



Earth, Marine
and Atmospheric
Science and
Technology

Aard-, Mariene
en Atmosferiese
Wetenskap en
Tegnologie

CSIR

WNNR

**HYDRO FACTORS AFFECTING SILTATION
IN THE
LOWER REACHES OF NATAL/KWAZULU RIVERS**

submitted to
Town & Regional Planning Commission, Natal

Issued by:
Division of Earth, Marine and Atmospheric Science
and Technology
CSIR
P O Box 320
STELLENBOSCH
7600

HYDRO FACTORS AFFECTING SILTATION
IN THE
LOWER REACHES OF NATAL/KWAZULU RIVERS

submitted to
Town & Regional Planning Commission, Natal

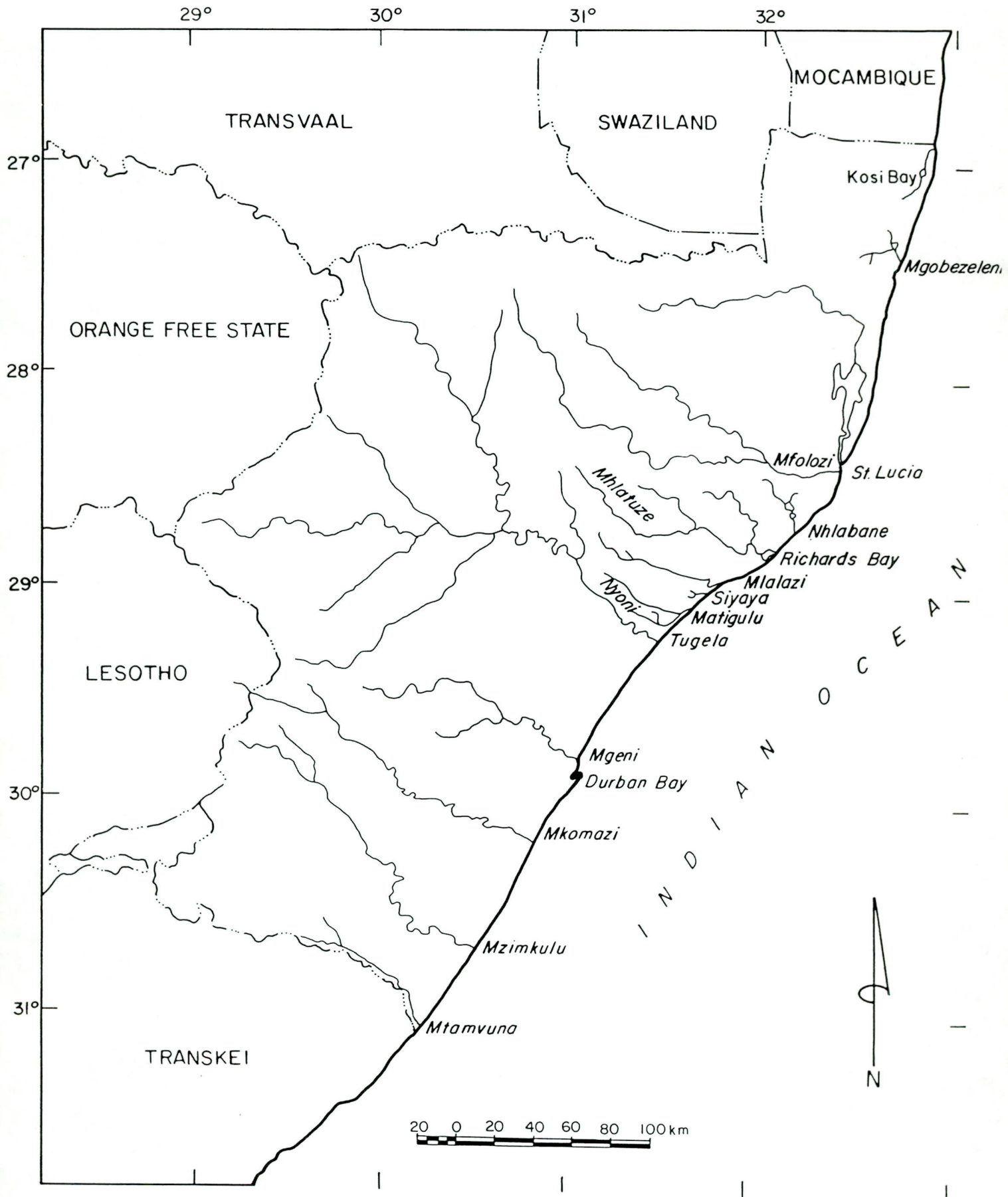
Keywords:

Siltation
Estuaries

November 1990

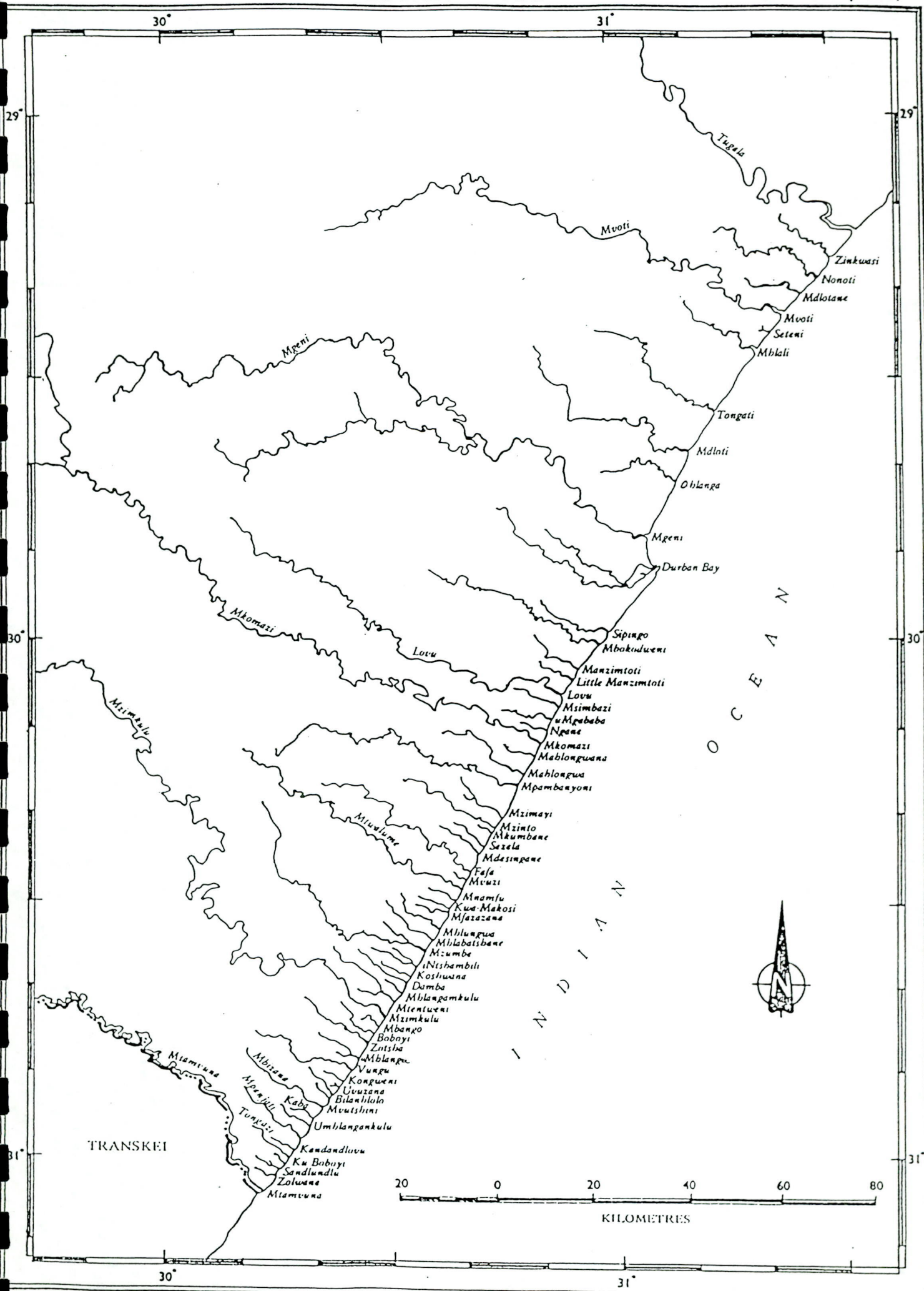
LOCALITY MAP

after Begg, 1984



LOCALITY MAP

(after BEGG, 1983)



FOREWORD

Several brief overviews for meetings and poster papers have been prepared by the author on hydro factors and siltation in selected estuaries of Natal. It is now deemed appropriate to compile a full report on this important topic, especially in view of the lessons learned from the 1987 major floods.

N.B. Regarding the tabular lists of the lower reaches/estuaries of Natal and KwaZulu rivers:

- (1) most of the lower reaches of these rivers are not estuaries *sensu stricto*
- (2) two of the "estuaries" are not evaluated in this report;
 - (i) Natal Bay (NS53) because this is an embayment fed by several rivers
 - (ii) St Lucia (NN19) because this system has been the subject of many comprehensive studies from which detailed data may be obtained
- (3) four estuary systems have changed in the recent past;
 - (i) the Mlazi (NS52), which is now a concrete-lined canal, flowed into the Sipingo (NS51) until 1952
 - (ii) the Nyoni (NN12) was captured by the Matigulu (NN13) in 1971.

SOURCES OF DATA

1. Aerial photography from the Chief Director of Surveys and Mapping, Mowbray, the University of Natal, the Air Survey Company of Africa Ltd. Durban and Aerial Photographic Service, Pietermaritzburg.
2. Old maps, reports and river cross-sections from the Natal Archives, Pietermaritzburg.
3. River cross-sections from Mr J.R. Alborough (NPA Roads Dept), Mr. E. Beesley (Sappi-Saiccor), Mr. J.P.M. de Robillard (Illovo Sugar Estates) and Mr. L. van der Merwe (CSIR).
4. Sidelines from physical river model studies on the Lovu and Mzumbe by the author.
5. Various references quoted at the end of the text.
6. Last, but far from least, various people to whom acknowledgement is given at the end of the text.

CONTENTS

Page

FOREWORD

SOURCES OF DATA

LIST OF TABLES

LIST OF FIGURES

PHOTOGRAPH

1.	PRESENT SITUATION	1
2.	NATURAL FACTORS	3
2.1	Topography General	3
2.2	Catchment Areas	4
2.3	Geology, Soils & Sediment Yield	5
2.4	Length, Elevation of Source and Gradient of Rivers (Table I)	5
2.5	River Mouth Characteristics (Table I)	7
2.6	Run-off	8
2.6.1	General	8
2.6.2	Variability (Tables III, IV & V) and Figures 2 and 3)	8
2.6.3	Wet/Dry Phases	9
2.6.4	Floods	9
2.7	Most Important Natural Factors, in brief, Affecting Siltation of the Lower Reaches	10
3.	HUMAN INFLUENCES	12
3.1	Land-use in the Catchments (Table VI)	12
3.1.1	Dams	12
3.1.2	Water Transference/Diversion	12
3.1.3	Farming Malpractices	13
3.1.4	Urbanization	13
3.1.5	Conservation	13

<u>CONTENTS</u> (Continued)	<u>Page</u>
3.2 Land-use in the Lower Reaches (Table VII)	13
3.2.1 Structures	13
3.2.2 Stabilization of Sand-spits	14
3.2.3 Farming Malpractices	14
3.2.4 Drainage of Swamps	14
3.2.5 Artificial Breaching of Sandbars	15
3.2.6 Dredging	15
3.3 Most Important Human Influences, in brief, affecting siltation of the Lower Reaches	16
4. CONCLUSIONS	16
5. FUTURE TRENDS	17
6. RECOMMENDATIONS	18
ACKNOWLEDGEMENTS	20
REFERENCES	21
TABLES	
FIGURES	
PHOTOGRAPH	

LIST OF TABLES

- I Physical factors
- II Sediment yield
- III Simulated run-off
- IV Simulated run-off/precipitation
- V Mzumbe simulated run-off, 1921-1975
- VI Land-use, catchments
- VII Land-use, lower reaches

LIST OF FIGURES

- 1 Mkomazi river bed levels 1875-1988
- 2 Mzumbe simulated annual run-off, 1921-1975
- 3 Mzumbe simulated monthly run-off, 1921-1975

PHOTOGRAPH

- 1 Fluvial delta, Mpenjati, 2-5-37

(Basic diapositive of this photo was obtained from the Chief Director, Surveys and Mapping, Mowbray)

1. PRESENT SITUATION

The current position regarding estuarine lengths of the 71 rivers under review is summarized below:

Estuarine length (km)	Number of rivers	%
$\leq 0,5$	20	28
$> 0,5 \leq 1$	18	25
$> 1,0 \leq 2$	14	20
$> 2,0 \leq 3$	12	17
> 3	7	10

Of the seven rivers with an estuarine length greater than 3 km only one, the Mtamvuna (NS1), is on the Natal south coast.

Many of the lower reaches are aggrading. Twenty-seven (38 %) of the rivers show a decrease in estuarine length this century, of which eight (11 %) show a further decrease from 1976-1983. The more significant decreases in estuarine length are listed below (after Begg and Natal Archives Data):

Estuarine Lengths in Km			
	Pre 1976	1976	Post 1976
Mbizana (NS10)	$>2,5$ (1925)	1,5	0,9 (1983)
Mzimkulu (NS20)	13-19 km (1900)	5,5	3 (1983)
Damba (NS23)		0,5	0,2 (1982)
Mzumbe (NS26)	1,9 (1918)	1,0	$\approx 0,5$ (1983)
Mtwalume (NS32)	4,7 (1930s)	1,7	
Mkomazi (NS43)	≈ 13 (1875) 5,5 (1920s)	3,0	$\approx 2,0$ (1983)
Lovu (NS47)	$\approx 3,7$ (1958)	1,1	
Sipingo (NS51)	4,5 (1962)	1,3	
Mgeni (NN1)		$\approx 6,2$	2,5 (1980)
Mvoti (NN7)		1,8	0 (1983)

Dr G. Begg's assessment of the siltation in the lower reaches of the rivers in 1985 may be summarized as follows:

Degree of siltation	Number of rivers	%
Nil (0)	8	11
Slight (1)	18	25
Moderate (2)	22	31
Severe (3)	23	33

Details of all the above facts with respect to the 71 rivers under review may be seen in Table I. The more important factors affecting aggradation/siltation/sedimentation of the lower reaches are discussed in Sections 2 (Natural Factors) and 3 (Human Influences).

2. NATURAL FACTORS

2.1 Topography General

The 593 km of Natal/KwaZulu's coastline is relatively straight. Its orientation from the Mtamvuna (NS1) to the Tugela (NN11), 274 km, is 28° - 33° . From the Tugela (NN11) to the Mlalazi (NN15), 44 km, it is 40° . Just to the north of the Mlalazi is the only major, sharp change in orientation of the coastline to 75° . At Richards Bay, the orientation is back to 44° , near the Mfolozi (NN18), it is 26° and at Kosi Bay it is 10° - the changes being gradual over this 243 km stretch of coastline.

The hinterland north of the Tugela (NN11) comprises a massive barrier of Pleistocene/Holocene sediments behind which lie several large lagoons. There is then a low-lying, sandy coastal plain which is 80 km wide in the north and which peters out near the Tugela. The rivers in this region therefore cross a coastal plain and often discharge into a lagoon rather than directly into the ocean. South of the Tugela (NN11), by contrast, the rivers are youthfully incised and discharge directly into the ocean. This is equally true of the major and the shorter rivers and is a very important factor regarding sedimentation near the coast.

"The ability of the estuaries and lagoons to absorb and store sediments is a function of the size of the sedimentary basin below the base level of erosion to be anticipated as a result of scour by flood discharges and tidal effects" (Orme, 1974). The lower reaches of Natal/KwaZulu's rivers were all excavated to well below present MSL (up to -50 m MSL, in proportion to size of catchment) during the Quaternary. During the Flandrian transgression which culminated around 5 000 BP, there was some sedimentation of marine origin and thereafter the sedimentation has been predominantly fluvial and/or lagoonal. The river channels of the lower reaches are now mostly near, at or even just above present MSL - as indicated by the estuarine lengths - (see Section 1 and Table I) and the aggradation pattern is one of a fluvial delta (Photograph 1) forming at the major check on river gradients, very near to the coast, during major floods. The fluvial delta extends gradually towards the coast with successive floods, as exemplified by the Mzumbe (NS26). This feature was identified on a topographical map compiled from aerial photography taken after the May 1959 flood and the fluvial delta was reproduced during physical model tests of the Mzumbe done by CSIR in 1980. This fluvial delta extends over the flood plain in the lower reaches, almost

to the mouth, and in places is +6 m to MSL. The "very fine lagoon" which extended inland up to the old railway bridges until 1918, as recorded in the Mzumbe annals (Natal Archives), no longer exists.

Such topographical changes can be identified from maps and reports but changes in the actual river channel may only be quantified if successive cross-sections are available, which is rarely the case. Orme (1974) has identified scour and fill ranges of up to 17 m in the lower reaches of Natal rivers. The net result of the scour and fill process is usually one of aggradation. Cross-sections taken at bridges for the old Natal south coast road give us a rare chance of quantifying this: for example:

- (a) the Mbizana (NS10) shows a bed level rise of ≈ 5 m from 1925 to 1974, and
- (b) the Mkomazi (NS43) shows a rise of ≈ 2 m in bed level from 1875 to 1961.

Mkomazi river bed levels from 1875 to 1988 are shown in Figure 1, the trends and fluctuations reflecting both the influences of run-off (Section 2.6) and land-use (Section 3.1).

Similar topographical changes of river bed level may be quantified indirectly when the discharge rating table at a gauging station changes due to a major flood: e.g. the bed of the Lovu (NS47) aggraded by ≈ 1 m in May 1959 at the NR bridge.

2.2 Catchment Areas (Table I)

The area of the catchment is an important factor regarding run-off, flow, sediment yield and mouth closure. Approximately 50 per cent of the catchments have areas less than 40 km². The areas may be grouped as follows:

Area (km ²)	No. of Catchments	%
1-10	8	11
11-20	16	23
21-50	15	21
51-250	13	18
251-500	4	6
501-1000	7	10
1001-2000	1	1
2001-4000	2	3
4001-8000	3	4
8001-16000	1	1
16001-32000	1	1

2.3 Geology, Soils and Sediment Yield

A detailed review of the geology and soils is outside the scope of this review. It is noteworthy, however, from a hydro point of view, that there are widespread areas of deep saprolites which are easily erodible.

From Rooseboom's map of sediment production in South Africa (1975), average maximum catchment sediment yields have been derived (Table II from Perry, 1986). Rooseboom's work is being updated but results for Natal/KwaZulu are little affected (Rooseboom pers. comm). The catchment yields understandably relate directly to catchment size regarding average maximum totals per year: N.B. the massive 8,8 million tons for the Tugela (NN11). Sediment yield rates are generally very high except for the few most northerly catchments. This reflects the nature of the topography, geology and soils.

Average annual sediment yield values must be viewed with caution and with a careful insight as to the nature of the sedimentation. High silt loads are (i) seasonal and (ii) linked to wet/dry phases and floods (Section 2.6). River mouth conditions also play an important role (Section 2.5).

2.4 River Lengths, Elevation of Sources and River Gradients (Table I)

Six (8 %) of the rivers are longer than 200 km. At the other end of the spectrum, 22 (31 %) are less than 10 km and 39 (55 %) are less than 20 km.

Nine (13 %) of the sources of the rivers are at an elevation of more than 1 000 m, 22 (31 %) > 500 m and 66 (93 %) > 100 m. This gives an idea of the potential energy involved.

However, it is the gradients of the rivers which are of the greatest importance - specially in view of the lack of a coastal plain in 63 (89 %) of the systems. The gradients of the rivers, except for the two most northerly rivers, are steep; some very steep. The following table gives a summary of the river gradients from the source to the mouth:

Gradients (1:)	No. of rivers	%
0-25	3	4
26-50	24	34
51-100	27	38
101-200	13	18
201-400	4	6

It is even more important to note the change from these steep overall gradients to those appertaining in the lowest reaches. A few examples will serve to illustrate this point:

River		Overall gradient	Gradient over lowest "x" km		
Mtamvuna	NS 1	1:84	1:769	over lowest	10 km
Mbizana	NS10	1:54	1:521	over lowest	2,4 km
Mzimkulu	NS20	1:135	1:1000	over lowest	16 km
Mzumbe	NS26	1:90	1:310	over lowest	3 km
Mtwalume	NS32	1:86	1:357	over lowest	4 km
Mpambanyoni	NS40	1:104	1:213	over lowest	19 km
			1:460	over lowest	2,3 km
Mkomazi	NS43	1:112	1:1111	over lowest	16 km
Manzimtoti	NS49	1:42	1:357	over lowest	3 km
Mgeni	NN1	1:127	1:385	over lowest	16 km
Tongati	NN4	1:67	1:645	over lowest	10 km
Mvoti	NN7	1:133	1:424	over lowest	32 km
			1:773	over lowest	4,3 km
Tugela	NN11	1:130	1:1905	over lowest	12 km
Mhlathuze	NN16	1:165	1:1075	over lowest	51 km
Mfolozi	NN18	1:240	1:1724	over lowest	100 km

2.5 River Mouth Characteristics (Table I)

Only five (7 %) of the river mouths never close, while 44 (62 %) are closed for more than 80 per cent of the year by a sandbar at the mouth. Estimates of mouth closure in Table I are based upon research during a dry phase and the percentages of the year the mouth is closed would be slightly less if records were available for many years covering both wet and dry phases (a 10 % reduction is indicated in the few cases where such records are available). The long periods of mouth closure promote siltation behind the sandbar. Furthermore, and very importantly, the rapid closure of many mouths following flood peaks (often only a matter of days) facilitates siltation during and immediately following the recession limb of a flood when the river is heavily silt laden.

A second mouth feature affecting siltation is that even when the mouth is open, the river is often deflected for some considerable length behind a spit. This results in reduced river gradients and thereby increased siltation. A summary of spit features is given below:

<u>S.-extending</u>	<u>N.-extending</u>	<u>Variable</u>	<u>Nil</u>
49 (69 %)	14 (20 %)	7 (19 %)	1 (1 %)
			(Mhlatuze - artificial)

NB: After major floods, the position varies temporarily as follows:

44 (62 %)	19 (27 %)	7 (10 %)	1 (1 %)
-----------	-----------	----------	---------

South of the Tugela (NN11), most of the spits are southerly-extending. North of the Tugela several spits are northerly-extending. Due to the change in orientation of the coast just north of the Mlalazi (NN15) in relation to the dominant littoral drift to the north, the coastline and the spits at the mouths of rivers NN12-15 are prograding. There has been one case of river capture (NN12 and 13) and, as for example with the Siyaya (NN14), the lengthening of the thalweg behind the spit by 785 m in the period 1937 to 1977 has resulted in reduced gradients and more siltation.

Rocky shelf/headland outcrops may aid the stability of mouth position and help to keep the mouth open. A summary of the situation follows:

<u>Rock → South</u>	<u>→ North</u>	<u>North & South</u>	<u>Nil</u>
41 (58 %)	3 (4 %)	7 (10 %)	20 (28 %)

2.6 Run-off

2.6.1 General

Natal/KwaZulu experiences a summer maximum of precipitation and hence of run-off and sediment yields. Some winter rains do occur, predominantly in the catchments south of the Tugela (NN11), as they lie in the path of cyclones moving round the coast from the Cape. Tropical cyclones, e.g. Domoina in January 1984, can affect the northern catchments. The upper reaches of the larger rivers in the high Drakensberg have a much higher run-off ratio from precipitation than any of the catchment averages shown in Table IV, being as much as 40 per cent. In the drier areas of north Zululand, run-off is very low (less than 5 per cent of the precipitation), largely due to percolation through the sandy coastal plain areas. No detailed estimates of run-off can be given for this region. Elsewhere in Natal hydrological data are scarce - in some cases for smaller coastal catchments, totally lacking - but simulated run-off data over 50 years (1925-1975) are available (Pitman *et al.*, 1981). These data, together with information on floods and notes from various sources including the Natal Archives, are invaluable for assessing wet/dry phases, major run-off periods and other features of the run-off. These data in turn give a basis for assessing variations in sediment yields although there is not a direct correlation. The sediment availability factor is very important. This gives rise to the double peak phenomenon in Natal's rivers (P J T Roberts, 1973) on an annual basis and necessitates one looking closely at antecedent soil moisture conditions prior to major flood flows. Run-off features, assessed on a catchment basis from the available simulated run-off data (Perry, 1986) are reviewed in Sections 2.6.2 and 2.6.3.

2.6.2 Variability (Tables III, IV & V) and Figures 2 and 3)

Mean annual run-off (MAR) is directly proportional to catchment size (Section 2.2) and thus the Tugela (NN11), Mzimkulu (NS20) and Mkomazi (NS43) rivers have the largest MAR (N.B. especially the Tugela). However, it is the nature of run-off which is of prime importance regarding sedimentation: it is very erratic. There is a summer maximum during which the intense nature of the rainfall leads to frequent peaks in the stream hydrographs. Winter

run-off, associated with depressions moving along the coast, is generally much lower and less intense. How much this general pattern of run-off varies from year to year, and even more markedly on a monthly basis, is seen in the coefficients of variation (Table III). Annual coefficients of variation range from 43 to 124 per cent while monthly coefficients of variation range from 26 to 219 per cent. There is an increase in variability, in general, from South to North.

Given such variability, median run-off values are well below the mean (Table III). This is specially marked when one views the monthly run-off where the median may be a little as 30 per cent of the mean. An example of monthly mean and median run-off values is shown for the Mzumbe (NS26) in Table V.

As the rivers transport the silt, the erratic nature of the run-off must necessarily lead to erratic patterns of sedimentation in the lower reaches: once again beware of averages, be they annual, seasonal or monthly. Two features which further exemplify this and which markedly affect both silt supply and deposition are wet/dry phases and floods. These are reviewed in Sections 2.6.3 and 2.6.4.

2.6.3 Wet/dry Phases

There is an approximately 18 year cycle of wet/dry phases in Natal/KwaZulu as can be seen in Figure 2. It should be remembered that wet periods (even floods!) may occur during a 9-year dry phase and conversely a dry period may occur during a 9-year wet phase. Important for siltation in the lower reaches is the fact that supplies are built up not only during the dry season but especially during a dry phase. Generally less silt is available in the catchments for transportation by the rivers during a wet phase. It is therefore very important as to when a flood occurs with respect to antecedent catchment conditions as will be reviewed in the next Section.

2.6.4 Floods

Long, dry phases are often broken by major floods. These major floods are not a rare phenomenon: in general four or five have occurred in all rivers over the last 100 years (Perry, 1989). Aerial photography clearly shows the different sedimentation patterns in the lower reaches of the rivers following the different types of major flooding. Antecedent conditions in the catchments are of paramount importance. Given dry conditions, particularly

after a prolonged drought there is more sediment available for removal by the rivers. With the prevalent steep gradients and a virtual lack of coastal plain, the first major check on river flood flow velocities is close to the coast. Here deposition on the flood plains and aggradation of river bed levels is greater during these so-called "dry floods" (incongruous yet apt!). The floods of May 1959 and Domoina (1984) fall into this category. By contrast, if catchment antecedent soil conditions are wet (following a period of sustained rainfall, particularly in a wet phase) there will be less sediment available for removal by the rivers. There will still be some deposition on the limited flood plain areas but these so-called "wet floods" are characterised by deeper scouring resulting in river bed degradation e.g. the floods of April 1856, March 1925, March 1976 and September 1987.

Concominantly with antecedent catchment conditions, the timing of a major flood with respect to post-flood conditions also affects siltation in the lower reaches. As already noted, a flood occurring within a dry season and/or dry phase will lead to greater deposition and aggradation. A major flood occurring at the beginning of the wet season - whether antecedent conditions are dry or wet - will tend to show (i) a prolonged recession limb (ii) a longer period of the mouth remaining open and (iii) where rivers can breach their sandbars and sand-spits naturally, a longer period for the normal sand-spit or sandbar configuration to re-form. The effects of (ii) and (iii) on siltation are more sediment carried out to sea and a longer duration period of degradation of river bed levels: e.g. it took 12-18 months for bed levels to regain their pre-flood elevations following the September 1987 floods in the lower reaches of the Mkomazi (NS43) and Mvoti (NN7).

2.7 Most Important Natural Factors, in brief, Affecting Siltation of the Lower Reaches

- (a) Catchment areas with widespread, easily erodible soils.
- (b) Generally steep river gradients with the first major check in gradient often lying very near to the coast.
- (c) Erratic run-off: seasonally high discharges varying significantly on annual and monthly bases and major floods.

- (d) River mouths often diverted/blocked by a spit/bar: in four cases (NN12-15), the spits are prograding.

3. HUMAN INFLUENCES

These will be considered

- (a) on a catchment basis and
- (b) by factors specifically affecting the lower reaches of the rivers.

3.1 Land-use in the Catchments (Table VI)

3.1.1 Dams

Dams are not a major factor at this stage of development in Natal/KwaZulu. Only 15 (21 %) of the river systems are affected and in several of these cases the dams are small and/or are situated in the upper reaches of the catchment. However, on two smaller rivers, Mkumbane (NS37) and uMgababa (NS45), there are dams close to the estuary which effectively trap silt loads during floods. In general, the few dams on the larger rivers are further upstream, allowing sufficient length of river course downstream for picking up ample silt supplies. Two exceptions should be noted, however: (i) the Inanda dam, recently constructed on the Mgeni (NN1) and (ii) the proposed Mvumase/Sunbury dams on the Tugela (NN11). Once these dams are full, the effect on siltation in their estuaries will depend upon management release policies. "Dry phase" conditions will prevail with less scouring of the river bed and the mouth will become narrower, shallower and subject to closure.

3.1.2 Water Transference/Diversion

This is also a factor which, although not important at present as only two rivers are affected, may merit more attention in the future. Regarding siltation, effects will vary from case to case. With the formerly joint systems of the Sipingo (NS51) and the Mlazi (NS52), the diversion of the heavily silt-laden Mlazi has eradicated silt deposition in the Sipingo "estuary". The diversion of flood waters from the Sipingo (NS51) into the Mbokodweni (NS50) is not important regarding a source of silt because little silt is generated in the Sipingo catchment: however, the increased velocities resulting from the combined flood flows have caused bank erosion in the lower Mbokodweni, thereby locally aggravating siltation. In the case of water transference from the Tugela, NN11, to the Vaal there is probably no effect on siltation in the lower reaches with the abundant remaining flow.

Careful planning and management will be needed however if waters from the Mkomazi, NS43, are taken to augment Durban's water supply because the lower reaches of the Mkomazi are aggrading.

3.1.3 Farming Malpractices

Fifty-four (76 %) of the catchments have areas under KwaZulu administration. Such areas show widespread removal of vegetation, over-grazing and unwise tillage practices leading to soil erosion. With the increase in population density and resulting increase in pressure on land-use in these areas, the problem has become progressively worse during this century, leading to an abundant silt supply from these regions.

The latter problem is not confined to KwaZulu, however. In Natal, sugar cane and banana plantations are widespread in 46 (65 %) and seven (10 %) of the catchments respectively. Farming in Natal has become more intensive this century, specially since the 1940s. This has led to (i) widespread removal of natural riverine vegetation and cultivation to the river banks - practices leading to increased river bank erosion and (ii) drainage of swamps with resultant loss of natural silt trap areas.

3.1.4 Urbanization

Urbanization in the catchments will eventually lead to less silt production but the reverse is often the case during earlier construction stages e.g. Kongweni (NS14) and Mbango (NS19). Furthermore, the higher run-off rates from urbanized areas can lead to increased bank erosion in areas downstream of the urbanization.

3.1.5 Conservation

Catchments which are strictly conserved, such as the small Zolwane (NS2) and the Mdlotane (NN8), show few siltation problems in their lower reaches. Well-managed forestry areas also tend to reduce the supply of silt.

3.2 Land-use in the Lower Reaches (Table VII)

3.2.1 Structures

Embankments across the flood plain: 51 (72 %) of the lower reaches are affected. These embankments for road and rail bridges have formed a series

of checks on river velocities during major flood flows since the turn of the century - increasingly so since the 1950s. This has led to increased siltation around these areas.

Weirs at the mouth: three rivers are affected. These structures inhibit the flushing out of sediments during flood flows, thereby aggravating siltation.

Canalization/channelling: channelling if due regard is given to the natural meander pattern and thalweg length, may not be detrimental e.g. recent channelling on the uMgababa (NS45) and the Lovu (NS47). However any canalization and channelling which severely alters the river course, markedly reducing the thalweg, has a very detrimental effect upon siltation - both within the "canal reach" and downstream of it. Canals themselves may become silted up e.g. earlier canals on the Mzumbe (NS26) and the Lovu (NS47) or areas further downstream may suffer increased siltation e.g. Mhlatuze (NN16) and Mfolozi (NN18).

Remnants of old structures: these are rubble causeways and piers linked with earlier bridge construction. Eight (11 %) of the river channels are affected. When such structures are left *in situ*, optimum hydraulic conditions are impeded and siltation is aggravated.

3.2.2 Stabilization of Sand-spits

This may be favourable for controlling aeolian sources of silt but if the stabilization is rigid, for purposes of providing routes for railways/roads at the river mouths, then the effect is detrimental. Such rigid stabilization was prevalent in the 1950s. In these cases the rivers can no longer break through the spits in times of major floods, flushing out of the estuary is inhibited and siltation aggravated behind the stabilized sand-spit. Twenty-three (32 %) of the estuaries are affected: two of them markedly adversely so, the Mzumbe (NS26) and the Mkumbane (NS37).

3.2.3 Farming Malpractices

The removal of riverine vegetation affects 36 (51 %) of the estuaries while cultivation to the river banks affects 30 (42 %). These malpractices give a "local" supply of silt, additional to those from similar farming malpractices in the catchment (Section 3.1.3).

3.2.4 Drainage of Swamps

Whether for agricultural or industrial purposes, the drainage of swamps affects 24 (34 %) of the lower reaches of the rivers. This results in (i) a loss of natural sediment traps and (ii) deposition in areas ever increasingly nearer to the river mouths.

3.2.5 Artificial Breaching of Sandbars

The river mouths are often subject to long periods of mouth closure (Section 2.5). For various reasons such as health factors and the inundation of property and/or cane fields, the sandbar at the mouth may be artificially breached. This practice occurs at 36 (51 %) of the river mouths quite frequently: four of the "estuaries" being adversely affected thereby.

Under natural conditions, the water level rises behind the sandbar until the pressure build-up causes the bar to breach naturally. The water level at which this occurs varies and in general is not known precisely: for the Zinkwasi (NN10) it is +1,2 m to MSL and for the Siyaya (NN14) it is +2,4 m to MSL. From water levels observed at bridges over 15 Natal South rivers, this important water level may be indirectly inferred: often +2 to +2,5 m to MSL. If the sandbar is breached prematurely by artificial means, there is often insufficient "head" for the effective flushing out of sediments.

Furthermore the river, under natural conditions, will tend to breach against rocks to one side of the mouth and water levels will not fall below the level of the rock sill (usually $\approx$ MSL). Random positioning of artificial breaching can result in the water level falling so low as to drain the system virtually dry.

If artificial breaching is deemed to be absolutely necessary, both the water level at which this is done and the position of the breached channel are very important: it is a complex matter. From a hydro point of view, it is better to allow water levels to rise and breach the bar naturally: this allows for the best flushing out of sediments with the least adverse effects.

3.2.6 Dredging

Given the ample silt supply provided by Natal's rivers, the pros and cons of dredging need to be assessed very carefully. Of the estuaries under review - only in one, the Umhlangankulu (NS8), has dredging been undertaken: this was

done in 1977 and 1989. Lesser and major floods between 1978 and 1987 negated the 1977 dredging and resulted in bed levels reaching those of 1976. Plans for the 1989 dredging incorporated silt traps on the river flowing into the lagoon. Unfortunately, the silt traps were destroyed in October 1989 flood flows and siltation is once again a problem (Cerff, pers. comm.). This case shows that unless the silt supply from the catchment can be reduced and effective silt traps built to prevent silt reaching the estuary/lagoon, the beneficial effect of dredging will be lost.

3.3 Most Important Human Influences, in brief, affecting siltation of the Lower Reaches

- (a) In the catchments, farming malpractices enhance natural factors to provide an abundant supply of silt.
- (b) In the lower reaches, human influences accelerating the natural rate of aggradation fall broadly into two categories:
 - (i) structures e.g. embankments across the flood plain, rigidly stabilized spits, weirs at the mouth, canals and
 - (ii) land-use malpractices e.g. removal of riverine vegetation, cultivation to the river banks and swamp drainage.

4. CONCLUSIONS

- (i) Siltation in the lower reaches of Natal/KwaZulu rivers is fluvio dominated.
- (ii) Siltation is severe and only seven of the 71 rivers have estuarine lengths greater than 3 km.
- (iii) Siltation rates are NOT steady: they rather represent a response to hydro factors (floods, wet/dry phases etc).
- (iv) The siltation is predominantly the result of natural factors (topography, river mouth configuration, geology, soils and run-off).
- (v) Siltation has been aggravated by human influences during this century, particularly since the 1940s.
- (vi) Although the important hydro factors affecting siltation are known in general, each of the lower reaches of the rivers reflects a unique combination of these factors.

5. FUTURE TRENDS

- (i) Of the 13 remaining estuaries, *sensu stricto*, all but the Mlalazi (NN15) and Kosi (NN21) will join the two which already may better be classified as "river mouths" - aggradation resulting in bed levels precluding any tidal exchange.
- (ii) In the smaller rivers subject to mouth closure, further siltation will result in swamp areas increasing and fresh-water conditions prevailing (except in drought conditions of hypersalinity).
- (iii) The few systems with prograding spits along the North coast will be subject to longer periods of mouth closure and increased siltation.
- (iv) It is very difficult to assess trends resulting from human influences but with the present awareness of factors encouraging siltation and measures being taken to control the situation, the trends already mentioned in (i) - (iii) could be slightly slowed down.
- (v) Global warming and the expected probable rise of approximately 1 m in MSL would rejuvenate the lower reaches of Natal/KwaZulu rivers. However, with the relatively steep gradients near the coast (except in the few most northerly "estuaries"), the increase in estuarine lengths would not be very great.
- (vi) How the global warming will affect the climatic situation is not fully understood. Consequently, forecasting future trends in siltation rates following any rejuvenation is not possible at this stage.

6. RECOMMENDATIONS

- (i) Detailed topographical mapping with river cross-sections is being done by CSIR in a few of the lower reaches. This should be extended to more systems and ideally cross-sections should be repeated every April and September and following any major flood event. This would facilitate
 - (a) the quantification of fluvial delta migration towards the coast and rates of aggradation in general
- and (b) the quantification and evaluation of the effects of a sea level rise.
- (ii) Catchment land-use changes since 1937 (the earliest date of aerial photography) should be undertaken in as many representative catchments as possible.
- (iii) The geological surveys of estuarine sedimentation currently being done by Natal University and the CSIR should be extended.
- (iv) More river sediment surveys would be invaluable. In the revision of the assessment of sediment yields currently underway by Rooseboom (pers. comm), more information on the patterns/erratic characteristics of the sedimentation - on a catchment basis, would be invaluable.
- (v) Run-off: (a) coastal catchments, particularly on the Natal South Coast, need more study (b) the Mgobozeleni (NN20) and Kosi (NN21) catchments should be included in the revision and update of the assessment of simulated run-off, currently being undertaken (Midgley pers. comm).
- (vi) The daily monitoring of mouth open/closed conditions, currently being done by SAPPI-SAICCOR and CSIR should be extended to cover all the mouths.
- (vii) Certain factors aggravating siltation in the lower reaches can be, and has been in the past, dealt with by an effective "Estuarine Action Committee". Such measures should be extended.

- (viii) The broader, important issues of **silt supply** can only be dealt with effectively on a catchment basis. There is an urgent need for the formation of "Catchment Water Authorities".

ACKNOWLEDGEMENTS

The writer would like to express her appreciation of the co-operation received over many years from

- (1) Dr G.W. Begg (Environmental Advisory Services, Durban) who provided many of the data herein. Furthermore, the many stimulating discussions resulting from Dr Begg's biotic index research and the writer's hydro classification studies have provided the impetus and outline for this report.
- (2) Mr E. Beesley (Sappi-Saiccor, Umkomaas) who provided many photographs and river cross-sections of the Mkomazi. Very importantly the many lively discussions held with Mr. Beesley on the Mkomazi and the Lovu have led to a very good understanding of these two estuaries.
- (3) Mr Z. Kovács (DWA, Pretoria) who generously gave of his time to discuss river flood behaviour.
- (4) Prof. A. Rooseboom (the University of Stellenbosch) who was always open to discussion of his sediment yield work.
- (5) Prof W.R.A. Alexander (the University of Pretoria) who provided many a lively and stimulating debate on siltation in estuaries.
- (6) Mr. F. Junor (NPB, Congella) who arranged an aerial survey and provided many an interesting discussion on siltation problems.
- (7) NTRPC personnel (Pietermaritzburg) who during discussions both at meetings and individually, have not only highlighted problem areas in Natal estuaries but have also shown what they, as planners, need to know.

REFERENCES

BEGG, G W (1978). The Estuaries of Natal. NTRP Report Vol. 41.

BEGG, G W (1984). The Estuaries of Natal, Part II. NTRPC Report, Vol. 55.

ORME, A R (1974). Estuarine sedimentation along the Natal coast, South Africa. Office of Naval Research, Technical Report No. 5.

PERRY, J E (1986). Basic physical geography/hydro data for Natal "estuaries". NRIO Data Report D8607.

PERRY, J E (1989). The Impact of the September 1987 floods on the estuaries of Natal/KwaZulu; a hydro-photographic perspective. CSIR Research Report 640.

PITMAN, W V, MIDDLETON, B J and MIDGLEY, D C (1981). Surface water resources of South Africa. Vols. V and VI, Hydrological Research Unit Report Nos 12 & 9/81.

ROBERTS, P J T (1973). An explanation of a "double peak" phenomenon in mean monthly suspended sediment concentrations for some South African rivers. DWA Technical Report No. 42.

ROOSEBOOM, A (1975). Sediment produksiekaart vir Suid-Afrika. Technical Report No. 61. Department of Water Affairs.

TABLE I

PHYSICAL FACTORS

NATAL ESTUARIES

Ref.	River	Catchment Area (km ²)	River Length	Elevation of Source (m)	River Gradient (1:)	Estuarine Length in 1976 (km)	Begg		
							Decrease in Estuary Length this century	Siltation Estimate	% of year Mouth Closed 1983
NS 1	MTAMVUNA	1 5 5 3	162	1 9 2 0	8 4	5		2	2
NS 2	ZOLWANE	7	6,5	2 5 9	2 5	0,21		0	17
NS 3	SANDLUNDLU	1 6	7,5	2 8 2	2 7	0,6		1	18
NS 4	KU-BOBOYI	3	4	1 0 7	3 7	0,53		2	83
NS 5	TONGAZI	1 7	8,5	3 8 5	2 2	0,35		1	16
NS 6	KANDANDLOVU	9	8	2 9 0	2 8	0,55		2	80
NS 7	MPENJATI	1 0 0	18	4 8 0	3 8	1,1	✓	3	65
NS 8	UMHLANGANKULU	9	6,5	1 8 0	3 6	0,85		2	92
NS 9	KABA	1 1	9	2 2 0	4 1	0,5		2	93
NS 10	MBIZANA	1 4 5	26	4 8 0	5 4	1,5	✓	3	68
NS 11	MVUTSHINI	7	6,5	1 8 0	3 6	0,25		1	86
NS 12	BILANHLOLO	2 1	12	2 4 0	5 0	0,5		1	75
NS 13	UVUZANA	8	2,5	1 3 0	1 9	0,23		2	85
NS 14	KONGWENI	2 0	6	1 8 0	3 3	0,85		1	60
NS 15	VUNGU	1 2 4	24	6 1 0	3 9	0,18		0	9
NS 16	uMHLANGA	3 8	12,5	3 4 0	3 7	0,95	✓	3	65
NS 17	ZOTSHA	5 7	20	4 1 5	4 8	2,50		1	78
NS 18	BOBOYI	3 2	14	3 7 0	3 8	0,38	✓	2	29
NS 19	MBANGO	1 3	8	1 3 9	5 8	0,65		0	95
NS 20	MZIMKULU	6 7 4 5	329	2 4 4 0	1 3 5	5,5	✓	3	3
NS 21	MTENTWENI	5 0	20	3 4 0	5 9	2,3		2	70
NS 22	MHLANGAMKULU	1 1	7	1 8 5	3 8	0,9		1	97
NS 23	DAMBA	2 5	11	3 0 0	3 7	0,5	✓	3	95
NS 24	KOSHWANA	1 1	6,3	2 0 0	3 2	0,48		1	86
NS 25	iNTSHAMBILI	3 3	12,5	2 1 0	6 0	0,55	✓	2	90
NS 26	MZUMBE	5 3 6	84	9 3 3	9 0	0,95		3	10
NS 27	MZIMAYI (South)	4 7	16	2 4 0	6 7	1,0		2	25
NS 28	MHLUNGWA	3 2	18	2 2 2	8 1	1,5		2	93
NS 29	MFAZAZANA	1 6	10,5	2 7 8	3 8	0,53	✓	1	89
NS 30	KWA-MAKOSI	1 6	7	1 8 3	3 8	0,75		1	83
NS 31	MNAMFU	1 6	9	2 3 3	3 9	0,75		1	89
NS 32	MTWALUME	5 6 5	85	9 8 5	8 6	1,7	✓	3	31
NS 33	MVUZI	8	6,5	1 7 8	3 7	0,7		0	99
NS 34	FAFA	2 3 1	66	9 1 8	7 2	3	✓	3	96
NS 35	MDESINGANE	6	5,2	7 6	6 8	0,5	✓	2	65
NS 36	SEZELA	2 0	12	1 8 0	6 7	1,8		0	95
NS 37	MKUMBANE	2 8	14	3 0 0	4 7	0,25	✓	3	81
NS 38	MZINTO	1 4 9	37	5 2 0	7 1	1,42		2	93
NS 39	MZIMAYI (North)	3 1	20	1 7 8	1 1 2	0,25	✓	3	88
NS 40	MPAMBANYONI	5 6 2	100	9 6 2	1 0 4	0,25	✓	3	23
NS 41	MAHLONGWA	9 2	23	4 3 0	5 3	1,9		2	75
NS 42	MAHLONGWANA	1 5	6	2 1 8	2 7	1,3		1	99
NS 43	MKOMAZI	4 3 1 0	298	2 6 5 0	1 1 2	3	✓	3	1
NS 44	NGANE	1 6	8	2 1 9	3 7	0,34		1	74
NS 45	uMGABABA	3 7	14,5	2 4 4	5 9	2,4		1	83
NS 46	MSIMBAZI	3 5	16	2 4 4	6 6	2,8		1	92
NS 47	LOVU	8 9 3	135	1 2 8 0	1 0 5	1,1	✓	3	17
NS 48	LITTLE MANZIMTOTI	1 8	15	1 6 5	9 1	0,8		1	54
NS 49	MANZIMTOTI	3 9	11,6	2 7 4	4 2	1,6		2	63
NS 50	MBOKODWENI	2 8 3	59	7 3 2	8 1	0,7		2	93
NS 51	SIPINGO common mouth	5 1	27	3 2 8	8 2	1,25	✓	1	99
NS 52	MLAZI until 1952	9 7 2	82	9 1 4	9 0				
NS 53	NATAL BAY					Not being studied			
NN 1	MGENI	4 4 3 2	232	1 8 2 9	1 2 7	6,2	✓	3	0
NN 2	OHLANGA	1 1 8	28	3 2 4	8 6	2,2	✓	2	96
NN 3	MDLOTI	5 2 7	81	8 5 4	9 5	1,5		3	64
NN 4	TONGATI	4 3 6	50	7 4 7	6 7	2		3	21
NN 5	MHLALI	3 0 4	46,5	5 8 0	8 0	2	✓	3	11
NN 6	SETENI	1 6	5	6 1	8 2	0,35		2	83
NN 7	MVOTI	2 8 2 9	197	1 4 7 9	1 3 3	1,75	✓	3	2
NN 8	MDLOTANE	4 3	13	1 2 2	1 0 7	2,25		0	95
NN 9	NONOTI	2 1 0	37,5	4 8 8	7 7	1,9		2	94
NN 10	ZINKWASI	7 3	22	2 2 9	9 6	7,4		2	84
NN 11	TUGELA	2 9 1 0 1	405	3 1 0 9	1 3 0	0,8	✓	3	0
NN 12	NYONI common mouth	1 1 5	25	1 5 2	1 6 4	7		2	5
NN 13	MATIGULU since 1971	8 8 0	96	7 6 2	1 2 6	7,5	✓	3	5
NN 14	SIYAYA	1 8	8	5 9	1 3 6	2,5	✓	3	96
NN 15	MLALAZI	4 9 2	54	5 4 9	9 8	11		2	0
NN 16	RICHARDS BAY								
NN 17	MHLATUZE	3 6 7 0	209	1 2 6 5	1 6 5	0,5	✓	3	0?
NN 18	NHLABANE	1 0 4	12	4 3	2 7 9	3	✓	0	80
NN 19	MFOLOZI	1 0 0 7 5	395	1 6 4 6	2 4 0	4,6	✓	3	5
NN 20	ST. LUCIA					Not being studied			
NN 20	MGOBEZELENI	3 3	6	1 5	4 0 0	0,75		0	10
NN 21	KOSI	± 5 0 0	30	7 5	4 0 0	16,0		1	0

TABLE I

PHYSICAL FACTORS

NATAL ESTUARIES

Ref.	River	Catchment Area (km ²)	River Length	Elevation of Source (m)	River Gradient (1:)	Estuarine Length in 1976 (km)	Begg		
							Decrease in Estuary Length this century	Siltation Estimate	% of year Mouth Closed 1983
NS 1	MTAMVUNA	1 5 5 3	162	1 9 2 0	8 4	5		2	2
NS 2	ZOLWANE	7	6,5	2 5 9	2 5	0,21		0	17
NS 3	SANDLUNDLU	1 6	7,5	2 8 2	2 7	0,6		1	18
NS 4	KU-BOBOYI	3	4	1 0 7	3 7	0,53		2	83
NS 5	TONGAZI	1 7	8,5	3 8 5	2 2	0,35		1	16
NS 6	KANDANDLOVU	9	8	2 9 0	2 8	0,55		2	80
NS 7	MPENJATI	1 0 0	18	4 8 0	3 8	1,1	✓	3	65
NS 8	UMHLANGANKULU	9	6,5	1 8 0	3 6	0,85		2	92
NS 9	KABA	1 1	9	2 2 0	4 1	0,5		2	93
NS 10	MBIZANA	1 4 5	26	4 8 0	5 4	1,5	✓	3	68
NS 11	MVUTSHINI	7	6,5	1 8 0	3 6	0,25		1	86
NS 12	BILANHLOLO	2 1	12	2 4 0	5 0	0,5		1	75
NS 13	UVUZANA	8	2,5	1 3 0	1 9	0,23		2	85
NS 14	KONGWENI	2 0	6	1 8 0	3 3	0,85		1	60
NS 15	VUNGU	1 2 4	24	6 1 0	3 9	0,18		0	9
NS 16	uMHLANGA	3 8	12,5	3 4 0	3 7	0,95	✓	3	65
NS 17	ZOTSHA	5 7	20	4 1 5	4 8	2,50		1	78
NS 18	BOBOYI	3 2	14	3 7 0	3 8	0,38	✓	2	29
NS 19	MBANGO	1 3	8	1 3 9	5 8	0,65		0	95
NS 20	MZIMKULU	6 7 4 5	329	2 4 4 0	1 3 5	5,5	✓	3	3
NS 21	MTENTWENI	5 0	20	3 4 0	5 9	2,3		2	70
NS 22	MHLANGAMKULU	1 1	7	1 8 5	3 8	0,9		1	97
NS 23	DAMBA	2 5	11	3 0 0	3 7	0,5	✓	3	95
NS 24	KOSHWANA	1 1	6,3	2 0 0	3 2	0,48		1	86
NS 25	INTSHAMBILI	3 3	12,5	2 1 0	6 0	0,55	✓	2	90
NS 26	MZUMBE	5 3 6	84	9 3 3	9 0	0,95		3	10
NS 27	MZIMAYI (South)	4 7	16	2 4 0	6 7	1,0		2	25
NS 28	MHLUNGWA	3 2	18	2 2 2	8 1	1,5		2	93
NS 29	MFAZAZANA	1 6	10,5	2 7 8	3 8	0,53	✓	1	89
NS 30	KWA-MAKOSI	1 6	7	1 8 3	3 8	0,75		1	83
NS 31	MNAMFU	1 6	9	2 3 3	3 9	0,75		1	89
NS 32	MTWALUME	5 6 5	85	9 8 5	8 6	1,7	✓	3	31
NS 33	MVUZI	8	6,5	1 7 8	3 7	0,7		0	99
NS 34	FAFA	2 3 1	66	9 1 8	7 2	3	✓	3	96
NS 35	MDESINGANE	6	5,2	7 6	6 8	0,5	✓	2	65
NS 36	SEZELA	2 0	12	1 8 0	6 7	1,8		0	95
NS 37	MKUMBANE	2 8	14	3 0 0	4 7	0,25	✓	3	81
NS 38	MZINTO	1 4 9	37	5 2 0	7 1	1,42		2	93
NS 39	MZIMAYI (North)	3 1	20	1 7 8	1 1 2	0,25	✓	3	88
NS 40	MPAMBANYONI	5 6 2	100	9 6 2	1 0 4	0,25	✓	3	23
NS 41	MAHLONGWA	9 2	23	4 3 0	5 3	1,9		2	75
NS 42	MAHLONGWANA	1 5	6	2 1 8	2 7	1,3		1	99
NS 43	MKOMAZI	4 3 1 0	298	2 6 5 0	1 1 2	3	✓	3	1
NS 44	NGANE	1 6	8	2 1 9	3 7	0,34		1	74
NS 45	uMGABABA	3 7	14,5	2 4 4	5 9	2,4		1	83
NS 46	MSIMBAZI	3 5	16	2 4 4	6 6	2,8		1	92
NS 47	LOVU	8 9 3	135	1 2 8 0	1 0 5	1,1	✓	3	17
NS 48	LITTLE MANZIMTOTI	1 8	15	1 6 5	9 1	0,8		1	54
NS 49	MANZIMTOTI	3 9	11,6	2 7 4	4 2	1,6		2	63
NS 50	MBOKODWENI	2 8 3	59	7 3 2	8 1	0,7		2	93
NS 51	SIPINGO common mouth	5 1	27	3 2 8	8 2	1,25	✓	1	99
NS 52	MLAZI until 1952	9 7 2	82	9 1 4	9 0				
NS 53	NATAL BAY					Not being studied			
NN 1	MGENI	4 4 3 2	232	1 8 2 9	1 2 7	6,2	✓	3	0
NN 2	OHLANGA	1 1 8	28	3 2 4	8 6	2,2	✓	2	96
NN 3	MDLOTI	5 2 7	81	8 5 4	9 5	1,5		3	64
NN 4	TONGATI	4 3 6	50	7 4 7	6 7	2		3	21
NN 5	MHLALI	3 0 4	46,5	5 8 0	8 0	2	✓	3	11
NN 6	SETENI	1 6	5	6 1	8 2	0,35		2	83
NN 7	MVOTI	2 8 2 9	197	1 4 7 9	1 3 3	1,75	✓	3	2
NN 8	MDLOTANE	4 3	13	1 2 2	1 0 7	2,25		0	95
NN 9	NONOTI	2 1 0	37,5	4 8 8	7 7	1,9		2	94
NN 10	ZINKWASI	7 3	22	2 2 9	9 6	7,4		2	84
NN 11	TUGELA	2 9 1 0 1	405	3 1 0 9	1 3 0	0,8	✓	3	0
NN 12	NYONI common mouth	1 1 5	25	1 5 2	1 6 4	7		2	5
NN 13	MATIGULU since 1971	8 8 0	96	7 6 2	1 2 6	7,5	✓	3	5
NN 14	SIYAYA	1 8	8	5 9	1 3 6	2,5	✓	3	96
NN 15	MLALAZI	4 9 2	54	5 4 9	9 8	11		2	0
NN 16	RICHARDS BAY								
NN 17	MHLATUZE	3 6 7 0	209	1 2 6 5	1 6 5	0,5	✓	3	0?
NN 18	NHLABANE	1 0 4	12	4 3	2 7 9	3	✓	0	80
NN 19	MFOLOZI	1 0 0 7 5	395	1 6 4 6	2 4 0	4,6	✓	3	5
NN 20	ST. LUCIA					Not being studied			
NN 20	MGOBEZELENI	3 3	6	1 5	4 0 0	0,75		0	10
NN 21	KOSI	± 5 0 0	30	7 5	4 0 0	16,0		1	0

TABLE II

SEDIMENT YIELD (after Rooseboom, 1975)

NATAL ESTUARIES

Ref.	Catchment	Average Maximum Yields	
		tons/year	tons/km ² /yr
NS 1	MTAMVUNA	43 4290	280
NS 2	ZOLWANE	4 200	600
NS 3	SANDLUNDLU	9 600	600
NS 4	KU-BOBOYI	1 800	600
NS 5	TONGAZI	10 200	600
NS 6	KANDANDLOVU	5 400	600
NS 7	MPENJATI	60 000	600
NS 8	UMHLANGANKULU	3 600	400
NS 9	KABA	4 400	400
NS 10	MBIZANA	72 500	500
NS 11	MVUTSHINI	2 800	400
NS 12	BILANHLOLO	8 400	400
NS 13	UVUZANA	3 200	400
NS 14	KONGWENI	8 000	400
NS 15	VUNGU	85 200	400
NS 16	uMHLANGA	15 200	400
NS 17	ZOTSHA	22 800	400
NS 18	BOBOYI	12 800	400
NS 19	MBANGO	5 200	400
NS 20	MZIMKULU	2 170 020	322
NS 21	MTENTWENI	20 000	400
NS 22	MHLANGAMKULU	4 400	400
NS 23	DAMBA	10 000	400
NS 24	KOSHWANA	4 400	400
NS 25	INTSHAMBILI	13 200	400
NS 26	MZUMBE	214 400	400
NS 27	MZIMAYI (South)	18 800	400
NS 28	MHLUNGWA	12 800	400
NS 29	MFAZAZANA	6 400	400
NS 30	KWA-MAKOSI	6 400	400
NS 31	MNAMFU	6 400	400
NS 32	MTWALUME	226 000	400
NS 33	MVUZI	3 200	400
NS 34	FAFA	88 150	382
NS 35	MDESINGANE	2 400	400
NS 36	SEZELA	8 000	400
NS 37	MKUMBANE	11 200	400
NS 38	MZINTO	59 600	400
NS 39	MZIMAYI (North)	12 400	400
NS 40	MPAMBANYONI	184 550	328
NS 41	MAHLONGWA	36 800	400
NS 42	MAHLONGWANA	6 000	400
NS 43	MKOMAZI	1 616 360	375
NS 44	NGANE	6 400	400
NS 45	uMGABABA	14 800	400
NS 46	MSIMBAZI	14 000	400
NS 47	LOVU	398 900	447
NS 48	LITTLE MANZIMTOTI	7 200	400
NS 49	MANZIMTOTI	15 600	400
NS 50	MBOKODWENI	113 200	400
NS 51	SIPINGO common mouth	20 400	400
NS 52	MLAZI until 1952	426 800	439
NS 53	NATAL BAY	Not being studied	
NN 1	MGENI	1 657 670	374
NN 2	OHLANGA	47 200	400
NN 3	MDLOTI	210 800	400
NN 4	TONGATI	174 400	400
NN 5	MHLALI	121 600	400
NN 6	SETENI	6 400	400
NN 7	MVOTI	813 850	288
NN 8	MDLOTANE	17 200	400
NN 9	NONOTI	84 000	400
NN 10	ZINKWASI	29 200	400
NN 11	TUGELA	8 798 000	302
NN 12	NYONI common mouth	41 280	359
NN 13	MATIGULU since 1971	224 440	255
NN 14	SIYAYA	1 800	100
NN 15	MLALAZI	49 200	100
NN 16	RICHARDS BAY	Not being studied	
NN 17	MHLATUZE	1 055 470	288
NN 18	NHLABANE	10 400	100
NN 19	MFOLOZI	2 364 240	235
NN 20	ST. LUCIA	Not being studied	
NN 21	MGOBEZELENI	3 300	100
NN 22	KOSI	500 000	100

TABLE III
NATAL ESTUARIES

SIMULATED RUN-OFF

Ref.	River	M A R (m ³ x 10 ⁶)	Coefficients of Variation V %		Median Annual Run-off (m ³ x 10 ⁶)	Median/Mean (%)
			Annual	Monthly		
NS 1	MTAMVUNA	303,78	43,4	96,4	264,36	87
NS 2	ZOLWANE	1,73	43,4	96,4	1,51	87
NS 3	SANDLUNDLU	6,40	51,9	125,6	5,65	88
NS 4	KU-BOBOYI	1,20	51,9	125,6	1,06	88
NS 5	TONGAZI	6,80	51,9	125,6	6,00	88
NS 6	KANDANDLOVU	3,60	51,9	125,6	3,18	88
NS 7	MPENJATI	25,52	51,9	125,6	22,51	88
NS 8	UMHLANGANKULU	2,00	51,9	125,6	1,76	88
NS 9	KABA	2,44	51,9	125,6	2,15	88
NS 10	MBIZANA	29,56	51,9	125,6	26,08	88
NS 11	MVUTSHINI	1,82	51,9	125,6	1,61	88
NS 12	BILANHILOLO	5,46	51,9	125,6	4,82	88
NS 13	UVUZANA	2,08	51,9	125,6	1,83	88
NS 14	KONGWENI	5,20	51,9	125,6	4,59	88
NS 15	VUNGU	26,44	51,9	125,6	23,32	88
NS 16	uMHLANGA	9,60	51,9	125,6	8,47	88
NS 17	ZOTSHA	14,40	51,9	125,6	12,70	88
NS 18	BOBOYI	8,53	51,9	125,6	7,52	88
NS 19	MBANGO	3,47	51,9	125,6	3,06	88
NS 20	MZIMKULU	1 478,21	38,8	80,0	1 345,60	91
NS 21	MTENTWENI	14,62	68,0	149,3	11,65	80
NS 22	MHLANGAMKULU	3,22	68,0	149,3	2,57	80
NS 23	DAMBA	7,31	68,0	149,3	5,82	80
NS 24	KOSHWANA	3,22	68,0	149,3	2,57	80
NS 25	INTSHAMBILI	9,65	68,0	149,3	7,69	80
NS 26	MZUMBE	71,03	68,0	149,3	56,60	80
NS 27	MZIMAYI (South)	8,14	68,0	149,3	6,49	80
NS 28	MHLUNGWA	5,55	68,0	149,3	4,42	80
NS 29	MFAZAZANA	2,77	68,0	149,3	2,21	80
NS 30	KWA-MAKOSI	2,77	68,0	149,3	2,21	80
NS 31	MNAMFU	2,77	68,0	149,3	2,21	80
NS 32	MTWALUME	60,02	68,0	149,3	47,82	80
NS 33	MVUZI	0,84	68,0	149,3	0,67	80
NS 34	FAPA	24,17	68,0	149,3	19,26	80
NS 35	MDESINGANE	0,90	68,0	149,3	0,72	80
NS 36	SEZELA	2,99	68,0	149,3	2,38	80
NS 37	MKUMBANE	4,18	68,0	149,3	3,34	80
NS 38	MZINTO	22,29	68,0	149,3	17,76	80
NS 39	MZIMAYI (North)	4,64	68,0	149,3	3,70	80
NS 40	MPAMBANYONI	52,02	68,0	149,3	41,45	80
NS 41	MAHLONGWA	12,04	68,0	149,3	9,59	80
NS 42	MAHLONGWANA	1,96	68,0	149,3	1,56	80
NS 43	MKOMAZI	1 036,17	42,8	84,0	954,45	92
NS 44	NGANE	2,90	63,8	124,1	2,31	80
NS 45	uMGABABA	6,71	63,8	124,1	5,34	80
NS 46	MSIMBAZI	6,35	63,8	124,1	5,05	80
NS 47	LOVU	111,78	63,8	124,1	88,91	80
NS 48	LITTLE MANZIMTOTI	3,78	63,8	124,1	3,01	80
NS 49	MANZIMTOTI	8,20	63,8	124,1	6,52	80
NS 50	MBOKODWENI	35,58	71,2	146,0	27,89	78
NS 51	(SIPINGO common mouth	6,41	71,2	146,0	5,03	78
NS 52	(MLAZI until 1952	91,00	71,2	146,0	71,34	78
NS 53	NATAL BAY		Not being studied			
NN 1	MGENI	682,88	57,0	107,1	561,45	82
NN 2	OHLANGA	26,00	71,3	160,6	19,82	76
NN 3	MDLOTI	116,99	71,3	160,6	89,16	76
NN 4	TONGATI	74,99	71,3	160,6	57,15	76
NN 5	MHLALI	49,40	71,3	160,6	37,65	76
NN 6	SETENI	2,60	71,3	160,6	1,98	76
NN 7	MVOTI	468,19	85,6	146,4	335,90	72
NN 8	MDLOTANE	9,10	85,6	146,4	6,53	72
NN 9	NONOTI	44,47	85,6	146,4	31,90	72
NN 10	ZINKWASI	15,46	85,6	146,4	11,09	72
NN 11	TUGELA	4 594,94	48,8	122,3	4 045,79	88
NN 12	(NYONI common mouth					
NN 13	(MATIGULU since 1971	201,07	77,1	156,5	149,22	74
NN 14	SIYAYA	5,25	87,8	160,5	3,83	73
NN 15	MLALAZI	117,01	87,8	160,5	85,37	73
NN 16	RICHARDS BAY					
	MHLATUZE	467,50	84,8	142,3	352,90	76
NN 17	NHLABANE	30,75	87,1	158,4	21,66	70
NN 18	MFOLOZI	887,28	123,9	218,7	565,79	64
NN 19	ST. LUCIA		Not being studied			
NN 20	MGOBEZELENI	NR	NR	NR	NR	NR
NN 21	KOSI	NR	NR	NR	NR	NR

TABLE IV

SIMULATED RUN-OFF/PRECIPTATION

NATAL ESTUARIES

Ref.	River	MAR (mm)	MAP (mm)	MAR/MAP (%)
NS 1	MTAMVUNA	196	956	20,5
NS 2	ZOLWANE	247	1 019	24,5
NS 3	SANDLUNDLU	400	1 194	33,5
NS 4	KU-BOBOYI	400	1 194	33,5
NS 5	TONGAZI	400	1 194	33,5
NS 6	KANDANDLOVU	400	1 194	33,5
NS 7	MPENJATI	255	1 074	23,7
NS 8	UMHLANGANKULU	222	1 040	21,3
NS 9	KABA	222	1 040	21,3
NS 10	MBIZANA	204	1 019	20,0
NS 11	MVUTSHINI	260	1 091	23,8
NS 12	BILANHLOLO	260	1 091	23,8
NS 13	UVUZANA	260	1 091	23,8
NS 14	KONGWENI	260	1 091	23,8
NS 15	VUNGU	213	1 031	20,7
NS 16	uMHLANGA	253	1 073	23,6
NS 17	ZOTSHA	253	1 073	23,6
NS 18	BOBOYI	267	1 080	24,7
NS 19	MBANGO	267	1 080	24,7
NS 20	MZIMKULU	219	960	22,8
NS 21	MTENTWENI	292	1 030	28,3
NS 22	MHLANGAMKULU	292	1 030	28,3
NS 23	DAMBA	292	1 030	28,3
NS 24	KOSHWANA	292	1 030	28,3
NS 25	INTSHAMBILI	292	1 030	28,3
NS 26	MZUMBE	133	903	14,7
NS 27	MZIMAYI (South)	173	1 038	16,7
NS 28	MHLUNGWA	173	1 038	16,7
NS 29	MFAZAZANA	173	1 038	16,7
NS 30	KWA-MAKOSI	173	1 038	16,7
NS 31	MNAMFU	173	1 038	16,7
NS 32	MTWALUME	106	932	11,4
NS 33	MVUZI	105	920	11,4
NS 34	FAFA	105	920	11,4
NS 35	MDESINGANE	150	985	15,2
NS 36	SEZELA	150	985	15,2
NS 37	MKUMBANE	150	985	15,2
NS 38	MZINTO	150	985	15,2
NS 39	MZIMAYI (North)	150	985	15,2
NS 40	MPAMBANYONI	93	895	10,4
NS 41	MAHLONGWA	131	1 004	13,0
NS 42	MAHLONGWANA	131	1 004	13,0
NS 43	MKOMAZI	240	982	24,4
NS 44	NGANE	181	1 040	17,4
NS 45	uMGABABA	181	1 040	17,4
NS 46	MSIMBAZI	181	1 040	17,4
NS 47	LOVU	125	936	13,4
NS 48	LITTLE MANZIMTOTI	210	1 079	19,5
NS 49	MANZIMTOTI	210	1 079	19,5
NS 50	MBOKODWENI	126	961	13,1
NS 51	SIPINGO common mouth	126	961	13,1
NS 52	MLAZI until 1952	94	861	10,9
NS 53	NATAL BAY	Not being studied		
NN 1	MGENI	154	945	16,3
NN 2	OHLANGA	220	1 028	21,4
NN 3	MDLOTI	222	1 104	20,1
NN 4	TONGATI	172	1 087	15,8
NN 5	MHLALI	163	1 085	15,0
NN 6	SETENI	163	1 085	15,0
NN 7	MVOTI	166	1 035	16,0
NN 8	MDLOTANE	212	1 100	19,3
NN 9	NONOTI	212	1 100	19,3
NN 10	ZINKWASI	212	1 100	19,3
NN 11	TUGELA	158	894	17,7
NN 12	NYONI common mouth			
NN 13	MATIGULU since 1971	202	1 129	17,9
NN 14	SIYAYA	292	1 286	22,7
NN 15	MLALAZI	238	1 209	19,7
NN 16	RICHARDS BAY			
NN 17	MHLATUZE	127	876	14,5
NN 18	NHLABANE	296	1 256	23,6
NN 19	MFOLOZI	88	849	10,4
NN 20	ST. LUCIA	Not being studied		
NN 21	MGOBEZELENI	NR	NR	NR
NN 22	KOSI	NR	NR	NR

TABLE V

SIMULATED RUN-OFF FOR MZUMRE NS. 26

CATCHMENT AREA= 536.050 KM.

M.A.R.

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	M.A.R.
1921	2.18	3.89	45.50	18.37	3.08	2.01	1.51	1.87	2.36	2.13	1.94	2.01	87.90	123.75
1922	8.47	12.83	6.74	4.00	16.27	9.22	4.00	2.32	1.40	1.40	1.42	1.15	69.22	97.46
1923	1.16	1.24	1.55	2.15	3.11	3.01	2.09	1.40	.97	.74	.74	1.06	19.23	27.07
1924	1.33	1.93	3.49	25.96	12.81	106.05	38.84	3.51	2.05	1.53	1.24	1.07	199.80	281.28
1925	1.36	1.58	1.36	1.22	1.48	3.71	3.71	2.45	2.04	1.83	1.32	1.37	23.03	32.42
1926	2.39	2.93	2.56	1.82	1.63	49.86	19.91	2.91	1.72	1.18	1.21	1.33	89.45	125.94
1927	1.79	1.90	2.20	2.68	3.48	3.57	2.54	1.58	1.17	.82	.83	1.00	23.66	33.31
1928	1.50	2.12	2.29	2.20	2.05	3.57	4.94	4.34	38.05	27.79	9.16	5.36	103.37	145.52
1929	6.81	6.30	4.55	4.80	4.52	3.04	2.16	1.43	1.47	1.53	1.56	2.39	40.76	57.39
1930	3.76	4.09	4.30	4.82	4.05	4.18	4.23	2.84	1.59	42.74	18.71	4.33	99.67	140.31
1931	3.46	3.03	2.72	2.87	3.85	4.60	3.77	3.20	2.86	2.12	1.48	1.21	35.17	49.52
1932	1.73	3.69	5.05	3.84	2.21	1.76	1.81	1.56	1.11	.92	.84	.82	25.35	35.69
1933	.85	2.23	11.56	28.01	11.95	4.23	3.73	3.21	2.30	2.33	2.43	1.89	74.73	105.20
1934	1.54	2.40	23.86	11.26	3.69	3.36	3.40	3.99	76.00	29.73	5.36	3.91	168.55	237.30
1935	2.78	1.97	1.15	1.21	2.68	4.25	3.56	4.09	4.72	3.42	2.10	1.64	33.61	47.32
1936	2.00	42.00	17.20	3.56	6.88	5.50	3.12	1.79	1.15	.97	1.26	1.46	86.99	122.46
1937	1.69	1.95	2.63	3.81	27.02	11.70	3.73	3.40	2.41	2.07	1.99	1.48	63.88	89.93
1938	1.87	2.76	3.51	3.74	15.61	9.23	4.29	2.91	2.10	1.83	1.90	3.26	53.01	74.63
1939	5.24	5.99	26.97	11.14	1.92	1.32	1.38	3.28	4.99	3.99	2.51	1.74	70.49	99.24
1940	1.40	8.38	6.80	4.01	2.29	1.93	2.05	1.52	1.01	.84	.82	1.02	32.08	45.16
1941	1.42	1.84	1.83	3.10	3.76	4.35	4.67	3.64	2.35	1.47	1.85	1.95	31.79	44.76
1942	2.95	5.14	17.88	9.45	4.00	11.84	34.33	14.95	4.98	4.04	4.85	4.62	119.03	167.57
1943	12.00	23.55	10.99	4.44	3.34	3.34	3.11	2.18	1.59	1.43	1.21	2.17	69.36	97.84
1944	4.49	4.45	2.53	1.43	1.78	3.56	3.79	2.76	1.93	1.40	1.08	.85	30.05	42.30
1945	1.36	1.59	1.16	1.08	1.52	2.37	2.57	1.92	1.25	.88	.67	.61	16.96	23.87
1946	.84	1.61	2.12	2.02	2.23	12.87	8.54	4.89	5.35	5.53	4.05	2.75	52.78	74.30
1947	2.12	28.67	14.62	7.72	5.94	6.11	5.89	4.54	2.74	1.64	1.12	.89	87.00	122.49
1948	2.52	3.58	2.73	1.91	1.67	2.26	2.77	2.33	1.52	1.05	.84	.96	24.16	34.02
1949	2.65	80.54	30.81	4.93	4.64	4.03	3.23	3.03	2.58	2.21	3.24	3.89	145.77	205.22
1950	3.53	3.27	30.89	39.67	13.54	5.14	4.51	2.77	1.61	1.06	1.40	2.77	110.24	155.20
1951	4.92	4.74	9.22	9.22	6.79	4.53	5.20	5.98	4.89	3.28	2.23	1.70	57.55	81.01
1952	1.54	1.76	2.25	3.26	5.94	4.77	2.66	1.59	1.06	.74	1.23	2.32	29.26	41.19
1953	3.36	4.46	2.16	4.52	3.39	3.14	2.65	2.24	1.06	1.77	1.43	1.91	35.18	50.94
1954	53.79	22.04	3.60	12.20	4.05	18.54	9.55	3.57	2.33	1.73	1.27	1.64	138.42	154.68
1955	2.61	3.44	3.36	1.99	2.50	51.68	21.85	4.88	3.40	2.66	2.43	2.63	103.44	145.63
1956	3.43	4.52	25.65	12.67	4.10	5.33	19.19	9.61	3.28	1.97	1.50	2.40	96.64	136.05
1957	11.99	8.50	4.34	3.79	16.92	9.27	36.20	15.14	2.93	1.81	1.30	1.25	113.43	159.70
1958	1.77	3.55	3.95	3.52	3.19	2.42	1.69	58.65	23.50	4.06	3.52	3.07	112.70	156.66
1959	3.00	3.03	2.51	1.88	1.67	2.13	3.30	3.59	2.62	1.80	1.40	1.43	28.37	39.94
1960	1.91	2.74	4.52	5.12	3.93	4.15	51.67	20.87	3.88	2.92	2.25	1.97	105.99	149.21
1961	2.08	2.57	2.54	2.52	3.26	10.59	6.87	3.38	2.07	1.32	1.36	1.46	40.00	56.32
1962	1.88	3.40	3.63	25.41	11.43	42.66	17.27	2.84	1.81	2.86	3.52	2.67	119.39	168.08
1963	2.90	3.70	18.94	27.97	10.88	3.41	2.53	1.96	2.17	2.54	2.17	1.84	81.11	114.19
1964	25.51	12.59	4.89	4.70	4.43	3.06	1.78	1.42	2.26	2.99	3.39	4.41	71.44	100.57
1965	13.38	11.59	7.13	4.93	4.53	2.87	1.89	2.44	2.95	2.44	1.83	1.61	56.60	79.08
1966	1.43	1.68	1.83	2.15	3.19	4.55	13.01	7.34	3.04	2.27	1.63	1.31	43.65	61.45
1967	1.55	3.04	3.29	2.86	2.24	2.28	2.24	1.69	1.14	.81	1.16	1.92	24.01	33.60
1968	2.60	2.62	1.97	1.16	1.04	2.37	3.23	4.22	4.29	3.17	2.53	1.92	31.00	44.46
1969	4.29	5.14	5.80	5.04	3.05	1.65	.90	1.05	1.86	2.17	2.43	3.00	58.39	54.05
1970	10.00	8.01	0.11	4.70	3.77	3.66	3.62	4.49	4.26	3.76	5.37	5.83	63.59	89.53
1971	5.25	4.74	5.20	5.14	12.69	7.31	2.98	2.13	2.13	2.28	2.14	1.57	53.59	75.45
1972	1.30	3.01	4.17	3.45	2.57	2.10	2.15	1.85	1.21	.86	1.14	2.05	25.86	36.40
1973	2.73	3.34	3.66	3.83	4.15	4.19	3.59	4.43	4.97	3.73	2.40	1.64	42.68	60.09
1974	1.45	1.81	3.61	13.05	11.41	6.39	3.74	2.24	1.42	.97	.73	1.21	48.02	67.60
1975	1.88	1.82	2.63	4.15	36.73	113.63	63.56	15.02	6.13	4.75	3.85	3.62	257.75	362.87
MEAN	4.61	7.21	7.91	7.02	6.27	11.06	8.57	5.08	4.89	3.83	2.42	2.14	71.03	81.26
S	7.92	12.50	9.61	8.11	6.60	22.02	12.94	8.32	11.29	7.43	2.69	1.14	48.26	67.95
V8	171.56	173.40	121.43	115.49	105.22	198.08	150.95	163.61	230.89	194.12	110.79	55.29	67.95	55.29
MEDIAN	2.18	3.34	3.66	3.84	3.76	4.15	3.59	2.91	2.17	1.83	1.50	1.74	56.60	56.60

MEAN ANNUAL RUN-OFF= 71.03 MILLION CUBIC METRES.

COMPILED FROM HPU REPORT NO. 9/41 DATA

TABLE VI

LAND-USE (CATCHMENTS)

Ref.	Catchments	Water Transference			LAND-USE from BEGG (1978, 1983)					
		Number	Date	DAMS Proposed	% KwaZulu	Sugar Cane Plantations	Banana Plantations	Other Farming	Industry Urbanization	Conserved Areas Forestry
NS 1	MTAMVUNA				78*					
NS 2	ZOLWANE									C
NS 3	SANDLUNDLU					✓	✓			
NS 4	KU-BOBOYI					✓*	✓			
NS 5	TONGAZI				63					
NS 6	KANDANDLOVU				48*		✓*			
NS 7	MPENJATI			1	67*					
NS 8	UMHLANGANKULU				16*		✓			
NS 9	KABA				33*	✓	✓			
NS 10	MBIZANA			1	70*	✓*				
NS 11	MVUTSHINI				15	✓				
NS 12	BILANHLOLO				3	✓				
NS 13	UVUZANA					✓*				
NS 14	KONGWENI	2							semi U	
NS 15	VUNGU				24	✓				
NS 16	uMHLANGA				47*	✓*				
NS 17	ZOTSHA				26	✓				
NS 18	BOBOYI				40*	✓*				
NS 19	MBANGO								semi U	
NS 20	MZIMKULU	1			70*	✓*				F
NS 21	MTENTWENI				35	✓ 65%*				
NS 22	MHLANGAMKULU					✓				
NS 23	DAMBA				64*					
NS 24	KOSHWANA					✓				
NS 25	iNTSHAMBILI	1	1980		26			✓		C
NS 26	MZUMBE				84*					
NS 27	MZIMAYI (South)				44*	✓*				C
NS 28	MHLUNGWA				25			✓		
NS 29	MFAZAZANA				100					
NS 30	KWA-MAKOSI				100					
NS 31	MNAMFU				80					
NS 32	MTWALUME				17	✓*				
NS 33	MVUZI					✓				
NS 34	FAFA				8	✓*				
NS 35	MDESINGANE					✓ 99%*				
NS 36	SEZELA	1			47	✓				
NS 37	MKUMBANE	1	1983		49*	✓*				
NS 38	MZINTO				3	✓ 97%*				
NS 39	MZIMAYI (North)	1				✓ 99%*				
NS 40	MPAMBANYONI				53*	✓ 47%*				
NS 41	MAHLONGWA				68*	✓				
NS 42	MAHLONGWANA					✓				
NS 43	MKOMAZI			W.T.	26	✓*	✓*			
NS 44	NGANE				91					
NS 45	uMGABABA	1	1958		100					
NS 46	MSIMBAZI				81	✓				
NS 47	LOVU				32	✓*				
NS 48	LITTLE MANZIMTOTI				39	✓				
NS 49	MANZIMTOTI				84*					
NS 50	MBOKODWENI				70*			✓		F
NS 51	SIPINGO common mouth	W.T.			37	✓			I	
NS 52	MLAZI until 1952									
NS 53	NATAL BAY					Not being studied				
NN 1	MGENI	4	19 42,50,63,75,89		24*	✓*	✓	✓		
NN 2	OHLANGA (Mhlanga)				15	✓*				
NN 3	MDLOTI	1			68*	✓*			I	
NN 4	TONGATI	2			44*	✓*			I	
NN 5	MHLALI				2	✓*				
NN 6	SEIENI					✓ 100%*				
NN 7	MVOTI	1			36*	✓*			I	
NN 8	MDLOTANE	2				✓ ≈ 100%				
NN 9	NONOTI					✓ ≈ 100%*				
NN 10	ZINKWASI					✓ 100%*				
NN 11	TUGELA	W.T.		2	30*			✓*	I	
NN 12	NYONI common mouth				75*					
NN 13	MATIGULU since 1971				56*	✓				
NN 14	SIYAYA					✓*				
NN 15	MLALAZI	1			72*	✓*				
NN 16	RICHARDS BAY									
	MHLATUZE	1	1980		53*	✓*		✓	I	F
NN 17	NHLABANE	1			73					F,C
NN 18	MFOLOZI				42*	✓*				
NN 19	ST. LUCIA					Not being studied				
NN 20	MGOBEZELENI				70					F,C
NN 21	KOSI				70					

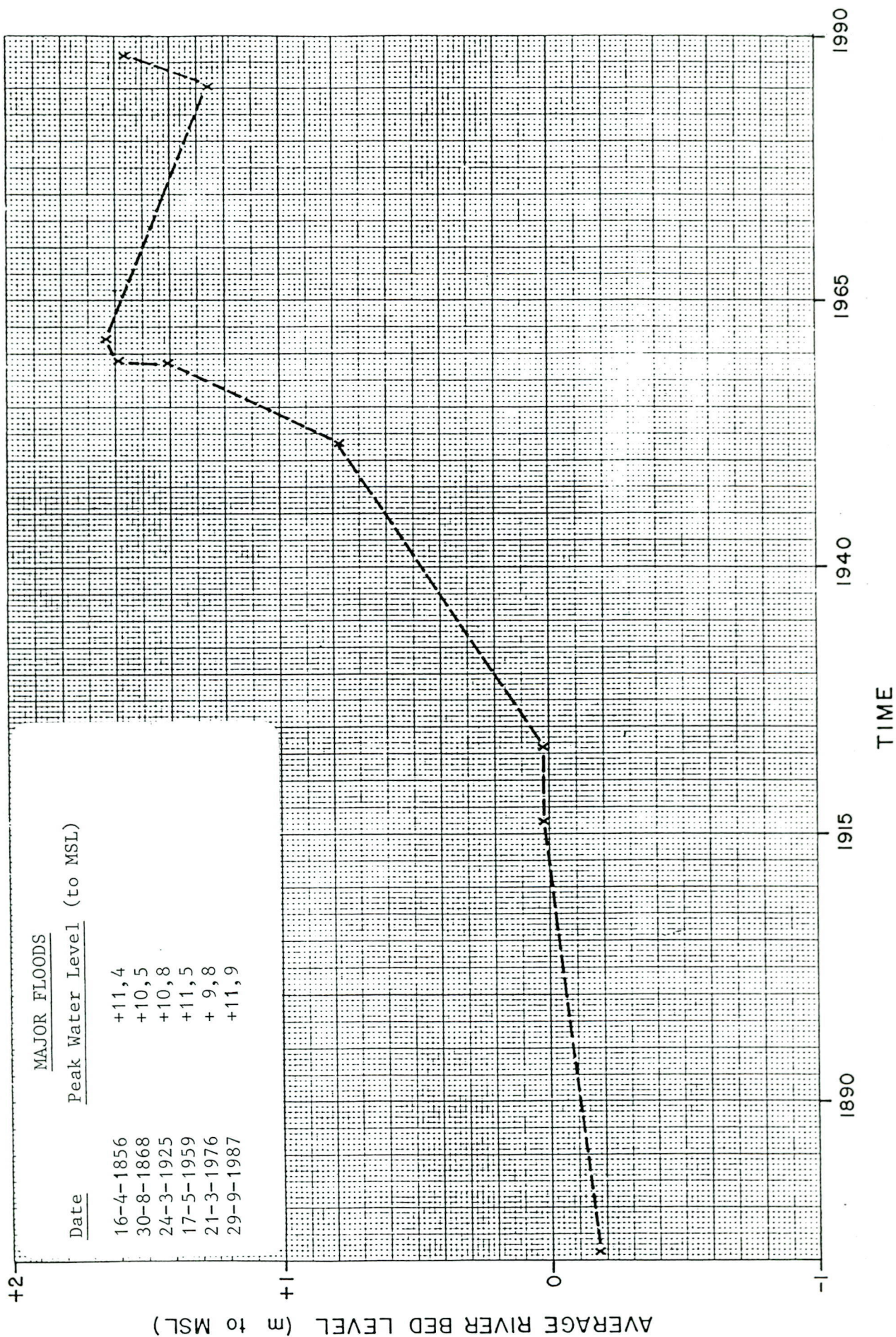
* Most important land-use factors in the catchments providing abundant silt supply

TABLE VII

LAND-USE (LOWER REACHES)

Ref.	River	Remnants of old bridges & causeways		Stabilization of Spit Old New	Weirs at Mouth at Head	Cultivation to River Banks	Removal Riverine Veg.	Swamp Drainage	Canalization Channelling	Bar artificially breached	Urbanization
		Embankments across Flood Plain									
NS 1	MTAMVUNA									✓	
NS 2	ZOLWANE										
NS 3	SANDLUNDLU	1									
NS 4	KU-BOBOYI					✓	✓ *				v. little
NS 5	TONGAZI										✓
NS 6	KANDANDLOVU	1									v. little
NS 7	MPENJATI	2								✓	
NS 8	UMHLANGANKULU						✓			✓	v. little
NS 9	KABA				✓ M					✓ *	✓
NS 10	MBIZANA										a little
NS 11	MVUTSHINI	1									✓
NS 12	BILANHLOLO	1								✓	✓
NS 13	UVUZANA	1									✓
NS 14	KONGWENI	1					✓			✓	✓
NS 15	VUNGU	1			✓ H						✓
NS 16	uMHLANGA (Mhlangeni)	1					✓ *			✓	✓
NS 17	ZOTSHA	3						✓			a little
NS 18	BOBOYI	1		✓ O						✓ *	a little
NS 19	MBANGO			✓ O							
NS 20	MZIMKULU	3 *		✓ N		✓	✓	✓		✓	✓
NS 21	MTENTWENI	2		✓ N		✓ *	✓	✓		✓	✓
NS 22	MHLANGAMKULU	2		✓ O			✓	✓			✓
NS 23	DAMBA	2		✓				✓ *		✓	✓
NS 24	KOSHWANA	3		✓ O			✓			✓ *	✓
NS 25	iNTSHAMBILI	2	R *	✓ O					C 1959-60		a little
NS 26	MZUMBE	3 *		✓ N *		✓					
NS 27	MZIMAYI (South)	2		✓ O						✓	✓
NS 28	MHLUNGWA	3 *		✓ O							v. little
NS 29	MFAZAZANA	2									
NS 30	KWA-MAKOSI	2		✓ N							
NS 31	MNAMFU	3		✓ N				✓			
NS 32	MTWALUME	2 * R						✓		✓	
NS 33	MVUZI	3		✓ N			✓ *				
NS 34	FABA	2			✓ M *	v. little	✓			✓	v. little
NS 35	MDESINGANE	1		✓ O	✓ M *	✓	✓				
NS 36	SEZELA	2				✓	✓			✓	a little
NS 37	MKUMBANE	1		✓ N *		✓ *	✓	✓			✓
NS 38	MZINTO	3 *		✓ N		✓ *	✓	✓		✓	✓
NS 39	MZIMAYI (North)	2								✓	
NS 40	MPAMBANYONI	3	R *			✓ *	✓	✓		✓	✓
NS 41	MAHLONGWA	3	R *	✓ O		✓ *	✓	✓		✓	a little
NS 42	MAHLONGWANA	3	R *	✓ N		✓	✓	✓		✓	a little
NS 43	MKOMAZI	2		✓ N		✓ *		✓		✓	a little
NS 44	NGANE	3				✓	✓	✓		✓	
NS 45	uMGABABA	3	R	✓ O		✓	✓	✓	C *	✓	
NS 46	MSIMBAZI	4				✓	✓	✓	C	✓	a little
NS 47	LOVU	3 * R		✓		✓		✓ *	C Ch	✓	a little
NS 48	LITTLE MANZIMTOTI	2					✓		Ch	✓	✓
NS 49	MANZIMTOTI	5		✓	✓ M		✓			✓ *	
NS 50	MBOKODWENI	3							C Ch	✓	✓
NS 51	SIPINGO common mouth	2					✓	✓	C	✓	✓
NS 52	MLAZI until 1952										
NS 53	NATAL BAY						Not being studied				
NN 1	MGENI	4 *						✓	C		✓
NN 2	OHLANGA (Mhlanga)	1				✓ *		✓			
NN 3	MDLOTI	1				✓ *	✓		Ch	✓	
NN 4	TONGATI	1				✓ *	✓			✓	
NN 5	MHLALI				✓ H	✓ *	✓			✓	
NN 6	SETENI					✓ *	✓				
NN 7	MVOTI					✓ *	✓ *			✓	
NN 8	MDLOTANE									✓	
NN 9	NONOTI					✓ *	✓			✓	
NN 10	ZINKWASI	1				✓ *	✓			✓	a little
NN 11	TUGELA					✓	✓ *			✓	
NN 12	NYONI common mouth										
NN 13	MATIGULU since 1971										
NN 14	SIYAYA						✓			✓	
NN 15	MLALAZI	2				✓ *	✓ *	✓		✓	
NN 16	RICHARDS BAY										
	MHLATUZE	2				✓	✓	✓ *	C *		a little
NN 17	NHLABANE									✓	
NN 18	MFOLOZI					✓	✓	✓ *	C Ch *		
NN 19	ST. LUCIA						Not being studied				
NN 20	MGOBEZELENI	1 *					✓			✓	
NN 21	KOSI						✓			✓	

* Land-use factors, in the lower reaches, most adversely aggravating siltation



NATAL ESTUARIES : MKOMAZI

RIVER BED LEVELS: OLD SOUTH COAST ROAD BRIDGE SITE (1875 - 1988)

FIGURE

1

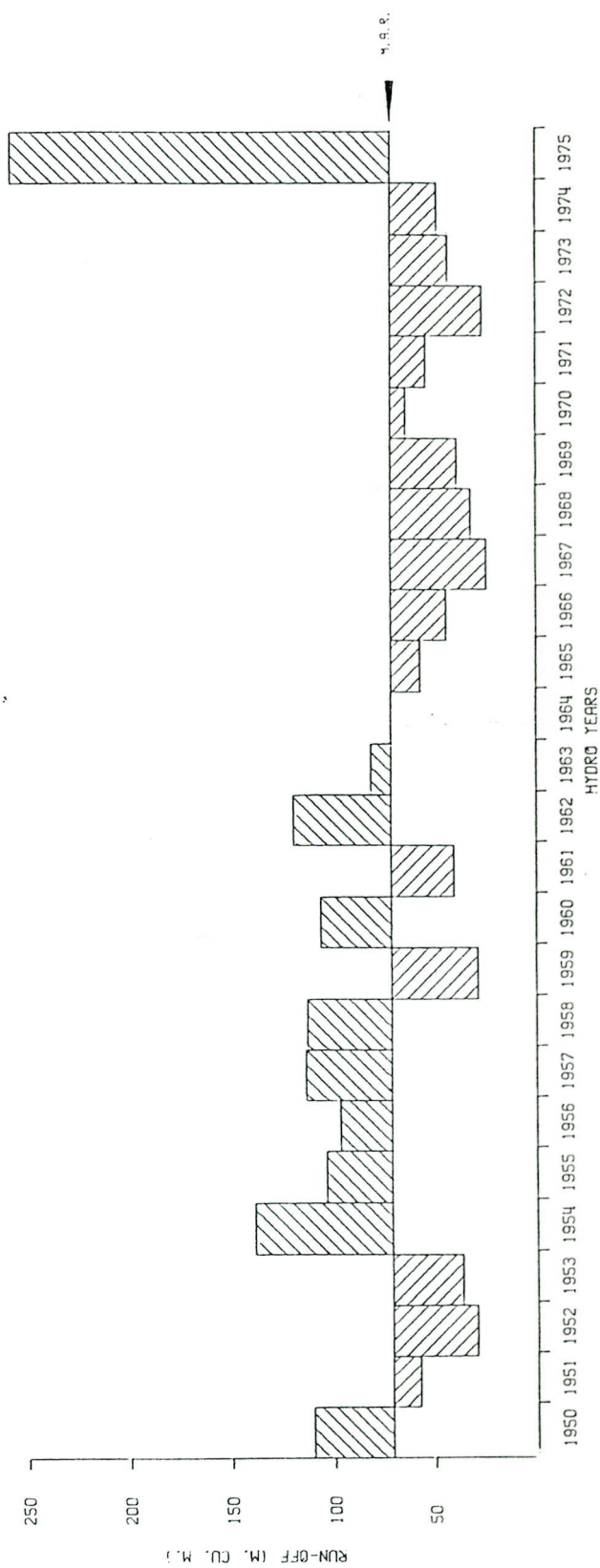
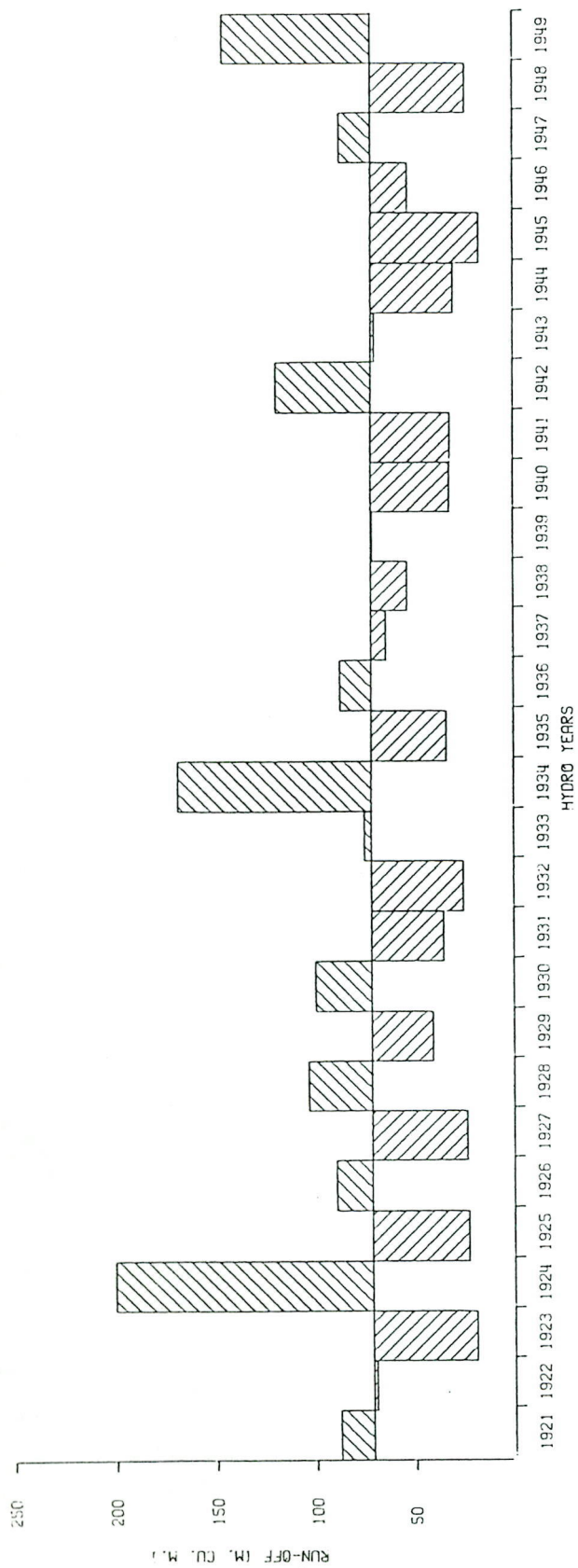


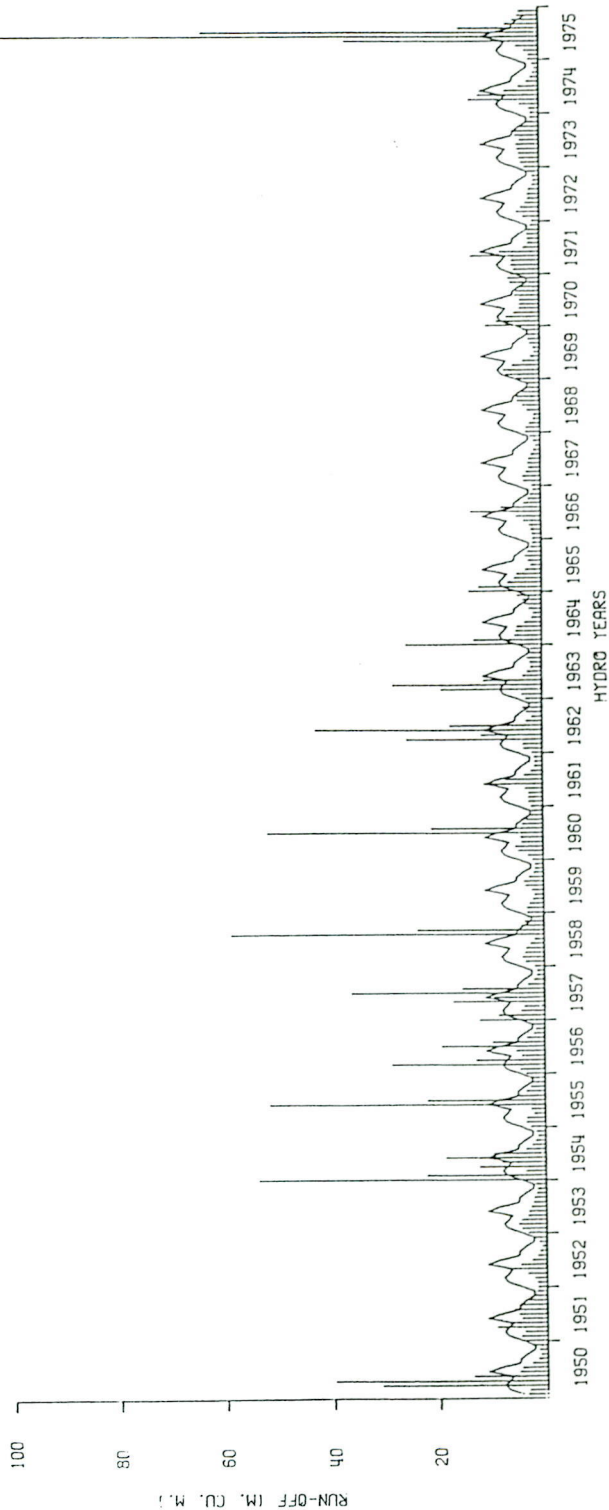
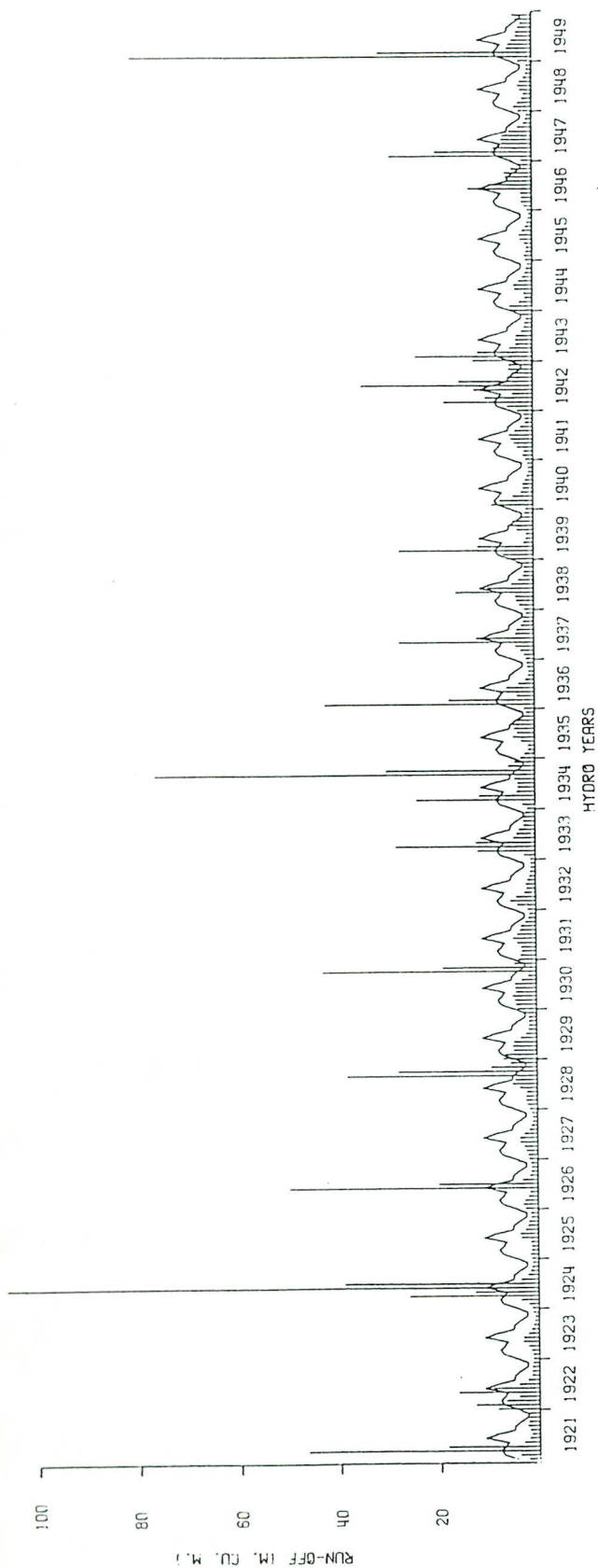
FIGURE 2

NATAL ESTUARIES - MZUMBE

SIMULATED ANNUAL RUN-OFF

1921-1975

NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY



MONTHLY MEANS

FIGURE

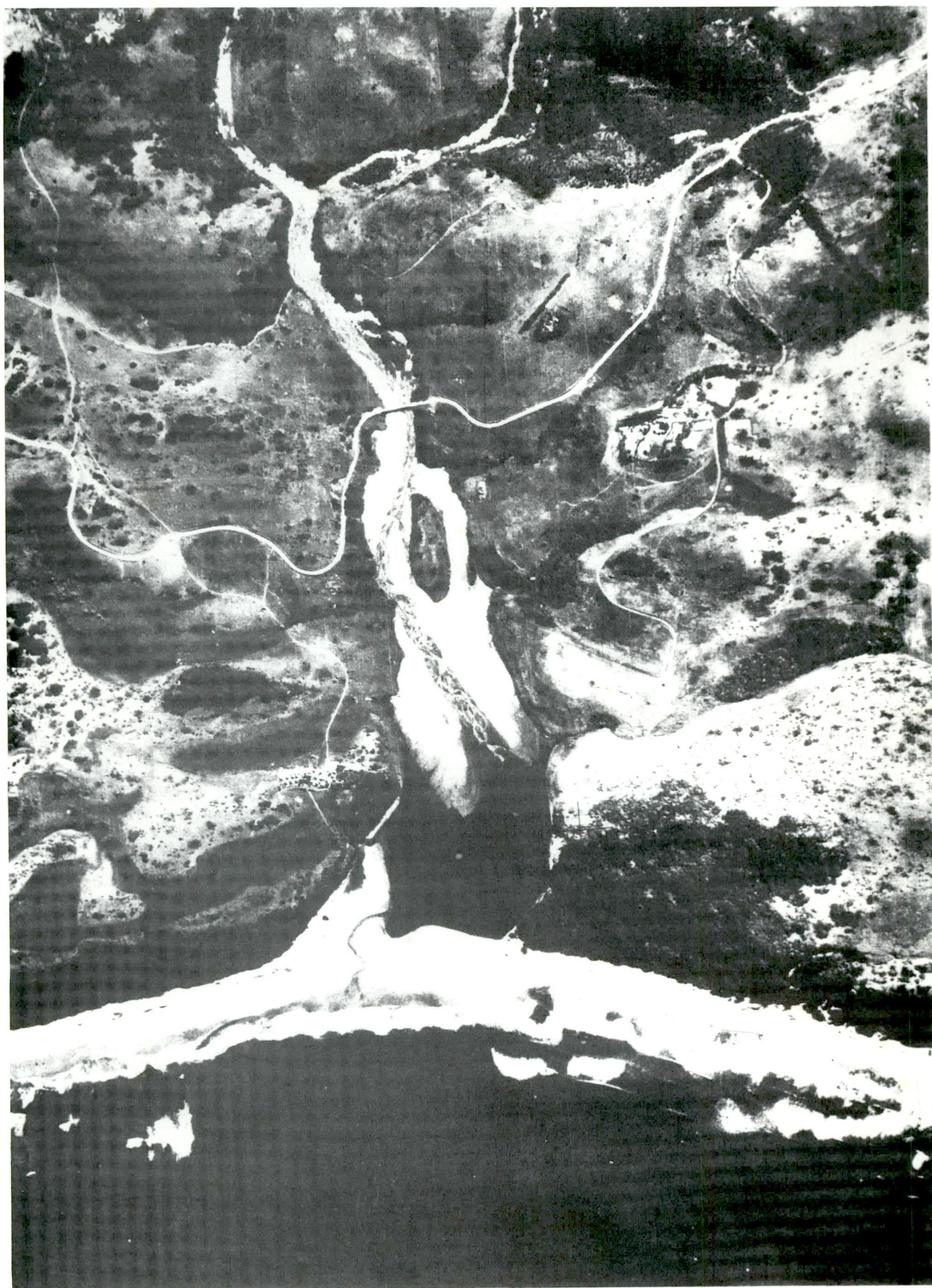
3

NATAL ESTUARIES : MZUMBE

SIMULATED MONTHLY RUN-OFF

1921-1975

NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY



SCALE: 1 : 10 000 approx



NATAL ESTUARIES: MPENJATI NS 7

FLUVIAL DELTA 2-5-37

PHOTOGRAPH

1