Management of Peel Inlet and Harvey Estuary

Report of research findings and options for management

Department of Conservation and Environment
Perth, Western Australia
Bulletin 170 May, 1984

Management of Peel Inlet and Harvey Estuary

Report of research findings and options for management

Department of Conservation and Environment
Perth, Western Australia
Bulletin 170 May, 1984

Report compilation

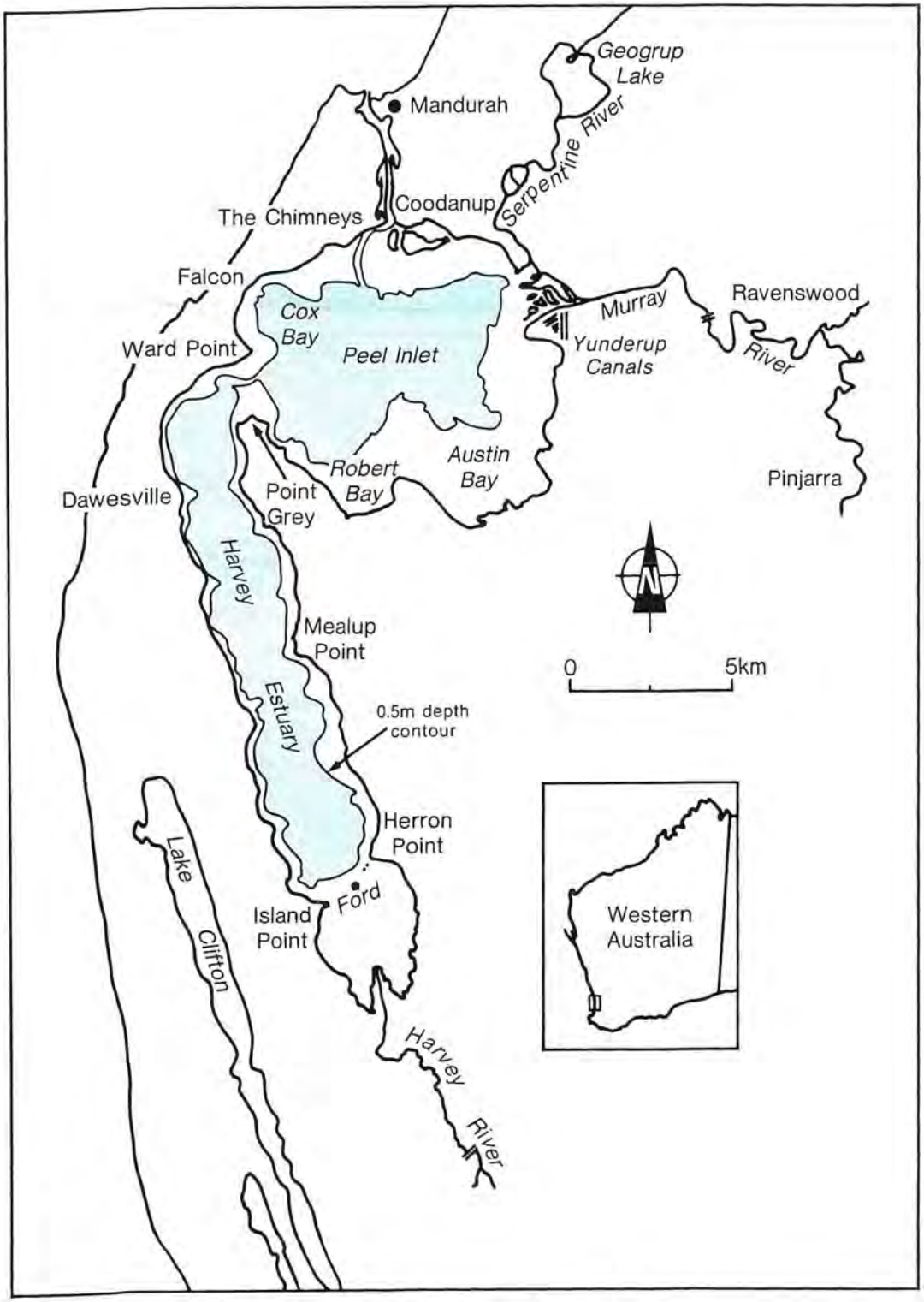
This report was compiled by Kinhill Stearns, Engineers, and the Department of Conservation and Environment (DCE) from a large number of DCE bulletins and reports prepared by the Peel-Harvey Study Group and from reports produced by the Centre for Water Research of the University of Western Australia. These publications are available at the Department of Conservation and Environment, 1 Mount Street, Perth.

- **Report compilation** — Dr R.E. Black (Kinhill Stearns)
Dr E.P. Hodgkin (DCE)
- **Editing:** — L.R. Snooks (Kinhill Stearns)
- **Technical illustration:** — T.J. Bennett
- **Report production:** — B.M. Stewart (DCE)
S.L. Tonkin (Kinhill Stearns)
A.L. Shillingford (Kinhill Stearns)

ISSN 0156-2983
ISBN 0 7244 68986

Cover: Photomicrograph of *Nodularia spumigena*. Courtesy A. Huber

CONTENTS



Peel Inlet and Harvey Estuary

Summary

Contents of this report

This report describes the history and findings of the research into the nature and causes of the algal problem of the Peel-Harvey Estuary. Environmental management objectives and ways in which these might be achieved are discussed, and the combination of management measures which forms the 'preferred strategy' is explained. Supplementary management options which require further investigation are also discussed, as well as some of the many 'solutions' commonly proposed over the past few years.

The report has been produced at this time to enable interested members of the public to be kept fully informed of progress in finding a solution to the estuary's algal problem.

The problem

Many West Australians use Peel Inlet and Harvey Estuary for various activities, such as fishing, swimming, crabbing, prawning, boating, picnicking, or as a general holiday focus. The permanent population of the Mandurah and Murray shires has also increased rapidly over the last few years, from approximately 13,300 people in 1976 to 21,400 in 1982, with residential communities as well as holiday accommodation expanding along the foreshores. The area is therefore important to a wide variety of people: fishermen who derive their living from the estuary waters, the people who live near the foreshores or who own holiday homes there, the vacationers attracted to the area, and the residents of Mandurah and the surrounding region who use the foreshores for picnicking and other passive recreation.

However, for many years, masses of green algae have been accumulating in the shallows along the shores of Peel Inlet, and decomposing into an offensive smelling black ooze. As early as 1960, fishermen complained about algae fouling their nets, and during the early 1970s the algal problem accelerated rapidly, developing into a serious social issue which persists to the present time.

During the last ten years, the Peel Inlet Management Authority has conducted a programme of raking and removal of algae from the worst affected areas in order to minimize the nuisance caused by rotting algae. While this alleviates the problem, the programme produces some undesirable effects: mounds of decomposing algae on beaches, and the inevitable loss of sand and vegetation through the necessary use of heavy equipment.

Search for a solution

The Western Australian Government is committed to finding and implementing the most appropriate measures to overcome the algal problem of the estuary, or at worst to contain it. Since 1976, the Government has funded a wide range of research programmes aimed at understanding the nature and causes of the algal problem in the estuary, determining practicable management measures likely to improve the condition of the estuary, and evaluating the proposed measures on a cost/benefit basis.

Research findings

What has emerged from this comprehensive research work is the unpleasant fact that there is no simple answer to the estuary's problems, even though the principal cause is clear: the excessive input of nutrients (especially phosphorus) to the estuary from agricultural land on the coastal plain. It is also clear that the problem will continue, and indeed become worse, unless action is taken to reduce the amount of nutrients available to algae in the estuary.

The management solution

The excess input of nutrients to the estuary has continued for many years, and it will be three to five years before the algal problem can be overcome. However, the research work indicates that a combination of management measures — the preferred strategy — has the potential to restore the estuary to a condition where the beaches will be largely free of weed and the water clear for most of the time.

This preferred strategy has three objectives:

- To continue removal of the accumulating weed: Present weed harvesting measures on a larger scale are recommended, in order to keep beaches adjacent to populated areas free from weed for most of the time.
- To reduce the input of phosphorus: The principal measure by which the input of phosphorus can be reduced is to modify the present fertilizer practices on the coastal plain. A pilot-scale campaign in 1983 has already indicated the beneficial effects which can be achieved by such a programme.
- To increase the flushing of estuary water to the sea: To achieve this, it will be necessary to construct a new channel from Harvey Estuary to the ocean. This proposal still requires further evaluation in terms of its level of effectiveness, the costs involved, and practical problems of construction.

In combination with the preferred strategy, other supplementary measures have also been identified as having the potential to contribute substantially to the long-term reduction in phosphorus input to the estuary or to the amelioration of the algal problem, and are recommended for further investigation and assessment.

Chapter 1 *The nature and causes of the algal problem*

The algal problem

The algal problem in the Peel-Harvey estuarine system takes several forms:

- **Weed accumulation along beaches:** Masses of large green algae, or weed, accumulate in the shallows of the northern (Coodanup) and western (Falcon) shores of Peel Inlet. This weed fouls previously clean beaches, and decomposes into a black, offensive smelling ooze. Weed also accumulates on other less populated foreshores, notably those west of The Chimneys, the Murray River delta, and in Austin Bay. Although Harvey Estuary is largely free of weed accumulations, there is some fouling of beaches north from Dawesville.

  In addition, large accumulations of drifting weed have been responsible for killing marginal rushes, with consequent bank erosion in parts of Peel Inlet and Harvey Estuary. The raking of weed from beaches has also caused shore erosion.

- **Sheets of algae in deep water:** Living and decomposing algae in deep water foul the nets of professional fishermen and tangle propellers of outboard motors, causing considerable inconvenience.

- ***Nodularia* 'blooms'**: Massive blooms of the blue-green alga called *Nodularia* occur almost every year, especially in Harvey Estuary. These blooms appear to be getting worse, and in calm weather *Nodularia* floats as an unpleasant scum on the surface. Like the large green algae, *Nodularia* drifts to the shore and decomposes with a nauseating smell; it also has deleterious effects on fish and crab populations. In the spring of 1978, a bloom of *Nodularia* turned the whole of Harvey Estuary green, and also flowed out into Peel Inlet. Since 1980, there have been annual blooms throughout the estuary in spring and early summer.

For fifteen years or more, the major nuisance algae in the estuary was *Cladophora*, known also as 'goat weed'. However, in recent years this has been replaced by other algae in Peel Inlet: first by *Chaetomorpha* ('rope weed') and *Enteromorpha*, and in 1983 by *Ulva* ('sea lettuce'). They all characteristically are washed into the shallows by wind and waves, where they decompose into a foul smelling black ooze. Another blue-green alga, *Oscillatoria*, has since appeared in Harvey Estuary. It forms a black slime over the bottom and, when it is growing actively, this slime breaks off and floats to the surface.

Studying the problem

In 1976, in response to mounting public concern, the Environmental Protection Authority of Western Australia requested its Estuarine and Marine Advisory Committee to commission a number of investigations into the problem. The aim of these investigations was twofold. Firstly, it was necessary to determine the nature and causes of the excessive growth and accumulation of weed in Peel Inlet and, if possible, to propose methods for its control. Secondly, it was vital to gain a general understanding of the working of this estuarine ecosystem, so that environmental problems could be foreseen and decisions made about management of the estuary on the basis of sound knowledge.

The report of the investigations into the nature and causes of the algal problem was published in 1980 in *The Department of Conservation and Environment Report No. 9*. The principal cause of the estuary's algal problem was clearly identified as an excess of plant nutrients, a condition known as eutrophication. It was shown that the amount of nutrients draining into the estuary had increased greatly since the 1950s, and that these nutrients were transported to the estuary in drainage water from agricultural land on the coastal plain. However, the report was able to indicate only in general terms how this condition could be prevented.

It was then necessary to determine precisely how the estuary and its catchment could be managed in order either to control the algal nuisance or to prevent its occurrence by reducing the amount of plant nutrients in the water. To this end, further investigations were undertaken, some of which are still in progress. Nevertheless, the findings reached to date have made it possible to identify a number of management measures, from which the preferred strategy for management of the estuary (described in Chapter3) has been developed. However, before the Government of Western Australia can decide whether this strategy should be adopted in full, further detailed evaluation of the costs and of any potential adverse impacts on the estuary must be undertaken. To achieve this goal, a project team has been appointed and will report to the Government by August 1984, with final recommendations being made early in 1985.

Causes of the problem

Features of the estuary

The following key facts about Peel Inlet and Harvey Estuary must be kept constantly in mind when discussing the nature and causes of the estuary's present problems:

- The estuary is a large, shallow body of water which has very restricted exchange with the ocean, because of the long, narrow Mandurah channel and the small tidal range.
- Flow from the three river systems (the Murray, Serpentine and Harvey) is strongly seasonal, with the flow of water being confined to about twelve weeks in winter.
- The evaporation rate from such a large, shallow body of water is high and, in combination with the restricted exchange and winter river flow conditions, results in an extreme salinity range varying from fresh water to nearly 1.5 times the salinity of sea water. There are only a few kinds of plants and animals which can survive this extreme range.
- Light penetration is a key factor influencing the character of plant life in the estuary namely seagrasses, species of large green algae and the microscopic plankton. When the estuary water is clear, sunlight penetrates to the bottom. However, suspended matter often greatly reduces light penetration, especially in Harvey Estuary.

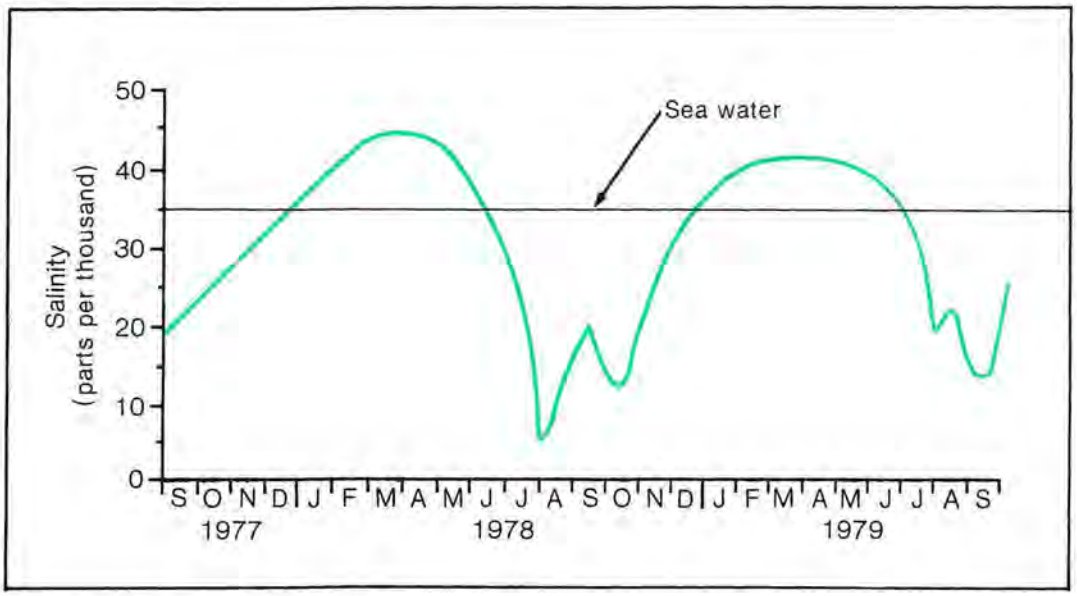


Figure 1: Salinity in Peel Inlet

Growth of algae

Conditions in the estuary have changed greatly since the first recorded complaints. Although the estuary is now eutrophic (rich in plant nutrients), thirty to forty years ago estuary water held only a small supply of nutrients. Then, the main plants were rooted seagrasses which caused no problems. Seagrasses still grow in shallow water, but it is the various kinds of free-floating algae which accumulate and decompose on the shores.

The principal nuisance plants now found in the estuary, and their requirements for growth, are as follows:

Weed (large green algae)

Cladophora, or goat weed, grows as small ball-like clumps of filaments. These balls lie unattached on the estuary floor, where they form a thick carpet, the lower layers of which decompose to form a black ooze over the bottom sediments. The individual balls are mobile and are transported by wind and waves to the shallows of Peel Inlet. There they accumulate and decompose.

Studies have shown that this weed grows best in the conditions of temperature and light found at the surface of algal beds in summer. It thrives in water with salinity levels ranging from fresh to saltier than sea water. Goat weed also requires certain levels of nitrogen and phosphorus for growth. However, the research has demonstrated that, as goat weed almost always contains sufficient nitrogen, its growth is strongly dependent upon the availability of phosphorus.

Although such detailed studies have not been carried out on the other species of nuisance weed which have replaced goat weed in the last three years (rope weed, *Chaetomorpha*; sea lettuce, *Ulva*; and *Enteromorpha*), it is known that they too require adequate light, temperature and nitrogen, and are critically dependent upon the availability of phosphorus.

Nodularia (blue-green algae)

Unlike the large green algae, *Nodularia* grows as microscopic filaments, countless numbers of which are suspended in the water, turning it green. Because they are lighter than water, the filaments float to the surface during calm weather, producing a scum (or bloom) on the surface which may be blown ashore and decompose there.

Studies have shown that the following factors must be present for a *Nodularia* bloom to occur:

- sufficient light
- warm water temperatures (greater than 18°C)
- salinity levels well below that of sea water
- an abundance of phosphorus
- a shortage of nitrogen.

Once a bloom is established, it remains more or less constant for several weeks, gaining its vital supply of phosphorus from the bottom sediments of the estuary and its nitrogen from the atmosphere.

The ideal conditions for a *Nodularia* bloom are found in spring or early summer, and most blooms have occurred during the period from late September to December. As the estuary becomes increasingly salty in summer, conditions become unsuitable for *Nodularia* blooms. However, in January 1982, the unseasonable heavy rains and subsequent flood resulted in the bloom persisting for many weeks into February because of the lowered salinity and fresh supply of phosphorus. By contrast, 1979 was a very dry year, with low river flow and hence low input of phosphorus to the system; consequently, no *Nodularia* bloom occurred. With this one exception, there has been an annual bloom of *Nodularia* in Harvey Estuary since 1978.

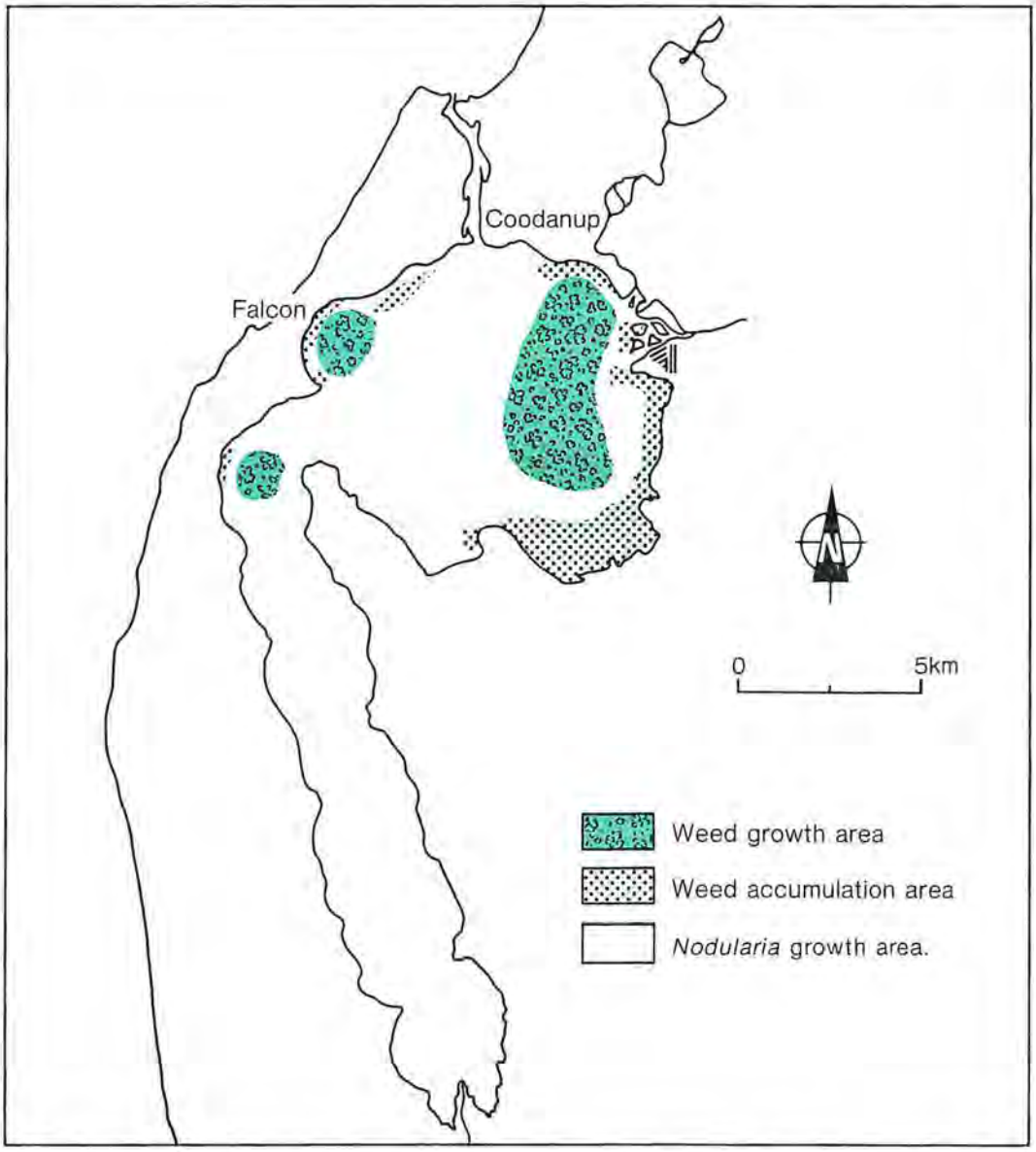


Figure 2: Principal areas of algae growth and accumulation in the estuary

Sources of nutrients

The increase in plant nutrient concentrations in estuary waters has been shown to be the principal cause of the comparatively recent dramatic development of the algal problem. The input of nitrogen and particularly of phosphorus has increased markedly over the past thirty years, providing an ideal environment for growth of the few species which can survive the extreme range of salinity.

Phosphorus

The main external source of phosphorus, on which algal growth is ultimately dependent, is from agricultural drainage on the coastal plain. Between the period 1949-1956 (when the Murray and Serpentine river waters were sampled by CSIRO) and 1978, there has been a great increase in the input of phosphorus to the estuary. Similar, though smaller, increases were recorded in nitrogen input over the same period. It is unfortunate that no data were collected for the Harvey River in the years 1949 to 1956, as it is clear from the recent studies that this river and its nearby drains are the largest source of phosphorus input to the estuary.

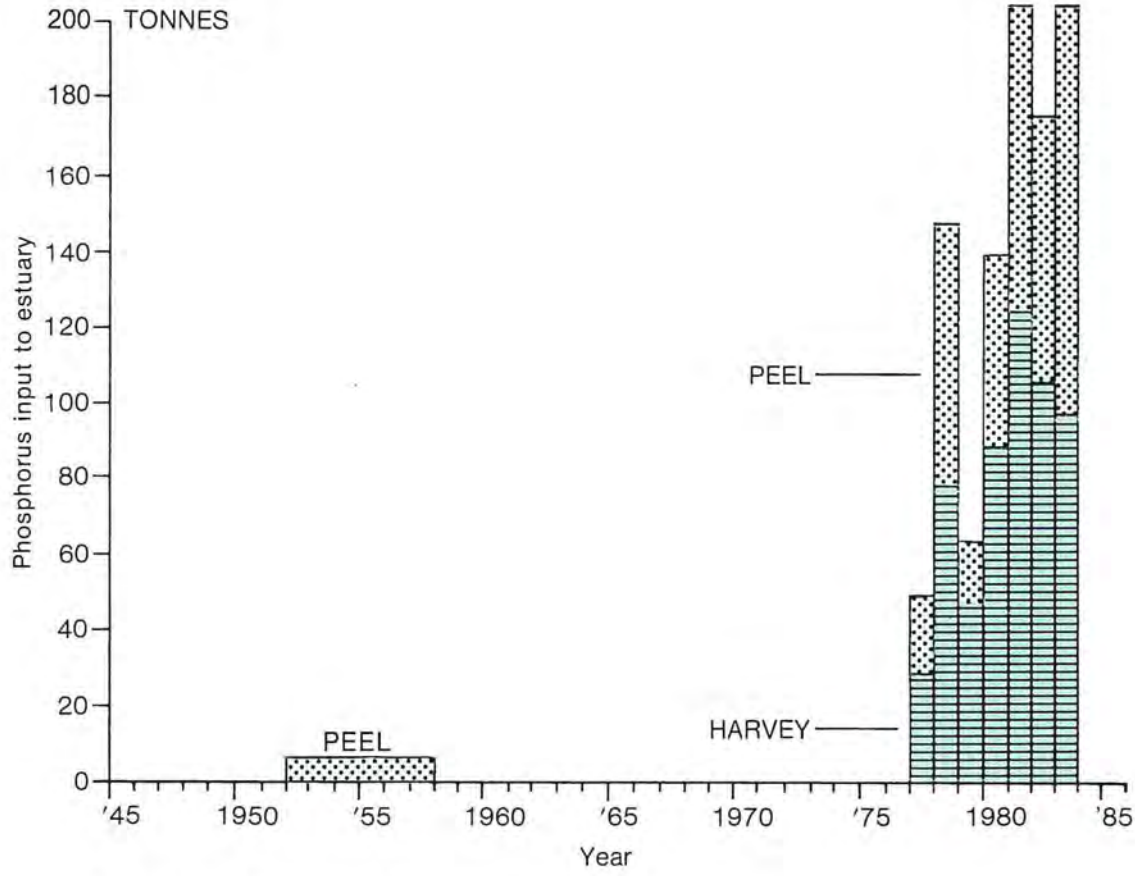


Figure 3: The input of phosphorus to the estuary

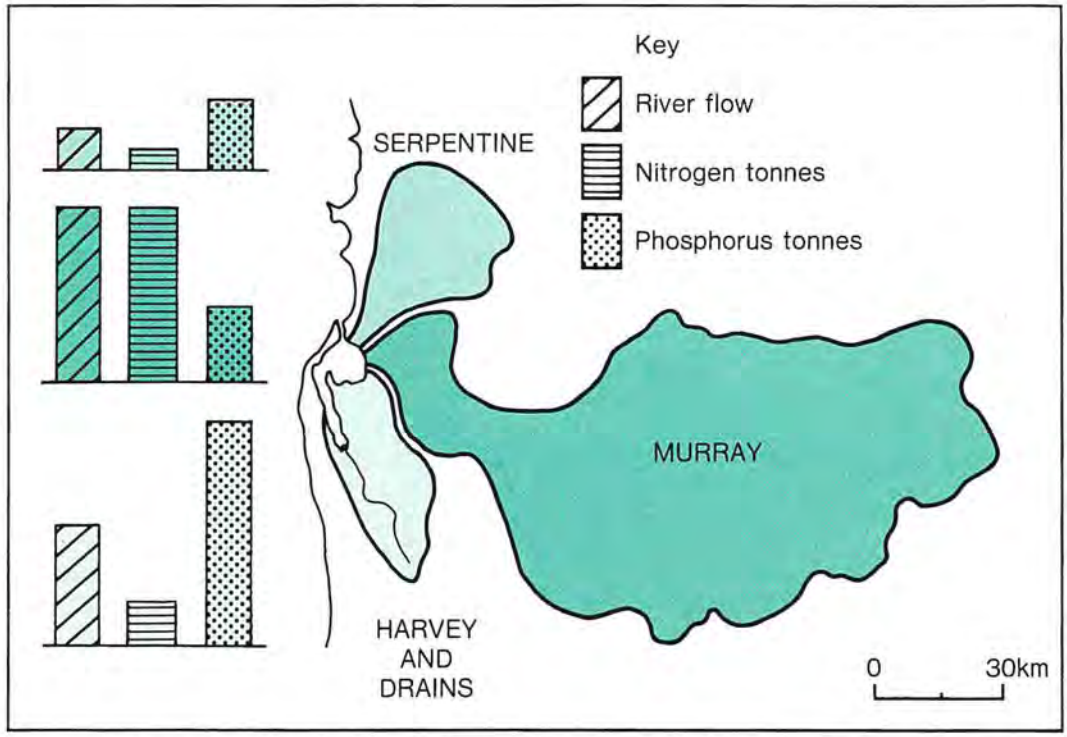


Figure 4: Average yearly river flows and nutrient inputs to the estuary

A vital factor in this phosphorus build-up is the amount of fertilizer applied to farms on the coastal plain, the drainage from which enters the estuary via the coastal plain's rivers and drains. These areas deliver about 90 per cent of the phosphorus load to the estuary from soils that are naturally phosphorus deficient, and which receive considerable annual applications of superphosphate.

This annual input of phosphorus to the estuary greatly exceeds the amount of phosphorus lost to the ocean by flushing, and the concentrations retained in estuary sediments have therefore continued to increase over the last thirty or more years. However, by no means all of this sediment phosphorus is available for algal growth, and it is unlikely that the sediment phosphorus would, by itself, support algal blooms for more than two or three years. These blooms are considered to be largely dependent on a fresh supply of phosphorus each winter, a phosphorus supply which corresponds closely to the input resulting from winter rainfall and river flow.

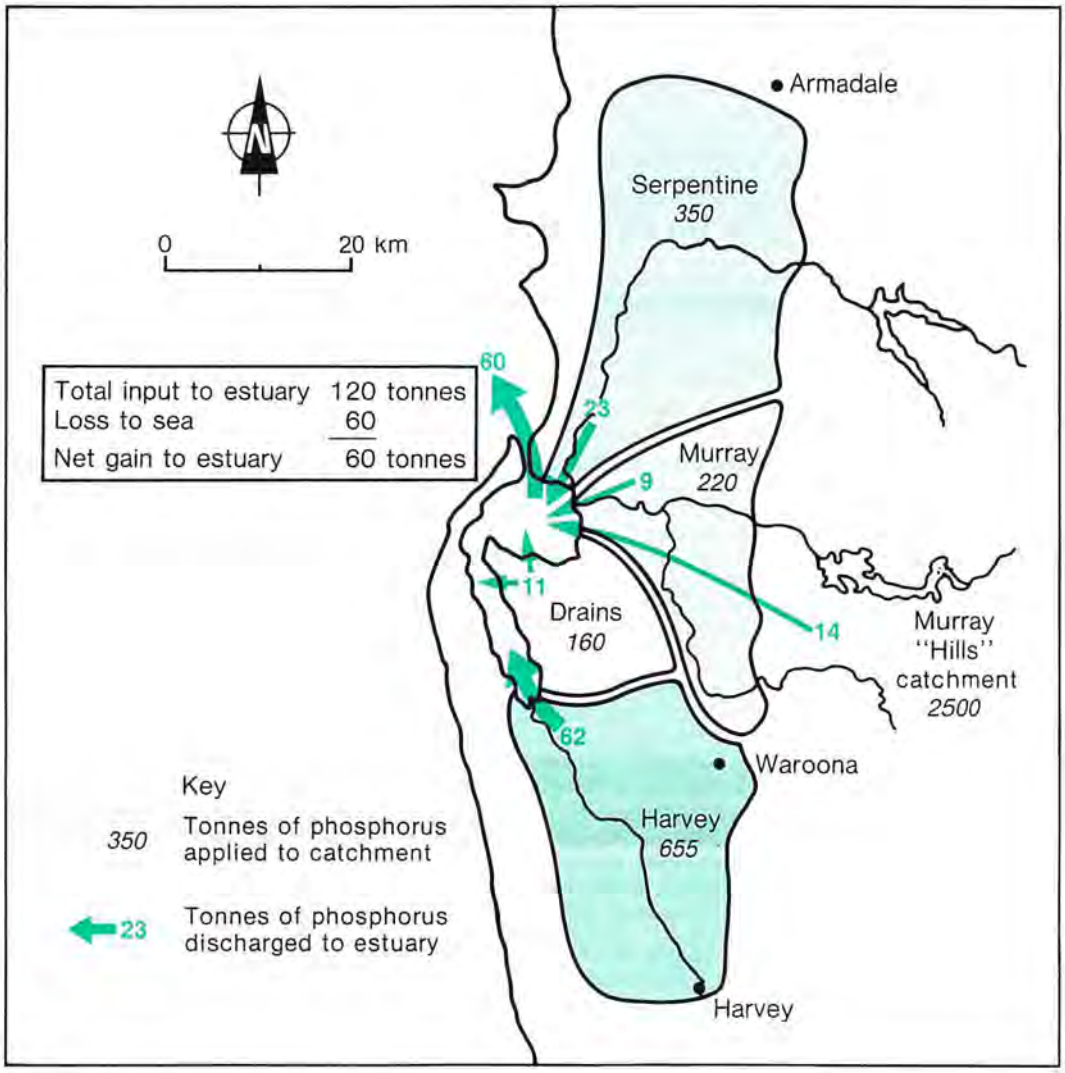


Figure 5: Where the phosphorus comes from *(1978 figures)*

The phosphorus cycle

The phosphorus brought to the estuary by river flow in winter is first used by diatoms, which are microscopic plant cells suspended in the water. They do not create a nuisance, but when they die and decompose the phosphorus is released and fertilizes a *Nodularia* bloom, just when conditions are most favourable for its growth. Then, when *Nodularia* decomposes in late summer, a fresh load of phosphorus is released into the water. In Peel Inlet this fertilizes a new crop of weed which flourishes in the warm, salty water of summer and autumn. The nuisance weed of Peel Inlet has seldom given much trouble in Harvey Estuary, probably because the suspended sediment in Harvey Estuary greatly restricts the light penetration necessary for such weed growth.

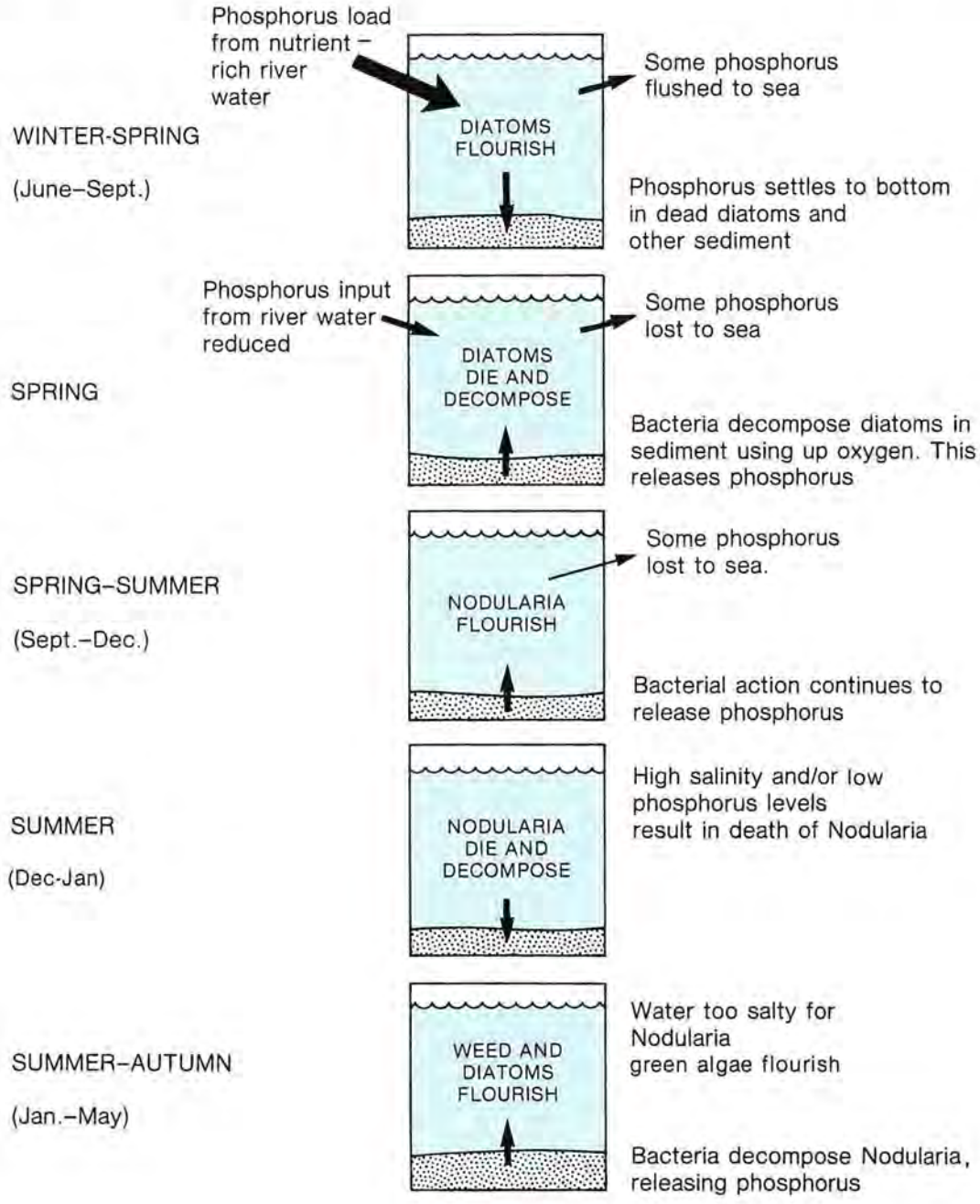


Figure 6: The phosphorus cycle in the estuary

Nitrogen

In years of average rainfall, most of the nitrogen input comes from the Murray River (that is, mainly from the hills catchment). For example, in 1978 the Murray River contributed an estimated 1,175 tonnes, while the combined contribution from the Serpentine and Harvey rivers was 445 tonnes. In 1979, a very dry year, only 100 tonnes came from the Murray River, although there were still 410 tonnes from the Serpentine and Harvey rivers combined.

As *Nodularia* can fix its own supply of nitrogen directly from the atmosphere, its growth is limited only by the amount of phosphorus available to it. Attempting to control nitrogen input would therefore have no effect on *Nodularia* growth.

Effect of dams

Since the earliest discussions of the estuary's problems, many people have believed that the damming of the major input rivers has had a considerable effect on the health of the estuary. The Serpentine River, and the North and South Dandalup Rivers (tributaries of the Murray River), have had major water supply dams constructed on them since 1960 to supply much needed water to a rapidly expanding Perth metropolitan population and, indeed, to Mandurah itself.

Although there are no data available to support the proposition, it is probably true that the total volume of water entering the estuary from the rivers has not changed a great deal over this time. However, the reduction in volume of nutrient deficient water from the forested hills catchments, as a result of the dams, has been offset by increased flow from the extensively drained and cleared coastal plain. Therefore, to the extent that the estuary is denied the cleansing effect of the impounded water, it can be said that the dams may have contributed to the eutrophication problems of Peel Inlet.

Chapter 2 *Management of the estuarine environment*

Management objectives

Based on the findings of the research work, it was concluded that the principal objective of the management programme should be to reduce the algal nuisance to acceptable levels without further damage to the estuarine environment. This objective was to be accomplished without causing loss of production of the estuarine fishery or of agriculture in the catchment.

Not everyone will agree on what constitutes an 'acceptable' level of algal abundance, but it was felt that an achievable and desirable aim would be that:

- *Nolularia* blooms should not occur more frequently than once in five years on average;
- weed should not foul beaches near populated areas.

Assessment of potential management measures

For the past few years, interested people and organizations have put forward theories and proposed various solutions to the estuary's problems. The suggestions have come from many sources — from the press, the general public, and the Peel Inlet Management Authority, as well as from the scientists and engineers on the study team.

There are two basic categories of measures proposed:

- **Control measures:** These involve a direct attack on the algae, for example by harvesting. However, these measures would not attack the cause of the problem.
- **Preventive measures:** These are designed to reduce the eutrophic state of the estuary which causes the problem (by, for example, reducing phosphorus input).

In 1983, all ideas were carefully assessed by a group from the Centre for Water Research at the University of Western Australia. This detailed evaluation was done in close collaboration with the Public Works Department, the Department of Conservation and Environment, the Department of Agriculture, the Waterways Commission, the Government Chemical Laboratories and other members of the Peel-Harvey Study Group. Many of the more than one hundred options which were identified were subsequently rejected because they were shown to be unlikely to restore the estuary to an acceptable state. The option of 'no action' was also rejected, on the grounds that the algal problem would continue, and that further deterioration of the estuary was to be expected.

Criteria for management

A small number of potential management measures were then fully evaluated on the basis of the following criteria:

- the likelihood of sufficiently reducing the high nutrient levels in the estuary within a reasonable time;
- the cost of implementing the proposal, both in terms of the initial capital cost and continuing costs;
- the possibility of adverse environmental effects;
- the short-term and long-term environmental impacts of the proposal.

Algal Problems

1

2

3

4

1. *Nodularia* accumulation on the beach.
2. Mass of weed washed up on the beach.
3. *Nodularia* bloom coming from Peel Inlet into Harvey Estuary.
4. Sampling a pile of *Cladophora* weed.

and Solutions . . .

1

2

3

4

5

1. Bulldozing decomposing weed on to the beach.
2. Bulldozer piling *Chaetomorpha* weed on the beach.
3. Off-shore weed harvester.
4. Explaining fertiziler studies to farmers.
5. The ultimate goal — clear, weed-free beaches.

Why has it taken so long to develop a management strategy?

Most of the factors which were identified as possibly contributing to the problems of eutrophication and weed growth in the estuary were strongly dependent upon the river flow into the system. However, this flow is very variable, both seasonally and from year to year. About 80 per cent of river flow comes in twelve weeks in winter, and during the period 1940 to 1983 the Murray River recorded annual flows as low as 56 million cubic metres and as high as 1,143 million cubic metres.

For this reason it was necessary to have accurate data on flow, nutrient loads, and weed abundance over a broad range of conditions. It was equally necessary to have a clear understanding of what happened to the nutrients once they reached the estuary; how much was available for plant growth and how rapidly it was used; and how much was lost to the sea. The definition of the nature and the careful quantitative assessment of the causes of the problem have therefore necessarily spanned several years. Theories, once developed as a result of examining the data collected, had to be tested over a full range of seasonal conditions, as inaccurate or inadequate data could lead to false predictions about the future state of the estuary and the probable effects of changes, as well as to false conclusions of how to prevent the algal problem.

Also, although the study team has sought information throughout the period of the studies from investigations of similarly eutrophic estuaries elsewhere in the world, such information has not been readily applicable. While it is not claimed that the situation in Peel Inlet and Harvey Estuary is unique, most eutrophic systems have been brought to that condition by nutrient input from isolated sources with high nitrogen and phosphorus concentrations, usually from sewage discharge. The catchment-wide nature of the nutrient source affecting the Peel-Harvey estuarine system has made the problem particularly difficult to solve.

Constraints which limit solutions

Financial considerations

The Government has already spent large sums of money on funding the necessary studies. Many of the measures proposed would involve a further and much greater financial commitment, both for their initial implementation and for their continuing operation. For example, the proposal to construct a new channel from Harvey Estuary to the ocean is estimated to cost approximately $25 million in 1983 dollars. In order to keep the channel open for navigation, maintenance costs could amount to about $500,000 annually. The high cost of bringing the estuary to an acceptable state will have to be borne by the community at large.

Nevertheless, as well as the benefits accruing to residents and to the tourist industry as a result of a cleaner, more attractive estuary, some of the proposed options would also produce some financial benefits. These include the saving from the reduction in the use of fertilizer on coastal plain catchments. Studies and field trials have already shown that, by changing the present fertilizer application practices and by the use of new slow-release fertilizers, it will be possible to reduce fertilizer application rates by up to 60 per cent without loss of productivity.

Economic and social considerations

A wide spectrum of views and interests can be found amongst the numerous users of the estuary and amongst those whose activities affect its condition, and there will be differences of opinion about what the aims of management should be. For example, while the weed in Peel Inlet has seriously detracted from the enjoyment of the foreshore by residents and holiday-makers, its presence has benefited the fishery by sheltering the fish from predators and by providing food for the many small animals on which the fish feed. It may not be possible to have clean and completely algae-free water as well as plentiful numbers of fish. Similarly, it is not possible to maintain productive agriculture on the coastal plain without fertilizing the paddocks and thus causing some loss of phosphorus to drainage.

Environmental considerations

Any management measure will alter the character of the environment in ways which are not easy to predict, and care must be taken to ensure that any management strategy adopted will do less damage to the environment than that caused by the present algal problem. Therefore, each suggestion for managing the estuary has to be carefully assessed, not only in terms of cost and technical feasibility but also with due regard to any undesirable side effects.

For example, if it is definitely established that a new channel from Harvey Estuary to the sea will flush sufficient phosphorus to the ocean to ensure that *Nodularia* blooms occur only rarely, it will still be necessary to ensure as far as possible that undesirable effects do not occur. The daily tidal range in the estuary would increase greatly, for instance, and it is not easy to be certain what side effects this might have. Also, if the flushing is too effective in removing nutrients, the estuary could become so nutrient deficient that the fishery would be adversely affected.

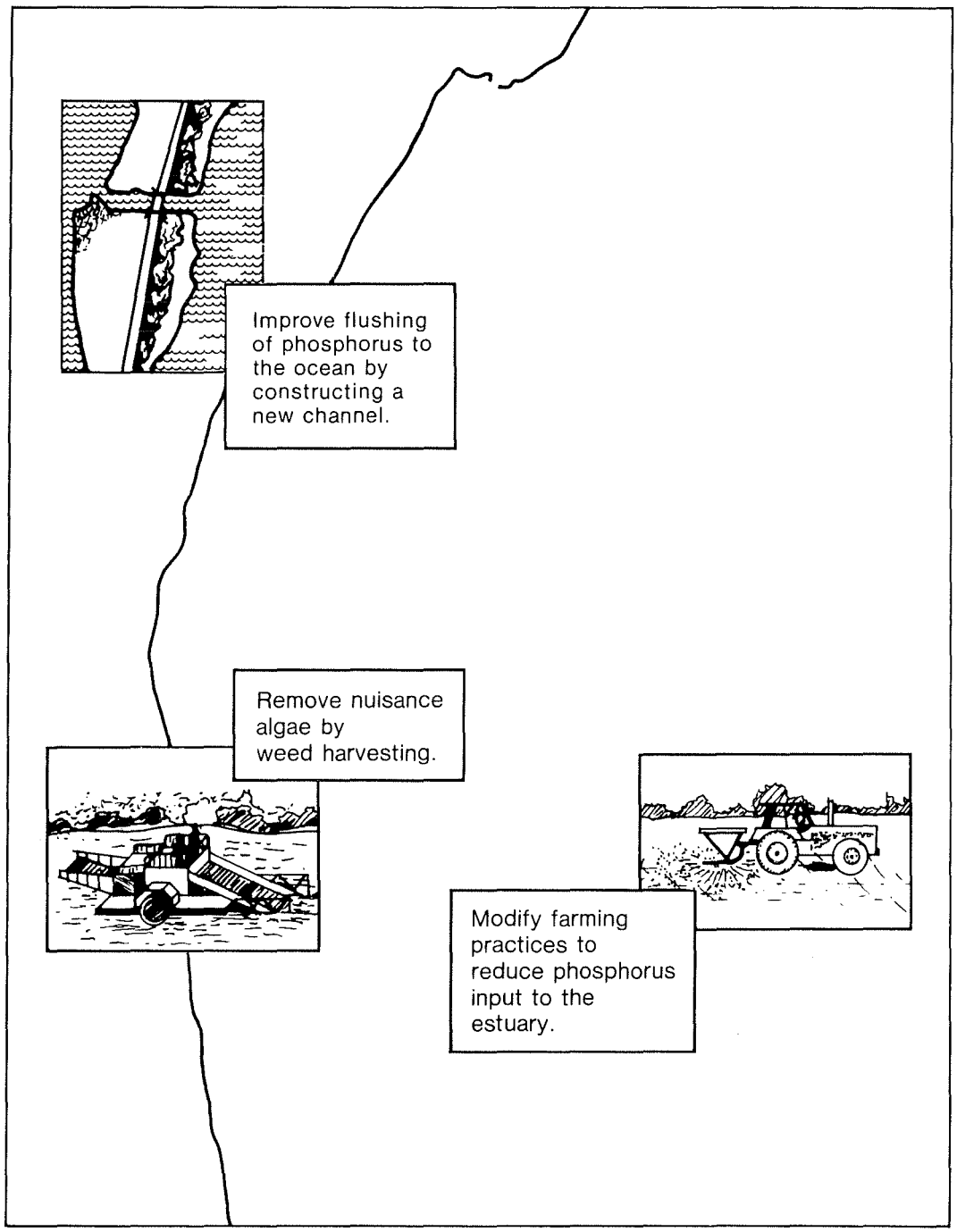


Figure 7: The preferred strategy

Chapter 3 *The preferred strategy*

The assessment of management options undertaken in 1983 showed that there is no single practicable measure which can achieve the management objectives within an acceptable time. However, it was shown that these objectives can be achieved by a combination of management measures. This combination of measures, referred to as the preferred strategy, consists of:

- harvesting of weed, in order to control the weed nuisance near populated areas;
- reducing the input of phosphorus to the estuary by modifying agricultural fertilizer practices on the coastal plain;
- increasing the loss of nutrients to the sea by improving tidal flushing.

However, the present condition of the estuary is the result of more than thirty years of excess nutrient input, and it is important to realize that even this combination of measures cannot be expected to reduce the algal nuisance to acceptable levels in less than three to five years.

In addition to these measures which form the preferred strategy, further supplementary measures which have the potential to make a valuable contribution to the control of the problem are discussed in Chapter 4.

Weed harvesting

At present, a weed harvester is used to collect weed from water of more than half a metre in depth, to prevent the weed from being washed into the shallows and accumulating on shores adjacent to populated areas, principally at Coodanup and Falcon. For many years, tractors equipped with rakes have been used to collect the beached weed, which is then trucked away and dumped.

A second offshore harvester has been commissioned in 1984, and it is anticipated that the two harvesters and tractors will be able to keep beaches adjacent to populated areas free from weed for about 85 per cent of the time. It is most important that this harvesting operation continue in conjunction with the recommended long-term preventive measures (such as reducing the phosphorus input to the estuary). However, the associated costs and environmental impacts of this harvesting need to be borne in mind:

- Annual operating costs are approximately $150,000.
- Weed must be raked up and dumped on the shores and left to drain before being trucked away. It is important that these piles of rotting weed should be left on the beach for as short a time as possible, because of their undesirable odour and unsightly appearance.
- Raking of beaches with tractors results in a loss of sand and some unavoidable damage to vegetation.

In the long term, if the preventive measures are successful, the need for harvesting should be considerably reduced, although it may be many years before this activity could cease entirely. Uses for clean weed, such as in the manufacture of stock feed, are being investigated.

Reducing phosphorus input by modifying agricultural practices

This measure aims to reduce the input of phosphorus to the estuary by adopting fertilizer practices appropriate to soils of the coastal plain. About 90 per cent of the phosphorus entering the estuary comes from land cleared for agriculture, and the amount of phosphorus lost from such farms depends upon several factors. These include the type of soil, the amount of cleared and drained land, the type of farming practice, and fertilizer use. Another key factor is the amount of winter rainfall. Little rain and low river flows result in only a small amount of phosphorus draining to the estuary, as occurred in 1979. Big river flows, such as those in 1981, carry large amounts of phosphorus and produce bumper crops of *Nodularia*.

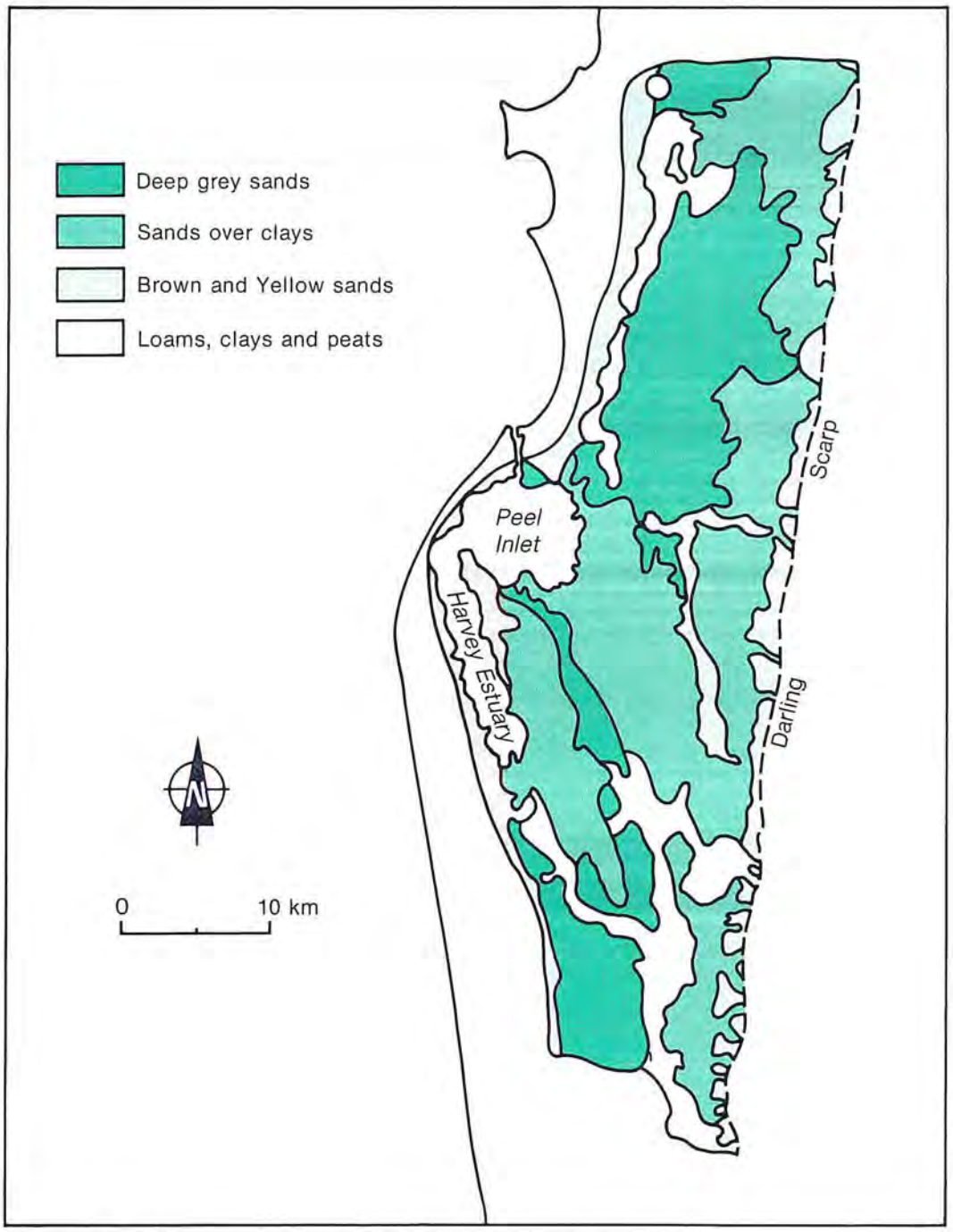


Figure 8: Soil types on the coastal plain catchment of the estuary

Soil types

Clay and loam soils have the property of 'binding' phosphorus so that little is released to drainage. However, the sandy soils (deep grey sands and sands over clays) which cover more than half the coastal plain catchment of the estuary are much less able to bind phosphorus. Not surprisingly, these soils are by far the largest source of phosphorus entering the estuary: it is estimated that 80 per cent of phosphorus in Harvey River water comes from the sandy soils. Nevertheless, the clay and loam soils also make an important contribution to phosphorus input to the estuary.

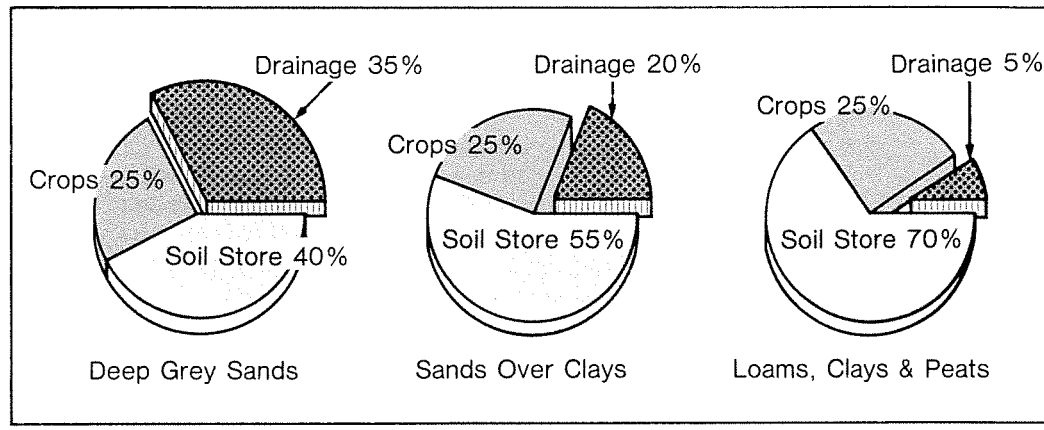


Figure 9: Phosphorus losses from different soil types

All coastal plain soils require the application of phosphorus fertilizers if they are to support productive agriculture and, in the past, it has been the practice of farmers to apply superphosphate at an annual rate of 200 kilograms to the hectare (one bag per acre). Over the years a store of phosphorus has built up in the soil, and it has been found that on many paddocks this store is now sufficient to maintain good pasture growth without further fertilizer use for one, two or even more years. Fertilizer application rates can therefore be considerably reduced without loss of production. The amount required can be determined by means of soil tests.

Superphosphate contains water soluble phosphorus, much of which is rapidly washed away by rainfall. However, phosphorus can also be supplied in the form of slow-release fertilizers which are not readily soluble in water and from which much less phosphorus is lost to drainage.

The fertilizer strategy

A substantial reduction in the amount of phosphorus draining to the estuary can therefore be achieved by applying the following modified fertilizer practices to all land on the coastal plain:

- using soil tests to determine the amount of phosphorus present in the soils;
- reducing the amount of phosphatic fertilizers used to the level shown to be required by soil tests, consistent with the maintenance of economic yields to farmers;
- using slow-release phosphorus and sulphur fertilizers instead of superphosphate, especially on sandy soils.

An effective explanatory programme to ensure maximum acceptance of these measures by farmers will also need to be undertaken.

A successful pilot fertilizer modification programme was carried out in 1983 with the co-operation of some 150 farmers whose properties were on deep sands and duplex soils in the Harvey Estuary catchment. This programme is now being extended to the entire coastal plain catchment of the estuary: an area of over 200,000 hectares. With the cooperation of the manufacturer (CSBP), the Department of Agriculture, the Department of Conservation and Environment, and the Government Chemical Laboratories, a new improved fertilizer has been developed for the coastal plain soils. This slow-release fertilizer, called 'New Coastal Super', has shown considerable promise and is now being marketed.

Research shows that the amount of phosphorus fertilizer used on the coastal plain could be reduced by at least 50 per cent while still maintaining productivity. The present phosphorus run-off represents a costly loss to farmers. In 1981, farmers in the Harvey River/Mayfields Drain catchment lost the equivalent of 16,000 bags of superphosphate into the estuary (representing a cost of around $120,000).

It is estimated that, when the recommended fertilizer practices are adopted, the input of phosphorus to the estuary will be reduced by 30 to 40 per cent. This is probably the maximum reduction which can be achieved in the short term, because 60 to 70 per cent of the phosphorus in drainage water comes, not from freshly applied fertilizer, but from the store in the soil which has built up over many years.

Increasing the loss of phosphorus to the sea

This 30 to 40 per cent reduction in phosphorus input to the estuary will not be sufficient, by itself, to prevent the recurrence of *Nodularia* blooms or the growth of nuisance algae. It will be necessary to reduce input by 70 per cent in order to achieve the management objectives. An additional measure is therefore necessary to reduce further the amount of phosphorus available to algae in the estuary. This can best be achieved by improving the flushing of estuary water to the sea.

The most effective method of flushing the estuary is to construct a new channel to connect Harvey Estuary to the ocean at an appropriate location. Preliminary calculations indicate that this channel should be about 200 metres wide and could be located in the vicinity of Dawesville. However, the precise location for the channel cannot be determined before detailed field investigations have been undertaken to establish:

- the nature of the material to be removed (sand, or soft or hard rock);
- the cost and practicability of land acquisition;
- the extent of maintenance works needed to keep the channel open (a factor which is particularly important if the channel is to be navigable).

Such a channel would greatly increase the rate at which estuary water was flushed to the sea, consequently increasing the loss of nutrients and thereby reducing the level of eutrophication in the estuary. This measure is likely to have the potential to reduce phosphorus available to algae in Harvey Estuary by 50 per cent and in Peel Inlet by 25 per cent.

Implementation of this measure, in conjunction with the fertilizer modification measures, would lower the phosphorus level sufficiently to achieve the management objectives. Neither measure alone will do so. The 1983 studies indicate that, together, these are the only two practicable measures which can, within three to five years, reduce the eutrophic condition to the point at which the problem is controlled, if not eliminated.

Effects of channel construction

Construction of the channel would be a major engineering project, involving the excavation and disposal of between 4 and 5 million cubic metres of material. This would have to be disposed of not far away. Training walls would also be needed at the ocean entrance to ensure adequate water exchange by preventing excessive shoaling at the mouth. A two-lane bridge would be required where the Old Coast Road crossed the channel route. Clearly, very detailed evaluation of this major proposal is required. A principal factor being considered in studies to date is the effect of the new channel on the hydraulic behaviour of the system, especially the effect on water levels. The present major water level changes in Harvey Estuary are on a five to fifteen day time scale, influenced by barometric conditions and often referred to as 'the barometric tide'. With a new channel, major water level changes would also take place on a daily time scale due to astronomic tides. These are expected to be about 80 per cent of the ocean tide. Such an increased daily tidal range would, for example, increase the area of shallow flats exposed at low water and also the frequency of periods during which such flats were dry.

Two changes to the coastline might occur as a result of these tidal differences. Erosion might take place north of the channel entrance, caused by an interruption of longshore sand drift and reduction in sand transport (as has happened at Mandurah). Also, shoaling might occur near the channel entrance, which would create a major problem in maintaining a navigable channel. Some form of sand-bypassing operation or routine maintenance might therefore be required to ensure navigability. This would cost approximately $2 million initially, and about $500,000 annually in maintenance costs.

With construction of the proposed channel, salinity in the estuary would become much closer to that of sea water for much of the year, and the duration of low salinity periods favoured by *Nodularia* would shorten. (As previously discussed, this blue-green alga requires not only appropriate levels of phosphorus, but also salinity levels below that of sea water. Blooms presently collapse in summer when salinity increases to that of sea water and above.) The effect of the channel flushing would thus be to considerably reduce the likelihood of *Nodularia* blooms occurring and the period within which they could occur.

Other probable beneficial effects include the following:

- The reduction in *Nodularia* and the creation of more saline conditions would favour marine species of both fish and crabs, particularly in Harvey Estuary where catches have declined greatly. These species would enter the estuary more readily as juveniles and grow to larger sizes.

- There would be an increase in the areas suitable for juvenile fish as a result of the improved water clarity and increased daily tides, which would allow large green algae (or weed) and seagrasses to extend their distribution south into Harvey Estuary. (As a side effect, however, some beach fouling by weed could also occur.)

Chapter 4 *Supplementary measures for further evaluation*

The preferred strategy set out in the previous chapter offers the best hope for restoring Peel Inlet and Harvey Estuary to a healthy condition. Although the measures proposed would, if implemented, take several years to be effective, they would result in the required reduction in phosphorus available for algal growth, and thus achieve the management objectives of preventing weed accumulating on the foreshores of populated areas and ensuring that *Nodularia* blooms become rare events.

There are several further proposals which may be useful as supplementary measures, although further evaluation of them is required before any recommendations on their implementation can be made. These supplementary options are:

- application of algicides
- amendment of leaching soils with bauxite residue
- treatment of rural point sources of nutrients
- changes in land use
- controls on clearing and on drainage construction.

Application of algicides

A possible way of attacking the algae is by using chemicals called algicides which, like herbicides, poison the plants or interfere with their growth. The use of some common algicides such as copper sulphate and other copper compounds cannot be recommended because of their probable toxic effects on fish. However, new organic compounds offer a better prospect for control, particularly of *Nodularia* and other blue-green algae, at a low cost.

Nevertheless, before such a measure could be recommended, answers would need to be known to the following questions:

- How effective will algicides be in such a large, well mixed estuary?
- Will there be any undesirable side effects?
- What will it cost to treat the whole estuary?
- How often will it be necessary to treat the estuary?

One chemical which appears promising is Terbutryn. Advice is now being sought on its potential for control of *Nodularia* and weed. Laboratory experiments have begun, but it will also be necessary to conduct small-scale field experiments to determine its effectiveness and the required frequency of application.

Further investigation will also be necessary to assess possible risks to desirable plants, such as seagrasses, from the use of Terbutryn or other algicides. Its impact on fauna, especially fish, crabs and prawns, will also need to be carefully assessed. Obviously, application of algicides could only be sanctioned if a careful review of the results of this investigation and of field trials showed it to be both successful and safe. Of course, algicides can do nothing to attack the cause of the algal problems (the eutrophic condition of the estuary), and their application would therefore have to be continued indefinitely.

Amendment of leaching soils with bauxite residue

This measure aims to reduce the quantity of phosphorus leached to drainage from sandy soils by incorporating the residue from bauxite mining into the soils in order to improve their capacity to retain phosphorus and water. In conjunction with the Department of Agriculture and the Department of Conservation and Environment, Alcoa of Australia is researching the use of suitably treated bauxite residue for this purpose. This would also provide a means of disposing of a major waste product of the alumina industry.

Alcoa currently disposes of about 8 million tonnes of residue each year, consisting largely of Darling Range soil which has been crushed and treated with caustic soda. It has been found that the finer part of this material, the half known as 'red mud', can be filtered and treated with gypsum to produce a loam suitable for spreading on and mixing into farm soils. This loamy residue has a high capacity to adsorb phosphorus, so less fertilizer would be lost to the estuary from sandy soils treated with the residue.

Preliminary research indicates that:

- Almost any amount of the residue greater than 200 tonnes per hectare will be beneficial.
- This measure has the potential to eliminate most of the loss of phosphorus from sandy soils. However, this could only be achieved over a ten to twenty year period.
- Because the residue increases water retention in the soils, it can increase pasture production on the dry, unproductive deep grey sands. These form less than 10 per cent of the coastal plain catchment.

Alcoa and the Department of Agriculture are continuing research into this technique because it has the potential to make a useful contribution to the long-term reduction of phosphorus input to the estuary. However, careful assessment will be required of the long-term effect of extensive use of the bauxite residue and of any problems associated with its implementation. This includes monitoring to ensure that there are no harmful side effects. Farmers are showing interest in the scheme.

Treatment of sources of concentrated nutrients

At present, 'point sources' of nutrients such as piggeries and feedlots contribute less than 10 per cent of the phosphorus input to the estuary. However, this type of industry is expected to increase and would thus make a greater nutrient contribution in the future, especially in the Serpentine River catchment.

Elsewhere in the world, aquatic or swamp vegetation has been used successfully to reduce the high nutrient concentrations from such point sources or from sewage effluent. Research will be continued into the potential for using these measures to treat nutrient-rich sources.

However, this method would not be effective in removing the relatively low concentrations of nutrients from the large volumes and high rates of water flow which drain into the estuary from agricultural run-off.

Changes in land use

The input of phosphorus to the estuary could also be reduced by replacing the present cultivation of shallow-rooted pasture plants with deep-rooted plants or trees which require little phosphorus and which would reduce the volume of drainage water. If 31,000 hectares of sandy soils in the Harvey Estuary catchment (Harvey River plus Mayfields Drain) were taken out of production, the reduction in phosphorus input to the estuary would be sufficient to solve the *Nodularia* problem in Harvey Estuary possibly within five to ten years.

However, resumption costs to achieve this compulsory change in land use would be very high — approximately $40 million in 1983 terms. Some financial return would be possible if this land were converted to forestry, either pines for timber or eucalypts for wood chipping. A cost/benefit evaluation of this form of control is being carried out by the Department of Agriculture.

Effects of clearing and on drainage construction

It has been shown that phosphorus leached to drainage from the sandy soils of the Harvey Estuary catchment contributes the great majority of phosphorus input to the estuary. About 22,000 hectares of sandy soils on the coastal plain are still uncleared and undrained. However, if all these generally unproductive soils were cleared, drained and fertilized, the input of phosphorus to the estuary would probably increase by a further 30 per cent.

Studies undertaken to date indicate that the rate of phosphorus discharge may be closely related to the density of drains in an area. As part of the continuing research into modification of agricultural practices previously described, further investigation will be made of the relationship between the density of drains and the rate of phosphorus discharge. This will enable definite recommendations to be made concerning any future construction of drains.

Chapter 5 *Other proposals considered*

Of the more than one hundred options assessed for their potential to control the algal problem, a preliminary screening based on the criteria of effectiveness, cost and environmental effects showed most to be unsatisfactory. However, three of these rejected options require comment because of their general appeal and a widespread belief in their effectiveness. These options are:

- enlarging the Mandurah Channel
- diversion of the Harvey River Main Drain
- dredging of the estuary's sediments.

Enlarging the Mandurah Channel

This proposal aims primarily to reduce the availability of phosphorus to algae in Peel Inlet by increasing the flushing of estuary water to the sea, hence reducing weed growth and possibly helping to flush weed to the sea. The measure would involve widening the channel to 200 metres along its entire length from the ocean to the deeper water of the Inlet. A proposed channel improvement of this nature has been investigated, and it is estimated that the cost would be between $5.2 and $7.7 million.

Beneficial effects which would result from this measure include:

- an estimated 30 per cent reduction in phosphorus available in Peel Inlet, which would result in a marked reduction in growth and accumulation of weed;
- shortening of the period during which salinity levels favour the growth of *Nodularia* in Peel Inlet.

However, the following points must be noted:

- Even in conjunction with the fertilizer modification measures, the phosphorus reduction would be insufficient to completely eliminate the weed nuisance.
- The measure would have very little effect on the retention of phosphorus in Harvey Estuary, and consequently would have only a minimal effect on *Nodularia* problems there.
- Much of the *Nodularia* nuisance in Peel Inlet results from its being driven from Harvey Estuary by wind and tidal currents. This would not be significantly countered by an improved Mandurah Channel.

Thus, implementation of this measure as a means of increasing the loss of phosphorus from the estuary cannot be recommended as part of the preferred strategy for reversing the eutrophic condition of the estuary. However, there may prove to be other grounds for implementing part or all of this measure, especially should a decision be made after further study not to proceed with a new channel from Harvey Estuary to the sea.

Diversion of Harvey River main drain

Two suggestions were studied for diverting the water of Harvey River Main Drain, with its load of phosphorus, to the sea: one required a barrage at Herron Ford, and the other a barrage at Point Grey, with tunnels to the ocean.

Diversion of drainage to the sea, with a barrage at Herron Ford

This suggestion involves the diversion to the ocean of sufficient flow in the Harvey Main Drain, South Coolup Drain and Mayfields Drain to prevent *Nodularia* blooms occurring for most of the time. Such diversion would prevent much of the Harvey

River catchment phosphorus from entering the estuary. The proposal requires a barrage to be constructed between Herron Point and Island Point to impound the fresh water inflow and divert it to the sea.

While studies indicate that this measure could be effective in reducing or eliminating *Nodularia* blooms in Harvey Estuary, it cannot be recommended for the following reasons:

- Construction of the barrage would result in up to 1,400 hectares being inundated. Part of this land is now a Nature Reserve, and some further land would also have to be resumed.
- The inundated areas would become a eutrophic lake, with problems similar to those experienced in the seasonal lakes of the metropolitan area.
- Diversion to the ocean would either be by gravity through tunnels and pipes, by low-level pumping through tunnels and pipes, or by a high-level pipeline with high-level pumping and open channels. These would involve very large capital costs (estimated at up to $50 million) as well as $1.2 million per annum in operating costs.

An alternative to this approach could involve diversion to the sea through the coastal lakes (Lake Clifton and Lake Preston). However, this would cause the coastal lakes to become eutrophic and their aquatic flora would become fresh water blue-green algae.

Diversion of drainage to the sea, with a barrage at Point Grey and tunnels to the ocean

This measure has been evaluated, but for the following reasons cannot be recommended:

- Harvey Estuary would become a eutrophic fresh water lake, with blooms of blue-green algae.
- There would be a significant inundation of land behind the barrage.

Dredging of the estuary's sediment

The estuary's sediment plays an important role in supplying phosphorus to the various kinds of algae. The sediment adsorbs phosphorus from the water, stores it, and releases it again for algae to use. It has been suggested that dredging the top 10 centimetres of sediment from the estuary bottom would considerably reduce the algal problem. However, for the reasons outlined below, this measure cannot be recommended:

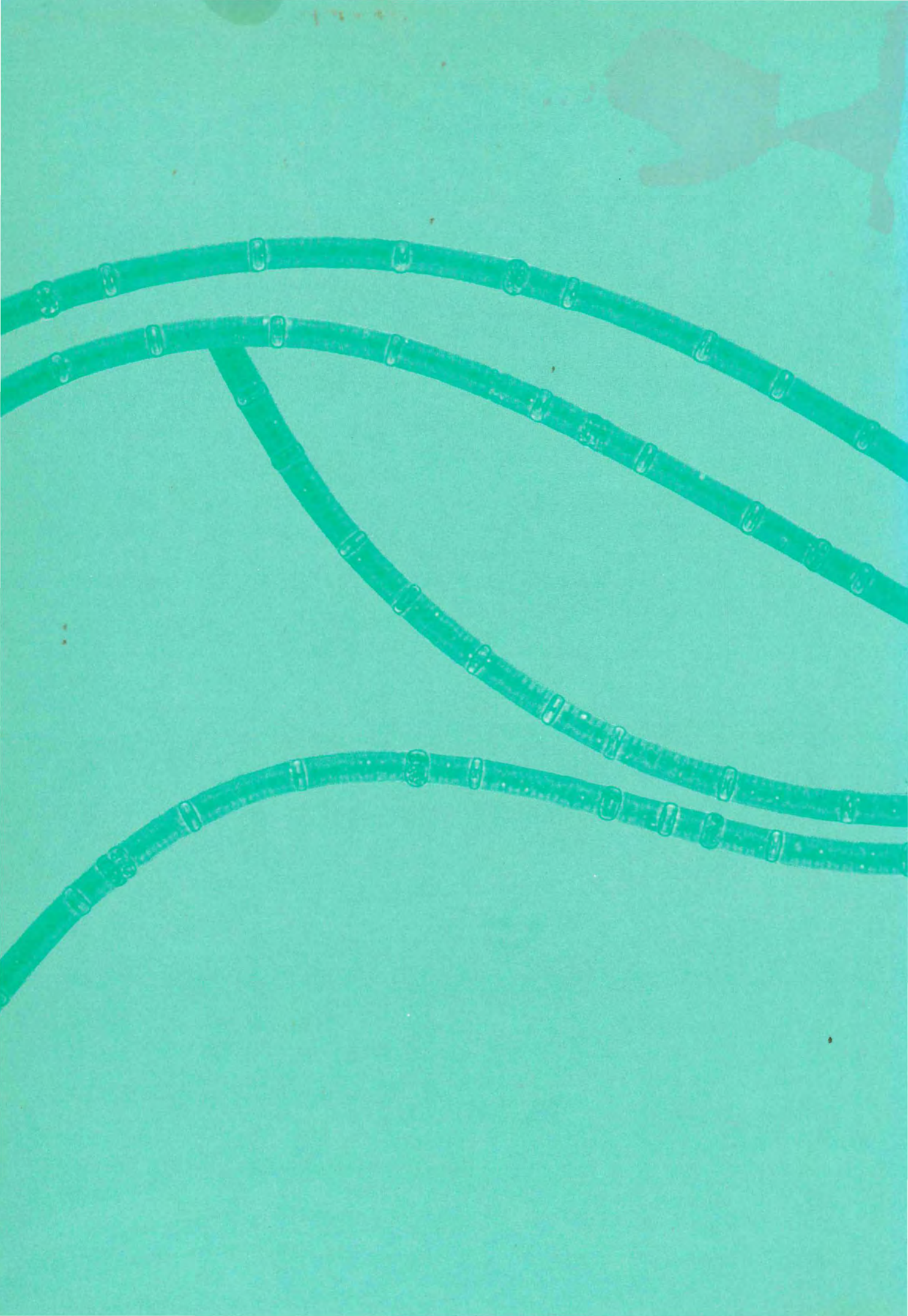
- It would take several years to dredge the whole estuary. Meanwhile, the sediment phosphorus store would build up again, because more phosphorus comes into the estuary each year in drainage water than is flushed to the sea by river flow or is lost by tidal exchange. Therefore, no long-term benefit would accrue.
- The measure would be very costly.
- Dredging would cause widespread environmental damage, especially to the juvenile fish nursery. A dramatic adverse impact on fish catches could be expected.
- Disposal of such huge volumes of spoil would be very difficult.

SUMMARY OF PROPOSED MANAGEMENT MEASURES

Option	Time required for impact	Status of evaluation
PREFERRED STRATEGY		
Weed harvesting from beaches	Short-term (annual impact)	Studies show need to continue harvesting.
Weed harvesting offshore	Short-term (annual impact)	Need to continue harvesting. Second harvester has been commissioned.
Agronomic: apply fertilizers only as required on the basis of soil tests. Use appropriate slow-release fertilizers	Medium-term (3–5 years)	Studies show a 30–40% reduction in phosphorus released to drainage can be achieved. Work is continuing, to evaluate long-term effects.
Creation of a new channel from Harvey Estuary to the ocean	Long-term (4–5 years)	Studies show that a fourfold increase in Harvey Estuary flushing would result. Engineering studies are continuing.
SUPPLEMENTARY OPTIONS FOR FURTHER EVALUATION		
Algicides	Short-term (2 years)	Only preliminary studies have been undertaken to date. Studies are continuing. Need to assess dangers.
Amendment of leaching soils with bauxite residue	Long-term (10–20 years)	Further evaluation required of costs and results. Has potential to greatly reduce phosphorus loss from sandy soils.
Wetland filters at point source of nutrient input (piggeries, sewage, etc.)		Point sources contribute less than 10% of phosphorus input. Studies are continuing.
Changes in land use from agriculture (requiring superphosphate) to forestry or parkland	Long-term (5–10 years)	Preliminary cost evaluation is being carried out. Studies are continuing.
Controls on clearing and on drainage construction	Long-term	It is preferable that no further clearing or drainage construction be undertaken. Studies are continuing.

SUMMARY OF OTHER MAJOR PROPOSALS CONSIDERED

Option	Time required for impact	Status of evaluation
Improvement to existing Mandurah Channel	Medium-term (3–5 years)	Studies show that these would not be completely effective in Peel Inlet and there would be no impact in Harvey Estuary. May need to be re-evaluated if Dawesville channel does not proceed.
Diversion of drainage to ocean (Herron Ford barrage)	Long-term	Probably very effective in lowering the phosphorus input from the Harvey River catchment, but would have considerable adverse environmental impact. Very costly.
Dredging of top 10 cm of estuary sediments		Problem will continue, as the estuary gains phosphorus input annually. Adverse effects on fish and other fauna. Very costly.
No action		Further deterioration is certain. The problem is shown to be increasing and changing in nature.



NEWS RELEASE

DEPARTMENT OF THE PREMIER AND CABINET
197 ST. GEORGE'S TERRACE,
PERTH, WESTERN AUSTRALIA 6000
PRESS SECRETARY TELEPHONE (09) 420 9595 TELEX AA 95078

P84/299
10/9/84

State Cabinet today gave the go-ahead for a full-scale feasibility study of the proposed channel at Dawesville to open the Peel Inlet to the sea.

This follows endorsement of the proposal last week by the Mandurah Shire Council and a meeting on Saturday between the Premier, Mr Brian Burke, and Dawesville land owners whose properties would be affected by the channel.

Cabinet also called for associated reports on the planning aspects of the channel and the proposed Mandurah ocean marina.

The Minister for Technology, Mr Mal Bryce, is also to report to Cabinet in about two months on the Parry Corporation's proposal for a marine technology park on the marina site and the Minister for Works, Mr Ken McIver, is to report on the most appropriate means of maintaining a permanent deep-water entrance to the inlet.

The Shire Council told the Government it gave a high priority to the establishment of a permanent deep-water entrance.

Mr Burke said the Government believed the Peel Inlet was one of the State's finest natural assets and every effort had to be made to arrest and reverse the deterioration that had occurred in its condition over the last few years.

"The Government has been told that unless urgent steps are taken, even average rain over the next few years would cause a significant worsening in the algal problems in the estuary which are already severe," Mr Burke said.

/2

"The Public Works Department has told us that the cost of constructing a navigable channel to the sea, including training walls and a sand by-pass system at the entrance, a two-lane bridge and roadworks is estimated to be $26 million. The work would take about two years.

"The feasibility study will deal with the location and design of the channel and the identification of possible effects on the coast and the estuary.

"The various studies required will mean it will be about nine months before a final decision to proceed with the channel can be made.

"No construction work will be done without the completion of an environmental review and management progamme," he said.

Mr Burke said existing Government programmes aimed at reducing algal growth in the inlet would continue.

These involved reducing phosphorous input into the estuary by encouraging farmers to modify their agricultural practices and continued weed harvesting.

Mr Burke said the Mandurah Shire Council had called a public meeting for 8pm on Wednesday, September 26 at the Reef Hotel at which Government officers would outline the channel proposal and other Government measures to clean up the inlet.

****

PEEL-HARVEY ESTUARINE SYSTEM STUDY

PROGRESS REPORT, MAY 1984

The Project Team, formed following the public meeting in February, has met fortnightly to review progress of investigations and implementation of management measures. The team consists of Dr Ron Black, Dr Peter Birch and Dr Ernest Hodgkin, together with members of the research groups involved in the areas under review, (about 40 people in all). The Policy Advisory Group (Heads of Departments or their deputies) has met monthly.

The 'Dawesville Cut'.

One of the principal concerns for both groups has been matters relating to the proposed channel from Harvey Estuary to the sea. A detailed programme and timetable for planning actions has been presented to the Policy Advisory Group, but as yet there has been no meeting between the Town Planning Department and the Mandurah Shire Council or landowners in the projected area of the cut. The Harbours and Rivers Division of PWD is investigating alternative plans for the cut, disposal of spoil and various aspects of the physical response to creating a new channel to the sea.

Mathematical Modelling

The important modelling programme on the effects of the cut only starts this month. The Centre for Water Research, UWA had great difficulty in securing the services of a suitably qualified and experienced modeller. It is hoped to have preliminary results from this study by August but definitive answers to the complex problems involved will not be available until early 1985.

Implementation of Approved Management Measures

Weed harvesting and clearing from the beaches. The excessive weed accumulation, on Coodanup beaches especially, in April resulted as much from equipment failure as from change in the nature of the problem itself. With the purchase of the new

tractors PIMA should be able to cope with any repetition of this situation. However, with the change in the weather pattern and the consequent persistent high tides there has been little weed accumulation on the beaches and it appears unlikely that there will be further serious trouble with rotting weed before next spring.

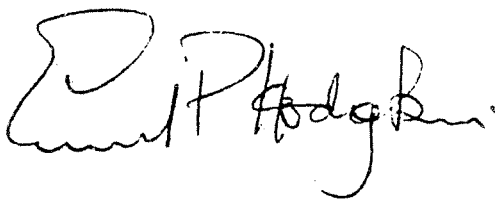
Fertilizer modification program. There has been good progress with this program. Over 400 farmers on the coastal plain catchment have had their soils tested and have been given follow-up recommendations with respect to their fertilizer requirements. The extension work required for this season is now almost completed and it is estimated that up to 70% of farmers will be using New Coastal Super. The lack of a suitable sulphur fertilizer for use where phosphorus is not needed has now been overcome. Government Chemical Laboratories has produced a trial batch of a granulated gypsum for field testing this winter. If, as is anticipated, this is successful the granulated gypsum will be made available for commercial distribution from CSBP in 1985.

The significance of this is that there will no longer be any need to use a phosphate-based fertilizer (either super-phosphate or New Coastal Super) as a source of sulphur for the 50% of farms which have built up more than adequate soil reserves of phosphorus to maintain pasture production. Only sulphur (as granulated gypsum) needs to be applied to these soils for up to three to five years. During this time much less phosphorus will be applied to the catchment than previously, the soil store will be depleted, and phosphorus loss to drainage will be reduced. At present, 70% of phosphorus entering the estuary comes from this soil store, but how fast the store will run down as the result of the changed fertilizer practices cannot be predicted at this stage.

Future Reports

The Project Team is committed to submitting two reports to Government, one in August 1984 and a final report about April 1985. It is now clear that the August report will not be substantially different from that of January 1984. Two of the

three principal management measures recommended have been implemented, namely continued and improved algal harvesting and the fertilizer modification program. There has been good progress with both and this will be reported. The third measure, to increase tidal flushing by making a new channel to the sea (the 'Dawesville cut') is still considered to be essential to an early solution to the algal problem. However, a firm recommendation for implementation of this costly measure cannot be made without further investigation. This involves: engineering criteria including a geophysical survey of the proposed route of the cut; problems relating to disposal of spoil from the cut; mathematical modelling to identify the physical effects of the cut on the estuarine environment (e.g. the extent and effects of the greatly increased daily tidal range); the anticipated effects of the physical changes on the ecology of the system. These will not be completed until February 1985. A firm recommendation with respect to the cut will be made in the subsequent report.



E.P. Hodgkin
RESEARCH CO-ORDINATOR

5 June 1984

PEEL/HARVEY ESTUARINE SYSTEM PHASE 3 STUDIES

HARVEY ESTUARY TO OCEAN CHANNEL

ALTERNATIVES FOR LAND ACQUISITION AND SPOIL DISPOSAL

Position Paper - April 1984

1. Options for Development without Canal Subdivision

Assuming that the proposed Harvey Estuary to Ocean Channel is to be developed by the Public Works (or new Marine) Department to maximise ocean water exchange at least construction cost and without the complication of additional contentious matters (e.g. canal estate subdivisions), there are three options for land acquisition and subsequent development, which are listed below in order of preference:

Option A1 (See Appendix 1 for preliminary costing details)

(i) negotiate for the State Government to purchase all land that would be affected by channel excavation or spoil disposal operations on the basis that all spoil from the land section of the channel excavation (~4 100 000 m^3) would be placed on low coastal heathland to the north and south of the channel area, between the existing Coastal Highway and the coastal foredune (see area marked in green on Figure 1),

(ii) arrange to place spoil dredged from the Harvey Estuary (~800 000 m^3) to reclaim a shallow portion of the Harvey Estuary in an area adjacent to existing foreshore reserves and to the north-east of the proposed channel (see Figure 1),

(iii) allow for the State Government to undertake future urban land subdivision of the filled heathland area (not canal subdivision), possibly through the State Housing Commission or the R&I Bank,

(iv) determine an appropriate land use for reclamation placed against the Harvey Estuary shoreline (including the feasibility of a canal estate) on the basis of detailed investigations carried out by the proposed developer, who has yet to be identified.

Option A2

(i) legislate for the State Government to acquire all land that would be affected by channel excavation or spoil disposal operations (either by purchase or resumption), undertake the channel excavation and spoil disposal works, and then subdivide the remaining filled (and improved) land for residential development as required.

Option A3

(i) negotiate for the State Government to purchase (or if necessary resume) all land required for the channel excavation,

(ii) negotiate to lease further land in private ownership for the purpose of spoil disposal from the land section of channel excavation,

(iii) allow land owners to put forward proposals for urban land subdivision of their land which has been filled,

(iv) proceed as per Option A1, for dredging, reclamation and land use matters associated with the disposal of spoil from Harvey Estuary (i.e. Items A1(ii) and (iv) refer).

Option A3 would not be favoured unless the major landowner (Wannanup Developments) was prepared to contribute a substantial amount towards the cost of placing fill material on its land. Otherwise, Wannanup Developments would stand to benefit excessively from the proposed channel works. In accordance with Options A1 and A2, it would be proposed that, on completion of the channel works, any filled land would be transferred to an appropriate State Government organisation for subdivision and resale in a manner which would recover the largest possible proportion of overall State Government expenditure on the works.

2. Options for Development with Canal Subdivision

It has been suggested that the State Government could gain some further financial advantage by using spoil from the ocean channel excavation to reclaim new land within Harvey Estuary which could then be made available for the development of a canal estate subdivision. It has been further suggested that it would help to resolve the existing impasse over the development of canals at Mandurah, if Parry's Esplanade and/or John Holland could be encouraged to relocate their proposed canal developments on this reclaimed land at Harvey Estuary.

For the ocean channel investigations, the Peel/Harvey Study Team is currently working in accordance with the assumption that, to maximise water exchange through the whole estuarine system, spoil should not be placed where it would significantly restrict the flow of water through the natural channel between Peel Inlet and Harvey Estuary. Therefore, a further land acquisition and spoil disposal Option B has been proposed (as shown in Figure 2) which on preliminary evaluation is considered to indicate the maximum area of land reclamation that could be allowed without significantly affecting the estuary water flow pattern.

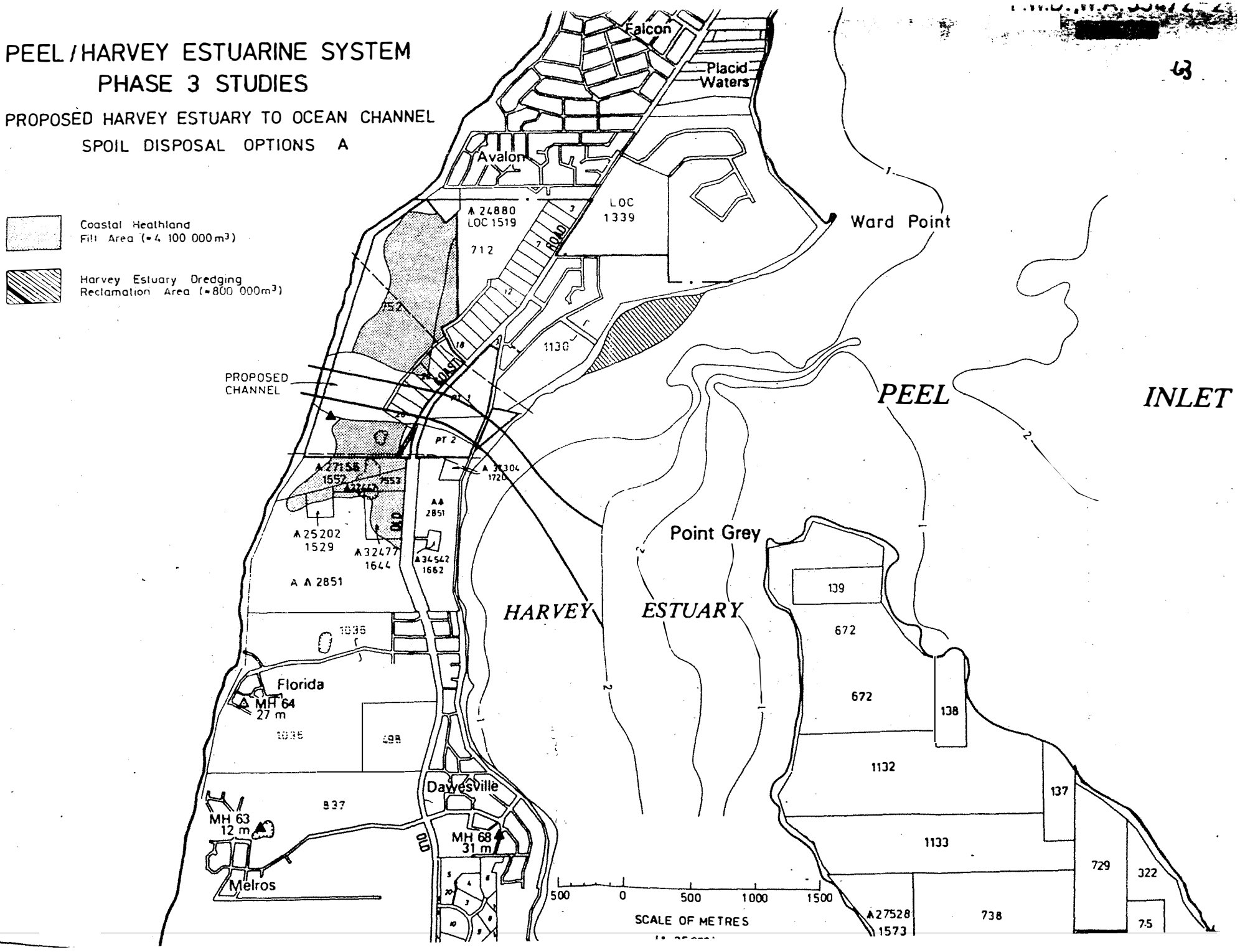
A canal estate equivalent in size to John Holland's Waterside Mandurah Stage 1 could be accommodated on this site if it were expanded to include adjacent undeveloped land owned by Wannanup Developments (i.e. Pt. Loc. 1130 marked in blue on Figure 2). The designated reclamation area would accommodate some of the spoil generated by the channel excavation, but a reasonable estimate of the spoil quantity could only be determined in conjunction with detailed town planning/engineering investigations of the proposed canal estate concept over a period of several months.

The area marked in green on Figure 2 represents a lesser land acquisition area which may be appropriate in circumstances where more spoil is to be used for estuary reclamation. In defining this area, it should be borne in mind that the exact channel alignment will not be fixed until after the ground investigations have been completed in December 1984. These may indicate that channel excavation costs could be reduced by moving the ocean entrance up to 800 m northwards from the location shown in Figures 1 and 2.

If Option B is favoured, then it would be recommended that an appropriate proponent organisation for the canal development works be identified urgently, so that it could contribute to the detailed planning process which would have to involve consultants experienced in canal estate subdivision development.

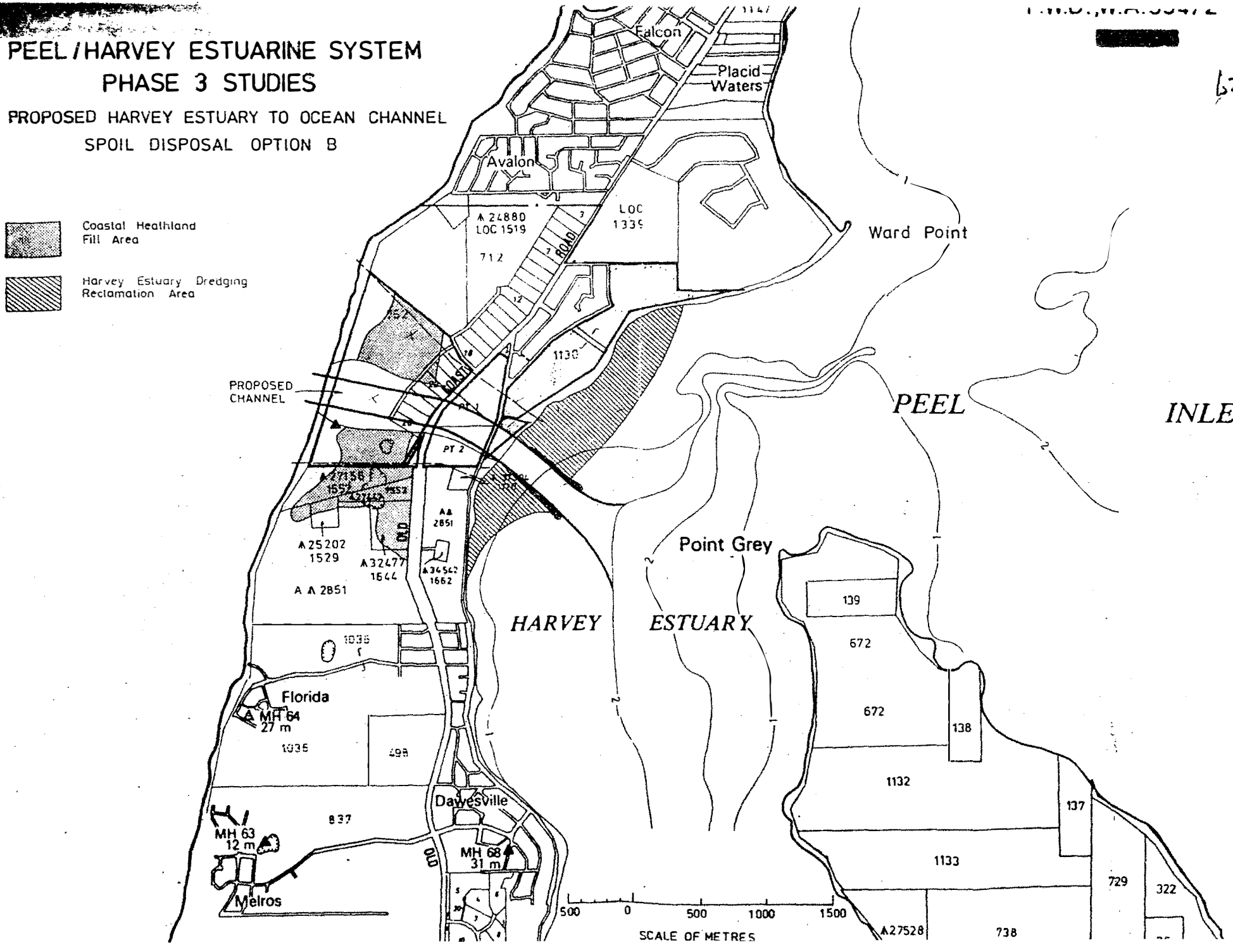
PEEL / HARVEY ESTUARINE SYSTEM
PHASE 3 STUDIES

PROPOSED HARVEY ESTUARY TO OCEAN CHANNEL
SPOIL DISPOSAL OPTIONS A



PEEL/HARVEY ESTUARINE SYSTEM
PHASE 3 STUDIES

PROPOSED HARVEY ESTUARY TO OCEAN CHANNEL
SPOIL DISPOSAL OPTION B



APPENDIX 1

Proposed Harvey Estuary to Ocean Channel

Preliminary Costing of Option A1

EXPENDITURE

(i) Land Purchase:

LOCATION	OWNER	AREA (ha)	ESTIMATED COST ($) per ha*	Total
Pt. Loc. 752	Wannanup Developments	129.3129	10 000	1 293 000
Loc. 752 Lot 19	R J Meade	2.1038	12 500	26 000
Loc. 752 Lot 20	N & B Hamblin	2.0315	12 500	25 000
Loc. 752 Lots 21-23	Wannanup Developments	6.1050	12 500	76 000
Loc. 752 Lot 24	B W Pusey	2.0748	12 500	26 000
Loc. 752 Lots 25-26	Wannanup Developments	4.0630	12 500	51 000
Loc. 1130 Pt. 2	S Y Lee & S L Tan	13.3521	20 000	267 000
Loc. 1130 Pt. 1	Wannanup Developments	17.3628	20 000	347 000
Pt. Loc. 1130	Tamnic Pty Ltd	4.1657	20 000	83 000
	TOTAL	180.5716		$2 194 000

*Conservative estimates based on known rural land valuations
- to be checked by the Valuer General's Office.

(ii) Ocean Channel Construction (200 m wide, with invert at RL -4.5 m)

ITEM	VOLUME m^3	ESTIMATED COST ($)≠ per m^3	Total
Dredging - ocean entrance	100 000	2.30	230 000
- Harvey Estuary	800 000	3.00	2 400 000
Excavation through land section			
- above AHD	2 600 000	1.50	3 900 000
- below AHD	1 500 000	3.00	4 500 000
Bridge and roadworks			5 000 000
Ocean entrance training walls			800 000
Sand bypassing (including capitalisation of operating cost)			5 000 000
Sub Total			21 830 000
Contingencies @ 10%			2 183 000
TOTAL			24 013 000
		say	$25 000 000

≠Source: Public Works Department Report No. CIS 83/3 entitled "Peel/Harvey Estuarine System Phase 2 Study, Engineering Investigations. Dredging and Flow Training Options", November 1983

(iii)Urban Land Sudvision Costs (for 700 m^2 lots)

ITEMS	EST. AREA AVAILABLE FOR SUBDIVISION (ha)	ESTIMATED COST ($) per ha	Total
Roadways) Water Supply) Power) Sewerage) Drainage) etc.)	150	55 300 Ø	8 295 000

ØSource: Conservative figure based on information from State Housing Commission via Town Planning Department
i.e. 7.9 lots per ha @ $7 000 per allotment

(iv) Total Ocean Channel + Land Development

Cost = (i) + (ii) + (iii) = $35 489 000

INCOME

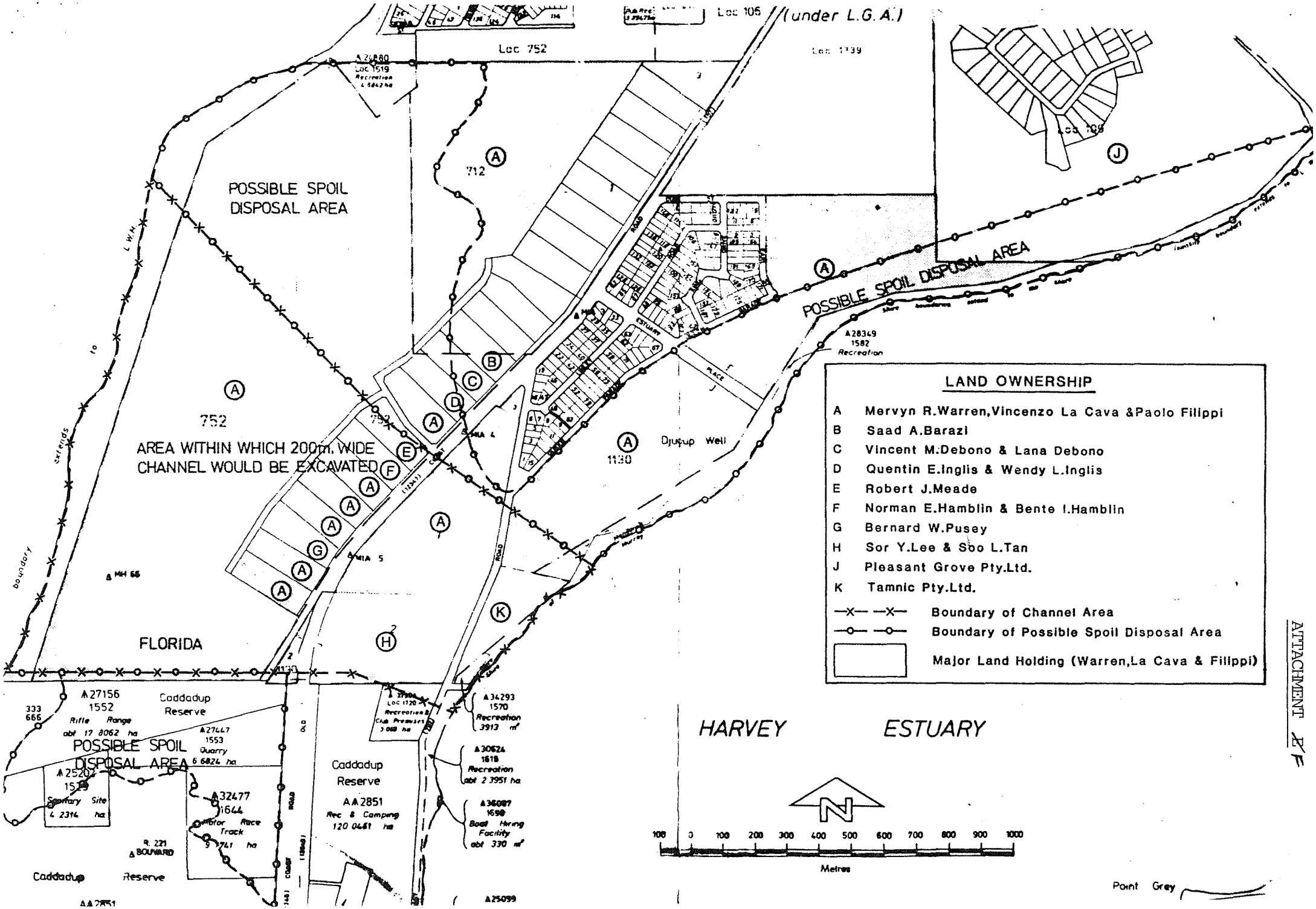
From resale of filled, subdivided and serviced land:

Total number of 700 m^2 allotments available for resale
= 150 ha x 7.9 lots per ha
= 1 185 allotments

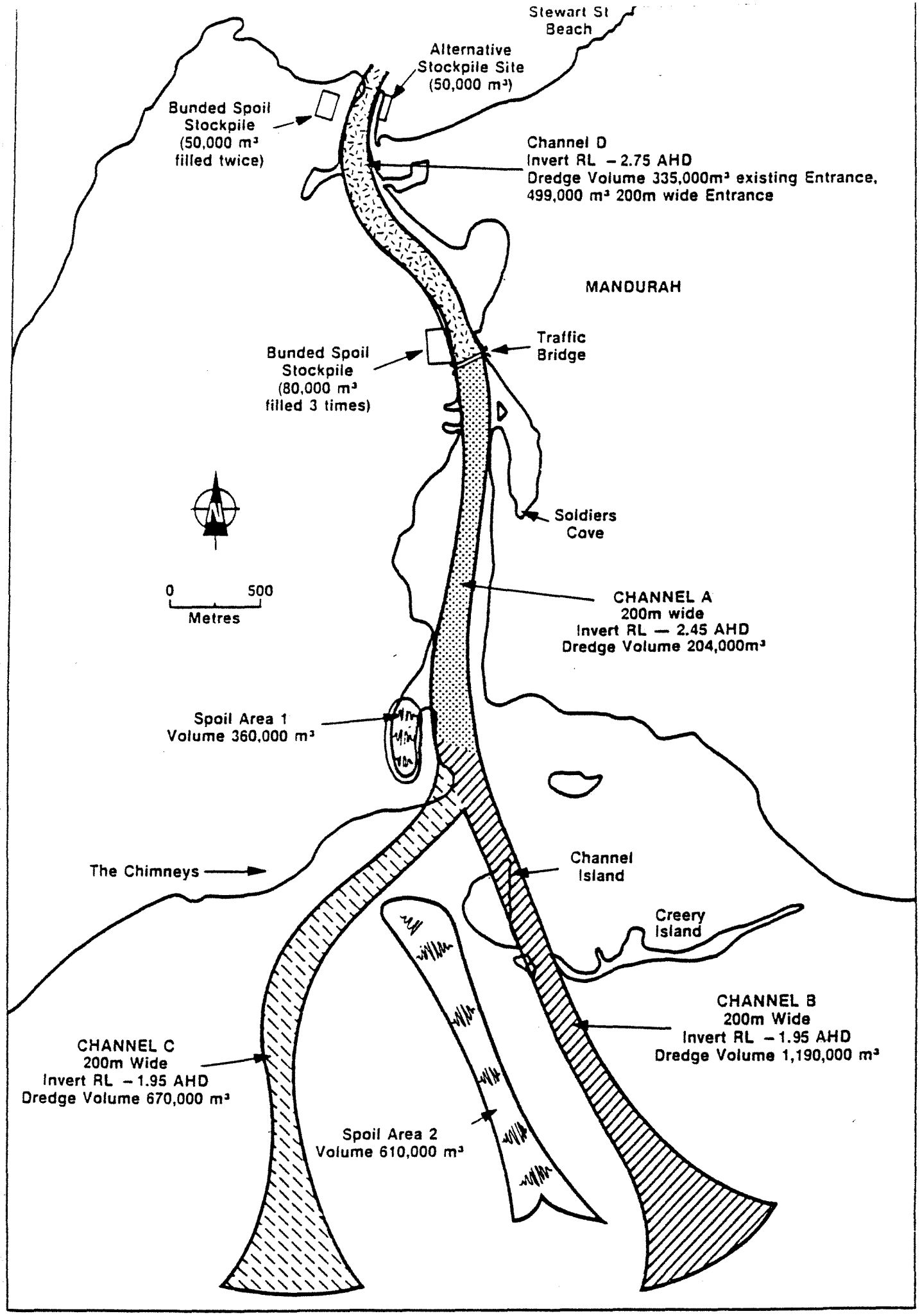
Estimated resale value of each 700 m^2 allotment°
= $13 000

Total recoverable by resale of filled, subdivided and serviced land
= $15 405 000

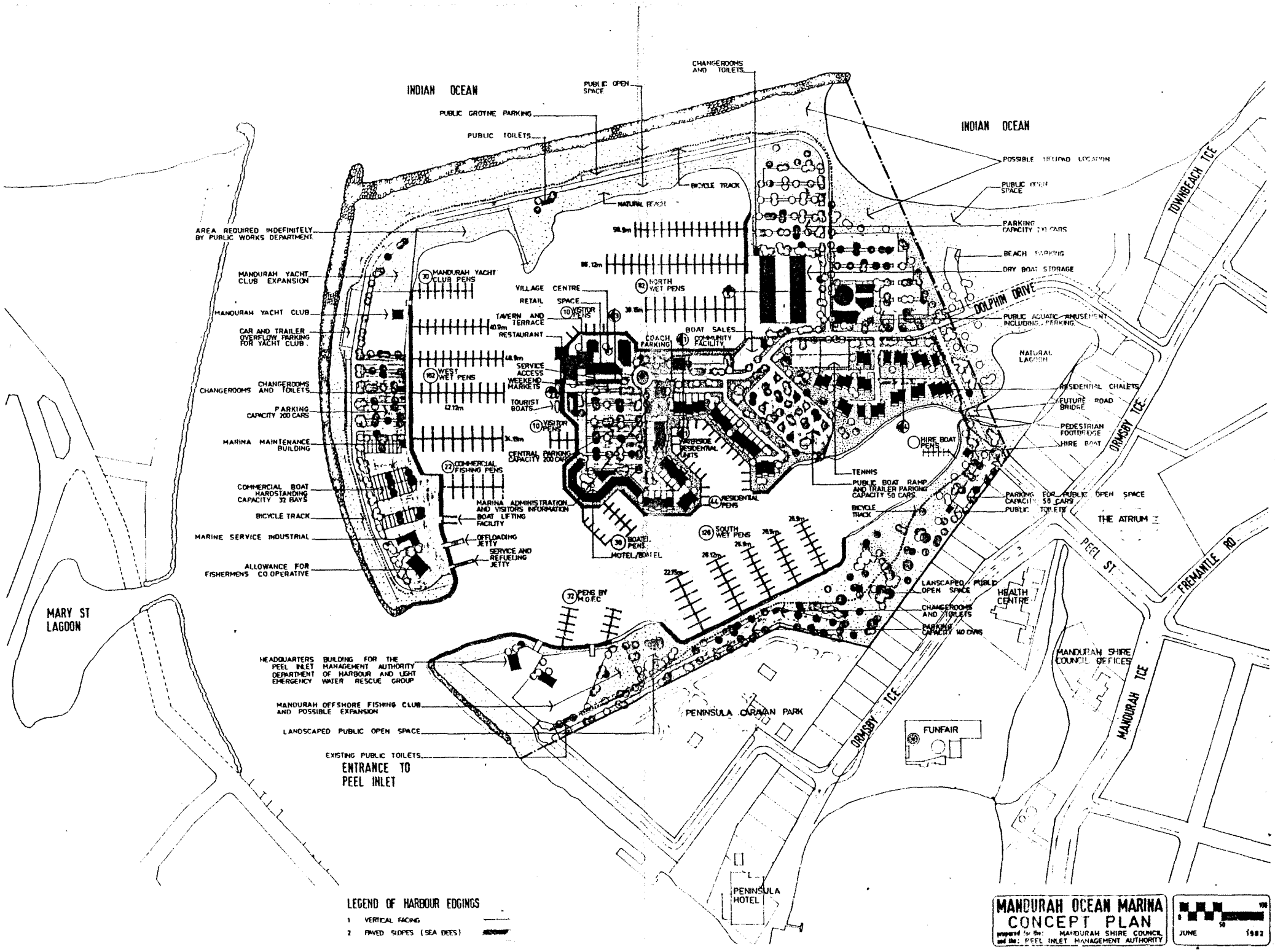
°Conservative estimate based on known urban land valuations - to be checked by the Valuer General's Office.

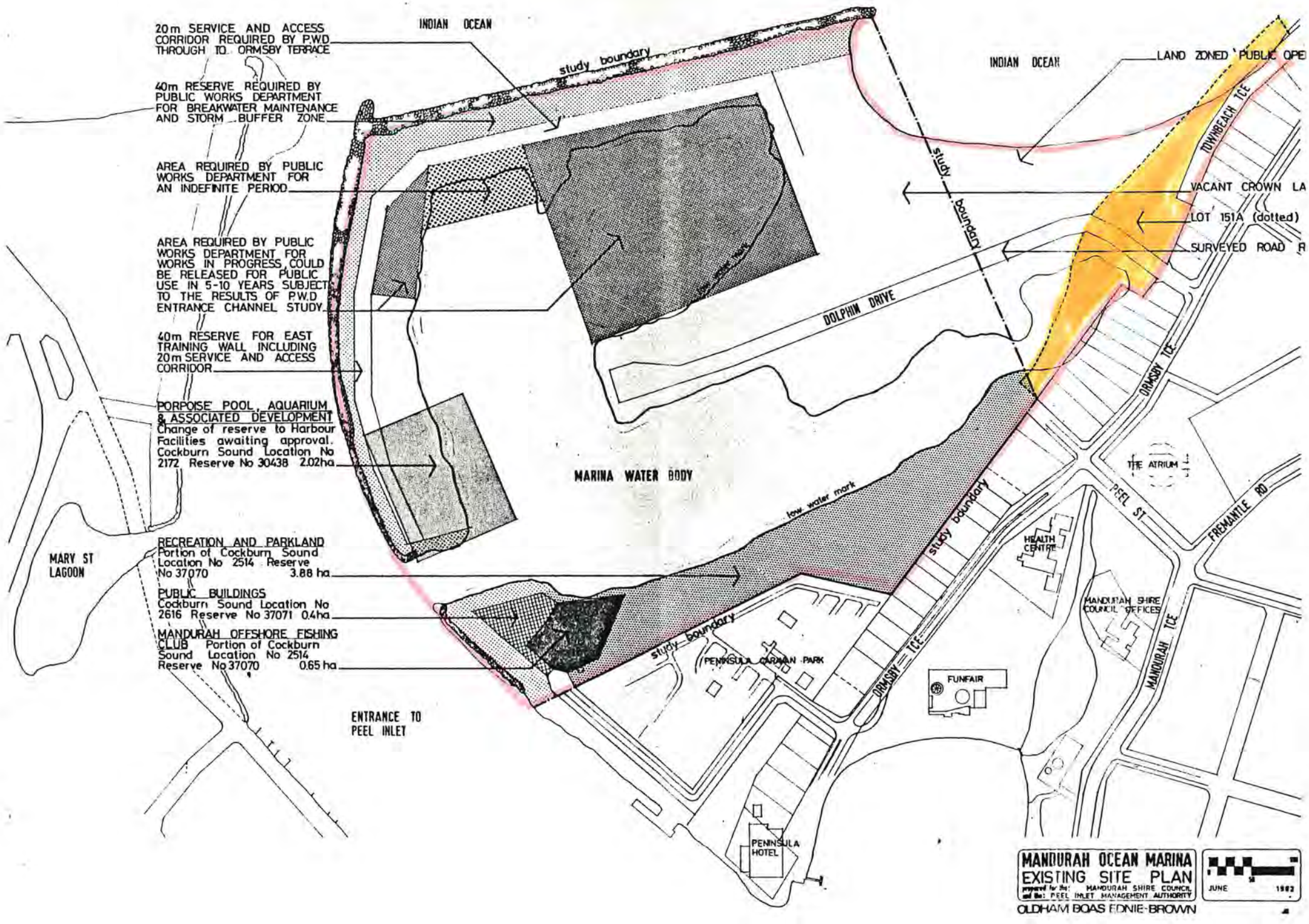


ATTACHMENT E



Possible areas of dredging for improvement of the existing Mandurah Channel


INDIAN OCEAN
PUBLIC OPEN SPACE
PUBLIC GROYNE PARKING
PUBLIC TOILETS
CHANGEROOMS AND TOILETS
INDIAN OCEAN
POSSIBLE HELIPAD LOCATION
PUBLIC OPEN SPACE
PARKING CAPACITY 210 CARS
BEACH PARKING
DRY BOAT STORAGE
TOWNBEACH TCE
DOLPHIN DRIVE
PUBLIC AQUATIC AMUSEMENT INCLUDING PARKING
NATURAL LAGOON
RESIDENTIAL CHALETS
FUTURE ROAD BRIDGE
PEDESTRIAN FOOTBRIDGE
HIRE BOAT
ORMSBY TCE
HIRE BOAT PENS
TENNIS
PUBLIC BOAT RAMP AND TRAILER PARKING CAPACITY 50 CARS
PARKING FOR PUBLIC OPEN SPACE CAPACITY 50 CARS
PUBLIC TOILETS
BICYCLE TRACK
THE ATRIUM
PEEL ST
FREMANTLE RD
LANSCAPED PUBLIC OPEN SPACE
HEALTH CENTRE
CHANGEROOMS AND TOILETS
PARKING CAPACITY 140 CARS
MANDURAH SHIRE COUNCIL OFFICES
MANDURAH TCE
ORMSBY TCE
FUNFAIR
PENINSULA CARAVAN PARK
PENINSULA HOTEL
AREA REQUIRED INDEFINITELY BY PUBLIC WORKS DEPARTMENT
MANDURAH YACHT CLUB EXPANSION
MANDURAH YACHT CLUB
CAR AND TRAILER OVERFLOW PARKING FOR YACHT CLUB
CHANGEROOMS AND TOILETS
PARKING CAPACITY 200 CARS
MARINA MAINTENANCE BUILDING
COMMERCIAL BOAT HARDSTANDING CAPACITY 32 BAYS
BICYCLE TRACK
MARINE SERVICE INDUSTRIAL
ALLOWANCE FOR FISHERMENS CO OPERATIVE
MARY ST LAGOON
HEADQUARTERS BUILDING FOR THE PEEL INLET MANAGEMENT AUTHORITY DEPARTMENT OF HARBOUR AND LIGHT EMERGENCY WATER RESCUE GROUP
MANDURAH OFFSHORE FISHING CLUB AND POSSIBLE EXPANSION
LANDSCAPED PUBLIC OPEN SPACE
EXISTING PUBLIC TOILETS
ENTRANCE TO PEEL INLET
MANDURAH YACHT CLUB PENS
VILLAGE CENTRE
RETAIL SPACE
TAVERN AND TERRACE RESTAURANT
COACH PARKING
COMMUNITY FACILITY
BOAT SALES
NORTH WET PENS
VISITOR PENS
WEST WET PENS
SERVICE ACCESS
WEEKEND MARKETS
TOURIST BOATS
VISITOR PENS
CENTRAL PARKING CAPACITY 200 CARS
WATERSIDE RESIDENTIAL UNITS
COMMERCIAL FISHING PENS
MARINA ADMINISTRATION AND VISITORS INFORMATION
BOAT LIFTING FACILITY
OFFLOADING JETTY
SERVICE AND REFUELING JETTY
RESIDENTIAL PENS
BOAT/EL PENS
MOTEL/BOATEL
SOUTH WET PENS
PENS BY M.O.F.C
LEGEND OF HARBOUR EDGINGS
1 VERTICAL FACING
2 PAVED SLOPES (SEA DEES)
MANDURAH OCEAN MARINA
CONCEPT PLAN
prepared for the: MANDURAH SHIRE COUNCIL and the: PEEL INLET MANAGEMENT AUTHORITY
JUNE 1982


20m SERVICE AND ACCESS CORRIDOR REQUIRED BY P.W.D THROUGH TO ORMSBY TERRACE
40m RESERVE REQUIRED BY PUBLIC WORKS DEPARTMENT FOR BREAKWATER MAINTENANCE AND STORM BUFFER ZONE
AREA REQUIRED BY PUBLIC WORKS DEPARTMENT FOR AN INDEFINITE PERIOD
AREA REQUIRED BY PUBLIC WORKS DEPARTMENT FOR WORKS IN PROGRESS, COULD BE RELEASED FOR PUBLIC USE IN 5-10 YEARS SUBJECT TO THE RESULTS OF P.W.D ENTRANCE CHANNEL STUDY
40m RESERVE FOR EAST TRAINING WALL INCLUDING 20m SERVICE AND ACCESS CORRIDOR
PORPOISE POOL, AQUARIUM & ASSOCIATED DEVELOPMENT
Change of reserve to Harbour Facilities awaiting approval. Cockburn Sound Location No 2172 Reserve No 30438 2.02ha
RECREATION AND PARKLAND
Portion of Cockburn Sound Location No 2514 Reserve No 37070 3.88 ha
PUBLIC BUILDINGS
Cockburn Sound Location No 2616 Reserve No 37071 0.4ha
MANDURAH OFFSHORE FISHING CLUB Portion of Cockburn Sound Location No 2514 Reserve No 37070 0.65 ha
INDIAN OCEAN
study boundary
low water mark
MARINA WATER BODY
MARY ST LAGOON
ENTRANCE TO PEEL INLET
DOLPHIN DRIVE
PENINSULA CARAVAN PARK
PENINSULA HOTEL
FUNFAIR
HEALTH CENTRE
MANDURAH SHIRE COUNCIL OFFICES
THE ATRIUM
PEEL ST
FREMANTLE RD
ORMSBY TCE
MANDURAH TCE
TOWNBEACH TCE
LAND ZONED 'PUBLIC OPE
VACANT CROWN LA
LOT 151A (dotted)
SURVEYED ROAD R
MANDURAH OCEAN MARINA
EXISTING SITE PLAN
prepared for the: MANDURAH SHIRE COUNCIL and the: PEEL INLET MANAGEMENT AUTHORITY
JUNE 1982
OLDHAM BOAS EDNIE-BROWN