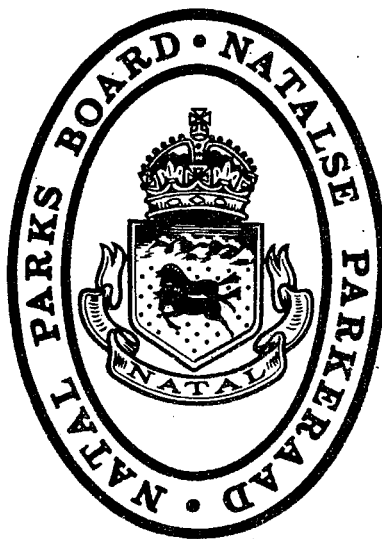


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LAKE ST. LUCIA RECLAMATION SCHEMES :
ENGINEERING PROGRESS AND PROPOSALS

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LAKE ST. LUCIA RECLAMATION SCHEMES :

ENGINEERING PROGRESS AND PROPOSALS

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1. INTRODUCTION

The prime objective of the engineering work carried out at Lake St. Lucia by the Reclamation Branch of the Provincial Building Services Department, Natal Provincial Administration, is the preservation of the lake system. In addition provisions for recreation activities will have to be made, especially in the St. Lucia Estuary area, because this area should be regarded as a holiday resort and recreation centre.

Basically the problems of the St. Lucia Lake system are : The rate of sediment deposition and the shortfall of fresh water inflow during certain climatical periods. Especially the siltation in the lake will have the most detrimental effects in the long term on the salinity regime in the lake system.

At the start of reclamation work in 1952, the emphasis was laid on the siltation problem in the St. Lucia Estuary/Lower Umfolozi River area. During the period of drought from 1965-1971, when salinities in the northern part of the lake system did rise beyond tolerable limits, the emphasis was shifted to the introduction of additional fresh water into the lake system at its southern (Umfolozi River) and northern end (Mkuze River).

As a result of all the work carried out over the years, the southern and most vital compartment of the lake system only just survived the crisis period 1970-1971. Due to a change in climate (wet cycle), conditions fortunately improved since then and the lake is at present in a very healthy state. However conditions can deteriorate again and it is therefore necessary that additional engineering works be undertaken to safeguard the southern compartment and to improve conditions in the northern lake area during prolonged droughts.

During the past eight years a considerable amount of research and investigations have been carried out on the technical aspects. This was recommended by the "Commission of Inquiry into the alleged threat to animal and plant life in St. Lucia Lake", which carried out comprehensive investigations during 1964-1966. As a result of all this research, some firm engineering proposals can now be made, which will be discussed in this paper.

Total expenditure on the lake St. Lucia project (1952-1975) stands at R 3 253 000 of which R 1 853 000 has been spent over the past eight years. During this last period (1968-1975) R 223 000 or 12% of the expenditure has been spent on research and investigations.

2. SEDIMENT DEPOSITION AND PROPOSED REMEDIAL MEASURES

Due to soil erosion in the catchment areas of the rivers flowing into the St. Lucia lake system, large quantities of sediments have been deposited in the lake. As a result of the siltation the lake is at present only about 1 metre deep below mean sea level. The Commission of Inquiry concluded in their report, that there is danger of the lake being filled up by sediments to sea level within the next 100 to 200 years. This period may even be less if soil erosion in the catchment area's is not checked. With proper soil conservation measures, however, the life of the lake may be extended indefinitely.

2.1 SEDIMENT DEPOSITION IN THE ST. LUCIA ESTUARY AND NARROWS LINK WITH THE SEA

The life in the lake system is dependant on an open connection to the sea (migration of aquatic life and sea water inflow). At the start of reclamation work in 1952, this link was blocked due to sediment deposition from the Umfolozi River. It was then decided to divert the Umfolozi River completely from the Estuary, to dredge and maintain an adequate link between the sea and the lake and to stabilize sand dunes and the estuary mouth. A considerable amount of work has been carried out and this has led to the existing situation of the St. Lucia Estuary area as shown on figure 1. The total amount of spoil dredged now stands at $10,1 \times 10^6 \text{ m}^3$ of which $5,6 \times 10^6 \text{ m}^3$ have been dredged during the past eight years.

2.1.1 SEDIMENT DEPOSITION IN THE ST. LUCIA ESTUARY MOUTH AND PROPOSED REMEDIAL MEASURES

In the past the Umfolozi River and the St. Lucia Estuary flowed in a small bay which had one common mouth to sea. This common mouth closed periodically but was broken open again during floods. As a result of drainage of the Umfolozi Flats (natural swamp filter) for sugarcane planting, in addition to littoral drift, silt was carried into the bay. Upon contact with sea water, silt deposition was accelerated, the bay became shallower and silting gradually extended into St. Lucia Estuary. This led to the decision to construct a separate mouth for the Umfolozi River.

The existing St. Lucia Estuary mouth tends to close regularly because the littoral drift carried in on the flood tide is not fully scoured out on the ebb. Continuous net shoaling thus decreases the tidal flow until the mouth is eventually blocked. In 1963 the Council for Scientific and Industrial Research recommended the building of a so called groyne-berm scheme to improve conditions in the estuary mouth. Several steps have been taken that relate to the C.S.I.R. recommendations. Two groynes have been built on the alignments and locations

proposed by the C.S.I.R., but the hardened berms have not been built (see figure 1). The groynes built of pockets filled with sand and cement, with a dolosse protection at the seaward end, were completed in April, 1969. They have helped to fix the Estuary mouth, but the natural existing scour channel meanders in between the groynes, depending on sand deposits in the mouth and Estuary. Despite the improvements, the mouth closed again in the winter months of 1970 and 1973. However the mouth was closed only for a period of three months, because it was re-opened artificially with the dredging equipment. In 1973 the entire sand trap area shown on figure 1 was completely filled with sediments (littoral drift). In total 682 000 m³ (471 000 m³ in 1973 and 211 000 m³ in 1974) sand was dredged and discharged mainly on the Southern bank. In 1975, 93 000 m³ sand was dredged in the sand trap to maintain the area open to the sea. This preventative maintenance dredging however cannot prevent the mouth from closing again, because due to wave action and strong currents it is not possible to dredge in the actual mouth area and just offshore when the mouth is still open.

It is possible, although at high costs, to try to make improvements to the existing mouth, but it is very difficult to predict beforehand what the effect will be with regard to the amount of maintenance dredging in the sand trap and the frequency of closing of the mouth. The most obvious possibilities to make improvements to the existing mouth are :

- (a) The construction of the hardened berms between the existing groynes as recommended by the C.S.I.R. The Administration was advised however not to implement the berms, because of strong doubts about the effect of the berms and the high cost to construct and maintain them.
- (b) The lengthening of the present northern groyne, the construction of a complete new sand tight southern groyne parallel to and at a short distance from the northern groyne, to create a narrow scour channel and the dredging of a large off-channel tidal basin near the mouth (see figure 2). Approximately 500 metres of groynes would have to be built at an estimated cost of R 500 000 (average of R 1 000 per metre length). To construct the off-channel tidal basin, approximately 2,5 x 10⁶ m³ would have to be dredged.

Numerous other suggestions have been made over the years to try to keep the estuary mouth open. Proposed improvements such as the construction of sluice gates, pumps, compressors etc. in the mouth area should all be considered as impractical and too expensive to construct and/or to operate.

An alternative solution to create a permanent open mouth is to construct a complete new estuary mouth at a more feasible location along the coastline. A very good

location exists just north of Maphelane, because of possible protection against littoral drift by a natural rockledge projecting out to sea. The new estuary mouth will then be combined with the Umfolozi River mouth as was the situation in the past. (see figure 3). However this combined mouth should only be considered when storage dams have been built on the river, so there is no longer danger of serious siltation anymore. Some form of breakwater/groynes system will be required to prevent the combined mouth closing due to littoral drift. The area between the breakwaters and the coast could be used for open mooring. A new estuary from Honeymoon Bend towards the combined mouth and a large off-channel tidal basin would have to be dredged. If the proposed combined mouth could be made navigable for small craft, ocean going yachts etc. there is a large area available in the lower river delta for marina development. The existing estuary mouth would have to be closed and that area could be developed for recreation purposes.

A thorough environmental engineering investigation of the area and a feasibility study should be undertaken for the proposed new scheme. Until more knowledge is gained about the new scheme, no costly improvements (groynes) will be made to the existing estuary mouth. Maintenance dredging will continue and in addition the off-channel tidal basin will be dredged when new dredging equipment is in operation in a few years time. This tidal basin could form part of the proposed new scheme. If the existing mouth should close again it will be re-opened with the dredging equipment. A closure of the mouth over a short period (two to three months) is not considered as dangerous, because an alternative link with the sea could be implemented via the existing channel, which links the Umfolozi River mouth with the Estuary (see figure 1). The Umfolozi River mouth does not close as frequently as the Estuary mouth.

2.1.2 SEDIMENT DEPOSITION IN THE NARROWS LINK WITH THE SEA

The Narrows link between the lake and the sea was also considerably silted up in 1951. This was presumably a result of the Umfolozi River flowing up the Narrows towards the lake, when lake levels were low or the mouth closed. The free movement to and from the sea of aquatic organisms and boats was hampered. It was therefore decided to cut a channel 90 m (300') wide and 1,8 m (6') deep from the Estuary bridge to the lake. Work began on this task at the beginning of 1967 using two cutter suction dredgers. Progress was steady and by the end of 1969 the channel had reached a point 13 km from the bridge. In cutting this channel 2 107 000 m³ of spoil were dredged from the Narrows and Shallows. Because doubts were expressed about the effects of cutting this channel on the lake salinities work was stopped. Only recently the results of model tests have shown that the dredged channel had a negligible effect on lake salinities

(increase of 2 ‰) and lake levels (drop in mean lake level of 0,03 m). The dredged channel had a positive effect in raising the minimum lake level by 0,08 m compared with the undredged situation.

If the existing link between the lake and the sea is considered to be sufficiently wide and deep for the migration of marine life and also for boating, than there is also no need from a technical point of view (sea water inflow) to extend the channel into the main lake and/or to redredge the channel which is at places partly silted up. This is because the proposed scheme to introduce fresh water from the Umfolozi River into the lake system has a much greater beneficial effect on salinities and levels than any manipulation with the Narrows link with the sea. The possibility to create a control in the Narrows will be discussed in Chapter 4.1.

2.2 SEDIMENT DEPOSITION IN THE ST. LUCIA LAKE

The volume of the lake is at present reduced to about $322 \times 10^6 \text{ m}^3$ at E.M.S.L.* as a result of sediment deposition over many years. The lake has a very unfavourable depth - area ratio (depth 1 m, area $328 \times 10^6 \text{ m}^2$ at E.M.S.L.). A change in volume will have an effect on the salinity regime of the lake.

There are a number of proposed remedial measures to improve conditions as well as in the catchments as in the lake itself.

The most important improvement which could be made is to take all possible steps to prevent erosion in the catchments of the rivers flowing into the lake. This was already as a matter of urgency recommended by the Commission of Inquiry. The construction of storage dams in the catchment of the rivers will be effective in reducing the silt load entering the lake, until the dams have filled themselves with sediments. These dams could also be used for the storage of fresh water for release as required during periods of drought (see chapter 3). These dams must be multi-purpose projects, such as the proposed dam on the Umfolozi River, otherwise the costs would be prohibitive.

Improvements in the salinity regime of the lake could also be achieved by measures in the lake itself, to counteract the effect of siltation. These measures are :

- (a) to reduce the surface area of the lake. This would have the effect of decreasing the volume of water lost by evaporation from the lake (decreasing inflow of salt water from the sea). An other advantage is that the inflow of fresh water has a greater effect on a smaller lake.

This could be achieved by creating "polders" in the lake and/or cutting off certain parts of the lake. Due to evaporation the "polders" will dry out and salt pans will be left.

* E.M.S.L. = Datum = Estuary mean sea level.

- (b) To deepen the lake, while maintaining the surface area constant. Such action would not alter the water circulation pattern, but through increased lake volume could dampen the salinity fluctuations in the lake, viz raising the lower salinities and lowering the higher salinities.
- (c) To decrease the surface area and to increase the depth of the lake. This solution is a combination of (a) and (b).

Model tests have shown that only when the lake geometry is drastically changed, will the effect on the salinity be noticeable. This means that large scale dredging works would have to be carried out. The costs thereof are very high, viz. if the lake volume were to be increased by 30%, approximately $100 \times 10^6 \text{ m}^3$ would have to be dredged at an estimated cost of R 70 million (R0,70 per m^3).

3. SUPPLY OF FRESH WATER TO LAKE ST. LUCIA AND PROPOSED REMEDIAL MEASURES

The Commission of Inquiry concluded in 1966 that because present low flows to the lake are not always adequate and with extended usage in the catchment are likely to become less so, an assured and controllable supply of fresh water is necessary to ensure that salinities do not rise too high. It is recommended that the construction of major storage dams in the St. Lucia catchment should be considered so as to assist in providing the necessary guaranteed supply of fresh water during dry periods.

Because of the alarming rise in salinities during the years 1966-1968, the consulting civil engineers Chew, Bowen and Mercer, were instructed to investigate the feasibility of obtaining fresh water from the Umfolozi and Mkuze River. During the period 1969-1971 when salinities were highest, channels were excavated and dredged at the southern and northern end of the lake system, in an attempt to increase the fresh water inflow to the lake. These channels were however not so successful and therefore additional works will have to be carried out to improve the supply of fresh water to the lake. Model tests and calculations have shown, that increasing the fresh water inflow is the most efficient remedial measure.

3.1 SUPPLY OF FRESH WATER FROM THE UMFOLOZI RIVER AND PROPOSED REMEDIAL MEASURES

The Umfolozi River is the largest potential source of fresh water for the St. Lucia lake system, but very little use is being made of the water flowing in this river.

In an attempt to divert fresh water from the river, a 4 km long channel was dredged during 1970 and 1971 linking the river with St. Lucia Estuary (see

figure 1). The channel is about 30 m wide and was dredged to a depth of 1,8 m below Estuary datum (E.M.S.L.). Because both ends of the channel are subject to strong tidal influence there is no head available for the river water to flow towards the Estuary. Besides under normal conditions at incoming tides the sea water is pushing the fresh river water upstreams of the intake point and salt water is flowing into the channel. Only during floods is there enough head available, but the channel is kept closed during the rainy season, to prevent the heavy silt laden river floods from entering the Estuary. The channel serves however a very useful purpose in that it is being used as an alternative link with the sea when the Estuary mouth is closed.

There are two different ways in which the Umfolozi River water could be diverted to the lake, viz :

- (a) via a channel linking the lower river with the Narrows and Shallows. This scheme could be implemented immediately and will use fresh water that otherwise flows out to sea.
- (b) via a channel linking the proposed future storage dam on the Umfolozi river with the Nyalazi river. This scheme is a long term plan and depends on the construction of a dam on the river.

Model tests and calculations have shown, that both schemes will be very beneficial for the entire lake system. Scheme (b) is the best of the two, because it will provide a guaranteed supply of silt free fresh water during dry periods. The latter scheme will result in a salinity gradient (fresh in northern part and sea water in southern part) which is considered as ideal. Scheme (a) will have the opposite effect on salinities. Because scheme (b) is a long term proposal it has been decided to go ahead with scheme (a) in the meantime. Plans have now been finalised to construct an initially 6 km long channel linking the Umfolozi River with St. Lucia Estuary (see figure 2). The intake point on the river for the proposed new channel is much more favourable than that of the existing channel, because it is approximately 8 km upstreams of the river mouth and is not tidal anymore. Because a considerable percentage of the fresh water will be lost to sea at outgoing tides, when supplied in the Estuary south of the bridge, it is proposed to extend the channel to the Mpate River (total length is then 16 km.) Proper intake works, at an estimated cost of roughly R 200 000 are being planned on the Umfolozi River. The estimated time to construct the channel is two years, for the initial 6 km length.

As shown on figure 2 an Everglades scheme consisting of waterways and islands is being planned at the Estuary side of the channel. The main objective of this scheme is to create a tourist attraction for launch tours to observe bird and animal life. Another objective of the Everglades scheme is to create a

storage area at the Estuary side of the channel to prevent salt water from flowing to far towards the river during periods of low fresh water flow in the channel. When the channel is extended to the Mpate River, the Everglades could be separated from the link channel (see figure 3).

Unfortunately a start on the construction of the channel could not yet be made, because of delays in the flooding investigation of the Umfolozi Flats, to determine the effects of the proposed flood protection bank on the flooding of sugar cane lands upstreams along the Umfolozi and Umsunduzi Rivers.

3.2 SUPPLY OF FRESH WATER FROM THE MKUZE RIVER AND PROPOSED REMEDIAL MEASURES

The Mkuze River is the largest river entering the lake. Before reaching the lake at the northern end, the river water has to flow through the Mkuze Swamps. The swamps act as a silt trap and storage area for the heavily silt laden river floods, and for that reason the Commission of Inquiry recommended that the Mkuze Swamps should be protected.

Due to erosion in the Mkuze catchment a large number of blockages in the riverbed had by 1970 formed an obstruction for free flow and very little fresh water reached the swamps. The blockages were removed in the lower river and in an attempt to try to increase the inflow of fresh water at the top end of the lake, where salinities were over 100 ‰, a 13,5 km long channel with a width of about 10 m was excavated during 1970 and 1971 from the Mkuze River near Mpempe pan to the Demezane pan. Over the last 4,5 km the channel follows the existing Mkuze river channel through the swamp. The channel had to be closed in June, 1974, because of considerable erosion in the top end of the channel. The erosion was caused by the fact, that this section was excavated in an area with a too steep gradient.

The main objective to construct a channel through or by-passing the swamps would be to try to divert the smaller flows from the Mkuze River directly into the lake. Major flows will reach the lake naturally as happened from the rainy season 1971-1972 to date. However the total run-off of the Mkuze River during dry years and especially during periods of drought (e.g. the period 1965-1970) is only a small percentage of the total evaporation loss from the lake. Model tests have shown that the benefits of such a channel would therefore be not so great and, more particularly, the costs of a channel by-passing the swamps would be very high.

Diverting the smaller flows of the Mkuze River into the lake would mean that the swamps would be charged less frequently and might not be fully charged, particularly in the southern part, by the end of the summer. The swamp

would therefore be more vulnerable to prolonged droughts.

Model tests have shown that only if a considerable part of the swamps were destroyed, would there be a sufficient increase in the supply of fresh water to improve conditions in the northern part of the lake during periods of drought. This is however unacceptable both from an engineering as well as from an ecological point of view. Because the Mkuze swamps is considered as a delicately balanced ecosystem, which forms an integral part of the whole lake, it was decided that in times of low run-off from the river, priority should be given to maintaining the swamp system. Before any further physical work is considered in the swamps extensive research and surveys are required to investigate the quantity of Mkuze River water that enters the lake, and to predict the effect that any engineering measures in the swamps may have on the ecology of the swamps system and on the supply of fresh water and sediments to the lake.

Conditions in the northern part of the lake system could be improved considerably of course, if an additional supply of fresh water could be provided during dry periods from the dam on the Pongola River.

4. OTHER PROPOSED REMEDIAL MEASURES

4.1 CONTROL OF FLOW OF WATER BETWEEN THE SEA AND THE LAKE IN THE NARROWS LINK

The objectives of such a control are :

- (a) to manipulate the volume of inflowing sea water when lake levels are low.
- (b) to store good lake water (low salinities) when lake level has risen above mean sea level due to run-off and rainfall.
- (c) to control short term movements of water due to wind action.
- (d) to divert all fresh water from the Umfolozi link channel into the lake.

The disadvantage of a control in the Narrows link is the interference with the migration of aquatic organisms between the lake and the sea. This could be overcome by creating a "biological lock" in the Narrows as suggested by Dr. J. Wallace, consisting of two gates at about 5 km distance of each other. Due to the high costs of the gates and anticipated problems in operating the "biological lock", the alternative could be the construction of one gate or barrier and a by-pass channel to constrict the flow. When the gate is closed, migration of aquatic organisms and boating could take place via this by-pass

channel. This channel should have sufficient length and a limited cross-sectional area to ~~construct~~ the flow between the sea and the lake considerably compared with the existing situation. Too high velocities in the by-pass channel are not acceptable for the migration of aquatic organisms and erosion dangers.

The most feasible location for such a combination of control barrier and by-pass channel is the Third Narrows near the Mpate River mouth (see figure 4). This location is far enough away from the sea to have no influence on the tidal movement in the Estuary mouth. All fresh water from the Mpate River could be diverted into the lake, the width of the cross-section at the Third Narrows is the smallest between the sea and the lake and there is sufficient room on the eastern side to construct the by-pass channel.

Model tests have shown that for the control to be effective it would have to be completely closed over a considerable length of time. The length of the narrow by-pass channel should be about 3 km. To what extent manipulating the control has any beneficial effect on water movement by wind action is not yet known.

The feasibility of implementing a control mechanism at the Third Narrows depends on whether the extra benefits over and above the additional supply of fresh water from the Umfolozi River, justify the costs, especially of the construction of the gate or barrier.

4.2 SECOND MOUTH OR PUMPING SCHEME IN NORTHERN PART OF LAKE SYSTEM.

The construction of a second mouth to lake St. Lucia at its northern end would convert the northern part of the lake into a tidal estuary with free movement of marine life into and out of the lake. This would be effective in reducing very high salinities, but permanent conversion of the lake to a salt water lake would have to be accepted by the ecologists. Model studies have revealed that the effect of a second mouth on lake salinities is limited, because of the large surface area and limited depth of the lake. For this reason and the very high estimated cost (between R 30 and R 40 million) to construct the new mouth, this proposed remedial measure should not be considered.

An alternative scheme is the pumping of sea water from the sea into the northern part of the lake, when salinity has reached high levels. Although extremely high salinities in the lake could be obviated in this way, the costs would be enormous. The costs of such a scheme would range from about R 5 million to R 20 million, depending on the flow catered for and whether the pumping is to be done by tidal action or by mechanical pumps. This pumping scheme is not so effective and should therefore also not be considered.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Securing an additional supply of fresh water from the Umfolozi River will improve conditions considerably during prolonged droughts. All other proposed remedial measures are not so effective and/or not feasible or too expensive.

5.2 SEDIMENTATION

5.2.1 A permanently open combined St. Lucia Estuary-Umfolozi River mouth should be constructed in the Maphelana area, but only after flood storage dams have been built on the Umfolozi River. A thorough environmental engineering investigation and feasibility study should be undertaken for this proposed scheme.

5.2.2 The existing Estuary mouth should be kept open and re-opened by dredging in the sand trap area, until the abovementioned scheme under (5.2.1) has been implemented. An improvement should be made by dredging an off-channel tidal basin in the southern bank near the mouth.

5.2.3 No additional dredging should be carried out in the Narrows-link with the sea to improve the inflow of sea water, when lake levels are low. Only maintenance dredging should be carried out if required for the migration of aquatic organisms and/or boating.

5.2.4 Remedial measures against sediment deposition in the lake should be taken in the catchment rather than in the lake itself, because of very high costs and damage to the natural environment.

5.3 FRESH WATER SUPPLY

5.3.1 The proposed new Umfolozi River - St. Lucia Estuary fresh water link channel should be constructed as soon as possible, before a new period of prolonged drought starts. This channel should be extended to the Mpate River mouth area.

5.3.2 If necessary in the future a link should be made between the proposed storage dam on the Umfolozi River and the Nyalazi River to secure an additional supply of fresh water to the False Bay compartment of the lake.

5.3.3 Blockages etc. should be removed from the lower Mkuze River to ensure that the fresh water reaches the swamps. The Mkuze swamps should be protected and no physical work should be considered in the swamps to try to facilitate movement of the river water towards lake St. Lucia, until the results of thorough investigations and research are available.

5.4 CONTROL OF FLOW OF WATER BETWEEN THE SEA AND THE LAKE IN THE
NARROWS LINK

A control gate or barrier at the Third Narrows with a by-pass channel to control the flow of water between the sea and the lake, should not be considered at this stage. Observations should first be made on the effect of the additional inflow of fresh water via the proposed new link with the Umfolozi River on the lake salinities and levels.

T. J. BLOK

JANUARY, 1976.



Forest Reserve

To Mpare
Link Channel

MEOLOZI RIVER
SOFTEN

off-channel
Tidal Basin

New Groynes

PROPOSED MEOLOZI RIVER
SLUIC ESTUARY LINK CHANNEL
AND EMERGENCY ESCAPE

Kwana Ocean

FIG 2



CHIKOY

Wetland Forest Reserve

SEDA

EVEHE

ANENJOKA

Waterfront Development

Off-channel
Tidal Basin

New Estuary

Penetration

CHIKOY

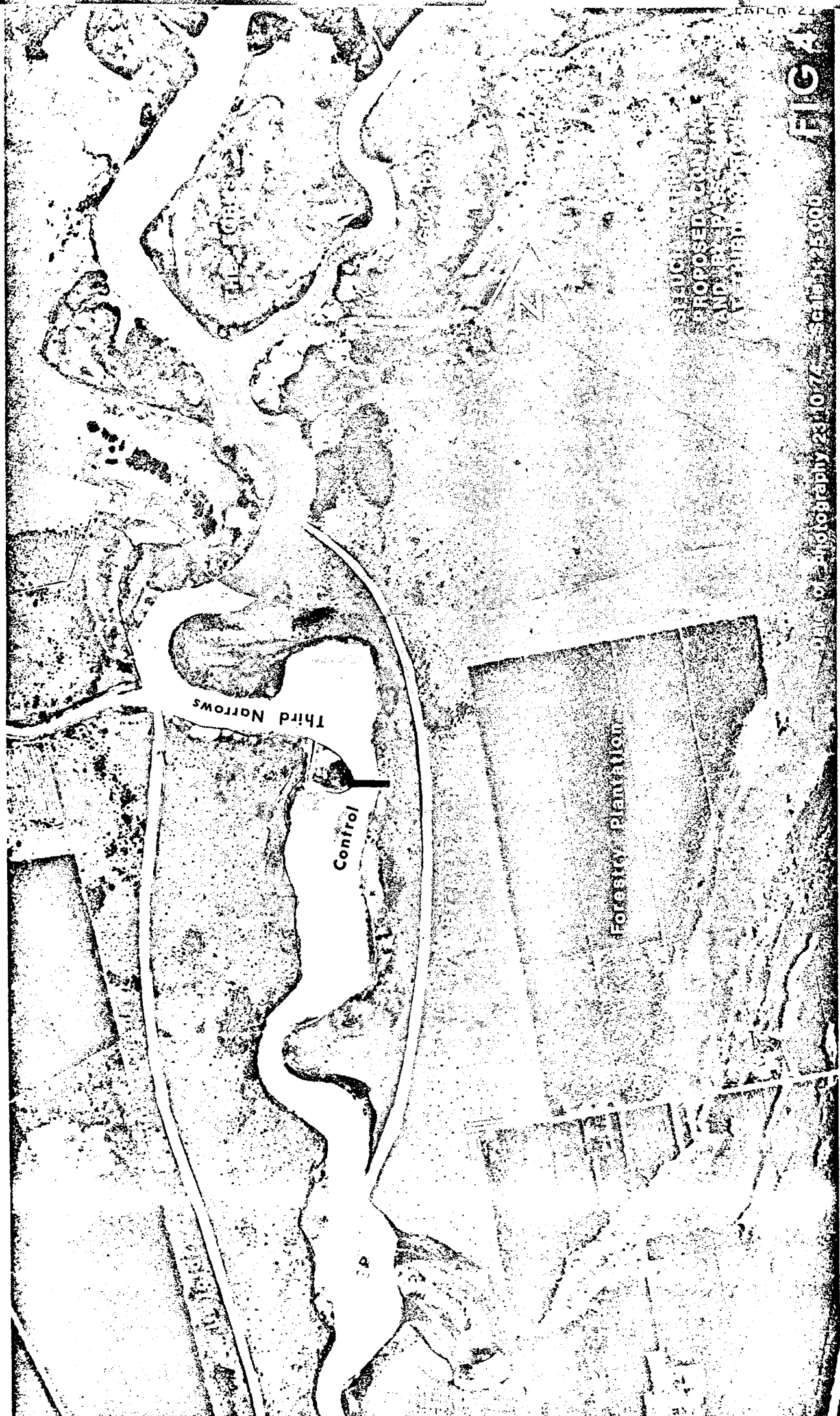
Combined
Mouth

SPACIUM ESTUARY

PROPOSED FUTURE SITUATION

FIG 2

Scale 1:25,000



Scale 1:25,000
PROPOSED CONTROL
AND PLANTATION

Scale 1:25,000
Photography 231075

Third Narrows

Control

Forestry Plantation

Scale 1:25,000
Photography 231075