CONFIDENTIAL

HYDROLOGICAL/HYDRAULIC STUDY OF CAPE ESTUARIES

THE SONDAGS ESTUARY

SEDIMENT DYNAMICS DIVISION

COASTAL ENGINEERING AND HYDRAULICS

NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY

COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

NRIO MEMORANDUM 8303

Stellenbosch, South Africa

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FOREWORD

Classification of the lower reaches of the Sondags River is a pilot study for a supplement to Part II of the work being done by the Estuarine and Coastal Research Unit of NRIO on the estuaries of the Cape. It follows the method developed for the hydrological/hydraulic study of the estuaries of Natal, details of which are given in Appendix A.

This hydrological study, based upon aerial photographs, also provides a background to the field exercise on the Sondags estuary which is being done by NRIO in collaboration with the Zoology Department of the University of Port Elizabeth in April 1983.

A preliminary air-photo interpretation of the geomorphology of the area by Dr D M Chapman (Sydney University) is given in Appendix B.

The computer programming was done by Mr J Serdyn and the report was prepared by Mrs J E Perry under the supervision of Dr D H Swart, Head of the Sediment Dynamics Division, Coastal Engineering and Hydraulics, NRIO.

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HYDROLOGICAL / HYDRAULIC STUDY OF CAPE ESTUARIES

DATA REPORT No. 1
SONDAGS CSE 5

ESTUARINE DYNAMICS (CESD)
NRIO / CSIR
STELLENBOSCH

FEBRUARY, 1983

BRIEF NOTES SONDAGS CSE5

Details of the classification of the lower reaches of the Sondags for 1939, 1960, 1969 and 1976 are given in Tables CSE 5/I-IV. River widths and details of lateral stability appear in Tables CSE 5/V and VI. Simulated run-off for the period 1921-1976 is given in Table CSE 5/VII and an abstract of results in Table CSE 5/VIII. The lines used for measurement of the river widths are indicated on a map reduced from the 1:50 000 topographical series (Figure CSE 5/1). Thalweg displacement from 1939-1976 is shown in Figure CSE 5/2. Graphs of simulated annual and monthly run-off are given in Figures CSE 5/3 and 4. Photograph CSE 5/1 shows the 1939 river course superimposed on a 1976 photograph from the orthophoto series for part of the reach from the national road bridge to the mouth. Photographs used for classification purposes are reproduced as Photographs CSE 5/2-5. A photographic mosaic to a scale of 1:25 000 was compiled from the basic 1:10 000 orthophotos. This was used for a master trace to fit the photographs for 1939, 1960 and 1969. Measurements for 1976 were taken direct from the original 1:10 000 orthophotos. Colour-aerial photography of the whole reach studied was taken in July 1974 and a reproduction is given in Photograph CSE 5/6 to illustrate the nature of the terrain.

The Sondags catchment area is 20 990 km^2 and the mean annual precipitation for 1921-1976 is fairly low (334 mm). The simulated mean annual run-off, using basic data from HRU Report 9/81, is 202 x $10^6 m^3$ which gives an average run-off/precipitation ratio of only 2,89% (with a range of 1,94% - 4,13% over the various sub-catchments). Of particular interest to this study is the nature of the rainfall and subsequent run-off. It is very erratic. Long, dry periods are broken by major floods and the occasional wetter phase (Figures CSE 5/3 and 4). Major floods occurred in March 1928, March 1961, August 1971, March 1974 and July/August 1979. Another flood was registered in January 1932 at Mentz Dam and at Barkly Bridge. This does not show up fully in the simulated run-off data, a matter which is currently being investigated. To what extent the flood plain area is inundated during such major floods is not known, although there is evidence that some of the older fluvial terrace has been flooded in recent times (Appendix B). In this study areal measurements involving the flood plain refer to the larger, older flood plain comprising mostly an extensive fluvial terrace.

The Sondags is estuarine for 21 km from the mouth (Rosie Report 3) with the upstream limit being variable. This represents 89 per cent of the reach from Barkly Bridge to the mouth. The river channel, in this context synonymous with bankfull conditions, is incised for most of the reach. The banks are often vertical and about 3-4 m high (Rosie Report 3). This channel area has remained fairly constant (300-314 ha) for the 1939-1976 period under review. The only lateral shift has been in the area of the new freeway bridge on the outer bend of a meander. However, the river area is almost equal to the channel area for the tidal stretch from stations 6-23 (Figure CSE 5/1). Upstream of station 6, the river follows a narrow, winding course within the wider channel formed during high flow periods. Sidebars are frequently seen within this upper stretch, during the long periods of low flow. Near the mouth, tidal shoals occur which affect the river course and along the right bank aeolian deposits are blown into the channel from the sand dunes. During major floods the fluvial bars, tidal shoals and aeolian deposits in the channel are flushed out.

The mouth of the Sondags remains open but the sand-spits at the mouth are a variable feature. It appears that following a very long dry period, as seen in Photograph CSE 5/2, the main spit growth is from the right bank and follows the direction of the littoral drift. However, following a major flood when an outer bar develops as a marked feature, a spit forms from the left bank and this may be the dominant spit for a long period (Photo CSE 5/5).

Regarding results from the classification period under review, consideration must be given to antecedent run-off conditions for the four sets of photographs used. Data are now available (HRU Report 9/81) from which simulated run-off may be compiled for the whole Sondags catchment (Table CSE 5/VII). Wet and dry phases may be seen in Figure CSE 5/3 and more detailed monthly run-off in Figure CSE 5/4. The following important facts emerge regarding the four sets of aerial photographs studied:

(i) 1939: taken during a month of below-average run-off and after a long dry phase. Two months prior to the photograph there was one month of above-average run-off.

(ii) 1960: taken during a below-average run-off period and after a long dry phase.

(iii) 1969: taken during a below-average run-off period and after a long dry phase.

(iv) 1976: taken during a month of average run-off but within a wet phase and only three months after floods.

We therefore see that the sinuosity of the reach is lower in 1976 and the average river width is greater. The average lateral displacement for the period under review is 29,3 m with a coefficient of variation of 24,9%. This suggests some instability but this is mainly the result of bars in the upper reach and tidal shoals near the mouth which are characteristic features of this river with its long dry phases. There is a little evidence for a downstream progression of the irregular meander pattern (Photo CSE 5/1) but in general the river channel itself is fairly stable. There was probably more lateral instability in the recent past following floods, prior to completion of the two dams in the catchment in the 1920s. An anti-erosion wall of about 2 km was built on the left bank of the middle stretch of the reach, presumably to control meander formation in that area. The dams will have the effect of attenuating the floods.

The dams also have an effect on the silt supply by trapping the sediment. However, there is a source of sediment from the Cape Fold Belt downstream of the Mentz Dam where the "shales and sandstones readily weather to yield a clay-rich sediment load with subordinate sand" (Rosie report 3). Other human influences which affect this reach of the Sondags include bridge building, jetties and farming. The freeway bridge with its embankments could affect *major* flood flows as it lies across a meander. The jetties aid sidebar formation and the influence of farming is minimal.

Overall, the Sondags estuary has been fairly stable for the period under review.

LIST OF TABLES

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REFERENCES

Pitman W.V., Middleton B.J. and Midgley D.C. 1981
Surface water resources of South Africa, Vol V.
Hydrological Research Unit Report No. 9/81.

Reddering J.S.V. and Esterhuysen K. 1981
Sedimentation in the Sundays estuary.
Rosie Report No. 3.

ABBREVIATIONS/SYMBOLS USED IN THE TABLES

M.A.R.	Mean annual run-off
L.B.	Left bank
R.B.	Right bank
P	Perimeter
$\bar{x}$	Arithmetic mean
s	Standard deviation
V	Coefficient of variation $\frac{s}{\bar{x}}$
MSL	Mean sea level
R	River
d/s	Downstream
____	Maximum value
....	Minimum value
N.R.	No record

TABLE CSE 5/II

CLASSIFICATION OF THE LOWER REACHES OF NATAL RIVERS

NRIO CSE 5

RIVER SONDAGS, 89 % ESTUARINE, REACH from Barkly Br to Mouth, 24,3 km from mouth. REF. DEA N 400

AERIAL PHOTO DATE Sept-Nov'60 SCALE 1:25 000 CATCHMENT AREA 20 990 km², M.A.R. 202 m³x10⁶, No. of DAMS 2

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley

Terrain: mountainous; hilly; ✓ undulating; plains

Vegetation: almost none; grass; sparsely forested (0-25%); moderately forested (25-75%); heavily forested (75-100%); swamp/bog; ✓ bush

Land-Use: none; ✓ scattered cultivation; partly cultivated; mainly cultivated; ✓ scattered settlement; partly built-up; urbanised

Valley Sides (~~Not~~ Well-defined) — marine terrace

Slumping: ✓ none; occasional; frequent

Vegetation and Land-Use	*Left*	*Right**
none		
grass	%	%
~~trees~~ bush	100 %	80 %
cultivated	%	%
built-up	%	%

Comments *bare sand dunes near mouth: 20%

Valley Characteristics

Measurements: valley length 20900 m; bottom width (av.) 1925 m; valley slope ____; height at head of reach ____ m to MSL

Terraces: none; indefinite; fragmentary; ✓ continuous

Relation of Channel to Valley Bottom (Vertical): not applicable; ✓ not obviously degrading (or aggrading); ✓ partly entrenched; entrenched; aggrading

Relation of Channel to Valley Sides or Resistant Terraces (Lateral): not applicable (no valley or free); occasionally confined; ✓ frequently confined; entrenched

Surface Geology: bedrock; lacustrine deposits; ✓ fluvial deposits; ✓ aeolian; sand covered 84 ha

Comments ____

River Mouth

Characteristics: ✓ open/~~closed~~; ✓ natural/~~artificial~~; canalized; ✓ sandy; rocks on right bank; rocks on left bank; outer bar; silt plume (fluvial); ✓ suspended sediment (marine)

Measurements:

	from L.B.	R.B.
right bank breakwater length	____ m	
left bank breakwater length	____ m	
rock sill level	____ m to MSL	
cliffs on right bank: height	____ m to MSL	
cliffs on left bank: height	____ m to MSL	
spit/~~bar~~: direction of growth	257, 280°*	66°
length of spit/~~bar~~	500 m*	285 m
length stabilized	NIL m	NIL
width	150 m	188 m

Comments * curved

FLOOD PLAIN AND CHANNEL FEATURES

Description of Flood Plain

Presence: none; indefinite; fragmentary; ✓ continuous

Extent: none; average width 1925 m; maximum width 3250 m; aerial length 17180 m; area 4237 ha

Vegetation: almost none; ✓ grass → bush; reed swamp ____ % area; sparsely forested; moderately forested; heavily forested

Forest Type: not ~~known~~/applicable; riverine: main channel, tributaries; coastal dune/evergreen; mangroves

Land-Use: mostly pasture; not cultivated, not built-up; cultivated 7 % area; crop/~~sorchards~~? wheat, lucerne; ✓ partly built-up*; mainly built-up

Comments *a little: 16,5 km from head of reach L.B

Channel Description N.B. Estimate of flow stage: LOW/~~HIGH LONG-TERM MEAN/HIGH~~

Pattern: straight; sinuous; irregular; regular meanders; ✓ irregular meanders; tortuous meanders; bifurcated; lake/s; lagoon

Measurements: thalweg 24337 m; *sinuosity 1,42; *open water area 150 ha; perimeter 50300 m; lake/lagoon area ____ ha; (river X-sections available: Barkly Br. 22-1-52); channel slope ____; channel width x̄ ____ m s = ____ m; river slope ____; river width x̄ 57,1 m s = 40,3 m

*~~Islands~~/Shoals***: none; occasional; frequent; split; braided

Type of Flow: stagnant/still; ✓ uniform water surface; uniform with rapid in reach; irregular; pool & riffle sequence

Bar Type: none; ✓ channel side bars; ✓ point bars; channel junction bars; mid-channel bars; diamond bars; diagonal bars; sand waves/large dunes

Comments *whole reach; ** at mouth

Obstructions/Constructions

Natural: ✓ none; logs; boulders; vegetation

Degree: ✓ none; minor; major

Comments ____

Man-made	*Degree of Obstruction/Constriction for Each*	*Position (from head of reach)*
✓ road bridge/s (2)	River confined	0 + 13,9 km
✓ rail bridge/~~s~~	River confined	0
causeway		
weir/dam		
fish traps		
embankment/s		
~~groynes~~ jetties	aiding sidebar formation	16 - 20 km L.B
canals		
✓ drainage furrows		8 km R.B
✓ others	anti erosion walls	8,5 - 10,5 km L.B.

Lateral Channel Activity

Lateral Activity: not detectable; ✓ downstream progression*; progression & cut-offs; mainly cut-offs; entrenched loop development; irregular lateral activity; avulsion

Nature of Banks: ✓ alluvium (silt/sand); natural levées; rock/boulders; protected/stabilized; ✓ cultivation to channel edge **

Bank Vegetation: ✓ none; weak; good; very strong; left bank ____ %; right bank ____ %

Lateral Stability: stable; ✓ slightly unstable; moderately unstable; highly unstable

Comments * not v. active; ** a little

TABLE CSE 5/III CLASSIFICATION OF THE LOWER REACHES OF NATAL RIVERS

NRIO CSE 5

RIVER SONDAGS, 89 % ESTUARINE, REACH from Barkly Br. to Mouth, 24,4 km from mouth. REF. DEA N 400

AERIAL PHOTO DATE May-June '69 SCALE 1:25 000 CATCHMENT AREA 20 990 km², M.A.R. 202 m³x10⁶, No. of DAMS 2

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley

Terrain
- mountainous
- hilly
- ✓ undulating
- plains

Vegetation
- almost none
- grass
- sparsely forested (0-25%)
- moderately forested (25-75%)
- heavily forested (75-100%)
- swamp/bog
- ✓ bush

Land-Use
- none
- ✓ scattered cultivation
- partly cultivated
- mainly cultivated
- ✓ scattered settlement
- partly built-up
- urbanised

Valley Sides (~~Not~~ Well-defined) – marine terrace

Slumping
- ✓ none
- occasional
- frequent

Vegetation and Land-Use	*Left*	*Right* *
none		
grass	___	___ %
~~trees~~ bush	100	80 %
cultivated	___	___ %
built-up	___	___ %

Comments: * bare sand dunes near mouth: 20%

Valley Characteristics

Measurements
- valley length 20 900 m
- bottom width (av.) 1925 m
- valley slope ______
- height at head of reach ____ m to MSL

Terraces
- none
- indefinite
- fragmentary
- ✓ continuous

Relation of Channel to Valley Bottom (Vertical)
- not applicable
- ✓ not obviously degrading, or aggrading
- ✓ partly entrenched
- entrenched
- aggrading

Relation of Channel to Valley Sides or Resistant Terraces (Lateral)
- not applicable (no valley or free)
- occasionally confined
- ✓ frequently confined
- entrenched

Surface Geology
- bedrock
- lacustrine deposits
- ✓ fluvial deposits
- ✓ aeolian
- sand covered 85 %

Comments ______

River Mouth

Characteristics
- ✓ open/~~closed~~
- ✓ natural/~~artificial~~
- canalized
- ✓ sandy
- rocks on right bank
- rocks on left bank
- outer bar
- silt plume (fluvial)
- ✓ suspended sediment (marine)

Measurements
- right bank breakwater length ______ m
- left bank breakwater length ______ m
- rock sill level ______ m to MSL
- cliffs on right bank: height ______ m to MSL
- cliffs on left bank: height ______ m to MSL

spit/~~bar~~:	from L.B.	R.B.
direction of growth	254° 278° *	73°
length of spit/~~bar~~	580 m *	300 m
length stabilized	NIL m	NIL
width	175 m	163 m

Comments * curved

FLOOD PLAIN AND CHANNEL FEATURES

Description of Flood Plain

Presence
- none
- indefinite
- fragmentary
- ✓ continuous

Extent
- none
- average width 1925 m
- maximum width 3250 m
- aerial length 17170 m
- area 4237 ha

Vegetation
- almost none
- ✓ grass > bush
- reed swamp ______ % area
- sparsely forested
- moderately forested
- heavily forested

Forest Type
- not ~~known~~/applicable
- riverine:
- main channel
- tributaries
- coastal dune/evergreen
- mangroves

Land-Use: mostly pasture
- not cultivated, not built-up
- cultivated 7 % area
- crop/s orchards + ? wheat, lucerne
- ✓ partly built-up *
- mainly built-up

Comments * a little: 16,5 km from head of reach. L.B.

Channel Description N.B. Estimate of flow stage: LOW/~~MEDIUM-LONG-TERM-MEAN/HIGH~~

Pattern
- straight
- sinuous
- irregular
- regular meanders
- ✓ irregular meanders
- tortuous meanders
- bifurcated
- lake/s
- lagoon

Measurements
- thalweg 24350 m
- *sinuosity 1,42
- *open water area 152 ha
- perimeter 50400 m
- lake/lagoon area ______ ha
- river X-sections available
- channel slope ______
- channel width x̄ ______ m s = ______ m
- river slope ______
- river width x̄ 52,6 m s = 31,1 m

~~Islands~~/Shoals ** ✓
- none
- occasional
- frequent
- split
- braided

Type of Flow
- stagnant/still
- ✓ uniform water surface
- uniform with rapid in reach
- irregular
- pool & riffle sequence

Bar Type
- none
- ✓ channel side bars
- ✓ point bars
- channel junction bars
- mid-channel bars
- diamond bars
- diagonal bars
- sand waves/large dunes

Comments *whole reach
** at mouth

Obstructions/Constructions

Natural
- ✓ none
- logs
- boulders
- vegetation

Degree
- ✓ none
- minor
- major

Comments ______

Man-made	*Degree of Obstruction/Constriction for Each*	*Position (from head of reach)*
✓ road bridge/s (2)	River confined	0 & 13,9 km
✓ rail bridge/~~s~~	River confined	0
causeway		
weir/dam		
fish traps		
embankment/s		
~~groynes~~ jetties	aiding side bar formation	16 – 20 km L.B.
canals		
✓ drainage furrows		8 km R.B.
✓ others anti erosion walls		8,5 – 10,5 km L.B.

Lateral Channel Activity

Lateral Activity
- not detectable
- ✓ downstream progression *
- progression & cut-offs
- mainly cut-offs
- entrenched loop development
- irregular lateral activity
- avulsion

Nature of Banks
- ✓ alluvium (silt/sand)
- natural levées
- rock/boulders
- protected/stabilized
- ✓ cultivation to channel edge **

Bank Vegetation
- ✓ none
- weak
- good
- very strong
- left bank ______ %
- right bank ______ %

Lateral Stability
- stable
- ✓ slightly unstable
- moderately unstable
- highly unstable

Comments * not v. active
** a little

TABLE CSE 5/IV CLASSIFICATION OF THE LOWER REACHES OF NATAL RIVERS

NRIO CSE 5

RIVER SONDAGS, 89 % ESTUARINE, REACH from Barkly Br to Mouth, 23,6 km from mouth. REF. DEA N 400

AERIAL PHOTO DATE 12-7-76 (ortho photo series) SCALE 1:10 000 CATCHMENT AREA 20 990 km², M.A.R. 202 m³x10⁶, No. of DAMS 2

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley

Terrain
- mountainous
- hilly
- ✓ undulating
- plains

Vegetation
- almost none
- grass
- sparsely forested (0-25%)
- moderately forested (25-75%)
- heavily forested (75-100%)
- swamp/bog
- ✓ bush

Land-Use
- none
- ✓ scattered cultivation
- partly cultivated
- mainly cultivated
- ✓ scattered settlement
- partly built-up
- urbanised

Valley Sides (~~Not~~ Well-defined) – marine terrace

Slumping
- ✓ none
- occasional
- frequent

Vegetation and Land-Use	*Left*	*Right* *
none		
grass		%
~~trees~~ bush	100	80 %
cultivated		%
built-up		%

Comments: bare sand dunes near mouth: 20%

Valley Characteristics

Measurements
- valley length 20900 m
- bottom width (av.) 1925 m
- valley slope ≃ 1:2090
- height at head of reach 10 m to MSL approx

Terraces
- none
- indefinite
- fragmentary
- ✓ continuous

Relation of Channel to Valley Bottom (Vertical)
- not applicable
- ✓ not obviously degrading
- ✓ partly entrenched or aggrading
- entrenched
- aggrading

Relation of Channel to Valley Sides or Resistant Terraces (Lateral)
- not applicable (no valley or free)
- occasionally confined
- ✓ frequently confined
- entrenched

Surface Geology
- bedrock
- lacustrine deposits
- ✓ fluvial deposits
- ✓ aeolian
- sand covered 45 ha

Comments

River Mouth

Characteristics
- ✓ open/~~closed~~
- ✓ natural/~~artificial~~
- canalized
- ✓ sandy
- rocks on right bank
- rocks on left bank
- outer bar
- silt plume (fluvial)
- ✓ suspended sediment (marine)

Measurements
- right bank breakwater length ____ m
- left bank breakwater length ____ m
- rock sill level ____ m to MSL
- cliffs on right bank: height ____ m to MSL
- cliffs on left bank: height ____ m to MSL
- spit/~~bar~~: direction of growth 254° - 283° *
- length of spit/~~bar~~ 610 m *
- length stabilized NIL m
- width 163 m

Comments: * curved; * curved

FLOOD PLAIN AND CHANNEL FEATURES

Description of Flood Plain

Presence
- none
- indefinite
- fragmentary
- ✓ continuous

Extent
- none
- average width 1925 m
- maximum width 3250 m
- aerial length 17086 m
- area 4237 ha

Vegetation
- almost none
- ✓ grass & bush
- reed swamp ____ % area
- sparsely forested
- moderately forested
- heavily forested

Forest Type
- not ~~known~~/applicable
- riverine:
- main channel
- tributaries
- coastal dune/evergreen
- mangroves

Land-Use: mostly pasture
- not cultivated, not built-up
- cultivated ____ % area
- crop/s
- ✓ partly built-up *
- mainly built-up

Comments: * a little: 16,5 km from head of reach L.B.

Channel Description

N.B. Estimate of flow stage: ~~LOW~~/NEAR LONG-TERM MEAN/~~HIGH~~

Pattern
- straight
- sinuous
- irregular
- regular meanders
- ✓ irregular meanders
- tortuous meanders
- bifurcated
- lake/s
- lagoon

Measurements
- thalweg 23630 m
- *sinuosity 1,38
- *open water area 202 ha
- perimeter 49600 m
- lake/lagoon area ____ ha
- river X-sections available
- channel slope ____
- channel width x̄ ____ m s = ____ m
- river slope ____
- river width x̄ 81,7 m s = 77,0 m

~~Islands~~/Shoals **
- none
- occasional
- frequent
- split
- braided

Type of Flow
- stagnant/still
- ✓ uniform water surface
- uniform with rapid in reach
- irregular
- pool & riffle sequence

Bar Type
- none
- ✓ channel side bars
- ✓ point bars
- channel junction bars
- mid-channel bars
- diamond bars
- diagonal bars
- sand waves/large dunes

Comments: *whole reach; ** at mouth

Obstructions/Constructions

Natural
- ✓ none
- logs
- boulders
- vegetation

Degree
- ✓ none
- minor
- major

Comments

Man-made	*Degree of Obstruction/Constriction for Each*	*Position (from head of reach)*
road bridge/s (3)	River confined	0; 13,9 km & 15,6 km
rail bridge/s	River confined	0
causeway		
weir/dam		
fish traps		
embankment/s		
~~groynes~~ jetties	aiding sidebar formation	16-20 km L.B.
canals		
✓ drainage furrows		8 km R.B
✓ others anti erosion walls		8,5 - 10,5 km L.B.

Lateral Channel Activity

Lateral Activity
- not detectable
- ✓ downstream progression *
- progression & cut-offs
- mainly cut-offs
- entrenched loop development
- irregular lateral activity
- avulsion

Nature of Banks
- ✓ alluvium (silt/sand)
- natural levées
- rock/boulders
- protected/stabilized
- ✓ cultivation to channel edge **

Bank Vegetation
- ✓ none
- weak
- good
- very strong
- left bank ____ %
- right bank ____ %

Lateral Stability
- stable
- ✓ slightly unstable
- moderately unstable
- highly unstable

Comments: * not v. active; ** a little

TABLE CSE 5/V RIVER WIDTHS

SONDAGS CSE 5

Station	Approx. distance along river course from Barkly Bridge (m)	River widths (m)				x̄	s	V%
		Date						
		April '39	Sept-Nov.'60	May-June '69	12-7-76			
1	0	20	20	20	25	21,3	2,5	11,8
2	1 000	12,5	12,5	12,5	20	14,4	3,8	26,1
3	2 000	12,5	12,5	12,5	25	15,6	6,3	40,0
4	3 000	12,5	12,5	20	28	18,3	7,4	40,5
5	4 000	12,5	12,5	12,5	35	18,1	11,3	62,1
6	5 000	12,5	20	22,5	38	23,3	10,7	46,1
7	6 000	12,5	35	27,5	38	28,3	11,4	40,3
8	7 000	25	50	25	45	36,3	13,1	36,3
9	8 000	25	37,5	27,5	55	36,3	13,6	37,5
10	9 000	37,5	37,5	45	55	43,8	8,3	19,0
11	10 000	37,5	37,5	45	50	42,5	6,1	14,4
12	11 000	37,5	45	50	50	45,6	5,9	12,9
13	12 000	62,5	50	50	60	55,6	6,6	11,8
14	13 000	62,5	50	50	55	54,4	5,9	10,9
15	14 000	55	57,5	62,5	70	61,3	6,6	10,8
16	14 750	62,5	62,5	70	80	68,8	8,3	12,1
17	15 500	62,5	62,5	62,5	80	66,9	8,8	13,1
18	16 500	62,5	62,5	62,5	78	66,4	7,8	11,7
19	17 500	87,5	87,5	97,5	105	94,4	8,5	9,0
20	18 500	90	87,5	100	105	95,6	8,3	8,6
21	19 500	100	87,5	100	105	98,1	7,5	7,6
22	20 500	112,5	87,5	95	160	113,8	32,6	28,6
23	21 500	175	125	100	200	150	45,6	30,4
24	22 500	325	187,5 (87,5 + 75 + 25)	97,5 (70 + 27,5)	390	250	132,1	52,9
25	23 500	62,5	87,5	47,5	90	71,9	20,5	28,5
x̄		63,1	57,1	52,6	81,7	63,6		
s		67,2	40,3	31,1	77,0			
V%		106,5	70,6	59,1	94,2			

TABLE CSE 5/VI LATERAL STABILITY

SONDAGS CSE 5

Station	Approx. distance along river course from Barkly Bridge (m)	Distance from maximum observed L.B. position to mid-river (m) — Date: April'39	Sept-Nov.'60	May-June'69	12-7-76	Max-Min	$\bar{x}$	s	V%
1	0	10	10	15	12,5	5	11,9	2,4	20,2
2	1 000	10	6,3	10	10	3,7	9,1	1,8	20,4
3	2 000	6,3	25	20	25	18,7	19,1	8,8	46,3
4	3 000	20,0	27,5	20	14	13,5	20,4	5,5	27,1
5	4 000	22,5	10	20	25	15	19,4	6,6	33,9
6	5 000	20	20	32,5	19	13,5	22,9	6,4	28,1
7	6 000	20	27	30	19	11	24	5,4	22,3
8	7 000	50	25	37,5	22,5	27,5	33,8	12,7	37,5
9	8 000	50	31,3	51,3	27,5	22,5	40,0	12,4	30,9
10	9 000	27,5	18,8	22,5	27,5	8,7	24,1	4,2	17,6
11	10 000	47,5	38,8	22,5	25	25	33,5	11,8	35,3
12	11 000	18,5	30	25	25	11,5	24,6	4,7	19,1
13	12 000	31,3	25	25	30	17,5	27,8	3,3	11,9
14	13 000	41	25	25	27,5	16	29,6	7,7	25,9
15	14 000	27,5	28,8	32	37	9,5	31,3	4,2	13,5
16	14 750	31,3	31,3	35	40	8,7	34,4	4,1	12,0
17	15 500	31,3	43,8	56,3	65	33,7	49,1	14,7	30,0
18	16 500	35	31,3	36	45	13,7	36,8	5,8	15,8
19	17 500	45	43,8	50	52,5	8,7	47,8	4,1	8,6
20	18 500	55	43,8	55	65	21,2	54,7	8,7	15,8
21	19 500	62,5	56,3	62,5	52,5	10	58,5	4,9	8,4
22	20 500	56,3	43,8	47,5	80	36,2	56,9	16,3	28,6
23	21 500	87,5	100	75	105	30	91,9	13,4	14,6
24	22 500	162,5	156,3	93,8	207,5	113,7	155,0	46,8	30,2
25	23 500	31,3	131,3	136,3	270	238,7	142,2	98,0	68,9
$\bar{x}$		36,0	41,2	41,4	53,2	29,3	44,0		24,9
s		19,6	36,1	28,1	60,9	48,5			13,3
V%		54,4	87,5	67,7	114,6	165,4			53,6

Average lateral displacement 1939-76 = 29,3 m

Average coefficient of variation 1939-76 = 24,9%

TABLE CSE 5/I

CLASSIFICATION OF THE LOWER REACHES OF NATAL RIVERS

NRIO CSE 5

RIVER SONDAGS, 89 % ESTUARINE, REACH from Barkly Br to Mouth, 24,2 km from mouth. REF. DEA N 400

AERIAL PHOTO DATE April '39 SCALE 1:25 000 CATCHMENT AREA 20 990 km², M.A.R. 202 m³x10⁶, No. of DAMS 2

RIVER VALLEY AND RIVER MOUTH FEATURES

General Description of the Terrain above the Valley

Terrain
- mountainous
- hilly
- ✓ undulating
- plains

Vegetation
- almost none
- grass
- sparsely forested (0-25%)
- moderately forested (25-75%)
- heavily forested (75-100%)
- swamp/bog
- ✓ bush

Land-Use
- none
- ✓ scattered cultivation
- partly cultivated
- mainly cultivated
- ✓ scattered settlement
- partly built-up
- urbanised

Valley Sides (~~Not~~ Well-defined) – marine terrace

Slumping
- ✓ none
- occasional
- frequent

Vegetation and Land-Use	*Left*	*Right* *
none		
grass		
~~trees~~ bush	100 %	80 %
cultivated	%	%
built-up	%	%

Comments *bare sand dunes near mouth: 20%

Valley Characteristics

Measurements
- valley length 20 900 m
- bottom width (av.) 1925 m
- valley slope ____
- height at head of reach ____ m to MSL

Terraces
- none
- indefinite
- fragmentary
- ✓ continuous

Relation of Channel to Valley Bottom (Vertical)
- not applicable
- ✓ not obviously degrading or aggrading
- ✓ partly entrenched
- entrenched
- aggrading

Relation of Channel to Valley Sides or Resistant Terraces (Lateral)
- not applicable (no valley or free)
- occasionally confined
- ✓ frequently confined
- entrenched

Surface Geology
- bedrock
- lacustrine deposits
- ✓ fluvial deposits
- ✓ aeolian
- sand covered 58 ha

Comments ____

River Mouth

Characteristics
- ✓ open/~~closed~~
- ✓ natural/~~artificial~~
- canalized
- ✓ sandy
- rocks on right bank
- rocks on left bank
- outer bar
- silt plume (fluvial)
- ✓ suspended sediment (marine)

Measurements
- right bank breakwater length ____ m
- left bank breakwater length ____ m
- rock sill level ____ m to MSL
- cliffs on right bank: height ____ m to MSL
- cliffs on left bank: height ____ m to MSL

spit/~~bar~~:	from L.B.	from R.B.
direction of growth	252°	73°, 54° *
length of spit/~~bar~~	240 m	590 m *
length stabilized	NIL m	NIL
width	113 m	119 m

Comments * curved

FLOOD PLAIN AND CHANNEL FEATURES

Description of Flood Plain

Presence
- none
- indefinite
- fragmentary
- ✓ continuous

Extent
- none
- average width 1925 m
- maximum width 3250 m
- aerial length 17240 m
- area 4237 ha

Vegetation
- almost none
- ✓ grass → bush
- reed swamp ____ % area
- sparsely forested
- moderately forested
- heavily forested

Forest Type
- not ~~known~~/applicable
- riverine:
- main channel
- tributaries
- coastal dune/evergreen
- mangroves

Land-Use: mostly pasture
- ✓ ~~not cultivated~~, not built-up
- cultivated 5 % area
- crop/s ~~orchards~~ wheat, lucerne
- partly built-up
- mainly built-up

Comments ____

Channel Description

N.B. Estimate of flow stage: fairly LOW/~~MED-LONG-TERM MEAN/HIGH~~

Pattern
- straight
- sinuous
- irregular
- regular meanders
- ✓ irregular meanders
- tortuous meanders
- bifurcated
- lake/s
- lagoon

Measurements
- thalweg 24 200 m
- *sinuosity 1,40
- *open water area 170 ha
- perimeter 49 100 m
- lake/lagoon area ____ ha
- river X-sections available
- channel slope ____
- channel width x̄ ____ m s = ____ m
- river slope ____
- river width x̄ 63,1 m s = 67,2 m

~~Islands~~/Shoals **
- none
- occasional
- frequent
- split
- braided

Type of Flow
- stagnant/still
- ✓ uniform water surface
- uniform with rapid in reach
- irregular
- pool & riffle sequence

Bar Type
- none
- ✓ channel side bars
- ✓ point bars
- channel junction bars
- mid-channel bars
- diamond bars
- diagonal bars
- sand waves/large dunes

Comments *whole reach
** at mouth

Obstructions/Constructions

Natural
- ✓ none
- logs
- boulders
- vegetation

Degree
- ✓ none
- minor
- major

Comments ____

Man-made	*Degree of Obstruction/Constriction for Each*	*Position (from head of reach)*
✓ road bridge/s (2)	River confined	0 & 13,9 km
rail bridge/s		
causeway		
weir/dam		
fish traps		
embankment/s		
groynes		
canals		
✓ drainage furrows		8 km R.B.
✓ others anti-erosion walls		8,5 – 10,5 km L.B.

Lateral Channel Activity

Lateral Activity
- not detectable
- ✓ downstream progression *
- progression & cut-offs
- mainly cut-offs
- entrenched loop development
- irregular lateral activity
- avulsion

Nature of Banks
- ✓ alluvium (silt/sand)
- natural levées
- rock/boulders
- protected/stabilized
- ✓ cultivation to channel edge **

Bank Vegetation
- ✓ none
- weak
- good
- very strong
- left bank ____ %
- right bank ____ %

Lateral Stability
- stable
- ✓ slightly unstable
- moderately unstable
- highly unstable

Comments *not v. active
** a little

TABLE CSE 5/VIII

ABSTRACT

SONDAGS (CSE 5)	1939 - 1976
1. Sinuosity	Range 1,38 - 1,42
2. River width	$\bar{x}$ Range 52,6 m - 81,7 m
3. Lateral displacement	$\bar{x}$ 29,3 m
	$\bar{V}$ 24,9%
4. Thalweg	Range 23630 m - 24380 m
5. Open water area	Range 150 ha - 202 ha
6. Cultivation	
Valley sides	Nil
Flood plain	Range 5% - 7,7%

7. Human influences

(a) Flood plain : mostly pastureland - a little cultivation to channel edge.

(b) Bridges:
Road and rail bridges with embankments at head of reach.

National road and Freeway with their embankments across the flood plain. (13,9 km and 15,9 km from head of reach respectively).

(c) Jetties: minor channel constriction but aiding sidebar formation, 16 - 20 km from head of reach (L.B.).

(d) Dams in the catchment:
Mentz Dam (1922)
Van Ryneveld Pass Dam (1924)

TRACED:
CHECKED:
DATE.
REF.

CAPE ESTUARIES: SONDAGS

LINES OF MEASUREMENT

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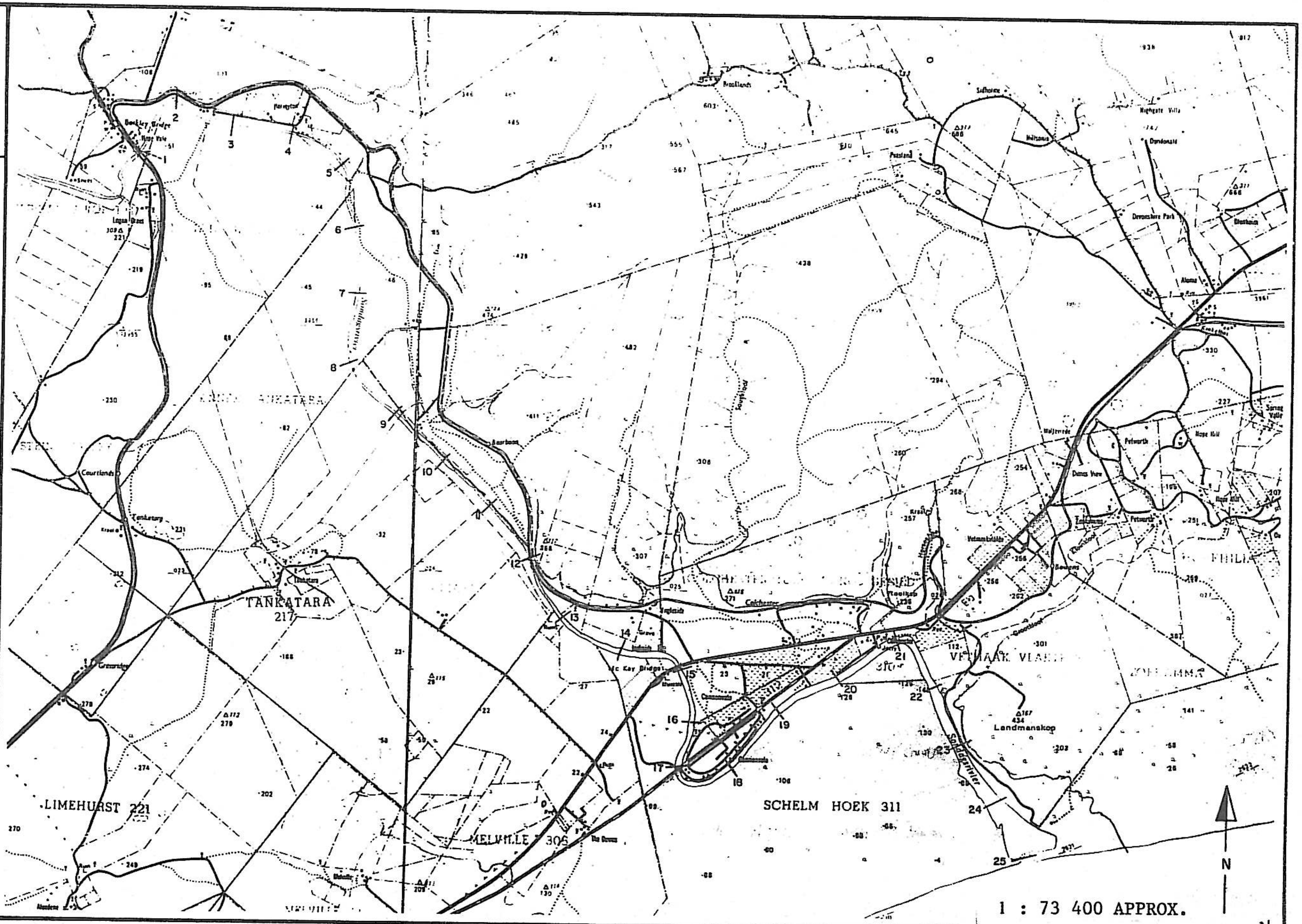
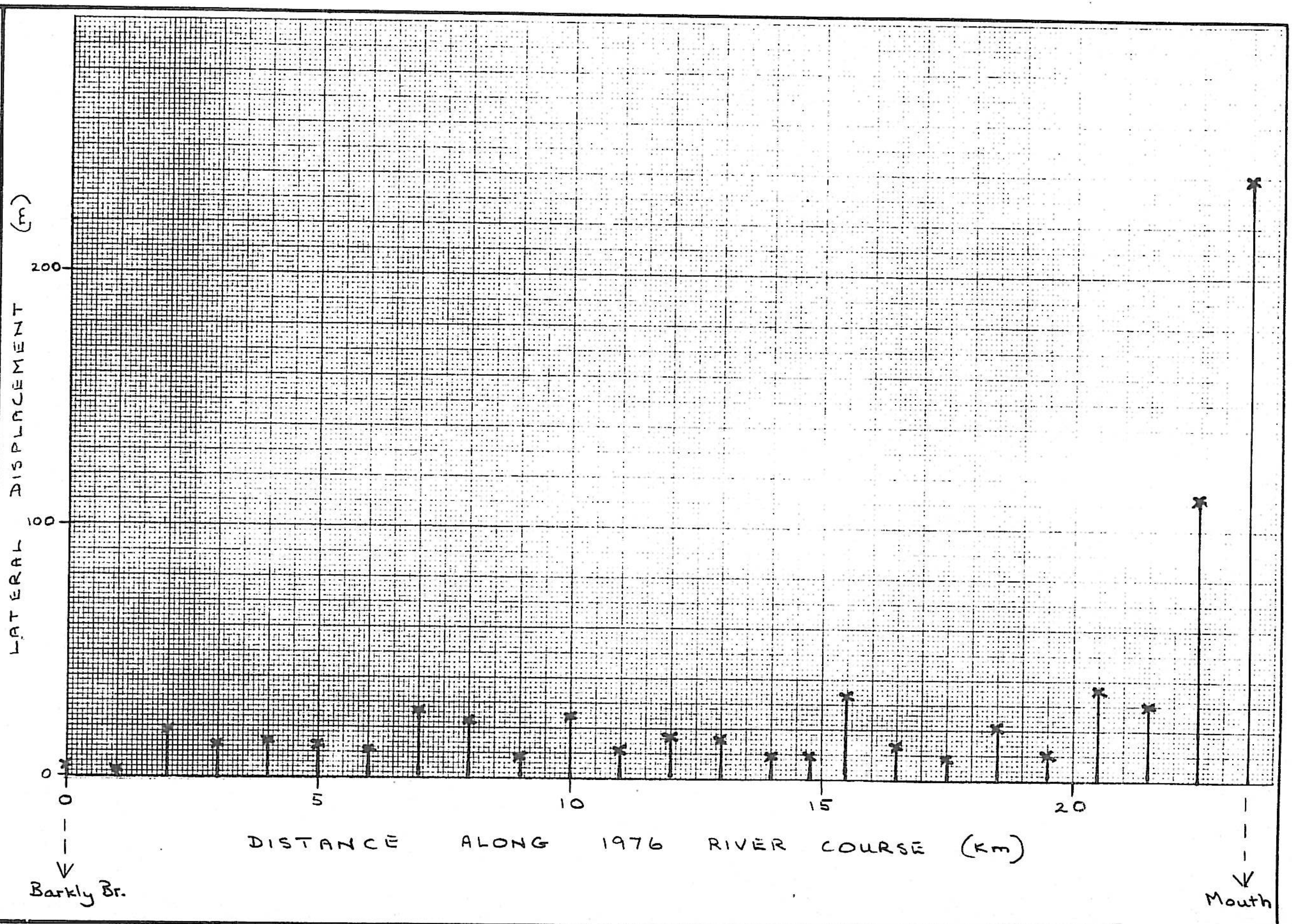
FIGURE

CSE 5/1





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CAPE ESTUARIES: SONDAGS

THALWEG DISPLACEMENT: 1939-76

FIGURE
CSE 5/2

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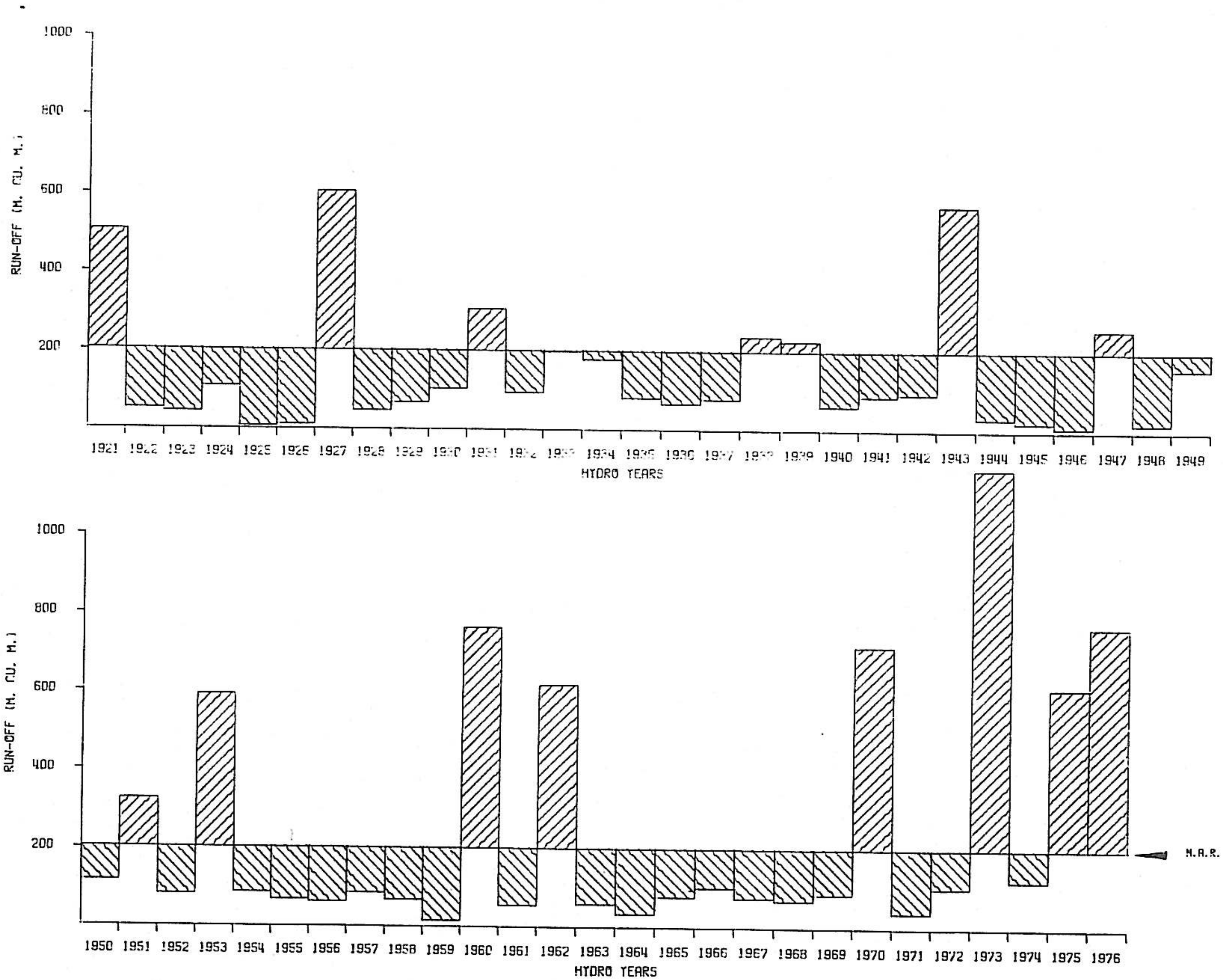

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CAPE ESTUARIES: SONDAGS
SIMULATED ANNUAL RUN-OFF
1921-1976

FIGURE
CSE 5/3

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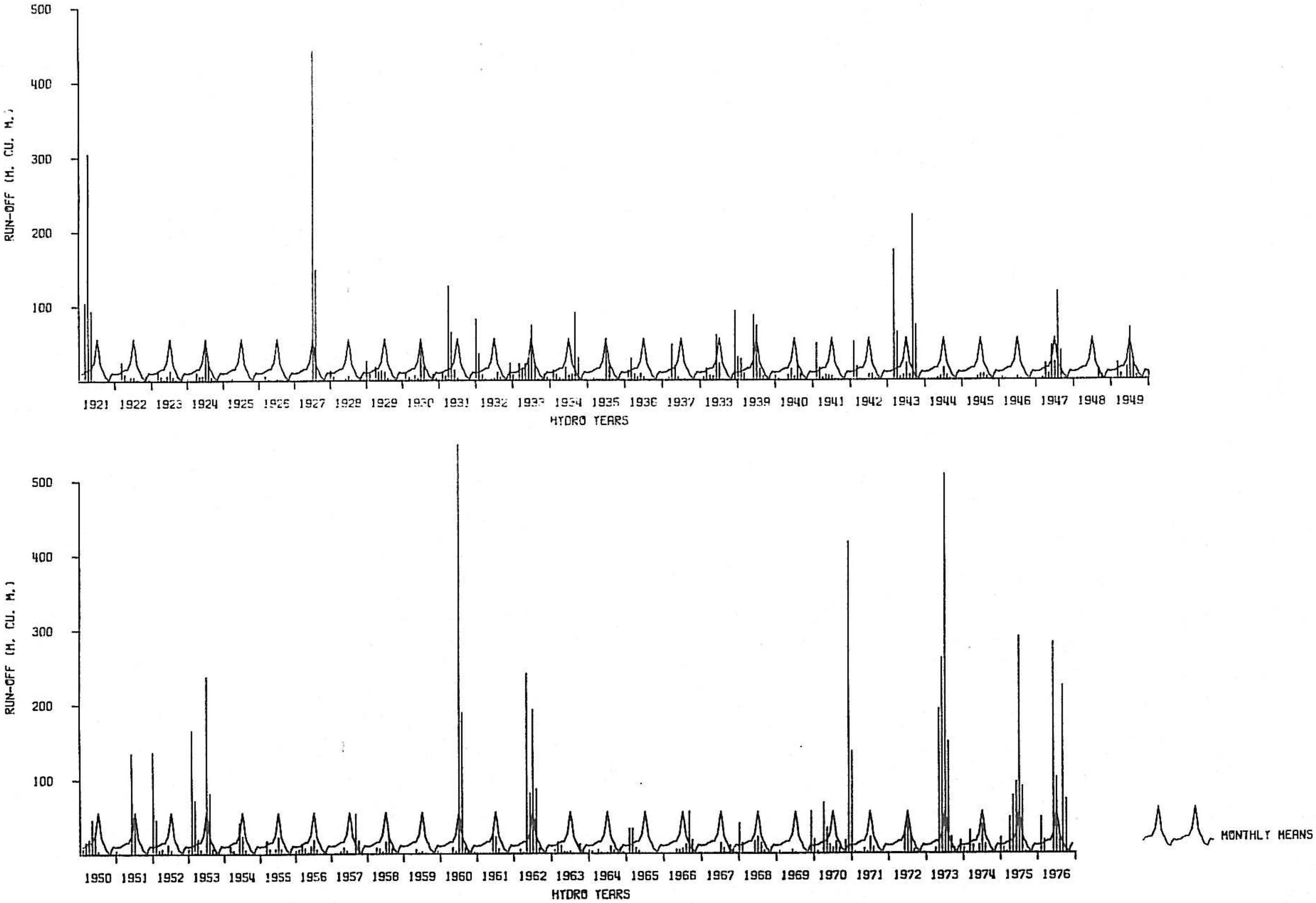

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DATE:
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CAPE ESTUARIES: SONDAGS

SIMULATED MONTHLY RUN-OFF

1921-1976

FIGURE

CSE 5/4

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TABLE CSE 5/VII SIMULATED RUN-OFF FOR SONDAGS CSE 5 CATCHMENT AREA= 20990.0 SQ. KM.

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1921	.01	104.34	304.94	93.31	1.23	.93	.36	.38	.36	.42	.18	.08	506.54
1922	.01	25.24	8.60	.60	3.35	4.11	1.64	.21	.15	5.28	1.75	0.00	50.94
1923	.10	13.48	4.49	1.26	5.51	12.67	3.66	0.00	0.00	0.00	0.00	2.19	43.36
1924	.73	.09	10.92	4.53	5.11	54.54	26.76	3.15	.27	.31	.09	1.23	107.73
1925	.41	1.50	2.67	.71	0.00	.03	.14	.15	.48	.15	0.00	.03	6.27
1926	.11	5.33	2.05	.10	.06	1.92	.63	.04	.01	.12	.10	.02	10.49
1927	0.00	.05	.93	.66	.12	442.26	148.74	.45	0.00	0.00	.09	13.02	606.32
1928	4.33	.03	1.04	.49	2.28	5.00	1.74	.14	.03	4.45	1.65	25.99	47.17
1929	10.76	.70	18.12	11.35	12.65	11.09	2.55	.01	.12	.03	.25	.07	67.70
1930	10.26	3.47	.05	6.88	2.30	51.31	18.53	.49	0.00	7.83	2.62	.04	103.78
1931	11.38	4.82	126.93	65.24	13.50	2.19	.08	.54	.19	.10	.03	82.26	307.26
1932	35.96	7.61	1.59	0.00	1.83	2.27	10.41	3.29	0.00	0.00	23.16	7.71	93.83
1933	0.00	22.34	14.41	22.04	29.62	74.28	24.45	.76	0.00	8.50	2.81	.01	199.22
1934	13.99	8.12	2.68	.68	17.79	6.18	7.84	91.25	29.84	.12	.10	.53	179.12
1935	.16	2.30	1.36	.20	2.00	55.80	18.47	.61	.18	.29	.10	0.00	81.47
1936	12.77	29.24	8.46	3.02	9.64	3.27	.12	.20	.07	0.00	0.00	.02	66.81
1937	.48	2.75	48.30	19.77	3.39	1.03	2.05	.64	.15	.08	.01	.01	78.66
1938	3.27	15.49	5.35	4.50	60.77	22.51	1.09	.08	.01	1.70	92.27	31.00	238.04
1939	28.64	9.49	.18	.26	86.93	73.77	15.13	4.08	1.34	.85	.28	5.64	226.59
1940	1.92	.48	.16	7.29	14.79	4.12	24.54	8.19	.02	.02	.07	.01	61.61
1941	49.73	16.58	2.66	7.36	5.15	4.25	1.41	.19	.02	0.00	.12	.23	87.70
1942	51.42	18.07	1.21	1.53	.41	7.62	8.35	2.05	1.90	.62	.71	.35	94.24
1943	.03	175.08	64.83	3.27	6.39	22.13	6.69	221.74	74.00	.02	0.00	.06	574.24
1944	1.82	.59	0.00	2.35	4.04	15.98	5.12	1.90	1.03	.40	.07	0.00	33.30
1945	0.00	0.00	0.00	.04	3.50	7.65	7.98	3.19	.42	0.00	0.00	0.00	22.78
1946	2.43	1.52	.29	.03	.18	3.14	1.53	.18	0.00	.10	.02	1.13	10.55
1947	.95	2.24	21.79	8.18	46.09	23.48	117.99	38.40	0.00	.07	.02	0.00	259.21
1948	.05	.01	.06	.15	.26	.08	.39	14.46	4.78	0.00	0.00	0.00	20.24
1949	0.00	22.28	7.57	.49	17.21	69.13	28.01	4.21	.64	.24	1.27	9.27	160.32
1950	5.89	15.65	19.60	45.79	21.47	3.20	.20	0.00	0.00	.50	.16	4.00	116.46
1951	1.59	.08	0.00	0.00	135.64	48.20	1.19	.08	.01	.18	.44	137.13	324.54
1952	45.68	4.02	6.06	1.60	12.29	4.29	.21	.05	0.00	0.00	.82	6.64	81.66
1953	165.26	73.12	19.86	4.76	.08	237.96	81.86	6.51	1.96	.14	.03	0.00	591.54
1954	.27	10.14	3.36	1.35	41.94	24.22	4.62	.39	.15	.04	.01	0.00	86.49
1955	.05	17.98	7.03	1.37	6.83	22.55	6.80	1.60	.53	0.00	0.00	3.53	68.27
1956	5.18	13.25	8.30	1.97	10.26	18.84	5.17	.01	.04	.01	.01	0.00	63.04
1957	.01	.04	2.45	9.03	2.73	0.00	.17	53.50	17.83	0.00	0.00	.24	86.00
1958	.11	.71	8.20	6.37	2.09	15.77	24.85	6.70	.04	2.32	1.11	.11	68.38
1959	.02	0.00	.21	4.77	1.57	2.65	1.21	.49	.12	0.00	2.72	.92	14.68
1960	.08	1.04	.61	8.08	2.69	549.24	188.77	7.93	2.10	.34	2.04	.65	763.57
1961	0.00	.59	.28	.22	24.52	22.24	5.20	.16	0.00	0.00	.97	.31	54.49
1962	.28	4.33	1.42	242.25	81.53	193.34	86.52	7.40	.02	.34	.12	0.00	617.55
1963	4.11	15.29	10.84	2.07	2.25	2.53	.91	.11	12.81	4.29	.41	3.36	58.98
1964	2.54	.74	4.39	1.52	.12	1.63	9.88	3.17	1.21	6.46	2.02	.03	33.71
1965	33.67	33.37	7.38	2.41	.88	.29	.17	.03	0.00	0.00	.02	.43	78.65
1966	.14	.28	.23	3.81	3.73	6.47	11.92	57.23	18.01	.40	.13	0.00	102.35
1967	.37	.24	.03	0.00	0.00	13.18	6.21	.64	10.46	3.48	.10	40.62	75.33
1968	13.55	.02	.08	.12	17.08	22.19	14.10	2.89	0.00	.01	0.00	0.00	70.04
1969	2.69	.97	.02	.01	3.94	1.31	0.00	.65	.24	.03	57.27	19.09	86.22
1970	2.26	.89	68.33	33.89	11.29	7.43	15.36	5.70	.40	17.38	417.70	137.31	717.94
1971	1.77	.60	.30	5.45	1.93	21.40	8.01	.30	0.00	0.00	0.00	0.00	39.76
1972	0.00	.01	.04	0.00	25.56	48.09	24.41	3.83	.03	.03	1.38	.46	103.84
1973	.30	.80	5.29	193.29	261.84	509.05	149.54	21.84	7.14	.17	17.18	5.73	1172.17
1974	.01	30.09	10.29	.18	10.33	37.71	11.71	.09	1.46	.55	.01	20.33	122.76
1975	6.78	1.81	48.34	76.77	95.90	290.38	89.16	1.92	.55	1.24	.42	0.00	613.27
1976	49.04	17.86	.77	.18	282.47	101.74	19.47	224.76	73.05	0.00	0.00	.01	769.35
MEAN	10.42	13.16	15.99	16.31	25.30	56.94	22.39	14.45	4.72	1.24	11.30	10.03	202.26

MEAN ANNUAL RUN-OFF = 202.26 MILLION CUBIC METRES

COMPILED FROM HRU REPORT NO. 9/81 DATA

SCALE 1 : 25 000 approx.

TRACED CHECKED DATE REF	CAPE ESTUARIES SONDAGS 29-7-74 (APRIL 1939 RIVER COURSE SUPERIMPOSED)	PHOTOGRAPH CSE 5/1

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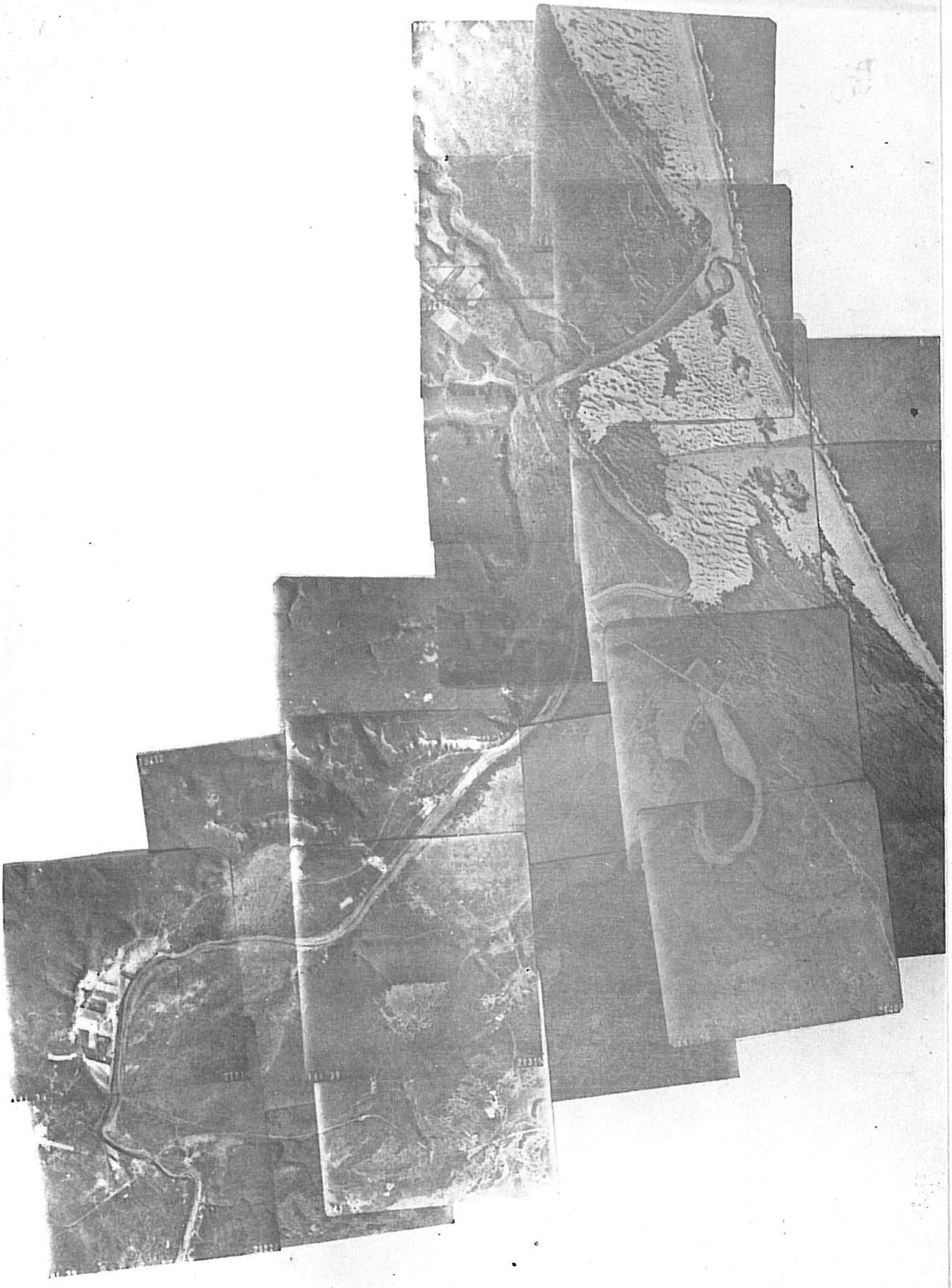

SCALE : 1 90 000 approx.

TRACED CHECKED DATE REF	CAPE ESTUARIES SONDAGS APRIL 1939	PHOTOGRAPH CSE 5/2

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SCALE : 1:90 000 approx.

TRACED CHECKED DATE REF	CAPE ESTUARIES: SONDAGS SEPTEMBER - NOVEMBER 1960	PHOTOGRAPH CSE 5/3

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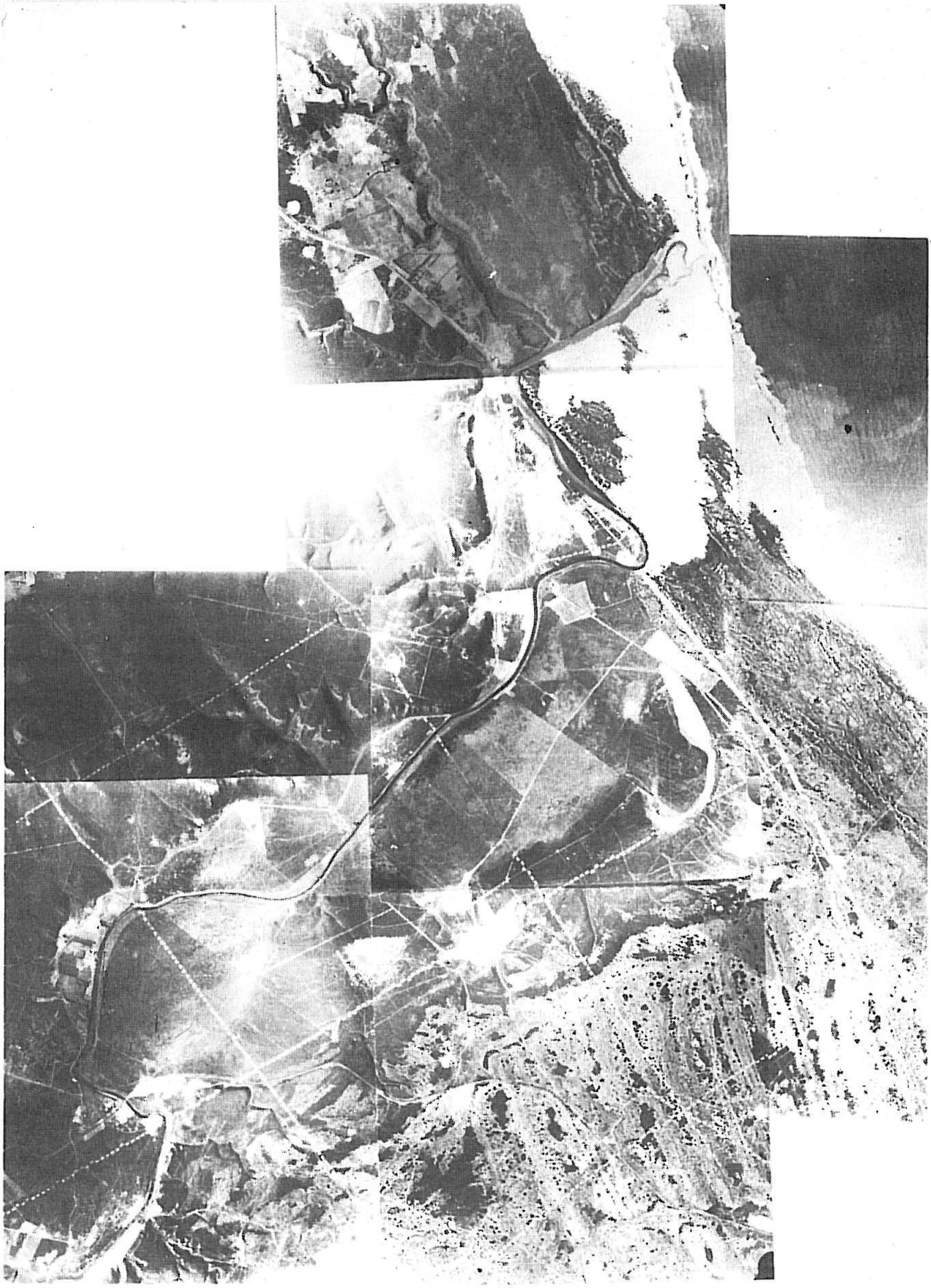

SCALE 1 90 000 approx.

TRACED CHECKED DATE REF	CAPE ESTUARIES SONDAGS MAY - JUNE 1969	PHOTOGRAPH CSE 5/4

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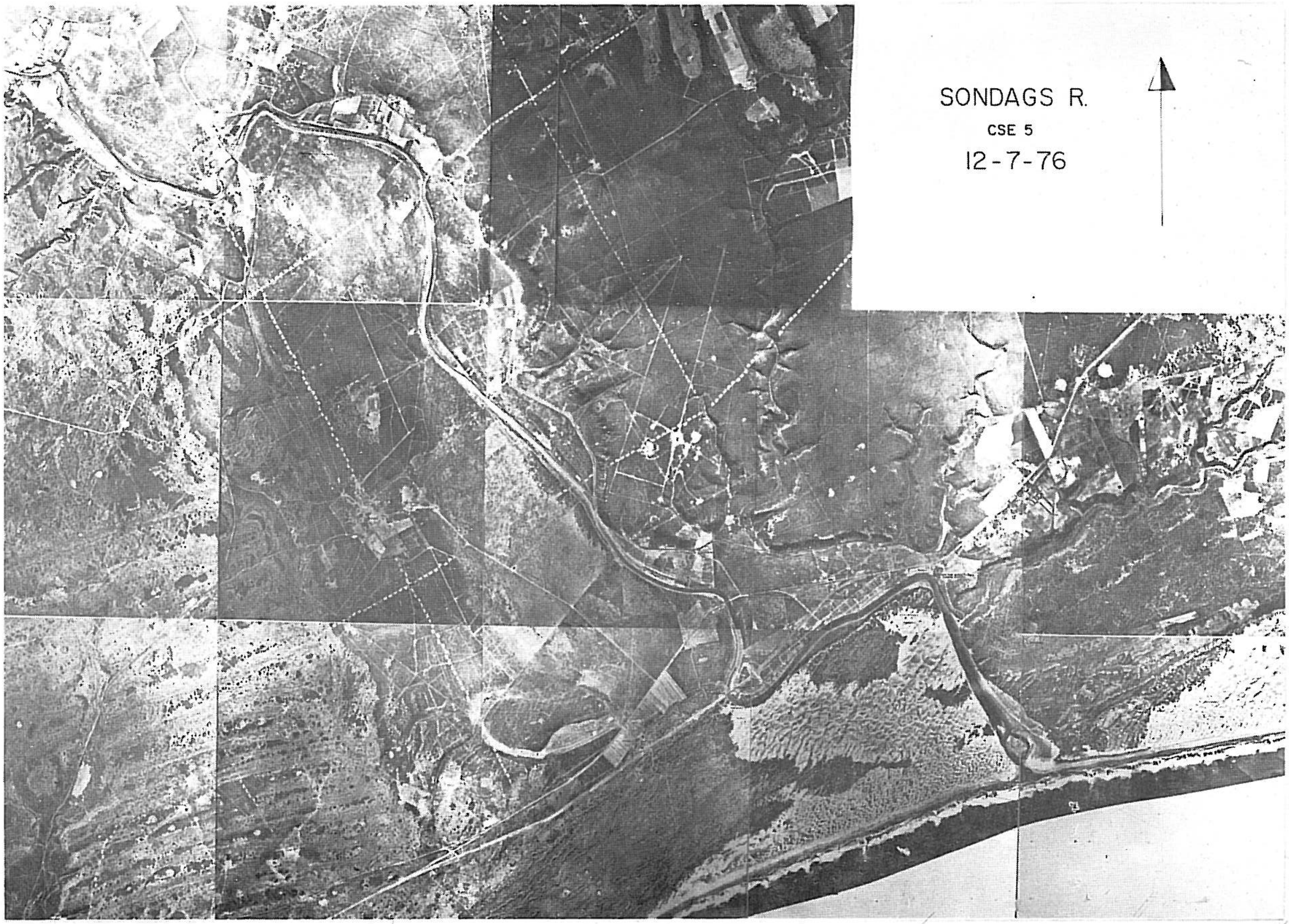


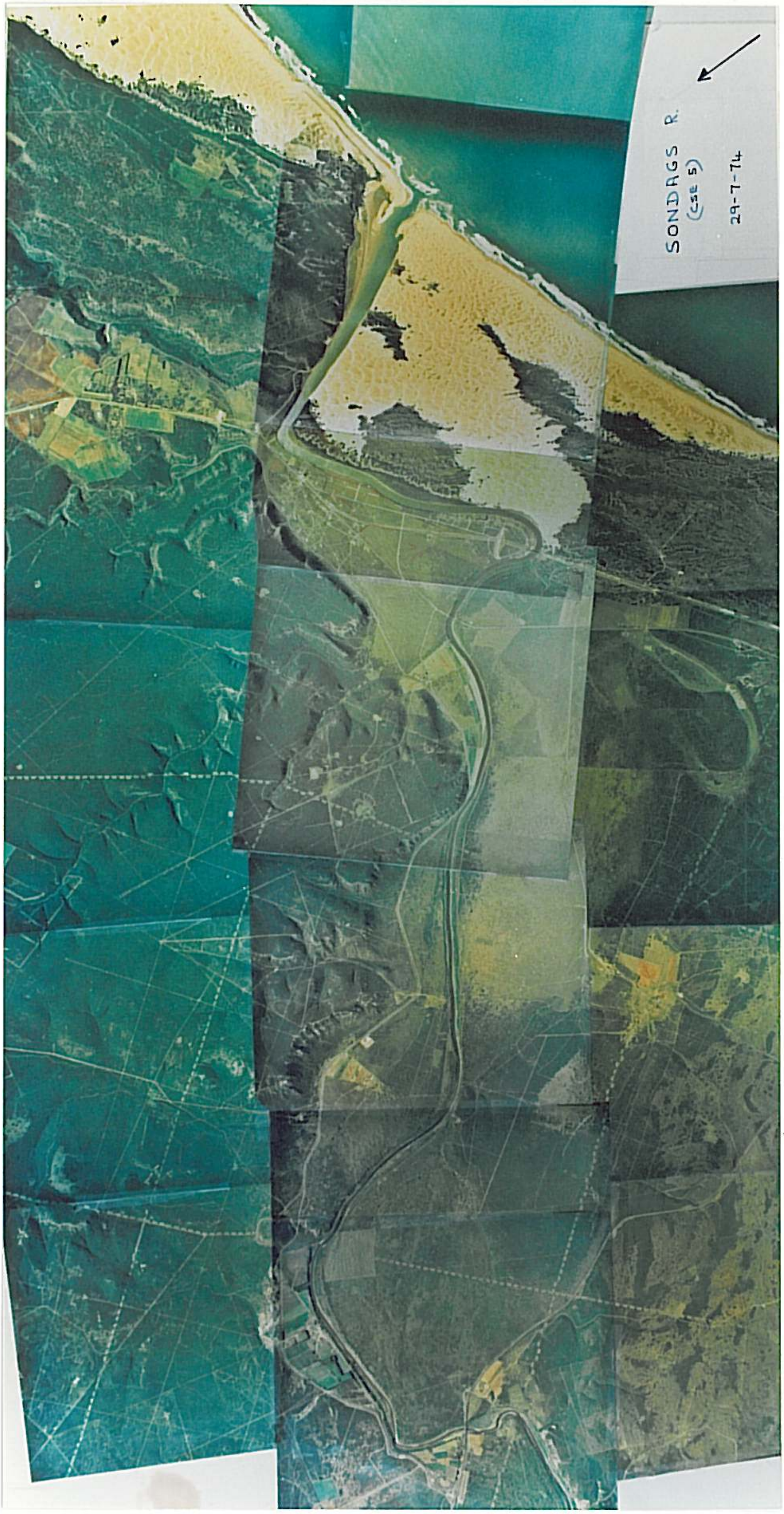
SCALE: 1:90 000 approx.

PHOTOGRAPH
CSE 5/5

CAPE ESTUARIES: SONDAGS
12-7-76
(ORTHOPHOTO SERIES)

NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY

TRACED
CHECKED
DATE
REF



SCALE 1 90 000 approx.

TRACED CHECKED DATE REF	CAPE ESTUARIES. SONDAGS 29-7-74	PHOTOGRAPH CSE 5/6

NATIONAL RESEARCH INSTITUTE FOR OCEANOLOGY

APPENDIX A

THE ESTUARIES OF NATAL: A METHOD OF CLASSIFICATION

1 INTRODUCTION

A hydrological/hydraulic study, aimed at acquiring an understanding of the long-term functioning of the estuaries of Natal is being done by NRIO (CSIR) for the Natal Town and Regional Planning Commission. Special emphasis is given to the influence of man on the natural river régime. The investigation falls into three phases, namely, evaluation of available data, classification of the estuaries and examination of specific problems in particular estuaries. These notes are concerned with phase two, classification of the estuaries. As hydrological data are scarce, a method of study has been devised to make the maximum use of the main data source available which is aerial photography dating back to 1937.

2 PROCEDURE

2.1 Basis

For each of the seventy-two estuaries, a suitable reach of the river is selected to include at least the known estuarine area. The upstream limit is usually a road or railway bridge which provides a good control position but occasionally a river confluence has to be chosen. This reach is then identified on enlargements of six vertical aerial photographs from 1937 to 1980 and re-photographed. Prints are then made on a scale of 1:10 000 using tracings of permanent features from 1:10 000 orthophotos to obtain the best possible fit. If the estuarine length is longer than 5 km the orthophotos are re-photographed and a "master mosaic" compiled to a suitably reduced scale. The orthophoto itself is often used for one of the six photographs selected for study. Tracings of the river courses for the six years are made on transparent film (one for each year) and used to compile an envelope of mobility of the river. Within this envelope of mobility, lines of measurement are marked at regular intervals from the upstream limit of the reach to the mouth together with a suitable datum line for measuring sand-spit lengths and directions. These items are transposed onto the six river course tracings together with an outline of the flood plain area (if present) which is assessed from the orthophoto. The remaining areas within the flood plain to be traced onto the six master river course film tracings are sand deposits, swamps and cultivation (from the 1:10 000 photographs).

2.2 Direct observations and measurements

The six aerial photographs are studied in detail with respect to (i) terrain above the valley, (ii) valley characteristics, (iii) river mouth, (iv) flood plain and (v) the river course and its channel. Several of the observations made are of a general descriptive and qualitative nature (e.g. terrain, land-use, settlement, relation of channel to valley bottom and sides, description of the river mouth, river pattern, lateral channel activity and man-made factors). Other observations require measurements. Some are done manually with a steel ruler or an opisometer, direct from the photographs: amongst these are vegetation and land-use on the valley sides and riverine vegetation. The remaining linear, areal and angular measurements are made using a flat-bed digitizer. These may be made direct from the photograph in the case of an orthophoto. Otherwise, for greater accuracy, they are made from the master film tracings - compilation of which is described in 2.1 above. Such linear and angular items measured include mid-valley lengths, thalwegs, valley widths, flood plain lengths and widths, wetted perimeters and sand-spit lengths, widths and directions. Areas measured on the digitizer include the flood plain, swamps, sand deposits, cultivation, open water and bars.

2.3 Indirect measurements and calculations

River widths are measured, averaged and the standard deviation calculated. If the channel widths (in this context synonymous with bank-full conditions) are markedly different from the river widths and clearly seen on the aerial photographs, these are also measured across the same lines of measurement used for the river widths. The sinuosity for the whole reach is calculated. In order to quantify the lateral stability, distances are measured from the maximum left bank position to mid-river (along the selected lines of measurement on the six master film tracings). From these measurements, an average lateral displacement and an average coefficient of lateral stability are calculated for the time period under review.

2.4 Recording of data

A table has been compiled to facilitate the observation and recording of salient points. The basic idea for this tabular classification was taken from Kellerhals et al (1976). Modifications were made to the initial table as the study progressed to include (a) local features of Natal rivers (b) estuarine conditions (e.g. river mouth characteristics) and (c) particular needs of the study (e.g. man-made influences). Data reports are prepared for each estuary. These contain the basic tabular classification forms for each photograph studied and tables showing river widths and lateral stability. Thalweg displacement is graphed. Other features selected for graphing vary from estuary to estuary, depending upon what is found to be pertinent. These may include open water areas (often found to be decreasing with time), thalweg changes, sinuosity changes and bar areas. Copies of the photographs used for classification are reproduced in the data reports together with a most recent aerial photograph onto which is superimposed the 1937 river course. The latter give a good visual indication of changes occurring in the estuaries over a period of approximately 40 years. Brief notes and an abstract of results are also prepared for each estuary. Data will be codified later and stored on computer for further analyses.

3. BACK-UP DATA

Hydrological data are scarce but simulated run-off is now available for tertiary catchments in Natal (HRU Report 9/81). These data are an invaluable aid to interpreting the aerial photographs because wet and dry phases together with antecedent soil moisture conditions can be defined. Rainfall analyses of wet and dry periods, using exponentially filtered monthly rainfall data (Zucchini 1975) are also very valuable - especially for smaller catchments for which no run-off data are available. When available, topographical surveys (for river gradients and cross-sections), physical model studies (for river flood behaviour), land-use studies for the whole catchment and archival data (old maps and cross-sections) are used to aid the study. For example, archival data has been used in one estuary to quantify river aggradation, making it possible to extend the period for which changes in the average river bed level could be calculated. At 21 estuaries, daily observations are made as to whether the mouth is open or closed. Water level stations are being established at 26 of the estuaries.

4 RESULTS

It has been found that major floods, riverine vegetation, swamp areas and sand-spits/bars at the mouth are the main natural factors influencing the behaviour of the estuaries. Man's influence is marked in land-use on the flood plain (and in the whole catchment area), the construction of embankments and bridges, groynes and breakwaters, dams in the catchment, the drainage of swamps, the removal of riverine vegetation, canalization and the stabilization of formerly mobile sand-spit and bar areas. Instability is clearly shown by sinuosity index fluctuations, large lateral thalweg displacements with a high coefficient of variation and longer thalwegs (behind prograding sand-spits). The converse may not mean stability, however. "Apparently stable" estuaries often show marked deterioration through decreased open water areas, narrowing river widths, increased bar areas and general aggradation.

5 CONCLUSION

This interpretation of fluvial features, based upon aerial photographs over a period of forty years, is expected to provide a key to the natural functioning of the estuaries of Natal and the estuarine responses to human influences. Thereby, this study will also facilitate conservation measures and/or planned development of estuarine resources by the Town and Regional Planning Commission, Natal.

FOOTNOTES

1 In the case of the Cape estuaries the earliest aerial photography available is that for 1939.

2 The basic form used for the tabular classification was compiled to suit the estuaries of Natal. As experience is gained in the study of the Cape estuaries, the form should be modified to suit local conditions, e.g. with respect to the following:

(a) vegetation
(b) land use
(c) character of the rivers (e.g. ephemeral streams for the lower rainfall areas)
(d) tidal features: the Cape estuaries may reflect more marine influences. The estuaries of Natal are dominated by fluvial factors.

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APPENDIX B

LOWER SONDAGS RIVER ENVIRONMENT

Preliminary Air-Photo Interpretation by David M Chapman 26.11.82

The following interpretation has been made on the basis of preliminary air-photo interpretation, mostly single photographs rather than stereo pairs. No supplementary environmental information was available, neither has ground truth been obtained. Hence the interpretations given should be regarded as tentative and subject to correction on the basis of ground truth.

The Quaternary features are emplaced within an environment provided by the dissection of a terrace which appears to be of marine origin. The feature strongly resembles uplifted marine abrasion terraces seen elsewhere in the world, formed in poorly consolidated argillaceous or fine sandy sediments of Tertiary or Cretaceous age. The terrace slopes gently seaward from a modal elevation of approximately 450' on the inland side, to approximately 250' on the seaward side (elevations are in feet, since the topographic map of the area is in imperial units). The inland margin of the terrace terminates at a linear feature orientated more or less parallel with the present shoreline and approximately 11 - 13 km from it. The linear feature is interpreted as an ancient shoreline and/or fault.

The Sondags River and its tributaries have incised deeply into the old terrace. During late Pleistocene and Holocene time the Lower Sondags has migrated laterally to excavate a floodway of considerable width, into which flood plain sequences of varying ages have been deposited. The oldest and uppermost of the remnant flood plains (i.e. fluvial terraces), has been used in places for the growth of row crops and citrus orchards, attesting to its contemporary flood-free status and well-drained soils. At least three generations of terraces are present, and field inspection would probably reveal more. The middle terrace level, which is by far the most extensive, does not support orcharding, although improved pastures have been extensively developed on it. The downstream-most segments of the middle terrace level bear faint traces of flood flow across them and have clearly been inundated in comparatively recent time (i.e.<100 years).

The lowest level (i.e. modern flood plain) is not extensive and exists principally in form of point-bar deposits. It is clearly distinguished as the lower level below the limit of residential development in the settlement of Cannonvale.

The Lower Sondags River exhibits the influence of tidal action upon channel morphology in unconsolidated materials. The channel displays a classic funnel shape for about 13 - 15 km from the mouth.

Sand bedforms are conspicuous in the upper channel of the Sondags River, down to about the location of Harveyton Farm. Below this point sand bedforms are only weakly evident in the channel and are not at all conspicuous in the tidal reach. This is not to say that sand transport from inland to the coast does not exist, but that it is not strongly in evidence in the lower channel.

The curious dogleg pattern of the Lower Sondags River channel is the result of the lower reach being constrained by an active dune field. At the very beginning of the present stillstand (i.e. when Holocene sea level first stabilised about 6 000 years ago) the mouth of the Sondags River was deflected eastward by spit accretion. The evidence of landforms is that the dominant wind direction and dominant longshore drift direction were from West to East at that time, as now. Shoreline progradation during the Holocene, together with a persistent South-West wind and West-to-East littoral drift, has ensured that the channel of the Sondags River has remained firmly positioned against the incised marine terrace remnant on the East bank ever since.

The bottom 1 000 metres or so of the channel is commonly occupied by tidal shoals, which frequently exhibit typical ebb and flood tide separation into different channels. The amount of sand stored in these shoals would typically be in excess of 500 000 cu. metres, and could conceivably reach up to a million cu. metres. These shoals would be flushed from the mouth during major fluvial floods and the sand would augment the sediment budget of the adjacent beaches. In this way a slug of sand would be supplied to the littoral drift system as a result of major fluvial events. However, immediately following such events, it would be expected that sand transport in the mouth would be flood-tide-dominated until such time as an equilibrium regime channel was re-established in the lower portion of the maximum tidal influence. Evidence for the latter phenomenon of net inland sand transport can be found in the 1972 set of photographs, where a flood tidal delta of virtually classic form is displayed. Sand is also supplied to the lower channel from the dune-fields (see below).

There are at least four, and possibly five, generations of sand dunes. These are, in descending order of age, as follows:

(1) In the environs of Aloedene Farm and to the West of the lower floodway of the Sondags River is a field of roughly parallel linear features spaced about 400 - 500 metres apart. These features are sub-parallel to the present shoreline and may be Pleistocene beach ridges of a very subdued type.

(2) Immediately to the East of the lower two kilometres of the Sondags River channel is the remnant of a formerly much more extensive field of high parabolic dunes. The remnant is at a modal elevation of 150 - 250' and quite clearly represents the terminal, inland margin of a dune-field which must have extended some distance further westward at one time. Although this dune-field could conceivably be co-extensive with (3) below, its form suggests that it was developed in an era of more abundant sand supply than the dune-field described in the following paragraph.

(3) By far the most extensive of the present coastal dune features is a dune-field of low parabolic dunes and dune ribbons formed by the exhaustion of parabolic dunes extended headward. This dune-field certainly underlies the inner transgressive dune sheet described below and may also underlie most of the outer transgressive sheet described below. The lower parabolic dune-field is at a modal elevation of less than 100', with local relief generally less than 50'. In drier periods, deflation has occurred to levels lower than the present dune water table, with the result that deflation hollows developed at that time are now occupied by swamps. On both sides of the river the lower parabolic dune-field terminates in a striking long walled terminal ridge up to 200' high.

(4) By far the most spectacular of the dune forms is the inner trans= gressive dune sheet. This feature, which has the classic form of a

mobile transgressive dune sheet, rises to heights of over 100 feet to the West of the Sondags River channel, and over 200 feet on the East. In places the swales of this dune-field expose the upper surface of the buried lower parabolic dune-field beneath. The remains of buried vegetation appear to be exposed in some of the swales, although if the sand is carbonate rich, the exposures may represent dissected aeolianite. Although the transgressive sheet is obviously mobile, the area covered by it has not expanded greatly since 1939 when the first set of aerial photographs were taken. As sand moves through the mobile sheet it re-enters the beach system by means of the river. In the lower three kilometres of channel, and also opposite the settlement of Cannonvale, there are prominent slip faces representing the discharge points for sand transported through the dune-field and entering the river channel. Sand so supplied to the river will ultimately be transported downstream and provide supplementation for the beach sediment budget. Hence, in the long term, it would appear that sand is recycled through the dunes by means of a system as follows: beach → deflation to dunes → dune migration into estuary → flood flushing to surf zone → wave action to beach.

The area of this dune sheet to the east of the channel has decreased since 1939, almost certainly as a response to sand-drift fencing and revegetation works carried out since that time.

(5) Finally, there is an outer transgressive dune sheet, immediately behind the present shoreline. This dune sheet has subdued linguoid dunes of very minor relief, being generally below 50' in elevation, and probably below 25'. To the East of the Sondags River the outer transgressive sheet abuts the inner transgressive sheet and probably supplies sand to the latter. However, on the Western side of the channel the outer transgressive sheet, whilst abutting the inner transgressive sheet for a distance of about 1 km, appears to be a discrete feature, with sand transport moving from the back-beach, through the dune-field, and into the lowermost km of river channel for recycling into the beach system. Again, although this dune-field has expanded in area since the 1939 photographs, the expansion has not been very great.

The beach in the environs of the Sondags River mouth is typical of a high energy dissipative surf zone as described in numerous papers by Wright and Short, of the University of Sydney (e.g. Short, 1979; Wright, et al; 1979), and briefly discussed in the monograph on the evolution of the New South Wales coast by Chapman et al (1982, pp 201-208).

In every case of the 15 time slices provided by the sets of aerial photographs available for analysis, the beach exhibited high energy dissipative surf zone conditions. At times the surf zone was up to and over 300 metres in width. During periods of relatively lower energy the surf zone was 150 metres or more across. During the latter periods of low energy, shoreward migrating shoals 250 - 350 metres in the shore-parallel dimension appeared in the surf zone. On one occasion these shoreward migrating shoals had become attached shoals with weak rips at 250 - 300 metre centres. More commonly, however, a more or less continuous outer bar is more characteristic of the surf zone, being periodically truncated by rips which extend through the surf zone at 250 - 500 metre centres. In no case was the surf zone observed to exhibit intermediate-rhythmic beach behaviour as described by Short (1979).

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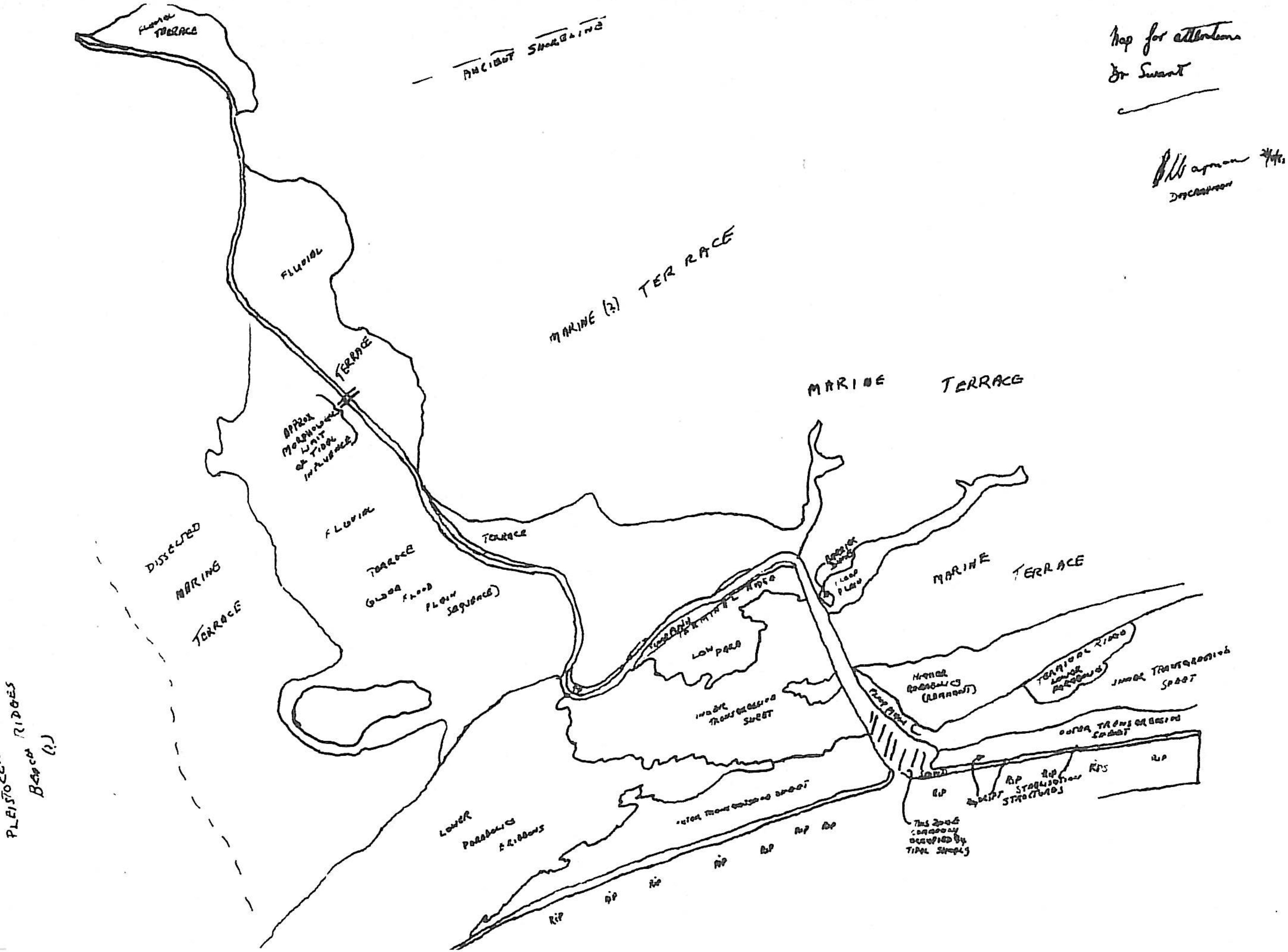
Map for attention Dr Swant
FLUVIAL TERRACE
ANCIENT SHORELINE
FLUVIAL
TERRACE
MARINE (?) TERRACE
MARINE TERRACE
APPROX MORPHOLOGICAL LIMIT OF TIDAL INFLUENCE
FLUVIAL TERRACE
TERRACE
DISSECTED MARINE TERRACE
MARINE TERRACE
INNER TRANSGRESSIVE SHEET
OUTER TRANSGRESSIVE SHEET
LOWER PARABOLICS & RIBBONS
PLEISTOCENE BEACH RIDGES (?)
RIP
DRIFT
STABILISATION STRUCTURES
RIPS