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Lower Tweed estuary environmental impact statement sand extraction, Area 5

RIVER MANAGEMENT PLAN

Lower Tweed Estuary

Environmental Impact Statement Sand Extraction – Area 5

December 1993

PUBLIC WORKS
NEW SOUTH WALES

PUBLIC WORKS

NEW SOUTH WALES

LOWER TWEED ESTUARY

ENVIRONMENTAL IMPACT STATEMENT

SAND EXTRACTION - AREA 5

December 1993

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ENVIRONMENTAL PLANNING AND ASSESSMENT ACT, 1979
ENVIRONMENTAL IMPACT STATEMENT

This Statement has been prepared on behalf of the Public Works Department of NSW being the applicant making the development application referred to below.

The Statement accompanies the development application made in respect of the development described as follows:-

EXTRACTION OF MATERIAL FROM THE BED OF THE TWEED RIVER IN THAT SECTION OF THE LOWER ESTUARY REFERRED TO AS AREA 5, EXTENDING APPROXIMATELY TWO (2) KILOMETRES DOWNSTREAM FROM BARNEYS POINT BRIDGE TO ROCKY POINT. THE AREA SO DESCRIBED IS ILLUSTRATED IN FIGURE 1.1 OF THIS EIS.

As required by clause 34 of the Environmental Planning and Assessment Regulation, 1980, the contents of this statement are set forth in the accompanying pages.

Certificate

I, DAVID CHARLES PATTERSON, ASSOCIATE OF WBM OCEANICS AUSTRALIA OF 99 LEICHHARDT STREET, SPRING HILL hereby certify that I have prepared the contents of this Statement in accordance with clauses 34 and 35 of the Environmental Planning and Assessment Regulation, 1980.

D Patterson
....
D.C. PATERSON
BE, BSc., Dip H.E. Delft, M.Eng Sc.

14th December 1993
....
Date

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EXECUTIVE SUMMARY

In developing a River Management Plan for the Lower Tweed estuary, NSW Public Works has undertaken an extensive program of information gathering and community consultation. The River Management Plan (RMP) was published in 1991 and now provides a detailed and sensitive basis with wide community acceptance for the future management of the lower estuary. The RMP includes consideration of a broad spectrum of issues, including environmental, economic, social and cultural concerns. It has received broad community support for its approach and objectives, to protect and responsibly manage the estuary as an important natural resource.

The proposal evaluated in this Environmental Impact Statement represents the first stage in the implementation of specific works as outlined in the RMP. The objectives for the RMP in Area 5 (Tony's Island Reach) include:

- removing sand shoals from the navigation channel downstream from Barneys Point Bridge
- reducing biting midge breeding areas at Tonys Bar
- increasing the diversity of marine habitats
- new bird roosting sites, especially for the Little Tern
- increasing water and foreshore recreation sites on the eastern side of the reach

The sand extraction proposal discussed in this report forms part of the RMP works for Area 5 intended to achieve these objectives and provide benefits to the community, while minimising an potential adverse impacts. WBM Oceanics Australia was commissioned by NSW Public Works to collate existing information and undertake specific studies in preparing this EIS to allow objective assessment of the environmental impacts of the proposed sand extraction.

The design of the sand extraction plan is consistent with the criteria and details established in consultation with the relevant Government agencies including the Department of Agriculture and Fisheries in developing the Lower Estuary River Management Plan. There have been some changes to policies with regard to buffer widths from mangrove and seagrass areas since that time. Nevertheless, the locations of the mangrove and seagrass areas (adjacent to the deep river channel) and potential turbidity plume behaviour are such that these areas and their associated fauna should not be adversely affected by the proposed works.

A quantity of approximately 0.92 million cubic metres would be extracted from this section of the river in establishing the navigation channel as proposed.

The proponent for the proposed sand extraction from Area 5, forming part of the range of river improvement and environmental enhancement works, is the NSW Public Works, with the support of the Tweed River Management and Planning Advisory Committee.

Community consultation has continued, and concerned parties have generally responded favourably to the planned dredging. The community rightly regard this proposal as an essential first stage in the responsible social, economic and environmental management of the Lower Tweed.

The proposed dredging will have a relatively minor impact on the tidal regime. They indicate a slight (4 %) increase in the tidal range upstream of Area 5, and a corresponding increase in tidal prism through the lower reaches of the river.

Significant benefits in the form of reduction in the peak flood levels and durations of inundation for the design flood events at Chinderah will be derived from the dredging.

There will be an increase in tide and flood-related velocities and sediment transport rates particularly in the area immediately upstream of Area 5. In the context of the tidal and flood hydraulic impacts as described in Sections 4.1 and 4.2, the only area in which bank stability might potentially be affected by the Area 5 dredging is the unstable southern embankment at Chinderah. It is recommended that a monitoring program be established to allow changes in the bank profiles, over time to be assessed. Further, the proponents are prepared to provide assurance that if bank stability is affected then rock armour will be installed along the banks. These could be included as conditions of consent to the dredging.

The incremental increases in the beach sand infeed quantities, expressed as an average over the 10 and 50 year periods are thus approximately 3 000 m^3/year over 10 years, and 1 100 m^3/year over 50 years.

These potential incremental losses to the beach system, although significant in the longer term, are relatively small when compared with the net rate of longshore transport past the river mouth to supply the beaches to the north.

In the event that entrance improvement works and artificial sand bypassing are implemented effectively, there should be no net losses of sand from the beaches.

The analysis results presented in Appendix 18 and Section 3.6 indicate that the sediments from Area 5 in the lower Tweed estuary have very low levels of contaminants and the resuspension of contaminated sediments as a result of dredging works would not occur.

Data from a variety of sources indicates that water quality in the Lower Tweed estuary in the vicinity of Area 5 is very good. Clarity, dissolved oxygen and nutrient levels are generally typical of high quality oceanic water.

Numerical modelling indicates that the proposed dredging will have beneficial effects on saline intrusion and tidal flushing. These improvements will ameliorate potential pollution from existing non-point sources (i.e. stormwater).

It is not expected that the sands to be dredged would have acid sulphate potential. No problems have been noted with the sands taken from the area to date. Nevertheless, it is recommended that the spoil be monitored with testing for acid sulphate potential. If, during dredging, a significant acidity potential is identified (in say stockpile areas), then EPA's Draft Guidelines for the Assessment and Management of Coastal Land Developments in Areas of Acid Sulphate Soils will be adopted.

Residences in the vicinity of the dredging operation will not be subject to adverse noise impacts, since simple measures will reduce the noise from the dredge to levels typical of the area. The preferred sand disposal sites are approved construction areas covered by separate EPA noise criteria.

Archaeological investigations were undertaken with the assistance of a representative of the Tweed Byron Aboriginal Land Council.

No significant archaeological or heritage sites were located in the area likely to be affected by the proposed sand extraction. The proposed works will not impact on any of the sites previously recorded for the Lower Tweed region.

There will necessarily be a short term loss of benthos in the dredged areas. These mobile sandy shoals contain significant life. However, they are of relatively less significance than those other shallow areas which will be preserved and/or enhanced through the RMP program of works.

The Dredge Plan will involve extraction of sands which could extend over a considerable time (up to 10 years), with dredging affecting a relatively small area at any time. There is opportunity for the dredged areas to become recolonised with increasingly diverse benthic organisms as the works proceed. As well, the small effects on tidal hydraulics will be gradual over the works time-frame, allowing progressive adaptation of the flora and fauna to those slowly changing conditions.

The dredging will provide significant ecological and fisheries benefits. Deepening of the main channel will provide conditions suitable for large pelagic fish and enhance angling in these locations.

Overall, the response of the fishing industry to the dredge plan has been positive. The benefits of the proposed works were generally appreciated, although, concern about the possible loss of fisheries habitat was expressed. Modification of Tony's Bar, not specifically part of the Area 5 dredging, for habitat enhancement purposes was perceived to be the most contentious element of the River Management Plan.

1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

This Environmental Impact Statement (EIS) provides an assessment of potential environmental impacts and benefits which would result from dredging in the section of the Tweed River referred to as Area 5 in the Lower Tweed Estuary River Management Plan. This area extends along Tony's Island Reach downstream from Barneys Point Bridge to Rocky Point (Figure 1.1).

The proposed sand extraction represents the first stage of implementation of the River Management Plan (RMP) which has been developed for the Lower Estuary region, defined as those tidal sections of the river downstream of Barneys Point Bridge and connecting to the Terranora Inlet reach.

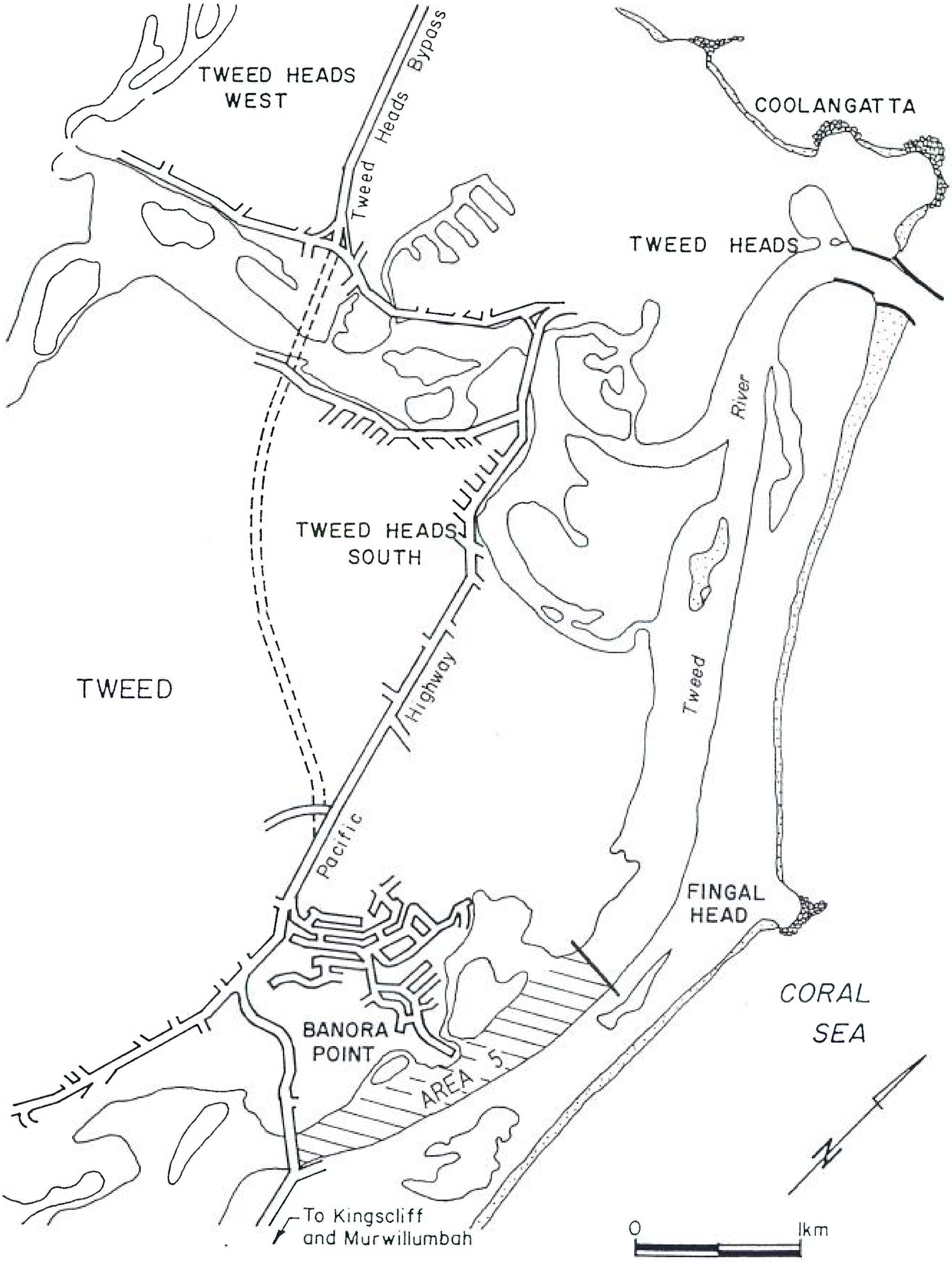
The introductory sections of the EIS provide background summaries of the extensive environmental and sociological studies recently undertaken for the Lower Tweed RMP, outlining the basis of the management policies and plans, including the proposed dredging, developed for river enhancement and utilisation which are both ecologically and economically sustainable.

Much of the general technical information presented in this EIS is sourced from the River Management Plan documents (PWD 1990, 1991a, b, c, d, e, f, g, h, i). Site-specific information and consultative input has also been obtained and has been reported in the appropriate sections.

The proposed management plan design for Area 5 is based on the general RMP findings, and subsequently refined to provide for:

- enhancement of the marine ecology including seagrass establishment, benthic community diversity and fish habitat
- midge control on Tony's Bar
- improved bird roosting areas on Tony's Bar
- improved navigation
- reduced flood levels at Chinderah

The specific works covered by this EIS are the sand extraction by dredging from the river, and placement of the sand at suitable locations onshore. It does not include subsequent uses of the sand and any associated transport away from the point of initial placement.



TWEED RIVER LOWER ESTUARY
AREA 5 - LOCALITY PLAN

FIGURE

1.1

The information provided herein on the proposed method and rates of extraction is the best currently available as projected to meet future sand resource needs for the region and to most cost-effectively achieve the objectives of the RMP.

1.2 RIVER MANAGEMENT PLAN

The sand shoals at the Tweed River entrance and within the Lower Estuary have endangered navigation since the earliest days of settlement. In recent times they have jeopardised the operations of the local fishing fleet and have inhibited recreational boating and boat charter activities (PWD 1990, 1991a). A brief history and synopsis of the overall problem in the Lower Estuary is presented in this section, to enable an appreciation of the proposed development, which would be the first step in a long term program of remediation and stabilisation.

In early attempts to improve navigation, river and entrance training works commenced prior to the turn of the century. Entrance training walls were built around 1900 and extended during the period 1962-65. In addition, the river channels have been dredged intermittently for over a century. These actions improved the situation for a time but the effects were short-lived and the entrance shoals have repeatedly returned. The entrance to the Tweed River continues to experience the ongoing ingress and deposition of coastal sediments (PWD 1990).

The river is subject to significant levels of point and non-point sources of contaminants (sediments, effluent discharge, etc). There are increasing demands on the river for navigational and recreational usage (PWD 1991c,e).

Hydrodynamic studies (PWD 1991d) examined lower estuary siltation and concluded that a range of environmental improvements would result from the following:

- removal/dredging of the bar formation at the mouth of the Tweed River;
- institution of a sand bypassing system to prevent reformation of such a bar; and
- dredging of the lower estuary.

Prior to any dredging plans being finalised, the River Management Plan for the estuary below Barneys Point and Boyds Bay bridges was formulated (PWD 1991a). The general form of Lower Estuary dredging works proposed as part of the RMP was evaluated by NSW Public Works (1991a,d,j), and is further discussed elsewhere in this document.

Development of the RMP for the lower sections of the river provided an opportunity for a range of socio-economic factors to be addressed and properly planned action to be taken for the overall community benefit. Interacting factors influencing the plan include:-

- recreational boating and fishing
- flooding and drainage
- water quality
- sand extraction
- bank and channel stability
- commercial fishing
- aesthetics, heritage and cultural matters
- ecology (particularly estuarine and avifauna habitat)
- public health (mosquitos/midges)

A tenet of the Plan for the river involves sand extraction, planned and responsibly implemented for maximum overall benefit. Development of the dredging plan for Area 5 has involved input from the community, various specialist consultants and Government agencies to achieve the best possible result (see PWD1991b,c,e,f,j).

1.2.1 Statutory Requirements

Development consent is required for the proposal. It is a designated development within the meaning of Schedule 3 of the Environmental Planning Assessment Regulation, 1980. This EIS is required to accompany the development application to the Tweed Council. The EIS has been prepared in accordance with clause 34 of the Regulation and bears a certificate required by clause 26(1) (b) of the Regulation.

In addition, pursuant to clause 35 of the Regulation, a number of specific matters have been addressed as required by the Director, Department of Planning. Details of these requirements are presented in Appendix 2, Terms of Reference.

1.2.2 The Proponent

The proponent for the proposed sand extraction from Area 5, forming part of the range of river improvement and environmental enhancement works, is the NSW Public Works, with the support of the Tweed River Management and Planning Advisory Committee.

1.3 AREA 5 SETTING AND LOCAL ISSUES

The Dredge Plan for Area 5 extends from Barney's Point Bridge and Rocky Point (Figure 1.1). This section of the river is approximately two kilometres in length and contains two extensive sand bars (Figure 1.2) which have developed since the last major dredging was conducted in 1976 (PWD 1990, 1991a).

The first is located immediately downstream from Barney's Point Bridge and impedes river navigation (and also provides a staging area for local water skiers). The second is adjacent to Tony's Bar and is located further downstream towards the northern limit of Area 5 on the western foreshore of the river.

The western shore of the river, including Tims Island, Tony's Island, Tony's Bar and Shallow Bay are recognised bird roosting and foraging areas (PWD 1991b).

The Banora Point Caravan Park fronts the river just below Barney's Point Bridge and residential development adjoins the foreshores at Banora Point. The Coolangatta Tweed Heads Golf Course lies at the northern limit of Area 5. The eastern bank of the river is defined by rock training walls.

The area offers a visual and recreational amenity for the local residents and visitors. Both recreational and commercial fishing activities are undertaken.

1.4 OBJECTIVES OF AND NEEDS FOR THE PROPOSED DEVELOPMENT

1.4.1 Benefits of the Proposed Development

The NSW Government wishes to improve the entrance and lower estuary. Rather than continuing to pursue short-term remedies, a long term strategic solution is sought based on a soundly based plan of management for the river.

The need for dredging of sections of the Tweed River was identified in the recently prepared River Management Plan for the Lower Tweed Estuary (PWD 1991a). An analysis of public comments on the Plan (CCM 1992, also see Section 1.7) indicated that the Tweed area community strongly supports the objectives proposed by the NSW Public Works, particularly dredging to improve navigability of the river's lower reaches, which include Area 5 (PWD 1991a).

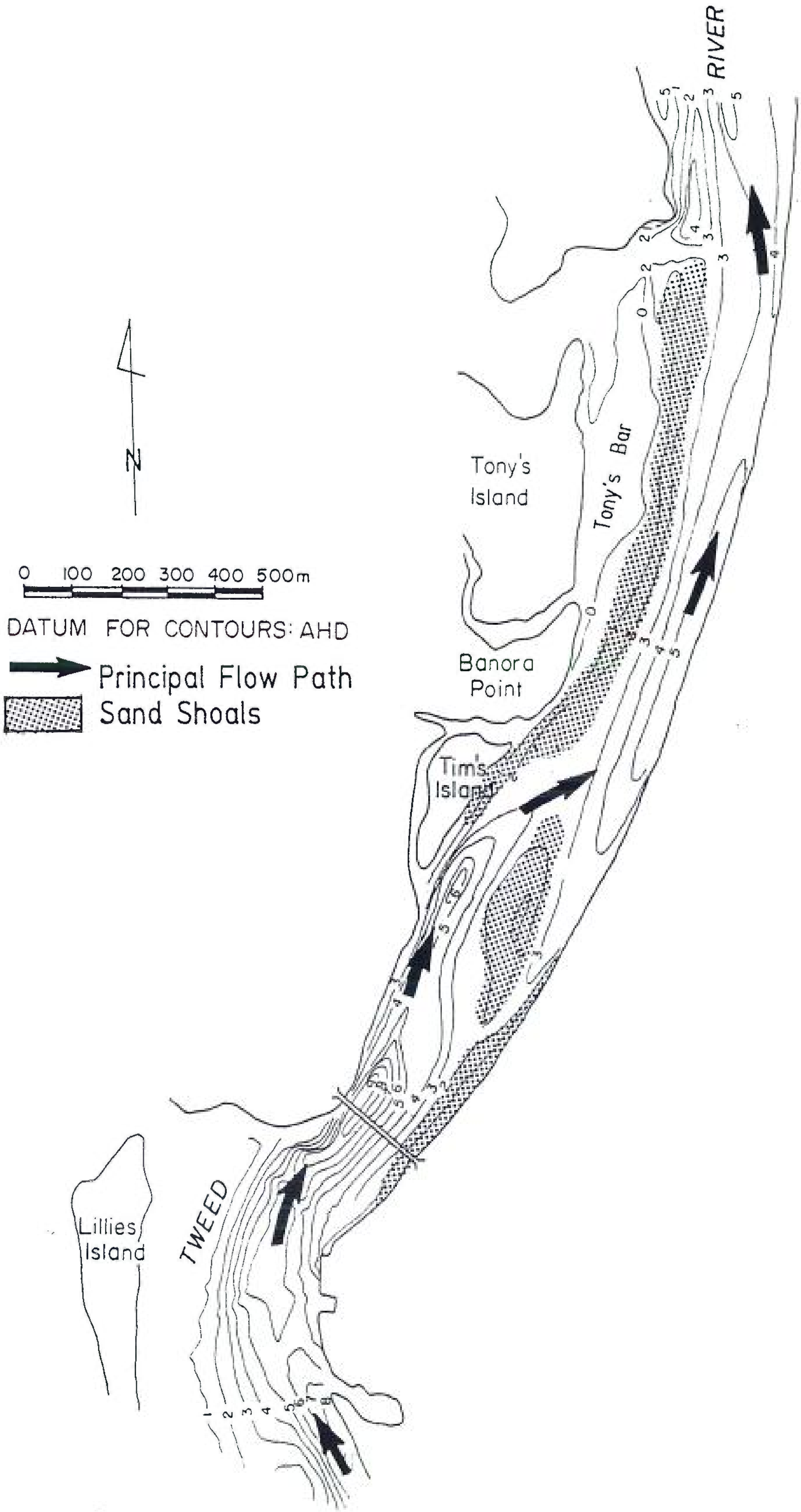
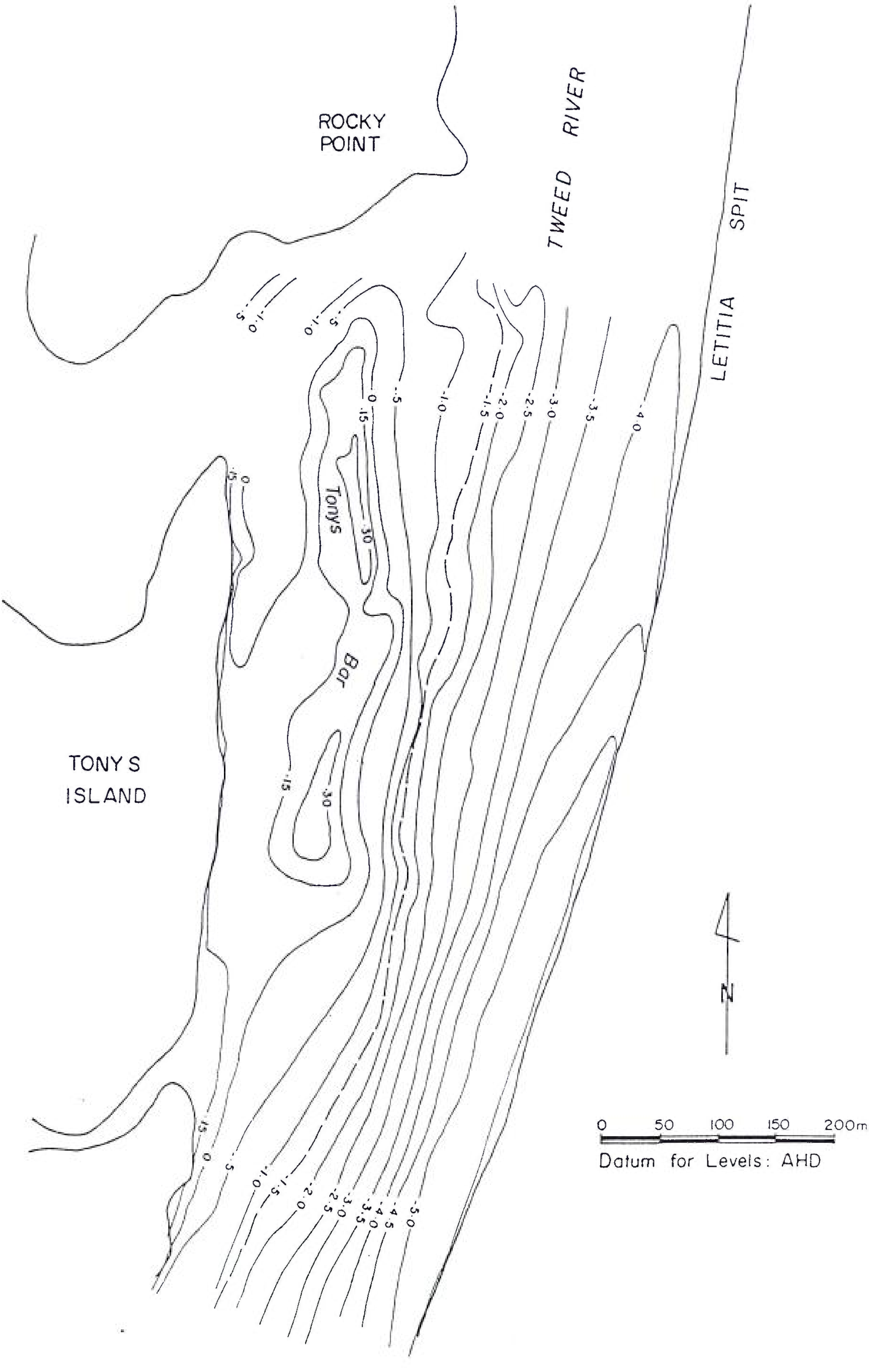


FIGURE 1.2

SAND SHOALS



FIGURE

TONY S BAR EXISTING CONTOURS

1.3

Dredging would introduce a number of benefits including:

- Navigation - there are a number of locations where navigation of the river is restricted or prohibited, particularly at low tide (PWD 1991a,d). These could be cleared. Safe navigation for fishing vessels and recreational craft is desirable, providing at least 3.5 m (ISLW) water depth.

- Water Quality - lower estuary dredging has the potential to increase saline intrusion to the river and improve tidal flushing.

- Sand Resources - the river sand is a resource which can be utilised for local industry and construction purposes. Royalties would accrue to the State for such utilisation of the sand.

- Environmental Enhancement - dredging and the royalties attracted offer opportunities and funds for undertaking other works which would enhance the recreational and ecological value of the river. At the same time the present ecological richness and diversity of the lower estuary can be maintained if such works are carefully planned and carried out.

  It is recognised that some adverse local ecological effects may be caused by the dredging works (PWD 1990, 1991a,b,d,j). Major enhancement opportunities exist however, and these would more than compensate for any of the adverse effects that might arise from dredging.

- Flooding - the proposed dredging would assist in reducing flood levels in the Lower Estuary/Chinderah area.

As noted in Section 1.0, comprehensive studies have been undertaken to identify and assess the most suitable options for improvement of the Tweed River which would achieve these benefits (PWD 1990, 1991a-j).

1.4.2 River Management Plan Components

The Dredge Plan and associated enhancement works for Area 5 initially presented in the River Management Plan (PWD 1991a,j) and subsequently refined (see Chapter 2 and Appendix 3 for details), have several components including:

- removal of the shoal below Barney's Point Bridge (Figure 1.2);
- creation of a channel adjacent to the eastern training walls;

- enhancement of fisheries habitats through the creation of deep holes, and shallow banks for seagrass regeneration;
- modification of Tony's Bar for the purpose of midge control; and
- modification of Tony's Bar for the purpose of creating a secure all-tides roost for a variety of shorebirds, waders and other estuarine birds, including the endangered Little Tern (*Sterna albifrons*).

Removal of the shoals has been reported to be possible without adverse ecological or hydrodynamic effects being experienced (PWD 1991b,d). The benefits which could flow from the proposed works would include improvements in saline intrusion, flood mitigation and enhanced navigability (PWD 1991a).

1.5 ALTERNATIVES TO THE DEVELOPMENT

The dredge plan adopted is the result of almost four years hydrodynamic, ecological and socio-economic evaluation (PWD 1990, 1991a) followed by design refinement incorporating community input. The proposed Dredge Plan has been developed and refined on the basis of consideration of a range of alternatives. Such alternative proposals include:

(i) undertake no sand extraction

(ii) revised dredging quantity

(iii) revised sand stockpile and removal locations and routes

(iv) revised sand extraction procedure

Comments on these alternatives are set out briefly below.

(i) **No Sand Extraction**

The RMP identified a clear community need for improvement of the river navigability, environmental enhancement and reduced flood levels in the Area 5 region. This could not be achieved in the absence of the proposed works.

(ii) **Revised Sand Extraction Quantity**

The extensive and detailed Dredge Plan refinement undertaken has sought to optimise the works to achieve the desired outcomes in the most cost-effective and sustainable manner. Ecological and water quality constraints on maximum dredging depths have been adhered to.

(iii) **Stockpile Site and Removal Routes**

The strategy for stockpiling and removing the sand has been modified as part of the consultation process in preparing this EIS.

Alternatives considered in developing the proposed scheme which is the subject of the present application were:

- identification of a specific stockpile site from which the sand could be removed by truck, necessarily involving assessment of the potential destinations, truck haul routes and traffic issues

- consideration of demand and possible deposition and/or stockpile site options to a degree sufficient to establish general project (sand extraction) feasibility, leaving assessments and approvals of the stockpile/haulage requirements of any specific future application to use this resource to be pursued by the applicant at that time.

The latter of these approaches has been adopted, since prediction of the specific timing and quantities of the future demand is not practicable at this stage and substantial changes to the road system in the area are being implemented.

(iv) **Sand Extraction Procedure**

Alternative dredging procedures such as grab hopper dredging have been considered. The proposed suction and/or cutter suction equipment is demonstrably the most effective in terms of:

- removal rate efficiency
- noise
- river turbidity
- sand transfer to deposition areas

1.6 CONSEQUENCES OF NO DEVELOPMENT

In the event that Area 5 dredging does not proceed, the Lower Estuary will continue to accumulate sand and sediment and the already unacceptable navigation hazards would become progressively worse, to the economic and social detriment of the community. Increasing impediments to tidal flushing of the lower estuary would be likely, with concomitant degradation of water quality and estuarine ecological values.

The opportunity to reduce flood levels and for use of the revenue gained to undertake environmental enhancement projects through the river system would be lost. Implementation of the River Management Plan would not be feasible.

1.7 PROJECT TIMETABLE

1.7.1 Operational Life of the Proposed Development

Dredging activities in Area 5 are planned to occur over a three to ten year period, depending on specific demand needs. During that time, enhancement works would be initiated, and in many cases completed. Some enhancement works may require 15-20 years to mature.

1.8 CONSULTATION

The proposed sand extraction forms part of implementation of the River Management Plan for the Lower Estuary. Considerable community consultation was undertaken in preparing the RMP, and the feedback obtained has been used in determining the most suitable management options and specific works design details.

This consultation was facilitated primarily through the NSW Public Works Tweed Entrance Project office in Tweed Heads over the period 1990 - 1991. All relevant aspects of the RMP were dealt with in that consultation process, as discussed in the management plan head report (PWD 1991a).

In establishing the terms of reference for the EIS, the Director of the Department of Planning was consulted by letters dated 9th August 1990 and 28th November 1991. Responses were received setting out the requirements of the EIS as included in Appendix 2.

Consultation requirements of the terms of reference have been satisfied. Responses received through that process are included in Appendices 4 and 5.

In addition, meetings, correspondence and telephone conversations with individuals and community groups relevant to the proposal, have been undertaken as outlined below.

1.8.1 Fishing Interests

Members of the fishing industry were consulted about the proposed works (CCM 1992). The purpose of the consultation was threefold:

- to ascertain the attitudes of commercial fishermen, representatives of recreational fishing organisations, oyster farmers and the local Fisheries Inspector towards the proposed dredging;
- to establish the pattern and extent of commercial fishing within Area 5; and
- to record any suggestions for river improvement works.

These and other community inputs are reported in Section 3.13.

The fishing industry consultations involved discussions with thirteen commercial fishermen, the representatives of four recreational fishing organisations, three oyster farmers and the Fisheries Inspector responsible for the lower Tweed estuary. The use of Area 5 by commercial fishermen was found to be varied and influenced in some circumstances by the flow conditions of the river. All of the commercial fishermen consulted were members of the Tweed Heads Beach and River Fishermen's Association. Three of the recreational fishing clubs are located in the lower Tweed area while the other club was based upstream at Uki. Oyster farmers who assisted with the study included the operators of leases adjacent to Area 5 and a representative from the local oyster growers' association. The individuals who participated in the study and their association with the area of proposed works are outlined in Appendix 5.

1.8.2 Conservation Interests

Considerable consultation was undertaken with both government agencies and community groups with authority and interest in conservation issues in the areas potentially affected as part of the development of the RMP through the Tweed Entrance Community Liaison Committee. As well, Tweed Council, landowners and community groups were consulted as part of assessments made to identify potentially beneficial and acceptable sand deposition and/or stockpile site options.

Further details of consultations on specific issues are presented in the relevant sections of this EIS.

1.8.3 Aboriginal and Heritage Interests

As outlined in Section 3.12, the aboriginal community has been involved in all of the NSW Public Works studies for the RMP and the Area 5 dredging through the Tweed Byron Aboriginal Land Council (TBALC). In particular, consultation with respect to potential use of land on Fingal Peninsular for stockpiling of sand was undertaken. That site has not been identified as a proposed stockpile site for the purposes of this EIS.

2.0 PROJECT CONTEXT AND DESCRIPTION

2.1 AREA 5 RIVER MANAGEMENT DETAILS

2.1.1 River Management Plan

It is recognised that the Tweed River is a vital link in the social and ecological fabric of the region, and its sensitive management will sustain the quality of the river and its ecology.

During 1989-90 the Tweed Valley community worked with Public Works Department on a feasibility study to resolve the problems of the Tweed entrance.

The study confirmed a widespread community perception that the tidal part of the Tweed River was a unique zone requiring a comprehensive river management plan to protect its valuable attributes and to ensure that present and future residents would be able to enjoy them to the full.

In July 1990 the Minister for Public Works, in response to the community's desire to protect the beauty and benefits of the region, initiated studies on which a sound Lower Tweed River Management Plan could be based.

The objectives of these studies were:

- to devise an overall concept for the estuary that encompasses all its varied assets and pays proper and fair regard to each
- to survey and set out the critical details of the problems confronting the river
- to develop strategies for the entire estuary for community consideration
- to set priorities for necessary actions

In preparing the management plan, individual areas of concern were carefully assessed by specialists in the disciplines of:

- marine and terrestrial ecology
- water quality

- water and sediment movement
- recreation planning
- archaeology
- visual assessment
- administrative systems

Specific objectives of the RMP were identified as follows:

(i) **recreation and conservation**
- improvement of natural habitats
- increase foreshore facilities for walking, fishing and picnicking
- provide opportunities for wetland enjoyment eg. boardwalk, bird watching sites, snorkelling
- encourage low key boating

(ii) **conservation**
- protect and extend significant habitats
- protect heritage areas
- develop education facilities
- improve stormwater quality

(iii) **commercial navigation**
- maintain channels for fishing fleet, oyster farmers and charter boats

(iv) **waterway improvements**
- dredge sand shoals to improve boating and provide habitat diversity

The State Government contributed towards developing the plan by commissioning baseline studies and offering professional advice. However, the long term success of this management initiative depended upon community involvement. Through the Tweed Entrance Community Liaison Committee, formed in 1989, the Government worked with the community to develop a satisfying and workable river management plan.

The development of the RMP was an evolutionary process which required refinement and adaptation with each piece of new information and increased understanding of the river.

The outcome was the identification of eighteen areas across the Lower Estuary for which specific opportunities and action were defined.

The eighteen areas are listed below. The key objectives for each area are listed in Appendix 6.

Area 1:	Jack Evans Boatharbour
Area 2:	Kerosene Inlet
Area 3:	Sponsors Reach
Area 4:	Wommin Reach
Area 5:	Tony's Island Reach
Area 6:	Rocky Point Reach
Area 7:	Ukerebagh Reach
Area 8:	Terranora Inlet
Area 9:	Boyd's Bay
Area 10:	Bridge to Bridge Reach
Area 11:	Entrance Reach
Area 12:	Caddy's to Wyuna Reach
Area 13:	Seagulls
Area 14:	Terranora Broadwater
Area 15:	Tweed West
Area 16:	Cobaki Broadwater
Area 17:	Shallow Bay
Area 18:	Terranora Canals

In August 1992, the RMP was formally handed over to Tweed Council, from the Liaison Committee, for implementation. Funding for the implementation is to come from royalties gained from dredging in the Tweed River.

Implementation is underway through the guidance of Tweed Council's Tweed River Management Plan Advisory Committee. A number of environmental enhancement works have been identified for inclusion in an Early Works Program. These appear to have a high priority and could be achieved at a realistic cost, and include:

- Area 5 proposals

- upgrading of inlets to Wommin Lagoon and Wommin Lake

- design of erosion control at Seagulls Estate Reserve

- Terranora Broadwater management improvements
- removal of sedimentation at major stormwater outlets
- habitat improvements at Ukerebagh Island

To date, development of the RMP has been based on the premise that the identified improvement of the Tweed River entrance with dredging and bypassing of the beach sand would proceed. Negotiations have been held between the Queensland and New South Wales Governments with regard to implementing the entrance improvements. Quite recently, tangible progress towards implementing that component of the Plan has been achieved. There is substantial benefit in proceeding with implementation of other components of the RMP of which the Area 5 sand extraction works have been given high priority. Further details of the Area 5 works are outlined below:

2.1.2 Area 5 (Tony's Island Reach) Plan Details

Area 5 extends from Barneys Point Bridge to Rocky Point (Figure 1.1). The average river width in this reach is approximately 300 metres.

The area has experienced extensive shoaling since the last major dredging in 1976 (between Tims Island and Barneys Point Bridge). Tony's Bar, located within this reach is an important foraging area for wading birds. The bar is under threat of continuing disturbance by people and domestic animals. A channel needs to be constructed to better separate the Bar from the mainland.

The eastern side of the river is contained by a rubble training wall, whilst the western shore is substantially a sandy beach. The main activities performed on the river include recreational and commercial fishing, water skiing and general navigation.

The detailed studies indicate that large shoals can be removed from this reach without adverse effects being experienced. Benefits that would result include improvements to saline intrusion, flood mitigation impact and obvious improvements to navigability.

The present situation with respect to the use and amenity of this reach is summarised below:

- the road bridge with the lifting span at Barneys Point provides an impediment to uninterrupted navigation of the river.

- a normal maintenance corridor extends over the training wall defining the eastern bank of the river

- the river is used for recreation and tourism

- a new road bridge is planned for Barneys Point with construction expected in approximately 18 months

- as far as the Rocky Point Reach, Fingal Road closely abuts the eastern edge of the river, heavily limiting the recreational potential of the river

- viewscapes are interesting and generally serene, except for the prominence of Fingal Road

Strategies for implementing the RMP in this area include:

- discourage general access to important habitat areas

- implement an acceptable dredge plan

- develop further recreational opportunities on the eastern side of the river

- progress plans for shoal removal and mitigation of midge problem at Tony's Bar

- prepare concepts for new recreational opportunities on the eastern side of the river

- create new secure bird habitat on remnants of Tony's Bar for the Little Tern and other endangered birds

- seek a high level of protection for vulnerable bird habitats

- closely monitor the impacts of any sand extraction

Details of the final plan design providing for these improvement and enhancement requirements are presented in Appendix 3, and are also discussed below in terms of the sand extraction component.

2.1.3 Proposed Sand Extraction Details

The dredge plan for Area 5 provides for sand extraction from Barneys Point Bridge to Rocky Point.

The present status and bathymetric configuration of the Area 5 section of the lower estuary is illustrated in Figure 2.1. A number of existing environmental problems and the complex and constricted nature of the tide/flood flow paths and navigation channel have been addressed in the design consideration.

The proposed Area 5 dredge plan, initially presented in the River Management Plan and subsequently refined, has several objectives including:

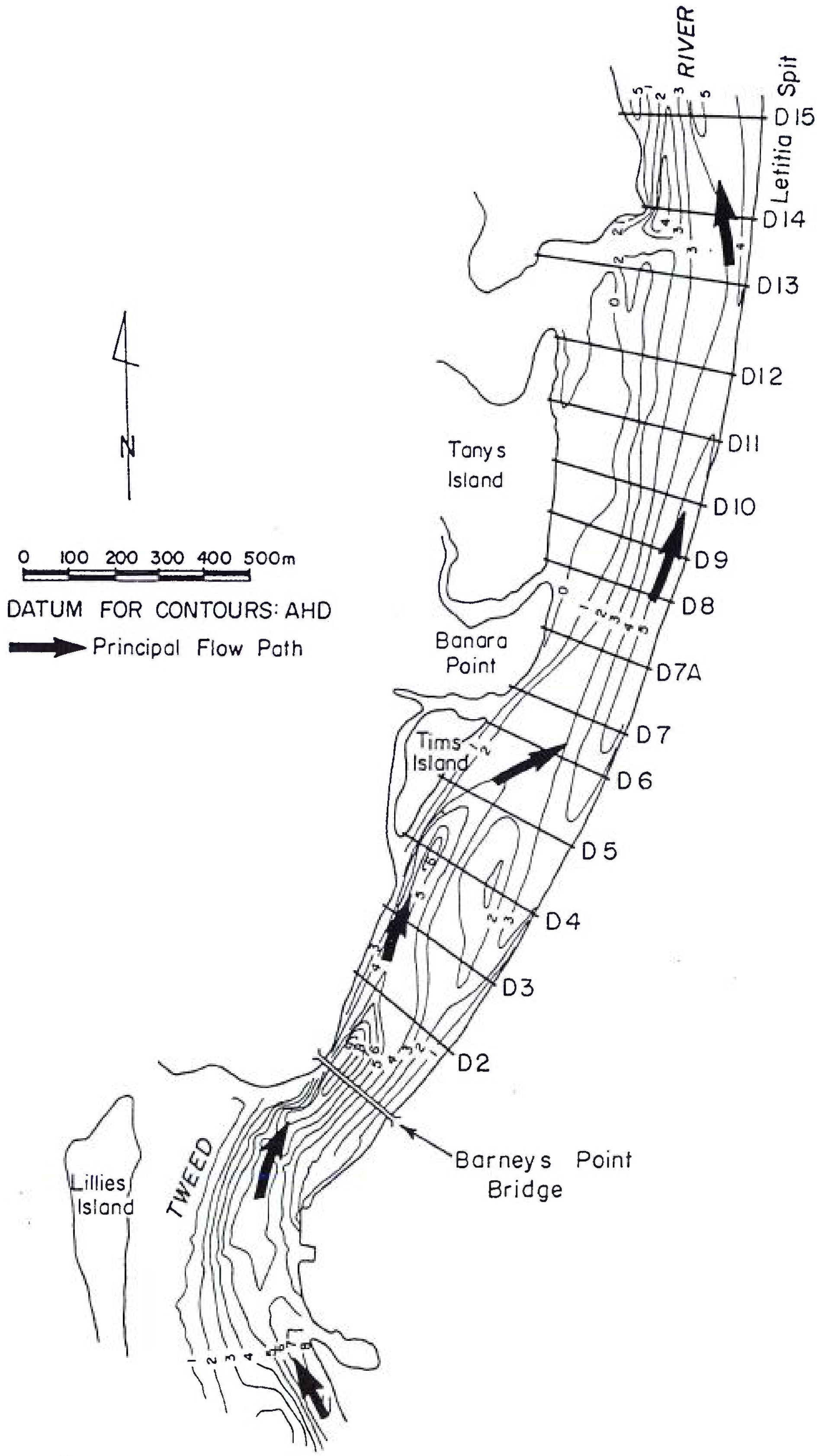
- removal of the shoal below Barney's Point Bridge
- creation of a channel adjacent to the eastern training walls
- enhancement of fisheries habitats through the creation of deep holes, and shallow banks for seagrass regeneration

Removal of the shoals is reported to be possible without adverse ecological or hydrodynamic effects being experienced, as outlined in Section 4.1. The benefits which could flow from the proposed works would include improvements in water quality, flood mitigation and enhanced navigability.

The Dredge Plan for this area is shown in Figures 2.2 and 2.3 in terms of the design river bathymetry and cross-section details. It provides for sand extraction to realign the main channel to a more direct course. Navigation channel banks would be steeper against the eastern river bank but slope more gradually towards the western river bank. The dredging is planned to conform with the conditions prescribed through the efforts of earlier investigations for the Tweed River in respect of bank and channel stability.

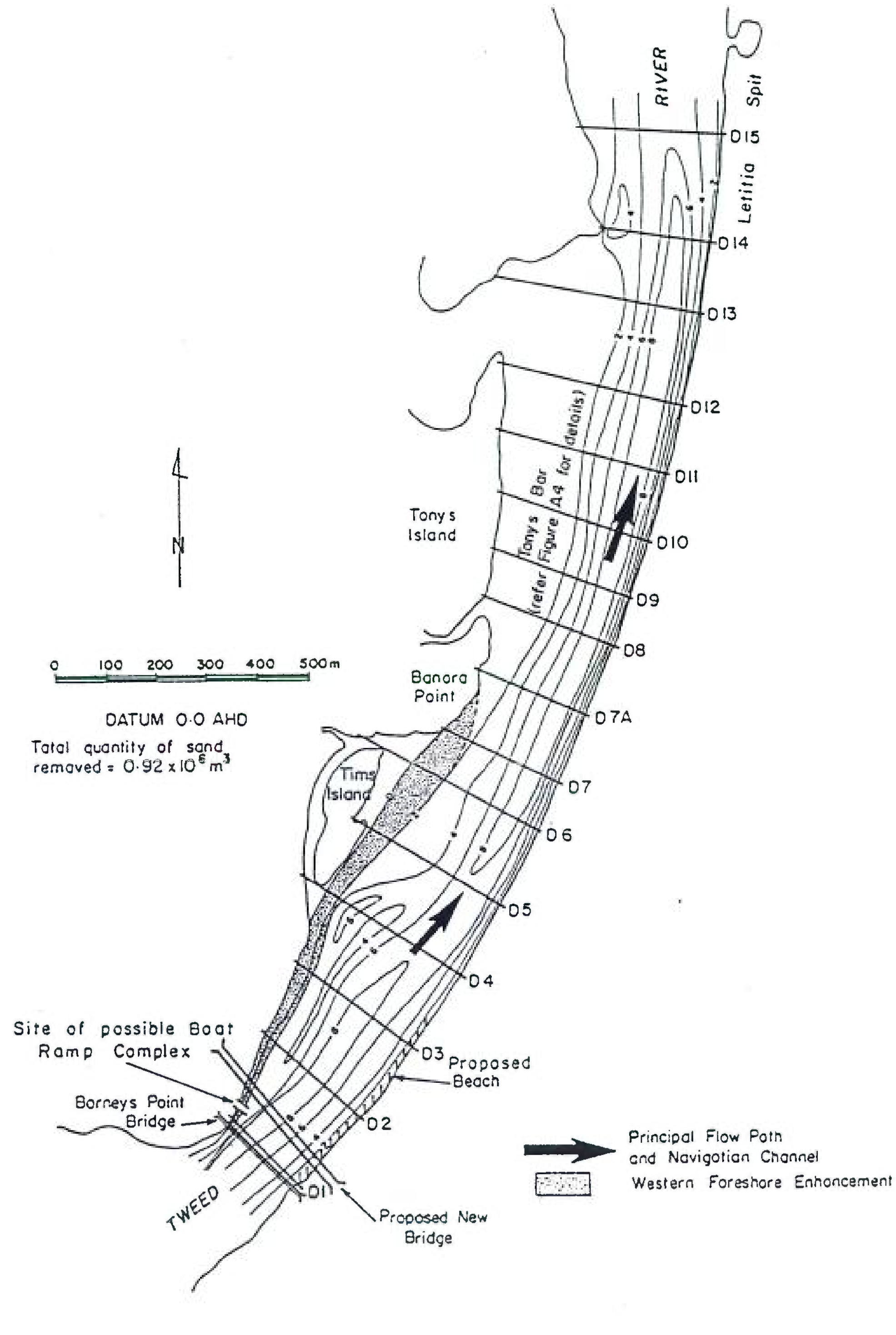
These conditions include the following:

- a minimum bank set-back of 10 metres from the -2.0 m AHD contour
- underwater batters no steeper than 1 in 6 from the toe of the bank set-back
- a maximum dredging depth of 8 metres below AHD



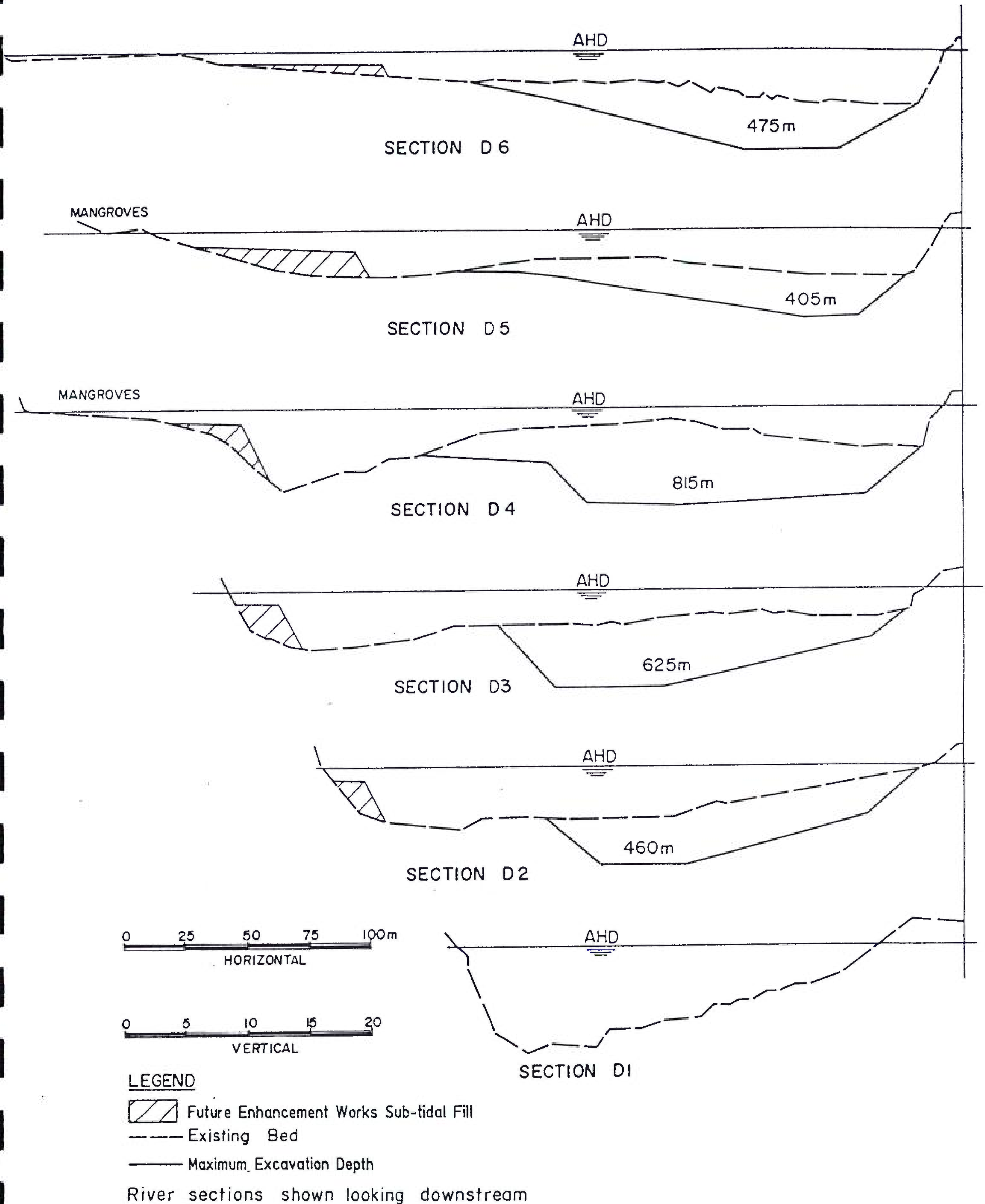
TWEED RIVER LOWER ESTUARY
AREA 5 - EXISTING BATHYMETRY

FIGURE 2.1



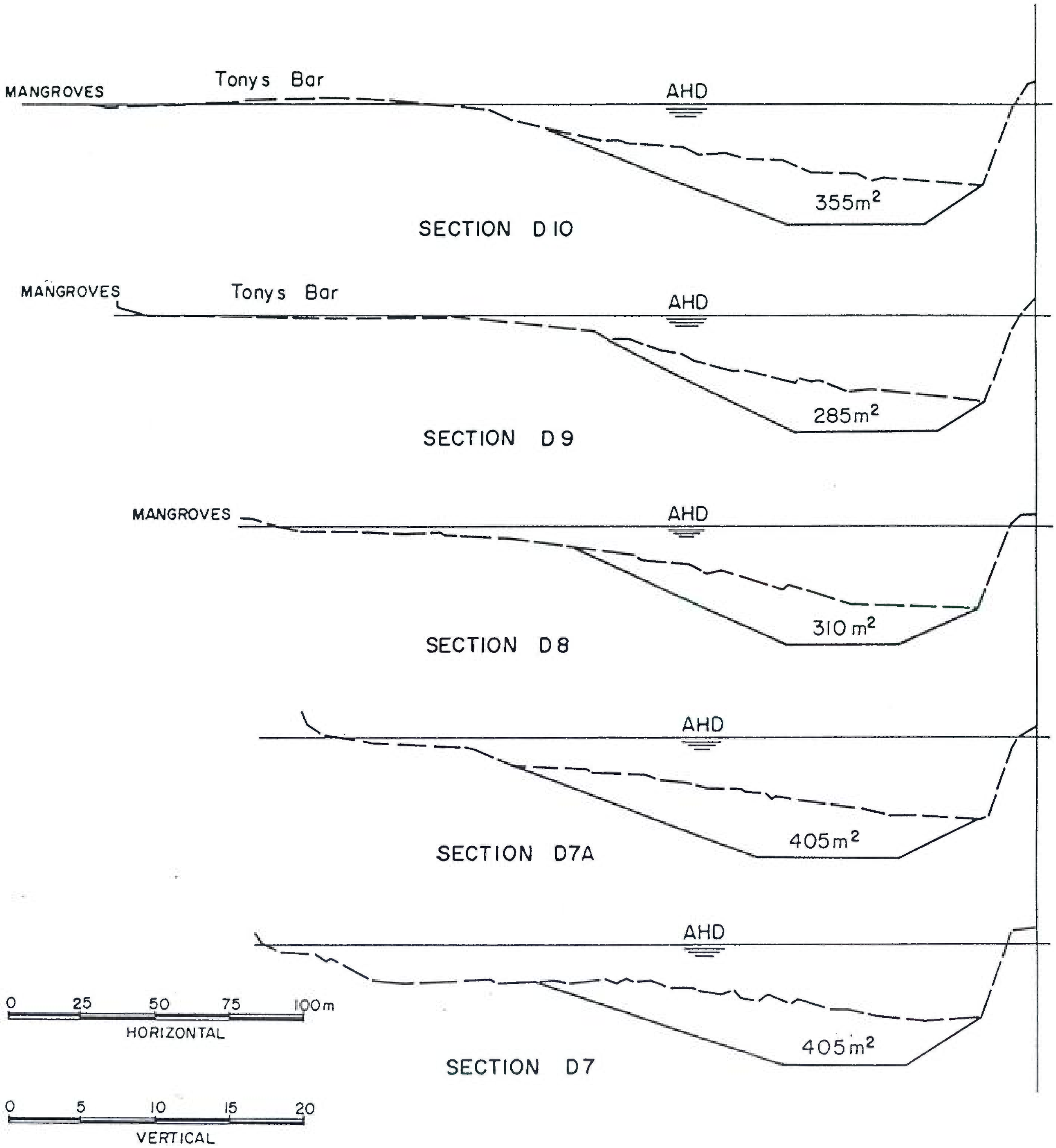
TWEED RIVER LOWER ESTUARY
AREA 5 - PROPOSED DREDGED BATHYMETRY

FIGURE 2.2



TWEED RIVER LOWER ESTUARY
AREA 5 - PROPOSED DREDGED CROSS-SECTIONS

FIGURE 2.3(a)



LEGEND

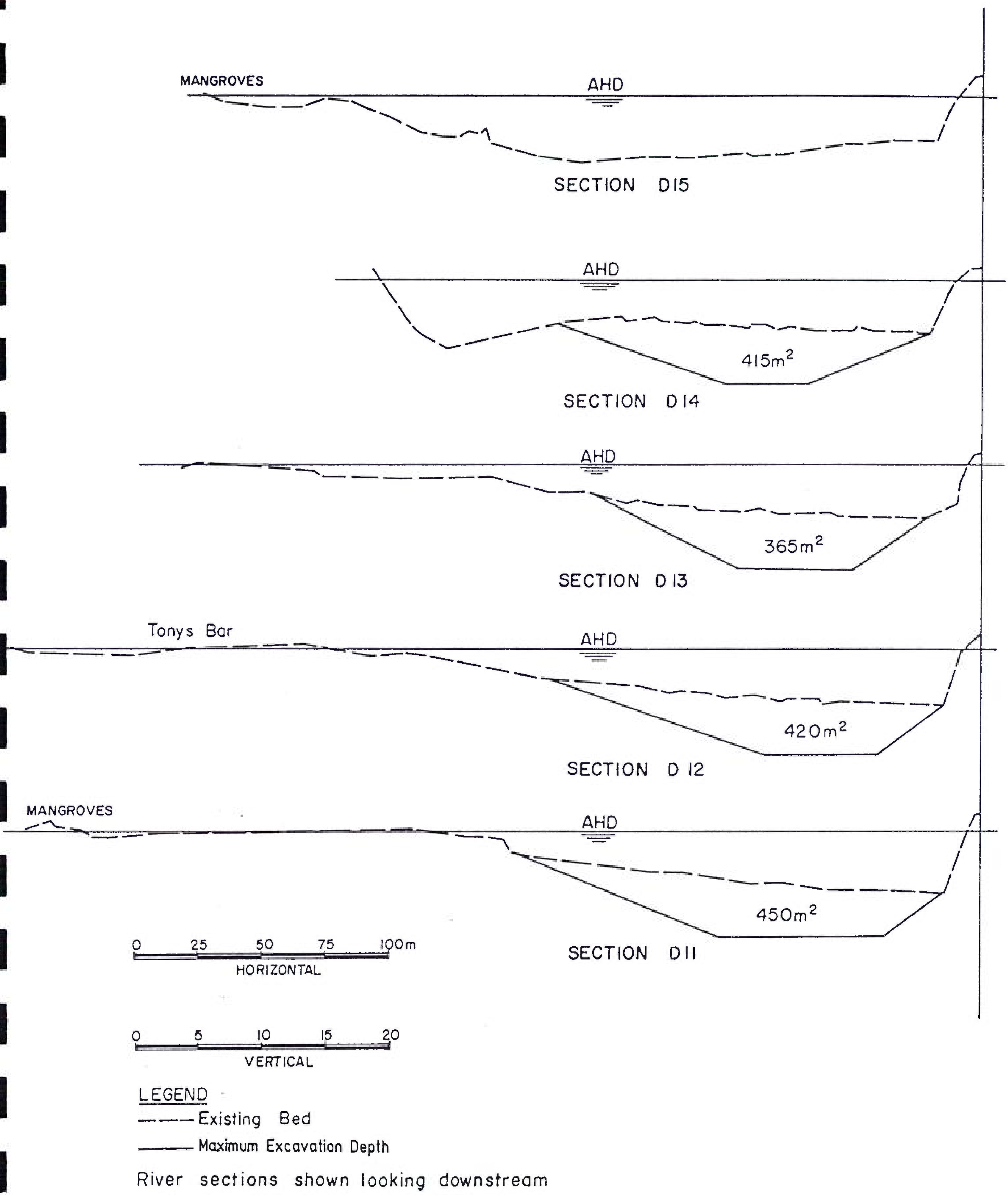
---- Existing Bed

—— Maximum Excavation Depth

River sections shown looking downstream

TWEED RIVER LOWER ESTUARY
AREA 5 - PROPOSED DREDGED CROSS-SECTIONS

FIGURE 2.3(b)



TWEED RIVER LOWER ESTUARY
AREA 5 - PROPOSED DREDGED CROSS-SECTIONS

FIGURE 2.3(c)

The abovementioned underwater batter requirement satisfies the Maritime Services Board requirement for "no (underwater) slope to be steeper than 1 in 3", and the Guidelines on Public Works requirements for sand and gravel extraction proposals in or near estuaries, which recommend side batters of 1:6 in sands. The Department of Agriculture and Fisheries Estuary Habitat Management Guidelines recommended batters not exceeding 1:7.

The design of the sand extraction plan is consistent with the criteria and details established in consultation with the relevant Government agencies including the Department of Agriculture and Fisheries in developing the Lower Estuary River Management Plan. There have been some changes to policies with regard to buffer widths from mangrove and seagrass areas since that time. Nevertheless, the locations of the mangrove and seagrass areas (adjacent to the deep river channel) and potential turbidity plume behaviour are such that these areas and their associated fauna should not be adversely affected by the proposed works.

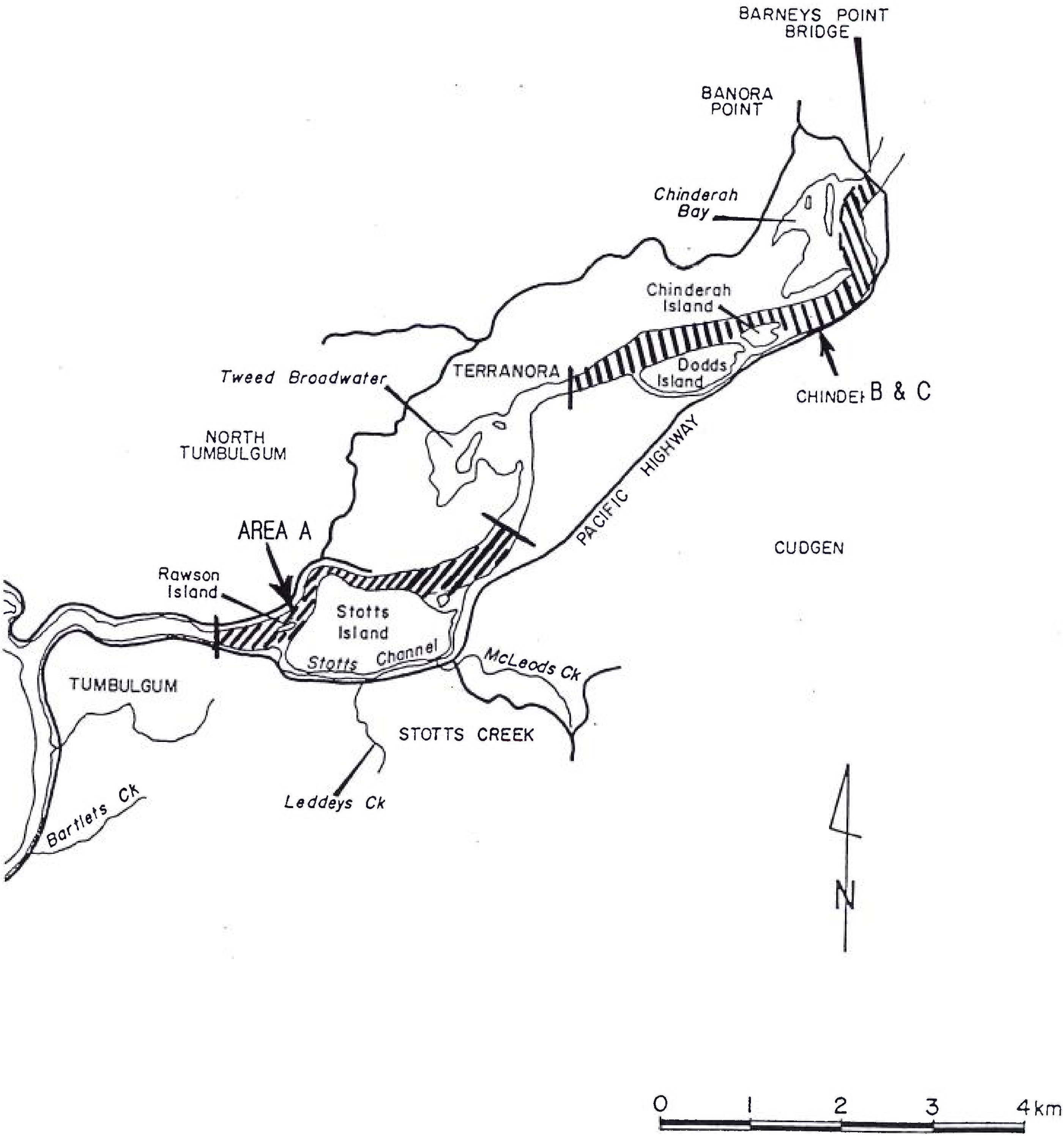
Depths within the river channels would be varied to provide physical diversity. Such areas with varying bottom depths are generally utilised by a greater range of aquatic fauna than areas with uniform depths. The existing western channel and a significant part of the central river sand shoals extending some 500 metres downstream from Barneys Point Bridge are retained, while improving the navigation channel on the eastern side. Shallow Bay and other offstream embayments will not be affected by the dredging.

A quantity of approximately 0.92 million cubic metres would be extracted from this section of the river in establishing the navigation channel as proposed. This is seen as a complementary adjunct to the proposed extraction from areas upstream of Barneys Point Bridge, for which approvals have already been granted. These dredging areas are referred to as Area A near Stotts Island and Areas B and C extending from Barneys Point Bridge to Tweed Broadwater (Figure 2.4).

2.2 LAND ZONING AND USES

2.2.1 Waterway Zoning

The bed of the Tweed River up to the High Water Mark is the property of the Crown and its administration is the responsibility of the Department of Conservation and Land Management. The bed of the Tweed River is subject to the provisions of the Local Environment Plan (LEP) in that any proposed works within the river system require the consent of Council.



TWEED RIVER UPPER ESTUARY DREDGING
AREA A and AREAS B & C

FIGURE
2.4

2.2.2 Zoning of Waterside Lands and Islands

The Tweed Shire Local Environmental Plan 1987 (LEP) forms the current local planning instrument for the Council area. General restrictions on development of land are set out in the LEP. Figure 2.5 provides the relevant mapping from the Tweed LEP covering the proposed Area 5 sand extraction area, potential landfill and stockpile sites and the reserve to accommodate the new highway.

The eastern perimeter of the proposed Area 5 sand extraction area is directly bounded by Fingal Road with land zonings adjacent to the Road which include 6(b) Proposed Open Space, 6(c) Recreation (Special Purpose), 2(b) Residential 'B', a small tongue of 1(a) Rural and 5(c) Special Uses (Arterial Road Reservation).

On the western perimeter of Area 5 zonings include; 6(b) Proposed Open Space, 7(a) Environmental Protection (Wetlands), 6(c) Recreation (Special Purpose) and 5(c) Special Uses (Arterial Road Reservation). The majority of land surrounding Area 5 is set aside and used for recreation (eg. golf course), open space and wetland protection. A relatively small number of homes are located within close proximity to Area 5, including the outskirts of Fingal Village, the settlement adjacent to Wommin Lake and residences at Banora Point.

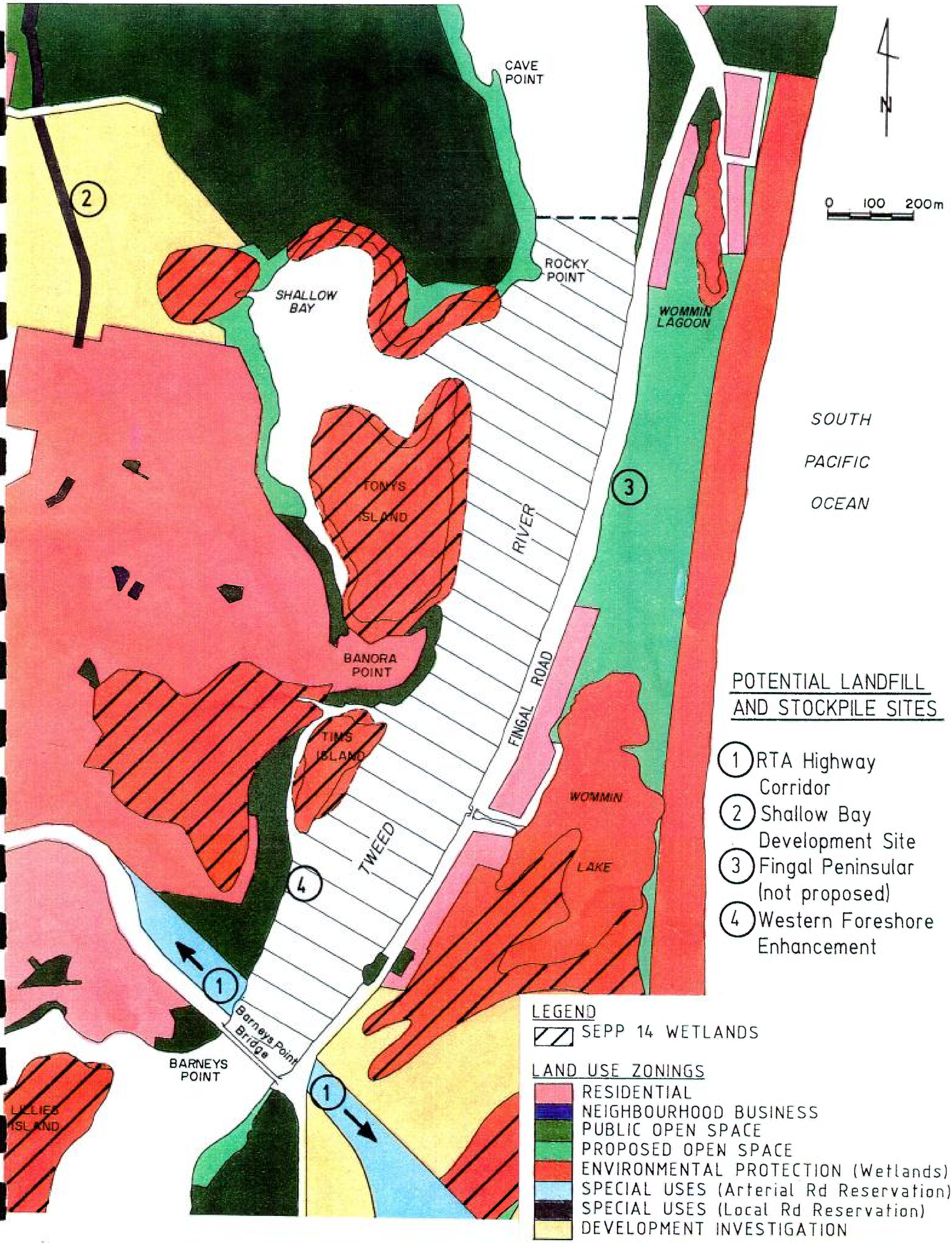
2.2.3 Sand Stockpile Sites

The stockpiling of sand is usually prohibited in Residential Zones, Open Space Zones, and especially any land zoned as 7(f) Wetlands. Zonings of waterside lands have implications for the proposal in so far as the permissibility of a stockpile site is concerned.

Following investigation of the Tweed Local Environmental Plan 1987 and its sundry amendments, together with consultation with Tweed Council, the opinion has been given by Council that the stockpiling of sand constitutes "extractive industry" as defined by the LEP (also see previous section). This being the case, this type of activity may usually be carried out only in one of the three zones:

- Zone 4(a) Industrial
- Area 5(a) General Rural
- Zone 5(a) Special Uses

Potential stockpile site options for dredging from the Lower Estuary were reviewed by Ian Hill and Associates (1990) and M.W. Allen & Associates (1990) (see Appendix 7). Several options were assessed to be acceptable. The proponent considered in detail the



LOCAL ENVIRONMENT PLAN
POTENTIAL LANDFILL & STOCKPILE SITES

FIGURE 2.5

Crown land zoned 6(b) "Proposed Open Space", adjacent to Fingal Road across the river from Tony's Bar (see Figures 1.1, 2.1) as a possible stockpile site, notwithstanding the present zoning on the land. Tweed Council agreed to the proponents' request for a variation of the LEP 1987, for a period of 10 years (the life of the project) in order to facilitate use of this site if needed.

However, after extensive further consultation with local community groups and Tweed Council, it was decided to not pursue that option. It has been established that the sand could be transported directly to the Road Reserve area for the highway and other suitable sites. It will be either used directly for fill for the RTA highway construction in that area, or stockpiled for subsequent removal by truck.

There are therefore no land planning constraints on the dredging or sand stockpiling operations.

2.2.4 SEPP 14 Wetland Zoning

State Environmental Planning Policy No. 14 (SEPP 14) designates coastal wetlands "of significance for environmental planning of the State".

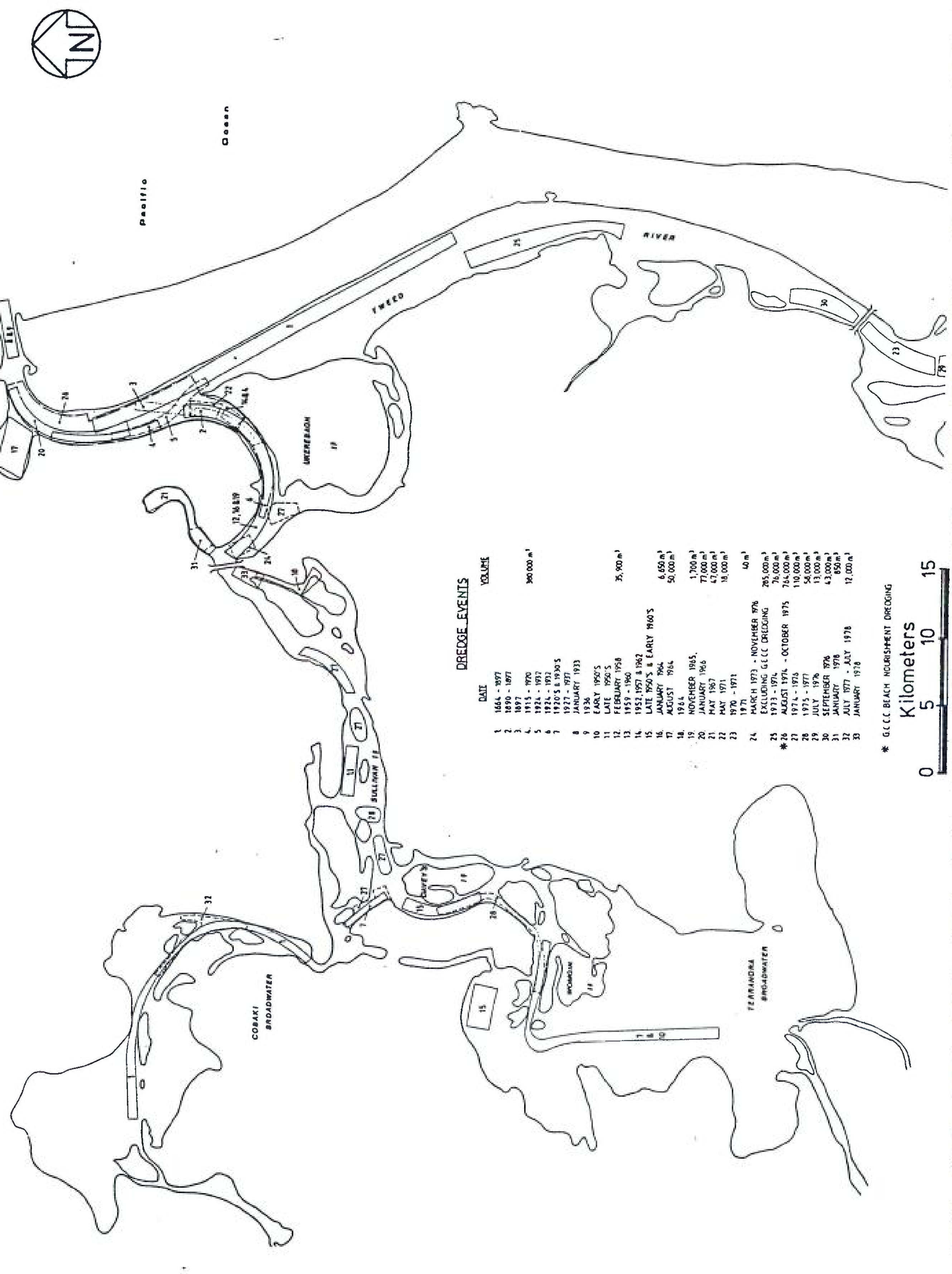
SEPP 14 areas are indicated on a 1:25 000 map series retained by the Department of Planning. Figure 2.5 includes those areas of SEPP 14 wetlands within or adjacent to Area 5, shown in relation to the Tweed LEP 7(a) Environmental Protection (Wetlands) areas.

2.3 CHARACTERISTICS AND ECONOMIC SIGNIFICANCE OF THE PREFERRED RESOURCE

2.3.1 Demand for Tweed River Sand

Test results indicate that the marine sands of the lower Tweed estuary are satisfactory in respect of its potential as high quality, general purpose filling sand (Patterson Britton 1989).

Operators within the local extractive industry are generally of the view that the sand resources of the lower Tweed River have little potential for use as a concrete sand. Its grading is too fine for direct use, and some cleaning and mixing with other coarser materials would be needed for such use.



LOCATION OF DREDGING 1884 JULY 1978
(after Druery and Curedale 1978)

FIGURE 2.6

Historically, there has been an ongoing demand for river sand in the Tweed region for landfill purposes. Figure 2.6 shows the general locations of dredging carried out over the period 1884 to 1978.

Over the last ten years dredging has been carried out in the lower Tweed River at rates varying from 90,000 to 400,000m^3 per annum (Patterson Britton 1989). It can be seen that dredging and sand extraction has been concentrated in the Terranora Arm because of the NSW Public Works extraction policy in respect of the sediment in the lower Main Arm. The sand has been used entirely for land fill purposes associated with canal subdivisions in Terranora and Cobaki Creeks as well as commercial and residential development in the south Tweed Heads and Cobaki areas.

2.3.2 Existing Alternative Sand Extraction Zones

The Tweed River Dynamics Study (1979) identified potential areas for sand extraction, subject to ecological appraisal. This list of areas was limited as no consideration was given to sand bypassing at the river mouth. More recent studies completed during preparation of the River Management Plan (PWD 1991a) have included evaluations of potential sand extraction zones.

Existing approved sand extraction zones exist within the Tweed River estuary. This includes areas upstream from Tumbulgum to Murwillumbah, Cobaki Broadwater (adjacent to Coolangatta Airport), and recently approved proposals to extract sand from the main arm of the river upstream of Barney's Point Bridge in areas referred to as Areas A, B and C (Figure 2.4)

2.4 PREFERRED SAND EXTRACTION ZONE

The Notional Dredge Plan developed for the Lower Estuary as part of the RMP was aimed to satisfy a range of hydrodynamic and ecological criteria (PWD 1991d) which enables sand extraction to depths of (typically) 5-6 metres near Barneys Point Bridge, up to 8 metres in localised areas to provide habitat diversity and in the more constricted river sections of the Lower Estuary, and 4-5 metres in reaches near Ukerebagh Passage. The quantity of sand available through this plan was estimated to be about 3 million m^3 (PWD 1991d) overall for the Lower Estuary.

The sand extraction strategy developed in the context of the River Management Plan (PWD 1991a) identified the dredging of Area 5 as the preferred first stage of dredging fundamental to solving the existing navigation and potential water quality problems in the Lower Estuary (PWD 1991a,j). Sand removal from this most upstream section of the main arm of the Lower Estuary has the least impact on tidal hydraulics and associated processes when compared with the effects of utilisation of the more downstream areas.

2.5 DREDGING OPERATIONS

The dredge to be utilised in Area 5 will be typical of those used in the Tweed estuary and will incorporate a cutter into the suction dredge head in order to reduce the volume of wastewater treatment operations by increasing the proportion of solids in the dredged slurry.

Typically, the type of dredge pump unit employed in the Tweed estuary is powered by a diesel motor producing approximately 200 kW power output, delivering slurry to the processing site at a rate of approximately 300 m^3/hour. Such pumps are designed for continuous pumping of highly abrasive materials such as sand, with minimum maintenance and high efficiency.

The dredge will be located at its particular extraction site by anchors and moorings approved by the Maritime Services Board and NSW Public Works. The same anchors and moorings will also be utilised to winch the dredge from one work site to another as required.

2.6 SAND STOCKPILING AND REMOVAL

2.6.1 Stockpile Site Selection

Hill (1990) reviewed the availability, criteria and options for the location of sand stockpile sites in the Tweed Heads area. As well, an evaluation and identification of suitable stockpile sites for storage of dredged sands and identification of suitable stockpile sites for storage of dredged sands from Terranora Inlet was undertaken by M.W. Allen & Associates (Allen 1990).

Of primary importance in the selection of stockpile sites is their juxtaposition with likely areas of future development and end-users of the sand.

Constraints on the stockpiling of sand, notwithstanding any restrictions due to the size and shape of the land, fall into four categories:

- Zoning considerations (see Section 2.2).
- Road and traffic conditions.

- Physical constraints (e.g. discharge pipeline corridors, return water requirements, etc)
- Socio-political considerations.

The first of the above constraints has been dealt with in Section 2.2. The remaining three are considered below.

Road and Traffic Conditions

All potential development and/or stockpile sites were inspected by Hill (1990), with consideration given, among other factors, to traffic and access conditions. Recommendations, appearing later in this report, have taken into account these observations and the results of detailed traffic studies including likely road upgrading requirements.

Return Water/Topographical Constraints

Any proposed stockpile site would need to be located on level ground, at

(a) a level not excessively high above the river level, and
(b) as far as is possible, visually unobtrusive.

Furthermore, the "return water" from the dredged material must be able to be conveyed from the stockpile sites to the parent waterway by the most economically viable method, having the least visual impact, with water quality parameters which equal or exceed the performance standards set by the Environment Protection Authority.

Socio-political Considerations

These matters were addressed during the community consultation process described in Section 1.8. Particular attention has been given to the requirements of the local Aboriginal community which has lodged a land claim over an area on Fingal Peninsular which was considered as a potential stockpile site (also see Section 3.12).

2.6.2 Stockpile Site Options

All potential development and stockpile sites within the general study area between Tweed Heads and Tumbulgum were inspected and investigated by Hill (1990) and updated in 1991. The potential stockpile site options are outlined in Appendix 7. Individual areas and their suitability, or otherwise, are outlined below, from Hill (1990), with reference also to Allen (1990).

(i) *Vacant Crown Land - Fingal Peninsula*

A potentially advantageous site, of approximately 1.5 ha to 2 ha in area, for the land-based operations is located on vacant crown land on the Fingal peninsular. It has frontage to Fingal Road approximately 2 km from the junction of Fingal Road with the Pacific Highway, as shown on Figure 2.6.

The site falls within Mapping Area 25 of the New South Wales Department of Lands "Fingal Peninsular Draft Land Assessment"; the relative section of the assessment has been included as Appendix 8 to this report.

The then Department of Lands report considered the land to have low environmental production and nature conservation significance, no forestry use, a high mining potential and it was considered most suitable for intensive or urban type recreation. Additional potential benefits of this site are as follows:

- Proximity to Area 5, potential end-users and services.
- The remoteness of most other suitable sites
- The relatively disturbed state of the flora on site, and the site generally (see Section 3.9).
- The opportunity to implement a rehabilitation program for the flora and fauna of the site in collaboration with local conservation and Aboriginal community organisations.
- The site area is of sufficient size to accommodate the plant, roadways, sand stockpile etc., with substantial areas remaining on which existing native vegetation could be retained and nurtured. Weeds could be removed and replaced with local species.

- Services and traffic corridor requirements are adequate although a number of management problems are raised in other sections of this EIS, all of which provide opportunities for long-term, cost-effective remedial works.

- Noise levels created by the proposed dredge and on-shore plant would be controllable using appropriate measures described in Section 4.6.

- The land is on the edge of the lower Tweed River floodway and is generally flat, with ground levels of the order of RL 1.5m to 1.8m AHD. It is not effected by flood events with a recurrence interval of once in six months, but is likely to be inundated in a 5% AEP flood.

(ii) *The Tweed Heads Area North of Terranora Creek and East of the Motorway*

There are no suitable sites within this area, nor is there significant development requiring sand fill, foreseen in the future.

(iii) *The South Tweed Area - Tweed River Foreshore and Lands between the Motorway and Tweed River, South to Barneys Point Bridge*

Site inspection by Hill (1990) and reference to the zoning maps indicated that there is no suitably zoned land along the river foreshores, or immediately adjacent, suitable for use as sand stockpile sites.

The majority of the lands are either zoned Wetlands, Public Reserve, Development Investigation, or Residential.

One site within this area, Development Site No. 4 is currently zoned 2(c) which permits a wide variety of uses. The site would require filling to bring the property level to the prescribed flood height, as well as requiring fill at a later stage for building purposes. A major open drainage system exists in the vicinity of this site to the Tweed River, in which the return water could readily be accommodated.

This site is unsuitable for the present proposal however, because of its remoteness from Area 5, and also because the land is privately owned, and may not be available.

(iv) *The South Tweed Heads/Banora Point West Development Area*

This large area is noted as Development Site No. 6.

A significant deposition and/or stockpile site could be located within this area to take advantage of the development which is anticipated to occur over the next 15 years or longer. The site is remote from Area 5, posing some problems for delivery of dredged material.

(v) *The Tweed River Foreshore Areas, South of Barneys Point Bridge to Tumbulgum*

The Tweed LEP 1987 indicates that the entire foreshore area between Chinderah and Tumbulgum is zoned agricultural protection 1(b2). Following gazettal of Amendment No. 17 to the Tweed LEP 1987, extractive industry may be a permissible activity requiring the consent of Council in respect of 1(b2) agricultural protection. This area is remote from Area 5 and would be a feasible option only if barging the sand was economically viable.

(vi) *The Chinderah Industrial Area*

The Chinderah industrial area is considered to be suitable for a major sand stockpile site. However, its remote location renders the location unsuitable as a stockpile site for Area 5 dredging activities.

2.6.3 Direct Landfill Options

Two potential development sites exist, requiring substantial quantities of fill and within the range permitting direct pumping to the site (with the use of one or two booster stations on the discharge line). These are:

- the RTA highway construction corridor
- the designated development investigation land extending west from Shallow Bay

All other known sites are beyond the acceptable range of pump delivery. Hence, they would require some form of land-based processing and trucking operation.

It is understood that the RTA works require a minimum of about 600,000 - 650,000 cubic metres over the next 2-3 years. Direct land fill to these works from Area 5 would be a highly efficient and beneficial use of the resource.

There are two areas of land immediately west from Shallow Bay for which fill is likely to be needed.

Both sites have potential as sites for direct disposal to landfill. In the past, the development of this property would have included a balance of earthworks by the construction of artificial lakes and waterways. It is noted that part of this area is also environmentally sensitive.

A tidal waterway, being in integral part of Council's eastern drainage scheme for South Tweed, will be required. With sand fill being available at a reasonable cost, one of the present property owners has revised this site development, to delete a proposed lake and will require between 100-150,000m^3 of filling. A further 120,000 m^3 will be required on the other site.

As an additional consideration, the potential for disposal of sand to development sites within the north-eastern section of the Tweed Shire is related directly to the obtaining of fill material via the construction of artificial waterways. In recent years, there has been a growing objection, by various authorities, to the construction of these waterways, notably from the Department of Fisheries. Enquiries indicate that, whilst the New South Wales Planning Authority is not currently contemplating any specific directions in this regard, it is possible that, at some point in the near future, it may become even more difficult to obtain approvals for the construction of tidal waterways.

This being the case, the potential for the disposition of dredged sand to direct land fill projects would be greatly increased.

In addition to the above landfill options, sand will be required for implementation of the western foreshore enhancement component of the RMP. Some 40,000 cubic metres of sand would be needed for this purpose.

2.6.4 Preferred Sand Removal and Stockpile Option

The precise nature of future demand for the sand resource cannot be predicted. It is known that there is a need for fill material for the RTA road works, the Shallow Bay development site and placement on the western foreshore as part of implementation of the RMP. There is also a continuing need for fill in other areas.

It is thus proposed that the RTA road corridor be used as the principal fill/stockpile area, and that the Shallow Bay site be pursued with respect to demand and associated permits for use as a fill site for the sand.

Should the RMP enhancement works proceed in conjunction with the river dredging, sand may also be directed to that purpose.

2.6.5 Operational Life

The planned working life of the project is anticipated to be up to 10 years depending upon demand and final resource volume.

2.6.6 Processing Equipment and Operations

Sand would be delivered to the disposal/stockpile areas as a slurry (approximately 20% sand, 80% water), via a delivery pipeline, the diameter of which is sized to suit the dredge pump - usually 200-250 mm diameter. The pipeline would pass under road pavements where necessary so as to cause no interference with the public use and traffic flow.

Processing operations would vary in minor detail, from operator to operator, depending on their preferences for, and/or availability at the time, of certain items of plant and processing components. The operations described hereafter are typical of the industry supplying sand to external sites for use as fill.

Within the processing site, the delivery line could, if required, discharge through a static screen to remove coarse material such as stone fragments, shells, sticks etc, before passing into a constant density tank. The trash from the screen would be stockpiled for later removal. The constant density tank consists of a tank with a hopper bottom, permitting the primary dewatering and removal of excess fines to the settling pond, whilst concentrating the sand slurry.

From the constant density tank, the concentrated slurry is typically pumped to a sand cyclone for secondary dewatering and removal of fines. The cyclone, a small cylinder with a cone-shaped base, is usually mounted at the top of a steel tower or boom, 6-10 m high, where the fine, lighter particles, turned to waste, are separated from the course, heavier sand particles by centrifugal force. The fines would be rejected with the waste water and either fed back into the constant density tank or discharged to the settling ponds. The sand product is discharged through the base of the cone to a stockpile mound for subsequent handling usually by conventional rubber-tyred front and loader.

In this case, where the sand is to be used directly for landfill at the discharge site, such screening and multiple handling may not be needed and pump-out placement within bunded fill areas would occur.

2.6.7 Dewatering, Settling Ponds and Return Waters

The standards established in EPA (1990) require that waste water contains less than 50mg/l of non-filtrable residues before it is returned back to the main water body - the Tweed River. The usual means of obtaining this standard is to pass the return water through a settling pond prior to discharge off site.

The EPA has advised that settling ponds should be large enough to hold at least two days' volume of waste water and have a minimum depth of 1 m. The pond should be desilted regularly so as to maintain a minimum depth of 800mm at all times. The dredge would deliver the slurry containing 20-30% solids at a rate of $300m^3$/hour to the processing plant, and settling ponds must be sized to comply with EPA recommendations, based upon this operating volume.

Overflow from the settling pond would be directed into a perimeter drain. The drain would be sized to readily accommodate this return flow and will be protected against scour. The final effluent would discharge via a pipe into the Tweed River. The pipe would have a flap discharge to prevent the entry of seawater during times of peak high tide.

2.6.8 Spillage Control and Safety

A bunded area, with a minimum storage capacity of 110% of the volume of any stored fuels and lubricants, would be provided on site as required by the Department of Water Resources and NSW Public Works. This area would be lined to Environment Protection Authority (EPA) standards (EPA 1990), to prevent percolation of any spillage into the groundwater.

The Maritime Services Board (MSB) requires that a contingency plan be developed to deal with any oil or diesel leakage from the dredge to the river. MSB navigational safety requirements will have to be met.

The land-based fill and/or stockpile sites will be approved construction or work areas, and all safety requirements for such areas will apply to the sand extraction works.

2.6.9 Number of Employees and Operating Hours

The hours of the land-based operation will be from 7.00am to 5.00pm, Monday to Friday, and 8.00am to 1.00pm, Saturday, as required by the Tweed Council. No work will be permitted on Sundays or public holidays. Two persons would be employed full-time at the land-based site.

2.6.10 Site Rehabilitation

On completion of the contract (expected to run for up to 10 years from commencement) all plant, equipment, offices and other infrastructure would be removed and any land disturbed by pipelines and dewatering activities returned to existing or required new surface levels. Cleared areas would be replenished with topsoil and revegetated to the satisfaction of the NSW Public Works and the local community.

As the sand processing and effluent treatment does not involve the use of any chemicals and given the provision of bunded and lined fuel storage areas, no contamination is anticipated. Appropriate site rehabilitation procedures would be implemented using locally grown native plants with minimal or no long term adverse impacts.

2.7 NOISE

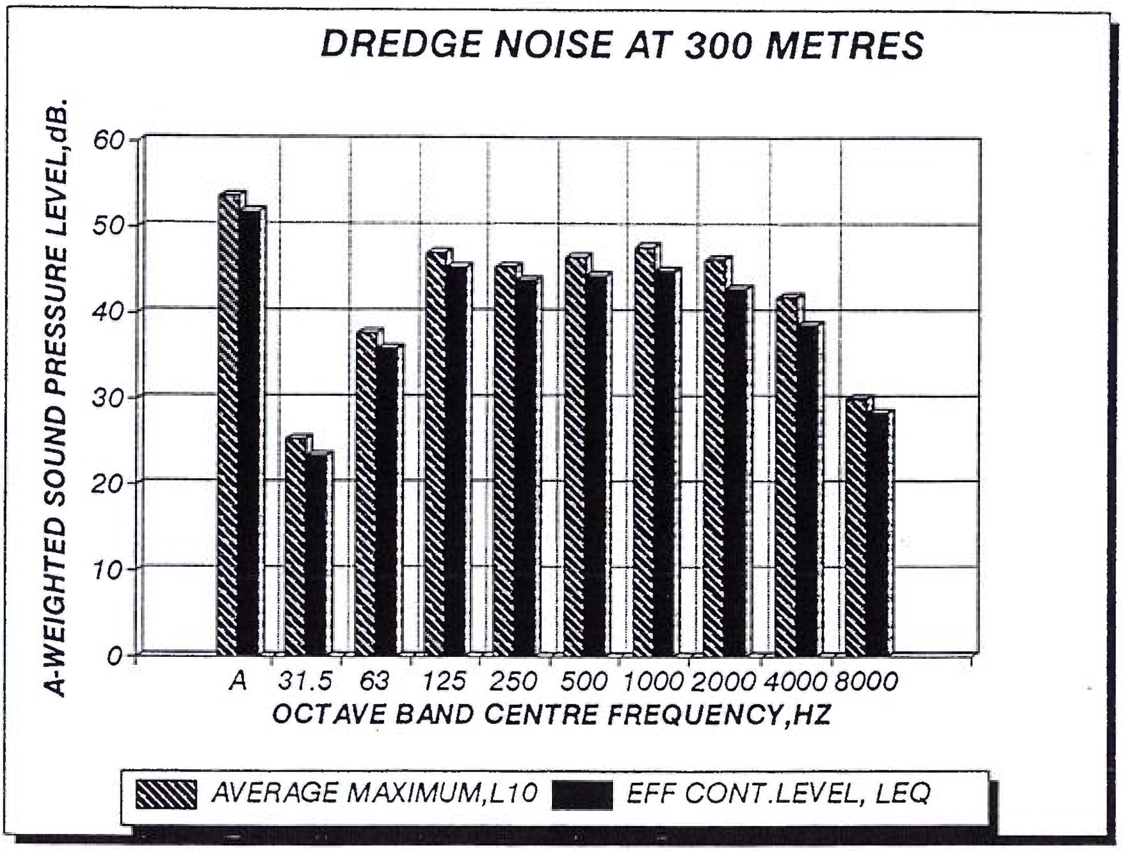
The area potentially to experience noise impact from the dredging of sand from the river is that in the vicinity of the dredge plant as described in Section 4.6 and Appendix 9.

Noise sources associated with the dredging proposal would be typical of those associated with river dredging. These are:

- Diesel motor, of nominal 200 kW rating, operating the suction pump on the dredge.
- Diesel motor, of nominal 100 Kw rating, operating the cyclone separator at the stockpile site and the cyclone itself.
- Diesel powered front end loader for stockpile handling and sand loading of trucks.

Noise associated with any truck haulage to specific demand sites would need to be assessed in gaining separate approvals for any such activities should they be proposed.

Measurements were made of a suction type dredge operating in Terranora Inlet. This dredge would be representative of the type expected to be used in the proposed dredging operations. Figure 2.7 depicts the average maximum and effective continuous sound pressure levels from the dredge at approximately nominal 300 metres. From previous dredge noise measurements an average maximum of 70 ± 2 dB(A) at 30 metres is a typical noise level for dredges of this type.



FIGURE

DREDGE NOISE AT 300 METRES

2.7

Measured levels of sources are presented in Table 2.1.

TABLE 2.1
SOUND PRESSURE LEVELS FOR VARIOUS SOURCES AT 30 METRES, dB(A)

SOURCE	dB(A)
Land based diesel engine	71
Front end loader	70 - 75
Suction dredge	72
Haul truck passby	80
Cyclone separator	65 - 70

3.0 DESCRIPTION OF THE EXISTING ENVIRONMENT

3.1 THE TWEED RIVER SYSTEM

The Tweed River system is located within the Tweed Shire, the northern-most coastal region of New South Wales (Figure 3.1). The main arm of the river has a length of about 40km and, together with its various tributary systems, has a total catchment area of about 1100km^2. It flows through the township of Tweed Heads near the mouth, Murwillumbah about 28km further upstream, and other developed areas such as Tumbulgum, Chinderah and Fingal.

The main arm of the river is joined by several tributary systems including:

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

The river flows to the sea immediately south of Point Danger, close to the border with Queensland. The Lower Estuary section of the river downstream from Barney's Point bridge to the mouth flows northwards more or less parallel to the coastline.

The river entrance has a width of about 160 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, then becoming 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 causes deeper water.

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 30km. 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. At Murwillumbah the tidal range is typically about 60% of that of the entrance.

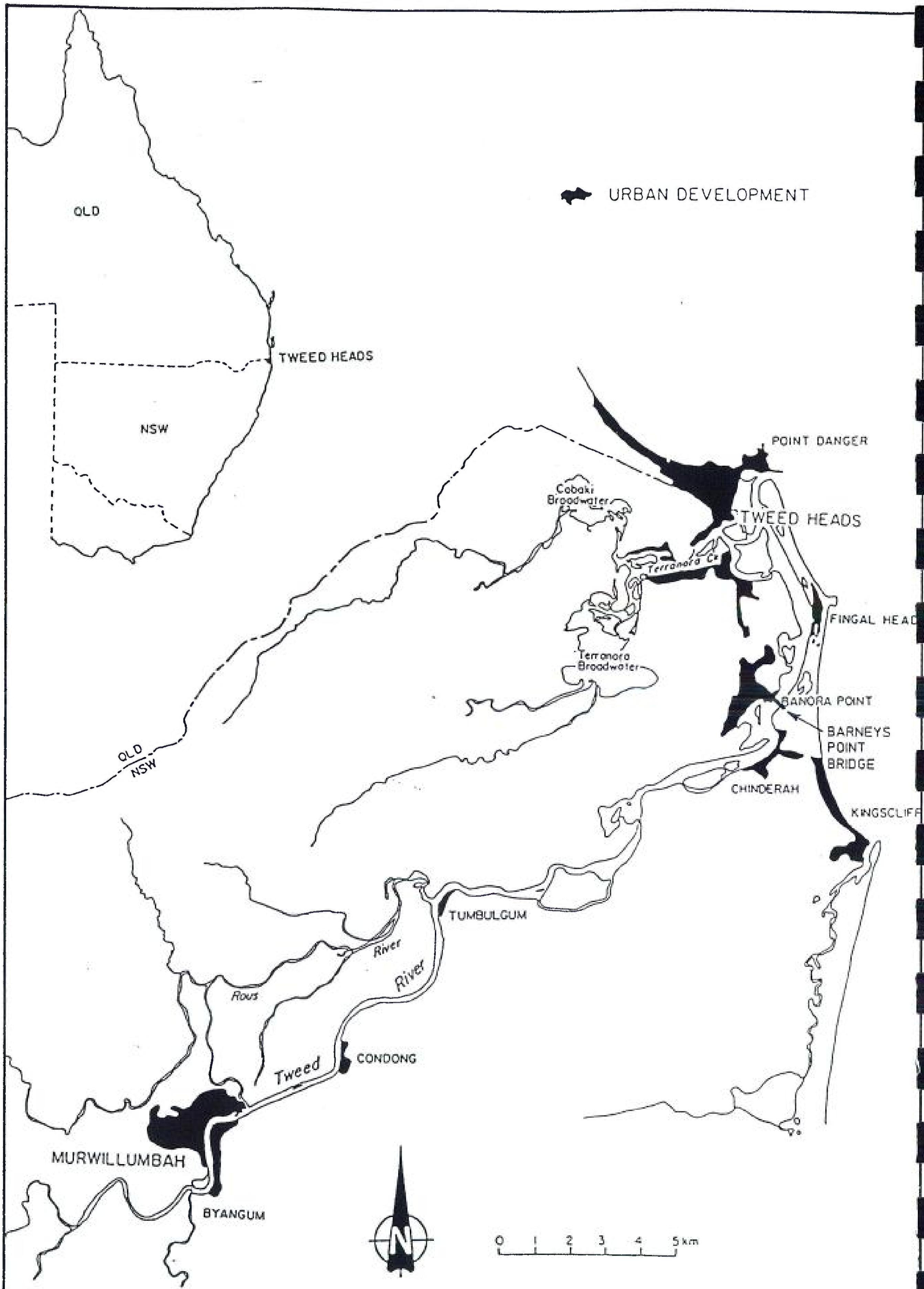


FIGURE 3.1

TWEED RIVER SYSTEM LOCALITY PLAN

The main contributing tidal tributaries are the Terranora and Cobaki Creek systems. These both pass through expansive broadwater areas in their upper reaches, tending to increase their tidal compartments. 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. The tidal range in the upstream areas of these systems it typically only 50% of that of the entrance.

The sediments of the upstream reaches of the river are primarily of fluvial origin. Downstream of about Barney's Point bridge and in the lower reaches of the Terranora and Cobaki Creek systems, the 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 the influences of tidal and flood flows which in turn can influence the controlling hydraulics.

Near the mouth, the river characteristics and associated hydraulic behaviour are also influenced by coastal processes involving a strong longshore movement of beach sand. This sand forms a bar at the mouth as it bypasses to the north and tends to enter the downstream reach of the river under the combined action of tidal currents and waves. This movement has been influenced in the past by river dredging and entrance training. During floods, sand tends to be moved out of the river to the bar and beach system.

The highly mobile sand shoals within and near the mouth have a substantial effect on tidal behaviour along the river. When the entrance is highly shoaled, with a shallow bar at the mouth, the tidal range may be highly attenuated, particularly low tide amplitudes. After floods or dredging which create a more open entrance channel, the tidal range and hence tidal prism in the river is greater.

The tides in the Tweed River are driven by the tidal variations in the ocean near the river mouth. As outlined above, tidal conditions in the river are also controlled by the river characteristics.

The ocean tide near Point Danger (Figure 3.1) has been measured at Snapper Rocks over many years, and predictions for that site are available as a secondary port derivation based on Brisbane in the Queensland Tide Tables. As well, tidal constants have been determined by the Queensland Department of Harbours and Marine, and predictions can be obtained based directly on those constants.

The NSW Public Works has operated a tide gauge immediately inside the Tweed River mouth for many years. This is the Tweed Regional Gauge. While this gauge is relatively close to the entrance, the water levels there may differ from those in the ocean as a result of:

- attenuation due to the entrance channel and bar
- elevation due to wave set-up
- elevation due to fresh water flows
- storm surges

Table 3.1 shows the most recent tidal planes at Snapper Rocks and the Tweed Regional Gauge. The analysis available for the Regional Gauge is that outlined in the report entitled Tweed River Tidal Data, 1971-88 (PWD 1988) while for Snapper Rocks, 1993 Queensland Tide Tables were used.

TABLE 3.1
TIDAL PLANES AT TWEED RIVER MOUTH (m AHD)

	SNAPPER ROCKS	TWEED REGIONAL
MHWS	0.65	0.67
MHWN	0.36	-
MWL	-0.01	0.10
MLWN	-0.38	-
MLWS	-0.67	-0.47

The method of analysis of these tidal planes substantially filters out the short term non-tidal influences on water level, such as storm surges and the larger wave set-up components. Nevertheless, it can be seen that there are differences in the results for the two sites, the Tweed Regional site having a somewhat smaller range affected mainly at low tide levels. This is considered to be predominantly due to frictional losses through the entrance/bar area.

The Snapper Rocks values have been adopted for the purposes of tidal modelling as being most representative of the ocean tide seaward of the river mouth.

3.2 SEDIMENTOLOGY OF LOWER TWEED RIVER

3.2.1 Quaternary Coastal Sediments of the Lower Tweed Valley

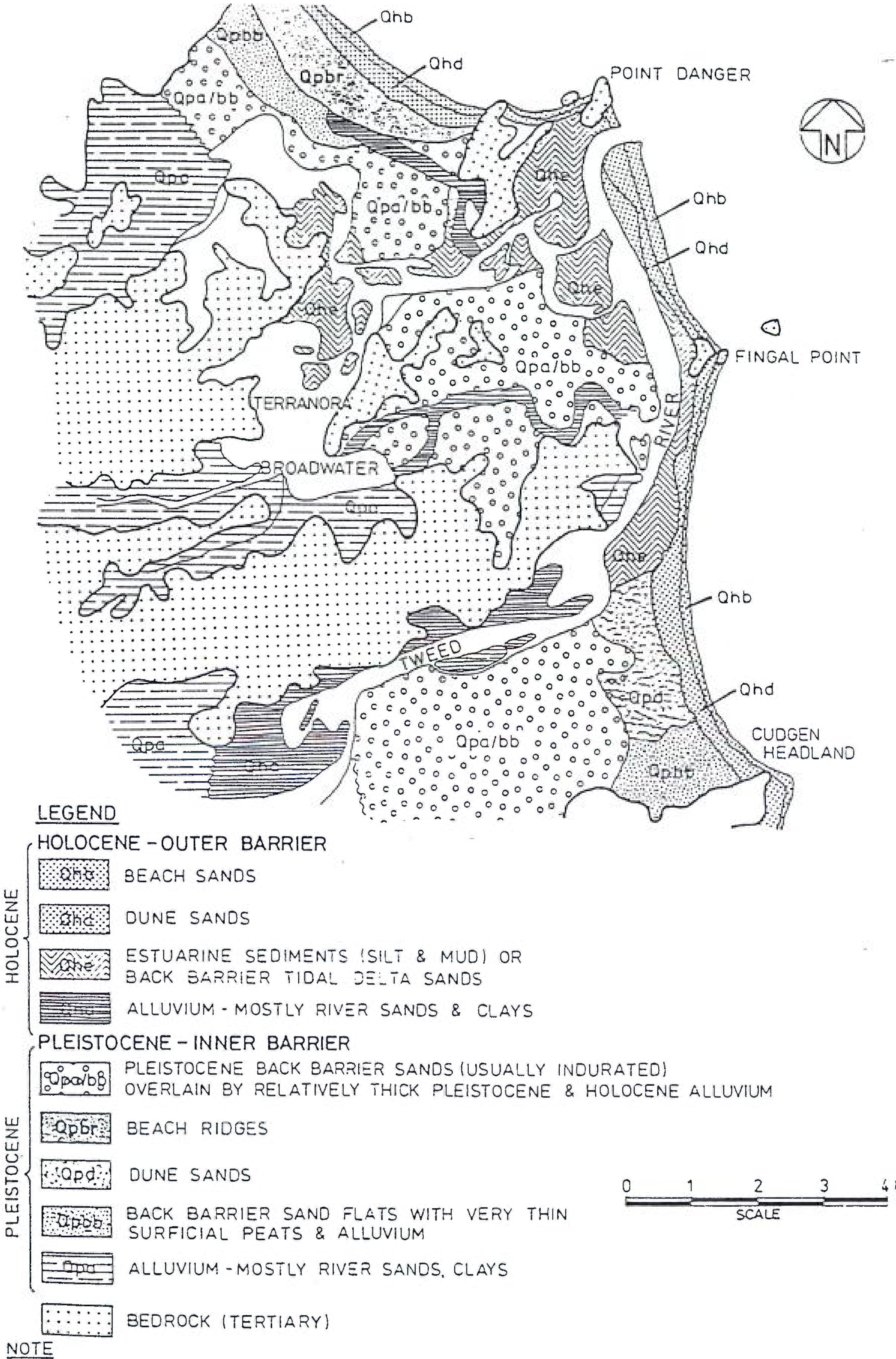
The general evolutionary model of the NSW coastal sand bodies can be used to help understand the distribution of marine sands in the lower Tweed Valley. Figure 3.2 shows the distribution of quaternary sediments in the Tweed valley, based on aerial photograph interpretation, limited field observations and limited drilling information. Figure 3.3 shows a typical example of inner barrier (Pleistocene) and outer barrier (Holocene) marine sand units similar to that present on the Tweed coastal plain. There has been reworking of both sediment units by estuarine processes, and mantling by Holocene fluvial sediments.

The Pleistocene inner barrier has a width of approximately 4 kilometres and was formed as transgressing sands became trapped by gradual infilling of bedrock embayments. It is well established that much of the sediments of the inner barrier sands are indurated. It is considered that the western boundary of the outer barrier sand is approximately a kilometre upstream of Dodds Island, in the Main Arm. The western boundary, therefore, corresponds to the eastern edge of Cobaki, Terranora and Tweed Broadwaters. The eastern boundary is generally within one-half kilometre of the present coastline.

The outer barrier comprises beach, dune and back barrier sand facies but it is narrow, having an average width of only half a kilometre. The beach sands comprise nearshore marine sands and are continuous with estuarine, marine delta sands which overlap Pleistocene back barrier sand facies in the area between Fingal Point and eastwards of Boyds Bay Bridge. The surficial sediments of the estuarine deltas, leading into Terranora Broadwater and Cobaki Broadwater have formed as a result of reworking of inner barrier sands by estuarine processes.

Littoral reworking of inner barrier and outer barrier sands has taken place in the Main Arm, upstream of Barneys Point.

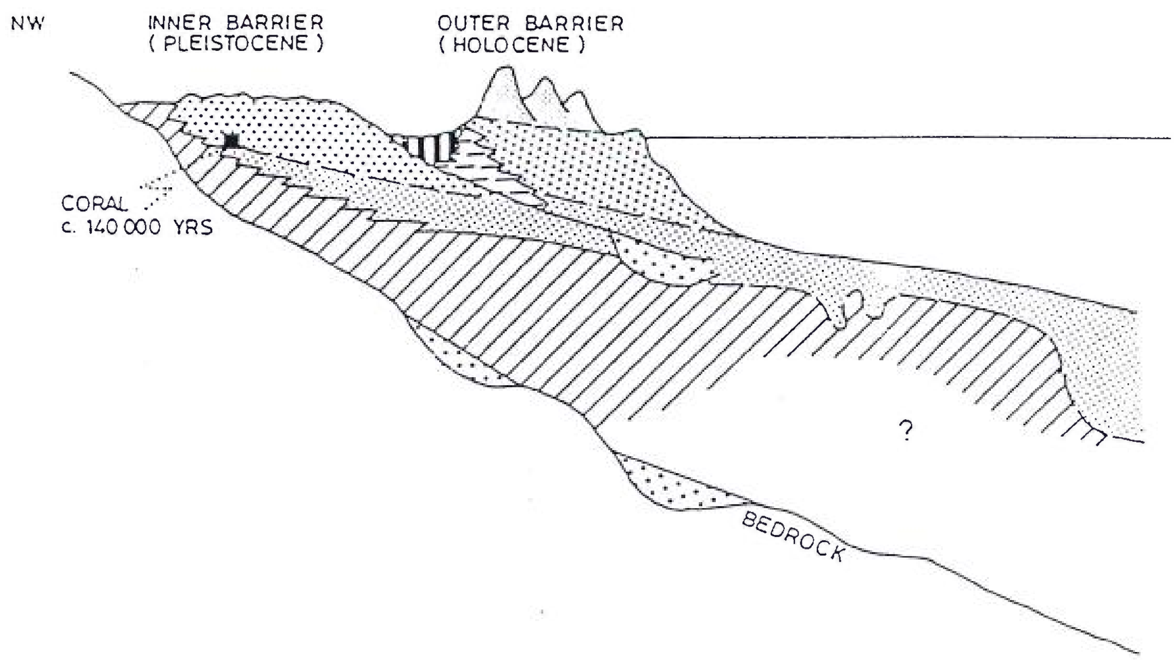
In the Main Arm, prograding alluvium comprising Holocene river sand and mud, has infilled the Tweed Broadwater and overlapped the Pleistocene back barrier sand facies to as far as Chinderah, a distance of some 7 to 8 kilometres. Consequently the sands of the lower Tweed River exhibit a strong marine character being typically well sorted and medium grained whereas upstream of Barneys Point the sediments become progressively finer and muddier until coarser well graded fluvial sands are encountered in the reaches upstream of Tumbulgum.



Source: PWD 1979

QUATERNARY SEDIMENTS OF THE TWEED VALLEY

FIGURE 3.2



LEGEND

- TRANSGRESSIVE DUNE SAND FACIES
- REGRESSIVE NEARSHORE AND BEACH SAND FACIES
- BACKBARRIER SAND FACIES
- TRANSGRESSIVE SAND FACIES AND INNER SHELF SAND
- ESTUARINE MUD
- ESTUARINE 'CLAY'
- FLUVIAL SAND AND GRAVELLY SAND

Source: Chapman D M. Geary M G, Roy P S & Thom B G - "Coastal Evaluation and Coastal Erosion in NSW", Coastal Council of NSW, 1982.

TYPICAL FACIES CROSS-SECTION INNER AND OUTER BARRIER UNITS

FIGURE 3. 3

3.2.2 Geotechnical Assessment

Sedimentology

The sedimentology of the sediments in the lower Tweed River reflects the basic regional Quaternary Geology discussed in Section 3.2.1. The Tweed River flows through Pleistocene and Holocene inner and outer marine sand barrier systems and the distribution of sand facies in the bed sediments reflects this regional geology.

A detailed assessment of the sand facies of the lower Tweed was carried out by the NSW Public Works (PWD 1979) and the sample locations are shown in Figure 3.4. There is an active Holocene marine sand delta comprising well sorted, fawn to buff coloured, shelly marine sand which extends upstream in the Main Arm where the surface Holocene marine sand is mixed to varying degrees with reworked Pleistocene marine sand. These reworked Pleistocene marine sands occupy all of Area 5 (Figure 3.4).

Sediment routing studies (PWD 1979 and the Estuarine Dynamics Report of the Tweed Entrance Feasibility Study) have demonstrated that over the last decade there has been a slow downstream movement of inner barrier sand in both Arms in response to the Gold Coast City Council dredging carried out in 1974/76. This process has resulted in a significant redistribution and build-up of inner barrier marine sands in the surface layers of the sediments of the lower Tweed estuary including Area 5. The effect has been significant and can be seen in the cores taken for this study.

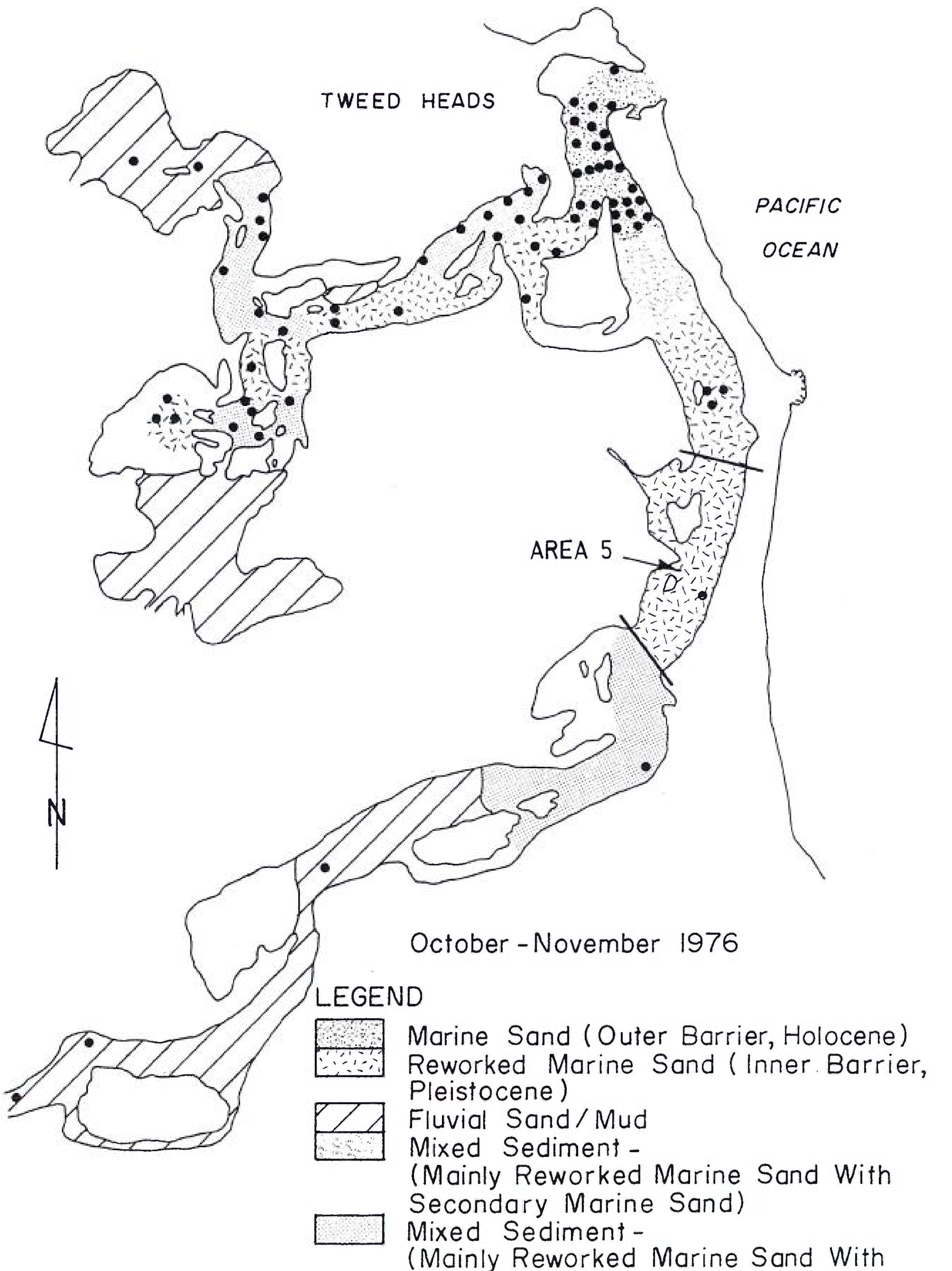
Field coring and sampling

The locations of shallow cores of the top two metres of the estuary beds in Area 5 (designated as B1 etc) are shown,along with typical core logs used in subsequent laboratory analyses, are shown in Appendix 10.

Laboratory analysis

Grain size, shell content and other organic content in respect of representative samples of the Area 5 sand (refer Appendix 10) have been analysed.

The test results indicate that the marine sands (i.e. both Inner and Outer Barrier sands) of the lower Tweed estuary are unsuitable as a fine concrete aggregate. The grading of the sand is poor and the shell content detracts from its use in high quality concrete.



SAMPLE LOCATIONS AND SAND FACIES OF THE LOWER TWEED RIVER

FIGURE 3.4

The sand deposit is relatively free of organics and the carbonate content ranged from 2.8% to 13.9%. Silt content varied from zero to 6% with the greater majority of the deposit containing less than 1%. The overall properties of the deposit are satisfactory in respect of its potential as a high quality, general purpose filling sand.

3.2.3 Magnitude of Lower Tweed Estuary Sand Reserves

The sand reserves of the Lower Estuary, that is the reserves bounded by the entrance, Boyds Bay Bridge and Barneys Point Bridge, were estimated initially for NSW Public Works (Patterson Britton and Partners 1989) on the basis of the 1986 hydrographic survey (NSW Public Works) and the following constraints.

- 10 m bank offset;
- underwater batter 1 to 3;
- maximum depth; Case 1 - -5 m AHD;
- maximum depth; Case 2: -10 m AHD;
- no dredging Ukerebagh Passage;
- no dredging Boyd's Bay;
- no dredging Tony's Island and Shallow Bay.

Based on the above, the potential sand reserves were estimated to be as follows:

DEPTH OF DREDGING (m) AHD	RESERVES (Mm^3)
-5	3.7
-10	12.7

Further detailed assessments utilising flatter underwater batters (1:6), and other design considerations in the Lower Estuary RMP studies indicate that, of those reserves, about 920,000 m^3 occur in Area 5 to depths locally up to about 8 metres.

3.2.4 Evaluation of Area 5 Heavy Mineral Reserves

A preliminary assessment of the heavy mineral grade and type was carried out by Coastal and Marine Geosciences (CMG) and reported in Patterson and Britton (1989). Details are presented in Appendix 10, including an assessment of the economic value of the heavy mineral reserves within the Lower Estuary.

CMG selected forty one samples for detailed analysis of the heavy mineral grade. Testing comprised:

- grain size analysis;
- heavy mineral separation by heavy liquid (bromoform) separation.

Petrographic analysis, using modal analysis of heavy mineral grain mounts, was carried out on seven heavy mineral concentrates to identify the relative percentages of heavy mineral species. A detailed report is contained in Patterson Britton (1989).

The analysis demonstrated that the heavy mineral content of the top two metres of the lower Tweed sand reserves is generally well disseminated. The total heavy mineral grade varied from 0.12% - 1.0% with an average of approximately 0.4%. The heavy mineral suite contained a range of mineral types and the economic component of the heavy mineral portion (i.e. rutile and zircon) varied from 0.07% to 0.52% of the total sand body, with an average of about 0.2%.

The estimates made assumed that the heavy mineral content is uniformly distributed throughout the sand body. As pointed out by Patterson and Britton (1989), this is unlikely to be the case but without further deeper drilling and sampling it is not possible to determine whether the deeper layers of the same body would have greater or lesser heavy mineral concentration.

Owing to the low mineral grade, any mining of heavy minerals would occur only as an adjunct of sand extraction.

Projected royalties from the mining of heavy minerals from the Lower Estuary, as a by-product of a major sand extraction operation, are summarised in Table 3.2.

TABLE 3.2
PROJECTED CASH FLOW - HEAVY MINERAL RESERVES

$1000's											
	1	2	3	4	5	6	7	8	9	10	10 yr Total
High	71	87	128	152	173	151	160	183	186	191	1.5M
Low	11	8	--	9	26	26	41	69	71	71	0.3M

Based on the preliminary information available, which has necessitated considerable extrapolation of limited surface data, heavy mineral mining is unlikely to be a significant factor in the commercial potential of the Lower Estuary sand reserves.

3.3 HYDRODYNAMIC CHARACTERISTICS OF THE LOWER TWEED ESTUARY

From the viewpoint of the river hydraulics, the key considerations relate to flooding/drainage, the tidal regime, and sedimentation processes including bed and bank stability. Beach sand infeed to the Lower Estuary is also strongly related to the hydrodynamic processes of the river.

Previous studies have shown that dredging of the river will provide benefits by reducing design flood levels and times of inundation. Drainage may be adversely affected in areas where potentially increased high tide levels inhibit the escape of local stormwater runoff. Somewhat increased storm tide penetration may also result.

Tidal processes are important for their effects on sedimentation, water quality (tidal flushing) and the influence of increased or decreased tide levels on navigation and ecological processes. Bed and bank stability may be affected by changes to either tidal or flooding hydraulic behaviour.

Assessment of these processes and the potential impacts of the proposed works have been undertaken using numerical modelling techniques as described below.

3.3.1 Numerical Models

A wide range of investigations of estuary and fluvial dynamics of the Tweed River system undertaken by WBM Oceanics Australia have utilised comprehensive numerical models of the river system and its floodplain. These models have been progressively updated as required to carry out the necessary assessments in terms of:-

- tidal hydraulics
- flood hydraulics
- sediment transport

The WBM Oceanics Australia hydrodynamic modelling programs used in this study all as follows:-

- ESTRY - 1 Dimensional tide and flood hydraulics
- SEDMOD - 1 Dimensional sediment transport
- TUFLOW - 2 Dimensional hydraulics, and
  - 2 Dimensional sediment transport

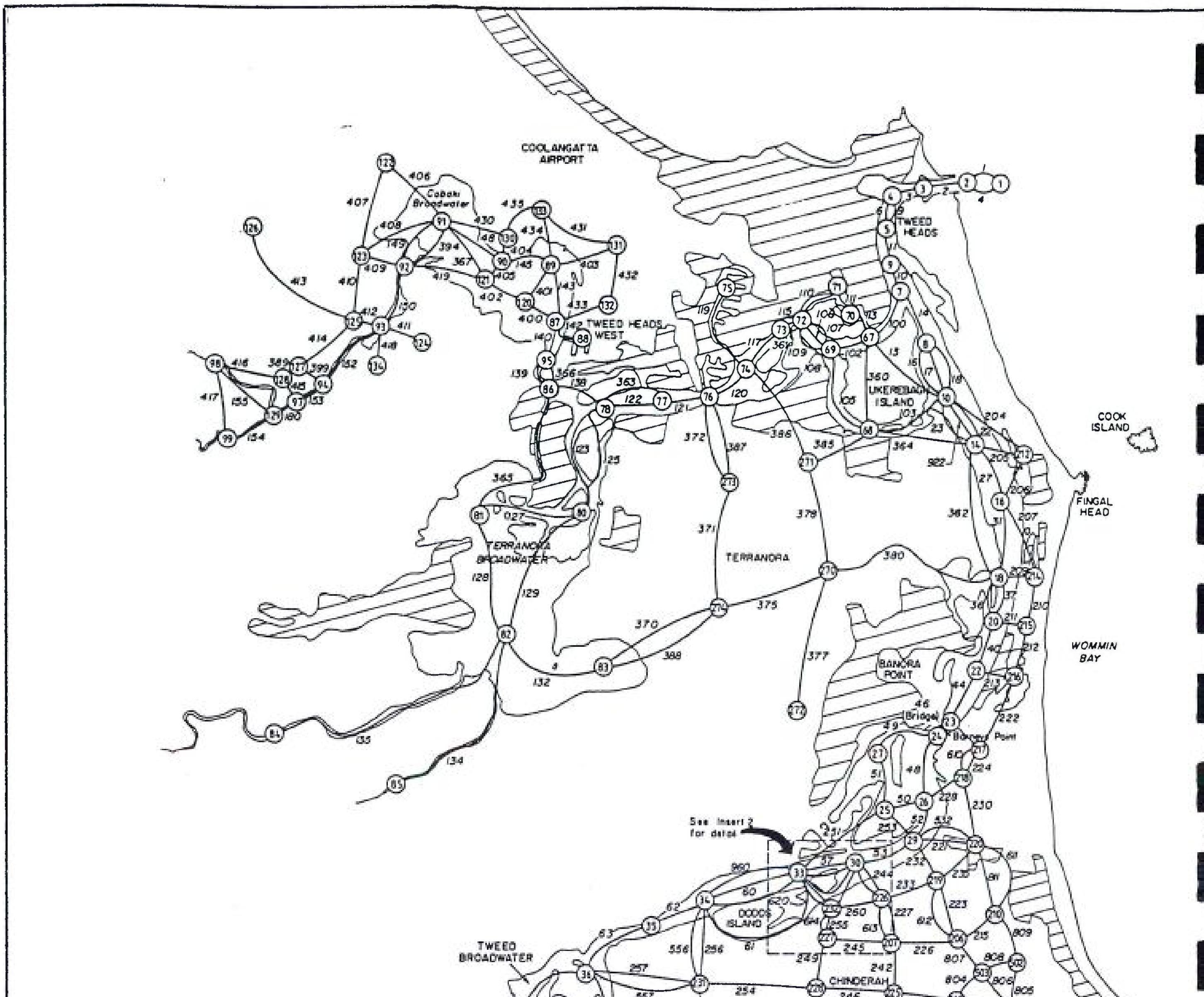
(a) One Dimensional Models

The computer modelling program ESTRY (Appendix 13) has been used to simulate the tidal and flooding hydraulics of the Tweed River system as a whole. ESTRY is a proven program for modelling hydraulic flow conditions in rivers, estuaries, and over floodplains. Models are established as a system of networked channels and storage nodes to represent complex and/or quasi two-dimensional areas. The tide/flood model network for the Tweed River is shown in Figures 3.5 and 3.6.

ESTRY is based on a finite difference numerical solution of the full 1-D unsteady fluid flow equations (momentum and continuity). For given ocean boundary levels and any freshwater inflows, the model uses the momentum equation to calculate the velocity and flow in the channels and the equation of continuity to calculate the water level at each storage node. Model nodes represent the storage in the system while the channels represent the flow characteristics. The nodal surface areas and channel cross-section vary with water level so that the model can reproduce the important influence of the higher level tidal flats and floodplain channels which become operative when the water level reaches a particular height. Because the program solves the full one-dimensional equation of motion, it can accurately reproduce the dynamic behaviour of tides and the interaction of upstream inflows with downstream tide or storm tide conditions.

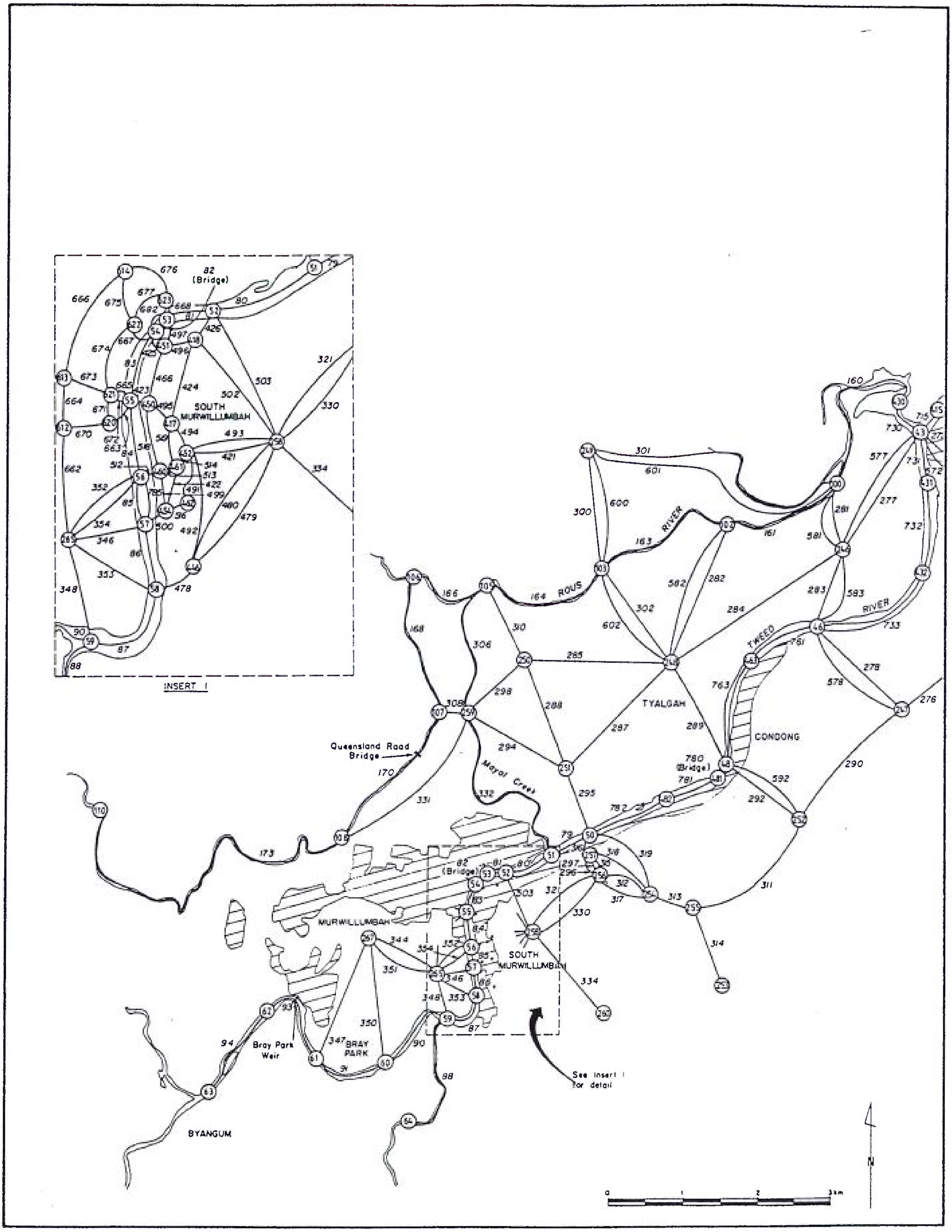
(i) **Tide Model**

A comprehensive ESTRY tide model of the Tweed River system was established for use in previous studies by WBM Oceanics Australia. All available survey data has been incorporated into the most recent model.



TWEED RIVER TIDE/FLOOD MODEL NETWORK
OCEAN TO TUMBULGUM

FIGURE 3.5



TWEED RIVER TIDE/FLOOD MODEL NETWORK
TUMBULGUM TO BYANGUM

FIGURE 3.6

The tide model was initially calibrated to spring tide data collected on September 25, 1980. After model refinement to update the channel bathymetry to that surveyed in 1989 and 1992, further verification was carried out using tidal level and flow data collected in 1988, 1990 and 1992. Details of the model configuration, calibration and verification are provided in other reports (eg. WBM Oceanics Australia 1989). Examples of the calibration and verification are illustrated in Appendix 11.

(ii) **Flood Model**

As for the tide model, a comprehensive ESTRY flood model of the Tweed River system was established for the fluvial dynamics investigation using all available survey data together with models which had been developed for earlier studies.

An updated model calibration was carried out for the April 1989 flood and verification (with appropriate channel bathymetry provisions) for the March 1974 and March 1978 floods in earlier studies. These are illustrated by means of peak flood level profiles in Appendix 12.

(iii) **Sediment Transport (one-dimensional)**

The WBM Oceanics Australia modelling program SEDMOD (Appendix 13) has been used to assess potential impacts on sediment transport associated with tides and floods caused by the dredging (see Section 4.3). The assessment has been undertaken in two stages which provide first for the dredging upstream of Barneys Point Bridge and then the extension of those effects to Area 5.

The program SEDMOD calculates potential sand transport on the basis of simplified channel representation and depth/width averaged flow rates from the ESTRY model. As such, the results are used primarily as an indication of relative impacts of the works rather than in an absolute sense.

Nevertheless, care has been taken in setting up the channel representation to ensure that the assumptions and simplifications of the program conform as closely as practicable to the nature of the river sections being considered. In some locations where the river has a multiple or complex channel configuration, a multiple parallel channel representation has been incorporated in the model for best results.

Consequently the absolute sediment transport rates are predicted to the best ability of SEDMOD, though these rates may at times be dissimilar to the actual sediment transport rates. However, the relative impact of the various dredging options on sediment transport potential will be reliably indicated by model results.

(b) Two Dimensional Hydrodynamic and Sediment Transport Models

Two separate sections of the Lower Estuary have been modelled in two dimensional (in plan) detail to provide comprehensive and reliable information on flow patterns and sediment transport processes in those areas. Modelling program TUFLOW (Appendix 14) was used for this purpose, allowing dynamic linking of these sections to the overall ESTRY river model.

The sections of the river modelled in 2-Dimensional detail are illustrated in Figure 3.7. Direct linkage of each of these river sections at both upstream and downstream boundaries allowed the overall models to be driven by the ocean tide (ESTRY) boundary and incorporate the full river system. Thus, proposed dredging changes were made in the 1-Dimensional ESTRY parts of the model, and associated changes to sediment transport quantified in the 2-Dimensional sections.

Sediment transport was calculated at each of the 2-Dimensional grid elements using the method of van Rijn (Delft Hydraulics 1990). This provides for both currents and waves. Wave action was incorporated in the calculations for sand transport near the river entrance area.

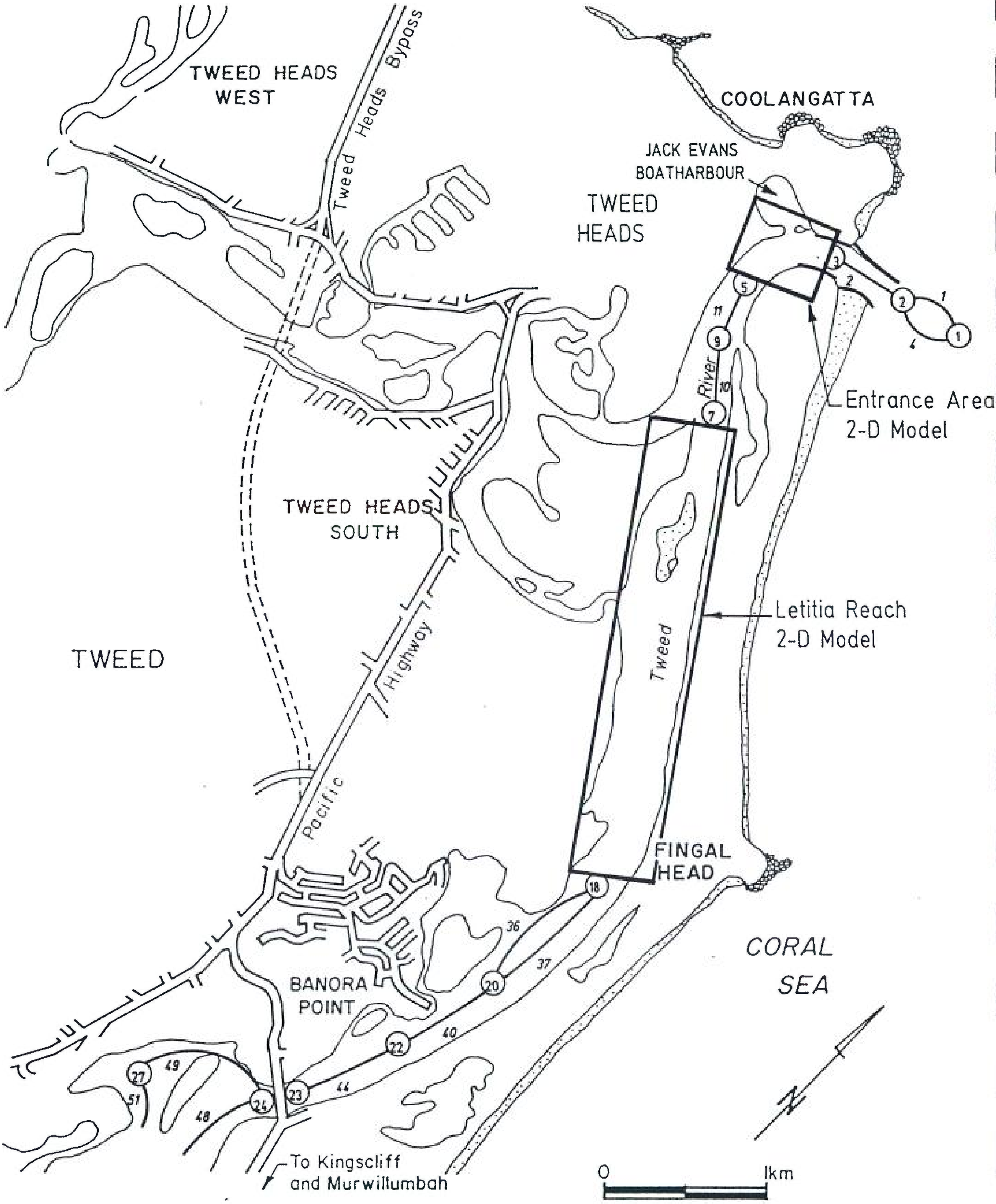
3.4 ESTUARY DYNAMICS

3.4.1 Historical Overview

The Tweed River estuary has undergone extensive modification associated with a range of works undertaken over the past 100 years. The entrance has been trained and the course of the river changed and controlled by revetments. Large quantities of sand have been dredged from the river for reclamation and other purposes.

These changes together with the regular occurrences of river floods and the action of tidal currents in supplying and re-distributing sand, makes it difficult to determine the nature of the natural dynamic equilibrium which would eventually develop if no further works wereundertaken. Nevertheless, an understanding of the works which have been carried out and the way in which the estuary has responded progressively over the years to these works provides a basis from which a reasonable assessment can be derived.

The Tweed River Dynamics Study (PWD 1979) outlines an excellent chronology of works and changes in the lower estuary since the 1870's. The information presented indicates that the area was formerly a broad maze of meandering channels and islands which has been transformed into the present configuration by river training and extensive reclamation.



TWEED RIVER LOWER ESTUARY
TWO-DIMENSIONAL MODEL SECTIONS

FIGURE
3.7

River and entrance training commenced before the turn of the century. This both provided a well defined confined path for the tidal and flood flows, and contained within this waterway area those sand shoals which had been deposited and were subject to ongoing change under the pre-existing natural estuary regime. Extensive reworking of the shoals then took place throughout the whole lower estuary and Terranora/Cobaki Creek river system.

Following river-training, there was reportedly a strong initial upstream migration of sand from the mouth towards the Terranora Inlet area. Even by 1915, development of Fingal Beach had outflanked the southern entrance training wall, allowing a strong infeed of sand to the river under the influences of tidal currents and relatively strong wave action. Regular dredging of the river was undertaken to improve its navigability.

As the estuary system developed towards a new equilibrium regime, the entrance bar at the river mouth developed. It is thought that, by about 1930, the bar configuration was again similar to that as originally surveyed in 1873. The largest flood on record which occurred in 1954 scoured a considerable volume of sand from the river, apparently exacerbating the condition of the bar and prompting action to extend the entrance training walls soon after.

3.4.2 Tweed Entrance Training Walls

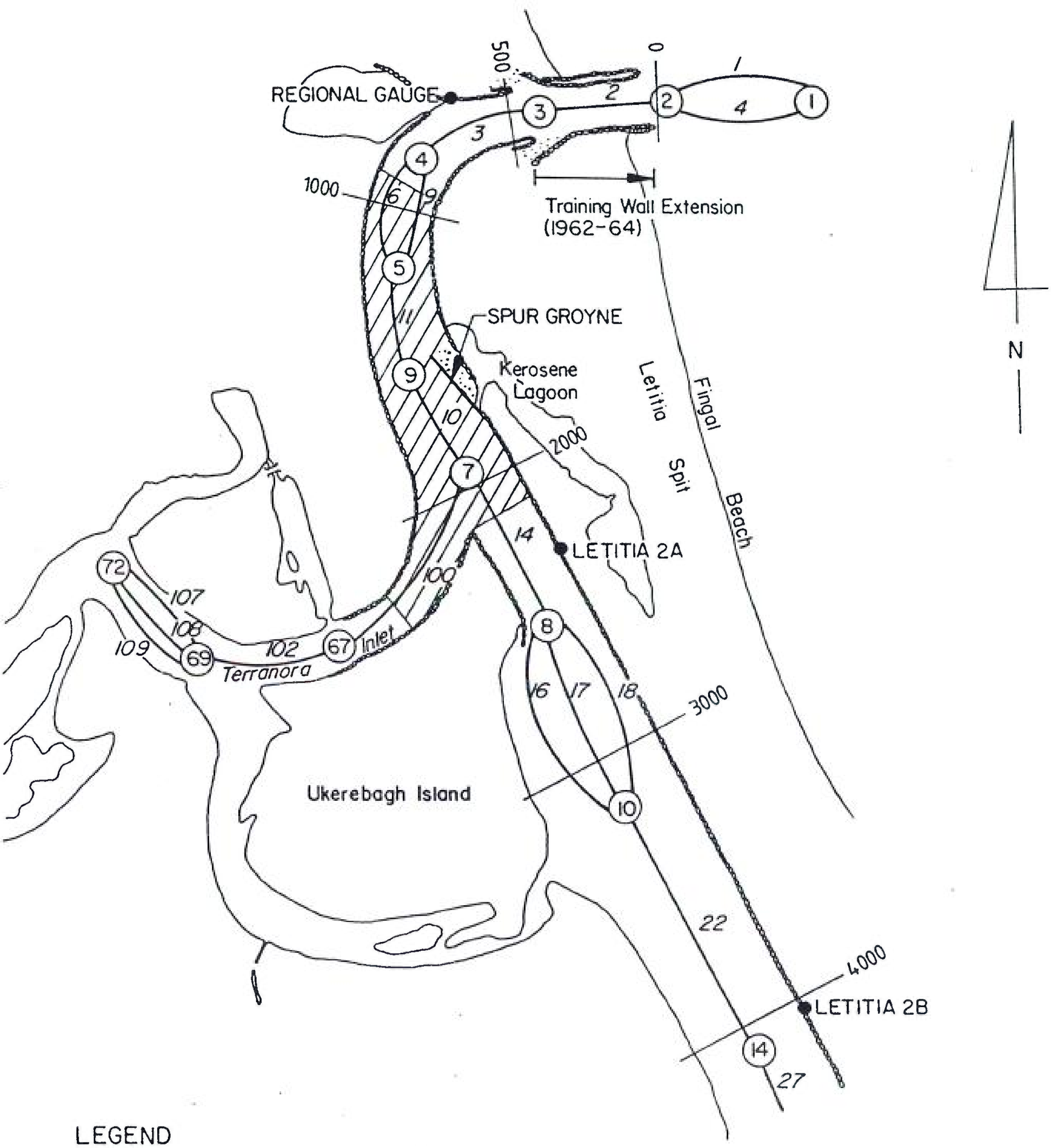
The original Tweed River entrance training walls were extended by about 400 metres over the period 1962 to 1964 (Figure 3.8). The entrance water width between the walls was maintained at about 160 metres, about 50 metres less than the typical river width immediately upstream.

The new trained entrance extended initially to the outer face of the entrance bar. A large portion of the longshore transport of sand along Fingal Beach was intercepted by the southern breakwater or diverted to deposition areas in the nearshore deeper water. The former strong wave-dominated inflow of sand into the entrance was greatly reduced. Tide and flood currents in the river were then able to modify the shape and behaviour of the sand shoals within the entrance under the changed regime conditions. This is illustrated in Figure 3.9.

The aerial photography record indicates substantial changes in the sand shoals as far upstream as the spur groyne by 1965. These changes appear to have involved:-

- an initial rapid upstream migration of the sand on the shallow southern side of the river

- a period of redistribution of the sand across the river width in the area between the spur groyne and the Regional Gauge



LEGEND

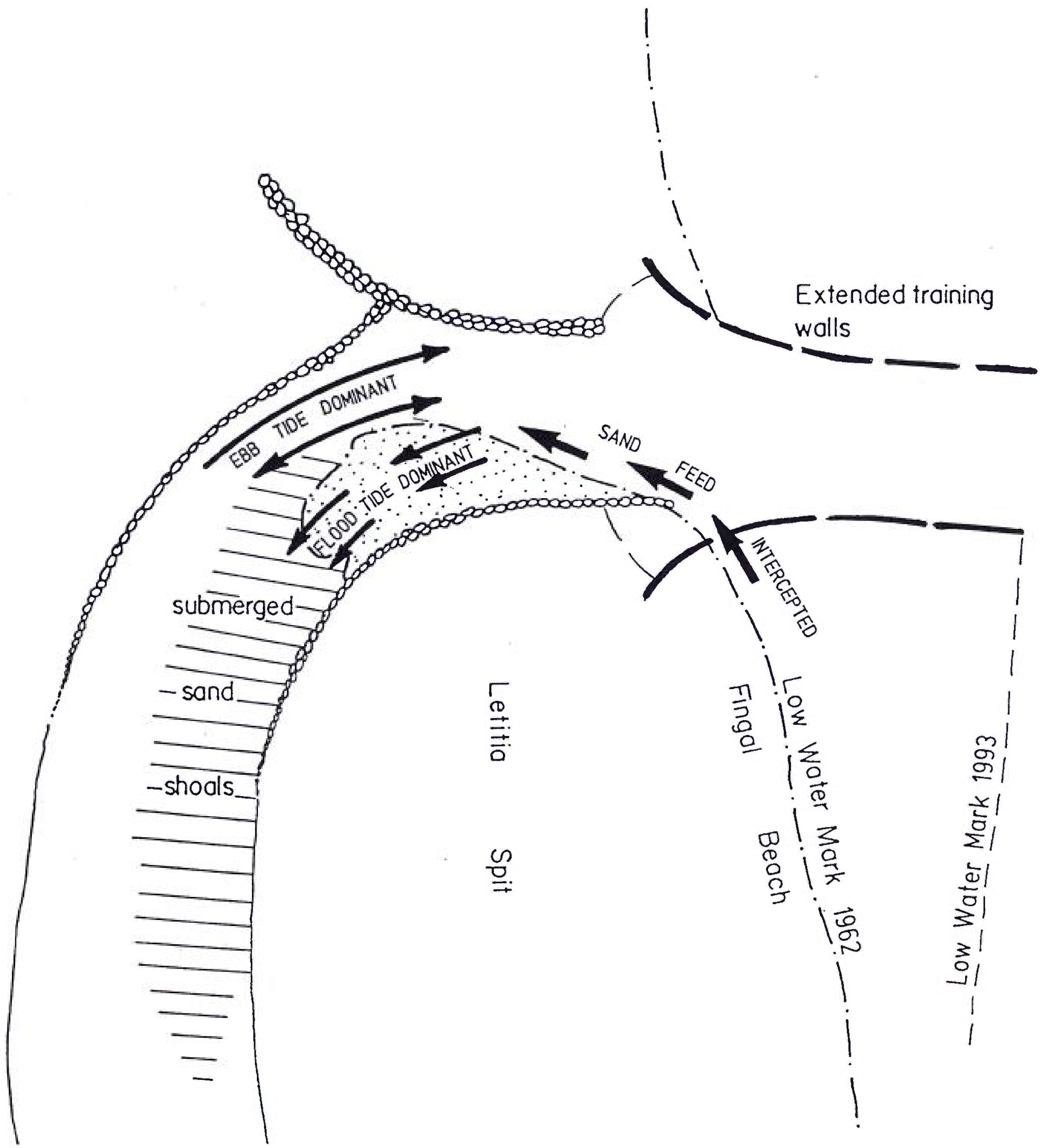
DREDGED AREA 1974/75

RIVER REVETMENT

TIDE LEVEL RECORDERS

TWEED RIVER LOWER ESTUARY
CONFIGURATION OF ENTRANCE AREA

FIGURE 3.8



SAND INFEED TO TWEED RIVER
MODIFICATION BY TRAINING WALL EXTENSION

FIGURE
3.9

- a strong outflow of sand particularly on the outer (northern) side of the river during floods, leading to a net loss of sand from this region of the river

The outflow of sand from this downstream section of the river would have been significant during the floods in 1967 associated with extensive cyclonic activity during that year. For the first time, because of the existence of the southern training wall, the scouring action of the flood flow would not have been counter-balanced by a strong wave-induced inflow from the beach system.

A significant net inflow of sand through the entrance under the combined influences of waves and currents is believed to have been induced by dredging of the lower parts of the river. This is demonstrated by the measured progressive siltation of the Lower Estuary following the extensive dredging in 1974/75 which can not be attributed to fluvial sediment supply alone. However, it is considered that conditions in the area downstream of the spur groyne, in terms of the dynamic equilibrium quantity of sand there may have been permanently altered by extension of the training walls.

As well, there has been a progressive and continuing growth of the entrance bar (Tomlinson and Foster 1986). This has had a significant influence on tide and flood flow in the Tweed River system. The evidence suggests that the bar is continuing to grow, with a seaward and northward extension of the sand deposition there. This is expected to continue at a progressively decreasing rate until a new condition in equilibrium with the longshore and onshore/offshore transport of sand is achieved.

3.4.3 Estuary Dredging

About 1.58 million cubic metres of sand were dredged from the lower estuary over the period 1966 to October 1975. Most recent of this included 235,000m^3 from Terranora Inlet for reclamation of several adjacent developments which took place during 1973-1976, and 765,000m^3 from the main river and part of Terranora Inlet during 1974/75 for nourishment of Kirra Beach, Gold Coast. The area from which the sand was removed is shown in Figure 3.8. The typical dredging depth was 6 to 8 metres below AHD, while depths in excess of 10 metres were dredged within Terranora Inlet.

The trend towards establishment of the new regime conditions following training wall construction was disrupted by the dredging. A new process of change in the sedimentation patterns along the river system began. The dredged area began to progressively infill once again with sand from both upstream and downstream. The supply from upstream was associated with flood and tidal flows, while most of the sand entered through the river entrance from the beach system.

3.4.4 Estuary Changes Since 1975

Separate studies have been undertaken of the rate and distribution of infilling of the lower estuary after 1975. These include the Tweed River Dynamics Study (PWD 1979), which includes information up to 1977, and the study of Tomlinson and Foster (1986) which dealt with quantification of changes both within the estuary and on the beach and bar system up to 1983. This latter work has been updated progressively as more survey data has come to hand, the most recent of which was obtained in March/April 1989.

The data of Tomlinson and Foster, as updated to 1989, is presented in Figure 3.10. This shows the progressive increase in the total quantity of sand within the lower estuary since 1975 as derived from survey data. The zero base-line adopted for presentation of the data is the adopted 1975 condition derived by Tomlinson and Foster. WBM Oceanics Australia also carried out an analysis of the 1960 survey information used as a guide to likely equilibrium conditions. This analysis differs somewhat, but is believed to be more representative than earlier estimates. However, the 1960 conditions may not reliably indicate the probable future lower estuary condition if no works are undertaken, since substantial dynamic changes affect the quantity of sand in the estuary at any time and extension of the training walls has affected the sand infeed behaviour near the mouth since that time.

The data presented indicates:

- a steady infill rate over the period 1975 to 1980 of about 80,000 cubic metres per year

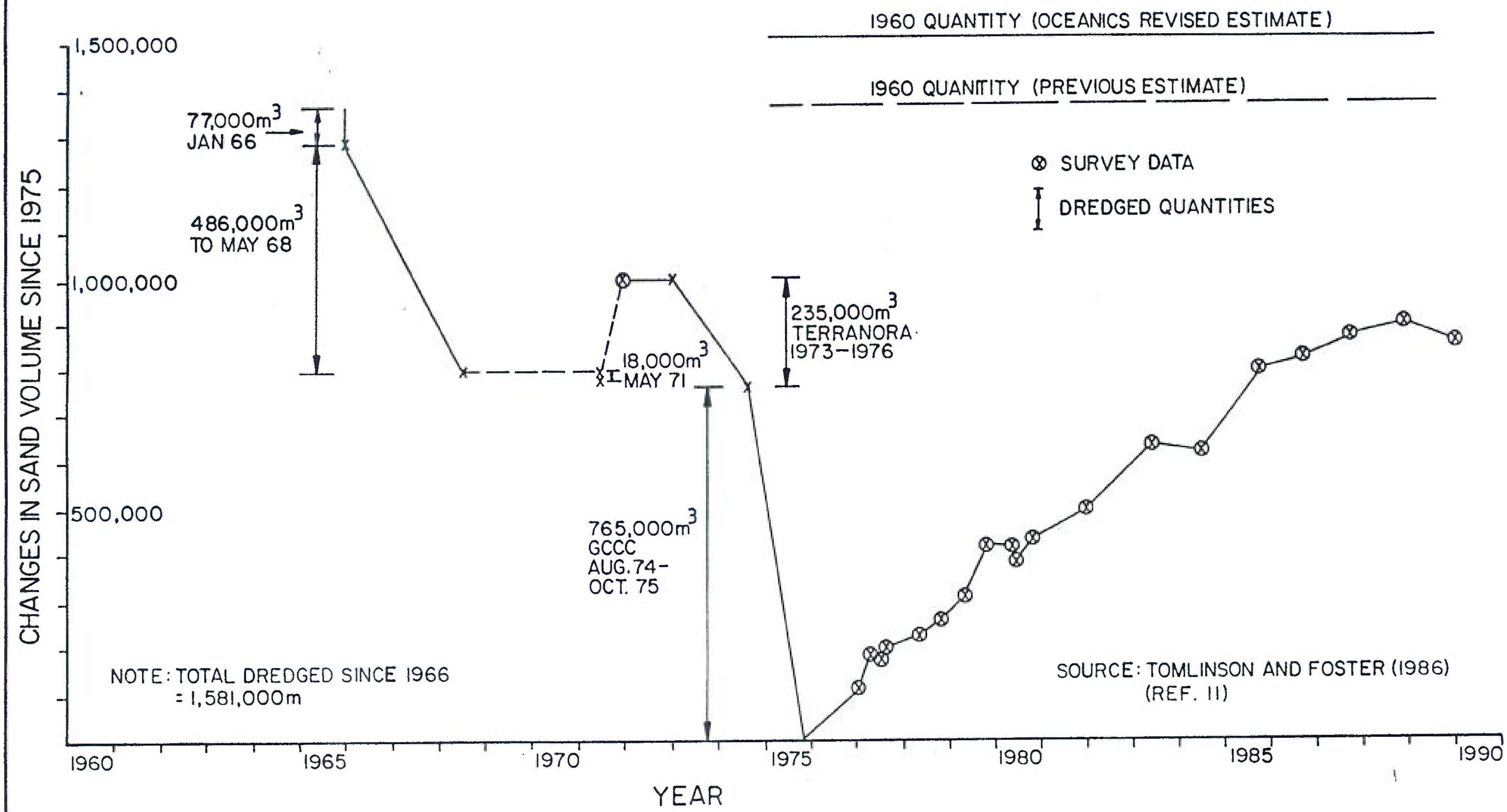
- the infilling rate is gradually decreasing as the estuary approaches its new equilibrium

- as the estuary infills, the effect of major floods in causing a short term net loss of sand from the lower estuary to the beach system is becoming more significant closer to the mouth

- a reasonable trend of infilling can be determined, from which extrapolation of likely future behaviour can be derived.

In addition to the overall total quantity of change, the distribution of erosion/accretion along the river has been determined as shown in Figure 3.11. This is presented in terms of the channel cross-section area below AHD versus distance upstream for various dates since 1978. Key features of this figure are:

- there has been a progressive infilling of the estuary as far upstream as about 2500 metres from the river mouth



SURVEYED SAND INFEED TO LOWER ESTUARY
(TOMLINSON AND FOSTER 1986)

FIGURE 3.10

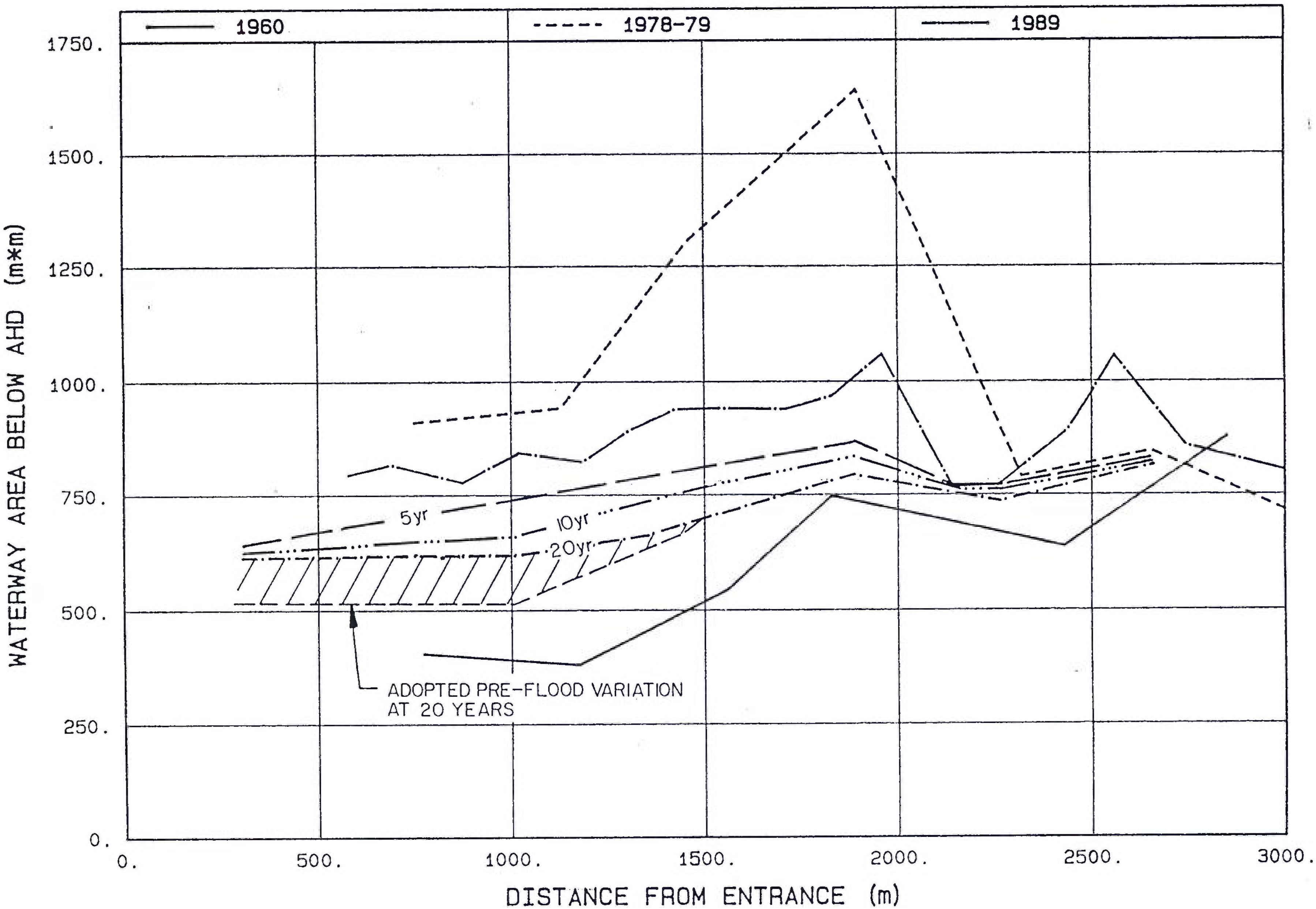


FIGURE 3.11

SURVEYED AND PROJECTED ESTUARY SILTATION
WATERWAY AREA VERSUS DISTANCE UPSTREAM

- the area of greatest and most rapid infilling is between chainages 1500m and 2000m from the mouth, that is, in the river reach between the spur groyne and Terranora Inlet, tending towards the 1960 situation

- Channel siltation between chainages 500m and 1000m has been relatively slight, suggesting that extension to the training walls may have modified the equilibrium regime in that area

- a localised zone of additional siltation was evident around chainage 1000m in 1986, but removed in 1989 during two relatively major floods

- between 1986 and 1989 there was net erosion of about 60,000m^3 immediately upstream of chainage 2200m and net siltation of about 80,000m^3 in the Terranora Inlet area. This suggests that the major contributing factor to this siltation was flood-related inflow from upstream, in view of the fact that the total sediment transport through that area would have been significantly more during those flood events than the net bed erosion as surveyed

3.4.5 Sand Transport Processes

Surveys have shown a substantial siltation of the lower estuary at and immediately downstream of the Terranora Inlet confluence. This resulted from sand transport associated with:

- net infeed through the entrance from the beach system
- local re-distribution of sediments within the Lower Estuary by tidal flows
- fluvial sediment supply associated with floods

The nature and relative importance of these infill sources have been investigated previously by WBM Oceanics Australia as discussed below.

(a) Sand Infeed Through the Entrance

The available evidence suggests that the dominant contribution to lower estuary siltation is the infeed through the entrance. Sand transport calculations made previously (WBM Oceanics Australia) suggest that there is potential for an upstream net inflow of sand by tidal currents adjacent to the southern river bank in the lower reaches, with a dominant net downstream potential transport:

- on the outer northern side of the river in that region

- in the main river channels close to the entrance, in the vicinity of the spur groyne, and along the Letitia reach of the river.

The aerial photography record shows evidence of a change in the nature of the sand inflow mechanism following extension of the training walls. The training walls appear to have altered the pattern of wave penetration to the entrance, and the associated pattern of beach sand infeed to the lower estuary such that there is no longer a continuous supply of sand from the beach to the Lower Estuary.

It is apparent that complex mechanisms additional to the main channel tidal flows are important in the process of sand infeed. These probably include:

- wave/current interaction within the entrance channel, particularly along the shallower southern side of the river

- some form of 'slug' like inflow past the spur groyne during flood tides such that the sand is not returned in the downstream direction by the ebb tides.

It is not feasible to model these wave, tidal and flooding processes comprehensively to reproduce the measured Lower Estuary siltation. However, it is apparent that the net rate of beach sand movement into the river depends largely on the tidal hydraulics together with minor wave action, and the degree to which the Lower Estuary approaches its dynamic equilibrium configuration. The infeed rate is presently decreasing as the equilibrium state is approached.

(b) **Flood-Related Sand Transport from Upstream**

Previous studies have shown that flood-related downstream sediment transport in the river is significant compared with tide-induced transport and the surveyed changes which have taken place since 1975. It indicated that transport rates associated with a 5% design flood are of the order of 15,000 cubic metres in the upstream areas, increasing to about 55,000 cubic metres immediately upstream of the Terranora Inlet confluence. The annual average fluvial supply of the river in the lower reaches has been assessed to be about 4,000 - 5,000 cubic metres per year.

The calculated flood transport capacities closer to the entrance are relatively higher, reflecting the additional flow from Terranora Inlet and local effects of previous dredging. The presence of exposed bedrock tends to limit the actual rates of transport below the calculated transport capacity in those areas. Thus model results overestimate the transport rates in the vicinity of the entrance training walls.

(c) **Sand Redistribution Within the Estuary**

There are slow but persistent tide-induced movements of sand within the Lower Estuary area. Previous studies have shown that, following the dredging of the 1970's, there has been a net downstream movement of sand by tidal flows towards the dredged area. This, together with flood-related transport has contributed to the surveyed infilling of the downstream reaches in the vicinity of the Terranora Inlet confluence.

The studies have also shown that, as the Lower Estuary becomes more congested with sand, the trend of downstream net tide-related transport reduces and may reverse.

As well, dredging in the more upstream reaches of the river may also tend to alter the pattern of net tidal sand transport to one of general upstream movement. This potentially is a mechanism for increasing the loss of sand from the beach system when the Area 5 sand extraction is undertaken, and is discussed in detail in Chapter 4.3.

3.4.6 Present Estuary Sedimentation Trends

The dredged lower estuary is continuing to infill with sand due to flood, tide and other influences. Figure 3.12 illustrates the trend line as derived for the available data and extrapolated into the future for the purposes of this study. This trend line indicates an average recent net infilling rate of about 40 000 m^3 per year. Of this, less than 5000 m^3 per year would be derived as the net deposition from flood-related supply.

It is recognised that occurrences of major floods and prolonged periods with only minor flooding will result in significant fluctuations in the mean trend of infilling of the lower estuary. Surveys and calculations show that major floods could temporarily scour in excess of 200 000 m^3 from the area covered by the surveys, moving the sand to the entrance bar and beach area. This sand would tend to be restored to the estuary by subsequent infilling from the beach system at a rate greater than the long term mean, until flooding again occurred in the river. Figure 3.12 illustrates the approximate range of fluctuation about the project mean infilling rate which might be expected.

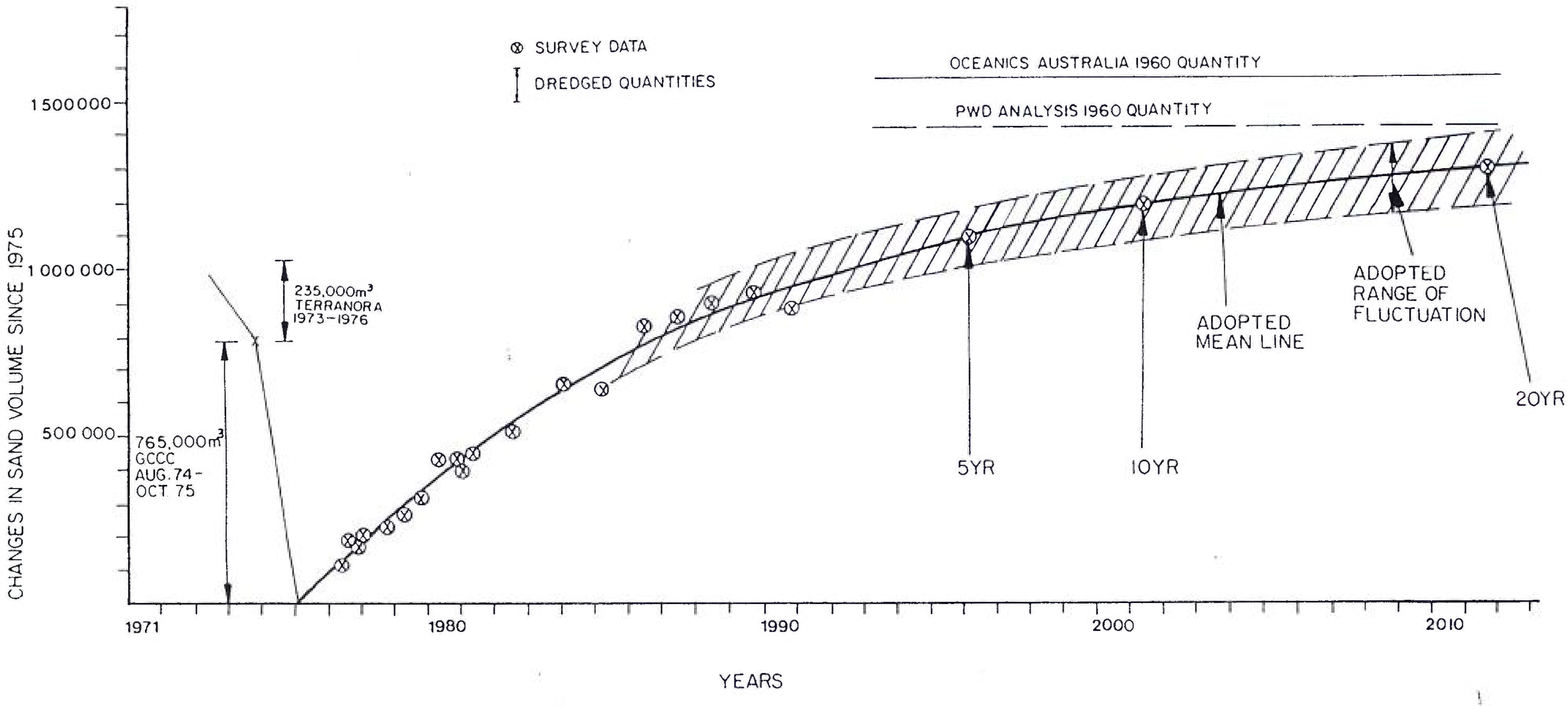
The previous entrance development feasibility study (Oceanics Australia 1989c) utilised the projected future trend of Lower Estuary siltation together with historical surveyed channel shapes to determine -

- the likely future total quantity of beach sand siltation in the estuary
- the probable distribution of the siltation along the Lower Estuary reaches
- the expected cross-section configuration of the siltation in each area

While these projections are somewhat subjective, they are considered reasonable, being based on the best available data and the following criteria:

FIGURE 3.12

LOWER ESTUARY SILTATION
PROJECTION OF FUTURE TREND



(i) The surveyed 1960 configuration can be used as a reasonable guide to the equilibrium condition for which no further net infeed would occur, allowing for apparent changes caused by the training walls constructed after that time.

(ii) The rate of net infilling of the Lower Estuary is a function primarily on the difference from the equilibrium regime condition at any time.

Consistent with these changes, the entrance and bar region is also continuing to accumulate sand and, in the absence of improvement works, will trend towards a dynamic equilibrium. This is expected to involve expansion in size outwards from the training walls rather than any significant further reduction in depth of the bar or channel.

3.5 WATER QUALITY OF THE LOWER TWEED ESTUARY

3.5.1 General Considerations

Water quality in an estuary such as the lower Tweed River reflects a combination of various influences including the following:

- Freshwater inflow.
- Tidal levels and flows.
- Discharges, both point and diffuse source.
- Atmospheric phenomena (e.g. winds, temperature, etc).

In this section the ambient water quality for Area 5 is described. Both current and historic data is presented.

3.5.2 Previous Investigations

A number of previous water quality investigations by a range of authorities have been completed. These are summarised below with relevant results being presented as required.

Department of Agriculture

The Division of Fisheries in the Department of Agriculture (the then NSW State Fisheries) conducted certain limited water quality surveys in 1978 - 79. These data were oriented towards fish resources (EPA 1987), and are of limited value for this study.

Environment Protection Authority

The NSW EPA conducted an investigation into the water quality of the lower Tweed River, and Cobaki/Terranora Broadwater system in October/November 1983 and January 1984 (EPA 1987). This investigation also included a study of the dispersion and movement of effluents discharged to these waterways from the Banora Point and Tweed Heads sewage treatment plants, and resulted in the recommendation, and subsequent adoption of modified effluent disposal strategies from these two sewage plants. This modification in discharge pattern, required to improve the flushing of effluent from the estuary, was quite significant (EPA 1987). For this reason, results in the monitoring data collected in 1983/84, particularly that from the Terranora Inlet system, may be of limited relevance to the present situation in the lower estuary.

Tweed Council

Since mid-1989, Tweed Council have undertaken periodic (approximately every eight weeks) surveys of water quality parameters in the Lower Tweed River and Terranora Inlet/Broadwater system. This monitoring programme is continuing.

NSW Public Works

As part of the Lower and Upper Estuary RMP studies, NSW Public Works commissioned WBM Oceanics Australia to carry out water quality surveys. These were undertaken at or as near as practicable to high water. This data is presented here in Figures 3.13(a) - (f), to supplement that of the EPA for 1983/84.

3.5.3. Compilation of Data

Those NSW Public Works, EPA and EPA-Tweed Council water quality gauging sites of relevance adjacent to and within the Area 5 section of the estuary are shown in Table 3.3.

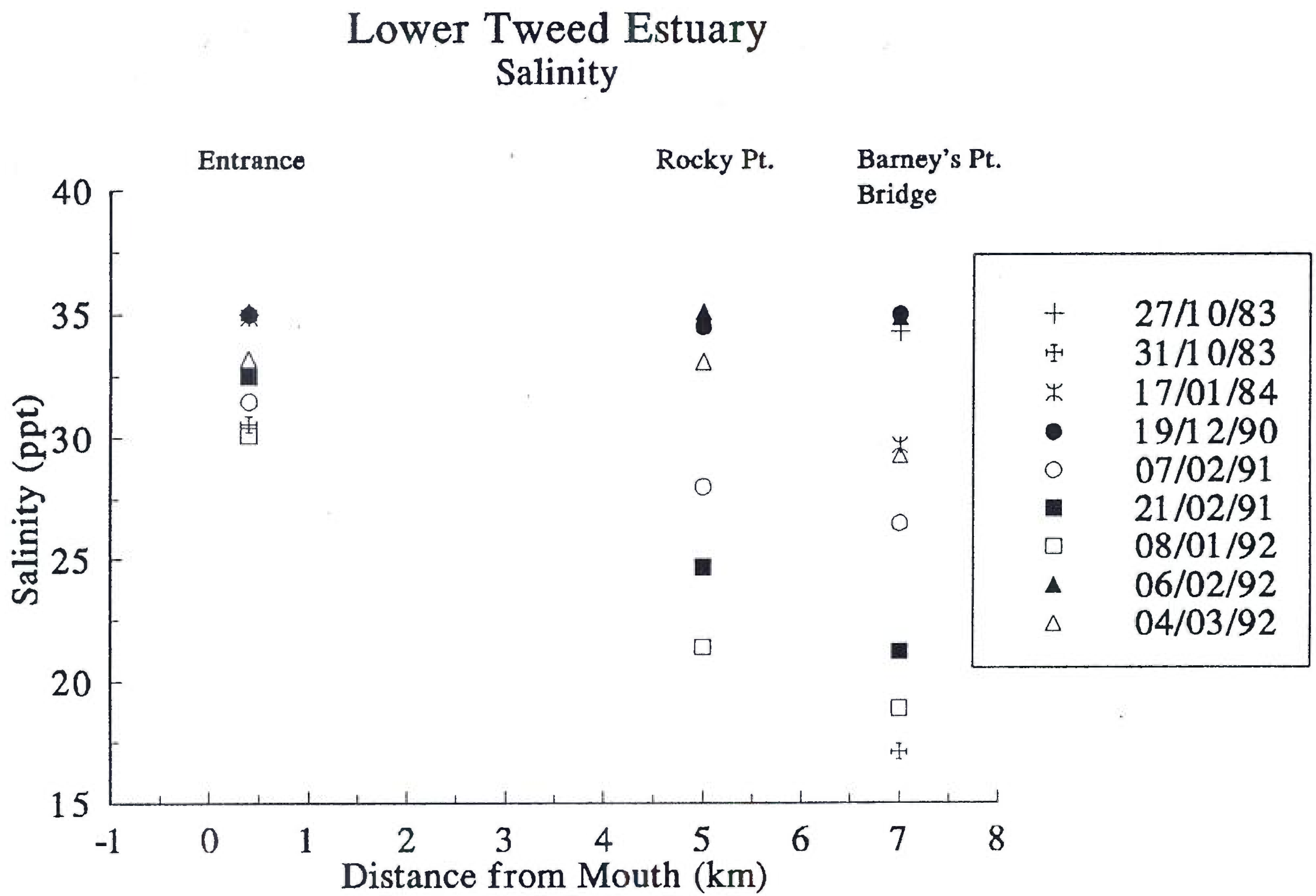
TABLE 3.3
WATER QUALITY GAUGING SITES, AREA 5

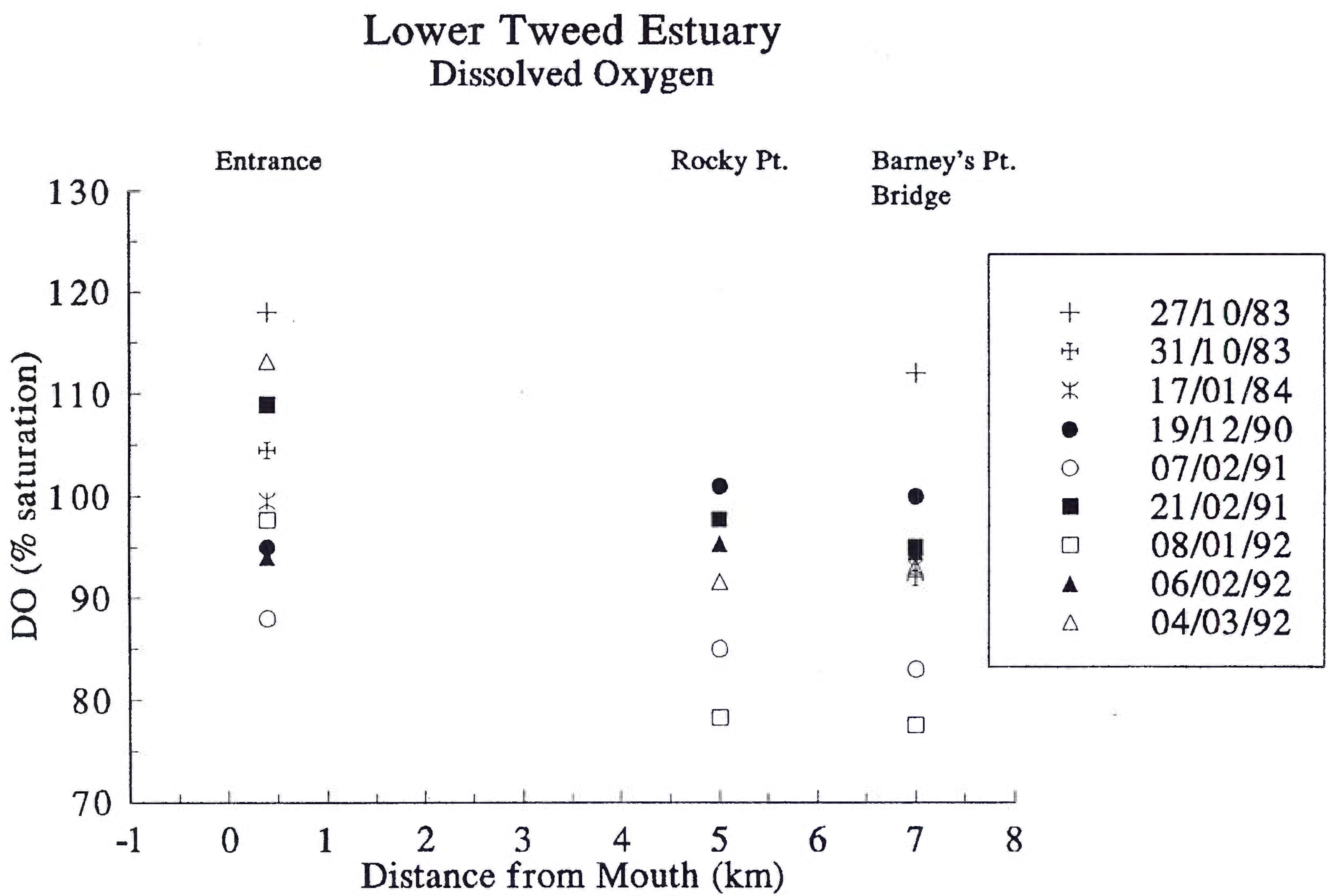
distance from mouth (km)	DESCRIPTION
0.5	Entrance (EPA, NSW Public Works)
5.0	Rocky Point (NSW Public Works)
7.0	Barneys Point Bridge (EPA, NSW Public Works)

AREA 5 WATER QUALITY SALINITY

FIGURE 3.13(a)

NOTE: The data for dates 1990 onward relate to samples at or near high water (PWD data). Tide Conditions during the earlier sampling are not known and that data may not be directly comparable.

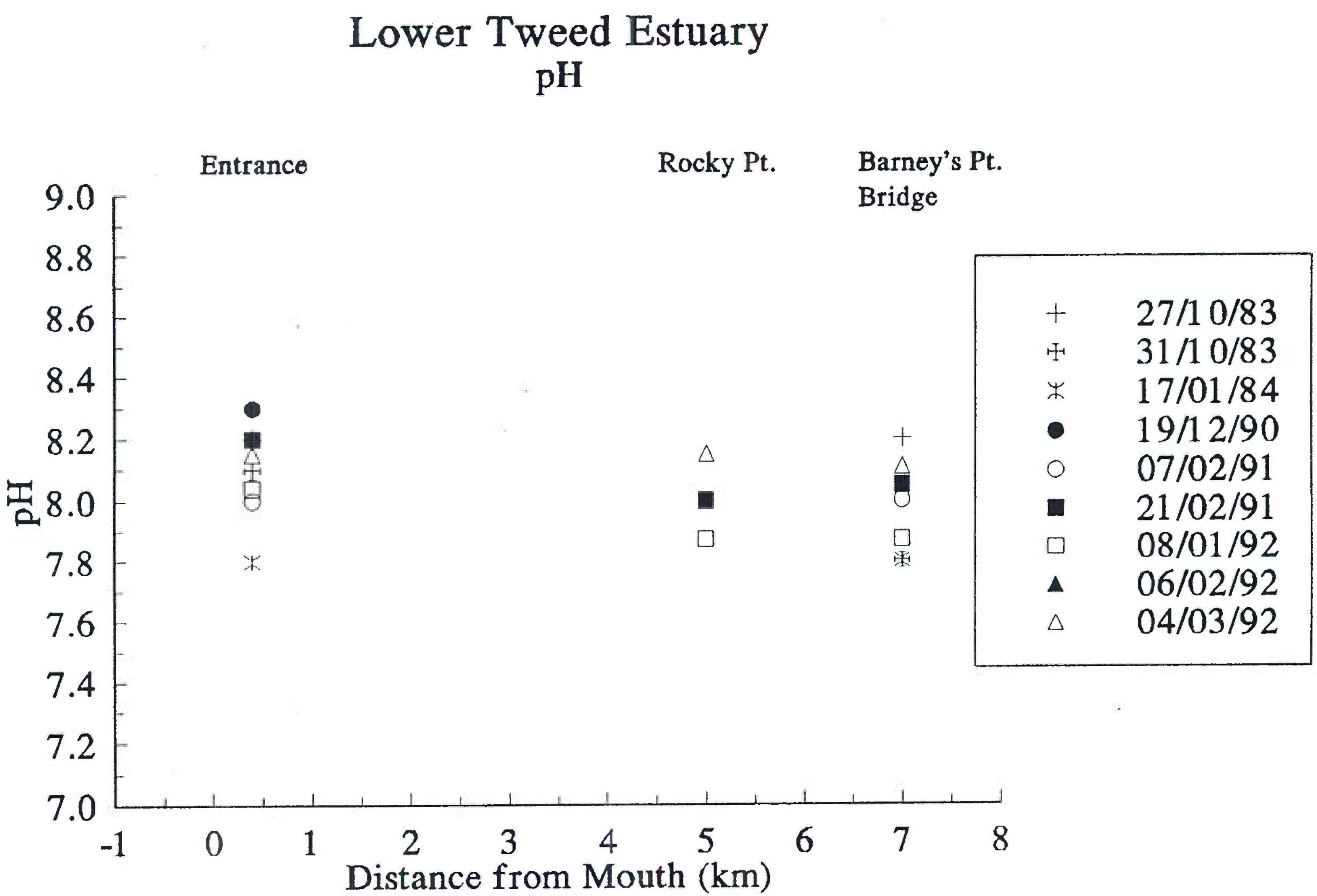




NOTE: The data for dates 1990 onward relate to samples at or near high water (PWD data). Tide Conditions during the earlier sampling are not known and that data may not be directly comparable.

AREA 5 WATER QUALITY DISSOLVED OXYGEN

FIGURE 3.13(b)



NOTE: The data for dates 1990 onward relate to samples at or near high water (PWD data). Tide Conditions during the earlier sampling are not known and that data may not be directly comparable.

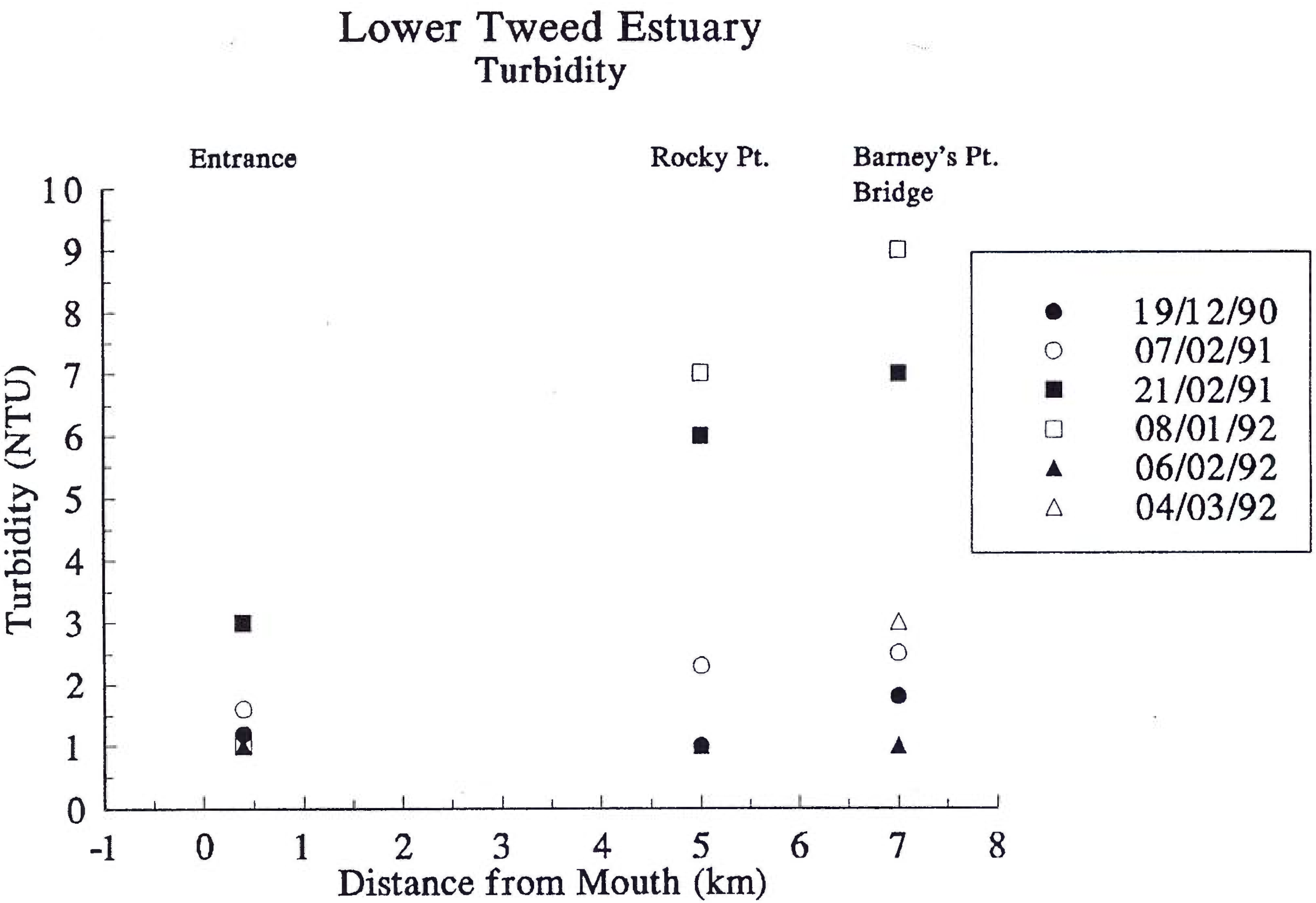
AREA 5 WATER QUALITY pH

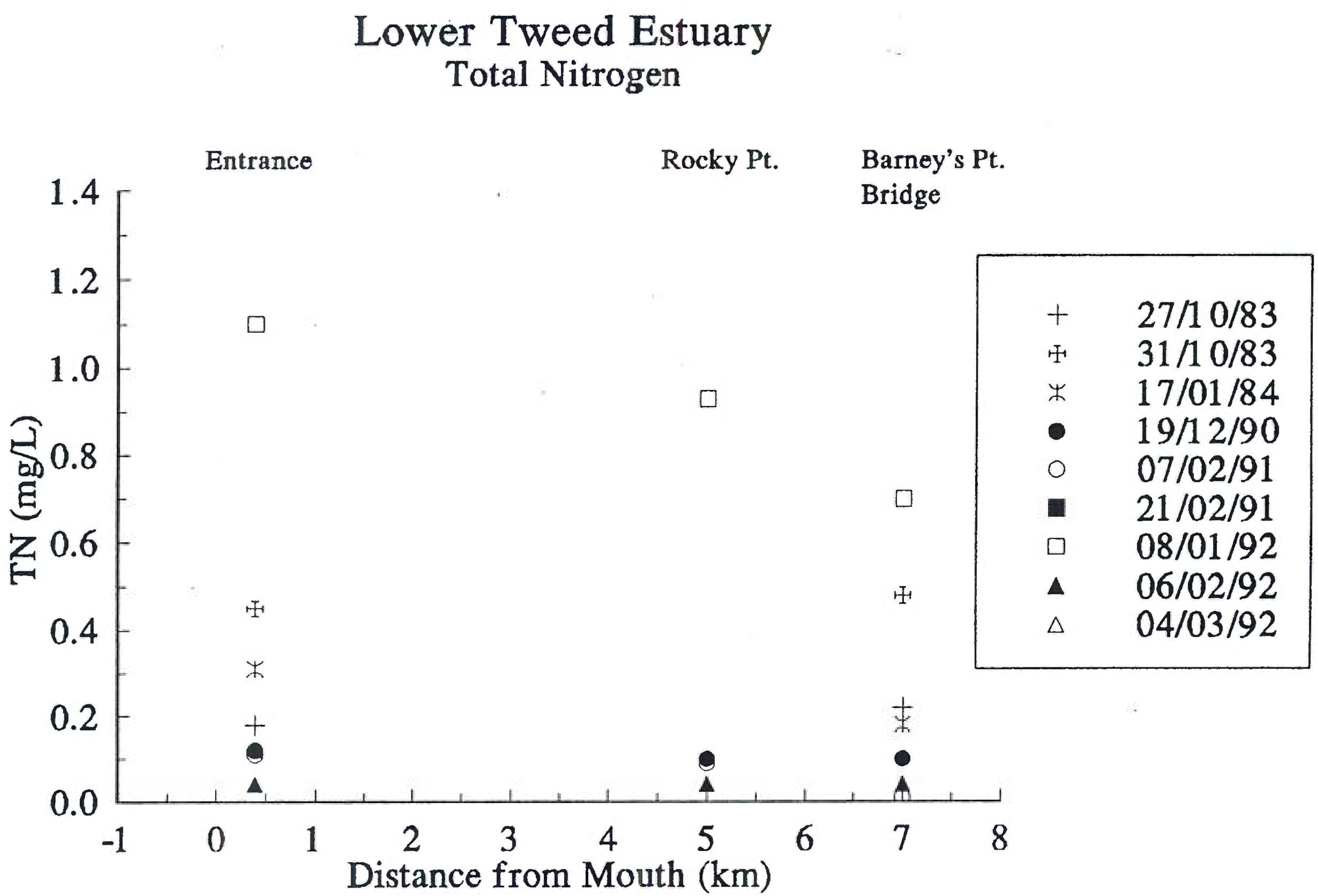
FIGURE 3.13(c)

AREA 5 WATER QUALITY TURBIDITY

FIGURE 3.13(d)

NOTE: The data for dates 1990 onward relate to samples at or near high water (PWD data). Tide Conditions during the earlier sampling are not known and that data may not be directly comparable.





NOTE: The data for dates 1990 onward relate to samples at or near high water (PWD data). Tide Conditions during the earlier sampling are not known and that data may not be directly comparable.

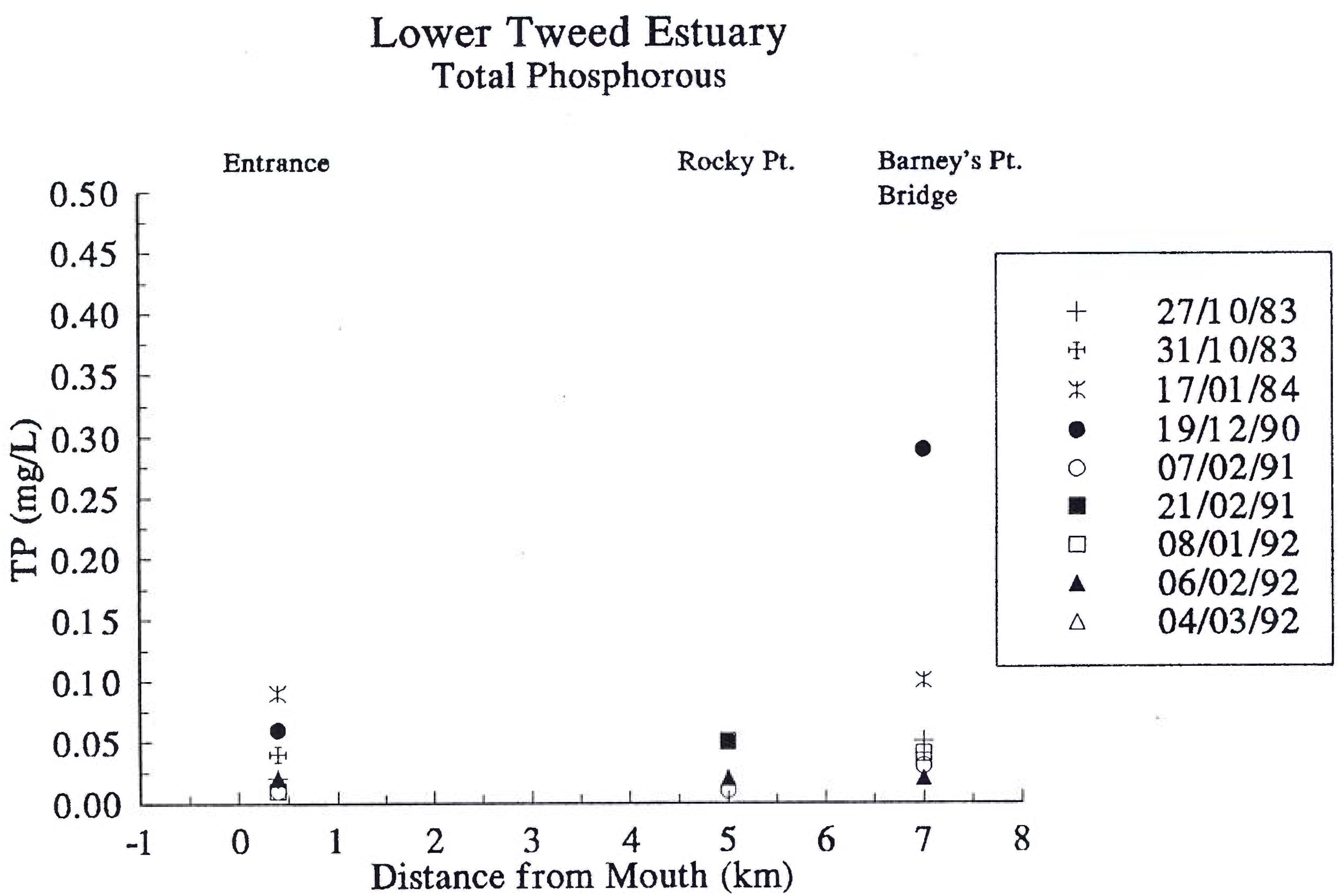
AREA 5 WATER QUALITY TOTAL NITROGEN

FIGURE 3.13(e)

FIGURE 3.13(f)

AREA 5 WATER QUALITY TOTAL PHOSPHOROUS

NOTE: The data for dates 1990 onward relate to samples at or near high water (PWD data). Tide Conditions during the earlier sampling are not known and that data may not be directly comparable.



Results of field and laboratory analyses for each of these sites are included in Appendix 15. The data is presented in graphical format in Figures 3.13(a) - (f). Additional in-situ data was obtained during benthic sampling and is presented in Table 3.4 below.

TABLE 3.4
WATER QUALITY DATA RECORDED AT DREDGE AREA 5 DURING BENTHIC SAMPLING SURVEY (DECEMBER 1991)

PARAMETERS	SURFACE	BOTTOM
Temperature (°C)	24.4	24.5
Salinity (ppt)	31.8	31.8
Ph	7.93	7.92
Conductivity	4860	4860
Turbidity (NTU)	10	5
DO (mg/l)	7.61	7.72

3.5.4 Discussion of Water Quality Trends

Inspection of those data presented in Figures 3.13(a) - (f) indicates that lower estuary water quality (downstream of Boyds Bay and Barneys Point Bridges) is very good, with occasional events of exceptional water clarity, high dissolved oxygen and low nutrient levels, typical of oceanic seawater (PWD 1991c).

Some soils in the Tweed Valley floodplain areas are of an acid-sulphate nature. There have been events in the past of significant discharges of acidic stormwaters to the river which may have affected all or part of Area 5. However, being relatively close to the mouth with rapid saline recovery potential, Area 5 would tend to be less affected and recover more quickly than sections of the river further upstream.

3.5.5 Mathematical Modelling

The MIT-Dynamic Network Model (Harleman *et al.* 1977) was adopted for the evaluation of tidal flushing and saline intrusion phenomena in the upper estuary of the Tweed River. This model was utilised for similar analyses in earlier lower estuary studies, with the version of model used in this study being improved in both detail and model validation throughout the upper estuary region of interest.

The model (Appendix 16) is a coupled hydraulic/water quality algorithm and was calibrated and verified to hydraulic data collected throughout the entire Tweed estuary between 13/1/92 and 17/1/92.

The hydraulic component of the model was recalibrated to a similar data set to that utilised for recalibration of the ESTRY tide model of the Tweed River. Model simulation of recorded water levels and flowrates is considered acceptable, and is illustrated in Appendix 17.

The water quality/salinity component of the model was verified in earlier estuary studies to salinity data recorded by the NSW Public Works at various locations in the river for a 4 day period following a 2 year recurrence interval flood in April 1989 (Appendix 17).

3.6 CONTAMINATION POTENTIAL OF MATERIAL TO BE EXTRACTED

3.6.1 Acid Sulphate Soil Potential

The material to be extracted from Area 5 is predominantly loose sand with some silt. The geological evidence suggests that it is either recent or reworked relict marine sand. The deep cores taken at the bridge crossing by the RTA (upstream end of Area 5) and previous dredging both within the area and immediately downstream near Rocky Point suggest that this type of material extends throughout the zone to be dredged. Being located within the long term location of the main Tweed River channel in an area with relatively high currents, it would have limited potential for deposition of soil/vegetation horizons commonly associated with potential acid sulphate soils. As such, it is not expected that the sands to be dredged would have such potential. No problems have been noted with the sands taken from the area to date.

It is recommended that the spoil be monitored with testing for acid sulphate potential. If, during dredging, a significant acidity potential is identified (in say stockpile areas), then EPA's Draft Guidelines for the Assessment and Management of Coastal Land Developments in Areas of Acid Sulphate Soils will be adopted.

3.6.2 Residue Analyses

Sediment samples were collected from Area 5 and analysed for oil/grease, heavy metals and pesticides, to identify any possible adverse impacts resulting from proposed dredging works (eg. suspension of contaminated sediments). Previous studies by NSW Public Works (1991b) indicated that the lower Tweed estuary is generally uncontaminated with respect to heavy metals, pesticides, oil and grease. The current study results are detailed in Appendix 18 and summarised in Table 3.5.

Investigation threshold values (Table 3.6) have been included for most metals. These values have been provided by ANZEC/NHMRC (1991) and are intended as a guide for terrestrial soils, above which further investigation is recommended. Additionally, Table 3.6 indicates background levels for heavy metals in terrestrial soils. It should be noted that these values are for total metal concentrations rather than bioavailable metal, which may be more appropriate. Chem Unit (1991) suggest a suitable threshold value for mineral oils in sediment to be 1000 ppm. This value was not exceeded in any of the samples tested from Area 5.

All values recorded were within the recommended background range and below the threshold values. No significant concentrations of any contaminant were measured in the samples.

TABLE 3.5
RESULTS OF ANALYSIS FOR OIL AND GREASE, HEAVY METALS AND PESTICIDES - AREA 5
(SEE FIGURE A6.1 FOR SAMPLE LOCATION)

Contaminant		Site							
		1	2	2 (-0.75m)	3	4	5	6	7
Total Oil and Grease mg/kg dry wt.		81	35	120	43	61	16	78	54
Heavy metals mg/kg dry wt.	Cadmium	<0.2	<0.2	<0.2	<0.4	<0.2	<0.3	<0.1	<0.3
	Chromium	6.4	1.1	1.1	13.0	7.3	1.0	2.5	1.7
	Lead	2.6	0.6	0.9	4.6	3.6	0.8	1.2	1.2
	Zinc	57	21	17	83	50	28	18	24
	Mercury	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Pesticides mg/kg wet wt.	Dieldrin	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	DDE	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

TABLE 3.6
BACKGROUND RANGES AND THRESHOLD VALUES FOR HEAVY METALS

Metal ppm	Background Range (Total) ppm	Threshold Values (Total) ppm
Cadmium	0.04-2	3
Chromium	0.5-110	50
Lead	<2-200	300
Zinc	2-180	-
Mercury	0.001-0.1	1

3.7 EXISTING NOISE ENVIRONMENT

3.7.1 Introduction and Methodology

Measurements were carried out in accordance with procedures described in Australian Standard 1055.1 - 1984, Part 1, General Procedures using Bruel & Kjaer Calibrator Type 4230 and RION NA29 Sound Level Analyser instruments.

The sound level analyser was used in its statistical analysis mode to determine the octave band and A-weighted percentile levels L_{10}, L_{90} and L_{eq}. Three measurements of 1500 samples each were made at each location over a period of 10 minutes.

Periodic checks of the microphone were made using the portable calibrator after the initial calibration before commencing measurements.

Monitoring locations

The following monitoring locations were used to provide a representative sample of the existing acoustic amenity in the vicinity of the proposed dredging zone.

Location 1: 2 Fingal Road
Location 2: Barneys Point Caravan Park, Boat Ramp Location
Location 3: 39 Fingal Road
Location 4: Crown Street Reserve Off Fingal Road
Location 5: Fingal Peninsular, Northern Perimeter Location
Location 6: Barneys Point Caravan Park, Mid Park Location
Location 7: 25 Hibiscus Parade, Banora Point
Location 8: Waterfront Park along Terranora Inlet, Keith Compton Drive Tweed Heads
Location 9: 6 Fairway Drive, Banora Point
Location 10: Aboriginal Cemetery, Letitia Road
Location 11: Tweed Heads Golf Course, Waterside Location
Location 12: Kerosene Inlet, Waterside Location

Measurement conditions

Weather conditions for measurements were as follows:

temperature:	20 - 25°C
relative humidity:	50%
wind:	light variable winds, < 18 kms/hour

3.7.2 Existing Continuous Background Noise Levels

Table 3.7 gives a summary of the results of ambient noise monitoring in terms of the statistical descriptors L_{10}, L_{eq}, L_{90} expressed as a dB(A) value. Table 3.8 gives the same locations ranked according to background level in descending order with the associated maximum allowable L_{10} sound pressure level for an introduced noise source according to the EPA criterion. Again all levels are expressed as dB(A) figures. It can be seen from

1 L_{eq} is the level of a steady sound which in a stated location has the same A-weighted sound energy as the measured time varying sound

Tables 3.7 and 3.8 that the location numbers have been chosen to match the relative ranking, out of the 12 monitoring sites, of background noise level at the given location.

Overnight hourly sampling was undertaken at the potential stockpile site location on Fingal Road. These results give an indication of the variation in the ambient noise levels and give values to use in the calculation of the L_{10}, 18 hour value for traffic. Figure 3.14 displays these results in a graph over a 30 hour period.

When assessing the impact of intrusive noise from introduced sources the potential for annoyance is determined from a comparison of the average maximum (L_{10}) level of the intrusive noise with the average minimum (L_{90}) level of the ambient noise. The L_{90} column in Table 3.8 is therefore of the most interest. The other percentile values given in Table 3.7 are for information only, however they are of use as a descriptor of the locations noise character, i.e. whether it fluctuates with time or is relatively steady. The L_{eq} and L_{10} values are useful for comparing intermittent intrusive noise sources such as truck movements with existing traffic noise conditions as has been defined in the section on criteria for traffic noise.

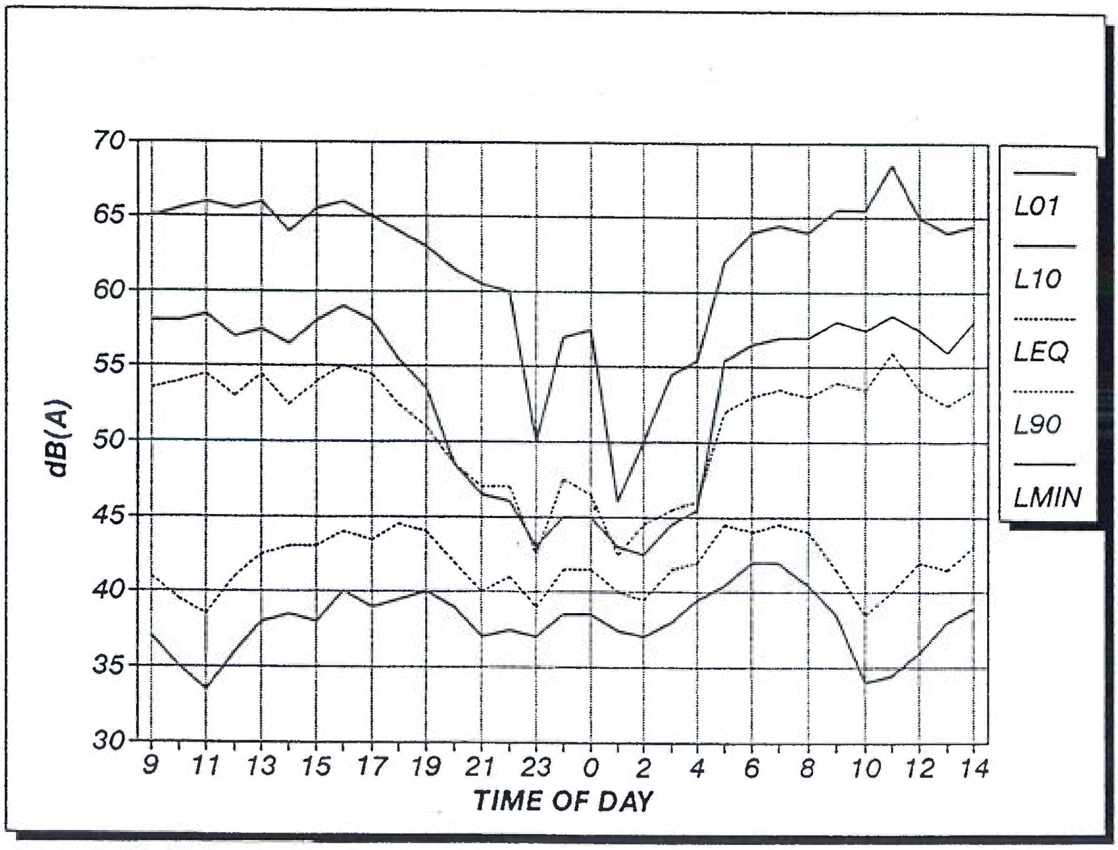
Figure 3.14 shows the variation in ambient noise level with time for 30 consecutive one-hour samples at the northern perimeter of the potential stockpile location in Fingal Road, Fingal Peninsular. The graph shows that the average maximum ambient levels reduce after 5:00pm at night and return to daytime levels at about 5:00am. The L_{10} ambient values at this location were used in the L_{10}, 18 hour calculation of traffic noise. The average minimum levels at this site show an unexpected dip at midmorning (we believe this may be associated with tidal effects).

The ambient noise conditions will vary with the time of day due to variations in the general level of activity and the use of noise producing machinery such as motor vehicles. For this study the dredging and land base activity will only occur during daytime and it is mainly the daytime ambient conditions that are of interest.

The area daytime midweek background noise levels are in the range of 40 - 45 dB(A) with higher levels at decreasing distance from the Pacific Highway traffic noise on Barneys Point Bridge - up to a background level of 55 dB(A) for the worst affected receivers (see Table 3.8). These levels are consistent with EPA recommended acceptable background noise levels for residences in a rural or residential area of 45 dB(A) during the daytime, with 55 dB(A) being the recommended maximum daytime background noise level for a residential area on a busy road. The EPA criterion column in Table 3.8 gives the maximum acceptable L_{10} level due to the introduced noise at a receiver location and is based on the background level plus 5 dB(A).

TABLE 3.7
AMBIENT dB(A) MEASUREMENTS

LOCATION	TIME	DAY	L10	LEQ	L90	TYPICAL SOURCES
GOLF CLUB	13.3	MON	46	44	42	Birds, wind in trees
			45	44	43	
			46	45	43	
	12	WED	44	43	37	
	13		42	41	37	
	14		43	44	37	
	15	MON	42	43	37	
NO. 25 HIBISCUS DRIVE	10.45	MON	61	56	48	(This sample contained commercial passenger plane noise)
			49	48	45	Distant Pacific Hwy Noise
			49	47	45	Birds
	12.3	TUES	52	51	42	
			46	44	41	
			48	46	42	
	13.35	WED	45	43	39	
NO. 6 FAIRWAY DRIVE	1	TUES	48	46	43	Birds, wind in trees
			44	44	42	
			44	43	41	
	2	MON	46	45	43	
			43	43	40	
			46	46	41	
	13.3	WED	45		41	
CEMETERY	14.45	TUES	51	51	39	Distant Wave Noise
	15.5	MON	59	57	40	Birds
			50	49	41	
			57	53	42	
	15.05	WED	45	43	37	
CROWN STREET PARK	3	MON	59	56	43	Cars on Fingal Road
			60	56	44	Distant Noise of Pacific Highway
			61	57	44	
	10.2	TUES	62	58	51	
			59	55	49	
			59	55	48	
RESIDENCES ADJACENT FINGAL PENINSULAR SITE	3.1	TUES	65	60	46	Cars on Fingal Road
	3.3	MON	60	60	45	
			61	63	44	
			60	57	43	
	3.3	WED	53	51	43	
BRIDGE @ 300 NO2 FINGAL ROAD	9.2	MON	63	62	55	Pacific Hwy Traffic Noise Dominant
			64	61	53	
			66	64	55	
	9.3	TUES	62	61	56	
			66	64	57	
			72	67	56	
BRIDGE @ 1200 NO39 FINGAL ROAD	10	MON	65	65	47	Cars on Fingal Road
			64	66	45	Distant Noise of Pacific Hwy Traffic
			66	67	47	
	19	TUES	65	65	51	
			67	66	50	
			73	69	53	
CARAVAN PARK BOAT RAMP	14.15	WED	60	57	52	Pacific Hwy Traffic Noise Dominant
			52	49	44	
			45	42	39	
			46	46	42	
CARAVAN PARK MID PARK	14	WED	52	49	44	Birds Pacific Hwy
KEROSENE INLET	14.45	WED	45	42	39	Unidentifiable Noise from Distant Sources Birds
TERRANORA INLET	16.3	WED	46	46	42	Boating Activity Cars on Drive



AMBIENT NOISE SAMPLING ON FINGAL ROAD

FIGURE 3.14

TABLE 3.8
DAYTIME BACKGROUND dB(A) RANK

LOCATION	L90	EPA CRITERION
1. NO2 FINGAL RD.	55	60
2. BOAT RAMP	52	57
3. NO39 FINGAL RD.	49	54
4. CROWN ST.	47	52
5. FINGAL PEN.	44	49
6. MID PARK	44	49
7. HIBISCUS PDE.	43	48
8. TERRANORA INLET	42	47
9. FAIRWAY DR.	42	47
10. CEMETERY	40	45
11. GOLF COURSE	39	44
12. KEROSENE INLET	39	44

The background levels would not be expected to decrease from those measured. Rather they would be expected to increase in some areas due to higher levels of holiday traffic and also due to increased levels of wave action on the beaches.

3.8 TRANSPORT INFRASTRUCTURE AND TRAFFIC

3.8.1 Introduction

This section of the study relating to transport infrastructure and traffic is based upon a report prepared by DJA (1991) for NSW Public Works Department. It has direct relevance to this EIS only with respect to understanding the sources of ambient noise levels at the site and consideration of potential options for transportation of the dredged sand to remote sites.

3.8.2 Traffic Flows

Existing traffic conditions are usually expressed in terms of AADT, annual average daily traffic; or AAWT, annual average weekday traffic whereas operating performance associated with (say) truck haulage of the sand to remote sites is investigated using peak traffic conditions.

Traffic flows are generally observed over a wide range of days and periods of the year. To account for this variation, observed conditions have been normalised to average daily or average weekdays flows. Where observations were made across different years, annual growth rate variations were also considered.

Figure 3.15 shows the AADT over time on the Pacific Highway south of Kirkwood Road. Between 1970 and 1986 the annual growth in traffic was observed to be a little below 7%. For the period 1982 to 1989, the traffic growth slowed to around 2.8% per annum.

Whilst the traffic on the Pacific Highway at Condong was also observed to have experienced a growth rate of around 7% pa, this level is unlikely to apply in local streets such as Fingal Road. The annual growth rate adopted for Fingal Road was 2%.

An analysis based on AAWT flows was adopted on the basis that any potential truck movements to do with the sale of extracted sand were likely to be more relevant to weekday traffic operations than other times. The 1989 AAWT flows are shown in Figure 3.16.

Monthly variation of AAWT obtained from the permanent traffic count station south of Kirkwood Road, as shown in Figure 3.17, was been examined to reveal the seasonal irregularity of the traffic flow in the area. From this data July traffic was found to represent the average month, however the peak monthly variation was shown to be about 5% above average. The Christmas holiday periods constantly sustained these higher flows.

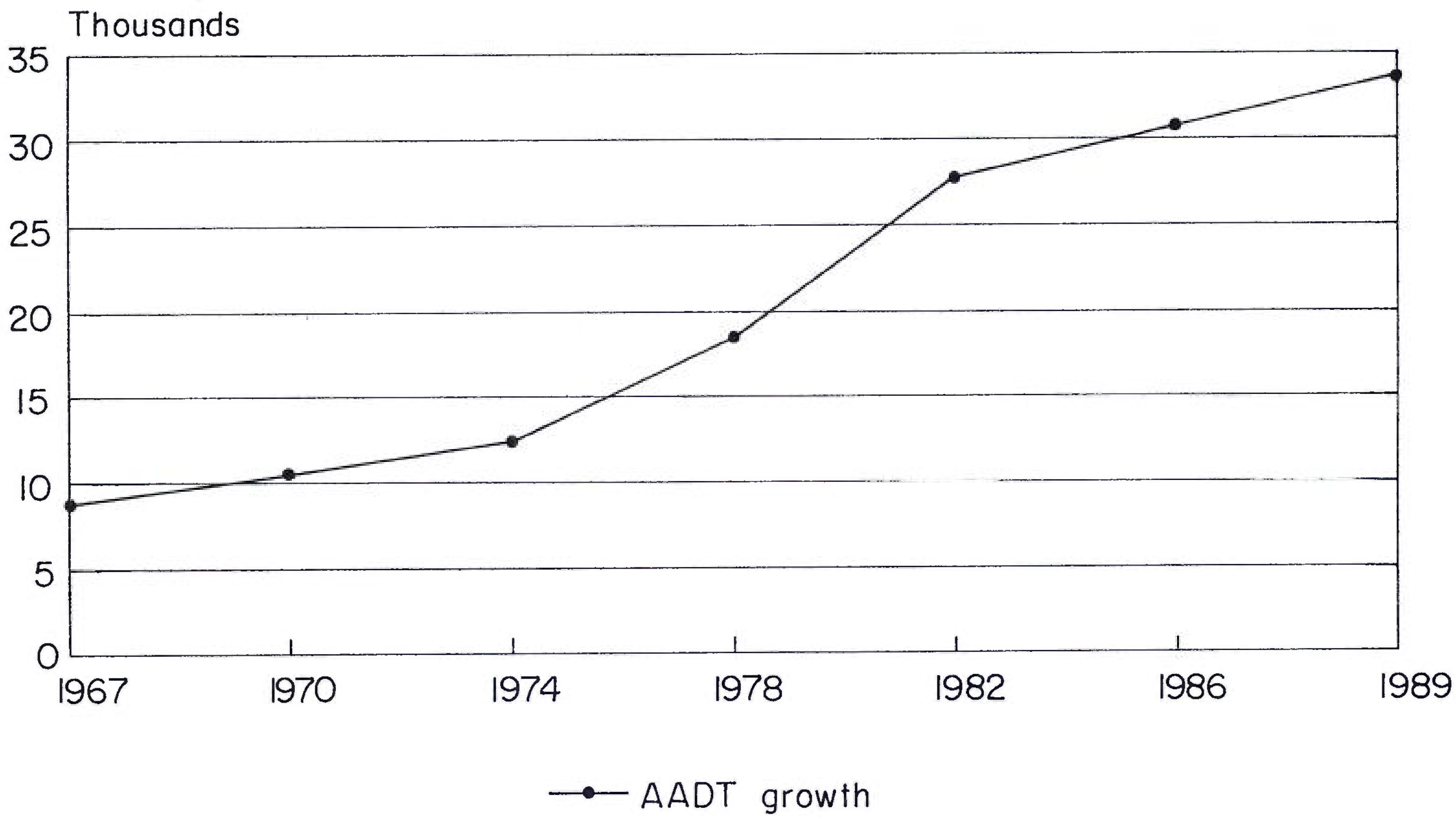
Fingal Road appeared as one of the more lightly trafficked streets in the local area, carrying 2400 vehicles per average weekday. This was 10% of the flow currently crossing Barneys Point Bridge. The traffic flows shown in Figure 3.18 represent the variations in intersection throughput at the Pacific Highway/Fingal Road junction for the periods for which counts were taken and which are compared with Thursday flows on Barneys Point Bridge. Correlation between the time of day variations may be found by comparing these profiles.

3.8.3 Mid-block Level of Service

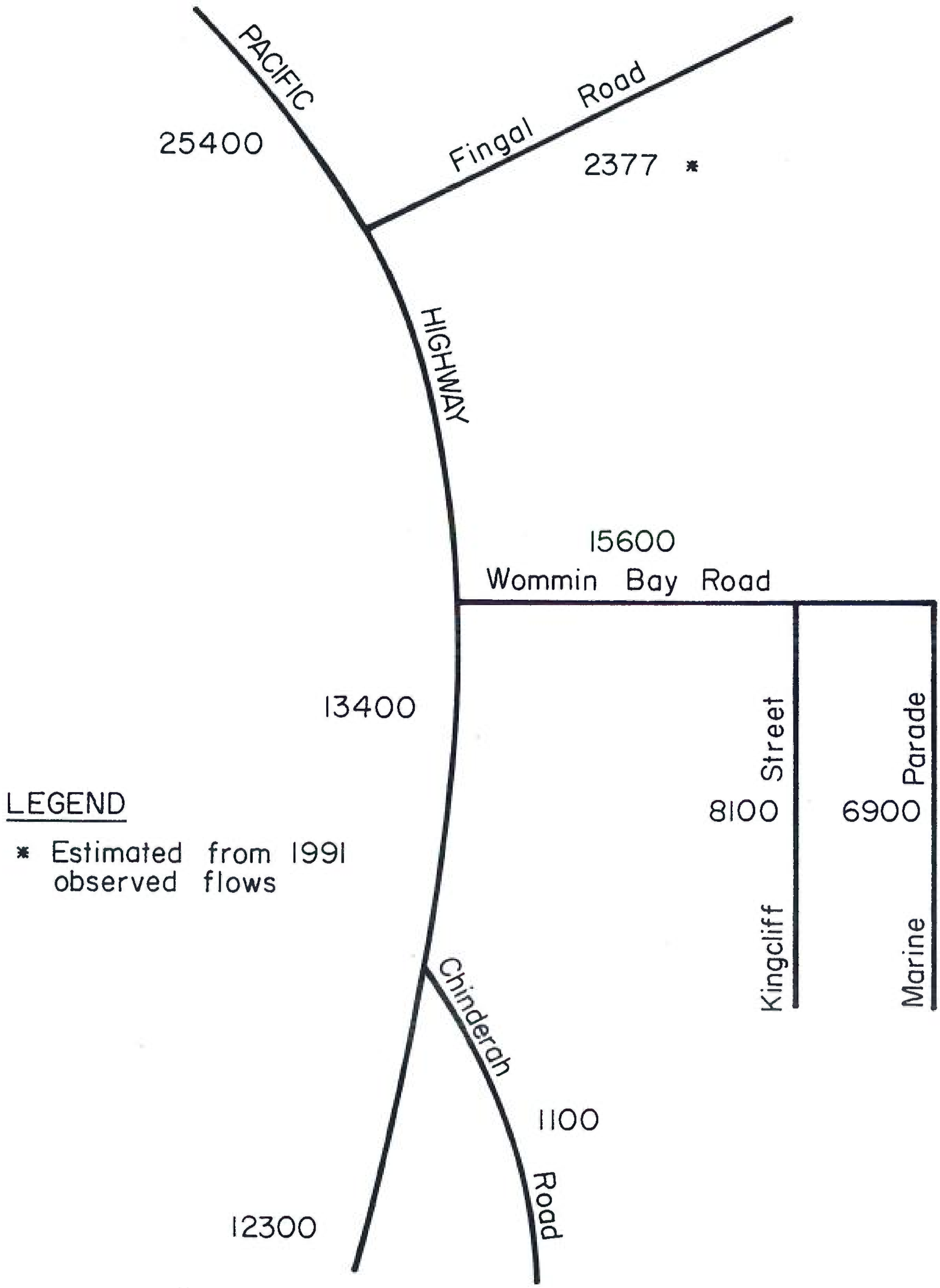
Mid block level of service (LOS) based upon the ratio of volume to practical capacity was adopted as the indicator of existing operating conditions in the local network. These have been summarised in Table 3.9.

FIGURE 3.15

TRAFFIC GROWTH, RTA COUNT SOUTH OF KIRKWOOD ROAD



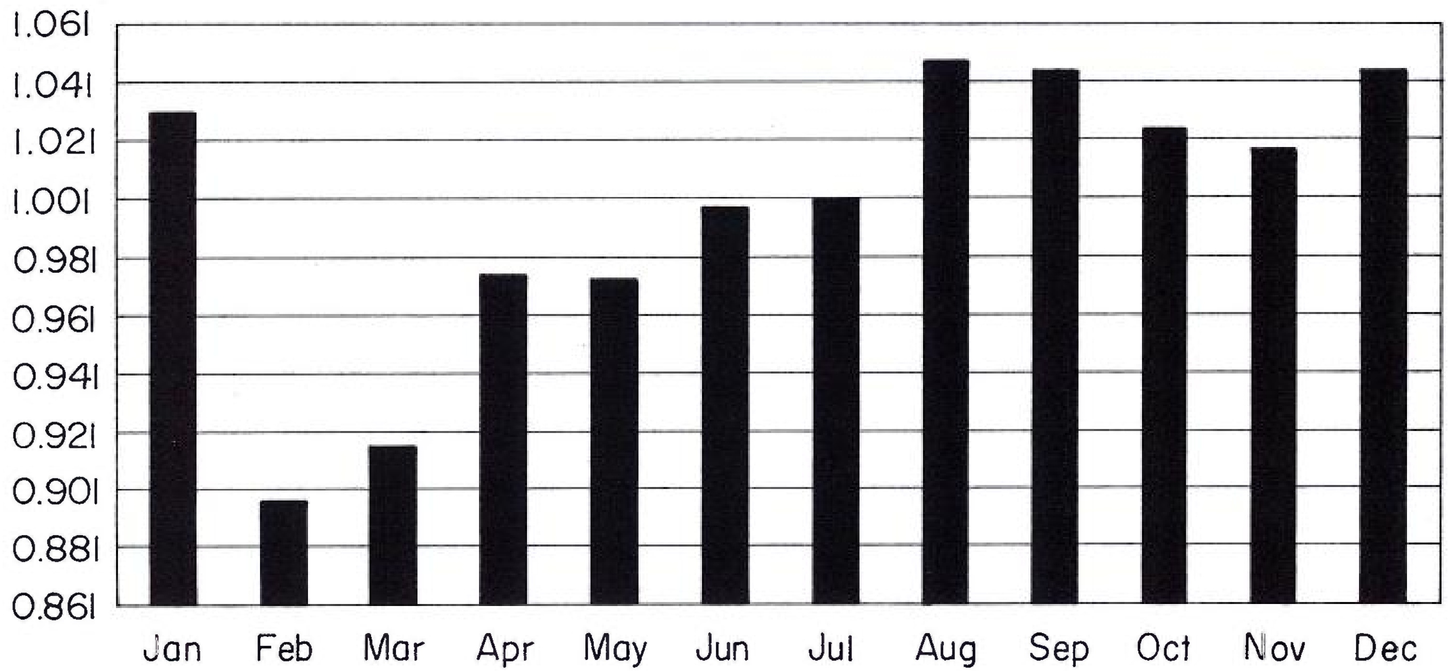
Source: Denis Johnston and Associates (1991)



Source: Denis Johnston and Associates (1991)

1989 AAWT FLOWS

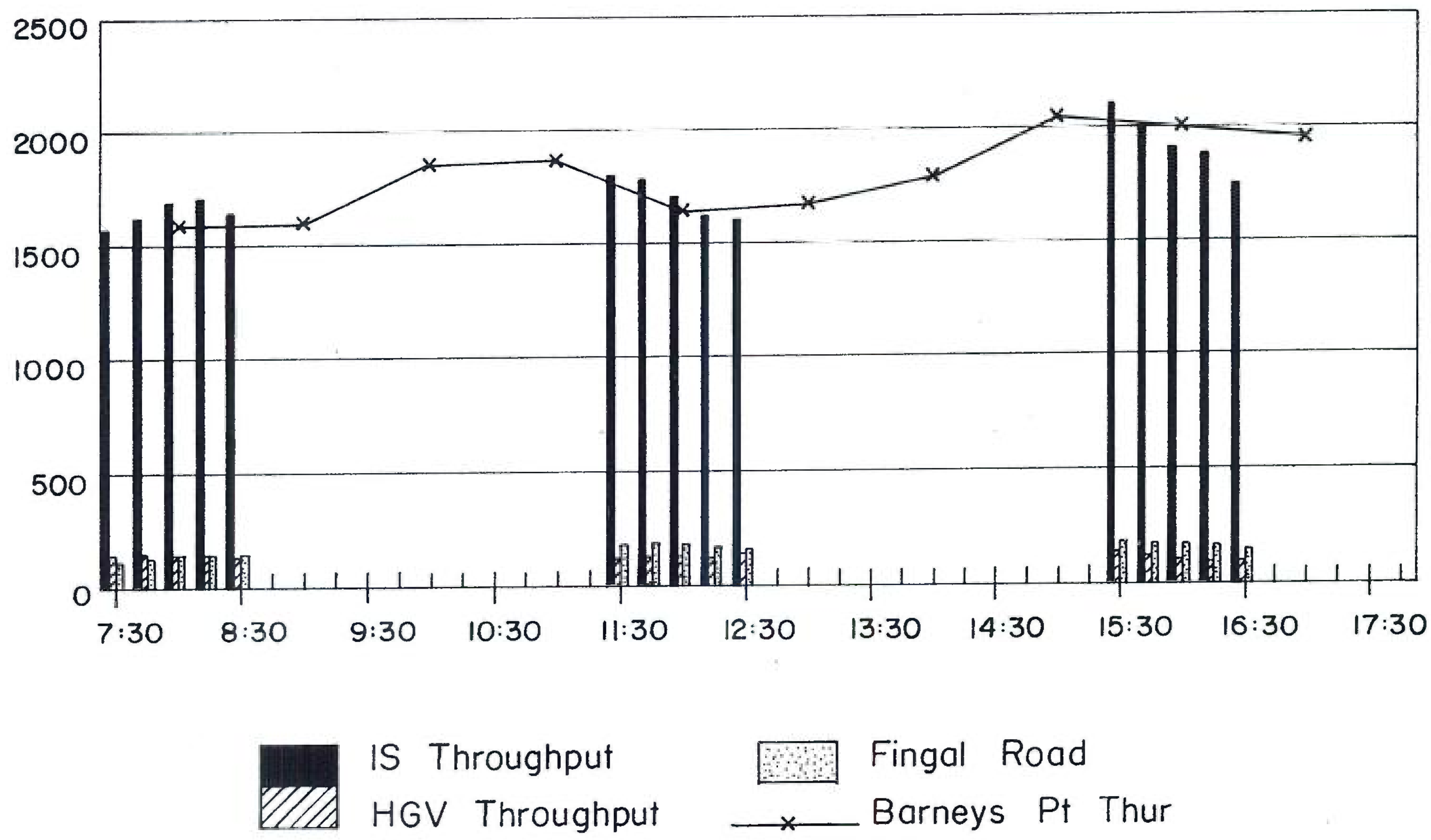
FIGURE 3.16



Source: Denis Johnston and Associates (1991)

TRAFFIC FLOW AS A FACTOR OF AAWT,
MONTHLY VARIATION OF AAWT AT SOUTH
OF KIRKWOOD ROAD

FIGURE
3.17



Source: Denis Johnston and Associates (1991)

FINGAL ROAD TRAFFIC FLOWS,
DJA COUNT JULY 1991

FIGURE 3.18

TABLE 3.9
MID BLOCK LEVEL OF SERVICE

Link	AWT	Practical Capacity vpd	V/C Ratio	LOS
Barneys Point Bridge	25400	20000	1.27	F
Fingal Road	2377	14000	0.17	A
Wommin Bay Road	15600	17000	0.91	E
Chinderah Road	1100	10000	0.11	A
Kingscliff Street	8100	18000	0.45	A
Marine Parade	6900	16000	0.43	A

It can be seen that Fingal Road currently enjoys an amenity approximating to that of a collector road and has a mid-block level of service of A (V/C ratio of 0.17). Wommin Bay Road is a distributor road, and has a mid-block level of service of E on the approach to the Pacific Highway. This implies that its peak period operation is approaching saturation.

The Barneys Point Bridge V/C ratio is theoretically in excess of 1.0 and this suggests that operating conditions are heavily constrained, particularly at peak holiday periods. This undesirable situation is exacerbated by the level of heavy commercial vehicles on the Pacific Highway and the effective bridge width restriction.

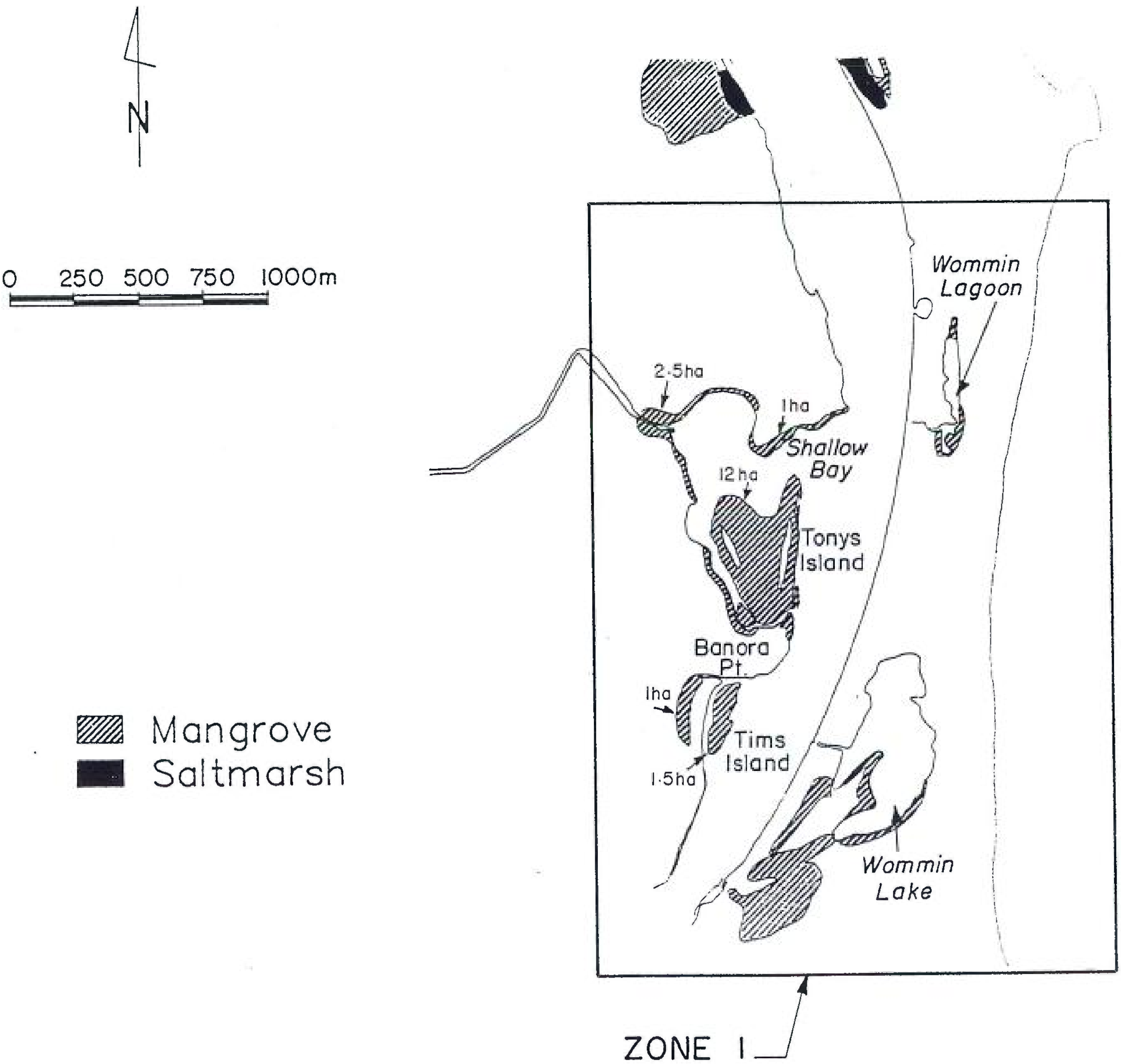
3.9 FLORA

The proposed sand extraction works will have potential effects on the aquatic vegetation of Area 5, including seagrasses and mangrove communities. Terrestrial sites such as the RTA road construction areas and designated development land near Shallow Bay are subject to assessment in EIS studies for those works and are not specifically dealt with herein.

3.9.1 Aquatic Vegetation of Area 5

The aquatic vegetation of Area 5 comprising mangroves and seagrass has been documented in NSW Public Works (1991b) and is outlined below.

Mangroves occur only as scattered plants along the eastern banks of the Tweed River (main arm) in Area 5 (Figure 3.19) as all of this section of river bank has been rock revetted. On the western river bank, mangroves occur in a discontinuous fringe, less than 15 m wide, from the northern end of Area 5 south to the most easterly extension of Rocky Point.



MANGROVE AND SALTMARSH DISTRIBUTION 1991
(modified from WBM Oceanics 1991)

FIGURE 3.19

Mangroves then form an almost continuous band of vegetation around Shallow Bay. Mangroves also cover most of Tony's Island in Shallow Bay.

A narrow (one to several trees wide) mangrove fringe occurs around the southern side of Banora Point, leading to Tims Island and a small tidally flushed inlet on the mainland opposite the island, which both support significant mangrove stands. No mangroves occur on the western river bank south of Banora Point to Barneys Point.
Seagrass distribution in Area 5 of the river is shown in Figure 3.20. Significant seagrass beds occur in and around Shallow Bay and together cover approximately 15 ha. Seagrass also fringes the western banks of the river just downstream of Rocky Point (0.8 ha). Several small seagrass beds occur off the eastern side of Tony's Island (0.7 ha) and around the southern end of Tims Island (0.4 ha).

3.9.2 Vegetation of the Fingal Peninsular Near Area 5

Land on Fingal Peninsular has been considered as a possible sand stockpile site. This is not being pursued in the present proposal. For completeness, a description of the flora of that area is presented in Appendix 19.

3.10 TERRESTRIAL FAUNA

3.10.1 Terrestrial Fauna of Fingal Peninsular Area

The terrestrial fauna of Fingal Peninsular in the vicinity of Area 5 was assessed by field observations conducted in June 1991 and by review of relevant reports such as the Tweed Shire Coastal Planning Study, Wildlife (1979), and several Environmental Impact Statements (see below). Direct observations made during the course of studies carried out in preparation of NSW Public Works (1991a) between November 1990 and June 1991 were also included in the study.

Birds were the dominant vertebrate group utilising the area. No evidence of small native mammals or amphibians was observed during the observation period described. Those reptiles occurring in the area are common throughout the lower Tweed region. These observations are discussed below.

Birds

A list of birds observed during visits to the Area 5 region is provided in Table 3.10. This is a composite based upon regular visits between November 1990 and June 1991. The area identified as a potential stockpile site was regularly traversed in order to visit Dreamtime

Beach during a study of shorebirds in the lower estuary (PWD 1991b). Birds present in the area were noted and recorded as part of the larger study (PWD 1991b). Additional site specific observations were carried out in June 1991. Only a small number of the species recorded were observed to utilise the area during any one observation period and were often restricted to limited sections on the site.

Thirty-nine species of birds were recorded on the potential stockpile land (Table 3.10). Many of the birds observed were associated with either the mangroves or swamp oak forest at Wommin Lagoon or Wommin Lake respectively. They included the White-faced Heron, Little Black Cormorant, Sacred Ibis, Peaceful and Bar-shouldered Dove, White-throated Gerygone, Mangrove Honeyeater and Magpie Lark.

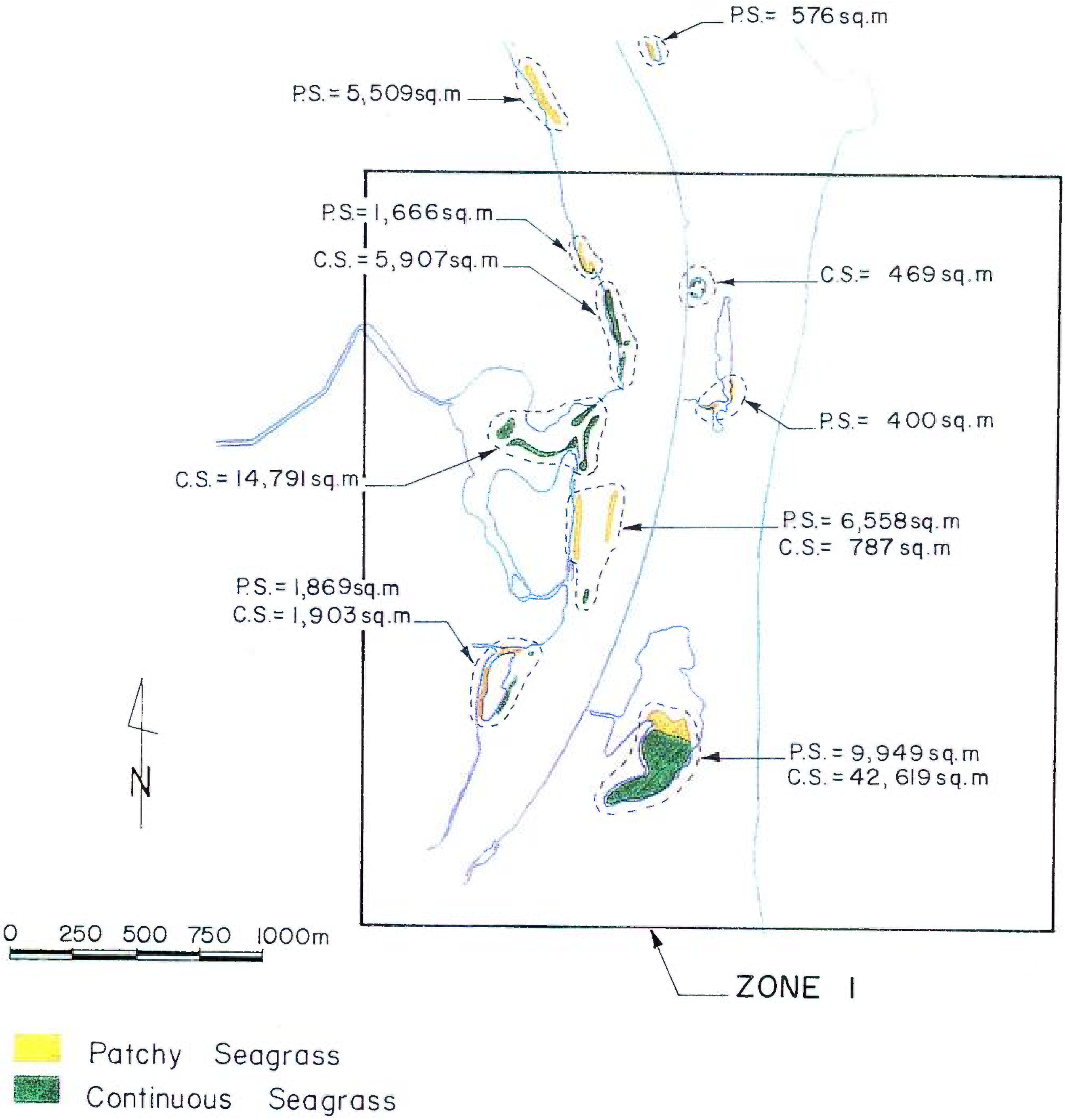
Others were observed only in the dense grass and shrub understorey at the rear of the frontal dunes eg. Coucal, Brown Quail, Grey-fantail, Fantail cuckoo, Rufous whistler, Red-backed Fairy-wren and Spangled Drongo.

The vegetation of the succession community provided limited forage for a variety of opportunistic and/or seasonally migratory species which utilised the nectar and insects associated with *Banksia, Casuarina* and native mistletoe (*Amyema* sp.) growing in this area. Typical examples include Rainbow Lorikeet, Silvereye, Little Wattlebird, Noisy Friarbird, Brown and White-cheeked Honeyeaters.

The relatively open ground in parts of the proposed site was at times occupied by Masked Plover, Cattle Egret, Magpie, Currawong, Butcherbird and Crow. The Bee-eater, Dollarbird and Kestrel were, at various times, observed hawking for insects or otherwise hunting from powerlines along Fingal Road, adjacent to the site. Introduced Sparrow, Mynah and Starling were also observed along the road, towards Fingal Village.

A number of species simultaneously using the site were observed on only one occasion, including the Figbirds, feeding in Bitou bush behind Dreamtime Beach, and the Variegated Wren in *Casuarina equisetifolia* on the front dune of the beach.

Migratory shorebirds, including those listed on the National Parks and Wildlife Service (Interim) Schedule 12 (1992), JAMBA (1981) and CAMBA (1988), with the exception of the Cattle Egret described below, do not make use of the site and immediately surrounding area.



SEAGRASS DISTRIBUTION 1991
(modified from WBM Oceanics 1991)

FIGURE
3.20

Cattle Egret (Ardeola ibis)

The Cattle Egret is the only migratory species, listed in JAMBA (1981) and CAMBA (1988), observed using the area. This species does not appear on the NPWS Revised (Interim) Schedule 12 (1992).

The Cattle Egret is common to abundant, and is increasing in numbers throughout the Tweed estuary, south east Queensland and Australia generally. Cattle Egrets were initially introduced to Australia early this century, but they are thought to have independently colonised from Asia and rapidly expanded over the continent in the past 50 years (Blakers *et al.* 1984). They may be found around all of the Australian coast and nearby hinterland, with the exception of the Nullarbor Plain. The species appears to be continuing to expand its range within Australia. In Tweed Shire the birds may be found in flocks exceeding 200 individuals (PWD 1991b) although small groups of 3 - 7 individuals are more usual. Individual egrets were observed feeding on open wasteland within the general area upon which stockpiling operations could be considered.

TABLE 3.10
BIRDS OBSERVED IN AREA 5 REGION

COMMON NAME	SCIENTIFIC NAME
Little Black Cormorant	*Phalacrocorax sulcirostris*
White-faced Heron	*Ardea novaehollandiae*
Cattle Egret	*Ardeola ibis*
Sacred Ibis	*Threskiornis aethiopica*
Whistling Kite	*Haliastur sphenurus*
Australian Kestrel	*Falco cenchroides*
Brown Quail	*Coturnix australis*
Masked Lapwing	*Vanellus miles*
Peaceful Dove	*Geopelia placida*
Bar-shouldered Dove	*Geopelia humeralis*
Rainbow Lorikeet	*Trichologlossus haematodus*
Fan-tailed Cuckoo	*Cuculus pyrrophanus*
Pheasant Coucal	*Centropus phasianinus*
Rainbow Bee-eater	*Merops ornatus*
Dollarbird	*Eurystomus orientalis*
Welcome Swallow	*Hirundo neoxena*
Black-faced Cuckoo Shrike	*Coracina novaehollandiae*
Rufous Whistler	*Pachycephala rufiventris*
Grey Fantail	*Rhipidura fuliginosa*
Willie Wagtail	*Rhipidura rufifrons*
Variegated Fairy-wren	*Malurus lamberti*
Red-backed Fairy-wren	*Malurus Melanocephalus*
White-throated Gerygone	*Gerygone olivacea*
Little Thornbill	*Acanthiza nana*
Little Wattlebird	*Anthochaera lunulata*
Noisy Friarbird	*Philemon corniculatus*
Mangrove Honeyeater	*Lichenostomus fasciogularis*
Brown Honeyeater	*Lichmera indistincta*
White-cheeked Honeyeater	*Phylidonyris nigra*
Silvereye	*Zosterops lateralis familiare*
House Sparrow *	*Passer domesticus*
Common Starling *	*Sturnus vulgaris*
Common Mynah *	*Acridotheres tristis*
Southern Figbird	*Sphecotheres viridis*
Spangled Drongo	*Dicrurus hottentottus*
Australian Magpie-lark	*Grallina cyanoleuca*
Pied Butcherbird	*Cracticus nigrogularis*
Australian Mapie	*Gymnorhina tibicen*
Torresian Crow	*Corvus orru*
*** Introduced species**	

Mangrove Honeyeater (Lichenostomus fasciogularis)

This species is an endemic counterpart of the more northerly varied honeyeater *(Lichenostomus versicolor)*. Natural hybrids occur between the two species where ranges overlap (Blakers et al. 1984).

This species has recently (February 1992) been classified as "vulnerable and rare" on the Revised (Interim) Schedule 12, National Parks and Wildlife Act 1974, presumably because of its restricted range and habitat preference.

The Mangrove Honeyeater has a limited range in New South Wales, however on recent evidence the species appears to be extending southwards, suggesting populations are expanding into suitable habitat (Blakers et al. 1984).

Blakers et al. (1984) note that the species is "said to be sedentary" and "may wander locally seeking flowering plants and visiting flowering shrubs in towns adjacent to mangroves".

In Tweed Heads this species is commonly observed in urban streets near the River, feeding in flowering native and exotic shrubs and trees. Within the Area 5 study area, specimens were observed in mangroves, *Melaleuca* and introduced shrubs around Wommin Lagoon, including backyards and nature strips.

This species is also locally common on and around Tweed Heads Golf Club, Shallow Bay and Tims Island on the western side of the study area.

Other vertebrates

No signs of native mammals were observed on the Fingal Peninsular site considered as a stockpile area. It is possible that the common Northern Brown Bandicoot *(Isoodon macrourus)* could occupy the areas of the horsetail oak/Bitou bush community behind the frontal dunes, where a dense shrub layer has formed. However, no signs of this species' characteristic digging activity were observed during traverses of the area. The predominance of introduced species such as bitou bush may limit both development of the necessary ground cover and food availability for this species in the area.

Domestic and feral dogs *(Canis familiaris)* and cats *(Felis catus)* are common throughout the area, as evidenced by tracks and direct observation. These predators may limit the occupation of an area by species such as bandicoots where appropriate natural cover and food supply is severely limited. Feral mice *(Mus musculus)* and Black Rats *(rattus)* could be expected in the area (Murray 1987).

Murray (1987) recorded a "depauperate reptile fauna of two skink species *(Carlia burnettii, Ctenotus taeniolatus)* which are widespread on sandy substrates on the NSW north coast" at nearby Fingal Village. The history of disturbance to the Fingal peninsula by sandmining and clearing combined with its isolation probably limit colonisation and recolonisation by small ground dwelling species (Murray 1987). *Ctenotus taeniolatus*, the Copper-tailed Skink, was the only reptile observed over the survey period. No amphibians (frogs) were found near Fingal Village and their absence was attributed to the lack of fresh surface waters and the proximity or intrusion of saline waters (Murray 1987).

The site consists of freely draining sandy soils which do not pond water, necessary to provide amphibian habitats. It is thus unlikely that amphibians occur in the area.

3.10.2 Estuarine Birds in Area 5

PWD 1990(b) summarises 5 years of quantitative estuarine and shorebird observations carried out by a number of investigators, using similar census methods.

Table 3.11 summarises data recorded during the intensive "simultaneous estimation" census conducted on 1 and 2 February 1990 (PWD 1990b). In this table, the maximum number of species observed at each site (either foraging, roosting or both) is presented along with the average total number of individuals counted at the sites during the two day period. The conclusions drawn below are also based upon data obtained over a 7 month and periods in 1989/90, and 1990/91.

The following points emerge from the seasonal data (PWD 1991b) and Table 3.11 (also refer Figure 3.21).

- Four primary habitat areas exist for migratory shorebirds in the lower Tweed estuary. These are Kerosene Inlet/South Head Beach area on Letitia Spit; Trutes Bay (inc. freshwater swamp); Tweed Heads Pony Club/Cobaki Broadwater, and Tony's Bar/Shallow Bay.

- Trutes Bay is the most important site overall for estuarine birds in lower Tweed estuary, in terms of both species diversity and average numbers.

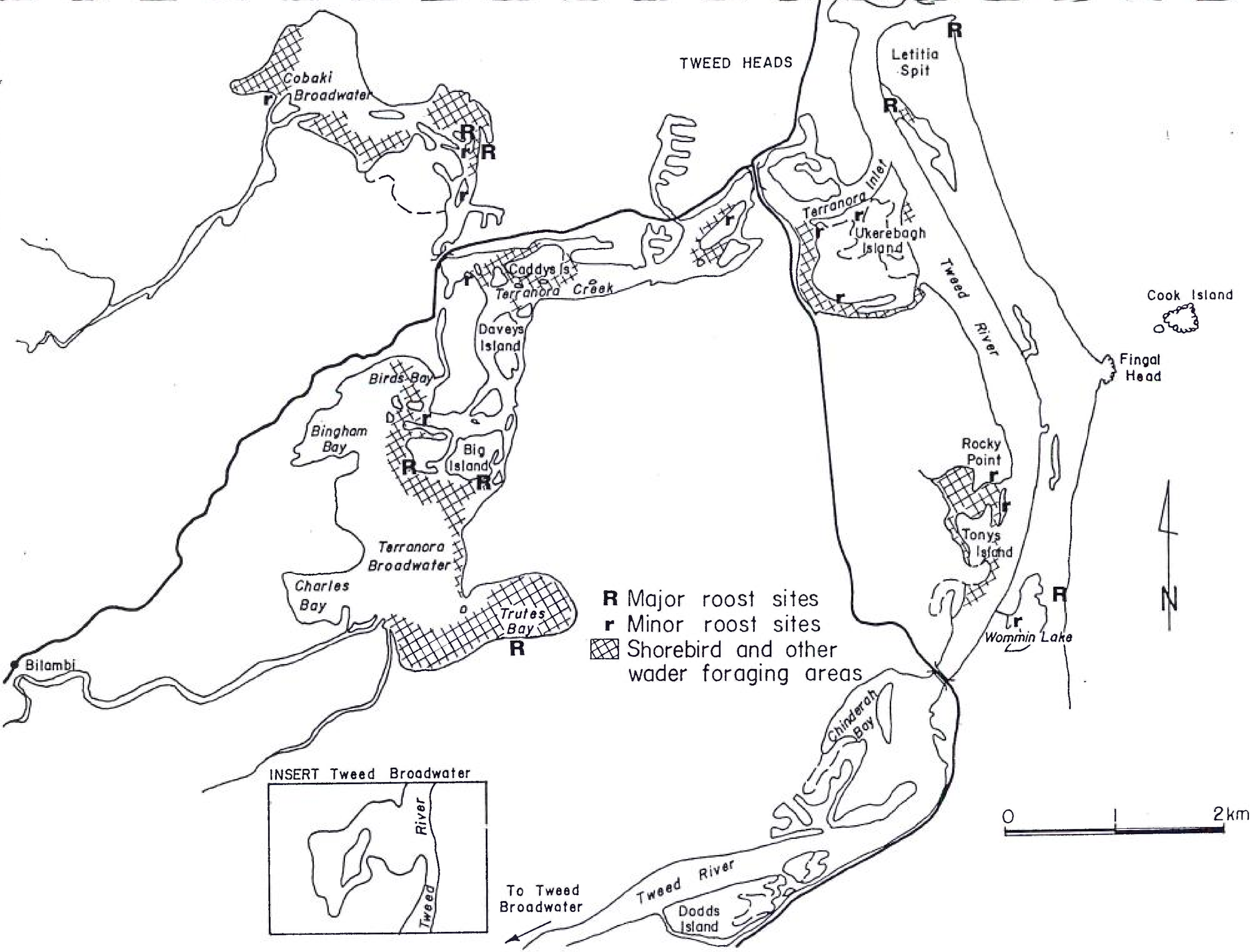


FIGURE 3.21

SHOREBIRD ROOST SITES AND FORAGING AREAS

Source: PWD (1991a)

- Tweed Heads Pony Club with Cobaki Broadwater adjacent, and Kerosene Inlet, South Head on Letitia Spit, are the next most important areas in terms of both diversity and the abundance of birds.

- In Area 5 Shallow Bay and Tony's Bar combined as a unit also provide an important foraging/staging and part-time roosting area for estuarine birds.

Among the estuarine birds utilising the Tweed estuary, 17 migratory and 10 non-migratory species are listed in JAMBA (1981) or CAMBA (1988) international treaties protecting listed estuarine birds and their wetland habitats. In addition, several species are listed as Vulnerable and Rare Fauna under the New South Wales National Parks and Wildlife Act Revised (Interim), Schedule 12, 1992. Several of the species listed in Schedule 12 may utilise Tony's Bar and Shallow Bay.

TABLE 3.11
SUMMARY OF SIMULTANEOUS COUNT DATA FOR ROOSTING AND FORAGING BIRDS 1 AND 2 FEBRUARY 1991

	(A) Migratory Species		(B) All Others		All Combined (A+B)	
	Maximum No. Species Observed	Av. No.s Individually Observed	Maximum No. Species Observed	Av. No.s Individually Observed	Maximum No. species Observed	Av. No.s Individually Observed
Trutes Bay	6	69	17	545	23	673
Womgin/Big Islands	5	34	4	8	9	77
Pony Club Cobaki	8	124	10	27	18	151
Broadwater	5	13	9	34	14	47
Tony's Bar*	6	15	10	20	16	35
Shallow Bay*	3	4	6	8	9	13
Ukerebagh Passage	4	2	4	2	8	10
Caddys Island	0	0	5	2	5	2
Canals	2	61	4	14	6	75
Dreamtime Beach	5	104	5	112	10	216
South Head Beach	6	18	12	167	18	185
Kerosene Inlet						
TOTAL		444		939		1383

* Area 5 habitat

Among the seabirds the Little Tern *(Sterna alba)* is classified as "Threatened" under NPWS Revised (Interim) Schedule 12. As a consequence, particular attention was given to these birds during the survey. A maximum of 17 individuals were observed during the study period, all in the Letitia Spit area (PWD 1991b). This area is several kilometres downstream of Area 5.

The number of Little Tern in the lower Tweed estuary appears to vary considerably from year to year. Martindale (1987) observed a maximum of 70 individuals. The New South Wales National Parks and Wildlife Service (NPWS) conducts regular counts of Little Terns throughout its range in the State. These studies have culminated in a biology and management summary document for this species (Smith 1990).

Mr David Charley (NPWS Alstonville, pers. comm.) confirmed that numbers of Little Tern were low in the Tweed estuary during 1990-91, compared with 1989-90 when about 60 individuals were observed. National Parks and Wildlife Service office at Alstonville holds records for Little Tern surveys in northern New South Wales which may be useful in detailed planning for the management of this species in the Lower Tweed estuary.

Little Tern in breeding plumage have not been observed on the Tweed river for several years (pers. comm. David Charley, NPWS). It is of interest to record that three birds in breeding plumage were recorded at Tony's Bar on 20/21 March 1991, and two individuals in February 1992. Two birds in transitional plumage were recorded at the same location on 17 April 1991, in the company of two White-winged Black Tern, a JAMBA and CAMBA listed species not recorded by Martindale (1987) or Holmes (1990).

Mr Charley (pers. comm.) reports that Little Tern bred at a beach site nearby to Kingscliff, southeast of Chinderah during 1991 - 1992.

The requirements of Little Terns have been considered in the options for environmental enhancement works provided in Section 5.5. Specifically, the creation of a suitable roost and potential breeding site is proposed at Tony's Bar. This would include areas protected from feral predators, human traffic, the provision of suitable substrate (shingle), sign-posting and a public awareness campaign. Any project of this type would only be conducted with the approval and cooperation of the New South Wales National Parks and Wildlife Service.

3.10.3 Biting Midges and Mosquitoes in Area 5

Three species of biting midge and four ground water breeding species of mosquitoes cause problems in Tweed Shire.

A brief summary of the biting midge and mosquito problem in and adjacent to Area 5 is presented below (also see Easton 1990, PWD 1991b). Mr Clive Easton, Entomologist, Tweed Council, kindly provided the breeding site distribution data presented in Figure 3.22.

Biting midge

Biting midge exhibit a very precise choice of breeding site, at distinctive levels on the intertidal continuum. A summary of known biological characteristics of these minute insects is provided below, followed by a brief description of control methods and problems associated with these methods.

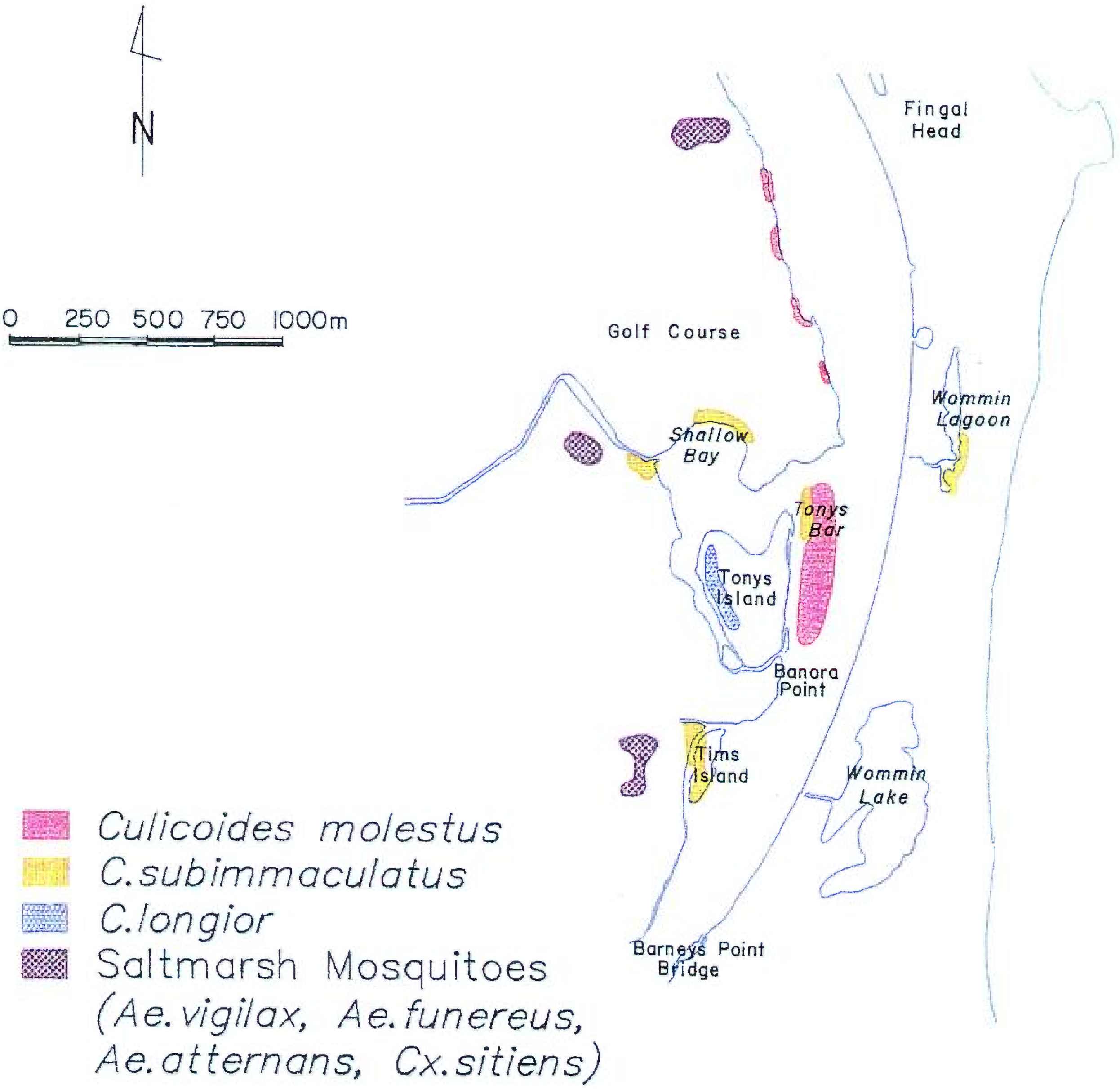
The environmental, legal and biological implications of the biting midge problem, with many examples taken directly from the Tweed estuary studies, are discussed in Smith and Bell (1990).

Although midge do not transmit diseases to humans in Australia, their economic impact as pests may be considerable (Smith and Bell 1990).

Culicoides longior

This species is only a problem to humans in those areas of the estuary which are close to its breeding sites. Its pest range (defined as the distance from a breeding area within which the species will cause regular infestation) is between 400m and occasionally up to 1km, depending upon the size of the breeding site and atmospheric conditions at the time of emergence.

C. longior breeding places in the Tweed are always 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 West Side of Tony's Island and a small, southwest corner of Tony's Bar are the principal breeding areas in Area 5 (Figure 3.22). Although larval densities are usually well below those of the other two species described below (usually 1000/m^2), the breeding areas are often extensive, making control difficult.



Source: PWD (1991a)

BITING MIDGE AND MOSQUITO BREEDING AREAS, ZONE 1

FIGURE 3.22

Culicoides molestus

Aptly named this species is often a serious pest. Pest range varies from about 400m (small breeding areas) up to 1.5km or more (major large or artificial sites).

Within Tweed Shire 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 in canal developments, and also most sandy river foreshores and suitable sandbars such as Tony's Bar (Figure 3.22). In appropriate habitat, larval densities may be very high, such as in some canal estates where densities of 3000 larvae/m^2 have been recorded. Tony's Bar has yielded exceptional midge larval densities of up to 30000 larvae/m^2. In the latter situation both distant as well as local residences are affected. Easton (1990) reports that residents on hilltops up to 1km from the breeding areas are often affected more adversely than those living close-by.

Culicoides subimmaculatus species complex

At least two closely related and almost identical species appear to inhabit the Tweed estuary (pers.comm, C.Easton). This species group appears to cause a seasonal problem in the Tweed estuary, appearing in large numbers after wet autumn/winter periods (Easton 1990). Its pest range and behaviour is similar to that of *C. molestus* however *C. subimmaculatus* breeds in clean or muddy sand in the open or under light mangrove cover between the mean high water neap and mean high water spring tide levels.

The second species of this group appears to live in similar habitat to that occupied by *C.molestus* (pers. comm. C. Easton), and inhabitants Tony's Bar and other Area 5 breeding sites (see Figure 3.22).

Biting midge control

The methods used for control of biting midges are briefly reviewed below. Environmental control methods (Reye 1990) may involve careful design of new projects, to ensure artificial midge breeding sites are not created, as happened with many early canal estates, and after creation of some "islands" in the Tweed estuary by dumping of dredge spoil.

Environmental modifications may be used to correct existing problems. Some methods may be expensive to implement but provide permanent solutions and result in long-term cost savings.

Another more economical control method, occasionally available, involves removal of a layer of sand/mud from sandbanks down to the mid-tidal level in order to eliminate midge breeding habitat.

Conversely, design (for example) of dredge spoil disposal sites in midge prone areas could ensure that:

- in-filling does not proceed above mid-tide level.

- filling could proceed until an "island" is exposed, with a profile which minimises exposed surface areas from above mid-high tide level.

- filled areas could be appropriately revetted, if the cost was justified (eg. to create useable space, protect threatened species) between mid-tide and highest tide levels, preventing colonisation.

- combinations of the above.

In natural wetlands and associated fauna habitats, environmental control methods may be undesirable as most of the methods are relatively crude and adversely impact upon all, or most of the biota of the habitats affected (eg. by draining, flooding, cessation of tidal flows).

Details of other control methods including planning legislation and pesticides are reviewed in NSW Public Works (1991b).

Mosquitoes

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. funereus,* breed in pools within saltmarsh and mangrove areas created after the highest spring tides (PWD 1991b). Heavy rain can also fill the same pools, and combinations of rain and high tides occasionally create huge areas of suitable breeding habitat.

Only minor breeding habitats have been identified adjacent to the western perimeter of Area 5 (Figure 3.22). These are managed by Tweed Council (pers. comm. C. Easten) and are not relevant to this proposal.

3.11 AQUATIC FAUNA

Aquatic fauna studies are based upon direct observations within Area 5 and longer term studies carried out by the consultants and others over the past five years (PWD 1991a,b; Murray 1987, WBM Oceanics 1991a).

3.11.1 Fish

The fish fauna of the lower Tweed estuary has been previously examined using SCUBA surveys (Ellway and Hegerl 1972) and bow trawls over seagrass beds in association with the Tweed Entrance Feasibility Report (PWD 1990). These studies concluded that the fish fauna of the study area is a diverse mixture of tropical and temperate, marine and estuarine forms. A detailed list of fish species recorded in the lower estuary is provided in the Tweed Entrance Feasibility Report (PWD 1990). In common with other studies conducted in estuaries, seagrass beds were noted to be important fish nursery grounds. Pollard (1976) concluded that mangrove lined estuaries, similar to the Tweed River, supported numerous species of fisheries importance.

A netting survey was undertaken in Area 5 as part of a larger study (PWD 1991a), to supplement existing information on the fish fauna of the study area and provide data to assist in defining impacts resulting from proposed dredging operations (see Appendix 20 for methods used). The results of the survey are reported below.

Results

Scientific and common names of all species taken in the lower estuary (15 sites) (PWD 1991a) survey are given in Table 3.12. Water quality measurements were taken in association with benthic sampling (see PWD 1991a).

TABLE 3.12

SCIENTIFIC, COMMON NAMES, ECONOMIC VALUE AND LIFE HISTORY STAGE OF FISH TAKEN DURING LOWER ESTUARY SURVEYS. (C= COMMERCIAL, R = RECREATIONAL; - = NO DIRECT ECONOMIC VALUE), (J = JUVENILE, A = ADULT)

SCIENTIFIC NAME	COMMON NAME	ECONOMIC VALUE	LIFE HISTORY STAGE
Acanthopagrus australis	Silver Bream	C/R	J/A
Achlyopa 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 nematophthalmus	Fringe-eyed Flathead	R	A
Dasyatis fluriorum	Brown Stingray	-	A
Gerres ovatus	Silver Biddy	-	J/A
Girella tricuspidata	Black Bream (Luderick)	C/R	J/A
Harengula abbreviata	Herring	-	J/A
Hyporhamphus australis	Sea Garfish	C/R	A
Liza argentea	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 Mullet	C	J/A
Myxus elongatus	Sand Mullet	C	J/A
Pelates quadrilineatus	Trumpter	-	A
Platycephalus arenanius	Sand Flathead	C/R	J/A
Platycephalus fuscus	Dusky Flathead	C/R	J/A
Plotosus anguillaris	Striped Catfish	-	J
Pomatomus saltatrix	Tailor	C/R	J
Rhabdosargus sarba	Tarwhine	C/R	J
Scomberoides lysan	Queenfish	R	J
Sillago analis	Golden-line Whiting	C/R	A
Pseudorhombus arsius	Large-mouth Flounder	C/R	J
Sillago ciliata	Summer Whiting	C/R	J/A
Sillago maculata	Winter Whiting	C/R	J
Tetractenos pleurogramma	Weeping Toadfish	-	J/A
Tetractenos hamiltoni	Common Toadfish	-	J/A
Tylosiurus macleayarus	Stout Long-tom	-	A

Mesh netting

A total of 168 fish of 16 species were taken throughout the 15 lower estuary sites, including Area 5, during the summer (January 1991) survey (Table 3.13, PWD 1991a) which involved 60 net soak hours. Most fish were mullet (*Liza argentea, Mugil cephalus*) or southern herring (*Harengula abbreviata*).

In autumn (March 1991), 164 fish of 14 species were taken throughout the estuary (Table 3.14, PWD 1991a). The numerically dominant fish were perchlets *(Ambassis marianus)*, mullet (*Liza argentea, Mugil georgii and Myxus elongatus)* and silver biddy *(Gerres ovatus)*.

Insufficient numbers were taken at any site to enable characterisation of specific sites, comparisons between sites, or statistical analyses.

Water conditions during both survey periods were atypical of those generally occurring in summer or autumn. No substantial rain had occurred for many months and as a result water salinity and clarity was high. The high water clarity resulted in nets being visible to fish. In several instances fish were observed to avoid the net.

Alternative meshing strategies, such as night netting and longer nets, were considered likely to lead to conflict with commercial operations or result in mistaken complaints of illegal netting. Discussions held with commercial fishermen suggest that fish catches had been low in the study area for several months. Most fishermen commented that significant rainfall was needed to improve catches.

TABLE 3.13
SUMMARY DATA FROM LOWER ESTUARY GILL NETTING SAMPLES FOR SUMMER (JANUARY 1991) SURVEY.

SCIENTIFIC NAME	NO. CAUGHT	LENGTH RANGE (mm)
Ambassis marianus	26	65-95
Arothron hispidus	1	230
Arrhamphus sclerolepis	6	190-245
Gerres ovatus	3	75-80
Harengula abbreviata	77	80-135
Hyporhamphus ardelio	1	220
Hyporhamphus australis	1	270
Liza argentea	33	100-280
Liza dussumieri	1	225
Mugil cephalus	6	190-280
Mugil georgii	4	150-230
Megalops cyprinoides	1	385
Pelates quadrilineatus	1	95
Platycephalus fuscus	1	190
Scomberoides lysan	5	100-250
Sillago ciliata	1	105

TABLE 3.14
SUMMARY DATA FROM LOWER ESTUARY GILL NETTING SAMPLES FOR AUTUMN (MARCH 1991) SURVEY.

SCIENTIFIC NAME	NO. CAUGHT	LENGTH RANGE (mm)
Ambassis marianus	129	90-110
Arrhamphus sclerolepis	2	280-290
Dasyatis fluviorum	1	250
Gerres ovatus	4	60-100
Girella tricuspidata	2	270-315
Harengula abbreviata	1	110
Hyporhamphus ordelio	1	240
Liza argenta	11	120-210
Meuschenia trachylepis	1	120
Mugil georgii	5	120-130
Myxus elongatus	4	120-150
Platycephalus fuscus	1	310
Rhadosargus sarba	1	70
Sillago analis	1	245

Seine netting

Summer and Autumn haul net surveys were undertaken in January and March 1991. A listing of the fish species recorded in those surveys is presented in Table 3.15.

For details of netting sites refer to PWD (1991b).

i) *Summer Survey*

A total of 85 individuals of 9 species were recorded in the summer haul net survey within Area 5 (Table 3.15). Sixty-five percent of the individuals and 78% of the species were of direct fisheries value (Table 3.12). Most species were present both as adults and juveniles.

TABLE 3.15
SUMMARY DATA FROM AREA 5 SEINE SAMPLES FOR SUMMER (JANUARY 1991) AND AUTUMN (MARCH 1991) SURVEYS

SCIENTIFIC NAME	JAN	MAR
Mugil georgii	9	17
Liza argentea	-	-
Mugil cephalus	-	1
Myxus elongatus	16	4
Liza dussumeri	-	-
Platycephalus arenanius	-	-
Platycephalus fuscus	1	2
Tetractenos pleurogramma	-	-
Tetractenos hamiltoni	-	-
Sillago ciliata	11	15
Sillago maculata	-	5
Arrhamphus sclerolepis	2	1
Hyporhamphus australis	2	-
Acanthopagrus australis	14	-
Rhabdosargus sarba	-	-
Monodactylus argentea	-	-
Harengula abbreviata	19	-
Ambassis marianus	-	-
Ambassis jacksonensis	-	-
Gerres ovatus	11	11
Callionymus limeceps	-	-
Pomatonus saltatrix	-	-
Megalops cyrinoides	-	-
Plotosus anguillaris	-	-
Girella tricuspidata	-	-
Achlyopa nigra	-	-
Gobiomorphus lateralis	-	1
Scomberoides lysan	-	1
Cymbacephalus nematophthalmus	-	-
Pseudorhombus arsius	-	-
Tylosurus macleayanus	-	-
TOTAL INDIVIDUALS	85	61
TOTAL NO. OF SPECIES	9	10

The most abundant Area 5 species were mullet (*Myxus elomgatus, Mugil georgii*), herring (*Harengula abbreviata*), bream (*Acanthopagrus australis*), summer whiting *(Sillago ciliato)* and silver biddies (*Gerres ovatus*). Three species were represented by two or less individuals (Table 3.15).

One-way ANOVA of all of the estuary sites, including Area 5 (PWD 1991a) indicated that sites were significantly different ($p < 0.05$) in terms of fish abundance but not in terms of the total number of species taken at each site ($p > 0.05$). Duncan's multiple range test showed that samples from the estuary entrance (site F0) had significantly less ($p = 0.05$) fish than all other sites except site F2 in Area 5. This reflected Area 5 affinities with and proximity to the entrance.

No significant difference ($p > 0.05$) was observed between all lower estuary sites in terms of the number of mullet (all species combined), bream, perchlets or herring taken in samples.

Summer whiting, silver bream *(A. australia)*, southern herring *(H. abbreviata)* and silver biddy *(G. ovatus)* were taken at all lower estuary sites (including Area 5), whilst mullet (*L. argentea, M. cephalus, M. elongatus*) were also common (82% of sites). Fantail mullet (*M. georgii*), garfish (*H. australis*), tarwhine *(R. sarba)* and perchlets (*A. marianus*) occurred frequently (44-55% of sites). All other species were taken occasionally (< 33% of sites).

Comparison of the species composition of samples taken at each site (Jaccard similarity values, PWD 1991a) indicated that most river sites were similar in terms of species composition.

Although detailed length-frequency data were not recorded, several trends in the size of fish occurring at different sites were observed. Summer whiting (*S. ciliata*) were abundant in canals but were mostly juveniles, and hence smaller than those taken at river sites (eg. Tony's Bar). Large whiting were commonly captured in the river, for example Tony's Bar in Area 5. In contrast, large mullet (*Liza argentea*) were frequently taken in the canals whilst mullet contained in samples from the river (eg. Area 5) were more often juveniles.

ii) *Autumn Survey*

A total of 61 individuals of 10 species were taken from the Area 5 river site during the autumn (March 1991) survey (Table 3.15). Seventy-four percent of the individuals and 70% of the species were of direct economic value.

The most abundant species were mullet *(Mugil georgii, Mugil cephalus, Myxus elongatus)*, summer whiting (Sillago ciliata) and silver biddies *(Gerres ovatus)*. Seven species were represented by less than, or equal to, 5 individuals.

Summer whiting *(S. cilata)*, sea mullet *(M. cephalus)*, silver biddy *(G.ovatus)* were taken at all sites in the lower estuary, including Area 5 (PWD 1991a) whilst sand mullet *(M. elongatus)*, bream *(A. australis)*, tarwhine *(R. sarba)* and herring *(H. abbreviata)* were common (83% of sites). The later 3 species were not however recorded in Area 5. Fantail mullet *(M. georgii)* and tiger mullet *(L. argenta)*, occurred frequently (66% of sites), whilst all other species occurred occasionally ($\leq$ 33% of sites).

Comparison of sites in terms of species composition (Jaccard similarity values; PWD 1991a) indicated that all sites were similar.

iii) *Comparison between summer and autumn surveys*

Paired t-test results indicated that there was no significant difference ($p > 0.05$) in the total number of individuals or species in Area 5 between summer and autumn surveys.

Similar numbers of mullet (all species combined), whiting, herring, silver biddys and perchlets were taken throughout the estuary, (including Area 5) during both surveys. Significantly less ($p < 0.05$) bream were taken in autumn than summer.

The species composition of all sites in both surveys was similar, with the same species (mullet, whiting, bream, herring, perchlets) numerically dominating samples.

A total of 30 fish species was recorded from in the NSW Public Works (1991a) survey of bare sandy substrates in the lower Tweed estuary, of which 9-10 species were recorded in Area 5.

The Tweed Entrance Feasibility Report (PWD 1990) reviewed relevant publications and concluded that the lower Tweed estuary (including the river entrance region) supported 149 species of fish. This total included numerous species that are commonly associated with rocky substrates (e.g. the extensive areas of rock training walls) and are infrequently found in northern N.S.W. estuaries which lack such substrates.

Undoubtedly a greater variety of species would have been recorded in PWD (1991a) if; mangrove, seagrass and rock areas were sampled; different netting techniques were used;

or if sampling was conducted over a longer period. Additionally, the survey was conducted during an atypically dry period of several months. Interviews with commercial and recreational fishermen indicated (PWD 1991a) that fish catches during the survey periods were poor compared to those likely to occur following high rainfall typical of summer months.

The sites sampled with haul nets in the present study were all sand banks/sandy shores and hence similar in terms of their physical characteristics, although the location of the sample sites varied from the estuary mouth to more upstream areas. Results indicated that all sites (including Area 5) had a similar fauna (irrespective of survey period), other than a few species which occurred infrequently.

The dominant species (in terms of abundance and frequency of occurrence) recorded in this study were mostly of economic importance. Bream, whiting and mullet are of substantial fisheries value and form 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 in the lower estuary. 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 (eg. inshore side of Tony's Island) are thus of considerable importance as nursery areas for species which are mostly of fisheries value.

Wetland areas (saltmarshes and mangroves) such as those occurring in Shallow Bay were not sampled in this study but 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.

The present fish survey indicates that shallow sandy substrates (including those within canal developments) provide nursery habitat for several species of direct fisheries value (e.g. bream and whiting).

3.11.2 Benthic Invertebrate Fauna of Area 5

Previous benthic monitoring programmes in the lower Tweed estuary, undertaken on a seasonal basis at a number of defined sampling sites, have been utilised to characterise the benthic fauna of defined regions of the Tweed River system (PWD 1991b).

In this section the results of a detailed benthic survey undertaken during December 1991 in Area 5 are presented.

The sampling programme and sites within Area 5 were selected in order to enable assessment of the benthic fauna present within the region prior to any dredging operations. Sampling methods and statistical analyses have been standardised across all lower Tweed estuary surveys. The data in this report therefore forms part of the ongoing baseline monitoring studies being conducted before the commencement of any works identified by the Plan of Management (PWD 1991a). See Appendix 21 for details of site selection, statistical analysis and taxonomic composition of samples.

Comparison of benthic sampling of sites within Area 5

Summary results of the number of species (diversity) and number of individuals (abundance) present at each sample site are shown in Table 3.16, with the detailed data presented in Appendix 21.

TABLE 3.16
SUMMARY DATA FOR AREA 5 BENTHIC SURVEY (DECEMBER 1991).
TOTAL ABUNDANCE AND NUMBER OF SPECIES FOR BENTHIC SAMPLING SITES WITHIN (Z1, Z2, Z3) AND ADJACENT (Z4) TO PROPOSED DREDGE AREA.

SITE	POLYCHAETEA		BIVALVIA		CRUSTACEA		OTHER		TOTAL	
	SPP.	NO.	SPP.	NO.	SPP.	NO.	SPP.	NO.	SPP.	NO.
Z1	2	8	6	13	3	26	1	1	12	48
Z2	3	10	4	13	2	16	2	2	11	41
Z3	5	31	4	8	2	2	3	17	14	58
Z4	24	117	4	14	6	26	4	31	38	188

A total of 335 individuals and 50 species were recorded from the four Area 5 sites (see Table 3.16; Appendix 21). Polychaetes dominated the benthic fauna both numerically and in terms of the number of species, accounting for approximately 50% of the total species diversity and abundance.

Benthic abundance and diversity

Summary results from the one-way ANOVA for the four sites within Area 5 indicated that:

- both the total number of benthic individuals and species varied significantly between sites ($p < 0.05$);

- the abundance and diversity of polychaetes, crustaceans and other benthic fauna (ie. gastropods and nemerteans) also varied significantly between sites ($p < 0.05$);

- the abundance and diversity of bivalves did not vary significantly between sites.

Duncan's multiple range test was utilised to identify specific differences between sites and results indicated that:

- both sites Z1 and Z2 (ie. midstream sand bank sites) were generally depauperate in benthos, with site Z2 having the lowest number of benthic species and individuals of all Area 5 sites examined.

- site Z3 (ie. sand bank drop off) had a significantly greater diversity and abundance of other benthic fauna (ie. gastropods, nemerteans) than sites Z1 and Z2, and a significantly greater number of polychaetes species and individuals than site Z1. However, site Z3 had a significantly lower number of crustacean species and individuals than all other sites.

- site Z4 (ie. the shallow site adjacent to the proposed dredging area) had a significantly greater number of benthic species and individuals than all other sites sampled in Area 5. Site Z4 also had a significantly greater diversity and abundance of polychaetes and other benthic fauna (ie. gastropods, nemerteans) than the remaining three Area 5 sites.

Species composition

The Jaccard similarity index was used to examine differences in species composition between sites within Area 5. The similarity matrix (Table 3.17) indicates that sites Z1, Z2 and Z3 all had a relatively similar benthic fauna (average Jaccard value J = 0.29).

Comparisons between site Z4 and the other three Area 5 sites show a substantially lower similarity index value (average Jaccard value J = 0.10), indicating that site Z4 represents a different habitat type which supports a distinctly different and more abundant benthic fauna.

TABLE 3.17
SIMILARITY MATRIX
(WHERE 1 DENOTES MAXIMUM SIMILARITY)
FOR BENTHIC SPECIES WITHIN AREA 5 (DEC 1991 SURVEY)

SITE	SITE		
	Z2	Z3	Z4
Z1	0.29	0.27	0.12
Z2		0.32	0.10
Z3			0.07

Examination of the species occurrence data (see Appendix 21) indicated the following:

Polychaetes:
Shallow site Z4 was characterised by the exclusive occurrence of certain polychaete families (such as Family Capitellidae, F. Lumbrineridae, F. Terebellidae, F. Phyllodocidae and the nephtyid species *II-IV* of F. Nephtyidae).

Bivalves:
Mactridae sp. I was found across all four Area 5 sites, while *Bivalve spp. I* and *X* occurred only in the deeper midstream sites Z1, Z2 and Z3.

Crustaceans:
Certain crustacean species were characteristic of certain sites. The crustacean species *Amphipod sp. IV* and *Paguroidea sp. I* occurred only in the midstream sandbank sites Z1 and Z2, while *Amphipod spp. V* and *VII* occurred only in the shallow site Z4.

Other:
Nassariid gastropods were found exclusively at site Z4, while nemertean worms occurred predominantly in sites Z3 and Z4. Echinoids (sea urchins) were found only in the deeper midstream areas (sites Z2 and Z3).

Overview

The benthic communities at the three midstream sites within the proposed dredging area varied depending on the depth and hydrologic character of the site examined. Midstream sites Z1 and Z2, situated on top of a subtidal sandbank, had comparatively poor benthic communities. The top of the sandbank, which is subject to relatively high current velocities and scouring, had a coarse sedimentary character with highly mobile surface sediments and hence would appear to provide little opportunity for the accumulation of detrital matter. As a result benthic animals which subsist primarily upon nutrients and detritus associated with the sediment (such as deposit feeding polychaetes) were poorly represented. These observations were reflected in the limited and depauperate benthic communities present, comprised predominately of burrowing filter feeding forms (such as bivalves and highly adapted crustaceans such as *Amphipod sp. IV*).

The benthos occurring in site Z3, situated on the downstream slope of the sandbank, had an abundance and diversity intermediate between the sites on the top of the sandbank (sites Z1 and Z2) and the shallow foreshore site outside the limit of proposed dredging operations (site Z4). The area in which site Z3 was located forms a "sheltered" area, in that it is relatively protected from most of the scouring and shifting impetus of the currents. Site Z3 is thus likely to maintain stable surface sediments and accumulate detrital material. Accordingly, site Z3 supported a substantially greater diversity of deposit feeding animals (such as polychaetes) and their predators (such as nemerteans), than sites on top of the sandbank (Z1 and Z2).

Site Z4, the shallow subtidal foreshore site situated outside the limit of proposed dredging operations, had a significantly more diverse and rich benthic fauna compared to the sites sampled within the proposed dredging areas of Area 5. In general, the numbers of species and individuals found in site Z4 were at least three times as great as those from sites sampled from within the proposed dredge area. Shallow banks such as that of site Z4 have mostly stable substrates, low current velocities, and hence accumulate detritus which is a major food source for benthos. Such shallow foreshore banks and bays are highly productive biological areas.

Comparison with other lower Tweed estuary benthic surveys

The benthic communities found within the Area 5 sites during December 1991 generally had similar species composition and distribution patterns to the benthic communities found in the nearby shallow and channel sites sampled in the December 1990 lower Tweed estuary survey, although some minor differences in faunal compositions were noted (eg. the presence of some bivalve species not previously recorded in the lower Tweed estuary studies).

Results of previous seasonal comparisons between the December 1990 and other lower Tweed benthic surveys indicate that the lower estuary has a resident group of species that are common and present from summer through to winter. The comparative similarity of species compositions from the December 1991 Area 5 survey and the December 1990 benthic survey further validates such a finding.

Patterns of benthic abundance and diversity also displayed the same general principles as in other lower Tweed estuary surveys (December/January 1990/1991, March 1991, June 1991), namely:

- shallow banks and bays (such as site Z4), particularly those which experience low current velocities, support rich and diverse benthic communities.

- exposed midstream sandbank sites (such as Z1 and Z2) and channel sites subject to high current velocities generally have depauperate benthic communities with comparatively low numbers of species and individuals.

- midstream sites which have some degree of protection or shelter from high current velocities and scouring (eg. Site Z3, which is on the dropoff slope of a midstream sandbank) display benthic abundance and diversity patterns midway between the impoverished exposed midstream sites and the enriched sheltered shallow banks or bays. Such "semi-sheltered" sites have some degree of substrate stability and detrital accumulation and hence can support a moderate diversity and abundance of benthos.

Results of the present survey and comparisons with other lower Tweed benthic studies indicate that:

- the benthic fauna within the dredge Area 5 is typical of that in the lower Tweed estuary in terms of species composition, distribution and abundance.

- the abundance and diversity of benthos within the area proposed for dredging varies from low (main channel and top of midstream sandbank) to moderate (sheltered downstream dropoff of sandbank).

- areas outside the proposed dredging area, and fringing the mangroves/seagrass beds, are highly productive containing a diverse and rich benthic fauna.

3.12 ARCHAEOLOGICAL AND HERITAGE ASSESSMENT

3.12.1 Introduction

Archaeological background

The Tweed River estuary has been the subject of considerable archaeological research. Existing studies fall into a number of categories: General, Specific, Excavations, Anthropological and Ethnohistorical Studies (Figure 3.23). They were all relevant in varying degrees to the study by Piper (1980). Surveys relevant to the general Area 5 area are described under their nominated categories below. Also see PWD 1991(f).

General surveys

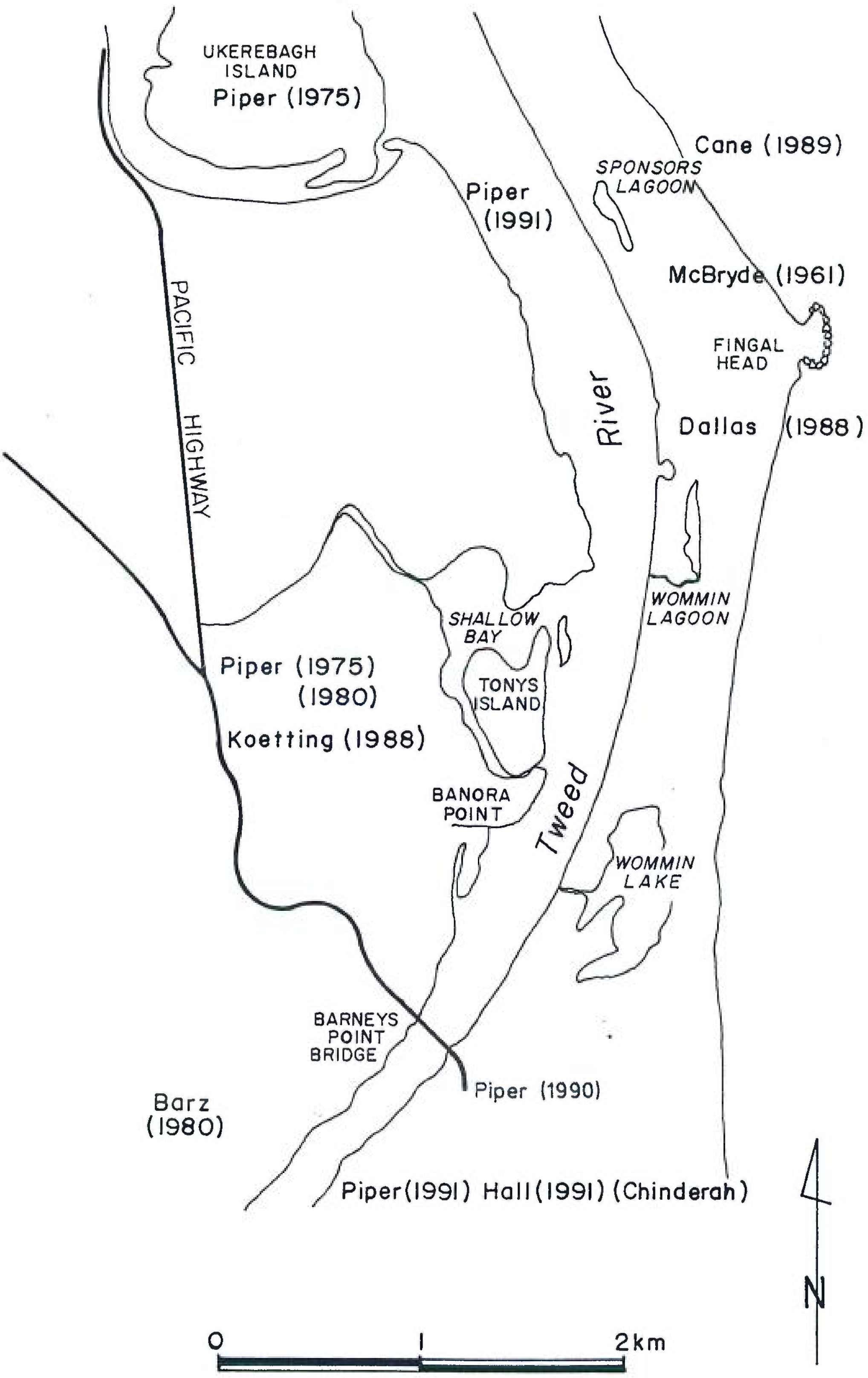
A general survey was conducted by McBryde (1961). She recorded sites on the Fingal Peninsula. Piper (1975) located, listed and assessed in general terms many sites in the estuary. These included bora rings, shell middens, quarry sites, open artefact and shell scatters and a large number of reports of single artefact finds.

Specific studies

- Piper (1980): records a list of sites for the NPWS above Barney's Point Bridge east of Terranora.

- Koettig (1988): provided a preliminary assessment, from site records only, with particular emphasis on the archaeological record at Fingal.

- Dallas (1988): prepared a Draft Report to Ocean Blue Resorts Pty Ltd assessing the archaeological evidence at Fingal in relation to the (then) proposed development at Fingal. Dallas visited the area, reviewed previous archaeological studies and concluded that no further survey within the proposed development site was warranted and recommended that an anthropological study of the Fingal Peninsula be conducted.



	Year	Type (see key below)
Mc Bryde	1961	AG
Piper	1975	AG/EH
Piper	1980	AS
Barz	1980	EX
Koettig	1988	AG
Dallas	1988	AS
Cane	1989	A
Piper	1990	AS
Hall	1991	AS
Piper (This Study)	1991	AS

KEY

AS	Archaeological - Specific
AG	Archaeological - General
EX	Excavations
A	Anthropoligical
EH	Ethnohistorical

Source: PWD (1991d)

LOCATIONS OF PREVIOUS ARCHAEOLOGICAL STUDIES IN AREA 5 AND SURROUNDS, LOWER TWEED ESTUARY

FIGURE 3.23

Further specific surveys for archaeological sites have been conducted by Piper (1990) which involved as assessment in the area of the proposed Chinderah bypass 1 km south east of Barney's Point Bridge. The study found that archaeological sites would not be affected by the proposed by-pass. Hall (1991) further assessed the Chinderah area west of the village in relation to the proposed by-pass and his results do not affect proposals relevant to this study.

Anthropological studies

Cane (1989) conducted a study of the Fingal Peninsula. He confirmed the strong links between the Aboriginal community and the Fingal Head/Peninsula area, and was able to define areas of significance on the Peninsula. These are areas of special importance as they represent strong links between the modern community and their historical and traditional past.

None of the sites identified in Cane (1989) are directly related to this proposal although the proposed stockpile site is subject to a land claim. Further detail is available in NSW Public Works (1991f), also see following sections.

Ethnohistorical background

Studies of surviving written records of Aboriginal lifestyle and culture have been made by McBryde (1974, 1978), Sullivan (1964, 1978) and Piper (1975). These studies attempted to examine Aboriginal society at the time of first European contact and subsequently, from the few written records of European observers.

Populations were considered dense on the coastal plains, no doubt reflecting the resource rich, marine, aquatic and forest food gathering potential. Opinions vary as to the manner of dispersement, from a semi settled pattern of settlement (Belshaw 1978), to one of seasonal movement between coast and foothills (McBryde 1978). Sullivan (1978) postulates a limited pattern of movement, between coast and river flats and adjacent high ground forests. Coleman (1980) suggests that movement was limited by the closeness of coastal tribal territories. Written observations suggested movement was only for ceremonial occasions, fighting and initiation, rather than seasonal food gathering purposes (Coleman 1980).

The aborigines of this study belonged to the Coodjingburra south of the Tweed River and the Moorung Moobar north of the River (Bray 1901).

Aboriginal consultations

From the outset the Aboriginal community have been involved in all NSW Public Works related studies in the lower Tweed estuary (see PWD 1991g). Discussions were held between NSW Public Works and the Tweed Byron Aboriginal Land Council between 1991 and 1993. From these discussions in 1991 an Archaeologist was nominated by the TBLALC to carry out a survey. It was agreed that a representative of the TBLALC participate in the field survey. This role was fulfilled by Mr Frank Krasna, Chairperson of the TBLALC, who subsequently participated in all of the field survey.

3.12.2 Field Investigation

Field investigation assessment criteria and methods are described in Appendix 13.

The results described here are those of Piper's (1991) survey.

Tweed River Eastern Bank

This section includes the river bank below Barney's Point Bridge to the southern breakwater of the Tweed River. It includes the Fingal Peninsular site, Fingal Head, Kerosene Bay and Letitia Spit. It is important to note that the modern bank of the Tweed River on its eastern side bears no resemblance to its original form. The modern bank is formed by training walls constructed in the 1890's. A great deal of the low lying areas behind these walls are the result of backfilling and sand pumping. From an archaeological point of view the modern eastern river banks are irrelevant.

No evidence for the presence of significant sites was obtained from the Fingal Peninsular site during the 1991 survey and previously in other studies. (PWD 1991f).

Tony's Island

A very small deposit of oyster shell was located with, no artificial material evident. The deposit is 25-30 cm below the surface covered by soil comprised of river silts appears to be only a single band, under dense littoral rainforest. The site appears to be only 4 m^2 in extent on higher ground (0-5M) above mud flats. There are several mounds which were assessed not to contain deposit on surface indications. The southern section of Tony's Island does have higher ground. Therefore the potential for sites is greater, due to its close proximity to potential food gathering zones of mudflats dissected by tidal creeks. Intensive investigation by Krasna and Piper failed to find any evidence of other sites. The ground cover however, consists of thick leaf and humus cover over a bed of river silts. Further more intensive investigation including core sampling may locate other buried sites. (Grid Reference Tweed Heads 1:25000 - 5464 7865).

3.13 SOCIO-ECONOMIC ENVIRONMENT

3.13.1 Existing Uses of the Lower Tweed Estuary Including Area 5.

Commercial fishery

The Tweed fishery has most recently been reviewed by McGowan (1989) in a report submitted to the NSW Public Works. Tweed Heads is considered to be a major fishing port and in 1985 had the fifth largest fishing fleet in the State of NSW. The fishing industry employs an estimated 250 people, either directly or indirectly, and contributes to the commercial fishery including the trawl fishery, the line and trap fishery and the ocean beach and estuary fishery.

Compared to the offshore fisheries, the ocean beach and estuary fishery is relatively small. In 1989 the ocean beach and estuary fishery supported about 24 full-time fishermen, twelve less than the figure for 1984 (McGowan 1989). Reductions in catches during the past 30 years have been reported by net operators and attributed to increasing numbers of fishermen (both commercial and recreational), loss of hauling grounds and the deterioration of habitats. Between 1930 and 1991, the area of seagrass within the lower Tweed estuary declined from approximately 200 hectares to 50 hectares, also see Section 3.9 and PWD (1991b). Estimations for the combined productivity of the trap and line fishery and ocean beach and estuary fishery are as follows:

- crustaceans - 50 tonnes/yr;
- fish - 260 tonnes/yr; and
- molluscs - 20 tonnes/yr (McGowan 1989).

Although no official data exists on the relative productivities of the two fisheries, the ocean beach and estuary fishery is thought to comprise 40% to 50% of the combined catch. McGowan (1989) notes that the aggregated value of the two fisheries is insufficient to support the present number of fishermen and suggests that perhaps many fishermen are only working on a part-time basis or, alternatively, that the estimated catches are inaccurate because of inadequate data.

Commercial estuary fishing involves either hauling (seining) or meshing (gill netting) depending on the species targeted and the characteristics of the river. Beaches, sand bank or spits with gradual slopes provide ideal sites for hauling while meshing is conducted in the main channels. Mullet, jewfish, flathead, black bream, silver bream, whiting and prawns (school prawns) are the predominant species (also see Section 3.11.1). The principal hauling grounds in the Tweed River are upstream of Barney's Point bridge although Tony's Bar is the most important area in the lower estuary and falls within Area 5 (PWD 1991b). Net fishermen are subject to a number of regulations including:

- prohibition on weekend fishing;
- restrictions on netting gear and techniques; and
- specific restrictions on certain areas.

Recreational fishing

The lower Tweed estuary is reportedly an excellent area of recreational fishing and attracts a large number of people particularly when specific fish are in season. The area is serviced by five public boat ramps. The ramp immediately below Barney's Point bridge falls within the proposed dredging area, while another ramp adjacent to Wommin Lagoon lies just outside Area 5. An additional private boat ramp provides river access for residents of the Banora Point Caravan Park.

The principal species caught by estuarine fishermen include whiting, flathead, jewfish, black bream, silver bream and mangrove jack. Pelagic species such as tailor are typically caught from the entrance training walls. Deep holes, particularly near the river mouth, are important fishing areas while sand banks, including Tony's Bar, are sources of yabbies for bait (PWD 1991b). A recent recreational study of the Lower Tweed Estuary (PWD 1991d) noted that fishing, both from the shore and from boats, was very popular within the area nominated for dredging.

Oyster farming

At present about ten to twelve oyster farmers operate in the lower Tweed estuary with most leases in the Terranora Broadwater (PWD 1991b). The nearest leases to the proposed dredging area are situated about one kilometre upstream of Barney's Point bridge near Chinderah Bay and downstream at the main arm entrance to Ukerebagh Passage, a distance of approximately 1.5 kilometres from the northern boundary of Area 5. The lease at Wommin Lake, previously held by Mr. Harrison, has reportedly been surrendered (*pers. comm.* Mr F. Kirkham). McGowan (1989) suggests that the combination of the oyster disease 'QX disease' and existing and future development of the river catchment, with a consequent increased incidence of pollution, is likely to place substantial pressure on the commercial viability of the oyster industry.

Water skiing and canoeing

Other water-based recreational activities which are conducted in Area 5 at regular intervals during each year include water skiing and canoeing (PWD 1991d).

Most water skiing occurs outside Area 5, south of Barney's Point Bridge, whilst a major annual canoeing event (marathon) includes Area 5 in the set course.

3.13.2 Community Attitudes Towards the Proposal

Commercial and recreational fishing

The initial intention was to interview all commercial fishermen with regards to the proposed dredging. However, this was later amended to include those fishermen who fished the area or who expressed a desire to comment on the proposed works. The attitudes of recreational fishermen were obtained by contacting representative of local fishing clubs. Although no oyster leases exist within Area 5, the owners of leases immediately downstream and upstream of the area were contacted. Additionally, the attitude of the local Fisheries Inspector to the proposed dredging was sought. Interviews were conducted during the period December 10 to January 9, 1991-92.

3.13.3 Attitudes of the Fishing Industry Toward the Proposed Dredging

During the course of the study, a number of issues were raised by members of the fishing industry either in relation to dredging operations generally or with regards to the specific proposal for Area 5. The issues that were identified included:

- shoal removal and channel improvement;
- habitat modification;
- water quality; and
- regulation of dredging activities.

Shoal removal and channel improvement

Commercial fishermen supported the dredge plan in so far as it proposed to remove the large shoal below Barney's Point Bridge and create a 100 metre wide channel adjacent and parallel to the eastern training wall. The shoal was generally acknowledged to be a navigation hazard and resulted in increased water velocities along the northern river bank which inhibits the regeneration of seagrass beds. The provision of a new channel was seen as a necessary step towards improving river access.

The three oyster farmers that were contacted fully supported the proposed dredging. Representatives from the three recreational fishing clubs at Tweed Heads differed in their familiarity with the proposal for dredging of the lower Tweed estuary. The Secretary of the Seagulls Fishing Club indicated that most of the members that he had spoken to fully supported the proposed works and felt that the sooner the dredging commenced the better (*pers. comm.* Mr Darby Raisin). The President of the Fishing Section attached to the Tweed Heads Rowing and Aquatic Club acknowledged that while he was aware of the recently completed River Management Plan for the lower Tweed estuary, he knew little about the proposal for dredging operations. Furthermore, the issue of dredging had not yet been raised in any of the club meetings (*pers. comm.* Mr Michael Quin).

Habitat modification

Many of the commercial fishermen recalled the existence of extensive seagrass beds within the area of proposed works which have since been destroyed by previous dredging activities (see Section 3.10) For example, the reclamation of land for the Banora Point Caravan Park resulted in the loss of significant areas of seagrass on the northern bank of the river near Tims Island. A submission to the NSW Public Works prepared by Mr Joe McLeod and his son concerning the River Management Plan provided ample historical evidence of the reduced distribution of seagrasses within the lower estuary.

The proposed works would result in the removal of seagrass between Tony's Island and Tony's Bar for the purpose of increasing channel depth and restricting access to the Bar. Dredging of the northern end of Tony's Bar would also involve the loss of some seagrass beds. Seagrass that is slowly regenerating upstream of Tims Island may be affected by the proposal to create a broad shallow area for the purpose of seagrass rehabilitation.

Commercial fishermen were divided over the acceptability of the proposed dredging adjacent to Tony's Bar. Some supported the plan because of the wider benefits of work would provide or felt that the loss of a small area of seagrass would have negligible impact on the fishery. It was suggested that the existing channel between the Bar and the shore should be extended further into Shallow Bay (*pers. comm.* Mr John Higgins). On the other hand, some fishermen were adamant that no dredging should occur in any of the shallows associated with the western bank of the river. The removal of the northern end of Tony's Bar was regarded as unnecessary by one fisherman since the width and depth of the channel was already sufficient (*pers. comm.* Mr Fred Barton). Mr Clyde Mossley (*pers. comm.*) expressed the viewpoint that water circulation in Shallow Bay would not be improved by an enlargement of the entrance at Tony's Bar. He proposed that the northern end of the Bar should be in fact be extended into the river to restore it to its previous size and provide a greater area of shallows.

The proposed creation of extensive shallows adjacent to the western bank for the purpose of facilitating seagrass regeneration was well received by commercial fishermen. Any action which resulted in the expansion of seagrass habitat was regarded as a positive step towards improving the productivity of the local fishery. Some individuals were of the opinion that the establishment of new seagrass beds was adequate compensation for the loss of habitat associated with Tony's Bar. However, several fishermen questioned the viability of the regeneration plan. In their view, pure sand pumped from the main channel onto the bank was unlikely to provide a suitable substrate for seagrass propagation. Mr Clyde Mossley (*pers. comm.*) suggested that the construction of a small spur wall on the western bank at Barneys Point Bridge would deflect the main flow of the river and create a backwash zone in which reduced water velocities and siltation would favour the growth of seagrass. Mr Joe McLeod (*pers. comm.*) proposed a similar construction at Rocky Point.

Deep holes

The proposed Dredge Plan contains a further proposal for enhancing fisheries habitat through the creation of several deep holes within the main channel. The proposal was not received enthusiastically by all commercial fishermen, probably because of the fishermen's experience with previous dredging activities. Past dredging of the river in some locations had created unnecessarily deep holes in which water quality had declined due to stratification. Some concern existed that similar conditions might be duplicated. The retention of shallows and sloping banks were considered to be more important for the fishermen who hauled in the area. A number of other commercial fishermen who supported the dredge plan considered the concept of establishing deep holes to have some merit. The Fisheries Inspector for the local area supported the proposal, acknowledging that the diversification of habitat would be beneficial to local fishing (*pers. comm.* Mr Steve Brinsley).

Habitat provision for the Little Tern (Sterna albiforns)

The proposal to create a permanent high tide roosting area on Tony's Bar for estuarine birds, including the Little Tern (*Sterna albifrons*, see Section 3.11.4), was viewed favourably by a number of individuals. Some expressed total support for the dredge plan including the concepts for bird habitat improvement. It was suggested that it might be necessary to construct a rock revetment wall in order to prevent sand movement initiated by tidal flow (*pers. comm.* Mr Pat Walsh).

Several commercial fishermen considered the proposal to be unacceptable if it involved the loss of seagrass associated with any proposed deepening of the channel between Tony's Island and Tony's Bar, which may be considered necessary in order to restrict access to the new roosting area.

Midge control

The proposed works for Tony's Bar have a second major purpose besides the provision of habitat for estuarine birds. The removal of some intertidal areas will substantially reduce the breeding area for biting midges which affect the residents of nearby Banora Point (*pers. comm.* Mr Clive Easton, Entomologist, Tweed Council, PWD 1991b). Overall, the control of midges was regarded as a worthwhile endeavour, although once again some commercial fishermen were opposed to any modification of Tony's Bar. It was suggested that an increase in the number of birds frequenting the area and consequent increase in bird droppings would aggravate the midge problem. Furthermore, midge larvae that occurred in intertidal areas were considered to be an important component in the diet of some commercial fish species (*pers. comm.* Mr Clyde McLeod).

Water quality

Comments on water quality were made by both commercial fishermen and oyster farmers during the course of the consultations. Some of the fishermen who supported the notional dredge plan did not voice any concern about the possible deleterious impacts of dredging on the water quality of the Tweed River. The creation of very deep holes as a result of poor dredging practices was criticised because they may contribute to declines in water quality (*pers. comm.* Mr Donald Mossley).

The operator of the oyster lease immediately above Area 5 supported the notional dredge plan and stated that water quality within the river system would be improved as a result of the proposed works (*pers. comm.* Mr Len Perandis). Support was also forthcoming from the oyster farmer who operates a lease near Ukerebagh Passage (*pers. comm.* Mr Dave

Schulz). It was suggested that the effect of dredging on the oyster leases was dependent upon the amount of silt released during the dredging operations.

Regulation of dredging activities

Past dredging within the Tweed River has resulted in the destruction of large areas of seagrass, an action that has not gone unnoticed by commercial fishermen. Other criticisms of dredging included the complaint that dredge operators had gone beyond the limits of their lease and that the river bed had been 'pot holed'. The reclamation of land for the Banora Point Caravan Park and the present dredging in Cobaki Broadwater were frequently cited as examples of uncontrolled and damaging dredging operations. The proposal to conduct further dredging aroused a degree of scepticism in some commercial fishermen about the manner in which the operation would be conducted. It was suggested that if the proposed dredging could not be conducted in a manner which avoided the formation of pot holes, then it should not proceed (*pers. comm.* Mr Donald Mossley).

Pattern and extent of commercial fishing

According to the local Fisheries Inspector, very little commercial fishing occurs within the lower Tweed estuary due to the high tidal flows and the existence of recreational boating and skiing. Shallow Bay and the downstream side of Tony's Bar are the most important areas for the commercial fishing that does occur within Area 5. The Bar is also an important location for recreational fishermen (*pers. comm.* Mr Steve Brinsley).

Mr Jerry Bobeldyk (*pers. comm.*) indicated that he fished both above and below Barneys Point Bridge depending on river flows. However, the area of proposed works was generally considered to be of little commercial value. One of the fishermen who were contacted fished entirely in section of river from Barneys Point Bridge to Terranora Inlet during the 1940s and 1950s, however, in recent years he had caught relatively few fish from the area (*pers. comm.* Mr Joe McLeod). The loss of substantial areas of seagrass during the years was frequently citied as the cause of declining fish stocks.

The western shore of the river in Area 5 is regarded by some fishermen to be fairly productive. Mr John Higgins (*pers. comm.*), who on average fishes in the area for a period of one and half weeks each month, stated that the shallow banks were one of the best whiting grounds in the area. The shallows in front of the caravan park and near Tims Island have been identified as being important fish nurseries (*pers. comm.* Mr Fred Barton) and for catches of sea mullet (*pers. comm* Mr Clyde Mossley). Shallow Bay is reportedly used by commercial fishermen about five nights per week (*pers. comm.* Mr Clyde

Mossley). Mullet and flathead were the principal species caught in the Bay according to Mr Pat Walsh (*pers. comm.*).

Suggested river improvement works

As a result of discussions with commercial fishermen, suggestions for two types of river improvement works were provided. Mr John Higgins (*pers. comm.*) suggested that dredging could benefit commercial fishermen by creating shallow banks with a gradient of 1:6 which would assist in hauling operations. A proposal for the construction of a spur wall at Rocky Point and Barneys Point Bridge was received from Mr Joe McLeod (*pers. comm.*) and Mr Clyde Mossley (*pers. comm.*) respectively. The purpose of walls were to deflect river flows and create a backwash zone that would facilitate seagrass regeneration as a result of reduced water velocities and siltation.

3.14 VISUAL ASSESSMENT

3.14.1 Introduction and Methodology

The lower Tweed estuary River Management Plan (1991) incorporated a visual assessment of the land/water interface along the foreshores of the study area (see PWD 1991f). Assessment of the visual quality of an area or region has become accepted as an integral part of the overall planning process in association with social, economic and environmental concerns.

The purpose of quantifying the visual quality of the lower Tweed estuary foreshores including Area 5, is to highlight the importance of the visual scene in the consideration of foreshore development.

The method used to determine visual quality at the land/water interface along the lower Tweed estuary was based on a modified version of the techniques used in MSB (1989). An outline of these techniques and the assessment carried out for Area 5, is presented in Appendix 22.

3.14.2 Results of Visual Analysis

The assessment of the visual quality of the foreshores of Area 5 revealed that the majority of the foreshore achieved the rating "high" visual quality class (for details of visual analysis see Appendix 22). The proportional length of foreshore covered by each classification of visual quality is shown in Table 3.18.

TABLE 3.18
LENGTH OF LOWER TWEED RIVER FORESHORE IN VISUAL QUALITY UNITS

Map No.	Highest	High	Medium-High	Medium	Medium-Low	Low	Total
Area 5	0	9,965	0	357	186	0	10,506
Total	18,172	52,011	2,160	12,852	2,089	563	87,845
%	0	19.2	0	2.8	8.9	0	12.0

Generally, the main landscape elements of Area 5 are landform/waterform, vegetation and water's edge. Notable features in the visual quality assessment include:

- Lands mainly fronted by seawalls, rubble or natural banks or occasional beaches and having minimal waterfront development or areas of similar status having relatively natural foreshore with close residential hinterland development, but again having minimal waterfront development.

- Lands with continuous high quality bushland, landscaped or topographic feature on the foreshores and slopes with unobtrusive or nil commercial/industrial, residential or institutional development on the slopes or hinterland beyond and with nil to minimal waterfront development.

- Small areas of highly developed waterfront land with minimal waterfront structures a small area with dominant structures such as the superstructure of bridges.

Very little of Area 5 is particularly visible eg. as seen from the Pacific Highway and from lookouts such as the Razorback Lookout in Tweed heads. However, although few areas of Area 5 are highly visible from main roads, some areas visible from recreation points such as Coolangatta-Tweed Heads Golf Course are important.

4.0 ENVIRONMENTAL IMPACT ASSESSMENT

4.1 TIDAL HYDRAULIC IMPACTS

4.1.1 Model Boundary Conditions

Model tests to assess impacts on the tidal regime were undertaken for two ocean boundary tide range conditions as adopted for previous evaluations on the Tweed River (Oceanics 1989 a). The larger spring tide has a maximum ocean range of 1.7 m, with the mean spring tide having maximum ocean range of about 1.3 m. For the purpose of this report, these tides have been referred to as 'spring' and 'neap' tides respectively. Each simulation commenced several days prior to output of results to ensure correct representation of the tidal conditions in areas such as the broadwaters which tend to experience a 'pumping up' effect.

4.1.2 Analysis Results

Appropriate modifications were made to tide model geometries to simulate the Area 5 Dredge Plan, with the effects of the presently approved future dredging works upstream of Barneys Point Bridge also shown. The impacts of these dredging works on the tidal regime are presented in this report as:

- longitudinal gradient plot of the maximum and minimum tide levels for the existing and as-dredged situations

- tabulated maximum and minimum tide levels at various locations along the river (Table 4.1)

- longitudinal plots of tidal prism for the existing and as-dredged situations

These plotted model results are presented respectively in Figures 4.1 and 4.2. They indicate a slight (4 %) increase in the tidal range upstream of Area 5, and a corresponding increase in tidal prism through the lower reaches of the river. Near the river mouth this increase in flow (and tidal prism) is about 2 %.

IMPACT ON TIDAL LEVELS
MEAN SPRING TIDE

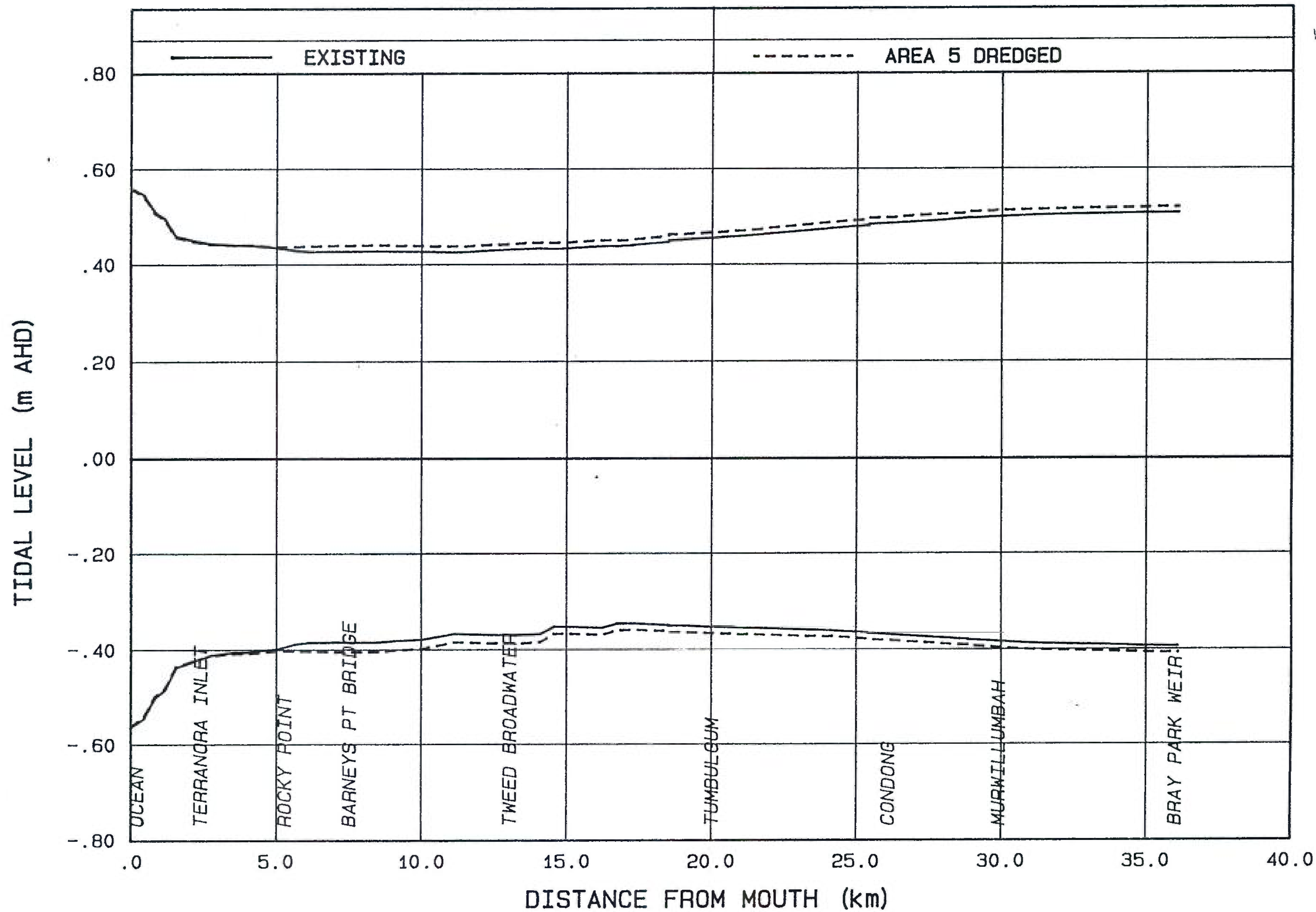


FIGURE 4.1

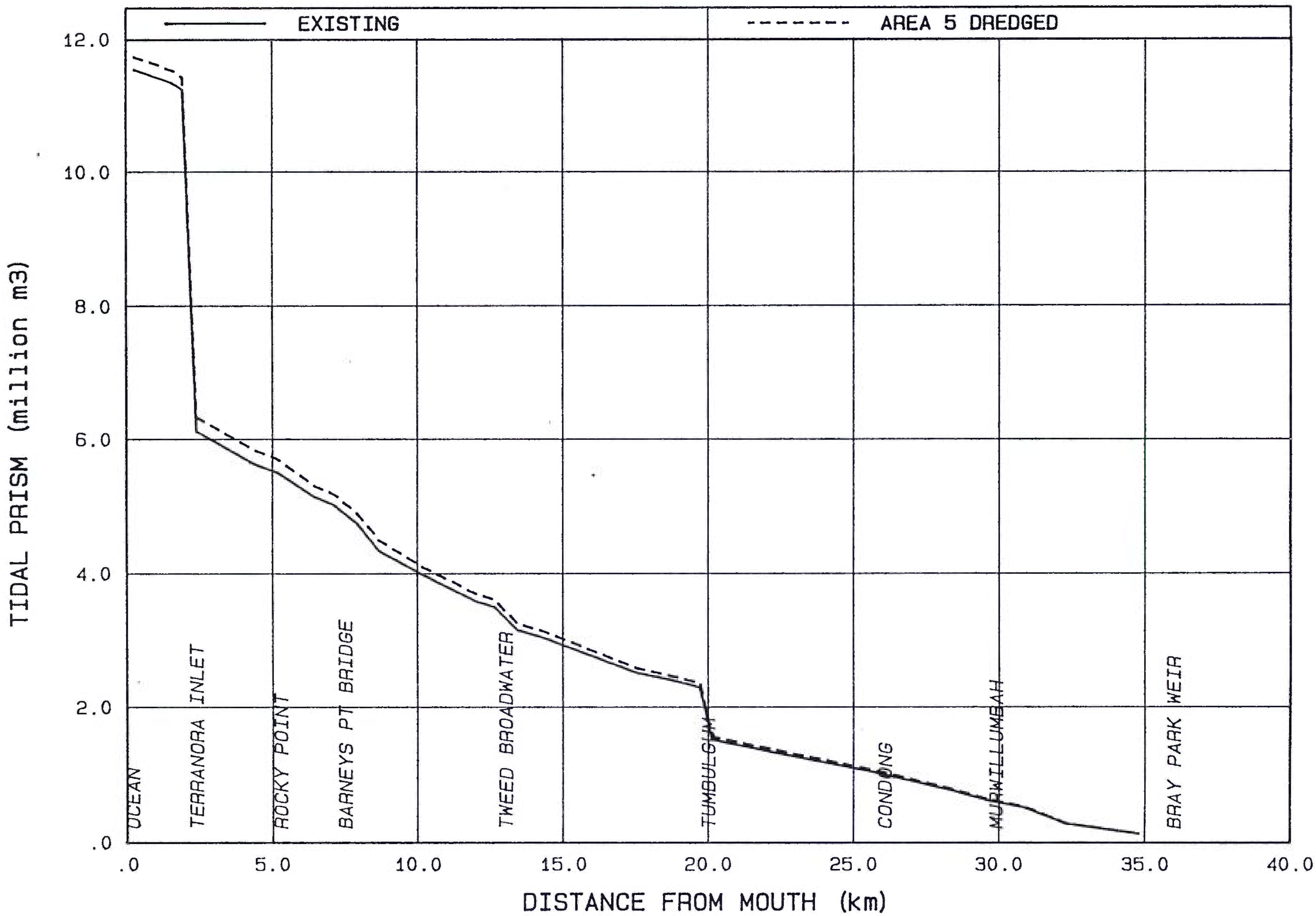


FIGURE 4.2

IMPACT ON TIDAL PRISM
MEAN SPRING TIDE

TABLE 4.1
IMPACTS ON TIDAL LEVELS

Node	Location	High Water Level		Low Water Level	
		Existing	Dredged	Existing	Dredged
7	Terranora Inlet	.46	.46	-.44	-.44
16	Fingal	.44	.44	-.41	-.41
18	Rocky Point	.44	.44	-.40	-.40
24	Barneys Pt Bridge	.43	.44	-.38	-.40
29	Chinderah	.43	.44	-.38	-.40
33	Dodds Island	.43	.44	-.38	-.40
36	Terranora Broadwater	.43	.44	-.37	-.39
39	Stotts Island	.43	.45	-.37	-.38
43	Tumbulgum	.45	.46	-.35	-.36
48	Condong	.48	.49	-.37	-.38
52	Murwillumbah	.50	.51	-.38	-.39
55	Murwillumbah	.50	.51	-.38	-.39

4.2 FLOODING IMPACTS

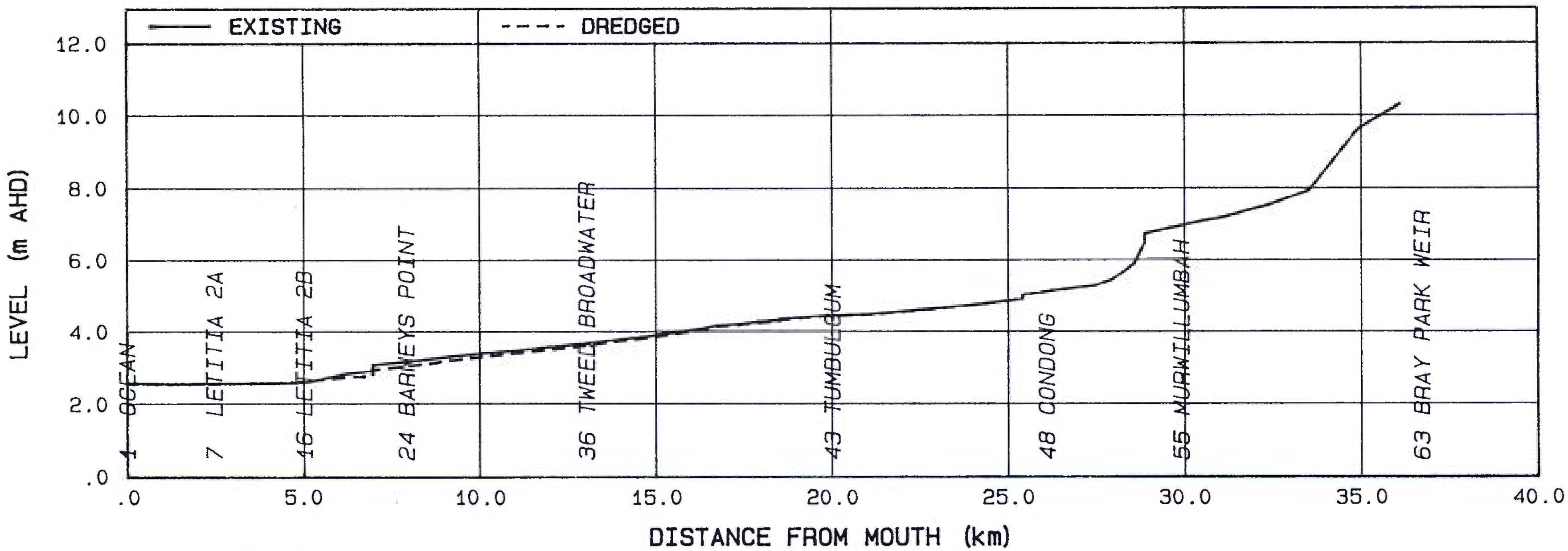
As outlined in Sections 3.3 and 3.4 the updated, calibrated and verified ESTRY numerical model has been utilised to assess the possible impact of the proposed dredging in Area 5 on the design flood processes of the river system.

A number of design flood and ocean tailwater scenarios have been tested. These are:

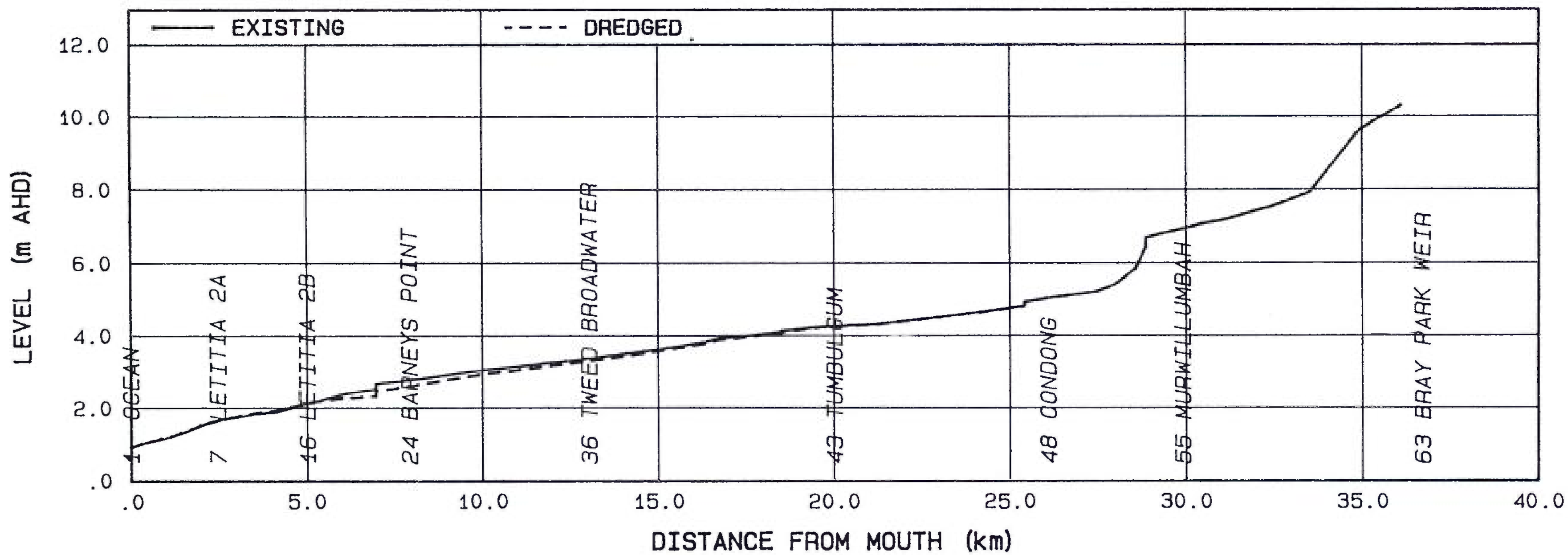
1%AEP Flood : high tailwater
1%AEP Flood : low tailwater
5%AEP Flood : high tailwater
5%AEP Flood : low tailwater

Details of the rainfall and catchment runoff inflows to the model for these design flood cases are outlined in earlier studies (Oceanics Australia 1989 d). The high tailwater incorporates a storm surge and tide with the peak storm tide of 2.6 m AHD coinciding with the peak rainfall in the catchments. Low tailwater has been adopted as a mean spring tide.

MAXIMUM FLOOD LEVELS
1% DESIGN FLOOD



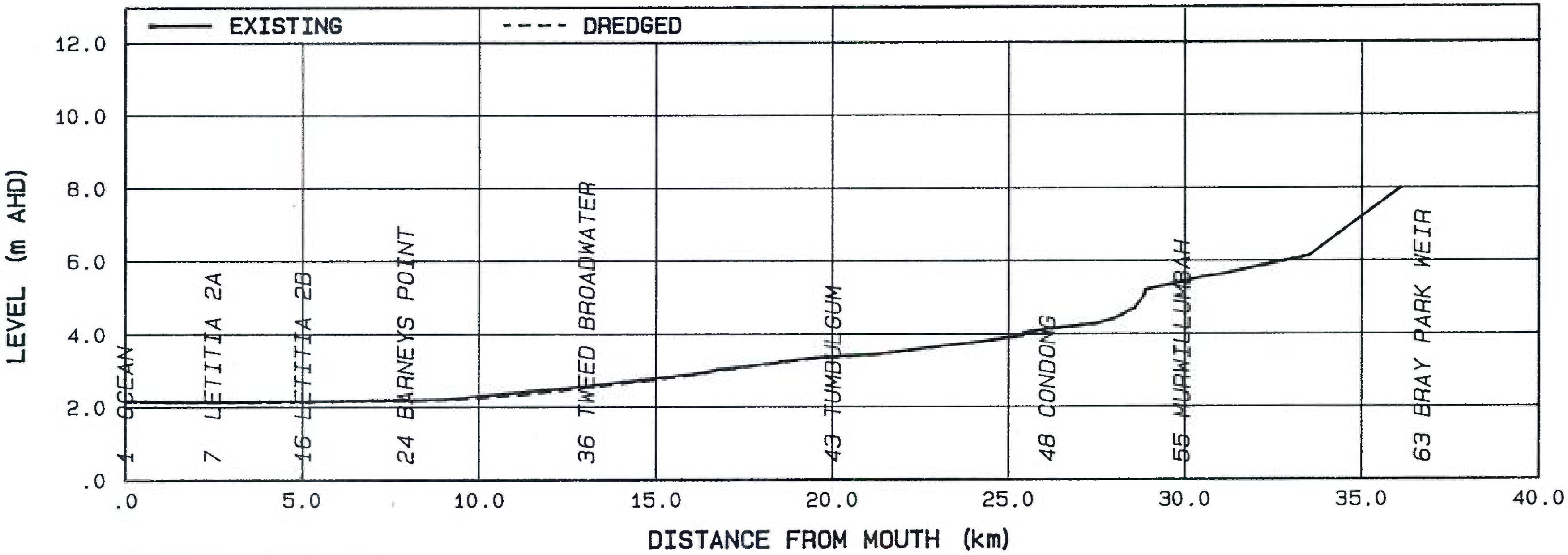
HIGH TAILWATER



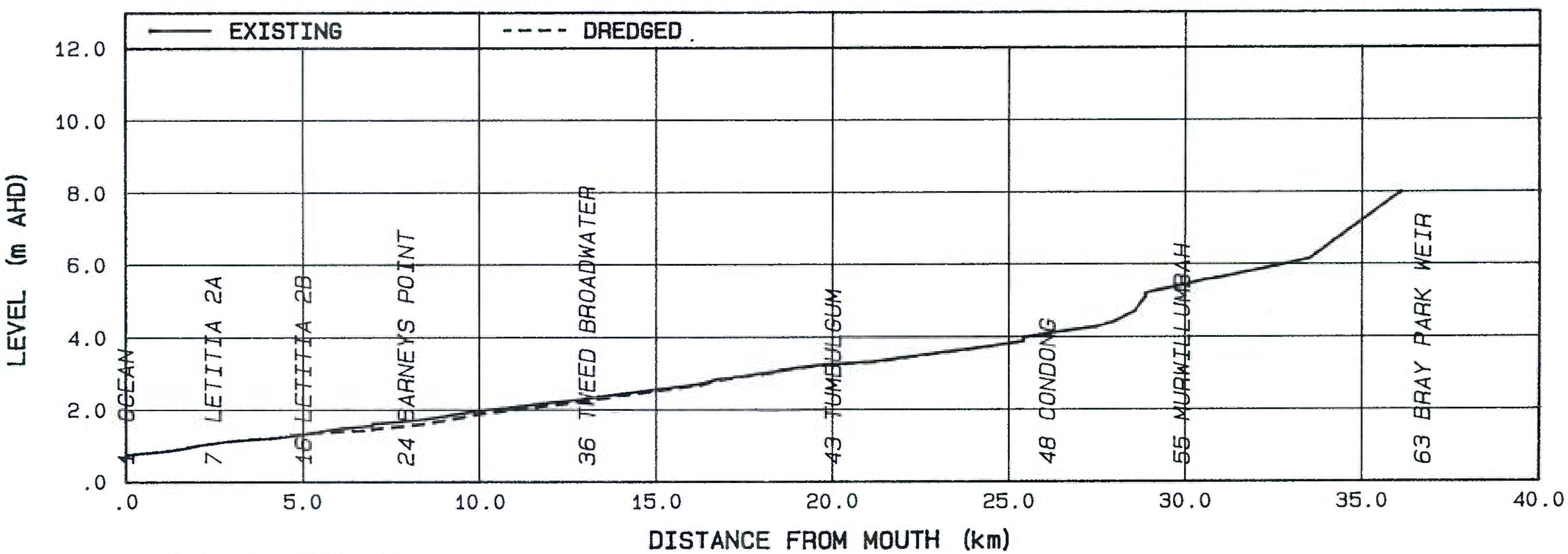
LOW TAILWATER

FIGURE
4. 3(a)

MAXIMUM FLOOD LEVELS
5% DESIGN FLOOD

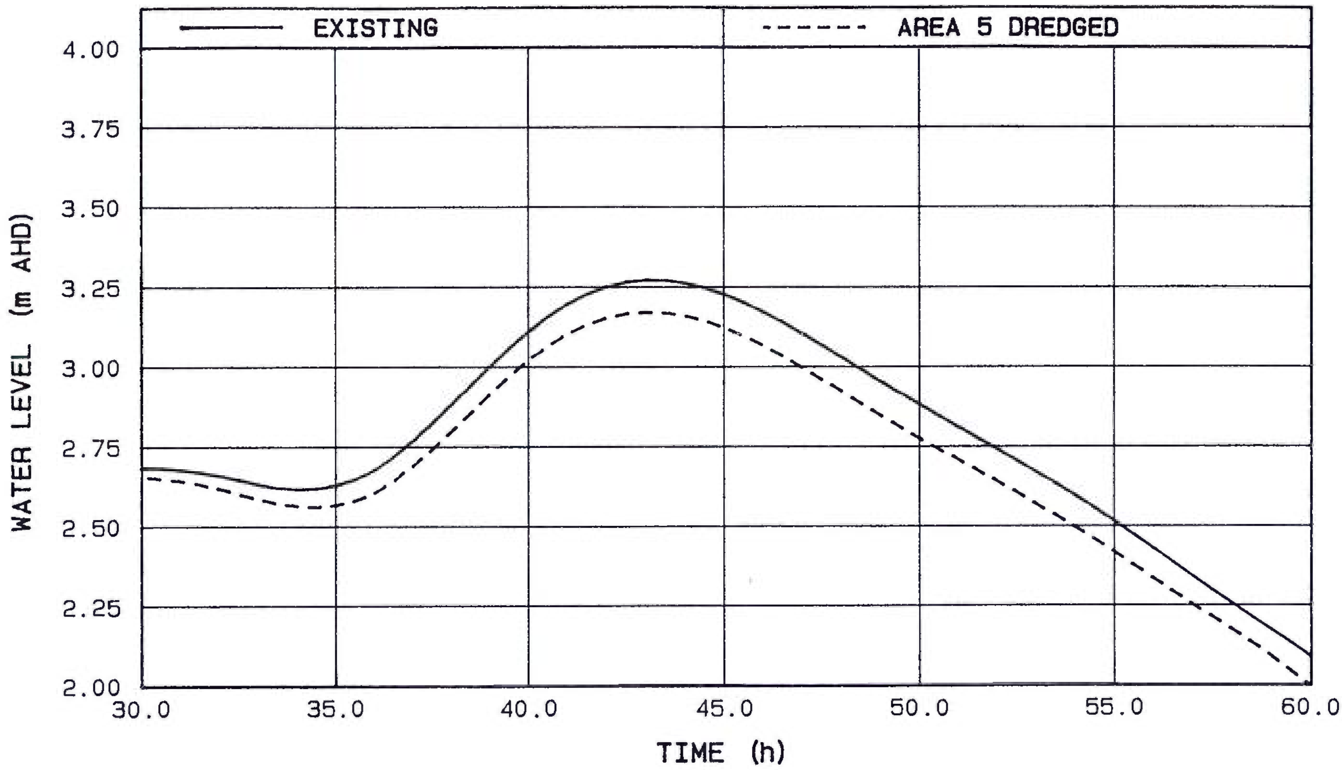


HIGH TAILWATER

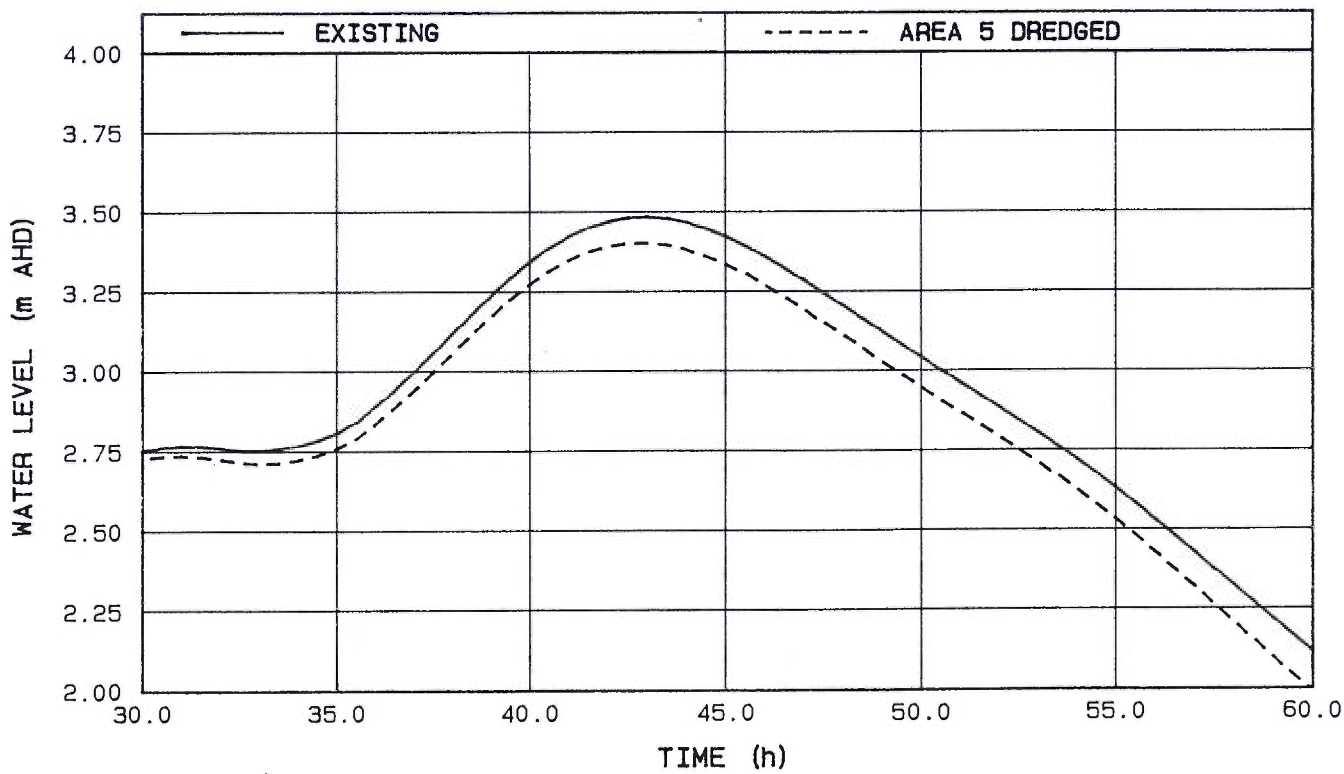


LOW TAILWATER

FIGURE 4.3(b)



CHINDERAH (NODE 220)



DODDS ISLAND (NODE 34)

FLOOD LEVELS
1% DESIGN FLOOD

FIGURE
4. 4

The results of the flood impact assessments are illustrated in Figure 4.3 in terms of longitudinal flood peak profiles along the main arm of the river, and Table 4.2(a)-(b) in terms of levels at specific locations. It can be seen that penetration of the storm tide dominates peak levels in the lower reaches for the high tailwater cases, and these do not alter significantly. There are indiscernible effects on peak levels in the Terranora Arm. There is a reduction in peak flood levels in the river upstream of Barneys Point Bridge, and a slight increase immediately downstream of the dredging at Fingal.

The reduction in peak flood levels in the river due to works associated with the proposed dredging is significant (about 15cm) at Barneys Point Bridge and diminishes with distance upstream. At Chinderah the reduction is about 8 - 12 cm for the 1% flood and up to 13 cm for the 5% flood. This benefit reduces to 5-7 cm at Stotts Island and less than 3 cm upstream of Tumbulgum.

The results presented in Figure 4.4 show a range of assessed impacts on levels and flows in terms of time through the 1% design flood event (high tailwater) on the floodplain at Chinderah and in the river near Dodds Island. It can be seen that peak flood levels on the floodplain are reduced by some 8-12 cm. The duration of inundation at the peak of the flood is reduced significantly, with less benefit at lower levels.

Although flooding of stockpile site 5 is expected to occur, this would persist for relatively short durations of two to three days this would be unlikely to result in any significant damage to the stockpile 5. Damage could occur to bund walling and silting of the settlement ponds but these would be readily rectified.

TABLE 4.2(a)

IMPACTS ON 1% AEP DESIGN FLOOD LEVELS FLOOD LEVEL (m AHD)

Node	Location	High Tailwater		Low Tailwater	
		Existing	Dredged	Existing	Dredged
7	Terranora Inlet	2.55	2.54	1.34	1.36
16	Fingal	2.57	2.57	1.89	1.91
24	Barneys Pt Bridge	3.08	2.94	2.66	2.48
29	Chinderah (river)	3.23	3.11	2.84	2.68
220	Chinderah	3.27	3.17	2.93	2.81
33	Dodds Island	3.39	3.30	3.05	2.94
36	Terranora Broadwater	3.60	3.53	3.29	3.21
39	Stotts Island	3.80	3.74	3.51	3.44
43	Tumbulgum	4.41	4.39	4.21	4.20
48	Condong	4.92	4.91	4.82	4.82
52	Murwillumbah	5.89	5.89	5.86	5.85
55	Murwillumbah	6.82	6.82	6.80	6.80

TABLE 4.2(b)

IMPACTS ON 5% AEP DESIGN FLOOD LEVELS FLOOD LEVEL (m AHD)

Node	Location	High Tailwater		Low Tailwater	
		Existing	Dredged	Existing	Dredged
7	Terranora Inlet	2.14	2.14	0.91	0.92
16	Fingal	2.15	2.15	1.20	1.21
24	Barneys Pt Bridge	2.19	2.18	1.62	1,48
29	Chinderah (river)	2.20	2.19	1.75	1.62
220	Chinderah	2.20	2.11	1.76	1.64
226	Chinderah				
33	Dodds Island	2.32	2.26	1.99	1.89
36	Terranora Broadwater	2.51	2.46	2.24	2.17
39	Stotts Island	2.70	2.66	2.45	2.40
43	Tumbulgum	3.34	3.33	3.21	3.19
48	Condong	3.96	3.96	3.89	3.89
52	Murwillumbah	4.71	4.71	4.71	4.71
55	Murwillumbah	5.29	5.29	5.30	5.30

4.3 SEDIMENT TRANSPORT AND BANK STABILITY

As an indicator of the dredging impacts, sediment transport calculations have been for the following two scenarios:

- the 5%AEP flood with low tailwater, and
- a mean spring ocean tide.

The results have been calculated for those reaches of the river upstream and downstream of Area 5 as:-

- the cumulative transport for the flood event, and
- the cumulative (net) tidal cycle transport expressed as an equivalent annual transport (700 tidal cycles).

It is emphasised that the calculation of sediment transport due to floods and tides in natural rivers is extremely complex. Influences of variable sediment particle size, channel bed form, tidal state and channel configuration have a significant bearing on the accuracy of the calculated results.

Calculated sediment transport rates depend acutely on flow velocity. As a result, the transport rates are sensitive to:-

- changes in flow (discharge) rates.
- dredging changes to channel flow areas.

Hence, the results shown should be regarded as indicative only, for the purpose of determining the relative impacts of the sand extraction works on local bank stability as discussed in Section 4.3.3. Further details of sand transport impacts relating specifically to effects on the rate of beach sand infeed to the Lower Estuary and resulting implications for the beach system are presented in Section 4.3.4.

4.3.1 Flood-related Sand Transport

The calculated flood transport rates are shown in Table 4.3.

TABLE 4.3
FLOOD SEDIMENT TRANSPORT - MAIN ARM 5% AEP FLOOD - LOW TAILWATER

Channel No.	Distance from Mouth (km)	Transport (thousand m^3)		Maximum Transport Rate (m^3/hr)		
		Existing	Area 5 Dredged	Existing	Area 5 Dredged	% Change
22/922	3.5	11.8	12.2	579	595	+2.8
27	4.3	2.2	2.3	129	134	+3.9
31	5.0	27.8	28.8	1278	1314	+2.8
37	5.7	53.9	10.3	2106	472	*
40	6.2	36.5	5.0	1506	250	*
44	6.8	12.2	1.3	528	74	*
48	7.7	10.1	13.2	398	542	+36.2
52	8.4	18.8	23.2	744	936	+25.8
53	9.1	38.1	48.0	1320	1698	+28.6
57	9.9	61.7	76.3	2082	2610	+25.4
60/966	10.9	21.5	27.5	721	907	+25.8
62	12.2	27.9	32.7	1020	1194	+17.1
66	13.5	39.2	45.4	1398	1626	+16.3

Note: (i) * Indicates dredged channel as part of the Dredge Plan.

The key indications from these results are:

- the major impact is caused by the dredging upstream of Barneys Point Bridge. The Area 5 dredging has only a minor incremental effect in most areas, with most change occurring within the dredging area itself.

- Transport rates through the dredged area are reduced substantially.

The dredged area will act to trap fluvial sediments which are transported toward the mouth. The historical and recent past behaviour of net movement of sediment within the river system and exchange of sands with the ocean beach system is complex and only partly understood. There is geological evidence that the lower reaches of the river (below Murwillumbah) are accumulating sediment in the long term, and it has been suggested that the net supply of fluvial sediment to the coast is negligible. River works over the past century would have altered the pre-existing natural river sediment processes.

The overall impact on flood-related sedimentation processes will be:

- induced scour of the channels both upstream and downstream of the excavated areas, and some infilling of the upstream dredged sections over time

- a slight increase in the flood-related movement of sand out of the river through the mouth

4.3.2 Tide-related Sand Transport

Tide-related sand transport rates per year are shown in Table 4.4.

TABLE 4.4
TIDAL SEDIMENT TRANSPORT - MAIN ARM MEAN SPRING TIDE

CHANNEL NO.	DISTANCE FROM MOUTH (km)	NET TRANSPORT (thousand m^3 per year)		PEAK TRANSPORT RATE (m^3/hr)	
		Existing	Area 5 Dredged	Existing	Area 5 Dredged
22	3.5	270	318	+0.10	+0.16
31	5.0	446	409	+1.01	+1.32
36/37	5.7	2906	-14	+5.32	-0.04
40	6.2	228	0*	+1.22	0*
44	6.8	-15	0*	-0.04	0*
48	7.7	-9	-14	-0.02	-0.03
53	9.1	-3	+63	-0.15	-0.22
62	12.2	-6	-12	-0.01	-0.02
66	13.5	-13	-26	-0.02	-0.03

Note: (i) * Indicates dredged channel as part of the Dredge Plan

(ii) Transport rates are net per tidal cycle times 700 tides per year (+ve downstream).

The key indications from these results are:

- The dredging will increase the peak sediment transport rates at all locations in the main arm of the Lower Estuary region

- Tide-related sand transport will be effectively reduced to zero or negligibly low rates in the dredged areas in Area 5

- The Area 5 dredging causes a slight incremental increase in transport through the Chinderah reach where bank erosion problems are evident

- The dredging will generally tend to increase the net sediment transport in the upstream direction

4.3.3 Impacts on Bed and Bank Stability

Dredging works associated with Area 5 dredging will have the effect of increasing the tidal range throughout the more upstream parts of the Tweed River. Associated with this increase, there will be a slight increase in tidal velocities and, potentially, sediment transport rates in undredged sections of the river. In such areas which may presently be experiencing bank erosion, these increases may exacerbate the existing problems.

There will also be an increase in flood-related velocities and sediment transport rates particularly in the area immediately upstream of Area 5. In the context of the tidal and flood hydraulic impacts as described in Sections 4.1 and 4.2, the only area in which bank stability might potentially be affected by the Area 5 dredging is the unstable southern embankment at Chinderah.

This situation is similar to that which exists for dredge Areas B & C (upstream of Barneys Pt Bridge), where the dredging within B & C may exacerbate the bank erosion problem immediately upstream. In that case, a monitoring program was established to allow changes in the bank profiles, over time to be assessed. Further, the proponents are required to provide assurance that if bank stability is affected then rock armour will be installed along the banks. These were conditions of consent to the dredging.

It is appropriate that such an approach be taken with the subject dredging works in Area 5.

It should be noted that the approved dredging in Areas B & C will substantially ease the potential for any Area 5 impact. If dredging in the channel adjacent to the eroding banks could be co-ordinated with the Area 5 dredging then it is considered that the Area 5 dredging would have negligible effect on any banks.

4.3.4 Beach Sand Infeed at Entrance

The physical processes involved in the transport of sand into and from the Lower Estuary associated with tide, flood and wave influences are extremely complex. Comprehensive simulation of Lower Estuary siltation over future longer term as a function of those fundamental processes to assess the impacts of the works is not practicable. In view of this, a longer term (average annual) net process method of assessment of Lower Estuary siltation has been evolved. This provides for the sand transport to and from that area as follows, based on the situation in which no further entrance improvement works are undertaken.

(a) **Beach Sand Infeed**

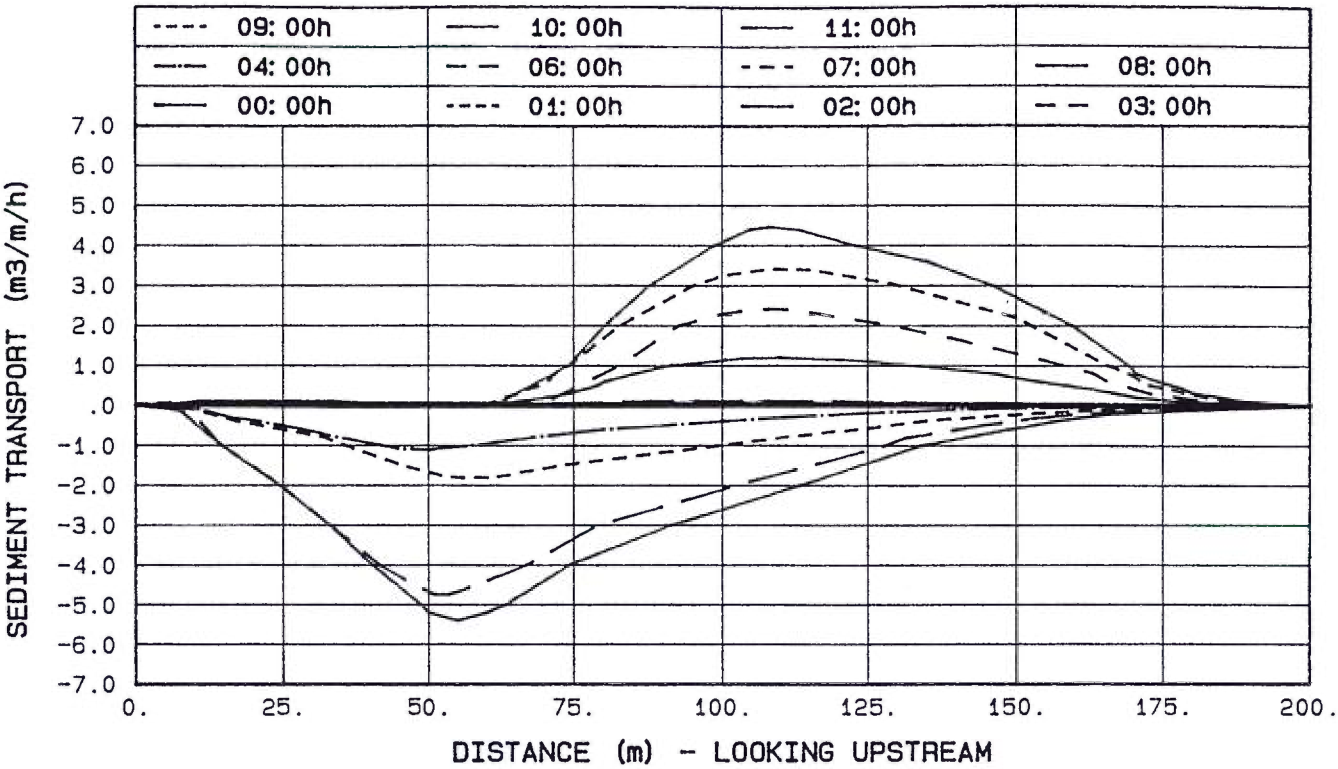
The annual net beach sand infeed is driven primarily by the tidal flow characteristics and will continue at a progressively decreasing rate until the Lower Estuary is filled to its equilibrium condition. It can be defined as a function of the degree of Lower Estuary siltation, expressed in terms of the quantity of infilling of the dredged area since 1975. The net infeed rate is dependent on the difference from the regime equilibrium condition, adopted as approximately the 1960 surveyed configuration, and the tidal hydraulics which can vary with the extent of river dredging and Lower Estuary siltation.

Analysis of Figure 3.12 indicates the following approximate relationship for the existing situation without further upstream dredging:

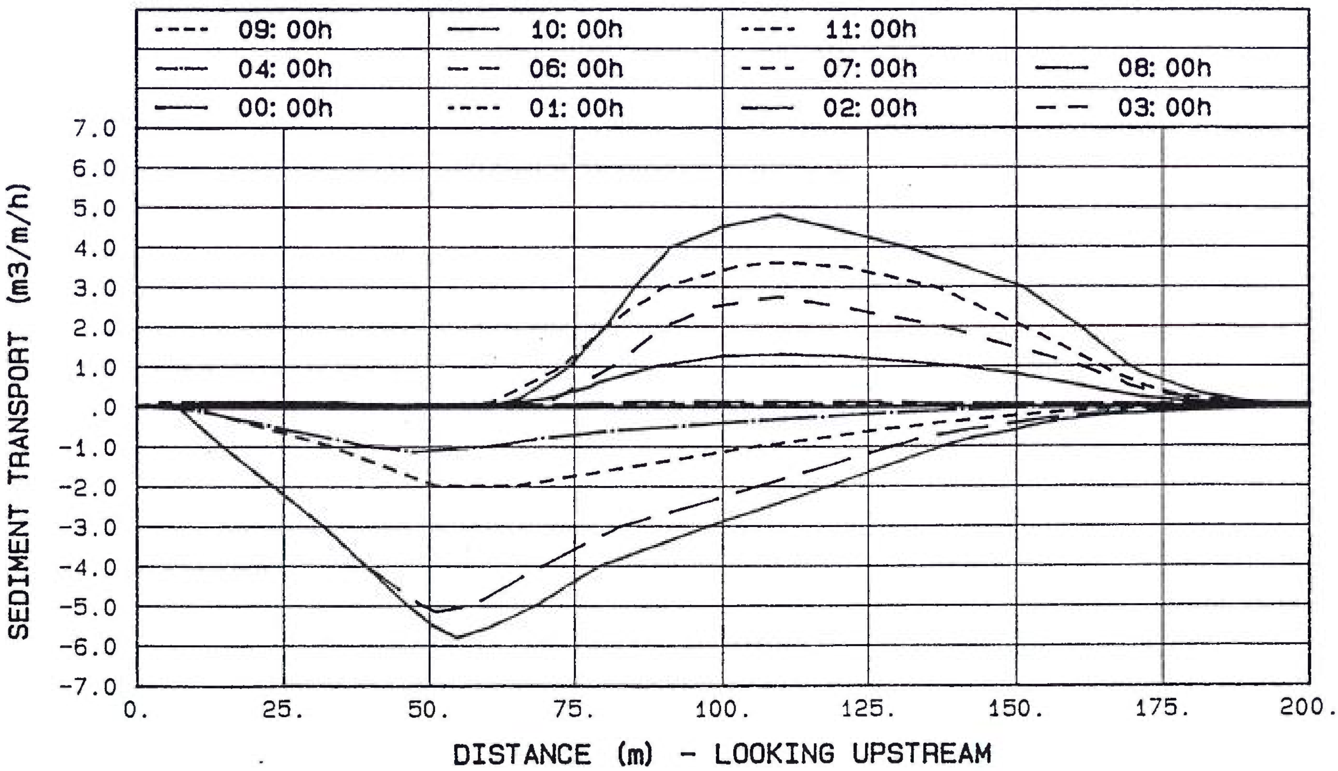
$$\text{Net Infeed} = 80{,}000 - 0.0519\,Q \qquad (m^3/yr)$$

where Q is the total siltation quantity since 1975.

Two dimensional hydrodynamic and sand transport modelling of the river entrance area in the vicinity of the Jack Evans Boatharbour has been used to assess the impact of the proposed dredging on the net rate of sand infeed past that area. As for the other river areas, this has been undertaken for a sinusoidal tide of mean spring tide range as an indicator of the typical tide cycle transport rates. While the results would not be expected to be quantitatively accurate in absolute terms, the proportional influences of the dredging have been used as the most feasible means of determining the dredging impacts in this area.



TWEED RIVER (Existing Situation)



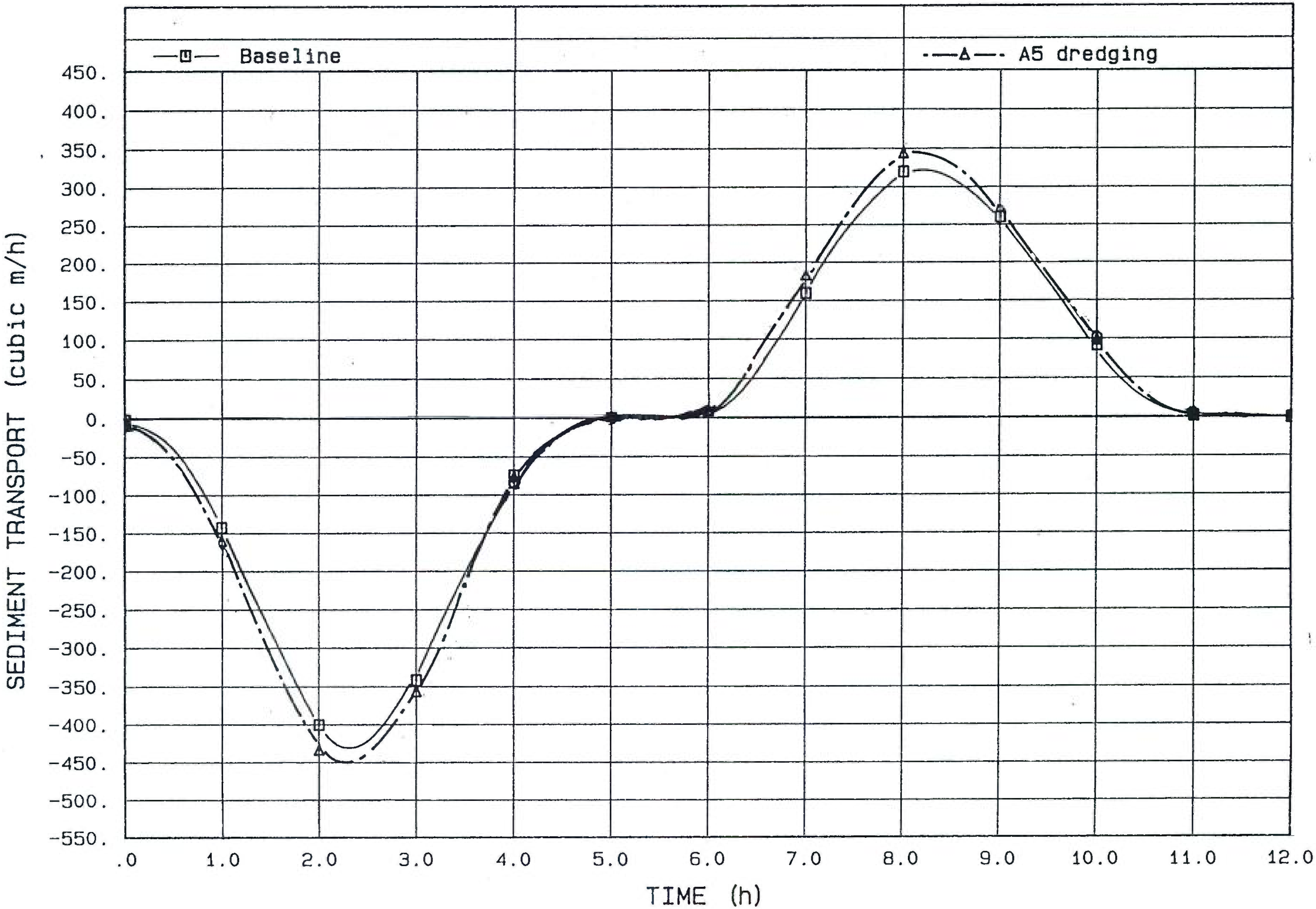
TWEED RIVER (Areas a5 dredged)

SAND TRANSPORT DISTRIBUTION ACROSS RIVER NEAR JACK EVANS BOATHARBOUR

FIGURE 4.5

FIGURE 4.6

TIME-DEPENDENT SAND TRANSPORT NEAR RIVER ENTRANCE



SEDIMENT TRANSPORT - TWEED RIVER

The results of these analyses are presented in Figures 4.5 and 4.6 and in Table 4.5, both as the absolute quantitative transport rates derived and as the proportional impacts on the net infeed rate. For determining the longer term Lower Estuary siltation processes, the above net infeed relationship has then been modified for the proposed dredging modelled to incorporate these proportional impacts.

TABLE 4.5
MODELLING RESULTS - IMPACT OF DREDGING ON SAND INFEED RATE OVER ONE MEAN SPRING TIDE CYCLE

CASE	SAND TRANSPORT RATE (CUBIC METRES PER TIDE CYCLE)			PERCENTAGE CHANGE IN NET INFEED POTENTIAL
	FLOOD TIDE	EBB TIDE	NET	
Existing (Baseline)	960	852	108	-
Area 5 Dredged	1033	906	127	+17.6%

Note: The changes induced by dredging as listed in Table 4.5 relate to full dredging. Because the dredging is undertaken progressively over a number of years, it is necessary to proportion these impacts correspondingly over the dredging period.

(b) **Tide-Related Supply From Upstream**

Following the 1974 dredging, sand has been moved by tidal flows along the Letitia reach of the river in the downstream direction towards the dredge hole. Previous studies (Oceanics Australia 1989c) show that as the Lower Estuary becomes more silted, this supply to the lower reaches reduces and may reverse.

In the state of dynamic equilibrium, the tidal sand transport in the upstream direction would be offset by the flood-related transport towards downstream.

Computer modelling has been used to determine the rate of tide-induced sand transport along the Letitia reach of the river. For greater detail in the present study, a two-dimensional model representation of that reach has been established, dynamically linked to the broader one-dimensional river model.

The proposed dredging of Area 5 has been tested in the model to determine the net tidal transport rates, providing for:

- the effect of progressive infilling of the lower estuary from the most recently surveyed 1989 base case situation
- extrapolation of the current 'baseline' case of no further works
- the effects of complete upstream dredging in Area 5

Each of the baseline and dredging scenarios was assessed for a range of Lower Estuary infill quantities, thus providing tidal transport rates as a function of those quantities (relative to the 1989 situation) as presented in Figure 4.7.

It can be seen that the present downstream net movement of sand reverses as the Lower Estuary becomes more infilled with sand, such reversal occurring earlier for the cases with greater upstream dredging. It is also to be noted that, as the Lower Estuary continues to infill, the rate of upstream transport decreases again due to attenuation of the tidal range and tide velocities upstream of the silted area.

(c) **Flood-Related Sand Supply**

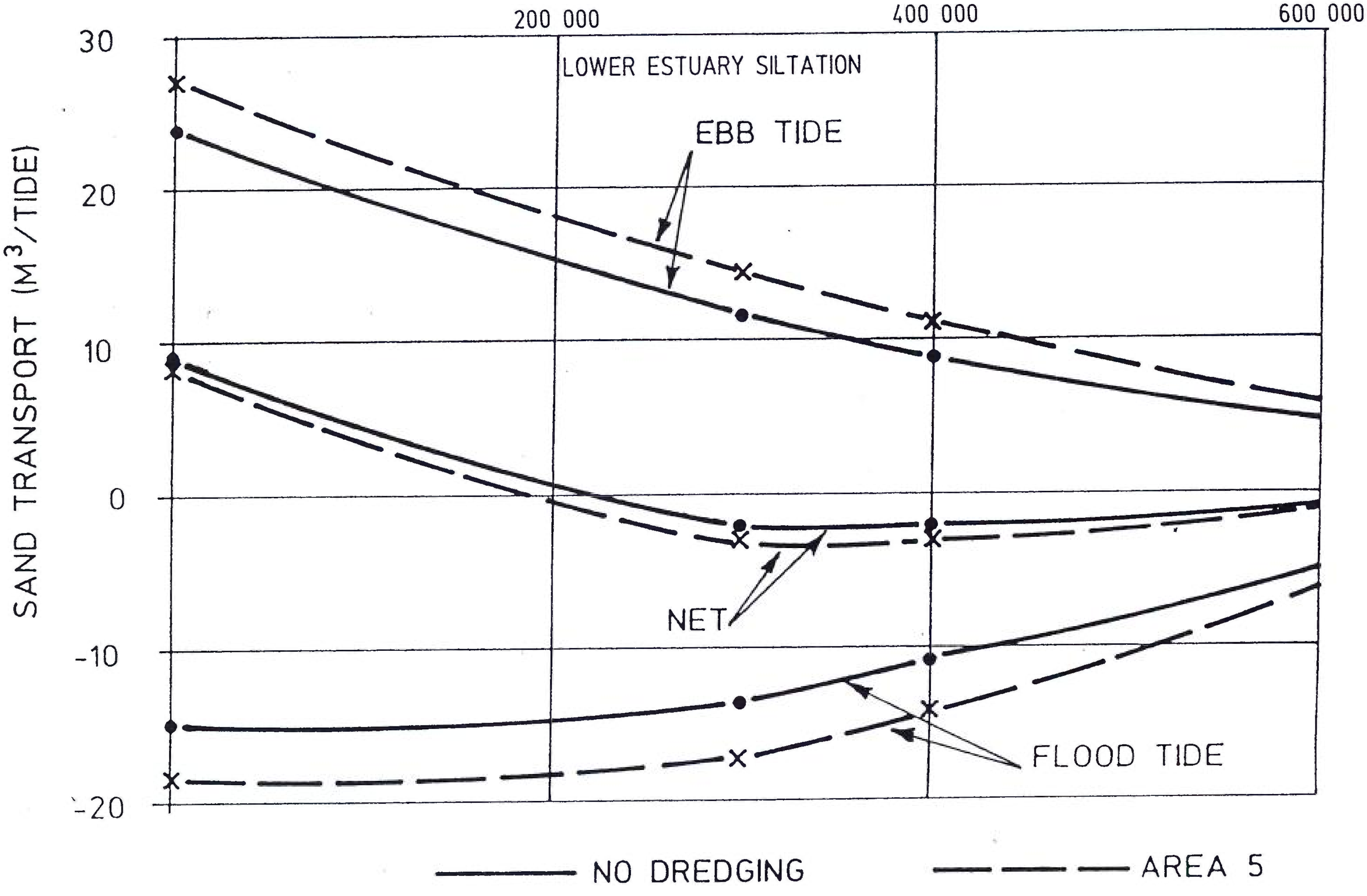
A detailed analysis of the mean annual flood-related sand transport rates in the Lower Estuary was undertaken in the Tweed Entrance Feasibility Study (Oceanics Australia 1989c). This indicated a general average transport of about 3 000 cubic metres per year, somewhat higher at 4 000 - 5 000 nearer the downstream dredged area. As the river mouth and lower reach areas become more silted, these rates will decrease while rates closer to the mouth may increase.

In the event that the upstream reaches (Areas A,B and C and Area 5) are dredged, these would be expected to intercept the fluvial supply and be subject to infilling from upstream at about 3 000 cubic metres per year.

The relationships derived above have been utilised in a time-varying Lower Estuary siltation model. This operates as a finite difference year by year integration of accumulation of sand in the lower reaches of the estuary, catering for the progressive influences of the siltation on the component entrance infeed, tidal and flood transport rates.

FIGURE 4.7

IMPACT ON TIDE-RELATED SAND TRANSPORT-LETITIA REACH



Scenarios assessed in this model include:

(i) No works - the estuary continues to infill in accordance with the presently projected trend forming the baseline case.

(ii) Dredging of Area 5

Two possible sand extraction schedules for Area 5 were assessed. The first assumes that Area 5 dredging occurs uniformly over the ten year period that is about 90,000 cubic metres per year. The second assumes a three year time-frame with about 600,000 cubic metres extracted in the first year and 150,000 cubic metres per year over the ensuing two years. In each case, the potential effect on sand transport relative to the effect assessed for full dredging is linearly proportional to the proportion of the total dredging undertaken to that time.

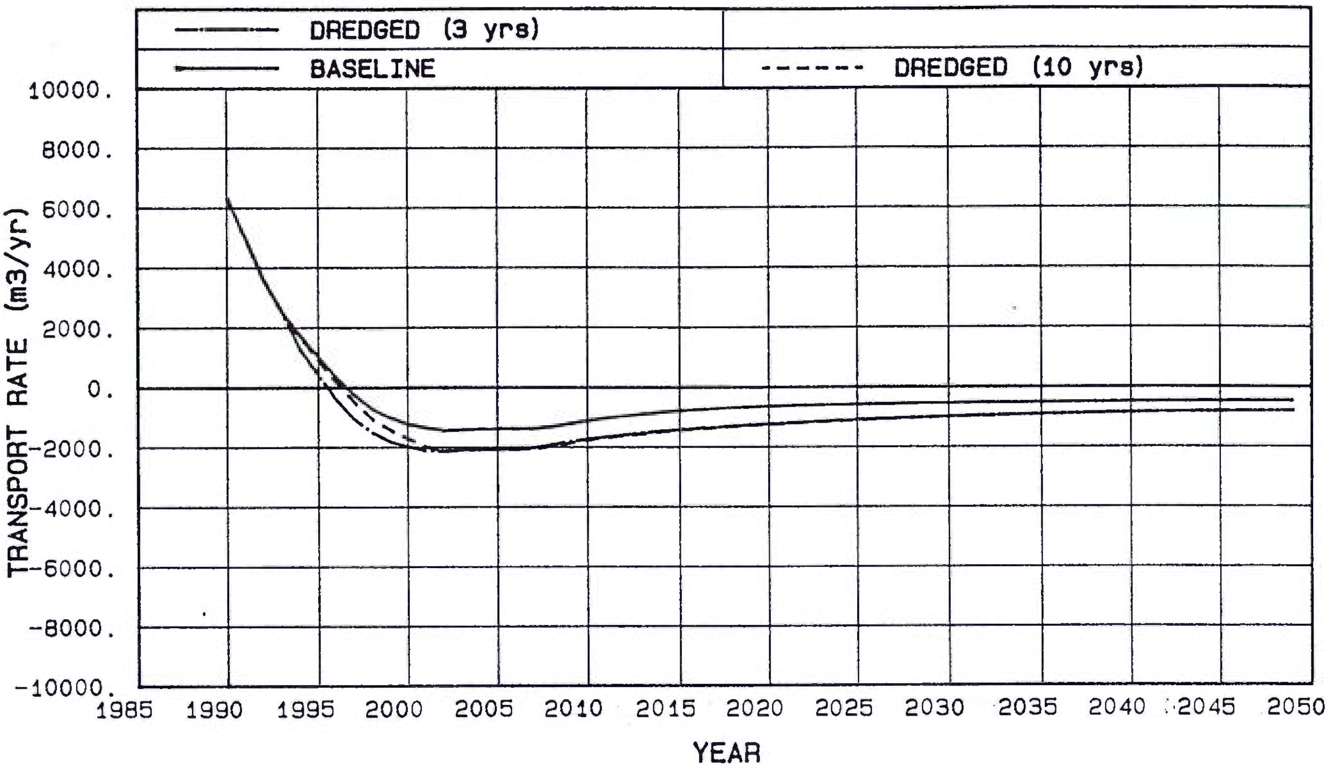
The results of the modelling are presented in Figures 4.8 - 4.10 in terms of -

- beach sand infeed
- tide-related transport rates
- resultant Lower Estuary siltation

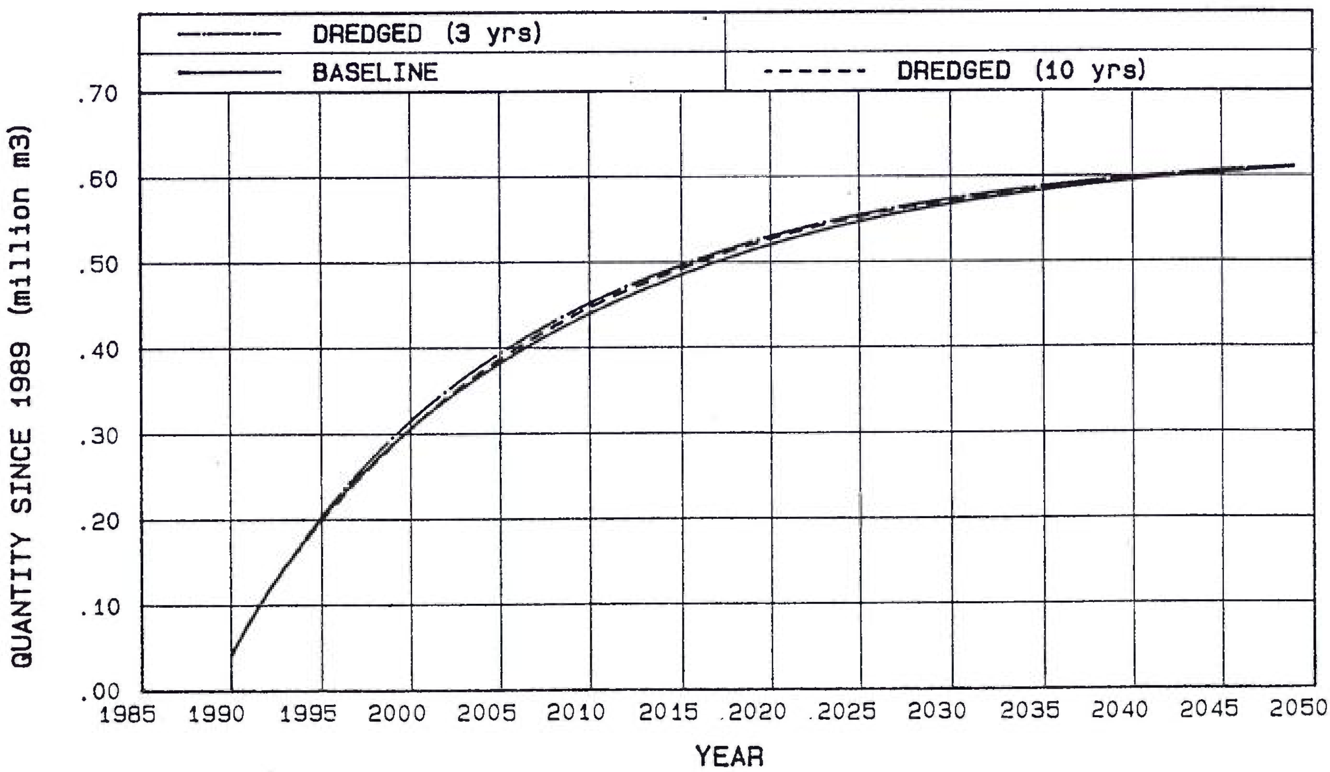
They can be summarised as follows:

(i) The increase in the rate of sand infeed through the river entrance caused by the dredging has the effect of speeding up the siltation of the Lower Estuary towards its dynamic equilibrium condition. At the same time, there is a reduction in the supply from upstream and eventual reversal of the tide-induced net transport, tending to delay the Lower Estuary siltation.

The increase in the infeed rate at the entrance dominates these processes. However its relative importance decreases progressively in the longer term and the gradual upstream movement of sand towards the dredged area becomes relatively more significant.



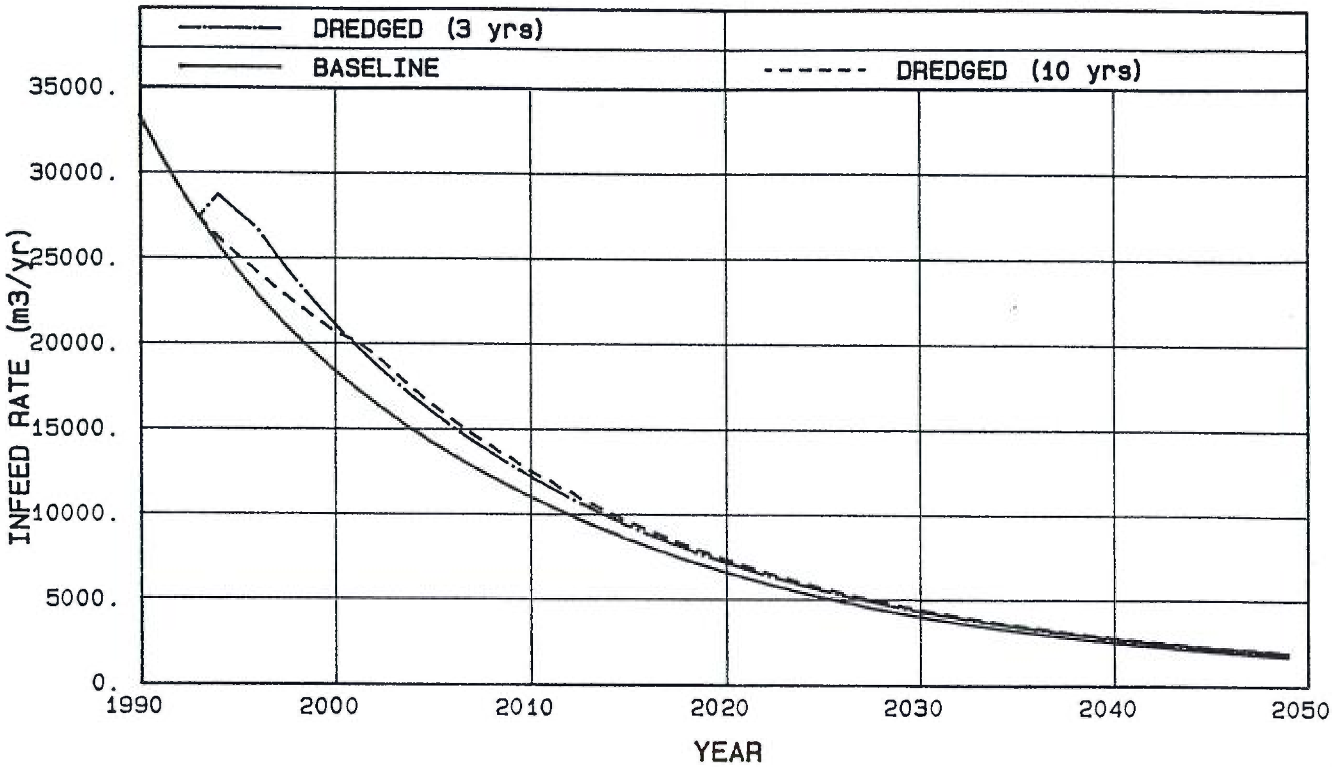
TIDE-INDUCED UPSTREAM TRANSPORT



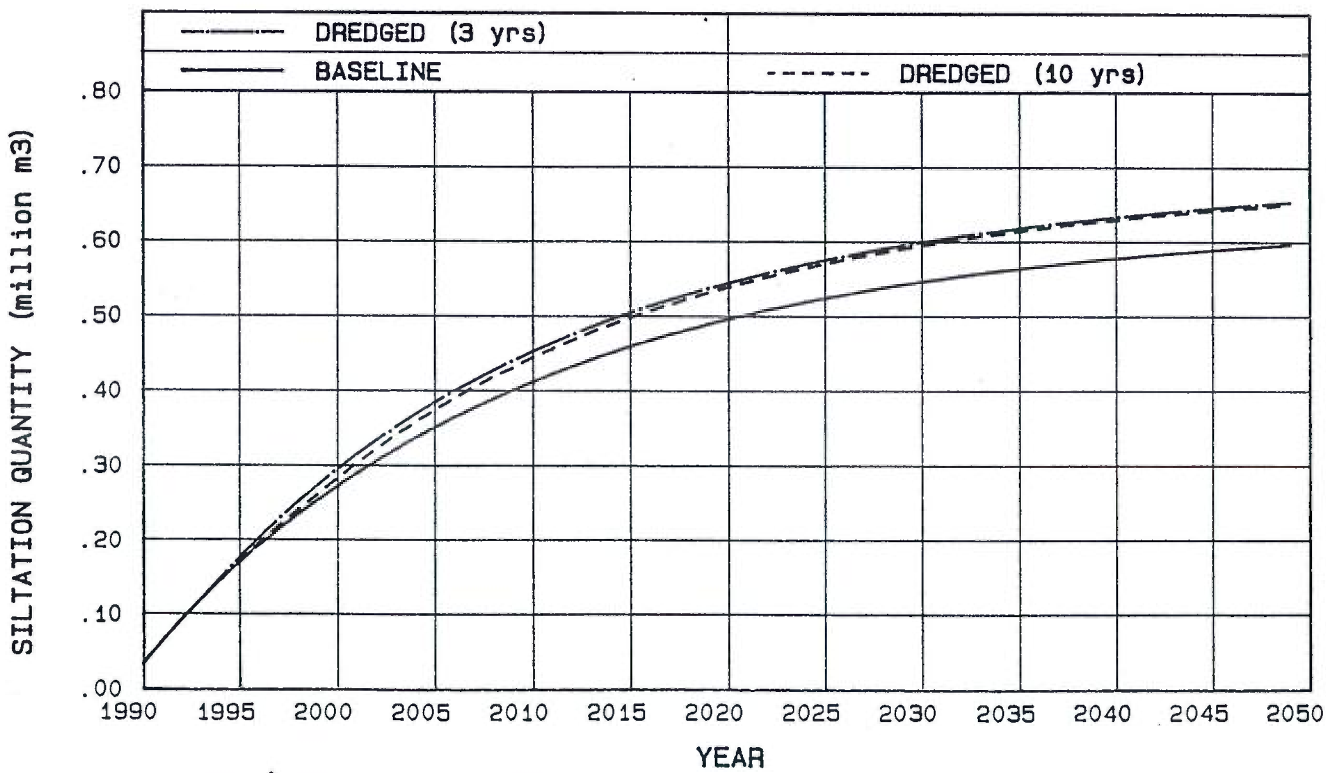
LOWER ESTUARY SILTATION

IMPACTS ON LOWER ESTUARY SILTATION AND TIDE-INDUCED UPSTREAM TRANSPORT

FIGURE 4. 8



ANNUAL BEACH SAND INFEED



CUMULATIVE BEACH SAND INFEED

IMPACTS ON BEACH SAND INFEED
DREDGING OF AREA 5

FIGURE
4. 9

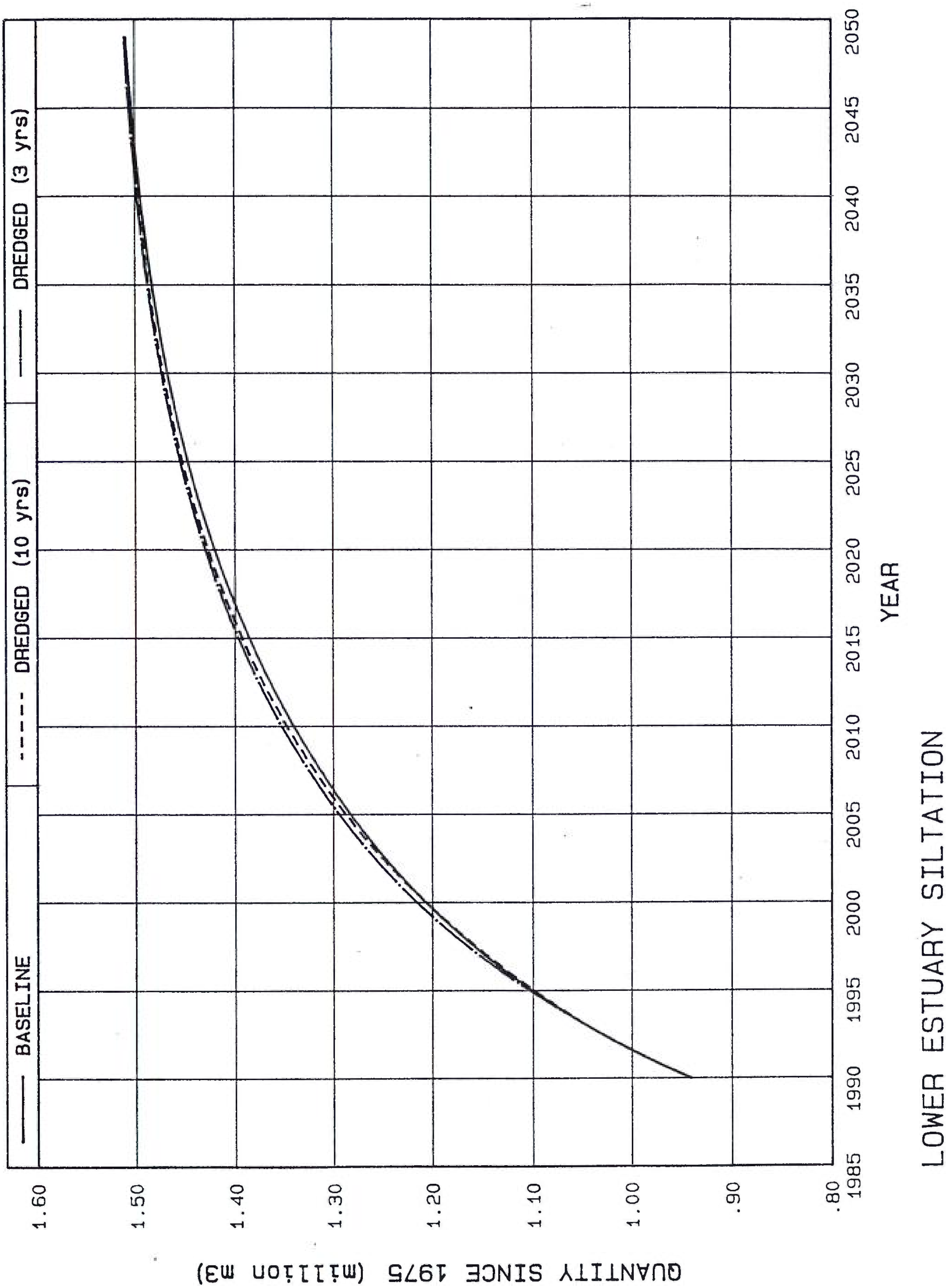


FIGURE 4. 10

LOWER ESTUARY SILTATION SINCE 1975
DREDGING OF AREA 5

(ii) Accordingly, the assessed incremental effect of the dredging depends on the time-frame considered. In the shorter term (say 10 years), the relative impacts are greater with cumulative beach sand infeed quantities to that time being as follows:

Baseline (no dredging)	:	351,900 m^3
Area 5 dredged over 3 years	:	385,400 m^3 (9.5% increase)
Area 5 dredged over 10 years	:	375,400 m^3 (6.7% increase)

(iii) In the longer term (50 years), the initial period of readjustment becomes of less significance and the incremental impacts of the dredging become progressively more related to the upstream loss of sand towards the dredged area. Cumulative beach sand infeed quantities to that time are as follows:

Baseline (no dredging)	:	589,300 m^3
Area 5 dredged over 3 years	:	645,700 m^3 (9.6% increase)
Area 5 dredged over 10 years	:	642,400 m^3 (9.0% increase)

(iii) The incremental increases in the beach sand infeed quantities, expressed as an average over the 10 and 50 year periods are approximately -

Area 5 dredged	:	3,000 m^3/year over 10 years
	:	1,100 m^3/year over 50 years

Additional studies undertaken (WBM Oceanics Australia 1993) show that, when the Area 5 dredging is considered in isolation or as an adjunct to the dredging of Areas ABC, the incremental increase in the feed of beach sand to the Lower Estuary does not exceed 4,000 m^3/year at any stage. It begins to decrease progressively after only several years following the dredging. The longer term cumulative additional loss of beach sand would be up to about 32,000m^3 at 10 years and 55,000 m^3 at 50 years.

These incremental losses to the beach system, although significant in the longer term, are relatively small when compared with the net rate of longshore transport past the river mouth to supply the beaches to the north. That rate is believed to be approaching the original natural rate of 500,000 cubic metres per year, that is some 25 million cubic metres over a 50 year period.

In the event that entrance improvement works and artificial sand bypassing are implemented effectively, there should be no net loss of sand from the beaches.

4.4 POTENTIAL FOR CONTAMINATION OF MATERIAL TO BE EXTRACTED

The results presented in Appendix 10 and Section 3.6 indicate that the sediments from Area 5 in the lower Tweed estuary have very low levels of contaminants and the resuspension of contaminated sediments as a result of dredging works would not occur. Concentrations of heavy metals, oil and grease detected in the sediment samples are generally negligible. No organophosphate pesticides or organochlorines, specifically dieldrin and DDE were detected down to an analytical accuracy of 0.001 mg/kg wet weight. No mercury was detected down to an analytical accuracy of 0.1 ppm and no cadmium was detected.

The concentrations of contaminants recorded from the Area 5 sediments are generally lower than those values recorded in association with the Tweed Entrance Feasibility Report (PWD 1990) and the Lower Tweed Ecological Study (PWD 1991b). The Lower Tweed Ecological Study placed emphasis on sampling sediments in bays, backwaters etc. as heavy metals are generally associated with particulates. Consequently, the Area 5 samples were obtained in midstream, the predominantly lower contaminant values may be expected when compared with those previously recorded (PWD 1990, PWD 1991b).

4.5 IMPACTS ON WATER QUALITY INCLUDING CONSIDERATION OF SEDIMENTS

4.5.1 General Considerations

The major source of pollutant entry into the Tweed River was associated with non-point source pollution, or stormwater runoff into the river. Hence it was apparent that evaluation of the proposed dredging on saline intrusion into the river following major freshwater flow events was of some importance, and it is for this reason that the MIT-DNM model was utilised.

Estuarine flushing under quasi-steady state conditions (i.e. uniformly varying) is also of some considerable importance, particularly with respect to the flushing of sewage discharges from the river. For this reason, in addition to saline intrusion analyses, assessments of the impacts of dredging on tidal flushing for a quasi-steady state salinity regime, were performed.

4.5.2 Contamination and Turbidity

The analysis results presented in Appendix 9 and Section 3.6 indicate that the sediments from Area 5 in the lower Tweed estuary have very low levels of contaminants and the resuspension of contaminated sediments as a result of dredging works would not occur.

The use of suction dredging and controls on return waters will ensure no adverse impacts on turbidity in the river. The standards established in EPA (1990) require that waste water contains less than 50mg/l of non-filtrable residues before it is returned back to the Tweed River.

As outlined in Section 3.6.1, the nature and location of the sands to be dredged are such that it is not expected that the sands to be dredged would have acid sulphate potential. No problems have been noted with the sands taken from the area to date. It is recommended that the spoil be monitored with testing for acid sulphate potential. If, during dredging, a significant acidity potential is identified (in say stockpile areas), then EPA's Draft Areas of Acid Sulphate Soils will be adopted.

4.5.3 Salinity Intrusion

The boundary conditions adopted for salinity intrusion evaluations were a repeated tide. Appropriate modifications were made to the geometry of the base case calibrated model to simulate the proposed dredging and model simulations performed for a 30 day period. The results of these assessments are summarised in Table 4.6.

TABLE 4.6
SALINE INTRUSION ANALYSIS SALT CONCENTRATION (g/L)
AFTER 28.25 DAYS (678 HOURS)

LOCATION	BASE CASE	AREA 5 DREDGED	RELATIVE CHANGE
Letitia 2a	35.00	35.00	-
Barneys Point	31.5	32.8	+4%
Tweed Broadwater	20.3	21.0	+3%
Tumbulgum	2.0	2.5	+25%
Condong	0.0055	0.0062	+13%

Table 4.6 indicates that the Dredge Plan will have a significant beneficial influence with respect to saline recovery through the penetration of ocean waters, and the flushing of waters from the Tweed Estuary following freshwater inflow events.

4.5.4 Tidal Flushing

The flushing time of a tidal water body is, assuming no other forcing functions (e.g. density differentials, wind induced currents, etc.), typically directly related to the ratio of mean tidal range to mean water depth. This is correct when considering the flushing of a single completely mixed basin, however, where flow occurs between interconnected 'basins', or along a lengthy estuary, this approach is not strictly correct.

To assess the flushing characteristics of the Tweed Estuary for the various dredging scenarios the following approach was adopted:

- a hydraulic/water quality model of the estuary was established for a 'typical' mean spring tide period, (MIT-DNM model)
- the estuary was assumed to have an initial 'pollutant' concentration of unity with an ocean concentration of zero, and
- the concentration of 'pollutant' remaining at locations throughout the estuary after a 28.25 day (678 hours) period was determined, this value providing a relative indication of the 'flushing time' of the water body.

The results of these assessments are presented in Table 4.7 below.

TABLE 4.7
TIDAL FLUSHING RELATIVE (%) POLLUTANT CONCENTRATION AFTER 28.25 DAYS (678 HOURS)

	BASE CASE	AREA 5 DREDGED
Tweed Regional	0.0	-
Letitia 2b	44	-13.6%
Barneys Point	57	-12.3%
Tumbulgum	59	-5.1%
Condong	86	-1.2%
Murwillumbah	77	-1/3%
Kynnumboon	98	-

Table 4.7 indicates that the proposed dredging, once completed, will generally improve tidal flushing throughout the main arm of the Tweed Estuary.

4.6 NOISE IMPACTS

4.6.1 Introduction

Noise aspects associated with the proposed dredging in Area 5 were investigated during December 1991.

This section presents the results of an investigation of the noise levels which may result from this activity, and its associated land based operations, with emphasis on the change from the existing noise levels. Components of the investigation include:-

(i) Prediction of noise associated with dredging and land based operations
(ii) Monitoring of existing ambient noise levels
(iii) Noise assessment and control measures

4.6.2 Assessment Criteria

The Environment Protection Authority (EPA) is the authority with responsibility for the control of environmental noise in New South Wales.

The EPA do not have particular guidelines with respect to noise from dredges. With regard to these activities the EPA requires that the usual noise criteria assessment be used i.e. that the average maximum sound pressure level (L_{10})* from dredging operations shall not exceed the average minimum ambient sound pressure level (L_{90}) by more than 5 Db(A)** when measured at the worst affected residence.

For the land based operations, i.e. the EPA requires that the noise level measured 1 metre from an affected residential facade should not exceed an L_{10}, 18 hours*** of 58 Db(A). This criterion applies equally to quieter urban areas and rural residences. For receivers of noise from the works, the goal set by the EPA is for an L_{10}, 18 hour value of 63 Db(A) not to be exceeded.

4.6.3 Summary of Noise Impacts

Noise from the dredging proposal has the potential to exceed the criteria at residential receivers adjacent to the proposed dredging area.

The suction dredge noise exceeds EPA allowable noise levels at residences exposed to these operations.

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* The L_{10} is the sound pressure not exceeded 90% of the time. The L_{90} is the sound pressure level exceeded 90% of the time. The sound pressure level is a ratio expressed in decibels of the r.m.s. sound pressure relative to a reference pressure of 20 micropascals. In fact S.P.L. = 20 $\log_{10}$ p/pref.

** Db(A) is a weighting to approximate the sensitivity of human hearing to frequency and is used in the measurement of the sound pressure level to give an improved measure of sound level.

*** L_{10}, 18 hours is the arithmetic mean of the 18 one-hourly values of L_{10} covering the period 6:00am to midnight on a normal working day.

Practical methods exist to reduce generated noise levels to meet the criteria and these are described in the next section (also see Appendix 9).

4.6.4 Noise Control Measures

Noise control treatments are required on the dredge and, potentially, for some stockpiling operations at the proposed sites.

Suction dredge treatments

The dredge noise level needs to be reduced from those typically found on untreated dredges. An average maximum dredge noise level (L_{10}) of 52 dB(A) at 30 metres is required to allow dredging to occur at any point in the river without causing disturbance. This level is achievable by enclosing the engine room and silencing the exhaust.

Land-based operations

The background sound level in the vicinity of the proposed stockpile sites is in the range of 40 - 50 dB(A) (see Table 3.8). Where the sand is to be utilised for landfill for approved works (eg. the RTA highway construction) relevant noise levels and noise control measures will apply with respect to those short term construction approvals. For any other land-based operations, average maximum level from stockpiling activities should not exceed a value of 50 dB(A) to meet the EPA criterion. To achieve this, where necessary, a 3 metre bund could be constructed on the perimeter of any stockpile operations area. This bund could have a covering of vegetation as a visual screen to operations.

4.7 IMPACTS ON FLORA AND FAUNA

4.7.1 Marine Ecology

In the RMP, it was recognised that some local adverse ecological effects associated with changes to the tidal hydraulic regime were likely as a result of the dredging works. For example, lower low tides would tend to increase the exposure of seagrass beds to air and sunlight, with some potential losses. Alternatively, higher high tides may result in progradation of the extent of mangroves.

However, most of the potential impacts relating to hydraulic changes were associated with the then proposed river entrance improvement works, no longer proceeding as an integral part of the Area 5 Dredge Plan. As outlined in the preceding sections, the Area 5 dredging in isolation will have minimal effects on the tidal regime and thus these ecological communities.

The design of the sand extraction plan is consistent with the criteria and details established in consultation with the relevant Government agencies including the Department of Agriculture and Fisheries in developing the Lower Estuary River Management Plan. There have been some changes to policies with regard to buffer widths from mangrove and seagrass areas since that time. Nevertheless, the locations of the mangrove and seagrass areas (adjacent to the deep river channel) and potential turbidity plume behaviour are such that these areas and their associated fauna should not be adversely affected by the proposed works.

There will necessarily be a short term loss of benthos in the dredged areas. These mobile sandy shoals contain significant life, as outlined in Section 3.11. However, they are of relatively less significance than those other shallow areas which will be preserved and/or enhanced through the RMP program of works.

The Dredge Plan will involve extraction of sands which could extend over a considerable time (up to 10 years), with dredging affecting a relatively small area at any time. There is opportunity for the dredged areas to become recolonised with increasingly diverse benthic organisms as the works proceed. As well, the small effects on tidal hydraulics will be gradual over the works time-frame, allowing progressive adaptation of the flora and fauna to those slowly changing conditions.

The dredging will provide significant ecological and fisheries benefits. Deepening of the main channel will provide conditions suitable for large pelagic fish and enhance angling in these locations. Other local enhancement and/or habit creation benefits which the Area 5 dredging will facilitate include:

- construction of gently sloping shallow subtidal areas along the western foreshore
- seagrass replanting in those areas
- modifications to Tony's Bar to increase the bird roosting area, provide protection from domestic and feral animals, and reduce biting midge breeding areas.

Additionally, the revenue gained from royalties from the sand will allow implementation of a range of other environmental enhancement works throughout the Lower Estuary area, as identified in the RMP.

Adverse ecological impacts will be minimised by the imposition of appropriate restrictions as follows:

Restrictions on Areas to be Dredged

A general restriction that dredging should not occur in river bank areas shallower than 2.0 m AHD has been observed in developing the Plan. Seagrass, bird, benthic and fish studies indicate that shallow shoreline areas (particularly bays/inlets) have a high ecological value. This restriction ensures that the most productive sections of Area 5 are not directly disturbed.

In some areas shoaling has extended from river banks to central portions of the river. In these instances, the Dredge Plan identifies removal of central portions of the river that are shallower than 2m AHD. An appropriate width of shallow shoreline has been retained, and with the possible exception of the narrow channel behind Tony's Island, seagrass beds would not be dredged in any area.

Tony's Bar has important ecological value and is used as a hauling ground by commercial fishermen. A large buffer area to a depth of 3.0m AHD has been provided to ensure the bar retains these values.

Buffer distances from mangroves (10m), seagrass (30m) and oyster leases (50m), as required at the time of development of the Lower Estuary River Management Plan by the NSW Department of Agriculture and Fisheries, have been observed in all areas covered by the RMP. Although these recommended buffer distances for some situations have been increased more recently, the proposed works are considered to be appropriate for this area.

Restrictions on Dredging Depths

The depth of dredging has been determined primarily on the basis of sand winning, hydraulic and water quality considerations. From an ecological viewpoint the main consideration in determining depths has been to ensure that recolonisation by a diverse range of species occurs, and the water column in dredged areas has negligible potential for stratification, with no substantial substrate or water quality changes.

4.7.2 Terrestrial Ecology

The adopted sand removal and stockpile strategy will ensure that there is no interference with any land areas on Fingal Peninsula. There will be no adverse impacts to the terrestrial flora or fauna there.

The identified potential fill/stockpile sites for the sand are either approved or proposed construction or development sites. No adverse impacts will result in those areas.

There may be some short term disturbance to shore birds in the area by noise or activities associated with moving the dredge or the discharge pipeline. However, there will be no impacts on major roost sites as identified in PWD (1991 b).

4.8 SOCIAL AND ECONOMIC IMPACTS

The River Management Plan for the Lower Estuary was developed to provide an opportunity to address a range of socio-economic factors and implement properly planned action to be taken for the overall community benefit. The Area 5 dredging represents an important component of implementation of the RMP.

The various factors affected and receiving benefit from the proposed works include:

- improved navigability of the river for both recreational and commercial purposes

- improved flooding characteristics, particularly in reduced flood levels and durations near Chinderah

- improved water quality, and increased opportunities for development in the Tweed Valley

- enhanced commercial and recreational fishing opportunities

- reduced biting midge nuisance

- provision of the sand resource to meet the demand for clean fill in the region

As set out in Section 4.3, there is a potential for some adverse impact on bank stability and thus the adjacent land at Chinderah. This can be avoided by ensuring that dredging in that area takes place in conjunction with or prior to the Area 5 dredging.

There is also the potential to increase the movement of beach sand into the Lower Estuary, representing a net loss to the beach system. This incremental loss has been quantified for the worst case scenario about 35,000 cubic metres over the initial 10 year period and about 55,000 cubic metres over 50 years. This may have an economic impact in the cost of maintenance of the beach system over time.

4.9 ARCHAEOLOGICAL AND HERITAGE IMPACTS

The significance of Aboriginal sites is assessed to a range of criteria, including:

- Significance to Aboriginal people.
- Scientific or archaeological significance.
- Their uniqueness in a local or regional archaeological context.
- Their value to the public for educational purposes.

The Aboriginal community may place value on a site due to its links with historic events, links with past economic lifestyles and values, and concern for the protection of burials.

The scientific value of a site is based upon its potential for future research and excavation. A site containing concentrated undisturbed subsurface material would be accorded high significance. Small shell and artefact scatters would usually be considered of low significance. In this area, (the Tweed region) due to the lack of remains in an area where it is reasonable to assume the archaeological material was once extensive, these low density sites have added significance.

Their value to the public for educational purposes would be ascertained after the factors above have been considered and management controls implemented.

The assessment of Aboriginal sites located within the survey area is based at this time on archaeological criteria. The Aboriginal significance of the sites located in this survey is as yet uncertain. However, given previous Aboriginal interests and concerns expressed through other studies, media and other information, it is safe to conclude that all sites will be regarded as being of great value.

All of the original bank has been altered by the construction of the river training walls. The survey concentrated on those areas believed to represent the original landscapes and therefore potentially contain archaeological sites. A large section of the original features in the Fingal Village areas were assessed, hence the survey was able to assess accurately the extent of the archaeological resource in this zone.

Although no sites of significance were detected on Fingal Peninsular adjacent to Area 5, because of the lack of remaining sites in an area where they were once abundant, the Aboriginal Community may place a greater significance on the value of any shells or artefacts remaining. Consequently any activities affecting that site should be carried out with sensitivity and collaboration with the local Aboriginal community. No such activities are foreseen

The Tony's Island site appears very limited in concentration and extent. Alone it may not be thought as having scientific value. However more detailed research into the area of higher ground in the south of the island may prove the existence of sub-surface deposits. The site may then derive greater significance than appears at present. This area would in no way be disturbed or impacted under the proposal.

Further consultations with NSW National Parks and Wildlife Service and the Aboriginal Community based upon a clear understanding of the effects of dredging and other works on these sites were recommended (PWD 1991e) to ensure site protection.
Other sites have been recorded in the vicinity of the river banks (Piper 1975), Koettig (1988). These sites are located on the slopes of the ridges which form Banora Point, Barney's Point and Terranora. As they are well away from the river banks they are not effected by the proposal.

4.10 VISUAL IMPACTS

The foreshores of Area 5 have generally high quality visual character ranging from areas of minimal waterfront development with seawalls through to areas dominated by natural wetland vegetation. Assessment of the visual quality of these foreshores revealed that some 95% of the total length of foreshores included was categorised as of "high" visual representing 19% of this category of foreshore in the lower Tweed estuary. By comparison, only 1.7% of the foreshore was categorised as of medium-low visual quality, representing 8.9% of this category of foreshore in the lower estuary.

The visual landscape of Area 5 requires protection and enhancement (see PWD 1991f).

Measures to maintain and enhance the visual quality of the Area 5 foreshores were included in the overall report by PWD (1991f) and included:

- adequate consideration being given to the visual impact of any development proposal for the foreshore or adjacent land;

- vegetation clearance controls on rural and natural landscapes;

- revegetation and restoration of areas classified as moderate visual quality or below (this could be complemented by designation of visual quality standards for foreshore development/redevelopment projects in key designated areas);

- physical improvements under the River Management Plan (tree planting, wetland creation etc).

5.0 ENVIRONMENTAL MANAGEMENT, MONITORING AND REHABILITATION

5.1 RIVER BATHYMETRY, HYDRAULICS AND BANK STABILITY

The hydrodynamic modelling assessments made for the RMP and updated for this EIS show that the proposed Area 5 dredging will result in:

- a slight increase in tidal range, tidal prism and flow velocities upstream from the dredging area

- somewhat reduced flood levels and duration of inundation in the Chinderah area

- a potential increase in sand transport and bank instability in the reach of the river immediately upstream of Barney's Point Bridge

- a relatively small but significant increase in the amount of beach sand feeding into the Lower Estuary

It is recommended that a monitoring program be established to allow changes in the bank profiles, over time to be assessed. Further, the proponents are prepared to provide assurance that if bank stability is affected then rock armour will be installed along the banks. These could be included as conditions of consent to the dredging.

Monitoring of tide and flood levels to quantify the small degree of change predicted is not practicable. Natural changes at, for example, the river mouth would cause variations in hydraulic characteristics substantially greater than those expected from dredging.

However, it is recommended that existing tide gauges along the river be maintained and the data analysed to demonstrate whether or not any significant changes do occur, particularly in the low tides. Correlation of the tidal data with dredging records and available information of entrance/river bathymetry would assist in identifying the probable cause of any such changes.

Monitoring of dredging profiles is recommended to ensure adherence to the stipulated criteria for clearances from river banks, seagrass, etc. These should preferably be performed in such a way that both river cross-sections and plan contours can be defined. This will permit:

- monitoring of extraction quantities

- checking of dredged bed depths
- identification and monitoring of benthic communities in different areas
- monitoring of infilling and any adjacent bed erosion processes

5.2 SEDIMENT PROPERTIES AND WATER QUALITY

It is anticipated from available data that the proposed dredging will involve relatively clean to slightly silty sand. As such, the proposed suction dredging technique should cause insignificant turbidity at the dredge intake and some turbidity in the return waters, controlled by the use of detention ponds.

It is recommended that monitoring be undertaken of any impact of the return water discharges on river turbidity. This should involve initial measurements prior to commencement of dredging and at intervals during the works to identify any significant increase in ambient suspended sediment levels.

Should a significant increase be identified, then independent checks on quality of the return waters may be needed.

It is not expected that the sands to be dredged would have acid sulphate potential. No problems have been noted with the sands taken from the area to date. Nevertheless, it is recommended that the spoil be monitored with testing for acid sulphate potential. If, during dredging a significant acidity potential is identified (in say stockpile areas), then EPA's Draft Guidelines for the Assessment and Management of Coastal Land Developments in Areas of Acid Sulphate Soils will be adopted.

Control of water quality is expected to form part of permit conditions for the works.

5.3 ECOLOGY

The dredging would be undertaken in conjunction with environmental enhancement works in the area (western foreshore, Tony's Island). The proposed undulating river bed is aimed at providing conditions for greater diversity of the benthic ecology.

It is anticipated that monitoring of these enhancement projects will be undertaken, and will encompass the area covered by the dredging.

5.4 NOISE

Noise levels from the dredge are to be controlled by fitting of muffler units to achieve a maximum of 52 db at 30 metres distance. An independent check of achieving this level is required.

5.5 ARCHAEOLOGY AND HERITAGE

No interference with any items of archaeological or heritage value is anticipated. Should this occur, then the finding will be reported immediately and advice sought on the most appropriate course of action for the circumstances at the time.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 PROJECT DETAILS

The need for dredging of sections of the Tweed River was identified in the recently prepared River Management Plan for the Lower Tweed Estuary. An analysis of public comments on the Plan indicated that the Tweed area community strongly supports the objectives proposed by the NSW Public Works, particularly dredging to improve navigability of the river's lower reaches, which include Area 5.

The dredging would introduce a number of benefits including:

- Navigation - there are a number of locations where navigation of the river is restricted or prohibited, particularly at low tide. These would be cleared to provide safe navigation for fishing vessels and recreational craft.

- Water Quality - lower estuary dredging has the potential to increase saline intrusion to the river and improve tidal flushing.

- Sand Resources - the river sand is a resource which can be utilised for local industry and construction purposes. Royalties would accrue to the State for such utilisation of the sand.

- Environmental Enhancement - dredging and the royalties attracted offer opportunities and funds for undertaking other works which would enhance the recreational and ecological value of the river. At the same time the present ecological richness and diversity of the lower estuary can be maintained if such works are carefully planned and carried out.

  It is recognised that some adverse local ecological effects may be caused by the dredging works. Major enhancement opportunities exist however, and these would more than compensate for any of the adverse effects that might arise from dredging.

- Flooding - the proposed dredging would assist in reducing flood levels in the Lower Estuary/Chinderah area.

As noted in Section 1.0, comprehensive studies have been undertaken to identify and assess the most suitable options for improvement of the Tweed River which would achieve these benefits.

The dredge plan for Area 5 provides for sand extraction from Barneys Point Bridge to Rocky Point. The dredge plan, initially presented in the River Management Plan and subsequently refined, has several objectives including:

- removal of the shoal below Barney's Point Bridge
- creation of a channel adjacent to the eastern training walls
- enhancement of fisheries habitats through the creation of an undulating river bed.

A quantity of approximately 0.92 million cubic metres would be extracted from this section of the river in establishing the navigation channel as proposed.

Development consent is required for the proposal. It is a designated development within the meaning of Schedule 3 of the Environmental Planning Assessment Regulation, 1980. This EIS is required to accompany the development application to the Tweed Council.

The proponent for the proposed sand extraction from Area 5, forming part of the range of river improvement and environmental enhancement works, is the NSW Public Works with the support of the Tweed River Management and Planning Advisory Committee.

The proposal evaluated in this EIS forms the first stage in the implementation of the Lower Tweed River Management Plan (PWD 1991). The RMP was the culmination of several years of research and community consultation with the aim of developing a sensitive management basis for the Lower Tweed River. This consultation was facilitated primarily through the NSW Public Works Tweed Entrance Project office in Tweed Heads over the period 1990 - 1991. All relevant aspects of the RMP were dealt with in that consultation process, as discussed in the management plan head report.

In compiling this report, WBM Oceanics Australia have drawn heavily on the RMP and the associated reports as they relate specifically to Area 5. Great care has been taken to ensure that this proposed sand extraction advances the objectives for Area 5 as described in the Plan.

Community consultation has continued, and concerned parties have generally responded favourably to the planned dredging. The community rightly regard this proposal as an essential first stage in the responsible social, economic and environmental management of the Lower Tweed.

6.2 HYDRAULICS, SEDIMENT TRANSPORT AND BANK STABILITY

The proposed dredging will have a relatively minor impact on the tidal regime. Results of the tide modelling are presented in Figures 4.1 and 4.2 and Table 4.1. They indicate a slight (4 %) increase in the tidal range upstream of Area 5, and a corresponding increase in tidal prism through the lower reaches of the river. Near the river mouth this increase in flow (and tidal prism) is about 2 %.

Significant benefits in the form of reduction in the peak flood levels and durations of inundation for the design flood events at Chinderah will be derived from the dredging.

Results of the flood impact assessments are illustrated in Figure 4.3 in terms of longitudinal flood peak profiles along the main arm of the river, and Table 4.2(a)-(b) in terms of levels at specific locations. Penetration of the storm tide dominates peak levels in the lower reaches for the high tailwater cases, and these do not alter significantly. There are indiscernible effects on peak levels in the Terranora Arm. There is a reduction in peak flood levels in the river upstream of Barneys Point Bridge, and a slight increase immediately downstream of the dredging at Fingal.

The reduction in peak flood levels in the river is significant (about 15cm) at Barneys Point Bridge and diminishes with distance upstream. At Chinderah the reduction is about 8 - 12 cm for the 1 % flood and 11-14 cm for the 5 % flood. This benefit reduces to 6-7 cm at Stotts Island and less than 3 cm upstream of Tumbulgum.

The results presented in Figure 4.4 show the assessed impacts on levels in terms of time through the 1 % design flood event (high tailwater) at Chinderah. Peak flood levels on the floodplain there are reduced by some 8-12 cm, and the duration of inundation of the higher flood levels is reduced significantly.

There will be an increase in tide and flood-related velocities and sediment transport rates particularly in the area immediately upstream of Area 5. In the context of the tidal and flood hydraulic impacts as described in Sections 4.1 and 4.2, the only area in which bank stability might potentially be affected by the Area 5 dredging is the unstable southern embankment at Chinderah.

This situation is similar to that which exists for dredge Areas B & C (upstream of Barneys Pt Bridge), where the dredging within B & C may exacerbate the bank erosion problem immediately upstream.

For the Area B & C case a monitoring program was established to allow changes in the bank profiles, over time to be assessed. Further, the proponents are required to provide assurance that if bank stability is affected then rock armour will be installed along the banks. These were conditions of consent to the dredging.

It is appropriate that such an approach be taken with the subject dredging works in Area 5.

It should be noted that the approved dredging in Areas B & C will substantially ease the potential for any Area 5 impact. If dredging in the channel adjacent to the eroding banks could be co-ordinated with the Area 5 dredging then it is considered that the Area 5 dredging would have negligible effect on any banks.

The increase in the rate of sand infeed through the river entrance caused by the dredging has the effect of speeding up the siltation of the Lower Estuary towards its dynamic equilibrium condition. At the same time, there is a reduction in the supply from upstream and eventual reversal of the tide-induced net transport, tending to delay the Lower Estuary siltation.

The increase in the infeed rate at the entrance dominates these processes. However its relative importance decreases progressively in the longer term and the gradual upstream movement of sand towards the dredged area becomes relatively more significant.

The incremental increases in the beach sand infeed quantities, expressed as an average over the 10 and 50 year periods are approximately 3 000 m^3/year over 10 years, and 1 100 m^3/year over 50 years.

These potential incremental losses to the beach system, although significant in the longer term, are relatively small when compared with the net rate of longshore transport past the river mouth to supply the beaches to the north.

In the event that entrance improvement works and artificial sand bypassing are implemented effectively, there should be no net losses of sand from the beaches.

6.3 SEDIMENT AND WATER QUALITY

The analysis results presented in Appendix 10 and Section 3.6 indicate that the sediments from Area 5 in the lower Tweed estuary have very low levels of contaminants and the resuspension of contaminated sediments as a result of dredging works would not occur.

The use of suction dredging and controls on the return waters will ensure that induced turbidity in the river is restricted to acceptable minimal levels.

Data from a variety of sources indicates that water quality in the Lower Tweed estuary in the vicinity of Area 5 is good. Clarity, dissolved oxygen and nutrient levels generally are typical of high quality oceanic water.

The standards established in EPA (1990) require that waste water contains less than 50mg/l of non-filtrable residues before it is returned back to the main water body - the Tweed River. To obtain this standard, the return water will be passed through a settling pond prior to discharge off site. The dredge would deliver the slurry containing 20-30 % solids at a rate of 300 m^3/hour to the processing plant, and settling ponds must be sized to comply with EPA recommendations, based upon this operating volume.

It is not expected that the sands to be dredged would have acid sulphate potential. No problems have been noted with the sands taken from the area to date. Nevertheless, it is recommended that the spoil be monitored with testing for acid sulphate potential. If, during dredging a significant acidity potential is identified (in say stockpile areas), then EPA's Draft Guidelines for the Assessment and Management of Coastal Land Developments in Areas of Acid Sulphate Soils will be adopted.

Numerical modelling indicates that the proposed dredging will have beneficial effects on saline intrusion and tidal flushing. These improvements will ameliorate potential contamination from existing non-point sources (ie. stormwater).

6.4 NOISE

Without attenuation, noise from the dredging operation would be likely to exceed the EPA criterion the dredge area (based on measurements of similar dredge in operation). However, practical methods are available to reduce noise to levels below the EPA criteria. These measures include enclosing the engine room and silencing the exhaust.

Disposal of the sand at the RTA highway corridor and Shallow Bay will not have significant noise impacts, since these sites will be required to meet separate EPA criteria. The preferred direct landfill option will not require the operation of a cyclone separator.

6.5 ECOLOGICAL ASPECTS

6.5.1 Marine Ecology

There will necessarily be a short term loss of benthos in the dredged areas. These mobile sandy shoals contain significant life, as outlined in Section 3.11. However, they are of relatively less significance than those other shallow areas which will be preserved and/or enhanced through the RMP program of works.

The Dredge Plan will involve extraction of sands which could extend over a considerable time (up to 10 years), with dredging affecting a relatively small area at any time. There is opportunity for the dredged areas to become recolonised with increasingly diverse benthic organisms as the works proceed. As well, the small effects on tidal hydraulics will be gradual over the works time-frame, allowing progressive adaptation of the flora and fauna to those slowly changing conditions.

The dredging will provide significant ecological and fisheries benefits. Deepening of the main channel will provide conditions suitable for large pelagic fish and enhance angling in these locations. Other local enhancement and/or habit creation benefits which the Area 5 dredging will facilitate include:

- construction of gently sloping shallow subtidal areas along the western foreshore
- seagrass replanting in those areas
- modifications to Tony's Bar to increase the bird roosting area, provide protection from domestic and feral animals, and reduce biting midge breeding areas.

Recommendations

A general restriction that dredging should not occur in river bank areas shallower than 2.0 m AHD has been observed in developing the Plan. Seagrass, bird, benthic and fish studies indicate that shallow shoreline areas (particularly bays/inlets) have a high ecological value. This restriction ensures that the most productive sections of Area 5 are not directly disturbed.

In some areas shoaling has extended from river banks to central portions of the river. In these instances, the Dredge Plan identifies removal of central portions of the river that are shallower than 2m AHD. An appropriate width of shallow shoreline has been retained, and with the possible exception of the narrow channel behind Tony's Island, seagrass beds would not be dredged in any area.

Tony's Bar has important ecological value and is used as a hauling ground by commercial fishermen. A large buffer area to a depth of 3.0m AHD has been provided to ensure the bar retains these values.

Buffer distances from mangroves (10m), seagrass (30m) and oyster leases (50m), as required by the NSW Department of Agriculture and Fisheries, have been observed in all areas covered by the RMP. The design of the sand extraction plan is consistent with the criteria and details established in consultation with the relevant Government agencies including the Department of Agriculture and Fisheries in developing the Lower Estuary River Management Plan. There have been some changes to policies with regard to buffer widths from mangrove and seagrass areas since that time. Nevertheless, the locations of the mangrove and seagrass areas (adjacent to the deep river channel) and potential turbidity plume behaviour are such that these areas and their associated fauna should not be adversely affected by the proposed works.

6.5.2 Terrestrial Ecology

The adopted sand removal and stockpile strategy will ensure that there is no interference with any land areas on Fingal Peninsula. There will be no adverse impacts to the terrestrial flora or fauna there.

The identified potential fill/stockpile sites for the sand are either approved or proposed construction or development sites. No adverse impacts will result in those areas.

There may be some short term disturbance to shore birds in the area by noise or activities associated with moving the dredge or the discharge pipeline. However, there will be no impacts on major roost sites as identified in NSW Public Works (1991 b).

6.6 ARCHAEOLOGY AND HERITAGE

Archaeological investigations were undertaken with the assistance of a representative of the Tweed Byron Aboriginal Land Council.

No significant archaeological or heritage sites were located in the area likely to be affected by the proposed sand extraction.

6.7 SOCIAL AND ECONOMIC IMPACTS

The socio-economic study commissioned by the NSW Public Works sought to satisfy the following objectives:

- to ascertain the attitudes of commercial fishermen, representative of recreational fishing organisations, oyster farmers and the local Fisheries Inspector towards the proposed dredging:

- to establish the pattern and extent of commercial fishing within Area 5; and

- to record any suggestions for river improvement works.

During consultations in 1991 and 1992 a number of issues were identified in relation to the potential impacts of the current dredging proposal. These issues can be categorised as follows:

- Shoal removal and channel improvement.
- Habitat modification.
- Water quality.
- Regulation of dredging activities.

Overall the response of the fishing industry to the notional dredge plan was positive. Members of the fishing industry were generally supportive of proposed measures to rectify problems associated with shoaling of the Tweed River. The removal of the shoal below Barneys Point Bridge received strong support as did the proposal to create a channel adjacent and parallel to the eastern training walls. Works associated with Tony's Bar were more contentious. While the removal of the northern end of the Bar was supported by some commercial fishermen, others criticised the plan because of the possible loss of seagrass.

The proposed regeneration of seagrass beds in shallows along the western shore was well received and to some extent afforded a degree of compensation for the immediate loss of fisheries habitat associated with dredging of Tony's Bar. The proposal to create deep holes to further enhance habitat diversity evoked mixed responses. Commercial fishermen were either sceptical about the suggestion, having witnessed the adverse effects of poor dredging practices in the past, or in agreement with the plan because of the potential benefits to fish productivity. While some individuals supported the provision of habitat for the estuarine birds others found the associated loss of seagrass unacceptable. For similar reasons, the dredging of the northern end of Tony's Bar in order to reduce the local midge problem was criticised.

The potential deleterious impacts on water quality were mentioned by several individuals including concern about the creation of 'pot holes' and resultant stratification and the re-suspension of sediments. Operators of oyster leases adjacent to Area 5 had no complaints about the proposed dredging and expressed the opinion that water quality would be improved through dredging. The regulation of dredging activities and monitoring of operations were regarded as necessary in order to ensure that proposed works were carried out a as originally planned.

Although commercial fishermen still utilise the area on a part-time basis, habitat destruction in the past has allegedly contributed to a decline in the fisheries value of Area 5. Shallow Bay and the shores near Tims Island provide good catches of mullet, while Tony's Island is regarded as one of the best whiting grounds in the Lower Tweed Estuary.

Recommendations

Two suggestions for river improvement works were received including the proposal that dredging could assist fishermen by creating sand banks with a gradient of 1:6 in order to facilitate hauling. Seagrass regeneration could possibly be encouraged by the construction of spur walls at Barneys Point Bridge and Rocky Point.

6.8 VISUAL ASSESSMENT

The foreshores of Area 5 are generally of very high visual character and include areas of minimal waterfront development and natural wetland vegetation. Area 5 represents a significant portion of the high visual quality areas remaining in the Lower Tweed.

The proposed development aims to protect and enhance the foreshore and landscape and the scenic qualities of the river front, by ensuring that:

(i) adequate consideration is given to the visual impact of the development proposed for the preferred stockpile site (i.e. disposal of sand at already designated construction sites).

(ii) a program of site enhancement and rehabilitation/revegetation will be implemented and promoted.

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APPENDIX 1

STUDY TEAM AND ACKNOWLEDGMENTS

This report has been compiled by the following staff of WBM Oceanics Australia.

Peter Ebsworth	Senior Terrestrial Biologist
Dean Patterson	Senior Hydraulic Engineer
Rick Morton	Senior Aquatic Biologist
Tony McAlister	Senior Hydraulic and Water Quality Engineer

The report draws on the Lower Tweed Estuary River Management Plan and other investigations associated with its formulation. These reports are listed below.

Report	**Prepared by**
(a) River Management Plan Reports	
River Management Plan	NSW Public Works
Technical Summary	NSW Public Works
Ecological Assessment, Technical Report No. 1	WBM Oceanics Australia
Appendices to Ecological Assessment Report	WBM Oceanics Australia
Influent Audit, Technical Report No. 2	WBM Oceanics Australia
Hydrodynamic Assessment, Technical Report No. 3	WBM Oceanics Australia
Recreation Study, Technical Report No. 4	Centre for Coastal Management, UNE
Archaeological Assessment, Technical Report No. 5	Adrian Piper
Visual Assessment, Technical Report No. 6	Centre or Coastal Management, UNE
Supplementary Information, Technical Report No. 7	NSW Public Works
Implementation Options, Technical Report No. 8	Centre for Coastal Management, UNE
Initial Monitoring, Technical Report No. 9	WBM Oceanics Australia
Appendices to Initial Monitoring Report	WBM Oceanics Australia
Preliminary Concepts, Technical Report No. 10	NSW Public Works
(b) Reviving the Tweed Reports	
Extractive Industries, Technical Report No. 3.4.8	Patterson Britton & Partners
Stockpile Areas, Technical Report No. 3.4.9	Ian Hill & Associates

THE
TWEED COUNCIL

PLEASE QUOTE COUNCIL REF. No.: GR1/1/3 PT4 94/153 [LTP14&a]

YOUR REF. No.:

FOR ENQUIRIES PLEASE CONTACT: Mr Warren Prestwich

TELEPHONE DIRECT: (066) (066) 720496

22 APR 1994

L11A69&A

20 April 1994

The Regional Manager
Department of Minerals & Energy
PO Box 574
LISMORE 2480

Dear Sir

Development Application - Extraction of material from the bed of the Tweed River in that section of the lower estuary referred to as Area 5, extending approximately two (2) kilometres downstream from Barneys Point Bridge to Rocky Point.

A Designated Development Application has been lodged by NSW Public Works Department for extraction of material from the bed of the Tweed River in that section of the lower estuary referred to as Area 5, extending approximately two (2) kilometres downstream from Barneys Point Bridge to Rocky Point. The proposal involves the dredging of the main river channel with the resultant removal of approximately 0.92 million cubic metres of river sand over a 3 to 10 year period at Tweed River from Barneys Point Bridge to Rocky Point.

Council is the consent authority for the application.

A copy of the application and Environmental Impact Statement are enclosed.

The application is currently being exhibited for public comment for a period of thirty (30) days commencing on **Thursday 21 April 1994 to Monday 23 May 1994.**

To assist Council in determining the application, your comments on the proposal are requested by **Monday 23 May 1994**.

Yours faithfully

G Smith

Garry Smith per WP
Manager Development Control
Development Services Division

Enc

THE TWEED
VALLEY OF CONTRASTS

CIVIC AND CULTURAL CENTRE, MURWILLUMBAH
P.O. BOX 816, MURWILLUMBAH. N.S.W. 2484
TELEPHONE: (066) 72 0400 — FAX: (066) 72 0429

ALL COMMUNICATIONS MUST BE ADDRESSED TO THE GENERAL MANAGER

TWEED SHIRE COUNCIL

ENVIRONMENTAL PLANNING & ASSESSMENT ACT, 1979 (SECTION 77(3))

FILE No. GR1/1/3 Pt4
SUBJECT No. 157, 194, 182, 115
RECD. 6 APR 1994
DOCUMENT TYPE
LOCATION CODE 450
EDP PROCESSED

DEVELOPMENT APPLICATION
(APPLICATION TO BE LODGED IN TRIPLICATE)

Applicants Name NSW PUBLIC WORKS DEPARTMENT
(Full Name - Block Letters)

Full Postal Address PO BOX 73 LISMORE NSW 2480

Telephone No. (Business Hours) 066-201605

A. Description of the Land to which the Development Application relates:- TWEED RIVER - BARNEY's POINT BRIDGE TO ROCKY CPOINT

No. or Name ______ Street, Road, etc ______ Locality ______

Unit No ______ (for Industrial/commercial uses) Side of Street ______
North, east, south or west.

Rate Assessment No. ______ Nearest intersecting Street ______

Lot ______ Sec No ______ D.P. ______ Portion ______

Parish ______ Area of subject land in m^2/ha ______

Present Use of Land or Buildings ______

* Note: A site plan (in triplicate) of the subject land must accompany the application - refer to Note 2 of Instructions for Completing Development Application.

B. Description of Development for which Development Consent is sought: DREDGING IN MAIN RIVER CHANNEL OF APPROXIMATELY 900,000 m3

Where development involves the erection of a building, the proposed use of that building when erected:-
-

* Note: Plans/drawings and other information (in triplicate) describing the development must accompany the application - refer to Notes 3 & 4 of Instructions for Completing Development Application.

C. Estimated cost of proposed development (Where it involves the erection of a building and the carrying out of work): $ SELF FUNDING

* Note: Refer to Note 1 of the Instructions for Completing Development Applications.

D. Environmental Impact of Proposed Development ______

The application is accompanied by -
* (a) An Environmental Impact Statement (in the case of designated development).
~~XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX~~
* Delete whichever is inapplicable.

* Note: Refer to Notes 5 & 6 of the Instructions for Completing Development Application.

Signature of applicant or person signing on behalf of applicant. Where not signed by applicant, state capacity in which application is signed.

Signature [signature] Capacity of Signatory Client Manager, Local Government North Coast Region, Public Works Date 30/3/94

Is the applicant the owner of the subject land? NO If not, the following must be completed

By the owner:- CONSENT OF THE OWNER: I WALTER SCOTT HAMBLY, REGIONAL MANAGER, CLS DEPT. OF CALM
of PO BOX 11, GRAFTON, on behalf of the Crown being the owner of the land to which this application relates hereby consent to the making of this application.

[signature]
Signature of Owner

11/1/94
Date

NOTE: Failure to supply ALL the foregoing information will result in delay in dealing with the application for which Council cannot accept responsibility and may result in refusal of the application.

* INSTRUCTIONS FOR COMPLETION ON REVERSE SIDE

OFFICE USE ONLY

Assessed fee 1600 - Fee Receipt No 6338 Date 6-4-94

IT:CS (WLE2131)

The General Manager
Tweed Council
P.O. Box 816
MURWILLUMBAH. N.S.W. 2484.

Contact: Mr. I. Taylor
Phone: (066) 201 605

- 5 APR 1994

Dear Sir

**Development Application for Dredging in the Tweed River,
River Management Plan, Area 5
Barney's Point - Rocky Point**

The purpose of this letter is to lodge a Development Application for dredging works in the Tweed River in the area known as Area 5 in the River Management Plan (RMP) which is the area generally from Barney's Point to Rocky Point.

As you are aware, your Council is at present implementing the recommendations of the Tweed River Management Plan for the Lower Tweed Estuary. This plan was prepared by Public Works for Council and is based upon a most extensive investigation of the physical, ecological and social attributes of the estuary.

The RMP identified 18 geographical areas in the lower estuary for which specific works and actions were recommended.

Area 5 was one of these areas. The management recommendations for Area 5 include improvements to the bird, fauna and fish habitats as well as improved navigation and reduced flood levels.

Central to the Area 5 recommendation is the dredging of the extensive shoals which exist in the main channel. Apart from achieving goals for Area 5 itself, this dredging is part of the "National Dredge Plan" which has been carefully designed to achieve benefits for the whole estuary.

The accompanying EIS deals with the proposed main channel dredging through Area 5. Attached to this letter is a completed D.A. form and a cheque for lodgement of $1,600.

Development Application for Dredging in the Tweed River,
River Management Plan, Area 5
Barney's Point - Rocky Point

To take advantage of the possibility of supplying sand to the RTA roadworks at Chinderah, the approval process for this EIS needs to be expedited to meet the RTA's program.

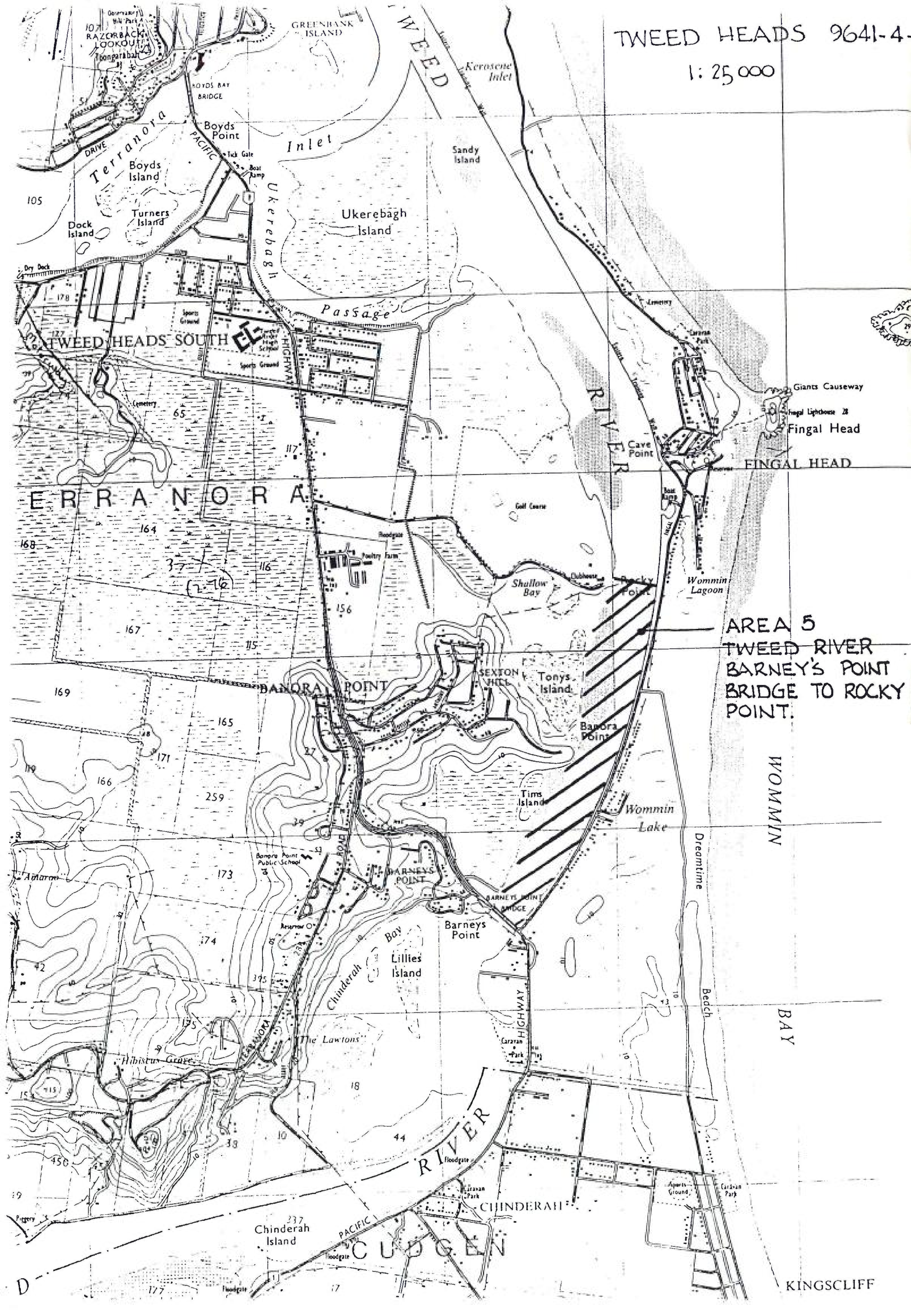
Accordingly Council's co-operation in advertising the EIS by 14th April, is requested.

If you have any queries, please telephone Mr. Ian Taylor, telephone 201 605.

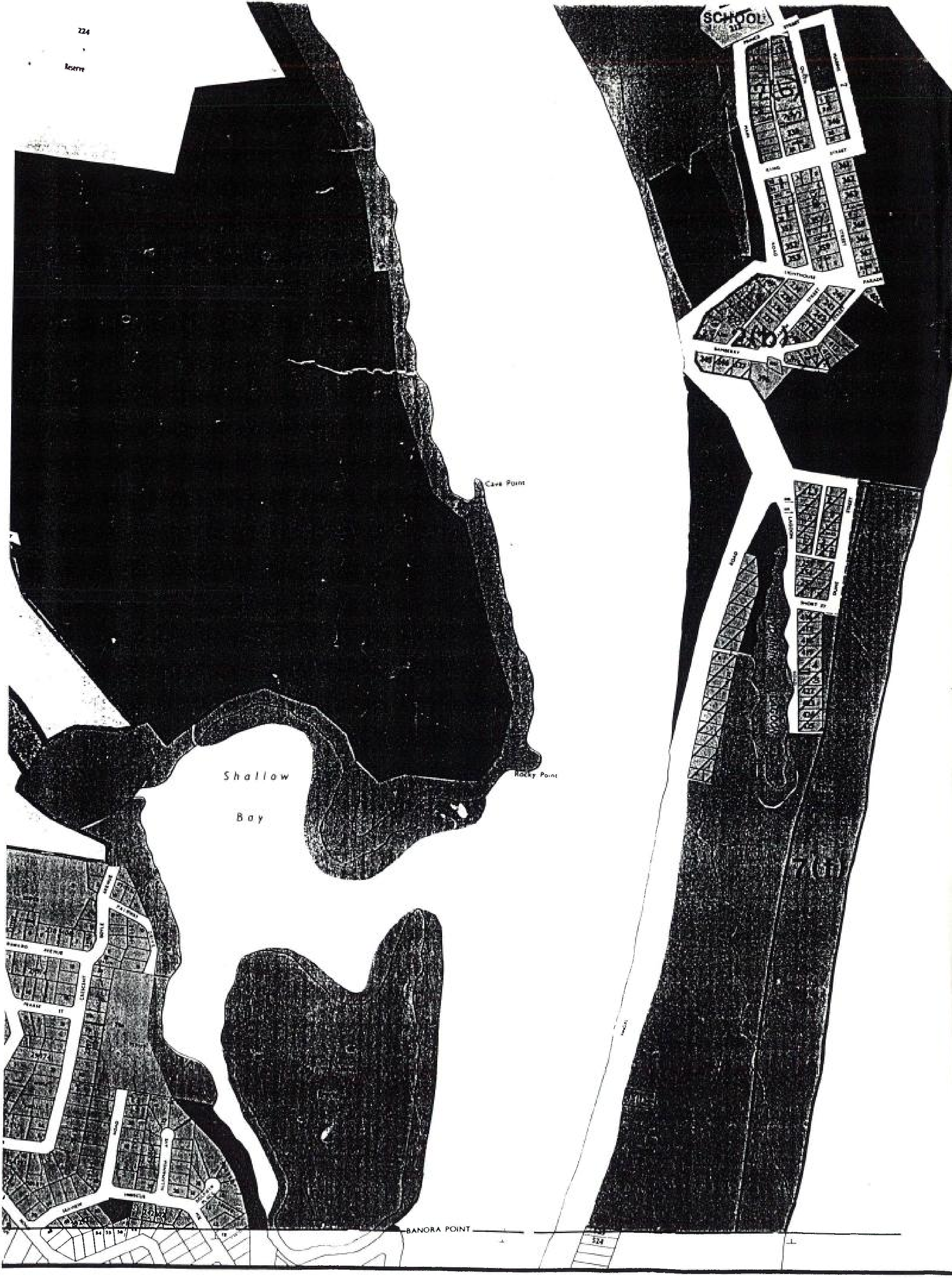
Yours faithfully

for M.K. Harrap
Client Manager
Local Government
North Coast Region

- 5 APR 1994



TWEED HEADS 9641-4-
1:25 000
AREA 5
TWEED RIVER
BARNEY'S POINT
BRIDGE TO ROCKY
POINT.
RAZORBACK LOOKOUT
GREENBANK ISLAND
Kerosene Inlet
TWEED
Boyds Bay Bridge
Boyds Point
Terranora
Inlet
Boyds Island
Sandy Island
Ukerebagh
Ukerebagh Island
Turners Island
Dock Island
Dry Dock
Passage
TWEED HEADS SOUTH
Sports Ground
Cemetery
RIVER
Cave Point
Giants Causeway
Fingal Lighthouse
Fingal Head
FINGAL HEAD
ERRANORA
Golf Course
Poultry Farm
Shallow Bay
Clubhouse
Rocky Point
Wommin Lagoon
BANORA POINT
SEXTON HILL
Tonys Island
Banora Point
Tims Island
Wommin Lake
WOMMIN
BAY
Banora Point Public School
BARNEYS POINT
BARNEYS POINT BRIDGE
Barneys Point
Reservoir
Chinderah Bay
Lillies Island
The Lawtons
Hibiscus Grove
HIGHWAY
Caravan Park
Dreamtime Beach
RIVER
Floodgate
CHINDERAH
Sports Ground
Chinderah Island
PACIFIC
CUDGEN
KINGSCLIFF



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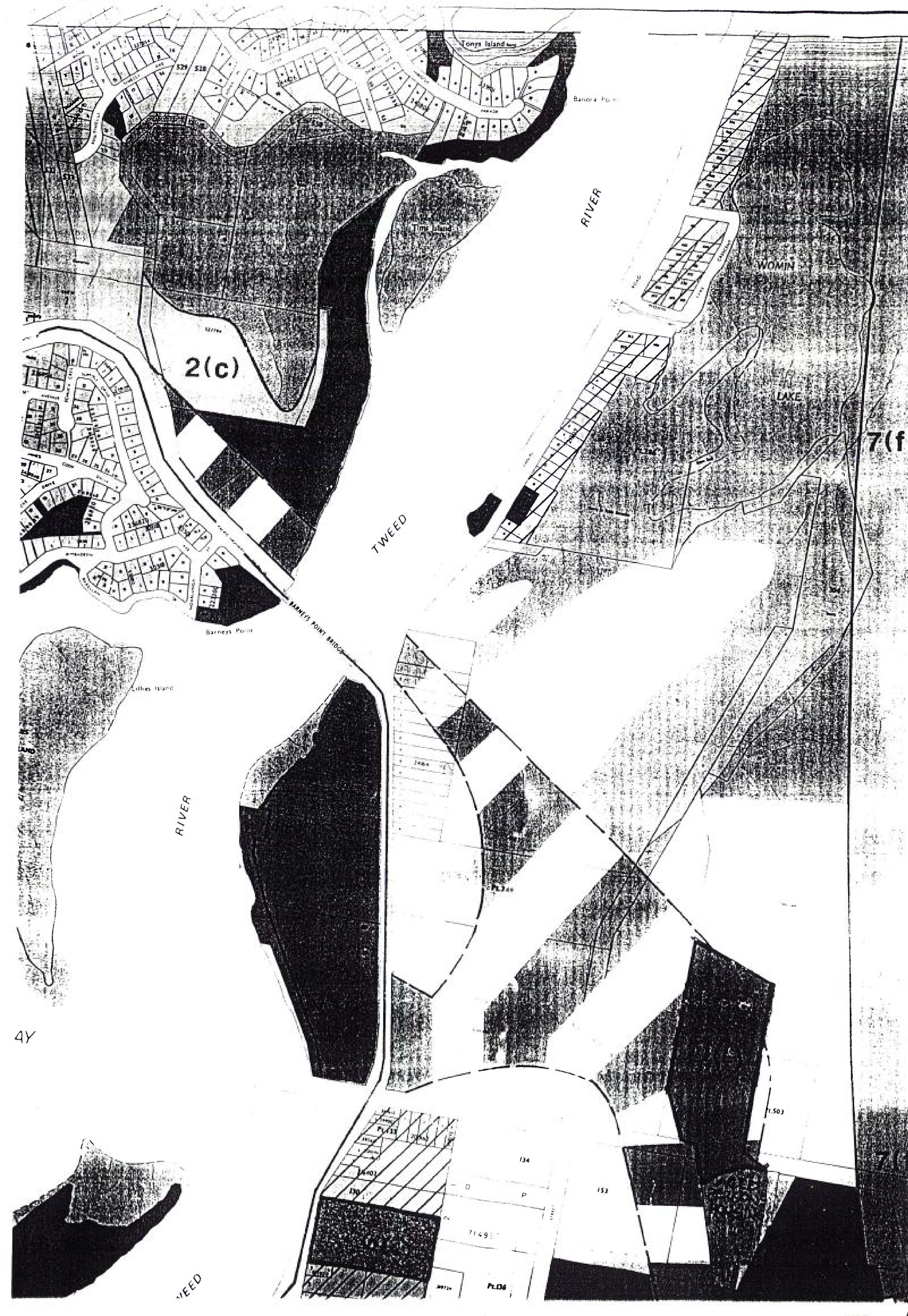


Tonys Island
Banora Point
2(c)
Tims Island
RIVER
TWEED
WOMIN
LAKE
7(f
Barneys Point
BARNEYS POINT BRIDGE
Lillies Island
RIVER
4Y
134
153
Pt.136
7

APPENDIX 2

TERMS OF REFERENCE

Department of Planning

Remington Centre
175 Liverpool Street, Sydney 2000
Box 3927 G.P.O. Sydney 2001
DX . 15 Sydney

Telephone : (02) 391 2000
Fax No : (02) 391 2111

Contact : J Brown
EXT: 2026

Our reference G90/00174

Your reference 2/2100/103

Public Works Department
Tweed Entrance Project
PO Box 1013
TWEED HEADS NSW 2485

Dear Sir

TWEED RIVER: PLAN OF MANAGEMENT

Thank you for your letter of 9 August 1990 indicating that you are consulting with the Director with regard to the preparation of an environmental impact statement (EIS) for the above development. The Department of Planning has considered your proposal to prepare a single EIS for a dredging strategy to cover the Lower Tweed Estuary. The Department concurs with your approach, outlined in your letter, and notes that where a specific proposal for dredging varies from the parameters studied in the subject EIS, further approvals will be required. In those circumstances, a separate EIS may also be required.

2. Development consent is required for the proposal and it is a designated development within the meaning of Schedule 3 of the Environmental Planning Assessment Regulation, 1980. An EIS must therefore accompany the development application to the Tweed Shire Council. The EIS shall be prepared in accordance with clause 34 of the Regulation (copy attached) and shall bear a certificate required by clause 26(1)(b) of the Regulation.

3. In addition, pursuant to clause 35 of the Regulation, the Director requires that the following matters be specifically addressed in the environmental impact statement:

- Provide a full description of the proposed dredging strategy, including location of sites to be dredged, the sequence in which sites are propsoed to be dredged, dredging methods including the rate of dredging from each site, and methods of sorting dredge spoil.

- Provide a full description of land based activities, including potential sites for the storage of dredge spoil, and for the location of any processing plant(s), and the size, scale and expected life of processing plant(s).

- Discuss possible means of disposal of the dredge spoil and/or processed sand, such as use for public works, for commercial sale. Identify the likely markets for sale of the material.

- Discuss the traffic and transport implications of the dredging strategy, including:

  - identification of the proposed traffic routes between the storage sites/processing plants and possible markets;

  - quantification of expected truck movements per hour between storage sites/processing plants and possible markets.

- Identify the potential sources of noise associated with the dredging strategy and the impacts of noise on surrounding residential areas. This should include a discussion of noise generated by trucks, processing plant(s), pumps and water based activities.

- Discuss the possible changes to flood patterns within the Tweed River, including any likely changes in flood levels and flows, as a result of dredging.

- Discuss the impacts of dredging on existing commercial and recreational fishing grounds within the River.

It is noted that some of the land identified as being within the study area is subject to State Environmental Planning Policy No. 14 - Coastal Wetlands. Wherever dredging and/or associated works are within, or are likely to immediately affect, land within State Environmental Planning Policy No. 14 - Coastal Wetlands, the Director requires that the following matters be specifically addressed in the EIS in addition to those listed above.

(i) Provide a location plan clearly indicating proposed dredging operations within the boundaries of all mapped wetlands under SEPP 14. This plan should also indicate the exact location of dredging proposed to be carried out adjacent to mapped SEPP 14 wetlands.

(ii) Identify the wetland's habitats and ecological values and its water characteristics including:

(1) a vegetation survey and map (preferably at a scale of 1:4000) to particularly indicate the occurrence of any rare or threatened plant species, their values and the extent of any weed infestation;

(2) a faunal survey describing the birds (both indigenous and migratory), reptiles, amphibians and mammals (including bats) of the area and the occurrence of any rare or threatened and protected species; and

(3) an analysis of the surface and groundwater quality and hydrological regime.

(iii) Discuss alternatives to the site and to the proposal including the reasons and justification for choosing the proposed development at this location.

(iv) a discussion of the environmental implications of the proposal including but not limited to the following:

(1) an assessment of the changes in the distribution and abundance of plant and animal species;

(2) a description of the design features incorporated in the proposed development to guard against actual and potential disturbances to the vegetation, fauna, water quality and hydrological regime; and

(3) a description of any proposed measures intended to guard against actual and potential disturbances to the vegetation, fauna, water quality and hydrological regime during the construction and operation of the proposal.

(v) a description of any proposed measures intended to offset losses in wetland values or other environmental impacts which may occur if the development is allowed to proceed such as:

(1) the preparation of a management plan which maintains or enhances wetlands not affected by the proposal; and

(2) the establishment either on site or nearby of a wetland habitat which functions to replace some values lost through the development or contributes other wetland values.

4. In preparing your EIS you should approach Tweed Shire Council. If land within SEPP No. 14 is affected, you should also approach the Fisheries Division of the Department of Agriculture and Fisheries. You should take into account any comments the Council and the Department of Agriculture and Fisheries consider may apply to the determination of the proposal.

5. You should specifically consult Tweed Shire Council with regard to the zoning of land affected by your proposal. In this regard, it is noted that under the existing planning controls, dredging is permissible with consent from the bed of the river but a prohibited use on certain land surrounding the river.

6. Should you require any further information regarding this matter please do not hesitate to contact us again.

Yours faithfully

Charles Hill 20/12/90
Acting Manager,
Assessments Branch
as Delegate for the Director

DEPARTMENT OF PLANNING
ATTACHMENT NO. 1

STATUTORY REQUIREMENTS FOR ENVIRONMENTAL IMPACT STATEMENTS

In accordance with Part IV of the Environmental Planning and Assessment Act, 1979, an environmental impact statement (EIS) must meet the following requirements.

Pursuant to clause 34 of the Environmental Planning and Assessment Regulation, 1980, as amended, the contents of an EIS shall include the following matters:

(a) full description of the designated development proposed by the development application;
(b) a statement of the objectives of the proposed designated development;
(c) a full description of the existing environment likely to be affected by the proposed designated development, if carried out;
(d) identification and analysis of the likely environmental interactions between the proposed designated development and the environment;
(e) analysis of the likely environmental impacts or consequences of carrying out the proposed designated development (including implications for use and conservation of energy);
(f) justification of the proposed designated development in terms of environmental, economic and social considerations;
(g) measures to be taken in conjunction with the proposed designated development to protect the environment and an assessment of the likely effectiveness of those measures;
(g1) details of energy requirements of the proposed development and measures to be taken to conserve energy;
(h) any feasible alternatives to the carrying out of the proposed designated development and reasons for choosing the latter; and
(i) consequences of not carrying out the proposed development.

The EIS must also take into account any matters required by the Director of Planning pursuant to clause 35 of the Regulation, which may be included in the attached letter.

The EIS must bear a certificate as required by clause 26(1)(b) of the Regulation.

DEPARTMENT OF PLANNING

ATTACHMENT NO. 2

ADVICE ON THE PREPARATION OF AN ENVIRONMENTAL IMPACT STATEMENT (EIS) FOR DREDGING OPERATIONS (EXTRACTIVE INDUSTRY)

A definition of extractive industry may be found in paragraph (n) to Schedule 3 of the Environmental Planning and Assessment Regulations, 1980, (as amended). These industries are operations undertaken for the purpose of mining sand, gravel, clay, turf, soil, rock, stone or similar substances. The definition of extractive industry specifically excludes coal, petroleum or minerals which are prescribed under the Mining Act, 1973. Extractive industries may take the form of dredging operations, quarrying operations, turf farms or various forms of land excavation etc. Processing of extracted material on the same site as the winning of the material may also constitute an extract industry.

Dredging operations have prompted considerable public controversy in the past since, among other things, they affect water quality and caused disturbance through noise from associated processing operations on land and generate heavy vehicle movement.

The purpose of this paper is to outline various issues relevant to the preparation and consideration of an EIS for dredging and associated operations. It is intended to assist the preparation of the EIS. However, 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 requirements for EIS preparation (see Attachment No. 1).

The matters nominated in this paper 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. On the other hand, there may be other issues, not included, that are appropriate for consideration in the EIS.

Information provided should be clear, succinct and objective and where appropriate be supported by maps, plans, diagrams or other descriptive detail. The purpose of the EIS is to enable members of the public, the consent authority (usually the Council) and the Department of Planning to properly understand the environmental consequences of the proposed development.

.. Description of the proposal.

The description of the proposal should provide general background information on the location and extent of the works proposed, an indication of adjacent developments, and details of the site, land tenure, zonings and relevant forward planning proposals and any other land use constraints.

This section should provide specific information on the nature, intent and form of the development. It should, as far as possible, include such details as the processes involved, water pollution safeguards proposed, and 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:

- Characteristics (e.g. physical and chemical properties, etc.) and economic significance of the resource.
- Possible availability of alternative resources.
- Extent of dredging proposed - depth of dredging and anticipated final alignment and slope of batters.
- Quantity of materials to be extracted.
- Methods of extraction/plans of operations.
- Details of any blasting and/or crushing.
- Type of machinery and equipment to be used for the dredging and stockpiling operations and for any processing plant.
- Noise levels and the effects of vibrations.
- Expected life of the operation.
- Number of persons to be employed.
- Hours of operation.
- Details of necessary stockpiling.
- Proposed means of disposal of dredged material.
- Access arrangements - truck routes, truck numbers etc.
- Site drainage and erosion controls.
- Proposals for rehabilitation.
- Maintenance and servicing facilities.

2. Description of the Environment.

This should provide details of the environment in the vicinity of the development site and also of aspects of the environment likely to be affected by any facet of the proposal. In this regard, 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.

Details of terrestrial and aquatic flora and fauna, particularly any rare or endangered species, and any archaeological features within the anticipated area of affectation of the proposal should be included together with details of the hydrological regime of the waterway taking into account the effects of tides, currents, wave and sediment movements (including bank/beach/bed erosion) and floods.

3. Analysis of Environmental Impacts.

Environmental impacts usually associated with dredging and associated operations are listed below. Where relevant to the specific proposal, these should be addressed in the EIS, taking into account the adequacy of safeguards proposed to minimise them.

- The flow of any affected rivers or watercourses.
- The effect of the extraction on the sediment transport rate of any affected rivers or watercourses.
- The bed and bank stability of any affected rivers during and after completion of the operations, and any need for recurrent maintenance dredging.
- Any possible siltation, sedimentation or downstream effects of the operation.
- Details of bedrock outcrops, sediment and material gradings and any likely changes due to extraction.
- Any likely cumulative effects of the proposed operation when considered together with other operations in the vicinity.
- Details of floods and any likely effects of the operation on flood liability of surrounding lands.
- The possible effects of flooding on the operation.
- Effects on terrestrial and aquatic flora and fauna.
- Any impact on commercial/recreational fish resources.
- The agricultural viability of land to be used as a stockpile site.
- Likely noise/vibration disturbance caused by the operations, including transport and stockpiling operations, on nearby residences.
- Other impacts of trucking movements, including access over railways and onto highways.
- Dust nuisance from any stockpiles of dredged material.
- Effects on water quality of nearby watercourses, including any effects on surface and subsurface waters from any leachates produced from the stockpile material.
- Water treatment and other pollution control measures.
- Disposal of waste material.
- Effects on the visual environment.
- Proposed landscaping measures.
- Proposed final use of the stockpile site.
- Any likely affectation of sites of Aboriginal archaeological or European heritage value if located in the vicinity of operations.
- Impact of the operations on navigation aspects for all types of shipping (commercial, recreational, etc.).

In addition, any potential for hazard or risks to public safety and any proposals to monitor and reduce environmental impacts should be included.

4. Contact with relevant Government Authorities.

In preparing the EIS, it is suggested that authorities, such as those listed below, should be consulted and their comments taken into account in the EIS.

- The State Pollution Control Commission in regard to air, water and noise impacts and relevant pollution control legislation requirements;

- The Soil Conservation Service regarding appropriate erosion control and rehabilitation procedures;

- The Department of Agriculture and Fisheries with regard to any prerequisite requirements for dredging operations;

- The Heritage Council of NSW if the proposal is likely to affect any place or building having heritage significance for the State; the National Parks and Wildlife Service if aboriginal places or relics are likely to be affected;

- The Maritime Services Board with regard to navigational aspects of shipping;

- The Public Works Department in relation to hydrological impacts and relevant legislative requirements.

It is the responsibility of the person preparing the EIS to determine those Departments relevant to the proposed development.

2100/130

PUBLIC WORKS

NEW SOUTH WALES

PUBLIC WORKS DEPARTMENT—Tweed Entrance Project
Unit 15, Tweed City Arcade, 69 Wharf Street
PO Box 1013 TWEED HEADS NSW 2485
Phone (075) 36 9421 Fax (075) 36 9397

Department of Planning
G.P.O. Box 3927
SYDNEY NSW 2001

Attn: Ms Jodie Brown

Dear Madam,

Lower Tweed Estuary
Proposed EIS for Sand Extraction

Reference is made to the Department's letter of 9th August 1990 and the Department of Planning's response of 20th November 1990 concerning a proposal to prepare an EIS for sand extraction from the Lower Tweed Estuary.

In the Department's letter of 9th August 1990, the intention to prepare a single EIS for sand extraction from the entire lower estuary (below Barneys Point Bridge) was foreshadowed.

The Department of Planning advised formal requirements for the EIS on this basis. Since correspondence was received from the Department of Planning, the Department has prepared and placed on exhibition a Draft River Management Plan (RMP) for the lower estuary. A copy of the two head documents and a copy of the Exhibition Summary for the RMP are attached for information. To date, public response to the RMP has been very supportive.

Whilst not seeking to prejudge the nature of the final outcome of the exhibition process, it is clear that draft proposals for the removal of specific areas of shoal from the lower estuary will continue to be a community priority. Anticipating the probability that dredging recommendations will be widely endorsed, the production of an EIS for sand extraction commenced mid 1991.

As was mentioned earlier, the original strategy for achieving an approval for sand extraction was to produce a single EIS that would extend over the majority of the area examined within the RMP studies. An EIS was commenced on this basis.

Major difficulties have however been encountered in drafting the document due to the considerable areas of uncertainty that must be addressed in relation to an operating period that may extend in excess of 10 years.

~~NSW PUBLIC WORKS DEPARTMENT, LEVEL 4, NO 1 CHIFLEY SQUARE, SYDNEY, NSW 2000. TEL: (02) 237 7777 FAX: (02) 237 7333~~

These difficulties include inter alia: difficulties in assessing long term demand for sand in the face of other market suppliers, difficulties in anticipating the progressive response of the river ecology to improvements, any possible disbenefits that may arise from proposed dredging and difficulties associated with predicting the timing of the proposed river entrance sand bypass now the subject of negotiations between Queensland and New South Wales. Other issues of concern, are the time and cost of producing an EIS that establishes the necessary specificity for a proposal that will continue for approximately 10 years.

It has also become apparent that an approval that may be granted for the Tweed River over a period of 10 years or so would limit the very desirable ability of being able to modify dredging designs in response to ecological and broader consequential adjustments of the river environment. Following a period of careful review, it has been decided to limit the scope of the initial dredging proposal to the area shown on the attached plan (i.e. the river reach between Barneys Point Bridge and Rocky Point). The dredge area will be known as 'Zone 1'.

At this point it is relevant to recognise that an overall dredging plan for the estuary has been prepared and is currently exhibited in the RMP. The plan is subject to revision in the light of new information that may arise in the exhibition phase. The dredging plan detailed in the proposed EIS will be in conformity with this overall extraction plan (subject to modifications recommended through the public exhibition period). Future extraction proposals will also need to be in conformity with this modified extraction plan.

Recognising that the RMP, which is to be finalised following the public exhibition process, will establish the basic parameters and general environmental limits for dredging within the estuary, it is anticipated that the amended process addressing the requirements for a full EIS will be properly, fully and efficiently served by the revised procedure outlined above.

Please contact Brian Dooley on (075) 369421 if further explanation is required and if any concern exists. Unless advice to the contrary is received, it will be assumed the requirements for an EIS for dredging from a reduced area (known as Zone 1) will, in other respects, remain as outlined in the letter from the Department of Planning dated 20th November 1990.

Yours faithfully,

Brian Dooley
Project Manager 28.11.91
Tweed Entrance

New South Wales Government

Department of Planning

Mr Brian Dooley
Project Manager Tweed Entrance
Department of Public Works
PO Box 1013
TWEED HEADS NSW 2485

Remington Centre
175 Liverpool Street, Sydney 2000
Box 3927 G.P.O. Sydney 2001
DX . 15 Sydney

Telephone : (02) 391 2000 Ext:
Fax No : (02) 391 2111

Contact : Ruth Burlakov
Ext. 2071

Our reference : G90/00174

Your reference : R/2100/130

9-1-92

Dear Mr Dooley,

EIS FOR SAND EXTRACTION OF THE LOWER TWEED ESTUARY

Thank you for your letter of 28 November 1991 regarding modification of the above proposal which was the subject of Director's requirements issued by this Department on 20 November 1990.

The approach you have outlined for dealing with environmental impact assessment of the above proposal is acceptable.

Yours sincerely

Neville Apitz

N Apitz
Assistant Director

APPENDIX 3

RMP DESIGN - AREA 5

RIVER MANAGEMENT PLAN DESIGN
TWEED RIVER LOWER ESTUARY - Area 5

BACKGROUND

Preliminary planning, together with the associated undertaking of a range of hydraulic, environmental and recreational studies, have been completed to form the basis of development of the River Management Plan (RMP) for the Tweed Lower Estuary below Barneys Point Bridge. Schemes to enhance community use and the ecological environment of the Lower Estuary have been prepared and displayed for public comment. A staged Notional Dredge Plan aimed at facilitating these enhancements forms part of the RMP.

This report briefly documents the design of the Dredge Plan for the first stage of works for Area 5 extending from Barneys Point Bridge to Rocky Point. This includes dredging and other works aimed at enhancement of the river ecology, flooding behaviour, recreational use of the foreshores, navigation and boating facilities, and improvements to Tonys Bar to cater for endangered seabirds and migratory birds and reduce biting midge breeding areas. Details of the Plan and background considerations are outlined below.

DESIGN CONSIDERATIONS

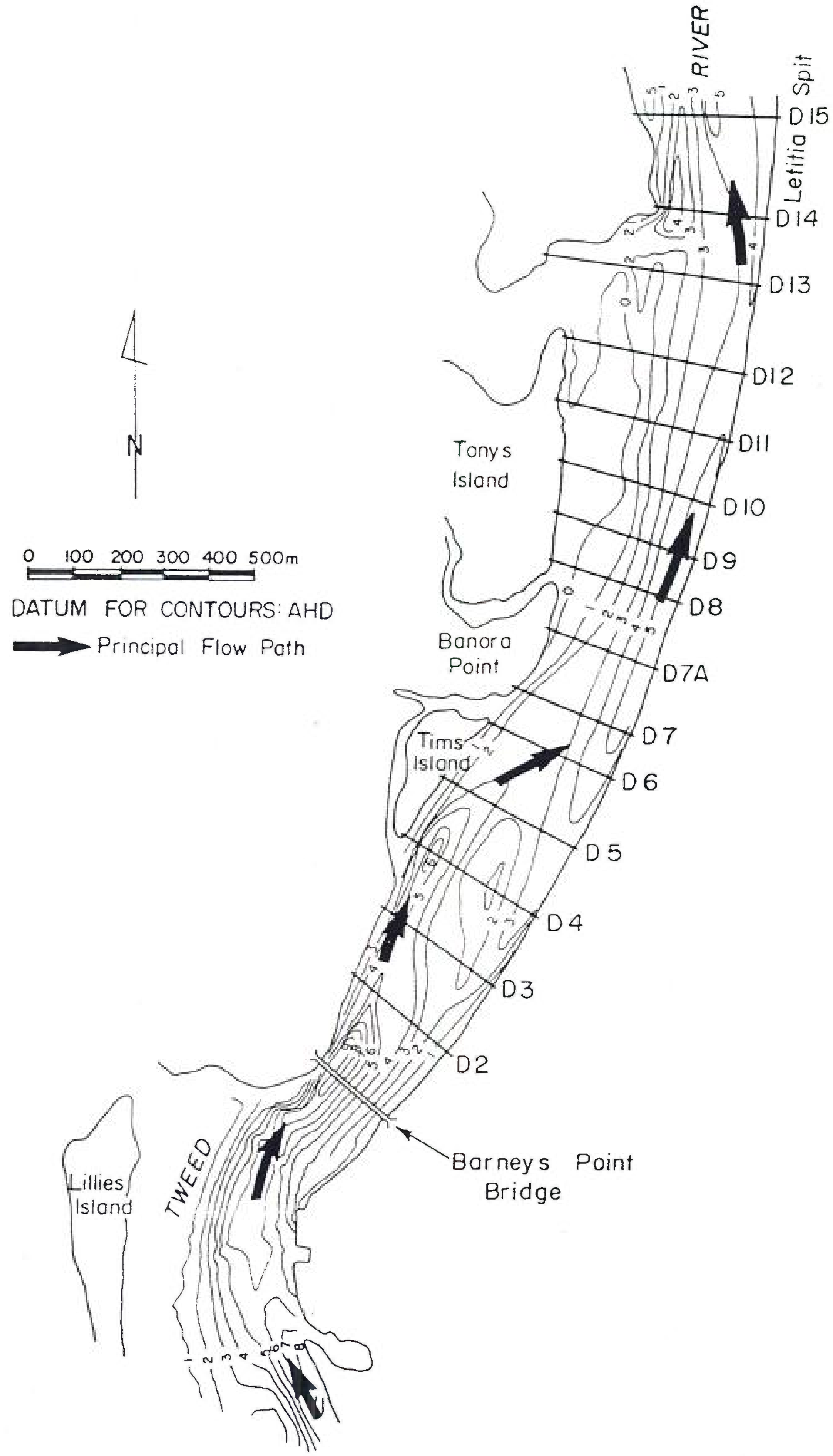
The present status and bathymetric configuration of the Area 5 area of the lower estuary is illustrated in Figure A3.1. A number of existing problem areas and the complex and constricted nature of the tide/flood flow paths and navigation channel are shown.

The primary aim in developing the attached River Management Plan has been to enhance the navigability, hydraulics, water quality, ecology and public amenity values of this portion of the river. The key strategy in developing the Plan is to confine the main navigation channel to the eastern side of the river whilst retaining and enhancing the western shores for ecological/fisheries purposes. Improvements to Tonys Bar and provision of boating and recreational facilities along the western foreshore could be provided. The proposed Dredge Plan and associated enhancement works are shown in Figure A3.2. Discussion of the principal design considerations for the Plan is outlined below.

Navigation Channel

The main channel presently occurs on the western side of the river from Barneys Point Bridge to Tims Island and then crosses to the eastern river bank.

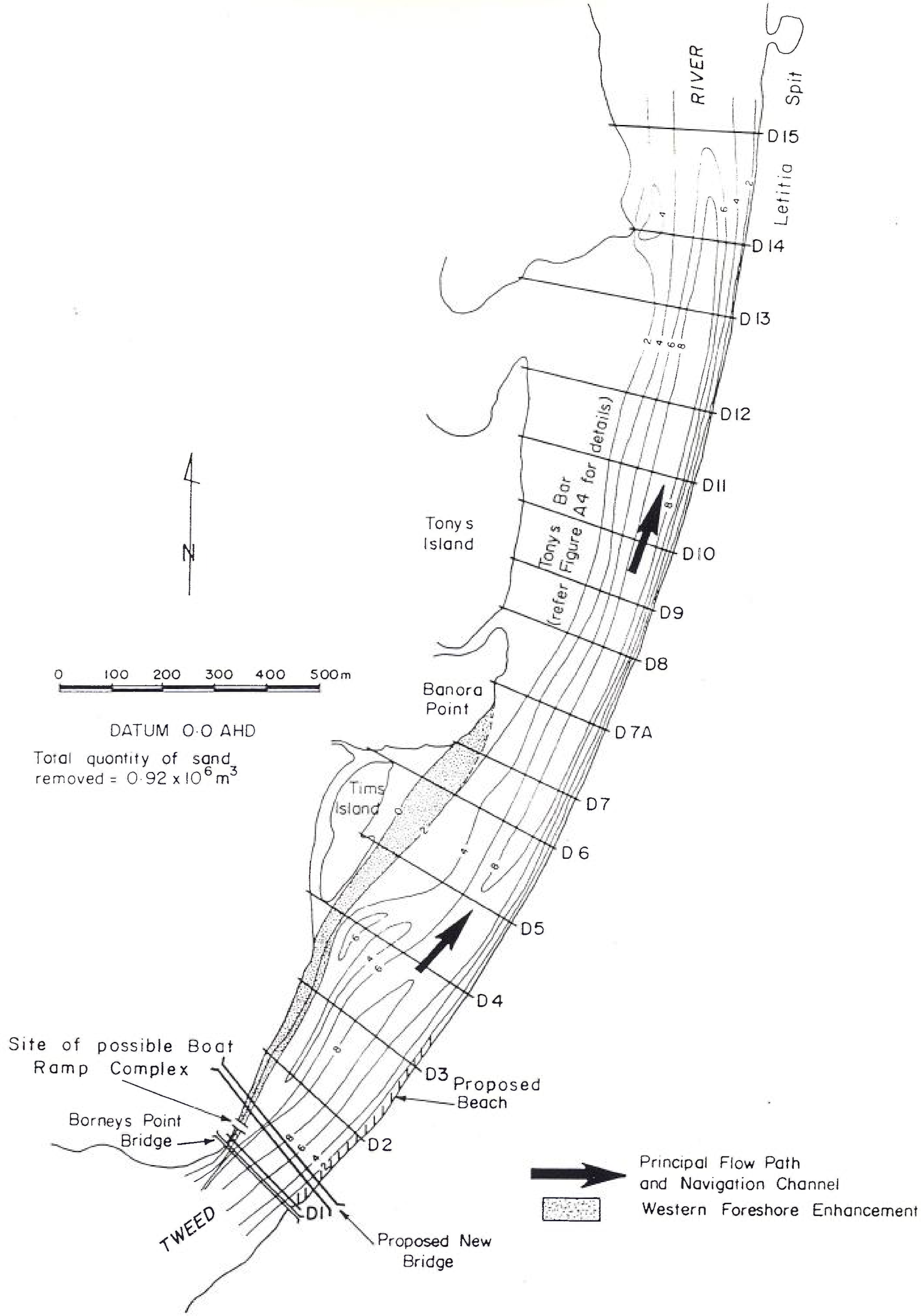
The proposed Dredge Plan for this area is shown in Figure A3.2. It provides for sand extraction to realign the main channel to a more direct course. Navigation channel banks would be steeper against the eastern river bank but slope more gradually towards the western



LOWER TWEED RIVER - AREA 5
EXISTING BATHYMETRY AND RIVER FEATURES

FIGURE A3.1

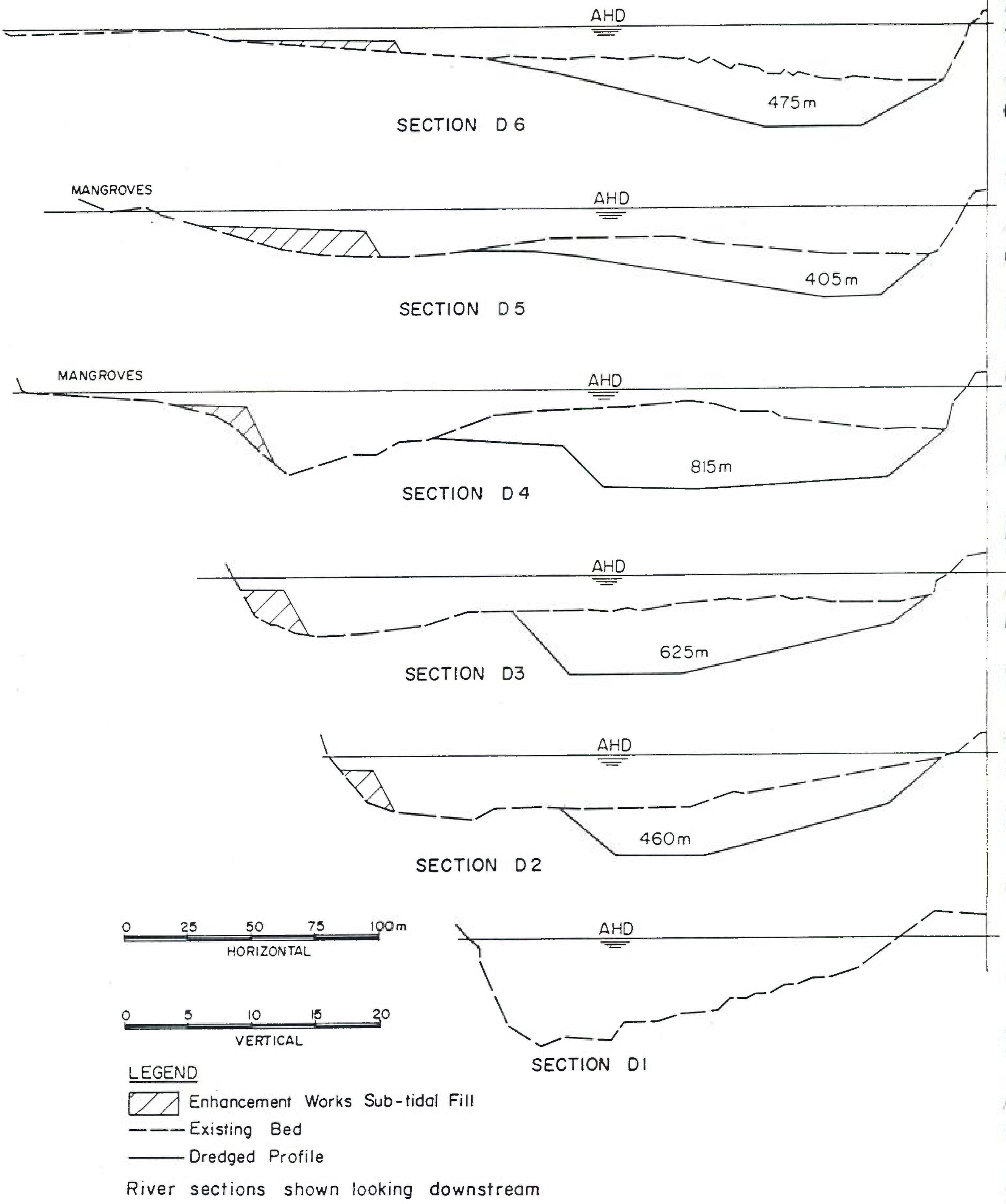
WBM OCEANICS AUSTRALIA



RIVER MANAGEMENT PLAN - AREA 5
DREDGE PLAN AND ENHANCEMENT OPTIONS

FIGURE A3.2(a)

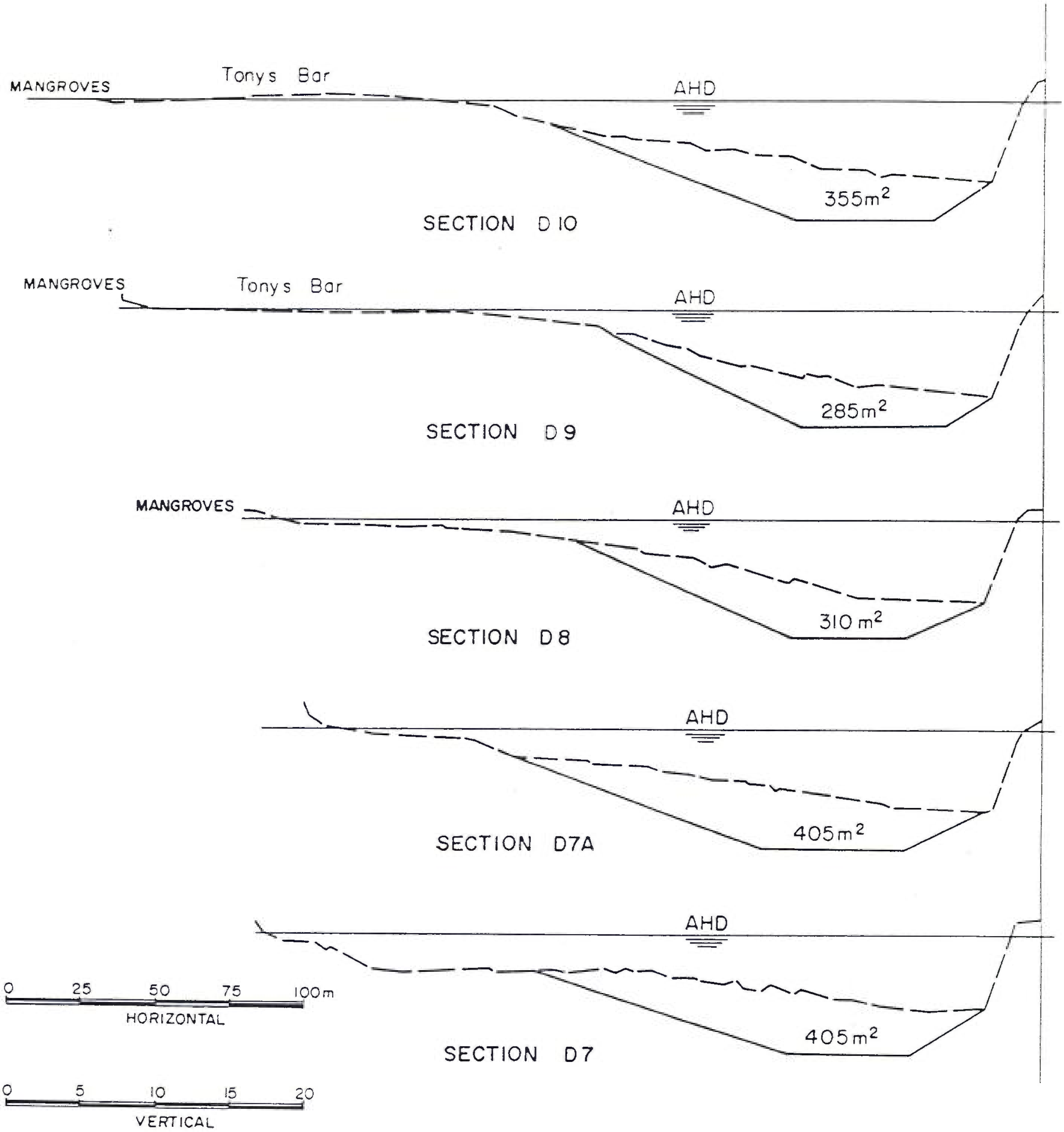
WBM OCEANICS AUSTRALIA



RIVER MANAGEMENT PLAN - AREA 5
DREDGE PLAN CROSS-SECTION DETAILS

FIGURE
A3.2(b)

WBM
OCEANICS AUSTRALIA



LEGEND

- - - - Existing Bed

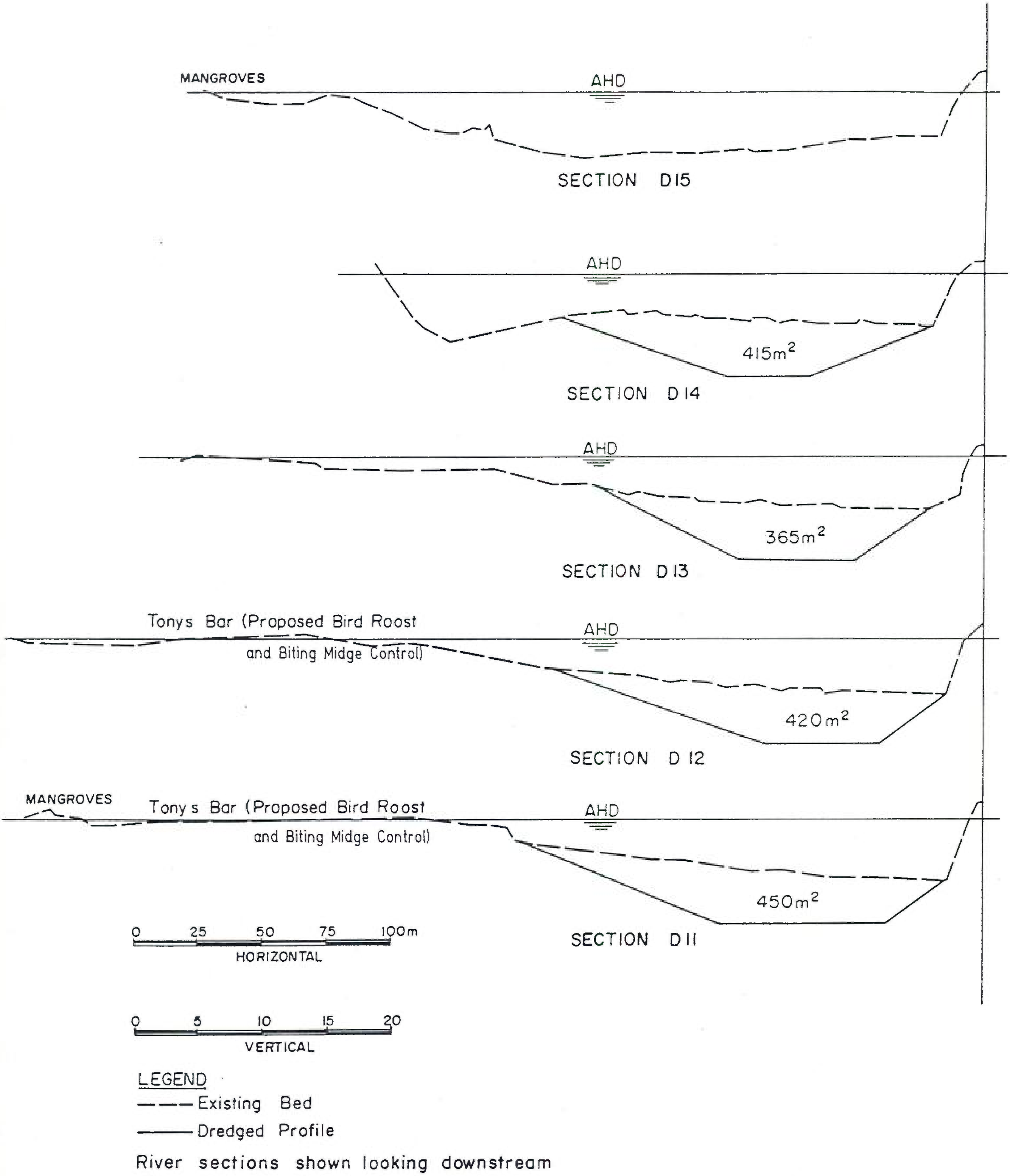
——— Dredged Profile

River sections shown looking downstream

RIVER MANAGEMENT PLAN - AREA 5
DREDGE PLAN CROSS-SECTION DETAILS

FIGURE
A3.2(c)

WBM OCEANICS AUSTRALIA



RIVER MANAGEMENT PLAN - AREA 5
DREDGE PLAN CROSS-SECTION DETAILS

FIGURE A3.2(d)

WBM OCEANICS AUSTRALIA

river bank. The dredging must conform with the conditions prescribed for the Tweed River in respect of bank and channel stability. These conditions would include the following:

- a minimum bank set-back of 10 metres from Mean High Water (MHW) mark;
- underwater batters no steeper than 1 in 6 from the toe of the bank set-back; and
- a maximum dredging depth of 8 metres below MHW (-6.6 m THD).

The abovementioned underwater batter requirement satisfies the Maritime Services Board requirement for "no (underwater) slope to be steeper than 1 in 3".

Depths within the river channels have been varied to provide physical diversity. Such areas with varying bottom depths are generally utilised by a greater assortment of aquatic fauna than areas with uniform depths. The existing western channel and a significant part of the central river sand shoals extending some 500 metres downstream from Barneys Point Bridge are retained, while improving the navigation channel on the eastern side.

Locally deepened areas can be provided to enhance fishing (commercial and recreational). These would form part of the navigation channel in this area, since the use of shallow areas adjacent to the navigation channel is not feasible within this relatively constricted reach of the river (although it would be in other river reaches). It is recognised that some conflicts between fishing and navigation could occur with such an arrangement however the channel is relatively wide (approximately 150 m) and vessels will have ample room to manoeuvre.

A quantity of approximately 0.92 million cubic metres would be extracted from this section of the river in establishing the navigation channel as proposed.

Filling of Western Foreshore Sub-Tidal Areas

Dredged sand can be used to reduce water depths adjacent to the western river foreshores. It is proposed that the sub-tidal areas shown in Figure A3.2, presently at RL -3 m to -5 m AHD, could be filled to depths of -1 m to -2 m AHD. This would involve placement by dredging associated with the navigation channel works, of about 35,000 - 40,000 cubic metres of sand. The design would have to be integrated with structures associated with the new bridge at the upstream end where a structure, either part of the bridge or a separate groyne, is needed to protect the sand fill. Sands to be dredged are likely to contain very low levels of silt. Any turbidity plumes resulting from fill placement should be relatively localised and not influence downstream seagrass beds. Further studies could be necessary to confirm this.

The main objectives of the shallowing process described above are to:

- maintain current velocities in the newly located navigation channel;
- direct floodwaters into the navigation channel;
- create additional shallow areas suitable for juvenile fish such as whiting and bream (ie. nursery habitat); and
- create additional habitat suitable for seagrass colonisation.

Seagrass does not presently occur on the western side of the river upstream of Tims Island and downstream of Barneys Point Bridge because no shallow areas are available. Filling of these presently deeper areas would provide conditions suitable for seagrass to extend its distribution from existing beds (eg. near Tims Island) or to naturally colonise new areas (eg. upstream of Tims Island). Seagrass could be transplanted into the newly created areas from other nearby areas.

The placement of fill near Tims Islands could adversely affect the existing seagrass beds which occur in waters of depth 0 to -1 m AHD. Once the filling configuration is finalised, the proximity of the seagrass beds and potential impacts could be assessed. Options to avoid impacts include temporary protective screens around seagrass beds or removal of seagrass areas for subsequent transplanting in areas where filling works have been completed.

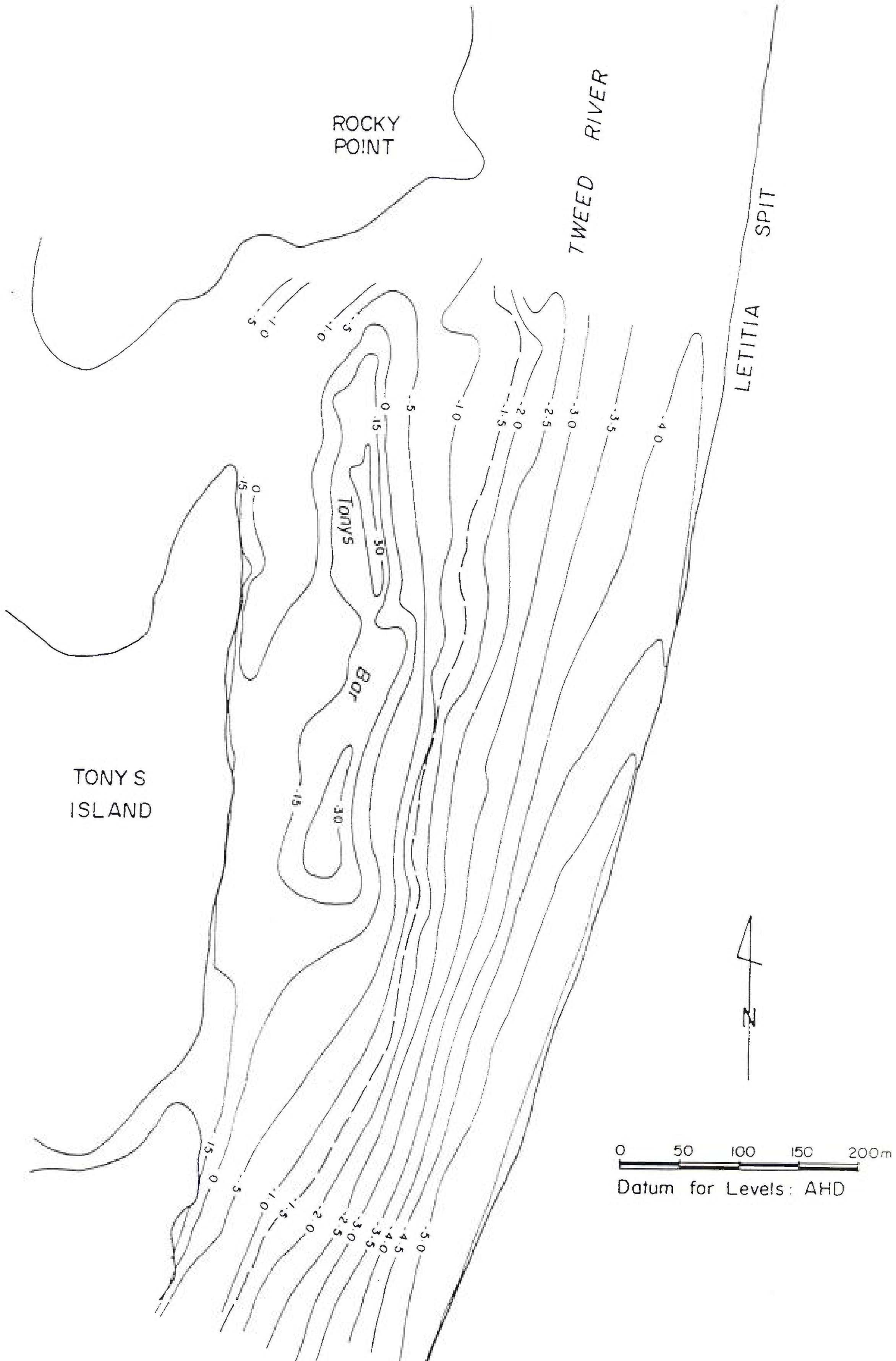
The creation of a beach and shallow (1 to 2 m deep) subtidal areas would provide a water-based recreational area in a reach of the river that presently offers relatively few such opportunities. The existing boat hire/swimming area on the opposite eastern river bank has only limited vehicular parking being immediately adjacent to Fingal Road.

Construction of a beach could also create an additional net hauling area for commercial fishermen. The filling works to create a broad shallow flat would provide ideal conditions for net hauling. This may compensate for some of the disruption to fishing operations caused by modification works on Tonys Bar.

Tonys Bar

Tonys Bar is important as a shorebird staging/roosting and foraging area. It is used by professional and recreational fishermen, particularly for net fishing and as a source of bait (yabbies). However, the bar is at such a level that it presents a very large breeding area for biting midges. The existing bar contours are shown in Figure A3.3.

The amenity and desired function of Tonys Bar, particularly for birds, can be upgraded as part of enhancement works for the area by modifying the sand levels in two ways. These are:



TONY S BAR EXISTING CONTOURS

FIGURE A3.3

WBM OCEANICS AUSTRALIA

- raising certain parts above high tide levels to provide an all-tide bird roosting area and eliminate biting midge breeding habitat, and
- excavating other parts below mean tide level to eliminate biting midge habitat.

It is not feasible to eliminate the biting midge areas altogether, but they can be substantially reduced. This is achieved by providing steeper foreshore slopes in the intertidal zone between mid-tide and high tide levels. Some sections can be constructed as revetments at a slope of about 1 in 2, while other sand beach areas could be about 1 in 8. The extent of revetment rather than beach should be maximised, subject to cost constraints.

A bird roosting area could be constructed as sandfill above tide and flood levels. A practical design for Tonys Bar to utilise sand presently on the Bar itself, redistributed to minimise biting midge habitat and maximise bird roosting areas has been determined.

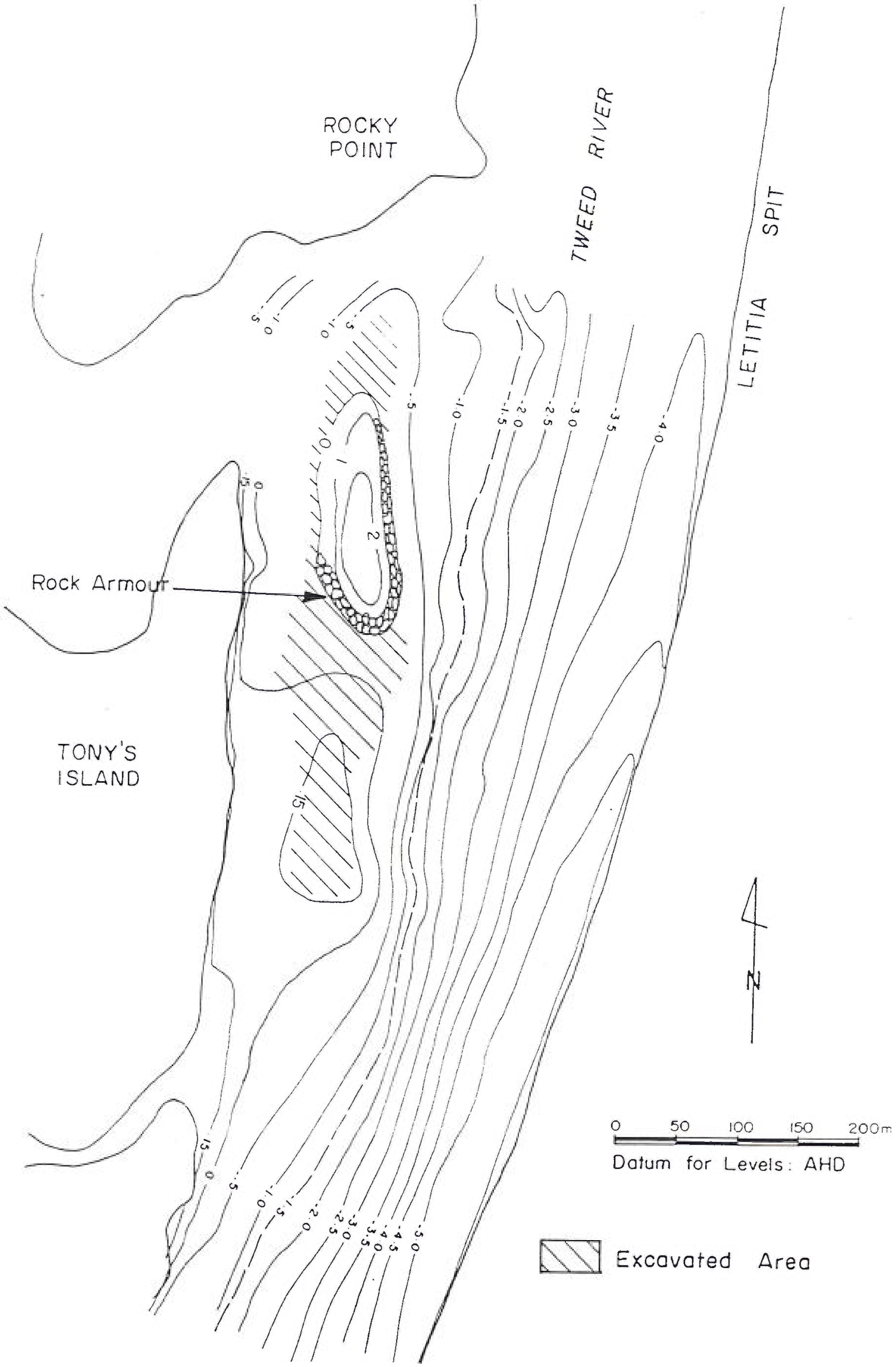
Figure A3.4 shows the modified levels, providing for a roosting area of about 0.7 hectares above high tide. The crest level for the island is at about RL 2.0 - 2.5 m. This will ensure maintenance of exposed roosting areas during all but the most extreme flood conditions. Construction could be undertaken over a period of 3-4 months using plant and materials barged across the river. Stage construction in the flood free period of the year would be feasible. About 7500 cubic metres of sand would need to be relocated from within the intertidal zone.

Tonys Bar is presently in a zone of high sand mobility and the bar/spit form exhibits dynamic behaviour associated with short term flood events, superimposed on gradual long term change. Works to change the island levels and nearshore bathymetry will continue to be subject to waves and currents which will tend to erode some areas and accrete others. The design requires some provision of protection from scour. In particular, the upstream end of the filled area needs armouring to prevent scour by flood flows. Ongoing maintenance will also be needed to remove biting midge areas which develop over time.

The existing seagrasses along the western side of the Bar would be left undisturbed as far as practicable.

Tims Island

Enhancement works could be undertaken to restore the vegetation communities (mainly mangroves and paperbarks) on Tims Island which is a designated SEPP 14 Wetland, but has been degraded by clearing. This would involve weed removal and replanting of appropriate vegetation. A boardwalk on the island through wetland vegetation is likely to be well patronised. Further investigations would be required should this option be pursued. The potential adverse impacts of providing access for people and domestic and feral animals would need to be considered.



TONY'S BAR BIRD ROOSTING AREA

FIGURE A3.4

WBM OCEANICS AUSTRALIA

Boat Ramp Facility

The Dredge Plan and the proposed new bridge construction provide an opportunity to construct a new boat ramp facility on the western foreshore. It could be located between the existing and new bridges. There may be a need to excavate an area to form a gently sloping beach suitable for ramp construction and for recreational use.

APPENDIX 4

CONSULTATION WITH GOVERNMENT AGENCIES AND COMMUNITY GROUPS

New South Wales Government

Environment Protection Authority

NSW Government Offices
49 Victoria Street
PO Box 498
GRAFTON NSW 2460

Our reference: 250442A DJK:SG

Your reference:

Contact:

Telephone: (066) 42 0535
Fax: (066) 42 0606

Project Manager - Tweed Entrance
Public Works Department
PO Box 1013
TWEED HEADS NSW 2485

Dear Sir

PROPOSED SAND EXTRACTION - LOWER TWEED ESTUARY

We refer to your letter of 26 February 1992 concerning the preparation of an Environmental Impact Statement (EIS) for the above proposal.

Formal approval for the dredging component of the works will be required under the State Pollution Control Commission Act, 1970. The following criteria will need to be satisfied and the EIS should address these matters:

1 **Water Pollution Control**

Dredge wastewaters will require detention or treatment prior to their discharge to any water course. The Environment Protection Authority (EPA) would require the discharged wastewaters to have a suspended solids concentration of less than 50 milligrams per litre, and this can normally be achieved by the use of ponds with a capacity of at least two days flow.

The EIS should also address the possible long term impact of the dredging in relation to water quality in the Lower Tweed Estuary.

2 **Noise Pollution Control**

The dredge operation has the potential to cause a noise impact. The EPA's general criteria is that the maximum noise level (L_{A10}) from the dredge, when measured at the boundary of the nearest affected residence, should not exceed the background level (L_{A90}) by more than 5dB(A). This allowance may be increased to 10dB(A) if the duration of dredging will be less than six months.

Noise from other plant and equipment (e.g. front end loaders, bulldozers and trucks) likely to be used on the site should also be considered.

If a noise impact is likely, the EIS should include a Noise Impact Statement and give details of any measures proposed to control the impact.

3 <u>Air Pollution Control</u>

Wind blown material may originate from sand stockpiles, filled ares and unsealed access roads. The EIS should detail any measures proposed to control such problems.

We trust these comments assist in the preparation of the EIS. Should you have any further enquiries please contact the undersigned.

Yours faithfully

D. J. Keats

- 3 MAR 1992

D J Keats
<u>for Director-General</u>

NSW NATIONAL PARKS AND WILDLIFE SERVICE

1st December, 1993.

NSW Public Works Department
P.O. Box 73
LISMORE 2480

Attention: Mr. I. Taylor

Our reference: F/0185
Your reference:

Dear Sir,

Re: EIS Lower Tweed Estuary, Proposed Sand Extraction: Area 5

Reference is made to your fax of 23rd November, 1993 concerning the above.

The E.I.S. should consider whether the proposed activities will have a significant impact on endangered fauna by taking into account the factors under S.4A of the Environmental Planning and Assessment act, 1979 (the "seven point test").

If it is then concluded that the activities will have a significant impact on the environment of endangered fauna, a fauna impact statement (FIS) must be prepared in accordance with section 92D of the National Parks and Wildlife Act 1974. Alternatively, by addressing S92D of the NPW Act, 1974 within the EIS, no separate FIS is required (i.e. it becomes an EIS/FIS equivalent).

More generally the proposed EIS should include a full description of flora and fauna at the site, and consider the impact of the proposed activity on these. Particular attention should be paid to wading birds.

We would also recommend that you conduct an archaeological assessment of the site by an appropriately qualified archaeologist in consultation with the Tweed-Byron Local Aboriginal Land Council.

Please contact Lance Tarvey at this office if you require further information.

G Holloway

Guy Holloway
DISTRICT MANAGER
LISMORE DISTRICT

Lismore District
Suite 9
Colonial Arcade
75 Main Street
Alstonville
PO Box 91
Alstonville 2477
Tel: (066) 28 1177
Fax: (066) 28 3937

Head Office
43 Bridge Street
Hurstville NSW
Australia
PO Box 1967
Hurstville 2220
Tel: (02) 585 6444
Fax: (02) 585 6555

NSW
NATIONAL
PARKS AND
WILDLIFE
SERVICE

25th February, 1992

Public Works Department
Tweed Entrance Project
P.O. Box 1013
TWEED HEADS 2485

Attention: Brian Dodey
Our reference: F/0269
Your reference:

Dear Sir,

Re: Stockpile Site Fingal Peninsula

Thankyou for your letter of the 3rd February, 1992. Your suggestions regarding proposed archaeological surveys of the site are accepted.

It is agreed that all excavations on-site should be carried out with care. In the event of artefacts or relics being uncovered development works should cease immediately and the Service informed.

Could you please provide a copy of Report No. 5 (Adrian Piper report) and report 3.4.1. to this office.

Yours faithfully,

David Charley
for DIRECTOR

Lismore District
Suite 9
Colonial Arcade
75 Main Street
Alstonville
PO Box 91
Alstonville 2477
Fax: (066) 28 3937
Tel: (066) 28 1177

Head Office
43 Bridge Street
Hurstville NSW
Australia
PO Box 1967
Hurstville 2220
Fax: (02) 585 6555
Tel: (02) 585 6444

MSB Waterways

North Region
P.O. Box J23
Office: Jordan Esplanade
Coffs Harbour Jetty NSW 2450

Telephone: (066) 51 3400
Facsimile: (066) 51 1352

Your Ref: R/2100/130

23 June 1992

Mr Brian Dooley
Project Manager
Public Works Department
PO Box 1013
TWEED HEADS NSW 2485

Dear Mr Dooley

Thank you for your letter to Carl Cormack, BSO Tweed Heads concerning the proposed sand extraction EIS for the area downstream of Barney's Point Bridge.

The MSB Waterways Authority requires the following.

1. The dredge to be appropriately marked for daylight operation.

2. The dredge to be appropriately lit from sunset to sunrise and during daylight at times of restricted visibility.

3. The two lateral channel markers may need to be moved during the operation. This must be done in consultation with the BSO Tweed Heads.

4. As the dredge will be operating in an area of extreme environmental sensitivity, an oil spill contingency plan should be developed for the operation and oil spill equipment should be located at or near the operation.

   Particular care must be taken by the dredge operators to avoid any pollution incidents during fuelling operations, maintenance or in the event of an accident. They should be aware of their responsibilities on this issue.

Thank you for referring this matter to us.

Yours sincerely

Lawrie McEnally
Operations Supervisor North/Inland

...TMENT OF MINERAL RESOURCES
...WALES GOVERNMENT

MINERALS AND ENERGY HOUSE
29-57 CHRISTIE STREET
CORRESPONDENCE PO BOX 536
ST LEONARDS NSW 2065
DX 3324 ST LEONARDS
TELEPHONE (02) 901 8888
FACSIMILE (02) 901 8777

The Projects Manager
Public Works Department
P.O. Box 1013
Tweed Heads NSW 2485

Our Ref : L91-0525
Your Ref: R/2100/103
For further information
Ring: J. O'Neill
Tel : 901-8254

Lower Tweed Estuary River Management Plan

Reference is made to your letter dated 16th October, 1991 regarding the Lower Tweed Estuary River Management Plan.

This Department concurs with your Management Plan in general, however is concerned that no allowance has been made or documented in the plan for the treatment of the dredged river materials for heavy mineral sands. Also of concern, is that there has been no provisions included to allow for future mining exploration or extraction of mineral deposits.

If documentation of these matters are included in your final draft then this Department would have no objections to the proposed Management Plan and would have no need to make any further comments.

If you should require further information please contact Mr. J. O'Neill on (02) 901-8254.

J L O'Neill 13/12/91
J. O'Neill
For Director General

PLEASE QUOTE COUNCIL REF. No.: GR1/1/3 PT3 400

YOUR REF. No.:

FOR ENQUIRIES PLEASE CONTACT: Mr M Swain

TELEPHONE DIRECT: (066) (066) 720456

L18A03

19 May 1992

Public Works Department
PO Box 1013
TWEED HEADS 2485

Dear Sir,

Lower Tweed Estuary - Proposed EIS Sand Extraction - Zone 1.

Thank you for your letter of 10 March 1992 advising of the proposed sand extraction above.

Together with consideration of the requirements of the brief from the Director of the Department of Planning and in an effort to avoid some of the delays incurred by proponents involved with applications with similar implications it is suggested that strong account be taken of the following:

* The need for substantial liaison/community consultation with residents adjacent to the lease area.

* Specific awareness of the extent of affectation on both local and S.E.P.P. 14 Wetlands with an indication of the following:

  - Identification of compensatory wetland areas and strategies for acceptable on going management practices.

* Liaison with all relevant government departments with a view to obtaining a reasonable degree of acceptance prior to completion of a formal document.

For any enquiries in relation to the above please contact Mr Swain of Council's Development Services Division.

Yours faithfully

Garry Smith
Manager Development Control
DEVELOPMENT SERVICES DIVISION

TWEED BYRON LOCAL ABORIGINAL LAND COUNCIL

P.O. Box 6160
Tweed Heads South NSW 2486
Telephone (075) 54 3238

16 June 1991

The Project Manager

Tweed Entrance Project
Tweed City Arcade
Unit 15, 69 Wharf Street
TWEED HEADS NSW 2485

STATEMENT

CONCERNING ABORIGINAL SITES AND PLACES
IN THE LOWER TWEED ESTUARY.

The Tweed Byron Local Aboriginal Land Council was contacted by Brian Dooley, the Project Manager for the Lower Tweed River Management Study currently being undertaken by the Public Works Department. We were contacted to give our preference for an Archaeologist to undertake an archaeological survey of the Lower Tweed River Estuary. The Archaeologist selected was Adrian Piper who has conducted other surveys in the Tweed Valley and has a good relationship with our community.

The survey was a visual one which has limitations of locating sites not known to our community. Many of the places of importance and sites have been undermined or destroyed over the past 150 years. The sites that remain are what is left of our history books other than oral information known by our community.

The area surveyed has numerous known sites, mainly consisting of Middens along the banks of the lake, river and adjacent areas. The Middens are also located on islands in the Tweed River Estuary.

There are also spiritual and mythological places such as, Kerosene Bay and The Caves (Quarry) which are very significant to our community.

16 June 1991

STATEMENT

CONCERNING ABORIGINAL SITES AND PLACES
IN THE LOWER TWEED ESTUARY.

We must insist that our Land Council be notified prior to any dredging and construction of stockpile sites and access roads. This would enable us to assess the impact of possible disturbance thereby making sure that the significance of known sites are not undermined. This would also decrease the possiblity of sub-surface sites from being destroyed or being interfered with.

Many members of our community are wary of the effects of proposals such as the one proposed, as they have witnessed the desecration of sites especially the Massacre Site during the sand mining era.

Our community wish to conserve what is left of our Cultural Heritage and appreciate the opportunity to express our views in this study.

Yours faithfully

Franc Krasna x

Franc Krasna Jnr
CHAIRMAN

LAND CLAIMS

Tweed Byron Local Aboriginal Land Council.

GRANTED

NO.	CLAIM NO.	COUNTY	LAND IDENTIFIER
1.	3287	ROUS	LOT 713 IN DP 728231& PART R. 82697
	GOVERNMENT APPEALING		
2.	72	ROUS	LOT 701 DP 704337
3.	73	ROUS	LOT 700 DP 704337
4.	CEMETARY	ROUS	CEMETARY FINGAL N.P.W.S.
5.	CHURCH	ROUS	LOT 276
6.	75	ROUS	LOT 283
7.	HOUSE ALLOTMENT	ROUS	LOT 636
8.	74	ROUS	LOT 662
9.	76	ROUS	LOT 706
10.	76	ROUS	LOT 707
11.	76	ROUS	LOT 705
12.	3086	ROUS	LOT 719 DP 820030

UNDER INVESTIGATION MARKED A.

NO.	CLAIM NO.	COUNTY	LAND IDENTIFIER
1A.	8087	ROUS	PORTION 503 & PT R 2509
2A.	3139	ROUS	LETITIA SPIT
	THIS CLAIM HAS BEEN REVISED AND DIVIDED INTO SEVEN SEPARATE CLAIMS. NUMBERED 3399, 3400, 3401 3402, 3403, 3404, 3405.		
3A.	3093	ROUS	PORTION 56, 57 & 321

DEPARTMENT
OF LANDS

(Division of DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT)

Our Ref: GF90 H 491 rd;jc
Contact: S. MacDonald
Phone: 066 420544

Project Manager,
Tweed River Management Plan,
NSW Public Works Department,
P.O. Box 1013,
TWEED HEADS. NSW 2485

ATTENTION: **Brian Dooley**

Dear Sir,

LOWER TWEED ESTUARY RIVER MANAGEMENT PLAN

The River Management Plan for the Lower Estuary provides a dynamic and extensive study for the Region. The project team is to be congratulated on the production of such an exhaustive study.

There are a number of areas I wish to make comment on in relation to areas of interest to the Public Land Management Division of the Department of Conservation and Land Management. These comments relate to areas of responsibility and administration of this Department.

The River Management Plan makes extensive recommendations to future land use on Crown land within Fingal Peninsula. This area comes under the administration of this Department. As part of our future planning for the area, a study titled "Fingal Peninsula Land Assessment" was publicly exhibited for 3 months in 1991. This study was prepared under Part 3 of the Crown Lands Act, 1989, and provides a basis for rational land use allocation of Crown land in accordance with the principles of Crown land management. The suggestions made for Fingal Peninsula in the River Management Plan and Recreation Study have been included with the submissions received from exhibition of the "Fingal Peninsula Land Assessment" report and will be considered along with other submissions. No final land use should be canvassed under the auspices of the River Management Plan.

One of the areas identified as a possible funding source for the implementation of the Plan is revenue from commercial dredging operations. It is understood that this revenue would be in the form of royalties accruing to the Crown from sale of the extracted material. The River Management Plan identifies 3.75 million cubic metres to be removed from the river and a further 1 million cubic metres from the construction of wetlands on Fingal Peninsula. Current extraction rates from the Tweed River and Cobaki Broadwater and proposed future extractions from 3 recently tendered areas of the Tweed River upstream of Barneys Point Bridge suggest a market demand of between 100,000 and 200,000 cubic metres from Crown land. There appears to be little further demand for material within the Region.

49 Victoria Street Grafton NSW Australia 2460 PO Box 11 Grafton NSW Australia 2460
Telephone (066) 42 0546 Fax (066) 42 0556

NEW SOUTH WALES GOVERNMENT

GRAFTON LANDS OFFICE

Public Works Department,
TWEED HEADS

GF90 H 491

(continued)

Extraction rates for the Tweed area for the past 3 years are as follows:

OPERATOR	QUANTITY (cubic metres)		
	1988	1989	1990
1. A. & L. Broadhurst Hill (Cabaki Broadwater)	0	0	0
2. Tweed River Sand Supply Tweed River	65376	72190	51519
Total	65376	72190	71845

For the quantity of material to be successfully tendered, further details on market demand for the identified 4.75 million cubic metres of material need to be identified. In addition, details of the effects on existing and currently proposed extraction operations within the Tweed River and Cobaki Broadwater require investigation.

This Department is the administrative authority responsible for issuing of Licences under the Crown Lands Act, 1989, for the extraction of materials (other than materials under the terms of the Mining Act, 1973) from Crown land. The plan as presented requires a large staff commitment of resources from this Department to enable the tendering, representation on Committees, Land Assessment, and issue and administration of licences for extraction of material. The cost of this administrative action is seen as a cost of the overall project. Funding for an in-house consultant to undertake such work on behalf of the Department should be included in overall costs.

The Study mentions the lodgement of several Land Claims over Crown land on Fingal Peninsula by the Tweed Byron Aboriginal Land Council. This Department is the administrative authority responsible for dealing with and negotiation of these claims.

Whilst claims are under investigation, no tenures can be granted by the Department of Conservation and Land Management over areas under claim. The information contained within your reports and uses proposed for the areas under claim will be considered in dealing with these claims.

Public Works Department,
TWEED HEADS

GF90 H 491

(continued)

The Study recommends an area between Wommin Lagoon and Wommin Lake as a stockpile site for the dredged material. This area is currently subject to an Aboriginal Land Claim and no consent/licence to stockpile material here can be given until resolvement of the claim. If the claim is granted, then it will be necessary to deal with the Tweed Byron Aboriginal Land Council. Land granted to land councils under the Aboriginal Land Rights Act, 1983 has equivalent status to freehold land.

The "Fingal Peninsula Land Assessment" has also made an assessment of suitable uses for this area. The area has been identified as Mapping Area 25 in the Land Assessment report with Recreation (Tourism) identified as suitable uses. The use of the area for a stockpile site appears to conflict with the identified suitable uses.

Within Appendix D of "Implementation Options - Technical Report No. 8, the Crown Lands Act, 1989 should be included in the list of principal legislation affecting the Tweed River.

The reports also make mention of sand mining in Cobaki Broadwater. The material extracted from the area under the administration of this Department, is sand and is not minerals under the meaning of the Mining Act, 1973. The term sand mining appears inappropriate as it normally only applies to areas where sand is being mined for the purpose of extracting minerals.

There are a number of recommendations in the reports for walking tracks to be constructed around foreshore areas. Many of these areas are public lands under the administration of this Department. The plans do not identify the sources of funding to construct these tracks. The current demands on available funding from this Department far exceed available funds so alternative sources need to be identified.

Should you wish to further discuss any of the points raised in this letter, please contact Mr Steve MacDonald at our Grafton Office.

Yours sincerely,

S.R. MacDonald, 17/1/92.
Regional Director,
NORTH COAST.

Chinderah Districts Residents Association Inc.

P.O. Box 259
Kingscliff
N.S.W. 2487.

Dated 9 June 1992

Department of Public Works.
Tweed Entrance Project
P.O. Box 1013
Tweed Heads. N.S.W 2485

Attention: Mr Brian Dooley, Project Manager.

Dear Sir,

Lower Tweed Estuary
Proposed Sand Extraction: Zone 'I'
Draft Land Assessment Report.

Reference: Your R/2100/1300 of 21 May, 1992.

We wish once again to inform you of this Associations unanimous support for the proposed sand traction in the lower estuary of the Tweed River, and so to inform you that, certain members have also eclared, that, should it be necessary, they would wish to ave portion of their properties considered for a stock pile t, should you wish to avail yourself of this offer, please ntact our Secretary - Mrs Debbie Jenkins, P.O. Box 259 ngscliff, or with our president, Mrs F.G. Cecil, 63 Phillip reet Chinderah 2487.

The only other matter we wish to raise is the likely te of release of the relevant Environmental Impact atement.

Yours Faithfully
Debbie Jenkins
Secretary.

/

Mr Gerry Bobeldyk
TWEED RIVER & BEACH FISHERMENS ASSOC.
2 Bimbadeen Avenue,
BANORA POINT NSW 2486

30th May, 1992

Mr Brian Dooley
TWEED ENTRANCE PROJECT - PUBLIC WORKS DEPT.
Unit 15, Tweed City Arcade,
TWEED HEADS NSW 2485

Dear Sir,

In relation to your letter sent to us re The Lower Tweed Estuary.

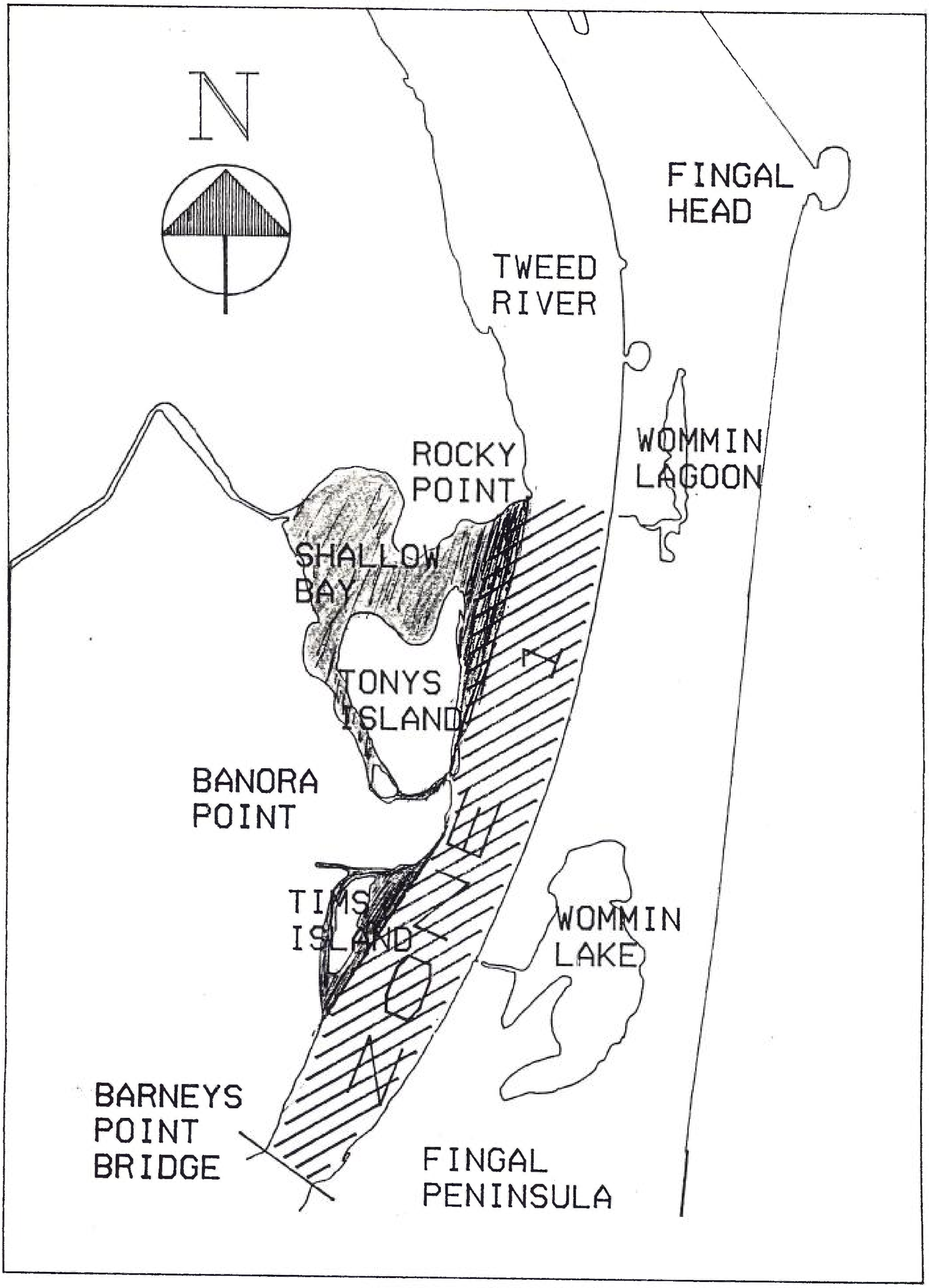
We would like to propose that areas marked in red on the supplied map be dredged or filled to an approximate depth of 1 metre for replenishment of sea grass, marine habitat etc..

Should you require any further information, please contact us.

Yours faithfully,
TWEED RIVER DREDGING COMMITTEE

F. J. Roberts
G. Bobeldyk
J.W. Higgins.
T. C. Mossley
A Parsons

d:\dgn\zone1.dgn May. 20, 1992 16:46:06



FINGAL DEFENDERS
INCORPORATED

'Keep Fingal Special'

47 Bimbadeen Avenue, Banora Point 2486 ph 075 24 4368

Submission to PWD River Management Plan.

Fingal Defenders Inc. is in general agreement with the Plan and congratulates the PWD Team and consultants on a very thorough and professional job.

As far as the proposals for the Fingal peninsula are concerned, the recognition of the regional recreational significance of this is welcomed. This reflects the long term planning objectives of Tweed Shire Council in this direction and the obvious need for both conservation and recreation uses for the area.

The new lakes and beaches will build on existing natural waterbodies and waterfront amenities and cater for recreation without compromising the need for the natural areas to remain as fish breeding areas and refuges for wildlife.

Improved flushing of the enclosed water bodies is essential and may be achieved by creating extra entrances.

While it is an expensive option, the idea of moving Fingal Road further to the east in the Wommin Lagoon-Wommin Lake area, to allow greater river bank open space should not be forgotten. Moving Letitia Road further east away from Kerosene Inlet to allow more lakeside space may also be a viable option in time, if the road is to be upgraded.

The sand processing site should be positioned in the area with the poorest vegetation. This is now further to the south than old photos show and a suitable area of dead Casuarinas and Blady Grass can be easily identified. This area should not be rezoned but a sunset clause inserted in the zoning to allow this use <u>and this use only</u> for a specified period, after which complete reconstruction and revegetation as a recreation cum conservation area should be mandatory. If there is a site off the peninsula for this sand processing this would be preferred.

With the new RTA highway, the most suitable access for sand vehicles is along Fingal Road. The reopening of Murphy's Road would have major repercussions on stability of the foredunes through increased traffic, on revegetating areas through vandalism and on the desire to develop that area for conservation and passive recreation.

Fingal Defenders welcomes the promise by your Minister to return royalties to the Tweed Estuary for this sort of enhancement. It will be appreciated by future generations and will add to the overall value of the lower Tweed as a recreation and natural attraction area.

Lee Scarlett.
President.

Lee Scarlett

APPENDIX 5

CONSULTATION WITH FISHING ORGANISATIONS

Table A5.1 - INDIVIDUALS AND REPRESENTATIVES OF FISHING ORGANISATIONS WHO PARTICIPATED IN THE CONSULTATIVE PROCESS

Name	Occupation/ Affiliation	Association with the Proposed Dredging Area
Barton, Fred	Commercial fisherman (FT)	probably spends about 1/4 of his fishing time in the area
Bobbledyk, Jerry	Commercial fisherman (FT) TRAC member	occasionally works in the area depending on the river conditions
Gibson, Paul	Commercial fisherman (FT)	fishes the area about 1-2 times/wk
Hannah, Ernie	Commercial fisherman (FT) THBRFA Secretary	does not fish in the river/estuary but works the beaches
Higgins, John	Commercial fisherman (FT)	on the average he would fish about 1 to 1.5 weeks per month in Area 5
McLeod, Joe	Commercial fisherman (FT)	during the 1940s and 50s used to fish entirely in the area from Barney's Point bridge to Terranora Inlet but now only fishes the area infrequently
Moseley, Clyde	Commercial fisherman (FT)	occasionally fishes in the area
Parsons, Aub	Commercial fisherman (FT)	only fishes above Barney's Point bridge
Roberts, Frank	Commercial fisherman (FT)	occasionally fishes in the area
Slockee, Bob	Commercial fisherman (FT) THBRFA President	infrequently fishes the lower estuary
Spedding, John	Commercial fisherman (FT) THBRFA President	infrequently fishes the lower estuary
Walsh, Pat	Commercial fisherman (FT)	regularly fishes in Shallow Bay
Dusi, Ivan	Uki Fishing Club - Secretary	most of the members are rock/beach fishermen and those that do fish the river do so above Area 5
Jordan, William	Fishing Section, Twin Towns Services Club - President	majority of club members fished below the proposed area of dredging
Quin, Michael	Fishing Section, Tweed Heads Rowing and Aquatic Club - Secretary	Club members fished all sections of the river including Area 5
Raison, Darby	Seagulls Fishing Club - Secretary	most members fished in Terranora Broadwater or above Area 5, although some fished from the banks in the area of proposed dredging.
Kirkham, Frank	Oyster farmer TROGA President TRAC member	representative of the local oyster growers' association
Perandis, Len	Oyster farmer	lease operator in Chinderah Bay
Schulz, Dave	Oyster farmer	lease operator near Ukerebagh Passage
Brinsley, Steve	Fisheries Inspector	Area 5 falls within his area of responsibility

Abbreviations:

FT	Full Time
TRAC	Tweed River Advisory Committee
THBRFA	Tweed Heads Beach and River Fisherman's Association
TROGA	Tweed River Oyster Growers' Association

APPENDIX 6

LOWER TWEED ESTUARY
RIVER MANAGEMENT PLAN

lower Tweed estuary

Developing a plan for the future

The lower Tweed is a complex river and estuary system.

Its value and usefulness is measured in terms of its wide range of qualities . . .
scenic beauty, biological productivity, recreation, and fishery resources.

Because of an expanding population a management plan is needed to keep the Tweed River both natural and useful.

September 1991
ISBN 0 7305 8627 8
PWD 91051

PUBLIC WORKS

Getting the basics right

The Tweed River is a vital link in the social and ecological fabric of the valley. Sensitive management will sustain the quality of the river and its ecology.

This publication is a report to inform the community of the work to date in developing a management plan for the lower Tweed River. It includes an overview of the management objectives and at the end, outlines options for 18 specific areas. You are encouraged to comment by using the enclosed card.

It is important for the community to come to an agreement on an overall concept.

During 1989–90 the Tweed Valley community worked with Public Works on a feasibility study to resolve the problems of the Tweed entrance.

The study confirmed a widespread community perception that the tidal part of the Tweed River was a unique zone requiring a comprehensive river management plan to protect its valuable attributes and to ensure that present and future residents would be able to enjoy them to the full.

In July 1990 the Minister for Public Works, in response to the community's desire to protect the beauty and benefits of the region, initiated studies on which a sound Lower Tweed River Management Plan could be based.

The objectives of these studies are:

- to devise an overall concept for the estuary that encompasses all its varied assets and pays proper and fair regard to each
- to survey and set out the critical details of the problems confronting the river
- to develop strategies for the entire estuary for community consideration
- to set priorities for necessary actions.

Detailed planning for individual parts of the estuary should proceed only if there is broad community agreement that the overall concept is consistent with its needs and goals.

Technical basis

Individual areas of concern have been carefully assessed by specialists in the disciplines of:

- marine and earth ecology
- water quality
- water and sediment movement
- recreation planning
- archaeology
- visual assessment
- administrative systems.

Reflecting the richness of the Tweed River as revealed in these studies, the total plan must encompass a range of interlocking considerations.

People

The current population of Tweed Shire is 58 000 and expected to double in the next 15 years. The region is also attracting more and more tourists.

It is a superb area for recreation and supports 15 community recreation clubs which use the waterway for activities such as sailing, rowing, canoeing and fishing. Primary and secondary schools use the river for educational and recreational purposes.

Already the existing facilities are showing strain, especially in the summer holiday season.

The technical studies have shown there are a number of areas which can be developed to cater for the future recreation needs of the rapidly growing population without compromising the integrity of habitat areas.

There is scope for increased recreation on the main arm and its eastern foreshore, accommodating both aquatic activities and greater foreshore recreation. Terranora Creek is suitable for low key aquatic and foreshore recreation. Terranora Broadwater has aquatic recreation potential if improved by dredging.

A number of possible recreation improvements in specific areas have been identified, varying from the creation of recreation beaches, boating facilities, and river access points to foreshore and lagoon walks and bird viewing areas.

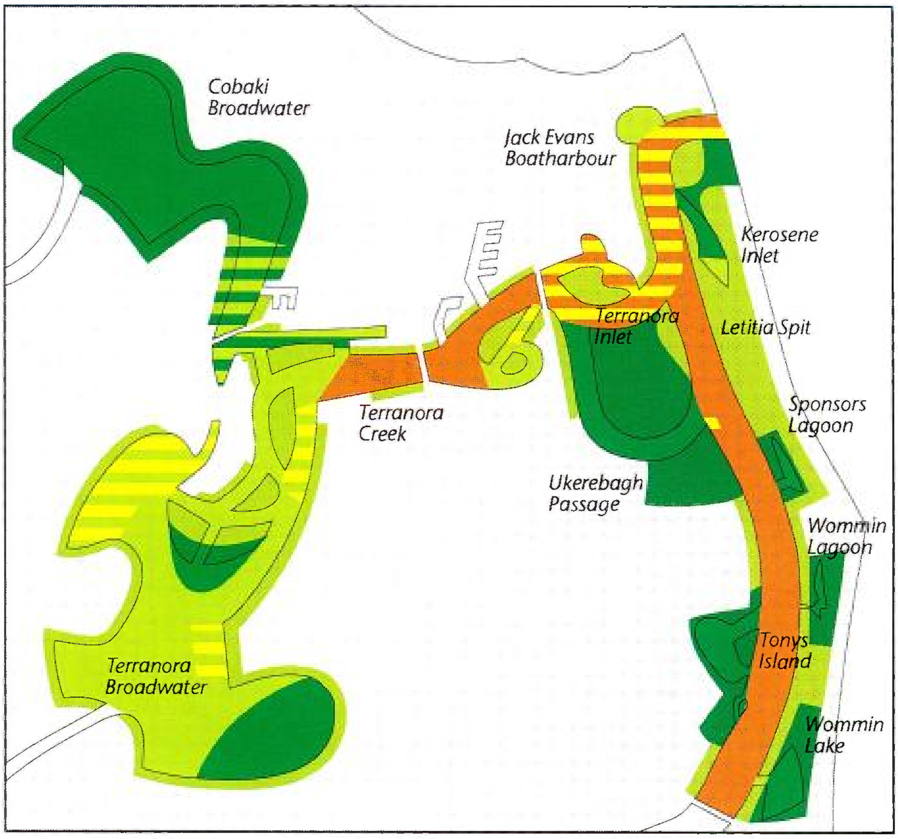
River management objectives

commercial navigation
- maintain channels for fishing fleet, oyster farmers and charter boats

waterway improvements
- dredge sand shoals to improve boating and provide habitat diversity

recreation and conservation
- improve natural habitats
- increase foreshore facilities for walking, fishing and picnicking
- provide opportunities for wetland enjoyment eg. boardwalks, bird watching sites, snorkelling
- encourage low key boating

conservation
- protect and extend significant habitats
- protect heritage areas
- develop education facilities
- improve stormwater quality



Fishing

The Tweed estuary supports a large and diverse commercial fishing industry. Most commercial species of fish, either as juveniles or adults, rely upon the habitats available within the estuary.

The principal commercial fishing activities within the estuary include net hauling, meshing and crab trapping.

Hauling operations generally occur upstream of Barneys Point Bridge but the lower estuary habitats are vital to sustain the industry. Tonys Bar is the most frequently used lower estuary hauling ground for mullet, whiting, bream, flathead and prawns.

Oyster farming is an important part of the fishing industry on the Tweed. It depends heavily upon good water quality (ie low concentrations of silt, pesticides, pathogens, heavy metals etc).

As well, Tweed Heads is a major fishing port for trawlers. The size of the fleet varies with fishing conditions and navigability of the river entrance but is presently the fifth largest in NSW. The fleet employs both directly and indirectly some 250 people and contributes approximately $12 million to the local economy. Although trawling occurs in the ocean, the principal trawler catch consists of prawns which rely upon habitats in the estuary (particularly seagrass meadows) as nursery grounds.

Environment

The Tweed estuary is in a region where plants and animals of both tropical and temperate origin overlap. The diversity of the region is exceptional and the resulting plant and animal communities are highly valuable.

Habitat areas are crucial to the ecology of the river's bird and marine life. The most significant areas comprise the saltmarshes, mangrove forests and seagrass meadows along the eastern edge of the main arm, Cobaki Broadwater, the delta islands of Terranora Broadwater, and a number of side bays and back channels in both arms of the estuary, particularly Ukerebagh Passage and the wetlands of Ukerebagh Island. All these areas teem with small marine life in the sediment and are vital links in the marine food chain and the overall ecology of the estuary.

The vegetation along the shorelines of the lower Tweed River and Broadwaters provides important habitats for land animals and reptiles. There are major bird roosts in the secluded western foreshores of the delta islands, Trutes Bay in Terranora Broadwater, the eastern shores of Cobaki Broadwater, Kerosene Inlet and Wommin Lake and adjoining areas. These roosts are essential for the breeding, and therefore survival, of the species which use them.

17 migratory and 10 non-migratory birds which occur in the lower Tweed estuary are listed in international bird treaties.

Heritage

Current studies discovered 14 previously unrecorded sites of archaeological importance. Proposals for the study area need to recognise the archaeological significance of the estuary foreshores.

Shoaling

Many areas of the river have extensive sand shoals which restrict navigation and opportunities for recreation. They include the shifting sands of Terranora Inlet and the main arm. The studies have found that these shoals are comparatively barren and are therefore less sensitive than the ecologically rich wetlands and shoreline margins.

Dredging would benefit both the ecology and fishing. It is required in two main areas:

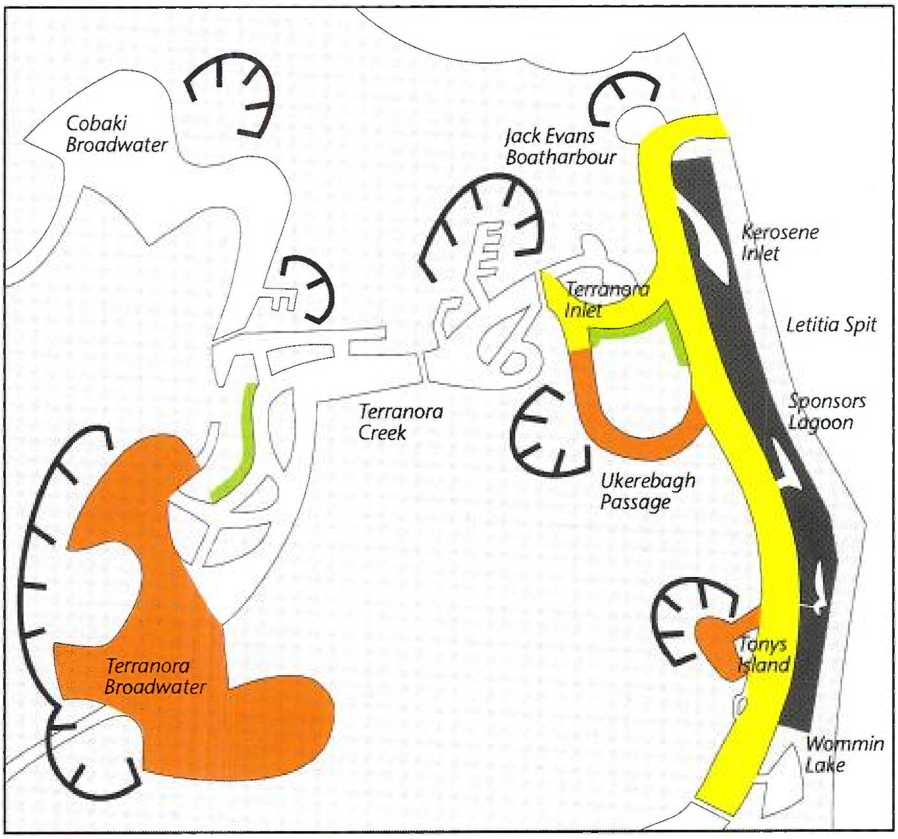
- Boyds Bay to the entrance

  Navigation channels need to be regularly dredged for the Tweed Heads fishing fleet.

- Barneys Point Bridge to the junction of the two arms

  Dredging here would produce many benefits. It would:

  - remove restrictive shoals which curtail recreational boating and constitute a hazard
  - increase the flow of sea water to enrich the habitats
  - create specific deep habitats which would promote a richer marine life and increase numbers of large fish
  - produce sand for local industry and construction
  - provide royalties to help fund the River Management Plan
  - lower flood levels and reduce flooding.



Problem areas

- stormwater drainage and general catchment run-off
- shifting sand shoals
- siltation
- exotic weed infestation
- bank erosion

Urban run-off and discharges

The pollution from urban run-off is already damaging some habitat areas and the amenity of some popular recreation areas. Key areas of concern are Shallow Bay, Tonys Island, Ukerebagh Passage, Jack Evans Boatharbour, Cobaki and Terranora Broadwaters.

The increasing population and associated development of the catchment is damaging the quality of the water in the river. Catchment run-off produces approximately 230 000 cubic metres of silt a year, mostly from areas under cultivation. Evidence suggests that the clearing of the slopes above Terranora Broadwater and in the Cobaki catchment have contributed to siltation and habitat degradation in these lakes.

The levels of some nutrients, such as phosphates, from stormwater run-off and sewage treatment plants will increase greatly under present population projections unless adequate management strategies are put in place.

Pesticides and fertilizers from agricultural areas require monitoring to ensure they do not reach unhealthy levels in the river.

Developing a plan for the future

The State Government has contributed towards developing a successful plan by commissioning baseline studies and offering professional advice. However, the long term success of any management initiative depends upon community involvement. Through the Tweed Entrance Community Liaison Committee, formed in 1989, the Government is working with the community to develop a satisfying and workable river management plan.

The development of a river management plan is an evolutionary process which requires refinement and adaptation with each piece of new information and increased understanding of the river.

One of the early steps was the Tweed Entrance Feasibility Study. This study found broad community support for improvements to the existing entrance which included dredging of the lower estuary.

The next step is the development of a Tweed River Management Plan which places any dredging within an overall context of management and enhancement of the whole estuary.

Adoption of a Plan requires the community to participate in the development of an overall concept for the river. Turn to page 12 to see how you can participate.

The Plan should ensure that any action taken in one particular area will not produce problems or become an obstacle to improvement in other areas.

Once the community agrees to an overall concept, detailed development plans will be prepared for review and approval by the community and appropriate authorities. A multitude of individual projects can then get under way to bring the Plan into being.

The Plan will involve:

- conservation and habitat improvement to protect and enhance important areas for bird life and marine animals, to improve the river as a fish nursery, and to restore areas which are currently degraded
- encouragement of increased recreation in suitable areas, including planning for future needs
- minimising pollution from urban run-off to preserve water quality and protect significant habitat areas
- waterway improvements to maintain commercial navigation channels and to open up areas where sand shoals restrict general navigation and recreational opportunities.

Putting the Plan into action

Because of its close contact with the community and its facilities for regular consultation, Tweed Shire Council is best placed to be involved in setting priorities for proposed works and reviewing those priorities and refining them in the light of changing river problems.

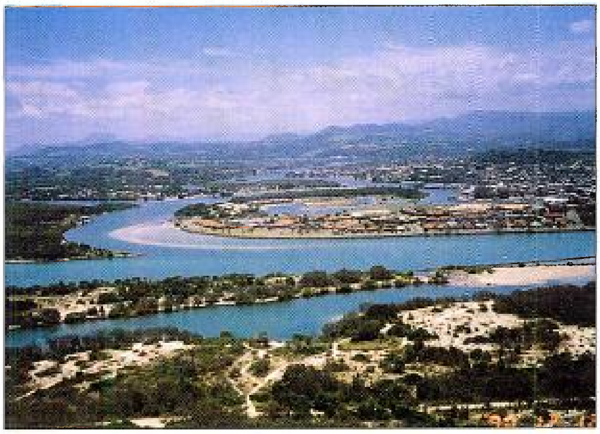
River improvement works will be funded by State Government based on sand royalties.

Already a number of environmental enhancement works have been identified for possible inclusion in an Early Works Program involving expenditure of $500 000. These are works which appear to have high priority and which could be achieved at a realistic cost, such as:

- upgrading of inlet to Wommin Lagoon
- creation of beaches along the eastern river training wall of the main arm
- design of erosion control at Seagulls Estate Reserve
- removal of sedimentation at major stormwater outlets
- improvements to Jack Evans Boatharbour.

Population and development

loading cream on river transport, Tweed Valley
courtesy of Lower Tweed River Historical Society



lower Tweed—mixture of urban and natural environment

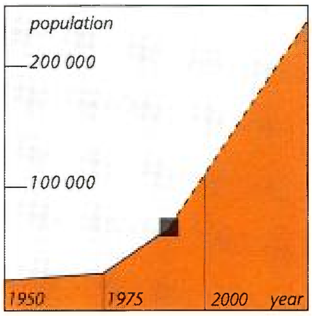
Early timber-getters found safe harbour and lush subtropical rainforest in the Tweed River.

Sugar cane farmers, dairy farmers and banana growers followed and cleared the fertile floodplain and slopes.

They developed agriculture at the expense of the natural environment of the lower Tweed.

The development of Tweed Heads accelerated after the construction of river training walls (1890s) and entrance breakwaters (1904) allowed regular shipping.

The natural habitat which remains on the lower floodplain is confined to the wetlands and foreshores of the estuary. These are threatened by continuing urban expansion.



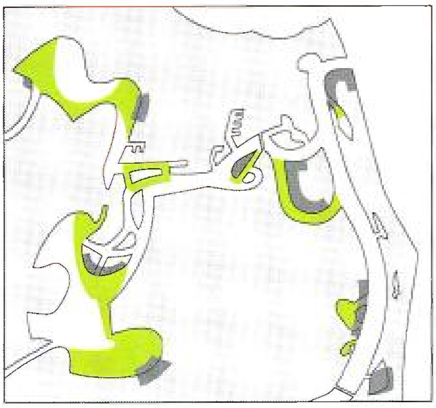
present population growth with predictions to 2025

The estuary and adjoining areas continue to be intensely used for residential, recreational and commercial activites.

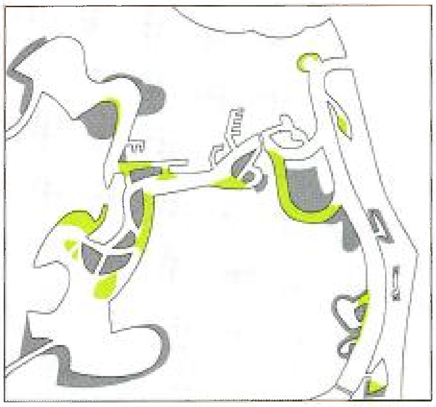
The community has stated its wish to have a River Management Plan which will preserve open space and focus on family recreation facilities.

River ecology

sampling the plants and animals living in the sediments of the Tweed River



bird roosting and feeding areas



mangrove and seagrass areas

Identifying the distribution of plant and animal life provides the planning tool to protect and enhance the ecology of the river.

This database showed that the Tweed River supports a shorebird population equal to those in the larger systems of the Clarence and Richmond Rivers.

The richness of bird and marine life is related to the area of mangroves and seagrasses. The Tweed has the eleventh largest mangrove coverage in NSW.

Many of the birds identified in the area are migratory and are protected by international treaties.

The Little Tern is classified as 'threatened' by NSW National Parks and Wildlife Service.

Little Terns were observed in the estuary during the survey and special consideration has been given to its requirements in the possible works.

Little Tern

Osprey

Tweed River main arm


the main arm and Letitia Spit


Kerosene Inlet

The main arm of the Tweed River and the wide tracts of Crown land on Letitia Spit have the capacity to provide high quality recreation as well as significant areas for plant and animal conservation.

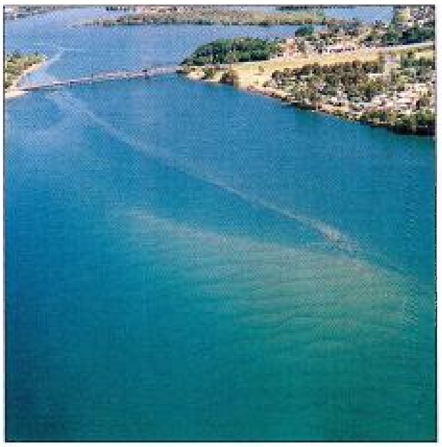
Kerosene Inlet area has been damaged by vehicular activity and should be buffered from this type of intense recreation. It is a significant bird roosting area which needs protecting.

With proper management it also offers an opportunity to integrate foreshore recreation and environmental conservation.

Improving navigation depths in the main channel would also offer opportunities to enrich the marine habitat. Deep holes combined with artificial reefs could create the habitat diversity that attracts large fish.

At Tonys Bar, works could include dredging both to reduce a biting midge breeding area and, using the extracted sand, to build a more secure roosting site for shorebirds.

Dredging would also improve tidal flushing in silted areas like Shallow Bay.

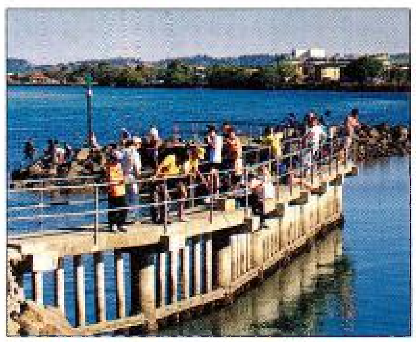

shoal below Barneys Point Bridge


Tonys Bar

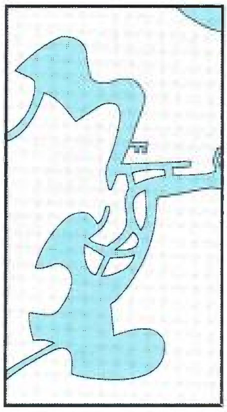
Jack Evans Boatharbour in the heart of the residential and business area is presently under-utilised. It offers opportunities for innovative facilities such as an underwater observatory and a snorkel trail winding through seagrasses and artificial reefs.

Carefully planned and attractive walkways, fishing piers and seating on the foreshore would be well used by residents and tourists.

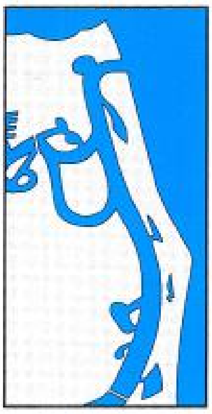

Jack Evans Boatharbour



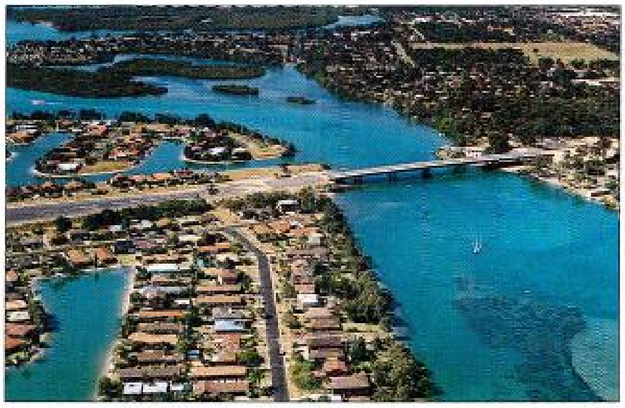
Terranora system



The different characters of the main arm and the Terranora system require distinctly different management solutions.



Terranora Creek is heavily urbanised and there is not the same scope for foreshore facilities as in the main arm.



Terranora has speed restrictions and the Broadwaters are presently too shallow for extensive boating activities.

In these areas there are opportunities for a different range of facilities.

Along Terranora Creek there are sites for boardwalks through mangroves, bird viewing platforms, educational facilities and picnic areas.

The Broadwaters are very shallow, particularly Cobaki, but they have significant habitat value. Cobaki is a bird roosting area and because it is inaccessible, it is best left as a conservation area. Seclusion is a vital part of bird habitats.

mangroves

shorebirds

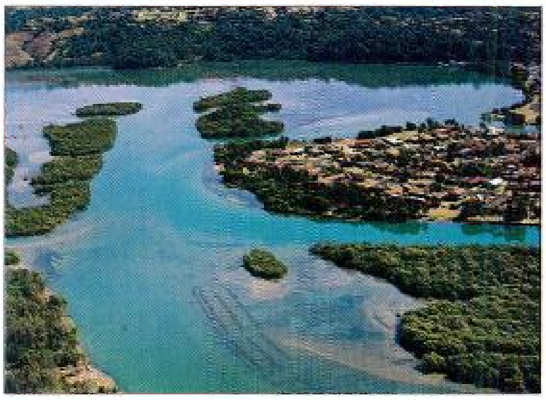
The extensive mangrove areas of Terranora offer opportunities for interesting boardwalks.

Features such as these elevated mangrove walks and bird watching platforms provide excellent opportunities to combine family recreation and education.

elevated boardwalks with information displays

parks with seating and picnic sites

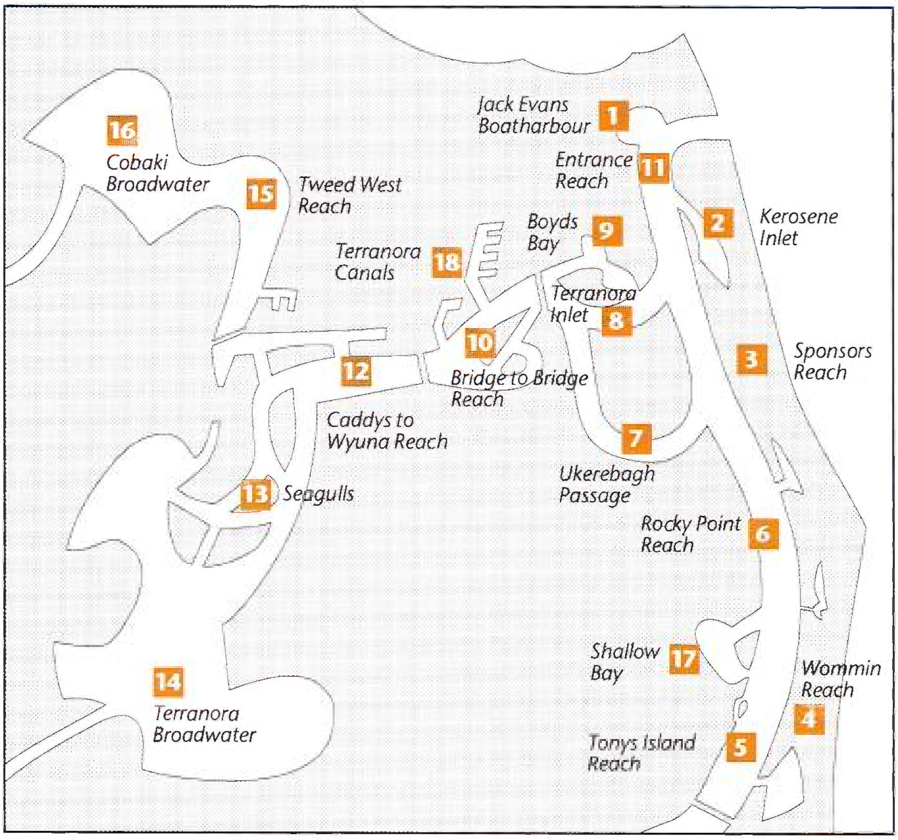
Terranora Broadwater is the centre of the oyster growing industry and dredging will be required to maintain navigation channels for the industry. Dredging within the Broadwater would allow a greater range of recreational boating.



Terranora Broadwater

oyster beds in Terranora

River management objectives



Within the lower Tweed, 18 areas have been identified for the purpose of defining specific problems and opportunities.

1 Jack Evans Boatharbour

recreation and conservation

Improve quality of stormwater discharge

Finalise detailed plans of new foreshore and recreation facilities

Finalise seagrass regeneration plan.

2 Kerosene Inlet

conservation

recreation and conservation

Rehabilitate degraded wetland

Extend existing wetland

Develop recreation sites

- improve access to river
- build beaches along river

Regenerate natural vegetation

- limit vehicles
- replace Bitou Bush with native species
- prevent power boat access to wetland

Buffer and protect bird roost areas.

3 Sponsors Reach

conservation

recreation and conservation

waterway improvements

Extend worthy conservation areas, particularly wetlands

Finalise plan for water recreation

Regenerate native vegetation to buffer Sponsors Lagoon

Finalise stormwater drainage plan to protect lagoon.

4 Wommin Reach

conservation

recreation and conservation

Extend worthy conservation areas, particularly wetlands

Improve tidal flushing of lake and lagoon areas

Create additional wetlands

Prepare EIS to identify and seek approval for sand processing site

Regenerate native vegetation buffers

Develop foreshore recreation sites.

5 Tonys Island Reach

conservation

recreation and conservation

waterway improvement

Finalise sand extraction plan

- remove shoals from main channel
- reduce biting midge (sand flies) breeding area at Tonys Bar
- increase diversity of marine habitats

Build and protect new bird roosting sites, especially for the Little Tern

Increase water and foreshore recreation sites on eastern side of reach.

6 Rocky Point Reach

conservation

recreation and conservation

waterway improvement

Finalise sand extraction plan

- remove shoals from main channel
- increase diversity of marine habitats

Protect and improve bird roosting sites on the western shore

Increase water and foreshore recreation sites on eastern side of reach.

7 Ukerebagh Passage

conservation

Increase public awareness of the area as the most important bird roost and fish nursery in the region

Protect from feral animals

Build bird watching platforms

Improve water quality

- maintain good tidal flushing
- install trash racks
- remove silt.

8 Terranora Inlet

commercial navigation

waterway improvement

Maintain navigation channel

- establish suitable dredge disposal sites

Limit access to Ukerebagh Island.

9 Boyds Bay

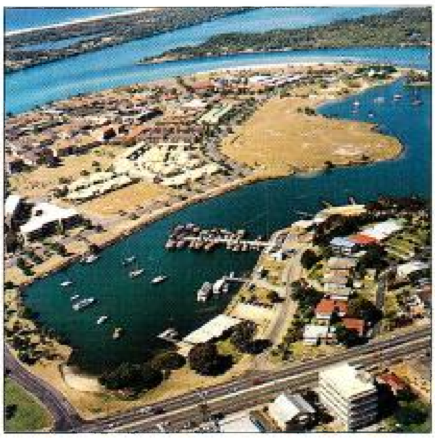
commercial navigation

waterway improvement

Maintain commercial port facilities

Improve water quality

Build sullage pump-out station.



10 Bridge to Bridge Reach

recreation and conservation

waterway improvement

Develop and encourage foreshore recreation

- walking trails, bird watching, picnicking

Improve water quality

- provide better public education
- develop long term effluent disposal plan
- install gross pollutant traps
- retain shallows to dilute and disperse discharges.

11 Entrance Reach

commercial navigation

waterway improvement

Maintain navigation channels in main arm and at junction of Terranora Inlet.

12 Caddys to Wyuna Reach

recreation and conservation

waterway improvement

Improve and protect important natural habitats

Develop foreshore recreation and education facilities

- walking trails, bird watching sites and information displays.

13 Seagulls

recreation and conservation

commercial navigation

Encourage a variety of uses

- oyster cultivation
- water and foreshore recreation

Repair bank erosion

- maintain boat speed limit.

14 Terranora Broadwater

conservation

recreation and conservation

commercial navigation

Develop plans for improvements

- boating channels
- natural habitats
- foreshore recreation (elevated boardwalks, birdwatching platforms, picnic sites)

Improve water quality

- install gross pollutant traps

Register heritage finds.

15 Tweed West

conservation

recreation and conservation

Prepare management plan

- protect significant bird and marine habitats
- develop walking tracks and viewing areas
- develop public information on habitat importance
- install educational displays.

16 Cobaki Broadwater

conservation

Finalise management plan

- protect significant natural habitats
- develop public information on habitat importance.

17 Shallow Bay

conservation

Improve important fish habitat

- encourage use of upstream silt traps
- deepen and extend southern channel
- prepare dredging plan to improve tidal flushing

Investigate shoaling processes.

18 Terranora Canals

Improve quality of urban run-off

Encourage regular canal maintenance.

lower Tweed estuary
Developing a plan for the future

Join the team

The best plan for the Tweed River will be one that is drawn from the ideas of all those who have an interest in the wellbeing of the estuary and the adjoining foreshores.

Your help

We want to hear your ideas and develop a Plan building on your suggestions.

Your thoughts

There are a number of ways you can provide your ideas:

1. Complete and return the card attached to this brochure by 6 December 1991
2. Write a letter explaining your ideas by 6 December 1991
3. Attend one of the public meetings that Public Works will advertise in October and November 1991.

More information

Visual displays are now in clubs and major shopping centres and at offices of Tweed Shire Council to explain river investigations to date.

A report on the Lower Tweed Estuary Management Plan and a Lower Tweed Estuary Technical Summary have been placed in Tweed Shire Libraries and are available for purchase at offices of Tweed Shire Council ($20 each).

The complete set of technical reports is available for inspection and purchase at the Public Works Tweed Heads Office.

River Management Plan reports

River Management Plan
Technical Summary
Ecological Assessment & Appendices
Influent Audit
Hydrodynamics Assessment
Recreation Study
Archaelolgical Assessment
Visual Assessment
Supplementary Information
Implementation Options
Initial Monitoring
Preliminary Concepts

Contacts for information and further discussion on any aspect of the development of a Tweed River Management Plan:

Public Works
Tweed Entrance Project Office

Unit 15, Tweed City Arcade
69 Wharf Street
Tweed Heads NSW

PO Box 1013
Tweed Heads NSW 2485

phone (075) 36 9421
fax (075) 36 9397

Tweed Entrance Community Liaison Committee

c/- Public Works
Tweed Entrance Project Office

APPENDIX 7

REVIEW OF SAND DEMAND AND STOCKPILE SITES

POTENTIAL SAND FILL AND STOCKPILE SITES

Most land development in the lower Tweed estuary area will include landfill, and may include the construction of artificial lakes or canals in order to provide:

(a) a saleable residential environment,
(b) management of stormwater, and
(c) a source of material to raise the level of the land to the statutory flood height level.

Potential destinations for extracted sands have been identified in the Hill (1990) report and these are illustrated in Figure 7.1. The timing of these needs, and volume of total fill required at each is shown in Table A7.1.

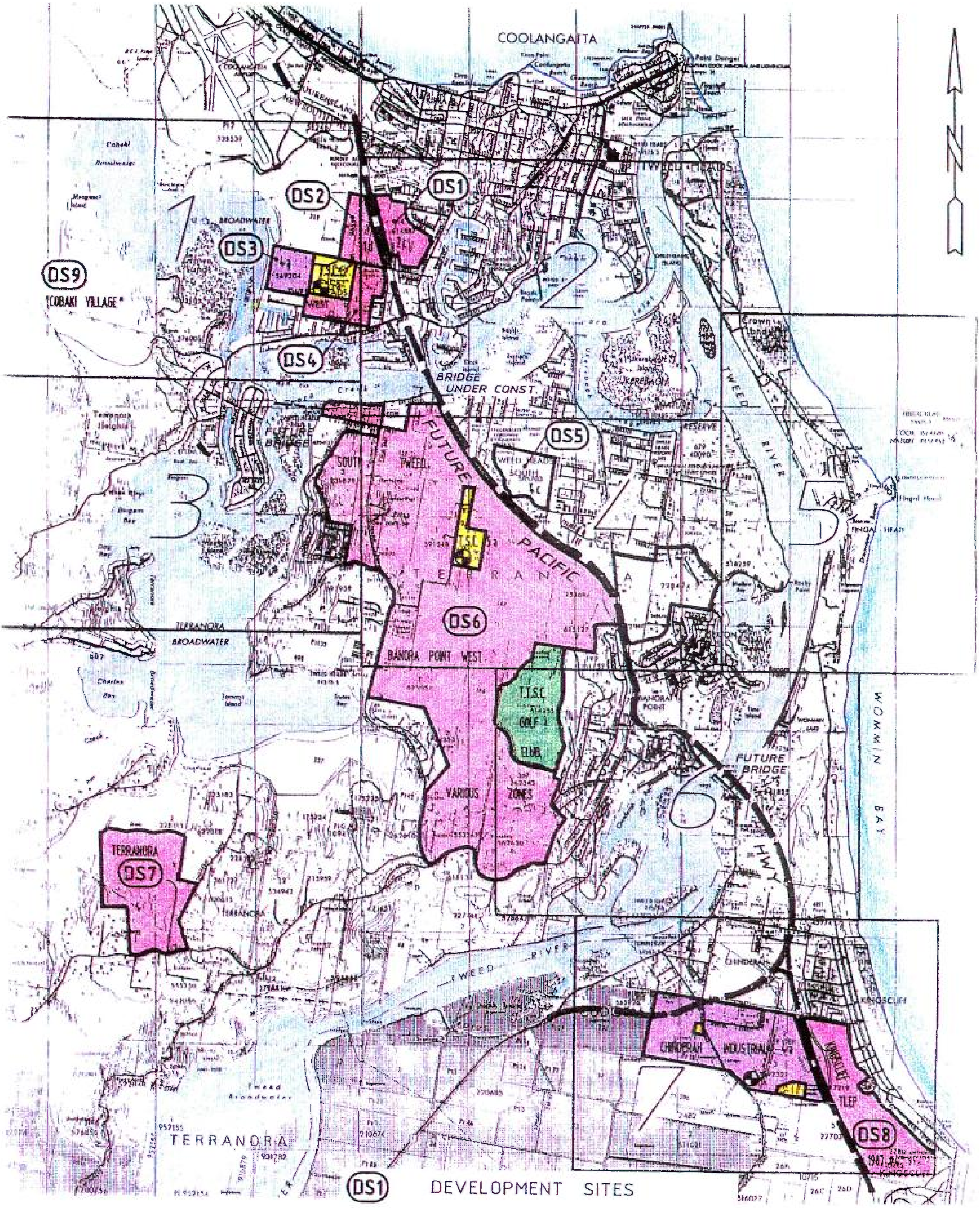
Within the general study area indicated by Figure A7.1, nine development sites (DS) have been identified as having the need for sand for development purposes. As outlined above, sand will be required for the majority of these development and several sites may require the importation of sand fill to directly raise the finished level to provide acceptable flood protection.

Approximately 0.92 cubic metres of sand are available for extraction from Area 5. NSW Public Works Department estimates that the extraction could occur over a three to ten year period, depending on the balance of the demand (if any) for the sand between the immediate nearby fill requirements (RTA road works) and those longer term remote needs.

It should be noted that four residential development sites (identified as locations 1, 6, 9 and 10 in Figure A7.1) are no longer available as they have either been abandoned for development or have obtained their fill from other sources since completion of the study.

The proposed runway extension of Coolangatta airport, requiring 800,000 cubic metre of sand, will possibly happen in a 5 to 15 year time frame and has not been included.

Table A7.1 gives an indication of the distribution of markets for which the stockpiled sand could be destined and indicates that the market could peak in the period 1993/94.



DS1 DEVELOPMENT SITES

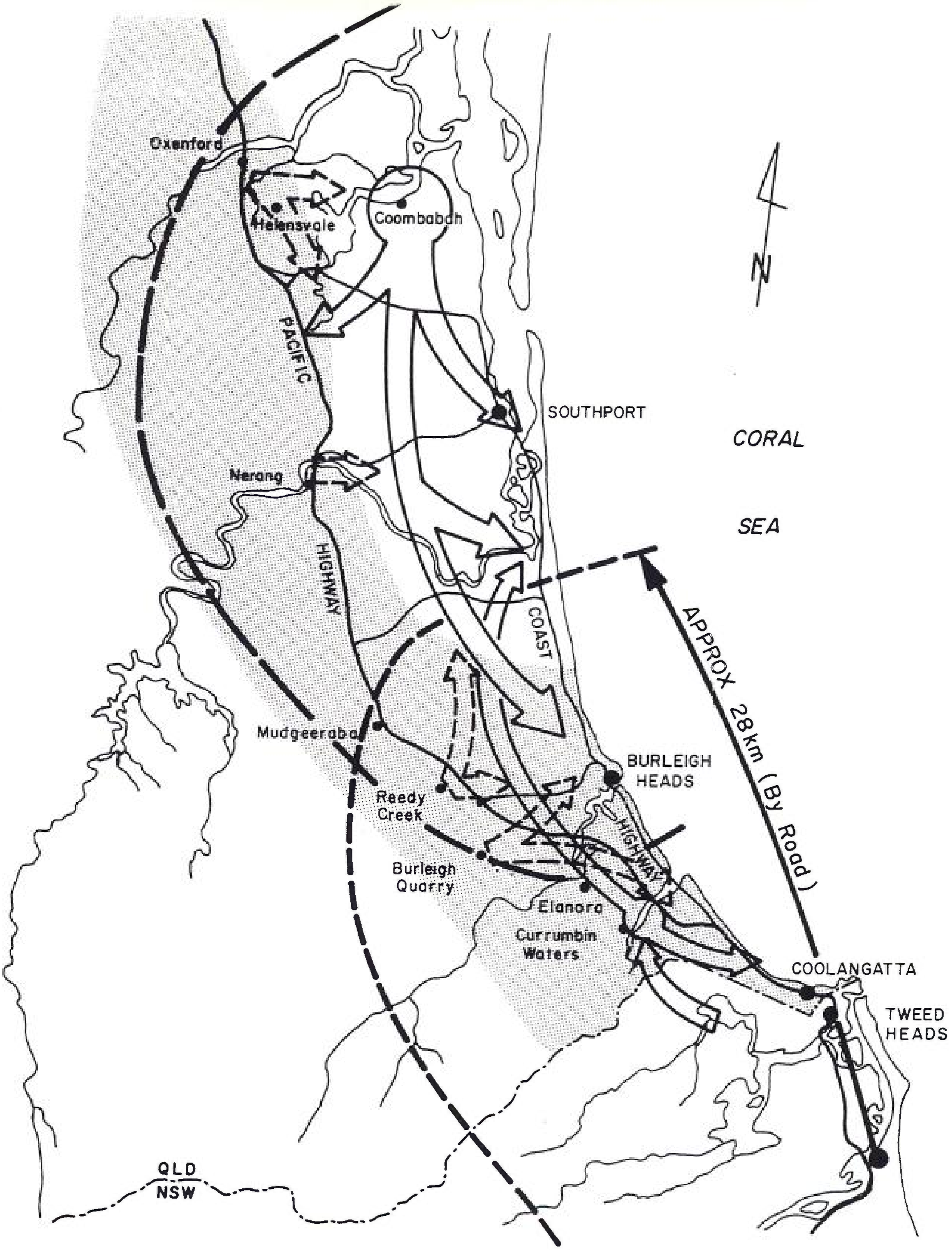
4a TOWN PLANNING ZONES

RECOMMENDED STORAGE SITES

GENERAL STUDY AREA AND RELEVANT SITES

FIGURE A7.1

WBM OCEANICS AUSTRALIA



LEGEND

Urban and Rural Residential Corridor, Albert Shire Council (Reference 9)

Approximate Competitive Zone of Northern Market Sector

Approximate Competitive Zone of the Lower Tweed River

Fill Sand

Quarry Waste and Clayey Sand

POTENTIAL SAND DEMAND ZONES

FIGURE A7.2

Table A7.1

ESTIMATION ON SAND EXTRACTION OF DEVELOPMENT SITES IDENTIFIED BY HILL (1990)

Dev't Site	Land Use	Mode of Tran	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
			Volume of Sand Fills Required										
Valid													
2	Ind	Trucked	-	41,667	41,667	-	-	-	-	-	-	-	83,334
3	Ind	Trucked	-	41,667	41,667	-	-	-	-	-	-	-	83,334
4	Res	Trucked	-	41,667	41,667	-	-	-	-	-	-	-	83,334
7	Res	Trucked	1,056	1,056	1,056	1,056	1,056	1,056	1,056	1,056	1,056	1,056	10,560
8	Res	Trucked	-	50,000	50,000	50,000	50,000	50,000	-	-	-	-	250,000
RTA	Road Wk	Trucked	-	125,000	125,000	-	-	-	-	-	-	-	250,000
*CAA	RW Ext	Trucked	?	?	?	?	?	?	?	?	?	?	800,000
RTA	Bridge	Pumped	166,667	166,667	166,667	-	-	-	-	-	-	-	500,001
5	Res	Pipeline	-	100,000	-	-	-	-	-	-	-	-	100,000
E	Res	Pipeline	-	83,333	83,333	83,333	-	-	-	-	-	-	250,000
Invalid													
1	Res	NA	-	-	-	-	-	-	-	-	-	-	-
6	Res	NA	-	-	-	-	-	-	-	-	-	-	-
9	Res	NA	-	-	-	-	-	-	-	-	-	-	-
10	Res	NA	-	-	-	-	-	-	-	-	-	-	-
Total	Cu M	Trucked	1,056	301,056	301,056	51,056	51,056	1,056	1,056	1,056	1,056	1,056	760,560
		Pipeline	166,667	350,000	250,000	83,333	0	0	0	0	0	0	850,000
		Total	167,723	651,056	551,056	134,389	51,056	51,056	1,056	1,056	1,056	1,056	1,610,560
Total	Ton	Trucked	1,584	451,584	451,584	76,584	76,584	76,584	1,584	1,584	1,584	1,584	1,140,840
		Pipeline	250,000	525,000	375,000	125,000	0	0	0	0	0	0	1,275,000
		Total	251,584	976,584	826,584	201,584	76,584	76,584	1,584	1,584	1,584	1,584	2,415,840

* No definite project commencement and completion date

** Excluding the 800,000 cu m (1,200,000 tonnes) sand fills requirement of CAA Site

The actual demand for trucked sand out of the Tweed estuary will depend upon the actual available fill sites and the market share that Tweed estuary sand can achieve, given that other sand extraction licences may be in operation in the area. Approvals for any such truck haulage would need tor be obtained separately from the sand extraction aspects dealt with in this EIS.

M.W. Allen & Associates
CONSULTING CIVIL ENGINEERS

P.O. Box 384, Tweed Heads, N.S.W. 2485
Telephone: (075) 54 1712

Our Reference:
MA:EM 9021
Your Reference:
IT:CM[LE709] CR005/5

8th August, 1990

The Regional Engineer
Department of Public Works
P.O.Box 22
LISMORE NSW 2480

ATTENTION: Mr Ian Taylor

Dear Sir

re: Dredging of Terranora Inlet - Phase I of E.I.S.

Further to your instruction, we have undertaken an evaluation and identification of suitable stockpile sites for storage of dredged sands from Terranora Inlet. In addition to the identification of suitable sites we have made a preliminary estimate of costs involved in the extraction of sand from Terranora Inlet, and its placement at the various sites as identified, and a cost comparison on a cubic metre basis of other sand supplies commercially available within this immediate area.

The sites considered in this assessment are as follows:

A. Replenishment of beach zones around Ukerebagh and Greenbank Islands (sand not available for resale).

B. Stockpiling on Southern End of Greenbank Island.

C. Stockpiling at existing sand pit on Coolangatta-Tweed Heads Golf Course.

D. Stockpiling on Letitia Spit.

E. Stockpiling or permanent placement on old "Egg & I" site, Pacific Highway.

F. Stockpiling or permanent placement on land S.W. of High School.

G. Stockpiling or permanent placement on land along Dry Dock Road.

All these potential sites are identified on the plan attached hereto, and the relative attributes of each site are described in detail in Annexures 'A' to 'G', also attached.

We have also attached hereto as Annexure 'H' a summary of establishment and operational costs likely to be incurred by any dredge operator engaged in the removal of this sand, together with a quotation received from Broadhurst-Hill for the supply of sand, both ex-pit and delivered to Dry Dock Road. Please note that these rates are for trucked or "loose" measure and would need to be factored by approximately 15 - 20% to equate to a similar solid measure as would be delivered by a dredge to a development site.

Based on the current proposal of an extracted quantity of material of 15,000 cubic metres, the scheme is manifestly commercially unviable, and Option 'A' would be the appropriate option for the Department to adopt. This, however, would need total funding of around $42,500.

However, additional quantities of sand are available in the proximate area to the current proposal and could be utilized to offset establishment costs. These sources are :-

[1] Additional material in the channel itself between Greenbank and Ukerebagh Islands. These can be obtained by increasing both or either the width and depth of the proposed channel.

[2] Material still available from the Lucknow Lease east of the Tick gates.

Should the additional quantities become available, then Options C-G become commercially attractive. Option B would appear to be objectionable and not a viable option due to transportational and planning restraints. Options C & D or direct placement onto land which is to be filled above flood level appear to be the most expedient courses of action.

However, as tenure of a deposition site has not been secured at this stage, the preparation of an E.I.S. based on specifications of the Department of Planning cannot be completed.

The following further actions recommended to your Department, therefore, are as follows:-

[i] Seek a variation to the specifications as issued by the Department of Planning to exclude assessment of the filled site. This is a reasonable request, as the Courts, in the past, have determined that stockpiling of filling is not "designated development". Copy of one such determination, in which the writer was involved, is enclosed for your information.

[ii] Seek an increased yield from the dredging operation in an endeavour to offset establishment costs and make the overall operation commercially viable and self funding.

[iii] Seek expressions of interest for the dredging and purchase of this increased quantity of filling. A total quantity of filling of around 100,000m³ would be an economic unit.

I trust that this information satisfies your instruction, but should you have any further queries, please contact the undersigned.

Yours faithfully

....
M. W. ALLEN

ANNEXURE 'A'

This option involves the pumping of sands from the two areas within Terranora Creek and placement of same as beach nourishment on the adjacent shores of either Greenbank or Ukerebagh Islands.

1. ZONINGS

Land below H.W.M. is unzoned land under Tweed L.E.P. (1987). Land above H.W.M. is 6(a) - Public Open Space.

2. PLANNING CONSIDERATIONS

This process would merely be the exercising by the Department of one of its fundamental duties prescribed under its charter - that is, the maintenance of navigation channels in waterways. No material would be available for resale, and the operation would not be designated development as defined in the Regulations to the E.P.A. Act.

The Department would merely need carry out an environmental assessment under Part V of the E.P.A. Act and carry out the works required.

Placement of sand on unzoned land (below H.W.M.) would not be subject to any prohibition under the Tweed L.E.P. (1987). Placement of sand above H.W.M. would be permissible under a Part V assessment by the Department, but would appear to be a prohibited activity should development application assessment and approval be sought from Council under Tweed L.E.P.

3. TRAFFIC IMPACTS

A nil traffic impact would be generated by this option. The only traffic generated would be infrequent and minimal movements to satisfy refuelling requirements of the dredge.

4. EFFLUENT AND SITE DRAINAGE

It would be impractical to attempt to provide proper effluent ponds for this type of operation, as a result, special concession would need to obtained from the S.P.C.C. However, the sand appears to be predominantly clean marine sand and is in small quantity. On these bases, the special considerations sought are not unreasonable.

5. NOISE

The only noise generated in this operation is that caused by the dredge itself. The area of extraction is not in close proximity to residential development and therefore the usual S.P.C.C. requirements of a maximum increase in noise level by 5 dB(A), measured at the nearest affected residence, can easily be accommodated.

6. VISUAL

The only visual impact will be the presence of the dredge and its discharge lines. This of itself is not objectionable and is only for a limited duration. No valid objection on this ground can be anticipated.

7. ADVANTAGES

As material is not being won and removed from the river system no royalty would be payable.

Due to relatively short leads a small dredge could be engaged to carry out the works.

No E.I.S. need be prepared.

8. DISADVANTAGES

No material would be available for resale to offset costs incurred.

9. POSSIBLE OBJECTIONS

The S.P.C.C. requirements of two days detention in sedimentation ponds could not be met, and would require special dispensation.

10. COST

Establishment Cost	\$ 5,000
Dredged Cost 15,000m^3 @ \$2.50	\$37,500
TOTAL COST	\$42,500

This cost would be fully funded by the Department.

ANNEXURE 'B'

This option involves the stockpiling of sand on the southern end of Greenbank Island and its future sale on a commercial basis.

Transport of the material from the stockpile site would be by truck. The stockpile itself would be upon Council land (Keith Curran Park), or upon land owned by the Lend Lease Corporation.

Enquiries to the adjacent owner (the Land Lease Corporation) have indicated that no further filling is required by them for their development on Greenbank Island. Their concurrence to a temporary tenure of a stockpile site would be required.

1. ZONINGS

Keith Curran Park : - 6(a) - Public Open Space
Private Land (owned by the Lend Lease Corporation) : 2(b) - Residential B Zone.

2. PLANNING CONSIDERATIONS

Conflicting opinions exist as to statutory requirements and the necessity to prepare an E.I.S. in this instance. The primary purpose of the exercise is to remove shoals from the river, which is manifestly a Part V Assessment. The sale of the material may preclude such assessment and could categorise the operation as "designated development'.

Whilst it is the writers view that the former description and purpose would apply in this instance, in deference to the stated position of the Department's Legal Branch, the latter will be assumed to apply.

Under a Part V assessment by the Department, material could be stockpiled and sold from either site nominated above.

However, should development application assessment and approval be sought from Council, then selling of the excess sand would constitute an industry and thus be a prohibited use in both zones.

3. TRAFFIC IMPACTS

The activity of the dredge would have a nil traffic impact.

However, sales of the won material would give rise to a considerable number of heavy vehicle movements to and from the stockpile site, the number being determined by the amount of sand won. this would create an adverse impact due to the intensely residential route that would need to be followed, dictated by the proposed stockpile site location.

4. EFFLUENT AND SITE DRAINAGE

Adequate areas of land exist to accommodate, with bunding, normal S.P.C.C. requirements of two days detention. Site can be drained directly to Terranora Creek without causing a nuisance to any other property, and without the necessity to traverse any other property.

The dredge site appears to be predominantly clean marine sands and this, coupled with the two days detention, will ensure a high quality effluent return to Terranora Creek.

5. NOISE

The noise generated by the dredging operation will be minimal only, and within the normal S.P.C.C. requirement of 5 dB(A) maximum increase in background noise level, measured at the nearest affected residence.

Transportation of sand by truck in sales will create additional traffic noise.

6. VISUAL

The dredge and discharge lines will provide a minor visual impact only, and be transient in nature.

A sand stockpile area on the undeveloped section of Greenbank Island will also be of minor visual impact, and again, transient in duration.

7. ADVANTAGES

The short dredging distance involved would require the operation of a medium sized dredge only. The stockpile site is in close proximity to potential purchasers.

8. DISADVANTAGES

The haul route for trucks would be along an intensely residential route, and also past a hospital.

9. POSSIBLE OBJECTIONS

Local residents would object to the proposed truck routes.

9. POSSIBLE OBJECTIONS continued

Residents within the Lend Lease Development could object to the possible dust nuisance that has a potential to be created at the stockpile site.

10. COSTS (exclusive of any royalty)

Establishment Cost		\$15,000
Dredging Cost 15,000m³ @ \$2		\$30,000
	TOTAL COST	\$45,000
Cost /m³		\$3.00

This is a very competitive rate for sand in the Tweed area even with an added \$2.00/m³ for royalty.

This operation would self fund and provide a surplus return to the Department.

ANNEXURE 'C'

The Coolangatta-Tweed Heads Golf Club have an existing sand stockpile site in the northern part of the Golf Course that would have existing use rights. It has been used in the past by Blundells when dredging from the Tweed River, but has not been used as a commercial operation in recent times. Option 'C' envisages pumping from the shoaled areas to this site.

1. ZONING

6(c) - Recreation (Special Purposes) Zone. (Golf Course)

2. PLANNING CONSIDERATIONS

Under a Part V assessment sand could be stockpiled and sold from this site.

Under Tweed Shire Council D.A. assessment, such an activity is a prohibited use within the 6(c) Zone. However, the non conforming existing use right would prevail, provided that such a use has not been discontinued for any continuous period of twelve (12) months subsequent to promulgation of Tweed L.E.P. (1987)

3. TRAFFIC IMPACTS

Dredging activity would produce a nil traffic impact.

Sales of won material would give rise to a considerable number of heavy vehicle movements to and from the stockpile site. The route of this heavy vehicle traffic would be in the main along Kirkwood Road to the Pacific Highway - a controlled intersection.

This is the same haul route used by heavy vehicles when operating from the existing pit.

The haul route is past some residential development but no alternative access exists.

4. EFFLUENT AND SITE DRAINAGE

The existing stockpile site is a little over one hectare in area and cannot be expanded. Due to its relatively small area the quantity of material able to be stockpiled is limited, especially when two days detention of dredge waters is required. The site would be suitable for storage of limited quantities at a time (say 30,000m^3) and be most suitable for sporadic dredge operations.

The site is easily drained to an existing watercourse separating the Golf Club land from Portion 224.

Careful management of effluent would be required when the sand pit approached its maximum capacity.

5. NOISE

The noise generated by the dredging operation will be minimal only and within the normal S.P.C.C. requirement of 5 dB(A) maximum increase in background noise level, measured at the nearest affected residence.

Transportation of sand by truck for sale will generate increased traffic volume and noise in Kirkwood Road.

6. VISUAL

The dredge and discharge lines will provide a minor visual impact only, and be transient in nature.

The same stockpile will only be visible by golfers using that section of the golf course, and will not be visibly objectionable to them. The only source of complaint may generate from those less gifted golfers with erratic slices.

7. ADVANTAGES

The existing use status of the sand pit would preclude viable objection on this basis, thus permitting resale of the sand from this site.

The stockpile site is remote from areas of population and should not generate any dust or noise nuisance.

8. DISADVANTAGES

The stockpile site is relatively remote from the dredging operation and will require a larger dredge plus booster units. Accessibility of the booster units for refuelling purposes is also difficult. The relatively small size of

8. DISADVANTAGES continued

the pit area would limit the amount of sand won in a continuous operation, and would be more suited to sporadic dredging operations.

9. POSSIBLE OBJECTIONS

Residents adjacent to the haul road. In addition to possible objectors, no tenure of the pit has as yet been offered by the Club despite our representations to them.

10. COSTS (exclusive of Royalty)

Discharge length - 2.5km
Dredge and two booster stations

Establishment Cost		\$75,000
Dredging Cost 15,000m^3 @ \$5/m^3		\$75,000
	TOTAL COST	\$150,000

Cost/m^3 \$10

When royalty is added to this rate, this source of supply would be marginally viable. Gross cost per cubic metre could be reduced in the event of a larger source being available against which to offset establishment costs.

ANNEXURE 'D'

Stockpiling of sand on Letitia Spit for either future use by R.T.A. in Chinderah By-pass construction or for future sales.

This involves pumping across the Tweed River via a submerged pipeline and stockpiling upon Crown Land. The R.T.A. have a substantial fill requirement for the Chinderah By-pass scheduled for construction in 1992.

1. ZONING

6(b) - Proposed Open Space Zone

2. PLANNING CONSIDERATIONS

For sand supply to the R.T.A., the proposed stockpiling of sand on Letitia Spit and subsequent transportation to a construction site would be permissible under both a Part V assessment, or an application for assessment and approval to Council.

For sand stockpiling and future random sales, the proposal is a prohibited use under the 6(b) zone, and therefore could not be approved by Council should application be made. Such an activity could only take place pursuant to a favourable Departmental Part V assessment.

3. TRAFFIC IMPACTS

The activity of the dredge will have a nil traffic impact.

However, either transportation by road by the R.T.A. to a construction site such as the proposed Chinderah By-Pass, or sand sales generally will have a positive impact on traffic, by generating a significant increase in heavy vehicle movements along fingal Road for its full length. One mitigating factor offsetting this adverse impact is the consideration that such traffic would be for a limited duration only - until such time as sand stocks are depleted - and then would not recur. The proposal therefore would have no permanent traffic impact.

4. EFFLUENT AND SITE DRAINAGE

The extent of Crown Land in the area is sufficiently large to enable the S.P.C.C. requirements of two days detention to be accommodated. The settled waters can be gravitated to

4. EFFLUENT AND SITE DRAINAGE continued

the main channel of the Tweed River well clear of Kerosene Inlet, this preventing any potential for pollution to this sensitive area.

5. NOISE

The noise generated by the dredging operation will by minimal only and with the normal S.P.C.C. requirement of 5 dB(A) maximum increase in background noise measured at the nearest affected residence.

Transportation of sand by truck, either for sale or for R.T.A. roadworks, will create additional traffic volumes and associated noise in Fingal Road.

This, however, would not be of permanent duration, and would occur only until all sand won from the Channel for this particular exercise had been disposed of.

6. VISUAL

The dredge and discharge lines will provide a minor visual impact only and pipelines across thee Tweed River will be submerged.

The sand stockpile on Letitia Spit will be remote from any residential development and will not be visibly intrusive at Letitia Spit, which is itself dunal in nature.

The life of the stockpile would also be only of limited duration and the area revegetated after completion of works.

7. ADVANTAGES

Site is remote from urban population centres and any potential nuisance effect on nearby residents will be minimal.

8. DISADVANTAGES

Stockpile site is remote for Commercial Sales. Site is approximately 5km north of the Chinderah By-pass site.

9. POSSIBLE OBJECTIONS

Residents along Fingal Road may object to heavy traffic hauling sand from pit area.

10. COSTS (exclusive of Royalty)

Discharge length - 1.5km
Dredge and one booster station

Establishment Cost	\$65,000
Dredging Cost 15,000m^3 @ \$3.50/m^3	\$ 7,000
TOTAL COST	\$52,500

Cost/m^3 \$8.30

This could be attractive to the R.T.A. especially if a larger supply is available, which would offset establishment costs and thus reduce overall cost per cubic metre.

ANNEXURE 'E'

The former "Egg & I" site, on the Pacific Highway, has a fill requirement of around 100,000m^3 to establish a flood free level. We have been in contact with the owner, a Mr Don Bilton of Tweed Heads, who has indicated an interest in acquiring sand filling for the site.

1. ZONING

Part Residential (c) - Special Residential and part Trade and Commerce under Tweed Shire Council D.C.P. No.3 - Banora Point West - Tweed Heads South.

2. PLANNING CONSIDERATIONS

Placement of filling on this site is a conforming use with Council consent. Rights of way over Golf Club land would need be negotiated and underboring of Soorley Street would be required.

Use of the site as a sand pit for future sales may also be a permissible use with Council consent.

3. TRAFFIC IMPACTS

The activity of the dredge will have a nil traffic impact.

Permanent placement of fill on site will also generate a nil traffic impact.

Sand stored on site for future sales will generate only a relatively minor proportionate increase in heavy vehicular traffic on the Pacific Highway

Access to the property from the Pacific Highway would need to be constructed.

4. EFFLUENT AND SITE DRAINAGE

Site area is approximately 12 hectares, and is of sufficient size to accommodate adequate detention ponds for two days effluent storage.

The site has direct access to a major drainage channel which discharges into the Tweed River.

Given the predominantly clean marine sand at the dredge site, and adequate settlement at the discharge site, no significant problem is seen to exist.

5. NOISE

The noise generated by the dredge will be minimal only and within the normal S.P.C.C. requirement of 5 dB(A) maximum increase in background noise level measured at the nearest affected residence.

Permanent placement of fill on site will generate no additional noise levels, apart from machinery used to prepare and finish the site works.

Transportation of sand by truck will create additional traffic volumes and associated noise, but when consideration is given to traffic movements and traffic noise currently generated by the present Pacific Highway, this increase will be negligible.

6. VISUAL

The dredge and pipelines will provide a minor visual impact only and for a limited duration.

Sand permanently placed on site will also have transient impact only, as retopsoiling of filled lands will immediately follow dredging.

A sand stockpile on site would have a minor visual impact and, again, would only be of temporary nature.

7. ADVANTAGES

Hydraulic placement of sand fill directly upon the land which is being filled. No vehicular traffic movement to and from deposition area.

8. DISADVANTAGES

Long length of discharge line required. Relatively high cost.

9. POSSIBLE OBJECTIONS

Minimal - provided that all usual safeguards are taken along the length of the line, and at the deposition site.

10 COSTS (exclusive Royalty)

Discharge length - 3.0km
Dredge and two booster stations

Establishment Cost	\$75,000
Underbore Soorley Street	\$ 5,000
Dredging Cost 15,000m³ @ \$5.00/m³	\$75,000
TOTAL COST	\$155,000

Cost/m³ \$10.30

With royalty added this source of supply is only marginally viable. Should a larger source be available (say 125,000m³ total) then cost per cubic metre is reduced to \$5.60, which would be an attractive rate to a potential purchaser.

ANNEXURE 'F'

The Sullivan family own land S.W. of the Tweed River High School and this has a large fill requirement if developed. Land is Lot 1, D.P. 585703, and is currently for sale by the Estate. Fill could be pumped directly to this site for permanent reclamation or alternatively, with the owners consent, deposited on this site as a stockpile.

1. ZONING

   2(c) Urban Expansion Zone under Tweed L.E.P. (1987).

2. PLANNING CONSIDERATIONS.

   Permanent placement of fill on this land to increase its level above the one in one hundred year flood level is a permissible use with Council consent.

   Sale of sand from the site would constitute an industry (not an extractive industry) and therefore also be a permissible use with Council consent.

3. TRAFFIC IMPACTS

   The activity of the dredge will have a nil traffic impact.

   Permanent placement of fill on site will also generate a nil traffic impact.

   Sand stored on site for future sales will generate a significant increase in local traffic in proximity to the point of sale.

   Haul routes could be established along the unformed part of Kirkwood Road to exit at the Pacific Highway at a controlled intersection or, alternatively, via Oxley or Sullivan Streets to Dry Dock Road.

   The former route would create a nuisance to residents of Blundell Boulevarde whose properties abut the unformed Kirkwood Road.

   The latter route is past school and recreation grounds and through a residential area and is not favoured.

4. EFFLUENT AND SITE DRAINAGE

This is a large site with adequate area to accommodate detention ponds for two days effluent storage as required by the S.P.C.C.

The site has direct access to a major drain which is located within the Tierneys Road/Kirkwood Road/Road Reserve. this drain discharges into Ukerebagh Passage.

Given the predominantly clean marine sand at the dredge site and adequate settlement at the discharge site, no significant pollution problem is seen to exist.

5. NOISE

The noise generated by the dredge will be minimal only and within the normal S.P.C.C. requirement of 5 dB(A) maximum increase in background noise level measured at the nearest affected residence.

Permanent placement of fill on site will generate no additional noise levels, apart from machinery used to prepare and finish site works.

Transportation of sand by truck will create a significant increase in heavy vehicle movements, with associated noise, on either access route.

6. VISUAL

The dredge and pipelines will provide a minor visual impact only, and for a limited time duration.

Sand permanently placed on site will also have transient impact only, as retopsoiling of filled lands will immediately follow dredging.

A sand stockpile on site would have a minor visual impact and, again, be only of a temporary nature.

7. ADVANTAGES

Hydraulic placement of sand fill directly upon the land which is being filled. No vehicular traffic movement to and from deposition area.

7. ADVANTAGES continued

If used as a stockpile site, the point of sale is centrally located in the South Tweed area and would minimise haulage costs.

8. DISADVANTAGES

Long length of discharge line and relatively high cost for small quantity. Proximity to School and residential development of stockpile site is also not desirable.

Access could be achieved by temporary road works within Kirkwood Road, together with structure over drain. Haul route would not be favoured by those residents of Blundell Boulevarde who also abut Kirkwood Road.

Tenure for stockpile site would need negotiation.

9. POSSIBLE OBJECTIONS

Residents of Blundell Boulevarde, both for stockpile site and for heavy vehicle routes, if material used for sales.

10. COSTS (exclusive Royalty)

Discharge length - 3.0km
Dredge and two booster stations

Establishment Cost	$75,000
Dredging Cost 15,000m³ @ $5.00/m³	$75,000
TOTAL COST	$150,000

Cost/m³ $10.00

This alternative would only be attractive commercially if a greater source of material can be located to offset establishment costs.

ANNEXURE 'G'

Some vacant, unfilled, large parcels of land still exist along Dry Dock Road. Their ownership has not been researched.

Direct placement of fill on to these properties or their temporary use as a sand pit is also an option.

1. ZONINGS

2(a) - Residential A Zone

2. PLANNING CONSIDERATIONS

Direct placement of fill to achieve a flood free level is a conforming use that can be carried out with Council consent. Use of the land as a stockpile for future sales is a prohibited use and could not be consented to by Council.

3. TRAFFIC IMPACTS

The activity of the dredge will have a nil traffic impact.

Permanent placement of fill on site will also generate a nil traffic impact.

4. The vacant sites in this location each contain an area of less than one hectare. Fill requirements would be small - approximately 15,000m^3 per site - and achieving two days detention of dredge waters would require intermittent dredge operation, especially approaching completion of the filling operation. This option would not be viable unless adjoining sites could be utilized. Site drainage can be effected by direct discharge into Terranora Creek.

5. NOISE

The noise generated by the dredging operation will be minimal only, and within the normal S.P.C.C. requirement of 5 dB(A) maximum increase in background noise levels, measured at the nearest affected residence.

Permanent placement of fill on site will generate no additional noise levels, apart from machinery used to prepare and finish site works.

6. VISUAL

The dredge and its pipelines will provide a minor visual impact only, and for a limited time duration.

Sand permanently placed on site will also have a transient impact only, as retopsoiling of filled lands will immediately following dredging,

7. ADVANTAGES

Hydraulic placement of sand fill directly upon the land which is being filled. No vehicular traffic movement to and from deposition area.

8. DISADVANTAGES

Long length of discharge line and relatively high cost for small quantity. Inadequate size of allotments to permit large scale filling and stockpiling.

9. POSSIBLE OBJECTIONS

Adjoining residents if control is not exercised over wind blown sand, or if insufficient care and attention is given to perimeter drainage.

10. COSTS (exclusive Royalty)

Discharge length - 3.0km
Dredge and two booster stations

Establishment Cost	\$75,000
Dredging Cost 15,000m³ @ \$5.00/m³	\$75,000
TOTAL COST	\$150,000

Cost/m³ \$10.00

This alternative would only be attractive commercially if larger quantities of fill material can be located and a site of sufficient size to accept dredge sand is identified.

ANNEXURE 'H'

SUMMARY OF ESTABLISHMENT AND OPERATIONAL COSTS

(A) Commercial Cost of Sand Supply from Broadhurst-Hill

i. Ex Pit (loaded) $8.00/m³

ii. Delivered Dry Dock Road $13/m³
(Approximately $0.70/m³/km)

N.B. Broadhurst-Hill volumes are trucked (bulked) quantities.

B) Larger Dredge (15")

Establishment costs (Incl. pipe)	$60,000
Booster Establishment (Incl. pipe)	$ 7,500
Economical Supply distance unboosted	1,000 metres

Operational Costs

(i) Dredge	$2.00/m³
(ii) Booster	$1.50/m³

(C) Medium Size Dredge (10/8 or Equivalent)

Establishment Cost (incl. Pipe	$15,000
Booster Establishment Costs (Incl. pipe)	$ 5,000
Economical supply distance unboosted	600 metres

Operational Costs

(i) Dredge	$2.00/m³
(ii) Booster	$1.50/m³

(D) Smaller Dredge (8/6 or equivalent)

Establishment costs (Incl. pipe)	$5,000
Booster Establishment (Incl. pipe)	$2,000
Economical Supply distance unboosted	400 metres

Operational Costs

(i) Dredge	$2.50/m³
(ii) Booster	$1.50/m³

APPENDIX 8

NSW DEPARTMENT OF CONSERVATION
AND LAND MANAGEMENT
FINGAL PENINSULA LAND ASSESSMENT
(EXTRACT)
1992

Extract from "Fingal Peninsular Draft Land Assessment"
Department of Lands, 1991

18. Location: Area adjacent to Tweed River between Wommin Lake and Wommin Lagoon

Description:

About 20 hectares of vacant Crown land and a small reserve of quarantine comprising of a sparse grassy heath type vegetation on an even slope (2-5%). Area has been extensively cleared in the past, possibly by burning, as evidenced by the widespread establishment of Blady grass (*Imperata cylindrica*) and remnant *Banksia integrifolia*. As in most other mapping areas, Bitou has begun to colonise the bare sandy patches. Many of these have been caused by 4WD access on unformed tracks. The Tweed Valley Flood Plain Management Strategy indicates that most of this area is likely to be inundated by 1 in 20 year floods (Cameron McNamara 1980) and is therefore likely to impose constraints on all but low impact development.

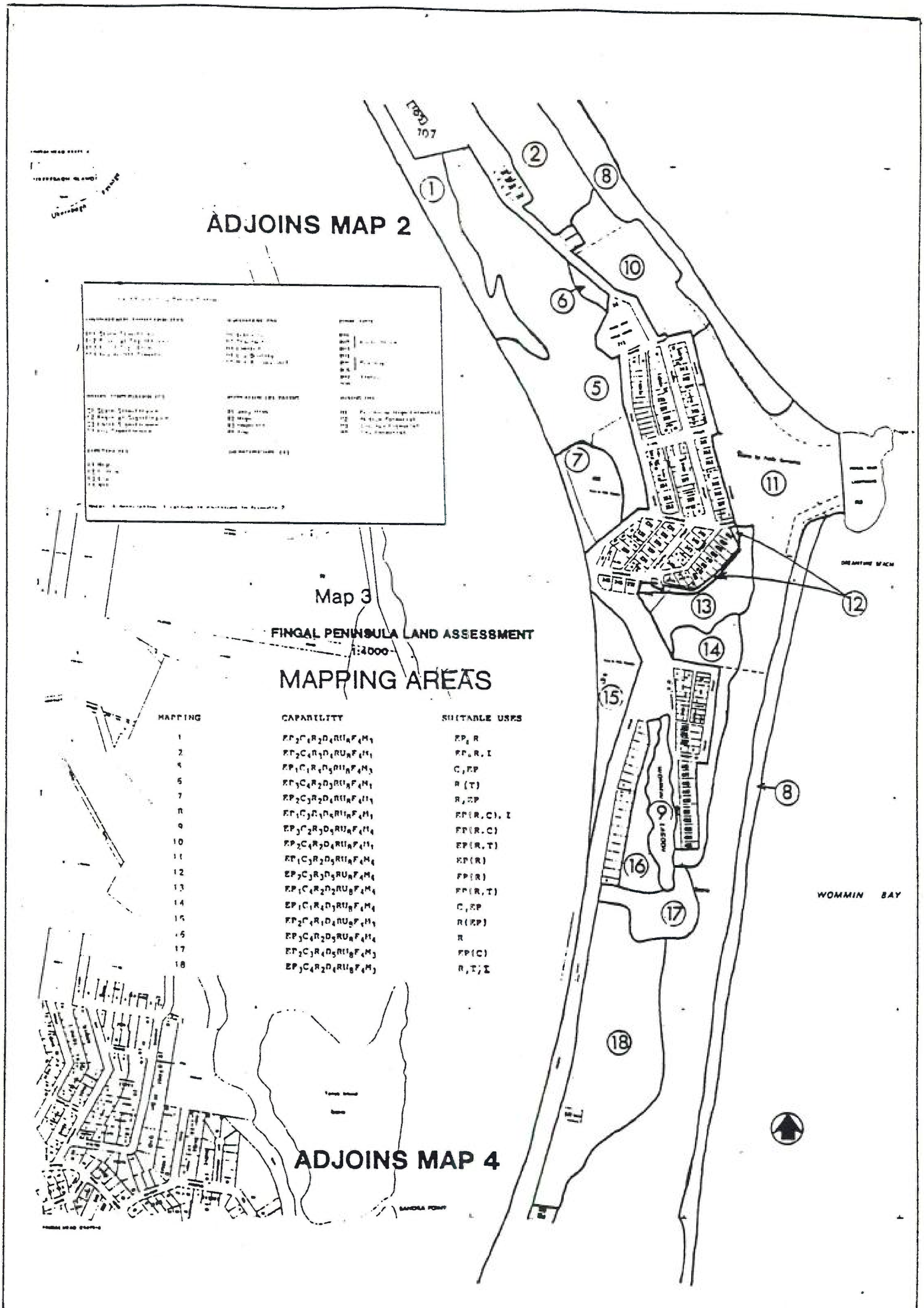
Environmental protection capability is of local significance. Due to its location on the narrowest part of Fingal Peninsular, this mapping area may be subjected to the influence of both coastal zone attack and periodic flood inundation.

Suitable Uses

Urban Recreation, Tourist Development, Infrastructure

The area is most suitable for intensive or urban type recreation. Low density tourist development is an alternative; however, the threat of occasional flooding and the need to protect this area from the threat of erosion may preclude many development options.

The PWD have suggested that this would in the short term (approx. 10 years) provide a preferred stockpile site for maintenance dredging of the Tweed River.



Map 3

FINGAL PENINSULA LAND ASSESSMENT

1:4000

MAPPING AREAS

MAPPING	CAPABILITY	SUITABLE USES
1	$EP_2C_4R_2D_4RU_8F_4M_1$	EP, R
2	$EP_2C_4R_3D_4RU_8F_4M_1$	EP, R, I
5	$EP_1C_1R_1D_5RU_8F_4M_3$	C, EP
6	$EP_3C_4R_2D_3RU_8F_4M_1$	R (T)
7	$EP_2C_3R_2D_4RU_8F_4M_1$	R, EP
8	$EP_1C_3R_1D_5RU_8F_4M_1$	EP(R,C), I
9	$EP_3C_2R_3D_5RU_8F_4M_4$	EP(R,C)
10	$EP_2C_4R_2D_4RU_8F_4M_1$	EP(R,T)
11	$EP_1C_3R_2D_5RU_8F_4M_4$	EP(R)
12	$EP_2C_3R_3D_5RU_8F_4M_4$	EP(R)
13	$EP_1C_4R_2D_2RU_8F_4M_4$	EP(R,T)
14	$EP_1C_1R_4D_3RU_8F_4M_4$	C, EP
15	$EP_2C_4R_1D_4RU_8F_4M_1$	R(EP)
16	$EP_3C_4R_2D_5RU_8F_4M_4$	R
17	$EP_2C_3R_4D_5RU_8F_4M_3$	EP(C)
18	$EP_3C_4R_2D_4RU_8F_4M_3$	R,T,I

APPENDIX 9

NOISE IMPACT ASSESSMENT

NOISE IMPACT ASSESSMENT

1. General

Attenuation of noise depends upon a number of factors. The most significant of these are:

a) Divergence, a function of distance between the source and the receiver and due to the spreading out of sound with distance.
b) Air absorption, a function of distance, temperature and relative humidity as well as frequency content of the source noise. Higher frequencies are attenuated more by air molecules.
c) Barrier screening, a function of height of the source and receiver, and of intervening screens or ground contours.
d) Vegetation absorption, a function of density of intervening vegetation.
e) Ground effect, a function of height of source and receiver, and of type of ground cover.
f) Wind attenuation, a function of wind velocity and of distance between source and receiver.

2. Nett Attenuations

Typical distances between noise sources involved in the proposal and affected residential properties ranges from 10 to 500 metres. Table A9.1 presents a summary of noise attenuations from sources over various distances where no screening occurs.

TABLE A9.1 - TYPICAL ATTENUATION OVER VARIOUS DISTANCES

Distance from source, metres	10	30	60	120	250	500
Divergence loss	28	38	44	50	56	62
Air absorption					1	3
Ground effect				1	1	3
Nett attenuation	28	38	44	51	58	68

APPENDIX 10

SEDIMENTARY ANALYSES, CORE LOGS AND HEAVY MINERAL POTENTIAL

SEDIMENTARY ANALYSES, CORE LOGS AND HEAVY MINERAL POTENTIAL

Several investigations of the sedimentary properties of the Tweed Lower Estuary including Area 5 have been undertaken. The key studies of significance for this EIS are as follows:

(i) The investigation undertaken by Patterson Britton & Partners on behalf of PWD entitled "Extractive Resources of Lower Tweed Estuary - Preliminary Market Assessment", October 1989. This has been produced by PWD under its "Reviving the Tweed" report series, Report No. 3.4.8, February 1991.

(ii) Borehole investigations undertaken for the foundations of the new RTA highway bridge.

Extracts from the results of these studies are presented in this Appendix.

2.2.2 Geotechnical Assessment

Sedimentology

The sedimentology of the sediments in the lower Tweed River reflects the basic regional Quarternary Geology discussed in **Section 2.1.2**. The Tweed River flows through Pleistocene and Holocene inner and outer marine sand barrier systems and the distribution of sand facies in the bed sediments reflects this regional geology.

A detailed assessment of the sand facies of the lower Tweed was carried out by the PWD (**Reference 2**) and a sample is shown in **Figure 7**. There is an active Holocene marine sand delta comprising well sorted, fawn to buff coloured, shelly marine sand which extends upstream in the Main Arm to Letitia 2A and a few hundred metres or so into the Terranora Arm.

Upstream of Letitia 2A the surface Holocene marine sand is mixed to varying degrees with reworked Pleistocene marine sand. The extension of Holocene sands into Terranora Creek to approximately Boyds Bay Bridge, is the result of active marine delta processes.

Pleistocene marine sands appear to occupy the area from Banora Point to approximately one kilometre upstream of Dodds Island. Fluvial sediment is actively overlapping these sands in the Main Arm, but apart from fine accumulations in off-channel backwater areas, fluvial sands do not extend downstream of Barneys Point Bridge. Hence, Chinderah can be considered as the present day front of active fluvial sand deposition in the river. This does not preclude very fine fluvial sediments from being transported through the estuary and offshore in times of significant flood flows. There is no overlapping of Pleistocene marine sands in the Terranora Arm because active fluvial sedimentation is restricted to the very small digitate deltas of Cobaki, Bilambil and Duroby Creeks.

Sediment routing studies *(***Reference 2** *and the Estuarine Dynamics Report of the Tweed Entrance Feasibility Study)* have demonstrated that over the last decade there has been a slow downstream movement of inner barrier sand in both Arms, in response to the Gold Coast City Council dredging carried out in 1974/76 (refer **Figure 1**). This process has resulted in a significant redistribution and build-up of inner barrier marine sands in the surface layers of the sediments of the lower Tweed estuary. The effect has been significant and can be seen in the cores taken for this study.

Field Coring and Sampling

The location of shallow cores of the top two metres of the estuary bed is shown in **Figure 8**.

Core logs and the location of samples *(designated as B1 etc)* used in subsequent laboratory analyses are shown in **Appendix A**.

A detailed sedimentological analysis of sediment samples has not been conducted. However based on previous studies (**Reference 2**) the light brown/fawn coloured sand facies in cores TR1 to TR9 constitutes mixed reworked marine sands with the proportion of reworked Pleistocene sand being greatest in the darker, speckly sediments in the vicinity of Banora Point.

The slightly light to pale grey sandy facies underlying the mixed sediments is likely to constitute Pleistocene, inner barrier marine sands.

The gravelly sand at the bottom of TR11A is interpreted as a channel lag deposit mantling bedrock which is known to outcrop in the bed of the entrance channel.

The 0.2 metre shelly sand deposit in TR2 most probably constitutes an older, but modern, estuarine surface in the vicinity of Tonys Island c. 1970, before lower estuary dredging was carried out by the Gold Coast City Council.

Laboratory Analysis

The results of grain size analyses, shell determination and other organic content in respect of twelve representative samples *(refer* **Appendix A** *for sample locations)* is provided in **Appendix B**.

The test results indicate that the marine sands *(ie. both Inner and Outer Barrier sands)* of the lower Tweed Estuary are unsuitable as a fine concrete aggregate. The grading of the sand is poor and the shell content detracts from its use in high quality concrete.

The sand deposit is relatively free of organics and the carbonate content ranged from 2.8% to 13.9%. Silt content varied from zero to 6% with the greater majority of the deposit containing less than 1%. The overall properties of the deposit are satisfactory in respect of its potential as a high quality, general purpose filling sand.

3. EVALUATION OF LOWER TWEED RIVER HEAVY MINERAL RESERVES

3.1 FIELD CORING AND SAMPLING

The locations of shallow cores of the top two metres of the estuary bed are shown in **Figure 8**.

Core logs and the locations of samples *(designated as S4 etc)* used in subsequent laboratory analysis are shown in **Appendix A**.

Visual inspection of the cores indicated no obvious seams of high mineral concentration apart from a thin lense, 3 mm thick, in core TR9. Hence a total of sixty three samples were collected to represent the top and bottom portions of each of the sand facies changes observed in the cores (**Section 2.2.2**).

3.2 HEAVY MINERAL ANALYSIS

A preliminary assessment of the heavy mineral grade and type was carried out by Coastal and Marine Geosciences *(CMG)* (**Appendix C**).

CMG selected forty one samples for detailed analysis of the heavy mineral grade. Testing comprised:

- grain size analysis;
- heavy mineral separation by heavy liquid *(bromoform)* separation.

Petrographic analysis, using modal analysis of heavy mineral grain mounts, was carried out on seven heavy mineral concentrates to identify the relative percentages of heavy mineral species. A detailed report is contained in **Appendix C**.

The analysis demonstrated that the heavy mineral content of the top two metres of the lower Tweed sand reserves is generally well disseminated. The total heavy mineral grade varied from 0.12% - 1.0% with an average of approximately 0.4%. The heavy mineral suite contained a range of mineral types and the economic component of the heavy mineral portion *(ie. rutile and zircon)* varied from 0.07% to 0.52% of the total sand body, with an average of about 0.2%.

Adopting an average R/Z content of 0.2%, the total volume of R/Z is estimated to be 7,400 m^3 and 25,400 m^3 having regard to dredging depths of -5 m AHD and -10 m AHD respectively.

The above estimate assumes that the heavy mineral content is uniformly distributed throughout the sand body. As pointed out by CMG (**Appendix C**) this is unlikely to be the case but without further deeper drilling and sampling it is not possible to determine whether the deeper layers of the sand body would have greater or lesser heavy mineral concentration.

3.3 PROJECTED CASH FLOW

The potential revenue from heavy mineral mining would involve royalties, leasing and land charges, taxes and other indirect benefits. Owing to the low mineral grade, any mining of heavy minerals will occur only as an adjunct of large scale sand extraction. Hence the heavy mineral royalty is the only revenue which would be derived from the heavy minerals. The other sources of revenue would accrue in respect of the sand extraction side of the operation and these are discussed in **Section 4.6.2**.

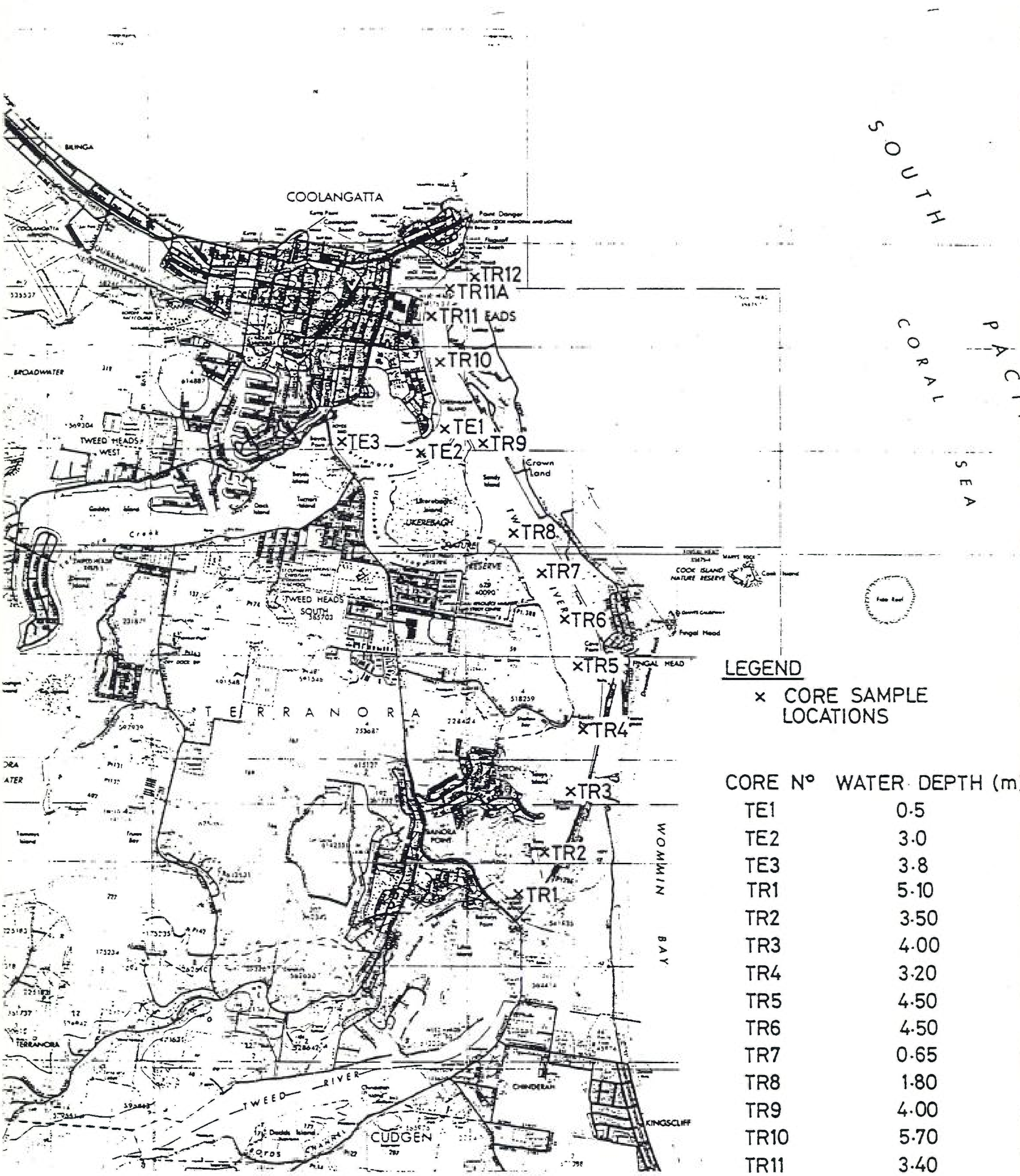
The royalty from heavy minerals is 4% of the FOB market price of the mineral which is currently \$700-800/tonne for Rutile and \$500-600/tonne for Zircon. Adopting an overall royalty of \$30/tonne, a R/Z grade of 0.2% (**Section 3.2**), a bulk density of sand of 1.7 tonne/m^3, specific gravity of silica of 2.65 and an average specific gravity of R/Z of 4.5 the concentration of R/Z, in a fully disseminated mode, is 0.0058 tonne/m^3. Hence the potential royalty from heavy minerals is approximately $17^c/m^3$. This is to be compared with current sand royalties of \$1.40 to \$2.00/m^3 (**Section 4.6.2**).

Based on the very preliminary information available for this report, which has necessitated considerable extrapolation of limited surface data, heavy mineral mining is unlikely to be a major factor in the commercial potential of the lower Tweed River sand reserves.

Projected royalties from the mining of heavy minerals, as a by-product of a major sand extraction operation, are summarised in **Table 1**. The royalties are calculated on $17^c/m^3$ of the projected total market demand for lower Tweed fill sand resources (**Table 12, Section 4.6.1**). The FOB price of R/Z is volatile and can fluctuate significantly. Hence no incremental growth *(ie. growth in excess of long term inflation rate)* has been applied to the royalty estimates.

TABLE 1 PROJECTED CASH FLOW - HEAVY MINERAL RESERVES

	\$1000's										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10 yr Total**
High	71	87	128	152	173	151	160	182	186	191	1.5 M
Low	11	8	-	9	26	26	41	69	71	71	0.3 M

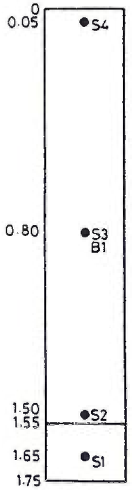


LEGEND

× CORE SAMPLE LOCATIONS

CORE N°	WATER DEPTH (m)
TE1	0·5
TE2	3·0
TE3	3·8
TR1	5·10
TR2	3·50
TR3	4·00
TR4	3·20
TR5	4·50
TR6	4·50
TR7	0·65
TR8	1·80
TR9	4·00
TR10	5·70
TR11	3·40
TR11A	4·80
TR12	5·80

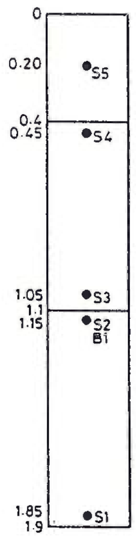
LOCATION OF SHALLOW CORES
LOWER TWEED ESTUARY



FAWN, SLIGHTLY SPECKLED, WELL SORTED, HOMOGENEOUS SAND.
MEDIUM/FINE GRAIN SIZE.

GREY/FAWN, SLIGHTLY SPECKLED, WELL SORTED, HOMOGENEOUS SAND.
FINE/MEDIUM GRAIN SIZE.

TE1

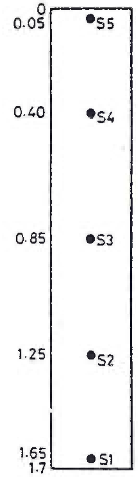


FAWN, SLIGHTLY SPECKLED, WELL SORTED HOMOGENEOUS SAND.
MEDIUM/FINE GRAIN SIZE.

PALE GREY-FAWN, SLIGHTLY SPECKLED, WELL SORTED HOMOGENEOUS SAND.
FINE/MEDIUM GRAIN SIZE.

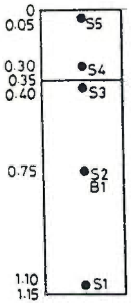
LIGHT GREY, SPECKLED, WELL SORTED, HOMOGENEOUS SAND.
FINE/MEDIUM GRAIN SIZE.

TE2



GREY, SPECKLED, WELL SORTED, HOMOGENEOUS SAND.
FINE/MEDIUM GRAIN SIZE.

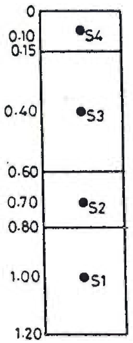
TE3



PALE GREY/LIGHT FAWN, WELL SORTED SAND
HOMOGENEOUS WITH DISSEMINATED BLACK INCLUSIONS (LITHICS)

PALE GREY/LIGHT FAWN WELL SORTED
SAND WITH MINOR SILT (SILT MINOR 1%).
APART FROM SILTY PATCHES, HOMOGENEOUS.

TR1



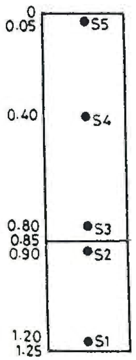
LIGHT BROWN, SPECKLED, WELL SORTED HOMOGENEOUS SAND.

PALE BROWN/FAWN SPECKLED WELL SORTED HOMOGENEOUS SAND.

PALE BROWN, SPECKLED SHELLY SAND. SHELL
DETRITAL AND COARSE - LAG DEPOSIT.

PALE GREY, SPECKLED WELL SORTED HOMOGENEOUS SAND.

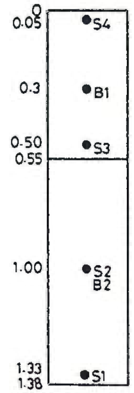
TR2



LIGHT BROWN/FAWN, SPECKLED, WELL SORTED, HOMOGENEOUS SAND.
MEDIUM GRAIN SIZE.

PALE GREY, SPECKLED, WELL SORTED, HOMOGENEOUS SAND.
FINE/MEDIUM GRAIN SIZE.

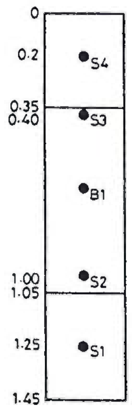
TR3



LIGHT BROWN/FAWN, WELL SORTED, SPECKLED HOMOGENEOUS SAND.
MEDIUM GRAIN SIZE.

PALE GREY, SPECKLED WELL SORTED HOMOGENEOUS SAND.
MEDIUM/FINE GRAIN SIZE.

TR4

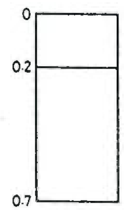


LIGHT BROWN/FAWN, WELL SORTED, SPECKLED, HOMOGENEOUS SAND.
MEDIUM GRAIN SIZE.

PALE GREY, SPECKLED, WELL SORTED, HOMOGENEOUS SAND.
MEDIUM GRAIN SIZE.

LIGHT GREY - MID GREY, WELL SORTED, SPECKLED, HOMOGENEOUS SAND.
MEDIUM/FINE GRAIN SIZE.

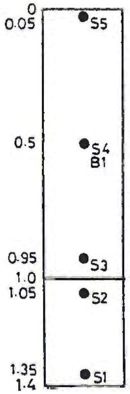
TR5



DARK BROWN/GREY SANDY SILT.

GREY, UNCONSOLIDATED MUD.

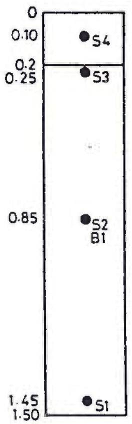
TR6



LIGHT GREY/FAWN, SPECKLED, WELL SORTED, HOMOGENEOUS SAND.
MEDIUM GRAIN SIZE.

PALE GREY/WHITE, SPECKLED, WELL SORTED HOMOGENEOUS SAND.
MEDIUM/FINE GRAIN SIZE.

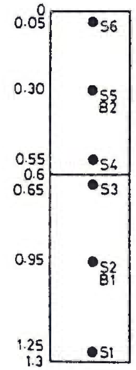
TR7



LIGHT BROWN/FAWN, SPECKLED, WELL SORTED, HOMOGENEOUS SAND.
MEDIUM GRAIN SIZE.

LIGHT GREY, SPECKLED, WELL SORTED, HOMOGENEOUS SAND.
MEDIUM/FINE GRAIN SIZE.

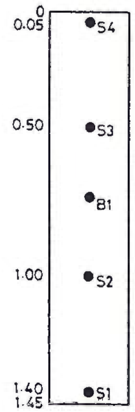
TR8



PALE GREY/LIGHT FAWN, SPECKLED, WELL SORTED, HOMOGENEOUS SAND.
MEDIUM GRAIN SIZE.

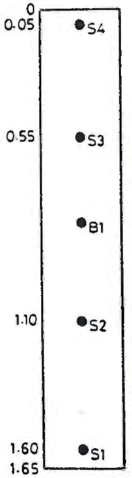
PALE GREY/GREY, SPECKLED, WELL SORTED SAND.
MAINLY HOMOGENEOUS.
ONE 3MM BLACK LENSE AT 0.7.

TR9



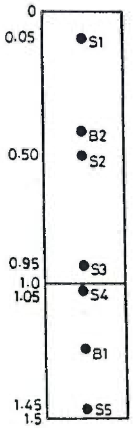
FAWN, SPECKLED, WELL SORTED, HOMOGENEOUS SAND.
MEDIUM/FINE GRAIN SIZE.

TR10



PALE GREY/WHITE, WELL SORTED, HOMOGENEOUS SAND.
MEDIUM/FINE GRAIN SIZE.

TR11



FAWN/PALE GREY, WELL SORTED, HOMOGENEOUS SAND.
MEDIUM GRAIN SIZE.

FAWN/LIGHT GREY, SHELLY, SAND WITH PEBBLES.
COARSE TO MEDIUM GRAIN SIZE.

TR12

NEW BRIDGE OVER TWEED RIVER

99·5 KM NORTH OF BALLINA AT BARNEYS POINT.

FILE NO 10/488·1465

JOB NO SJ-218

S:W

7/91

SITE PLAN

NOT TO SCALE.

N.B.

1/ o PROPOSED BORE HOLE SITE.

2/ ● ACTUAL DRILLED SITE OF BORE HOLE.

3/ LIGHT FILL PLACED ON SITE OF PIER 3
HOLES No 4 5 6.

4/ N.S. NATURAL SURFACE.

5/ LEVELS FROM PIER 4 TO ABUT B WERE TAKEN BY S:W.
FROM SSM No 33306 RL BEING 2·456 AND LEVELS FROM
ABUT A TO PIER 3 WERE TAKEN BY DAVID ANDERSON (REGISTERED SURVEYOR)

NON-CORE DRILL HOLE-GEOLOGICAL LOG

PROJECT: BRIDGE OVER TWEED RIVER | HOLE NO: 7
FILE / JOB NO: G2026
LOCATION: BARNEY'S POINT | SHEET 1 OF 6
POSITION: PIER 4 CH: 560.500 9.15 m L OF ℄ | SURFACE ELEVATION: | ANGLE FROM VERTICAL: 0°
RIG TYPE: P160 | MOUNTING: TRAILER/BARGE | CONTRACTOR: R.T.A. | DRILLER: S. WATTS
DATE STARTED: 6/5/91 | DATE COMPLETED: 8/5/91 | DATE LOGGED: 6/5/91 7/5/91 | LOGGED BY: JT | CHECKED BY: GK

DEPTH (m)	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
0	WASH BORING WITH HW CASING (0–2.80)	NO RETURN DUE TO WASH BORING	E						SILTY SAND: DARK GREY. FINE TO MEDIUM GRAINED. SOME FINE BLACK PARTICLES PRESENT.	W		ALLUVIUM
1												CASING RUNS HW - 2.80 m NW - 11.90 m NW - 19.20 m NW - 21.90 m NW - 24.50 m
2.80	HQX ROLLER 3 7/8" (2.80–8)	0% LOSS (POLYMER)			2.80 SPT 1,1,1 N*=2 3.25						VL	* NO SPT SAMPLE RECOVERED
4.60					4.60 SPT 4,2,2 N*=4 5.05						L	
6.0					6.0 SPT 4,0,4 N*=8 6.45				6.05 SAND: LIGHT GREY. FINE TO MEDIUM GRAINED. SOME FINE BLACK PARTICLES PRESENT.		L	
7.50					7.50 SPT 5,6,8 N*=14 7.95						MD	
8												

See Standard Sheets for details of abbreviations [redacted] of desc[redacted]

ROADS AND TRAFFIC AUTHORITY, NSW

[redacted]

NON-CORE DRILL HOLE-GEOLOGICAL LOG

PROJECT: BRIDGE OVER TWEED RIVER | HOLE NO: 7
FILE / JOB NO: G2026
LOCATION: BARNEY'S POINT | SHEET 2 OF 6
POSITION: PIER 4 CH: 560.500 9.15 m L OF ℄ | SURFACE ELEVATION: | ANGLE FROM VERTICAL: 0°
RIG TYPE: P160 | MOUNTING: TRAILER/BARGE | CONTRACTOR: R.T.A. | DRILLER: S. WATTS
DATE STARTED: 6/5/91 | DATE COMPLETED: 8/5/91 | DATE LOGGED: 8/5/91 | LOGGED BY: JT | CHECKED BY: GK

DEPTH (m)	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
8	HQX ROLLER 3 7/8" (8–12)	10% LOSS (POLYMER)	E						SAND: LIGHT GREY. FINE TO MEDIUM GRAINED. SOME FINE BLACK PARTICLES.	W		ALLUVIUM
9.0					9.0 SPT 8,9,11 N*=20 9.45						MD	
10.50					10.50 SPT 13,18,22 N*=40 10.95				AS ABOVE		D	
12.0	ROCK ROLLER 2 15/16" (12–16)				12.0 SPT 11,17,22 N*=39 12.45				AS ABOVE		D	
13.40					13.40 SPT 8,14,10 N*=34 13.85						D	
14.90					14.90 SPT 5,14,22 N*=36 15.35						D	
16												

See Standard Sheets for [redacted] tails a[redacted] tions [redacted] basis o[redacted] ions

ROADS AND TRAFFIC AUTHORITY, NSW

[redacted]

[redacted] NON-CORE DRILL HOLE-GEOLOGICAL LOG [redacted]

[redacted] BRIDG[redacted]ED RIVE[redacted]	HOLE NO : [redacted]
LOCATION : BARNEY'S POINT	FILE / [redacted] : G20[redacted]
	SHEET 3 OF 6
POSITION : PIER 4 CH: 560.500 L OF ℄	SURFACE ELEVATION : — ANGLE FROM VERTICAL : 0°
RIG TYPE : HW + NW — MOUNTING : TRAILER/BARGE	CONTRACTOR : R.T.A. — DRILLER : S. WATTS
DATE STARTED : 4/5/91 — DATE COMPLETED : 8/5/91 — DATE LOGGED : 6/5/91	LOGGED BY : JT — CHECKED BY : GK

DRILLING — DEPTH | DRILLING & CASING | DRILLING FLUID TYPE & LOSS | DRILLING PENETRATION | GROUND WATER LEVELS | SAMPLES, TESTS, ETC | RL (m)

MATERIAL — GRAPHIC LOG | CLASSIFICATION SYMBOL | MATERIAL DESCRIPTION: Soil Type, Colour, Plasticity or Particle Characteristic, Secondary & Minor Components | MOISTURE CONDITION | CONSISTENCY RELATIVE DENSITY | STRUCTURE & other observations

Depth (m)	Drilling & casing	Drilling fluid	Penetration	Samples, tests	Material description	Moisture	Consistency	Structure & other observations
16 – 20.50	HW/NW WASH [illegible]	20% LOSS (POLYMER)	E		SAND: LIGHT GREY. FINE TO MEDIUM GRAINED. SOME FINE BLACK PARTICLES PRESENT.	M	MD	ALLUVIUM
16.60 – 16.85				16.60 SPT 7,11,17 N*=28 16.85				
18.0 – 18.45				18.0 SPT 9,9,11 N*=20 18.45			MD	
18.80					GRAVELLY SAND: AS ABOVE SIZE OF GRAVELS NOT KNOWN.			
19.0					SILTY CLAY: DARK GREY. MEDIUM PLASTICITY.			
19.40 – 19.75				19.40 U50 19.75				* U50 WAS NOT RECOVERED
19.90 – 20.35				19.90 SPT 2,3,2 N*=5 20.35				
20.50					END OF NON-CORE AT 20.50 m			
22					(SEE CORED DRILL LOG SHEET)			

See Standard Sheets for details of abbreviations & basis of descriptions.

[redacted]COR[redacted]RILL[redacted]E L[redacted]

PROJECT : BRIDGE OVER TWEED RIVER	HOL[redacted] : [redacted]
LOCATION : BARNEY'S POINT	FILE / JOB NO : G2026
	SHEET 4 OF 6
POSITION : PIER 4 CH: 560.500 9.15 m L OF ℄	SURFACE ELEVATION : — ANGLE FROM HORIZONTAL : 90°
RIG TYPE : P160 — MOUNTING : TRAILER/BARGE	CONTRACTOR : R.T.A. — DRILLER : S. WATTS
CASING DIAMETER : HW + NW — BARREL (length) : 3.0 m NMLC	BIT : DIAMOND — BIT CONDITION : GOOD
DATE STARTED : 4/5/91 — DATE COMPLETED : 8/5/91 — DATE LOGGED : 7/5/91	LOGGED BY : JT — CHECKED BY : GK

DRILLING — DEPTH | PROGRESS: DRILLING & CASING, WATER | % CORE LOSS / RUN % / DRILL DEPTH | SAMPLES & FIELD TESTS | RL (m)

MATERIAL — GRAPHIC LOG | DESCRIPTION: ROCK TYPE: Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, etc as applicable) | WEATHERING | EST STRENGTH $I_s(50)$ MPa (EL, VL, L, M, H, VH, EH)

FRACTURES — NATURAL FRACTURE SPACING (mm) | VISUAL | ADDITIONAL DATA (joints, partings, seams, zones, etc) Description, orientation, infilling or coating, shape, roughness, thickness, other

Depth (m)	Drilling & casing	Water	Core loss / drill depth	Description	Weathering	Est strength	Fracture spacing	Additional data
16 – 20.50				(SEE NON-CORE LOG SHEETS)				* NOTE: P.P. = POCKET PENETROMETER TEST; H.B. = HANDLING INDUCED BREAK; D.B. = DRILLING INDUCED BREAK
20.50	NMLC CORING	10% LOSS (POLYMER)	40.0%	START CORING AT 20.50 m				
20.50 – 21.12				LOSS 0.62 m (20.50-21.12 m) * (CUTTINGS WERE DARK GREY SILTY CLAY)				
21.12				SANDY CLAY: GREY + REDDISH BROWN. FINE TO MEDIUM GRAINED SAND. MEDIUM PLASTICITY.		N/A	N/A	21.36 m P.P. = 196 KPa; 21.60 m P.P. = 245 KPa; 21.85 m P.P. = 294 KPa
22.0			22.05	AS ABOVE EXCEPT WITH GRAVELS UP TO 30 mm 70 mm COBBLE PRESENT				
22.28 – 22.50			48.9% 22.50	LOSS 0.22 m (22.28-22.50 m)				
22.60				AS ABOVE				70 mm COBBLE
22.60				SANDSTONE: GREY + YELLOW BROWN. FINE TO MEDIUM GRAINED. SOME PEBBLES PRESENT.	EW		N/A	
23.56				AS ABOVE EXCEPT RED BROWN.				
24								90 mm PEBBLY LAYER (UP TO 50 mm)

See Standard Sheets for details of abbreviations & basis of descriptions.

NON-CORE DRILL HOLE-GEOLOGICAL LOG

PROJECT : BRIDGE OVER TWEED RIVER
LOCATION : BARNEY'S POINT
HOLE NO : 8
FILE / JOB NO : G2026
SHEET 1 OF 5

POSITION : PIER 4 CH: 560.300 ℄ | SURFACE ELEVATION : | ANGLE FROM VERTICAL: 0°
RIG TYPE : P160 | MOUNTING : TRAILER/BARGE | CONTRACTOR : R.T.A. | DRILLER : S. WATTS
DATE STARTED: 2/5/91 | DATE COMPLETED: 4/5/91 | DATE LOGGED: 2/5/91 | LOGGED BY: JT | CHECKED BY: GK

DEPTH	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
0	WASH BORING WITH HW CASING	NO RETURN DUE TO WASH BORING	E						SILTY SAND: COLOUR NOT KNOWN (POSSIBLY DARK GREY) FINE TO MEDIUM GRAINED.	W		ALLUVIUM CASING RUNS HW - 3.05 m NW - 20.40 m
3	ROCK ROLLER 3 7/8"	0% LOSS (POLYMER)			3.05 SPT 2,1,1 N*=2 3.50				SILTY SAND: DARK GREY. FINE TO MEDIUM GRAINED.		VL	
6					6.20 SPT 1,1,- N*=1 6.65				AS ABOVE.		VL	
6.80									SAND: LIGHT GREY. FINE TO MEDIUM GRAINED. SOME FINE BLACK PARTICLES PRESENT.			

See Standard Sheets for details of abbreviations [redacted] of desc[redacted]

ROADS AND TRAFFIC AUTHORITY, NSW

NON-CORE DRILL HOLE-GEOLOGICAL LOG

PROJECT : BRIDGE OVER TWEED RIVER
LOCATION : BARNEY'S POINT
HOLE NO : 8
FILE / JOB NO : G2026
SHEET 2 OF 5

POSITION : PIER 4 CH: 560.300 ℄ | SURFACE ELEVATION : | ANGLE FROM VERTICAL: 0°
RIG TYPE : P160 | MOUNTING : TRAILER/BARGE | CONTRACTOR : R.T.A. | DRILLER : S. WATTS
DATE STARTED: 2/5/91 | DATE COMPLETED: 4/5/91 | DATE LOGGED: 2/5/91 | LOGGED BY: JT | CHECKED BY: GK

DEPTH	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
8	ROCK ROLLER 3 7/8"	10% LOSS (POLYMER)	E						SAND: LIGHT GREY. FINE TO MEDIUM GRAINED. SOME FINE BLACK PARTICLES PRESENT.	W		ALLUVIUM
9					9.10 SPT 7,9,11 N*=20 9.55						MD	* NO SAMPLE RECOVERED
10									AS ABOVE			
12					12.0 SPT 9,14,21 N*=35 12.45						D	
13									AS ABOVE			
15					15.0 SPT 16,22,27 N*=49 15.45						D	
16												

See Standard Sheets for [redacted] details [redacted] ations & basis [redacted] ptions

ROADS AND TRAFFIC AUTHORITY, NSW [redacted]

NON-CORE DRILL HOLE-GEOLOGICAL LOG

[redacted] BRIDG[redacted] ED RIVE[redacted] HOLE NO : 8 [redacted]
FILE / [redacted] : G20[redacted]
LOCATION : BARNEY'S POINT
SHEET 3 OF 5

POSITION : PIER 4 CH: 560.500 ℄ SURFACE ELEVATION : ANGLE FROM VERTICAL : 0°
RIG TYPE : P160 MOUNTING : TRAILER/BARGE CONTRACTOR : R.T.A. DRILLER : S. WATTS
DATE STARTED : 2/5/91 DATE COMPLETED : 4/5/91 DATE LOGGED : 2/5/91 LOGGED BY : JT CHECKED BY : GK

DEPTH	DRILLING: DRILLING & CASING	DRILLING: DRILLING FLUID TYPE & LOSS	DRILLING: DRILLING PENETRATION	DRILLING: GROUND WATER LEVELS	DRILLING: SAMPLES, TESTS, ETC	DRILLING: RL (m)	MATERIAL: GRAPHIC LOG	MATERIAL: CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
16 – 18.70	RICK MIXLIN 3¼"	20% LOSS (POLYMER)	E		18.30 SPT 8,10,15 N*=25 18.75				SAND: LIGHT GREY. FINE TO MEDIUM GRAINED. SOME FINE BLACK PARTICLES PRESENT.	W	MD	ALLUVIUM
18.70 – 19.20									18.70 SAND: AS ABOVE EXCEPT WITH GRAVELS. SIZE NOT KNOWN. (POSSIBLY FINE TO COARSE SIZE).			
19.20									19.20 CLAY: DARK GREY. MEDIUM PLASTICITY.			
20.45 – 21.49	RICK MIXLIN 2⅞"	0% LOSS			20.45 U50 20.80 SPT 4,5,5 N*=10 21.25				SANDY CLAY: DARK GREY. FINE TO MEDIUM GRAINED SAND. SOME SHELLS PRESENT.			U50 * ONLY 0.15 m RECOVERED. DROPPED OUT OF TUBE USELESS FOR TESTING.
21.49									END OF NON-CORE AT 21.49 m			
									(SEE CORED DRILL LOG SHEET)			

See Standard Sheets for details of abbreviations & basis of descriptions.

R T A ROADS AND TRAFFIC AUTHORITY, NSW

QS-562-1294

[redacted] CORE [redacted] RILL [redacted] E L [redacted]

PROJECT : BRIDGE OVER TWEED RIVER HOL[redacted] : 8[redacted]
LOCATION : BARNEY'S POINT FILE / JOB NO : G2026
SHEET 4 OF 5

POSITION : PIER 4 CH: 560.500 ℄ SURFACE ELEVATION : ANGLE FROM HORIZONTAL : 0°
RIG TYPE : P160 MOUNTING : TRAILER/BARGE CONTRACTOR : R.T.A. DRILLER : S. WATTS
CASING DIAMETER : NW - HW BARREL (length) : 3.0 m NMLC BIT : DIAMOND BIT CONDITION : GOOD
DATE STARTED : 2/5/91 DATE COMPLETED : 4/5/91 DATE LOGGED : 3/5/91 LOGGED BY : JT CHECKED BY : GK

DEPTH	DRILLING: PROGRESS – DRILLING & CASING	DRILLING: PROGRESS – WATER	DRILLING: CORE LOSS (RUN %) / DRILL DEPTH	DRILLING: SAMPLES & FIELD TESTS	DRILLING: RL (m)	MATERIAL: GRAPHIC LOG	MATERIAL: DESCRIPTION ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, etc as applicable)	MATERIAL: WEATHERING	MATERIAL: EST STRENGTH I_s (50) MPa (EL VL L M H VH EH)	FRACTURES: NATURAL FRACTURE SPACING (mm)	FRACTURES: VISUAL	FRACTURES: ADDITIONAL DATA (joints, partings, seams, zones, etc) Description, orientation, infilling or coating, shape, roughness, thickness, other
16 – 21.49							(SEE NON-CORE LOG SHEET)					NOTE P.P. = POCKET PENETROMETER TEST H.B. = HANDLING INDUCED BREAK D.B. = DRILLING INDUCED BREAK
21.49							START CORING AT 21.49 m					
21.49 – 22.0	NMLC CORING	100% RETURN (POLYMER)					SANDY CLAY: GREY WITH SOME BROWN. FINE TO MEDIUM GRAINED. MEDIUM PLASTICITY.		N/A	N/A		21.85 m P.P. = 319 kPa
22.0 – 22.50			22.20				22.0 GRAVELLY SANDY CLAY: GREYISH BROWN. FINE TO COARSE SIZE GRAVELS. FINE TO MEDIUM GRAINED SAND WITH SOME COARSE GRAIN PRESENT.					65 mm COBBLE
22.50 – 22.67			8.7%				LOSS 0.17 m (22.50 - 22.67 m)					
22.67 – 24							22.67 SANDSTONE: YELLOW BROWN + GREY. FINE TO MEDIUM GRAINED. SOME PEBBLES UP TO 25 mm.	EW / EW-MW		N/A		22.80 m P.P. = 270 kPa H.B. 23.65 m P.P. = 368 kPa

See Standard Sheets for details of abbreviations & basis of descriptions.

R T A ROADS AND TRAFFIC AUTHORITY, NSW

QS-563-1294

NON-CORE DRILL HOLE-GEOLOGICAL LOG

PROJECT : BRIDGE OVER TWEED RIVER
LOCATION : BARNEY'S POINT
HOLE NO : 9
FILE / JOB NO : G2026
SHEET 1 OF 5

POSITION : PIER 4 CH: 560.500 9.15 m R OF ℄ | SURFACE ELEVATION : | ANGLE FROM VERTICAL : 0°
RIG TYPE : P160 | MOUNTING : TRAILER/BARGE | CONTRACTOR : R.T.A. | DRILLER : S. WATTS
DATE STARTED : 29/4/91 | DATE COMPLETED : 1/5/91 | DATE LOGGED : 29/4/91 | LOGGED BY : JT | CHECKED BY : GK

DRILLING: Drilling & Casing: ROCK ROLLER $3\frac{7}{8}$" | Drilling Fluid Type & Loss: 10% LOSS (POLYMER) | Drilling Penetration: E

DEPTH	SAMPLES, TESTS, ETC	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
0		SILTY SAND: BROWNISH GREY. FINE GRAINED. SOME FINE BLACK PARTICLES PRESENT.	W		ALLUVIUM
1					CASING RUNS HW - 2.50 m HW - 6.10 m NW - 19.40 m NW - 20.80 m NW - 22.40 m
2.50 – 2.95	SPT -,1,1 N*=2			VL	* NO SAMPLE RECOVERED
4.45 – 4.90	SPT 3,3,3 N*=6	SILTY SAND: AS ABOVE EXCEPT FINE TO MEDIUM GRAINED AND DARK GREY.		L	
5.95 – 6.40	SPT 3,2,3 N*=5	SOME SHELL FRAGMENTS PRESENT.		L	
7.0		SAND: LIGHT GREY. FINE TO MEDIUM GRAINED. SOME FINE BLACK PARTICLES PRESENT.		MD	
7.50 – 7.95	SPT 7,9,10 N*=19				* NO SAMPLE RECOVERED

See Standard Sheets for details of abbreviations & basis of descriptions

ROADS AND TRAFFIC AUTHORITY, NSW

NON-CORE DRILL HOLE-GEOLOGICAL LOG

PROJECT : BRIDGE OVER TWEED RIVER
LOCATION : BARNEY'S POINT
HOLE NO : 9
FILE / JOB NO : G2026
SHEET 2 OF 5

POSITION : PIER 4 CH: 560.500 9.15 m R OF ℄ | SURFACE ELEVATION : | ANGLE FROM VERTICAL : 0°
RIG TYPE : P160 | MOUNTING : TRAILER/BARGE | CONTRACTOR : R.T.A. | DRILLER : S. WATTS
DATE STARTED : 29/4/91 | DATE COMPLETED : 1/5/91 | DATE LOGGED : 29/4/91 | LOGGED BY : JT | CHECKED BY : GK

DRILLING: Drilling & Casing: ROCK ROLLER $3\frac{7}{8}$" | Drilling Fluid Type & Loss: 10% LOSS (POLYMER) to 12.2, 20% LOSS (POLYMER) | Drilling Penetration: E

DEPTH	SAMPLES, TESTS, ETC	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
8		SAND: LIGHT GREY. FINE TO MEDIUM GRAINED. SOME FINE BLACK PARTICLES PRESENT.	W		ALLUVIUM
9.0 – 9.45	SPT 6,8,10 N*=18			MD	* SPT - 0.05 m SAMPLE RECOVERED
10.50 – 10.95	SPT 10,13,15 N*=28	AS ABOVE		MD	* NO SAMPLE RECOVERED
12.15 – 12.60	SPT 17,22,28 N*=50			D	
13.90 – 14.35	SPT 14,25,29 N>50	AS ABOVE TRACE OF SHELLS PRESENT IN SPT		VD	
15.40 – 15.85	SPT 13,19,26 N*=45	AS ABOVE TRACE OF BLACK FIBROUS MATERIAL		D	

See Standard Sheets for details of abbreviations & basis of descriptions

ROADS AND TRAFFIC AUTHORITY, NSW

NON-CORE DRILL HOLE-GEOLOGICAL LOG

[redacted] BRIDG[redacted]EED RIV[redacted]
LOC[redacted] BARN[redacted]

HOLE NO : 10
FILE / [redacted] G20[redacted]
SHEET [redacted] OF 5

POSITION : PIER 5 CH: 609.000 9.15 m L OF ℄ | SURFACE ELEVATION : | ANGLE FROM VERTICAL: 0°

RIG TYPE : P160 | MOUNTING : TRAILER/BARGE | CONTRACTOR : R.T.A. | DRILLER : S. WATTS

DATE STARTED : 13/4/91 | DATE COMPLETED: 17/4/91 | DATE LOGGED: 13/4/91 14/4/91 | LOGGED BY : JI | CHECKED BY : GK

DRILLING / MATERIAL

Drilling & casing: WASH BORING WITH HW CASING (0 – 3.15); ROCK ROLLER 3 7/8" (3.15 – 7.75)
Drilling fluid type & loss: 50% LOSS (POLYMER)

Depth	Drilling Penetration	Samples, Tests, Etc	Material Description (Soil Type, Colour, Plasticity or Particle Characteristic; Secondary & Minor Components)	Moisture Condition	Consistency Relative Density	Structure & other observations
0	L		SAND: LIGHT GREY. FINE TO MEDIUM GRAINED. SOME FINE BLACK PARTICLES PRESENT. SOME SHELL FRAGMENTS PRESENT.	W		ALLUVIUM CASING RUNS HW - 3.15 m HW - 17.70 m HW - 19.10 m
3.15		3.15 SPT 4,2,4 N*=6 3.60	AS ABOVE		L	* NO SAMPLE RECOVERED
4.40		4.40 SPT 6,7,7 N*=14 4.85	AS ABOVE		MD	* NO SAMPLE RECOVERED
6.05		6.05 SPT 4,7,10 N*=17 6.50	AS ABOVE		MD	* NO SAMPLE RECOVERED
7.30		7.30 SPT 5,9,8 N*=17 7.75	AS ABOVE		MD	* 0.15 m SAMPLE RECOVERED

See Standard Sheets for details of abbreviations & basis of descriptions

RTA ROADS AND TRAFFIC AUTHORITY, NSW

08-582-1290

NON-CORE DRILL HOLE-GEOLOGICAL LOG

[redacted]JECT [redacted]VER TWEE[redacted]
LOCATION : BARNEY'S POINT

HOLE NO [redacted]
SHEET 2 OF 5

POSITION : PIER 5 CH: 609.000 9.15 m L OF ℄ | SURFACE ELEVATION : | ANGLE FROM VERTICAL: 0°

RIG TYPE : P160 | MOUNTING : TRAILER/BARGE | CONTRACTOR : R.T.A. | DRILLER : S. WATTS

DATE STARTED : 13/4/91 | DATE COMPLETED: 17/4/91 | DATE LOGGED: 14/4/91 | LOGGED BY : JI | CHECKED BY : GK

DRILLING / MATERIAL

Drilling & casing: ROCK ROLLER 3 7/8"
Drilling fluid type & loss: 50% LOSS (POLYMER)

Depth	Drilling Penetration	Samples, Tests, Etc	Material Description (Soil Type, Colour, Plasticity or Particle Characteristic; Secondary & Minor Components)	Moisture Condition	Consistency Relative Density	Structure & other observations
8	E		SAND: LIGHT GREY. FINE TO MEDIUM GRAINED. SOME FINE BLACK PARTICLES PRESENT.	W	D	ALLUVIUM
8.50		8.50 SPT 16,24,2[illegible] N*=49 8.95				
10.70		10.70 SPT 14,19,2[illegible] N*=40 11.15	AS ABOVE		D	
12.10		12.10 SPT 21,34,[illegible]7 N*>50 12.45			VD	* SPT ONLY HAMMERED 0.35 m AS N WAS > 50
13.65		13.65 SPT 23,35,[illegible]6 N*>50 14.0	AS ABOVE		VD	* AS ABOVE
15.30		15.30 SPT 13,24,[illegible]0 N*>50 15.75			VD	

See Standard Sheets for details of abbreviations & basis of descriptions

RTA ROADS AND TRAFFIC AUTHORITY, NSW

08-582-1290

NON-CORE DRILL HOLE-GEOLOGICAL LOG

PROJECT : BRIDGE OVER TWEED RIVER
LOCATION : BARNEY'S POINT

HOLE NO : 10
FILE / JOB NO : G2026
SHEET 3 OF 5

POSITION : PIER 5 CH: 609.000 9.15 m L OF ℄ | SURFACE ELEVATION : | ANGLE FROM VERTICAL: 0°

RIG TYPE : P160 | MOUNTING : TRAILER/BARGE | CONTRACTOR : R.T.A. | DRILLER : S. WATTS

DATE STARTED: 13/4/91 | DATE COMPLETED: 17/4/91 | DATE LOGGED: 14/4/91 | LOGGED BY : JT | CHECKED BY : GK

DEPTH	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
16	ROCK ROLLER	50% LOSS (POLYMER)	E						SAND: AS PREVIOUS	W		ALLUVIUM
									16.50 GRAVELS: POSSIBLY FINE SIZE-UNKNOWN DUE TO ROCK ROLLERING			
					16.90				16.65 CLAY: GREY + RED BROWN. MEDIUM TO HIGH PLASTICITY.			
17					SPT 4,6,8 N*=14							
					17.35				END OF NON-CORE AT 17.35 m			
18									(SEE CORED DRILL LOG SHEETS)			
19												
20												
21												
22												
23												
24												

CORED DRILL HOLE LOG

PROJECT : BRIDGE OVER TWEED RIVER
LOCATION : BARNEY'S POINT

HOLE NO : 10
FILE / JOB NO : G2026
SHEET 4 OF 5

POSITION : PIER 5 CH: 609.000 9.15 m L OF ℄ | SURFACE ELEVATION : | ANGLE FROM HORIZONTAL : 90°

RIG TYPE : P160 | MOUNTING : TRAILER/BARGE | CONTRACTOR : R.T.A. | DRILLER : S. WATTS

CASING DIAMETER : HW - NW | BARREL (length): 3.0 m NMLC | BIT: DIAMOND | BIT CONDITION : GOOD

DATE STARTED: 13/4/91 | DATE COMPLETED: 17/4/91 | DATE LOGGED: 15/4/91 | LOGGED BY : JT | CHECKED BY: GK

DRILLING | MATERIAL | FRACTURES

DEPTH	PROGRESS: DRILLING & CASING	PROGRESS: WATER	(CORE LOSS) (RUN %) DRILL DEPTH	SAMPLES & FIELD TESTS	RL (m)	GRAPHIC LOG	DESCRIPTION ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, etc as applicable)	WEATHERING	EST STRENGTH I_s (50) MPa EL VL L M H VH EH	NATURAL FRACTURE SPACING (mm)	VISUAL	ADDITIONAL DATA (joints, partings, seams, zones, etc) Description, orientation, infilling or coating, shape, roughness, thickness, other
16							(SEE NON-CORE LOG SHEETS)					
17							START CORING AT 17.35 m					* NOTE * H.B. = HANDLING INDUCED BREAK D.B. = DRILLING INDUCED BREAK
	NMLC CORING	50% LOSS (POLYMER)					CLAY: GREY WITH SOME YELLOW BROWN + MAUVE. SOME FINE TO MEDIUM SIZE GRAVELS CLAY BECOMING SANDY AT 17.55 m		N/A	N/A		
18							17.84 CLAYEY GRAVELS WITH SOME COBBLES. YELLOW BROWN. FINE TO COARSE SIZE GRAVELS.					
			20.2% 18.44				LOSS 0.22 m (18.22 - 18.44 m)					
							AS PREVIOUS BECOMING GRAVELLY CLAY AT 18.55 m		N/A	N/A		
19			55.7% 19.05				LOSS 0.34 m (18.71 - 19.05 m)					
	ROCK ROLLER						ROCK ROLLERED TO CLEAR "FALL-IN" (GRAVELS)					
	NMLC CORING	100% RETURN (POLYMER)					PEBBLY SANDSTONE: BLUEISH GREEN. FINE TO MEDIUM GRAINED. PEBBLES UP TO 50 mm. COBBLES UP TO 85 mm. FELDSPAR GRAINS THROUGHOUT.	EW TO HW				80 mm COBBLE
20												50 mm PEBBLE
			20.25					HW				H.B.'s
												H.B.
21												H.B. AROUND COBBLES
												D.B. H.B.
22								MW HW TO MW				H.B.
												H.B's AROUND COBBLES
												85 mm COBBLE H.B. ON CLOSED JT 25° H.B's
23			22.80				22.70 SANDSTONE: GREYISH GREEN. FINE TO MEDIUM GRAINED.	MW				DRILL LIFT H.B. ON CLOSED JT 70°
												25° 80-90° 50° 60° 80° 55° 40° CLOSED JOINTS OPENED ON HANDLING
24												

NON-CORE DRILL HOLE-GEOLOGICAL LOG

PROJECT :	BRIDGE OVER TWEED RIVER	HOLE NO :	11
LOCATION :	BARNEY'S POINT.	FILE / JOB NO :	G2026
		SHEET	1 OF 5
POSITION :	PIER 5 CH: 609.000 ℄	SURFACE ELEVATION :	ANGLE FROM VERTICAL: 0°
RIG TYPE :	P160	MOUNTING : TRAILER/BARGE	CONTRACTOR : R T A
DRILLER :	S WATTS		
DATE STARTED :	17/4/91	DATE COMPLETED : 19/4/91	DATE LOGGED : 17/4/91
LOGGED BY :	JT	CHECKED BY :	GK

DEPTH	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
0	WASH BORING WITH HW CASING								SAND: LIGHT GREY. FINE TO MEDIUM GRAINED. SOME FINE BLACK PARTICLES PRESENT. SOME SHELL FRAGMENTS PRESENT.	W		ALLUVIUM. CASING RUNS HW = 3.15m NW = 19.0m NW = 21.70m
3		WG LOSS (MUD MIX)			3.15 SPT 3,4,5 N*=9 3.60				AS ABOVE.		L	* NO SAMPLE RECOVERED.
6	ROCK ROLLER 1 7/8"				6.30 SPT 6,5,8 N*=13 6.75				AS ABOVE. SOME BLACK SILTY MATERIAL AT BOTTOM OF SPT.		MD	

See Standard Sheets for details of abbreviations & basis of descriptions

ROADS AND TRAFFIC AUTHORITY, NSW

GS-502-1288

NON-CORE DRILL HOLE-GEOLOGICAL LOG

PROJECT :	BRIDGE OVER TWEED RIVER	HOLE NO :	11
LOCATION :	BARNEY'S POINT.	FILE / JOB NO :	G2026
		SHEET	2 OF 5
POSITION :	PIER 5 CH: 609.000 ℄	SURFACE ELEVATION :	ANGLE FROM VERTICAL: 0°
RIG TYPE :	P160	MOUNTING : TRAILER/BARGE	CONTRACTOR : R T A
DRILLER :	S WATTS		
DATE STARTED :	17/4/91	DATE COMPLETED : 19/4/91	DATE LOGGED : 17/4/91 18/4/91
LOGGED BY :	JT	CHECKED BY :	GK

DEPTH	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
8	ROCK ROLLER 5 7/8"	50% LOSS (POLYMER)	E						SAND: LIGHT GREY. FINE TO MEDIUM GRAINED. SOME FINE BLACK PARTICLES PRESENT.	W		ALLUVIUM
9					9.10 SPT 13,19,29 N*=48 9.55						D	
12					12.20 SPT 15,24,31 N*>50 12.65						VD	
15					15.20 SPT 15,21,33 N*>50 15.65						VD	

See Standard Sheets for details of abbreviations & basis of descriptions

ROADS AND TRAFFIC AUTHORITY, NSW

GS-502-1288

NON-CORE DRILL HOLE-GEOLOGICAL LOG

PROJECT : BRIDGE OVER TWEED RIVER
LOCATION : BARNEY'S POINT.
HOLE NO : 11
FILE / JOB NO : G2026
SHEET 3 OF 5

POSITION : PIER 5 CH: 609.000 ℄ SURFACE ELEVATION : ANGLE FROM VERTICAL: 0°
RIG TYPE : P160 MOUNTING : TRAILER/BARGE CONTRACTOR : R T A DRILLER : S WATTS
DATE STARTED: 17/4/91 DATE COMPLETED: 19/4/91 DATE LOGGED: 18/4/91 LOGGED BY : JT CHECKED BY : GK

DEPTH	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
16	ROCK ROLLER 3 7/8"	50% LOSS (POLYMER)	E						SAND: AS PREVIOUS. 6.20			ALLUVIUM
					16.50				GRAVELS: SIZE NOT KNOWN DUE TO ROCK ROLLERING. COULD BE UP TO COBBLE SIZE. 6.50			
					SPT 5,11,18 N*=29 16.95				SAND: BROWN. FINE - MEDIUM GRAINED.			
17									17.20 CLAYEY SAND: YELLOW BROWN. FINE TO MEDIUM GRAINED. - LIGHT GREY.			
					17.90				17.40 SANDY CLAY: YELLOW BROWN WITH SOME GREY. MEDIUM PLASTICITY. FINE TO MEDIUM GRAINED SAND.			
18	WASH BORING WITH NW CASING				SPT 3,5,7 N*=12 18.35							
19									END OF NON-CORE AT 18.93m			
									(SEE CORED DRILL LOG SHEETS).			

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CORED DRILL HOLE LOG

PROJECT : BRIDGE OVER TWEED RIVER
LOCATION : BARNEY'S POINT.
HOLE NO : 11
FILE / JOB NO : G2026
SHEET 4 OF 5

POSITION : PIER 5 CH: 609.000 ℄ SURFACE ELEVATION : ANGLE FROM HORIZONTAL : 90°
RIG TYPE : P160 MOUNTING : TRAILER/BARGE CONTRACTOR : R T A DRILLER : S WATTS
CASING DIAMETER : NW + HW BARREL (length): 3.0m NMCL BIT: DIAMOND BIT CONDITION : GOOD
DATE STARTED : 17/4/91 DATE COMPLETED: 19/4/91 DATE LOGGED: 18/4/91 LOGGED BY: JT CHECKED BY: G K

DEPTH	DRILLING & CASING	WATER	CORE LOSS /RUN % / DRILL DEPTH	SAMPLES & FIELD TESTS	RL (m)	GRAPHIC LOG	DESCRIPTION ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, etc as applicable)	WEATHERING	EST STRENGTH I_s (50) MPa EL VL L M H VH EH	NATURAL FRACTURE SPACING (mm)	VISUAL	ADDITIONAL DATA (joints, partings, seams, zones, etc) Description, orientation, infilling or coating, shape, roughness, thickness, other
16							(SEE NON-CORE LOG SHEETS)					
18							START CORING AT 18.93m					NOTE O.B. = DRILLING INDUCED BREAK H.B. = HANDLING INDUCED BREAK P.P. = POCKET PENETROMETER.
19	NMLC CORING	90% RETURN (POLYMER)					SANDY CLAY: YELLOW BROWN - GREY. MEDIUM TO HIGH PLASTICITY. FINE TO MEDIUM GRAINED WITH SOME COARSE GRAIN PRESENT. 19.63		N/A	N/A		19.25m P.P. = 147 kPa 19.55m P.P. = 221 kPa
20			20.70				SANDY GRAVELLY CLAY: YELLLOW BROWN WITH SOME GREY. FINE TO COARSE GRAIN SAND. FINE TO COARSE SIZE GRAVELS. 20.72					19.88m P.P. = 343 kPa O.B. 20.30m P.P. = 245 kPa DRILL LIFT
21			21.15 13.6%				CLAYEY GRAVELS: YELLOW BROWN - WHITE FINE TO COARSE SIZE GRAVELS.					
							LOSS 0.32m (21.19-21.51m)					
22							PEBBLY SANDSTONE: LIGHT GREEN. FINE TO COARSE GRAINED. PEBBLES UP TO COBBLES UP TO FELDSPAR GRAINS THROUGHOUT. 23.10	EW TO HW HW				70mm COBBLE. O.B.'s AROUND PEBBLES. H.B. ON CLOSED JT 80° 130mm COBBLE.
23			23.50				INDURATED SANDSTONE: GREENISH BROWN. FINE GRAINED SAND TO SILT SIZE. 23.48	MW				70-80° JT Fe PR RF H.B.s ON Fe CLOSED JTs DRILL LIFT
							AS ABOVE EXCEPT GREY.	SW				85° JT Fe CLOSED-OPENED ON DRILLING 40-80° JT Fe PR RF. JTs Fe CLOSED - OPENED ON DRILLING

[redacted] Standard [redacted] for details of a[redacted]ans & basis of descriptions.

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[redacted] NON [redacted] DR[redacted]HOLE [redacted]LOG[redacted] LOG [redacted]

P[redacted]	[redacted]ER TWEE[redacted]	HOLE [redacted]	12
LOCATION :	BARNEY'S POINT.	FILE / [redacted]	G2026
		SHEET	1 OF 5
POSITION :	PIER 5 CH: 609.000 9.15m R of ℄	SURFACE ELEVATION :	ANGLE FROM VERTICAL: 0°
RIG TYPE :	P160	MOUNTING : TRAILER/BARGE	CONTRACTOR : R T A
DRILLER :	S WATTS		
DATE STARTED :	20/4/91	DATE COMPLETED : 22/4/91	DATE LOGGED : 20/4/91
LOGGED BY :	JT	CHECKED BY :	GK

DEPTH (m)	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	SAMPLES, TESTS, ETC	MATERIAL DESCRIPTION (Soil Type, Colour, Plasticity or Particle Characteristic, Secondary & Minor Components)	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
0	WASH BORING WITHIN HW CASING	30% LOSS (POLYMER)		SAND: LIGHT GREY. FINE TO MEDIUM GRAINED. SOME FINE BLACK PARTICLES PRESENT.	W		ALLUVIUM CASING RUNS HW - 2.45 m NW - 19.75m
2.45			2.45 SPT 5,7,4 N*=11 2.90			MD	* NO SAMPLE RECOVERED.
3.95	ROCK ROLLER 5 7/8"		3.95 SPT 6,7,7 N*=14 4.40	AS ABOVE		MD	* NO SAMPLE RECOVERED.
5.45			5.45 SPT 5,8,9 N*=17 5.90	AS ABOVE.		MD	* 0.10m SAMPLE RECOVERED.
6.90			6.90 SPT 7,8,10 N*=18 7.35			MD	* NO SAMPLE RECOVERED.
8							

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PROJECT :	BRIDGE OVER TWEED RIVER	H[redacted]	12
LOCATION :	BARNEY'S POINT.	FILE / JOB NO :	G2026
		SHEET	2 OF 5
POSITION :	PIER5CH: 609.000 9.15m R of ℄	SURFACE ELEVATION :	ANGLE FROM VERTICAL: 0°
RIG TYPE :	P160	MOUNTING : TRAILER/BARGE	CONTRACTOR : R T A
DRILLER :	S WATTS		
DATE STARTED :	20/4/91	DATE COMPLETED : 22/4/91	DATE LOGGED : 20/4/91 21/4/91
LOGGED BY :	JT	CHECKED BY :	GK

DEPTH (m)	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	SAMPLES, TESTS, ETC	MATERIAL DESCRIPTION (Soil Type, Colour, Plasticity or Particle Characteristic, Secondary & Minor Components)	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
8	ROCK ROLLER	30% LOSS (POLYMER)		SAND: LIGHT GREY. FINE TO MEDIUM GRAINED. SOME FINE BLACK PARTICLES PRESENT.	W		ALLUVIUM.
8.40			8.40 SPT 14,24,26 N*=50 8.85			D	* NO SAMPLE RECOVERED.
9.70			9.70 SPT 14,23,24 N*=47 10.15			D	
11.20			11.20 SPT 12,23,31 N*>50 11.65	AS ABOVE		VD	
12.70			12.70 SPT 17,25,25 N*=50 13.15			D	
14.40			14.40 SPT 13,25,28 N*>50 14.78	AS ABOVE.		VD	* SPT ONLY HAMMERED 0.38m AS N VALUE WAS GREATER THAN 50.
15.90			15.90 P.T.O.				
16							

NON-CORE DRILL HOLE-GEOLOGICAL LOG

BRIDGE OVER TWEED RIVER
BARNEY'S POINT.

HOLE NO : 12
FILE / JOB NO : G2026
SHEET 3 OF 5

PIER 5 CH: 609.000 9.15m R OF ℄ — SURFACE ELEVATION : — ANGLE FROM VERTICAL : 0°

P160 — MOUNTING : TRAILER/BARGE — CONTRACTOR : R T A — DRILLER : S WATTS

ED : 20/4/91 — DATE COMPLETED: 22/4/91 — DATE LOGGED: 21/4/91 — LOGGED BY : JT — CHECKED BY : GK

DRILLING				MATERIAL					
PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
		SPT 22,24,23 N*>50 16.28				SAND: LIGHT GREY. FINE TO MEDIUM GRAINED. SOME FINE BLOCK PARTICLES PRESENT.	W	VD	ALLUVIUM * SPT ONLY HAMMERED 0.38m AS THE N VALUE WAS GREATER THAN 50.
		17.30 SPT 9,6,6 N*=12 17.75				17.28 GRAVELS WITH SAND: LIGHT GREY - DARK GREY. FINE TO MEDIUM GRAINED SAND. SMALL % OF CLAY.			
		18.70 SPT 3,3,4 N*=7 19.15				17.90 SANDY CLAY: YELLOW BROWN. FINE GRAINED SAND. MEDIUM PLASTICITY. AS ABOVE EXCEPT GREY.			
						END OF NON-CORE AT 19.53m (SEE DRILL CORE LOG SHEETS)			

: Sheets for
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abbreviations
descriptions

RTA ROADS AND TRAFFIC AUTHORITY, NSW

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CORED DRILL HOLE LOG

PROJECT : BRIDGE OVER TWEED RIVER
LOCATION : BARNEY'S POINT.

HOLE NO : 12
FILE / JOB NO : G2026
SHEET 4 OF 5

POSITION : PIER 5 CH: 609.000 9.15m R OF ℄ — SURFACE ELEVATION : — ANGLE FROM HORIZONTAL : 90°

RIG TYPE : P160 — MOUNTING : TRAILER/BARGE — CONTRACTOR : R T A — DRILLER : S WATTS

CASING DIAMETER : NW - HW — BARREL (length): 3.0m NMLC — BIT : DIAMOND — BIT CONDITION : GOOD

DATE STARTED : 20/4/91 — DATE COMPLETED: 22/4/91 — DATE LOGGED : 22/4/91 — LOGGED BY : JT — CHECKED BY : GK

DEPTH	DRILLING & CASING	WATER	CORE LOSS (RUN %) DRILL DEPTH	SAMPLES & FIELD TESTS	RL (m)	GRAPHIC LOG	DESCRIPTION ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, etc as applicable)	WEATHERING	EST STRENGTH I_s (50) MPa EL VL L M H VH EH	NATURAL FRACTURE SPACING (mm)	VISUAL	ADDITIONAL DATA (joints, partings, seams, zones, etc) Description, orientation, infilling or coating, shape, roughness, thickness, other
16–19.53							(SEE NON-CORE LOG SHEETS) START CORING AT 19.53m					* NOTE H.B. = HANDLING INDUCED BREAKS. P.P. = POCKET PENETROMETER.
19.53	NMLC CORING	100% RETURN (POLYMER)					SANDY CLAY: GREY WITH SOME YELLOW BROWN. FINE TO MEDIUM GRAINED. MEDIUM PLASTICITY. SOME GRAVELS UP TO 50mm.					19.70 P.P. 147 kPa CORE BROKEN FROM DRILLING. 20.30 P.P. 196 kPa
							CLAYEY SAND/SANDY CLAY: GREY WITH SOME YELLOW BROWN. FINE TO MEDIUM GRAINED SAND. SOME GRAVELS UP TO 50mm.		N/A	N/A		20.90m P.P. 166 kPa 21.40m P.P. 147 kPa DRILL LIFT
21.71			21.70 11.5%				CLAYEY GRAVELS (QUARTZ)					
							LOSS 0.23m (21.87 - 22.10m)					
22.10							PEBBLY SANDSTONE: BLUEISH GREEN. FINE TO COARSE GRAINED. PEBBLES UP TO 60mm.	SW - EW LAYERS				60mm PEBBLE. 50mm PEBBLE.
22.84			23.70 23.86				INDURATED SANDSTONE: GREY. FINE GRAINED.	SW				90°, 75°, 50°, 15°, 70°, 50°, 10°, 30° — CLOSED JOINTS. OPENED ON DRILLING + HANDLING. 50° — DRILL LIFT 60° 40° — DRILL LIFT

See Standard Sheets for
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[redacted] basis. of descriptions.

RTA ROA[redacted]ND T[redacted] AUT[redacted]Y, NSW[redacted]

PROJ[redacted]OGE [redacted]ED RIV[redacted] NON-C[redacted]DRIL[redacted]LE-[redacted]OGIC[redacted]OG [redacted]LE N[redacted]13 [redacted]

FILE / JOB NO G2025

SHEET 1 OF 3

LOCATION : BARNEY'S POINT

POSITION : PIER 6 CH 657.500 9.15m L of ℄ | SURFACE ELEVATION : | ANGLE FROM VERTICAL: 0°

RIG TYPE : P160 | MOUNTING : TRAILER/BARGE | CONTRACTOR : RTA | DRILLER : S. WATTS

DATE STARTED: 9/4/91 | DATE COMPLETED: 12/4/91 | DATE LOGGED: 9/4/91 | LOGGED BY : JT | CHECKED BY : GK

DEPTH	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
0		50% LOSS (POLYMER)	C						SAND: LIGHT GREY. FINE TO MEDIUM GRAINED. SOME FINE BLACK PARTICLES PRESENT SOME SHELL FRAGMENTS PRESENTS.	W		ALLUVIUM CASING RUNS • HW - 3.20m • NW - 12.75m • NW - 17.50m • NW - 19.0m
3					3.20 SPT 3,3,5 N*=8 3.65				AS ABOVE		L	• NO SAMPLE RECOVERED.
4					4.35 SPT 4,7,12 N*=19 4.80						MD	• ONLY 0.10m SAMPLE RECOVERED
5					5.70 SPT 6,8,10 N*=18 6.15				AS ABOVE		MD	• 0.20m SAMPLE RECOVERED.
7					7.10 SPT 8,14,25 N*=39 7.55						D	
8												

See Standard Sheets for details of abbreviations & basis of descriptions

ROADS AND TRAFFIC AUTHORITY, NSW

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FILE [redacted]O :

SHEET 2 OF 3

LOCATION : BARNEY'S POINT.

POSITION : PIER 6 CH:657.500 9.15m L of ℄ | SURFACE ELEVATION : | ANGLE FROM VERTICAL: 0°

RIG TYPE : P160 | MOUNTING : TRAILER/BARGE | CONTRACTOR : R T A | DRILLER : S WATTS

DATE STARTED: 9/4/91 | DATE COMPLETED: 12/4/91 | DATE LOGGED: 10/4/91 11/4/91 | LOGGED BY : JT | CHECKED BY : GK

DEPTH	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
8		50% LOSS (POLYMER)	C						SAND: LIGHT GREY. FINE TO MEDIUM GRAINED SOME FINE BLACK PARTICLES PRESENT	W		ALLUVIUM
9					8.85 SPT 9,15,22 N*=37 9.30						D	
10					10.25 SPT 12,8,4 N*=12 10.70				10.0 APPROX. SAND: AS ABOVE EXCEPT WITH SOME FINE SIZE GRAVELS.			
10.5		0% LOSS (CASED TO 12.75m)							10.50 SANDY CLAY: DARK GREY. FINE GRAINED SAND. LOW PLASTICITY. • CLAY IS SOFT - NW CASING PUSHED THROUGH WITH EASE.			
12.5					12.75 SPT 5,7,9 N*=16 13.20				12.50 GRAVELLY CLAY: BROWN WITH SOME GREY. MEDIUM TO HIGH PLASTICITY. FINE TO COARSE SIZE GRAVELS.			
13.2									END OF NON-CORE AT 13.20m (SEE CORED DRILL LOG SHEETS)			
16												

See Standard Sheets for details of abbreviations & basis of descriptions

ROADS AND TRAFFIC AUTHORITY, NSW

NON-CORE DRILL HOLE-GEOLOGICAL LOG

PROJECT :	BRIDGE OVER TWEED RIVER	HOLE NO :	14
LOCATION :	BARNEY'S POINT.	FILE / JOB NO :	G2026
		SHEET	1 OF 4
POSITION :	PIER 6 CH: 657.500 ℄	SURFACE ELEVATION :	
ANGLE FROM VERTICAL :	0°	RIG TYPE :	P160
MOUNTING :	TRAILER	CONTRACTOR :	R T A
DRILLER :	S WATTS	DATE STARTED :	25/3/91
DATE COMPLETED :	27/03/91	DATE LOGGED :	25/3/91
LOGGED BY :	AS	CHECKED BY :	GK

DRILLING / **MATERIAL**

DEPTH	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
0–3.50	ROCK ROLLER NW CASING	0% LOSS POLYMER	E		2.80m SPT 6,14,10 N=26 3.25m				SILTY SAND: PALE GREY, BROWN. FINE GRAINED.	W	MD	• NO SAMPLE RETRIEVED.
3.50–7.50	NW CASING				6.40m SPT 6,12,11 N=23 6.85m				3.50m SAND: PALE GREY, BROWN. FINE GRAINED.			• NO SAMPLE RETRIEVED.
7.50–									7.50m SILTY SAND: GREY, BROWN. FINE GRAINED WITH SHELL FRAGMENTS.			

NON-CORE DRILL HOLE-GEOLOGICAL LOG

PROJECT :	BRIDGE OVER TWEED RIVER	HOLE NO :	1A
LOCATION :	BARNEY'S POINT.	FILE / JOB NO :	G2026
		SHEET	2 OF 4
POSITION :	PIER 6 CH: 657.500 ℄	SURFACE ELEVATION :	
ANGLE FROM VERTICAL :	0°	RIG TYPE :	P160
MOUNTING :	TRAILER	CONTRACTOR :	R T A
DRILLER :	S WATTS	DATE STARTED :	25/3/91
DATE COMPLETED :	27/3/91	DATE LOGGED :	25/3/91
LOGGED BY :	AS	CHECKED BY :	GK

DRILLING / **MATERIAL**

DEPTH	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
–9.60	ROCK ROLLER NW CASING	10% LOSS (POLYMER)	E						SILTY SAND: AS PREVIOUS.	W	MD	
9.60–11.70					9.50m SPT 5,2,2 N=4 9.95m				9.60m CLAY: GREY, BROWN. HIGH PLASTICITY.	M	St	'OU' VALUES 150-160 kPa
11.70–13.45					12.80m SPT 6,5,5 N=10 13.25m				11.70m CLAY: YELLOWISH BROWN. HIGH PLASTICITY.		Vst	'OU' VALUES 320-350 kPa
13.45–14.67			F						13.45m PEBBLY SANDSTONE: YELLOWISH BROWN. FINE GRAINED, WITH ROUNDED PEBBLES UP TO 20mm IN SIZE.			EW - EL.
14.67									14.67m END OF NON-CORE DRILLING.			
									• SEE CORE DRILL HOLE SHEET FOR INFORMATION.			

NON-CORE DRILL HOLE-GEOLOGICAL LOG

PROJ[redacted] BR[redacted] T-LED [redacted] HOLE NO: 15
LOCATION: BARNEY'S POINT. [redacted] FILE / JOB [redacted] NO: G2026 [redacted]
SHEET 1 OF 4

POSITION: PIER 6 CH: 657.500 9.15m R OF E | SURFACE ELEVATION: | ANGLE FROM VERTICAL: 0°
RIG TYPE: P160 | MOUNTING: TRAILER | CONTRACTOR: R T A | DRILLER: S WATTS
DATE STARTED: 18/3/91 | DATE COMPLETED: 21/3/91 | DATE LOGGED: 17/3/91 | LOGGED BY: AS | CHECKED BY: GK

DEPTH	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
0	NW CASING, WASH BORE	10% LOSS POLYMER	E						SAND: PALE GREY. FINE GRAINED. SLIGHTLY SILTY	W	VD	
3					2.90m SPT 12,32,40 N=72 3.35m							
4.5									4.50m SILTY SAND: PALE BROWN. FINE GRAINED, WITH SOME SHELL FRAGMENTS.		D	
5.3					5.30m SPT 15,18,21 N=39 5.75m							NO SAMPLE RETRIEVED.
6.5									6.50m SAND: PALE BROWN. FINE GRAINED. SLIGHTLY SILTY. WITH SOME SHELL FRAGMENTS.			
7					6.95m SPT 15,22,23 N=45 7.40m							

See Standard Sheets for details of abbreviations & basis of descriptions

ROADS AND TRAFFIC AUTHORITY, NSW

GB-342-1288

NON-CORE DRILL HOLE-GEOLOGICAL LOG

[redacted] ECT: [redacted] DGE OVE[redacted] IVER [redacted] HOLE NO: 15
[redacted] ION: [redacted] NEY'S P[redacted] FIL[redacted] NO: [redacted]
SHE[redacted] OF [redacted]

POSITION: PIER 6 CH: 657.500 9.15m R OF E | SURFACE ELEVATION: | ANGLE FROM VERTICAL: 0°
RIG TYPE: P160 | MOUNTING: TRAILER | CONTRACTOR: R T A | DRILLER: S WATTS
DATE STARTED: 18/3/91 | DATE COMPLETED: 21/3/91 | DATE LOGGED: 19/3/91 | LOGGED BY: A S | CHECKED BY: GK

DEPTH	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
8	NW CASING, WASH BORE	10% LOSS (POLYMER)	E		8.40m SPT 10,14,18 N=32 8.85m				SAND: AS PREVIOUS.	W	D	
9.8					9.80m SPT 16,16,18 N=34 10.25m							
10.2									10.20m PEAT: BLACK	M	S	
10.6									CLAY: DARK BROWN. MEDIUM TO HIGH PLASTICITY. SLIGHTLY SILTY.		M	100 kPa
12.8									12.80 SANDY CLAY: DARK BROWN TO BROWN. LOW PLASTICITY. FINE GRAINED.	W	VS	
13					13.00 SPT 4,2,5 N=7 13.45							
13.15									13.15m SILTY SAND: BROWN. FINE GRAIEND.		L	
14									14.00m CLAY: YELLOWISH BROWN + GREY, BROWN. HIGH PLASTICITY.	M	St	150 kPa - 160 kPa
14.45					14.45m SPT 4,22,23 N=45 14.90m							
14.7									14.70m PEBBLY SANDSTONE: YELLOWISH BROWN.			EW - EL.
15									14.90m END OF NON-CORE DRILLING. SEE CORE DRILL HOLE SHEET. FOR INFORMATION.			

See Standard Sheets for details of abbreviations & basis of descriptions

ROADS AND TRAFFIC AUTHORITY, NSW

GB-342-1288

NON-CORE DRILL HOLE-GEOLOGICAL LOG

PROJECT :	BRIDGE OVER TWEED RIVER.	HOLE NO :	16
LOCATION :	BARNEY'S POINT.	FILE / JOB NO :	G2026
		SHEET	1 OF 5
POSITION :	PIER 7 CH: 706.000 9.15m L of ℄	SURFACE ELEVATION : R.L.-4.608m	ANGLE FROM VERTICAL : 0°
RIG TYPE :	P160 MOUNTING : TRAILER	CONTRACTOR : R T A	DRILLER : S. WATTS
DATE STARTED : 2/3/91	DATE COMPLETED : 7/3/91	DATE LOGGED : 2/3/91 LOGGED BY : A.S.	CHECKED BY : G.K.

DEPTH	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
0	ROCK ROLLER NW - NW CASING	10% LOSS POLYMER	C						SILTY SAND: GREY, BROWN AND BROWN. FINE GRAINED, WITH ABOUNDED SHELL FRAGMENTS AND FINE GRAVEL SIZE QUARTZ.	W	VL	ALLUVIUM.
2.5–3					2.50m SPT 3,1,0 N=1 2.95m							• NO SAMPLE RETRIEVED.
3.30m									SAND: PALE GREY, BROWN. FINE GRAINED, WITH SHELL FRAGMENTS AND ROUNDED PEBBLES UP TO 10mm.		MD	
4–4.6		70% LOSS POLYMER			4.15m SPT 5,6,7 N=13 4.60m							• NO SAMPLE RETRIEVED.
5.6–6					5.60m SPT 5,7,10 N=17 6.05m							• NO SAMPLE RETRIEVED.
6–7		70% LOSS POLYMER										
7.00m					7.20m SPT 18,23,26 N=49 7.65m				SILTY SAND: PALE GREY, BROWN. FINE GRAINED, WITH ABOUNDED SHELL FRAGMENTS AND ROUNDED PEBBLES UP TO 150mm.		D	

See Standard Sheets for details of abbreviations & basis of descriptions.

ROADS AND TRAFFIC AUTHORITY, NSW

GS-302-1299

NON-CORE DRILL HOLE-GEOLOGICAL LOG

PROJECT :	BRIDGE OVER TWEED RIVER.	HOLE NO :	16
LOCATION :	BARNEY'S POINT.	FILE / JOB NO :	G2026
		SHEET	2 OF 5
POSITION :	PIER 7 CH: 706.000 9.15m L of ℄	SURFACE ELEVATION : R.L.-4.608m	ANGLE FROM VERTICAL : 0°
RIG TYPE :	P160 MOUNTING : TRAILER	CONTRACTOR : R T A	DRILLER : S. WATTS
DATE STARTED : 2/3/91	DATE COMPLETED : 7/3/91	DATE LOGGED : 3/3/91 LOGGED BY : A.S.	CHECKED BY : G.K.

DEPTH	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
8.5	ROCK ROLLER NW CASING	20% LOSS POLYMER	C						SAND: PALE GREY, BROWN. FINE GRAINED. SLIGHTLY SILTY, WITH OCCASIONAL SHELL FRAGMENTS.	W		
9–10					8.80m SPT 13,18,23 N=41 9.25m						D	
11					10.63m SPT 15,23,24 N=47 11.08m							
11.70m					11.80m SPT 2,3,7 N=10 12.25m				SILTY SAND: DARK GREY, BROWN, WITH OCCASIONAL CLAY LUMPS, SHELL FRAGMENTS AND TREE ROOTS. • 12.37m (300mm THICK BAND) SANDY GRAVELS.		MD	
13			VF									
12.67m			C		13.00m SPT 19,8,9 N=17 13.45m				CLAY: YELLOWISH BROWN AND PALE BROWN, HIGH PLASTICITY. SLIGHTLY SANDY WITH SPARSE FINE GRAINED ROUNDED GRAVELS.	M	M	'QU' VALUES. 120 kPa - 140 kPa.
13.65m									END OF NON-CORE DRILLING.			

• SEE CORED DRILL LOG SHEETS FOR INFORMATION.

• NON-CORE DESCRIPTIONS BASED ON WASH BORE DRILLING.

See Standard Sheets for details of abbreviations & basis of descriptions.

ROADS AND TRAFFIC AUTHORITY, NSW

GS-302-1299

NON-CORE DRILL HOLE-GEOLOGICAL LOG

P[redacted] BRI[redacted]EED RI[redacted] HOLE NO : 17
LO[redacted] BAR[redacted]NT. FILE / [redacted] G20[redacted]
SHEET 1 OF 4

POSITION : PIER 7 ON ℄ CH: 706.000	SURFACE ELEVATION :		ANGLE FROM VERTICAL : 0°
RIG TYPE : P160	MOUNTING : TRAILER	CONTRACTOR : R T A	DRILLER : S. WATTS
DATE STARTED : 8/3/91	DATE COMPLETED : 11/03/91	DATE LOGGED : 8/3/91 LOGGED BY : A.S.	CHECKED BY : G.K.

DEPTH	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
0	NW CASING ROCK ROLLER	20% LOSS (POLYMER)	E						SILTY SAND: PALE GREY TO GREY, BROWN FINE GRAINED, WITH SHELL FRAGMENTS.	W	VL TO L	
3					2.95m SPT 4,1,3 N=4 3.40m							* NO SAMPLE RETRIEVED.
6									6.00m SAND: DARK GREY TO GREY, BROWN, FINE GRAINED, WITH SOME MEDIUM GRAINED SAND AND SHELL FRAGMENTS.		MD	
6.5					6.50m SPT 11,11,13 N=24 6.95m							
8												

See Standard Sheets for details of abbreviations & basis of descriptions.

ROADS AND TRAFFIC AUTHORITY, NSW

GS-562-1290

NON-CORE DRILL HOLE-GEOLOGICAL LOG

PROJECT [redacted] BRIDGE OVER [redacted]ER. HOLE NO : 17
[redacted]ATION [redacted]Y'S POI[redacted] F[redacted] NO [redacted]
S[redacted] OF [redacted]

POSITION : PIER 7 ON ℄ CH: 706.000	SURFACE ELEVATION :		ANGLE FROM VERTICAL : 0°
RIG TYPE : P160	MOUNTING : TRAILER	CONTRACTOR : R T A	DRILLER : S. WATTS
DATE STARTED : 8/7/91	DATE COMPLETED : 11/3/91	DATE LOGGED : 9/3/91 LOGGED BY : A.S.	CHECKED BY : GK

DEPTH	DRILLING & CASING	DRILLING FLUID TYPE & LOSS	DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES, TESTS, ETC	RL (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & other observations
8	NW CASING ROCK ROLLER	20% LOSS (POLYMER)	E						SAND: YELLOWISH BROWN AND PALE GREY, BROWN. FINE GRAINED, WITH SOME SHELL FRAGMENTS. AND OCCASIONAL PEBBLES UP TO 15mm.	W	D	
9					9.00m SPT 12,19,24 N=43 9.45m							
11.5											L	
12					12.00m SPT 3,4,3 N=7 12.45m							
12.3									12.30m CLAYEY SAND: DARK BROWN, FINE GRAINED. SLIGHTLY SILTY, WITH TREE ROOTS.			
13			F						* 13.00m (300mm) SANDY GRAVEL.			
13.3					13.50m SPT 13.62m				SILTY SAND: PALE GREY, BROWN. FINE GRAINED, SLIGHTLY CLAYEY WITH ABOUNDED PEBBLES UP TO 200mm			* SPT REFUSAL 33 BLOWS FOR 120mm
14									14.00m SANDY CLAY: YELLOWISH BROWN AND BROWN. MEDIUM TO HIGH PLASTICITY, WITH ABOUNDED PEBBLES UP TO 100mm.			EW PEBBLY SANDSTONE ALTERED TO SANDY CLAY WITH PEBBLES.
14.65									14.65m END OF NON-CORE DRILLING.			
									* SEE CORE DRILL HOLE SHEET FOR INFORMATION.			

See Standard Sheets for details of abbreviations & basis of descriptions.

ROADS AND TRAFFIC AUTHORITY, NSW

GS-562-1290

NON-CORE DRILL HOLE-GEOLOGICAL LOG

PROJECT : BRIDGE OVER TWEED RIVER.
LOCATION : BARNEY'S POINT
HOLE NO : 18
FILE / JOB NO : G2026
SHEET 1 OF 4

POSITION : PIER 7 CH: 706.000 9.15 m OF ℄ SURFACE ELEVATION : ANGLE FROM VERTICAL: 0°
RIG TYPE : P160 MOUNTING : TRAILER CONTRACTOR : R.T.A. DRILLER : S. WATTS
DATE STARTED : 12/3/91 DATE COMPLETED : 15/03/91 DATE LOGGED : 12/03/91 LOGGED BY : AS CHECKED BY : GK

DRILLING: DRILLING & CASING (HW, NW CASING ROCK ROLLER) | DRILLING FLUID TYPE & LOSS (10% LOSS (POLYMER)) | DRILLING PENETRATION (E) | GROUND WATER LEVELS | SAMPLES, TESTS, ETC | RL (m)

MATERIAL: GRAPHIC LOG | CLASSIFICATION SYMBOL | MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components | MOISTURE CONDITION | CONSISTENCY RELATIVE DENSITY | STRUCTURE & other observations

Samples, tests, etc	Material description	Moisture condition	Consistency relative density	Structure
	SILTY SAND: PALE BROWN AND BROWN, FINE GRAINED.	W	L	
2.70 m SPT 2,2,3 N=5 3.15 m				
	4.00 m			
	SAND: GREYISH BROWN + BROWN, FINE WITH SOME MEDIUM GRAINED, SLIGHTLY SILTY, SPARSE SHELL FRAGMENTS AND SOME PEBBLES UP TO 5 mm.		D	
4.60 m SPT 7,12,1 N=31 5.05 m				
6.90 m SPT 9,13,17 N=30 7.25 m				

See Standard Sheets for details of abbreviations & [redacted] descriptions

ROADS AND TRAFFIC AUTHORITY, NSW

NON-CORE DRILL HOLE-GEOLOGICAL LOG

PROJECT : BRIDGE OVER TWEED RIVER.
LOCATION : BARNEY'S POINT
HOLE NO : 18
FILE / JOB NO : G2026
SHEET 2 OF 4

POSITION : PIER 7 CH: 706.000 9.15 m R OF ℄ SURFACE ELEVATION : ANGLE FROM VERTICAL: 0°
RIG TYPE : P160 MOUNTING : TRAILER CONTRACTOR : R.T.A. DRILLER : S. WATTS
DATE STARTED : 12/03/91 DATE COMPLETED : 15/03/91 DATE LOGGED : 13/03/91 LOGGED BY : A.S. CHECKED BY : GK

DRILLING: DRILLING & CASING (NW CASING ROCK ROLLER) | DRILLING FLUID TYPE & LOSS (10% LOSS (POLYMER)) | DRILLING PENETRATION (E) | GROUND WATER LEVELS | SAMPLES, TESTS, ETC | RL (m)

MATERIAL: GRAPHIC LOG | CLASSIFICATION SYMBOL | MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary & Minor Components | MOISTURE CONDITION | CONSISTENCY RELATIVE DENSITY | STRUCTURE & other observations

Depth	Samples, tests, etc	Material description	Moisture condition	Consistency relative density	Structure
		SAND: AS PREVIOUS.	W	D	
9	8.60m SPT 10,21,29 N=50 9.05 m				
10		9.80 m SILTY SAND: DARK BROWN TO BROWN. FINE GRAINED. SLIGHTLY CLAYEY.		VL	
	10.20m SPT 1,1,1 N=2 10.65m				
11					
12		* ROUNDED PEBBLES UP TO 5 mm IN SIZE BELOW 12.00 m			
	12.10m SPT 7,7,9 N=16 12.55m	12.40 m SAND: BROWN. FINE TO MEDIUM GRAINED.		MD	
13		13.50 m PEAT: DARK BROWN TO BLACK.	M TO W		
	13.65m SPT 8,29,26 14.06m				
14		13.90 m SILTY SAND: DARK BROWN - BROWN. FINE WITH SOME MEDIUM GRAINED. ROUNDED PEBBLES UP TO 30 mm IN SIZE.	W		- SPT REFUSAL 110 mm (26 BLOWS)
15		14.80 m CLAY: PALE BROWN. MEDIUM PLASTICITY. SLIGHTLY SILTY, WITH PEBBLES UP TO 40 mm IN SIZE.	M	M	100 -120 KPa
		15.43 m END OF NON-CORE DRILLING			
		* SEE CORE DRILL HOLE SHEET FOR INFORMATION			
16					

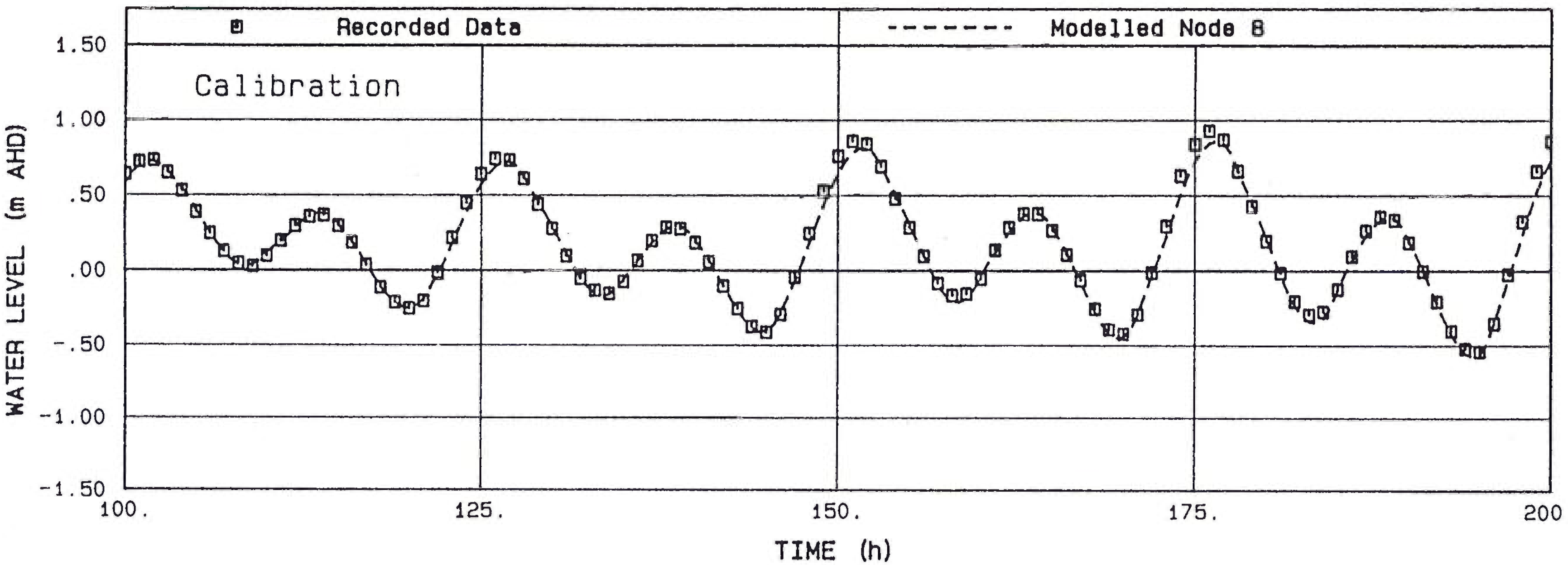
See Standard Sheets for details of abbreviations & basis of descriptions

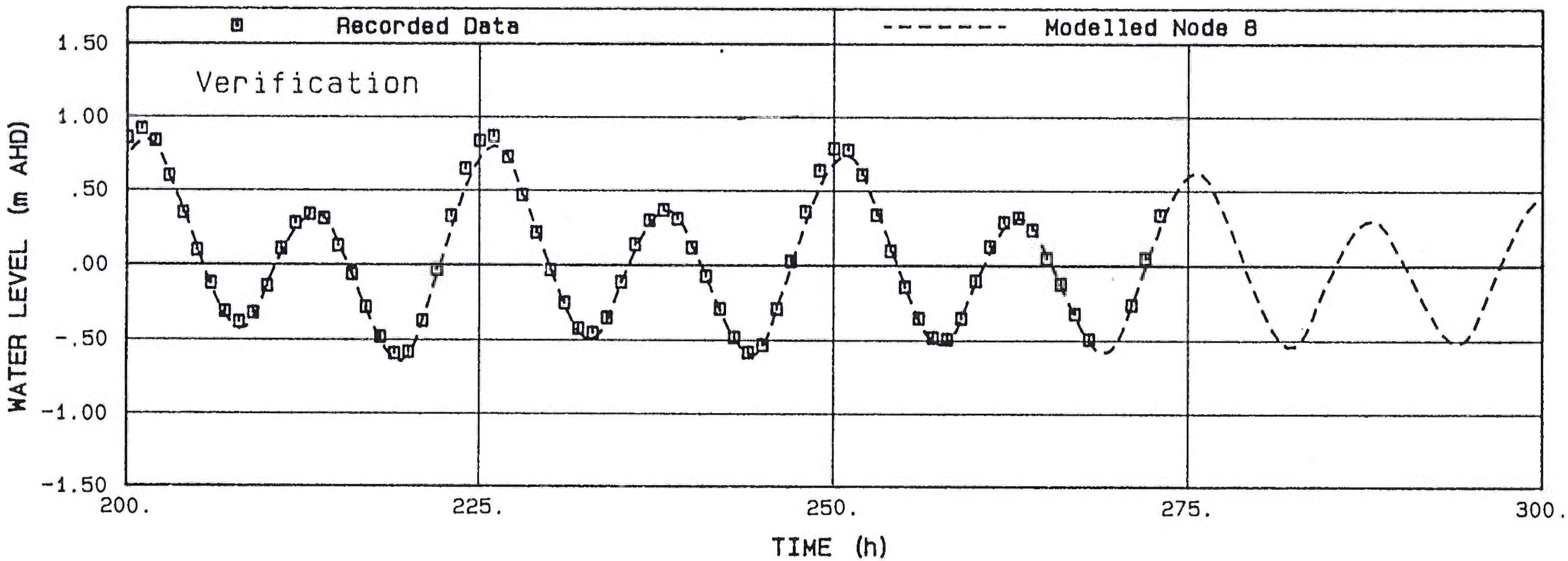
ROADS AND TRAFFIC AUTHORITY, NSW

APPENDIX 11

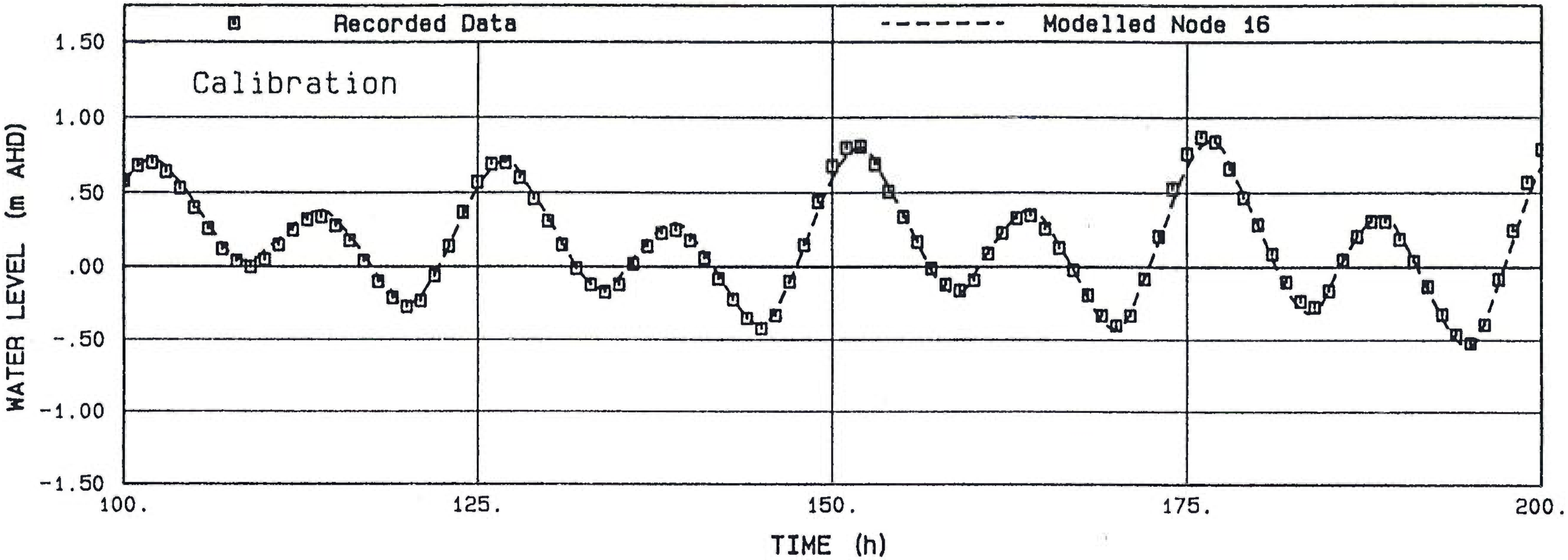
TIDE MODEL VALIDATION

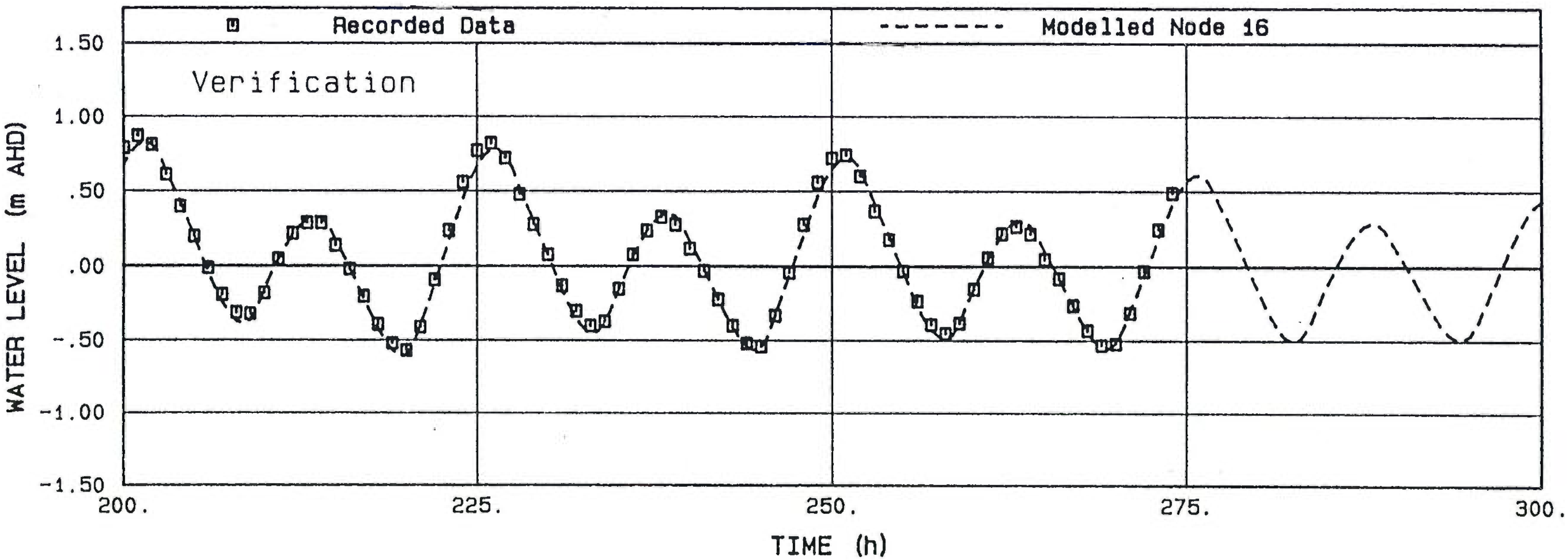
ESTRY TIDE MODEL VALIDATION - 1992
LETITIA 2A



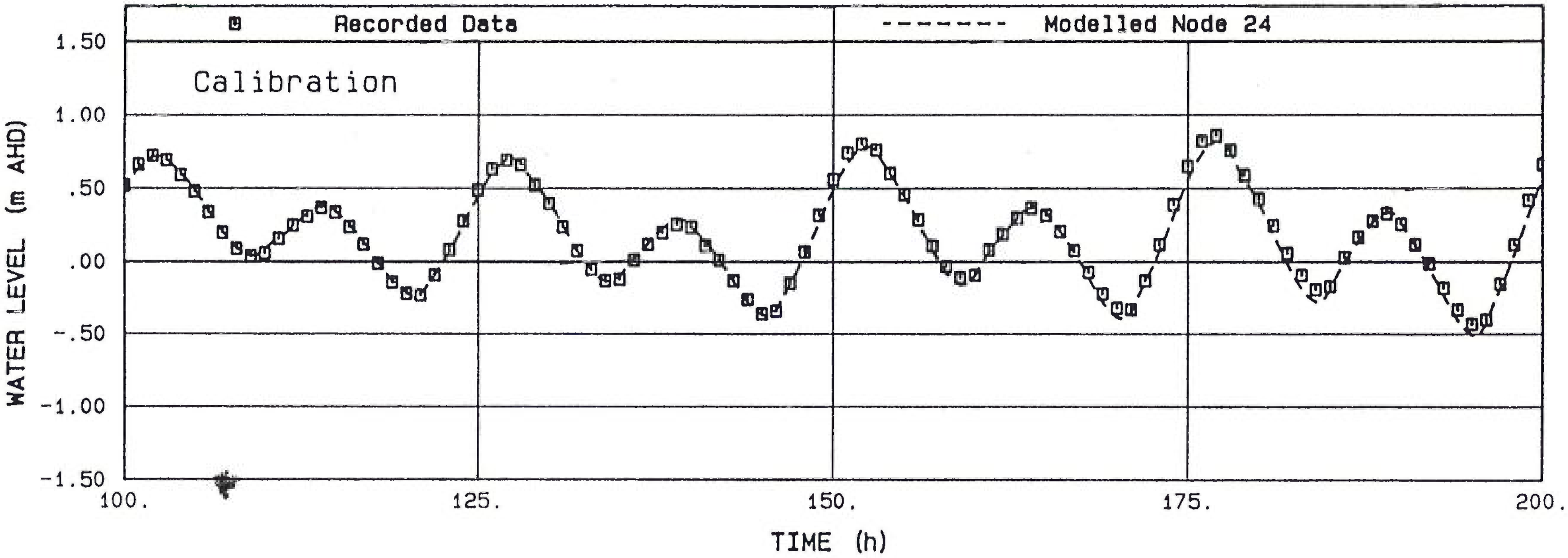


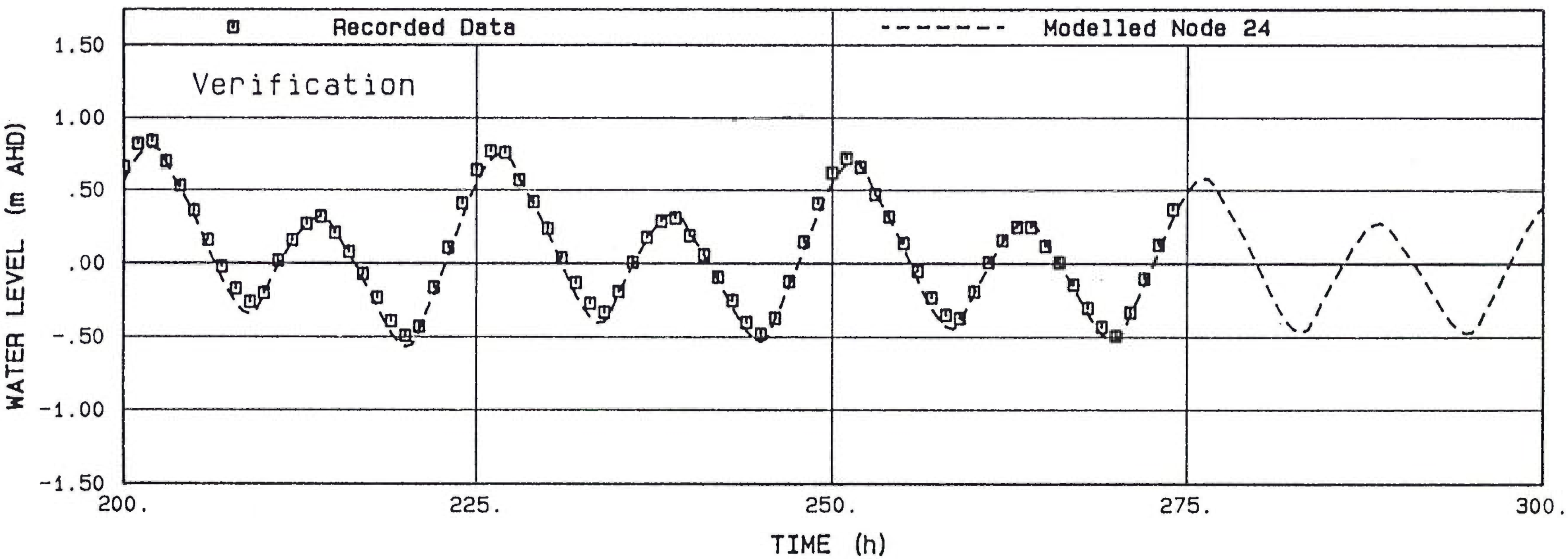
ESTRY TIDE MODEL VALIDATION - 1992
LETITIA 2B





ESTRY TIDE MODEL VALIDATION - 1992
BARNEYS POINT





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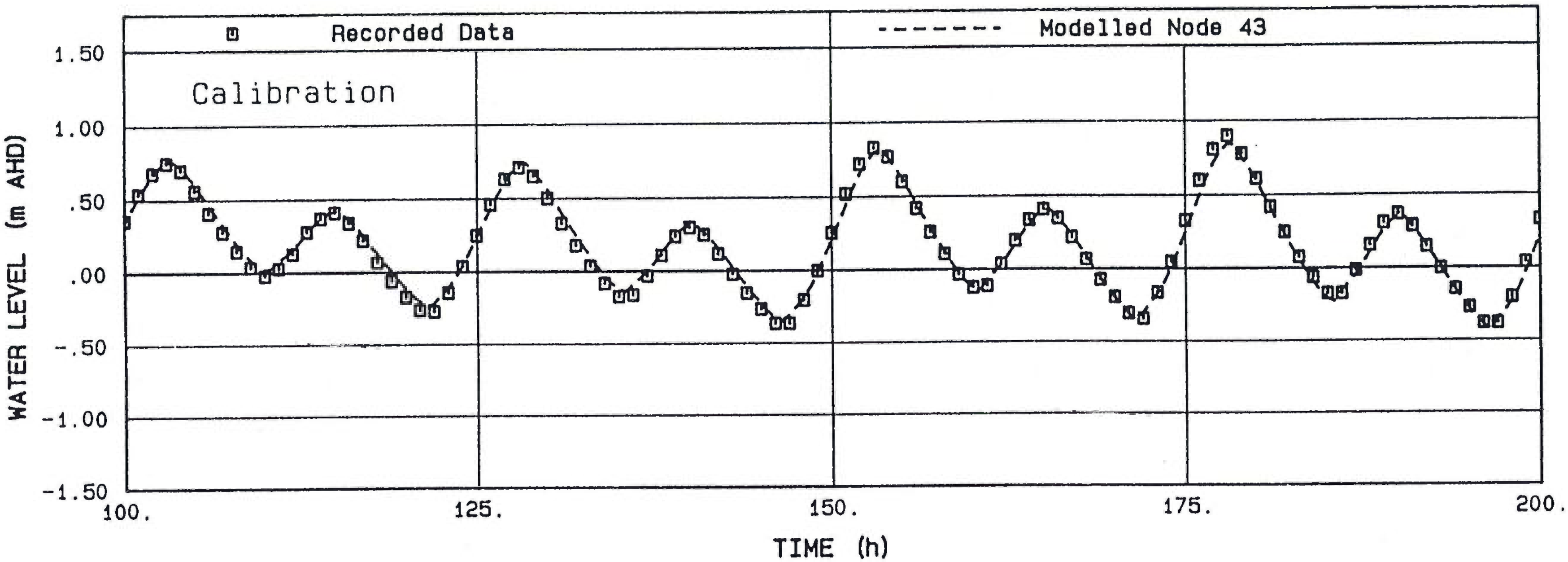
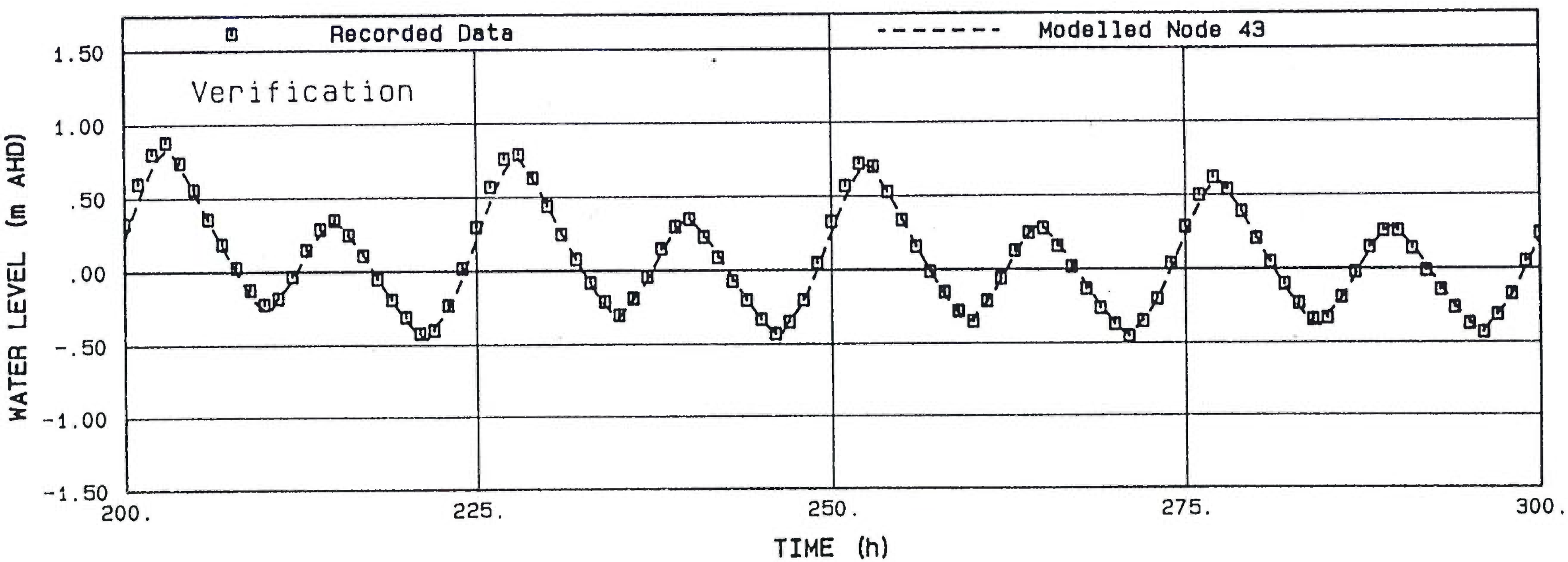
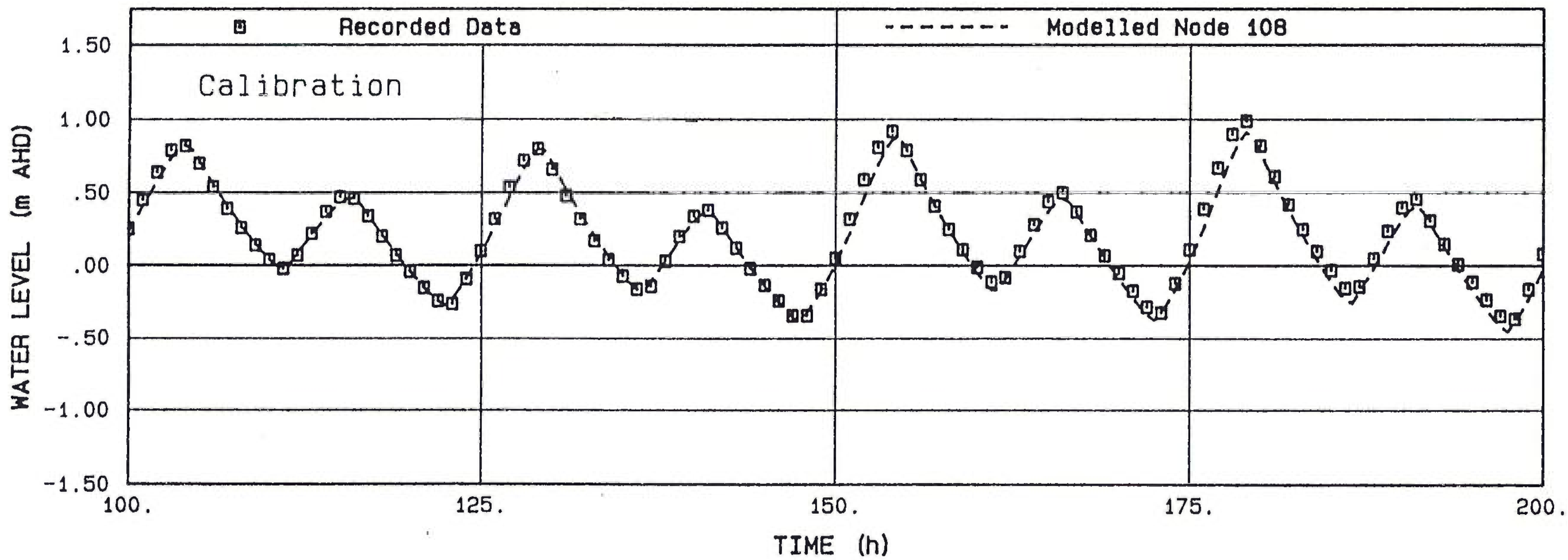
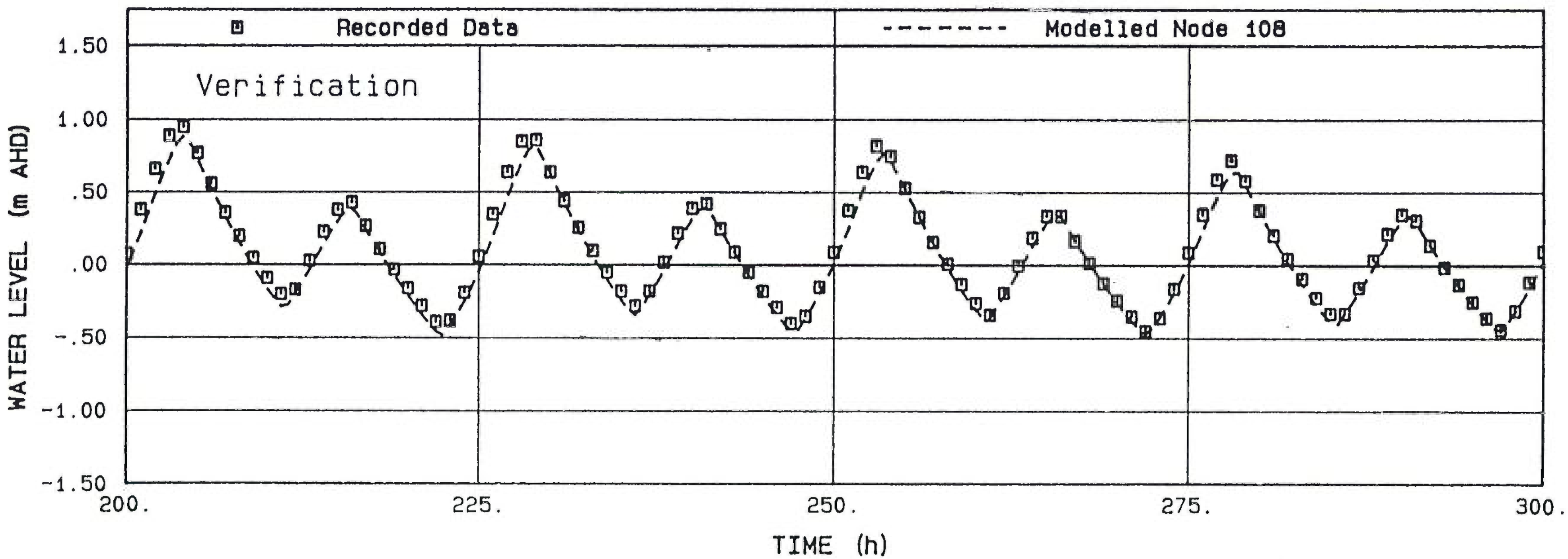
TUMBULGUM





ESTRY TIDE MODEL VALIDATION - 1992
KYNNUMBOON





ESTRY TIDE MODEL VALIDATION - 1992
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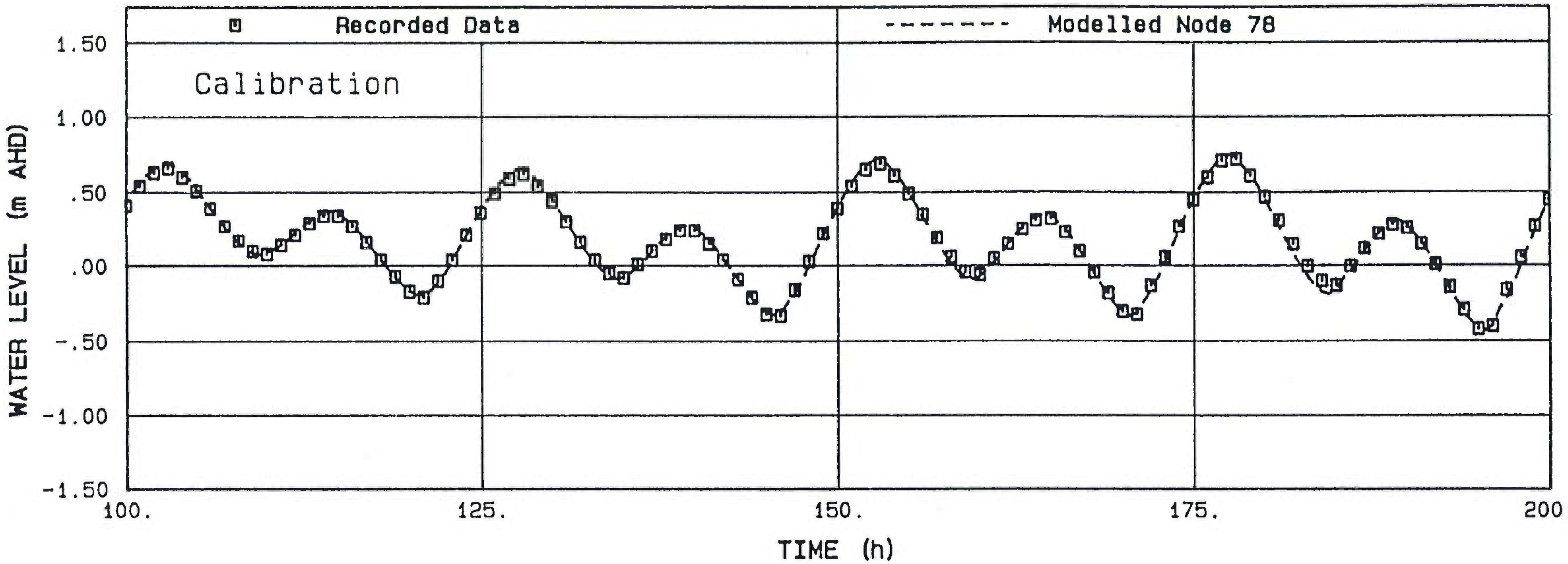
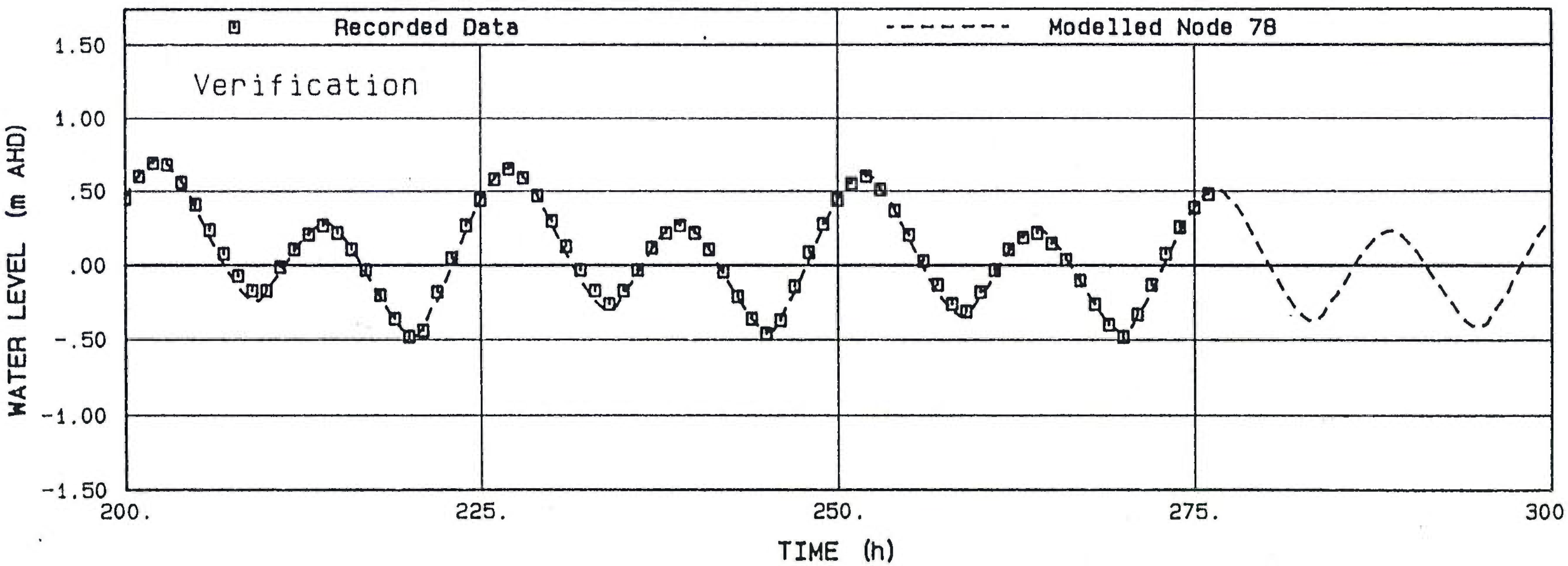
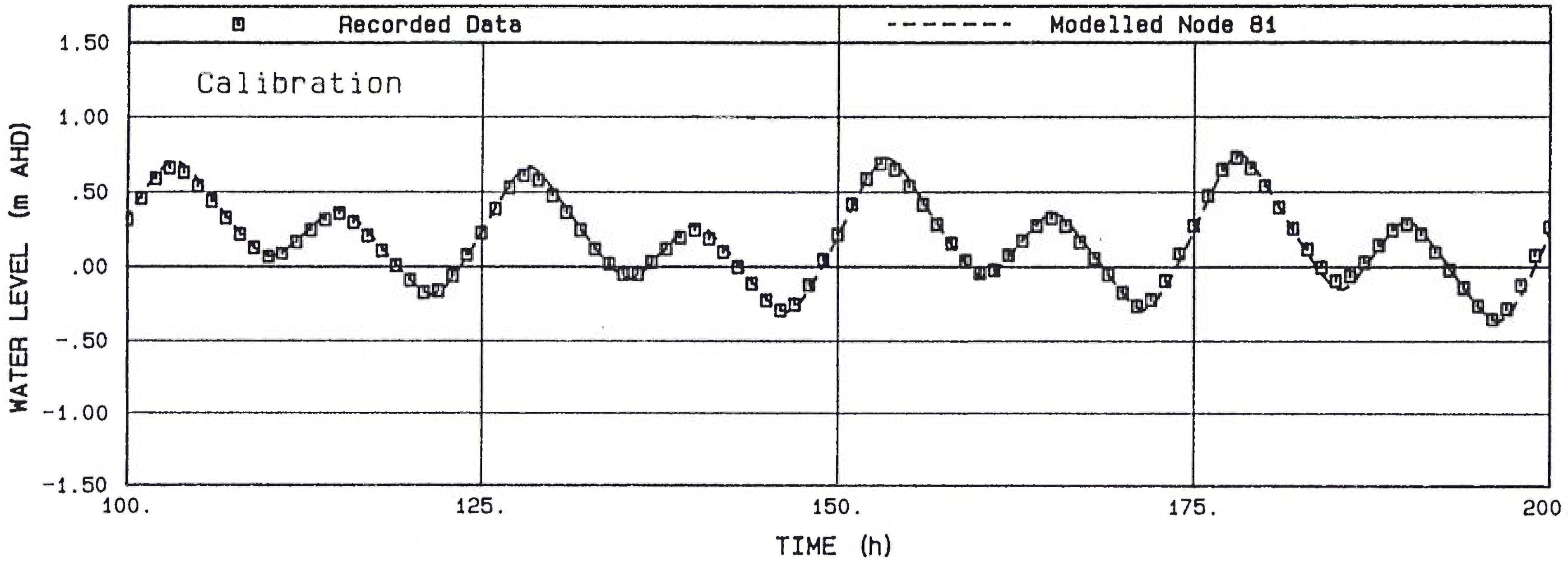
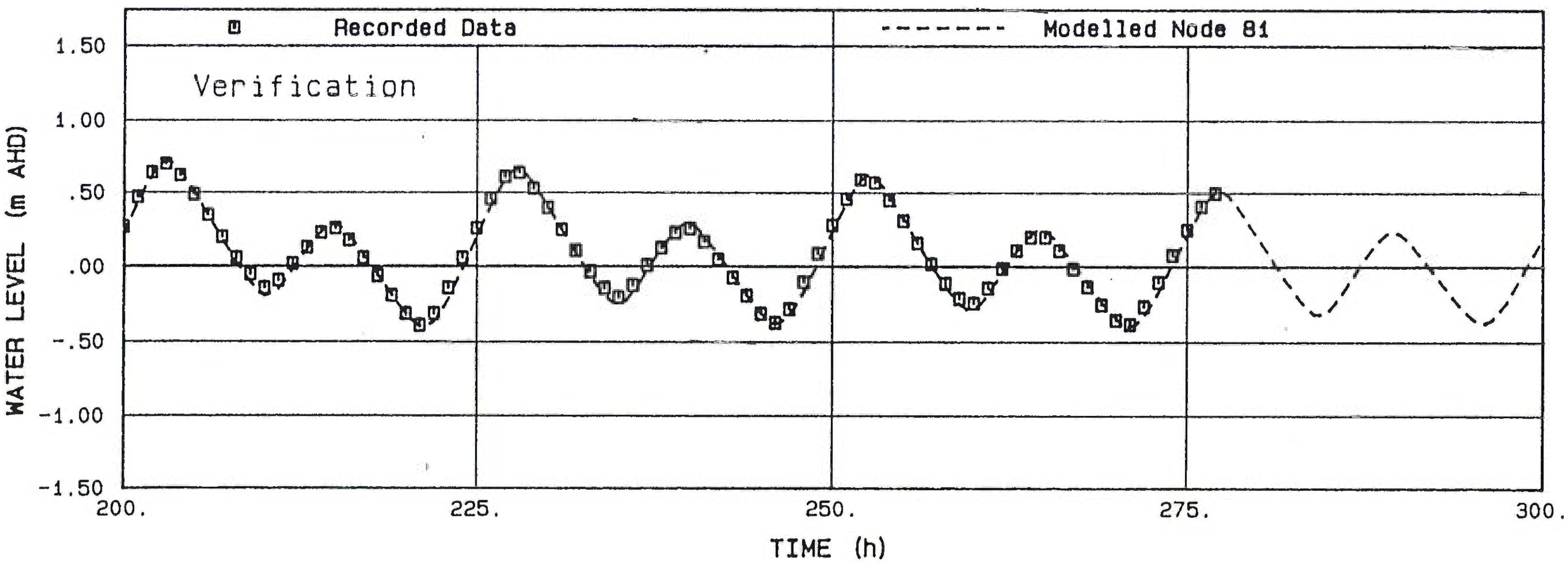


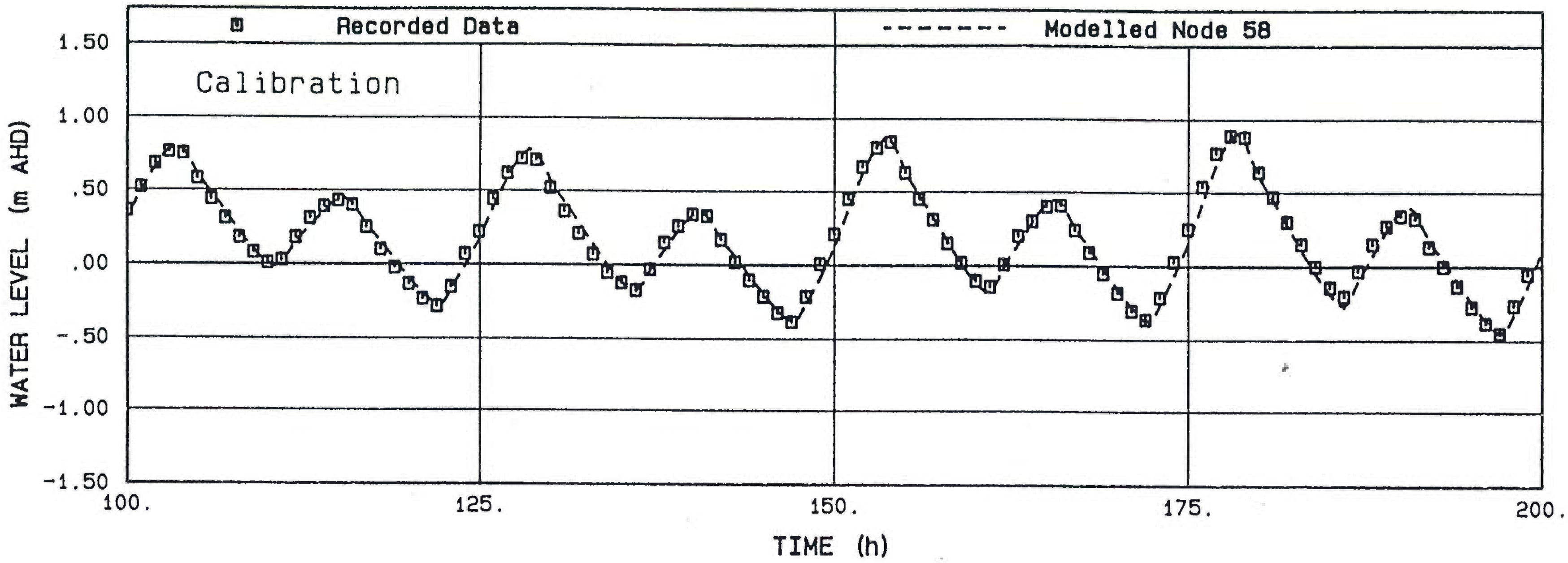


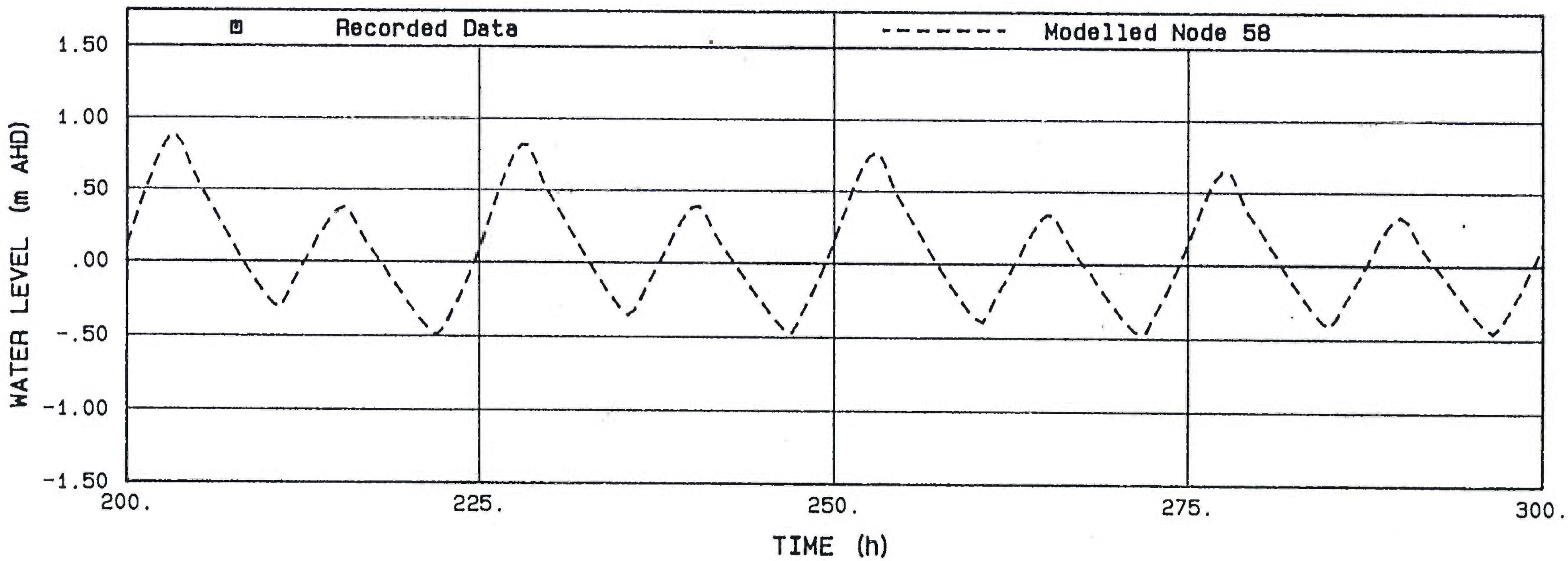
ESTRY TIDE MODEL VALIDATION - 1992
TERRANORA



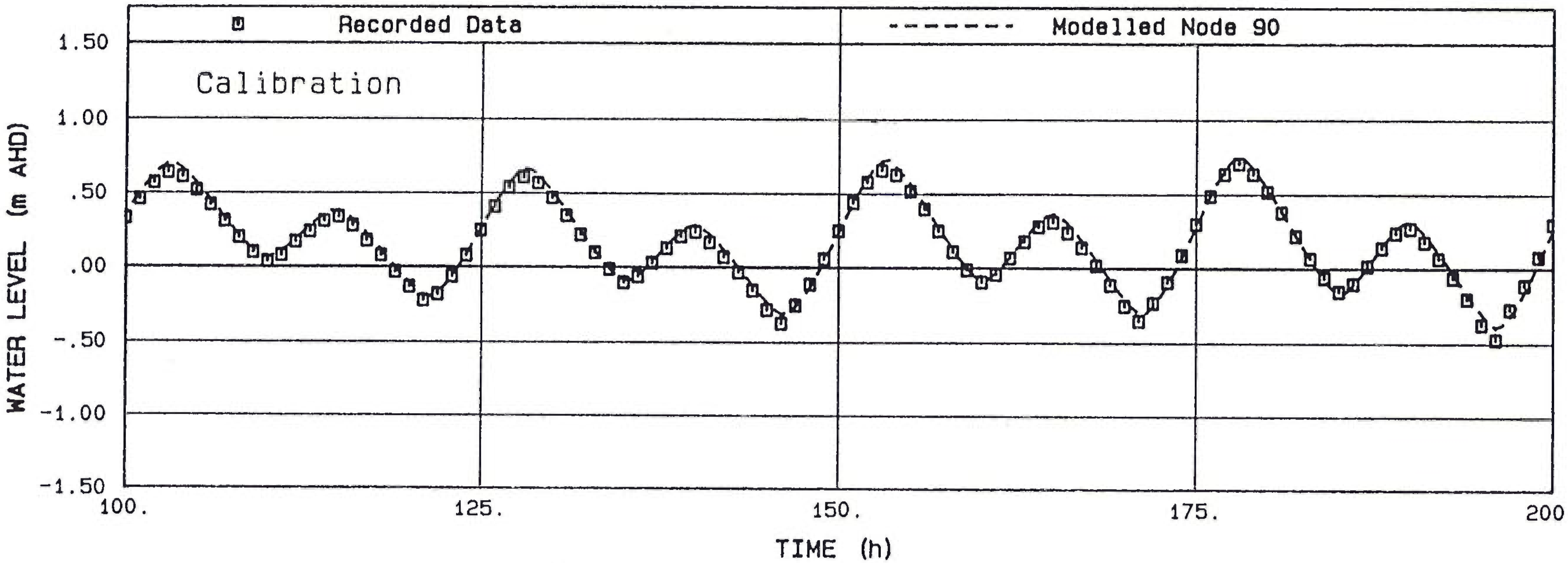


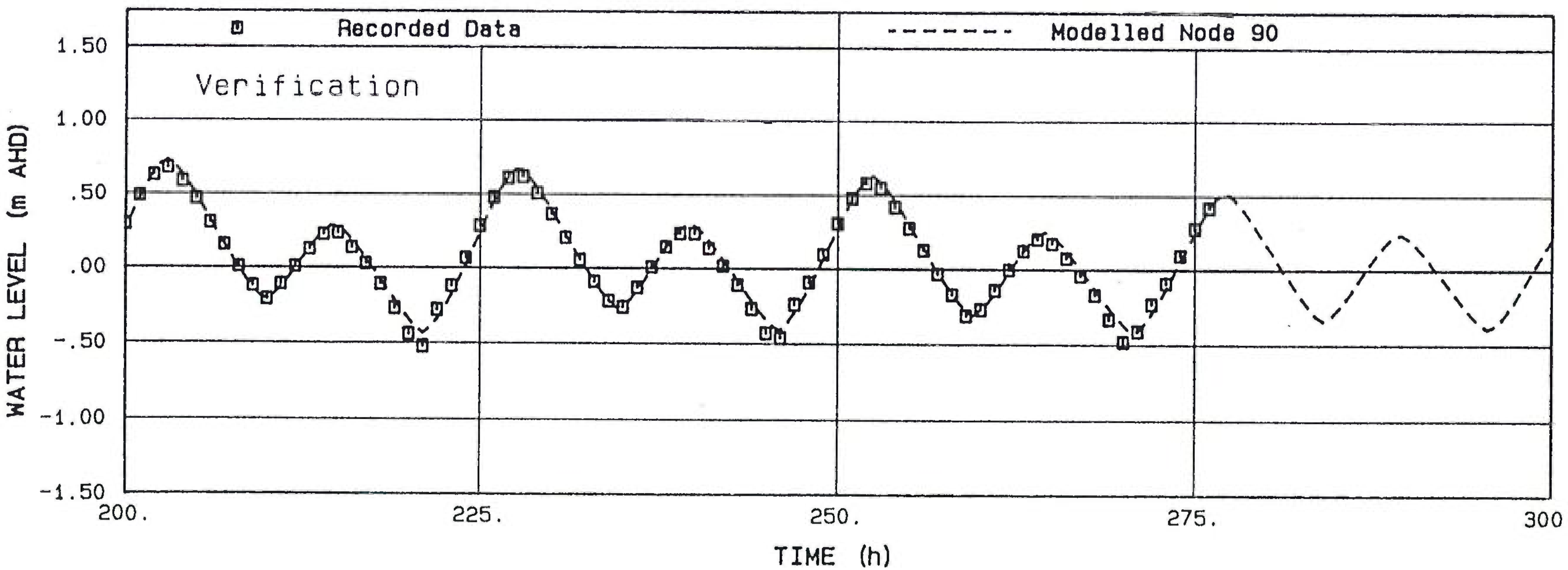
ESTRY TIDE MODEL VALIDATION - 1992
MURWILLUMBAH

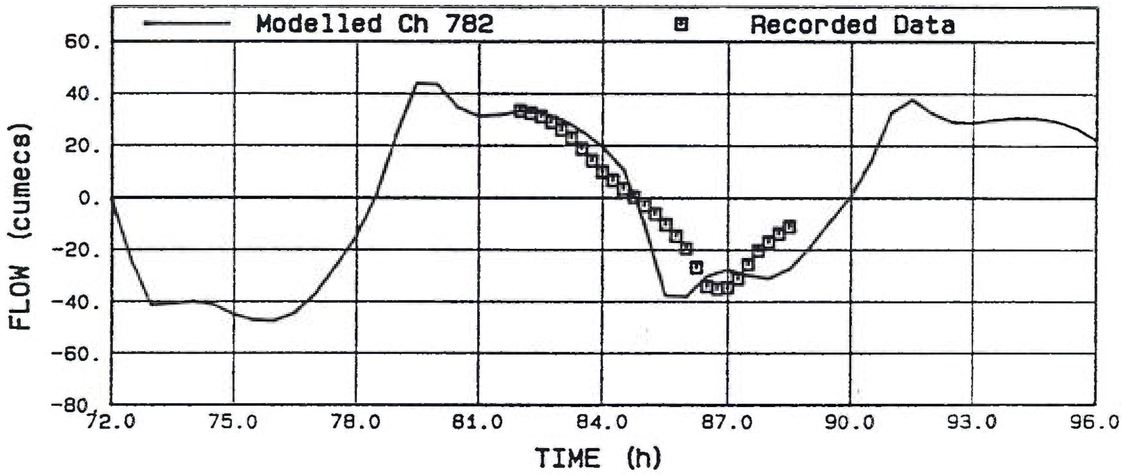




ESTRY TIDE MODEL VALIDATION - 1992
COBAKI







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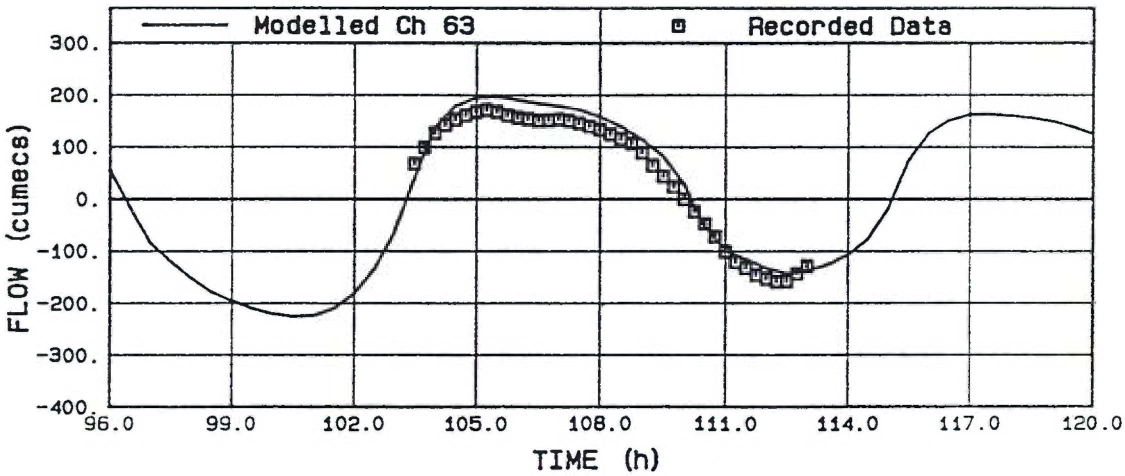
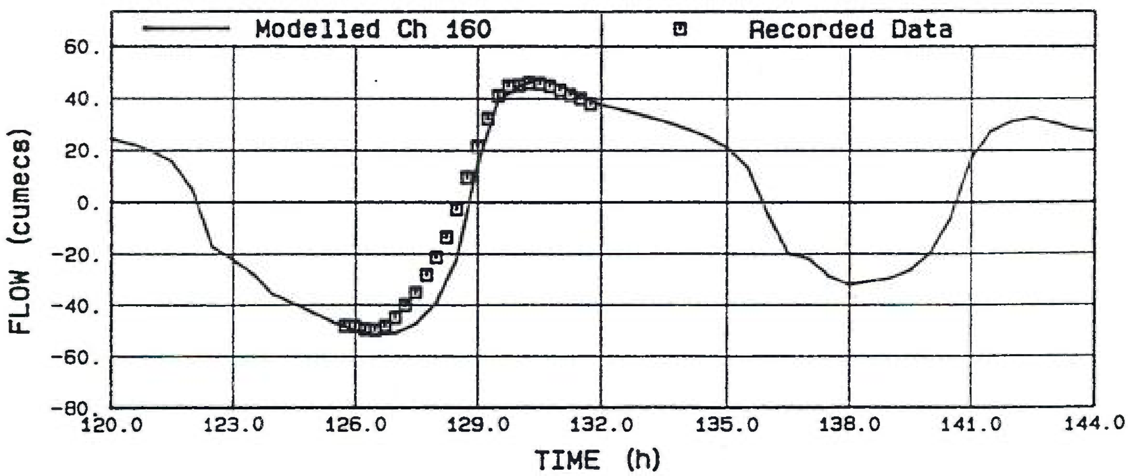


U/S of Dodds Island



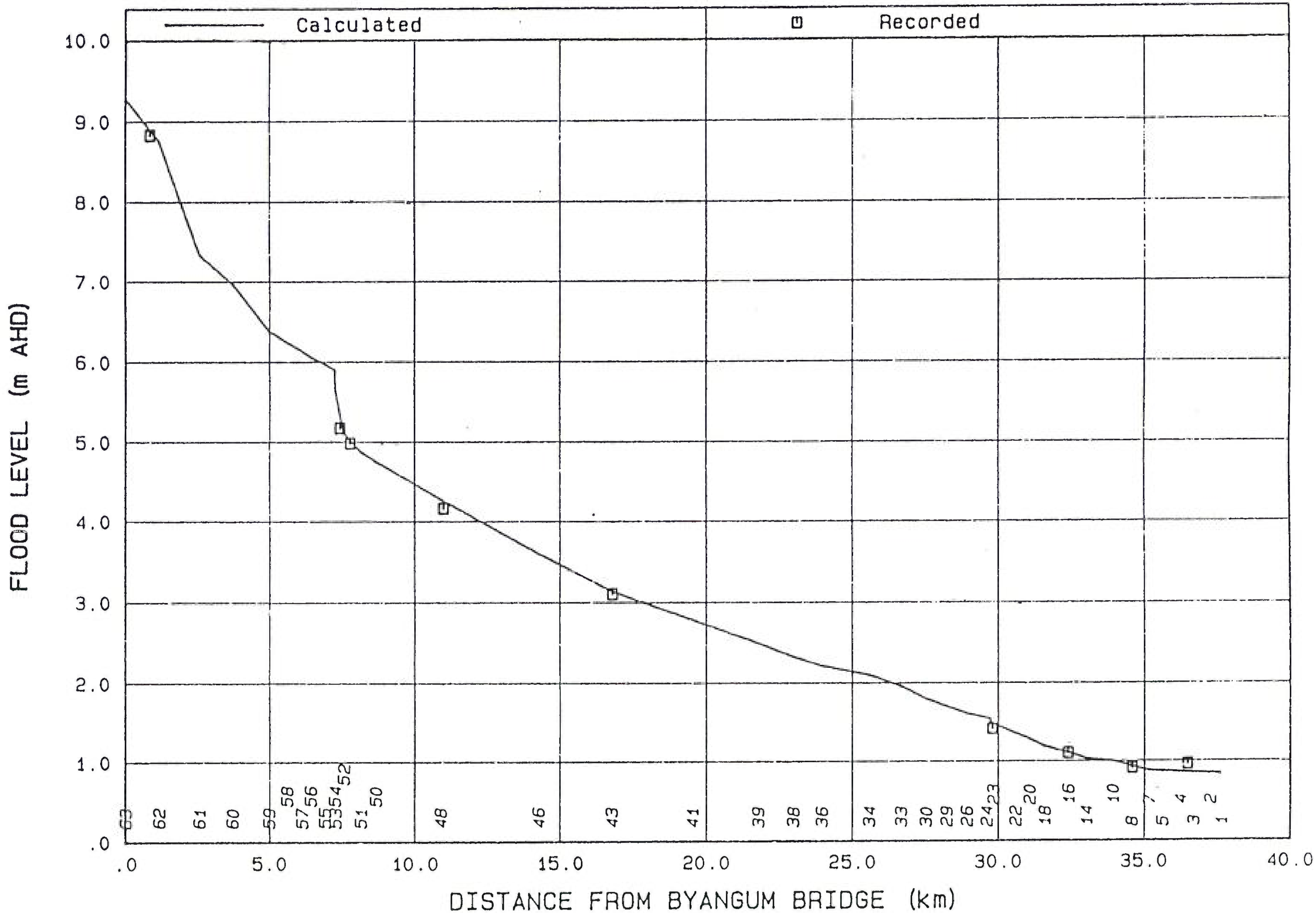
Rous River

ESTRY TIDE MODEL VALIDATION - 1992
FLOWS - CONDONG,DODDS IS.,ROUS R.

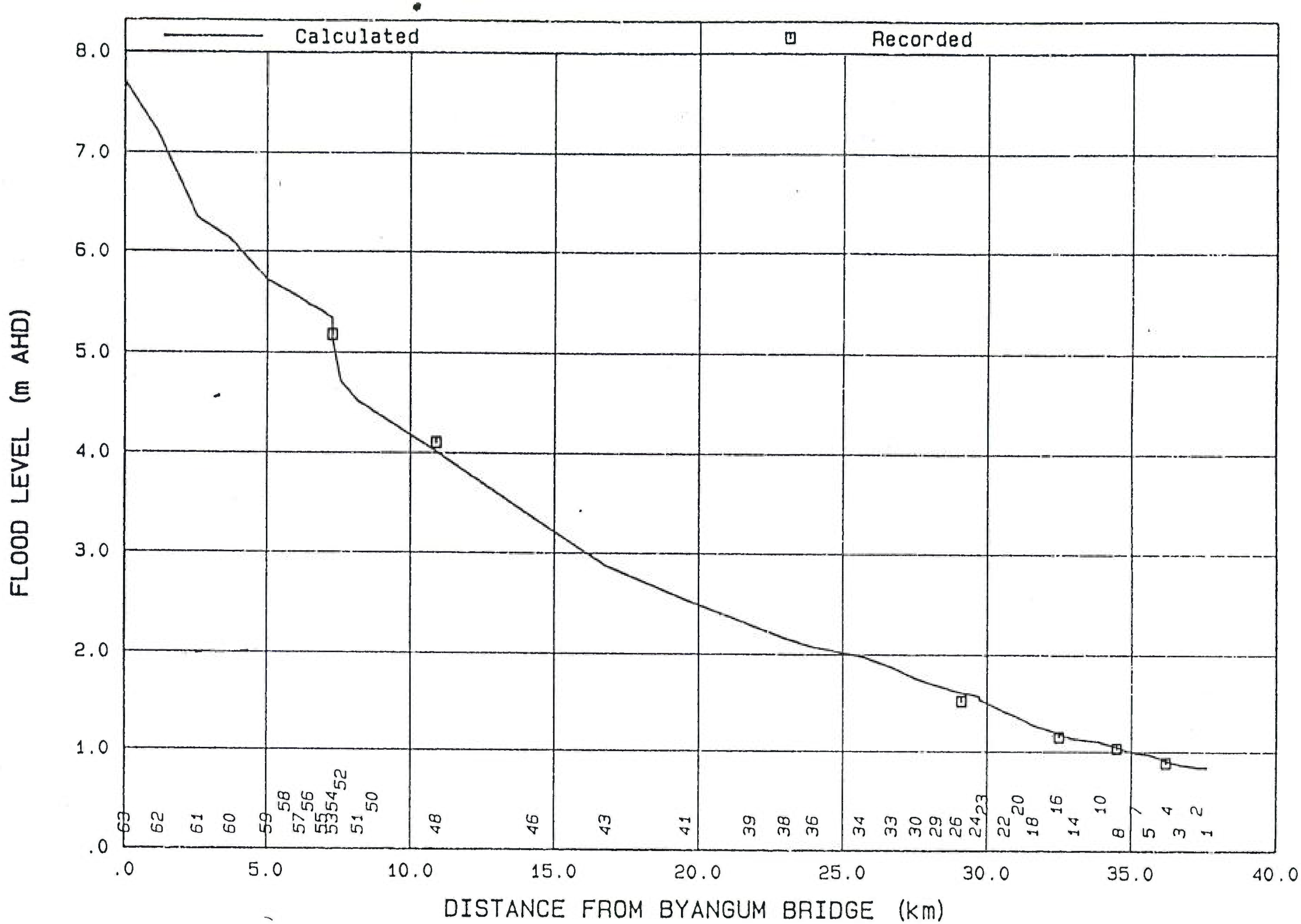
APPENDIX 12

FLOOD MODEL VALIDATION

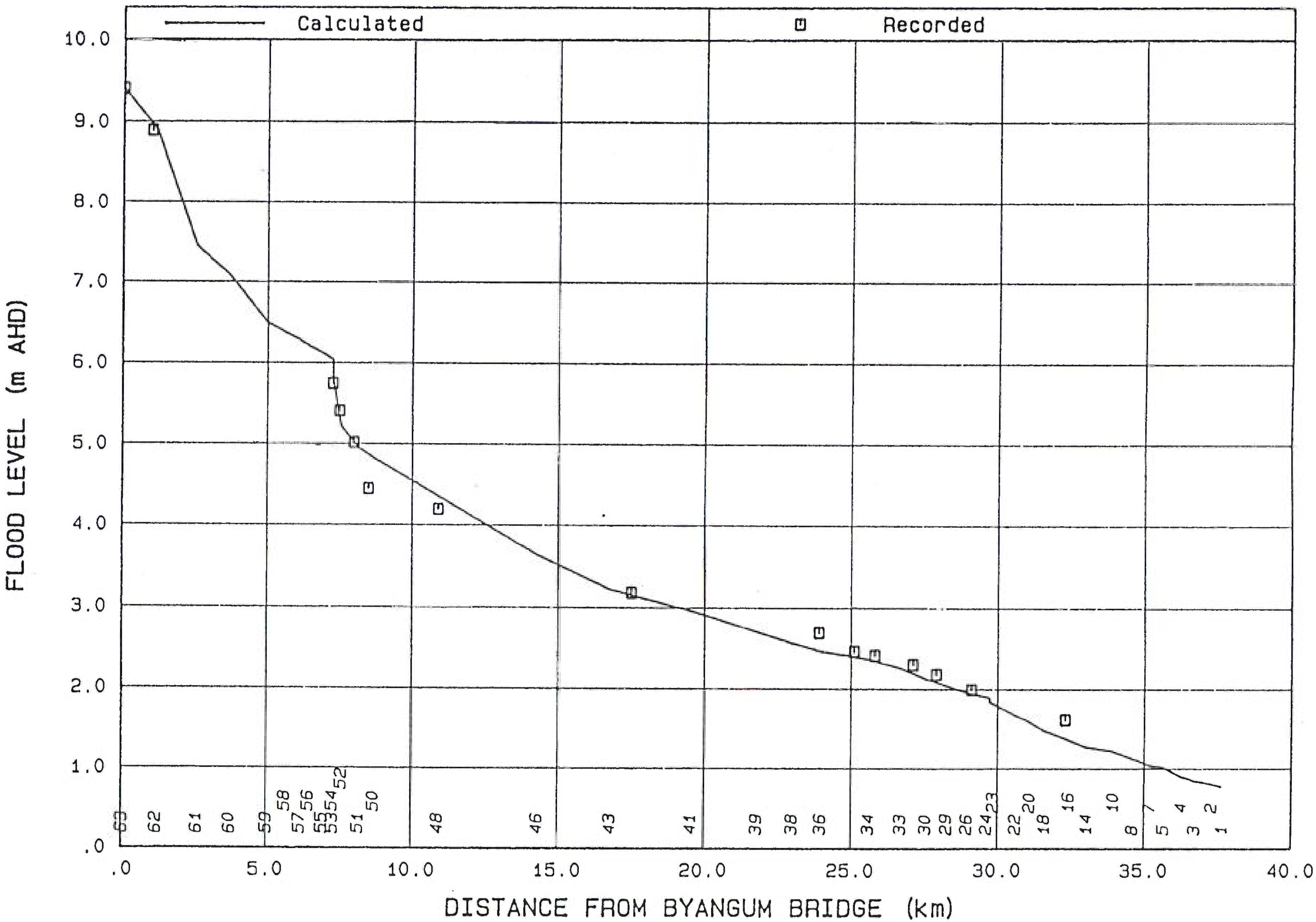
ESTRY FLOOD MODEL VALIDATION
APRIL 1989 - PEAK LEVEL PROFILE



ESTRY FLOOD MODEL VALIDATION
MARCH 1978 - PEAK LEVEL PROFILE



ESTRY FLOOD MODEL VALIDATION
MARCH 1974 - PEAK LEVEL PROFILE



APPENDIX 13

ONE-DIMENSIONAL MODELLING PROGRAMS ESTRY AND SEDMOD

ESTRY

FOR MODELLING FLOODS AND TIDES

ESTRY is a powerful hydrodynamic flow program suitable for mathematical modelling floods and tides through a network of interconnected flowpaths and storages.

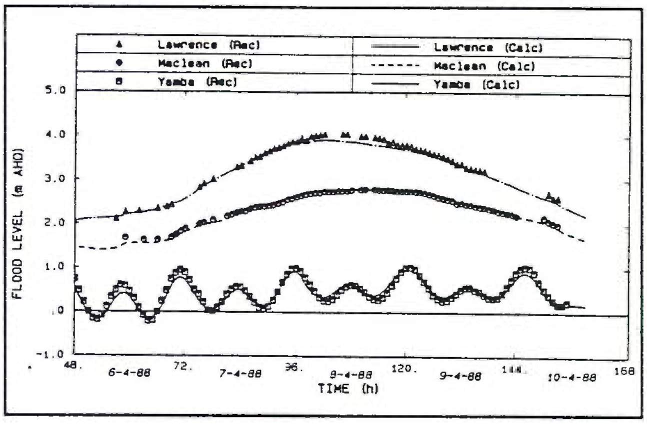
ESTRY is the ideal engineering tool for the following types of investigations:

1. Floodplain management: to reliably quantify flood hazards, etc.
2. Impact assessment: to quantify the effects of land filling and flood mitigation works on flood levels and flows; effects of river works, canal excavation, tidal barrages etc. on rivers and estuaries.
3. Drainage System Design: for optimising open channel drains, culverts, road crossings and retention basins.

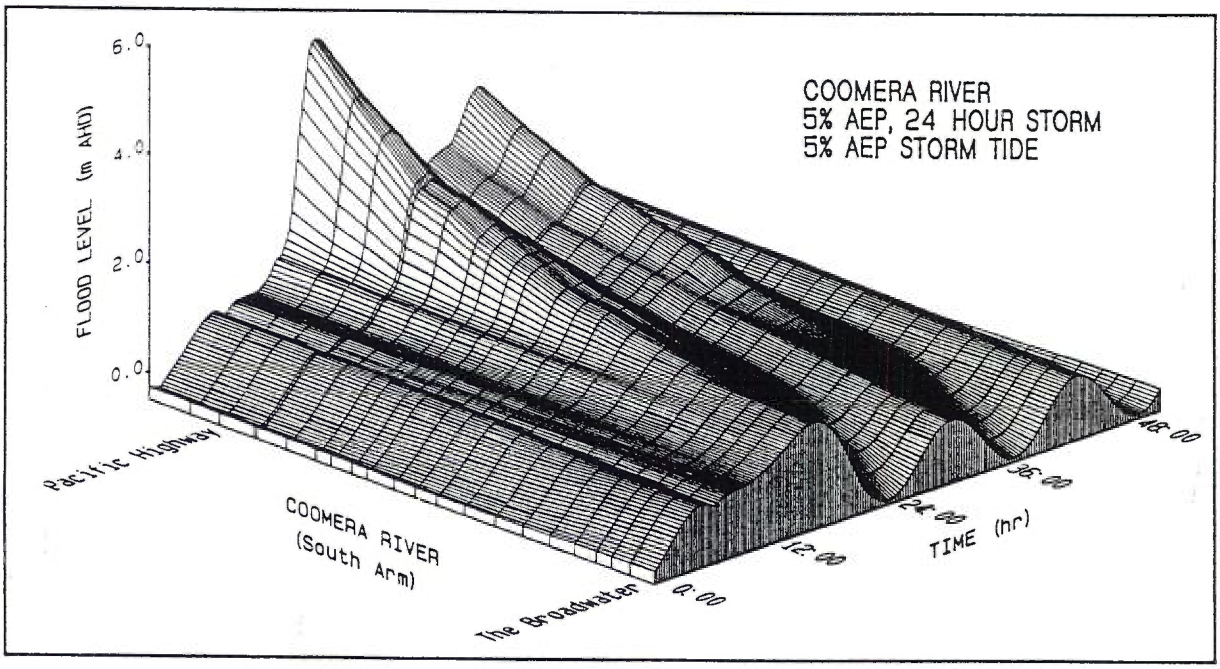
The program has been developed and continually upgraded by WBM Pty Ltd since 1973 and has been successfully used on more than one hundred investigations, with models ranging from simple single channel applications to network representations with several hundred channels.

As the program solves the complete St. Venant equations for steady flow, the dynamic features of an estuary are accurately reproduced, including tidal amplification. The program is ideally suited for modelling storm tide penetration and tidal interactions with river flows from stormwater runoff.

There is a considerable amount of flexibility in the way the network elements can be interconnected, allowing realistic simulation of a wide variety of typical two-dimensional flooding and tidal flow situations. Multiple braided streams, parallel channels and complex river branching can all be easily modelled.



CLARENCE RIVER - APRIL 1988 FLOOD VERIFICATION



A special feature of the program is the ability to include non-horizontal gradient channels in situations of overbank flow to or from floodplains or, for example, for ocean entrance channels. Channel structures such as weirs and culverts (with or without floodgates) as well as bridges can be incorporated into the model network.

A range of useful and easy to interpret colour graphics presentations of results is available. These include two and three-dimensional representations of water levels, velocities and discharges in the form of the time-series and locality based data plots.

ESTRY is used also for modelling sediment transport and water quality by means of supplementary programs developed for those purposes. The sediment transport program SEDMOD provides for several transport formula options which can be chosen or modified to suit particular applications. Water quality may be modelled using either eulerian (QALTY) or lagrangian (WATQAL) techniques as appropriate.

References:

MORRISON, W.R.B. and SMITH, P.A. (1976). A Practical Application of a Network Model. 'Numerical Simulation of Fluid Motion'. Published by North Holland Pub. Co. Amsterdam.

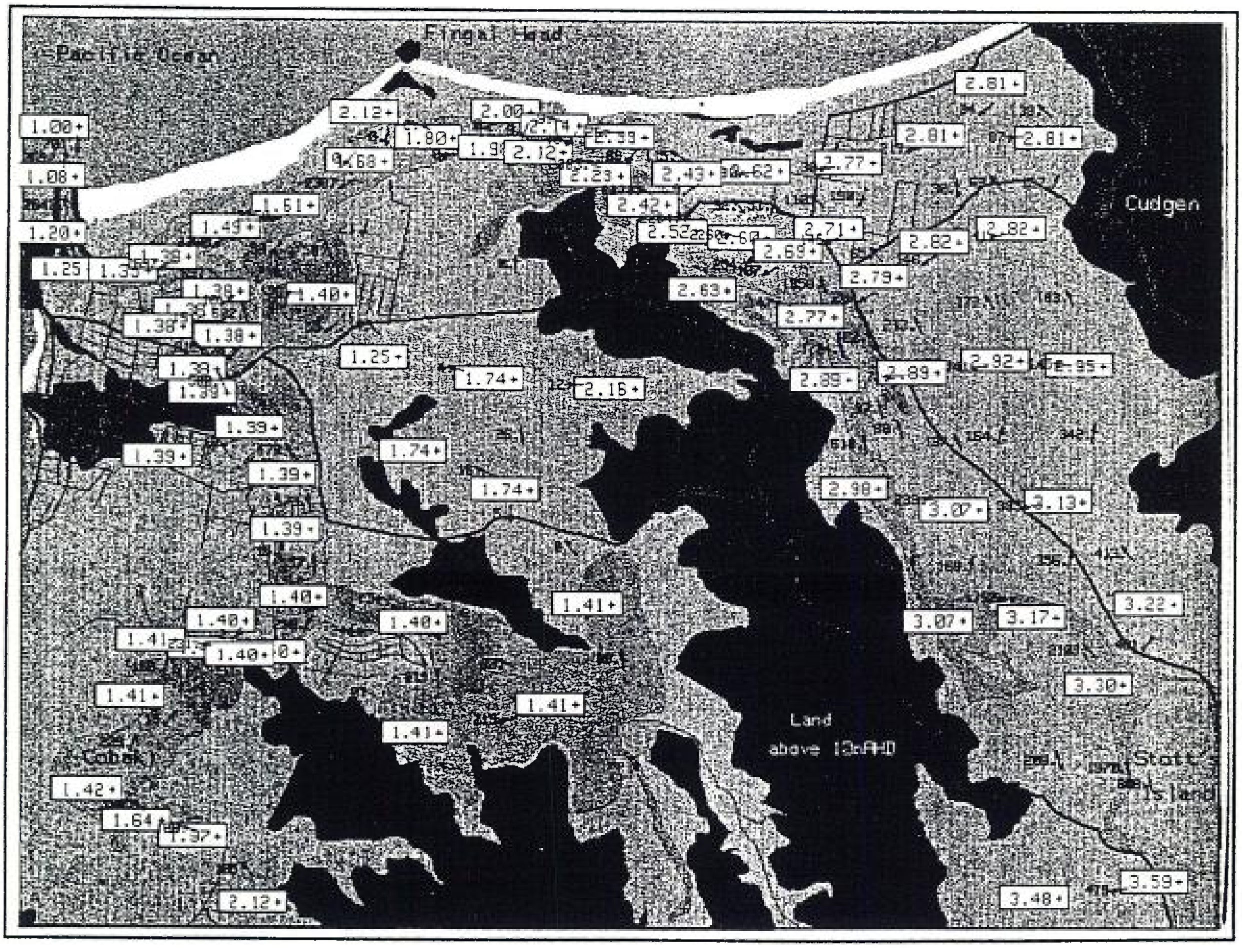
MORRISON, W.R.B. and SMITH, P.A. (1980). Mathematical Modelling of Floods and Tides - Pitfalls and their Solutions. I.E. Aust. Qld. Division Technical Papers. Vol. 21, No. 11.

HERRINGE, R.A. and HENLEY, J.W. (1984). Mathematical Modelling for Floodplain Management in the Tweed Shire, N.S.W. Presented at the Conference on Hydraulics in Civil Engineering, Adelaide. Instn. of Engrs., Aust. National Conference Publication No. 84/7.

HARDING, P.E. (1985). An introduction to the use of the Dynamic Flood Program ESTRY. Presented at the joint ACADS/IE AUST. Workshop on Applied Dynamic Flow Modelling of Open Channel Flow, Nov. 1985. ACADS Publication No. U235.

HERRINGE, R.A. (1985). Real Applications of Dynamic Flow Models. Ibid.

SYME, W.J. (1988). Computer Graphic Techniques - An Essential Tool for Interpreting and Analysing a Dynamic Flow Model. Watercomp '89, Melbourne, Australia.



Flood Levels and Flowrates - Tweed River System, NSW

SEDMOD

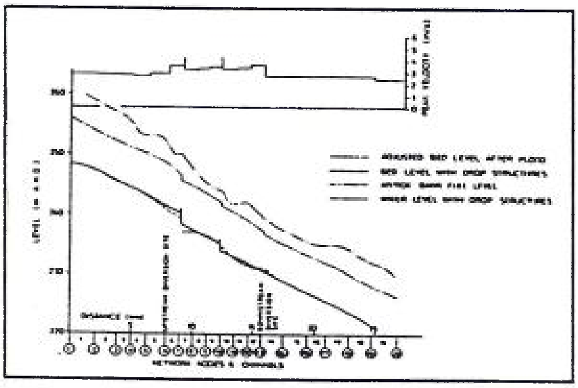
FOR MODELLING BED MOVEMENT IN RIVERS AND CHANNELS

SEDMOD is a bed load transport modelling program designed to accompany the dynamic flow program ESTRY. For all flow paths of the ESTRY network model, SEDMOD calculates the bed load transport rates and the total accumulation of material at each of the network nodes.

In this way, the bed movement during either flood or tide events can be quantified and this approach has been used to successfully model situations ranging from tidal estuaries to ephemeral rivers.

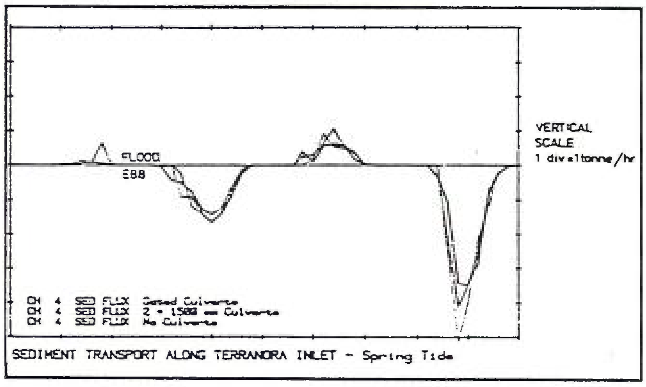
SEDMOD is a useful tool for the following types of investigations.

1. Prediction of long term siltation/scour trends in existing estuaries and rivers.
2. Impact assessments of the effects of any activities which alter the hydraulics of a waterway, such as canal or marina developments, diversion channels, dredging, land reclamation and river training works.
3. Design of artificial channels for irrigation, drainage or river diversion.



The program was originally developed using a modified form of the Ackers-White (1973) bed load transport formulae. These modifications were based on calibration of these procedures when applied to the Tweed River (N.S.W. Public Works Department, 1978). However, it is a relatively simple exercise to include any alternative sediment transport formulae which require the same type of hydraulic input data.

The flexibility in the way the network elements can be interconnected, as controlled by the hydrodynamic program, allows simulation of sediment transport in multiple braided streams, parallel channels and complex river branching. The relative stability of the different river reaches and the impacts of any proposed works on the stability of the natural river system can be easily quantified.



SEDIMENT TRANSPORT ALONG TERRANORA INLET - Spring Tide

Output from the programs includes instantaneous sediment transport rates during the simulated event as well as the total accumulation/deficiency at nominated locations over the study area. The output is presented in tabular form as well as in files suitable for graphic plots.

By simulating a series of flood or tide events, as determined from the flood or tide statistics for the study area, it is possible to quantify long term scour/accretion trends by taking into account the probability of occurrence of each event. In addition, the sediment carrying capacity of each individual flood or tide event provides an indication of the damage potential of each event.

A user's manual is available and the program is fully backed by experienced personnel who have been involved in the development and use of the modelling procedures for several years.

References:

ACKERS, P. and WHITE, W.R. (1973). Sediment Transport: New Approach and Analysis. Proc. ASCE., J. Hyd. Div., 99, HY11. November.

PUBLIC WORKS DEPARTMENT OF N.S.W. (1979). Tweed River Dynamics Study - Phase 1. Report No. PWD78009, January.

APPENDIX 14

MODELLING PROGRAM TUFLOW

TUFLOW

TWO-DIMENSIONAL UNSTEADY FLOW PROGRAM

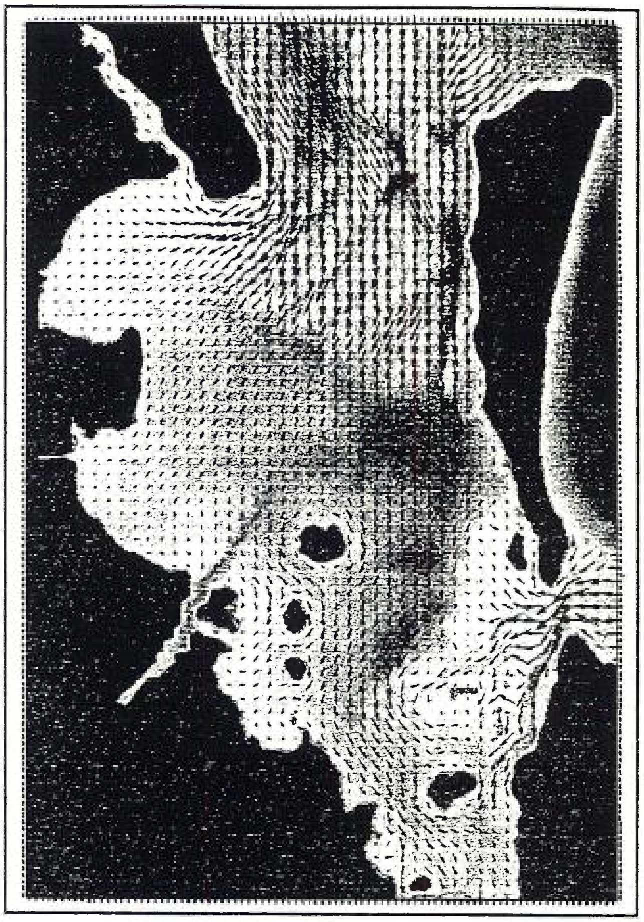
Tuflow is a computer program for the simulation of Two-dimensional Unsteady Flow in coastal waters, estuaries and rivers. It is supported by a comprehensive computer graphics system and can be linked to ESTRY 1-D network models. Application of the TUFLOW modelling package is specifically orientated towards:

1. Establishment of tidal behavior in coastal bays and harbours, leading to impact assessments on hydraulic, water quality, sediment transport ad siltation processes.

2. Simulation of complex two-dimensional flows around natural or artificial obstructions in bays, rivers and estuaries for impact assessment and/or civil design purposes.

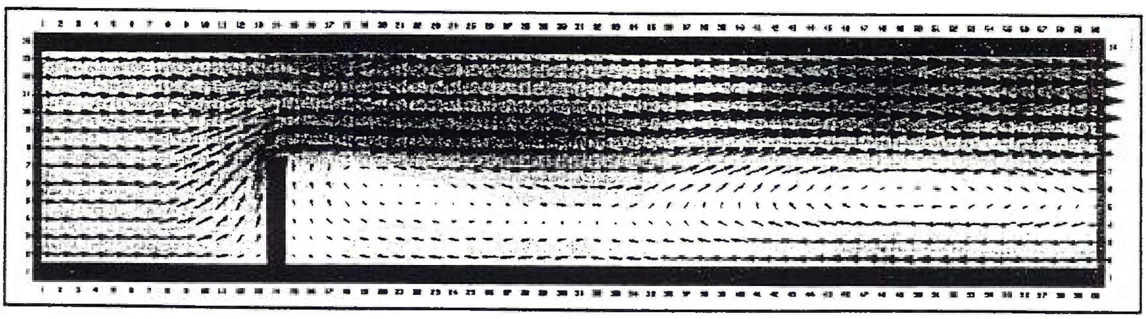
The solution technique is based on the work of Stelling, 1984. The two-dimensional Shallow Water Equations (SWE) of continuity and momentum are solved using an Alternating Direction Implicit (ADI) scheme over a staggered grid. The ADI scheme is similar to that used in the more commonly known RAND Corporation program (Leendertse, 1967) but incorporates a higher order of accuracy and much improved boundary representation. This leads to a significantly more stable, robust and versatile solution.

Algorithms are employed for simulating the flooding and drying of intertidal flats (Stelling, 1986). Other features include the application of wind stresses, radiation stresses due to waves, the Coriolis force and variable barometric pressure.



Flood Tide - Moreton Bay
Velocity Vectors, Bathymetry/Land
Contour Shaded
Model Details: 137 by 89, 500 m grid

Boundaries are represented as any combination of water levels, flows or velocities. The boundaries of the Stelling scheme are treated as non-reflective, allowing accurate representation of flow into or out of the model.



Flow Past a Solid Wall - Test Case
Velocity Vectors, Velocity Contour Shaded
Model Details: 60 by 14, 25 m grid.

A special boundary feature is the ability to interface a TUFLOW model to any number of ESTRY 1-D network models (Syme, 1989). The area of complex flow is modelled in two dimensions while additional areas can be modelled using the more economical 1-D solution technique. The 1-D and 2-D schemes are run in unison allowing impacts from a development proposal to be established over the entire waterway. The feature can facilitate significant reductions in the area covered by the 2-D model due to increased flexibility when defining the boundaries. This leads to a reduction in costs or greater accuracy by using a finer 2-D grid.

The TUFLOW modelling package has been developed as part of a joint research project with the University of Queensland's Department of Civil Engineering.

TUFLOW is supported by a comprehensive computer graphics system. Special features of the system are:

1. Digitized input of spot values or contour lines for data over the 2-D grid such as the bathymetry, fiction coefficients, wind and wave climate.

2. Automatic generation of values by interpolation from the spot values or contour lines mentioned above.

3. Output of water levels, velocities and all input data in the form of values, vectors, contour lines and colour shaded contours. Contouring maybe carried out using linear or cubic interpolation.

4. Zoom functions.

5. Windowing to allow the comparison of results for two or more simulations or the same simulation at different times.

Once the hydraulics have been established by TUFLOW, analyses of water quality, sediment transport and siltation processes can be made. These processes are simulated using other computer programs such as QALTY, SEDMOD and SUSMOD.

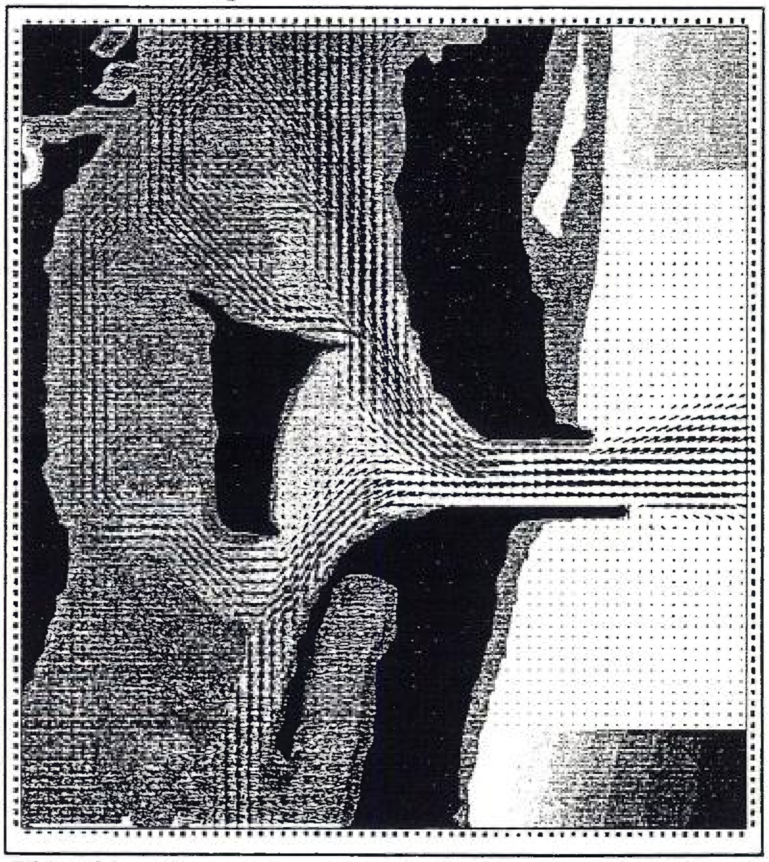
References:

LEENDERTSE, J.J. (1967). Aspects of a Computational Model for Long-period Water-wave Propagation. Memorandum RM-5294-PR, Rand Corp., Santa Monica, California.

STELLING, G.S. (1984). On the Construction of Computational Methods for Shallow Water Flow Problems. Rijkswaterstaat Communications, No. 35, The Hague, The Netherlands.

STELLING, G.S., WIERSMA A.K., WILLEMSE J.B.T.M (1986). Practical Aspects of Accurate Tidal Computations. Journal of Hydraulic Eng., ASCE, v112 n9.

SYME, W.J., APELT, C. (1989). The Development of a 2-D Numerical Flow Program with Linkage to 1-D Network Models. Paper in preparation for Conference of Hydraulics in Civil Engineering, 1990.



Ebb Tide - Nerang Seaway Velocity Vectors, Water Level Contour Shaded. Model Details: 60 by 39, 50 m grid

APPENDIX 15

WATER QUALITY REGIME

GLOSSARY OF TERMS AND PARAMETERS

SECCHI- Secchi Disc, a field device used to measure the transparency of water. The Secchi Disc gives a subjective, qualitative estimate of the transparency or clarity of a vertical water column as indicated by the depth (m) at which sunlight reflected by the disc becomes extinguished to the observer viewing from above.

SAL - Salinity refers to the total concentration of "salts" in solution in mg/l and is a measure of the total ions present. Salinity is a critical factor in the life cycle of many organisms. Marine and freshwater organisms can usually tolerate only small variations in salinity, whereas estuarine ones must be able to withstand the range between these two extremes.

Salinity also affects the amount of oxygen which water can hold in solution: the higher the salinity, the less oxygen can be dissolved.

TEMP - Water temperature variations are very important to aquatic life. All organisms have a maximum temperature limit beyond which they may die. For estuarine fish it is around 35°C, which is not much greater than maximum summer temperatures of 30 - 32°C. Most organisms are more tolerant of temperature drops than rises. Minimum temperatures in the Tweed River waters are around 11 - 12°C.

Temperature is measured also for use in the correction and interpretation of conductivity and dissolved oxygen readings, and in assessing the effects of thermal discharges.

D.O. The dissolved oxygen concentration of the water is measured as a percentage of the saturation solubility of oxygen in water for a given temperature and salinity.

Oxygen is essential to most forms of aquatic life. To be used by organisms it must be in dissolved form and in sufficiently high concentration. Because there are usually substances or organisms which consume oxygen present to varying degrees, it is usual for D.O. levels to be below the saturation value. In some situations, however, it is possible to have concentrations greater than the saturation value, when the water is said to be "supersaturated".

N.F.R. - Non Filterable Residue is the quantity of organic and inorganic matter (in mg/l) suspended in the water column which can be collected by filtration of the water sample. Typically the matter collected by filtration consists of sediment, which may be detrimental to aquatic organisms.

TURB - Turbidity is a function of the quality and quantity of suspended particulate material in water, usually measured in Nephelometric Turbidity Units as the proportion of incident light scattered at 90 degrees by suspended materials.

NO_x-N - The nutrient Nitrogen may be present simultaneously in water in a number of forms. Nitrate and Nitrite Nitrogen are two of the component forms of Nitrogen compounds as they occur in water. Their concentration is measured in mg/l. They may be introduced directly to waters from excessive use of nitrogenous fertilisers and in treated sewage effluents. They are also produced in receiving waters as a result of nitrification of Ammonia (NH_3).

TKN - Total Kjeldahl Nitrogen is a measure of the component form of nitrogenous compounds existing in water, consisting of Ammonia and Organic Nitrogen. Ammonia is a toxic substance to fish and other aquatic life forms. It is unstable and is broken down by bacteria into nitrite and then into nitrate. These processes require dissolved oxygen.

Organic Nitrogen is primarily derived from the amino acids present in living tissue and may come from sources such as plant matter, faecal matter in sewage or food wastes. In the presence of oxygen it is readily degraded by bacteria into Ammonia.

TOT. N - Total Nitrogen consists of all nitrogenous compounds present in water - Organic Nitrogen, Ammonia Nitrogen, Nitrite and Nitrate Nitrogen, measured in mg/l.

O.P. - Phosphorus is another essential nutrient and is important in regard to the eutrophication (over enrichment) of water bodies. Orthophosphate (O.P.) is the primary nutrient necessary for the growth of aquatic plants (algae). It can originate from the use of phosphate fertilisers but the major non-natural source is domestic sewage where it comes from proteinaceous wastes and detergent additives.

TOT. P - The total phosphorus concentration consists of orthophosphate plus additional phosphorus which may be bound to sediments within the water column.

pH - The pH is a measure of the alkalinity or acidity of water. The pH scale ranges from 0 to 14 with the midpoint indicating neutrality. A pH value less than 7 is acidic. Each unit change in the pH value expresses a change of 10 times the preceding state. Thus water of pH 5 is 10 times more acidic than water with a pH of 6.

TABLE A15.1
WATER QUALITY RESULTS - SITE 1 (RIVER ENTRANCE)

DATE	SECCHI (m)	DEPTH (m)	SAL. (g/l)	TEMP. (^{0}C)	D.O. (% sat).	N.F.R. (mg/l)	TURB. (NTU)	NO_x-N (mg/l)	TKN (mg/l)	TOT.N (mg/l)	O.P. (mg/l)	TOT.P (mg/L)	pH.
27/10/83	-	0.5	33.7	23.0	118	3.2	-	<.01	.22	.22	<.01	.05	8.2
		4	34.8	22.6	106								
31/10/83	-	0.5	16.8	25.5	95	3.9	-	<.01	.48	.48	<.01	.04	7.8
		4	17.4	25.1	89	-	-	-	-	-	-	-	-
17/1/84	-	0.5	29.7	23.6	93	7.6	-	.01	.17	.18	.01	.10	7.8
19/12/90	1.8	0.2	35	23.5	100	2.6	2.6	<.01	<.1	<.1	<.01	.29	-
		1	35	23	99	-	2.5	-					
		2	35	23	101	-	1.7	-					
		3	35	22.5	101	-	1.4	-					
		4	35	22.5	101	-	1.4	-					
		5	35	22.5	101	-	1.4	-					
7/2/91	1.2	0.1	26	27.9	83	-	2.1	-	-	0.01	-	.03	8
		1	26.5	27.9	83	-	2.3	-	-	-	-	-	-
		2	26.5	27.8	82	-	2.6	-	-	-	-	-	-
		3	26.5	27.8	81	-	2.3	-	-	-	-	-	-
		4	26.5	27.7	85	-	3.0	-	-	-	-	-	-
21/2/91	0.8	0.2	16.8	26.1	91	-	7	-	-	-	-	-	7.9
		1	17.7	26.1	91	-	9	-	-	-	-	-	7.9
		2	19.9	26.0	92	-	9	-	-	-	-	-	8.0
		3	21.2	25.9	93	-	9	-	-	-	-	-	8.0
		4	21.7	25.9	93	-	7	-	-	-	-	-	8.0
		5	24.6	25.9	95	-	7	-	-	-	-	-	8.1
		6	26.8	25.9	99	-	8	-	-	-	-	-	8.1
8/1/92	1.4	0.2	18.5	27.0	74.4	-	9	-	-	.70	-	.04	7.77
		2.0	18.6	27.3	76.2	-	10	-	-	-	-	-	7.78
		4.0	19.1	27.3	76.4	-	9	-	-	-	-	-	7.80
		5.0	19.2	27.3	83.4	-	8	-	-	-	-	-	7.80
6/2/92	2.7	0.2	34.70	26.90	93.0	-	1.6	0.04	<0.01	.04	-	.02	8.30
		0.7	34.71	26.91	94.0	-	1.4	-	-	-	-	-	8.30
		1.8	34.82	26.76	94.3	-	1.0	-	-	-	-	-	8.29
		2.9	84.95	26.64	95.1	-	0.5	-	-	-	-	-	8.29
		3.9	34.96	26.64	95.3	-	0.5	-	-	-	-	-	8.30
		4.9	34.98	26.64	95.6	-	0.2	-	-	-	-	-	8.30
		5.9	34.99	26.66	95.6	-	0.5	-	-	-	-	-	8.30
4/3/92	2.6	0.2	20.5	25.6	99.7	-	7	-	-	-	-	-	8.06
		2.0	31.9	25.5	108.1	-	2	-	-	-	-	-	8.11
		4.0	32.3	25.5	112.0	-	2	-	-	-	-	-	8.12
		6.0	32.4	25.5	110.7	-	2	-	-	-	-	-	8.13

TABLE A15.2
WATER QUALITY RESULTS - SITE 3 (ROCKY POINT)

DATE	SECCHI (m)	DEPTH (m)	SAL. (g/l)	TEMP. (°C)	D.O. (% sat).	N.F.R. (mg/l)	TURB. (NTU)	NO_x-N (mg/l)	TKN (mg/l)	TOT.N (mg/l)	O.P. (mg/l)	TOT.P (mg/L)	pH.
19/12/90	2.7	0.2	34	23	102	10	1	<.01	<.1	<.1	<.01	.05	-
		1	34.5	22.5	101	-	0.9	-	-	-	-	-	-
		2	34.5	22.5	102	-	0.9	-	-	-	-	-	-
		3	34.5	22.2	100	-	1	-	-	-	-	-	-
7/2/91	1.4	0.2	28	27.6	86	-	2.2	-	-	0.9	-	.01	8
		1	28	27.6	84	-	2.3	-	-	-	-	-	-
		2	28	27.6	84	-	2.5	-	-	-	-	-	-
21/2/91	1.0	0.2	21.2	25.8	97	-	7	-	-	-	-	-	8
		1	22.4	25.8	94	-	6	-	-	-	-	-	8
		2	24.8	25.8	96	-	6	-	-	-	-	-	8
		3	30.2	25.8	104	-	5	-	-	-	-	-	8.1
8/1/92	1.8	0.2	21.2	26.8	76.7	-	7	-	-	0.93	-	.05	7.86
		2.0	2.13	27.0	78.4	-	7	-	-	-	-	-	7.87
		3.0	21.8	27.0	78.6	-	8	-	-	-	-	-	7.87
6/2/92	3.5	0.2	35.03	26.81	95.3	-	0	0.04	<0.01	.04	-	.02	8.3
		1.0	35.11	26.58	95.5	-	0	-	-	-	-	-	8.3
		1.8	35.13	26.52	95.4	-	0	-	-	-	-	-	8.3
		2.8	35.17	26.33	95.2	-	10	-	-	-	-	-	8.3
4/3/92	<4.0	0.2	33.1	25.4	112.1	-	0	-	-	-	-	-	8.16
		2.0	33.2	25.5	107.6	-	1	-	-	-	-	-	8.15
		4.0	33.2	25.5	107.6	-	1	-	-	-	-	-	8.15

APPENDIX 16

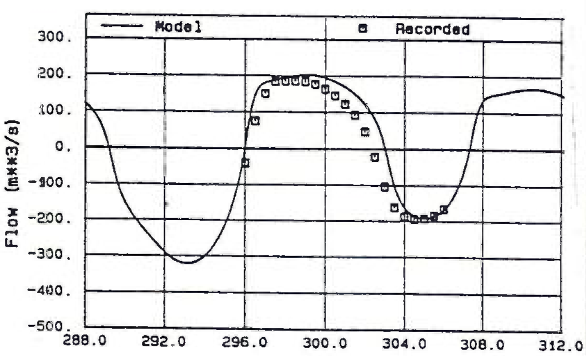
MIT-DNM WATER QUALITY MODELLING PROGRAM

MIT-DNM

FOR MODELLING WATER MOVEMENT AND WATER QUALITY IN RIVERS, CHANNELS AND ESTUARIES

MIT-DNM is a one-dimensional, transient and variable cross-sectional area, hydrodynamic and water quality model. It is designed to simulate tidal and riverine hydrodynamics, and associated salinity and water quality in river/estuarine networks. The model is capable of simulating the tidal and salinity dynamics in a network of estuarine reaches in a linked format ie. the salinity/density gradient is integrated within the hydrodynamic solution scheme. The MIT-DNM model has been used in numerous engineering investigations both in Australia and overseas.

The MIT-DNM model is based on the one-dimensional and transient equations of continuity, momentum and mass conservation. The model is organised around two basic components: hydrodynamic and water quality. The model solves the continuity and longitudinal momentum equations which are coupled to the salt mass equation through a state equation which describes the relationship between salinity and density.



MIT-DNM MODEL
HYDRAULIC DATA

Longitudinal dispersion within the water quality component of the model is formulated as the sum of the effects of density - induced circulation, and those of cross-sectional deviations in concentration and velocity. Thus the influence of salt-wedge type influences on saline penetration into an estuary following a freshwater flow event, and the interplay between salt movement, and freshwater baseflows can be simulated.

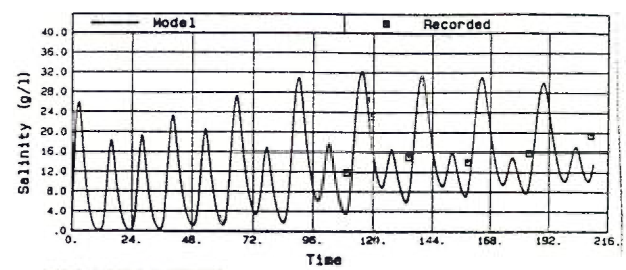
The model uses a finite element technique for the numerical solution of the governing equations. This technique provides a means to discretise the domain of interest into unequal segments, thus making it possible to increase the spatial resolution of concentration profiles within a river or estuary where the gradients of such concentrations are relatively steep. Furthermore, it provides the means to better schematise a riverine or estuarine system with a dendritic shoreline.

Water quality model simulations can be performed for some or all of the following parameters:

- salinity,
- temperature,
- BOD/DO,
- nutrients, and
- chlorophyll a.

Inter-relationships between some or all of the above parameters, with appropriate reaction coefficients, are simulated.

Output from the model includes instantaneous water surface elevations, flow velocities, and water quality constituent concentrations at any location throughout the simulated network.



MIT-DNM MODEL
SALINITY DATA

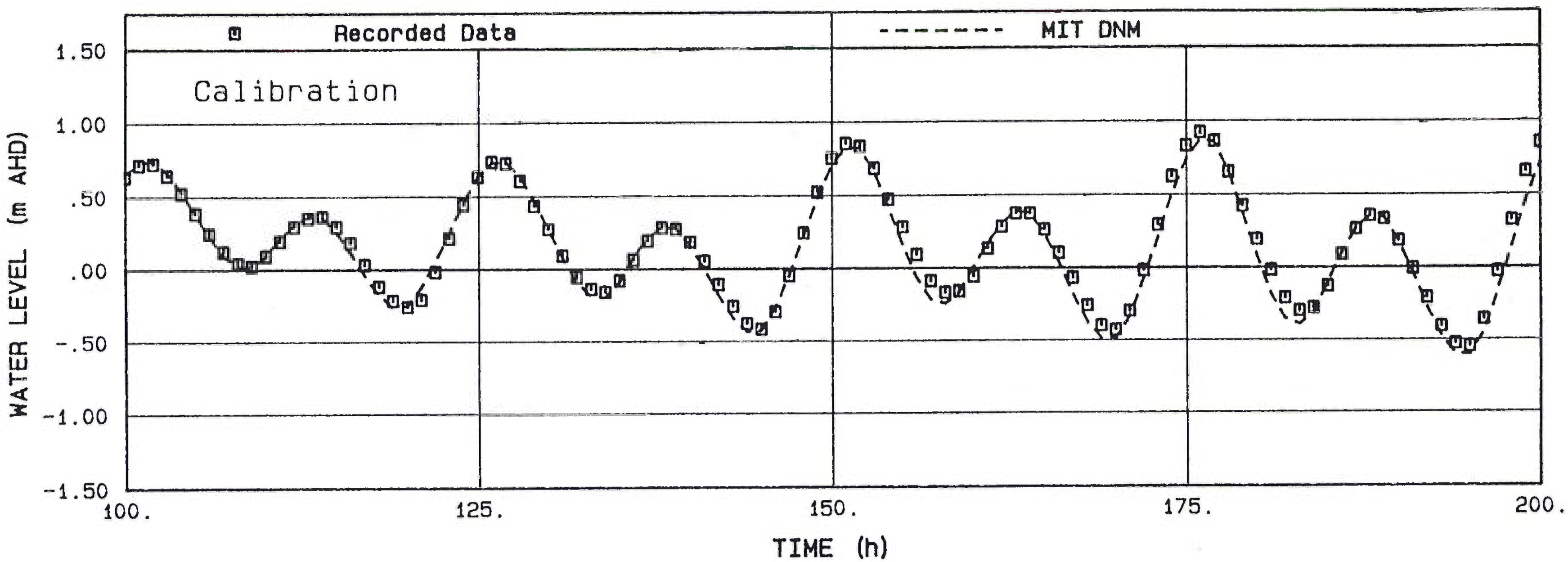
References:

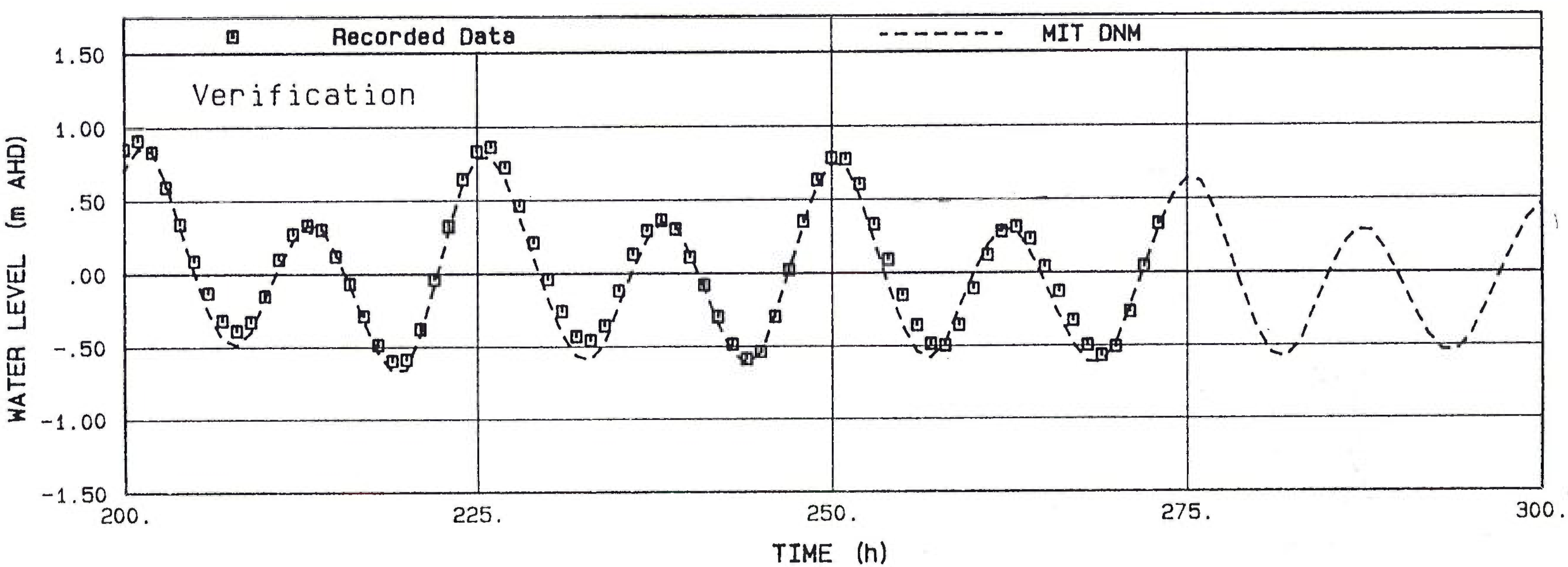
Harleman D.R.F. et.al. (1977), Users Manual for the M.I.T. Transient Water Quality Network Model, USEPA -600/3-77-010, January 1977

APPENDIX 17

WATER QUALITY MODEL CALIBRATION

MIT DNM MODEL HYDRAULICS - LEVELS
Letitia 2A





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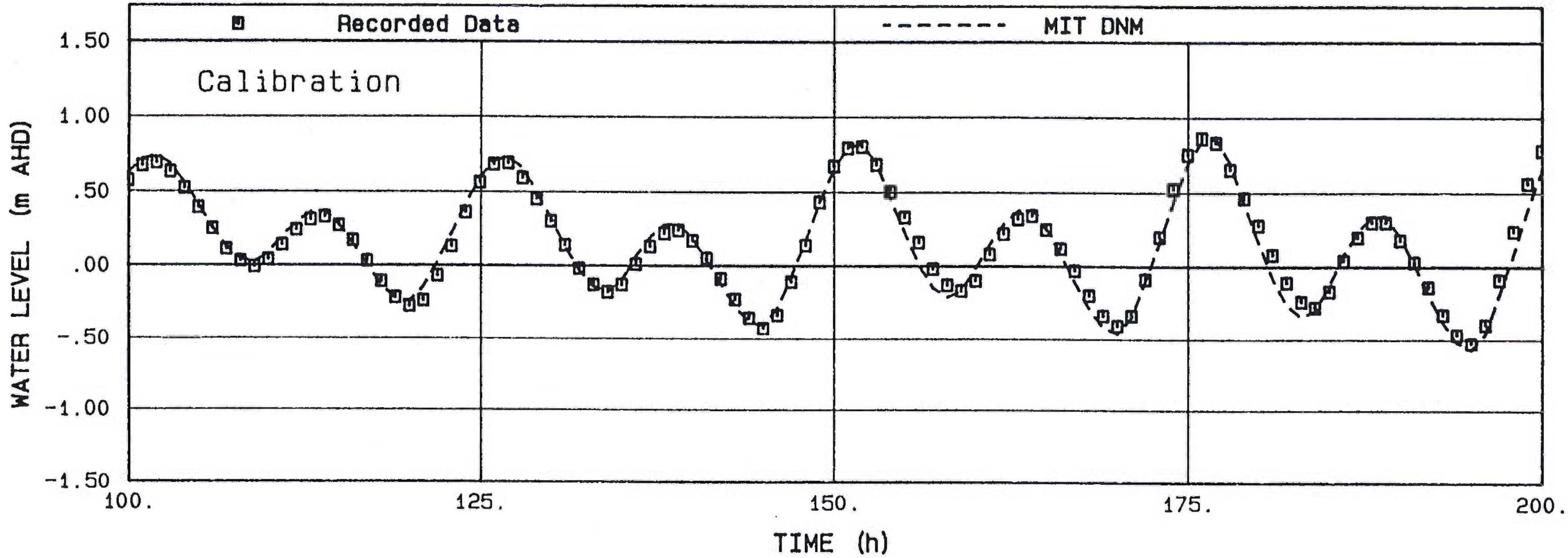
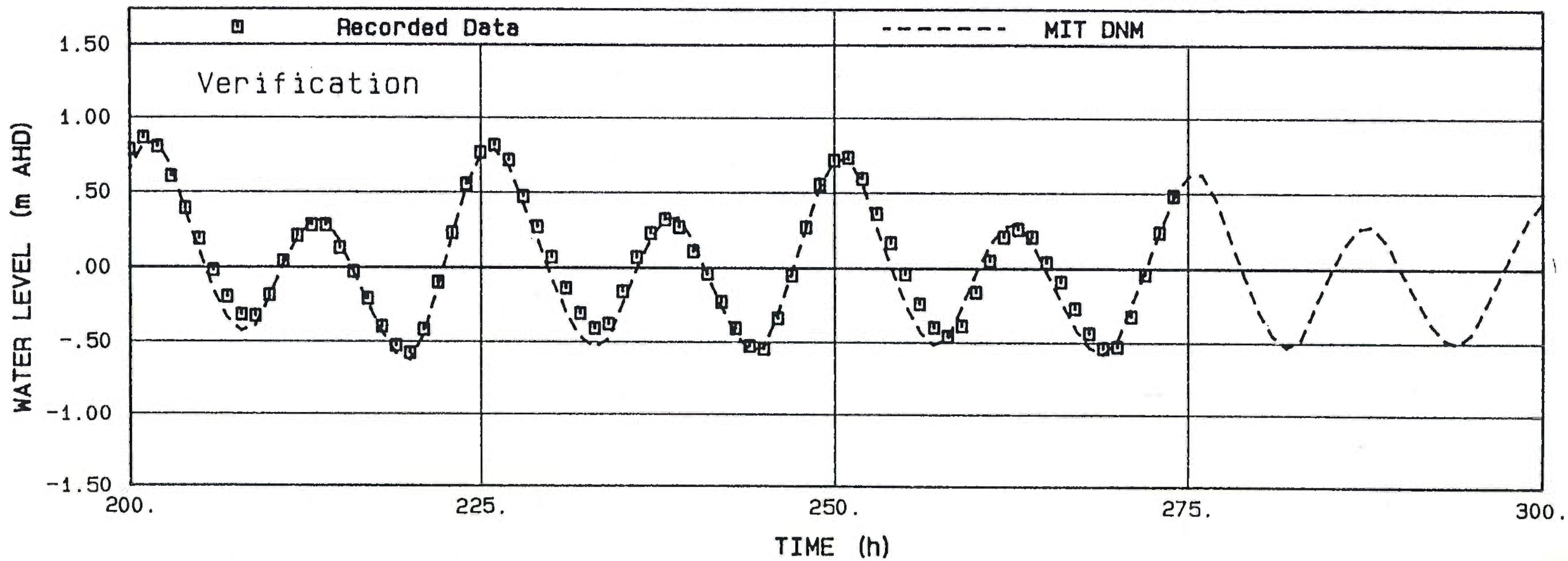
Letitia 2B





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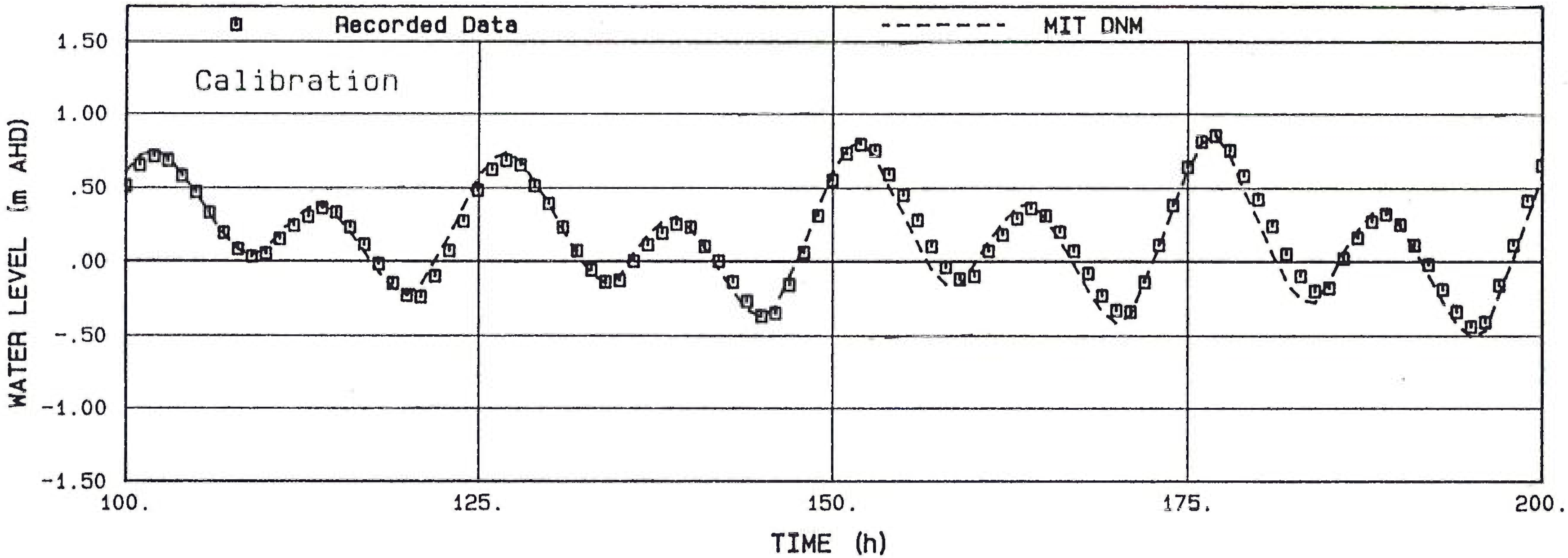
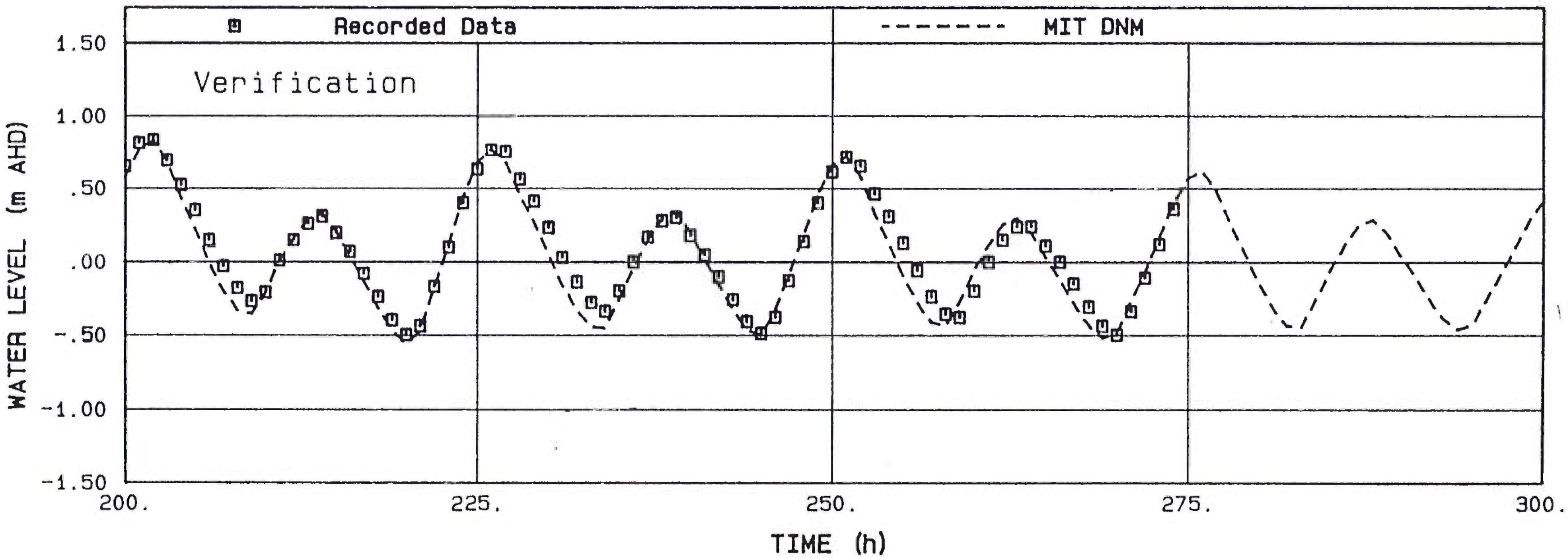
Barneys Point





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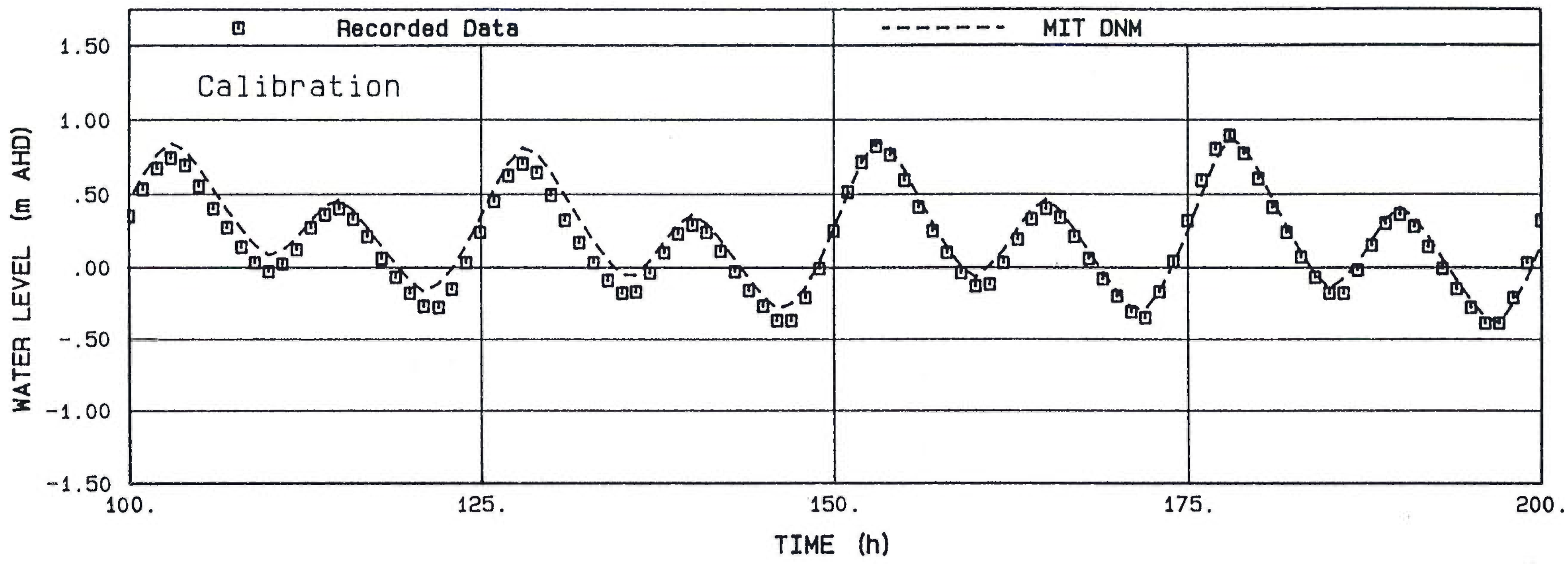

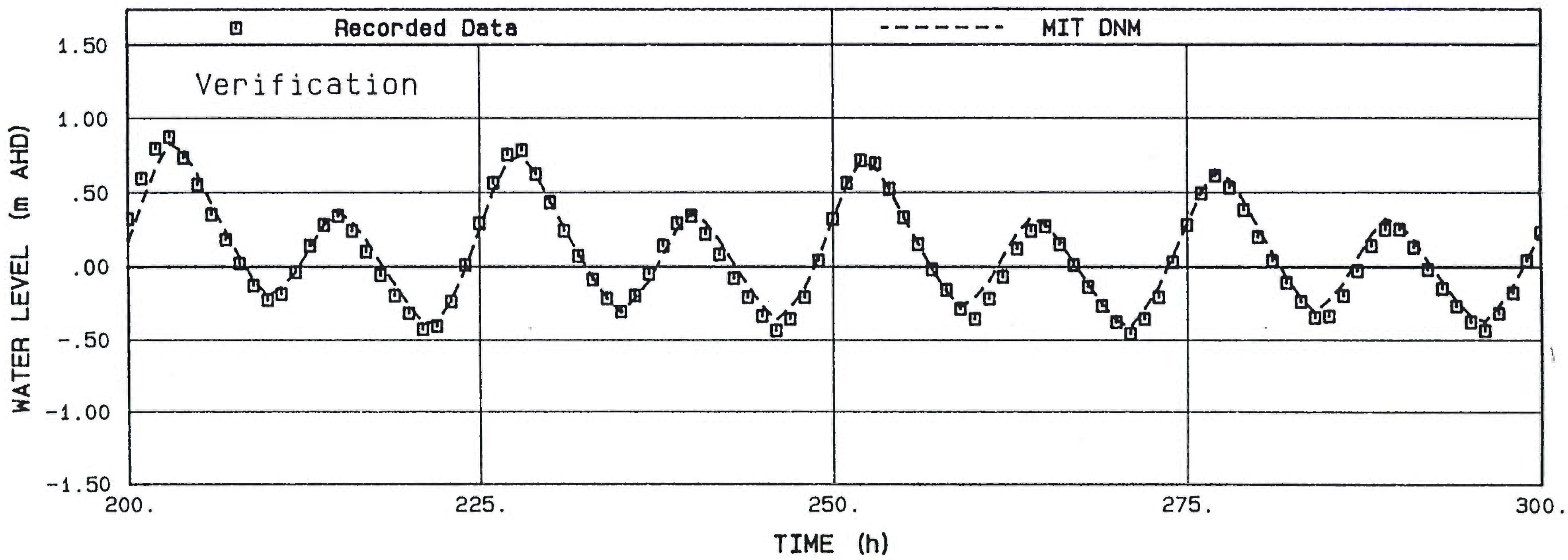

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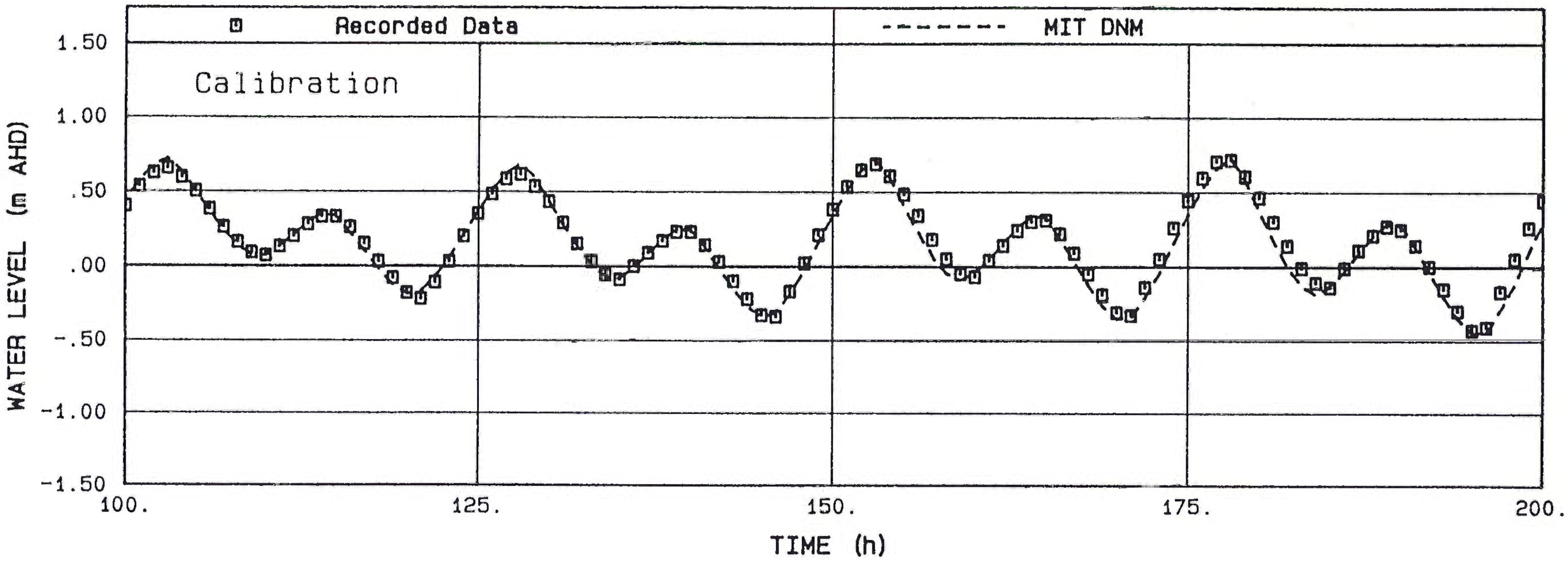
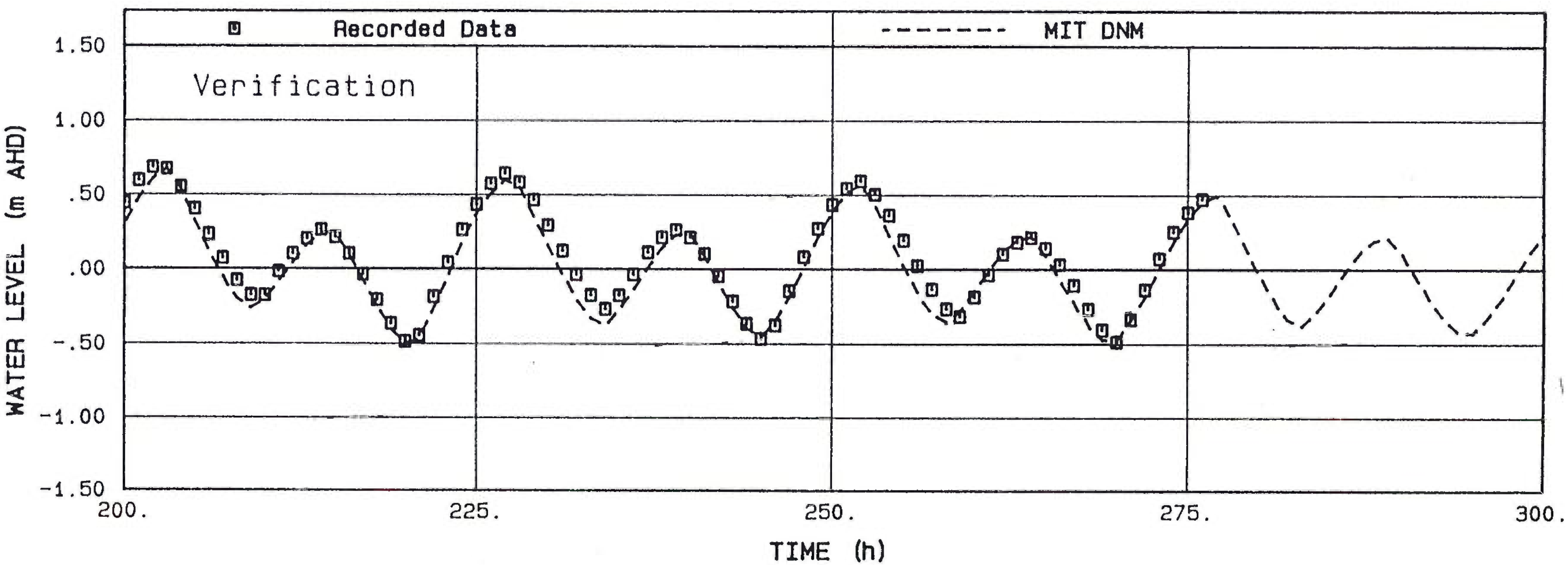
Dry Dock





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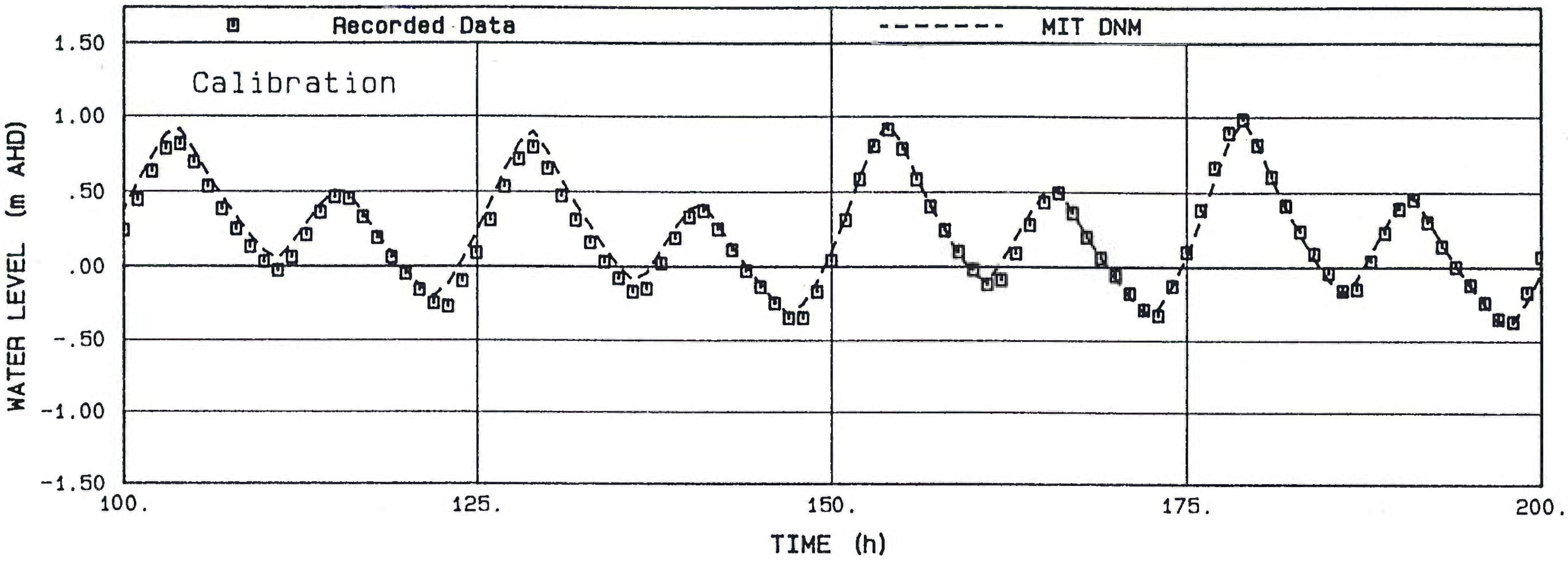
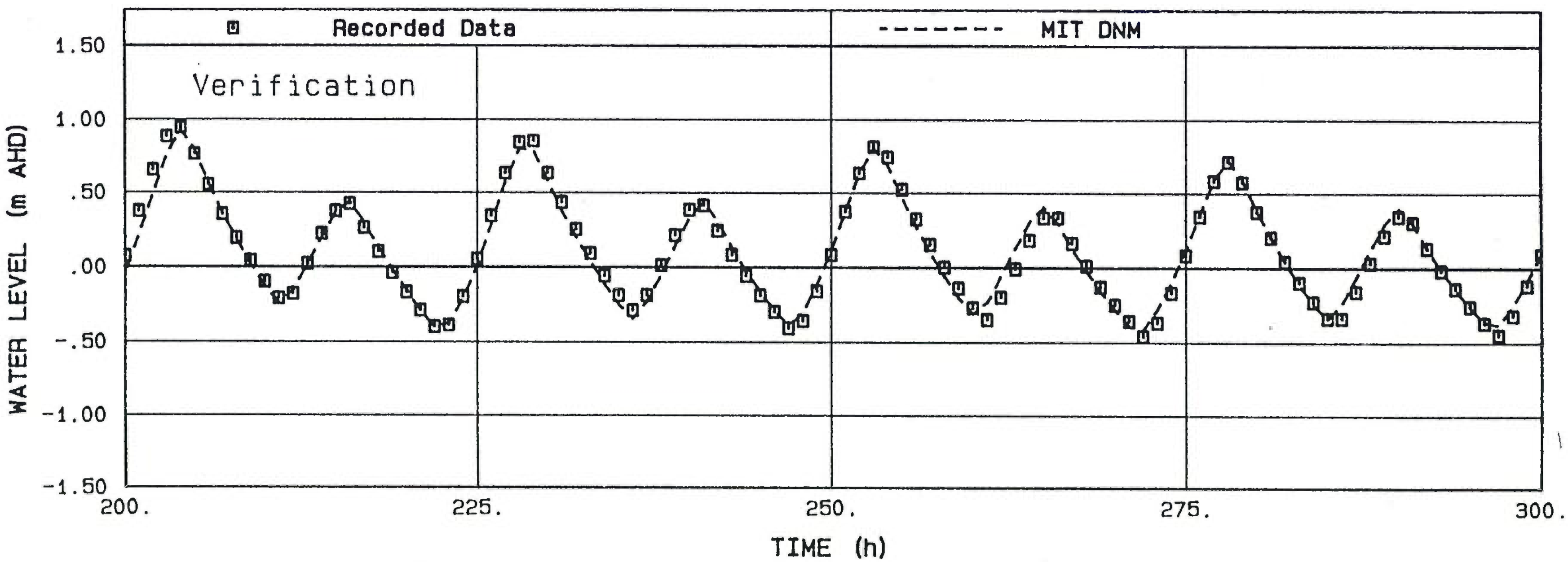
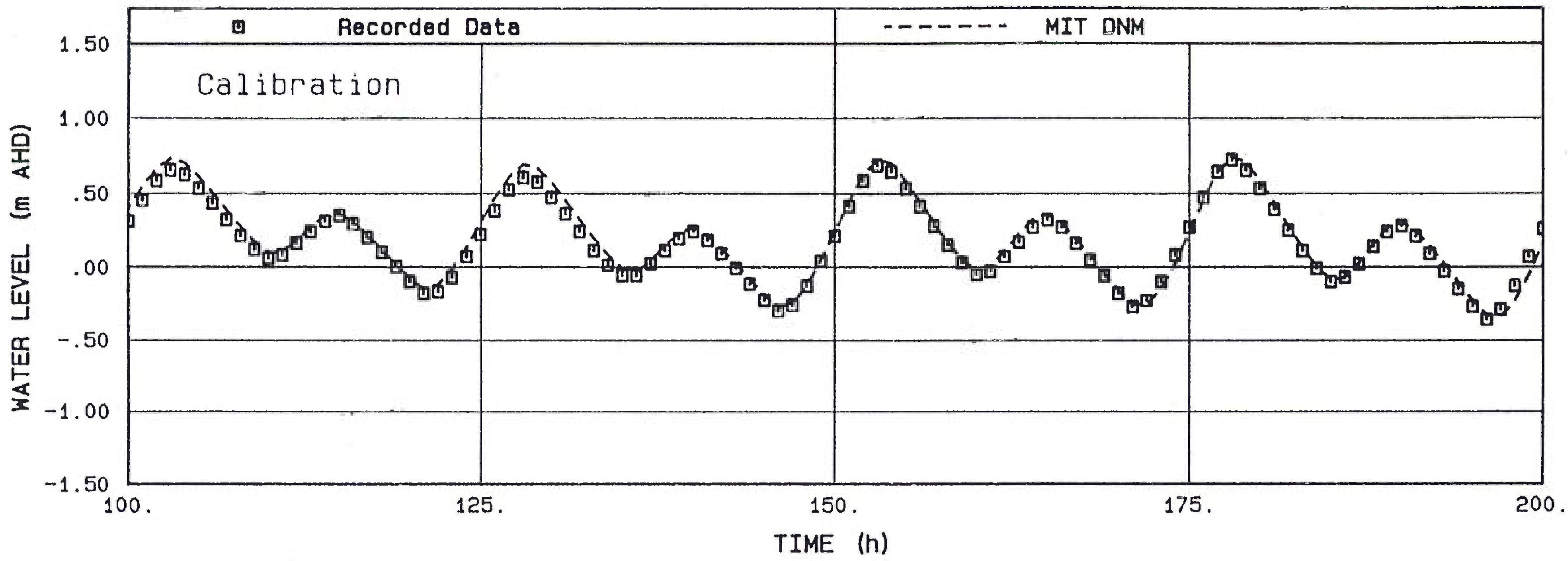
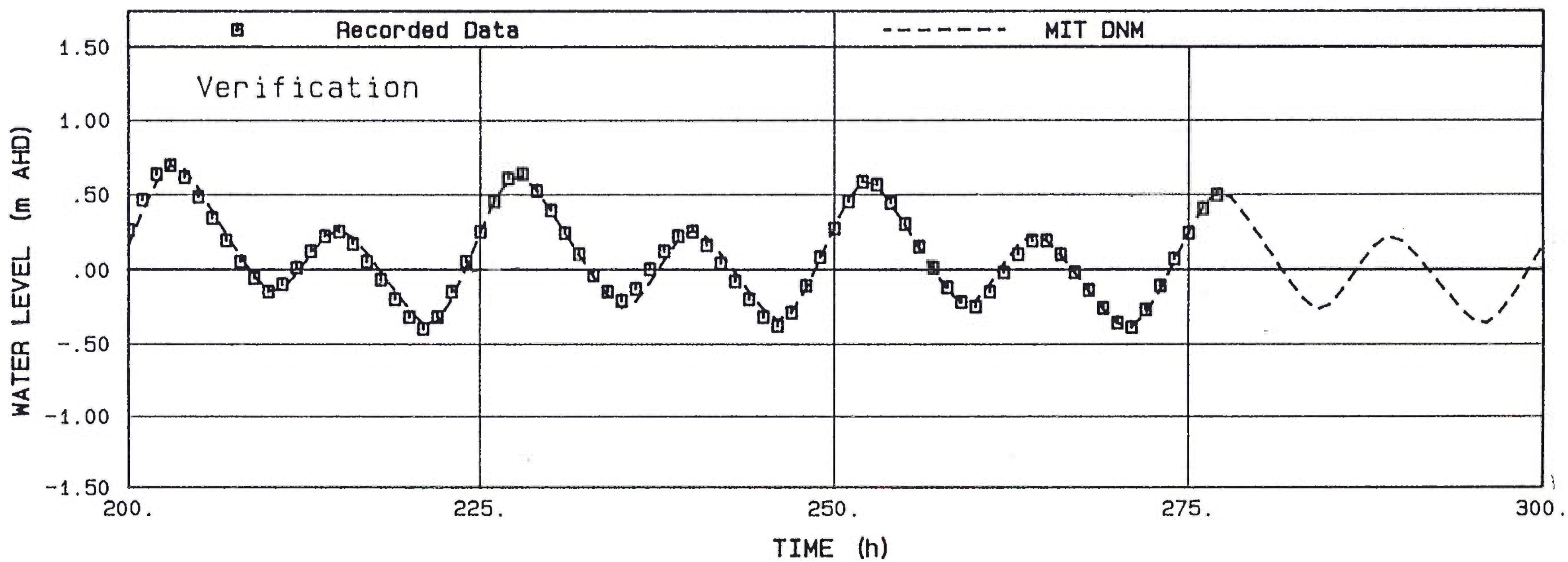




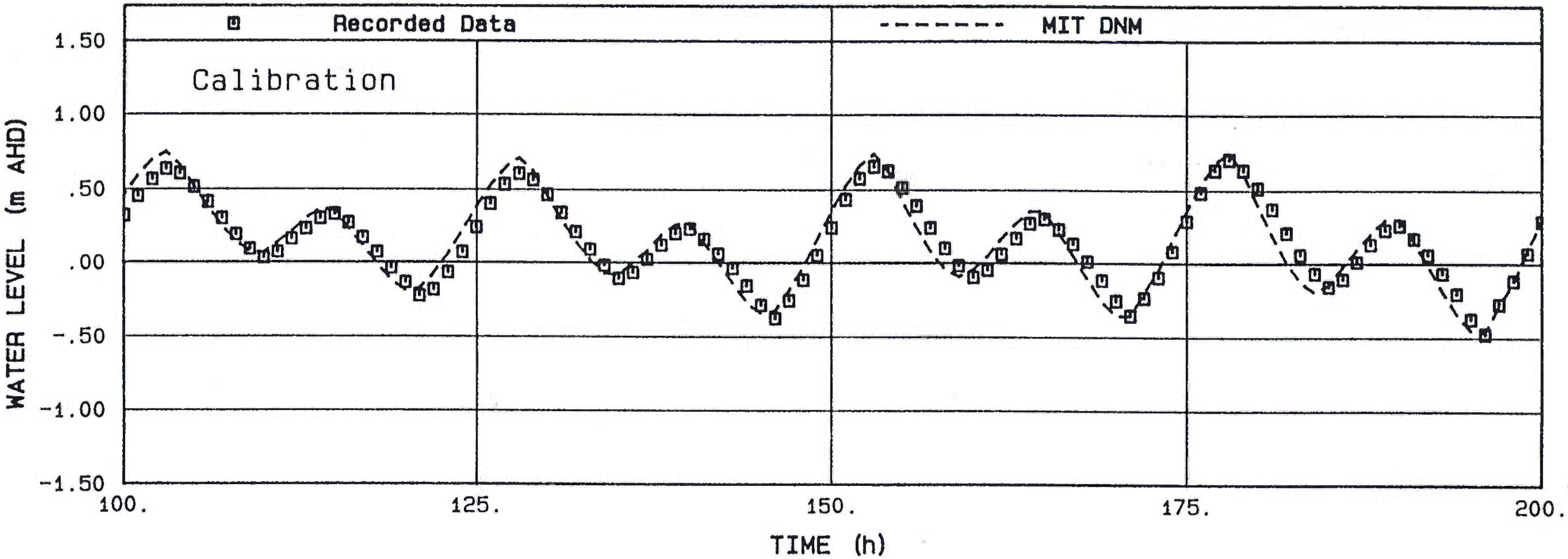


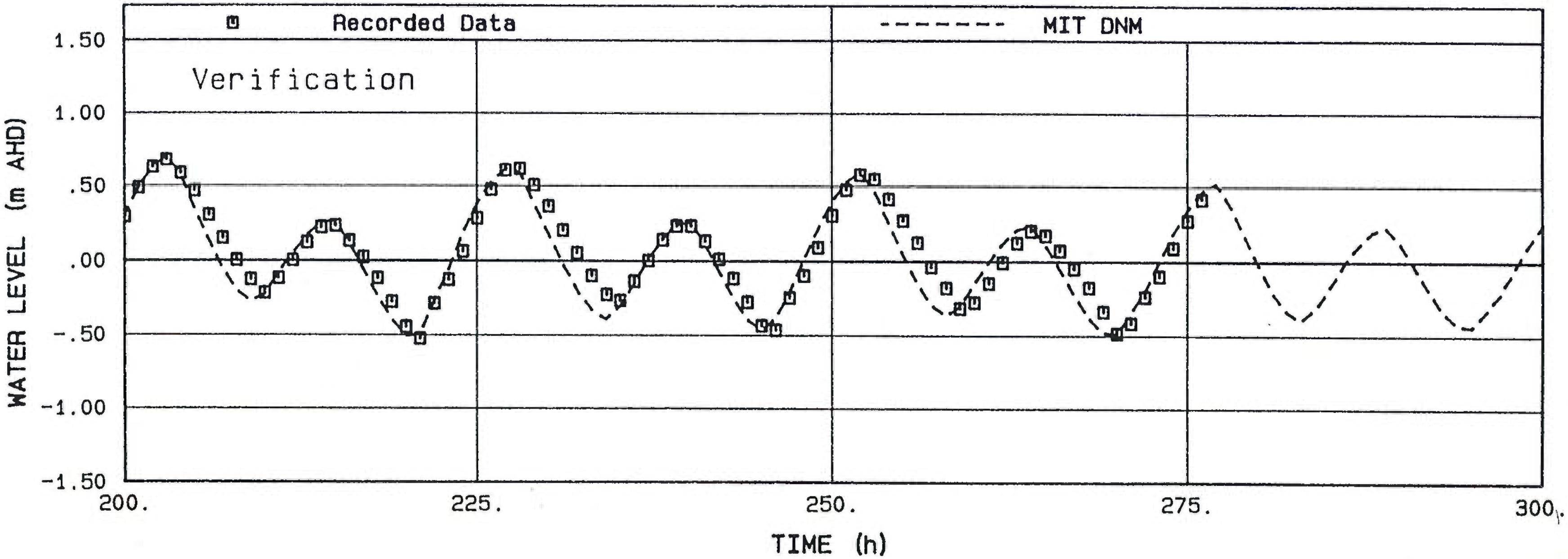


MIT DNM MODEL HYDRAULICS – LEVELS
Terranora

FIGURE

MIT DNM MODEL HYDRAULICS - LEVELS
Cobaki





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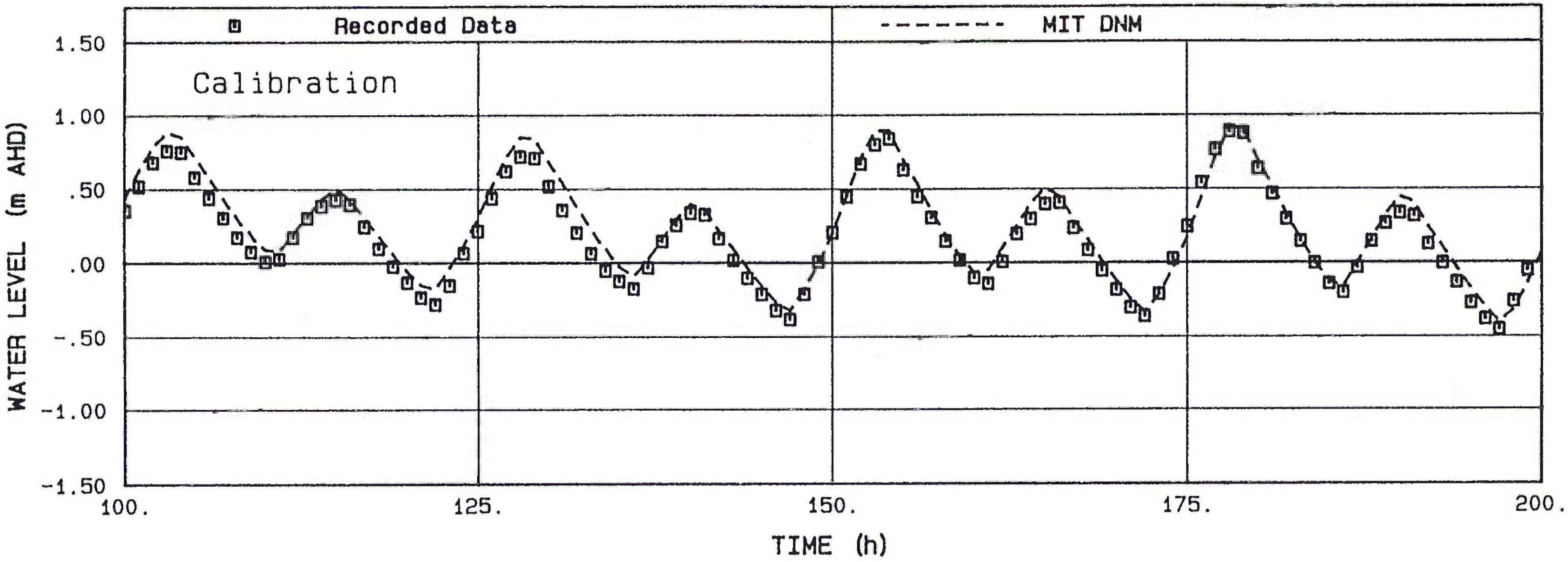
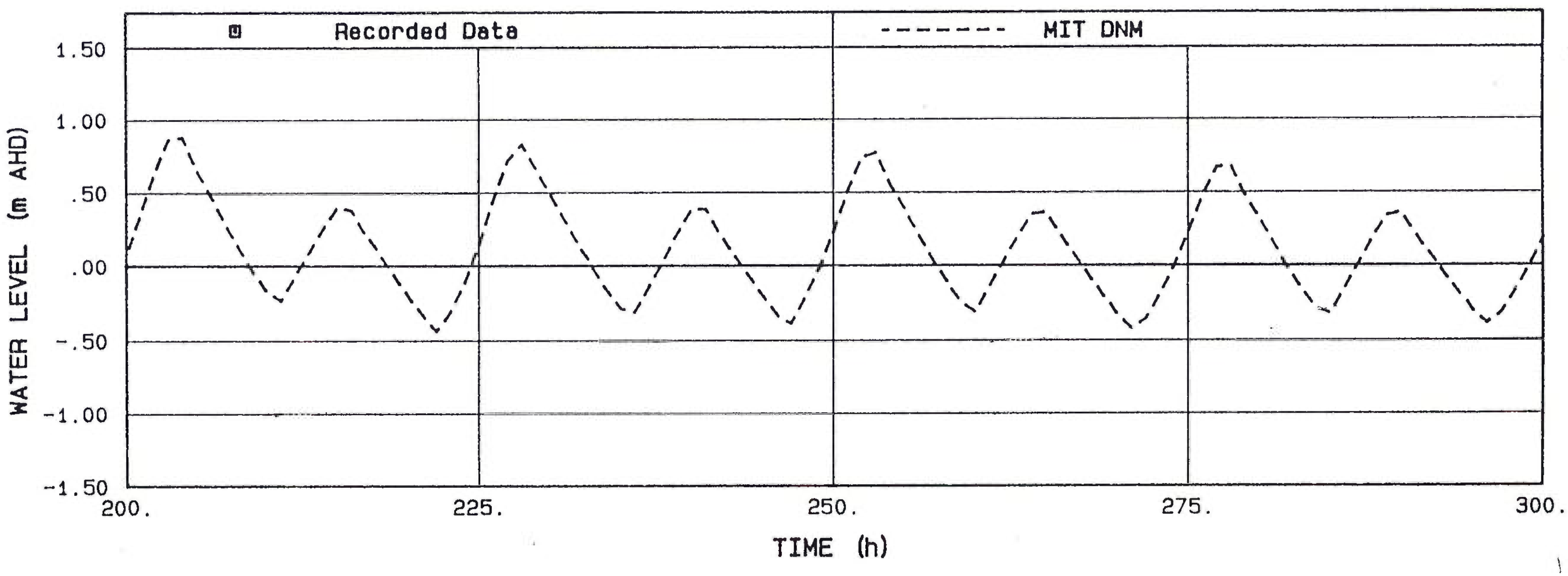
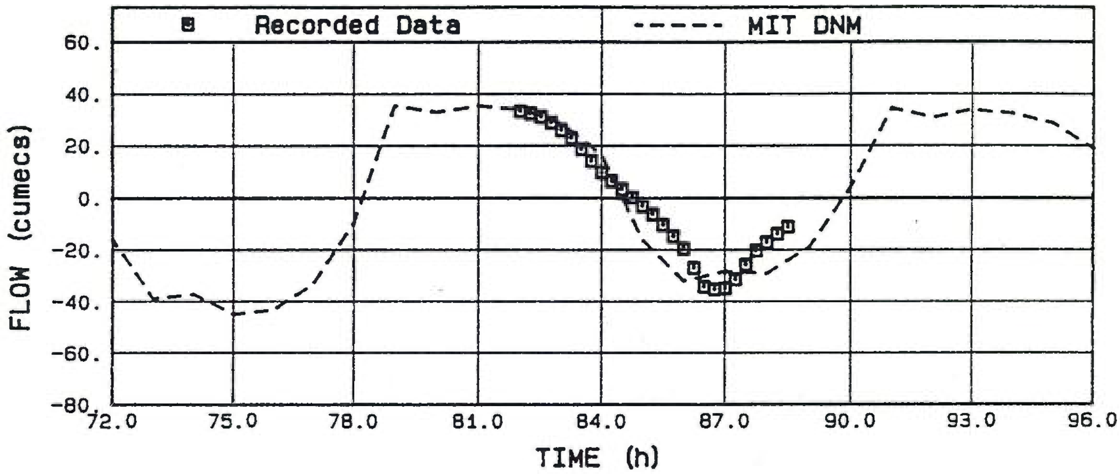
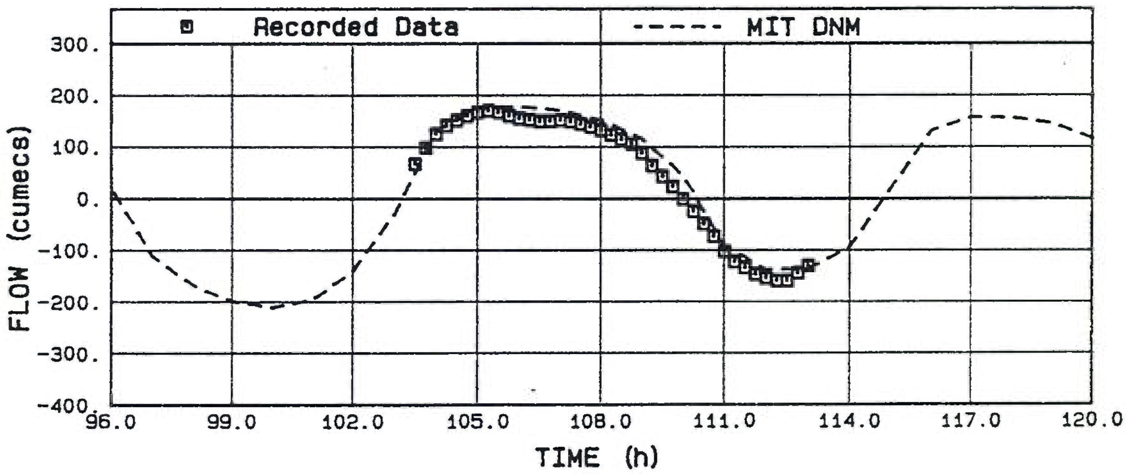
Murwillumbah



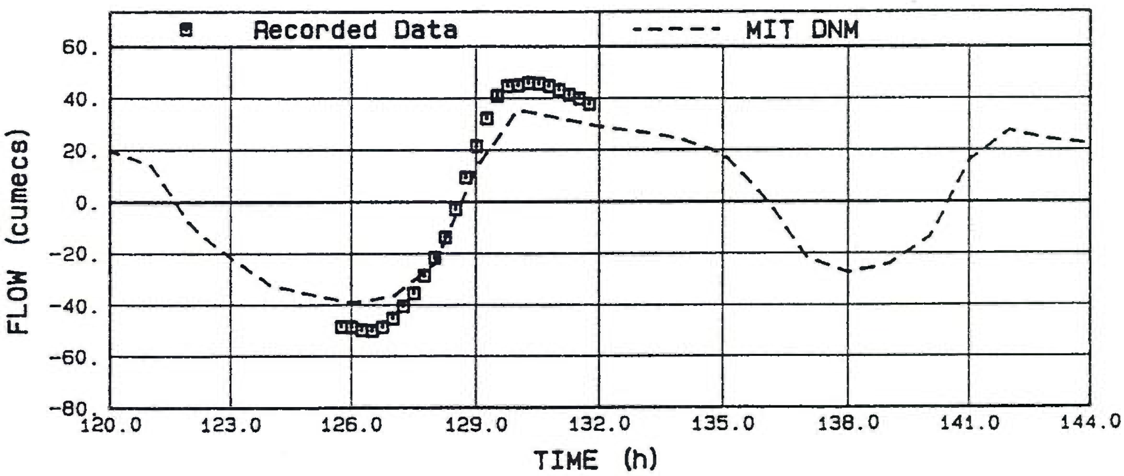




Condong



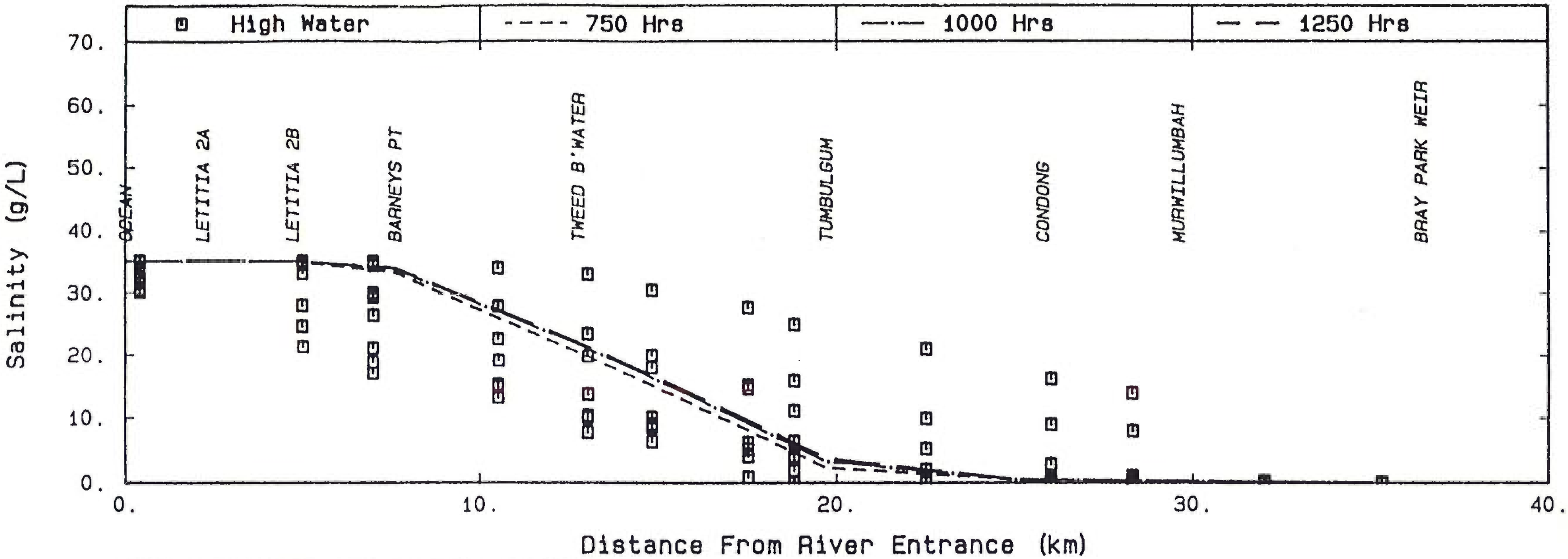
U/S of Dodds Island



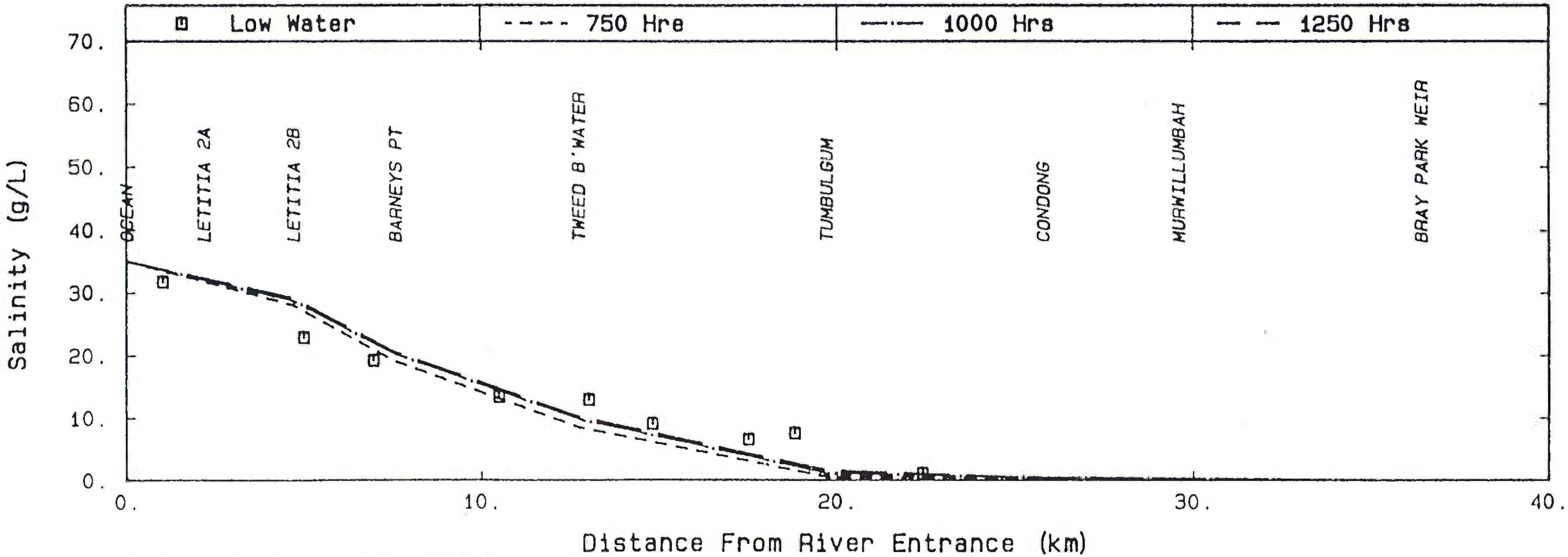
Rous River

MIT DNM MODEL HYDRAULICS - FLOWS

MIT DNM MODEL VERIFICATION
TIDAL EXCURSION OF SALINITY PROFILE



HIGH WATER SALINITY SURVEY



LOW WATER SALINITY SURVEY

APPENDIX 18

SEDIMENT CONTAMINANT ANALYSIS

Simmonds & Bristow Pty. Ltd. (Inc. in Qld)
A.C.N. 010 252 418

Analysts & Consultants to the Water Industry

30 Shottery Street,
Yeronga, Queensland,
Australia, 4104.
Telephone: (07) 848 7699
Fax No.: (07) 892 3345

Ref. NO. 18809/18809B
WBM LTD

ANALYSIS OF SEDIMENT SAMPLES
JOB NO. 7278

Sampled By: Client

S & B METHOD NO.	SAMPLE DESCRIPTION DATE RECEIVED SAMPLE REGD. NO.	1 4.12.91 66942	2 4.12.91 66943	3 4.12.91 66944	4 4.12.91 66945	5 4.12.91 66946	6 4.12.91 66947	7 4.12.91 66948	- .75 m 17.12.91 67482
WC405.11	Total oil & grease mg/kg dry wt	81.	35.	43.	61.	16.	78.	54.	120.
OS010	Cadmium mg/kg dry wt	<0.2	<0.2	<0.4	<0.2	<0.3	<0.1	<0.3	<0.2
"	Chromium mg/kg dry wt	6.4	1.1	13.	7.3	1.0	2.5	1.7	1.1
"	Lead mg/kg dry wt	2.6	0.6	4.6	3.6	0.8	1.2	1.2	0.9
"	Zinc mg/kg dry wt	57.	21.	83.	50.	28.	18.	24.	17.
WC065.	Mercury mg/kg dry wt	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
OS020	Dieldrin mg/kg wet wt	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	DDE mg/kg wet wt	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
G030.	Moisture Content %	24.	14.4	34.9	30.2	14.1	21.4	16.7	20.5

SIMMONDS & BRISTOW PTY. LTD

PER. ....

29th January 1992

Simmonds & Bristow Pty. Ltd. (Inc. in Qld)
A.C.N. 010 252 418

Analysts & Consultants to the Water Industry

30 Shottery Street,
Yeronga, Queensland,
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Sampled By: Client

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"	Lead mg/kg dry wt	2.6	0.6	4.6	3.6	0.8	1.2	1.2	0.9
"	Zinc mg/kg dry wt	57.	21.	83.	50.	28.	18.	24.	17.
WC065.	Mercury mg/kg dry wt	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
OS020	Dieldrin mg/kg wet wt	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	DDE mg/kg wet wt	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
G030.	Moisture Content %	24.	14.4	34.9	30.2	14.1	21.4	16.7	20.5

SIMMONDS & BRISTOW PTY. LTD

PER. [signature] ....

29th January 1992

APPENDIX 19

FLORA AND FAUNA OF FINGAL PENINSULAR NEAR AREA 5

Vegetation in the area falls into the four following categories:

- mangroves
- swamp oak forest
- horsetail oak/bitou bush community
- succession community

Mangroves occur at the northern end of the area around the southern shores of Wommin Lagoon. Swamp oak forest fringes the northern shores of Wommin Lake at the southern end of the area. The front dune behind Dreamtime Beach was sandmined and now supports horsetail oak and bitou bush. The remainder of the area is only sparsely vegetated and is referred to below as a succession community.

Mangroves

Mangrove vegetation occurs around the southern shores of Wommin Lagoon (Figure 3.19. *Avicennia marina* (grey mangrove) is the numerically dominant mangrove species, but also present are *Rhizophora stylosa* (red mangrove), *Bruguiera gymnorhiza* (orange mangrove), *Aegiceras corniculatum* (river mangrove) and *Excoecaria agallocha* (milky mangrove). The largest trees are *Avicennia marina*, which are 4 to 6 m tall, branch close to the ground, and form a broad canopy relative to their height.

Small areas (each less than $30m^2$) of rush vegetation fringe the landward edge of the mangroves, including *Juncus kraussii* (sea rush), *Baumea juncea* (bare twigrush), *Isolepis nodosa* (knobby club rush) and *Fimbristylis ferruginea* (fringe rush). These areas of rush are probably tidally inundated only a few times a year on very high tides, but are included as mangrove vegetation in Figure 3.19. Many of the introduced plant species listed below are colonising the southern, landward edges of the rush vegetation.

Mangroves and associated estuarine wetland vegetation are accorded a high conservation value in the Tweed Shire, as they are not well represented in National Parks and similar reserves in New South Wales (Briggs and Leigh 1988, Specht et al. 1974).

Swamp Oak Forest

Swamp oak (*Casuarina glauca*) forms a narrow band of forest vegetation 3 to 5 m in width around the northern shores of Wommin Lake. Swamp oak is numerically dominant in the overstorey, though the paperbark teatree (*Melaleuca quinquenervia*) also occurs albeit in smaller numbers.

A shrub layer is generally absent. Ground vegetation, where it occurs, is dominated by grasses, sedges and rushes including those listed in the mangrove section above. Swamp oak forest is also of high conservation value in the Tweed Shire.

Horsetail Oak - Bitou Bush Community

Horsetail oak (*Casuarina equisetifolia*) and bitou bush (*Chrysanthemoides monilifera*) are the numerically dominant species along the front dune behind Dreamtime Beach. This area, along with much of the other dune areas of Fingal Peninsula, was sandmined then re-vegetated with these two species (Graham 1990).

Bitou bush was accidentally introduced to New South Wales around the turn of the century. It was used in sandmining rehabilitation because of its ability to establish in disturbed coastal environments. Now, however, it is regarded as a pest species because it readily colonises undisturbed native plant communities.

The horsetail oak/bitou bush community is well established and appears to have successfully stabilised the front dune. However, while this man-made community persists it prevents the native plant communities from re-colonising the area.

Succession Community

A sparsely treed succession community occurs between Fingal Road and the frontal dune. Aerial photography from 1982 shows the area as bare sand with a few scattered trees. In 1991 most areas have a relatively continuous ground cover, except along the many off-road vehicle tracks that traverse the area.

Tree cover is very sparse and introduced plants are numerous. Trees present include *Banksia integrifolia* (coast banksia), *Casuarina glauca* (swamp oak), *Casuarina equisetifolia* (horsetail oak), *Hibiscus tiliaceus* (cotton tree) and *Macaranga tanarius* (heart leaf). A native mistletoe *(Amyema cambagei)* grows on some of the *C. glauca* trees.

Shrub species include *Acacia sophorae*, *Leptospermum laevigatum* (coast tea-tree) and three introduced species, *Baccharis halimifolia* (groundsel bush), *Lantana camara* (lantana) and *Chrysanthemoides monilifera* (bitou bush). The latter species was used to revegetate sand-mined areas on the Fingal Peninsula, along with the native tree *Casuarina equisetifolia* (Graham 1990).

The ground cover is a mixture of native and exotic species of grasses, herbs and scrambling plants including:

Phragmites australis	(common reed, cosmopolitan*)
Imperata cylindrica	(blady grass, cosmopolitan*)
Ipomoea cairica	(coast morning glory, native of tropical Africa)
Bryophyllum tubiflorum	(mothers of millions, native of southern Africa)
Tagetes minuta	(stinking roger, native of south America)
Macroptilium atropurpureum	(siratro, native of central America and southern USA)
Crotalaria pallida	(streaked rattlepod, native of Africa)
Rhynchelytrum repens	(Red Natal grass, native of Africa)
Melinus minutiflora	(molasses grass, native of tropical Africa)
Carpobrotus glaucescens	(pigface, native)
Ambrosia artemisiifolia	(annual ragweed, native of north America)
Eragrostis tenuifolia	(elastic grass, cosmopolitan of tropical areas)
Chloris gayana	(Rhodes grass, native of Africa)
Saccharum officinarum	(sugar cane, a grass of subtropical and tropical New Guinea, India, China and South-east Asia).

* Occurs naturally on several continents

The succession community area has been highly disturbed in the past, and is still subject to disturbance by off-road vehicle traffic. This vegetation is of very low fauna conservation value, and of no botanical conservation value.

Rare or Threatened Plants

No rare or threatened Australian plants as set out in Briggs and Leigh (1988) were found in the area.

Potential Fingal Peninsular Sand Stockpile Site

The site identified as potentially acceptable for sand stockpiling has the following characteristics:

- the vegetation is depauperate, the result of clearing and sandmining of the site followed by revegetation with a limited number of plant species

- it is mostly unforested and supports mainly introduced and native grasses and herbs

- it has, until recent times (mid-1991), been subject to continuing disturbance mainly from the indiscriminate driving of cars and motor bikes across the area, severely inhibiting the establishment of vegetation of any value

- no rare plants are present

- the introduced pest species Bitou bush *(Chrysanthemoides monilifera)* is common on the site and its presence restricts the establishment of native plant species

Use of the site for sand disposal could provide an opportunity for the rehabilitation and enhancement of adjacent areas of vegetation. Introduced, weed species, particularly Bitou bush, could be incrementally removed and replaced with native species. The process of its removal would need to be gradual because at present Bitou does contribute to stabilisation of the dunes of Letitia Spit and its sudden removal over a large area could lead to erosion problems.

Rehabilitation or restorative works carried out on the dune vegetation could be carried out in consultation with the local Dune Care group.

APPENDIX 20

FISH NETTING METHODS

Fish Fauna Study Methods

Sampling was conducted in summer (January 1991) and autumn (March 1991) and involved mesh (gill) and haul netting (seining). All sampling was undertaken during the day on flooding tides. Captured fish were identified to species and counted. The length range of each species was measured to the nearest 5mm, fork length (F.L.) if the tail was forked or to total length (T.L.) if it was not. Dasyatids were measured for maximum body width. Netting operations were conducted under a N.S.W. Department of Agriculture and Fisheries permit. In almost all instances fish were released in good condition.

One-way ANOVA (Sokal & Rholf 1969) in conjunction with Duncan's multiple range test (Walpole 1974) was used to test for differences in numbers of individuals, species and the most abundant species at each site with each survey period. A paired t-test was used to compare results from the summer survey with those from the autumn survey. Abundance data were logarithmically transformed prior to statistical analysis because of heterogeneity of variances. Summary statistics are arithmetic. The similarity of species composition between sites was calculated using the Jaccard (1908) similarity index described by Clifford & Stephenson (1975) {$J = x/(s+x)$, where x is the number of co-occurrences of an attribute; s is the sum of non-co-occurring attributes in both samples; J is the co-efficient of similarity; note that co-absences are ignored}.

Mesh Netting

Two Area 5 sites were sampled in summer and autumn. These sites conformed with benthic sampling locations (see Figure Section 3.11.2). Site B2 in Shallow Bay included seagrass areas whereas the remaining sites in Area 5 was on bare substrate. Four 33 m nets were set for 1 - 1.5 hour before retrieval. Each net had a different mesh size to permit capture of a wide size range of fish (25 mm mesh, 3 m deep; 50 mm mesh, 3 m deep; 75 mm mesh, 4 m deep; 100 mm mesh, 4 m deep).

Seine Netting

One site in Area 5 (off Tony's Bar) was sampled in summer and autumn. Few areas suitable for hauling seines occur in the lower Tweed estuary, consequently sample sites did not concur with mesh netting (benthic sampling) sites. Numbering of the haul site conforms (as far as practical) to benthic sample site numbering. The Area 5 site had bare sand substrates. Seagrass beds in Shallow Bay were not sampled using this technique. Hauling nets over seagrass beds commonly leads to highly variable results (due to mesh clogging and the lead-line lifting from the substrate) and repeated sampling may damage the beds.

A 70 m long, 4.5 m deep, 18 mm mesh haul net was used to sample each site. At each site two hauls were made on two consecutive days (i.e. 4 hauls/site).

APPENDIX 21

BENTHIC INVERTEBRATE FAUNA

RESULTS OF THE ANALYSES OF
BENTHIC SAMPLES FROM AREA 5
(DECEMBER 1991)

Site selection

Benthic samples were taken at 4 sites (Z1-Z4), all of which were subtidal.

Three sites, Z1, Z2 and Z3, were all situated in midstream areas and were within the regions of Area 5 identified for future dredging operations. Sites Z1 and Z2 were located on top of a midstream sandbank at depths of -1.5 m and -1.6 m, respectively. Site Z3 was positioned on the downstream dropoff of the sandbank at a depth of -3.7 m, subject to different hydrologic conditions compared to sites Z1 and Z2.

The fourth site, Z4, was situated outside the limit of proposed dredging operations on a shallow sandbank (-1.0 m) adjacent to Tims Island. This site was selected to provide a comparison between the diversity and richness of benthic fauna within the area proposed for dredging and that of shallow subtidal foreshore areas exempt from potential dredging operations.

Sampling technique

Benthic samples were taken using a Van Veen grab (0.028 m^2 gape). Seven replicate grabs were taken at each site. Samples were sieved through a 1 mm mesh, the retained material preserved in 8% formalin/seawater and rose bengal and returned to an in-house laboratory for sample analysis. Benthic fauna was identified to family level and the abundance of each 'like-form' (species) recorded.

Water quality measurements (salinity, temperature, pH, dissolved oxygen levels, turbidity) were also taken at the time of sampling to characterise environmental conditions within the dredge zone. These are presented in Table 3.4 (see Section 3.5.3).

Data analysis

Data was grouped for the polychaete, bivalve and crustacean families. Benthos from other families were collated into a category termed "other". All samples have been retained for more detailed analysis if required.

A one-way ANOVA (Sokal & Rohlff 1969) in conjunction with Duncan's multiple range test (Walpole 1974) was used to test for differences between the number of individuals and species (in terms of polychaetes, bivalves, crustaceans, other benthos and total benthic fauna) between sites within Area 5.

Abundance data was logarithmically transformed prior to statistical analysis to adjust for heterogeneity of variances. Summary statistics are arithmetic. The degree of similarity between sites in terms of species composition was calculated using the Jaccard (1908) similarity index, as described by Clifford and Stephenson (1975) [$J = x/(s + x)$, where x is the number of co-occurrences of an attribute, s is the sum of non-co-occurring attributes in both samples; J is the coefficient of similarity; note that co-absences are ignored]. The index can range from 0 (no species in common) to 1 (identical species in both samples).

All statistical calculations were undertaken using the statistical computer package SPSSPC.

INDIVIDUAL SAMPLE LISTING FROM AREA 5 SAMPLES

SAMPLE NO. Z1-1

	NUMBER IN SAMPLE
POLYCHAETA	
Nephtyidae I	1
BIVALVIA	
Bivalve IX	1
Mactridae I	2
CRUSTACEA	
Amphipod I	1
Amphipod IV	1

SAMPLE NO. Z1-2

	NUMBER IN SAMPLE
POLYCHAETA	
Nephtyidae I	2
CRUSTACEA	
Amphipod IV	4

SAMPLE NO. Z1-3

	NUMBER IN SAMPLE
POLYCHAETA	
Sigalionidae I	1
Polychaete fragment	1
BIVALVIA	
Mactridae I	2
CRUSTACEA	
Amphipod I	1
Amphipod IV	5
NEMERTEA	
Nemertean I	1

SAMPLE NO. Z1-4

	NUMBER IN SAMPLE
POLYCHAETA	
Nephtyidae	1
BIVALVIA	
Bivalve I	1
Bivalve VII	1
Mactridae I	1
AMPHIPODA	
Amphipod IV	1

SAMPLE NO. Z1-5

	NUMBER IN SAMPLE
POLYCHAETA	
Nephtyidae I	1
Orbiniidae fragment	1
BIVALVIA	
Bivalve III	1
CRUSTACEA	
Amphipod IV	2
Paguridae I (Hermit Crab)	1

SAMPLE NO. Z1-6

	NUMBER IN SAMPLE
POLYCHAETA	
Nephtyidae I	1
BIVALVIA	
Bivalve XII	1
Bivalve XIII	1

SAMPLE NO. Z1-7

	NUMBER IN SAMPLE
POLYCHAETA	
Nephtyidae I	1
BIVALVIA	
Bivalve VII	1
Mactridae I	1
CRUSTACEA	
Amphipod IV	10

SAMPLE NO. Z2-1

	NUMBER IN SAMPLE
POLYCHAETA	
Nephtyidae I	1
BIVALVIA	
Bivalve I	1
Bivalve VII	1
Mactridae I	1
ECHINODERMATA	
Echinoidea I	1

SAMPLE NO. Z2-2

	NUMBER IN SAMPLE
POLYCHAETA	
Nephtyidae I	1
BIVALVIA	
Bivalve X	1
Mactridae I	4
CRUSTACEA	
Amphipod IV	1
GASTROPODA	
Naticidae I	1

SAMPLE NO. Z2-3

	NUMBER IN SAMPLE
POLYCHAETA	
Nephtyidae I	2
Sigalionidae I	1
CRUSTACEA	
Amphipod IV	2

SAMPLE NO. Z2-4

	NUMBER IN SAMPLE
POLYCHAETA	
Nephtyidae I	1
Sabellidae III	1
BIVALVIA	
Mactridae I	3
CRUSTACEA	
Amphipod IV	3

SAMPLE NO. Z2-5

	NUMBER IN SAMPLE
POLYCHAETE	
Nephtyidae I	3
Unidentified fragment	1
BIVALVIA	
Bivalve I	1
Bivalve X	1
CRUSTACEA	
Amphipoda IV	2
Mysidae I	1

SAMPLE NO. Z2-6

	NUMBER IN SAMPLE
POLYCHAETA	
Spionidae VII	1
CRUSTACEA	
Amphipod IV	2
Mysidae I	1

SAMPLE NO. Z2-7

	NUMBER IN SAMPLE
CRUSTACEA	
Amphipod IV	4

SAMPLE NO. Z3-1

	NUMBER IN SAMPLE
BIVALVIA	
Bivalve I	1
Bivalve X	2
NEMERTEA	
Unidentified fragment	1

SAMPLE NO. Z3-2

	NUMBER IN SAMPLE
POLYCHAETA	
Glyceridae I	1
Nephtyidae I	1
Spionidae VII	2
Spionidae X	1
BIVALVIA	
Solemyidae I	1
Unidentified fragment	1
CRUSTACEA	
Penaeidae II	1
ECHINODERMATA	
Echinoidea II	1

SAMPLE NO. Z3-3

	NUMBER IN SAMPLE
POLYCHAETA	
Goniadidae I	3
Nephtyidae I	1
BIVALVIA	
Bivalve X	1
Mactridae I	1
NEMERTEA	
Nemertean	1

SAMPLE NO. Z3-4

	NUMBER IN SAMPLE
POLYCHAETA	
Goniadidae I	1
Nephtyidae I	1
NEMERTEA	
Nemertean I	4

SAMPLE NO. Z3-5

	NUMBER IN SAMPLE
POLYCHAETA	
Nephtyidae I	1
Spionidae VII	2
Spionidae X	2
BIVALVIA	
Bivalve X	1
CRUSTACEA	
Amphipod I	1
NEMERTEA	
Nemertean I	3
ECHINODERMATA	
Echinoidea I	1

SAMPLE NO. Z3-6

	NUMBER IN SAMPLE
POLYCHAETA	
Nephtyidae I	1
Spionidae VII	2
BIVALVIA	
Mactridae I	1
NEMERTEA	
Nemertean I	1
ECHINODERMATA	
Echinoidea I	1

SAMPLE NO. Z3-7

	NUMBER IN SAMPLE
POLYCHAETA	
Goniadidae I	7
Nephtyidae I	1
Polychaete fragment	1
Spionidae VII	4
NEMERTEA	
Nemertean I	4

SAMPLE NO. Z4-1

	NUMBER IN SAMPLE
POLYCHAETA	
Capitellidae I	3
Capitellidae II	5
Magelonidae I	1
Nephtyidae III	1
Phyllodocidae I	1
Polychaete fragments	
Spionidae VI	1
Spionidae VII	1
Spionidae VIII	1
Terebellidae I	7
BIVALVIA	
Bivalve VI	3
Mactridae I	1
CRUSTACEA	
Amphipod II	1
Callianassidae I	2
GASTROPODA	
Naticidae I	1
NEMERTEA	
Nemertean I	4

SAMPLE NO. Z4-2

	NUMBER IN SAMPLE
POLYCHAETA	
Capitellidae II	4
Capitellidae IV fragment	
Lumbrineridae I	1
Magelonidae I	3
Nephtyidae II	1
Spionidae VI	2
Spionidae VIII	1
Spionidae IX	1
Terebellidae	4
BIVALVE	
Bivalve VII	1
CRUSTACEA	
Callianassidae I	7
Anthuridae I	1
GASTROPODA	
Nassariidae I	1
NEMERTEA	
Nemertean	2
Turbellaria	
Platyhelminth I	1

SAMPLE NO. Z4-3

	NUMBER IN SAMPLE
POLYCHAETA	
Lumbrineridae I	4
Nephtyidae IV	1
Nereidae II	4
Orbiniidae I	1
Sigalionidae I	1
CRUSTACEA	
Amphipod V	1
Amphipod VII	1
NEMERTEA	
Nemertean I	3

SAMPLE NO. Z4-4

	NUMBER IN SAMPLE
POLYCHAETA	
Capitellidae II	2
Capitellidae IV	1
Lumbrineridae I	4
Nephtyidae II	1
Oweniidae II	2
Phyllodocidae I	1
Terebellidae I	1
BIVALVIA	
Bivalve VII	1
Bivalve VII	1
Mactridae I	1
GASTROPODA	
Nassariidae I	1
NEMERTEA	
Nemertean I	1

SAMPLE NO. Z4-5

	NUMBER IN SAMPLE
POLYCHAETA	
Capitellidae II	3
Capitellidae IV	3
Lumbrineridae I	7
Nephtyidae III	1
Sabellidae I	1
Spionidae VIII	2
Terebellidae I	2
BIVALVIA	
Bivalve VI	1
CRUSTACEA	
Anthuridae I	1
Amphipod VII	2
GASTROPODA	
Nassariidae I	3
NEMERTEA	
Nemertean I	5

SAMPLE NO. Z4-6

	NUMBER IN SAMPLE
POLYCHAETA	
Capitellidae IV	2
Capitellidae V	1
Lumbrineridae I	3
Nephtyidae II	1
Nephtyidae III	2
Nereidae II	1
Spionidae IX	1
Terebellidae I	2
BIVALVIA	
Bivalve VI	1
NEMERTEA	
Nemertean I	5

SAMPLE NO. Z4-7

	NUMBER IN SAMPLE
POLYCHAETA	
Capitellidae II	3
Capitellidae Iv	1
Lumbrineridae II	1
Nephtyidae II	1
Nephtyidae III	3
Oweniidae II	2
Phyllodocidae I	4
Spionidae VI	1
Spionidae VIII	1
Terebellidae I	5
BIVALVIA	
Bivalve VI	4
CRUSTACEA	
Caridae I	1
GASTROPODA	
Nassariidae I	3
NEMERTEA	
Nemertean I	1

APPENDIX 22

VISUAL AMENITY ASSESSMENT

VISUAL ASSESSMENT

The techniques used by the MSB (1989) survey aimed to maximise objectivity in the assessment of visual quality by following a sequential process. The net result of such an approach is to provide two bases for objective appraisal ie.:

(i) that any third party using the same criteria would advise similar ratings; and
(ii) that the criteria used apply consistently to the area being studied. Thus, although specific landscape elements in the Tweed may vary from those in other river systems, there are internalised reference points for classification leading to overall consistency.

The version of this process adopted for the lower Tweed estuary survey involved an assessment of both the Visual Unit and Visual Quality Class attributes of the foreshores of the study are (see below). A visual field survey was undertaken from the waterways in the study area during early May 1991. This survey recorded as objectively and as systematically as possible the type of vegetation, land use, topography and land status that existed at the land/water interface. This involved obtaining a photographic record of the foreshore together with the completion of additional notes on accompanying base maps. Although the entire visual catchment from the waterway was studies, the immediate foreshore zone from the river bank to approximately 50-100 metres inland was given priority since this was where the most visual variety and impact occurred.

The series of photographs, which was generally recorded at right angles to the direction of travel of the boat (ie. from river mid stream relative to the shoreline), was used to correspond to the Visual Unit classifications described in the next section. Visual Unit information was then mapped into a graphic representation at a scale of 1:10,000 (see Figures A22.1).

Each Visual Unit section of foreshore was then analysed using the table for determining Visual Quality Classes shown in Table A22.1. This information was also graphically represented at a scale of 1:10,000 to show visual quality classes ranging from lowest to highest along the foreshores of the study area (Figure A22.2).

Visual unit and visual quality assessment criteria

Visual unit assessment criteria

Using the MSB (1989) definition, a visual unit is an area containing common distinguishing characteristics due to its land form, vegetation, land status and use. Visual units are required for the determination of the visual assets of an area, and subsequently for the definition of Visual Quality Classes.

The visual unit classification scheme used in the lower Tweed estuary study is described below from MSB (1989) and relates to the land/water interface characteristics that exist along the foreshores.

Visual Unit A

(a) Highly developed commercial and/or industrial lands or public Government lands with an industrial commercial and/or residential backdrop and containing little or no vegetation or landscape treatment and with associated waterfront structures.

(b) As per (a) but with nil or minimal waterfront structures.

Visual Unit B

(a) Highly developed commercial and/or industrial lands or public/Government lands with an industrial commercial and/or residential backdrop and with full or partial landscaping or bushland or mangrove facade and with associated waterfront structures.
(b) As per (a) but with nil or minimal waterfront structures.

Visual Unit C

Fully developed residential properties with dominant built form and varying levels of vegetation ranging from nil to a medium density vegetation zone along the foreshore and encompassing a variable density of waterfront structures.

Visual Unit D

(a) Residential properties usually of low residential density, effectively screened from the water by either high amenity bushland or high quality landscaped gardens and/or high quality foreshore topography and with associated waterfront structures.

(b) As per (a) but with nil or minimal waterfront structures.

Visual Unit E

Reserves or Government lands with nil to sparse vegetation or landscaping and usually with a high density residential or commercial/industrial backdrop and fronted by high density waterfront development.

Visual Unit F

Reserves, Government lands, zoned "open space" lands and freehold properties in close proximity to reserves/roads, with open lawn and/or sparse vegetation, mainly fronted by seawalls, rubble or natural banks or occasional beaches and having minimal waterfront development or areas of similar status having relatively natural foreshore with close residential hinterland development, but again having minimal waterfront development.

Visual Unit H

High density bushland, landscaping and/or agricultural land ascending continuously to the ridgeline with nil to minimal rural residential development on the slopes and with nil to minimal waterfront development.

Figure A22.1 shows the locations and spatial extent of each of the visual units identified in the Area 5 study area. Five of the eleven possible visual unit categories are represented in Figure A22.1.

Visual quality class assessment criteria

The component parts of each visual unit were analysed with a view to assembling a list of appropriate assessment criteria. To this end, five assumptions underlying the assessment of visual quality were made and these are reproduced from MSB (1989).

(a) *Natural vs Developed Environments*

Foreshores of natural bushland and coastal vegetation are considered to have a higher visual quality or value than those that are urbanised.

(b) *Physiography*

Dramatic topographic conditions such as cliffs and escarpments descending to the shore are considered to have more aesthetic value than flat or gently sloping terrain adjacent to the shoreline.

(c) *Enclosure vs Exposure*

In general, more enclosed water bodies, such as narrow bays adjoined by steep elevated headlands or ridges, are considered to have a higher aesthetic value than broad water bodies with indistinct or distant edge definition.

(d) *Diversity vs Uniformity*

Environments of diverse landform and land use are considered to be higher in value than those with undifferentiated landform or homogenous in land use. Thus an urbanised shoreline with elements of natural vegetation, parks, combined with perhaps a marina, some beach reserves and rock outcrops is considered to be more aesthetically exciting than a uniform landform, with continuous uninterrupted residential development abutting a continuous undifferentiated shoreline.

(e) *Urbanised Environments*

Within the man-made environments, the following elements are considered to affect aesthetic value:

- The presence of attractive architecture, ie. urban areas in harmony with the landscape in terms of form, texture, colour and scale.

- The presence of historical or culturally significant features.

- The presence of recreational foreshore facilities can enhance the visual quality of an area of bland, sterile appearance with dominant built form and negligible vegetation, by way of introducing a change in texture to the foreshore which helps to redress the imbalance of dominant built form. It is acknowledged that the quality and obtrusiveness of the foreshore facilities are in turn relevant and in some past instances have merely reflected the lack of character of the land built form by extension of the theme to the foreshore land/water interface. A compounding of the undesirable elements of visual character into a dominating unsympathetic whole has often then resulted.

  Conversely, in areas of high visual appearance, with well designed built form, sympathetically integrated with the natural or man-made environment, foreshore development may introduce an intrusive detraction to the overall visual quality or again may be sympathetically integrated within the development parameters.

The visual quality class adopted for the respective visual units is the mean of the quality range or if a mean is not applicable then the highest class is adopted and is indicated by boxes in Table A22.1.

TABLE A22.1
VISUAL UNITS

	A(a)	A(b)	B(a)	B(b)	C	D(a)	D(b)	E	F	G	H
Visual Quality Class											
Highest											[X]
High							[X]	X	[X]	[X]	X
High/Moderate				X	X	X	X	X	X		
Moderate			X	[X]	[X]	X		X			
Moderate/Low		[X]	[X]	X	X						
Lowest	[X]	X	X								

An exception to the strict nexus between visual units and visual quality classes, is made in the case of port areas. The visual unit designation (Visual Unit E) which truly describes the actual port facilities equates to a low visual quality class standing. Because of the dynamic character of the port operations with the interest of large ships, constant activity and in some cases the dramatic city backdrop, the low visual quality class standing is not considered to adequately quantify the visual experience. A modified assessment has therefore been made, which elevates the standing of these areas in visual quality class stratum.

AREA 5 VISUAL UNITS

FIGURE A22.1

WBM OCEANICS AUSTRALIA

FIGURE A22.2

AREA 5 VISUAL QUALITY CLASSES

WBM OCEANICS AUSTRALIA