coastline

Maintaining the Adelaide Coastline

SOUTH AUSTRALIAN COAST PROTECTION BOARD

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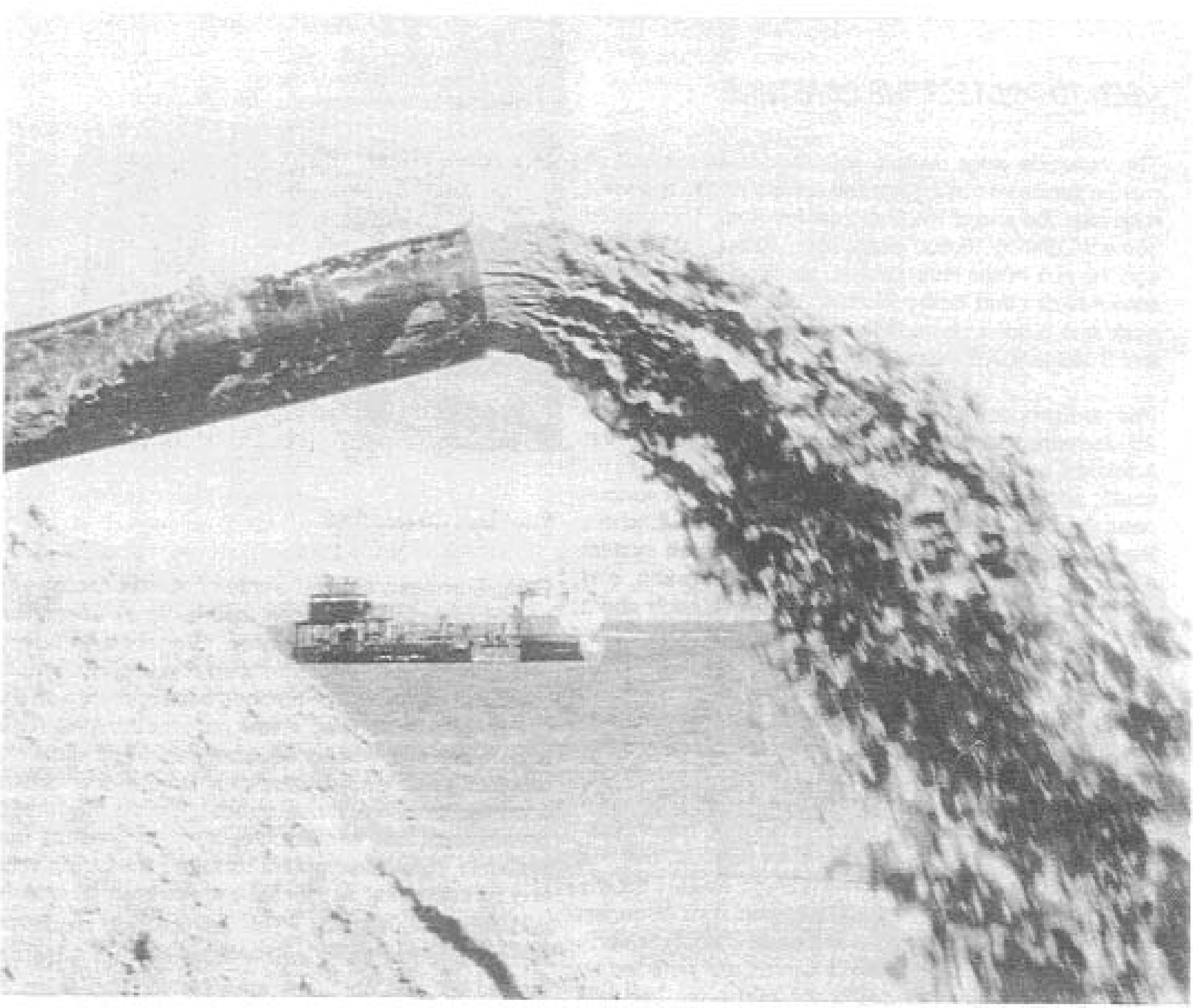


Dredging along the Adelaide Metropolitan Coastline

INTRODUCTION

The beaches between Kingston Park and Port Adelaide provide a natural resource which is used for recreation al purposes. They also afford protection to coastal development, particularly during storm attack, by reducing wave energies. However, the metropolitan dune system is slowly eroding due to the natural coastal processes, and it has become necessary to provide a management strategy to maintain the sandy beaches and protect the coastal development.

This "COASTLINE" provides a basic explanation of why* there is a need to maintain the coast, how the coast is monitored so that its problems can be better under stood, and what is being done to manage the situation. More detailed information can be obtained from the references listed at the end of this publication. "COAST LINE No. 27" provides a basic understanding of the geomorphological history of the Adelaide coast, the impact of European settlement on the dune system and the coastal processes at work on the coastline. "COASTLINE No. 29" provides information about the economic value of the Adelaide beaches and their significance to the Adelaide community.

NEED TO PROTECT THE COASTLINE

The Adelaide dune system was formed as a result of marine sediments being worked ashore as the sea level rose after the end of the last great Ice Age. This started some 10,000 to 15,000 years ago. About 7,000 years ago the rise in sea level slowed, resulting in diminishing amounts of sand being worked ashore into the dune system to a point where little has come ashore over the last 3,000 to 4,000 years.

Prior to European settlement of the Adelaide region, the 28 kilometre section of coast between Brighton and Port Adelaide had been formed into a continuous, north. south, silicious, Holocene sand dune system by various natural processes. It was broken only at Glenelg where the Patawalonga entered the sea. This dune system averaged between 200 and 300 metres; in width, and generally comprised 2 or 3 parallel ridges, each about 70 to 100 metres wide, separated by narrow depressions or swales.

The fact that sand is no longer being naturally added to the dune system would not be a major concern if the dune system was stable. However, the coastal processes occurring on the Adelaide coast produce a net northerly movement of sand along the beach system. The coastal processes are complex, but the biggest effect is from the predominant south westerly winds blowing across the Gulf St Vincent waters, generating waves which tend to advance in a north to north easterly direction. While these waves are distorted by various factors, such as the shape of the sea bed and **the different coastal** features, they generally strike the metropolitan coast at an oblique angle and have sufficient energy to work the sand grains along the beach in a net northerly direction. It is estimated that the northerly littoral drift is currently between 30,000 and 50,000 cubic metres per year. This leads to ongoing erosion of the dune system, particularly in the southern areas such as Brighton and North Glenelg.

With the coastal processes occurring, the sand dune system would erode in the southern areas and migrate northward. If allowed to continue, the beach system would attempt to maintain equilibrium using sand from the reserves stored in the dune system to compensate for the sand migrating northward along the beach. If the dune system provided an infinite sand supply, this natural process could continue virtually indefinitely, however, the dune system is now finite because it is not being naturally replenished. Without artificial replenishment the continuing coastal processes would erode the beaches until the sand veneer was removed to expose the underlying Hindmarsh clays and harder substrata. This natural phenomenon was not understood when European settlement occurred in the Adelaide region.

Sand Loss, Glenelg 1960

Early European coastal settlement was focussed at nodes of safe anchorage, primarily at Largs Bay, Semaphore, Grange, Henley, Glenelg and later at Brighton. These nodes tended to spread along the coast and dune system in ribbon development with links to the Adelaide square. It was not until the 1940's, particularly the post war period, when rapid infill of the metropolitan coast and development on the dune system occurred between these nodes. By the mid 1960's development had almost completely covered the dune system. This development included the public roads and infrastructure, residential and commercial property, and public open space. This unknowingly meant that the reserves of sand in the dune system were now "locked up" and no longer available to supplement the sand losses occurring due to the natural coastal processes.

Storm Damage, Brighton 1971

Development which has occurred on the dune system has required protection against storm damage. Early protective works had a short lifetime because of the limited understanding of the coastal processes at work during a storm. Expenditure on storm damage repairs and protection works has been considerable over the years. For example, 88,000 pounds (approx $14M in 1993 dollars) was expended on protective works after the 1948 storm; 230,000 pounds (approx $21M in 1993 dollars) after the 1953 storm; 88,000 pounds (approx $4M in 1993 dollars) after the 1960 storm. Sea walls now protect about 14 kilometres of the metropolitan coastline. These protection measures "locked up" the sand reserves and acted to accelerate the natural beach erosion on the metropolitan coastline.

In the 1960's the Metropolitan Seaside Councils Committee together with the State Government, commissioned the University of Adelaide to conduct a detailed study of the metropolitan coast to provide a better understanding of the coastal processes and problems of erosion of the metropolitan beaches. This detailed Erosion Report, published in 1970 and commonly called the "Culver Report" after its primary author Dr Bob Culver, concluded that the basic problem with the beach system was that there was no naturally continuing replenishment source of sand. When combined with the net northerly littoral drift, the ongoing increase in mean sea level and the development on the dune system, the long term effect is the need to artificially maintain the beaches, or eventually lose them.

The Culver Report recognised the need to act urgently to artificially maintain the metropolitan coast as well as provide adequate storm protection for properties constructed on the dune system. The Report recommended the establishment of the Coast Protection Board, which was constituted under the Coast Protection Act in 1972, to co-ordinate and facilitate these urgent activities. Since its formation, the Board has continued its role in maintaining and protecting the metropolitan coast with the technical and administrative assistance of the Coasts and Marine Section of the Environment Protection Agency of the Department for Environment, Heritage and Aboriginal Affairs.

MONITORING THE METROPOLITAN COASTLINE

Since its formation, the Coast Protection Board has placed a high priority on data collection and monitoring programs. This is primarily to enable a better under standing of the coastal problems, and provide a sound basis for making decisions about the most cost effective strategy available for resolving them. The beach profile monitoring program is an important aspect of managing the Adelaide coastline.

The profile network, which has been regularly surveyed since 1975, consists of a series of survey lines, spaced on average 500 metres apart between southern Kingston Park and the southern North Haven breakwater, and extend across the active beach zone to about 1 kilometre offshore. In 1989, modelling surveys were also undertaken utilising recent improvements in survey technology and GIS processing software. Contour and surface difference maps can be produced from the modelling surveys as well as more accurate estimates of sand volume changes.

It is possible to monitor the beach levels over time, or provide information about sand movements and rates of movements particularly after storm events and sand replenishment programs, or show areas of erosion and accretion, etc. Due to uncertainties attached to the actual data collected and the numerous variables associated with its acquisition and analysis, care must be taken when interpreting the results. Conclusions drawn from short term data can be misleading when dealing with coastal data, which is why long term data is, so valuable for decision- makers.

It is difficult to provide a summary of the results from the monitoring program because it is dependent on what information is required and what problem needs to be resolved. For example, it is possible to use the data to determine the extent of erosion or accretion at specific locations over certain periods, or, at the other extreme, to determine the impacts to the total metropolitan sys tem over a period. As an example, the 1977 and 1989 data has been used in Figures 1 and 2 to illustrate how the metropolitan coast has varied over this period. It should be noted that the data used includes the effects of the sand replenishment programs undertaken during this period.

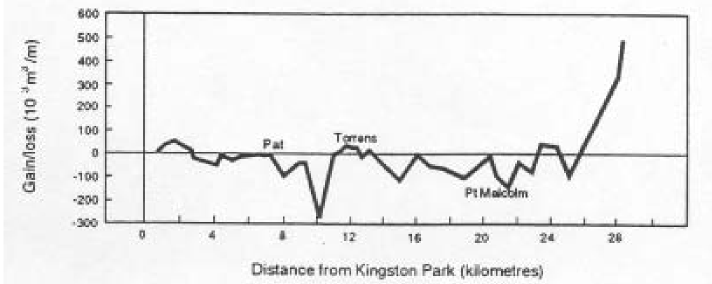
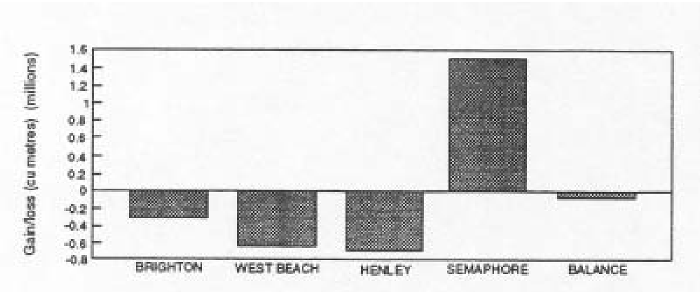


Figure 1
Sand Volume Changes 1977-1989

Figure 1 provides an estimate of the sand volume change along the metropolitan coast between 1977 and 1989. It can be seen that most of the coast has suffered a loss of sand. The exceptions being at the northern end of the system at Largs Bay to North Haven (due to the net northerly littoral drift effect), the Torrens Outlet (due to the hydraulic barrier effect of the outflows on the sand migrating northwards), and at Kingston Park (due to the beach replenishment program).



Brighton region = Kingston Park to Glenelg Breakwater
West Beach = Glenelg to Torrens Outlet
Henley = Torrens to Pt Malcolm
Semaphore = Pt Malcolm to North Haven

Figure 2
Regional Volume Loss/Gain 1977-1989

Figure 2 divides the metropolitan coast into four compartments to illustrate the regional gains and losses of sand along the metropolitan beaches between 1977 and 1989. The Brighton, West Beach and Henley regions all show a net loss of sand during this period, while the Semaphore region shows a net gain. Overall the losses appear to be in balance with the gains in the total system.

While these two examples give a brief insight into how the data can be used, of more importance is the fact that the data has been collected since 1975, and with the assistance of computer technology can be relatively easily processed to provide a good scientific basis for resolving problems.

MANAGEMENT STRATEGIES AVAILABLE FOR THE METROPOLITAN COASTLINE

The "Culver Report" in 1970 recommended that sand replenishment be undertaken as a matter of urgency, in addition to other protective works, and that other sources of sand should be investigated for future replenishment programs. In response to these recommendations, the Coast Protection Board established a sand replenishment strategy using sand collected from northern beaches and trucked to southern beaches and vulnerable foreshore sites. Beach replenishment has continued to be the Board's preferred management strategy, although since 1989 the replenishment has been by dredging sand ashore from offshore sand sources. Figure 3 shows the annual expenditure on sand replenishment for the metropolitan coast.

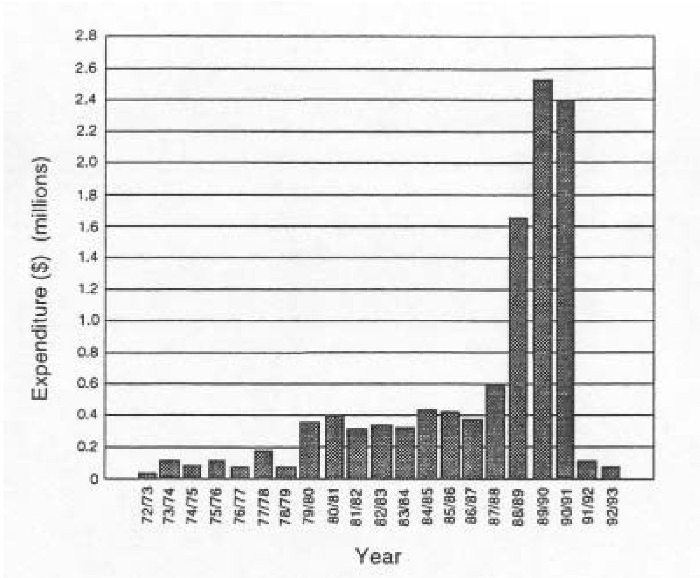


Figure 3
Metropolitan Beach Replenishment
Actual Annual Expenditure

The Board has periodically investigated alternative strategies for maintaining the metropolitan coast in an attempt to provide the most cost effective solution available. Major study reports were prepared by the Coastal Management Branch in 1984 and 1992 for the Board. The Board considers this an important task because of the changing technology and costs of the available alternatives, the ongoing research which is providing a better understanding of the coastal processes, and the need to conserve the natural coastal resource for as many future generations as possible at an affordable cost to the present community.

Coast protection strategies can be categorised into the following three fundamental philosophies.

a. Let the natural processes continue unobstructed. This involves the retreat of all coastal development to a point where the natural coastal processes can proceed uninhibited by manmade obstacles. In effect, this "unlocks" the sand reserves in the dune system, and permits natural erosion to occur while sand is continually transported in a net northerly direction.

b. Provide solutions which alter the rate of erosion of the coastline. This could be achieved by supplying erosion material through a beach replenishment program to counteract or retard the natural losses, or providing structures which dissipate the wave energy such as sea walls or breakwaters. This philosophy enables development to be retained on the dune system.

c. Provide solutions which obstruct or retard the littoral drift process. This could be achieved by constructing groynes across the active beach zone, or offshore breakwaters to alter the wave patterns, or constructing artificial headlands. These solutions enable selective accretion and erosion at predetermined locations along the coastline.

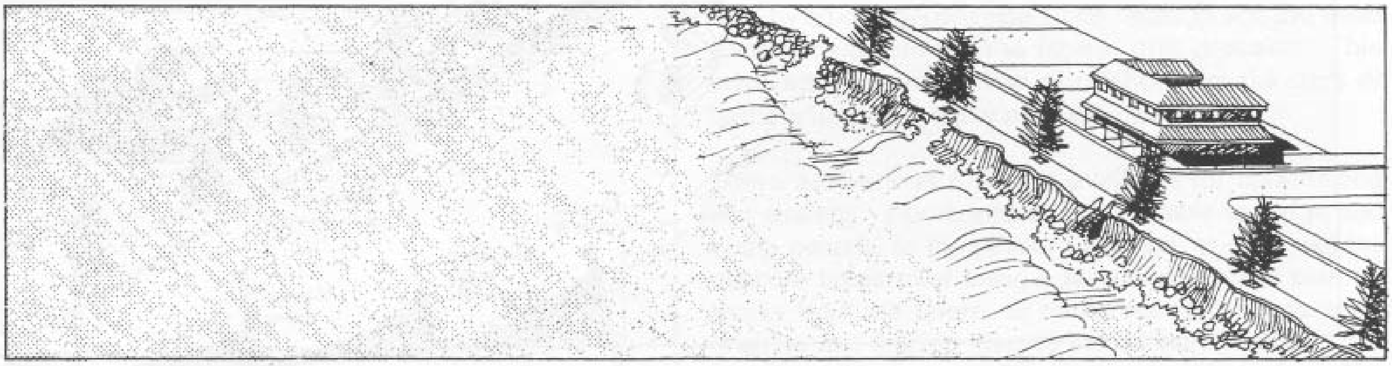


Figure 4
Natural Retreat

It should be noted that on the metropolitan coast, the last two philosophies are not entirely separable, because anything which affects the wave energy must also change the littoral drift rate which is driven by this energy.

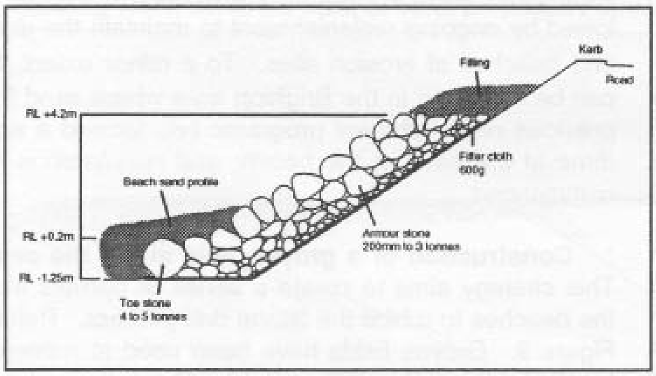


Figure 5
Seawall Defense

While it is possible to determine the economic cost of relocating the existing development back from the coast, this option has never been considered a viable option because of the social impact such a strategy would have on the community. In addition, when costed over normal planning periods such a community cost could not be justified. The cost of this option could be expected to be in the 100's of millions of dollars. However, in terms of good planning, it is important to recognise that the development fronting the coast is in a high risk area and steps should be taken through planning legislation, such as Supplementary Development. Plans (SDP's), to ensure development does not encroach further seaward.

It is, therefore, necessary to consider engineering solutions which will provide protection to existing coastal development and maintain the sandy beaches. There are a number of options available, with different meth-ods being available for each option. The following list outlines the basic options:

* **Sea wall defense:** This strategy involves constructing sea walls, such as a rip rap wall, along the coast. Refer to Figure 5.

Examples of these are numerous, such as north of the Patawalonga Outlet at North Glenelg. Sea walls are primarily employed to protect property and development. Without supplementary beach replenishment on the metropolitan coast, they will not prevent the beaches eroding because of the littoral drift problem. They should not be considered as a total solution unless the beach can be sacrificed.

There is currently about 14 kilometres of sea wall along the metropolitan coast, but it is important to note that much of this is now a "last line of defense" in the event of major storms because of the success of the beach replenishment program.

* **Ongoing beach replenishment:** This strategy involves the replacement of sand at erosion locations on the metropolitan coast to counteract the ongoing coastal processes. It aims to maintain the amenity of the beaches at, a particular level, and reduce storm

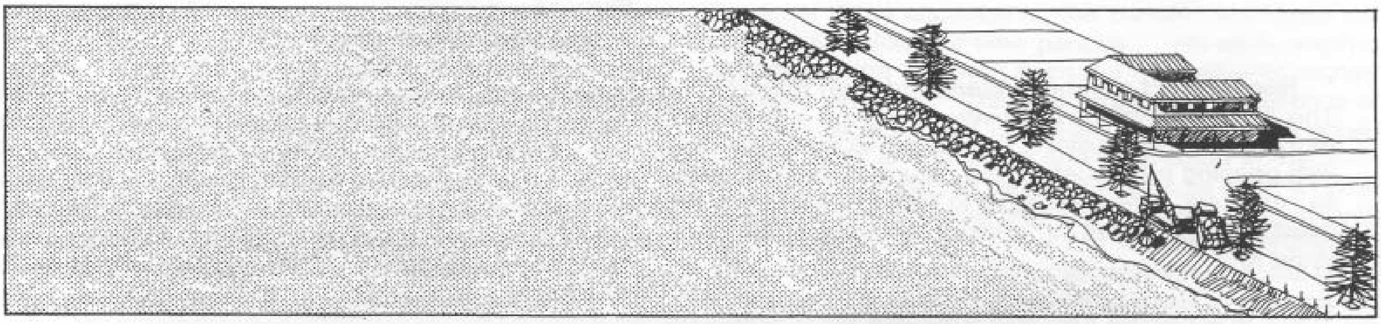


Figure 6
Rock Seawalls Only

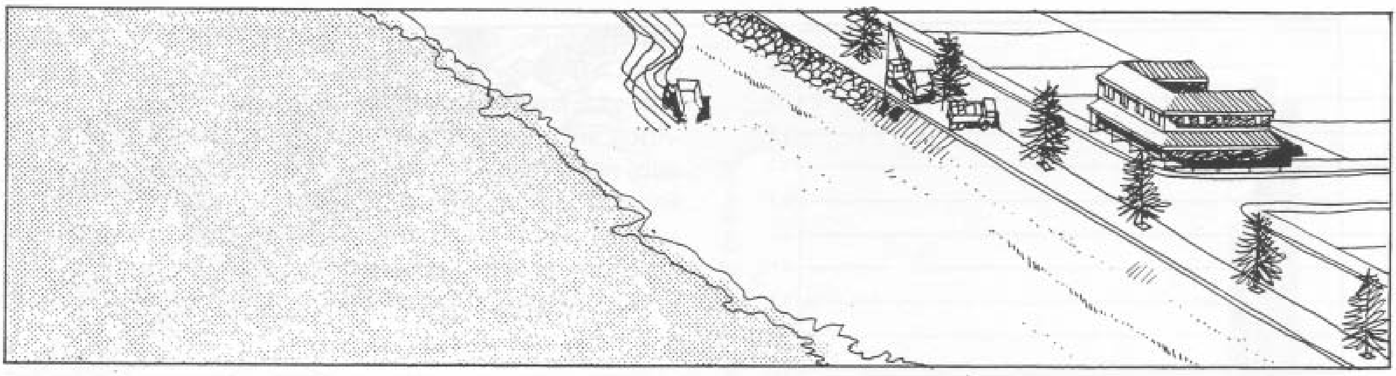


Figure 7
Trucking /dredging Sand

damage to properties and development by attenuating wave energy. However, it should be remembered that during major storms the beach replenishment strategy combines with the existing sea wall defenses to protect the vulnerable coastal properties.

Replenishment can be undertaken using sand from within the beach system or external to the beach system. The advantage of an external source is that it enables additional sand to be added to the finite supply onshore which would have benefits in the long term against beach loss due to sea level rise. The currently used offshore source also provides a coarser sand to be input into the system. This can act to retard the littoral drift process and hence over time reduce the volume of sand required for replenishment. There are various methods available for undertaking. beach replenishment. These include trucking sand from land sources and accreting beaches, dredging sand from offshore sources, and pumping sand through a pipeline from a source to the erosion sites.

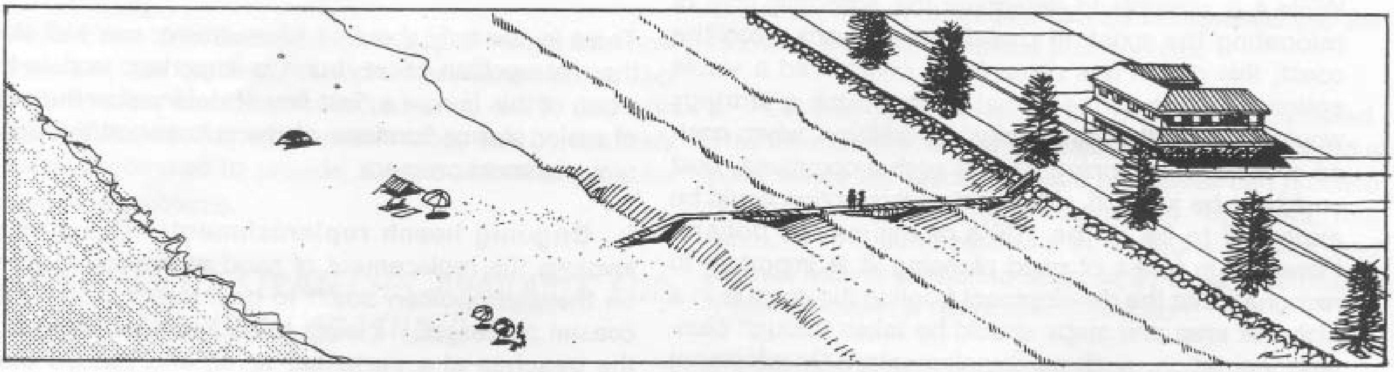


Figure 8
Major Beach Replenishment

* **Reconstruct a dune system and then maintain it:** This strategy involves artificially recreating a dune system in front of the existing coastal development so that, with ongoing maintenance, the natural coastal processes can occur. The alternative to this is moving back the coastal development to "unlock" the sand in the dune system.

There are various methods available for undertaking this strategy. These include dredging sand from off shore sources, barging sand from more distant sources, trucking sand from land sources, and pumping sand through a pipeline from a source. The reconstruction of a dune system is reliant on sufficient sand being avail able from external sources and dune stabilisation techniques, such as vegetating the dune. The strategy would involve a major replenishment program initially to establish a dune system on the existing beaches, followed by ongoing replenishment to maintain the dunes and beaches at erosion sites. To a minor extent, this can be observed in the Brighton area where sand from previous replenishment programs has formed a small dune at the back of the beach, and revegetation has commenced.

* **Construction of a groyne field along the coast:** This strategy aims to create a series of barriers along the beaches to inhibit the littoral drift process. Refer to Figure 9. Groyne fields have been used at numerous locations throughout the world. The influence of a groyne on the metropolitan coast can be observed at the Patawalonga outlet. A groyne or barrier placed across a beach system will cause accretion to the coast on the upstream side and erosion on the downstream side. It is therefore necessary to determine the spacing of these barriers so that the changes to the coast do not adversely affect the coastal properties. Groyne fields will alter the appearance of the coast, and the aesthetic value of the coastline must be considered prior to constructing a groyne field.

There are various methods available for undertaking this strategy. It is possible to use different materials to

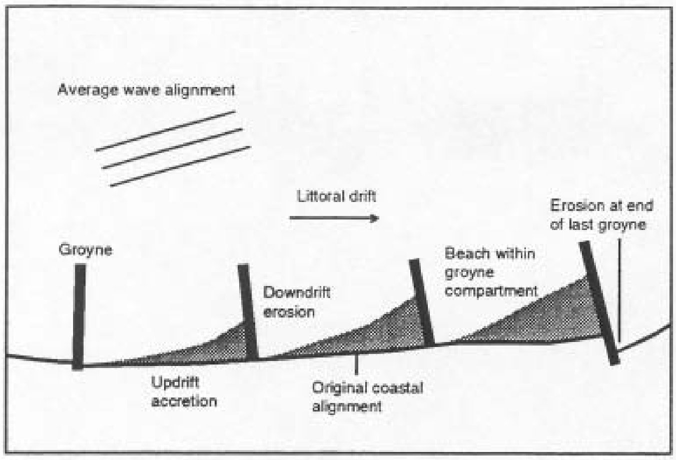


Figure 9
Conventional Groyne Field

construct the barriers in a groyne field. For example, they could be constructed as rock groynes, timber retaining walls, concrete walls or other proprietary structures; such as sand filled geotextile bags, or rock filled gabions. On the Adelaide coast suitable rock is readily obtainable close to the coast, and the cost of constructing rock groynes is estimated to be the cheapest method currently available. It should also be remembered that groyne fields alter the shape of the coastline, and as part of the construction process in establishing a groyne field on the metropolitan coast it would be necessary to supplement the existing beach with a replenishment program to prevent loss of coastal property. Once established there would also be a need to continue a sand replenishment program, because sand will continue to migrate in a net northerly direction, albeit at a slower rate to that presently observed, due to the coastal processes. This ongoing replenishment process would supplement the leakages of sand from one groyne to the next.

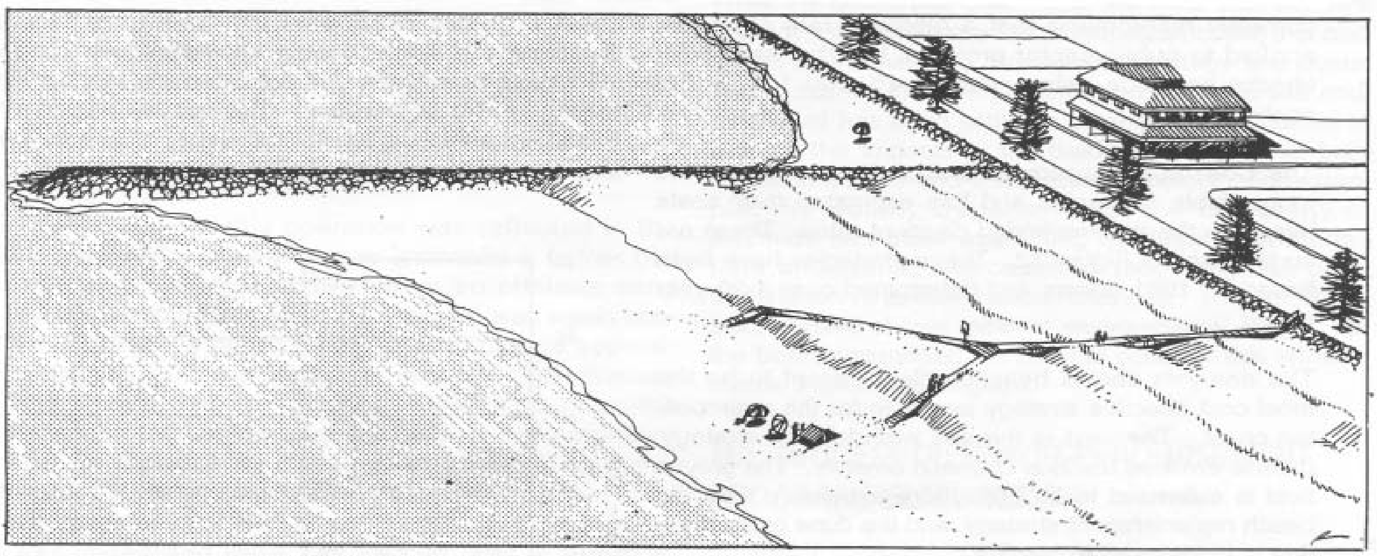


Figure 10
Groynes

* **Offshore breakwaters:** This strategy aims to attenuate or reduce the wave energy reaching the beaches and, by so doing, minimise storm damage and the wave energy available for the littoral drift process. This involves the construction of offshore breakwaters or barriers running roughly parallel to the coast.

There are various methods available for undertaking this strategy. For example, it is possible to barge and dump material to the offshore location, or construct the offshore breakwater using a temporary access path for trucks from the shore, or constructing caissons units onshore and floating them to the offshore location. It is also possible to use different materials to form the breakwaters. For example, quarried rock, or manufactured concrete armour units, or concrete or steel caisson units, or proprietary structures such as sand filled geotextile fabric bags or rock filled gabions. Floating breakwaters have been suggested from time to time, but experience elsewhere in the world indicates that they would not be suitable for the metropolitan coast because of the large period swell component of the local waves. Various configurations of offshore breakwaters can be designed to impact differently on the metropolitan coast. This would be a very expensive strategy when compared to the other alternatives, primarily because of the quantity of material involved and the high construction costs.

For all of these alternatives, the benefits and costs will accrue over different time periods. This adds another variable to the problem because the value of money changes over time. This is a result of the existence of real interest rates, that is, the difference between actual interest rates and inflation, and is reflected in the community's preference to receive benefits as soon as possible, and pay costs as late as possible. A commonly used method for eliminating this variable is to convert all the costs and benefits to an equivalent dollar value at a particular point in time. It is usual to convert the costs to todays dollars and call the result "the present value". To achieve this, a "discount rate" is applied to future benefits and costs of projects. State Treasury

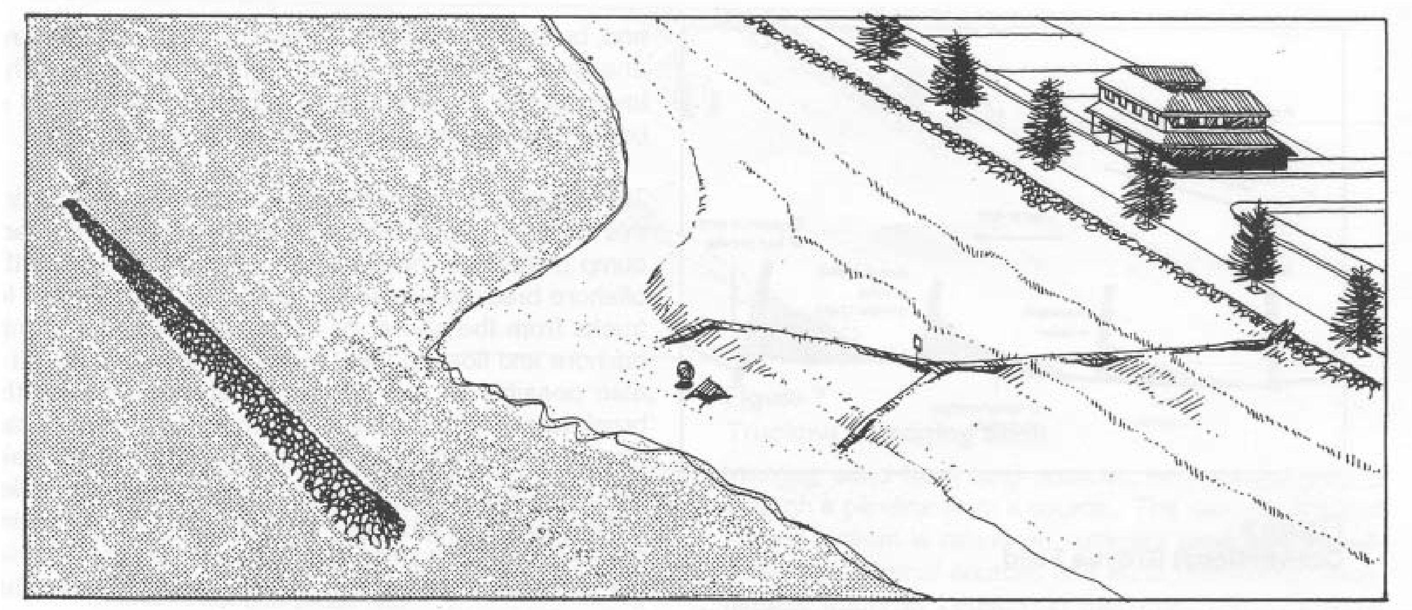


Figure 11
Break Waters

currently recommend that a discount rate of 7% be applied to public sector projects, but that sensitivity checks be made using rates of 4% and 10% in the analysis.

The Coasts and Marine Section, Environment Protection Agency has assessed the more viable strategies and has estimated their costs based on the recommended discount rates. These are summarised in Figure 12. These strategies have been based on 1991 dollars and determined over a 20 year period.

The analysis shows beach replenishment to be the most cost effective strategy available for the metropolitan coast. The next is the sea wall defense strategy, but this involves the loss of beach amenity. The groyne field is estimated to be 60% more expensive than the beach replenishment strategy, and the dune reconstruction is 112% more expensive.

BEACH REPLENISHMENT - THE MOST COST EFFECTIVE OPTION CURRENTLY AVAILABLE

Since its formation, the Coast Protection Board has maintained the beach replenishment strategy as the primary metropolitan coast protection strategy. Between 1972 and 1988 the Board maintained a replenishment program which averaged about 100,000 cubic metres of sand per year. During this period the method of replenishment was by trucking sand from northern beaches to the vulnerable southern locations. The cost of this method is dependent on the haul distance, but ranges from $2 to $5 per cubic metre of sand trucked.

In 1988, the Board obtained approval from State Cabinet and the South Australian Planning Commission to undertake an increased 3 year replenishment pro gram using a sand source on Torrens Island and an off shore source at North Haven instead of taking sand off the northern beaches. The purpose was to supplement vulnerable locations deemed to be at high risk in the event of major storm attack. The beach levels at Somerton and North Glenelg were extremely low and if left without remedial action could have led to the under mining of the sea walls. The sand dunes at West Beach were eroding at an unacceptable rate and were also in need of replenishment.

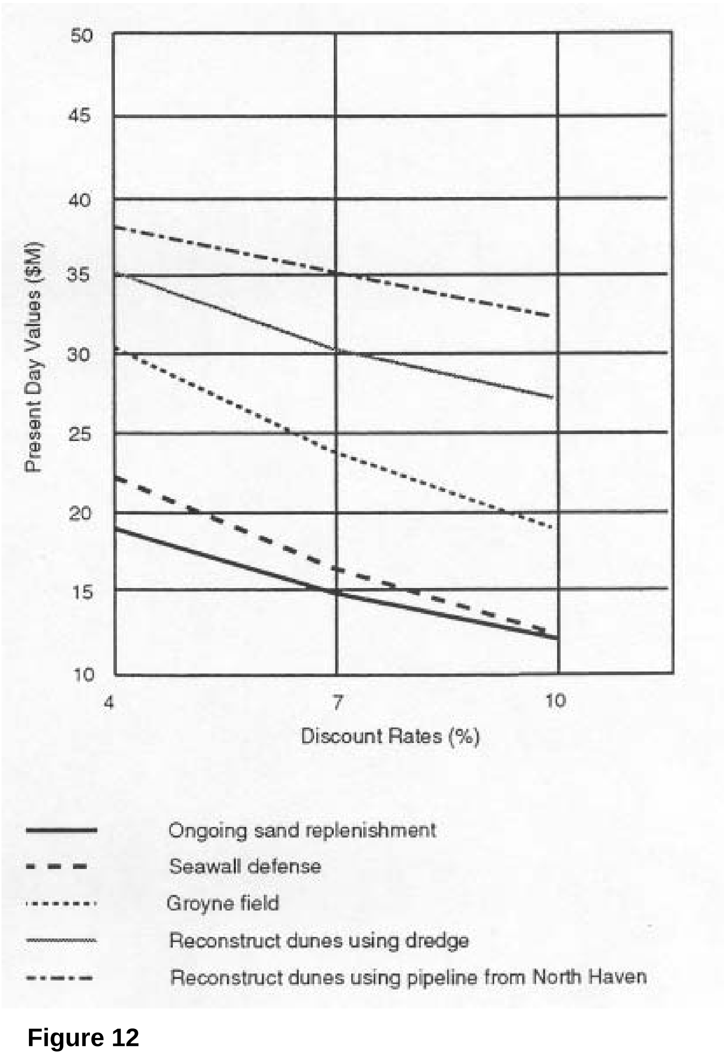


Figure 12
Summary of Alternative Strategies

From 1988 to 1990, approximately 190,000 cubic metres of sand was excavated and trucked from Torrens Island to North Gleneig at a cost of about $7 per cubic metre, and approximately 100,000 cubic metres of sand was pumped ashore at North Haven by a small cutter suction dredge and then trucked to Somerton at a cost of about $8 per cubic metre.

In 1990, State Cabinet approved a further Board recommendation that a trial dredging operation be undertaken in lieu of the previously used trucking operation. This had the advantage of being able to input coarser sand into the beach system from offshore sand sources, and minimise the trucking hazard from the beaches. Approximately 100,000 cubic metres of sand was dredged by Australian Dredging and General Works Pty Ltd, from the offshore sand source at North Haven using a split hopper dredge called "the Pelican" and pumped ashore at North GleneIg. From the tenders received for this work, this small dredge with a hopper capacity of almost 1,000 cubic metres, was the most economic dredge for the volume of sand to be moved and the conditions prevailing on the metropolitan coast. The cost was about $12 per cubic metre (including mobilisation costs for the dredge, that is getting the dredge to the site) or about $9 per cubic metre if mobilisation costs are excluded.

The success of this operation was reflected in the Government's endorsement to undertake a further trial dredging operation in 1991 from an offshore sand source at Port Stanvac. "The Pelican" was again contracted, after a public tender call, to dredge approximately 100,000 cubic metres of sand from Port Stanvac and discharge it onto the beach at Brighton. Towards the end of the contract, the dredging company indicated that the Government could make a potential saving Of about $0.5M on mobilisation costs if the programmed 1991/92 metropolitan beach replenishment program was undertaken while "the Pelican" was in Adelaide. After an assessment was made of the dredging opera tion and costs, the Minister for Environment and Planning agreed to an extension to the contract based on the contractor's offer. A further 100,000 cubic metres was dredged from the Port Stanvac site. The cost of this 200,000 cubic metre dredging program was about $11 per cubic metre (including mobilisation costs) or $8 per cubic metre if mobilisation costs are excluded. The beach replenishment program averaged about 200,000 cubic metres per year in the three year period from 1988.

The Board has assessed the beach replenishment program since this period, and has now determined that to maintain the beach amenity at its current level, and provide adequate protection to the coastal property, it is necessary to provide an annual replenishment program of about 160,000 cubic metres. To achieve this, it is necessary to undertake a biennial dredging program and a supplementary trucking program. This is estimated to cost about $2.5M biennially, with the dredging contract being about $2.1 M. The next scheduled dredging replenishment contract is expected to be

The Pelican Dredge used on the Adelaide Coastline

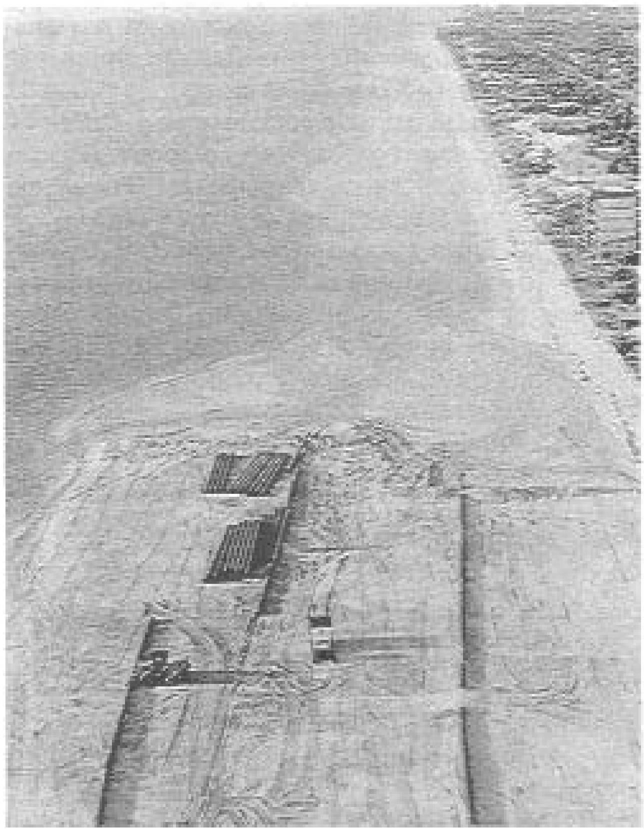
undertaken early in 1994.

While the Board has determined the most cost effective strategy for maintaining the metropolitan coast, it is also aware of the need to monitor the strategy and costs, and to assess the environmental impacts. To this end, the Board has been active in commissioning studies to monitor the impacts of the dredging program, at both the sand source and the discharge points. For example, the Botany Department of the University of Adelaide has been examining the impact on marine flora and fauna, and coastline modelling has been undertaken to assess coastal changes. To date, these studies have shown minimal environmental impact, but the Board recognises the need to continue this environmental monitoring program.

THE SUCCESS OF BEACH REPLENISHMENT PROGRAMS ELSEWHERE

It is important to note that the Board's beach replenish ment strategy is not unique. In fact, it is estimated that over 70% of the world's sandy coastlines are eroding, and the soft engineering option of beach replenishment is used throughout the world as a solution to this problem. This solution has gained increasing acceptance over the last 30 years. The following examples have been chosen to indicate the extent of use of the beach replenishment method, but it should be noted that numerous other examples exist and could be cited.

The most active nations have been the Netherlands, Germany, Great Britain, Denmark, United States and Australia. Arguably, the Dutch have been the leaders in the use of beach replenishment and in scientific advances that have led to cost reductions. The Dutch rely on natural and artificially reinforced sand dunes, combined with nourishment of berms and levees, to provide their major coastal defenses. Between 1952 and 1989, about 60M cubic metres of material has been used for Dutch replenishment programs. For example, In the United States, over 600km (450km on the Atlantic seaboard and over 150km on the Gulf and Pacific seaboard) of the coastline have been replenished at a cost in excess of $US8 billion. The majority of this work has been undertaken since 1970, during which time significant advances have been made in planning, monitor ing and maintenance of the programs. The beach replenishment programs commenced primarily as a result of the severe damage and erosion along the US East Coast caused by major hurricanes in the 1950's. By far the largest and most successful beach nourishment undertaken was the Miami Beach project completed in 1980. Over 1OM cubic metres of sand was placed along 17km of coast at a cost of approx $US64M. More recently, the Hollywood and Hallandale beach replenishment project in Florida was completed in 1991. This project involved placing approximately 1 M cubic metres of dredged sand on the beaches at a cost of about$US9.5M.



Sand Key, Florida Replenishment Project

In Great Britain, the widespread natural occurrence of gravel beaches has led to increasing and successful use of replenishment programs, especially the south eastern coastline such as Hampshire and Sussex. The scale of projects is tending to increase, for example, at Seaford 1.5M cubic metres of sea dredged gravel was placed in the late 1980's at a cost of 12M pounds. Sand replenishment has also been successfully prac ticed at other locations, particularly at Bournemouth. The use of gravel replenishment has also been used in Vancouver, Canada to abate erosion of unconsolidated Cliffs.

Sand replenishment has been satisfactorily used in France at Moulin Blanc, Cannes, Monaco and Marseille, and in Portugal at Praia da Rocha along the Mediterranean Coast. In Belgium, at Zeebrugge, about 8.5M cubic metres of sand was dredged offshore and placed along an 8km section of beach in the 1980's. In New Zealand sand replenishment has been used in the Wellington Harbour, Tauranga Harbour, Pohara Beach and Washdyke Lagoon. A beach replenishment program has proved to be very successful in Durban, South Africa after over 30 years of implementation, and in Varadero, Cuba for over two decades to maintain prime tourist infrastructure. Other examples exist at Copacabana Beach in Brazil, Singapore, Bora Bora, and Bar Beach-in Nigeria.

Since the early 1980's other nations have endorsed the use of beach replenishment. Most notably, the Soviet Union which moved away from hard engineering structures in 1981 and undertook 6 beach replenishment programs along the Black Sea Coast accounting for 70ha of additional beach along 48km of coast.

The Japanese Government has joined the growing trend to create and replenish beaches, primarily due to increased desires by the Japanese community for recreational amenities and beachfront access. Since the early 1970's nine beach replenishment projects supporting seaside parks have been constructed in Tokyo Bay, and by 1990 twenty one beaches had been replenished throughout Japan, with a further sixty six planned projects awaiting commencement or underway.

In Australia, between 1975 and 1987, approximately 20km along the shore of Port Phillip Bay in Victoria were successfully replenished. Probably the best known beach replenishment program in Australia is at the Gold Coast (Kirra/Bilinga Beaches) in Queensland. The first major beach replenishment program commenced at the Gold Coast in the mid 1970's and until 1990 about 5M cubic metres of sand had been used for the beach replenishment program. In 1990, a major replenishment program was undertaken at the Gold Coast during which over 3M cubic metres of sand was dredged ashore. This project received an excellence award in 1991 from the Queensland Division of the Institution of Engineers, Australia.

These few examples demonstrate the widespread use of beach replenishment for maintaining the beach amenity and protecting the coast. Beach replenishment is an internationally recognised soft engineering solution for coastal recession problems, and its application has proved successful and popular throughout the world.

CONCLUSIONS

The Coast Protection Board has been given the task of maintaining the amenity of the metropolitan beaches and protecting the coastal property from storm damage. It initially commenced the beach replenishment strategy in 1972 based on the recommendations of the "Culver Report". Since then, it has actively investigated and assessed the various strategies available for achieving the most cost effective solution to the communities problem, and has always sought to maximise the beach amenity and minimise potential storm damage.

The beach replenishment program, combined with the established sea wall defenses, provides the best engineering solution and least cost, long term strategy. The ultimate test for this strategy is in its performance during major storm events. In hindsight, we know what storm damage can occur, based on the events in the 1940's, 50's and 60's. However, by comparison storm damage since undertaking the beach replenishment strategy has been much less significant. For example, the storms in the 1980's, while estimated to be of similar intensity to previous events, did not result in the same level of dam age as the previous ones.

It is easy to become complacent by this significant improvement, but it must always be remembered that the Adelaide coast is artificially maintained, and without the ongoing efforts of the Coast Protection Board, the Coasts and Marine Section, and the State and Local Governments, the beaches would be quickly lost, leaving the community with a huge investment in vulnerable coastal property which would be at a high risk of dam age.

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