) the effect of the development or activity on local climate;
(h) the social and economic impact of the development or activity;
(i) the visual impact of the development or activity on the scenic quality of land in the neighbourhood of the development or activity;
(j) the effect of the development or activity on soil erosion and the silting up of rivers or lakes;
(k) the effect of the development or activity on the cultural and heritage significance of the land.

An environmental impact statement referred to in Sections 77(3)(d) and 112(1) of the Act shall be prepared in written form and shall be accompanied by a copy of Form 2 or Form 8 (as appropriate) signed by the person who has prepared it.

The EIS must also take into account any matters required by the Director of Planning pursuant to clauses 52 and 85 of the Regulation, which may be included in the attached letter.

Attention is also drawn to clause 115 of the Regulation regarding false or misleading statements in EISs.

Nominated Determining Authority
Where there are a number of determining authorities, Section 110A of the Act provides for the Minister to make one of them the nominated determining authority. This avoids duplication of procedures and simplifies the exhibition of the EIS. It is recommended that you discuss with the other determining authorities which one should become the nominated determining authority and advise the department accordingly. Normally it is the proponent agency that becomes the nominated determining authority.

Public Exhibition
When the EIS has been completed, six (6) copies should be forwarded to the Secretary, (Attention: Manager, Government Infrastructure Assessments Branch) pursuant to Section 112(2) of the Act, together with details of the exhibition period and public display locations. This should occur prior to public exhibition of the EIS in order that simultaneous exhibition of the EIS occurs in the

offices of the Department, council and determining authority as required by section 113 of the Act and clause 88 of the Regulation.

Procedures for public exhibition of the EIS are set down in clauses 55 to 57 and 87 to 88 (under Part IV and V respectively) of the Regulation.

Representations and Submissions
Any submissions (Part IV) and representations (Part V) made in response to public exhibition of the EIS should, as soon as practicable, be forwarded to the Secretary in accordance with sections 87 and 113(3) of the Act.

Seeking Approval of the Minister for Planning
Under Division 4 of Part 5 of the *Environmental Planning and Assessment Act* 1979, the proponent, pursuant to Section 115B, can seek the Minister's approval once it has obtained and exhibited an EIS, examined and considered any representations, and forwarded copies of all representations to the Department.

The Department's Best Practice Guidelines encourage proponents, when seeking approval, to provide:

- a comprehensive report which addresses in detail its consideration of issues raised in representations, any proposed changes to the activity, and any further measures to mitigate impacts; and

- all relevant technical information relating to the proposed activity.

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DEPARTMENT OF PLANNING

Attachment No. 2

MARINE AND ESTUARINE DREDGING OPERATIONS

ADVICE ON THE PREPARATION OF AN ENVIRONMENTAL IMPACT STATEMENT

INTRODUCTION

Pursuant to S112 of the *Environmental Planning and Assessment Act* 1979, where a proposal is a prescribed activity or where a proposal is likely to significantly affect the environment, a determining authority must, before deciding whether to proceed with the proposal consider an environmental impact statement (EIS) in respect of the proposal.

Dredging is a type of extractive industry. A definition of this may be found in Schedule 3 of the *Environmental Planning and Assessment Regulation* 1994. These industries are operations undertaken for the purpose of mining sand, gravel, clay, turf, soil, rock, stone or similar substances.

Note: the definition of extractive industry specifically excludes coal, petroleum or minerals listed under mining legislation.

Processing of extracted material on the same site as the winning of the material may also constitute an extractive industry.

PURPOSE

The aim of the EIS is to enable members of the public, the determining authority and the Department of Planning to properly understand the environmental consequences of the proposal.

The purpose of this attachment is to outline various issues relevant to the preparation and consideration of an EIS for marine and estuarine dredging and associated operations.

It is the applicant's responsibility to identify and address, as fully as possible, the matters relevant to the specific development proposal in complying with the statutory requirements for EIS preparation (See Attachment No. 1).

The matters nominated in this attachment are not intended as a comprehensive identification of all issues which may arise in respect of dredging and associated operations.

Some of the issues nominated may not be relevant to a specific proposal. Conversely, there may be other issues, not included, that are appropriate for consideration in the EIS.

Information provided should be clear, succinct and objective. Where appropriate, it should be supported by maps, plans, diagrams or other descriptive detail.

An executive summary should be provided in the EIS and be available separately for public information.

MATTERS TO BE CONSIDERED IN THE EIS

1. BACKGROUND TO THE PROPOSAL

The general background to the proposal

should include

- details of the site(s), land tenure, zonings and relevant forward planning proposals
- justification of the proposal considering environmental, social and economic benefits and costs
- information on the location and extent of the works proposed
- an indication of adjacent developments
- the consequences of not proceeding with the proposal
- an assessment of the ecological sustainability of the proposal; a definition of this is given in Schedule 2 of the *Environmental Planning and Assessment Regulation* 1994

The statutory procedures for implementing the proposal should also be described in the EIS.

2. DESCRIPTION OF THE PROPOSAL

This section should provide specific information on the nature, intent and form of the development such as

- processes involved
- economic significance of the resource
- proposed water pollution safeguards
- disposal of wastes

A description should also be provided of associated land operations including any processing and/or disposal, stockpiling and transport of materials from the site and use of the end product if likely to have environmental implications.

Particular details that may be relevant include

- purpose of dredging
- availability of alternative resources
- extent of dredging proposed including depth of dredging
- quantity of material to be extracted
- physical and chemical characteristics of the resource
- methods of extraction and/or plans of operations
- details of any necessary stockpiling
- proposed means of disposal of dredged material
- site establishment/staging of construction
- type of machinery and equipment to be used for the dredging and stockpiling operations and for any processing plant
- noise levels and effects of vibration
- expected life of the operation
- number of persons to be employed
- hours of operation
- maintenance and servicing of facilities
- access arrangements - truck routes, truck numbers, etc
- erosion controls both above and below the waterline
- operational strategies for extraction giving full consideration to natural patterns (magnitude and frequency) of sediment transport
- design features to guard against actual and potential disturbances to flora, fauna, water quality, geomorphology and hydrology
- proposed measures for preventing and/or minimising actual and potential disturbances to flora, fauna, water quality, geomorphology and hydrology
- proposed measures to offset any habitat losses or related impacts which may occur such as
  - preparation of an environmental management plan (EMP) which maintains or enhances habitats not affected by the proposal, and/or
  - establishment either on site or nearby of similar habitats which function to replace some or all of the values lost

through development

- integration with existing management plans (if any)
- rehabilitation proposals - progressive and/or on completion including any relevant landscape plans

3. DESCRIPTION OF THE ENVIRONMENT

This should provide details of all aspects of the environment likely to be affected by any facet of the proposal. Discussion should not be restricted solely to the area in the immediate vicinity of the proposal but should also consider the broader picture where appropriate.

Physical, natural, social, archaeological, and economic aspects of the environment should be described to the extent necessary for assessment of the environmental impact of the proposed development.

The Physical Environment

- physiographic setting including
  - regional setting
  - coastal geomorphology and geology (including depositional history)
  - nearshore and estuarine bathymetry
- meteorology including
  - wind regime
  - implications of global climate change
- coastal processes including
  - characteristics of the local and regional wave regimes
  - characteristics of local and regional currents
  - nearshore sediment transport dynamics; this should include a definition of the nearshore zone, identification of sources of sediment, and identification and quantification of sediment transport mechanisms (all estimates should quantify the uncertainty associated with their calculation)
  - the relative significance of episodic sediment movement (due to storms, etc) versus more regular movement
- estuarine processes including
  - hydrodynamics of the estuary and the associated influence on sediment transport
  - sources of sediment and their relative contributions
  - impacts of any existing dredging works on sediment transport dynamics
- water and sediment quality considering
  - historic trends in water quality
  - acid sulphate potential of sediment

The Ecological Environment

- vegetation covering
  - aquatic flora (marine and estuarine) especially those species of significance to fauna populations
  - terrestrial flora
  - any SEPP 14 wetlands which may be directly or indirectly affected by the proposal
- aquatic fauna including
  - zooplankton
  - pelagic fish and invertebrates
  - benthic fauna (interstitial fauna, macrofauna and scavengers) with consideration given to the potential for recolonisation of disturbed areas of the seabed
  - marine mammals and reptiles
- terrestrial fauna
  - indigenous and migratory birds
  - terrestrial mammals, reptiles and amphibia

If the development proposed involves clearing, filling, draining or levee construction in any SEPP 14 wetland the EIS should address the following matters, pursuant to clause 52 of the Regulation:

- identification of the wetland's habitats, ecological values and water characteristics including a vegetation survey map (preferably at a scale of 1:4000) indicating the occurrence of any rare or endangered

plant species, their values, and the extent of any weed infestation

- a fauna survey describing the birds (both indigenous and migratory), reptiles, amphibians and mammals; the likely occurrence of any rare, endangered and protected species should also be noted
- a full description of the surface and groundwater regimes considering both quantity and quality

The Cultural Environment

- buildings, items and places of architectural and heritage significance including those of aboriginal heritage
- maritime archaeology with respect to
  - identification of any submerged archaeological sites (shipwrecks, wharves, jetty deposits, slipways, etc) likely to occur within the study area (proposed offshore and onshore abstraction areas, jetty sites, pumping stations, etc) through historical research of archival material and remote sensing if required
  - description and assessment of the significance of any identified sites relics or places
- commercial and recreational activities
  - commercial fishing such as linefishing, netting and trawling
  - recreational fishing
  - fishing clubs, associations and charter operators
  - recreational diving including spearfishing, SCUBA diving and associated clubs
  - swimming and surfing
- shipping and boating
  - commercial shipping
  - shipping paths
  - vessel numbers
  - recreational boating
- coastal land uses
- visibility
- noise and air quality (where appropriate for impact consideration
- utilities and communications
- socio-economic aspects including:
  - local commercial and industrial activities
  - development and employment potential

4. ANALYSIS OF ENVIRONMENTAL IMPACTS

Assessment of environmental impacts should not be confined solely to the immediate area of dredging operations but should also consider impacts (in terms of both time and space) beyond this. Those impacts usually associated with dredging and related activities are listed as follows.

Where relevant to the specific proposal, these should be addressed in the EIS taking into account the adequacy and effectiveness of safeguards proposed to minimise them during both establishment and operation.

In addition, any potential for hazard to public safety and any proposals to monitor and reduce environmental impacts should be included.

Biophysical Impacts

- effects of the proposed activities on terrestrial vegetation with consideration given to
  - those species listed in Schedule 13 (Protected Native Plants) of the *National Parks and Wildlife Act* 1974
  - inadequately reserved plant communities
  - the regional importance of any remnant bushland
- impacts on aquatic flora particularly those species having significance for the maintenance of aquatic fauna populations
- direct and indirect impacts on any SEPP 14 wetlands
- impacts on terrestrial and aquatic fauna considering
  - habitat requirement

- local, regional and State significance of the populations and habitats found
- assessments of the extent of habitat modification likely to occur and the resultant impacts to resident and transient fauna populations
- assessments of 'edge effects' and impacts on fauna of the surrounding area due to severance of movement corridors
- the need for a Fauna Impact Statement (FIS) where fauna listed in Schedule 12 of the *National Parks and Wildlife Act* 1974 is likely to be significantly affected

- assessment of the potential for recolonisation of disturbed areas of the seabed by benthic flora and fauna.
- direct, indirect and cumulative impacts on the hydrodynamics of the estuary and nearshore zone, the relationship of these impacts to existing dredging activities and implications for sediment transport
- the bed and bank stability of any affected rivers during and after completion of operations and any need for recurrent maintenance dredging
- any possible siltation, sedimentation or downstream effects of the operation
- any likely cumulative effects of the proposed operation particularly when considered in conjunction with other activities affecting the waterbody
- effects on surface and subsurface water quality due to leachates from stockpiled material
- water treatment and other pollution control measures
- disposal of waste material
- stormwater runoff, erosion and siltation potential; measures to control impacts, especially from material stockpiled during construction, should be addressed

Social/Cultural/Community Impacts

- impacts on commercial and/or recreational fish resources
- details of flooding and any likely effects of the operation on flood liability of surrounding lands
- the agricultural viability of land to be used as a stockpile site
- likely noise and/or vibration disturbance caused by operations, including transport and stockpiling, on nearby residences (a map depicting anticipated noise contour levels in relation to residences and inhabitants involved may be necessary)
- air quality impacts such as dust nuisance from any stockpiles of dredged material
- effects on the visual environment
- proposed landscaping measures
- proposed final use of the stockpile site
- any likely affectation of archaeological sites of Aboriginal or European heritage value whether submerged or on land
- comparisons of the direct and indirect environmental, economic and social costs of the impacts and benefits arising from the project
- consideration of local and regional economic and social impacts of the proposal

Transportation Impacts

- impacts of trucking movements including access over railways and onto highways
- impact of operations on navigation aspects for all types of shipping (commercial, recreational, etc)

Hazard Assessment

This should cover the assessment of hazard and risk to the biophysical and human environments resulting from both the construction and operation of the proposal.

Factors for consideration include

- the integrity of all facets of the operation during exposure to natural hazards such as flooding and severe storms

- any aspects of the operation that could have significant detrimental impacts on the environment, e.g. chemical and fuel spills
- formulation of a hazard management plan outlining anticipated risks and response strategies

5. IDENTIFICATION OF MITIGATION AND MANAGEMENT MEASURES

A compilation of the relevant actions, safeguards, mitigation, amelioration, compensation and monitoring requirements identified in the EIS should be included. Approvals and/or consents that must be obtained before the project is commenced or in operation should be identified.

An outline of the requirements, content and commitment to the preparation of an Environmental Management Plan (EMP) or similar management tool shall be provided.

CONSULTATION WITH RELEVANT GOVERNMENT AUTHORITIES

In preparing the EIS, it is suggested that authorities, such as those listed as follows, should be consulted and their comments taken into account in the EIS.

- the Department of Agriculture with regard to any effects on agricultural land
- the Department of Conservation and Land Management regarding appropriate erosion control and rehabilitation procedures and use of Crown land
- the Environment Protection Authority in regard to air, water and noise impacts and relevant pollution control legislation requirements
- NSW Fisheries regarding requirements for dredging operations or any other aspects of the development likely to affect fish life
- the Maritime Services Board with regard to navigational aspects of shipping
- the Department of Mineral Resources in relation to any minerals which may be affected by the project
- the Department of Public Works in relation to hydrological impacts and relevant legislative requirements
- the Heritage Council of NSW if the proposal is likely to affect any item, building or place having heritage significance for the State

It is the responsibility of the person preparing the EIS to determine those Departments relevant to the proposal.

SUPPORTING INFORMATION

The EIS should make reference to all relevant studies and investigations that have been carried out in support of the proposals. This supporting documentation should be made available during the period of public display of the EIS.

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LAND & WATER CONSERVATION

COASTAL, FLOODPLAIN & RIVERINE RESOURCES DIRECTORATE

TWEED RIVER ENTRANCE SAND BYPASSING PROJECT

TO	: Department of Environment : Kinhill Engineers : Hyder Consulting	FILE No.	R 2100/156
FAX No.	: (07) 3221 0768, (07) 369 4816, 9247 9237	SENDER	S. Lawson
ATTENTION	: Russell Murray/Michael Allen : Tom Connor/Peter Cummings : Hugh Swinbourne/Maria Scolaro	PHONE	(02) 372-7720
YOUR REFERENCE	:	FAX No	(02) 372-7799
		PAGES TOTAL (INCLUDING THIS PAGE)	3

SUBJECT: Supplementary Director-General's Requirements **DATE:** 22 November 1996

Attached fax copy of the NSW Department of Urban Affairs and Planning, Director-General's Requirements for the Permanent Bypassing System EIS/IAS, issued on 21 November, 1996.

for S. Lawson 22-11-96
A Dyson
Project Director
Tweed (NSW)

Hyder Consulting
RECD
22 NOV 1996
MS 22.11.96
HS Faxed
FILE 6259-B
ACTION

● McKell Building, 2-24 Rawson Place, Sydney NSW 2000 ● Telephone (02)372 8877 ● Fax (02)372 7566

Department of Land and Water Conservation incorporates the Water Services Policy Division of the former NSW Public Works and the former Departments of Conservation and Land Management and Water Resources.

New South Wales Government
Department of Urban Affairs and Planning

Mr Alan Dyson
Project Director, Tweed River Entrance Sand Bypassing Project
Dept. of Land and Water Conservation
Level 12, McKell Building
2-24 Rawson Place
SYDNEY NSW 2000

Contact: Chris Masters
Our Reference: G94/00236/001
Your Reference:

Dear Mr Dyson

Tweed River Entrance Sand Bypassing Project
Permanent Sand Bypassing System

Thank you for your letter of 25 October 1996 on behalf of the Minister for Land and Water Conservation regarding reconsultation with respect to the Director-General's Requirements for the above proposal.

You are advised that all the matters specified in the Director's Requirements issued on 29 September 1994 are still applicable to this proposal. In addition, pursuant to clause 85 of the *Environmental Planning and Assessment Regulation 1994*, the following matters shall also be specifically addressed in the EIS:

- Consideration of the relevant provisions of the *North Coast Regional Environmental Plan 1988* (as amended), the *Tweed Local Environmental Plan 1987*, the draft *Tweed Shire Strategic Plan 1996* and the NSW Government's draft Revised Coastal Policy. Consideration should also be given to all relevant Queensland environmental planning instruments (EPIs). Where applicable to the proposal, any apparent inconsistencies between Queensland and NSW EPIs should be highlighted and the nature of these clearly described.
- Results of consultation with the Department of Aboriginal Affairs (NSW), the local Aboriginal Land Council(s) and representatives of the local Aboriginal community.
- Consideration of the provisions of Fish Habitat Protection Plan No. 1 (March 1995) made under the *Fisheries Management Act 1994*.
- Identification and assessment of cumulative impacts of the proposal with particular reference to:
  i) activities associated with Stage 1 of the project;
  ii) other extractive operations undertaken within the lower Tweed River; and
  iii) other coastal engineering works undertaken within the region which could

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1 Farrer Place, Sydney 2000
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Facsimile: (02) 9391 2111

potentially have an influence on the proposal.
The time period over which the second and third items should be considered should extend back at least 10 years.

- Description of appropriate mitigation measures for all identified impacts. This is to include an assessment of their likely effectiveness giving consideration to possible synergistic effects of individual impacts, mitigation measures, and of impacts and mitigation measures together.
- Provision of an outline of an Environmental Management Plan (EMP) for both the construction and operational stages of the proposal. Specific reference should be made to the manner in which the EMP will be integrated with existing management activities being undertaken for Stage 1 of the proposal. Monitoring, auditing and reporting procedures should also be described.

It should also be noted that reference to the Department's Heritage Branch in the original Director's Requirements should now be taken to read the Office of Heritage.

Should you have any enquiries regarding this matter please contact Chris Masters on 9391 2026.

Yours sincerely

David Mutton 21/11/96

David Mutton
A/Manager
Major Assessments and Hazards Branch
As Delegate for the Director-General

Appendix B

THE QUEENSLAND "TERMS OF REFERENCE FOR AN ENVIRONMENTAL IMPACT STUDY"

TWEED RIVER ENTRANCE SAND BYPASSING PROJECT

PERMANENT BYPASSING SYSTEM

TERMS OF REFERENCE FOR AN IMPACT ASSESSMENT STUDY

GOLD COAST QLD

Prepared by

Planning and Assessment Section
Department of Environment and Heritage

NOVEMBER 1994

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PRELIMINARIES

1. BACKGROUND

The Heads of Agreement for a project to bypass sand moving northward parallel to the Australian Coastline across the Tweed River entrance was signed by the Premiers of Queensland and New South Wales on 31 March 1994. The project comprises an initial dredging and nourishment component involving the placement of two million cubic metres of sand on Gold Coast beaches, followed by the construction and operation of a permanent bypassing system. This Terms of Reference (TOR) only relates to the permanent bypassing system

The TOR is provided to assist in the preparation of an Impact Assessment Study (IAS) under the *State Development and Public Works Organization Act 1971* to cover the placement of the sand in Queensland. The New South Wales Government has provided separate guidelines for the dredging component and it is intended that a single report based on both sets of guidelines will be produced.

The recommended presentation and content for the Queensland component are provided in this document. However, relevant issues should be incorporated into the appropriate sections of the combined report and a consistent presentation used throughout.

2. STYLE AND FORMAT

Information provided should be objective and, where appropriate, supported by maps, plans, diagrams or other descriptive detail. It should be produced on A4 size paper capable of being photocopied double sided with maps/diagrams also A4 or A3.

The report should be written in a clear, concise and analytical style that is easily understood by the general reader. It is not required to be encyclopaedic, but should be complete in itself.

NOTE: In preparing the IAS, it is in the proponent's responsibility to address the impacts of the proposal to the degree necessary to enable the public authorities to be informed of all relevant impacts of the proposal. The level and nature of investigations should be relative to the likely extent and scale of impacts.

Lists of individuals and organisations consulted and results of these consultations/studies should be included as appendices along with technical information, relevant plans and illustrations. It is the proponent's responsibility to ensure that only suitably qualified and experienced persons undertake the study and prepare the report and the names and curricula vitarum of all personnel involved should be presented. Appropriate permits must be obtained from relevant authorities for any flora/fauna collections.

CONTENTS

The IAS is to address the issues set out below and generally follow the format as suggested in this document.

1. EXECUTIVE SUMMARY

An Executive Summary generally following the format of the IAS of no more than 5 pages is to be included.

2. TERMS OF REFERENCE

These Terms of Reference are to be included in the IAS report.

3. INTRODUCTION

3.1 The Proponent

- Title of Proposed Development
- Details of the proponent

3.2 Objectives of the Project

- Broad statement of objectives of the project.

3.3 Scope of the Proposal

- Background to the proposal.
- Envisaged time for construction and establishment of each component of the project.

3.4 Approval Process

- Outline the environmental assessment process to be followed and the role of the IAS in the approval arrangements.
- Existing and proposed Commonwealth, State and Local Government legislation applying to the proposal, including the status of any applications for approval and further approvals required for the project.

4. SITE DETAILS

- Location.
- World Heritage and National Estate status of the site and surrounds.
- History and current use of the site and immediately adjacent land and waters.
- Existing facilities on the site and adjacent land.
- Existing and proposed town planning and other statutory provisions affecting the site and the area in general.
- Present and proposed tenures of the site and land associated with the development.
- Native Title issues.
- Any additional roads which need to be opened or closed, either temporarily or permanently, to service the development.
- The width and boundary of any erosion prone areas over the site.

- Bathymetry.

5. PROPOSED DEVELOPMENT

A description of the proposal and general background information including:

- a statement of the objectives of the proposal.
- location (including map) and site plan of the site;
- deposition area;
- schedule of work outlining the time scale, hours of operation and scheduling of dredging;
- method of deposition and equipment to be used;
- The reliability of equipment especially in the context of sand accumulation in machinery;
- details of existing and proposed beach and nearshore cross-sections and plan shapes in the nourishment area;
- details of any works proposed in the erosion prone area or which are likely to have an effect on coastal management including the location of such works in relation to the erosion prone area boundary;
- details of proposed drainage in the project vicinity particularly with regard to any stormwater runoff across the beach;
- methods to stabilise nourishment areas against wind erosion;
- report on the measures proposed to safeguard public access to the beach and nearshore areas during the construction phase of the work and during operation of the sand by-passing system.
- details on traffic generated; and
- legislative requirements which apply to the works.

5.1 Alternatives

Describe the alternatives considered in the selection of the methods and locations to be used to achieve the objectives of the proposal and reasons for the options chosen.

6. DESCRIPTION OF THE AFFECTED ENVIRONMENT

This section should provide a description of the existing environment both in the region of the deposition and surrounding regions to serve as a baseline against which the impacts of deposition can be assessed. The results of any relevant studies should be included.

6.1 Geology

Discuss the geology of underlying materials and any influences of material properties on water quality.

6.2 Water Quality and Hydrology

Assess the existing water quality of the area likely to be affected by the proposal in terms of physical, chemical and biological characteristics. Parameters include nutrient status (organic/inorganic), dissolved carbon and oxygen, salinity, pH, turbidity, suspended solids, pathogenic organisms, toxic substances, bottom sediments and heavy metals.

Monitoring should include parameters which would assist the description of impacts on water quality, water movement and biological productivity. These include tidal ranges, current velocities and directions at different tidal states, longshore currents and their effect on sand transport, bathymetry, current drainage patterns on site, climatic conditions, present beach conditions and beach behaviour.

6.3 Marine Flora, Fauna and Ecological Relationships

- major flora species and communities present, mapped where relevant, including littoral and aquatic plants (particularly presence of seagrass/mangroves in adjacent waters likely to be impacted by silt plumes i.e. within a radius of 1 km from the site);
- any rare or endangered species;
- the extent of the disturbance of natural vegetation;
  NOTE: All plants growing on tidal lands are protected under the Fisheries Act 1976.
- fauna present or likely to be present in the area and the significance of species or communities noting biological productivity and ecological function, including fisheries habitat such as yabby banks etc. which would be adversely impacted by the removal of habitat or changes to current patterns (giving areas involved) and areas and types of new habitat which will be created;
- rare or endangered species or unusual community associations;
- habitat requirements;
- sensitivity of species to changes (if known);
- extent, integrity and importance of communities;
- important ecological relationships with consideration in context with surrounding waters;
- representation of these communities in surrounding areas;
- value of commercial species;
- use of area by migratory species; and
- movement corridors.

6.4 Archaeological and Heritage Values

Describe any prehistoric or historic sites, relics or culturally significant features which may be impacted.

7. IMPACTS

Identify potential impacts discussing the reliability and validity of impact predictions. Direct/indirect, temporary/irreversible, and adverse/beneficial effects should be identified.

7.1 Biophysical Environment

- impacts on flora and fauna and the marine ecosystem;
- extent of loss of important communities and implications of this;
- impact of dispersion of deposition solids;
- impacts of noise from traffic, equipment and pumps during operation;
- impacts on navigation;
- impacts associated with any radioactive sand encountered;
- impacts on coastal processes, including waves (especially the impact of off-shore sand deposits on wave characteristics at surfing beaches such as Kirra beach), currents, longshore transport, onshore-offshore transport and coastal and seabed morphology;
- impacts of any sand borne contaminants; and

- impact on stormwater run-off across the beach, and impact on the tidal and flood behaviour of any watercourses in the vicinity of the works.

7.2 Water Quality
- impact of deposition on water quality.

7.3 Social Impacts
- impact on property owners and proposed development;
- impact on the commercial and recreational fishing industry;
- impact of works on use of the site by the public (including swimmers, surfers, anglers, divers and snorkellers);
- visual and aesthetic impacts; and
- impact on archaeological and heritage values.

8. ENVIRONMENTAL MANAGEMENT

Detail environmental controls, safeguards, planning conditions and design features, and describe proposed management arrangements, making reference to relevant legislation, policies and standards:

With respect to identified adverse impacts, describe the action proposed to mitigate or accommodate these impacts. These actions should be presented as an environmental management program in accordance with the principles listed below. This should describe proposed monitoring of the project's performance. Reporting arrangements should have regard to administrative responsibilities.

Monitoring programs should aim to:
- measure any differences between predicted and actual impacts;
- ensure safeguards are being effectively applied; and
- identify any unpredicted impacts which may require remedial measures.

The reporting program should detail:
- procedures for reporting on monitoring programs and proposed recipients of reports;
- monitoring proposals, including provisions for adequate baseline data;
- steps to be taken to correct detrimental effects identified by monitoring; and
- any habitat enhancement projects or projects to encourage recovery.

Specific matters of environmental management include:
- measures to control the plan position of the beach at the deposition sites;
- methods of controlling the impact of silt plumes (likely direction of transport, distance and chemical composition);
- methods by which water and habitat quality will be maintained;
- methods by which equipment will be maintained especially in the context of sand accumulation in machinery;
- methods of maintenance for any off-shore piping; and
- protection of rare, endangered or otherwise valuable species.

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9. CONSULTATION

The Queensland Commercial Fishermen's Organisation, the Queensland Sport and Recreational Fishing Council and local fishing clubs proximal to the area affected should be consulted. In addition, community groups, such as the Surf Rider Foundation and environmental groups, should be consulted. Written comments (suitably referenced i.e. author, date, organisation) provided by each sector of the Fishing Industry or an agreed-to summary of the consultation process with each sector regarding any disruption of the existing fish habitat and its dependent fisheries and any possible disruption to fishing activities (eg.,trawling, beach netting, bait gathering) should form part of the report.

The consultant should also contact the Coastal Management sections of the Head Office and Southeastern Regional Office of the Department of Environment and Heritage to ascertain the required level of detail to be supplied.

10. CONSULTANTS, STUDIES AND REFERENCES

Details of consultants and studies which they have undertaken in the course of proposal formation and preparation of the report should be provided.

Describe any further studies or investigations, either proceeding or intended.

Cite any sources of information used in preparing the document.

APPENDIX A

ADVISORY BODIES

Manager
Social Impact Assessment Unit
Community Services Development Division
Department of Family Services
and Aboriginal and Islander Affairs
GPO Box 806
BRISBANE QLD 4001

Principal Environment Manager
Land Use and Fisheries Division
Department of Primary Industries
80 Ann Street
BRISBANE Q 4000

Director
Marine and Ports Division
Queensland Transport
41 George Street
BRISBANE Q 4000

Regional Manager
Metropolitan South Coast
Queensland Transport
PO Box 107
SOUTHPORT QLD 4215

The Secretary
Queensland Fish Management Authority
10th Floor Unisys Centre
157 Ann Street
BRISBANE QLD 4000

Chief Executive Officer
Gold Coast City Council
PO Box 5042
GOLD COAST MAIL CENTRE QLD 4217

General Manager
Tweed Shire Council
Tweed Heads Civic Centre
Brett Street
TWEED HEADS NSW 2485

The Secretary
Queensland Commercial Fishermen's
Organisation
PO Box 392
CLAYFIELD QLD 4019

The Secretary
Sunfish
Queensland Sport and Recreational
Fishing Council
PO Box 212
MARGATE QLD 4019

Executive Officer
Australian Littoral Society
PO Box 49
MOOROOKA QLD 4105

Hon. Secretary
Wildlife Preservation Society of Queensland
Gold Coast and Hinterland Branch
PO Box 2441
SOUTHPORT QLD 4215

Appendix C

Appendix C

Matrix Of Compliance To NSW Directors' Requirements And Queensland Terms Of References

New South Wales Directors Requirements	Where located in this EIS/IAS
1. Summary of EIS	Before Chapter 1
2. Statement of objectives of the development or activity.	1.1
3. Analysis of any feasible alternatives to carrying out the development or activity:	6.0
a. consequences of not carrying out the development or activity,	1.5
b. reasons justifying carrying out the development or activity.	9.0
4. Analysis of the development or activity including:	
a. a full description of the development or activity,	1.1, 5.0
b. general description of the environment likely to be affected by the development or activity,	4.0
c. the likely impact on the environment of the development or activity and	7.0
d. a full description of the measures proposed to mitigate any adverse effects of the development or activity on the environment.	7.0
5. Reasons justifying the carrying out the development or activity having regard to biophysical, economic and social considerations and the principles of ESD.	7.8.2
6. Compilation of measures referred to in 4d.	7.0, 8.0
7. A list of approvals which must be obtained.	2.4
8. Assessment should include:	
a. soil contamination,	4.1.5
b. flora and fauna,	4.5, 7.5
c. air, noise and water pollution,	4.6.11, 7.6.8, 4.6.9, 7.6.7, 4.1.9
d. human health,	N/A
e. hazards,	7.6.11
f. traffic,	7.6.9
g. local climate,	4.1.7
h. social and economic,	4.6, 7.6
i. visual,	4.6.7, 7.6.5
j. soil erosion,	N/A
k. cultural and heritage significance.	7.6
9. General background to the proposal:	
a. site details,	5.0
b. land tenure, zoning and planning,	4.6.1
c. justification,	9.0
d. location and extent of works,	5.2
e. adjacent developments,	4.6.1
f. consequence of not proceeding with proposal,	1.5
g. ESD.	7.8.2

New South Wales Directors Requirements	Where located in this EIS/IAS
10. Description of proposal:	
a. process,	5.0
b. economic significance,	7.6.4
c. water pollution safeguards,	5.7.9
d. waste disposal,	5.7.9
e. purpose,	1.3
f. availability of alternate resources,	N/A
g. extent of dredging,	5.2
h. quantity of material,	5.4
i. physical and chemical characteristics,	4.1.3, 4.1.5, 4.1.6
j. methods of extraction,	5.5
k. details of stockpiling,	N/A
l. disposal of dredged material,	5.2.1
m. staging of construction,	5.6.1, 5.7.3
n. machinery and equipment,	5.5
o. noise and vibration,	7.6.7
p. life expectancy,	5.7.6
q. number of persons to be employed,	5.7.2
r. hours of operation,	5.7.3
s. maintenance and servicing,	5.7.1
t. access,	5.5.7.3, 4.6.12
u. erosion control,	N/A
v. operational strategies,	5.7
w. minimisation of environmental impacts,	7.0
x. mitigative measures of off set habitat lost,	7.0
i. EMP,	8.0
ii. habitat establishment	N/A
y. integration of existing management plans,	8.0
z. rehabilitation proposals.	8.0
11. Description of the environment	
a. physical,	4.1 - 4.4
b. ecological,	4.5
c. cultural.	4.6
12. Analysis of environmental impacts:	
a. biophysical,	7.1 - 7.5
b. social, cultural and community,	7.6
c. transport impacts,	7.6.9
d. hazard assessment,	7.6.11
13. Identification of mitigation and management measures.	8.0
14. Consultation with relevant government authorities, including:	2.0, Appendix D .
a. EPA,	
b. DLWC,	
c. NSW Fisheries,	
d. Waterways Authority (formerly Maritime Services Board),	
e. NPWS,	
f. Heritage Council of NSW,	
g. Tweed Council,	
h. Queensland Department of Environment,	
i. servicing authorities,	
j. Department of Aboriginal Affairs,	

New South Wales Directors Requirements	Where located in this EIS/IAS
k. local Aboriginal land councils, l. local Aboriginal community.	
15. Supporting information.	Reference, Technical Appendices
16. Interaction and linkages between NSW and Queensland objectives.	1.1, 2.2, 2.3
17. Alternative proposals and reason for their rejection	5.5.3, 6.0
18. Description of hydrodynamics of the lower estuary and nearshore zone affected by the proposal.	4.1 - 4.4
19. Assessment of the effect of training walls on nearshore and estuarine currents and likely changes brought about by sediment removal.	4.2
20. Impact of hydrodynamic changes on coastal and estuarine habitats.	7.5
21. Description of sediment budget. a. sources of sediment, b. nature of sediment transport, c. changes to sand transport, d. indication of accuracy of sediment transport rates and volumes.	4.1 - 4.4
22. Operation of the sand bypassing facility, a. natural sediment movement, b. remedial dredging.	 5.4 5.7.8
23. Pipeline Option: a. description of route, b. construction and operation, c. existing land and water use, d. noise and vibration, e. pelagic and benthic marine life, f. sediment collection location, g. sediment delivery locations, h. flora and fauna, i. recreational and commercial fishing.	 Figure 5.2.2 5.7 7.6.1 7.6.7 7.5.1 5.2 5.2 7.5 7.6.4
24. Impacts on water quality: a. turbidity and sediment quality, b. acid sulfate potential.	 7.1.3 7.1.2.1
25. Manner in which proposal accords with the Tweed River Management Plan and existing dredging operations.	7.4, 8.0
26. Disposal of material not required for beach nourishment.	5.7.9,
27. Marine archaeology.	4.6.4, 7.6.2
28. SEPP 14 wetlands.	2.4, 4.5, 4.6.1.1, 7.5.2
29. Outline of EMP.	8.0
30. Consideration of: a. *North Coast Regional Environmental Plan 1988*, b. *Tweed Local Environmental Plan 1987*, c. *Draft Tweed Shire Strategic Plan 1996*, d. Revised coastal policy, e. relevant QLD EPIs,	2.4, 4.6.1
31. Consideration of *Fisheries Management Act 1994*.	2.4

32. Cumulative impacts associated with: a. Stage 1, b. other extractive operations undertaken in the Lower Tweed River, c. other coastal engineering works.	7.0
33. Mitigation measures for all identified impacts.	7.0
34. Outline for EMP for construction and operation: a. integration of existing management activities from Stage 1, b. monitoring, auditing and reporting procedures.	8.0

Queensland Terms of Reference	**Where located in this EIS/IAS**
1. Summary of IAS (no more than 5 pages).	Before 1.0
2. Terms of Reference included in IAS report.	Appendix B
3. Introduction: a. Details of the proponent, b. objectives of the project, c. scope of the proposal, d. approval process.	 1.2 1.1 1.0 2.0
4. Site details including: a. location, b. World Heritage and National Estate status, c. history and current use of site, d. existing facilities, e. existing and proposed state planning and other statutory provisions, f. present and proposed tenures, g. Native Title issues, h. additional roads required, i. width and boundary of erosion prone areas, j. bathymetry.	 1.1, 5.0 4.6.1 1.3.3, 4.6.1.1 4.6.1.1 2.4, 4.6.1 4.6.1 4.6.1.2 5.5.7.3 N/A 4.1-4.4, 7.1 - 7.4
5. Description of proposed development including: a. objectives of proposal, b. location and site plan, c. deposition areas, d. schedule of work, e. method of deposition and equipment to be used, f. reliability of equipment, g. details of existing and proposed beach and nearshore cross sections and plan shapes in nourishment areas, h. details of works proposed in erosion prone areas, i. proposed drainage, j. wind erosion, k. safeguard of public access to beach and nearshore areas during construction and operation phases, l. details on traffic generated, m. legislative requirements, n. consideration of alternatives.	 1.1 Figure 5.2.2 5.2 5.6 5.2 5.7.7 5.2 N/A 4.1.1, 7.1.1 N/A 7.6.11 7.6.9 2.4 5.5, 6.0

6. Description of the affected environment including: a. geology, b. water quality and hydrology, c. marine fauna, flora and ecological relationships, d. archaeological and heritage values.	 4.1.2 5.7.9, 7.4.1 7.5 7.6.2
7. Impacts including: a. biophysical environment: - flora and fauna and marine ecosystems, - loss and implication of important communities, - dispersion of deposition solids, - noise from traffic equipment and pumps, - navigation, - radioactive sand, - coastal processes, - sand bourn contaminants, - stormwater, tidal and flood behaviour.	 7.1-7.5 7.5 7.5, 7.7 7.1-7.4 7.6.7 7.6.6 N/A 7.1-7.4 7.4.1
8. Water quality: a. impact of deposition on water quality.	 5.7.9, 7.4.9
9. Social impacts a. property owners, b. commercial and recreational fishing industry, c. public use, d. visual and aesthetic, e. archaeological and heritage.	 7.6.1 7.6.4 7.6.4 7.6.5 7.6.2
10. Environmental management	8.0
11. Consultation with authorities including: a. Department of Family, Youth and Community Care, b. Department of Primary Industries, c. Queensland Transport (Marine and Ports Division), d. Queensland Transport - South Coast, e. Queensland Fish Management Authority, f. Gold Coast City Council, g. Tweed Shire Council, h. Queensland Commercial Fishermen's Association, i. Sunfish - Queensland Sport and Recreational Fishing Council, j. Marine Conservation Society (formerly Australian Littoral Society), k. Wildlife Preservation Society of Queensland, l. Surf Rider Foundation, m. Department of Environment (Coastal Management), n. Department of Environment (South Eastern Region))	2.0, Appendix D

Appendix D

Appendix D

Liaison with Authorities & Community Groups

Letters of consultation were sent by Hyder Consulting (formerly Acer Wargon Chapman) on behalf of the Joint Venture, the NSW Department of Land and Water Conservation (DLWC) and the Queensland Department of Environment (DoE), to a number of government departments and authorities at Commonwealth, State and Local Government level and to numerous non-governmental organisations between March-August 1996. The initial letter from DLWC and DoE introduced the project and discussed the nomination of DLWC as the Determining Authority. The letter from Hyder Consulting sought comments relating to areas of concern or interest in the EIS/IAS. Authorities who did not respond to the first letter from Hyder Consulting were sent a follow-up letter. Those authorities who still provided no response were contacted by telephone and/or fax.

Listed below is a brief summary of the responses from the authorities and community organisations consulted.

1.1. Responses from Authorities Listed in the New South Wales 'Directors Requirements' and Queensland 'Terms of Reference'

In accordance with the NSW 'Directors Requirements' and Queensland 'Terms of Reference', the following authorities were consulted:

NSW Department of Land and Water Conservation (DLWC);
NSW Fisheries;
Commonwealth Environmental Protection Agency (CEPA);
NSW Environmental Protection Authority (EPA);
Heritage Council of NSW;
NSW Waterways Authority (WA);
NSW National Parks and Wildlife Service (NPWS);
Department of Urban Affairs And Planning (DUAP);
Queensland Department of Environment (DoE)
Queensland Department of Primary Industries (DPI);
Queensland Department of Families, Youth and Community Care;
Queensland Department of Transport - Marine and Ports Division;
Queensland Department of Transport;
Queensland Fish Management Authority;
NSW Department of Aboriginal Affairs;
Tweed Shire Council;
Gold Coast City Council;

Following is a summary of matters raised by these authorities.

1.1.1. Department of Land & Water Conservation (Central Body and North Coast Region)

State Land Matters

- As the Department of Land and Water Conservation is a landowner and Determining Authority under Part V of the *Environmental Planning and Assessment Act 1979 (EPA Act)*, the Department must meet its obligations in accordance with the *EPA Act 1979* (Clause 91).

- As the Minister is responsible for administering the *Crown Lands Act 1989*, consent to any proposed occupation of Crown land will need to be given.

- Providing no material is removed from the coastal system and the prior consent of the Minister is obtained, no licence for sand extraction is required.

- Should an onshore pipeline be selected as the preferred discharge option for beach nourishment, details should be provided to this office for consideration of any need to issue a lease/licence or easement.

- It is expected that waiving of the requirement for the undertaking of a land assessment under Part 4 of the *Crown Lands Act 1989* would be supported by the Minister.

- The Fingal area is subject of claims under the *Aboriginal Lands Rights Act 1983* and under the *Commonwealth Native Title Act 1993*. The implications of these acts would need to be investigated.

General Issues

- The EIS/IAS should address the impact of the sand bypass on tidal planes in the Tweed River.

- The impact of lowered tidal levels on exposure of potential acid sulphate soils within the estuary should be examined.

- The EIS/IAS should address the impact of the sand bypass upon the major shoal adjacent to Kerosene Inlet (such as erosion) and any consequential impacts (such as increased tidal range). Possible measures to maintain this shoal (such as nourishment) should also be considered.

- Possible impacts to adjacent beaches and river bank stability with increased tidal flows following dredging.

1.1.2. NSW Fisheries

The main issues raised by NSW Fisheries include:

- Potential impact on commercial and recreational fishing activities along Fingal Beach (compared to control locations) during and at the conclusion of works intended for the beach site.

- Potential long-term changes to tidal hydrodynamics and implications for estuarine and oceanic fish habitats.

- Any actions intended to ameliorate both the effects on commercial and recreational fishing activities and/or the impacts on estuarine and oceanic fish habitats.

1.1.3. Commonwealth Environmental Protection Agency (CEPA)

The CEPA indicated that the proposal does not appear to involve any Commonwealth decision or approval requirements and the *Environment Protection (Impact of Proposals) Act 1974* therefore does not apply.

1.1.4. NSW Environment Protection Authority (EPA)

The EPA recommend that the EIS should address the following matters:

- Assessing control measures to minimise impact of dredging on local water quality. The dredge wastewater should contain a non-filterable residue of <50 mg/l which will generally require detention or treatment of the water prior to discharge. Assessment of the wastewater discharge will need to verify the quantity of fines, silt and contaminants in the dredge material and address water pollution at the discharge point. Measures to mitigate water pollution should be provided.

- Assessing noise impact on local residents (refer Chapter 171 EPA's "Environmental Noise Control Manual" for guidelines for maximum noise levels from construction sites). If potential exists for a noise nuisance from the project the EIS/IAS should include a Noise Impact Statement (NIS). Noise from all plant and equipment to be used on site should be assessed. Details should be provided of any control measures proposed to ensure compliance with the EPA's noise guidelines. If the system will operate 24 hours per day noise assessment should take into account night time background noise levels. A noise monitoring program would be recommended. Maximum noise level (LA10) should not exceed background noise levels (LA 90) by more than 5dB (A).

- Assessing wind blown material from stockpile, filled areas and unsealed access roads and suggesting mitigatory measures to control dust emissions.

- Assessing all potential water, air and noise impacts of both the construction and operation phases of this work. Setting up a 24 hour hot line for pollution complaints should be considered. Incidents should be reported to the relevant authorities.

- Plant and equipment should be assessed for air emissions during operation. Electric powered pumps should be considered for noise and air pollution.

- Addressing the ongoing influence of the variations in tidal range on groundwater levels and the possibility that changes may lead to oxidation of acid sulphate soils (ASS) and concomitant water quality issues from acidic runoff (refer EPA document on "Acid Sulphate Soils Guidelines for Land Management in Coastal Areas").

- An analysis of the sediments to be transported as a result of this proposed development should also be undertaken to ensure that their placement does not lead to water quality problems in the enrichment areas.

- Oil storage area will require bunding and an emergency oil spill contingency plan drawn up before operations commence and measures to minimise impacts outlined.

Assessment of the pressures on water quality and local transport systems as a result of increased tourism and recreational activities.

1.1.5. Heritage Council of New South Wales

Heritage office maintains a public register of items protected under the *Heritage Act 1977*. Consult Roads and Traffic Authorities Section 170 Register relating to the protection of items owned by the RTA. Consultant should contact local Aboriginal Land Council, Australian Heritage Commission and local historical societies.

Heritage significance of the study area and impact of proposal should be assessed. Under Section 146 of the *Heritage Act 1977* relics discovered through proposed works should be reported to the Heritage Council.

If shipwrecks are found during the course of the project all work must cease in the area and the Heritage office notified immediately. The Director of the Heritage Office is the NSW delegate for administration of the *Commonwealth Historic Shipwrecks Act 1976*.

1.1.6. Waterways Authority

The Authority would like the following matters to be considered in the Environmental Impact Statement/Impact Assessment Study:

Safety

- Location of structures and pipelines with regard to navigation safety including lighting and marking requirements.
- Assess impact of system on location of navigation channels and need to relocate navigation aids.
- Assess possible changes in wave patterns and wave break areas in relation to safety of vessels for different tidal conditions, particularly in relation to the region around the Tweed River bar.
- Include cost of navigation aids that need to be installed or relocated should be included within the overall project costs.

Environment

- Impact of pollution arising from an accident (presumably a vessel colliding with sand bypass structure), vessel sinking or loss of equipment needs to be assessed. Provision for an oil pollution plan for the projects and oil pollution combat equipment needs to be readily available in the event of an incident. Such equipment should be provided by the company or agency responsible for implementing the bypassing system.
- Impact of noise pollution from the project.

1.1.7. NSW National Parks and Wildlife Service

The following matters to be given particular attention:

- Tweed Estuary and Final Nature Reserve Proposals - the EIS/IAS should consider any impacts from the proposal on the nature conservation values of areas proposed for inclusion in this Nature Reserve.

- Areas of cultural significance - especially Fingal Head for Aboriginal community significance.

- Threatened plants, animals, habitats and communities - the EIS/IAS should consider the likely impacts on threatened flora and fauna, fauna habitats and ecological communities, including marine and estuarine fauna, flora and habitats, as defined by the *Threatened Species Conservation Act 1995*. Particular attention to potential impacts from the activity on the habitats of wading birds and shorebirds.

- Cumulative and indirect impacts of current and proposed works on aquatic or riparian flora and fauna as well as cultural values should be examined in the EIS/IAS. Impacts which may be an indirect result of the activity include:
  - erosion;
  - mobilisation of existing shoals;
  - altered hydrology or hydraulics;
  - release of pollutants such as acid sulphates;
  - alterations to marine or estuarine fauna habitats; and
  - changes to tidal regime.

- Impacts resulting from sand extraction methods, storage of spoil, and activities ancillary to the primary activity should also be addressed. The extent and nature of any changes to the tidal regime should be detailed.

- EIS/IAS should provide for flexible response to monitoring to detect unforseen environmental impacts.

- The NPWS suggests that the impact monitoring program prepared for the Stage 1 project should be included in the Stage 2 EIS/IAS. Due to the permanence of the proposed project, the EIS/IAS should address the need to prepare comprehensive monitoring and contingency plans.

1.1.8. Department of Urban Affairs and Planning (Heritage Branch)

The Department suggests the following:

- Register of ship wrecks to be consulted (existing study of ship wrecks in Tweed River areas is available).

- Consultation with:
  - local aboriginal land council;
  - National Trust of NSW;
  - Australian Heritage Commission; and
  - local historical societies, etc.

- Assess heritage/archaeological significance of area.

- Under Section 15 of the *Historic Shipwrecks Act 1976* a permit to disturb a protected historic shipwreck must be obtained from the Director-General of Urban Affairs and Planning as the State Delegate for the Minister for Communications and the Arts.

1.1.9. Queensland Department of Environment (Central Body and South-eastern Region)

Under Section 86 of the *Harbours Act* if the study area below the Mean High Water Mark (Spring Tides) is to be filled and or if structures into the waterways are proposed a Section 86 *Harbours Act* approval may be required. If so a formal application must be made to the Directors South Eastern Regional Office, Coastal Management Section.

Attention is drawn to the *Environment Protection Act 1994* and the current drafts of Noise, Air, Water and Waste Environment Protection Policies. Current water quality data may be available from the Gold Coast City Council.

The environmental management plan should consider long term monitoring of beach profiles, wave action, and the entrance of the Tweed River.

Consideration should be given to any possible decommissioning if the system became ineffective. Assessment of the potential impacts caused by its replacement should also be considered.

1.1.10. Queensland Department of Primary Industries - Southern Fisheries Centre

Fisheries supports broad issues identified in Newsletter 4 for the project. Fisheries request that recreational and commercial fishing be given consideration and that QCFO and Sunfish are contacted.

A permit is required under Section 51 of the *Queensland Fisheries Act 1994* if there is to be any potential damage of marine flora .

1.1.11. Department of Families, Youth and Community Care

This Department has lead agency responsibility in Queensland for social impact assessment. Contact can be made with the department regarding socio-economic considerations.

1.1.12. Queensland Department of Transport - South East Region

The following two acts should be considered in the preparation of the EIS/IAS*: Transport Operations (Marine Safety) Act 1994* and *Transport Operations (Marine Pollution) Act 1995.*

1.1.13. Queensland Department of Transport - Marine and Ports Division

All issues have been addressed in South East Region response.

1.1.14. Queensland Fisheries Management Authority (QFMA)

The Authority raised two issues for consideration:

- Gaining safe access to the Tweed River port for recreational and commercial fishing vessels.
- Ensuring minimal disruption to the environment in the area adjacent to and north of the river mouth.

Queensland Department of Primary Industries, Fisheries and Forestries have jurisdiction over environmental matters in marine areas along with the Department of Environment. Consultation was also made with this Authority however no formal reply has been received.

1.1.15. NSW Department of Aboriginal Affairs

The following issues will need to be addressed in the EIS:

- Existing land claims pursuant to the NSW *Aboriginal Land Rights Act 1983* lodged by the Tweed Byron Local Aboriginal Land Council;
- existing Native Title land claims in the area;
- impacts on the rights of potential Native Title holders;
- socioeconomic impact on the Aboriginal Communities living on and around the Fingal Peninsula; and
- the existence of an impact on any Aboriginal sites in the immediate vicinity of any of the works.

1.1.16. Tweed Shire Council

EIS/IAS should address possible habitat enhancement opportunities within the Tweed River estuary and mitigate against long term changes in the estuary from the establishment and operation of the permanent sand bypassing system. Attention is drawn to objectives and strategies of the Lower Tweed Estuary Management Plan and the "Little Tern" study by WBM Oceanics Australia for specific habitat options. The EIS/IAS should also address the impact of the project of hydrodynamics, sedimentation and ecology of Wommin Lake and Wommin Lagoon of Fingal Peninsula.

1.1.17. Gold Coast City Council

Gold Coast City Council is the local Authority responsible for normal local government functions in the Queensland section of the study area. Under the Deed of Agreement and Heads of Agreement Council

is responsible for half the Queensland construction, maintenance and operation costs. The primary objectives of Council are to ensure uninterrupted sand supply to Southern Beaches and ensure that surf quality is not detrimentally affected.

1.2. Responses from other Public Authorities

1.2.1. Beach Protection Authority Queensland

The coastline of Gold Coast City lies within Coastal Management Control District No. 11 as declared under the *Beach Protection Act 1968.* Erosion prone areas have also been declared along the coast in accordance with plan number SC3363E. The Authority's Buffer Zone Policy Statement sets out recommended uses for lands contained within erosion prone areas.

The Gold Coast City is also the subject of a Coastal Management Plan prepared under the *Beach Protection Act.*

1.2.2. Queensland Department of Tourism Small Business and Industry

Tourism is a vital part of the Gold Coast regional economy. The sand bypassing system may have important impacts on regional tourism. The Tourism Development Branch supports the establishment of a permanent sand bypassing system to replenish sand on the southern Gold Coast beaches and improve the safety of the Tweed River bar and river water quality.

The technology chosen and the method of operation of the system should be designed to minimise the impact on the environment, on local people and on visitors to the area.

1.2.3. Queensland Department of Mines and Energy

This Department administers mining tenure in the state of Queensland under the *Mineral Resources Act 1989.*

This Department does not have any administrative jurisdiction over sand used for extractive industry purposes. For the project the processing of mineral sand is more likely to occur within NSW than within Queensland, therefore it is unlikely that the provision of mining title within the Project area will be required from this Department.

No existing mining titles or applications occur in the Project area. This Department does not have any activities/facilities/interests that are relevant in the preparation of the EIS. It appears from Newsletter 4 that appropriate issues will be addressed.

The Department believes this to be valuable and ground-breaking project of benefit to both Queensland and New South Wales.

1.2.4. NSW Department of Mineral Resources

EIS to address possibility of recovering of heavy minerals from the sand before it is delivered to the discharge points north of the Tweed River. The Department believes that it could be economic to extract the heavy mineral content from the sand being transported to Queensland.

The normal approach to assessing this economic potential would involve systematic sampling of the offshore sand mass, analysis of the recovered samples and determination of heavy mineral content and grades. This could also be achieved by systematically sampling the sand stream after the sand bypassing system is installed. It is recommended that a heavy mineral separation plant is included in the design of the permanent

Should this recommendation be implemented the EIS should include plans for rehabilitation of the plant separation site.

Requirements for EIS from Department of Urban Affairs and Planning A3.9(c)(d) and (e) are appropriate, but (a) and (b) relating to visual amenity and effects on public usage of the beach are probably not relevant.

1.2.5. Australian Heritage Commission

There are a number of places in the vicinity on the proposed works which are in the Register of the National Estate Database. These places are:

- Ukerebagh Nature Reserve;
- Cook Island Nature Reserve;
- Tweed Heads South Bora Ground;
- Lighthouse at Fingal Head;
- Fingal Head Coastal Conservation Area;
- Sponsors Lagoon Midden; and
- Ukerebagh Midden.

Impacts of the proposal on these areas needs consideration.

1.2.6. Queensland Department of Local Government and Planning

Zoning and landuse in the area are the responsibility of Tweed Shire Council and Gold Coast City Council under the *Local Government (Planning and Environment) Act 1990.* Therefore information should be obtained from these agencies.

1.2.7. Aboriginal and Torres Strait Islander Commission

No formal reply.

1.2.8. NSW Department of Public Works and Services

No formal reply.

1.2.9. NSW Police Service

The proposal will not have any effect on operations of the service.

1.2.10. NSW Department of Natural Resources

No formal reply.

1.2.11. Queensland Department of Primary Industries - Division of Fisheries and Wetlands

No formal reply.

1.2.12. NSW Department of Natural Resources - Water Resources Commission

No formal reply.

1.2.13. Queensland National Parks and Wildlife Service

No formal reply.

1.2.14. Queensland Police Service

The proposal will not have any effect on operations of the service.

1.3. Utilities

1.3.1. Telecom Australia

Telstra has no objections to this project proceeding.

1.3.2. Pacific Power

No formal reply.

1.3.3. Optus

No impacts are anticipated as all cables are located further inland than the entrance.

1.3.4. South East Queensland Electricity Board (SEQEB)

Safety of public and site workers prior to the commencement of any site works in Queensland. The contractor must contact SEQEB to ascertain if and proposed works conflict with SEQEBs assets. These assets may be either underground or overhead. Some of the danger areas include excavation equipment and long sections of pipe coming into contact with SEQEBs overhead mains.

Any installation in Queensland requiring electricity supply, would require negotiation with SEQEB as to the method and conditions of supply.

1.3.5. North Power

The primary environmental matters to be considered in relation to the electricity supply to the project, is the route of the line, whether it be overhead or underground, and the effect on the local environment caused by the construction and maintenance of the line.

1.3.6. AGL

AGL does not have any reticulation or assets affected by the proposal and therefore has no objection to the system.

1.3.7. Queensland Electricity Commission

No formal reply.

1.4. Other Organisation/Community Groups

1.4.1. Air Sea Rescue Point Danger

Air Sea Rescue would like to be involved in the process of deciding on the bypass option to be chosen. The organisation has a preference for a permanently placed system, such as the South Port Seaway example. Their concern is that a mobile system could be removed with changes in Government and cost cutting. The rescue crews regularly need to traverse the Tweed Bar when conditions are difficult and therefore would like to see a permanently safe system.

The organisation has also provided invaluable input into the EIS/IAS as noted in the relevant sections of this document.

1.4.2. Tweed Heads Coolangatta Professional Fishermens Association

The Association is very happy to see the project go ahead.

1.4.3. Surf Life Saving Queensland Inc.

The organisation supports moves to replenish and stabilise the beaches of the southern Gold Coast. The organisation is concerned that the sand carried through the sand bypass system may possibly cause a build up of debris in the nourishment area.

1.4.4. Queensland Commercial Fishermens Organisation

The Organisation recognise that impacts to be experienced by the industry is expected to be minimal because the increased sand movement will be a return to the natural system of some decades ago.

1.4.5. Sunfish - Queensland Sport and Recreational Fishing Council

The Organisations concerns relate to environmental effects, safe egress by boats and access to fishing vantage points. A public access jetty like the Seaway sand pumping jetty could be an enhancement to recreational fishing in the area.

1.4.6. Australian Marine Conservation Foundation (formerly Australian Littoral Society)

No formal reply.

1.4.7. Wildlife Preservation Society of Queensland

No comment regarding the project.

1.4.8. Tweed Byron Local Aboriginal Land Council

No formal reply to community consultation however the organisation has provided invaluable input into the EIS/IAS as noted in the relevant sections of this document.

1.4.9. Pooningbah Community Aboriginal Corporation

The organisation has preference to a permanent sand bypassing structure. The organisation would like consideration of extra traffic which would be generated into the Fingal Peninsula and the possible requirement of sealing the road and implementation of traffic calming measures north of residents on Letitia Spit. In addition the general public should have access to fish from the structure and therefore additional car parking closer to the beach area. If electricity is required to the site it should be located underground. Monitoring should occur both at Fingal, Dreamtime Beach, the wetlands, lakes and lagoons of the Tweed estuary.

The placement of sand at the north of the river entrance should be at several locations and measures to alleviate the impact on migratory birds which frequent Letitia Spit should also be implemented.

The organisation has also provided invaluable input into the EIS/IAS as noted in the relevant sections of this document.

1.4.10. Fingal Community

No formal reply

1.4.11. Foundation for Aboriginal and Islander Research Action (FAIRA)

EIS should include indigenous issues and this inclusion can only be done in consultation with the traditional Aboriginal owners. David Dillon currently has a land claim in the area.

1.4.12. Gold Coast and Hinterland Environment Council

Wishes to be kept informed of future actions in the project.

1.4.13. Coastal Solutions

The company have offered thier services as a specialist surfing consultant for the project.

1.4.14. North Coast Environment Council Inc.

No formal reply.

1.4.15. Oceanwatch

Wishes to be kept informed of future actions in the project.

1.4.16. Coast and Wetlands Society Inc.

Particular concerns regarding saltmarshes which can be impacted due to slight changes in tidal conditions. Concern that slight changes in tidal regimes may result in an unward expansion of mangroves resulting in further loss of saltmarsh which is already one of the rarest habitats in NSW.

1.4.17. Nature Conservation Council of NSW

No formal reply.

1.4.18. NSW Aboriginal Land Council

No formal reply.

1.4.19. Tweed Dive

Considers movement of water in and out of channel since Stage 1 to be greater. Channel has become more unpredictable since Stage 1 dredging. Danger has moved from where bar used to create surf waves to inside entrance breakwater where pressure waves develop on ebb tide. Navigation conditions were best immediately after the *Krankeloon* dredged the channel. Company must negotiate channel regularly and therefore must time his dives to channel conditions.

The organisation has also provided invaluable input into the EIS/IAS as noted in the relevant sections of this document.

1.4.20. NSW Commercial Fishers, Regional Industry Convenor (formerly NSW Commercial Fishing Advisory Council)

Main concern of offshore commercial fishers is that there is enough water depth so they can be assured a safe passage. Also that they do not lose any beach access as a result of the project. The organisation requests that the project does not take place in the mullet season which is between May and June, as it would greatly affect this valuable fishery.

1.4.21. Surf Riders Foundation Australia

No formal reply to community consultation however the organisation has provided invaluable input into the EIS/IAS as noted in the relevant sections of this document.

1.4.22. Tweed River Management Plan Advisory Council

Response as outlined in response from Tweed Shire Council.

1.4.23. Point Danger Branch of Surf Life Saving

The organisation is looking forward to the project going ahead.

1.4.24. Other

No formal reply was received from:Tweed River Entrance Community Liaison Committee, Southern Gold Coast Chamber of Commerce, Gold Coast Environment Centre, Kingscliff Fishing Club, Murwillumbah Services Club Fishing Club, NSW Surf Lifesaving Association, Tweed Heads Amateur Fishing Club, Caldera Environment Centre, Twin Towns Services Club Fishing Club, Tyalgum Fishing Club, Snapper Rocks Surfriders Club and Kirra Board Riders Club.

Appendix E

SURF-RIDERS SURVEY

Prepared by Kinhill Engineers

PROGRESS REPORT
16 February 1996

Data collected has been coded and analysed. A brief summary of outcomes to date follows:

360 forms have been coded - 90 at each of Duranbah, Snapper Rocks, Greenmount and Kirra. No attempt has been made to separate or trim daily data from early monitoring from the later weekly data.

Ranking of surfing conditions *(1 to 7 'dismal' to 'excellent')* has been undertaken . Overall result to date:

		RANK
Dismal	34%	1
Very poor	20%	2
Poor	20%	3
OK	17%	4
Good	7%	5
Very good	1%	6
Excellent	1%	7

The low ranking have generally resulted from flat or low seas. Cross-correlation with wave heights showed that 54% of the 'negative' rating above occurred with wave being less than 0.25 m. Average ranking improved with increasing wave height. The average rankings *(4 = neutral)* are shown below:

No waves	1.03
0-0.25 m	1.89
.25 - -0.5 m	2.72
.5 - 1.0 m	2.63
1.0 - 1.5 m	3.90
1.5 - 2.0 m	4.61
> 2 m	3.00 *(only 2 samples)*

The prime reasons for each ranking given were sought *(multiple answers)* and resulted in:

Wave size	50.3%
Wave form	50.8%
Wind	34.7%
Sand	6.1%

Ride length	7.2%
Other	26.1%

No cross-correlation with ranking value has been attempted.

Although unlikely to surprise, the data was consider in correlating numbers of board riders with surf ranking eg. average ranking scores for increasing board rider numbers were:

No riders	1.15
1 - 5	2.19
6 - 10	2.94
11 - 20	3.40
21 - 30	4.03
31 - 50	4.53
51 - 75	5.0

All data can be broken down on a beach basis as required *(eg. Duranbah, Kirra, etc.)*.

It is noted that data on the 'wave break pattern' and 'reasons for ranking' are quite explicit *(30 and 52 different categories respectively)*, but has not been detailed herein. Some categories have small numbers.

Most frequent 'wave break patterns' were:

Choppy	20%
Fast peeling	19%
Slow peeling	17%
Flat	10%
Dumping	6%

Most frequent individual reasons for ranking were:

Small waves	26% *(12% at Duranbah)*
Onshore wind	26%
Small swell	15% *(addition to "small waves")*
Clean/clean little peelers	15% *(3% Duranbah; 19% Greenmount, Kirra)*
Choppy/lumpy	10%
Good for learners	12%
Inconsistent swell	6%

Appendix F

BEACH AMENITY SURVEY

Prepared by Kinhill Engineers

PROGRESS REPORT

16 February 1996

Interviews were conducted on four days:

• 15 January 1996	Monday	18 interviews
• 19 January 1996	Friday	77 interviews
• 21 January 1996	Sunday	40 interviews
• 22 January 1996	Monday	57 interviews
	Total	192 interviews

Interviews were spread over five beaches:

- Rainbow Bay (55);
- Greenmount (57);
- Coolangatta (29);
- Kirra (30);
- North Kirra (21).

Since interviewees often represented a larger group, the 192 interviewees represented 895 adults and children *(461 adults; 211 children over 10 years; 173 children under 10years)*. Respondents themselves varied from teenagers to +60 years (19% < 30 years; 31% in 30-39; 37% in 40-49; 13% > 50).

Some selected outcomes are:

Reasons for going to beach *(multiple selection)*

- swim/surf/sand = 74%
- swim/surf = 64%
- on holiday = 56%
- kids = 51%
- tan = 24%
- socialise = 20%
- exercise = 17%

Main reason

- swim/surf = 34% *(Kirra 53%)*
- on holiday = 22% *(Rainbow 33%)*
- swim/surf/sand = 18% *(Kirra 10%)*
- socialise = 7%

	• exercise	=	2%
	• tan	=	1%
Factors for THIS beach *(multiple)*	• proximity	=	52%
	• safety	=	38%
	• surf	=	19%
Normal activities *(multiple)*	• swim	=	97%
	• 'Beach'	=	92%
	• bodyboarding	=	43%
	• exercise *(non-swim)*	=	41%
	• surfboarding	=	11%

Rankings (1 to 7 extremely bad to extremely good)

Sandy beach - overall	83% ranked 5,6 or 7	
	only 2% ranked < 4 'OK'	
Coolangatta	scored best of 'extremely good' (21%)	
Coolangatta	69%	combining ranks 6 & 7
Greenmount	54%	combining ranks 6 & 7
Kirra	53%	combining ranks 6 & 7
Rainbow	51%	combining ranks 6 & 7
North Kirra	29%	rank 5 scored 57%

The following records the total response percentage who scored ranks of 5, 6 or 7 *(good, very good and extremely good)*; 4 - OK is not included. Some individual beach results are shown as additional information.

Sandy beach - size, extent: 82% *(Coolangatta 97%; North Kirra 95%; Rainbow 71%)*

Sand quality: 79% *(Kirra 93%; Rainbow 89%; Coolangatta 72%; Greenmount 70%; North Kirra 67%)*

Sand colour: 79% *(Kirra 90%; Greenmount 70%)*

Water Area Overall: 83% *(Coolangatta 93%; North Kirra 62%)*

Swimming, Wading: 76% *(only 3% scored less than 'OK' - nil at Coolangatta and Kirra)*

Bodysurfing:	*74% (12% < 'OK')*
Bodyboarding:	*61% (10% < 'OK')*
For children:	*78% (6% < 'OK')*
Water comfort:	*94% (1% < 'OK')*
Water appearance:	*92% (2% < 'OK')*
Bathing safety:	*83% (3% < 'OK)*

Respondent characteristics *(no cross-correlation attempted to date)* are shown below:

Residents *(27%)*: of these 26% visit daily; 42% > once a week; 19% once a week; 13% other

Visitors *(73%)*: of these 43% were annual visitors; 39% irregular; 12% first timers; 5% once a week.

Of the annual visitors *(60 respondents)*, 38% had visited for more than 10 years; 22% from 6 to 10 years and 20% from 3 to 5 years.

Of non-irregular visitors, 54 respondents had seen change in **last few months**. Of these, 48% said 'bigger beach or more sand', 23% said 'eroded' or less sand on beach *(9% component came from Rainbow)*; 11 said 'more shade, amenities, etc.; 4% said 'more black sand' at Greenmount.

Similarly 97 respondents had noticed a change since **last year**. Of these, 57% said 'bigger beach or more sand'; 15% said 'eroded or less sand' *(8% at Rainbow)*. Of the respondents who noticed a change since last year at each beach: Rainbow 28% 'bigger' 28% 'less' *(28%/28%)*; Greenmount 52%/13%; Coolangatta 89%/0%; Kirra 80%/13%; North Kirra 79%/7%.

Of the respondents, 160 attempted a comparison with a year ago on a range of attributes. The resulting percentages who scored 'worse/same/better' respectively were:

Sand quality	14%/70%/16%
Sandy beach	5%/56%/39%
Watery beach	11%/80%/9%
Water form	9%/71%/20%
Overall aesthetics	0%/71%/29%

Of the 181 respondents who gave their postcode, 93 *(51%)* were from Queensland; 77 *(43%)* from NSW; and 10 *(6%)* from Victoria.

Appendix G

Appendix G - Octave Band Noise Measurements

Table G1 Noise Measurements 1996

Octave Band Sound Pressure Level (dB(A))														
Date	Location	Time	Descriptor	31.5	63	125	250	500	1000	2000	4000	8000	Overall	Comments
28/11/96	12	3.20am - 3.33am	L_{10}	19	33	41	45	46	47	44	40	34	52	Measurement at Endeavour Place in building lee - very windy night 20 - 25 knots generally. Local wind speed adjacent mic. 2 - 7 knots. Background
			L_{90}	≤10	24	34	39	43	43	39	34	28	48	and ambient noise level determined by wind and surf. Temperature 24°C, Humidity 84%.
	11	3.49am - 4.02am	L_{10}	15	30	38	42	43	44	43	44	29	50	In lee of buildings on Boundary Street midway between Hill and Ward Streets. Local wind speed < 2 knots. Background
			L_{90}	≤10	22	32	38	40	41	39	39	23	47	and ambient set by wind and surf, very occasional traffic movements: delivery vans
	10	10.10am - 10.25am	L_{10}	24	37	45	50	52	54	51	50	42	60	8th floor balcony Greenmount Resort Hotel, wind now moderated , local wind speed - nil.
			L_{90}	20	28	39	45	49	49	46	39	27	54	Background set by plant noise and surf, L_{10} noise levels controlled by traffic noise. Temperature 29°C, Humidity 60%.
12/12/96	14	12.43am - 2.56am	L_{10}	15	31	41	47	49	47	43	43	28	53	Car park overlooking Pt Danger and Snapper Rocks, background is surf, some insect noise and bats.
			L_{90}	≤10	25	37	44	46	45	41	38	25	51	Wind <1 knot northerly. Temperature 23°C, Humidity 87%.
		1.10am - 1.23am	L_{10}	15	31	41	47	50	48	43	43	26	54	Wind now increased to 2 knots.
			L_{90}	≤10	25	37	44	47	45	41	39	23	51	Ebb tide.
	13	1.25am - 1.38am	L_{10}	12	29	37	42	47	46	41	36	23	51	Kirra Point southern end of lookout
			L_{90}	≤10	23	33	39	44	43	39	33	21	49	car park.
		1.41am - 1.54am	L_{10}	11	28	36	41	45	44	40	34	21	49	Line of sight to Coolangatta beach.
			L_{90}	≤10	23	33	38	42	42	38	31	19	47	Background and ambient controlled by
		1.57am - 2.10am	L_{10}	12	28	37	42	45	45	41	33	21	50	surf. Infrequent traffic on local roads.
			L_{90}	≤10	23	32	38	42	42	37	31	19	47	Minimal insect activity. Wind 0-2 knots.

continued

Octave Band Sound Pressure Level (dB(A))														
Date	Location	Time	Descriptor	31.5	63	125	250	500	1000	2000	4000	8000	Overall	Comments
12/12/96	11	2.23am - 2.36am	L_{10}	≤10	26	36	38	37	34	30	29	23	43	Corner of Endeavour and Bay Street, very still - nil wind. Some insect
			L_{90}	≤10	19	29	33	35	32	28	27	18	39	noise. Background determined by distant surf, waves breaking on Tweed River
		2.39am - 2.52am	L_{10}	≤10	27	32	35	34	34	30	29	25	41	Bar adjacent Letitia Spit, and by local plant noise.
			L_{90}	≤10	19	29	32	32	31	28	27	21	38	Temperature 22.5°C. Humidity 87%.
	9	3.03am - 3.16am	L_{10}	≤10	20	28	31	32	33	32	31	23	39	Calm conditions, light rain. Main noise source is surf from direction of Fingal Head and occasional distant traffic
			L_{90}	≤10	15	25	29	28	28	27	26	20	36	movements on Pacific Highway. Some fishing boat activity on Tweed River.
	12	3.37am - 3.40am	L_{10}	≤10	23	31	35	37	37	36	42	25	45	Brief measurement outside 203 Boundary Street, light rain, background
			L_{90}	≤10	19	28	33	35	34	32	30	21	41	controlled by plant noise and some crickets.
	15	3.49am - 3.52am	L_{10}	13	33	40	43	41	41	40	34	20	48	Measurement position overlooking Duranbah beach.
			L_{90}	≤10	24	36	40	38	38	37	30	17	46	Background is controlled by surf.
		4.11am - 4.24am	L_{10}	16	31	41	44	41	43	42	36	21	49	Other noise sources include vehicle movement on Boundary Street.
			L_{90}	≤10	24	35	40	39	40	38	32	18	46	Wind south-westerly 1-3 knots. Temperature 22°C, Humidity 92%.
	15	4.34 am- 4.47am	L_{10}	12	28	39	44	41	43	47	55	45	56	Near sun rise. Bird noise dominates L_{10}, 55 db(A) at 4000 Hz. Few breaking.
			L_{90}	≤10	23	36	41	39	40	40	35	21	47	waves at Duranbah - 1 metre swell.
	14	4.55am - 5.08am	L_{10}	15	31	41	48	49	49	47	42	34	54	Background noise dominated by surf. Some vehicles. Wind 2-3 knots, light
			L_{90}	≤10	25	37	44	46	45	41	35	23	51	rain falling.
15/12/96	13	1.05am - 1.18am	L_{10}	18	36	44	44	48	49	49	39	25	54	Background and ambient set by surf. Light wind 2-5 knots.
			L_{90}	11	27	35	40	43	43	39	31	18	48	Temperature 20°C, Humidity 74%.
	12	1.35am- 1.48am	L_{10}	≤10	24	32	36	37	36	33	27	21	42	Very still conditions. Plant noise
			L_{90}	≤10	20	30	34	35	34	30	23	17	40	and distant surf set background.

continued

Octave Band Sound Pressure Level (dB(A))														
Date	Location	Time	Descriptor	31.5	63	125	250	500	1000	2000	4000	8000	Overall	Comments
15/12/96	16	2.00am - 2.13am	L_{10}	13	26	35	37	38	37	32	36	16	43	Francis Street Road end main noise source is distant surf. Fingal Head - quite boomy, some insect noise from adjacent fig tree. Light breeze from land - 1 knot.
			L_{10}	≤10	23	32	35	36	35	30	22	14	41	
	17	2.20am - 2.33am	L_{10}	11	24	32	34	35	36	31	23	15	41	Corner of Solander Street and Keith Compton Drive. Background is set by surf and cooling tower noise from the hospital.
			L_{90}	≤10	20	28	31	33	34	28	20	13	39	
	9	2.40am - 2.53am	L_{10}	11	26	33	35	37	34	27	20	14	41	Background is surf, some distant traffic (very intermittent) on Pacific Highway (Boyds Bay Bridge).
			L_{90}	≤10	21	30	33	33	31	24	17	13	38	
	17	2.59am - 3.12am	L_{10}	12	24	32	36	38	37	32	25	18	42	Background is cooling tower and surf. Some distant traffic including vehicles on bridge.
			L_{90}	≤10	20	29	33	35	35	29	21	14	40	
	9	3.21am - 3.34am	L_{10}	13	27	35	38	37	36	31	31	18	43	Distant surf controls background.
			L_{90}	≤10	23	32	35	36	34	28	23	14	41	
	12	3.41am - 3.44am	L_{10}	12	30	37	38	38	39	35	29	22	45	Plant noise and surf on sand bar (Letitia Spit) control background. Other sources include insects, lawn sprinkler and truck movements at adjacent Tweed Mall.
			L_{10}	≤10	20	30	34	35	34	30	26	19	41	
	11	4.00am - 4.13am	L_{10}	17	37	44	45	47	51	47	39	29	55	Plant noise controls background. Other noise sources - crickets, occasional vehicles.
			L_{90}	≤10	26	34	37	38	37	33	27	16	44	
	15	4.21am - 4.34am	L_{10}	18	31	41	42	42	44	48	56	47	58	Strong surf sea breaking between heads. Other sources boat engines from vessels at mouth. Bird song from early morning flocks controls L_{10}. 56 dB(A) at 4000 hz.
			L_{90}	12	27	37	39	40	42	38	30	16	47	
		4.37am - 4.50am	L_{10}	17	32	41	43	43	45	42	34	19	50	Surf noise controls background and ambient noise, no bird song.
			L_{90}	12	27	38	40	41	42	39	30	15	48	
	14	4.58am - 5.11am	L_{10}	21	36	44	49	52	52	46	39	28	57	Surf noise from sea breaking at Snapper Rocks. Wind is 5 knots, gusts 8-10 knots. Temperature 10°C, Humidity 74%.
			L_{90}	14	29	39	46	48	47	42	35	22	52	

continued

Octave Band Sound Pressure Level (dB(A))														
Date	Location	Time	Descriptor	31.5	63	125	250	500	1000	2000	4000	8000	Overall	Comments
17/12/96	12	12.25am - 12.38am	L_{10}	14	28	35	37	43	45	45	40	35	50	Plant noise controls background. Other sources include wind in trees
			L_{10}	≤10	20	29	32	35	35	32	32	31	42	and insects. Land breeze 5-6 knots. Temperature 24°C, Humidity 77%.
	16	12.44am - 12.37am	L_{10}	≤10	18	31	31	36	36	33	36	20	41	Plant noise from commercial areas to west, local insects. Very little
			L_{90}	≤10	18	25	28	33	33	30	30	17	39	surf noise.
	17	1.07am - 1.20am	L_{10}	-	-	-	-	-	-	-	-	-	-	Background is plant noise from hospital. Some insect noise.
			L_{90}	≤10	16	22	28	34	35	31	25	23	40	Measurement of L_{10} disrupted - security guard vehicle.
	9	1.26am - 1.39am	L_{10}	≤10	19	27	30	35	34	29	22	17	39	Background noise includes surf at
			L_{90}	≤10	15	24	27	32	32	27	19	15	37	Fingal Head, some traffic on Pacific
		1.41am - 1.54am	L_{10}	≤10	23	29	31	36	35	30	24	18	40	Highway and insects. Very light
			L_{90}	≤10	15	24	28	32	32	27	20	16	37	land breeze.
	16	2.05am - 2.18am	L_{10}	≤10	20	28	33	37	35	32	37	19	41	Plant noise from commercial areas to west control background and ambient.
			L_{10}	≤10	14	24	29	34	33	30	34	17	40	Wind 0-5 knots. Temperature 24°C, Humidity 77%.