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Title THE INFLUENCE ON ST LUCIA ESTUARY OF CHANGES IN THE MFOLOZI

Source 1976 PROC. ST LUCIA SCIENTIFIC ADVISORY COUNCIL WORKSHOP:CHARTER'S CREEK:FEB. 1976

Keywords UMFOLOZI=MOUTH*ESTUARY=MOUTH*HYDROLOGY,LAKE*

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ABSTRACT

Mathematical models have been developed to facilitate assessment of the mutual effects of past activities in the mouth region of the Mfolozi and St. Lucia estuary and to predict the probable influence of future proposals. The nature of the conflict of interests is revealed.

Provision of a separate mouth for the Mfolozi in the early 1950s had relatively little effect either way but creation of protective embankments and dykes has created backwater effects and future developments will aggravate the position unless carefully planned and engineered. The mathematical model provides the tool with which to turn conflicting interest into mutual advantages.

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INTRODUCTION

The wording of the title of this paper is slanted in favour of the sponsor of the symposium; it could well have read: *The effects of changes at St. Lucia on the canefields of the Mfolozi*. The fact is that there is a conflict of interests and this can best be resolved on the basis of impartial analyses. The area of concern, as shown on Figure 1, is bounded to the west by the railway bridge, to the south by the Msunduze, to the east by the Indian ocean and to the north by the Mtubatuba-St.Lucia road embankment.

The major part of the Mfolozi flood plain, downstream as far as section 2.1a Figure 1, is planted to sugar-cane the products of which contribute substantially to foreign exchange earnings; as is widely known, export of South African sugar stood until recently second only to gold as an earner of foreign exchange.

On the other side of the coin, St. Lucia is a wild life sanctuary of world renown; its protection on behalf of the nation and the world has been entrusted to the Natal Parks Board. Ill-conceived activities in either the Mfolozi flood plain or the estuary mouth area can have profoundly detrimental effects on both,and can be costly to the nation.

It is against the foregoing background that we discuss the nature and the effects of the changes, both faits accomplis and prospective changes.

THE NATURE OF THE CHANGES

At one time the entire Mfolozi/St.Lucia estuary mouth area was an inhospitable malaria-infested swamp. Intensified occupation and unwise land management of the catchment of the Mfolozi has,over the years,led to sharply increasing sediment yields,while drainage of the swamps for the planting of sugar-cane has given rise to silting problems in the lower reaches of the St. Lucia estuary.

The Umfolosi Sugar Planters Co-operative Ltd., on behalf of the sugar farmers, have endeavoured to overcome the problems of bank cutting and deposition of sand in the lands by channel revetment and re-alignment. The Natal Provincial Administration, on behalf of the Parks Board, on the other hand, tried to prevent progressive silting of the estuary by creating in 1952 a separate mouth for the Mfolozi.

As the result of progressive channel-straightening and other measures undertaken by the sugar farmers, the course of the Mfolozi today occupies the high ground along the northern edge of the flood plain while the real thalweg lies away to the south along the course of the tributary Msinduzi, the bed gradient of which flattens almost to zero towards the confluence near the mouth. It is therefore to be expected that, whenever the Mfolozi bursts banks, the floodwaters must pour across the canefields towards the Msunduze. The trouble is that in so doing the river deposits its burden of sand and silt on the lands in its path, thus putting many hectares out of production either permanently or until such time as reclamation can be effected - always at heavy cost. It follows, too, that floodwaters escaping from the river channels spread widely in the lower reaches of the flood plain, inundating the cane for inordinately long periods as the water slowly drains off to the sea or evaporates.

To overcome the problem of sand deposition on the canelands the Co-operative intended to construct a side spillway downstream of the railway bridge in the hope that the sand load could be constrained to remain in the river channel allowing only the clear water to overflow onto the lands. The Co-operative has been persuaded to abandon this idea and to await the outcome of an intensive investigation[1] into the economics of possible alternative remedial measures. Preliminary results of this investigation indicate that it may be feasible to lower the frequency of inundations by increasing the bank-full capacities of the Mfolozi and Ms nduz channels from the present 500 m^3/s or so to about 2000 m^3/s.

To obviate the difficulties resulting from flat gradients and poor drainage in the lower reaches it may be feasible to adopt

a scheme of poldering of the low-lying areas and rapidly pumping away excess water before the cane succumbs.

Another possibility that has been examined is the attenuation of flood discharges by means of upstream storage. Indications are, however, that, even in this highly productive area, protection by a single-objective flood control dam cannot be economically justified. If a multi-purpose scheme, embracing irrigation of the area between the Mfolozi and the Mkuze, injection of fresh water to False Bay, provision of industrial and domestic water supplies to the Richards Bay complex as well as flood control in the Mfolozi flats, were to be worked up it is possible that protection by this means would prove attractive.

Turning to St. Lucia, we find that bypassing of the Mfolozi did not solve the problem of blockage in the estuary and in fact cut off one of the sources of fresh water to the lake. It became necessary to undertake more or less continuous dredging of the estuary mouth and, in an effort to re-establish the flow of fresh water to the system, a short link channel from the Mfolozi to Shark Bay was cut. Moreover, to protect the estuary against a break-through along this cut during high flood, it was essential to throw up a dyke across the flood plain. This dyke gradually became redundant, however, as the levees created by dumping of dredger spoil along the banks of the estuary rose higher and higher.

Since the sand that was continually blocking the estuary, necessitating constant dredging, appeared to have its source in the coastal dunes, a programme of dune reclamation by encouraging the growth of vegetation was instituted. The result is that the Mfolozi mouth is narrower today than when there was a single mouth.

In Figure 2, the coastal topography, roughly as it was in 1951 before the opening of the separate Mfolozi mouth, has been superposed on that of today. As may be seen, apart from the re-alignment of the river channel, the tops of the dunes to the south of the estuary mouth are much higher today than they were in 1951.

Growth of the levees is illustrated in Figure 3. By 1973 the levees had reached general heights of from 3,0 to 3,5 m. To the north, as mentioned earlier, the flood plain is traversed by an embankment constructed after 1963 to heights of 3,0 m to carry the Mtubatuba-St.Lucia roadway. Effectively, therefore, the estuary is isolated from the Mfolozi by levees and embankments over 3 m in height above GMSL.

It has been proved conclusively by the mathematical models developed in the HRU[2]* that fresh water supplied to the estuary cannot reach the lake in sufficient quantities unless injected well upstream of Honeymoon Bend or unless, of course, the estuary mouth happens to be blocked. Among the measures to ameliorate conditions in the lake is the proposal to provide a link-channel from the Mfolozi in the position shown on Figure 3. The details of the proposal are described in a report by Weiss, Hutchison and Midgley[3] but the present concern is the protective embankment associated with this link. The suggestion is that this embankment should be 3,0 to 3,5 m high and, if located on a line extending towards the left bank of the Mfolozi where it enters the ocean, it could provide protection as well for prospective developments to the north, such as a combined mouth for the Mfolozi and estuary and the Natal Parks Board proposed "everglades" scheme.

Because of the constricting effect of the embankments and levees discussed above it has been proposed that the dunes should be lowered in the vicinity of the Mfolozi mouth to form a spillway about 500 m wide to accommodate high flood flows in the Mfolozi without causing excessive backwater into the canelands. Appropriate sand stabilization on this spillway would of course be essential, along with maintenance to control the natural growth of the dunes.

The Natal Provincial Administration some years ago instituted studies by the CSIR[4] and by an overseas consultant[5], aimed at designing measures to obviate the necessity for continual dredging to keep the mouth open. The proposals arising from these studies have come to naught primarily on account of cost but also through persuasion to await the outcome of appraisal by the mathematical modelling[1,2] being undertaken in the HRU.

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* Hydrological Research Unit

Recently has come the proposal by an engineer of the Provincial Administration that serious thought should be given to re-creating a common mouth for the estuary and Mfolozi. This would necessitate a slight re-alignment of the protective embankment and again, to compensate for the narrowing of the flood plain, there would be the need of the wide spillway to the sea to accommodate high flood flows.

It is evident from the various measures proposed that the interests of the Mfolozi sugar farmers and of the St. Lucia authorities become intimately mingled and cannot logically be tackled unilaterally.

IMPLICATIONS OF THE CHANGES

The implications of some of the early activities (i.e. some decades ago) both in the Mfolozi flats and in the lower reaches of the estuary are self-evident and do not bear labouring here. It is worth mentioning, however, that had the Mfolozi not been diverted from the thalweg it would have been difficult to design a relatively inexpensive diversion to the estuary by way of the proposed link-channel. The possibility is real that the Mfolozi may in future change course and revert to the thalweg. Should this happen the proposed diversion structure would probably have to be re-located further upstream.

Provision of an upstream storage scheme embodying a flood-attenuation component would not necessarily be a panacea for the sugar farmers. Arresting of the greater proportion of the silt load, for instance, would affect the downstream river regime in an as yet unknown manner. Provided the bed levels and location of the channel in the vicinity of the intake to the proposed link-channel remained sensibly unaltered, the supply of fresh water to Lake St. Lucia could but be improved.

Poldering of the low-lying canelands would reduce the flood attenuation capacity of the flood plain and possibly tend to encourage downstream extension of the canelands with aggravating effects on flood peaks.

Figure 4 has been compiled to illustrate the attenuating effect of the storage associated with over-bank flow through the flood plain. Clearly, canalization and raising of levees to confine the river or increase the bank-full capacity can but decrease the attenuation capability and increase the frequency of high discharges at the mouth. Backwater effects would be aggravated but, on the other hand, closure of the mouth should be less frequent.

If a common mouth were to be re-established, the turbulence associated with high discharges and expansion of flow in the confluence area will doubtless cause unpredictable shoaling and scouring in the vital mouth region.

Upstream storage, suitably manipulated, can undoubtedly reduce peak discharges but only at the expense of prolonging the flood duration. No harm is done provided over-bank flow does not occur but the effects of prolonged shallow inundation of canelands - albeit infrequently - is infinitely more detrimental than brief deep flooding, no matter how frequent.

Perhaps of most concern to the sugar farmers is an appraisal of the backwater effects of the levees and embankments across the lower Mfolozi flood plain, along the estuary mouth and proposed link-channel (including the effect of the diversion structure itself). To the St. Lucia authorities, on the other hand, the main interest would lie in the capabilities of the proposed link-channel, possibly also the merits of re-creating a combined mouth.

To satisfy these interests the results of a series of runs on a simulation model[6] of the system are illustrated in Figure 5. Water levels on the lower flood plain and in the vicinity of the Mfolozi-estuary mouths are calculated for floods of various magnitudes in relation to conditions at the mouth(s) in 1951, 1957, 1963 and 1973 as well as in relation to conditions projected into the future.

For the purposes of these illustrations, flood hydrographs associated with return periods of 10, 75 and 200 years were routed

through the system. These return periods were chosen because the observed hydrographs of the 1973, 1957 and 1963 floods corresponded respectively with the 10-, 75- and 200-year events.

It is evident from examination of the stage hydrographs in Figure 5 that had the 1951 mouth condition prevailed (i.e. a single mouth for Mfolozi and estuary) inundation by the 1973, 1957 and 1963 floods would have been more severe than in fact was the case during those floods. (In Figure 5, the full black lines in all cases lie below the corresponding black dashed lines). Under today's conditions at the mouth, however, medium to large floods would clearly be responsible for inundations (lasting one to two days) at depths 0,3 m or so greater than would have been the case under the 1951 mouth conditions. Total depths of inundation on the lower canefields, it was found, would have been from 1,0 to 3,5 m. Small floods, on the other hand, would today still result in marginally smaller depths of inundation than in 1951. The reason why today's conditions create different effects on the flood plain is that the levees have been steadily increasing in height as dredging proceeded. Should the levees reach a general height of 5 m, even the 200-year flood will be prevented from escaping to the estuary.

Section 3.1a on Figure 1 indicates the approximate upstream limit of backwater effects associated with the different mouth conditions examined.

Figure 5 should be read with caution. Mouth conditions are dynamic in character, subject to deposition of sand and silt; moreover, the degree to which levees, dunes and silt deposits are naturally or artificially stabilized can alter the inundation pattern in an unpredictable manner. It should be borne in mind, too, that there exist no field data with which to calibrate for the 1951 condition. The results given in Figure 5 must therefore be accepted as qualitative rather than quantitative comparisons. Although possible inundation of the lowermost canefields by medium to large floods is clearly more severe for the 1973 than for the 1951 condition, the degree of apparent deterioration is minor and indeed comparable with the accuracy with which conditions can be simulated.

Turning now to the main concern of the Parks Board, we can summarize the results of the link-channel report[3] by stating that substantial quantities of Mfolozi water can be diverted into the estuary and thence to the lake. As yet unpublished work by Hutchison[2] provides a quantitative appraisal of the proposal to divert water from the Mfolozi by predicting the reduced frequency and duration of excessive salinity conditions in the lake attributable to the link-channel.

The advantages to the Board of re-creating a combined mouth would be the protection afforded to a large expanse of marshland that could be converted into Everglades, at the expense, though, of having to open the dunes in the form of a spillway to obviate excessive backwater during high floods.

CONCLUSION

Changes in the Mfolozi flood plain and in the lower reaches of the St. Lucia estuary have been outlined and the mutual effects discussed.

It appears that as conditions stand today any increase in flood inundation of the canefields (i.e. to depths greater than before the separate Mfolozi mouth was constructed in 1952 and ascribable to backwater effects of banks and levees constructed by the Provincial Administration to protect the estuary) can be obviated by removing a strip of dune land near the Mfolozi mouth.

If the levees continue to rise through dumping of spoil from dredging in the estuary and if a common mouth is provided with resultant further restriction of the flood plain, it will be necessary to open up the dunes to a width of about 500 m. Should the levees attain a general height of 5 m above GMSL even the 200-year flood could be prevented from spilling into the estuary.

The proposal to divert water from the Mfolozi to Lake St. Lucia is sound, provided the outfall of the link-channel is well upstream of Honeymoon Bend. Considerable quantities of fresh water can be injected into the St. Lucia system with beneficial effects.

The idea of bringing the estuary into the Mfolozi mouth, with the appropriate protecting levee, has merit in that a large area protected from floods would become available for development, e.g. as Everglades. Whether there would be an improvement in the extent to which dredging must be carried on is questionable. Much deeper investigation than has so far been undertaken would be necessary before such a scheme could safely be tackled.

It would of course be possible to create and protect a development area without actually combining the mouths merely by adjusting the alignment of the embankment.

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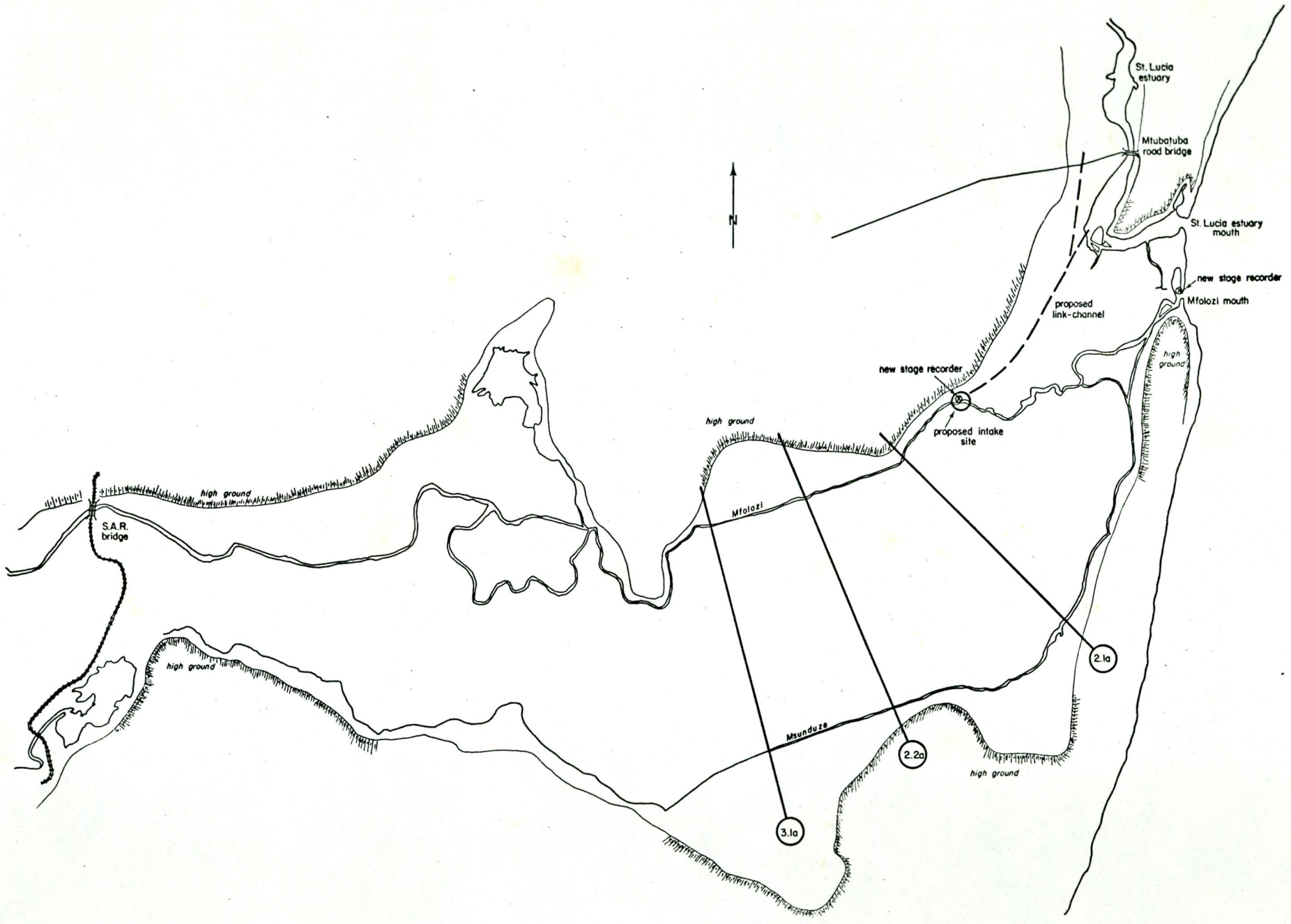

Fig. 1 GENERAL PLAN VIEW OF MFOLOZI MOUTH AREA

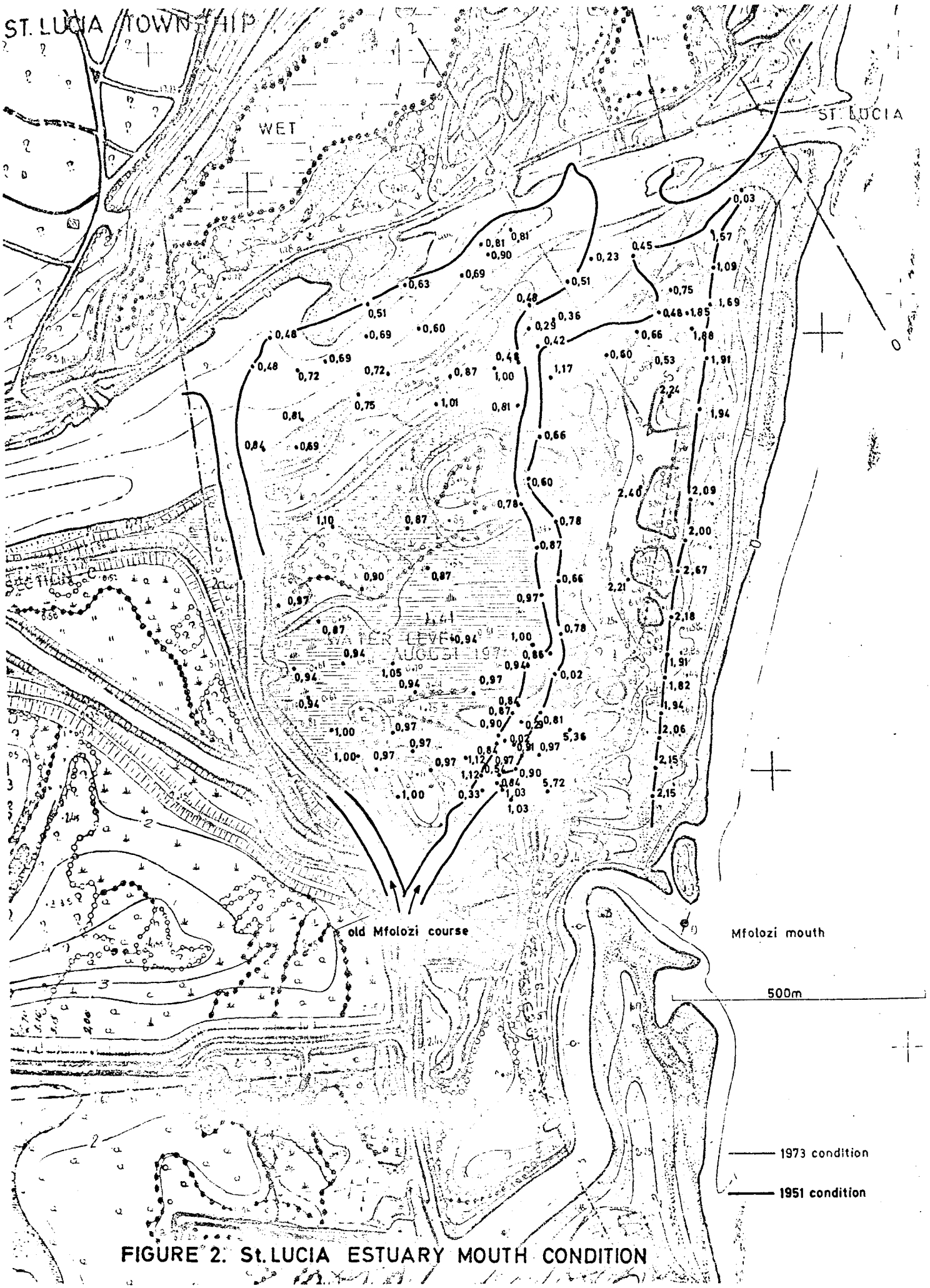

FIGURE 2. St. LUCIA ESTUARY MOUTH CONDITION

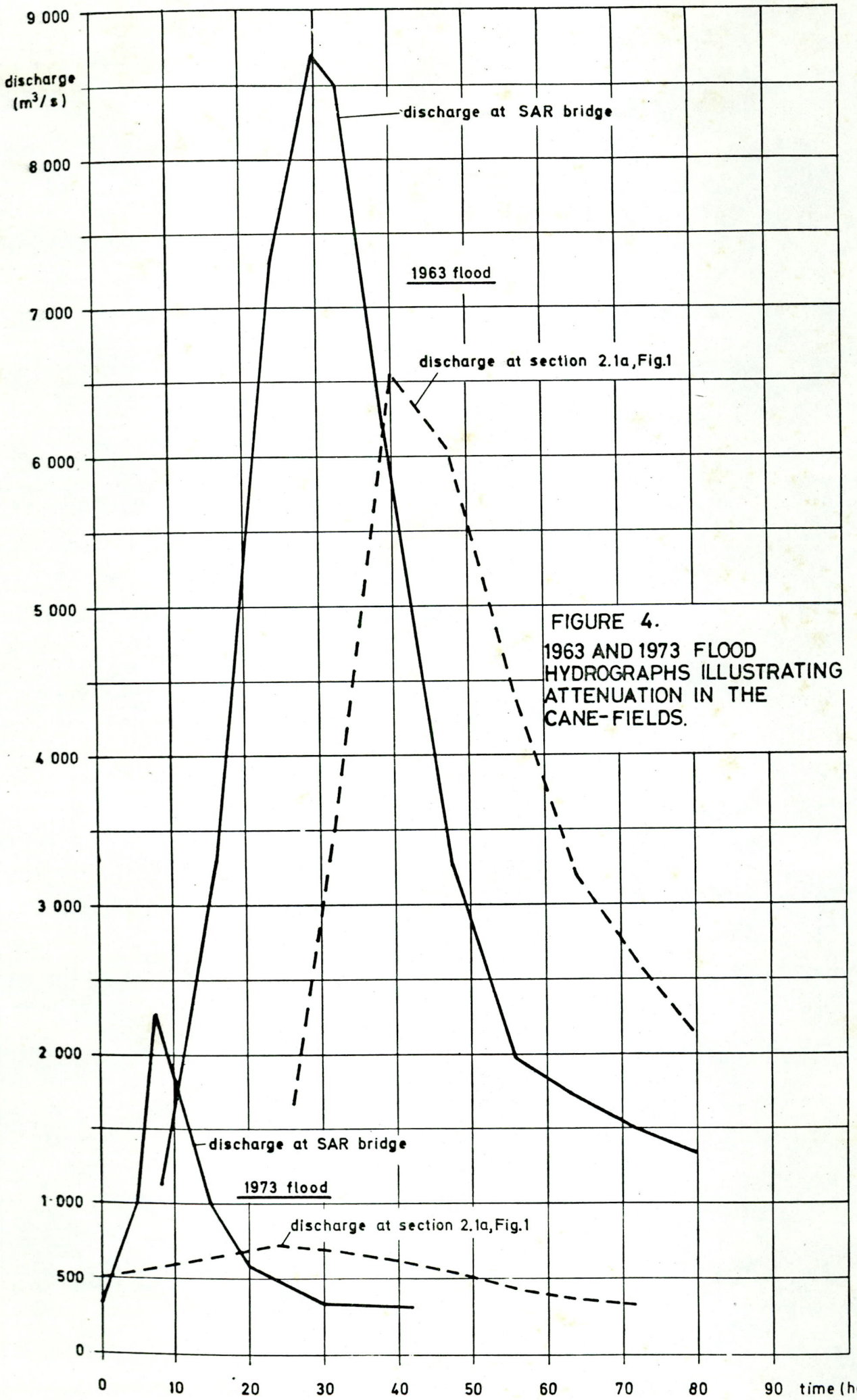

FIGURE 4.
1963 AND 1973 FLOOD HYDROGRAPHS ILLUSTRATING ATTENUATION IN THE CANE-FIELDS.

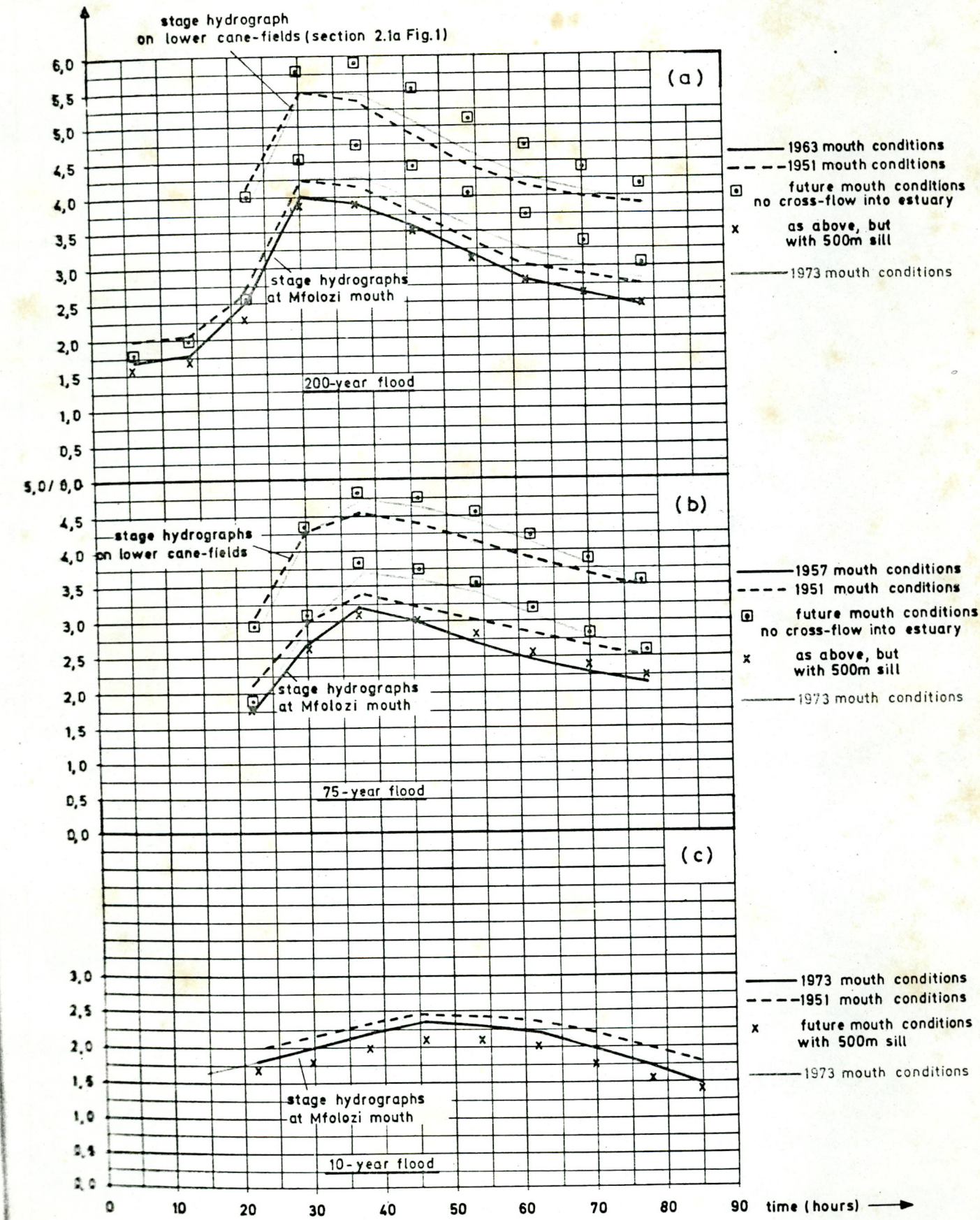

FIGURE 5. STAGE HYDROGRAPHS AT MFOLOZI MOUTH AND ON LOWER CANE-FIELDS FOR VARIOUS MOUTH CONDITIONS.