Port Hacking Marine Delta

 Replies to questions raised by the Dredging and Recreation Sub-Committees of the Port Hacking Planning and Advisory Committee.
Dear Sir

PORT HACKING MARINE DELTA - MANAGEMENT OPTIONS REPORT
QUESTIONS RAISED BY THE DREDGING AND RECREATION
SUB-COMMITTEES

Thank you for forwarding to the Department the questions raised on the
Department's Management Options report by the Dredging and Recreation Sub-
Committees in their letter to you dated 25 September 1986.

As you know, the Management Options report was intended to reach a wide cross-
section of the public and therefore much of the technical detail concerning the
investigation of the shoaling processes, and the management options and their
impacts was presented essentially in an overview manner. The Department is
pleased to provide additional information on the specific questions raised by the
Sub-Committees, and this is contained in the attached report.

As you would appreciate, the preparation of written responses to queries is very
time consuming. It is therefore requested that, wherever possible, any further
queries the Committee may wish to raise be handled verbally with the Department's
representatives on the Committee.

Yours faithfully

B.M. Druery
Supervising Engineer
ESTUARY MANAGEMENT
PORT HACKING MARINE DELTA
MANAGEMENT OPTIONS REPORT

REPLIES TO QUESTIONS RAISED BY THE DREDGING AND RECREATION SUB-COMMITTEES OF THE PORT HACKING PLANNING AND ADVISORY COMMITTEE

The following sets out replies to the questions raised by the Dredging and Recreation Sub-Committees of the Port Hacking Planning and Advisory Committee in a letter to the Chairman of the Committee dated 25 September 1986. The numbering of the replies corresponds to that used for the questions in the Sub-committees’ letter.

1. **TIDAL FLOW**

1 (i)(a)&(b)

The model of Port Hacking was a combined one-dimensional (1-D) and two dimensional (2-D) mathematical model based on a knowledge of bathymetry and the usual equations of conservation of mass and conservation of momentum. Over the last 10-15 years these models have become the mainstay of engineering investigations into hydrodynamic phenomena. The Department has considerable experience with mathematical modelling beginning with very large model studies of the Tweed and Tuggerah estuaries, conducted in the mid-70’s.

The crucial stages in the development of a mathematical model of a particular system like Port Hacking is its calibration and verification which involves adjustment of friction factors in order to satisfactorily reproduce field measurements of tidal levels, tidal velocities, and tidal flow paths.

The bathymetry used in the model was primarily the 1978 Public Works Department hydrosurvey, completed at a cost of $100 000. More localised surveys of dynamic shoal areas, eg the middle ground shoal, were also carried out as necessary to define significant bathymetric changes post 1978.

The raw tidal data on which the model was based was collected over the period 1978 to 1985 at different locations throughout the estuary and under a variety of tidal conditions. The methods employed to collect the data comprised three main techniques (refer Data Sheets 4, 6 and 7):

- **TIDAL GAUGING** - tidal velocity measurements were taken at discrete points throughout the water column (0.9D, 0.7D, 0.5D, 0.3D, 0.1D where D is the water depth) at several locations across the gauging line, and the velocities integrated with the time-varying cross sectional area to derive tidal discharge. Measurements were carried out over a full ebb and flood tidal cycle, ie 13 hours, using directional current meters lowered from work boats anchored in the tidal stream.

- **TIDAL FLOW PATHS (FLOAT TRACKING)** - surface and shallow sub-surface drogues were deployed and tracked using a vessel equipped with electronic position fixing equipment. Real-time analysis and plotting of the drogue tracks was carried out using an on-board computer.
AUTOMATIC WATER LEVEL AND FLOW SENSORS - a system of remotely operated current meters, wave/tide poles, and tide recorders was established throughout the estuary to continuously record water level and velocity data. Data included measurements, twice each second, of the rapid water surface and near bed oscillatory currents which occur as a result of wave action at the mouth and in the Simpsons Bay area.

The total cost of this data acquisition over the last seven years has been about $150,000 and it provides a very comprehensive set of measurements which describe the spatial and temporal behaviour of water level variation and flow in Port Hacking throughout the normal range of spring, neap and seasonal tides. Appendix 'A' summarises the extent of the tidal data collection.

1 (ii)(a)

As a follow-on from Question 1(i), it is presumed 1981 should read 1985.

Tidal velocity measurements have continued to be taken since 1985 at Pole 0, Pole 1 and Pole 2 (refer Appendix 'A'). No further tidal gauging or tidal flow path measurements have been taken since 1985.

Tidal velocities at Pole 0 and Pole 2 have not undergone any discernible change since 1985. Velocities at Pole 1 however, have altered in response to changing shoal patterns in that area. For example, peak spring ebb and flood velocities have reduced by 80% as the main ebb channel has taken a more easterly alignment.

1 (ii)(b)

It is important to appreciate that at this stage the Departments' studies have been aimed at establishing the feasibility of all management options. The actual change in tidal velocities which would be associated with any particular option would be dependent on further preliminary and detailed design. For instance, in the case of the tombolo option, the actual local velocity field in the vicinity of the tombolo would be dependent on factors such as the location, width and depth of the entrance between the tombolo and Hungry Point, and the length and alignment of the rock "headland". These aspects would be determined by further model studies (physical and mathematical) during the next stage of the project. The detailed design would give consideration to wave-current interaction and ramifications for factors such as navigation conditions and wave diffraction/refraction.

For purposes of the options study, the arrangement of the tombolo was as shown on p.29 of the report, ie gap width of approximately 200 m. Under this particular arrangement, the existing and predicted tidal velocities are as set out in Table 1.

Detailed mathematical model simulations showing velocity magnitude contours and velocity flow paths, at peak discharge, are shown in Appendix 'B'. Plots relevant to the tombolo option are:

B.1 Existing Condition (ie 1980 bathymetry)
Flood Tide - velocity magnitude contours and flow paths.

B.2 Existing condition (ie 1980 bathymetry)
Ebb Tide - velocity magnitude contours and flow paths.
B.3 and B.5  Tombolo Simulation - Flood Tide.  
Note eddy circulation into Simpsons Bay will promote excellent flushing and water quality.

B.4 and B.6  Tombolo Simulation - Ebb Tide.  
Note flow pattern demonstrates good penetration into Simpsons Bay with concentration against N.W. corner of tombolo.

B.11 and B.12  Existing Condition (ie 1980 bathymetry)  
Velocity time series and velocity direction time series.  
Location 1 - Channel south of Turriel Point (see B.1 - B.2).  
Location 2 - Channel between Burraneer Point and Deeban Spit (see B.1 - B.2).

B.13 and B.14  Tombolo Simulation  
Velocity time series and velocity direction time series.  
Locations 1 and 2 as above.  
Note no change in velocity directions re comparison of B.12 and B.14 indicating minimal impact on pattern of flow in vicinity of Turriel Point.

<table>
<thead>
<tr>
<th>Location</th>
<th>Existing Ebb</th>
<th>Existing Flood</th>
<th>Predicted Ebb</th>
<th>Predicted Flood</th>
</tr>
</thead>
<tbody>
<tr>
<td>. CSIRO Wharf</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1/0.2</td>
<td>0.1/0.2</td>
</tr>
<tr>
<td>. Between Hungry Point and Cabbage Tree Point</td>
<td>0.3</td>
<td>0.3</td>
<td>0.7/0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>. Northern extremity of the tombolo</td>
<td>0.2 - 0.3</td>
<td></td>
<td>0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>. Channel between Burraneer Point and Deeban Spit (location 2 B.1-B.4, refer B.11 &amp; B.13)</td>
<td>1.0</td>
<td>1.3</td>
<td>0.85</td>
<td>0.90</td>
</tr>
<tr>
<td>. Area south-east of Turriel Point (location 1 B.1-B.4, refer B.11 &amp; B.13)</td>
<td>0.2</td>
<td>0.4</td>
<td>0.2</td>
<td>0.35</td>
</tr>
</tbody>
</table>
1 (ii)(c)

Similar general comments can be made as for Question (ii)(b) above, ie the model results show the feasibility of the option. They should not be viewed as final design predictions.

For purposes of the options study, the arrangement of the Deeban Spit training wall was as shown on p.27 of the report, ie. channel width of approximately 150m. Under this particular arrangement, the existing and predicted tidal velocities are as set out in Table 2. Detailed mathematical model simulations showing velocity magnitude contours and velocity flow paths, at peak discharge, are shown in Appendix ‘B’.

Plots relevant to the Deeban Spit Training Wall are:

B.1 Existing Condition (ie 1980 bathymetry)
   Flood Tide - Velocity magnitude contours and flow paths.

B.2 Existing Condition (ie 1980 bathymetry)
   Ebb Tide - Velocity magnitude contours and flow paths.

B.7 Deeban Spit Training Wall Simulation
   Flood Tide - Velocity magnitude contours and flow paths.

B.8 Deeban Spit Training Wall Simulation
   Ebb Tide - Velocity magnitude contours and flow paths.

Note: With regard to B.7 and B.8 - both ebb and flood tide flows against Deeban Spit are weakly directed South to North. Hence sand would build up as a fillet against the training wall.

TABLE 2 - DEEBAN SPIT TRAINING WALL OPTION
Peak Ebb and Flood Velocity (ms⁻¹) for a Tide of 1.5m Range
(Note: Mean Spring Range 1.34 metres)

<table>
<thead>
<tr>
<th>Location</th>
<th>Existing Ebb</th>
<th>Existing Flood</th>
<th>Predicted Ebb</th>
<th>Predicted Flood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel between Burraneer Point and Deeban Spit</td>
<td>1.0*</td>
<td>1.3*</td>
<td>1.4*</td>
<td>1.4*</td>
</tr>
<tr>
<td>Channel south of Turriel Point</td>
<td>0.7**</td>
<td>0.9**</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>CSIRO Wharf</td>
<td>0.1*</td>
<td>0.1*</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>Between Hungry Point and Cabbage Tree Point</td>
<td>0.3*</td>
<td>0.3*</td>
<td>0.4*</td>
<td>0.4*</td>
</tr>
</tbody>
</table>

* Peak depth averaged velocity (2-D simulation)
** Peak section averaged velocity (1-D simulation)
1 (ii)(d)

Again, similar general comments can be made as for Question (ii)(b).

For purposes of the options study, the arrangement of the groynes at Lilli Pilli was as shown on p.27 of the report, i.e. channel width of approximately 120 m. Under this particular arrangement, the existing and predicted tidal velocities are as set out in Table 3.

**TABLE 3 - MAIN CHANNEL FLOW AT LILLI PILLI**

Peak Section Averaged Ebb and Flood Tide Velocity (ms^{-1}) for a Tide of 1.5m Range (Note: Mean Spring Range 1.34 metres)

<table>
<thead>
<tr>
<th>Location</th>
<th>Existing Ebb</th>
<th>Existing Flood</th>
<th>Predicted Ebb</th>
<th>Predicted Flood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel between Lilli Pilli groynes and Gogerly's Point</td>
<td>0.5</td>
<td>0.6</td>
<td>No Change (Increased Depth Compensates)</td>
<td></td>
</tr>
</tbody>
</table>

1 (ii)(e)

The absolute accuracy of the model is dependent on the accuracy of the field data used for calibration viz;

- ± 20% on velocity
- ± 30% on tidal discharge
- ± 0.05m on tidal level

It needs to be appreciated that while these indicate levels of confidence in predicting the absolute value of a specific water level or velocity etc, the relative accuracy of the model is much greater. Relative accuracy refers to the ability of the model to correctly predict behavioural trends, i.e. direction or sense of change. The only proviso is that the change should not depart too much from the conditions for which the model is calibrated and verified. There are no hard and fast rules on this and the relative accuracy is a matter for the judgement and experience of the modeller.

The Port Hacking system is relatively "well behaved", e.g. there are no flow separation points and no confined jet action which would impair the relative accuracy of the model. Hence, the Department is satisfied that the relative accuracy of the model predictions is very good. The absolute accuracy of the model predictions is within the margins outlined above.
1 (iii)(a)

It is not the intention, nor is it necessary, to completely eliminate sand movement in order to achieve stable navigation channels. The aim is to design the channels so that the natural scouring action of tidal flows is sufficient to sustain the required depth, taking into account any sediment which may be supplied to the channel.

A naturally occurring example of the above situation in Port Hacking is the channel between the northern end of Deeban Spit and Burraneer Point. This channel is stable at a depth of approximately 6 m below Indian Spring Low Water (ISLW) although considerable sediment movement occurs along the channel during each ebb and flood tide, and sediment is supplied to the channel by means of a net northerly littoral drift along Deeban Spit. Peak depth-averaged tidal velocities through the channel for a mean spring tidal range are more than 1 metre per second.

From experience with the design of all the trained river entrances of NSW the Department has found that the entrance channels achieve dynamic equilibrium, under situations of high sediment flux, when the peak depth averaged velocity is about 1 metre per second (MHWS). These entrances however are on the open coast and operate with high littoral sand supplies. In the case of the tombolo option, there would be no sediment supply to the entrance between the tombolo and Hungry Point. The magnitude of peak depth-averaged tidal velocities to achieve a stable channel depth in excess of 4m below ISLW would be in the order of 0.6 to 0.8 metres per second. These values are reflected in the mathematical modelling results for the tombolo option presented on p.30 of the report.

1 (iv)(a)

The volume of sand required to form the tombolo would be in excess of that which would be available from initial dredging to form the self scouring navigation channels. The sand quantities dredged from the channels would therefore be "completely absorbed" by construction of the tombolo.

The additional areas from which sand would be dredged to construct the tombolo (mainly Simpsons Bay) are shown on p.28 of the report. There would be many alternatives for the final bathymetric pattern of areas such as Simpsons Bay.

1 (iv)(b)

Dredging of the navigation channels to achieve stable depths in excess of 3 and 4 m below ISLW is definitely envisaged and these costs have been included in the overall project cost (pages 38 and 45 of the report).

1 (iv)(c)

Not applicable.
2. WAVES AND WATER CIRCULATION

2 (v)(a)

Higher tidal velocities would occur at the entrance to, and within, the channel between the tombolo and Hungry Point following construction of the tombolo, than currently exist in these areas, eg refer model results on p.16 and p.30 of the report. Increased ebb tide velocities would tend to steepen waves, (ie reduce wave length) although this effect would be more than offset by the increased water depths (4m and greater) which would increase the wavelength of incident waves. A preliminary analytical assessment of the effect of increased ebb tide velocities on wave steepness is outlined in part (c) of this question.

Further studies are to be carried out in the next stage of the project, involving physical modelling, to examine wave and current interaction in more detail.

2 (v)(b)

In the case of the Deeban Spit training wall option, the wave climate within Simpsons Bay including Bonnie Vale Beach would be expected, in time, to increase as the area deepens due to onshore movement of the middle ground shoal (p29 of report). Tidal velocities within Simpsons Bay would reduce following construction of the training wall (refer p.16 and p.30 of the report and Appendix 'B').

Higher tidal velocities would occur at the entrance to, and within, the channel between the training wall and Burraneer Point following construction of the wall, than currently exist in these areas. As for (a) above, the increased ebb tide velocities would tend to steepen the incident waves but this effect would be more than offset by the natural deepening of Simpsons Bay which would increase the wavelength of incident waves.

A preliminary analytical assessment of the effect of increased ebb tide velocities on wave steepness is outlined in part (c) of the question below.

Further studies, involving physical modelling, would be required to establish wave and current interaction in more detail.

2 (v)(c)

The interaction of waves and currents at the entrance to estuaries, particularly the steepening and possible breaking of swell waves during ebb flows, is a fundamental and critical consideration in the design of any entrance.

Waves steepen (ie the distance between wave crests reduces and wave height increases) when waves travel into shallow water and when they travel over an opposed current such as the ebb current at river entrances. Wave steepness increases with continued shallowing and opposed current strength until the critical steepness is reached and the wave breaks.

Wave steepness is of concern to mariners because vessels can broach in the presence of steep waves and run the risk of capsizing. In relation to the wave conditions which exist at the entrance to Port Hacking now, as compared to those which would apply for the tombolo etc option, it is necessary to carefully examine
the compensating effects of increased depth which reduces wave steepness, and the effect of increased ebb currents which will tend to increase wave steepness.

These theoretical considerations demonstrate that in relation to both the tombolo and training wall options, the reduction in wave steepness due to the increase in water depth more than compensates for any tendency for increased wave steepness due to the increase in maximum ebb current.

The wave/current interaction is best studied with the aid of physical models, and this would form an important part of the next stage of the Port Hacking project. It is, however, possible to give some indication of the likely interactions, using well established analytical techniques (refer Appendix C).

2 (vi)

Water circulation in Simpsons Bay for the tombolo option was studied using the results of the 2-D mathematical modelling. The results are set out in diagrammatic form in Appendix ‘B’ (see previous discussion).

2 (vii)

It is presumed that "wave fronts" should read "wave orthogonals" in this question. Re-alignment of Deeban Spit to a right angle with the wave orthogonals, together with a small rock stabilising groyne/headland would not achieve the same effect as that proposed by the Bonnie Vale tombolo.

The rock stabilising groyne/headland would have to be sufficiently long to train tidal flows, and to fully impound the quantities of sand which would move onshore naturally from the middle ground shoal as well as the substantial quantities which would be pumped into Simpsons Bay from channel dredging. In practice, this rock feature would have to be of similar length to the Deeban Spit training wall and would effectively become that option.

The re-alignment etc of Deeban Spit would also not provide a number of the significant benefits of the Bonnie Vale tombolo, viz:

- creation of additional foreshore land and access to the waterway featuring two beaches;
- creation of a wave protected estuarine bay suitable for development of recreational facilities and conducive to the establishment of seagrasses and a marine biological nursery;
- creation of a stable entrance channel greater than 4 m in depth, connected to the natural 4 m offshore depth contour. This would create the opportunity for cruise ferries to operate in and out of Port Hacking;
- provide a much safer alternative route for the Bundeena ferry in times of bad storms.
3. NAVIGATION AND LANDSCAPE CONSIDERATIONS

3 (viii)

The projected main channel depths for each of the options are discussed in pages 37 and 38 of the report and are summarised in Table 4.

**TABLE 4**
Summary of Options re: Channel Depths

<table>
<thead>
<tr>
<th>Option</th>
<th>Main Channel Depths</th>
</tr>
</thead>
<tbody>
<tr>
<td>. No Adjustment to Natural Processes</td>
<td>Only those channels on the Cronulla-Bundeena ferry route would be maintained. Ruling depths would be approximately 2 m ISLW with no increase in channel widths. Ruling channel depths further upstream would be expected to reduce to approximately 1 m ISLW.</td>
</tr>
<tr>
<td>. Maintenance Dredging</td>
<td>All recognised navigation channels would be maintained. Ruling depths would be approximately 2 m ISLW, with no increase in channel widths.</td>
</tr>
<tr>
<td>. Commercial Sand Extraction to Maintain Channels</td>
<td>All recognised navigation channels would be maintained. Ruling depths would be approximately 2 m ISLW. Some increase in channel widths would be likely.</td>
</tr>
<tr>
<td>. Engineering Works to Stabilise Channels</td>
<td>Channel depths to 4 m ISLW up to Burraneer Point, 3 m ISLW thereafter. Channel widths would be increased substantially.</td>
</tr>
<tr>
<td>. Major Commercial Sand Extraction</td>
<td>Dredge depths may vary but would be expected to be a minimum of 8.5 m ISLW in broad dredge areas. In channel areas, the maximum dredge depths would be limited by stable channel side slopes, but would be expected to exceed 4 m ISLW.</td>
</tr>
</tbody>
</table>
The actual minimum constrictions for the Bonnie Vale tombolo and the Deeban Spit training wall would be subject to further investigation and detailed design, involving physical and mathematical modelling and could be modified to suit particular navigation or recreational requirements. For purposes of the options study the constrictions adopted were as follows:

- Bonnie Vale tombolo - constriction 200 m
- Deeban Spit training wall - constriction 150 m

Construction plans will be dependent upon the final Waterway Management Plan which will determine to what extent proposed facilities and defined usage areas place constraints on construction. Detailed design and documentation, involving construction programming, will comprise an important component of subsequent stages of the Port Hacking project. In so far as the options study is concerned, the main elements used to determine the construction time spans for the Deeban Spit training wall and Bonnie Vale tombolo options, and the estimates of the time spans are set out below:

**Deeban Spit Training Wall**

The main "construction" items in this option are the groynes at Lilli Pilli, the training wall, and the associated dredging of navigation channels.

The length of time for construction of the groynes at Lilli Pilli would be dependent on whether floating plant is used, or whether it would be possible to use land-based plant in association with road access provided as part of a reclamation concept at Lilli Pilli. The actual placement of the groynes would be expected to be completed within a period of 8 weeks.

The training wall at Deeban Spit would be constructed by conventional end tipping of rock from trucks. The time to construct the wall would be mainly a function of the rate at which rock can be placed and trimmed as the wall progresses offshore. Adopting a typical placement rate of about 30 tonnes per hour, and taking into account the total quantities of rock required (approximately 50 000 tonnes) and the number of working weeks per year, a period of about 12 to 14 months would be required for construction of the wall. Allowing time for advance stockpiling of good quality primary armour rock at the quarry, construction of an access road along Deeban Spit from Bonnie Vale, and some downtime due to weather, a total construction period of approximately 24 months would be reasonable for the completion of the training wall.

The dredging which would be carried out as part of the Deeban Spit training wall option would be expected to involve removal of approximately 300 000 cubic metres of material over a period of five years. A preliminary dredging programme has been established based on historical dredging records and the anticipated response of the channels to construction of the engineering works. This is set out in Table 5. The timing of the dredging is expressed in terms of years from commencement of construction of the training wall and groynes, which it is assumed would take place in Year 1.
### TABLE 5
Preliminary Dredging Programme

<table>
<thead>
<tr>
<th>Location</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoal at end of training wall</td>
<td>10 000</td>
<td>10 000</td>
<td>10 000</td>
<td>10 000</td>
<td>10 000</td>
<td>50 000</td>
</tr>
<tr>
<td>Channel into Gunnamatta Bay</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>50 000</td>
<td>50 000</td>
</tr>
<tr>
<td>Channel across mouth of Burraneer Bay</td>
<td>35 000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>35 000</td>
</tr>
<tr>
<td>Channel near Lilli Pili</td>
<td>140 000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>140 000</td>
</tr>
<tr>
<td>Total</td>
<td>185 000</td>
<td>10 000</td>
<td>10 000</td>
<td>10 000</td>
<td>60 000</td>
<td>275 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Say</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>300 000m³</td>
</tr>
</tbody>
</table>

In summary, for the Deeban Spit training wall option, the training wall and groynes at Lilli Pili would be completed within two years. Dredging would commence at the same time as the training wall and groyne construction, and continue for a further three years after these works were completed.

**Bonnie Vale Tombolo**

The main "construction" items in this option are the tombolo (including the rock "headland" at the northern end), and the associated dredging. The tombolo is formed by material dredged from the navigation channels and from Simpsons Bay. The tombolo construction and dredging activities are therefore directly dependent.

The construction time span would be dependent mainly on the size of the dredge and the hours which it would be permitted to operate. Taking this second factor first, the likely hours of operation for the dredge would be 10 to 12 hours per day, 5 days per week. It is anticipated that a relatively large capacity cutter suction dredge, possibly capable of delivering solids at rates of up to 1 000 cubic metres per effective hour would be used (by comparison, the cutter suction dredges which have been used recently for maintenance dredging have a capacity of about 100 cubic metres of solids per effective hour).

Use of a high capacity dredge would have a number of advantages. The dredge would ensure relatively rapid construction of the tombolo, which would be desirable from an environmental point of view, and also assist in minimising sand losses from the unprotected tip through natural processes such as storms. It would also more efficiently accommodate some of the longer pumping distances involved.
The tombolo would be constructed from shore in a northerly direction, and involve use of external containment bunds to achieve good control on side slopes and a satisfactory quality of return water. The rock "headland" at the northern end of the tombolo would be constructed towards the end of the operation using land-based plant.

All up, the anticipated construction time for the tombolo and the associated dredging, including construction of initial access roads and mobilization of dredging plant, is approximately two years.

3 (xi)
The first three options considered for Port Hacking, viz

- No Adjustment to the Natural Processes
- Maintenance Dredging of the Channels
- Commercial Sand Extraction to Maintain Channels

do not offer any additional improvements to the entrance to Port Hacking than have been provided in the past by maintenance dredging. Some difficulties would also still be expected to be experienced at the entrance to Port Hacking during adverse weather in the case of the Deeban Spit training wall option.

The tombolo option offers the potential for a safer harbour in two main respects:

- it provides a "deepwater" entrance, of 4 m below ISLW, which is connected to the natural 4 m offshore depth contour;
- it creates a large area of sheltered waterway in Simpsons Bay, protected from both ocean swell and strong southerly winds (it is significant to note that Gunnamatta Bay for example, although sheltered from ocean swell, is exposed to strong winds from the south).

The major commercial sand extraction option also provides a deepwater entrance, but does not provide any sheltered waterway in Simpsons Bay.

The question of whether Bate Bay is a safe entry to Port Hacking in extreme conditions is outside the scope of the Department's study of the shoaling processes within Port Hacking. This question would be more appropriately addressed to the Maritime Services Board, as the Government's authority on navigation.

The use of the term "safe harbour" in the Department's report is in the context of the tombolo option providing significantly improved conditions for entry into Port Hacking by craft forced to do so at times of adverse weather.

3 (xii)
The tombolo would essentially amount to a duplication of Deeban Spit, only further seaward, and would present a similar visual character and impact. It is anticipated that the height of the tombolo would be approximately the same as the higher points of Deeban Spit, ie probably approximately 5.5 m above ISLW.

No insuperable problems are expected in relation to the establishment of vegetative cover on the tombolo. The Public Works Department and the Soil Conservation
No insuperable problems are expected in relation to the establishment of vegetative cover on the tombolo. The Public Works Department and the Soil Conservation Service have successfully completed a large number of beach improvement and mining rehabilitation projects along the NSW coast involving the establishment of stable vegetative cover in exposed environments similar to those which would be experienced on the tombolo. A nearby example is the dune restoration and stabilization works at Kurnell.

The introduction of vegetation on the tombolo would be carefully planned with and probably carried out by the Soil Conservation Service and would involve consideration of ground modelling (contouring), use of wind breaks and prescribed beach access routes through the frontal dune, topsoiling, and use of species consistent with those from a natural succession, indigenous to the area.

Typically, the fully exposed foredune would be initially stabilised by planting of marram grass and coastal spinifex. After approximately one year, coastal wattle would be planted. Species such as banksia and teatree would be planted after a period of one and a half to two years. Eucalypts would be planted in the less exposed locations.

A good indication of the ability to sustain a community of indigenous species in Port Hacking, and the attractive landscape this provides, can be found on the vestigial islands off Maianbar.

A further indication of the ability to establish a rich vegetative cover of indigenous species on a substrata of clean, sluiced marine sand can be seen in Appendix D which shows this taking place at Noosa Heads, Queensland, during the period 1979-1984. The westward extension of Noosa Beach was a project similar in concept and size to the proposed Port Hacking tombolo.
4. DATA SHEETS

4 (xiii)

Radio-isotope sand tracing was performed on one occasion at each of the locations shown on the plan in Data Sheet 10. Each sand tracing exercise was carried out over a period of 3 weeks and hence covered a full spring/neap tidal cycle, and on occasions included storm activity.

Extensive consideration was given to the analysis of sand movement throughout the estuary under a wide variety of tidal and seasonal conditions. Radio-isotope sand tracing was, of course, only one of a number of techniques used. Other techniques included:

- measurement of dropover movement (Data Sheet 8)
- measurement of bedform movement (Data Sheet 9)

Measurements of dropover movement at eight sites throughout the estuary are continuing to take place at approximately six monthly intervals. A comprehensive data set comprising more than five years of records is now available.

Other techniques used to analyze sediment movement on a longer term time scale have included:

- photogrammetry
- comparison of historical hydrosurveys
- interpretation of sedimentological and geomorphological characteristics
- drilling, coring and radiocarbon dating of shell material

All of the above information has been evaluated and integrated to develop a comprehensive understanding of sediment movement in Port Hacking.

4 (xiv)

In the assessment of the impact or significance of a particular storm event, it is essential to gain an understanding of how often that particular storm event may be expected to occur, ie the frequency of occurrence of the event or, alternatively, the rarity of the event.

Measurements of wave height in Port Hacking did not commence until late 1983, and therefore at the time of the 1984 June/July storms described in Data Sheet 11, less than 12 months of records were available from which to assess the rarity of the storms. Clearly, an assessment of the rarity of the June/July 1984 storms based on the Port Hacking records alone would have been potentially misleading. For this reason, the Port Kembla wave records for these storm events were examined, and the longer term wave data which is available for Port Kembla used to more confidently predict the rarity of the storms.

The "particular statistics" concerning wave heights in Port Hacking are set out in Data Sheet 5. These indicate that significant wave heights in the vicinity of Pole 0 are less than 0.5 m for about 100 days per year or about 30% of the time. It is also of interest to note that wave heights in Port Hacking at Pole 0 are, on average, only about 25% of the wave heights recorded in deepwater off Port Kembla. As wave energy is a function of wave height squared, the wave energy in Port
Hacking at Pole 0 is less than 10% of the wave energy in deep water offshore from Port Kembla.

Wave heights within Port Hacking, seaward and inshore off the middle ground shoal, are very sensitive to water level. This is illustrated in Data Sheet 11, which presents simultaneous measurements of storm wave heights at Pole 0 (seaward of the shoal) and Pole 1 (inshore of the shoal). In such cases, the effect of storm surge (superelevation of the water level above normal astronomical tidal levels) is particularly significant, since it enables penetration of larger waves further inshore and can lead to increased foreshore erosion.

4 (xv)

The 1851 hydrosurvey was limited in detail and extent, and was examined mainly qualitatively to establish broadly the bathymetric features existing at that time.

The 1871 hydrosurvey was more detailed and covered a greater extent of the waterway than the 1851 hydrosurvey. The 1871 hydrosurvey was compared quantitatively to recent hydrosurveys, taking into account factors such as:

- survey datums used
- likely accuracy of the soundings
- likely accuracy of the plan position of the soundings

A comparison of longitudinal sections of the seabed between Burraneer Point and Jibbon Head in 1871 and 1978, showing the erosion of the seaward face of the marine delta over this time, is presented in Data Sheet 13. This plot was taken from survey comparisons carried out as part of the Department's 1980 report (PWD 80023; refer Appendix 'E')

4 (xvi)

The use of air photo interpretation and photogrammetry to assess historical change would appear to be adequately described in Data Sheet 14.

Photogrammetry was employed in particular to establish the time history of movement of the dropover crests over the approximate 50 year period of photographic record from 1930 to 1983. The results were used to assess whether the detailed dropover measurements taken by divers over the past five years are reasonably representative of longer term historic dropover behaviour.

4 (xvii)

This question has been answered in the reply to Question 1 (i)(a)&(b).
APPENDIX A

PORT HACKING TIDAL DATA COLLECTION - SUMMARY

<table>
<thead>
<tr>
<th>Figure</th>
<th>Exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>1965</td>
</tr>
<tr>
<td>2.</td>
<td>15/3/79</td>
</tr>
<tr>
<td>4.</td>
<td>14/3/79</td>
</tr>
<tr>
<td>5.</td>
<td>10/9/79</td>
</tr>
<tr>
<td>6.</td>
<td>19/2/80</td>
</tr>
<tr>
<td>7.</td>
<td>20-22/2/80</td>
</tr>
<tr>
<td>8.</td>
<td>3-4/6/81</td>
</tr>
<tr>
<td>9.</td>
<td>8/3/83</td>
</tr>
<tr>
<td>10.</td>
<td>3/5/85</td>
</tr>
<tr>
<td>11.</td>
<td>13-14/8/85</td>
</tr>
</tbody>
</table>

Automatic Recorders

LOCATION DIAGRAM
14th MARCH 1979

METERING LINE WITH BUOY LOCATIONS

FIG. 4
LOCATION DIAGRAM
10 SEPTEMBER 1979

FIG. 5
LOCATION OF METERING LINES AND TIDEBOARDS
19th FEB. 1980
PORT HACKING

FLOAT TRACKING AREA AND THEODOLITE STATIONS
20th - 22nd FEB. 1980
LOCATION DIAGRAM

PORT HACKING
3 AND 4 JUNE 1981

METERING LINE WITH BUOY LOCATIONS.
PORT HACKING LOCALITY PLAN
DROGUE TRACKING 8-3-83 AND 3-5-85
PORT HACKING RADIOISOTOPE SAND TRACING
CURRENT METERING 13th - 14th AUGUST 1985
AT SITES 1-14.
PORT Hacking 2D
EXTENDED MODEL 1.5m SIN TIDE (ORIGINAL BED 1980)
TIME 15.51
2D MODEL TIME SERIES
PORT HAKING 2D
EXTENDED MODEL 1.5M SIN TIDE (ORIGINAL)
2D MODELL TIME SERIES
PORT HACKING 2D
EXTENDED MODELL 1.5M SIN TIDE (ORIGINAL

VELOCITY DIRECTION (DEG)

TIME (HRS)
2D MODEL TIME SERIES
PORT HAKING 2D EXTENDED MODEL
BED ESTIMATE 1990, 1.5M SIN TIDE

TOMBOL

VELOCITY DIRECTION (DEG)
0 -100 -200

TIME (HRS)
0 2 4 6 8 10 12 14 16 18 20 22 24 26
APPENDIX C - ANALYTICAL ASSESSMENT OF WAVE/CURRENT INTERACTION

The work by Herchenroder (Effects of Currents on Waves, US Army Corps of Engineers, CETA 81-14, October 1981) provides a relatively simple means for assessing the modification to a wave in the presence of a current. These assessments have been made for the tombolo and training wall options using a typical swell wave period of 10 seconds, and peak tidal velocities (about mid tide level). A reasonable range of bed levels has been used to test the sensitivity of the results.

The following symbols are used:

\[ V \] - maximum ebb current (\( \text{ms}^{-1} \))
\[ d \] - water depth (m)
\[ H \] - wave height (m)
\[ L \] - wave length (m)
\[ H/L \] - wave steepness
\[ R_H \] - dimensionless wave height factor \( H_v/H_A \), where \( H_v \) is the height of the wave when the current is present, and \( H_A \) is the height of the wave when no current is present.

The results are as given in Table C.1 and Table C.2.

### TABLE C.1
Effect of Tombolo on Wave Conditions (at proposed entrance location)

<table>
<thead>
<tr>
<th>Existing</th>
<th>Future</th>
<th>H Existing</th>
<th>(H/L) Existing</th>
</tr>
</thead>
<tbody>
<tr>
<td>V d L R_H</td>
<td>V d L R_H</td>
<td>H</td>
<td>(H/L)</td>
</tr>
<tr>
<td>0.3 3 50.4 1.01</td>
<td>0.6 5 61.5 1.02</td>
<td>1.01</td>
<td>0.83</td>
</tr>
<tr>
<td>0.3 4 58.0 1.01</td>
<td>0.6 6 67.7 1.02</td>
<td>1.01</td>
<td>0.87</td>
</tr>
<tr>
<td>0.3 5 64.8 1.01</td>
<td>0.6 7 72.6 1.02</td>
<td>1.01</td>
<td>0.90</td>
</tr>
</tbody>
</table>

For the range of probable existing and future depth combinations, and increase in maximum ebb current from 0.3 \( \text{ms}^{-1} \) to 0.6 \( \text{ms}^{-1} \), the wave height increase is only in the order of 1%, and the wave steepness in fact reduces by about 10 to 15%. The explanation for the wave steepness decrease is that the change (increase) in wave length due to the increase in water depth is much more significant than the increase in wave height due to the increase in maximum ebb current.

### TABLE C.2
Effect of Training Wall on Wave Conditions (seaward of end of wall)

<table>
<thead>
<tr>
<th>Existing</th>
<th>Future</th>
<th>H Existing</th>
<th>(H/L) Existing</th>
</tr>
</thead>
<tbody>
<tr>
<td>V d L R_H</td>
<td>V d L R_H</td>
<td>H</td>
<td>(H/L)</td>
</tr>
<tr>
<td>0.7 1 23.9 1.02</td>
<td>1.0 2 33.6 1.03</td>
<td>1.01</td>
<td>0.72</td>
</tr>
<tr>
<td>0.7 2 36.7 1.02</td>
<td>1.0 3 43.0 1.03</td>
<td>1.01</td>
<td>0.86</td>
</tr>
<tr>
<td>0.7 3 46.2 1.02</td>
<td>1.0 4 50.6 1.04</td>
<td>1.02</td>
<td>0.93</td>
</tr>
</tbody>
</table>
For the range of probable existing and future depth combinations, and increase in maximum ebb current from 0.7 ms\(^{-1}\) to 1.0 ms\(^{-1}\), the wave height increase is only in the order of 1 to 2\%, and, as for the tombolo option, there is in fact a significant reduction in the wave steepness.
PORT HACKING : COMPARISON OF HYDROSURVEYS

FIGURE 13

(PORT HACKING SEDIMENT STUDY- AUGUST 1980)