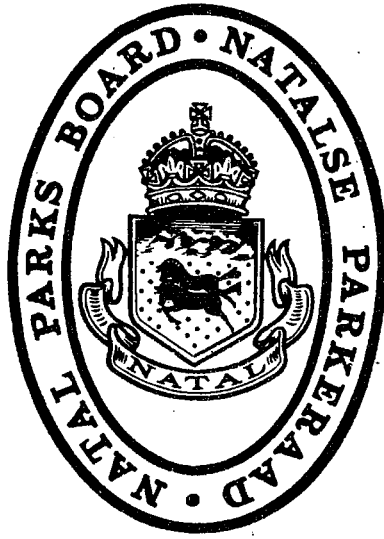


ST LUCIA DOCUMENT COLLECTION



**Author** HUTCHISON I P G

**Title** HYDROLOGICAL RESEARCH UNIT REPORT, 2 DECEMBER 1970

**Source** 1970 UNPUBLISHED REPORT

**Keywords** HYDROLOGICAL=MODEL\*

HYDROLOGICAL RESEARCH UNIT REPORT - 2 DECEMBER 1970

I. INTRODUCTION

The estuary dynamic and dispersion model as well as the preliminary lake and catchment models are now working satisfactorily. Using these models the following tasks are to be carried out:-

- 1) Testing the effectiveness of various "remedial" schemes that do not involve additional supply of water to the lake. The general principle to be applied here is that of deriving maximum benefit for the lake from existing water resources. This task will entail simulation of the behaviour of the lake in relation to each remedial measure in turn. For the present, all proposals will be evaluated in terms of resultant effect on mean lake salinity. Some of the schemes envisaged are -

- i) diversion of Umfolosi water into the estuary
- ii) a canal bypassing the Mkuze swamp
- iii) modification of the estuary discharge properties by widening or constriction.

Costs of these schemes will also have to be estimated.

It must be pointed out that the foregoing corrective measures are in the nature of short-term temporary solutions.

- 2) At the same time attempts must be made to evaluate the following long-term solutions:
  - i) injection of additional fresh water from the Pongola river
  - ii) pumping in sea water at the northern extremity
  - iii) changing the lake geometry (i.e. decreasing the area and/or increasing the depth

- iv) changing the geometry of the estuary with or without the C.S.I.R. berm scheme
- v) diverting Umfolosi river into the lake upstream of the Narrows.

Final detailed analyses of these schemes can be accomplished only after more detailed investigations of the river catchments and of the eastern shores have been undertaken and after mathematical dynamic and dispersion models of the lake have been developed. Verification tests of the existing estuary model have still to be concluded.

Note: Whatever scheme is chosen the approach should be gentle guidance rather than forcing of nature.

## II. CATCHMENT MODELS

Rainfall trends are illustrated in Fig. 1. The following table lists the average annual volumes of runoff in millions of cubic metres reaching the lake from the various catchments under virgin conditions and as affected by upstream irrigation usage.

Catchment	Virgin condition		Affected condition		Remarks
	mean annual runoff	%	mean annual runoff	%	
	$10^6 m^3$	%	$10^6 m^3$	%	
Eastern Shore	45	11	45		200 mm of runoff and seepage assumed. No adjustment made.
Mkuze river	216	51	198		Swamp area of 116 km <sup>2</sup> (45 sq.m.) Area of irrigated sugar cane 4716 Ha.
Mzinene river	30	7	30		No adjustment made.
Hluhluwe river	76	18	20		Runoff for affected condition is taken to be runoff from catchment downstream of Hluhluwe dam - spill neglected.
Nyalazi river	54	13	54		No adjustment made.
	<u>421</u>	<u>100</u>	<u>347</u>		

The general trends in runoff are shown in Fig. 2.

Note: Synthetic values of monthly flow from the various catchments for the period 1918-1970 are stored on a computer disc.

Future work: As more detailed runoff data become available more accurate estimates of catchment losses and usages can be made. The behaviour of the Hluhluwe dam will have to be simulated. Flow frequency (duration) curves and typical flood hydrographs will have to be compiled for all inflows to the lake in order to permit salinity and silt distributions to be determined.

### III. ESTUARY DYNAMIC AND SALINITY DISPERSION MODEL

#### Development and results to date:

The mathematical model operates on the basis of the sections shown in Fig. 3. For given tidal elevations at or near the mouth and lake levels at the northern end one can obtain, with the aid of the model, water depths, velocities and salinity concentrations at all the intermediate sections. Lateral discharges into the estuary as well as net evaporation from the water surface can be taken into account by the model.

From the available topographic details of the estuary two sets of data were extracted - one based on an undredged estuary and the other on a dredged estuary. (The effective depth of dredging was assumed to be 1.7 m).

With the above data coupled with tide hydrographs transposed from Durban harbour and water level recordings within the estuary, preliminary verification runs indicated that behaviour of the model and prototype agreed reasonably well. The friction parameters in the model can be accurately assessed, however, only if prototype discharges are known. Water levels are not sufficiently sensitive to changes in friction coefficient but are highly sensitive to local prototype cross-sectional area and depth.

To complete the verification of the model the following

- (1) Further survey work - see section V of this report.
- (2) Tidal data in the sea just off the mouth of the estuary.
- (3) Discharges or velocities at at least one prototype cross-section used in the model.

Preliminary output from the model is shown as a plot of lake level versus inflow into the lake in Fig. 4. For this analysis an average tidal amplitude of 1 m was used. Mean sea level was assumed to be 0.18 m below mean water level in Shark basin which was the datum for all survey work. (This figure corresponds to the elevation of the lake above mean sea level at which no net in- or outflow occurs. It also agrees with the average difference between mean sea level and mean water level in Shark basin as given in the C.S.I.R. report - Ref. 1).

The maximum mean discharge of 6.5 cumecs into the lake through an undredged estuary (at lake level = 3.5 m) is of the same order as that arrived at by the Commission of Enquiry (see report Ref. 2) and by Dr. James and D. Horne in Ref. 3, viz. 7.1 and 8.5 cumecs respectively.

#### Future developments:

Further model verification runs are needed (each of approximately 1 week's duration). These will entail

- (a) an initial re-survey of the cross-sections used in the model up to at least  $1\frac{1}{2}$  m above present datum followed by periodic check surveys to determine changes with time
- (b) knowledge of the general history of behaviour of the estuary mouth is needed as well as detailed surveys covering the period of each verification run. One needs to know the approximate length and type of channel that existed at the mouth at various times of the year to establish a range of mouth types for use in evaluating past interchanges of flow between the lake and the sea. More detailed surveys

covering a shorter period will be required for performing verification runs of the estuary model

- (c) required also are as many as possible continuously recorded estuary levels and discharges during the same period as that of the detailed survey of the mouth
- (d) silt samples must be taken at various sections in the estuary - ideally at say hourly intervals for the duration of one or several tidal cycles within the duration of the verification run
- (e) rainfall, evaporation, wind, salinity and lateral inflow should be measured on say a daily basis for the duration of the model verification run. The coarse time increment is permissible because these factors have a relatively small effect on the estuary flow and are difficult to measure accurately at low time resolution.

After final verification one should be able, with the aid of the estuary model, to predict with some confidence the behaviour of the silt, salt and water in the estuary under any conditions that may be imposed upon the system.

#### IV. LAKE MODEL

##### Development and results to date:

The present model employs results derived from operation of the catchment models and the discharge curves derived from the estuary model. The hydrological equation is solved for the lake and empirical equations are developed for evaluating the flushing effects of the monthly in- and outflows. The constants in these equations were optimized from comparisons of model and prototype salinity values.

The results of these preliminary

Future developments and results:

A detailed dynamic and dispersion model of the lake is to be developed. It will be based on a two-dimensional version of the estuary model. The uses to which this model will be put are :-

- (1) To study the circulation and salinity distribution within the lake for various boundary conditions - i.e. for a series of lake levels and inflow hydrographs.
- (2) To evaluate the constants in the empirical dispersion equations used in the mass balance model described above.
- (3) To evaluate similar dispersion equations as well as head loss equations within the lake for a more complex mass balance model consisting of several large lake compartments.

The above procedure is necessary as long-term simulation (i.e. covering several years) can be performed only with the mass balance lake models.

The verifying process for the detailed lake model would follow a similar pattern to that of the estuary model.

V. SURVEY REQUIREMENTS FOR 1971

In order of importance, presuming the lake survey has been completed, the following survey work is needed:

- (i) Descriptive (quantitative) history of mouth geometry
- (ii) Re-survey of model cross-sections up to  $1\frac{1}{2}$  metres above mean water level and checking for any change
- (iii) Detailed survey of mouth during estuary model verification periods. These test periods should coincide with the operation of the tidal recorder off the mouth and the velocity meter at Esengeni. Ideally these test periods should also coincide

fully open, constricted, etc.) They would therefore have to be run at various times of the year - starting as soon as possible.

- (iv) Contour map and soil survey of the area through which a canal for diverting water from the Umfolosi river to the estuary would pass. This is required for design and cost analyses purposes.
- (v) Contour map and soil survey of the area between Selly's lakes and the sea for investigation of a proposed seawater pumping scheme
- (vi) A line survey plus a few representative cross-sections along the proposed Mkuze swamp diversion canal - also for design purposes
- (vii) General soil surveys of the lake and estuary surrounding for planning possible constrictions or barrages.

#### REFERENCES

1. Report on St. Lucia Estuary Siltation: Hydraulic Model Study. C.S.I.R. Contract Report No. C MEG 562 Sept. 1963.
2. Report of the Commission of Enquiry into the alleged threat to Animal and Plant life in St. Lucia Lake. 1964-1966. Government Printer.
3. The Propagation of Water Waves in Channels by C.W.D. Horne. M.Sc. Thesis submitted at University of Natal.