

# GOLD COAST BEACH REPLENISHMENT PROGRAM

REPORT No. 72

## THE IMMEDIATE GROWTH OF SPINIFEX VEGETATION IN PUMPED-UP DUNES

### (1) INTRODUCTION

In 1974, the Gold Coast City Council embarked upon a major program of beach replenishment for their local beaches, that had suffered considerable erosion during the cyclone induced wave conditions of early 1972 and early 1974. In terms of the Beach Protection Act 1968-1970 of the State of Queensland, these beach nourishment projects were required to comply with a series of criteria, as laid down by the State's Beach Protection Authority. Two particular criteria were nominated as part of the beach replacement process. Firstly, an artificial dune of substantial proportions was required to be constructed at the rear of the beach, and secondly, that once constructed, this new dune was to be immediately protected by the planting of Spinifex grasses. This report therefore records the City Council's efforts to meet these requirements.

### (2) THE NOURISHMENT WORKS

In mid 1974, two major nourishment contracts were let by the Council. At Kirra,  $1 \times 10^6 \text{m}^3$  was dredged from the Tweed River to the Kirra beaches, to the North,  $1.4 \times 10^6 \text{m}^3$  was concurrently dredged from the Southport Broadwater to Mainbeach and Surfers Paradise. In both contracts, the initial sand placement strictly followed the criteria nominated by the B.P.A. As described by Smith (1977), the requirement to rigidly place a given renourishment volume per unit length, whilst at the same time constructing the "theoretical" dune profile, was found to be operational nonsense. It was very rapidly observed that Nature was a much better designer of nourishment works, than was the B.P.A. Nature, through her day to day variability of the wave climate interacting with the applied sediment, soon demonstrated where the nourishment volumes had to be placed, to gain a new beach of effective even profile. Council's engineers therefore re-adjusted the beach placement (whilst still maintaining a near constant volume/unit length deposition) to attain a parallel beach, where the action was — i.e. in the surf zone. Then if any volume happened to be left-over

from the surf zone, then and only then, was an artificial dune built-up.

Thus, where initially a fine looking dune had been constructed at the expense of a ragged beach, the alternative end result was a fine looking beach with a ragged dune! Council's engineers had no doubt as to which approach was preferable. To be fair to Council, it must be recorded that when these alternative results were reported by phone to B.P.A., they elicited an absolute zero reaction. There was not only a lack of any guidance, but no real response at all either. Council therefore pressed on and completed the works on the even parallel beach alternative. At the same time, as any artificial dune areas became available, they were immediately planted with Spinifex seed to the B.P.A. requirements, but to the Council's astonishment, practically every crop failed. Many Spinifex seeds germinated, but as soon as their shoots began to appear, they withered and died. Again, the B.P.A. neither offered any explanation as to why the crops were failing, nor any advice as to how the problem might be solved. The Council therefore mounted its own investigation aimed at determining the reasons for the failures.

### (3) SPINIFEX GROWTH INVESTIGATION

In October 1974, Council set up a series of trial plantings in a pumped-up dune at Mainbeach and at the same time, staked-out equivalent areas of a natural dune on the Spit. The growth of runners and seeds planted on the pumped dune was then compared with the natural. Sand temperatures, organics, moisture content, pH value and salt content, were also measured on the two trial areas. Initially extra trials were made in the pumped dune to accelerate the Spinifex by extra mulching and fertiliser applications. In addition some plots were also irrigated with fresh water for the same reason, but these were soon terminated when the real reasons for crop failure became more obvious.

In the pumped test plots, the number of Spinifex shoots per unit area were counted per week and root growth was also assessed by excavating unit areas of the plots at the same time. Even at the very commencement of the comparative trials, one of the most ominous discoveries was made during the simple planting operation. The pumped-up dune

sand was very much more compact and dense, than the natural dune. This naturally followed from the method of placement. A pumped dune sand, placed completely saturated, was at maximum density, whereas the blown dune sand was at minimum density — anybody who has climbed any natural dune, can notice this difference immediately. The resistance to root growth within a sand body, is proportional to its density — but its water percolation and salt leaching properties are inversely proportional to its density. Density however, makes little difference to the near-surface soil temperature, all sand deposits are heat-sinks, but a higher air content reduces night-time heat re-radiation.

#### (4) RESULTS

In hind-sight, a great deal of work was expended on this study that was in-effectual and wasteful. However, at the time the crucial parameters that inhibited pumped dune *Spinifex* growth, were quite unknown. The first consideration was to examine the differences between the pumped sand and the natural dune. A standard B.S. sieve train analysis demonstrated that the pumped sand  $D_{50}$  was 0.30mm compared with the natural dune  $D_{50}$  of 0.21mm. All that this indicated was that the natural dune sand was very much "finer", but this was only to be expected. Wind blown dune sand is nearly always dominated by the smaller grains winnowed from the parent beach-sand population. Nothing significant could be detected from this data.

The next topic examined, was the results of natural rain-fall. Here it was found that on the pumped dune, 9mm of rain in 4 hours only penetrated 12mm below the sand surface and 42.4mm of rain in the day only penetrated 90mm. The same day's rain on the natural dune penetrated some 200mm and since it was measured that *Spinifex* roots prospered only between 100 and 150mm below the surface in the natural dune, this seemed to represent an important growth parameter. The natural dunes, with their sand in a loose packing, held a suitable permeability to rainfall, to allow adequate rain moisture to reach the *Spinifex* root level. The pumped sand on the other hand, did not.

A series of irrigation tests on the pumped dune plots, was then mounted. An array of different agricultural aerial rotating spray devices were then employed. The efficiency of these spray distrib-

utors was found to be remarkably low, the most efficient only delivered 45% of its metered input water onto the actual sand surface. The rest of the fresh water evaporated before the residue landed on the surface. It was found that a nett surface application rate (in one operation) of 150gal/m<sup>2</sup> was required to penetrate the pumped sand to 150mm depth to Spinifex root level and leach out the NaCl to acceptable Spinifex growth tolerance levels. Artificial irrigation of the pumped dune sands was clearly un-economic. This irrigation dosage it may be noted, represented the equivalent of an entire years natural rainfall for Southport, i.e. 800 to 1000mm.

In this, the reason for the failure of all the mulching and "booster" fertilising treatments on the pumped sand trial plots became obvious. Without sufficient sand permeability in the pumped material, there was inadequate natural moisture at root level to leach-out excess salt, induce root growth, and activate the pellet fertiliser.

The final research conclusion was that the crucial Spinifex growth inhibitor was the salt content of the sand. The basic comparisons between the pumped sand trial plots and the equivalent areas of the natural dune where the Spinifex growth was sparse and where it was good, is set out in Table I. The salt content of the sand is expressed in parts/thousand of solid NaCl over the dried weight of sand. In this, the pumped sand residue held over a thousand times the salt content of the best natural dune plot. Indeed, the pumped sand grains were almost completely covered with salt crystals. From Table I, it can be deduced that moisture content was irrelevant, organic content and pH were significant, but the dominant Spinifex growth control was clearly exerted by the NaCl content.

This conclusion was supported by the beach events of 1976 (i.e. a year after the trials). Then the pumped beach sand was drenched by cyclonic rains and blown by high winds onto the back-beach sand drift fences. Almost immediately a burst of Spinifex growth developed in the newly-blown sand deposits, triggered perhaps by the high density of seeds planted the year before. All the Spinifex seed had been placed with a fertiliser. It seems therefore, that the wind induced rolling of the sand grains removed not only the excess salt crystals, but also ensured that they came to rest at a minimal packing. In

this state, the pumped sand had reproduced the natural dune conditions and by allowing easy moisture penetration and low root growth resistance, it had reverted to an effective medium for Spinifex growth. The additional benefit of applied fertiliser was also probably advantageous. It was also noted that a sudden Spinifex "delayed" success also occurred at the two other beach replenishment placements (effected in 1974-75) at Kirra and Palm Beach, after the same 1976 cyclonic weather.

#### (5) CONCLUSIONS

All of Council's research indicates that it is impracticable to grow "instant" Spinifex in very recently placed artificial dunes, formed from sands pumped directly into position with salt water. The principal inhibiting agency is the high NaCl content, held by the pumped material. Until this excess salt is removed by abrasion and natural leaching, it is pointless to expect any successful crop.

The B.P.A. were correct in requiring the beach nourishment dunes to be stabilised with Spinifex, but very much in error in their strict instructions as to how — and more critically — when the Spinifex was to be cultured. If the B.P.A. did not learn this lesson, at least the City Council did. From about half way through the Surfers Paradise nourishment contract, no further dunes were formed by direct pumping. For the last half of the contract, any spare sand left from meeting an even surf-zone beach, was left at mid-beach and then dozed into the back-beach, to form a dune preferably after rain, but nearly always after some natural drying. In this way, the maximum operational salt removal by leaching and abrasion was attained. After this procedure was instituted, Spinifex growth was thereafter much more rapid and effective.

#### (6) ACKNOWLEDGEMENTS

The monitoring and site experiments executed on the trial dune areas, were carried out by Technician R.W. Waldof, then of Gold Coast City Council's soils laboratory. The dune planting operations and all Spinifex monitoring efforts, after mid-1975, were conducted by Foreman R.W. Matthews, who also assisted in preparing this report.

TABLE I  
COMPARATIVE SPINIFEX GROWTH ENVIRONMENTS

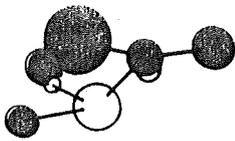
<u>Sand Location</u>	<u>Spinifex</u> <u>Growth</u>	<u>Salt Content</u> <u>parts/1000</u>	<u>Organic</u> <u>Content %</u>	<u>Moisture</u> <u>Content %</u>	<u>pH</u>
Pumped Dune	Failure	100-400	negligible	2.5-6.0	6.5-8
Natural Dune	Sparse	2.0	0.01	0.5	8.5-8.7
Natural Dune	Good	0.1	0.5	3.0	8.5-8.7

REFERENCE

Smith, A.W. "The Surfers Paradise Beach Replenishment Project — A Case Study" 3rd. Aust. Conf. on Coastal and Ocean Eng. I.E. Aust. Nat. Conf. Pub. No. 77/2 (1977).

25th May, 1985.

A.W. Sam Smith  
Engineer.



INGEKOMEN 9 JAN. 1987

QUEENSLAND INSTITUTE OF TECHNOLOGY

Gold Coast Beach Replenishment Program

REPORT No. 82

THE MANUAL ON ARTIFICIAL BEACH NOURISHMENT

(1) This report represents a preliminary review of the above manual, in terms of current research and experience on the Gold Coast. The manual was prepared by a working group, generally drawn from Rijkswaterstaat and the Delft Hydraulics Laboratory, both of the Netherlands. The manual has drawn upon world-wide data, but unfortunately the Gold Coast experience is reported in only fragmentary and inadequate terms. This would not be surprising, most of the work carried out on the Gold Coast, has never been properly documented and no definitive text yet exists. Furthermore, with one exception, none of the published accounts have been written by the engineers who actually effected the works and were able to monitor their behaviour for many years thereafter. It now seems unlikely that a full review of the Gold Coast nourishment works will ever be prepared, but some documents and data going back to 1972 do exist. They are however in only a partially processed state, and much of the data is still quite raw.

(2) The most complete review of the site lessons, learned from the 1973-75 Gold Coast works, is a set of lecture notes that form part of the "Coastal Engineering" final year engineering elective at Queensland Institute of Technology, in Brisbane. The notes are used for lecture No. 9 and a copy is attached as Appendix A, to this report. In terms of 1986, we would see little that need be changed since the notes were written back in 1983, but they are by no means complete nor fully up to date. Since the lecture notes are largely self explanatory, we will not discuss them in detail and the reader can draw his own conclusions about them. We therefore discuss more general matters that may be absent or only partially explored, in the "Manual" and/or the attached notes.

(3) Looking back, the most important lesson we now appreciate to be the matter of the "life-span" of a nourishment slug, on a littoral drift beach. Our field observations, show us that a nourishment slug, placed on a high littoral drift beach, migrates bodily along

with the drift but diffusing slowly as it does so. The process is slow, and the effect is partially obscured by the noise generated by day to day beach response to the variable ambient wave climate. The Surfiers Paradise slug of  $1.5 \times 10^3 \text{ m}^3$  was tracked from its colour. The nourishment material held a high shell content and from the air, it made the sand in the swash zone orange, instead of the more usual yellow. The Kirra slug of  $1.0 \times 10^3 \text{ m}^3$  held no colour difference, but it could be readily followed on aerial photographs, direct observation and surveys. From these and other studies, we conclude that the local average long term littoral translation velocity, is close to  $1.4 \text{ km/year}$ . The slug placed at Kirra, is currently (1986) sited within the Northern zone of Palm Beach, and the Surfiers slug is now partially in the Broadwater, with the rest, further North on Stradbroke Island. The migration of the Surfiers Paradise slug, has not been particularly noticeable as far as the total beach is concerned. The slug has merely been replaced by another long natural slug from the South, where the beaches were much wider in 1975 than the Surfiers beach, prior to nourishment. The effects at Kirra on the other hand, have been dramatic. With almost the total littoral drift into the Gold Coast, being trapped by the Tweed Training Walls, the original nourishment site is now an extreme starvation shadow zone, the slug is long gone.

(4) We now believe that the overall economy of a beach nourishment, depends heavily upon the slug's drift rate and the time it may remain, within the local beach "cell". A slug placed at Kirra, may take 25 years to reach Surfiers Paradise, but it will benefit every part of the beach cell for a while, during its migration past each point. In terms of total beach width gain by time, a Kirra slug will be 5 or 6 times more efficient than a slug placed at Surfiers. On a littoral drift coast therefore, the most economic nourishment will follow from a placement site at the extreme up-drift point of the embayment. Then the slug will attain a maximum operational "life".

(5) Another allied factor that currently concerns us, is the percentage of a littoral slug that is sited within the littoral drift cross sectional prism. If we look at Fig. 5 of Appendix A, material placed in Zone A, will be completely clear of the littoral prism, so it will suffer no migration at all, until storm waves wash it into

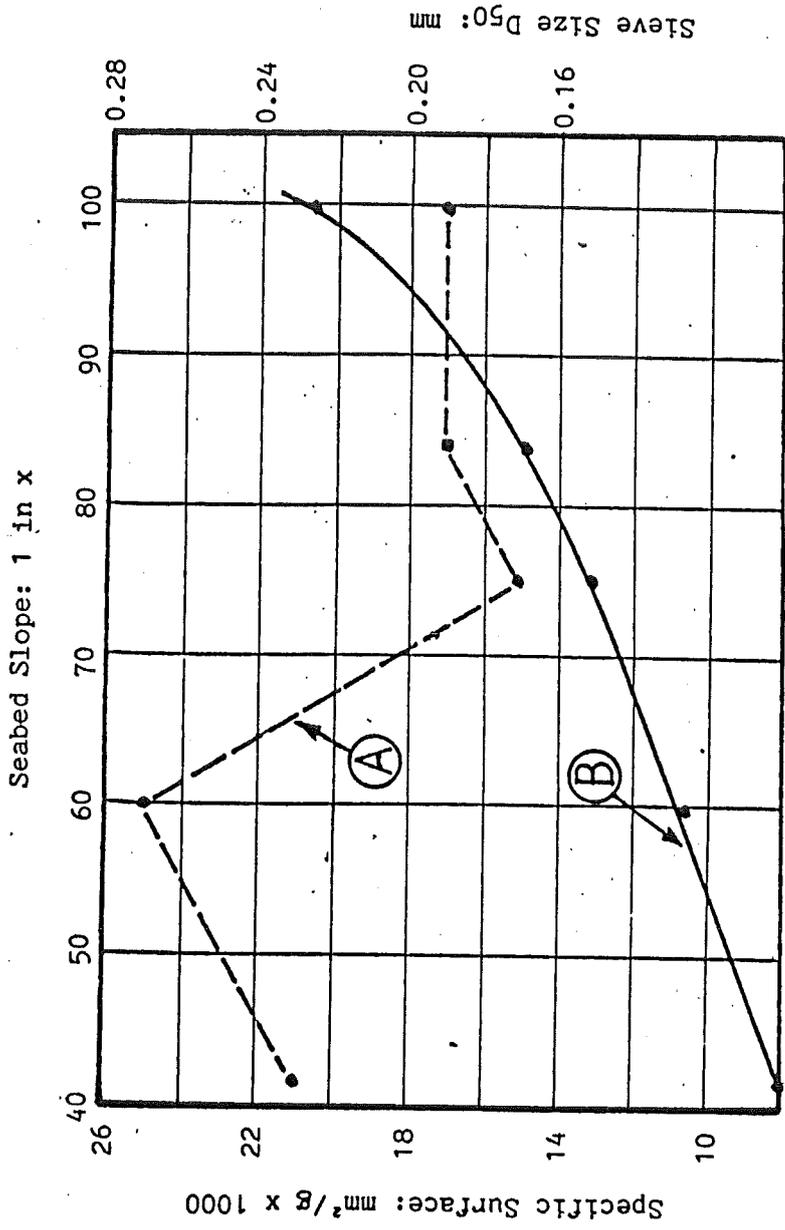
the prism. A placement in Zone B, will have perhaps half of its slug outside the prism, but the other half will be in a migrating state continuously.. Its drift will be a maximum. Material placed in Zone C, on the other hand, will probably remain seawards of the littoral prism, so it will remain unmoved until the right wave conditions begin to sweep it shorewards. We see here therefore, a new highly variable factor that should also be considered. The selection of the optimum nourishment position, its life, its transportability and its protective capacity, clearly forms a high variability effectiveness matrix. We have however, made a start in assessing the littoral drift prism, by the simple application of  $Q = AV$ , but we as yet know nothing about the detailed variation in the transport velocity within the boundaries of the prism. We have been highly concerned on the other hand, to learn that measurements taken on the visible beach, tell us nothing about the behaviour of the littoral prism, other than over the very long time span i.e. > 10 to 20 years. We also have concluded that there exists a threshold to littoral transport, that is principally related to the sediment "size" and the wave period as well as the wave height. This requires monitoring surveys of beach nourishment profiles, to be taken offshore to water depths of 20 to 25 metres — an expensive operation.

(6) In Appendix A, we proposed a beach fill compatibility criteria with the native, based upon the parameter of Specific Surface. Subsequent work carried out in 1985, has provided some evidence that there does exist a direct relationship (actually Log-linear) between the seabed slope of a natural beach and the  $F_{50}$  sediment value. The data for Kirra Beach is thus shown plotted as Fig. 1 attached. This is only a first step of course, but it seems to be at least encouraging. We think that the concept should merit a great deal more study in the future.

(7) This must remain a brief and very provisional note, much prototype data remains to be processed and analysed, but we may at least take this to be a start. Normally we would wait until this data processing had been completed, but what we have written, may represent an interim reply to the request from Drs. Pilarczyk, when he was recently on the Gold Coast. He asked for at least some comment on his draft manual.

20th Dec. 1986.

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A.W. SAM SMITH. (Engineer.)



Curve A = Sieve Size

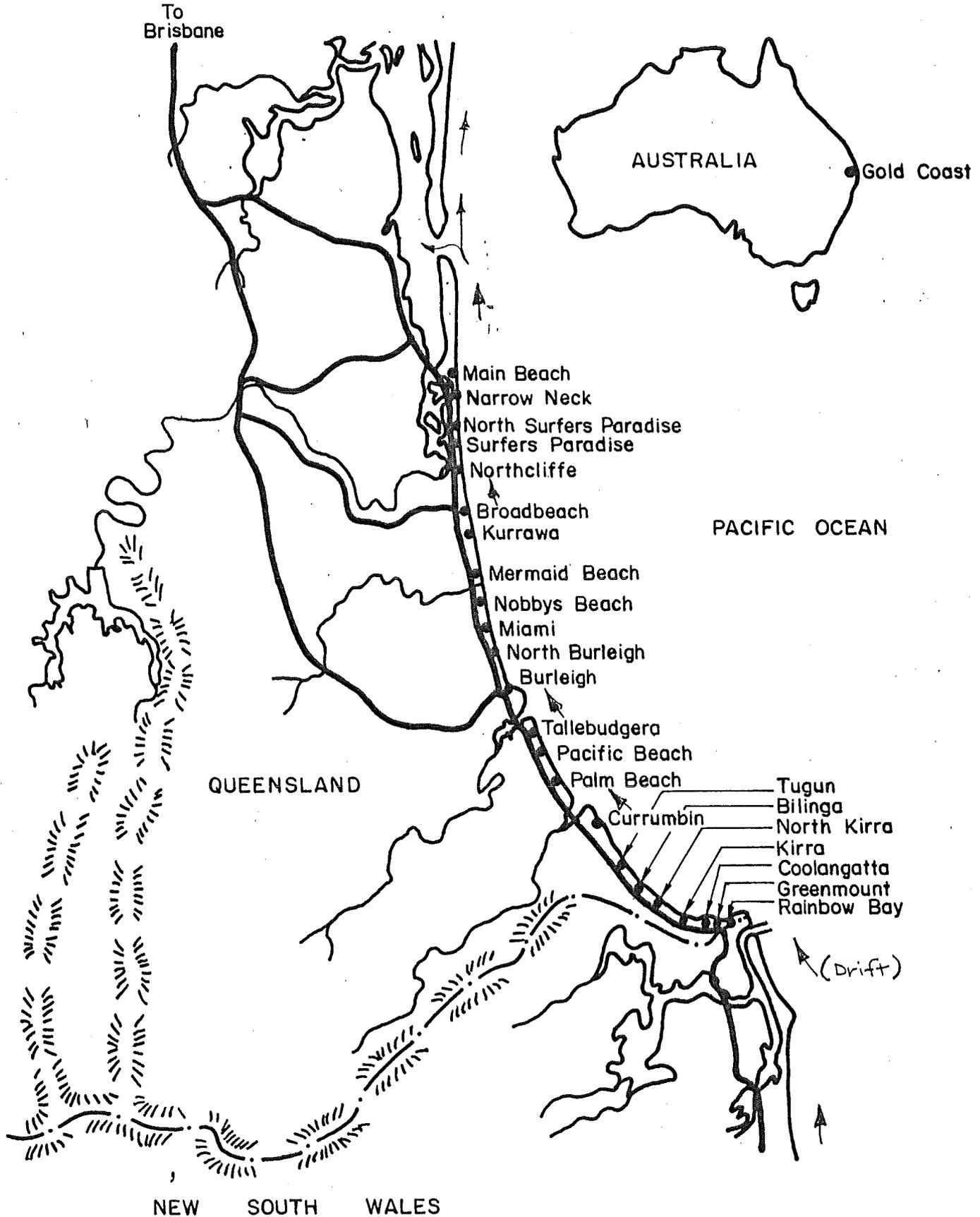
Curve B = Specific Surface

FIG. 1

Sediment Properties versus Seabed Slope. Kirra Beach 1985. Linear-linear Plot.

FIGURE 2

THE GOLD COAST



APPENDIX A  
CEB 561 LECTURE 9  
BEACH NOURISHMENT

(1) FUNCTION

The basic objective of beach nourishment is to repair the ravages of past erosion and secular recession by constructing a new beach seawards of the existing, and using sediments from elsewhere than the particular beach system. This concept is extremely direct and simple, any extra sediment introduced into a beach system must be of benefit to maintaining the beach and increasing its amenity.

On the other hand, the success rate of major beach nourishment exercises has not been very high. In many cases millions of dollars have been expended on large new artificial beaches, only for the added sediments to almost completely vanish within a year or two. The reasons for these failures has often not been at all clear at the time. Perhaps this should not be surprising, if many of the physical processes affecting natural beaches are barely understood, then it may become impossible to predict the stability of a new beach, constructed from different sediments, under the same processes.

To date, even after six years post-construction research, into the behaviour of large nourishment projects on the Gold Coast, the main conclusion reached, is that the design of a nourishment beach is very complex and beset by high areas of uncertainty.

The concept of beach nourishment however, remains an extremely attractive option to all Coastal Engineers, it is clearly a "soft" option much more compatible with Nature, than the "hard" options of groynes, revetments and breakwaters. The side effects of an artificial beach, should also be very much less than those generated by hard structures, and potential detrimental construction effects upon beach amenity should be almost zero.

The problem is that Nature's hydraulic processes are variable and continuous. They may also be quite implacable, if Nature is presented with an artificial

beach she doesn't like, then she will very rapidly change it until she does. Such is the history of actual beach nourishment.

## (2) TYPES OF NOURISHMENT

All beach nourishment consists of merely providing the beach with more sediment, but within this, there are two main classes of nourishment work. These depend upon the type of the natural beach being addressed, being:-

### (a) Captive Beaches.

For this classification, a captive beach may be defined as one that is fully contained between headlands such that there is no significant littoral drift either into, or out of the particular system. For such a beach, the volume of new sediment to attain any given average extra beach width should be finite, and losses from the system should theoretically be nil. A captive beach nourishment should only be exposed to onshore-offshore sediment transport, and maintenance demands should be very low.

In practice however, significant sediment losses may be generated in two ways. If the new sediment contains a higher proportion of fines than the native, then wave energy may abstract these from the new beach and transport them into deep water offshore, where they may be lost. Then, if the nourishment material volume is very large, the beach may prograde sufficiently out to the headlands, that littoral transport becomes re-activated by Nature, and losses will eventuate around the downdrift headland. Any pre-assessment of these factors however, is extremely difficult.

### (b) Littoral Drift Beaches.

these are beaches where the sediments move in the onshore-offshore mode, but that in addition, there is a net littoral drift in one direction that is significant. About half the N.S.W. coastline would fall

into this category. The actual littoral drift must be driven by the obliquity of the ocean swell to the beach, but it is a process not amenable to reliable mathematical calculation. A beach nourishment slug placed on such a coast must respond in the same manner as the natural beach did beforehand. Under variable wave climate, sediment will always move onshore and offshore, but there will also be a nett loss out of the slug due to littoral drift.

The amount of sediment required for a given area of beach "gain" on a littoral drift coast may call for much larger volumes than for a captive beach, to make up for these littoral losses. Observations on the Gold Coast indicate that under strong littoral drift conditions, nourishment slugs not only diffuse longitudinally (or smear themselves on to the beach) but the entire slug also migrates with the net drift. Semi-isolated slugs of nourishment material, even if they are 3 to 5 km. long thus demonstrate a limited "life", on a long ocean beach. If a nourishment slug placed in front of any particular beach zone, is going to migrate away from that zone within a few years, then if the desired beach width "improvement" is to be maintained, then progressive re-nourishment becomes a necessity.

In economic terms, these conditions are very different from captive beaches. Not only is nourishment an expensive operation in the first place, but usually where nourishment is a viable economic option, because of the value of assets in hazard, then in these areas there are few deposits of suitable nourishment material available. More than likely, by the time the material is most needed, it is found that all the suitable deposits have already been built upon!

Clearly, in terms of sensible and rational coastal planning and management, a pre-requisite of any coastal subdivisions on suspect areas coastline, must be the identification of suitable areas where deposits of

effective nourishment sediments actually exist. These areas and deposits, should then become reserved for future use by delineating them as public reserve or open space on the local land planning schemes. All developers within the locality should then be required to donate the land over the suitable deposits, or in lieu contribute in cash so that the Local Authority may resume these critical areas. Unfortunately, in many areas in N.S.W., it is now too late, but this is no reason for not applying this concept in the future.

It may be noted that once the beach nourishment reserve deposits have actually been utilised, and placed on the beach, the most economical procedure is to completely remove the material and allow a lake to replace it. Whilst such extractive excavations may provide a valuable avenue for Local Authority rubbish disposal, the normal fact is that a lake provides just as valuable a public reserve as does a more static "park". Indeed much experience suggests that lakefront properties in urban areas reach similar rating values, as do properties actually fronting the beach itself. Such lakes also hold high value for acting as "ponding basins" within local areas, to delay peak urban rainfall run-off, and mitigate flash flooding. It is all a simple matter of comprehensive hydraulic planning and design. The total economic benefits to the Local Authority may however, all be positive, particularly when looked at over the medium to long term. Increased long term rates may well offset some of the capital costs of the initial extraction, and lake maintenance should be absolutely minimal.

### (3) BEACH NOURISHMENT BEHAVIOUR

In theory, if artificially placed beach is composed of exactly the same sediments as the natural beach, then it should behave in exactly the same manner, and display exactly the same geometry — except that it is more seawards. Unfortunately in Nature, this is almost an impossibility.

On real ocean beaches, particularly those exposed to a reasonably high wave energy climate, it is found that the sediment properties tend to vary across the beach and down into the sea-bed to water depths readily reaching seven metres. Fig.2 for example demonstrates the variation in the average sand gradings, based on D50 (by sieve analysis) of the top 3 metres of seabed along five widely spaced survey lines on the Gold Coast. The sand samples were all recovered within a few days of each other, and during a period of normally fine weather, yet they are all from within a single zeta form embayment. The spread of particle size is certainly very significant, but all with a general trend for the particles to become finer, the further offshore.

In some strange manner, not at all currently understood, Nature has some call to sort its beach sediments, and in particular, to place the largest where, on the average, the hydraulic energy/sediment interface is the strongest. Clearly if a nourishment sand resource deposit that is of even particle size were to be placed on any of these native beaches, it could not be immediately in equilibrium with them. To attain equilibrium, the new nourishment sand would also require to be sorted, and itself migrate to the natural beach zones of the same grading.

One of the major problems of using suitable nourishment resource deposits is that they are usually located in adjoining estuaries, as dunes, or in the immediate offshore deepwater seabed. In placing these deposits where ever they have finally collected, Nature has also exerted sorting and variation upon them. Hydraulic sorting occurs in estuarine shoals, dunes usually consist of the more rounded sediment grains that have been separated by wind, and deepwater seabed deposits are either the fines moved offshore from the existing beach, or coarser sediments left behind from previous beach forms migrating up the seabed from a long term progressive rise in sea-level. The chance of finding an economic nourishment source, that is perfectly balanced with the ambient active beach zone, must therefore be somewhat remote.

The results may be readily predictable. If the nourishment work is carried out during ordinary mild weather, then a resource material coarser than the average native, will tend to remain perched at the top of the beach. On the other hand, a much finer resource material must be expected to migrate off-shore immediately, seeking the deeper water conditions that suit it. On the other hand, as soon as the next great storm arrives, all the seabed will become mobile, and the extremely high hydraulic energy will ensure that all the beach and seabed sediments will become completely inter-mixed and the resultant will be a sediment displaying the average of both the native, and the nourishment sediment populations. The final post-storm beach properties will thus tend to demonstrate the final resultant of the interaction between native and nourishment materials. Until the next major storm arrives however, the local resource manager may perceive the nourishment operation as what in truth is either an exaggerated temporary success, or as an apparent total loss. Yet the end mean result can only be beneficial after the storm. There is in fact, nothing that the local resource manager can do about it anyway, but at least there is now a larger volume of sediment available within the swept prism. The basic fact then, is that more sediment available, then the work absorption capacity of the total beach system can only be increased.

Although it cannot be currently regarded as conclusive in any way, enough evidence has accumulated over recent years, to suggest that an excess of fines at the bottom of the swept prism, may perhaps be capable of filtering out an equivalent volume of incident wave energy, as an excess of coarse material near the top of the beach. Unfortunately research into this phenomenon is again in its infancy, and much basic work remains to be investigated. Yet, this might well be one of Nature's simple mechanisms for absorbing wave energy, with whatsoever seabed sediments, that might be actually available. It is certainly already established that the slope of a beach, for constant wave energy, is proportional to the size of the beach particles. Gravel beaches are steep, coarse sand is in-between, and fine sand beaches tend to be much flatter.

Yet all these conditions mean nothing to the normal beach-front resident, his Local Authority and often even to his State Government Department. To all of these, only so often, the only criteria of success of a beach nourishment project, is an immediate and dramatic increase in the width of the visible beach. This may, or may not happen of course, depending upon the nourishment resource actually utilised, but the public usually demand only the greatest visual "impact", and not the greatest total optimum coastal "protection". For as long as this social conflict continues, then all beach nourishment exercises may well be plagued by this class of public acceptance, particularly afterwards!

It may also be a truism, that many beach nourishment exercises in the past, have been mounted for simple immediate political reasons, and without any serious research into their potential consequences. They have often been rushed into fruition purely on the simple hypothesis that "sediment is sediment", and even if beach widening vanishes after a few years, then the rate-payers will have forgotten about it all anyway. This represents of course almost irresponsible engineering. As discussed below, the actual design processes necessary to evaluate a rational beach nourishment project, are complex, frustrating, and in the end, based almost entirely upon concepts of probability, that within current knowledge, cannot be reliably defined. As with many other frontier disciplines, beach nourishment remains much more an "art" than a "science".

In summarising, the results of any beach nourishment exercise, it must be repeated that regardless of the Designer's intent, Nature will select for herself what she will do with the extra sediment offered to her. She will certainly construct a new variable "regime" beach from the new sediment input. But then the beach may flatten or steepen in a quite unpredictable manner, it depends upon the next ambient wave climate, and the degree of inter-mixing between native and nourishment material. These are all, in the current state

of knowledge, almost complete intangibles; reliable data on the actual behaviour of nourishment injections to natural beaches, remains remarkably sparse. Much has been observed, yet little is really understood.

Yet the basic principle remains, Nature will always maintain a suitable dynamic beach from any beach nourishment material, it may well vary the form of the new beach, but the end result will always represent an effective maximum energy absorption system. As such, Nature will always adjust the behaviour of an "artificial" beach to suit her needs, but the final beach behaviour must always be "natural". A beach must always remain a beach, and it will always react to natural processes. It will always react to natural hydraulic forces in an optimum manner, but for an economy of words, these potential reactions are discussed below, under the considerations of the Design of Nourishment Works.

#### (4) FAILURE MODE

As discussed above, beach nourishment can never result in a "failure". Every cubic metre of extra sediment can only improve the resistance of a beach to both short, and long term erosion. The more sediment available, then the more must be the total energy absorption capacity of a beach. On the other hand, there are limits to this concept. If a very fine nourishment material is applied to a coarse native beach, most will migrate into deep water. Then nothing of the new work may remain on the visible beach at all. In this case it is more in terms of human amenity, that the exercise may be regarded as a failure. The beach may have been strengthened, but not effectively, because the added material was unsuitable for the immediate task.

In other cases, beach nourishment projects have been popularly regarded as failures, simply as a result of the manner that the work was carried out. If a large volume of new sediment is placed on the top section of an existing beach during fine weather, then the smallest waves cannot gain access to the

material, and re-distribute it into the wave energy zones that need it most. The new material will remain as a perched slug of sediment over the above water beach. The public then views this as a marked visible success. Most of the sediment is there, it can be seen to have built up the beach. Then, when higher energy waves occur, the perched slug is rapidly distributed into the swept prism. The beach has suddenly become narrowed above sea level, so the public immediately perceives this as an "erosion", and as a "loss". In these terms, the constructors and designers of the scheme, have generated their own public relations disaster. Perhaps unwittingly, they have led the public to expect that once the new sediment has appeared on the beach, then it will stay there forever. This is not the behaviour mode of dynamic beaches, but under the circumstances, who can really blame the public for regarding the work as an apparant failure?

#### (5) DESIGN OF NOURISHMENT WORKS

Within current states of coastal process knowledge, no beach nourishment project can be properly and fully designed, nor can the post-placement behaviour of the new sediment be accurately predicted. However, even within our very imperfect understanding of detailed beach processes, many of the likely sediment response modes can be considered in advance, but largely only in terms of possibilities and probabilities.

Over recent years many nourishment projects have been carefully observed and monitored during the construction phase, and sometimes for a few years afterwards. Subsequent analyses of these operations however, has only demonstrated that whilst many nourishment processes have identified, a sufficient volume of data to quantify them, has never become available. This should not be surprising. The equivalent data for the detailed processes on natural beaches does not exist either, and it will be many years before it can be accumulated in any case. Then, at the political level, the nourishment works construction, and funding authorities, usually perceive the work to be so simple and obvious,

that they are extremely reluctant to expend extra monies on extensive data collection.

Nevertheless, within all these constraints, there are at least seven factors that should be considered before mounting a beach nourishment exercise. As such, the consideration of these factors, particularly in probabilistic terms, together with their potential inter-relation, represents what "design" steps as are actually available for this class of work. These are:-

(a) Material Type.

This remains the dominant design parameter, and in fact often almost the only one considered. The energy absorption, or stability factor, of any sediment, is generally directly proportional to its size. In Nature, as discussed above, the larger the particle then the steeper the beach, and conversely smaller the particle, the flatter the beach, all for the same wave energy climate.

For natural beach particles that may vary in size, but hold a similar shape, or geometry, there is much evidence to suggest that this is an almost universal natural "law" for beach behaviour. For particles of an unusual shape however, this "law" appears to lapse to much extent. It is conventional to "size" beach particles by sieving, or passing them through decreasingly sized apertures. This process actually "measures" the second largest "width" of a particle, but as long as the particles all maintain a similar shape, then it represents a reasonably reliable indicator of its "size". For long flakey, highly angular, or natural shell-like particles however, sieving is not effective in measuring the particle "size". Under these circumstances it becomes necessary to invoke a more basic parameter of particle shape — such as its specific surface. However, if the parameter of specific surface is used to classify sediment particles, then again, there appears to be a correlation, the higher the specific surface, then the flatter the beach, and vice versa. It may be noted that small particles hold a high specific surface, and large particles a low one.

In practical terms what may thus be expected, is that if the nourishment material is coarser than the native, then nourishment will result in a steepening of the natural beach, and finer nourishment material will result in a flatter beach. At this stage, it may be relevant to consider the extremes. If coarse gravel is dumped at the top of a fine beach, then it will tend to stay there in the form of a steep scarp, because the innermost wave energy is incapable of moving it. On the other hand, if a load of very fine sand or silt, is dumped on to the beach, it will very rapidly be completely washed away into deep-water. In this case, the sediment is so fine, and requires such a flat beach slope to let it exist in any stationary place at all, that the ambient wave energy will maintain it in suspension until it is lost from the system.

For the last thirty years therefore, the operation of any beach nourishment scheme has been based upon the intent to utilise nourishment material that was either the same, or coarser in "size" than the native. In social terms, this is sound engineering. If a coarser nourishment material results in a steeper average beach, then it must also result in a wider "visible" beach. This is what the public and the ratepayers expect, and on this basis they will regard the nourishment exercise as a success. Then, they may even be prepared to pay for the next exercise.

In many localities however, the potential sources of nourishment material, are "finer" than the native. Then the project designer is faced with the usual quandry. Should he recommend nourishment, simply because it must help in any case, or should he consider the visual impact of the potentially new flattened beach, and recommend that nourishment is not a viable option? Indeed, should he recommend "hard" options, such as groynes or revetments, when he knows that they may well be less successful overall? Unfortunately, this is just the stuff that Coastal Engineering is made from.

In fact of course, the use of a finer nourishment material than the native,

may still restore the beach to a given visible width. It is just that much more nourishment material will be required -- then it may become a simple matter of economics. If finer nourishment material can be obtained at much lesser cost than coarser material, then it may become rational to utilise much larger volumes of fine material to attain the same end result. Then, if no coarser material is available, the use of fine material alone may remain the only option.

Over the years, many theoretical studies have been made, in an effort to predict the various amounts of nourishment, or as the Americans call it "borrow" material to achieve a given volume or width for the new replenished beach. As far as is known, none of these theoretical relationships have ever been calibrated against any real prototype, so a great deal of uncertainty is involved in the application of these relationships. Much of the early "underfill" and "overfill" ratio research was based upon a complex series of property moments derived from simple sieve testing. Recent research however, has suggested that particle properties based upon simple sieving, may be somewhat unreliable, when applied to real beach particles.

The most recent theoretical approach to this matter within Australia, based on the work of Smith & Gordon therefore, has been to consider the particle property of specific surface, instead of some nominal sieve parameter. Within this realm, the only basic assumption made in the theory, is that the beach slope will be proportional to a combination of the wave energy and the sediment specific surface. This assumption is certainly no worse, than those involved in other theories, it is at least simple and direct, and it remains quite open for future prototype proof. In fact nothing better is yet available, so it at least represents some starting point for assessing beach nourishment probabilities. This particular theory, of course, like all the others extant, has yet to be rigorously substantiated in the field, so it must still remain currently, as just another theory.

On the other hand, this theory allows for a direct estimate to be made for any given borrow material's beach slope, compared with the native. In fact the native material already exists, and its regime beach slopes can be directly measured by survey. The theory thus merely allows for some reasonably rational approach, for calculating a beach slope change, and does not rely on postulating absolute beach slopes from first principles, and all in the first place. Clearly, once a beach slope change, has been estimated, then an approximate volumetric requirement calculation is easy, for any grade of borrow material.

As an example, Fig.3 demonstrates how the theory may be applied, for the comparison of two potential borrow materials, both of very different sediment shape properties. This diagram is clearly simplistic, but it at least represents a starting point, that may well be of practical consideration. In particular, the diagram assumes a nourishment volume larger than critical, and that no intermixing has had time to occur (see below). These particular factors however, may be of considerable significance within any actual beach nourishment exercise that may be mounted, so again this class of slope estimate must be considered as representing potential limits to the beach system response. Or again, a matter of plain probability. In many engineering enterprises, it is often just as valuable, to know within which "ball-park" one is operating, than to know of any individual particular "state" that may happen transiently from time to time.

Until such time that rigorous research provides a more reliable concept, then the beach nourishment designer designer may well not expect anything better.

(b) Intermixing.

It is impossible to place large volumes of nourishment material instantaneously, and the real rates of deposition are comparatively slow. Since the seabed of any beach is mobilised by all wave action, then as soon as new borrow material

is applied to a beach within wave access, then intermixing of both sediments commences immediately.

If both native and borrow materials are identical, then this will have little effect on the beach slope or geometry. If the borrow material is different however, then intermixing must result in a new sediment population that will hold various proportions of both borrow and native. The degree and extent of the intermixing will depend upon the ambient wave climate. In a very calm sea, intermixing will be slight, extend to only a shallow depth of the seabed, and occur comparatively close to the shore. During a great storm, on the other hand, comparatively vast volumes of beach sediment are carried offshore, to form the storm bars. Under these conditions, it must therefore be expected that extensive mixing will occur throughout almost the entire swept prism. After a storm therefore, the total beach population must be expected to have changed to a fully mixed, with final properties approaching the average (on volumetric proportions) of both.

In particular, if the nourishment material is placed during fine weather low wave energy conditions, then intermixing will be small. The borrow material will then tend to form a perched slug at the top of the active beach. Then a great deal of extra beach width has apparently been gained for a reasonably moderate volume of new material. When the next storm arrives however, intermixing out to the toe of the storm swept prism will generate a new mean slope, and the visible beach will recede. The volume of sediment in the system remains the same, but an apparent "loss" has resulted. The general principle is shown in Fig.4 which is self explanatory.

The design of a nourishment exercise should therefore, include considerations of un-mixed and fully mixed profiles. Since each case demonstrates the extreme probabilities for the new beach slope.

The effects of intermixing, must also become a function of not only the dif-

ferences between borrow and native, but also the relative proportions of these likely to reside with the swept prism. Again as a crude estimate, and using the postulate that beach slope may be a function of particle specific surface, then Table I again demonstrates a reasonable approach to the probabilities of slope change due to various proportions of borrow and native — for a finer, and coarser class of borrow material.

On real high energy beaches of course, the seabed sediment gradings are not constant, but tend to become finer progressively offshore. There may thus be no average slope, but if the new borrow material also becomes sorted as has the native, then the new beach slope should reach a similar shape to the native, but maintain an overall average steeper or flatter slope. Such diagrams are very amenable to simple graphical integration. Under current states of knowledge however, it is doubtful if this class of refinement is totally warranted. Merely to hold some appreciation of the gross probabilities may be more than adequate at present. It should ultimately be possible to measure the actual changes and intermixing by a full program of profiling and sediment intermixing on the prototype.

#### (c) Placement Position.

As an extension to the above, it may be concluded that the rate of intermixing will not only be proportional to the ambient wave energy, but also where the nourishment slug is placed upon the swept prism. In Fig.5 for example, three potential deposition positions for a nourishment slug are shown. Slug A has been put on top of the beach where there will be no penetration by the fine weather swept prism. This slug will remain almost entirely unaffected by the sea until the first great storm arrives. Then it must be entirely transported into the swept prism and become fully intermixed. As such, and discussed above, the Public will regard this as a total loss.

Slug B, on the other hand, has been placed half into the fine weather prism. Much of the slug will be immediately activated, and partially intermixed.

The dominant natural beach demand for more sediment is generally within the zone where the waves peak-up, and then break. Slug B, will therefore, result in some increase in the visible beach, but not too much, and at the same time, the capacity of the fine weather active zone, has also become prograded.

The perfect placement of Slug B of course, would be such, that the toe of the slug co-incided with the mobile toe of the fine weather swept-prism.

In practice this degree of "fine-tuning" is impracticable. Nevertheless, Slug B represents a sound compromise. The slug has immediately nourished the current wave zone, but much has still been left on the beach, ready for the future storm. The public's expectations of a wider beach, have been met to a reasonable extent, but not to an excessive degree of impermanence. During a great storm, the public is ready to expect significant beach recession, but not to the extent, that what to them, appears to be the whole system, has been "lost".

The placement position of Slug B in the position shown, is also of great immediate benefit to the scheme designer. Since a fair proportion of new material, has actually been placed in the surf, then the form and geometry of the "new" wet beach, may give the designer a valuable insight into how the combined materials are behaving, and how they may further do so in the future. If there is any detectable mean change in beach slope, then the investigator may readily measure this by survey, and this may give him a reliable guide as to what may actually happen, under more energetic future wave climates. Much has been actually placed in the surf, but not too much, yet there is enough to actually observe its response behaviour.

Finally, in Fig.5, Slug C has been placed in much deeper water near, or even below the toe of the fine weather swept-prism. This in fact is, the depositional site of many nourishment projects that have utilised borrow material dredged from offshore, and dumped in water depths suitable for large displacement barges and other plant. This depositional position is however, by no means

irrational or stupid engineering. Although Slug C is outside the fine weather swept prism, it is however, perfectly placed to be immediately available to act as the main offshore bar, as soon as the next significant storm arrives. If the main offshore storm bar is already in position, then when the storm does arrive, then Nature will have no need to erode the beach, to form the bar -- it is already there. Accordingly, when the storm does arrive, the total beach storm recession must be less, and there will be no time-lag needed to form the bar either. If the next storm is of short duration, Slug C may well provide almost complete erosion protection, and even if the storm is prolonged, valuable extra time has been gained.

The problem with the Slug C siting, is that it provides no extra beach resistance during fine weather, and its effect on mild condition secular recession, will be negligible. Indeed, a steady rise in sea level, will even progressively reduce its overall potential effects on the beach. On the other hand, once the great storm does arrive, and Slug C becomes incorporated within the offshore storm bars, then the ultimate progressively reducing wave climate back to mild conditions, will sweep the slug back up on to the near-shore beach, just as natural storm bars are handled by Nature anyway. Then Slug C will become of permanent nourishment value, but it may take many years before this event arrives. Again, the Public associate nourishment value, with what they actually see. The Slug C position, represents only long term extreme event insurance, and an insurance that will not be activated until the event actually happens, and not even be visible, until much later thereafter.

In many ways, the Slug B position probably approaches the optimum. Here, the mild weather active beach zone has been improved. Much of the new material is immediately available for mild conditions, more for moderate storms, and its entirely for large storms, and all in the manner that Nature handles beach sediments. The Slug A position is of much reduced benefit. In fact, Slug A might be regarded as "cosmetic engineering", or an effort to promote

a dramatic visual impact, but all at the expense of a practicability deficit. In fact, when a type A slug begins to erode, it generates an alarming looking vertical scarp, that holds even worse public relation impact, the Public can't then even gain access to the beach!

As discussed above, the zone C slug is basically long term storm insurance. It is not visible, and it may remain dormant for many years before it ever becomes activated. Nevertheless, in simple engineering terms, it must well be considered to represent more practical value than Slug A alternative. In mounting a beach nourishment exercise, at least the designer should consider all these alternatives very carefully, and opt for the best value he may obtain, under ambient political and funding possibilities. To opt for the easy, and the obvious, may well later generate public opposition, that may preclude further sound work, or call for immediate "hard" alternatives in an attempt to repair the visual damage that results. Many beach nourishment projects that were casually conceived, have resulted in the construction, for example, of groynes — all merely to attempt to maintain the highly visible "initial" gain in immediate beach public amenity, usually the fine weather width.

#### (d) Critical Volumes.

In again extending the arguments set out above, it may be noted that the nourishment project designer may then become faced with the basic problem of assessing the provision of a critical sediment volume. As shown in Fig.6, for example, if the designer wishes to attain a permanent extra beach width under all conditions, then the nourishment sediment slug must extend seawards sufficiently to ensure that even during the worst of storms, then the new beach variation will be equal, or better, than the native beach. A simple calculation may then demonstrate that this resultant will call for extraordinarily large volumes of borrow material, and this does not allow for significant intermixing. Particularly, if the new borrow material is finer, or

coarser, than the native, then the new sediment volume must be capable of absorbing the entire new swept prism completely, within the volume of the new nourishment material. On most N.S.W. exposed ocean beaches, this may call for placing new material out into water depths exceeding 7 metres, or approaching even a kilometre offshore! This is often quite an impossibility.

In practical terms therefore, the designer may be forced to opt for a lower standard of protection during great storms, and merely provide a more available volume of sediment for the longer comparative periods of milder weather. Again, the public usually do not expect zero damage from major events, but they do expect a beach improvement most of the time from beach nourishment works. To repeat, this is an exercise in probability, and there exist to date, negligible design guidelines. It is in fact perhaps rather fortunate, that most of the public, are not able to observe in place, actual beaches during great storms. Perhaps otherwise, their expectations and demands would represent the entirely un-attainable!

When the intermixing of borrow and native beach sediments is taken into account, then the provision of a critical volume — or a new volume capable of providing the extra beach protection standard required, it becomes even more complex. Then we must consider two main probabilities. Not only is there the probability of intermixing involved, but also what is the probability of the intermixed material being effective in the face of the future probability of various storms of various intensity? In this, we are clearly beyond the realms of statistical engineering knowledge. Yet, if the potential behaviour of a replenishment exercise is to be addressed, then these factors must be considered.

Clearly, there must be a critical beach nourishment volume below which the extra protection purchased is ineffectual, just as there must be some critical volume above which the extra protection is excessive. The balance may be fine at times, but again it may only be expressed in terms of probability. At the

moment, the only known manner in which to investigate variable intermixing, and any resultant critical volume, is to postulate variable proportions of both in the same manner as Fig.4, and by trial and error, but maintaining the same gross cross-section, plot various hypothetical cross sections. At least when these are compared with various "design" swept prism shapes, then some "feeling" for the outer limits of the potential new beach may be considered. However, to repeat again, the urgent need is to measure the actual performance of several prototypes and calibrate the basic hypothesis -- until this is actually executed, little "design" progress can be achieved. On the whole however, beach nourishment exercises are so expensive, that this basic field research is an urgent consideration.

Unfortunately, even the basic input to considering the profile probabilities of real beaches, i.e. the study of the swept prism, is also relatively still in its infancy, whilst much work has been attempted, only small progress has yet been attained. Much more work is required in computing actual beach prisms, and in particular, equating them against the return periods and probabilities of major storms and cyclones. At its most simplistic level, perhaps the major lesson derived from the study of actual Australian beach nourishment schemes, is that the concept that nourishment is a straightforward un-complicated operation of the most static, sterile, and predictable kind, has been proven to be false.

#### (e) Critical Placement Values

Another disturbing feature of prototype nourishment programs, is that there also appears to be another factor that concerns the placement rate, and the placement position. It seems that the wider the grading difference between native and borrow materials, then the more important are these factors, but the intensity of the wave climate, seems also to be involved.

For example, if the borrow material is finer than the native, and an attempt is being made to form a zone B slug as on Fig.5, and if a very modest place-

ment rate is adopted, then natural intermixing will absorb all the new material much quicker than it can be placed. Sediment pumping to this site, may then continue for many weeks, but no visible progress in beach widening may be attained at all! In fact if the borrow material is much finer than native, and intermixing is complete, the new average flatter beach slope, may even result in a visible beach recession.

If this class of immediate inter-mixing is to be minimised, then the new finer material must be placed as quickly as possible, so that in effect a complete "mantle" of new material may result with the minimum intermixing. Then the results of Fig.6 may be attainable without overly degrading the slope stability of the original native beach.

Then if the beach in question, is also exposed to a high littoral drift, then the intermixing slope degradation effect may be highly amplified. In this case not only is the new sediment becoming dispersed "offshore", but a large proportion of it may also be carried "alongshore". If the new mixed Borrow and Native sediment, is finer than the native, then the "rate" of littoral drift for any given ambient wave energy must also increase.

In fact, on the Gold Coast, when a fine estuarine sand was pumped on to Palm Beach at a low rate, high water content slurry, for nearly a month, nothing of the work could be seen at all within 72 hours of the pumping termination. Nor did any visible effect of the new sediment supply ever appear on either this, or its downdrift beaches. If dangerous excessive intermixing is to be minimised therefore, there must thus exist a critical placement rate.

If the borrow material, on the other hand, is much coarser than the native, then other responses are possible. For example, a coarse borrow material placed as slug B in Fig.5, must be of immediate beach strengthening effect. Even in the position of slug A, it will immediately initiate a beach steepening

as soon as it becomes activated. If this new coarse material is, however, placed in the slug C position, then under ordinary average mild wave conditions, it will never come ashore at all, it will simply be too difficult to move. The very reverse conditions, however, will apply to a finer borrow material. Then placing the material as a C type slug, may be much more beneficial than an A type slug. Nevertheless, during any great storm, whenever it arrives, complete intermixing must be expected, for all cases.

At this stage it may be also noted, that borrow and native intermixing will be proportional to the wave energy, and the time over which this energy is actually applied. Thus, on a high littoral drift beach, the time that the waves have access to mix sediments will be increased by the long-shore movement, in addition to the offshore distribution. Clearly, to place a fine borrow material initially at the updrift end of a littoral drift beach, can only ensure that the combined intermixing will be a maximum, and overall increased beach stability a minimum. The deposition of a finer borrow material under these conditions, should commence from the down-drift end of the beach, and be carried out as quickly as possible to inhibit intermixing. Then, even some sand "groyne" effect may also be generated (see below).

With a coarser borrow material than native, on the other hand, the optimum placement sequence options remain much wider. Such new material will be very satisfactory if placed at the updrift end of the beach, since the new "average" beach slope will be readily and rapidly attained. The result then, will not be as dramatic as if the new coarse material placement starts at the downdrift end. In that position, intermixing is inhibited, so a greater visual beach widening impact will be immediately generated. Yet at least in starting from the updrift end, average conditions will stabilise much more quickly, and extremes in wave climate will be much less variable and obvious, from then on.

From this, it may be concluded therefore, that there also exists a critical

placement position or sequence. Then, if the borrow material resources demonstrate a highly spatial variation in grain properties, then these variables should become of real concern in determining which borrow materials should be used first, the order within which they are to be finally utilised, and just where each variable deposit should be placed on the prototype.

(f) Littoral Drift Effects.

For Eastern Australian ocean beaches, much evidence has accumulated, that suggests that littoral drift does not occur as a steady "stream", but that it occurs in "pulses", or "slugs". Whilst neither the cause nor the detailed behaviour of this class of littoral transport are yet fully understood, nevertheless, this phenomenon applies a further variable to nourishment projects on littoral coastlines. Experience to date has however, shown that the management of nourishment works that have been based on varying the placement rate and position on a native beach, have been able to "iron-out" these pulsatic modulations given a reasonably constant borrow material, by simply arranging the placement to continuously attain a new "straight" beach resultant.

Whether in fact, this is rational engineering, or not, remains inconclusive, but at least this procedure has been successful in coping with both natural slug transport, and variable borrow material, on the prototype. On the other hand, where the nourishment management has been applied on the basis of a constant volume of borrow sediment, per unit length of beach, pulse behaviour and beach crenulations have merely been accentuated. It is not the "positive" extra beach width crenulation that is important. With an accentuated "negative" beach width crenulation, a dangerous local beach erosion may sweep the down-drift beach beyond the current deposition zone, and cause significant damage to existing features. This phenomenon has been observed already.

(g) Groyne Effects.

In ordinary beach nourishment projects on littoral drift coasts, it has often

been postulated that the initial significant sediment deposition must, and will generate an immediate "sand groyne" that will trap updrift sediment, and generate a downdrift sand shadow. At least on the Gold Coast, this predicted nourishment behaviour has never been detected.

It is believed, that in fact the reason why it has never been detected, lies with the natural phenomenon of almost instantaneous borrow and native sediment intermixing, as discussed above. Nature holds an immense capacity to organise beach sediment response, as a purely dynamic operation, by means of intermixing, slope change, wave re-fraction and resultant wave incidence, to always minimise littoral drift. The sampling of real beaches (see Fig.2) has always demonstrated that the simple concept of the constant beach, the constant sediment properties, and the constant beach slope, is a myth.

Nature is much more subtle than that. Real beaches demonstrate an incredible "macro", as well as "micro" variation within all the ambient natural processes and the response of the sediments available to accommodate these processes. It may again be noted that Nature holds an almost infinite capacity to sort herself out --- then, if we offer her a beach nourishment that does not suit her, then she will sort out us as well.

#### (6) EFFECTS ON AMENITY

One of the main attractions of beach nourishment as a means of "controlling" beach erosion, has been that its side effects on amenity are almost zero. Mobile sediments represent one of the most sterile habitats for biota in the world, and those that do exist there, are almost equally mobile, and transient in their habitation. The sand crab that can run as fast as a human can walk, and the shellfish that can burrow faster than his human predator can dig, are merely examples of this.

Many studies have been made on the environmental effects of beach nourishment,

but all have demonstrated little of detrimental effect, and even these have been short-lived. This should be expected, because beach nourishment consists merely of placing more natural materials on a natural site, where an ambient deficiency exists. Nature may not quite handle them as we might expect, but the contribution must always be positive, and in the end, useful.

The general picture is that beach nourishment is a powerful coastal management tool, with the maximum potential for benefit to all. On the other hand, it is often uneconomic to provide the nourishment volumes necessary to ensure more than short-term benefit. Finally, the design and execution of beach nourishment schemes is neither simple, nor direct. A great deal of on-site study will be required before the results of such schemes become fully predictable, and until this result is attainable, the hazards of a "failure" loom alarmingly high.

Gold Coast,  
8th May, 1983.

A.W. Smith.  
Engineer.

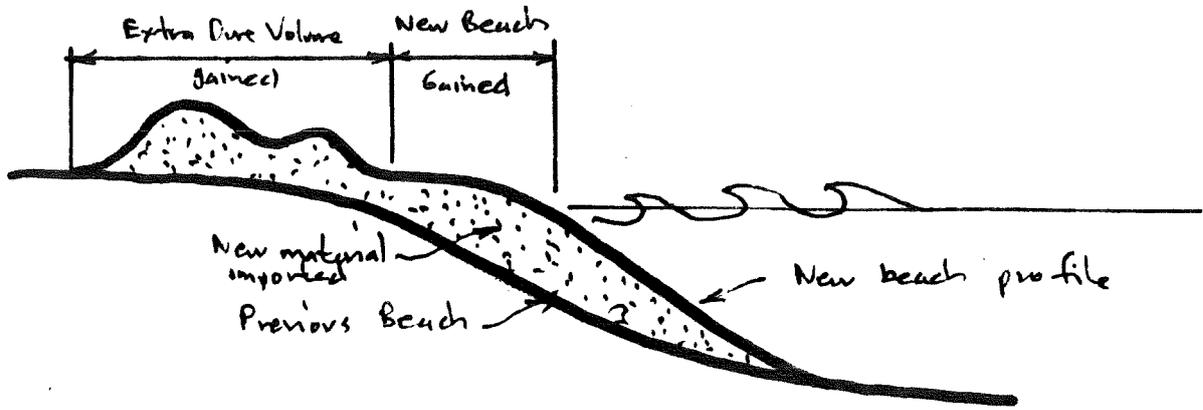
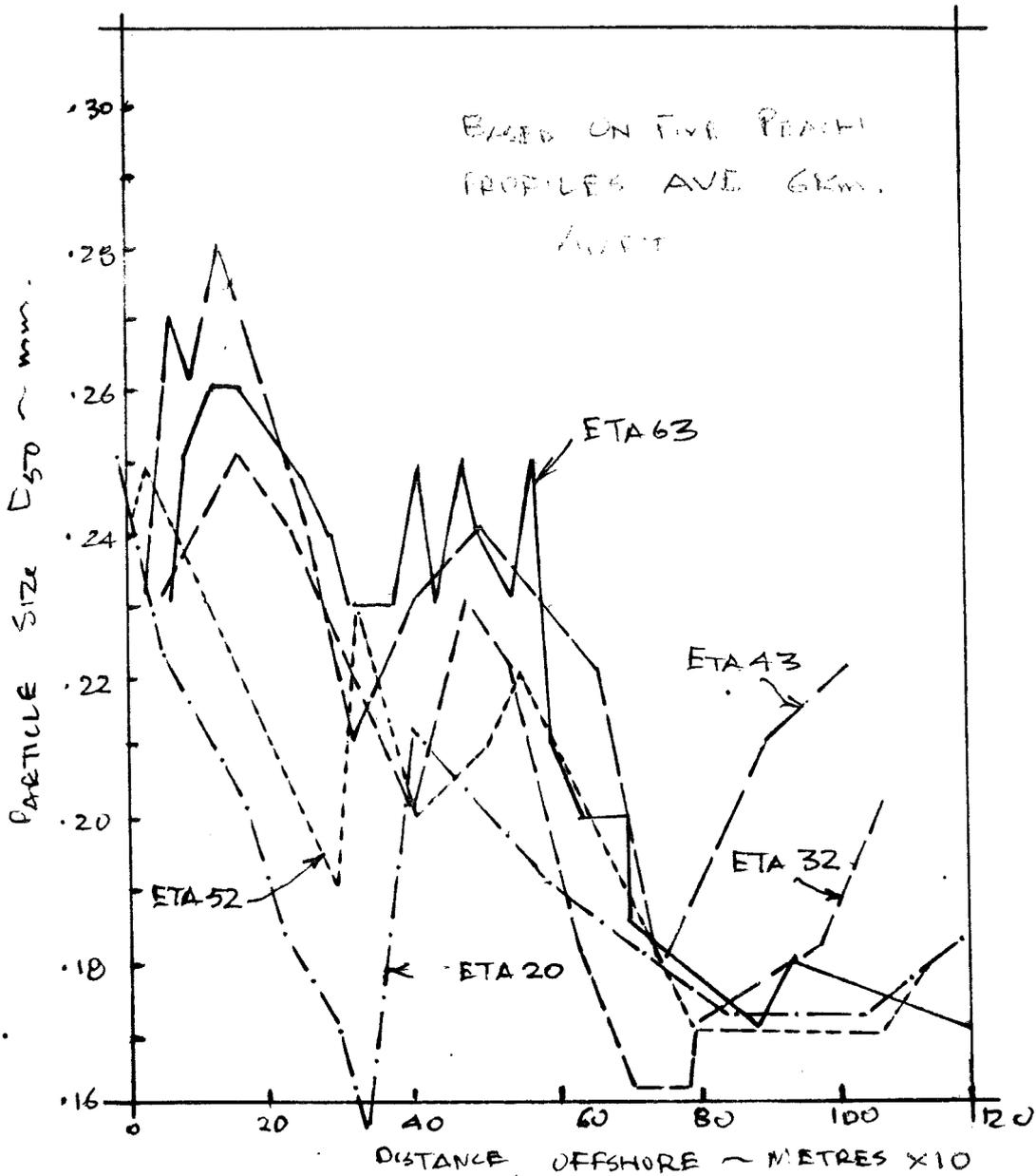
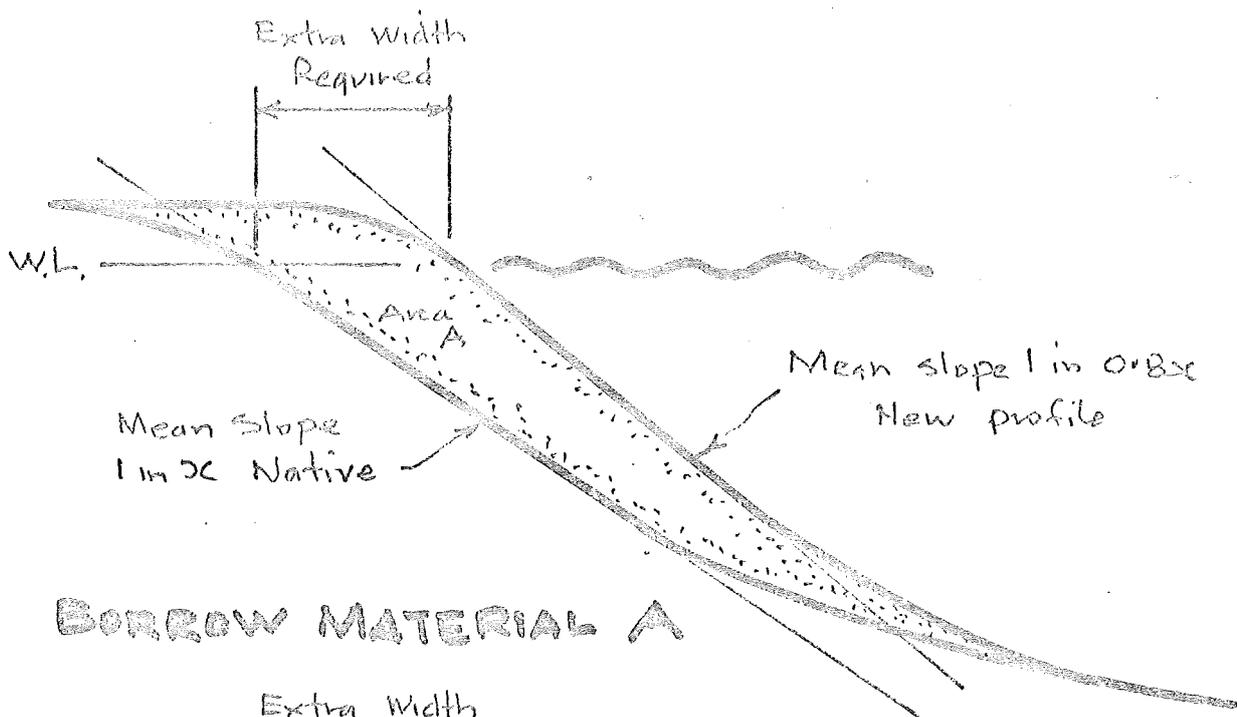


FIG 1 - BASIC CONCEPT OF BEACH NOURISHMENT

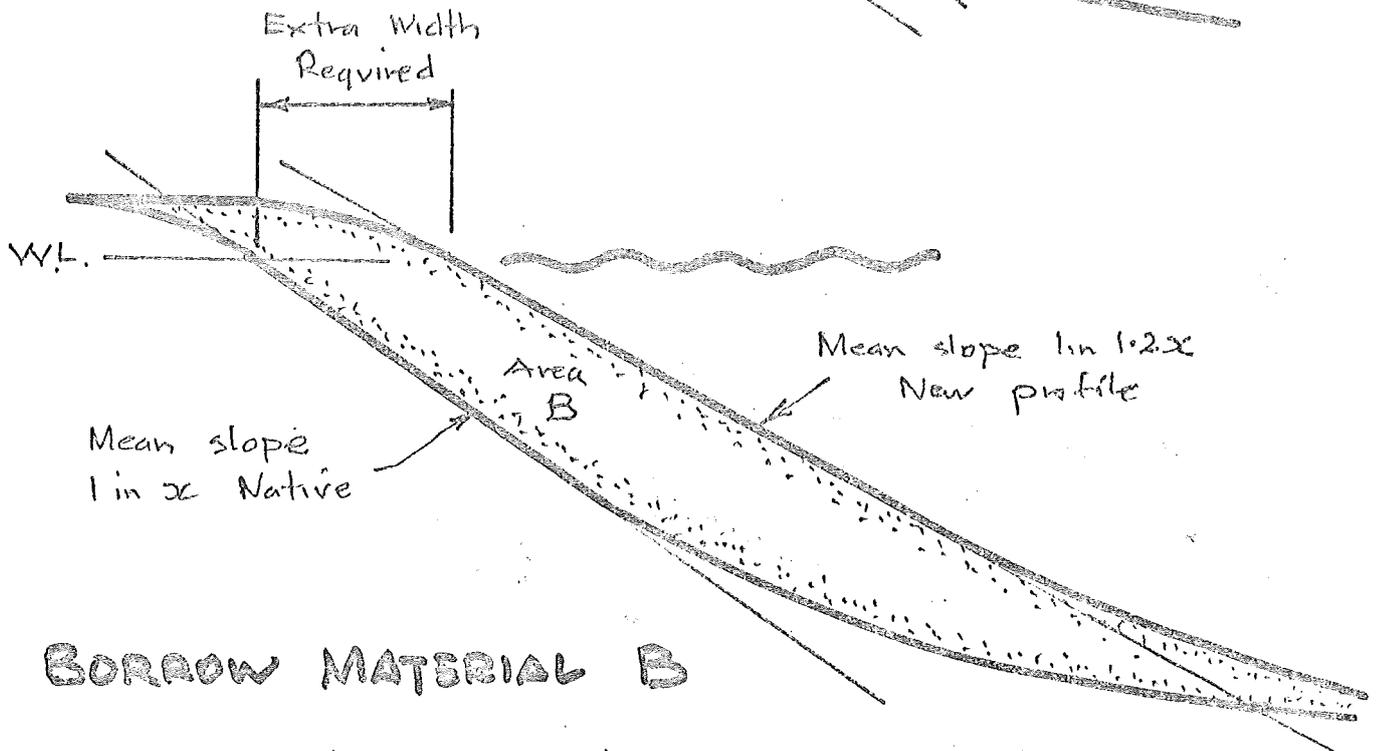


(75T)

FIG 2 - VARIATION IN SAND ON OCEAN BEACH



**BORROW MATERIAL A**



**BORROW MATERIAL B**

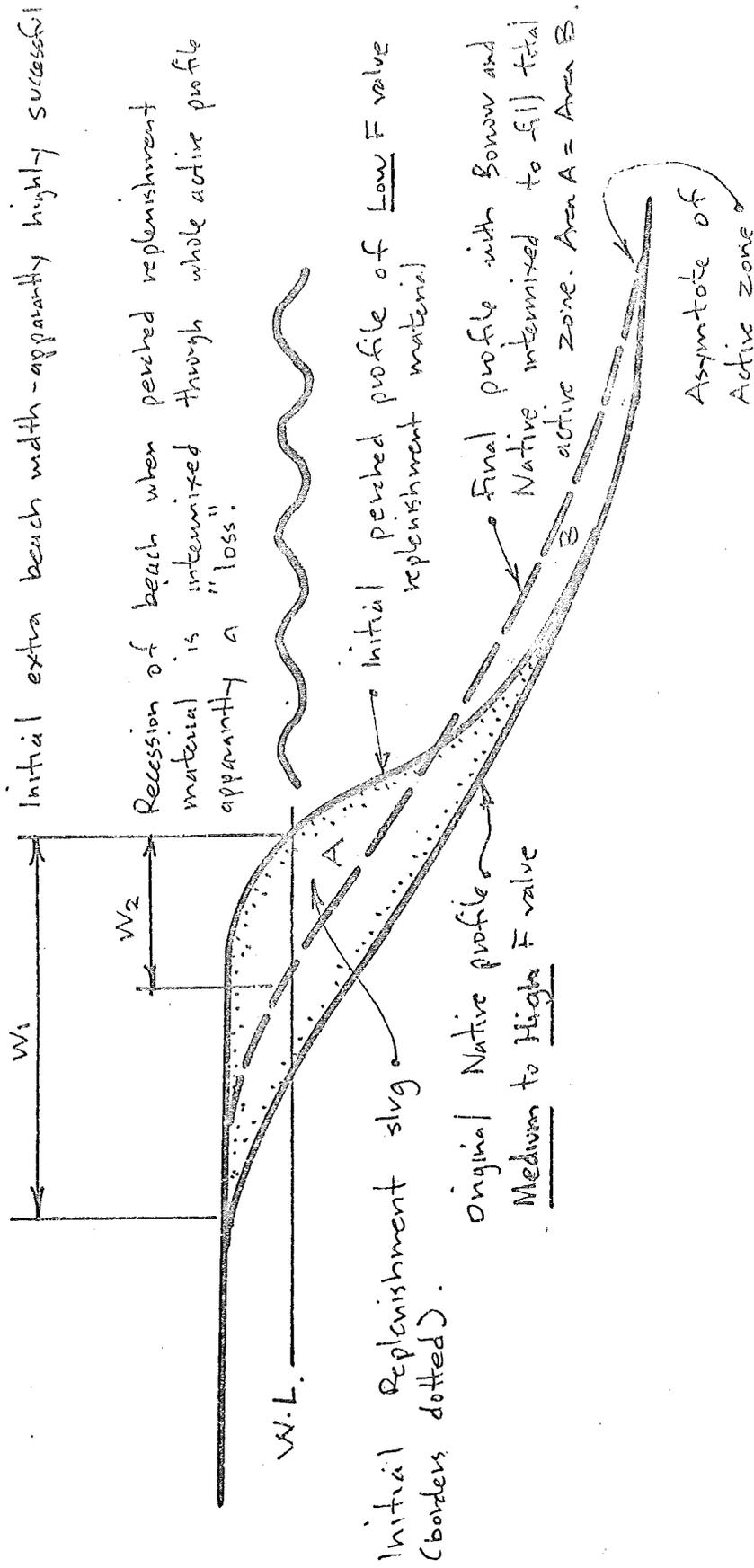
Graphical construction based on:—

Borrow A	$F_{50} = 8000$
Native	$F_{50} = 10000$
Borrow B	$F_{50} = 12000$

Ratio of Areas  $\frac{B}{A} = 1.75$

COMPARISON OF BORROW MATERIALS

FIG. 3.



DEVELOPMENT OF PERCHED REPLENISHMENT SLUG.

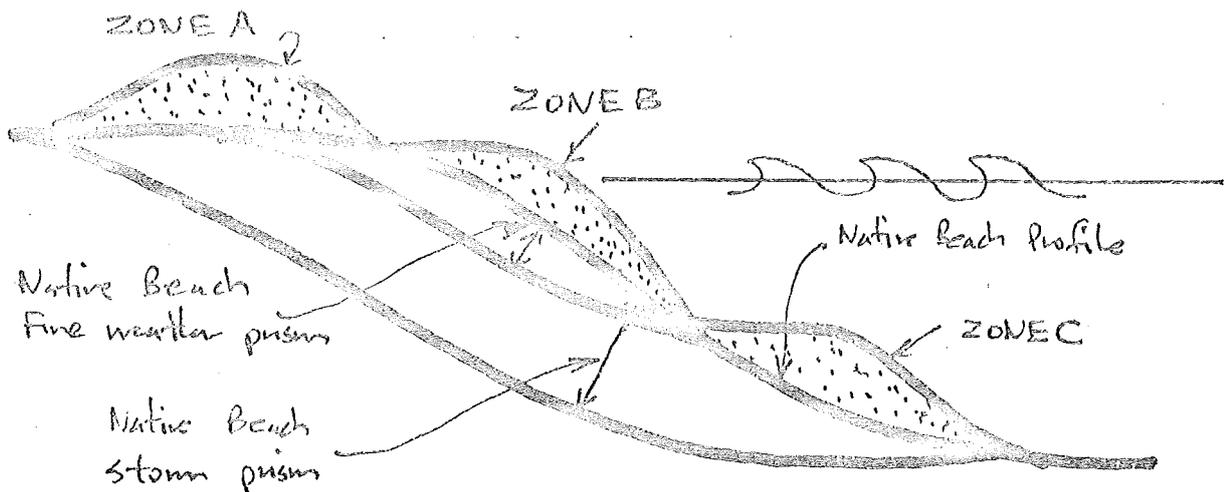


FIG 5 - TYPICAL BEACH NOURISHMENT PLACEMENT SITES

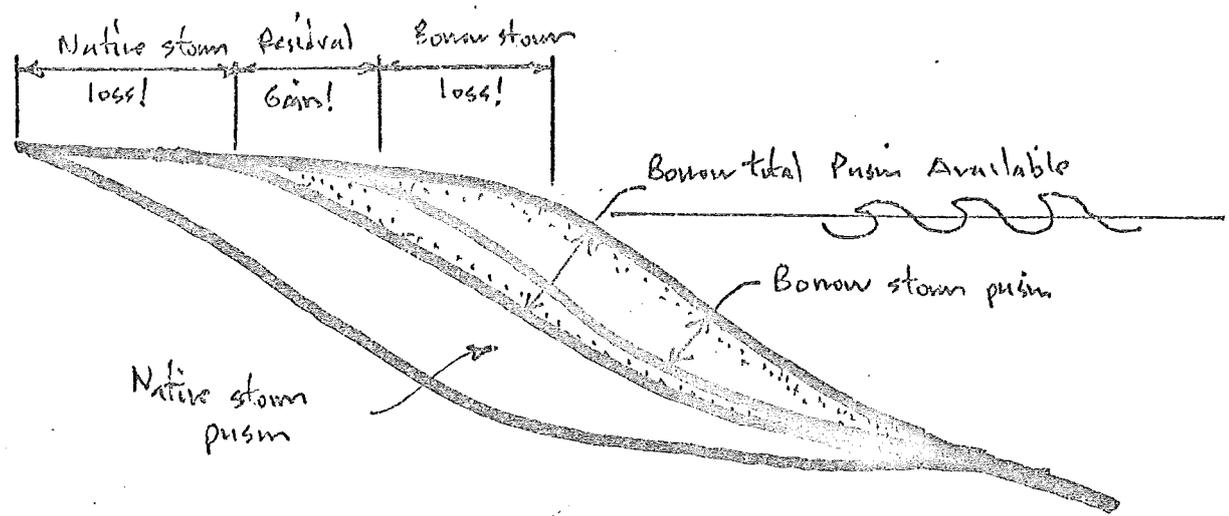


FIG 6 - BENEFIT OF BORROW OVERFILL

In this diagram borrow material is coarser than native.

TABLE I

INTERMIXING EFFECT ON BEACH SLOPE

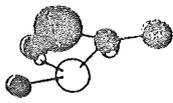
(A) Native F 10,000  
Borrow F 8000

<u>% of Borrow</u>	<u>New F<sub>50</sub></u>	<u>Mean Beach slope</u>	
0	10,000	1 in 50	Native
25	9500	1 in 47.5	
50	9000	1 in 45	
75	8500	1 in 42.5	
100	8000	1 in 40	

(B) Native F 10,000  
Borrow F 12000

<u>% of Borrow</u>	<u>New F<sub>50</sub></u>	<u>Mean Beach slope</u>	
0	10000	1 in 50	Native
25	10500	1 in 52.5	
50	11000	1 in 55	
75	11500	1 in 57.5	
100	12000	1 in 60	

Note — 1 in 50 Native Beach slope purely arbitrary but utilised for this example.



GOLD COAST BEACH REPLENISHMENT PROGRAM

REPORT No. 86.

THE EFFECTS OF FILTER CLOTH IN BOULDER WALLS.

(1) The most striking development in the design and construction of coastal structures over recent years, has been the application of geotextile (or as it is locally called "filter cloth") in a variety of ways. Filter cloth is now available in a wide range of patterns, textures and forms — the choice is already becoming bewildering. Its applications are equally diverse. Its most common use is as a replacement for tertiary armour in rubble walls, but it is also widely used beneath rubble structures and toe mattresses, in an effort to inhibit settlement of the rubble. Sand filled groynes have been built with the material and it is apparently commonly regarded as an ideal structural barrier, between any fine sediment and any larger sized armour. The coastal literature abounds with descriptions of all the different types of these textiles, together with many suggestions as to where they could be applied. Much is made about what the fabrics should be able to do, but little is available about what they actually do do, and how they finally behave in service on the prototype.

(2) There are already probably over half a dozen or so boulder walls constructed on the Gold Coast, where filter cloth has been applied as a direct replacement for the traditional clay-shale soil filter layer. Unfortunately none of these walls have yet been exposed to any real wave energy input, so they all remain quite untested to date. If we want "hard" site data on the behaviour of rubble walls, backed with filter cloth in service, then we have to turn to California for our testing ground. Here our most potent reference is Fulton-Bennett & Griggs (1986). Under storm conditions, these authors observed that filter cloth underlays beneath rubble walls, did not prevent significant wall settlement nor did they remain stable as porous backing membranes, behind secondary armour. These are disquietening observations, perhaps we should reconsider what we expect from these geotextile materials in coastal works.

(3) The classical approach is to consider filter cloth as a porous layer behind the rubble wall, that will allow ground water from behind the material to flow through it, but at the same time, prevent

the background fine materials (e.g. sands and silts) from doing the same. The intent in this, seems to be twofold. Firstly, high hydraulic pressures behind the structure, will be avoided, and secondly, loss of background fines by piping or flow into the structure, will be prevented. Following the same reasoning, filter cloth is often laid under the base and toe of the primary and secondary armour, to prevent wall settlement — settlement in this sense, being attributed to sediments piping "up" through the larger armour units. In both these locations, filter-cloth should be (in theory) highly effective and much more efficient than traditional natural granular material "filters". Perhaps however, we are seeing Hardin's Law in action, i.e. "You cannot only do one thing". We might thus suspect that geotextile filter cloth, as it is usually applied in rubble walls, is actually generating unexpected "side-effects".

(4) To comprehend the Californian experience, we first look at their filter cloth backed rubble wall failure scenario, as shown by Fulton-Bennett & Griggs. This is shown in Diagram 86.1 attached, being a direct copy of their Fig. 11. The most striking feature of the diagram, is the manner in which nearly half the main armour — and perhaps a quarter of the secondary armour — has been transported well seawards. The second significant feature, is how the armour that remained, has adopted a clear concave-up surface profile. This is very different from our normal Gold Coast boulder wall failure mode, where the armour tends to settle vertically around the toe, and very few units are rolled far seawards. Now a great deal of power is required to roll armour seawards along a very flat slope, against the incoming wave energy. We deduce therefore that there can be only one agency capable of doing this, and that is wave reflection. We note that incident waves striking armour units, push them against their background and try to compress the wall. Reflected waves on the other hand, can readily roll units seawards, since there is nothing but water to ~~re~~strain them, and the reflected waves will sweep seawards between the incoming incident waves. Once the local Gold Coast walls are exposed to constant green water in front of them, it is easy to observe wave reflection coefficient of 0.5 or more for the smaller waves, so there is no doubt that rubble walls do hold a real wave reflection capacity. We begin to suspect therefore, that in the Californian scene, the filter cloth is accentuating the wave reflection phenomenon in some way.

(5) To obtain another clue, we compare the type of wall shown in Dia. 86.1 with the standard Gold Coast wall, as shown in Dia. 86.2. The comparative feature of the Gold Coast wall, is the thick filter layer, constructed from natural clay-shale material. This layer in service, is actually almost completely impervious, it relies on its own weight to resist the groundwater loadings from behind it. When a new Gold Coast wall is initially exposed to wave action, the first thing that is seen is that the water in front of it, turns yellow. The waves that penetrate the armour, wash the clay from around the shale gravel in the "filter" layer. This provides a naturally and progressively graded layer of tertiary armour, along the leading face of the clay-shale layer and the larger the incident wave, the thicker this layer becomes. Up to some limit, the wall becomes "tempered" by wave exposure. By comparison, filter cloth has constant fixed hydraulic properties, and although it may be fully porous to groundwater seepage, it is completely opaque to waves. This must follow from the inherent porosity of filter cloth. For seepage through filter cloth, we are probably thinking of flow velocities of a couple of metres/hour, but a 10 sec. wave hitting the wall, will hold a celerity of 5.5m/sec. if it has degraded to the fully solitary state, or 15.6m/sec. if it is of almost deepwater form. When a wave strikes the face of a rubble wall, the celerity of the mass of water is dissipated by armour friction and turbulence, but it requires quite a long wave "run" through the armour, before the wave energy is exhausted. Local Gold Coast experiences, suggest that a total "porous" armour thickness of between five and seven metres, is required to completely dissipate the kinetic energy of waves, with an impacting height of only 2.5 to 3 metres. We see then that if any "dynamically" impervious layer is situated within the wave dissipation run, then whatever wave that hits the layer, must be instantly reflected.

(6) Then we note that as a dynamically opaque membrane, a layer of filter cloth, will accentuate the internal wave uprush, the backrush forces and the water volumes held within the armour. To water flow, filter cloth is slippery, so in addition to limiting the horizontal wave mass penetration, the water flow volumes within the armour in the up and down directions, will be much higher as well. If the backflow and the reflected wave, happen to coincide, the "tensile force" capacity of the face armour, can be readily overwhelmed.

Total failure then will become a rapid certainty. The provision of a filter cloth membrane here, then begins to appear to represent a very dangerous expedient. Its very existence will contain the wave backrush, entirely within the toe armour zone and merely ensure that the face armour must be rolled seawards and separate, instead of settling vertically. If the toe armour settles vertically, it may continue to act as a wall foundation, but if it becomes translated seawards, it simply separates and becomes "lost". As a final straw from Dia. 86.1, we also observe that the concave-up armour and filter shape during the filter process, concentrates the wave uprush and makes it backflow much faster — the membrane slope keeps increasing shorewards. This is the reverse of the behaviour of a clay shale layer, under serious wave attack.

(7) On the Gold Coast, all the boulder walls are constructed against a background of pure sand. In California however, it appears that many are built against a background of a cliff face, and such a face would very efficiently reflect wave power, whether the filter cloth was there or not. We may now begin to appreciate why rubble walls in California, tend to be much less effective than their counterparts on the Gold Coast. We would deduce that the rubble walls in California are dominated by wave reflection behaviour and they are not in fact, built nearly "thick enough" to eliminate this problem. Our very sobering conclusion can only be that filter cloth is not a direct substitute for tertiary armour. If filter cloth is used, then the primary and secondary armour layers, must be increased in thickness or some tertiary armour must be provided as well.

(8) Although the number of prototype case studies that we have discussed herein, is small, our interpretation of them seems to add up to an ominous warning. Wave reflection in a rubble mound structure, is a potent force. The writer has seen an eight tonne boulder rolled 5m seawards, by 3.0m waves, reflected off a vertical concrete monolith behind the boulder. We deduce that a filter cloth membrane, laid too close to the rubble armour face, can effect similar results. As such, it seems reasonably clear that the use of filter cloth in rubble walls, where this factor is not considered, is a potentially highly dangerous practice. As far as we can tell to date, the deleterious side-effects of filter cloth, almost certainly outweigh

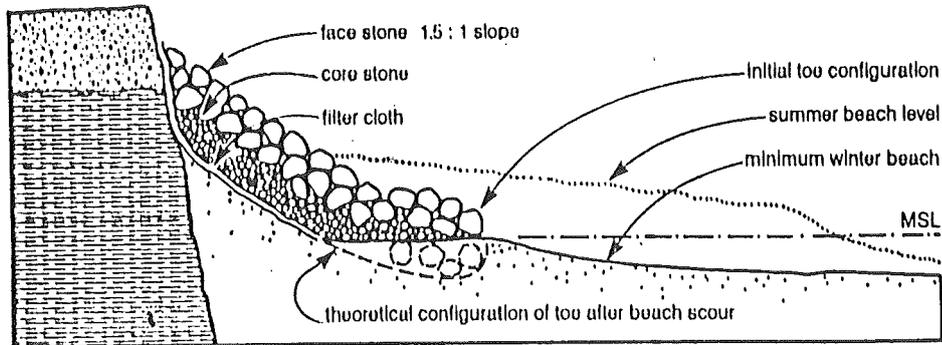
its apparent "design" advantages. Until such time as new site orientated design concepts, become developed, we do not think that it should be used as a replacement for tertiary armour, in rubble walls on the Gold Coast.

(9) REFERENCE

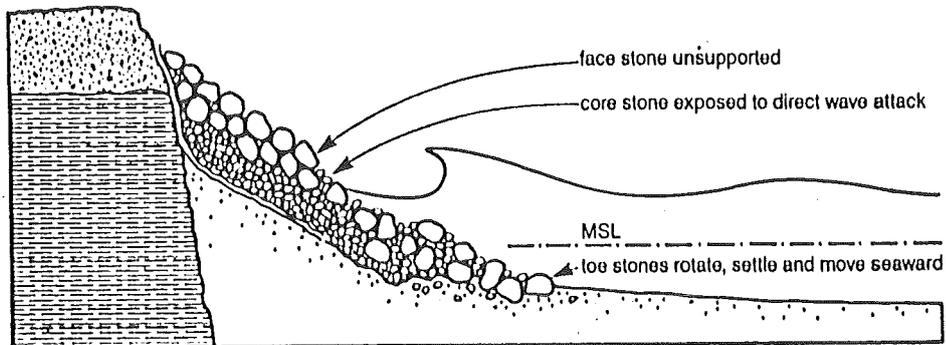
Fulton-Bennett, K. & Griggs, G.B. "Coastal Protection Structures and Their Effectiveness". University of California at Santa Cruz. (1986).

25th March 1987.

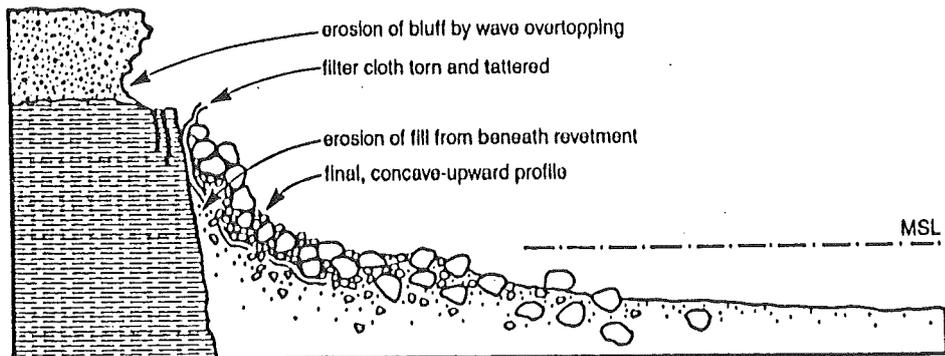
A.W. SAM SMITH.  
Engineer.



**Figure a**  
Initial revetment configuration and theoretical "hinging" of revetment toe.

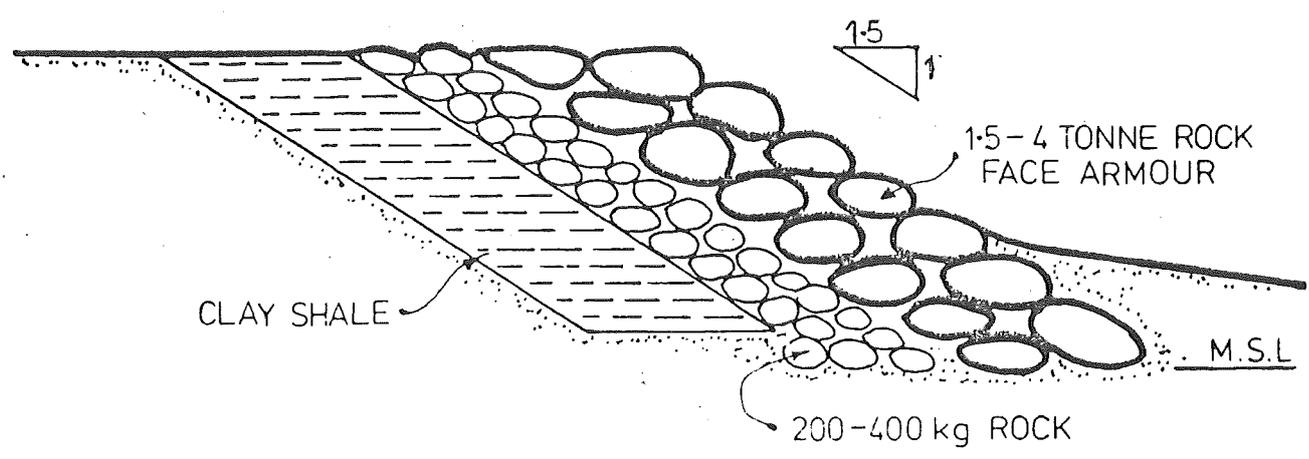


**Figure B**  
Initial stages of observed toe failure (may be very rapid); note both seaward and downward movement of rock.



**Figure C**  
Final stages of observed revetment failure.

DIAGRAM 86.1



GOLD COAST STANDARD

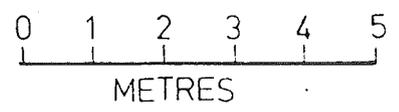
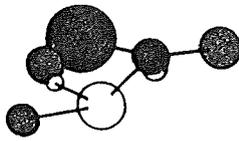


DIAGRAM 86.2



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GOLD COAST BEACH REPLENISHMENT PROGRAM

REPORT No. 89

SEAWALLS AS LITTORAL DRIFT DEFLECTORS

(1) INTRODUCTION

A feature of barrier island crossing systems, be they creeks, rivers or tidal outlets, is the sand body that usually forms around and in the outlet. In Nature, the sand body may adopt any of a myriad of shapes and form. The form of the sand body is seldom constant, but varies depending upon the particular balance of the various hydraulic forces, that may be interacting within the entrance at the time. The most persistent influence is generally the tide. In ebb dominated tidal conditions, the sand body may form largely in the exterior of the crossing, and vice versa for a flood dominant tide. Under balanced conditions, the body may be nearly symmetrical, but where significant creek or river flows contribute to the outlet's flow, the variability increases immensely. The peak flow in creeks and rivers, occurs during major floods, but unlike the tides, major floods are almost random sporadic events.

To coastal engineers who are concerned with the stability and health of ocean beaches, it is the flood tide dominant entrances with low creek or river flows and infrequent flooding, that are of the greatest concern. In this class of crossing, the tidal salt wedge effect, tends to unbalance the average water flow on the bed of the crossing, and this results in a net inward flow of sediment, into the estuary. If there is little sediment input from the creek or river, the flood dominant estuary, may then become a major sink for sediments, washed in from the beach. On a high littoral drift beach, these outlet sinks can trap very large volumes of sediment and significantly "rob" the natural drift supply. Sometimes the infrequent major floods may wash most of the sand body back into the ocean, but sometimes they may not. In this event, the in-washed sediments may remain as relict sand-banks within the estuary. To the Coastal Engineer, these deposits then become a total loss to the beach system. The visible "hallmark" of these entrances, is that the beach on the downdrift side of the crossing, is more landward than on the updrift side, the littoral drift loss generates an "erosion shadow".

## (2) GOLD COAST EXAMPLES

The Gold Coast is a large Zeta embayment, but near the centre there are two semi-subdued small headlands, that define the outlets of two small creeks, see Fig. 89.1. These are called Currumbin Creek and Tallebudgera Creek, and both discharge through active tidal estuaries that breach the barrier dune and beach system. Both creek catchments are steep. their flooding is erratic and of short duration. The tidal salt wedge effect is strong in each of the estuary outlets. For the last 50 years, both creeks have been almost continually infilling with ocean beach sand. The only recorded flood that significantly scoured and cleared either of the creek mouths, occurred in 1931.

The quasi- equilibrium size or form of the internal delta sand mass for either creek, remains entirely unknown since both estuaries have been progressively dredged, to win land-fill material, since before the fifties. The total volumes of sand removed from the creeks, is also unknown, but it is believed that some  $1.5 \times 10^6 \text{m}^3$  has been dredged from Currumbin Creek and perhaps  $0.25 \times 10^6 \text{m}^3$  from Tallebudgera Creek. It was not appreciated until the early seventies, that all these dredging operations were actually only robbing the natural littoral drift, the tidal inflow, given time, merely replaced the extracted sand directly from the beach. Palm Beach is the sandy seafront immediately down-drift of Currumbin Creek. From the late fifties until the early eighties, this beach suffered from a serious recession, yet the remainder of the whole Zeta embayment, appeared largely unchanged. It took quite some time before the probable relationship between these two events, became at all obvious.

The rate at which the tide could wash sand back into a dredged hole in the estuary of Currumbin Creek, was determined in 1974. As an experiment, a dredge was used in an attempt to form a deepwater entrance, in the throat of the outlet. Pumping at a rate of between 200 and 300  $\text{m}^3/\text{hour}$ , the dredge made good progress for the first two days. However, on the third day this progress ceased, the dredged sand was being replaced by material from the beach, as quickly as it was dredged. Finally on the fourth day, Nature began to win. The incoming sand flowed past the dredge on both sides, and the dredge was left operating at full capacity, in an ever diminishing pond. At this point, the dredge was turned around and with the help

of a second dredge, it was just able to return to the estuary. Approximate surveys suggested that when the Currumbin Estuary was fully dredged to the inception of the outlet throat, some 200,000m<sup>3</sup> of sand flowed back into the dredge hole, in only two years. The total net littoral drift through the Gold Coast embayment, is of the order of 550,000m<sup>3</sup>/year — Currumbin Creek was a remarkably hungry "sink". The behaviour of Tallebudgera Creek, followed the same pattern, but on a much reduced scale.

Then when both the creek estuaries had been dredged, an unexpected political "side-effect" developed. Once the estuaries had been converted to blue-water conditions, the public found them to be of immense amenity for sheltered boating, fishing, bathing and sailing. As the public usually does, it rapidly grew to demand that the estuaries be kept perpetually in the deep-water state. The political pressure applied has grown strident, strong and remains continuous.

### [3] LITTORAL CLOSURES

Unfortunately the political side effects, did not stop there either. Once it had become practice to dredge the creek estuaries, it became a popular fallacy, that a large measure of flood control of the creeks, had been attained. It is now no longer known how seriously this fallacy became widely accepted, but whether it was or not, it is now clear that the levels of housing land near the estuary, had been set on the assumption that the creek outlets, would always stay open. This would seem a most reasonable expectation— a major flood as had occurred in 1931, should have been quite capable of eroding an expanding escape channel, at any time across the beach.

It was in the event, Nature herself that demonstrated this expectation could be false. Early in 1972, the Gold Coast was attacked by a tropical cyclone storm wave train, that shoaled very obliquely from the South. This whipped up the littoral drift rate to unprecedented levels, and the high sand transport volumes, completely closed-off both creek entrances. In spite of the heavy rainfall, the cyclone carried with it, the resulting floodwater failed to breach the littoral drift induced beach berm closures, and hundreds of houses suddenly became in hazard of imminent extensive flooding. Both creeks were ultimately opened in the nick of time, by the liberal application of manpower and bulldozers, but the margin

against severe inundation had been narrow indeed. It finally began to dawn upon the Gold Coast City Council engineers, that these two creeks had developed into coastal problem areas, of a very significant magnitude.

It is easy now to clarify the issues at stake, but in mid 1972, the overall picture looked a great more clouded. As is usually the case, the engineers of the time, stumbled from consideration to consideration, very much by trial and error, but after about six months, their objectives became distilled into:-

- (a) The primary need was to prevent the closure of both creeks, by high cyclone induced littoral drift.
- (b) The second need, was to reduce the inflow of sediment into both estuaries.
- (c) The third and allied need, was to reduce the estuarine tidal sand body demand and thus reduce the maintenance dredging, necessary to keep the estuaries largely "blue-water".

It was obvious that some structural conclusion would be necessary, and ultimately both creeks were provided with what were simply called "groynes" at the time, but what would now be classified as "Littoral Drift Deflectors". It would be obvious that if the beach littoral drift, could be arranged to largely by-pass the immediate influence of the estuarine outlets, then all three of the "needs" set out above, might be reasonably effected. The two seawalls that were finally built, were designed by entirely different procedures, and they look very different, so each will be described separately below.

#### (4) CURRUMBIN SEAWALL

In late 1972, the Gold Coast City Council finally embarked upon a long term program of coastal protection and coastal enhancement works. The basic guidelines and the physical process data-base then available, was the Delft Hydraulics Laboratory Report R257 (1970). This report had been commissioned by the Queensland State Government in 1968, perhaps largely as a response to the erosive cyclone season of 1967. The report was remarkably advanced for its time,

and it clearly identified the littoral drift infilling behaviour, that generated the on-going sand losses into Currumbin Creek. Its basic recommendation, called for the construction of a seawall joining Currumbin Rock, to the mainland. This became the starting point for the new seawall designers, it being perceived by the Council, that Currumbin Creek was the most urgent problem in need of immediate address.

The Council engineers' first action, was to study and re-analyse the Delft recommendations and supporting data. By that time, the same engineers had been on duty on the actual beaches, throughout the 1972 cyclone erosion — they had already observed the "real thing" in action, during a major storm event. The Delft investigators had thought that if the proposed wall connecting Currumbin Rock to the mainland was constructed, then natural bypassing would be strongly inhibited and a mechanical bypassing system would be necessary. Having observed cyclone induced headland bypassing, the engineers were not at all sure that this need be so, and their research seemed to support their doubts. Their historical search suggested that in the past, Currumbin Rock had been connected to the mainland by a sand spit, at least as often as had the sand spit been absent. Their search also suggested that the existence of a connecting sand spit, might well be associated with a wide beach on downdrift Palm Beach, and vice versa.

The engineers therefore mounted an almost daily monitoring exercise on the prototype, to observe the inlet sediment behaviour in detail. At the time, the connecting sand spit was absent, and for this state, their interpretation of the sediment transport behaviour is shown as Fig. 89.2. With no sand spit in place, the water depth in the gullet reached nearly 6m at low water, so something like 70% of the total littoral drift along Currumbin Beach, was flowing through the gap. This ensured that a continual supply of semi-fluid sand, was being placed exactly where the flood tide could wash it into the estuary, with the minimum of effort. One only had to stand on the shore, under the right lighting conditions, to be able to see the littoral drift, actually flowing under only moderate waves at peak tidal flow.

The second scenario for the creek entrance with the sand spit in

place, is then shown as Fig. 89.3. At the time, this scenario was only very tentative, a similar mechanism appeared to occur on the prototype at other headlands and groynes, but none of these sites were in any way associated with a coincident creek outlet. In fact, the bypassing process shown in Fig. 89.3, was partially incorrect and the actual mechanism was not detected until over ten years later. Fortunately however, the basic principle was right enough. Waves with a suitably high energy content, could and did, bypass large volumes of sand around headlands, in water depths of between 2 and 10 metres. This put the main littoral drift seawards of the wave breaking line, where the tidal currents were not strong enough to wash too much sand into the creek.

The wall designers of course, had no idea how effective the headland bypassing would be, nor whether it would be only a temporary or permanent process. Nevertheless, the Delft Laboratories had said the wall was necessary, and the engineers had been told to build it, so in spite of their reserve, they set about doing so.

At this stage, the most important visual feature of the wall, became adopted. The provisional structural design of the wall had been for a straight wall across the narrowest section of the gullet, connecting Currumbin Rock to the mainland. The then Mayor of the Gold Coast had a good eye for beach hydraulics, and he suggested that a connecting wall formed in an arc concave to the South East in plan, would look better and probably "act" better. To the designers, this was a novel thought, so they went away to think about it further. It then only took them a day or two to conclude that a curved wall could be proportioned, such that it held two major benefits over a straight wall. These were:-

- (a) A concave shaped wall almost encroaching into the creek, provided the maximum width of refilled beach, where the wall "height" was a maximum. This meant that the centre of the wall would be exposed to the ocean, much more infrequently than would a straight wall, so the beach would recover much more rapidly after any storm erosion.
- (b) If the concave shape of the wall in plan, was made exactly the same shape as adopted by storm wave fronts, refracting

through the gullet (when it was blue water) then the impacting waves would "touch down" everywhere upon the wall, at the same instant. This would then not only minimise wall damage, but it would also minimise wave reflection, progressive wave "set-up" and inhibit the development of escape head rip currents, capable of washing large volumes of sand offshore.

In the event, the wall was designed and constructed in accord with these premises, and surprisingly both have since been found to be valid. In 1974, the wall was exposed to two major cyclone wave attacks. A 90% simultaneous wave touch-down was observed and no dangerous rip currents developed at all. Since 1974, the wall has never been re-exposed, but it remains there as the final defence against a breach during any future extreme event. It was however, the bypassing behaviour of the wall and rock, that astonished the designers the most, it "worked" much better than ever expected. The rate of infilling of Currumbin Creek dropped to 25% or less, compared with "open gullet" conditions, and the major sand input now occurs during Southerly littoral drift states, as induced by the comparatively infrequent wave trains arriving from the North. The Currumbin seawall is in fact, one of those rare "accidental" successes. The designers of the time, held only a very limited understanding of barrier island outlet dynamics and real littoral bypassing modes. In retrospect, it was pure luck that actually graced their efforts.

#### (5) TALLEBUDGERA SEAWALL

When the City Council engineers came to address the design for a bypassing structure for Tallebudgera Creek, they were much more confident. They knew by then, that the designed resultant was attainable, so they determined to effect a final design in a proper way, and not rely upon intuition. At that time, the Currumbin seawall was not complete, but its final behaviour could already be predicted. The City Council therefore, commissioned a model study of the Tallebudgera Creek outlet, by the Water Research Laboratory of the University of New South Wales. The study, as reported by Tuck & Foster (1973) remains to this day, as quite brilliant. The laboratory constructed a "process" model of which "scaling" values were immaterial, i.e. the model was made to reproduce the behaviour of the prototype, and the wave input, the littoral drift and the tidal prism were varied until the model did act just like the

prototype. This was only possible, because by then, the City Council had amassed a large data bank of observations, surveys, dye tracer studies and aerial photographs of the real outlet in action. This is shown in Fig. 89.4.

The form of the Tallebudgera Seawall is shown in Fig. 89.5. The Wall is not a normal groyne at right angles to the beach, but is very obliquely aligned to the mean beach line. This necessary feature was determined on the model, which likewise demonstrated that no additional benefits could be attained by either curving the wall, or adding a seawards end spur to it. The seawall was constructed in two stages. By that time the Council engineers had learned a little more about coastal process uncertainty. They thus adopted the policy of initially constructing a coastal wall, rather smaller or shorter than was thought desirable, monitoring its behaviour for some time, and then progressively adding to, or changing the structure until it was acting as required. As might be expected, the Tallebudgera seawall has been much more efficient than the Currumbin wall, in deflecting the littoral drift. In its Stage I geometry, the Tallebudgera Wall reduced the sediment infilling rate, to about 20% of the "pre-wall" state, and the final wall extension has nearly halved this again. To date, this wall has been an unequivocal success.

#### (6) CONCLUSIONS

The Gold Coast experience of littoral drift deflecting structures, covers only two cases. However, this experience does suggest that with an adequate prototype process data collection, and an adequate "process" orientated flume model, it should be possible to design and construct barrier island outlet structures that may effectively:

- (a) By-pass a large percentage of the littoral drift nearly continuously.
- (b) Reduce the natural sediment infilling rate.
- (c) Reduce the size and volume of the natural sand body that usually forms in these outlets.

It must be noted that this class of structure, cannot be expected to generate a deep-water or navigable outlet, the littoral drift is only deflected seawards of the strongest tidal currents. Littoral

drift by-passing and a permanent deep-water outlet, are two completely incompatible states. A permanent deep-water outlet, demands nil natural littoral drift by-passing, and vice versa. You simply cannot have it both ways.

(7) POSTSCRIPT

This account of course, has been able to be written with the complete benefit of much hind-sight. At the time (1972-74) the engineers involved, wasted a great deal of time in exploring what ultimately turned out to be fruitless avenues of speculation and research. For months on end, they were confused, unsure and in grave doubt that they were even approaching a sensible viable conclusion. This must usually be the way with many coastal projects, even though they are often later reported in the most positive of terms. The Gold Coast engineer's total reliance upon continuous field observation and process monitoring, ultimately paid off, but how narrow was their margin between relative success and failure, is something that will probably never be known.

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19th April, 1987.

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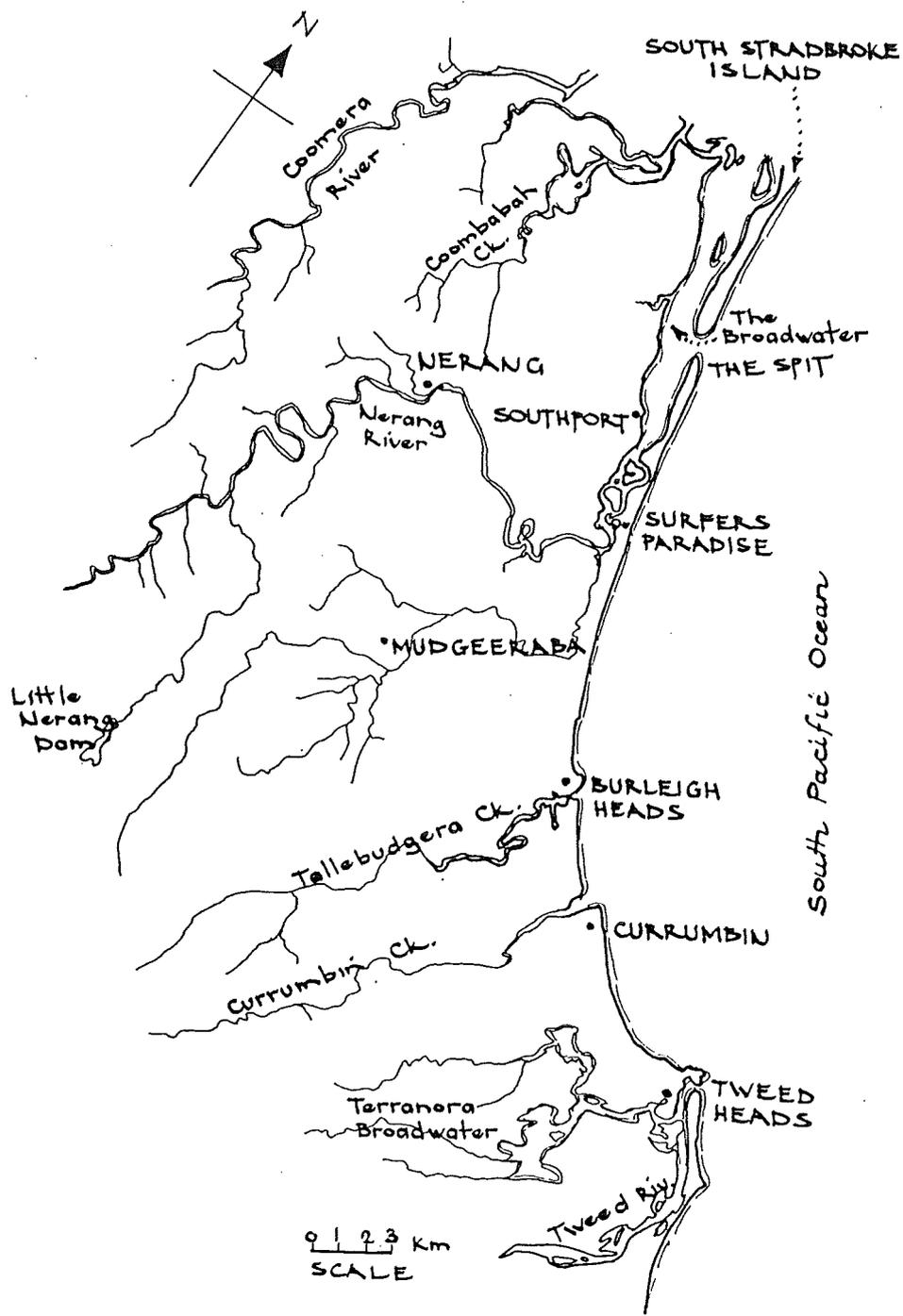


FIG. 89.1

Locality Plan.

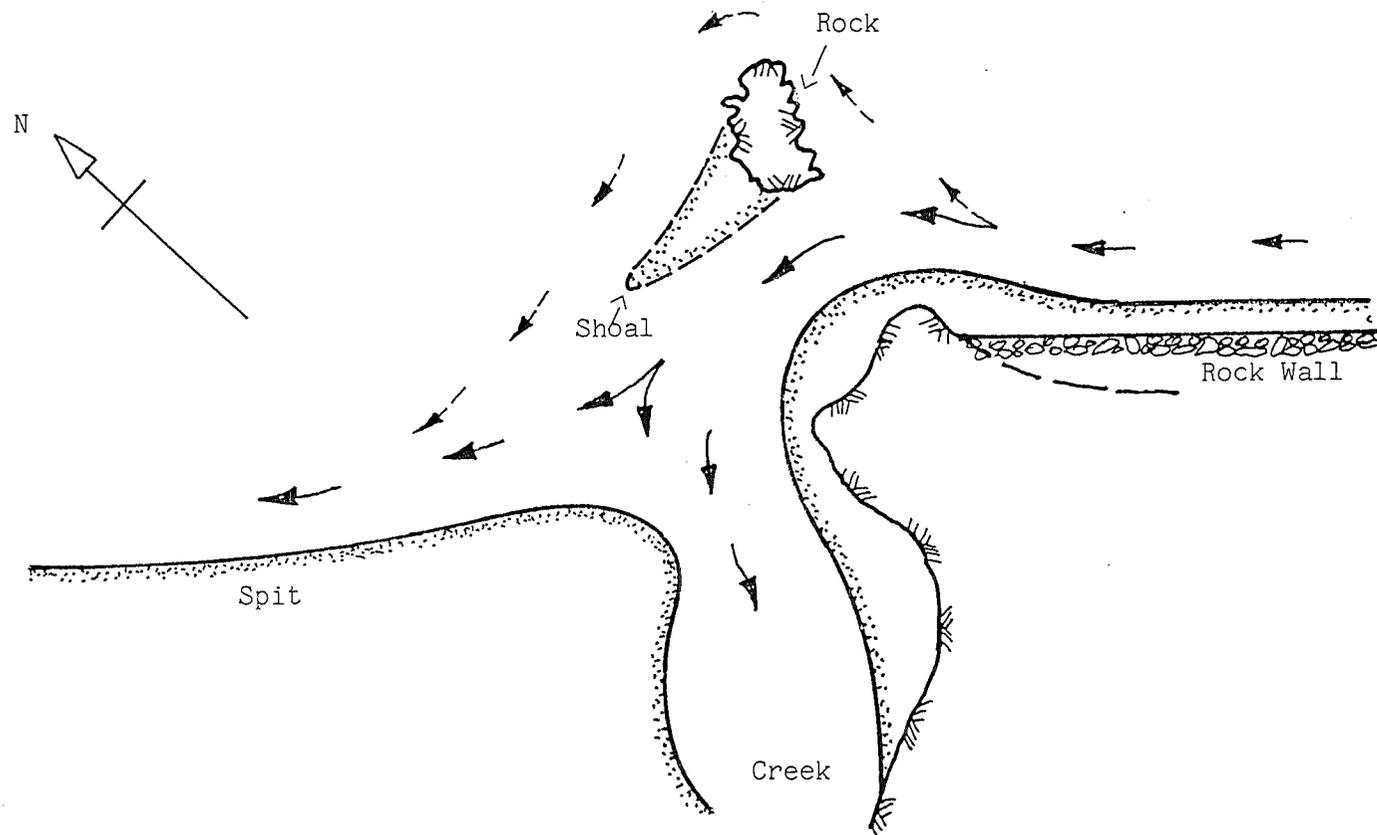


FIG. 89.2

Typical Currumbin Creek Before Seawall.

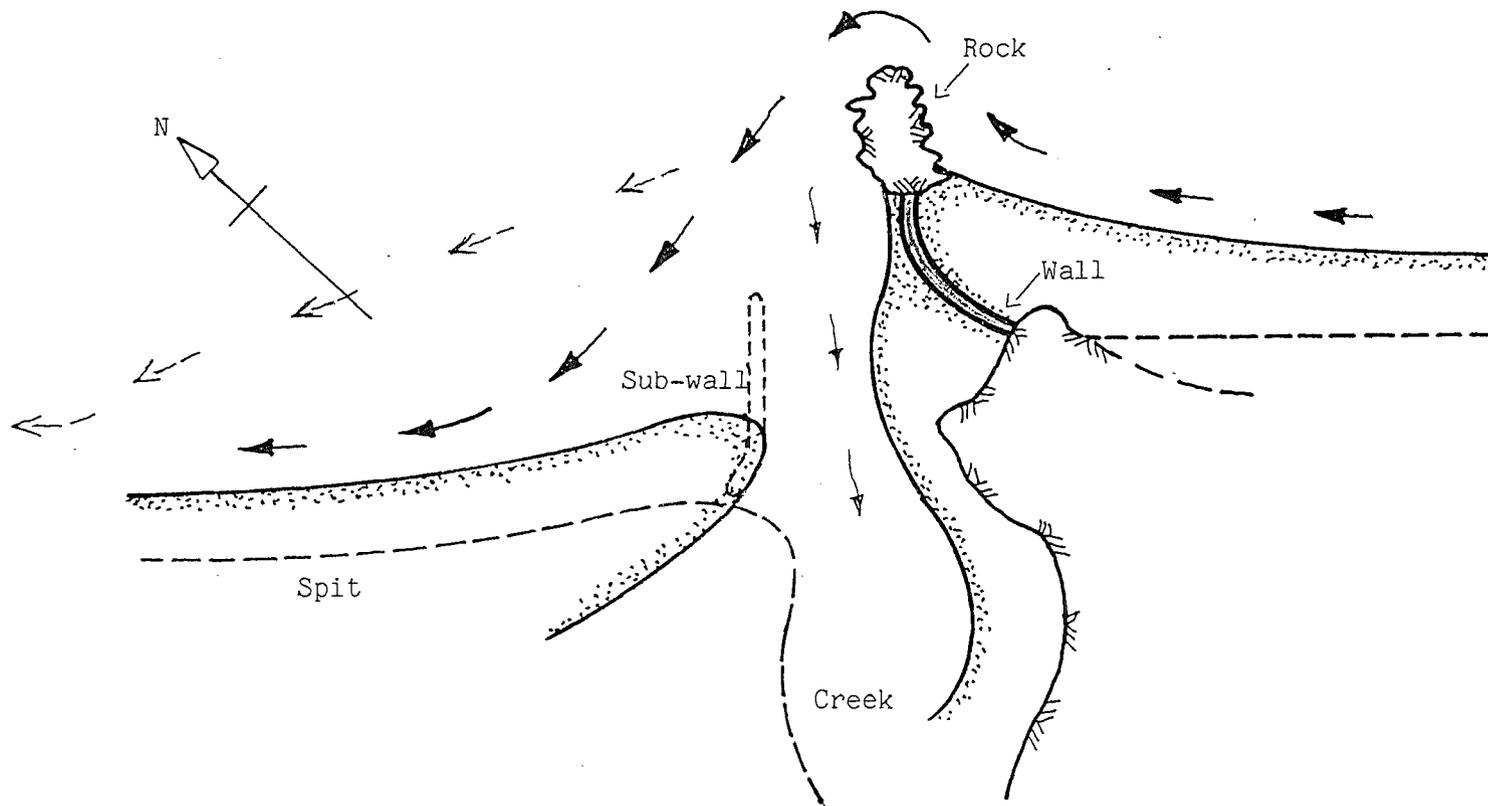


FIG. 89.3

Typical Currumbin Creek After Seawall

Solid arrows show transport as deduced in 1973. Dash arrows show actual transport as detected in 1984. Sub-wall was built to stabilise end of spit.

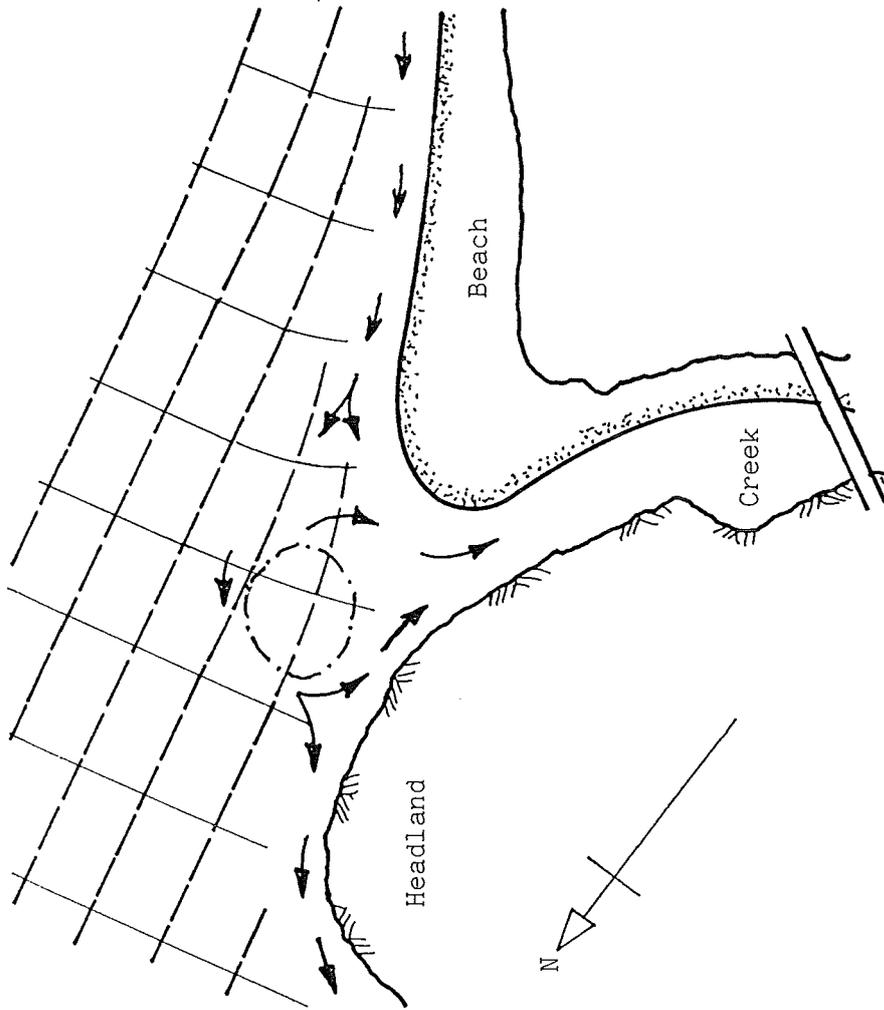


FIG. 89.4

Typical Tallebudgera Creek Before Seawall  
After Tuck & Foster (1973).

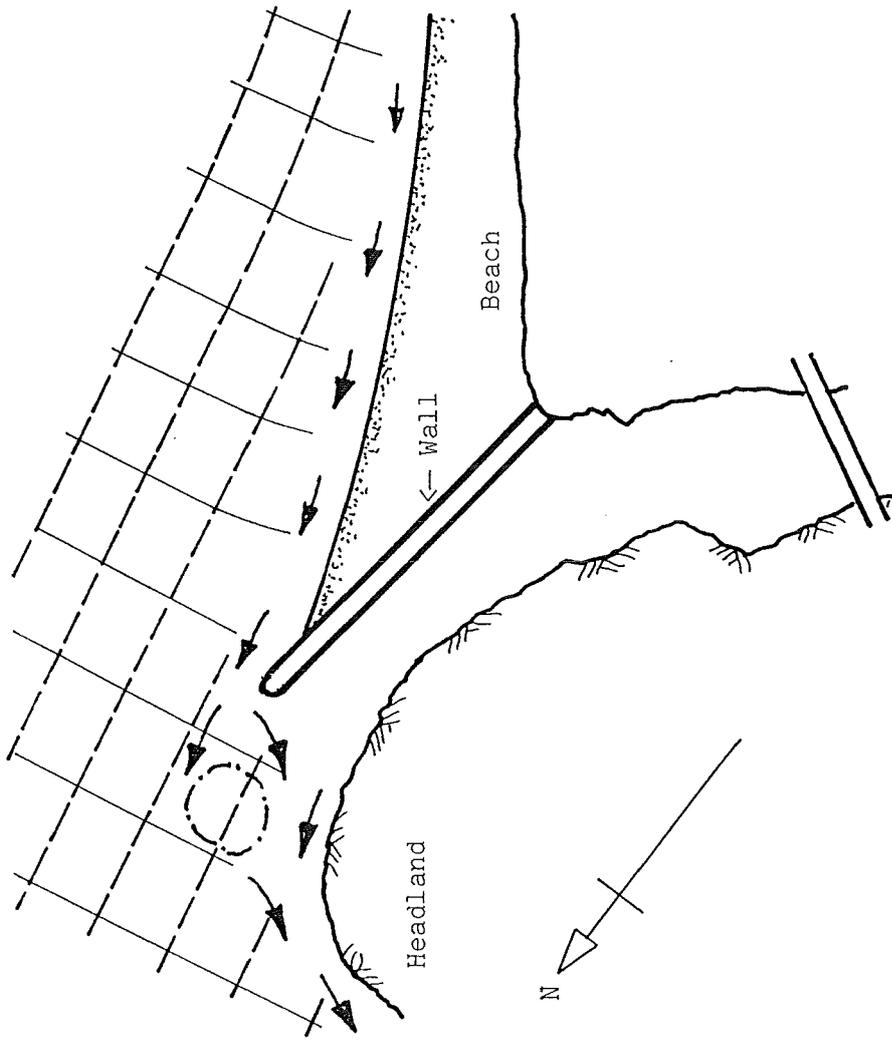


FIG. 89.5

Typical Tallebudgera Creek After Seawall

After Tuck & Foster (1973)



FIG. 89.6

Currumbin Seawall Oct. 1982

Rock and nearly buried seawall at left. Sub-wall central with spit to right. Note straight line of bypassing shoal.

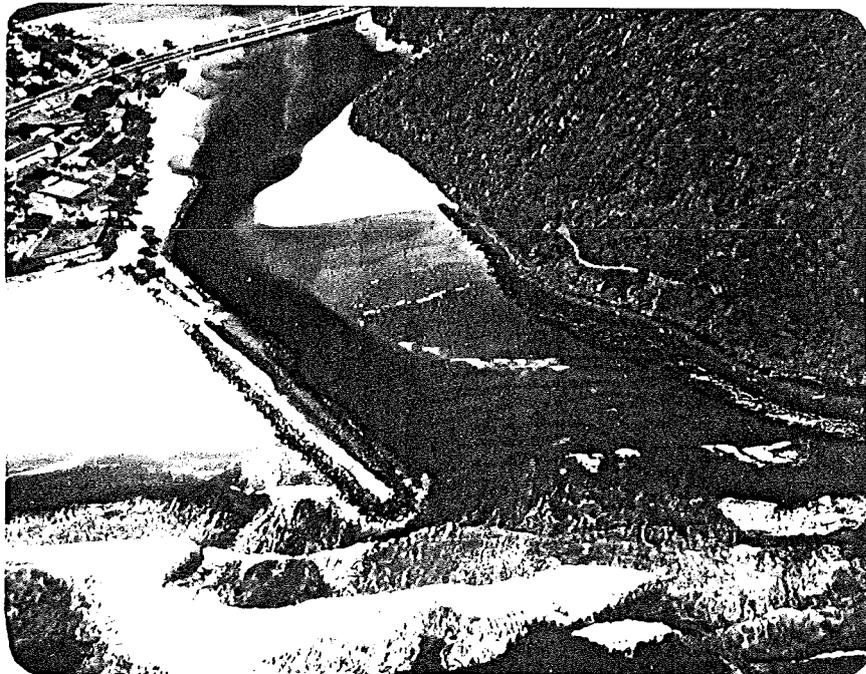


FIG. 89.7

Tallebudgera Seawall, March 1986.