RICHMOND RIVER AT BALLINA

NORTH CREEK DREDGING
MANAGEMENT STUDY

Report No. 84009

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FOREWORD

In terms of the Rivers and Foreshores Improvement Act, 1948, the Public Works Department has a responsibility for rivers in the area extending from the mouth to the upstream limit of tidal influence. Development proposals such as sand and gravel extraction, canal subdivision or protection against bank erosion, may cause changes in river behaviour. The Department has a statutory responsibility to advise on, or to impose conditions, relating to such developments.

Within this context, a dredging management study has been undertaken in respect of North Creek, a tributary of the Richmond River.

In the past, extensive dredging of sand from the creek has been carried out, and further dredging is contemplated.

The present study has been undertaken because of the potential sensitivity of the adjacent coast and the impact that dredging could have on the fragile coastal system.

The study is essentially advisory in character, and is designed to assist the Crown Lands Office in determining an appropriate management strategy. The study does, however, have wider implications, and will be of assistance to authorities such as Ballina Shire Council, as well as to members of the public with an interest in the area.

W. K. PILZ, O.B.E.,
DIRECTOR OF PUBLIC WORKS.
DREDGING MANAGEMENT PLAN: SUMMARY FIGURE

NORTH CREEK ON THE RICHMOND RIVER AT BALLINA

Integrated Survey Grid as shown on C.M.A. OrthophOTO Map: BALLINA XS400-1.

ZONE C
ZONE B
ZONE A
Missingham Bridge

500 metres
Grid north
Magnetic north
SUMMARY

North Creek is a tributary of the Richmond River joining the main river 1.5 km from the coast, at Ballina.

Extensive dredging of sand from this Creek has been undertaken previously and further dredging has been proposed. Applications for quarry licences to remove sand are forwarded to the Public Works Department for comment. In order to avoid the piecemeal approach that inevitably occurs when dealing with individual applications, the Department prepares a dredging management plan over a compartment of an estuary whenever circumstances allow. This allows the provision of more comprehensive advice on the overall effects of dredging from various areas within the waterway.

This study of North Creek was undertaken because of the potential sensitivity of the adjacent coast to the impacts of dredging from the coastal sediment system.

The methodology of the study involved identifying those areas of North Creek that, if dredged, would be infilled by sand from the ocean beaches. For those areas, the infill rate of dredged holes was assessed. Consideration was also given to the effect of dredging on estuarine behaviour. These matters were determined through a synthesis of the following information:

- historical changes in the estuary;
- recorded infilling of dredged holes;
- interpretation of sand movements from aerial photographs and ground inspections;
- tidal velocities, gradients and flow rates;
- sediment characteristics; and
- calculated sand transport rates.

The outcome has been the identification of three zones in the Creek (see Summary Figure opposite) over which the following dredging controls are recommended:

Zone A: High infill rate of dredged holes by sand from the coast. No dredging.

Zone B: Low infill rate by sand from the coast. Dredging not desirable but limited dredging considered if no other practicable site is available. Monitoring of subsequent infilling would be required.

Zone C: Very limited interaction with the coastal sand system. Dredging proposals would be reviewed subject to receipt of an evaluation of the dredging effects on channel and bank stability, flooding and tidal hydraulics.
# Table of Contents

1.0 INTRODUCTION .................................................. 1  
   1.1 Description of the Area ................................. 1  
   1.2 Nature of the Problem ................................. 1-3  

2.0 RECENT HISTORY OF NORTH CREEK ......................... 4  
   2.1 Historical Plans ......................................... 4  
   2.2 Recent Changes .......................................... 4  
   2.3 Dredging Record ......................................... 4  

3.0 DESCRIPTION OF SAND MOVEMENTS ............................. 7-8  

4.0 TIDAL HYDRAULICS ........................................... 9  
   4.1 Gauging of Tidal Flows ................................ 9-10  
   4.2 Influence of Waves ..................................... 10  
   4.3 Floods ................................................... 12  

5.0 SEDIMENT TRANSPORT .......................................... 13  
   5.1 Sediment Characteristics .............................. 13-14  
   5.2 Sand Transport Rates ................................... 16-18  
   5.3 Infill Rates ............................................. 18-19  

6.0 DREDGING MANAGEMENT ......................................... 20  
   6.1 Existing Approvals and Pending Applications .......... 20  
   6.2 Assessment of Applications ............................. 20  
   6.3 Recommendations ........................................ 21-22  

7.0 ACKNOWLEDGEMENTS ............................................ 23  

8.0 GLOSSARY ...................................................... 24-25  

9.0 REFERENCES ..................................................... 26
List of Figures
(Figures follow page 26)

1. Locality Plan
2. Bathymetric Plan
3. North Creek In Its Natural State
4. North Creek In The 1890's Showing Training Works
5. Dredging Activity Interpreted From Aerial Photographs
6. Observed Infill Rate of Dredged Holes
7. Qualitative Model of Tidal Sand Transport
9. Metering Locations
10. Tidal Curves Comparison
11. Discharge and Water Level at Missingham Bridge Line
12. Velocities at Metering Buoys at Missingham Bridge Line
13. Tidal Velocities in Lower North Creek, 21.7.82
14. Direction of Tidal Currents on 21.7.82
15. Location of Sediment Samples
17. Recently Approved or Pending Dredging Applications
18. Dredging Management Plan

List of Plates

<table>
<thead>
<tr>
<th>Plate Description</th>
<th>Page Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. North Creek, 1947</td>
<td>5</td>
</tr>
<tr>
<td>2. North Creek, 1979</td>
<td>6</td>
</tr>
<tr>
<td>3. Lower North Creek, 1.7.69</td>
<td>8</td>
</tr>
<tr>
<td>4. Waves Propagating Through The Bridge</td>
<td>11</td>
</tr>
<tr>
<td>5. Waves Breaking on Flood-Tidal Delta</td>
<td>11</td>
</tr>
<tr>
<td>6. Dredged Hole Opposite Meldrum Park</td>
<td>15</td>
</tr>
<tr>
<td>7. Active and Inactive Tidal Flats</td>
<td>15</td>
</tr>
</tbody>
</table>
1.0 INTRODUCTION

North Creek has been subject to a number of sand dredging operations in the past, and there are further proposals either approved or pending. Because of the potential of dredging within this area to interact with the coastal sediment budget, an investigation of sand movements within the lower part of the Creek has been undertaken and a dredging management plan produced. The management plan is intended to control dredging operations to ensure that adverse impacts on the estuary and the coast are kept to an acceptable minimum.

1.1 Description of the Area

North Creek joins the Richmond River at Ballina, at a point 1.5 km upstream of the coast (see Figure 1). The Creek drains Newrybar Swamp, and the catchment forms only a very small part of the total Richmond River catchment.

In its lower reaches the creek has a large width with generally shallow depths and extensive shoals. This lower section of the Creek (nominally downstream of the canal) is dominated by estuarine processes (i.e. tidal currents), whereas upstream of the Shell Road bridge the Creek is fluvially dominated (it is still tidal but flood discharges largely determine the channel section). In between these sections there is an intermediate zone. It is the lower section dominated by estuarine processes that is of primary concern with regard to dredging.

The entrance to North Creek faces directly through the river mouth, which is orientated south-east, into the direction from which the heaviest ocean wave energy originates. Therefore, it is subject to considerable wave action. Field inspections reveal that waves approaching the entrance peak-up steeply in height and often break on the shoal immediately in front of Missingham Bridge. They propagate into North Creek and may break and reform two or three times until all their energy is expended.

Reasonably up-to-date bathymetric data are available, as the Creek was sounded in 1979. A simplified version of the survey plan is illustrated on Figure 2, portraying the extensive intertidal shoals (Flood-tidal delta, Town Shoal and Middle Shoal) and the narrow ebb channel.

1.2 Nature of the Problem

Extensive investigations by the Department into estuarine and coastal sediment dynamics (see for example PWD 1978a, 1978b,
1979, 1982a) and by other specialists into geomorphological development of the coast, for example see Roy and Crawford (1977) and Thom et al. (1978), have led to the development of the following understanding of coastal sediment processes:

- the lower parts of the estuaries are infilled with a plug of marine sand deposited in the estuaries by two primary mechanisms:
  
  i) onshore movement of sand during the last post glacial marine transgression. As the coastal sand barriers formed 6000 to 3000 years ago, sand was washed across them and incorporated into the estuaries' beds;

  ii) tidal currents and waves infill the lower parts of the estuaries with marine sands up to a limiting state called a "regime" condition*. This simply means that after the estuaries have shoaled to a certain degree, the sand flushing ability of the ebb tidal flows balances the sand infeed from the coast.

- sand is scoured from the shoals in the lower estuary by flood discharges and deposited on the coast (i.e. over the seawards edge of the bar). Following these events sand is transported back into the estuary during fair weather to re-establish the regime condition.

- if sand is dredged from the lower estuary shoals composed of marine sand, the dredged hole will be infilled by sand carried in from the coast to re-establish the pre-existing bathymetry. The infilling represents a loss of sand from the coastal sand budget and contributes to coastal erosion.

- preliminary appraisals suggest that there is a net movement of sand northwards along the coast past the mouth of the Richmond River and past Lennox Head to the north. A northward movement of coastal sand has also been established at Byron Bay 25 km to the north of the Richmond River.

- coastal erosion is occurring at Lennox Head and, unless further remedial works are undertaken, assets will ultimately be threatened. Dredging the active marine shoals within the Richmond River and removing this material from the littoral system would be expected to increase the rate of this erosion at Lennox Head. Other beaches north of the Richmond River entrance would also erode to make up the deficit in the littoral sand budget.

* Some of the smaller estuaries and some of the coastal lakes may not develop a regime, but may shoal to complete closure under adverse conditions such as accretive waves that build up the beach at the entrance, or the absence of freshwater discharges to scour the inlets.
It is therefore necessary to identify the active marine shoals of North Creek and to exclude these from further sand extraction.

The active marine shoals can be identified from a synthesis of the following information:

i) historical changes within the estuary;

ii) response of the bathymetry to previous dredging;

iii) bedform features;

iv) tidal velocity data;

v) sediment types;

vi) sediment transport calculations.

Information gained from the first five items allow a descriptive model of the estuarine processes to be developed. Item (vi) allows for an approximate estimation of the infill rate of dredged holes in the lower estuary to be made. These aspects are discussed in the following sections.
2.0 RECENT HISTORY OF NORTH CREEK

2.1 Historical Plans

In its natural state North Creek outlet channel (Figure 3) was at the location now covered by the causeway at the northern end of the bridge. The channel bifurcated around a middleground intertidal shoal. Middle Shoal existed in a form similar to today. Upstream of the present boat ramp location, the estuary was also similar to its existing condition.

The training walls were built in the 1890's (Figure 4), and the half tide wall, which was intended to redirect the estuarine flows, was probably built at the same time. This wall was ineffective, and today it crosses the ebb channel, causing an obstruction to navigation.

2.2 Recent Changes

Aerial photographs dating from 1947 reveal that only minor changes have occurred over the past 35 years, see Plates 1 and 2. The main change over this period has been a gradual deterioration of the channel in Middle Shoal, which was originally the northern one of the two main channels shown on Figure 3. Shoaling of this channel indicates that there is active sand movement onto this area.

2.3 Dredging Record

Dredging history prior to the aerial photographic record is unknown. Since 1947 various dredge holes are evident on the aerial photographs, which give at least a partial record of dredging. Known dredging activities are illustrated on Figure 5.

The infill rate of the dredged holes varies greatly over relatively short distances (see Figure 6), pointing to equally great variation in the rates of sand transport in the area.
3.0 DESCRIPTION OF SAND MOVEMENTS

Prior to undertaking a tidal gauging of an estuary it is desirable to develop a preliminary understanding of flow patterns, to facilitate deployment of metering locations that would yield the most useful data. Flow patterns over a sand bed are portrayed in the scale and orientation of the bedforms. Therefore a preliminary model of sand movements is developed and is used as a base on which to plan field studies and to test ideas on estuarine response.

Study of aerial photographs indicated that the lower (i.e. downstream) part of North Creek experiences the most active tidal sediment transport. The indicators used are:

i) the occurrence and orientation of major bedforms;

ii) dredge hole infilling;

iii) wave activity;

iv) colour of the sediments, i.e. clean (mud free) sediments are interpreted as being more active, because mud is removed when the bed is reworked during sand transport.

A qualitative model of tidal sand movements based on the above is sketched on Figure 7. From this it can be seen that sand entering North Creek through Missingham Bridge traverses the entrance flood-tidal delta and then either:

- drops into the ebb channel and is flushed back out into the main river;

- drops into the ebb channel and moves across onto Middle Shoal (across face BC). It then traverses this shoal, finally dropping into the ebb channel across face CD. From there it would either be flushed back into the main river, or repeat a cycle back across Middle Shoal;

- moves along the western side of the ebb channel (EG) until flushed downstream at some stage by tidal flows or flood discharges.

It can be seen (Figure 8) that there are a number of circulation cells leading to many possible paths that an individual sand grain may follow. Similar patterns of sand movement across flood-tidal shoals and into an ebb channel are encountered at the entrances of many estuarine lakes and creeks, see PWD 1982a and PWD 1983. Circulatory sand movements also occur in the larger river entrances, but the pattern is often less clear because of more complex shoal arrangements.
The influx of sand across the flood-tidal delta negated the attempt to train the channel by the half-tide wall (Figure 4). The exposure of the training wall on the flood-tidal delta varies with time: it was buried on the 1969 and 1973 aerial photographs and exposed in 1979, providing a reference to the scale of sand movements on the flood-tidal delta.

An uncommon feature is the distinct S shaped step in the ebb channel (HF on Figure 7 and Plate 3). The right hand side (looking downstream) is one to two metres deeper than the left hand side and has upstream orientated dunes. Thus there is a circulation cell within the ebb channel itself. The step may be washed out by floods, as it was not evident during field work in July 1982. The presence of the training wall on the bed of the ebb channel, together with sand dropping off Middle Shoal, may have some influence on the formation of this step. The shape of this step indicates that this part of the channel is dominated by downstream sand transport under tidal flows.
4.0 TIDAL HYDRAULICS

4.1 Gauging of Tidal Flows

A tidal gauging was undertaken on 21.7.82 to verify the sediment transport patterns described in the preceding section, and to provide further information necessary to calculate sediment transport rates. Because the primary area of concern appears to be downstream of the boatramp, the gauging stations were mainly located between the boatramp and Missingham bridge.

The key results are graphed as follows:

- Figure 9 Metering locations
- Figure 10 Tidal Curves Comparison
- Figure 11 Discharge and Water Level at Missingham Bridge Line
- Figure 12 Velocity at Metering Buoys
- Figure 13 Tidal Velocities in lower North Creek, 21.7.82
- Figure 14 Direction of Tidal Currents on 21.7.82

There is a reduction in tidal range between Missingham bridge and the canal (see locations on Figure 9) of about 0.3 m. An examination of instantaneous tidal gradients (not shown) revealed some steepening of surface gradients towards the bridge in the downstream end of the Creek. Steepening of gradients implies increased dissipation of tidal energy caused by faster flow velocities and subsequently greater bed shear and sand transport. Thus sand movements can be inferred to be on a larger scale closer to the bridge than further upstream.

Nevertheless, the gradients are comparatively mild compared to those in many other estuarine lake and river systems along the coast. This is thought to be the outcome of two factors:

- the waterway is wide in the lower creek, thus not excessively restricting flows;
- the tidal prism is small because the estuary is short and tapers to narrow widths upstream, thus limiting the volume required to be filled with tidal flows.

The velocities graphed on Figure 13 show:

- the marked ebb velocity bias in the ebb channel (buoys 1A, 2A, 2B). Velocities in the channel further upstream were about equal on incoming (flood tide) and outgoing (ebb) flow, but this should be seen in the context of a bias in inflow volume over outflow: (i.e. discharge through line 1: ebb $2 \times 10^5$ m$^3$; flood $5 \times 10^5$ m$^3$);
- the marked flood tide velocity bias over the shoals;
- peak velocities (both flood and ebb) are in excess of 0.3 m/s, the threshold of sand transport, indicating that the whole area is active to a degree;
peak velocities in the dominant direction of flow (upstream over the shoals, downstream in the ebb channel) generally exceed 0.6 m/s in Zones 1 and 2 (ranging up to 0.8 m/s), but they are lower further upstream. In Zone 3 (Middle Shoal) they are about 0.35 m/s and in Zone 4 0.3 to 0.6 m/s, being slowest at the upstream-most buoy. Thus the scale of sand transport decreases upstream (being dependent on velocity raised to a power quoted in the range from 3 to 6).

4.2 Influence of Waves

Waves greatly increase sand transport even when propagating in a direction opposing the current, because the water particle accelerations induced by the passage of the wave act to suspend sand from the bed. Once in suspension, very weak currents will transport sand (see Bijker 1968). Therefore, the transport threshold of 0.3 m/s mentioned above is not applicable under waves. After a wave breaks, the translating water mass has its own current which transports sand in the direction of wave travel.

Waves are generated by winds within the creek, or by ocean swell penetrating through the bridge waterway. Swell refracts and diffracts into the estuary, breaking and reforming a number of times.

The gauging found:

- that waves (both wind and swell) significantly affected currents on Middle Shoal. Shallow depths over that shoal render the bed active to waves with a period as short as 1 second (i.e. wind waves). Waves of height from 0.07 m to 0.30 m were observed on this shoal during the gauging;
- extensive wave action on the flood-tidal delta, see Plates 4 and 5;
- swell was gently rocking the metering boat at the upstream-most buoy (Zone 4, Buoy D).

Thus ocean waves affect the entire area covered by the gauging, but decreasing in intensity as they move upstream. Bigger waves offshore would not necessarily correlate with maximum wave energy in North Creek, as the waves then break on the ocean side of the bridge, leaving reduced energy to penetrate onto the flood-tidal delta.
Plate 4 Waves Propagating Under The Bridge, 09.30 hrs on 21.7.82, Boat at metering buoy C of Zone 1 (Figure 9). Offshore wave height approx. 2.6 m. Note: photo looks directly through breakwaters and shows broken waves across river entrance.

Plate 5 Waves Breaking on Flood-Tidal Delta, 11.00 hrs. on 20.7.82, Offshore wave height approx. 4.0 m
4.3 Floods

Oceanics (1976 and 1980) have studied the flooding response of this estuary. Maximum flood flow reported by Oceanics for a 1 in 50 year recurrence flood through Missingham Bridge was determined to be 200 cubic metres per second with maximum average velocities of 0.4 m/s. Tidal peak discharges were gauged by the Department to be 350 m$^3$/s (Figure 11) with velocities in excess of 0.8 m/s (Figure 12). The computed flood flows are probably under-estimated, and they are more likely to be commensurate with tidal flows. Because of the limited occurrence of floods, the lower estuary would, therefore, be tidally dominated.

Flood discharges would assist tidal flows with the infilling of any dredged holes, either through fluvial sediment deposition or, in the lower reaches, by reworking the marine sands. In the marine dominated section of the Creek, the nature of the sediments reveals fluvial sediment infeeding to be limited. Therefore, flood transport of fluvial sediment is probably of minor importance compared with tidal transport of estuarine/marine sands, and an analysis of flood hydraulics and fluvial sediment transport has not been attempted.
5.0 SEDIMENT TRANSPORT

The qualitative model of sand transport discussed previously (see Figure 7) can be refined to an extent through examination of sediment types, and from sand transport calculations using the results from the tidal gauging.

5.1 Sediment Characteristics

Sediment samples were taken at the locations shown on Figure 15. Selected samples were washed and the mud content determined as shown on the Figure. Closest to the bridge the sand is clean, grading into sands with a significant mud content further upstream. Line AB on Figure 15 shows a division between the two types, but it is not implied that the boundary is sharply defined.

As noted previously, the dredge hole opposite Meldrum Park has persisted for many years, and the tidal flats upstream have a marked mud content (Sample 21 Figure 15) indicating that active sand transport does not occur across this shoal. The different sediment types are shown in situ on Plates 6 and 7. The shoals further upstream (which have been dredged) are less muddy (e.g. Sample 16), and relatively fast flood tide currents were observed over this area during the tidal gauging, suggesting that this area is more active than the shoal immediately upstream of Meldrum Park.

When examined under a binocular microscope, more fundamental differences in the nature of the sand grains could be detected. A number of sand types have been determined in the coastal zone (Roy and Crawford (1977) and PWD (1979)), of interest here are:

i) fluvial sand - comprising lithic and angular quartz grains. These grains are derived from terrestrial rocks, and they constitute the sand infed by catchment runoff;

ii) marine sand - comprising well rounded quartzose grains with usually less than 5% lithics. The character of the sand is the outcome of marine abrasion and chemical weathering;

iii) reworked marine sand - comprising dominantly quartzose grains of either leached appearance or with brown humic coatings. This sand has been reworked by rivers where they intersect coastal sand barriers. This group is often located between the previous two sediment types.

Thus the type of sediment grouping present at a site gives a clear indication of the origin of the sediments and hence the dominant processes transporting sand.
It was found that the clean sands of the flood-tidal delta, Middle Shoal and the channel between them, are predominantly light fawn coloured marine sands derived from the coast, although the surface samples had a slight content of fluvial quartz grains. As these fluvial quartz grains were not detected in similar quantities in upstream samples, they may have fed into North Creek from the main river. Lithic content was small.

Upstream of Samples 9 and 10 the marine character of the sands gradually changed as the content of reworked marine grains increased. By Sample 15 the sands were brown coloured, caused by a humic coating on the grains. Lithic and fluvial quartz content remained small, indicating that the North Creek catchment is not supplying significant quantities of sand size grains to the lower part of the Creek. The decreased penetration of active marine sands corresponded with decreasing strengths of the tidal currents observed during the gauging. Between Samples 14 and 17, downstream-orientated sand dunes were recorded by echo-sounder trace. Because of the relatively weak tidal currents in this area, these were probably of flood discharge origin, indicating a downstream supply of reworked marine sand in this part of the Creek during flood conditions.

It is apparent that dredged holes downstream of line B'B on Figure 15 would be predominantly infilled with sands ultimately derived from the coast. Upstream of B'B dredge holes will infill by reworking material from shallow areas of the bed of the Creek. Dredging in this area would be unlikely to contribute to coastal erosion.
Plate 6 Dredged Hole Opposite Meldrum Park
Active sand transport (left hand side) has not completely infilled the dredged hole over a 30 year period

Plate 7 Active and Inactive Tidal Flats
Looking downstream, muddy sand in foreground, clean sand in background (very slow progression upstream)

(camera positions shown on Figure 2)
5.2 Sediment Transport Rates

A descriptive model of lower North Creek hydrodynamics and sediment movements has been presented in the previous sections. Some quantification of this model was done using the data obtained from the tidal gauging, however, the accuracy of the results is limited.

In the absence of very extensive data, accurate computation of sediment transport rates in estuarine systems of this type is not feasible for a number of reasons, particularly because of the difficulty of evaluating the parameters in the sediment transport equations. These parameters, including current velocities, wave action and water surface slopes, are highly variable at any given time, because the flow is not confined to a well defined uniform channel. Through the tidal cycle these parameters vary greatly in response to change in water depths over the shoals, which induces marked redistribution of flows and modifies the extent of wave penetration.

The strength of the flows responds to ocean tidal range, therefore, sediment transport is greater during springs tidal range than during neap periods. The tidal gauging was undertaken during a high springs tide, but with a marked bias on the flood tide compared with the ebb (see Figure 11). This tide was selected to give an indication of maximum inflow conditions (i.e. sand infilling). The presence of waves greatly complicates sediment transport analysis because wave shear at the bed varies with the period of the waves, the water depth and whether the wave is broken or unbroken.

An approximate analysis of sediment transport rates was undertaken using the method of Ackers & White (1973) but no attempt was made to account for wave action. In the ebb channel, wave action penetrating through the bridge has limited influence. It is of marked influence on the flood-tidal delta, and of much reduced but still significant influence on Middle Shoal because although wave heights are small, tidal currents are also reduced. In these latter circumstances, wave shear stirring the bed may allow sediment transport in circumstances where currents alone would be unable to initiate movement. There are computational techniques for handling sediment transport under currents and waves (e.g. Bijker 1968), but inadequate data is available in this case to warrant such an approach. Nielson (1981) estimated that waves breaking on the bar at the entrance of a small estuary increased sediment infeed by a factor of three over that calculated by Ackers & White's method. The flood-tidal delta at North Creek is more sheltered than an ocean bar and also the bed is adverse (i.e. it slopes upward), so that a factor of 1.5 to 2 may be more appropriate near the entrance to North Creek.

The results obtained (excluding wave influence) are shown on Figure 16. These reveal:
a marked decrease in the scale of transport proceeding upstream;

very high rates of sand inflow across the flood-tidal delta. The downstream end of the Creek does not appear to be accumulating sand, therefore the total sand inflow must in the longer term (i.e. years) be balanced by the outflow. Sand outflow is activated by tidal transport, largely along the ebb channel, with a contribution from flood scour of the bed. The relatively limited ebb transport compared with the large inflow of sand during the gauging, reflects both the diurnal inequality of the tide gauged (small ebb $2 \times 10^6$ m$^3$, large flood $5 \times 10^6$ m$^3$) and the contribution of flood scour. In addition, ebb transport occurs across the flood-tidal delta, but this was not computed;

in the ebb channel along the reach between tideboards 3 and 5, downstream sand transport exceeded upstream transport (despite the flow imbalance favouring upstream transport). Such a transport imbalance does not occur (otherwise the channel would be deepening). Therefore, a lateral infeeding of sand into the ebb channel off Middle Shoal can be inferred in order to achieve the necessary balance of sand inflows and outflows in the channel. The estimated rates in tonnes/tide are shown below:

- upstream of Middle Shoal, sand transports in the channel (say opposite the mangroves, see reach DJ on Figure 16) are much
reduced and are about in balance. Loss of significant quantities of marine sand into dredge holes upstream of point D is unlikely.

To extrapolate from the results of sediment transport (shown on Figure 16) for this single spring tide, to compute annual quantities of transport is even less certain. A fairly rigorous attempt to do a similar analysis for the Tweed River has been undertaken (PWD, 1979). Based on that work, it is estimated that the sediment transport quantities computed for the single flood and ebb tides, gauged at North Creek, could be multiplied by 200 and 350 respectively to give an indication of annual rates (without wave action). These different scale-up factors (being bigger for the ebb) reflect the unequal tidal ranges on the day of the tidal gauging, which were: flood tide range 1.9m, ebb tide range 1.1m (at Missingham Bridge). The approximate annual quantities of sand transport that come out of this can be used to estimate the infill rate of dredged holes.

5.3 Infill Rates

When considering the filling of dredged holes, and the likely impact of this on the coast, the estimated quantities should be seen in the context of the alongshore sand transport rate. This is not known for the coast at the Richmond River entrance, but in the Byron Bay to Hastings Point coastal compartment (located 25 to 60 km to the north) the net rate of sand movement has been calculated to vary from 65,000 m$^3$/p.a. in the south, increasing to 200,000 m$^3$/p.a. at the northern end (P.W.D. 1978b). For the purposes of this report, a representative value of 100,000 m$^3$/p.a. past the Richmond River entrance is adopted.

i) Flood-tidal delta
Very high infill rates; after allowing for the influence of waves, the rate is estimated to be 200 to 400 tonnes/m/year (120 to 240 m$^3$/m/year). This means that the infilling of a hole dredged, for example, 6m deep would advance 20 to 40 m/year. The infill rate would depend on the shape of the dredged hole, with infilling potentially accounting for 10-25% of the net alongshore transport rate.

ii) Middle Shoal
Low infill rate; 6 to 18 tonnes/m/year (4 to 11 m$^3$/m/year). This means that the infilling of a hole dredged to 6m would advance at 1 to 3 m/year. A hole dredged 100x100x3 m (30,000m$^3$) would infill in 20 to 70 years representing a loss to the littoral system of about 1,000m$^3$/year (say 1% of the net alongshore transport north past the Richmond River ocean entrance). The actual infill rate would depend on the location and shape of the hole.

* tonnes/m/year = tonnes per metre width across the shoal per year
iii) **Ebb Channel**

Along Section AB (Figure 16) very high infill rates could be expected as this forms part of the flood-tidal delta sand circulation cell.

Along Section BC moderate to high infill rates are indicated, as this section receives sand loading directly off the flood-tidal delta. Sand must flow across this section to move onto Middle Shoal, and this part of the channel also transmits sand that has moved off Middle Shoal (into Section CD) and is being flushed downstream. The infill rate is estimated to be 100 tonnes/m/year south to north (60 m³/m/year) and 40 tonnes/m/year (25 m³/m/year) west to east. As an example, a hole 40m wide by 80m long by 4m deep would infill in about 2 years (neglecting the action of flood discharges).

Along Section CD low infill rates of about 24 tonnes/m/year (15 m³/m/year) would occur. The majority of the sand would be derived from Middle Shoal, with a smaller percentage moving upstream along the channel.

Because of the action of the hydraulic and sedimentary processes in restoring the Creek to its regime condition, the sand that infills any dredged holes in these three areas would ultimately be derived through a loss to the littoral system. Supply from further upstream would be slight, and would be dependent on floods transporting sediment from the section of the Creek dominated by fluvial processes.
6.0 DREDGING MANAGEMENT

6.1 Existing Approvals and Pending Applications

Recently approved or pending dredging applications in North Creek are shown on Figure 17:

Area A: Reportedly 50,000 m³ has been dredged from this area for nearby landfill;

Area B: The Department approved dredging of 60,000 m³ to fill an area on which it is proposed to build an industrial estate (District letter to Land Board Office 15.10.81);

Area C: The Department has approved dredging of 60,000 m³ for general sale (District letter to Land Board Office 8.10.82);

Area D: Ballina Shire Council proposes to remove 30,000 m³ for filling to construct approaches of the proposed new Missingham bridge. Departmental advice has been deferred pending the results of this investigation;

Area E: Shown as a general quarry licence area on Department of Lands plan "North Creek, Ballina".

6.2 Assessment of Dredging Applications

In the evaluation of dredging applications a number of aspects need to be considered by the Department. The primary matters are:

- the impact of the dredging on the system hydraulics and the related effects on sediment movements and channel stability;
- the impact of the dredging on the littoral drift rate and the sensitivity of developments on the coast to a decrease in the incoming littoral drift (which will be made up by coastal erosion).

If significant impacts are expected, it may be relevant to consider alternative sources of supply.
6.3 **Recommendations**

From this investigation a reasonably clear model of sand movements has been developed and approximate scales of sand transport rates assessed.

The infill rates of dredged holes are seen to vary greatly over short distances, and have been summarized on Figure 18 in three zones:

Zone A: High Infill Rates  
Zone B: Low Infill Rates  
Zone C: Very Limited Infill by Active Marine Sands.

The coast to the north of the Richmond River is already severely eroded, and the continuing coastal erosion places some of the existing developments at Lennox Head at potential risk. Therefore, at this location it is unacceptable to significantly increase the rate of erosion.

Accordingly, it is recommended that dredging be managed as follows:

**Zone A** is to be excluded from dredging;

**Zone B** is not a preferred area for dredging. It could be considered for some limited dredging provided that:

- the dredging is for estuary related purposes rather than for extractive purposes (i.e. not for sale or fill of low lying areas);

- dredging is restricted to minor areas within Middle Shoal (this shoal is designated on Figure 2). Generally the shoal margin adjacent to the channel should remain intact, unless a connection is required between a dredged hole and the channel to assist tidal flushing or for boat access;

- infilling of the dredged area is monitored for a period of up to ten years. This monitoring of infill rates would be undertaken by the Department, with the costs to be met in advance by the applicant.

It is expected that applications for quarry licences within this Zone would normally be rejected by Lands Department. Should Lands consider that a proposal may be compatible with the above requirements, then the Public Works Department would assess it. If an application is concurred with an indication of monitoring costs would then be advised.
Zone C is considered to be suitable for dredging from a sediment dynamics viewpoint. Applications would still be subject to detailed evaluation of the effects of dredging on channel and bank stability, and consideration of the influences on flooding downstream, and on tidal hydraulics.

Dredging of intertidal shoals in this zone would act to increase the tidal volume flowing into the Creek, and increase tidal flow rates and velocities through Zones A and B. This could lead to increased upstream transport of marine shoals into Zone C, but it is likely that the effects on sand infeeding would be acceptably small.

Some modification of the previously approved dredge area within this zone (Area B on Figure 17) is warranted. It is desirable to retain a slice of the shoal separating the dredge area from the channel, as sketched on Figure 18. This would leave a sufficient area from which 60,000 m$^3$ could be won. Such an arrangement would assist the channel (along reach JD on Figure 16) to retain its alignment and depth. By preserving the channel alignment, this would also enable ebb flows in reach DC (Figure 16) to transport downstream the sand that deposits into the channel from Middle Shoal, and thus prevent shoaling in this location.
7.0 ACKNOWLEDGEMENTS

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           A. Montefiore Eng. Board
8.0 GLOSSARY

Coastal Sediment Budget

A means of determining movements of sand on the coast by accounting for sources of sediment added to the coast (e.g., from rivers, cliff erosion, shell production) and losses of sediment (e.g., alongshore to other beaches, into estuaries, offshore, mining, wind blown into the hinterland). By defining a sediment budget, coastal erosion (or accretion) can be quantified.

Dredging Management Plan

Such a plan designates areas within an estuary where the scope of dredging is specified. Generally described by a plan with an attached explanation - in this report see Figure 18 and section 6.3. It outlines "in principle" the Department's requirements. Detailed conditions may subsequently be imposed on a dredging application. Other authorities may also impose restrictions or conditions.

Ebb Tide

Flow of water out of an estuary caused by tidal fluctuation of the ocean.

Ebb Channel

The channel in the lower reaches of an estuary which runs between intertidal shoals. It is generally dominated by ebb currents and hence features downstream sand transport.

Estuary

A waterbody in which seawater is measurably diluted by freshwater.

Estuarine Processes

Movements of water and sediments caused by tidal and meteorological energy inputs.

Flood Tide

Flow of water into an estuary caused by tidal fluctuation of the ocean.

Flood Tidal Delta

A sand shoal often found near the entrance of an estuary, formed by incoming tidal flows.
Fluvial
"Relating to rivers", i.e., it describes freshwater flows and the sediments carried by them.

Instantaneous Tidal Gradient
The slope of the water surface of a tidal flow at an instant in time.

Littoral System
Sand movements in the zone at the ocean shore, including sand transport along the coast and into and out of estuaries.

Marine Sand
Sand whose characteristics have been influenced by the ocean. Found on the coast, offshore and in estuaries (ocean end). Characterised predominantly by rounding of sand grains (caused by wave induced abrasion).

Marine Transgression
The inundation by the ocean of the part of the continental shelf exposed during the ice-age, as the ice melted. The rising ocean waters pushed sand across the shelf to form the coastal sand deposits at the present day ocean edge (i.e., sand plains, dunes and beaches).

Spring Tide
Tides occur in weekly cycles of "springs" and "neaps". Spring tides have a greater range (higher high and lower lows) than neaps because the influence of the moon and sun on the tides is combined. During neaps, the sun and moon gravitational forces are out of phase. There are two spring cycles and two neap cycles each lunar month.
9.0 REFERENCES


FIGURES
NORTH CREEK
BATHYMETRIC PLAN
1979.

Datum: 100 m below Richmond River Valley Datum.


0.86 m

R.R.V.D.

0.7 m

Boat ramp

Middle Shoal

Balling

Flood-Tidal

Delta

Missingham bridge

SHOWS VIEWING
Direction of Plate 6.

FIGURE 2
Figure 3

NORTH CREEK IN ITS NATURAL STATE

Similar to today

Middle Shoal

Middeground

Shoal

Present foreshore alignment

causeway

Location of present day Missingham Bridge
NORTH CREEK IN THE 1890s
SHOWING TRAINING WORKS

FIGURE 4
DREDGING ACTIVITY INTERPRETED FROM AERIAL PHOTOGRAPHS

FIGURE 5.
OBSERVED INFILL RATE OF DREDGED HOLES

FIGURE 6.
No suitable aerial photographs available showing bedforms.

Letters A - H discussed in text.

Scale 1:10 000

QUALITATIVE MODEL OF TIDAL SAND TRANSPORT

FIGURE 7.
SAND CIRCULATION CELLS UNDER TIDAL FLOWS

FIGURE 8.
TB.4 = location of tideboard number 4.

Note: Tideboards were renumbered after the field work (i.e., they differ from numbers in raw data.)

* E = location of velocity metering station.
Each zone was covered by a separate boat crew.

Tidal gauging undertaken at North Creek on 21.7.82.

TB 8 at Fort Denison
TB 9 at Cooffs Harbour
Tideboard numbers are the same as in Manly Hydraulics Lab report, in preparation.
COMPARISON OF WATER LEVELS MEASURED
AT NORTH CREEK ON 21/7/82.

TIDAL CURVES COMPARISON

FIGURE 10
NORTH CREEK: ZONE 1
TIDAL FLOW AND WATER LEVEL
21-7-82

EBB VOLUME $2 \times 10^8$ m$^3$
FLOOD TIDE VOLUME $5 \times 10^8$ m$^3$

Discharge
FLOOD TIDE FLOW
Water level at T.B.2.

EBB FLOW

DISCHARGE AND WATER LEVEL AT MISSINGHAM BRIDGE LINE

FIGURE 11
DEPTH AVERAGED NORMAL COMPONENT
OF VELOCITIES SHOWN

See location of these
metering points on Figure 9.

NORTH CREEK: ZONE 1.
VELOCITIES ON 21.7.82.

VELOCITIES AT METERING BUOYS AT MISSINGHAM BRIDGE LINE
Tidal Velocities in Lower North Creek, 21-7-82

Figure 13

All velocities are profile depth averages without vector adjustment for orientation of flow direction.
Direction of Tidal Currents on 21.7.82.
LOCATION OF SEDIMENT SAMPLES

FIGURE 15

- Indicates sample number (from surface unless marked (c)).
- (c) Indicates a sediment core taken to 1.5 m depth.
- Im.13% Indicates sediment from 1 m depth had fines content (<0.075 mm) of 1.3% by weight.
- Samples taken 22.7.82
- Scale: 0 - 400 m

Legend:
- Sand
- Significant fines
- Quartzose sand
- Clean
- Dredge hole
- Maldrum Park
- Old training wall
- Mangroves
- 11.1% 200 m upstream
SAND TRANSPORT UNDER TIDAL FLOWS

FIGURE 16
RECENTLY APPROVED OR PENDING DREDGING APPLICATIONS

FIGURE 17
DREDGING MANAGEMENT PLAN

NORTH CREEK ON THE RICHMOND RIVER AT BALLINA.

Integrated Survey Grid as shown on C.M.A. orthophoto map: BALLINA x5400-1.

Undredged strip to be retained. Minimum width 30m, 1:6 batter into dredge-area.

EXISTING DREDGED HOLE

EXISTING ROCKWALL AND DREDGE HOLE

ZONE A

ZONE B

ZONE C

AREA B

DREDGING MANAGEMENT PLAN

FIGURE 18