DURBAN BEACHES RECLAMATION : PRACTICAL ASPECTS

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1 INTRODUCTION

Much controversy has revolved around the stability of Durban's beaches over the years and in its concern for this valuable tourist asset, the Durban City Council commissioned several studies culminating in a commission in 1961, jointly with the South African Transport Services, with the Council for Scientific and Industrial Research in which they were required to investigate the possibilities of maintaining the harbour entrance channel at certain depths and to find some means to stabilise and improve the Durban beaches.

1.1 Early History

In the period 1851-1903 harbour entrance channel works initiated disturbance to the beach equilibruim, causing the beaches to progress generally seawards. It was thought that this was the result of greater protection against swells from the south.

However, increase in the harbour channel depth over the period 1903--1926 caused beach losses north of Vetch's Bight, whilst in that Bight itself further deposition took place. (See Fig. 1). From 1905 onwards sand has been dredged from a sand trap to the south of the harbour entrance (Cave Rock Bight) and since 1925 the dredging rate has been relatively constant at about 600 000 m^3 per annum. Subsequent to 1926 more deposition occurred in Vetch's Bight but the general beaches continued to erode and in 1935 the Council commissioned the first sand pumping scheme with a view to nourishing the South and Central Beaches.

Sand was delivered by the South African Transport Services (S.A.T.S.) dredgers from the mooring at the North Pier to the Vetch's Pier area from where it was re-dredged by the Council scheme and pumped northwards as far as the present day South Beach.

1.2 Post-War Period

Erosion of the northern beaches continued and in the period 1950-1953 sand was pumped directly to Vetch's Bight from an area to the south of the South Pier by means of a submarine pipeline across the harbour entrance. Owing to insufficient sand collection within reach of the dredging plant, the original system with the S.A.T.S. dredgers pumping sand from the North Pier was resumed.

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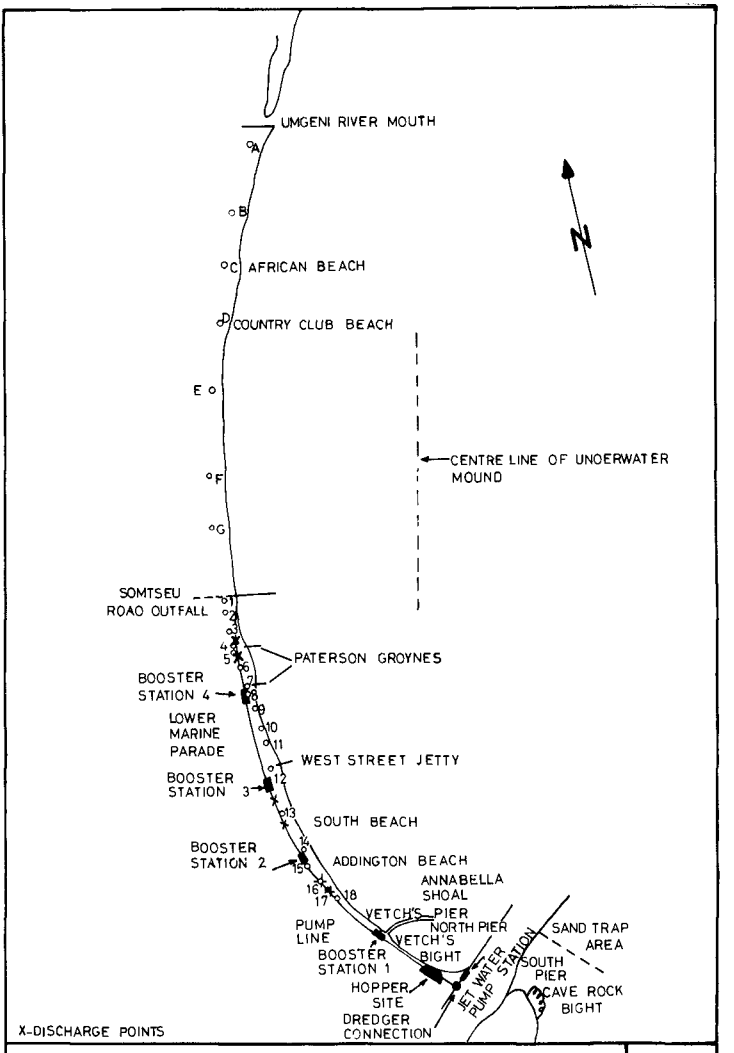


BEACH RENOURISHMENT IN THE SOUTHERN AREA — FIG 1

The two Paterson Groynes were built between 1954-1956 in the hopes of stabilising the Central Beaches but this was not realised.

Over ths yeare most of the material dredged by the S.A.T.S. has been dumped in a specific area at sea, called the "Dump" and it has besn found that this tends to focus wave energy, under certain conditions, near the Paterson Groynes.

1.3 Recent Developments

As was stated previously, the C.S.I.R. was commiesioned in 1961 to investigate, in depth, Durban's beach problems and several recommendations were made after extensive field and model studies. However, a further C.S.I.R. report was submitted to the Council in 1964 recommending that an underwater, offshore mound be constructed using S.A.T.S. dredgings. It was considered that the mound would offer good protection to the beaches by reducing incoming wave energy and it was thought that the beaches would improvs as a result of the presence of the mound. The mound was constructed between 1966 and 1974 but could not be raised to its full design height mainly because of the draught requirements of the dredgers.

However, further studies showed that the mound was not as effective as first thought and the littoral drift continued. The area to the eouth of Somtseu Road was subject to long term erosion at the rate of 70 000 m^3 per annum and the area to the north of Somtseu Road was in a long term state of equilibruim.

After correlation of the voluminous previous reports and findings, and of the considerable field data which had been collected as part of the monitoring programme, the C.S.I.R. submitted in 1977 a report outlining firm recommendations for a beach restoration scheme. Basically these were as follows:-

(i) The mound should not be completed to its design dimensions.

(ii) Establish a controlled zone covering the area 40 m landward of the 1977 highwater line throughout the Bight area; permit no building within this zone; and provide a stockpile of suitable renourishment material for use during storm conditions to protect critical areas.

(iii) Provide an initial beachfill to the area south of the Paterson groynes to restore these beaches to a more acceptable width.

(iv) 90 000m^3 of Cave Rock Bight material should be dumped annually on the beaches south of Somtseu Road, i.e. 60 000 $m^3/yr.$ on Addington and South Beach and 30 000 $m^3/yr.$ on North Beach.

(v) The Paterson groynes should be replaced by two low level structures. Subsequently, it can be decided whether further such structures should be constructed.

1.4 Action Taken by Council

The Council accepted (i) above and immediately put into effect (ii). It was decided in princple that (iv) should be handled by a conventional by-pass sand pumping scheme utilising the S.A.T.S. dredgers, as in the past. The technical feasibility of the construction of low level groynes is being investigated by a private firm commissioned by the Council.

Some 600 000 m^3 of beachfill was supplied by contract dredger to the Addington and South Beach areas during August and September 1982. This contract was negotiated with an overseas consortium working in Richards Bay at the time and the cost to the Council was about R2,3 m. This involved a trailer cutter suction dredger dredging material from an area seawards of the sand trap and pumping it ashore along a temporary pipeline from the S.A.T.S. dredger connection. Work was on a round-the-clock basis and usual output was about 20 000 m^3/day.

1.5 Programme for the Sand Pumping Scheme

The general conceptual design of the Durban beaches sand pumping scheme was finalised early in 1980 and immediately thereafter the detailed design work started. Tenders for the supply and installation of the mechanical/electrial equipment were invited in early 1981 and in April 1981 this contract was awarded on a "design and construct" basis, the City Engineer's Department having set out the technical concept of the scheme, the required output, concentrations, etc.

Shortly thereafter the civil and architectural contracts were put in hand and the commissioning of Stage I took place during August/September 1982. Commissioning of Stage II will take place in mid 1983.

2 Description of Scheme

2.1 Overall Concept and Modus Operandi

The focal point of the scheme is the hopper/administration site which lies near the North Pier. In this site are the tastefully designed administrative building which also houses the first booster station and the semi-circular reinforced concrete hopper which will receive and temporarily store sand from the S.A.T.S. dredgers. As stated previously the S.A.T.S. dredgers carry out maintenance dredging in the sand trap immediately to the south of the South Pier, generally dumping this material out to sea in a depth greater than 60 m. Alternatively, the vessel may tie up at the dredger connection at the North Pier and pump the sand through the "short line" to discharge into the Council's hopper.

Against the historical backdrop of the problem an agreement has been concluded with the S.A.T.S. in which they have undertaken to furnish 50 000 m^3 of sand per annum, free of charge. Any sand pumped in excess of this will be charged for at a rate of about R2,00/m^3.

Initial Beach Fill : Southern Beaches - Before

Initial Beach Fill : Southern Beaches - After

General View of Hopper/Administration Site.

Jet Water Station in Harbour Entrance.

The sand will then be re-dredged from the hopper by means of equipment housed on a mobile bridge by the injection of water pumped from the nearby jet water station, and delivered to the first booster station. From there the sand/water mixture will be boosted to four further stations with the final discharge point being near the Somtseu Road stormwater outfall. Sand can be discharged onto the beaches at a number of intermediate sites. The C.S.I.R. recommended that a minimum of 70 000-100 000 m^3 of sand is required on the beaches south of Somtseu Road annually to maintain the status quo and the scheme is designed to provide this quantity plus an anticipated 100 000 m^3 per annum to build up the beaches.

Booster stations are about 700 m apart to ensure unformity of equipment and the pumping main is a H.D.P.E. (high density polyethylene) pipe of 400 mm O.D., Class 6,3. The system has been designed to deliver a maximum concentration of 30% by volume. Total length of the pumping main is some 3,5 km and it should be noted that the entire scheme is automated and will be controlled from the hopper site. The power and signal cables run along the beach on the same route as the pumping main. The S.A.T.S. dredgers will deliver about 2000 m^3 of sand into the hopper at a time (total capacity 4 000 m^3), and this material will then be pumped onto the beaches (where required) at some 300 m^3 per hour in an 8 hour shift.

Total cost of the scheme, including the first two low level groynes and the initial fill is expected to be in the region of R10 000 000.

2.2 Mechanical and Electrical Equipment

2.2.1 Electrical supply and criteria

The supply in the area from the electrical grid is 11 kV and considering the stringent specification in relation to noise levels in residential areas it was decided to lay down that all motors were electric. The 11 kV supply is stepped down at the hopper site to 6,6 kV for the main booster station motor and to 400 V for the jet water pump motor, the dredge pump and other ancilliary equipment, for example drainage pumps, ventilation fan motors, etc. The remaining booster stations are all fed by landline from the hopper site (6,6 kV) with the respective ancilliaries at each station being catered for by separate 400 V feed.

Control of the scheme is by electrical signal transmitted by means of a "hard wire" system.

2.2.2 Mechanical data

2.2.2.1 Jet water station

The jet water pump is a vertical industrial turbine pump, the motor being rated at 150 kW and capable of delivering 1 800 m^3 of sea water per hour at a head of 18 m at 985 r.p.m. This is a mixed flow pump (nominal size 450 mm) and the impeller is manufactured from a special cast iron alloy known as Ni-resist. Other elements of the

View of Bridge Showing Control Cabin and Underslung Dredge Pump.

Jetting and Dredging Nozzles.

pump are also selected to resist corrosion, e.g. the column is Ni-resist, shaft stainless steel.

This pump station, as with all the other stations of the scheme, is force ventilated to dissipate heat generated.

2.2.2.2 Dredge pump unit

The dredge pump is underslung on the mobile bridge to ensure proper operation and is a centrifugal type slurry pump driven by a motor developing 185 kW, delivering 1 750 m^3 of sand/water mixture per hour at a head of 10-11 m at 390 r.p.m. The pump is belt driven and is identical to the main booster pumps.

2.2.2.3 Booster pump stations

The booster units (total of five) all consist of a centrifugal type slurry pump coupled to a motor rated at 450 kW, also delivering 1 750 m^3 of sand/water mixture per hour at a head of 30-35 m at 585 r.p.m. Here the motors drive the pumps through poly-vee drive belts. Nominal size of the pumps is 350 mm and materials of interest are:-

Impeller and casing - "MYTAK 1001"
Shaft - EN 8

Figure 2 shows a typical internal plan of a booster station.

3 DESIGN ASPECTS

3.1 Hydraulic Design

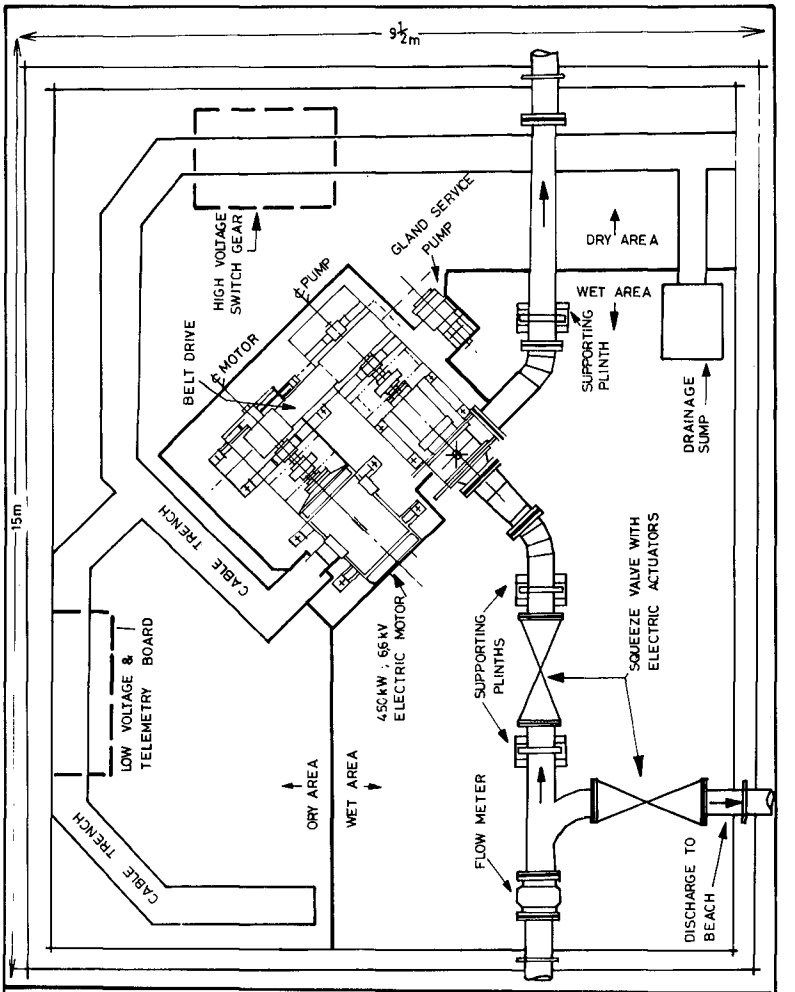
The design of the scheme is based on the calculation of critical velocity using the formula derived by Durand and the various parameters involved are dependent on the sand particle size and grading, the concentration to be pumped, the specific gravities of the solids and transporting fluids and the pipe diameter. The formula takes the following form:-

$$Vc = Fl\sqrt{2gD\,\frac{(S-Sl)}{(Sl)}}$$

where Vc = critical pipeline velocity.
Fl = factor dependent on particle size and concentration.
g = acceleration due to gravity.
D = pipe diameter.
S = S.G. of solids.
Sl = S.G. of transporting fluid.

The power requirement was then derived taking into consideration the various losses and safety margins.

In calling for tenders for the supply and installation of the mechanical and electrical plant, the City Engineer's Department specified broadly the criteria to be met by the scheme, amongst



TYPICAL INTERNAL PLAN OF A BOOSTER STATION

FIG 2

View of Panel in Control Cabin.

Typical Booster Motor and Pump Set.

others that it should be capable of pumping concentrations of slurry from 0% to 30% of sand of volume. It was therefore the successful tenderer's responsibility to ensure that these criteria were met and that the scheme operated as designed.

3.2 Selection of Pipe Material

At the outset it was decided that the pipeline should be made of a material which had the following properties:-

(i) Extremely resistant to abrasion.
(ii) Robust.
(iii) Easy to handle.
(iv) Good cost/benefit.
(v) Resistant to corrosion.
(vi) Easily jointed.
(vii) Locally manufactured (availability).
(viii) Flexibility.

After an extensive literature survey and a study of a system already in operation at Richards Bay the choice of high density polyethylene was made. H.D.P.E. pipe scored high in all the above properties and although more expensive than, say, plain steel, was not by any means the most expensive material available and by all accounts appeared to have at least equivalent resistance to internal abrasion.

The valves on the line are all the squeeze type with butyl-type rubber sleeves with helicoil wire reinforcing and have remotely controlled, electrically driven actuators.

The pipe was generally heat welded into 39 m lengths which were then joined by means of stub ends and galvanised steel backing flanges. Stainless steel studs (grade 316) are used throughout for bolting the line together. The long term resistnce to corrosion of this jointing system in the beach environment will be closely monitored.

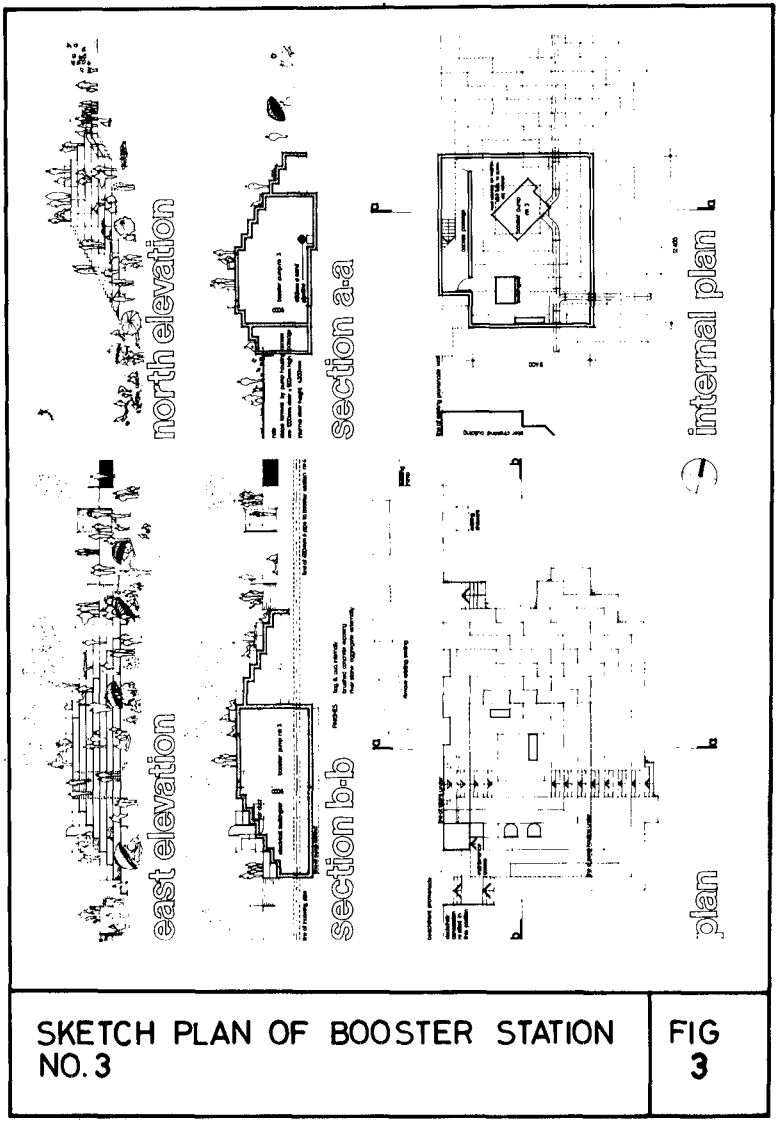
3.3 Architectural Treatment

Each of the buildings relevant to the scheme were handled separately and were designed to blend in with their individual surroundings. All were designed by the Architectural Branch of the City Engineer's Department except the hopper site building which was conceptually designed by the in-house architects, but owing to volume of work, a firm of private architects was commissioned to bring the project to completion.

Great care had to be taken with these structures to ensure that they would complement the Durban Beachfront Development Plan which is in the process of finalisation. The photographs of booster stations 1 and 2 and the figures 3 and 4 of booster stations 3 and 4 show the designs. Of particular importance was the choice of external finishes which had to combine ruggedness with an aesthetically pleasing product. Of interest is the architectural treatment of the outer wall of the hopper which sports abstract scenes painted with a highly resistant epoxy compound.

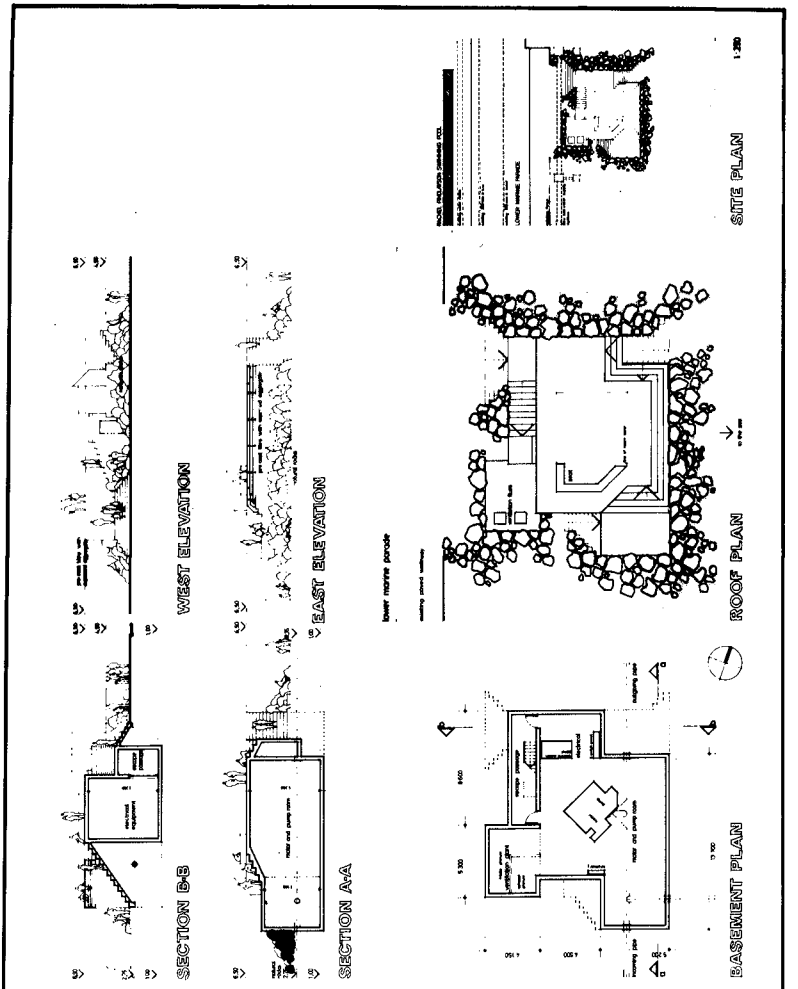
View of Booster Station No. 1

View of Booster Station No. 2



SKETCH PLAN OF BOOSTER STATION NO. 3

FIG 3



SKETCH PLAN OF BOOSTER STATION NO. 4

FIG 4

Special attention was paid to sound attenuation techniques as most of the etructures are in a seneitive locality being a combination of residential, hospital and recreational areas. It was also decided to make an attempt to reduce the transmission of vibration from the motor sets to the outer walls and roofs of the booster stations by providing completely separate foundations for the motor sets. Each motor pump base slab is on a separate pile group and the slab itself ie ieolated from the reet of the station floor slab. Noise levels were limited to 60 dB at 2 m from the structures.

To help reduce the noise levels outside the stations, walls and roofs are of reinforced concrete, solid wooden double doors are used and the ventilation inlets and outlets all pase through special muffler boxes to attenuate sound.

3.4 Civil Engineering Structures and Related Activities

The civil side of the booster stations and the hopper site building was handled by the Materials and Structures Division of the Roads Branch of the Depratment and included all reinforced concrete design as well as the requisite piling designs. The pile system of each building was designed to withstand a certain depth of scour resulting from abnormal sea attack, even though this is unlikely to occur.

The reinforced concrete sand storage hopper and the jet water station were implemented by "design and construct" contracts and had to match in with the architectural and/or mechanical/electrical requirements. The laying of the HDPE pipe and cables was handled Departmentally.

3.4.1 Sand storage hopper

This structure has a rectangular cross-section and is roughly a semi-circular annulus eubtending 152o at its centre. Centre line length of the hopper ie 109 m, depth ie 5,5 m, width 13 m and inside radius 34,15 m. The hopper can accommodate two loads from the SATS dredgers representing some 4 000 m^3 of material. Invert level of the hopper is at - 2,1 m msl and to resist buoyancy a system of tension piles was employed. In drastic instances of scour these piles can also easily double as normal compression piles to support the hopper. Static water level in the hopper is +2,4 m msl.

The hopper is simply filled by one inlet pipe at the one end, this being the discharge directly from the dredger. At full capacity the sand lies at a gradient of about 1/20 along the length of the hopper. The overflow is at the other end of the hopper and this is contained in a channel which routes the water directly back into the sea. Adequate scour protection is provided at the seaward end of the overflow channel.

Along the inner curve of the hopper is a water proof trough of 3,7m depth to accommodate the dredge pump which is mounted slung under the bridge. The top of the inner hopper wall is finished with an epoxy aggregate grout to a close tolerance to allow the bridge

wheels of bonded rubber to run smoothly and to give good operational life.

3.4.2 Jet water station

The conceptual design of this station was to give the effect of a submarine conning tower. The superstructure itself presented no problems but the founding on the North Pier was difficult as the pier was constructed some considerable tims ago and basically consists of a rubble core and loose stone pitched side slopes.

Finally, a portion of the side slope was fully grouted (under water) and the vertical column to house the pump was pre-casted and grouted into position. The superstructure was then cast on top of the column and fixed to the pier by means of grouted bars.

3.4.3 Pipe laying

To tie in with Phase I of the scheme, the jet water line from the jet water station to the hopper site (H.D.P.E., 450 mm, Class 4) and the pumping line (H.D.P.E., 400 mm, Class 6,3) from the hopper site to the West Street Jetty area was laid. Because of the high number of Contractors and sub-contractors already on site it was decided to lay the pipeline using Departmental labour. The gangs and equipment were more amenable to a "stop-start" work situation which resulted from tie-in to booster stations, beach area availability, etc.

By and large the pipe was laid in the highest part of the beach prism with approximately 600 mm to 800 mm of cover. The jointing system has been described under section 3.2. The supply Contractor welded the pipes into the 39 m lengths on site and these were then taken over in batches by the Department, and transported along the beach to the required laying area.

The laying operation was generally easy. It had been decided to lay the 6,6 kV main feed cable and the signal cable at the same time as the pumping main and in the same trench. After the trench was excavated (some 2 m bottom width) the services were merely laid at the requisite centres and the backfilling operation followed immdiately to ensure as little open trench as possible remained overnight on the beach. A laying rate of up to 100 m/day was commonly achieved. Finally the laid pipe was hydraulically tested to 1,5 times working pressure.

3.5 Control Systsm

The entire scheme is controlled by one man from the control cabin and is started merely by initiating one signal. Each booster station is started on flow, i.e. as it is recorded that there is flow just on the upstream side of a station, it starts. There is an intsrlocking system within each booster station which allows it to start up in a definite sequence as follows:-

(i) Inlet ventilation fan.
(ii) Extract ventilation fan.

(iii) Gland water pump.
(iv) Main motor.

Pressure starting devices were not used because of instrument sensitivity problems.

If any component breaks down the system shuts down automatically and if an overload should result an audible alarm sounds in the cabin. To stop the system the Superintendant only has to cancel the original signal.

4 MONITORING

4.1 History of Monitoring

Monitoring of the beaches was initiated by the C.S.I.R. in the early sixties and included the usual facets of this operation. The C.S.I.R. continued to organise and control all monitoring up until 1976 when their Coastal Engineering staff in Durban were transferred to Stellenbosch. It was considered logical, therefore, at the time, to hand over all monitoring functions to the City Engineer's Department as it was apparent that the City Council would be taking over control of the whole beach aspect progressively in the ensuing period.

Since 1976 virtually all monitoring functions have been controlled and organised by the Department and the scope of the programme has been widened considerably. A brief description of each aspect follows.

4.2 Visible Beach Survey

This is carried out each month by a firm of private surveyors. A total of 32 sections is surveyed and visible beach volume is calculated and recorded. Each section is defined by a co-ordinated beacon generally fixed at the upper part of the beach, the readings being taken from these beacons down to at least Chart Datum. The 32 sections cover the beaches from Addington to the mouth of ths Umgeni River. A plot of these volumes shows a long term degradation of the visible beaches.

Recently it was decided to establish six more sections north of the Umgeni mouth covering the beaches up to the northern City boundary. These sections are very widely spaced and are only read every 2 months at this stage to keep an overall check on the beaches there.

4.3 Nearshore Hydrographic Survey

Every month, between section 2 and 12 a shallow water survey is done covering from Chart Datum (approximately) to about 5 m of water. The survey team consists of the same private surveyors as above assisted by Departmental technicians and a motorised rubber dingy manned by 2 lifesavers from the Parks, Recreation and Beaches Department.

Soundings are taken by hand line and as all parties concerned are in radio contact, a simultaneous fix can be made. Rssults are plotted on a format, which, at a glance, shows the relative movsment of any particular contour.

Although this is a rather unsophisticated method and has only been done for about 2 years, practice and good teamwork has ensured acceptabls accuracy.

4.4 Offshore Hydrographic Survey

This survey basically covers the area from the surf zone to just seaward of the offshore mound. Originally these surveys were initiated by the construction of the mound and were all dons by the C.S.I.R., at first at frequent intervals but latterly every year only. In early 1981 this function was taken over by the Departmsnt and at pressnt the survey is being carried out quarterly again, partially to consolidate the team and also to satisfy all parties concerned of accuracy and consistency.

The Natal Anti-Shark Msasures Board hire the Dspartmsnt one of their boats and crew for the "water" side and once again the shore team consists of ths surveyors and Departmental Technicians. A sophisticated echo sounder is mounted in the boat and a continuous trace is produced on every run which co-incide with the sections mentioned in 4.2 (excluding those to the north of the Umgeni). Again, all are in radio contact and simultaneous fixes can easily be made. Additional sections are run over the northern end of the mound to assist the C.S.I.R. in their latest refraction studiss.

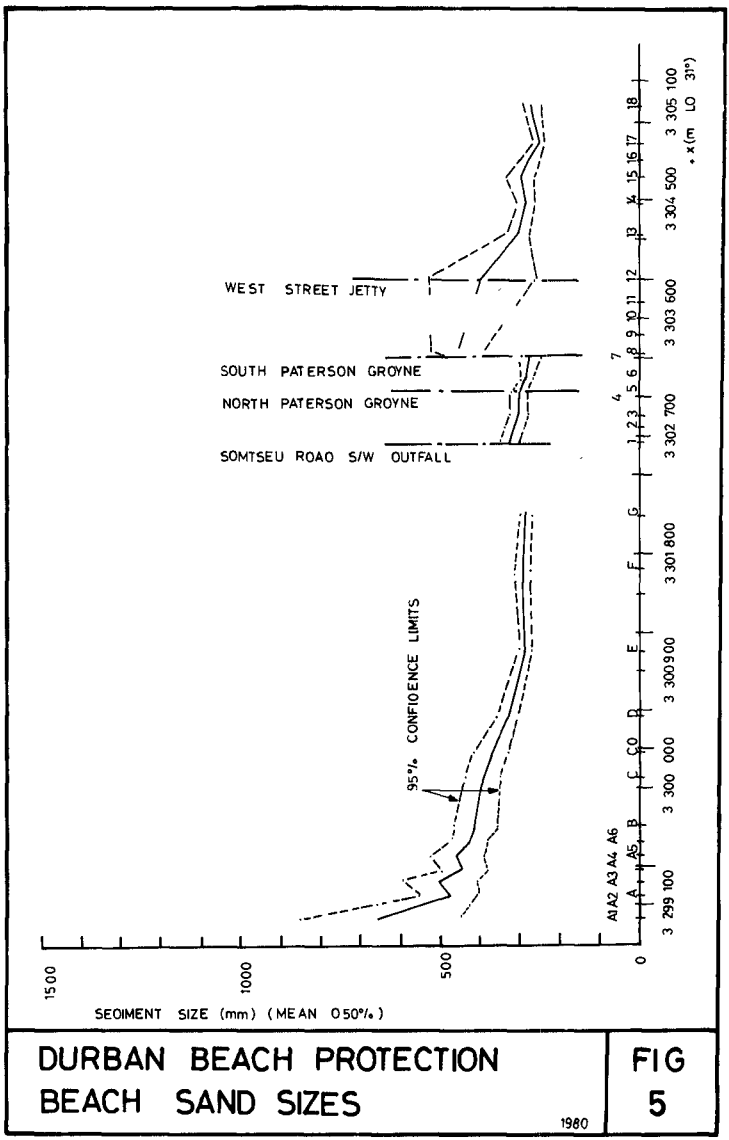
At this stage it is fslt that accuracy is within 250 mm either way and as this is improved so will the frequency of survey be dscreased, initially down to twice a year and possibly evsntually to once a year. The results are plotted as a contoured bathymstric chart.

4.5 Beach Sand Size Sampling

Sand samples are taken from the inter-tidal zone every month at each of the sections betwsen Addington and the Umgeni mouth. Four samplss are taken at each location, one from the high water mark, one from the low water mark and two from the third points (approximately) in between. These are not mixed together, but are analyssd separatsly, at present by a local soils laboratory, undsr annual contract.

It may be dscidsd in the future to mix the samplss from each section as there appears to be a trend towards this. Furthermore, the process will be speeded up by the use of a vsrtical tubs typs (water filled) rapid sand grader.

Figure 5 shows sand size distribution along the beaches.


WEST STREET JETTY
SOUTH PATERSON GROYNE
NORTH PATERSON GROYNE
SOMTSEU ROAO S/W OUTFALL
95% CONFIDENCE LIMITS
SEDIMENT SIZE (mm) (MEAN 050%)
1500
1000
500
0
A1 A2 A3 A4 A5 A6
A B C D E F G
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
3 299 100
3 300 000
3 300 900
3 301 800
3 302 700
3 303 600
3 304 500
3 305 100
x (m LO 31°)
DURBAN BEACH PROTECTION
BEACH SAND SIZES
1980
FIG
5

4.6 Wave characteristics Recording

For many years the C.S.I.R. had a clinomster set up south of the harbour entrance to measure wave direction, height and period. This instrument was read by a private person who was trained for the work. When the Department took over the monitoring function this system was not interfered with and recently a second clinometer was installed in a tall hotel on the beachfront roughly oppoeite section 3.

The clinometer is a relatively simple instrument produced by the C.S.I.R. and is read 3 times a day. Although not the most accurate of instruments, it does provide a good and reliable insight into and data of wave direction, height and period.

In the middle of 1981, a wave rider bought by the University of Natal, Durban, was installed on the landward side of the mound. The monitoring side of this is handled by the Department whose staff make daily checks on the instruments and change and forward the magnetic and paper tapes to the relevant authorities. Periodically, checks on the wave rider itself are carried out from a boat and of course, every nine months it is uplifted for cleaning, checking, battery change, etc.

4.7 Deep Sea Sand Sampling

This operation will run hand in hand with the tracer sand aspect and samples will be taken on a grid pattern, initially every 3 months. It is thought that a grab-type sampler will be best and that a sea bed surface sample will be sufficient. However this may have to be modified in the light of experience when the schsme is undsr way.

4.8 Wave Refraction Analyses

Since the early sixties, the C.S.I.R. have done numerous wave refraction studies of the Durban Bight. Because of the techniques involved, the past studies were probably relatively "coarse" and recently the C.S.I.R. have developed, it is hoped, a much more reliable programme to handle areas such as Durban.

Previous studies showed that the old SATS dump helped to concentrate wave energy in the vicinity of the Paterson Groynes. The new study may confirm this and it may give pointers as to which are the best localities for dumping sand with the sand pumping echeme. Of particular interest will be the wave patterns around the northern end of the offshore mound as it is thought that certain wave directions will be so refracted as to give rise to undeeirable concentrations of energy on parts of the northern beaches.

4.9 Current Surveys

Attempts have been made to establish current patterns in the sea area landward of the mound. Floats with drogues some 4 m below the surface have been used but to date no significant results can be pressnted as the drogue movemente have not shown a sufficiently

reliable pattern. It has been proposed that the SATS dredgers dump material in the area landward of the mound but any peculiarities in current velocity here must be known beforehand.

4.10 Tracer Sand

At this point in time it is thought that the injection of 1 m^3 of tracer sand per load of 2 000 m^3 will be sufficient. A traditional paint-coated sand will be used but results of finds will have to be treated on a strictly qualitative basis. Depending on the results, a different type of tracer may have to be employed in the future.

5 RESULTS

At present, commissioning of Phase I is taking place. A few small problems have arisen but these are being rectified by the relevant Contractor or Sub-Contractor and it is expected that Phase I will shortly be taken over by the Department. The operation of the scheme appears to be very easy and maintaining a steady concentration presents no problems. Unfortunately, therefore, no results can be presented at this stage.

6 CONCLUSION

No conclusions or recommendations can be offered until the scheme has been operating for some time.

7 ACKNOWLEDGEMENTS

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