Tuggerah Lakes Entrance Training Walls Technical Discussion

Patterson Britton & Partners

Training Walls

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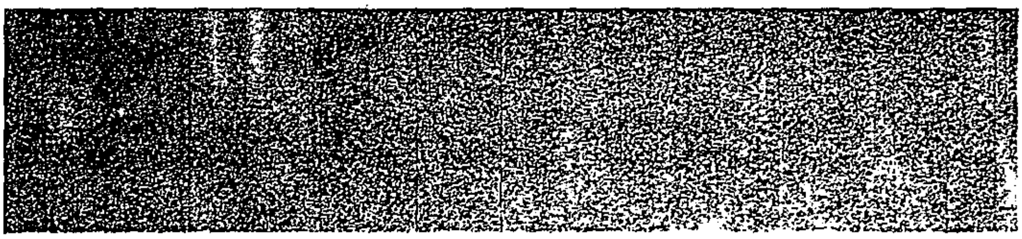

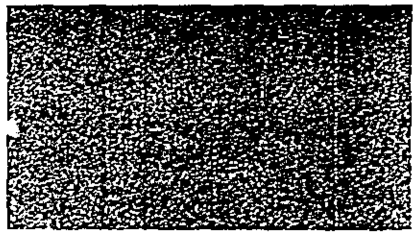

Tuggerah Lakes, Entrance Training Walls: Technical Discussion

APRIL 1994

Patterson Britton
& Partners Pty Ltd
consulting engineers

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GLOSSARY OF TECHNICAL TERMS

Amenity	Those features of an estuary that foster its use for various purposes, eg. clear waters and sandy beaches make beach-side recreation attractive.
Channel Scour-Entrance Scour	The deepening and widening caused by high flows associated with floods or large tides or storms.
Degradation	A reduction in the area of estuarine habitat; or in the well being, health and viability of estuarine ecosystems; or in estuarine amenity.
Discharge	Volumetric flow rate of water, typically measured in terms of cubic metres per second *(m^3/s)*.
Dissolved Oxygen	Atmospheric oxygen that dissolves in water. The solubility of oxygen in water depends upon temperature and salinity.
Ebb Tide	The outgoing tidal movement of water within an estuary.
Flood Tide	The incoming tidal movement of water within an estuary.
ISLW	Indian Springs Low Water. Tidal levels seldom drop below ISLW.
Littoral Drift Processes	Wave, current and wind processes that facilitate the transport of sediments along a shoreline.
Littoral Sediment Budget	The balance of sediment entering and leaving a section of shoreline. If more leaves than enters, erosion ensues.
Marine Sediments	Sediments in coastal waters moved along the coast by littoral processes.
Mid-Tide Level	The average of successive high tide and low tide levels.
1% Flood	Flood with an average return interval of 100 years.
Residence Time	Refers to the time a given volume of water stays within a locality; high residence times are associated with poor flushing.

Storm Surge

The increase in coastal water levels caused by the barometric and wind setup effects of storms. Barometric setup refers to the increase in coastal water levels associated with the lower atmospheric pressure characteristic of storms. Wind setup refers to the increase in coastal water levels caused by an onshore wind driving water shorewards and piling it up against the coast.

Tidal Range

The difference between successive high water and low water levels.

1. INTRODUCTION

The Tuggerah Lakes Restoration Project commenced in 1988 and will be completed in 1995. It comprises $13M of works to repair the environmental damage caused by development of the lakes' catchment. The Project strategy includes the management of the sand shoals at the entrance to prevent entrance closure and thereby maintain regular tidal flushing of the lakes.

Council uses a mobile dredge, specifically built to operate in the entrance environment, to remove any build up of marine sand which threatens closure of the entrance. The dredge has carried out one major entrance dredging exercise, since commissioning approximately 12 months ago.

In March, 1994, Council commissioned Patterson Britton & Partners to prepare a technical discussion of the feasibility of establishing training walls at the entrance. The discussion was required to cover a range of entrance management objectives from the mere prevention of entrance closure to the provision of a navigable entrance. The discussion was also required to include a brief examination of likely environmental impacts and provide indicative costs associated with entrance training concepts.

This report has the following structure:

- *THE NATURAL ENTRANCE* - The physical processes of the entrance, in its natural state, are discussed along with a brief profile of the present environment. This sets the scene for any form of entrance management.
- *MANAGEMENT OF ENTRANCE SHOALS BY DREDGING* - Council's current management of the entrance by periodic dredging is discussed.
- *ENTRANCE RESTRAINING WALL* - The 1988 concept of a geotextile restraining wall is discussed.
- *CREATION OF A NAVIGABLE ENTRANCE* - Some brief comments are made about the impact of training tidal flows on entrance navigability.
- *TWIN ENTRANCE TRAINING WALLS* - The feasibility of constructing twin entrance training walls only is discussed.
- *TWIN ENTRANCE TRAINING WALLS WITH MAJOR CHANNEL DREDGING* - The feasibility of constructing twin entrance training walls in conjunction with major channel dredging, to improve entrance navigability for larger vessels, is discussed.

Considerable coastal processes data and geotechnical data is necessary to firmly establish the feasibility of entrance training works and arrive at estimates of cost. The discussion and analysis in this report is based on the broad experience of constructing training walls along the NSW coast. Specific sketches of entrance possibilities, at Tuggerah Lakes, are not included. Possible wall dimensions and costings are discussed as indicative ranges only.

The discussion provides Council with an appreciation of the relative merits of providing training walls at the entrance to Tuggerah Lakes.

2. THE NATURAL ENTRANCE

Managing the entrance to Tuggerah Lakes requires an appreciation of the natural processes involved. There are a number of characteristic features of the entrance (refer **Figure 2.1**):

- entrance channel;
- entrance throat;
- entrance sand spit;
- upstream sand shoals;
- rock shelf along southern shoreline;
- beach along southern shoreline;
- rock outcrop;
- entrance sand bar.

Sand on the entrance bar, and near the entrance sand spit, moves onshore and towards the entrance channel under the combined action of breaking waves and flood tide currents. The sand is carried through the entrance throat, each flood tide, and deposited on the upstream sand shoals. During each ebb tide, sand is removed from the entrance channel and the northern and southern channels, transported back through the entrance throat and deposited on the entrance sand bar.

There is a circulation of sand involving the entrance sand bar, entrance sand spit and the upstream sand shoals (refer **Figure 2.1**). As the transport of sand by the flood tide is assisted by wave action, there is more sand, on average, going onto the upstream entrance shoals than leaves them. Hence they gradually build up over time.

When the entrance channel is wide, tidal flows are strong and they can carry the sand almost to the bridge. However as the upstream sand shoals grow, they gradually throttle tidal flows and the limit of effective sand movement retreats towards the entrance throat. This gradual contraction of the area of active sand movement, as an entrance heads towards closure, is a feature of all unstable estuary entrances. Smiths Lake is a very clear example (refer **Figure 2.2**) where a succession of flood tide delta lobes reflect sequential reduction of tidal flows and the extent of sediment mobility.

A local southerly reversal of littoral drift causes the entrance sand spit to grow southwards. This forces the entrance channel and throat onto the southern rock shelf. As the entrance channel and throat narrows, against the southern rock shelf, tidal flows are restricted even further. Ultimately, the throat can become so narrow and tidal flows so weak, that the entrance sand bar can move onshore and close the entrance.

Floods rejuvenate the closure cycle by scouring a wide and relatively deep channel through the entrance sand spit. Floods generally remove a substantial portion of sand from the surface of the upstream entrance shoals. They may even cut a pronounced channel through them. After a flood, the wide, scoured entrance allows strong tidal flows which promote rapid sand infeed and the process of build up of the entrance shoals and southerly migration of the sand spit, leading to throttling of the entrance, commences anew. For example, after the 1990 flood, channel depths up to 3 metres were measured.

2.1 DISCUSSION OF ISSUES

2.1.1 Physical Processes

LAKE LEVELS - The wide expanse of upstream sand shoals and the narrow entrance channel, dissipate most of the energy of the ocean tide. Consequently, under average conditions, the lakes have a small tidal range, only of the order of centimetres and an elevated average water level *(ie. mid tide)* which varies between 0.2 to 0.3 metres above Mean Sea Level. When a major flood scours the entrance, the average water level in the lake can drop to 0.1 metres and the tidal range, within the lake, may approximately double for a short period.

COASTAL PROCESSES - The sand circulation at the entrance is part of an overall dynamic relationship with North Entrance Beach. As such, the cyclical build up of sand on the upstream entrance sand shoals is likely to be associated with minor fluctuations in the shoreline of the beach.

The entrance sand spit and broad expanse of the upstream sand shoals, provide effective protection against ocean swell. Even during major storms, only slight wave energy reaches the southern and northern shoreline, upstream of the entrance.

In the same way as the upstream sand shoals and the narrow entrance channel throttle tidal flows, they also restrict the penetration of storm surge into the estuary. In many coastal settlements, storm surge can be the dominant flooding mechanism, ie. as distinct from a river or lake rise due to catchment runoff. However, the heavily shoaled nature of the entrance to Tuggerah Lakes effectively prevents storm surge penetration.

ENTRANCE SHOALS - As indicated above, the entrance shoals "come and go" depending upon the relative intensity and frequency of floods.

FLOODING BEHAVIOUR - Major floods have peak discharges which are over forty times greater than peak ebb tide discharge, during average, shoaled entrance conditions. They require, therefore, a substantially greater entrance channel to discharge the large volumes of water involved and avoid excessive flood levels in the Lake.

Floods achieve this by scouring the entrance sand spit and the bed of the entrance channel. Major floods have in the past scoured the entire entrance sand spit, and a major portion of the upstream sand shoals, creating a water width of over 500 metres *(at the entrance)*. Even in the moderate 1990 flood, the water width increased several hundred metres.

ENTRANCE THROAT DIMENSIONS - Under average tidal conditions, the throat has a width of 25-35 metres and a depth of about 2 metres at mid tide.

ENTRANCE SAND BAR - Depths over the entrance sand bar are variable, depending upon storm conditions but are likely to be seldom more than 0.5 metres at low water *(no surveys available).*

2.1.2 Other Issues

NAVIGATION - The entrance is too shallow and hazardous for navigation by the general public. Small, specialised local craft, piloted by experienced locals, can navigate the entrance at high tide.

FLEXIBILITY - In its natural state, the entrance is totally flexible and able to adjust to all storm and flood events.

ENTRANCE AMENITY - The entrance area is very popular with holiday makers. The broad expanse of sandy shoals has low tidal currents and is used for swimming, amateur fishing and prawning. When seas are slight, children float down the ebb tide "rapids" on boogie boards and people wade across the entrance and onto North Entrance Beach at low tide. At times of high velocity, swimming can be hazardous in the vicinity of the entrance throat. The entrance, in its natural state, is central to the pattern of usage by holiday makers and the local community.

AESTHETICS - The natural beauty of the entrance is fundamental to its long standing appeal.

LAKE FORESHORE HABITATS - The habitats of the lake foreshores have evolved in response to the elevated mean lake level *(ie. 0.2-0.3 metres above Mean Sea Level)* and the relatively small tidal range. Many of the lake foreshores are very flat and shallow and have developed extensive seagrass beds. These areas are crucial to the well being of the lakes fishery.

ENTRANCE CLOSURE - Under natural conditions, the entrance can close. When the entrance is closed, fish and prawn recruitment is prevented, tidal flushing ceases, water quality deteriorates and tourist amenity is degraded. A closed entrance can increase flood levels in the lake.

3. MANAGEMENT OF ENTRANCE SHOALS BY DREDGING

3.1 DESCRIPTION

The natural imbalance in the circulation of sand between the entrance sand bar, adjacent beach system and the entrance shoal, causes the entrance channel to gradually choke with sand. This imbalance can be addressed by judicious dredging.

Dredging to prevent entrance closure, and maintain regular flushing of the lake, is Council's preferred entrance management approach.

The dredge augments the natural return of sand to the beach system by transferring sand generally from the upstream sand shoals, immediately upstream of the entrance throat, to North Entrance Beach. Sand placed on the beach is gradually reworked towards the entrance channel and is returned to the upstream sand shoals, via the natural processes described in **Section 2**. However, if the quantity of sand transferred to North Entrance Beach, during short periods of high output dredging, is approximately equal to the nett influx of marine sand through the entrance between dredging periods, the upstream sand shoals will tend to stabilise. Hence dredging can prevent the general build up of the upstream sand shoals and slow down, if not completely eliminate, the gradual throttling of tidal flows. Because the throttling of tidal flows is reduced, the entrance will stay open for much longer periods.

3.2 ENTRANCE THROAT DIMENSIONS

Regular dredging of a fixed quantity of sand will not maintain an entrance of constant dimensions. In the absence of floods, gradual deterioration can occur, albeit much slower than in the absence of dredging, because the entrance sand spit can still migrate southwards. Also, dredging is carried out in discrete areas, for efficiency, because skimming of the surface of the sand shoals is not feasible. Hence dispersion and redistribution of sand, throughout the upstream sand shoals, could lead to loss of flood tide flow across broad, flat sand sheets.

During a prolonged absence of floods, it may be necessary to carry out reconfiguration dredging to address these issues. The versatility of this management technique lends itself to continuous monitoring of the system and appropriate adjustment to suit circumstances. As such, reconfiguration dredging to relocate an entrance that has migrated too far south or rejuvenate an area of local shoaling in the upstream sand shoals, can be easily carried out. On the converse side, should the entrance be heavily scoured by a significant flood, the need for dredging would be deferred for a time.

3.3 DREDGE CAPACITY

Measurements carried out during dredging trials in March/April 1991 indicated that, to be effective, the dredge must be capable of moving 60,000 m^3 over a dredging period of 12 weeks. Council's dredge was built to specification to achieve this.

3.4 DISCUSSION OF ISSUES

3.4.1 Physical Processes

LAKE LEVELS - Tidal levels in the lakes are controlled primarily by the narrow and relatively shallow entrance channel and the geometry of the upstream sand shoals. As dredging merely maintains the channel and shoals in an average condition, average lake levels are maintained.

ENTRANCE SHOALS - The upstream entrance shoals are maintained in their average condition. Chronic build-up of the shoals is avoided.

COASTAL PROCESSES - There are no significant coastal process impacts as the technique is compatible with the natural circulation of sand that occurs at the entrance (refer **Section 1**).

FLOODING BEHAVIOUR - The full potential width of the entrance remains available for scouring by large floods compared with any structure which might prevent erosion of the entrance sand spit. By retarding the closure of the entrance channel it could be argued that, on average, the entrance channel is likely to be larger at the beginning of a flood than compared to natural conditions. An initially larger entrance channel would facilitate flood scour. However the impact is not likely to be significant in terms of peak flood levels in the lakes.

TIDAL VELOCITIES AND FLOWS - Based on recent measurements, tidal flows and velocities through the entrance throat, under spring tide conditions, are likely to be maintained at 100-150 m^3/s and 1-2 m/s, respectively.

ENTRANCE THROAT DIMENSIONS- Apart from when the entrance is modified by floods, entrance throat depth and width will generally be maintained at 2 to 2.5 metres and 25 to 35 metres, at mid tide level, respectively.

ENTRANCE SAND BAR - Dredging can be expected to have no significant impact on the natural depth regime of the entrance sand bar.

3.4.2 Other Issues

NAVIGATION - Entrance dredging does nothing to modify offshore entrance bar characteristics. Hence the entrance will remain unnavigable.

FLEXIBILITY - Dredging retains full entrance flexibility. The dredging program can be easily tailored to suit changing circumstances. When the dredge is not required for use at the entrance, it can be used for environmental dredging around the lake foreshores. This is a significant bonus of the scheme.

ENTRANCE AMENITY - The entrance is a popular tourist attraction and people wade/swim at the entrance depending upon its natural condition. Dredging has only a slight impact on this by creating a temporary dredge hole and the temporary occupation of North Entrance Beach by a mound of dredged sand. By and large, the area east of the bridge, and away from the entrance, will remain a relatively safe swimming/wading area.

AESTHETICS - Apart from a 12 week dredging deployment period, the natural appearance of the entrance would not be affected. Dredging can be planned to avoid periods of peak entrance usage.

LAKE FORESHORE HABITATS - As tidal levels in the lake are maintained, there are no adverse impacts on lake foreshore habitats. Degradation of foreshore habitats associated with entrance closure *(ie. no tidal flushing)* is avoided.

FISH RECRUITMENT - Present levels of prawn larvae and juvenile fish recruitment would be maintained. By preventing total closure, there will always be an entrance at key times of seasonal recruitment. Hence, over the long term, an increase in the lake fishery could be expected.

3.5 COSTS

Capital cost of dredge *(1994 dollars)*	-	$0.9M
Annual running costs *(entrance dredging only)*	-	$150,000 pa
Dredge refit and maintenance costs	-	Of the order of $150,000 - $300,000 every four years or so.

4. ENTRANCE RESTRAINING WALL

4.1 DESCRIPTION

In 1988, the concept of a southern restraining wall was examined as part of a concept for a fixed dredging system based on the use of jet pumps *(PWD, 1988)*. A restraining wall was considered necessary to eliminate the possibility that the entrance sand spit could outflank the location of fixed pumps which were under consideration at that time. The proposed concept of the restraining wall is shown in **Figure 4.1**.

A restraining wall would stabilise the location of the entrance channel and prevent it from becoming perched on the southern rock shelf. Consequently tidal flows would not be constrained by the rock shelf and the channel would be able to develop its full depth potential, thereby minimising the throttling of tidal flows. During protracted periods of dry weather, the entrance would stay open for much longer than in the past and there would be some chance that it would never close.

A restraining wall would extend seawards to the high water mark of previous accreted shorelines *(ie. when the entrance was closed)*. The 1988 concept design incorporated both eastern and western walls, as shown in **Figure 4.1**. The latter would provide internal training of flood flows and prevent outflanking of the base of the eastern wall.

4.2 DISCUSSION OF ISSUES

4.2.1 Physical Processes

A restraining wall would not alter the physical processes operating under natural conditions (**Section 2**); the entrance would merely take longer to close, if at all. Hence there would be no change to:

- lake levels and tidal flows;
- coastal processes;
- behaviour of entrance shoals;
- flooding behaviour.

As the entrance channel would be prevented from becoming perched on the southern rock shelf, it would tend to be a little deeper, on average, than under natural conditions.

4.2.2 Other Issues

NAVIGATION - There would be no significant benefit to navigation; the entrance would remain unnavigable.

FLEXIBILITY - All the flexible/adaptable features of the natural system would be retained.

ENTRANCE AMENITY - There would be loss of entrance amenity as a restraining wall would limit access to the water from the southern shore. A restraining wall could pose a hazard to young children who could lose their footing and fall into the deep water against the wall. This would be in contrast to the gently shelving sandy beaches at the edge of the shoreline under present conditions.

AESTHETICS - The 1988 restraining wall concept involved the use of sand coloured geotextile tubes. Whilst this would tend to blend, the wall would give a hard artificial line which would diminish the natural look and "feel" of the entrance area. In time, marine growth/slime would discolour the restraining wall.

HABITAT IMPLICATIONS - As the natural physical processes would not be altered, there would be no adverse implications for lake habitat.

CONSTRUCTION IMPACT - The main advantage of the geotextile concept was the avoidance of trucking of heavy armour stone through the streets of The Entrance. The main construction disturbance would be associated with a temporary lack of access to the southern shore during construction.

4.3 COSTS

Capital costs *(1994 dollars)*	-	$800,000
Replacement cost *(1994 dollars)* *(present value of replacement assuming a 10-15 year life)*	-	$250,000
Annual maintenance	-	$7,000

5. CREATION OF A NAVIGABLE ENTRANCE

5.1 DISCUSSION

To create a navigable entrance, it is essential to create a sufficiently deep channel through the entrance sand bar. Ideally, the channel should be relatively stable in location so that it can be easily marked by navigation leads.

The depth of the channel would have to be sufficient, at low water, to cater for the draft of the intended vessel type plus an allowance for underkeel clearance, particularly in the presence of waves. The types of vessels that could navigate the entrance can be divided, for convenience, into two classes:

- *shallow draft vessels* - local pleasure craft with shallow draft, such as fishing boats with outboard engines. For these vessels to "safely" navigate the entrance at most times, a low water depth on the bar of no less than 1 metre would be necessary;
- *large draft commuter vessels* - a much greater low water depth on the bar would be required to allow vessels such as Central Coast/Sydney ferries to navigate the entrance at all times. Based on discussions with Sydney Ferries *(UTA)*, in relation to the smaller ocean going vessels such as wave piercing jet cats and hydrofoils, a low water bar depth of the order of 3.5-4 metres would be required. Bar depths of this order would be suitable for most large pleasure craft including yachts.

5.2 TRAINING OF TIDAL FLOWS

The location and depth of the navigation channel through the entrance bar, at the mouth of the numerous rivers and lakes in New South Wales, is traditionally stabilised by construction of entrance training walls.

Entrance training walls constrict the tidal flow and create a strong ebb tide "jet" which scours the entrance channel, between the walls, as well as a defined channel through the offshore sand bar. The breakwaters need only extend beyond the surf zone *(under storm conditions)* so as to force the entrance bar seawards of the surf zone and to prevent most of the littoral drift from getting into the entrance. The walls are also extended to provide protection from cross currents when travelling through the surf zone.

5.3 SINGLE TRAINING WALLS

Some mention of the applicability of a single training wall is necessary because it could be contemplated as an apparently obvious extension of the restraining wall concept.

Many entrances have single entrance training walls, eg. Macleay River, Manning River, Moruya River, Nambucca River, Wallis Lake *(pre 1966)* and Hastings River *(pre 1977)*. Single training walls have proved to be almost worthless in achieving safe navigable bar crossings. Irrespective of whether the walls have been placed updrift or downdrift of the estuary mouth, the walls have trapped littoral deposits and the entrance bar is generally shallow, very mobile and treacherous to navigate. **Figure 5.3** shows the Nambucca entrance as an example.

A single training wall, at the entrance to Tuggerah Lakes, would not create safe navigation conditions.

6. TWIN ENTRANCE TRAINING WALLS

6.1 DESCRIPTION

Twin entrance training walls would need to extend seaward of the alignment of the entrance sand spit and North Entrance Beach, a minimum distance of about 150-300 metres. A firm design estimate of the length of the walls would require detailed coastal process and geotechnical investigation. Both walls would have to extend shorewards and be connected to the northern and southern shorelines to prevent outflanking by storms and floods. Overall, each training wall would have a minimum length of the order of 500 metres including shoreline connections.

Based on the limited flow data available, suitable entrance bar depths for shallow craft could be achievable with a wall spacing of about 100-130 metres. This spacing would be equivalent to some of the medium size river entrances with training walls, eg. Tweed River (refer **Figure 6.1**).

It would not be possible to create a bar depth suitable for large commuter vessels. Quite simply there is insufficient tidal power in the natural system to create a bar depth of the order of 3.5 metres, at low water. To illustrate this point, the majority of trained entrances in New South Wales have bar depths which are in the range 2 to 3 metres, at low water. Apart from the major ports, it is only the extremely large systems such as the Clarence River and Richmond River which have bar depths, at low tide, in excess of 3 metres.

6.2 DISCUSSION OF ISSUES

6.2.1 Physical Processes

LAKE LEVELS - The substantial widening and deepening of the entrance throat would cause an immediate increase in tidal range in the lake and lowering of the mid tide level, ie. the average lake level would be lower. The changes would increase with time as the upstream sand shoals erode due to the disruption of the natural sand circulation, as noted below *(see ENTRANCE SHOALS)*.

The impact on lake levels would be quite noticeable, even initially.

COASTAL PROCESSES - The local southerly reversal of littoral drift, at the entrance to Tuggerah Lakes, would cause a build up of sand against the northern training wall to form a characteristic sand fillet. These sand fillets are common along all trained river entrances in New South Wales. **Figure 6.2.1** shows the fillet of sand that has accumulated against the northern training wall at Port Macquarie.

Depending upon offshore sediment pathways and the interaction of the offshore reefs with littoral processes, the coastal compartment created by a southern training wall would tend to fill up with sand also.

A build up of the sand on both sides of the entrance training walls, at Tuggerah Lakes, would constitute a permanent loss of sand from the littoral sediment budget. This would lead to erosion and retreat of the shoreline of North Entrance Beach. The exact pattern of erosion would depend upon the final configuration of training walls.

The trained entrance channel would be considerably deeper and wider than that under natural conditions. This would allow considerable ocean swell to penetrate the entrance. The southern foreshore, which has extensive retaining walls and foreshore facilities, would receive wave attack possibly requiring protective works. Wave penetration onto the northern foreshore may lead to minor erosion problems.

The gradual removal of the upstream sand shoals *(refer below)* would increase the penetration of ocean swell and expose The Entrance to greater storm surge flooding. The actual effect will be moderated, to an extent, by the ability of the entrance training walls to pierce the surf zone and reduce the wave setup component of storm surge. The overall impact is likely to aggravate flooding both at The Entrance and in the lake.

ENTRANCE SHOALS - The circulation of sand involving the upstream sand shoals, the entrance sand bar and nearshore littoral transport would be cut off:

The ebb tide would continue to scour the upstream sand shoals and transport sand onto the new entrance sand bar which would form opposite the mouth of the training walls. Sand moving onshore from the entrance sand bar would tend to be trapped by the entrance training walls in the northern and southern sand fillets. Hence the sand conveyed back onto the upstream sand shoals, by the flood tide, would be greatly reduced. Because of the reduced influx of marine sand, the upstream entrance shoals would progressively shrink over time.

This process has been going on for almost thirty years at Forster (refer **Figure 6.2.2**). Construction of a second breakwater in 1966 interrupted a sand circulation, very similar to, but much larger than, that which exists at the entrance to Tuggerah. Since 1966, the entrance shoals equivalent to the upstream sand shoals at Tuggerah, have eroded (refer **Figure 6.2.2**). The erosion has been so great that the bridge piers, which used to be located in the middle of the sand shoals, have lost support and corrective bridge works have been necessary.

Since 1966, tidal range in Wallis Lake has increased more than three fold as a result of the loss of the sand from the entrance reaches of the estuary *(ie. from about 4 cms in 1966 to more than 13 cms by 1980; Nielsen and Gordon, 1980).*

FLOODING BEHAVIOUR - Entrance tidal scour requires narrow entrance training walls whereas high flood discharges require wide entrance training walls. Hence navigation objectives can be at the cost of increased flood levels. It is usual for a compromise to be found.

A fixed entrance width of 100-130 metres would severely constrain the discharge capacity of the entrance to Tuggerah Lakes, under major flood conditions. As a consequence there would be an increase in peak flood levels on the lake. The effect is likely to be significant, possibly of the order of 0.3-0.5 metres for a 1% flood. Detailed flood analysis would be required to determine an absolute value.

ENTRANCE THROAT DIMENSIONS - The entrance throat would be fixed at the wall width of 100-130 metres and a relative constant entrance channel depth of the order of 2 to 3 metres could be expected.

ENTRANCE SAND BAR - The training walls would cause a permanent channel to form through the bar with a ruling depth of the order of 1 m below ISLW.

6.2.2 Other Issues

NAVIGATION

- Shallow Draft Vessels - It would be feasible to create safe navigation conditions for local pleasure craft.
- Large Draft, Commuter Vessels - It would not be feasible to create safe navigation conditions for large draft commuter vessels by the construction of entrance training walls alone. Quite simply, there is not enough energy in the system. Other complementary works would be required such as major channel dredging (**Section 7**).

FLEXIBILITY - Entrance flexibility would be lost:

- the entrance would not be able to discharge major floods without a significant increase in lake flood levels;
- progressive erosion of the upstream sand shoals would occur;
- there would be a loss of control of the tidal regime in the lake, ie. there would be an immediate lowering, followed by progressive lowering, of the average lake level;
- the range in the tide of the lake would increase progressively.

ENTRANCE AMENITY - The wading/swimming sand shoal amenity of the existing entrance would be replaced by training walls, wall fishing opportunities and an explosion in recreational boating usage. It could be expected that there would be a significant change in foreshore facilities and character to service the increased boating. Tidal flows would be increased in the area downstream of the bridge. The increased velocities plus boating activities would increase the hazards to swimmers/waders. The entrance channel would be very hazardous to swimmers because of the strong currents and difficult foreshore access.

In short, the amenity of the area would alter to suit different user groups.

AESTHETICS - The natural beauty of the entrance would be lost. The area would remain attractive but it would take on more of an artificial "port" feel with much greater emphasis on boats and related foreshore facilities.

LAKE FORESHORE HABITATS - The drop in average lake levels and increased tidal range would have a significant impact on the many hectares of shallow lake margins. Large areas of gently sloping lake margins *(including organic muds)* would be exposed, exacerbating the problems of noxious odours, seagrass die-back and poor circulation of water amongst shallow lake margins. Die-back of seagrass beds, due to over-heating in water that has got too shallow, would add to odour problems and affect the productivity of the fishery and important marine bird foraging areas. Reduced circulation in shallow lake margins would lead to increased algal growth due to increased residence time and solar heating.

The amenity of the lake foreshore would be compromised by substantial reduction in the average lake level.

FISH AND PRAWN RECRUITMENT - The permanently open and relatively deep entrance could be expected to enhance recruitment of prawns and fish including larger commercial fish species.

ACCESS FOR SHARKS - Fisheries experts have indicated in respect of other entrance training projects, that entrance deepening increases the likelihood of ingress of large marine organisms such as porpoise and sharks. The likelihood of shark attack, no matter how remote, would be a significant unwanted risk to many present users of the area.

CONSTRUCTION IMPACTS - The cheapest and most practical means of constructing entrance training walls is by means of rubble mound techniques. Heavy armour stone would be placed on the outside of the training walls, to provide protection against storm waves.

The nearest quarries which could supply the requisite size of high density basalt are located at Seaham *(large armour stone)* and Peats Ridge *(underlayer/core material)*. The product from local quarries at Gwandalan *(Munmorah Conglomerate)* and Wyong *(Wyong Sandstone)* may not necessarily meet the technical specification for marine application. Stone would be transported by heavy trucks along main roads and by appropriate routes through The Entrance. Something of the order of 10,000-20,000 truck loads would be involved, depending upon truck capacity. The wall would take about 12-18 months to construct.

6.3 COSTS

A major factor in the amount of rock required to construct stable rubble mound walls is the tidal and flood scouring that takes place between the training walls. Rock quantities have to allow for the final, stable wall cross-section. Detailed investigation is required to establish firm estimates of quantities.

Based on very preliminary indications of rock supply and tipping costs, from the nearest suitable quarries, the approximate cost of constructing twin training walls to provide entrance conditions suitable for navigation by shallow draft pleasure craft only, would be in the following range:

- twin training wall construction, including allowance for surveys, investigation, design and construction supervision
    - $13-20 million *(depending upon suitability of local stone)*
- indicative maintenance costs associated with periodic storm damage and maintaining safe public access, could be taken as $1.0 to $1.5 million every 10 years;
- in terms of an order of cost, the above can be compared to the cost *(1994 dollars)* of twin training walls at Brunswick Heads, Evans Head and Wagonga Inlet of $10 million, $11 million and $10 million respectively;
- the foregoing cost ranges do not make allowance for road damage caused by heavy trucks carrying the stone from the quarries to the entrance.

7. TWIN ENTRANCE WALLS WITH MAJOR CHANNEL DREDGING

7.1 DESCRIPTION

As noted previously, Tuggerah Lakes is too small a system to generate safe navigable conditions for large commuter vessels and large pleasure craft by the construction of entrance training walls alone. If a large navigation channel was dredged, connecting the lake to the entrance, the tidal range of the lake and the peak ebb discharge would be increased enormously. The physical dimensions of the channel involved would have to be substantial, probably something of the order of 40-60 metres in width and several metres deep.

Under these conditions, the tidal flows generated would be large enough to create bar conditions suitable for the safe passage of large commuter vessels. It is considered that training walls would need to have a width of approximately 60-80 metres. They would need to be no longer than that already suggested for the previous case of no dredging.

Training walls of this spacing would be equivalent to some of the smaller river entrances with training walls, eg. Brunswick River, Evans River, Bermagui River and Wagonga. Wagonga Inlet is shown as an example, refer **Figure 7.1**.

7.2 DISCUSSION OF ISSUES

7.2.1 Physical Processes

LAKE TIDAL LEVELS - The average lake level would be reduced to approximately mean sea level and tidal range would be increased many-fold.

COASTAL PROCESSES - The impact on coastal processes would be the same as the previous case *(ie. twin walls without major channel dredging)* except that the nourishment of North Entrance Beach, with some of the sand from the channel dredging, would compensate for coastal sediment budget deficit.

ENTRANCE SHOALS - Because of the direct removal of a large area of the entrance shoals; there would probably be no additional long term losses. However there would be considerable reworking and adjustment of the channel due to high tidal flows.

FLOODING BEHAVIOUR - The increase in lake flood levels would be even greater than the previous case. The potential flood damages associated with increased flood levels in the lake would warrant additional flood discharge facilities. These would increase the overall cost of the scheme.

ENTRANCE THROAT DIMENSIONS - The width of the entrance throat would be fixed at 60-80 metres. A relative constant channel depth, between the entrance training walls, of 6-8 metres could be expected.

7.2.2 Other Issues

NAVIGATION - Navigation by large commuter vessels and large pleasure craft would be feasible.

FLEXIBILITY - As previous case *(ie. twin walls without major channel dredging).*

ENTRANCE AMENITY AND AESTHETICS - As previous case *(ie. twin walls without major channel dredging)*, except tidal velocities throughout the area downstream of the bridge would be too high for swimmers..

LAKE FORESHORE HABITAT - The substantial drop in the average water level of the lake would have profound consequences for the ecology of the shallow lake foreshores. Enormous areas of the lake foreshore, including extensive mud banks and areas rich in black organic ooze, would be exposed at low tide and there would be considerable die-back of foreshore seagrasses and loss of valuable fish nursery and bird wading habitat.

Noxious odours would be ubiquitous and extensive treatment of lake margins would be required. Many of the benefits of the Tuggerah Lakes Restoration Project would be negated by the large drop in lake level.

The substantial increase in tidal flows would, however, greatly improve water quality throughout the lakes.

FISH AND PRAWN RECRUITMENT - As previous case *(ie. twin walls without major channel dredging).*

ACCESS FOR SHARKS - As previous case *(ie. twin walls without major channel dredging).*

CONSTRUCTION IMPACTS - As previous case *(ie. twin walls without major channel dredging).* In addition, a dredge delivery line would run along the northern foreshore as the capital dredging was carried out.

7.3 COSTS

Considerably more rock would be required, as compared to the previous option, because of the much deeper entrance channel. Also the much deeper entrance bar conditions would allow greater storm waves to impact on the wall. Hence larger and more expensive armour stone would be required.

The cost of twin training walls, capital dredging and allowance for investigation, design and construction supervision is:

$17-$28 million *(depending upon suitability of local stone).*

Indicative maintenance costs associated with periodic storm damage and maintaining safe public access, could be taken as $1.5-2.5 million every 10 years.

These costs do not make allowance for road damage caused by heavy trucks carrying stone from the quarries to the entrance.

8. SUMMARY REMARKS

The salient aspects of each entrance management approach can be summarised as follows:

Approach	Capital Cost	Ongoing Cost	Maintenance Cost	Comments
Periodic Dredging **(Section 3)**	$0.9 million	$150,000 pa	$150,000 - $300,000 approximately every 4 years	• Entrance unnavigable. • Entrance aesthetics and amenity maintained. • Lake levels maintained. • Flood discharge potential maintained. • Adaptable to suit changing entrance conditions.
Entrance Restraining Wall **(Section 4)**	$0.8 million	$250,000 present value of replacement based on 10-15 year life	$7,000 pa	• Entrance unnavigable. • Entrance aesthetics compromised. • Entrance amenity adversely impacted. • Lake levels maintained. • Flood discharge potential maintained.
Twin Entrance Training Walls **(Section 6)**	$13-20 million	–	$1.0 to 1.5 million every 10 yrs approx.	• Entrance navigable by small pleasure craft. • Average lake level lowered. • Potential for erosion of North Entrance Beach. • Erosion of entrance foreshores due to penetration of ocean swell. • Loss of entrance shoals. • Increased flood levels. • Entrance aesthetics and amenity changed substantially.

cont'd

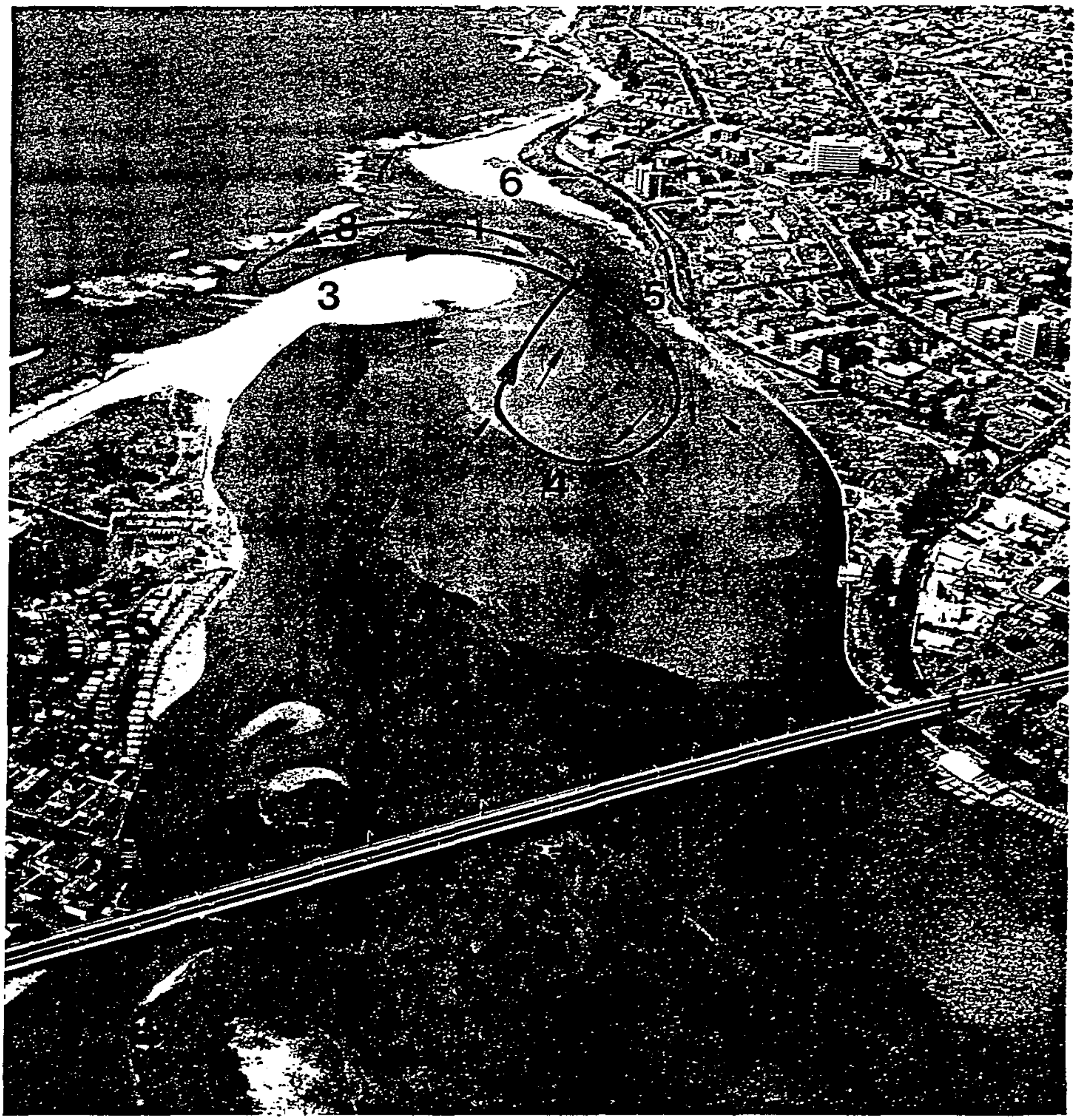
Approach	Capital Cost	Ongoing Cost	Maintenance Cost	Comments
				• Adverse impacts on lake foreshore habitat. • Increased lake flushing and recruitment of fish and prawns. • Ease of access for large marine animals including sharks. • Adverse construction impacts.
Twin Entrance Walls with Major Channel Dredging **(Section 7)**	$17-28 million	–	$1.5 to 2.0 million every 10 yrs approx.	• Entrance navigable by large commuter vessels and large pleasure craft including yachts. • Average lake level drops to mean sea level. • Potential for erosion of North Entrance Beach. • Erosion of entrance foreshores due to penetration of ocean swell. • Loss of entrance shoals. • Increased flood levels. • Entrance aesthetics and amenity changed substantially. • Profoundly adverse impacts on lake foreshore habitat. • Increased lake flushing and recruitment of fish and prawns. • Ease of access for large marine animals including sharks. • Adverse construction impacts.

9. REFERENCES

Nielsen A F and Gordon A D - Tidal Inlet Behavioural Analysis, Proceedings 17th International Conference, Coastal Engineering, Sydney, 1980.

Public Works Department - Tuggerah Lake Entrance Improvements, Entrance Restraining Wall. Concept Design Report, October 1988, Report No. PWD 88069

FIGURES



LEGEND

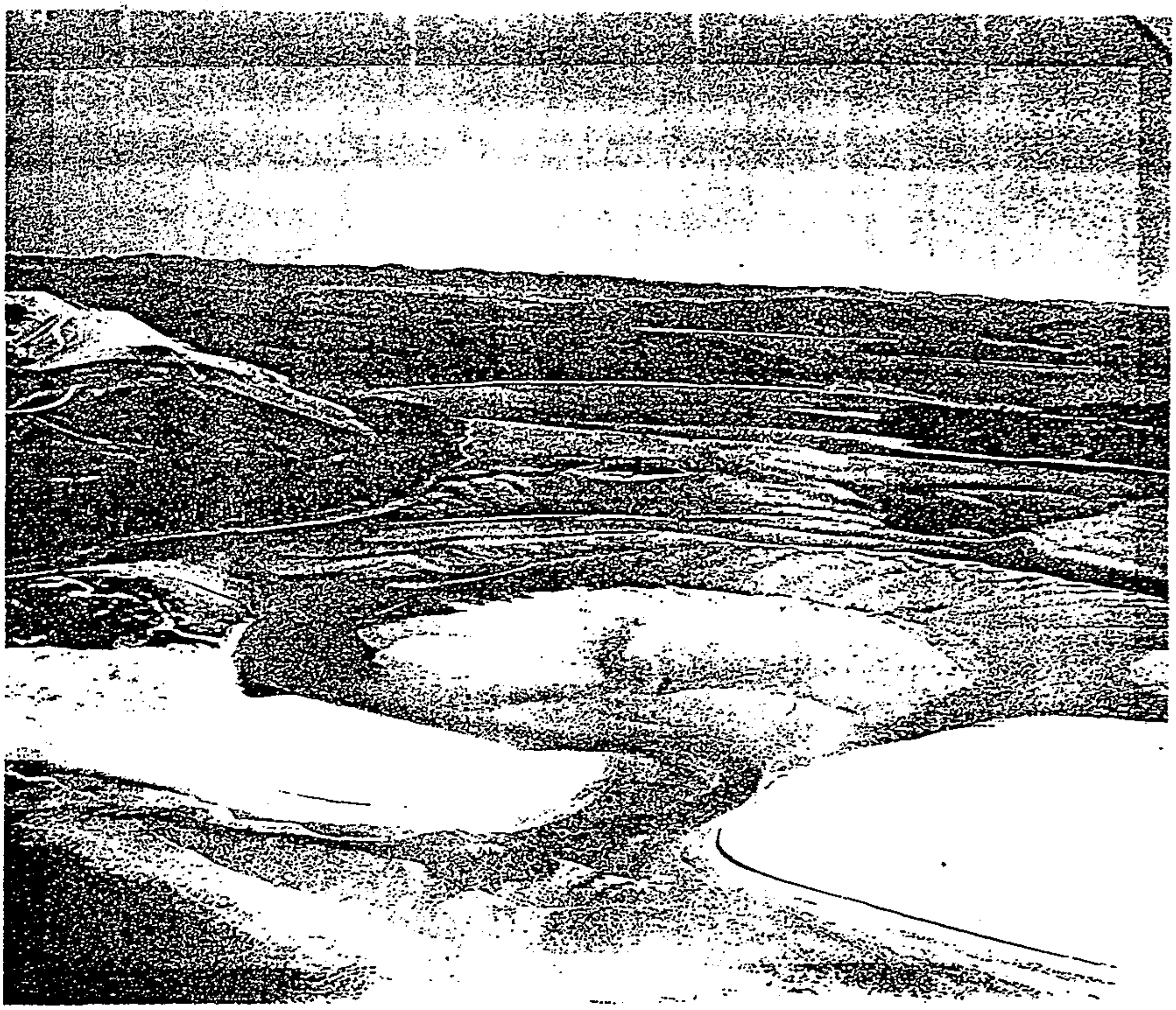
1 ENTRANCE CHANNEL
2 THROAT
3 SAND SPIT
4 UPSTREAM SAND SHOALS
5 ROCK SHELF ALONG SOUTHERN SHORELINE
6 BEACH ALONG SOUTHERN SHORELINE
7 ROCK OUTCROP
8 NEARSHORE ENTRANCE SANDBAR

SAND TRANSPORT PATHWAYS

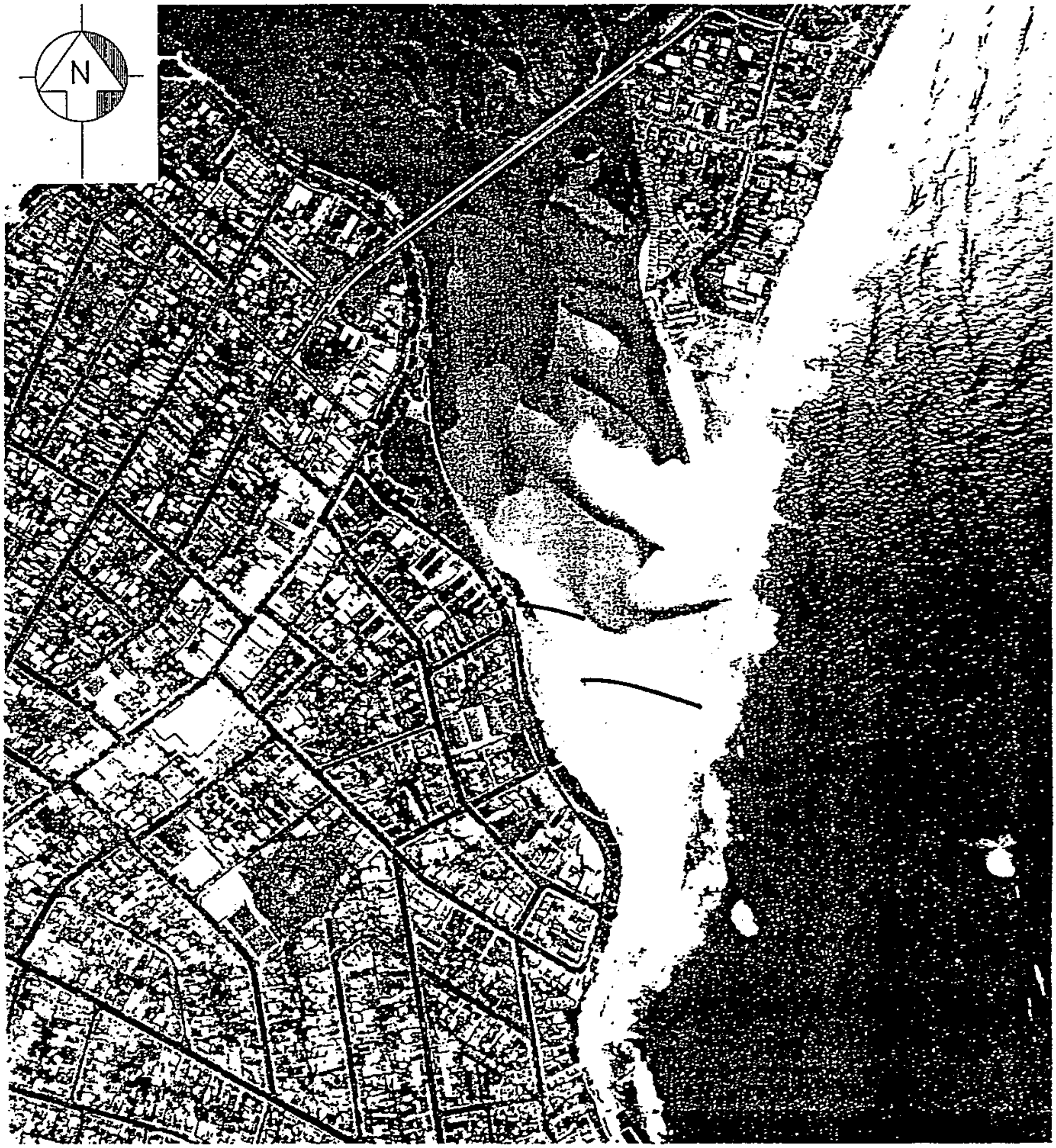
OVERALL SAND CIRCULATION (INDICATIVE ONLY)

J1816/R1005

FEATURES THAT CHARACTERISE THE ENTRANCE TO TUGGERAH LAKES



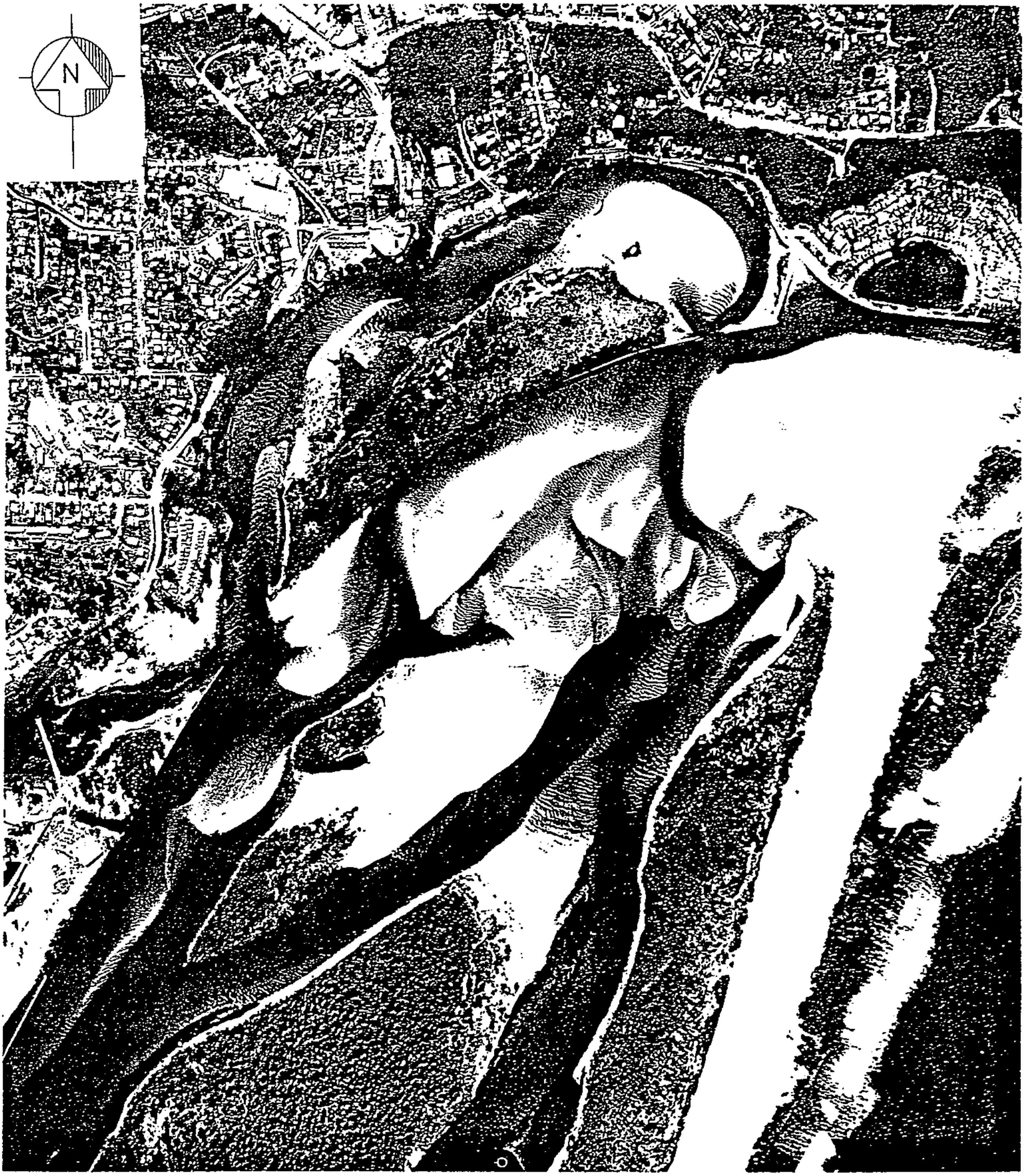
SMITHS LAKE ENTRANCE SHOALS



SOURCE: REPORT No. P.W.D.88069
OCTOBER,1988

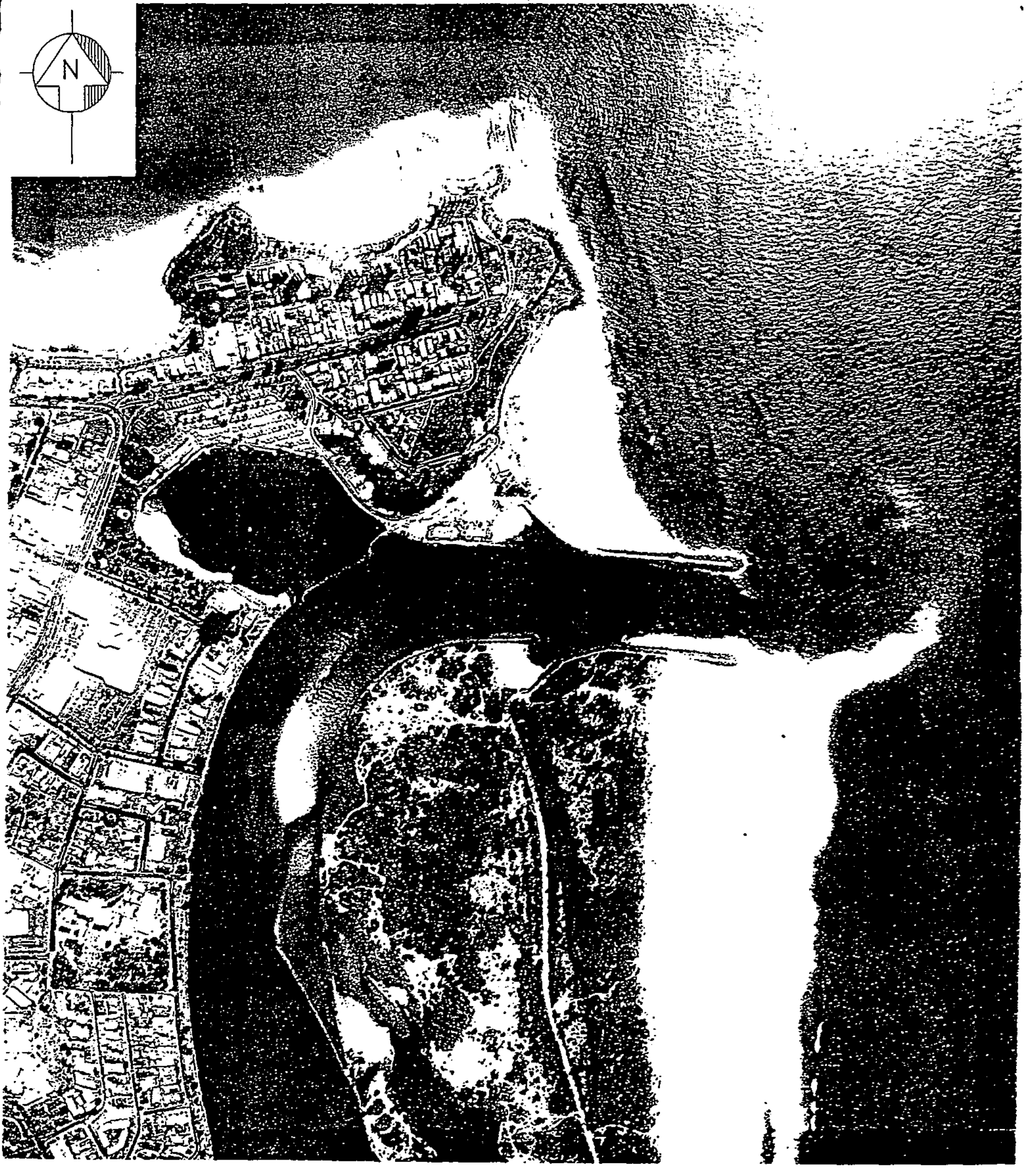
PROPOSED ARRANGEMENT OF RESTRAINING WALL SUPERIMPOSED ON MARCH 1987 AERIAL PHOTOGRAPH

J1816/R1005



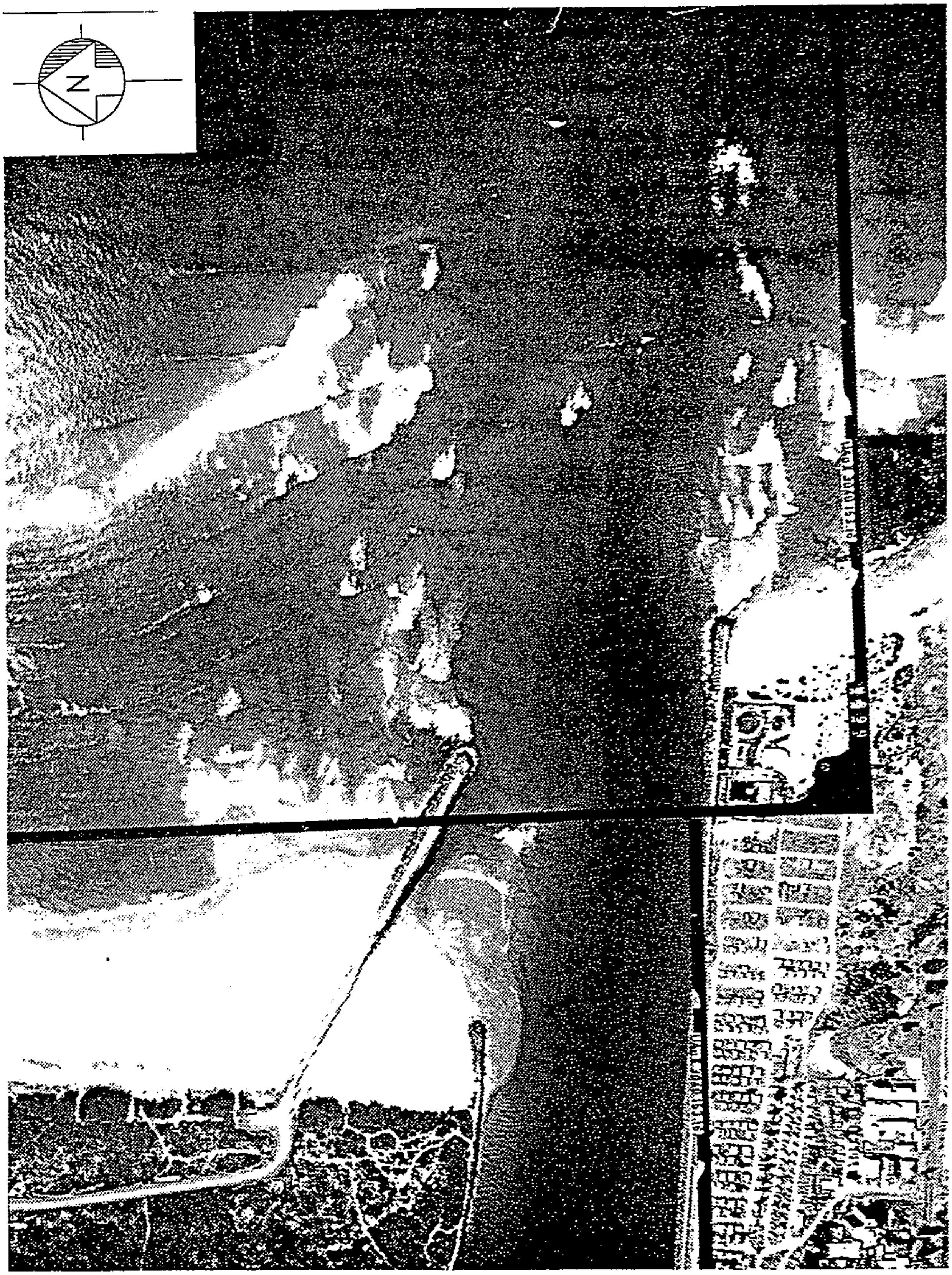
NAMBUCCA RIVER ENTRANCE

FIGURE 6.1



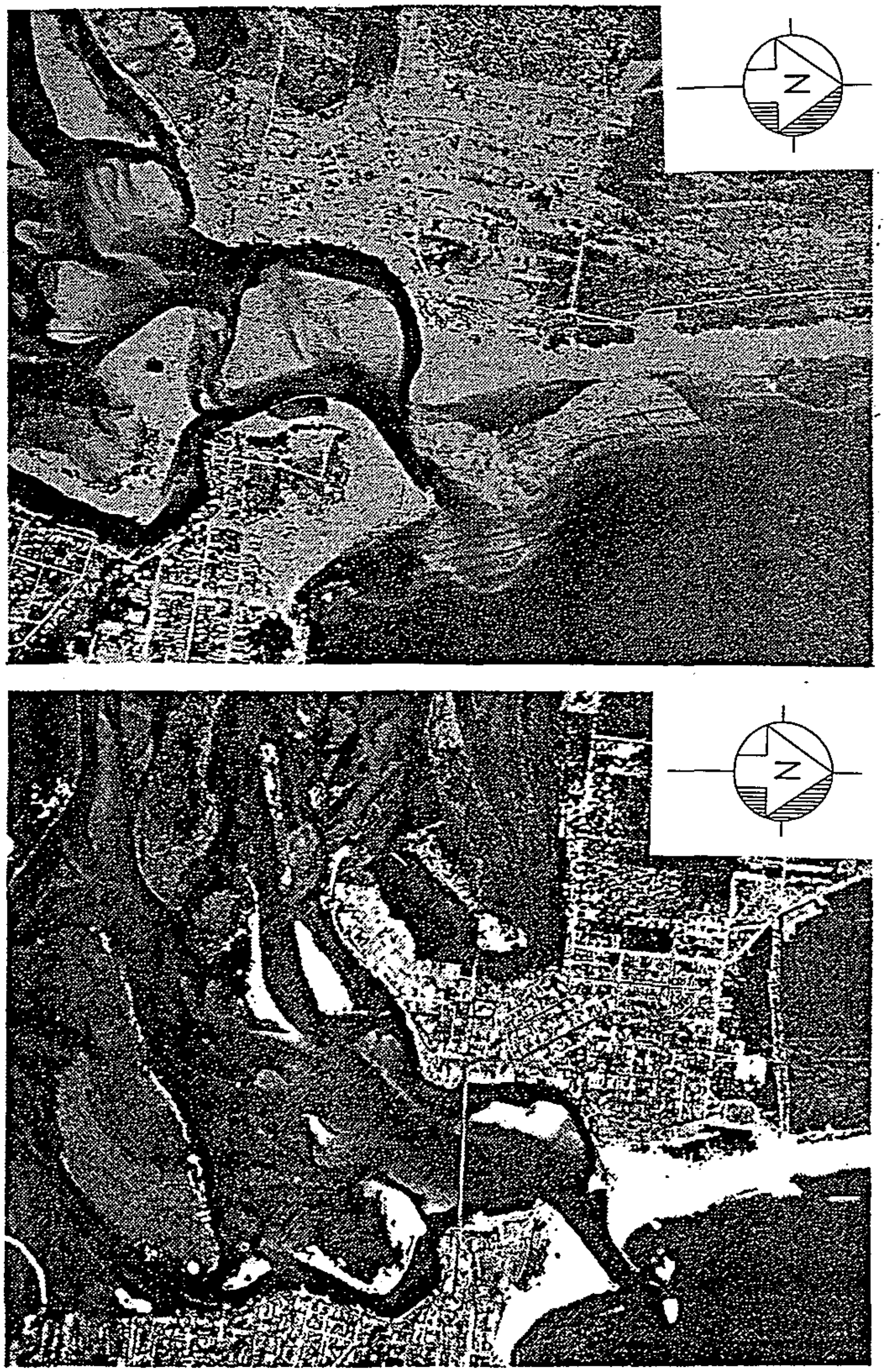
TWEED RIVER ENTRANCE

FIGURE 6.2.1



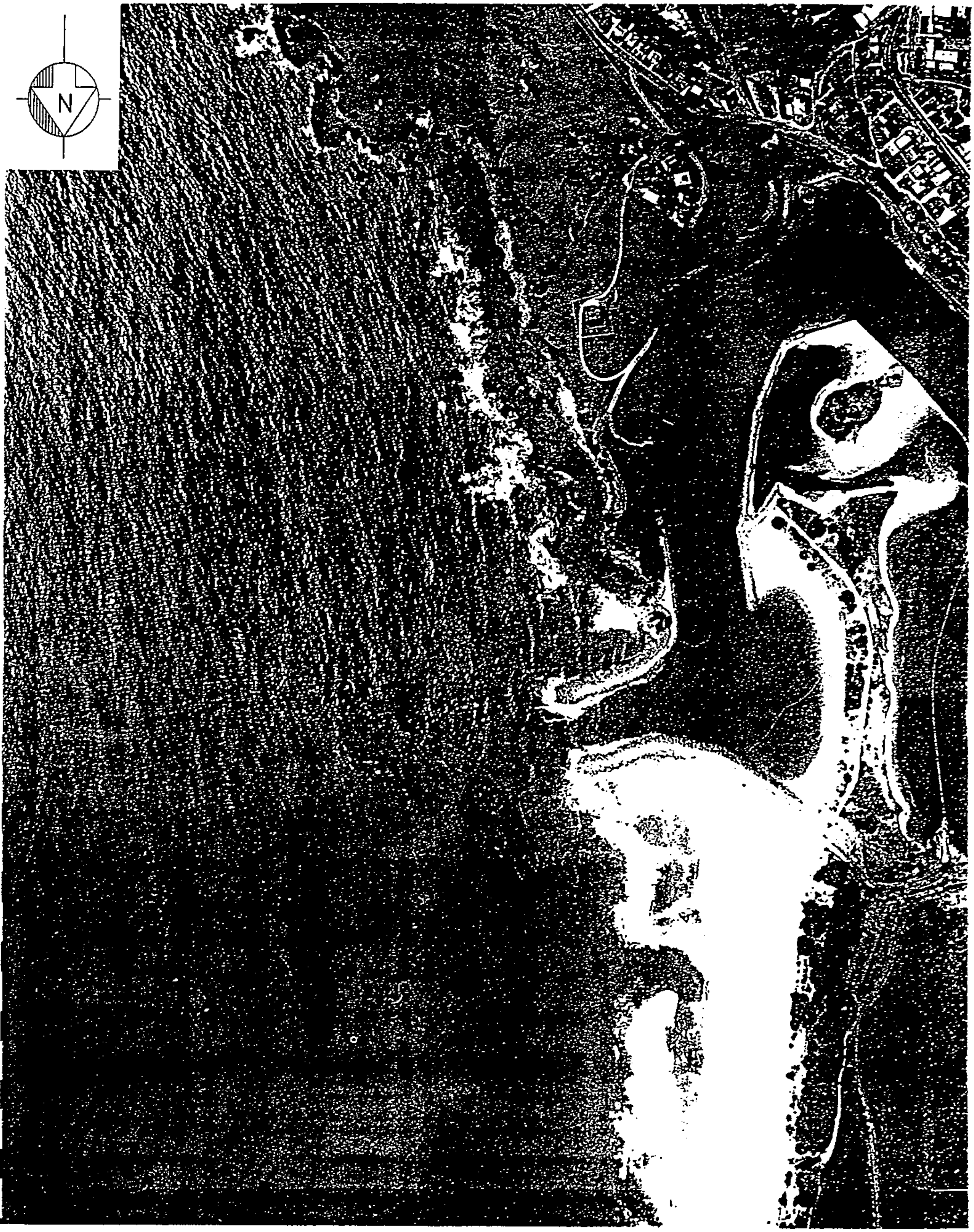
PORT MACQUARIE AUGUST 1977
DURING CONSTRUCTION OF NORTHERN
TRAINING WALL SHOWING SAND BUILDING
UP ON NORTHERN BEACH FILLET

FIGURE 6.2.2



SOURCE: NIELSON & GORDON - TIDAL INLET BEHAVIOURAL ANALYSIS, PROCEEDINGS 17TH INTERNATIONAL CONFERENCE COASTAL ENGINEERING, SYDNEY, 1980

WALLIS LAKE INLET IN 1952 AND 1974
(NORTHERN BREAKWATER CONSTRUCTED IN 1966)



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WAGONGA INLET