CHAPTER 4 : DISCUSSION AND CONCLUSIONS OF TIDAL CREEK AND MANGROVE EXTENSION IN THE ALLIGATOR RIVERS REGION

4.1 INTRODUCTION

Changes in the spatial characteristics and distribution of tidal creeks and mangroves in the Alligator Rivers Region have been reconstructed from each set of the available aerial photography (1950, 1975, 1984 and 1991) as documentation of recent changes. Analysis and interpretation of changes in network magnitude and length properties of tidal creeks have determined the rate and trends of tidal creek extension on the different river systems in the Alligator Rivers Region. Similarly, the rate and spatial patterns of mangrove colonisation in the Alligator Rivers Region were described for each river system, and paralleled with the rate and growth trends of the tidal creeks. The morphological land surface components in the vicinity of extending tidal creek headwaters of the different channel segments defined by Chappell *et al.*, (1988) were identified and described. Maps of the present site morphologies were constructed at scales less than 1:20,000 as a detailed record of the extent and characteristics of the processes of saltwater intrusion. Field survey and observations were combined with evidence of change from aerial surveys as the basis for a more detailed description of the mechanics of tidal creek extension and saltwater intrusion.

4.2 CHANGES IN THE DISTRIBUTION OF TIDAL CREEKS AND MANGROVES IN THE CONTEXT OF THE WIDER ALLIGATOR RIVERS REGION

The changes in the spatial characteristics and distribution of the tidal creeks and mangroves in the eastern Alligator Rivers Region indicate that the saltwater reach has expanded along extending creek lines from 1950 to 1991. A similar trend of saltwater intrusion has been observed and mapped on the Mary River plains, west of Kakadu National Park. Knighton *et al.* (1992) noted that two main creeks, Sampan and Tommycut Creeks, have experienced rapid tidal creek extension since the late 1930's-early 1940's. Using network magnitude as a measure of the network size, both creeks experienced an exponential rate of growth. Unlike the growth trends which have occurred on the Mary River plain over the same time period, the East and West Alligator Rivers have developed in a linear trend. Similarly, tidal creek development on the South Alligator River and the Wildman River has been only weakly exponential. The exponential growth rate experienced by

Sampan and Tommycut Creeks befits a growth trend that conforms with trends observed in experimental networks (Knighton *et al.*, 1992). Unlike the tidal river estuaries which are characteristic of the Alligator Rivers Region, the Mary River catchment is drained by a number of dendritic tidal creeks that bifurcate from the sea. Therefore, the exponential growth trends observed on the Mary River plains reflect the development of a dendritic network of tidal creeks. Alternately, the Alligator Rivers Region is drained by a series of estuarine channels. Tidal creek growth of each of the main river channels has occurred in localised areas of extension and tributary growth along the length of the river. The predominantly linear trend of network growth determined for the main rivers of the Alligator Rivers Region reflects the absence of large expanding dendritic creek networks, such as that formed on the Mary River plains.

Despite variation in the progress of network expansion between the tidal rivers of the Alligator Rivers Region and their western neighbour, the Mary River floodplains, both floodplains have exhibited similar trends of growth. Knighton *et al.* (1992) noted that the pre-existence of channel lines provided the principle routs for main channel extension on the Mary River. Remnant tidal channels on the floodplain which have been infilled or partially infilled since the Holocene, have formed palaeochannels. Palaeochannels are generally some of the lowest-lying topography within a coastal plain (Woodroffe and Mulrennan, 1993) and hence act as catchments for the development of seepage zones responsible for the initiation of channel scouring. Knighton *et al.* (1992) observed the progress of network expansion on the Mary River plains to have predominantly followed the path of palaeochannels. Tributary growth was confined within the palaeochannel boundaries.

Similar trends of tidal creek expansion were observed for the South and East Alligator Rivers. The most vigorous rates of tidal creek extension, dominantly through headward extension, were concentrated within low-lying palaeochannel swamps of the South and East Alligator Rivers. This trend of growth is indicative of the significance of slight topographical variations on tidal creek development.

Knighton *et al.* (1992) drew further attention to the impact of buffalo swim channels on the trends of saltwater intrusion on the Mary River plains. Noting the susceptibility of pre-existing palaeochannels to saltwater inundation and subsequent incision, large buffalo swim channels formed during the Wet season may become vulnerable to saltwater intrusion and tidal scouring in the Dry season. The distribution of buffalo swim channels in the Alligator Rivers Region have not been indicated on the map compilations of recent changes. Given the relationship observed between main swim channels and tidal creek extension on the Mary River plains, areas of rapid growth in the Alligator Rivers Region may be partly attributed to buffalo activity.

4.3 CONCLUSIONS

The aim of this thesis was to determine the rate, spatial extent and geomorphological character of saltwater intrusion in Kakadu National Park. The gross spatial distribution and growth patterns of changes in the eastern Alligator Rivers Region have been mapped from available aerial photography (1950, 1975,1984 and 1991) in a manner consistent with that adopted by Knighton *et al.*, (1992). Tidal-creek growth was measured as a topological variable of network magnitude. Change in mangrove colonisation over time was measured in terms of the total mangrove area. Documentation of the recent tidal creek and mangrove changes in the Alligator Rivers Region will enable direct comparison of the spatial extent of the estuarine channels in Kakadu National Park with adjacent areas in the Alligator Rivers Region. Prior to this research, comparisons between different regions was difficult due to variations in both scale and format. Subsequently, the maps compiled of recent tidal-creek extension and mangrove encroachment of the Wildman, West, South and East Alligator Rivers may assist in the determination of the geographic extent of the implications of saltwater intrusion, spatial variation in the rates of change, and the area of wetlands affected by salt water intrusion.

Detailed examination of the spatial distribution and growth patterns of tidal creek and mangrove growth was conducted at specific sites exhibiting change. The component morphological units of the specified sites were identified and described from aerial surveys, field mapping and observations. The field sites were selected due to the differing processes or trends of saltwater intrusion dominating different segments of the river. The intrusion of saltwater over the salt flats into the *Melaleuca spp.* forest on the East Alligator River appears to be influenced by the impacts of storm surge and overbank flooding. Alternately, the headward extension of one channel tributary into the Kapalga salt flats, off the cuspate segment of the South Alligator River, is testament to the incising processes of tidal scour causing tidal-creek extension. In contrast to these trends, the small tributary branching from Munmarlary on the sinuous segment of the South Alligator River has exhibited little tidal creek growth. The spatial distribution and patterns of mangrove colonisation along the Munmarlary creek line suggest that the tidal creek headwaters may be abstracting, indicative of a decline in the tidal influence. Detailed descriptions of the morphological units of each site have provided the baseline for future measurement and assessment of the change.

Saltwater intrusion through tidal-creek extension has been identified as the major coastal management problem in the Alligator Rivers Region, incorporating Kakadu National Park as its eastern component (Bayliss *et al.*, 1995). Whilst the trends of saltwater intrusion have been well documented in the literature for the South Alligator River and Mary River plains, the geographic extent of the problem, and the spatial variations in the rates of change had not been determined in detail. The research described herein has identified and documented areas at risk, as well as the changes which have occurred over the last 50 years.

4.3.1 Future Research and Monitoring

This research has acted to complete documentation of the trends and extent of saltwater intrusion of the wider Alligator Rivers Region. Future research should incorporate continued monitoring programs to record future changes, processes and rates of saltwater intrusion across the wider Alligator Rivers Region. Whilst the extent of the problem has been well defined in the literature, and the trends of saltwater intrusion are generally well-understood, little research has addressed the mechanics or processes of saltwater intrusion. This research has described the present morphological components of field sites from different river segment through field observations and detailed mapping. These sites should be adapted as a basis for future monitoring of changes related to the impact of saltwater intrusion. Given the threat saltwater intrusion poses on the freshwater wetlands within the Alligator Rivers Region, a future monitoring program is an essential task for management, in order to delineate areas at risk.

REFERENCES

Bayliss, B.L., Brennan, K.G., Eliot, I., Finlayson, C.M., Hall, R.N., House, T., Pidgeon, R.W.J, Walden, D. and Waterman, P. (1995) Vulnerability assessment of the possible effects of predicted climate change and sea level rise in the Alligator Rivers Region, Northern Territory, Australia, pp 17-20, 43-46. Environmental Research Institute of the Supervising Scientist, Jabiru, NT.

Bayliss, P. B.L. and Yeomans, K.M. (1989) Distribution and abundance of feral livestock in the 'Top End' of the Northern Territory (1985-86), and their relation to population control, *Australian Wildlife Research* **16** : 651-676.

Chappell, J. (1988) Geomorphological dynamics and evolution of tidal river and floodplain systems in Northern Australia, In Northern Australia: Progress and Prospects, Volume 2: Floodplains Research (ed. by Wade-Marshall, D. and Loveday, P.), pp 34-57. Australian National University North Australia Research Unit, Darwin.

Chappell, J., Cowell, P.J., Woodroffe, C.D. and Eliot, I.G. (1996) Coastal Impacts of Enhanced Greenhouse Climates, Coastal Risk Management, England.

Chappell, J. and Woodroffe, C.D. (1985) Morphodynamics of Northern Territory tidal rivers and floodplains, In Coasts and Tidal Wetlands of the Australian Monsoon Region (ed. by Bardsley, K.N., Davie, J.D.S. and Woodroffe, C.D.), pp 85-96. Australian National University North Australia Research Unit, Darwin.

Davie, J.D.S. (1985) The mangrove vegetation of the South Alligator River, Northern Australia , In Coasts and Tidal Wetlands of the Australian Monsoon Region (ed. by Bardsley, K.N., Davie, J.D.S. and Woodroffe, C.D.), pp 53-62. Australian National University North Australia Research Unit, Darwin.

Day, J.W., Conner, W.H., Constanza, R., Kemp, G.P. and Mendelson, L.A. (1991) Impact of sea level rise on coastal ecosystems, In Climate and sea level changes: Observations, projections and implications (ed. by Warrick, R.A., and Wigley, T.M.L.). Cambridge, England, Cambridge University Press.

Downs, L.L., Nicholls, R.J., Leatherman, S.P. and Hautzenroder, J. (1994) Historic evolution of a marsh island: Bloodsworth Island, Maryland, *Journal of Coastal Research* **10** (4) : 1031-1044.

Duggan, K. (1985) Erosion and sediment transport in the lowlands of the Alligator Rivers Region, Northern Territory, In Coasts and Tidal Wetlands of the Australian Monsoon Region (ed. by Bardsley, K.N., Davie, J.D.S. and Woodroffe, C.D.), pp 53-62. Australian National University North Australia Research Unit, Darwin.

Ellison, J.C. (1993) Mangrove retreat with rising sea-level, Bermuda, *Estuarine, Coastal and Shelf Science* **37** : 75-87.

Ellison, J.C. and Stoddart, D.R. (1991) Mangrove ecosystems collapse during predicted sea-level rise: Holocene analogues and implications, *Journal of Coastal Research* **7** : 151-165.

Finlayson, C.M., Bailey, B.J. and Cowie, I.D. (1989) Macrophyte vegetation of the Magela Creek Flood Plain, Alligator Rivers Region, Northern Territory. Reserach report 5, Supervising Scientist for the Alligator Rivers Region. AGPS, Canberra.

Finlayson, C.M. (ed.) (1995) Wetlands Research in the Wet-Dry tropics of Australia, Environmental Institute of the Supervising Scientist, Darwin.

Finlayson, C.M., Bailey, B.J., Freeland, W.J. and Fleming, M.R. (1988) Wetlands of the Northern Territory, In The Conservation of Australian Wetlands (ed. by McComb, A.J. and Lake, P.S.), pp 103-126. Surrey Beatty & Sons Pty Ltd., NSW.

Finlayson, C.M. and Woodroffe, C.D. (1995) Wetlands vegetation of the Alligator Rivers Region, In Ecology and Landscape Evolution in the Alligators Rivers Region, Northern Territory (ed. by Finlayson C.M.), Geobotany Monograph Series, Junk, The Hague.

Fogarty, P. (1982) A preliminary survey of environmental damage associated with activity of feral buffalo. Conservation Commission of the Northern Territory, Tech. Rep.

Hegerl, E.J., Davie, P.J.F., Claridge, G.F. and Elliot, A.G. (1979) The Kakadu National Park mangrove forests and tidal marshes, Vol. 1. A review of the literature and results of a field reconnaissance to the Australian national Parks and Wildlife Service, Canberra.

Hoffman, J.S. (1984) Estimates of future sea level rise, In Greenhouse Effect and Sea Level Rise (ed. by Barth, M.C. and Titus, J.G.), pp 79-103. New York, Van Nostrand Reinhold.

Knighton, A.D., Mills, K. and Woodroffe, C.D. (1991) Tidal-creek extension and saltwater intrusion in Northern Australia, *Geology* **19** : 831-834.

Knighton, A.D., Woodroffe, C.D. and Mills, K. (1992) The evolution of tidal creek networks, Mary River, Northern Australia, *Earth Surface Processes and Landforms* **17** : 167-190.

Lee, D.M. and Neal A.B. (1984) The climate in northern Australia, In Northern Australia: The Arenas of Life and Ecosystems on Half a Continent (ed. by Parker, D.), pp 29-55. Academic Press, Sydney.

Nanson, G.C. and Croke, J.C. (1992) A genetic classification of floodplains, *Geomorphology* **4** : 459-486

McAlpine, J.R. (1976) Climate and water balance, In Lands of the Alligator Rivers area, Northern Territory (Story et al.), pp 35-49. CSIRO Land Research Series 38.

McArthur, W.M. (1991) Reference Soils of South-Western Australia, Department of Agriculture, Western Australia.

O'Neil, G.C. (1983). An investigation of recent geomorphological change on a section of the South Alligator River floodplain, Kakadu National Park. Report to the Australian National Parks and Wildlife Service. Canberra.

Pearman, G.I. (1988) Greenhouse : Planning for Climate Change, CSIRO, Melbourne.

Rayment, G. E. and Higginson, F. R. (1992) Australian Laboratory Handbook of Soil and Water Laboratory Methods, Inkata Press, Melbourne.

Semeniuk, V. (1994) Predicting the effect of sea-level rise on mangroves in North-western Australia, *Journal of Coastal Research* **10** (4) : 1050-1076.

Shreve, R.L. (1967) Infinite topologically random networks, *Journal of Geology* **75** : 178-186

Stanton, J.P. (1975) A preliminary assessment of wetlands in Queensland, CSIRO Australian Division of Land Use Research Technology, Memo. 10.

Stocker, G.C. (1970) The effects of water buffaloes on paperbark forest in the Northern Territory, *Australian Forest Research* **5** : 29-34.

Strahler, A.N. (1964) Quantitative geomorphology of drainage basins and channel networks, In Handbook of Applied Hydrology (ed. by Chow, V.T.), Section 4-II. McGraw-Hill, New York.

Taylor, J.A. and Tulloch, D. (1985) Rainfall in the Wet-Dry tropics: Extreme events at Darwin and similarities between years during the period 1870-1983, *Australian Journal of Ecology* **10** : 281-295.

Vertessy, R.A. (1990) Morphodynamics of Macrotidal Rivers in Far North Australia, PhD thesis, ANU, Canberra.

Wasson, R.J. (ed.) (1992) Modern Sedimentation and Late Quaternary Evolution of the Magela Creek Plain, Reassert Report 6, Supervising Scientist for the Alligator Rivers Region, Australian Government Publishing Service, Canberra.

Wells, A.G. (1985) Grouping tidal systems in the Northern Territory and the Kimberley Region of Western Australia on presence/absence of mangrove species, In Coasts and Tidal Wetlands of the Australian Monsoon Region (ed. by Bardsley, K.N., Davie, J.D.S. and Woodroffe, C.D.), pp 119-132. Australian National University North Australian Research Unit, Darwin.

Whitehead, P.J., Wilson B.A. and Bowman D.M.J.S. (1990) Conservation of coastal wetlands of the Northern Territory of Australia: the Mary River floodplain, *Biological Conservation* **52**, 85-111.

Williams, A.R. (1984) Changes in Melaleuca forest density on the Magela floodplain, Northern Territory, between 1950 and 1975, *Australian Journal of Ecology* **9**, 199-202.

Woodroffe, C.D. (1987) Relative sea level in the South Alligator River Region, North Australia, during the Holocene, *Search* **18** (4) : 198-200.

Woodroffe, C.D. (1995) Response of tide-dominated mangrove shorelines in Northern Australia to anticipated sea-level rise, *Earth Surface Processes and Landforms* **20** : 65-85.

Woodroffe, C.D., Chappell, J.M.A., Thom, B.G. and Wallensky, E. (1986) Geomorphological Dynamics and Evolution of the South Alligator River and Plains, Northern Territory, Australian National University North Australia Research Unit, Darwin.

Woodroffe, C.D., Chappell, J.M.A., Thom, B.G. and Wallensky, E. (1989) Depositional model of a macrotidal estuary and floodplain, South Alligator River, Northern Australia, *Sedimentology* **36** : 737-756.

Woodroffe, C.D. and Mulrennan, M.E. (1993) Geomorphology of the Lower Mary River Plains, Northern Territory, Australian National University North Australia Research Unit and Conservation Commission of the Northern Territory, Darwin.

APPENDIX 1

Sources and Coverage of Aerial Photography

Date	Scale	Height	Colour	Source	Coverage
1950	1: 50,000	25,000′	B/W	AUSLIG	Arnhem Highway, north to coast
1975	1:25,000	12,500′	Colour	Aerial Surveys	Arnhem Highway, north to coast; includes South and East Alligator Rivers
1984	1:25,000	Unknown	Colour	AUSLIG	Kakadu National Park
1991	1:25,000	13,000′	Colour	AIReSEARCH	Kakadu National Park

APPENDIX 2

Field Notes at Kapalga - Monday, 18 August 1997

Mouse and Ray set up base station at a known geodetic site (Kapalga NTS 018) at approx. 2.00 pm

Steph, Ray and Mouse drove by 4WD vehicles and quads to the Kapalga site, which 1950 and 1975 aerial photographs indicate to have once been a Melaleuca swamp. As evident on the 1991 photos, a tidal channel and associated mangroves now extends into the area that had been populated by these trees.

Steph mapped the saltflat areas (comments: no trees, dead or alive) with the GPS rover receiver mounted on a quad bike. Included the boundary of small dead tree pockets in the centre.

Mouse and Ray surveyed the site addressing the practicalities of mapping creek lines and mangrove boundaries etc. Ray took photos of features of the site - creeklines, mangroves, saltflats......., and 'apparatus'.

Steph and Mouse ran up the creekline from the upstream extent of the channel with the GPS on the quad, placing a point reading at the end of each tributary; and at single mangroves. The creekline was characterised by black, muddy creacked clays, wetted at high tide and outlined by a grass levee bank. The creekline ended in an area of dead paperbark.

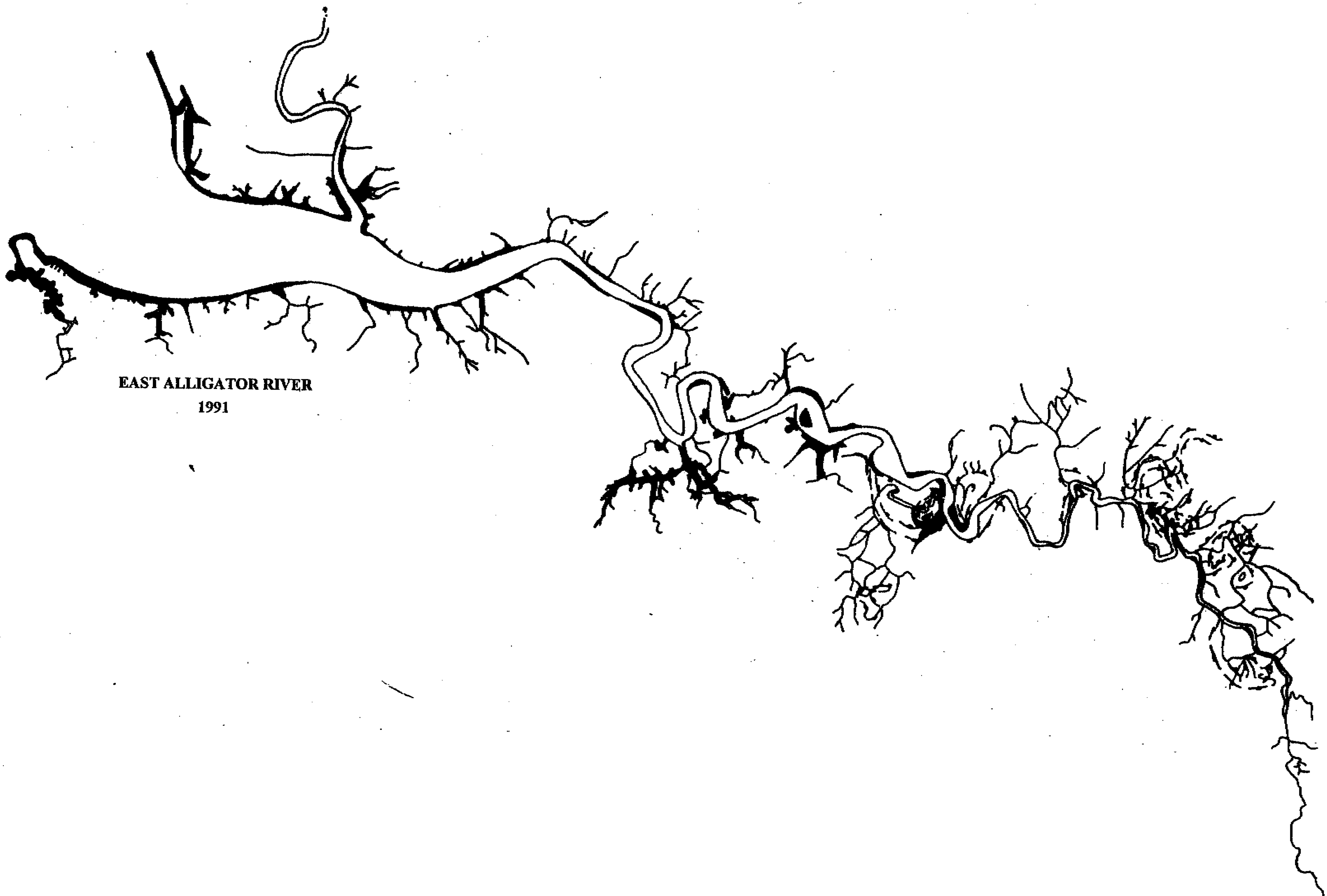
Mouse ran two orthogonal transects across the bare saltflat area with the GPS on quad in order to see if any depression is apparent.

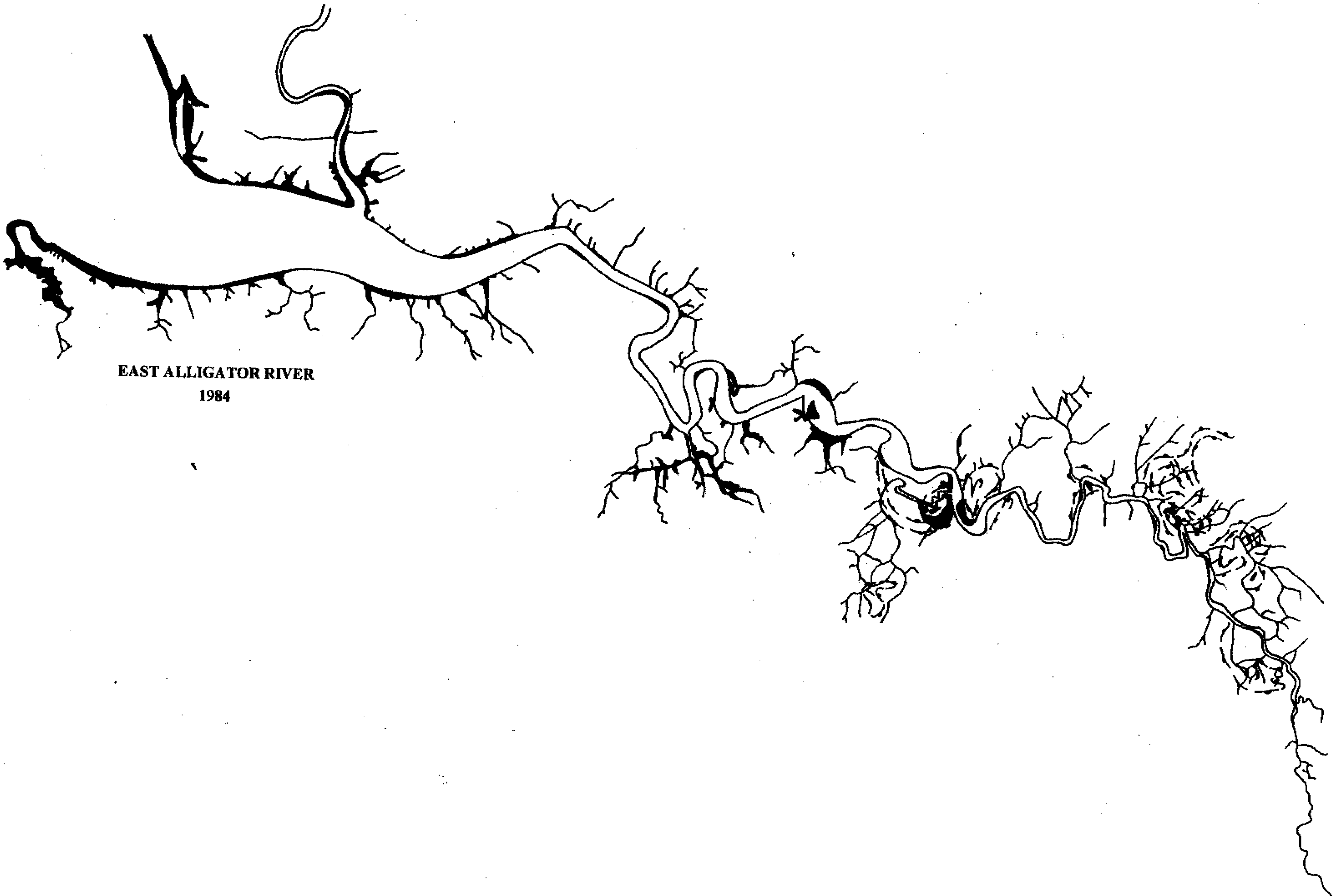
Ray and Steph walked a transect - N/W from the creekline (Generic point; comments: MAN 3) to the Melaleuca forest. Soil samples collected from - 10cm depth from <u>eight sites</u> along the transect:
S1 levee bank, S1creek bed, S1 N/W side of bed under mangrove, S2 saltflat, S3 dead trees,
S4 *Eleocharts dulcis* (reed) patch, S5 *Psuedoraphis spinescens* (grass) patch, and S6 Mel forest.
Mouse took a GPS reading at each sample site. EC and possibly particle size analysis to be conducted on samples back at *eriss* or UWA.

Departed the Kapalga site and dismantled the base station, leaving tripod standing for the following day. Returned to *eriss* - 6.30 pm. Mouse down-loaded data and began processing.

General Observations:
saltflat areas:

- cracked clays, areas of reed *Eleocharis dulcis.*
- scattered logs in random directions (transition between dead paperbark boundary and defined saltflat boundary)
- pools of water (freshwater / saltwater?)
- evidence of pig diggings

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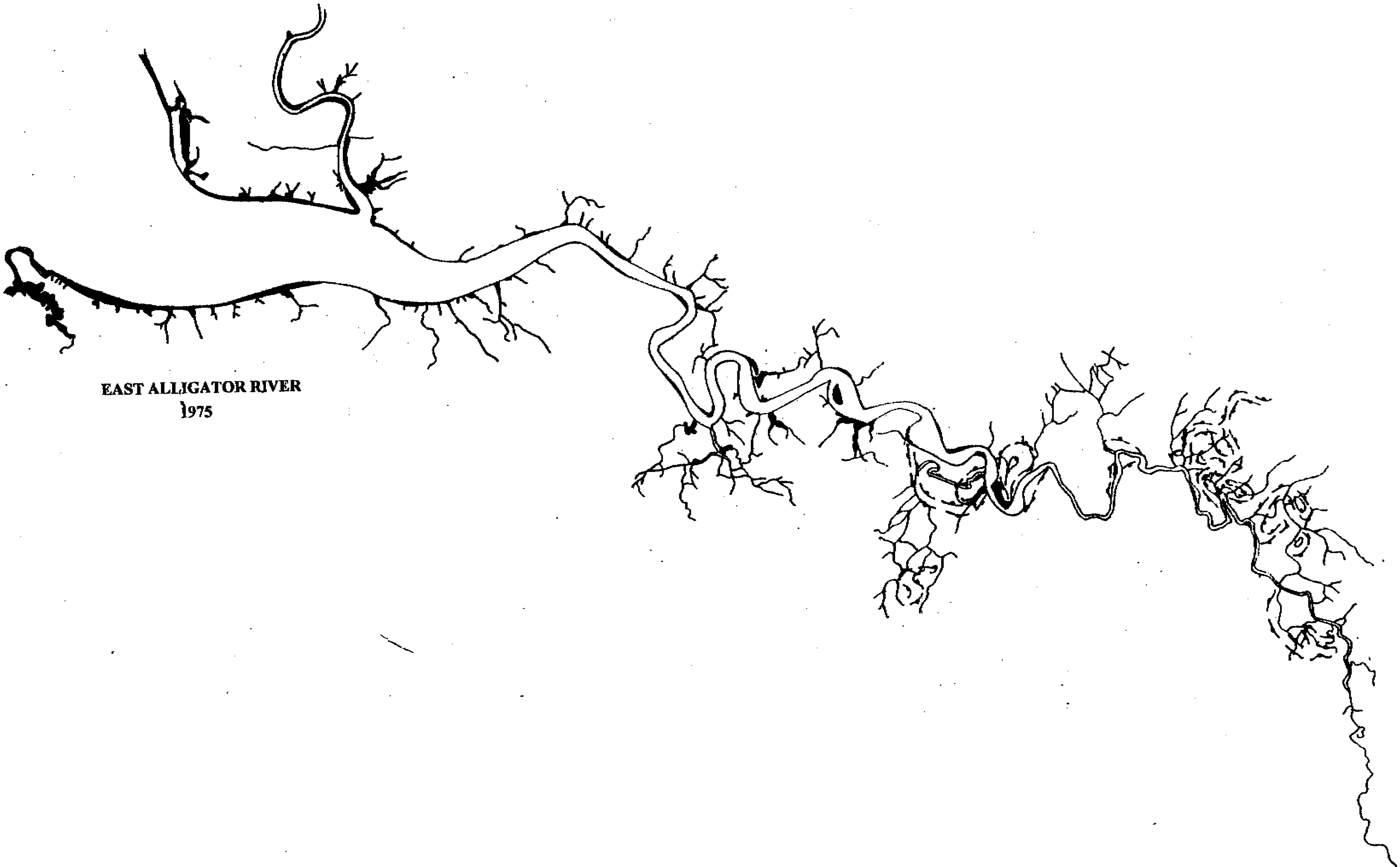
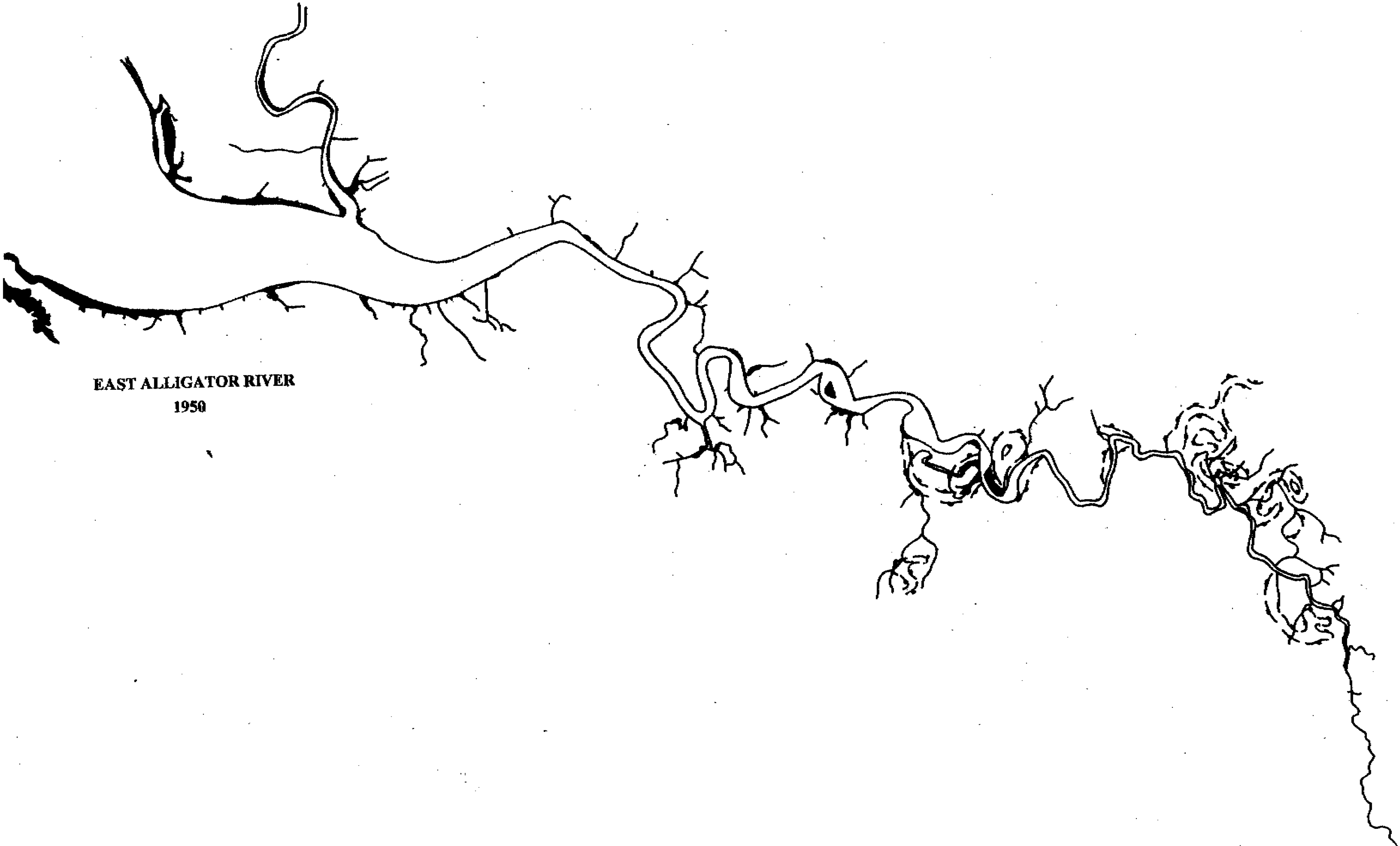
1984



EAST ALLIGATOR RIVER
1975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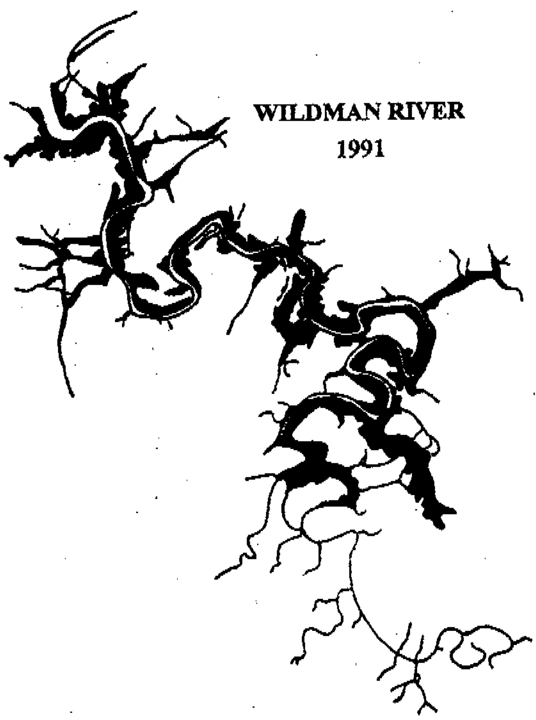
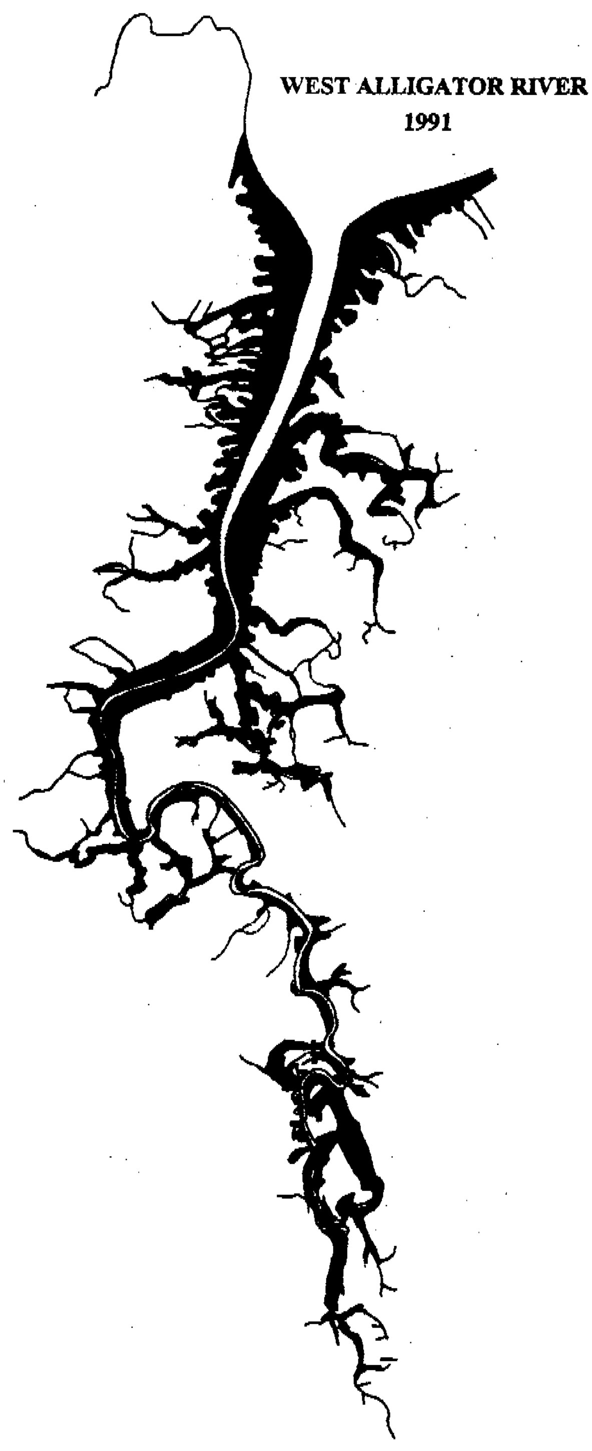
1950


WILDMAN RIVER
1991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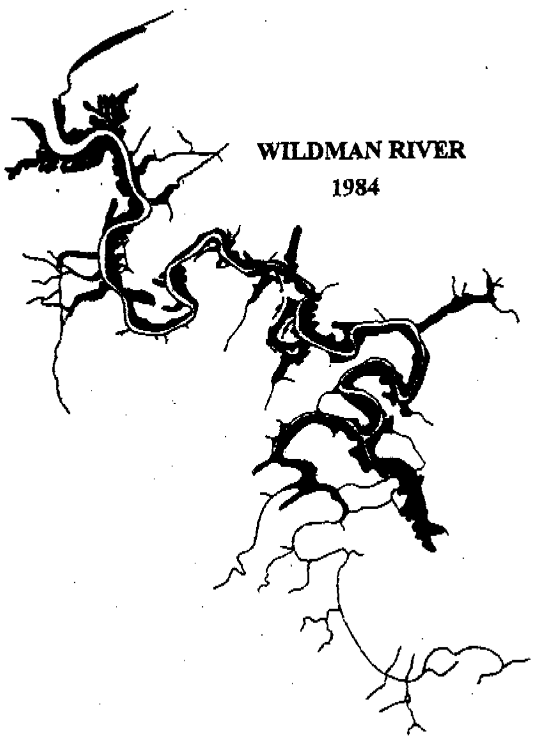
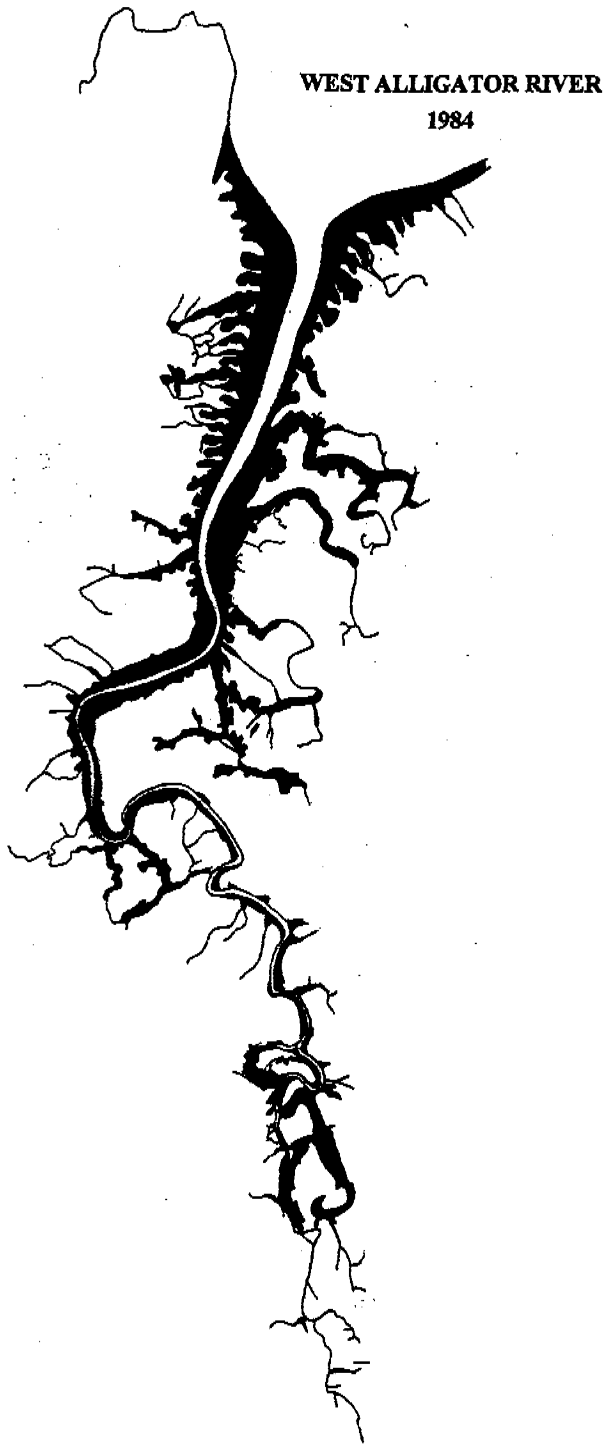

WILDMAN RIVER
1984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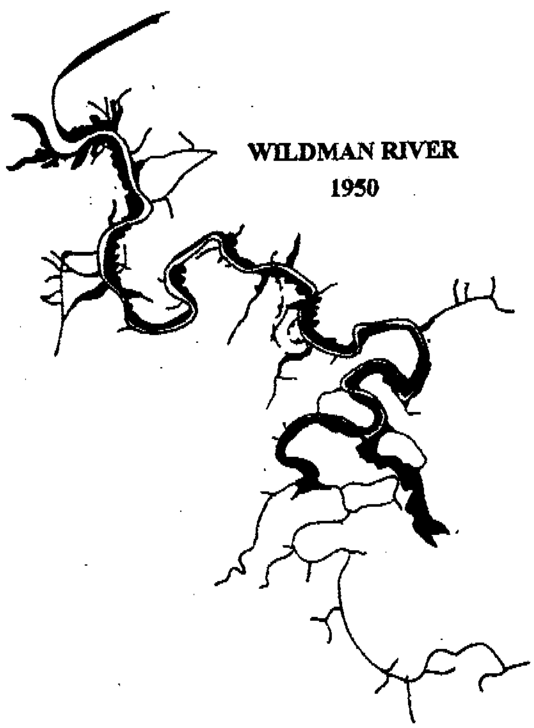
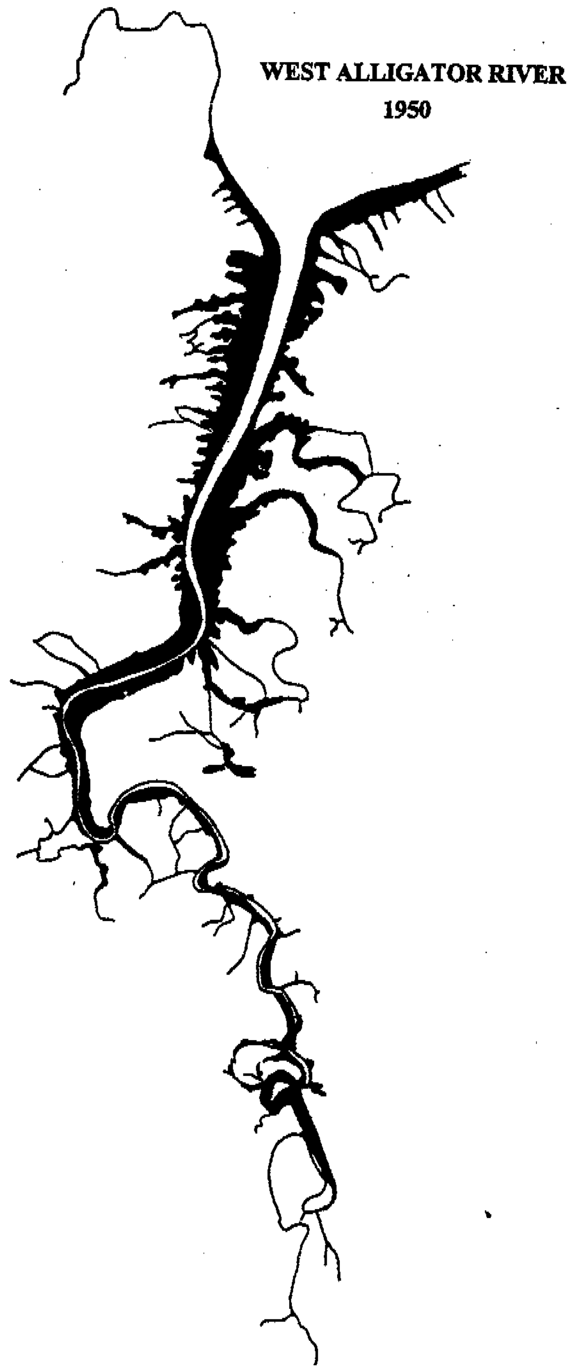
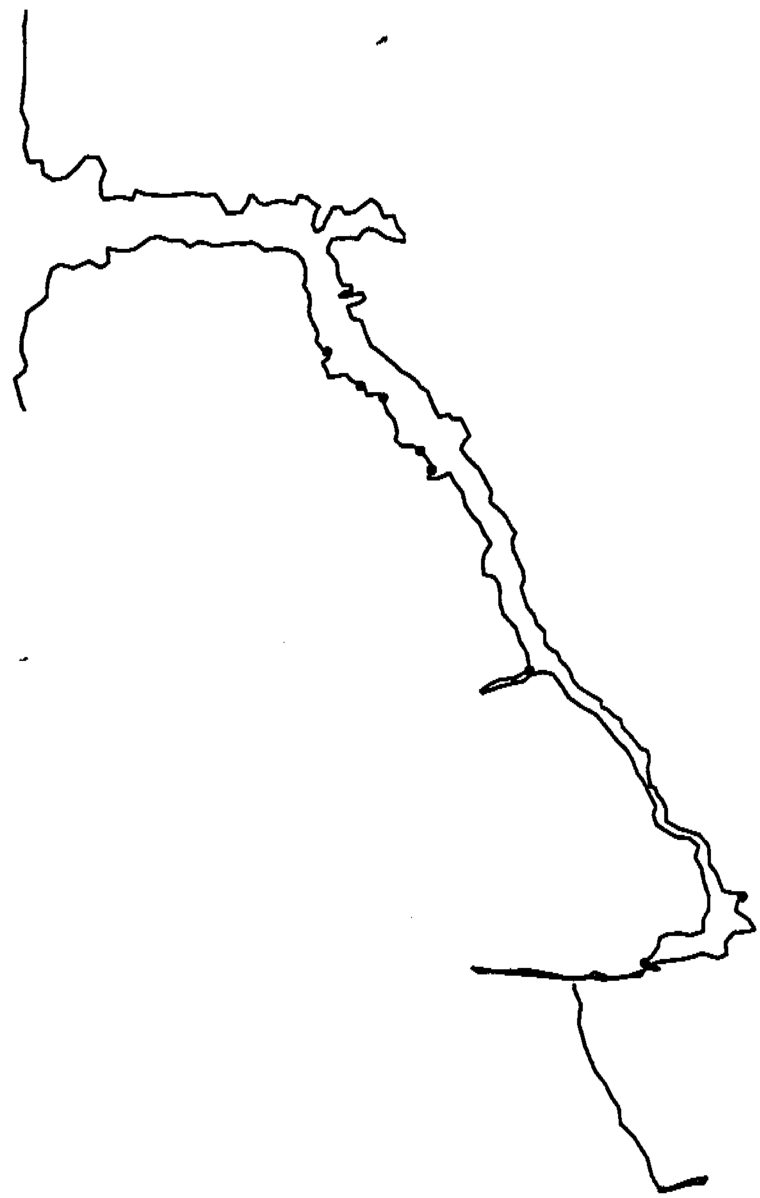

WILDMAN RIVER
1950


WEST ALLIGATOR RIVER
1950

Tidal Creek Extension, Munmarlary



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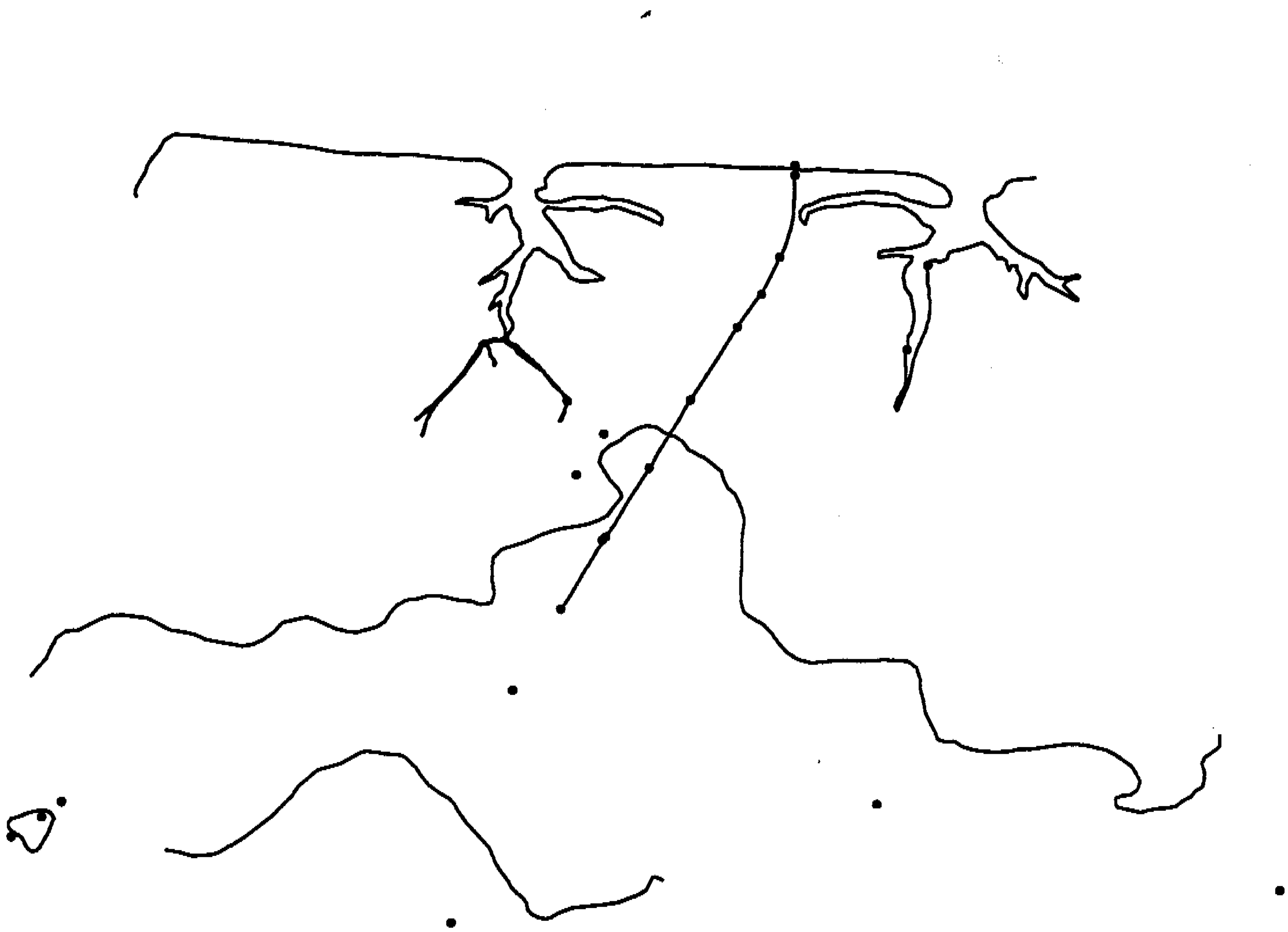
Projection: Albers Equal Area

Tidal Creek Extension, Point Farewell



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Tidal Creek Extension, Kapalga

Scale: 1:45,000
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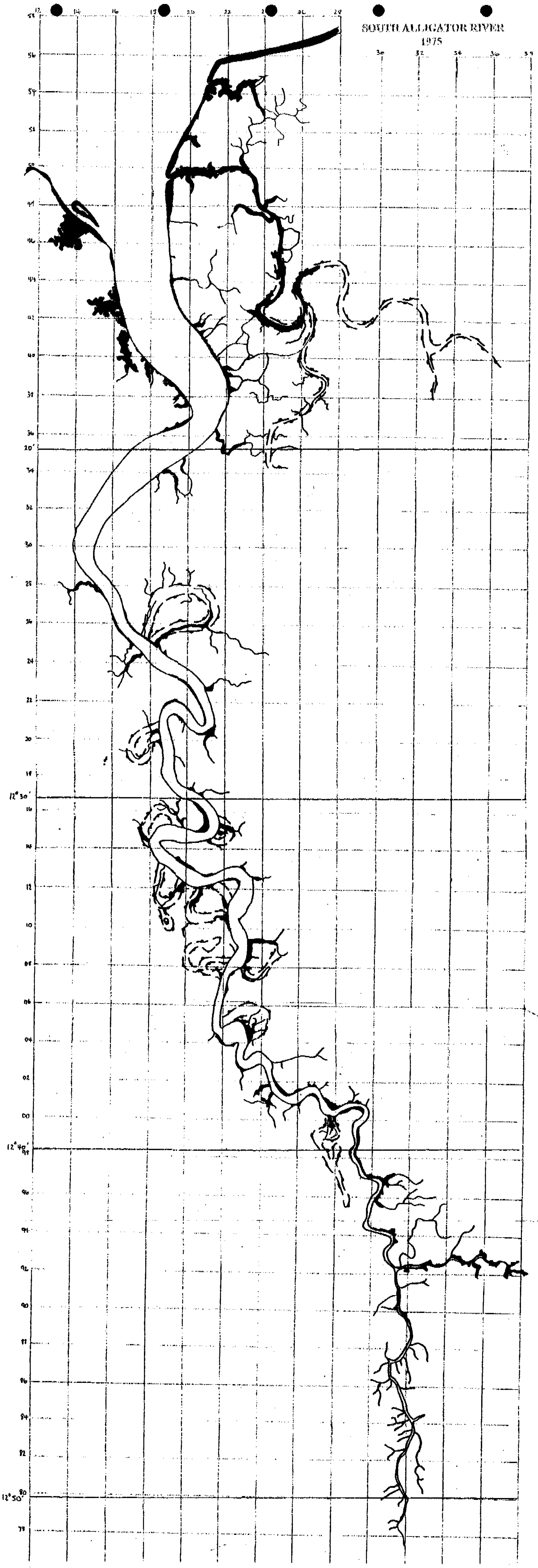
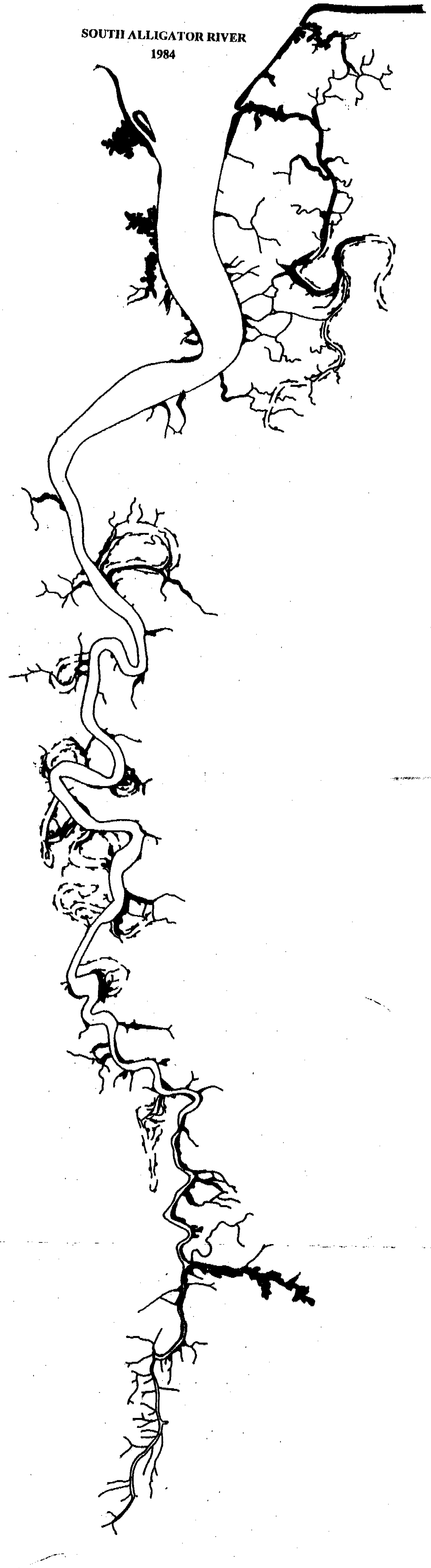

SOUTH ALLIGATOR RIVER
1975

SOUTH ALLIGATOR RIVER
1984



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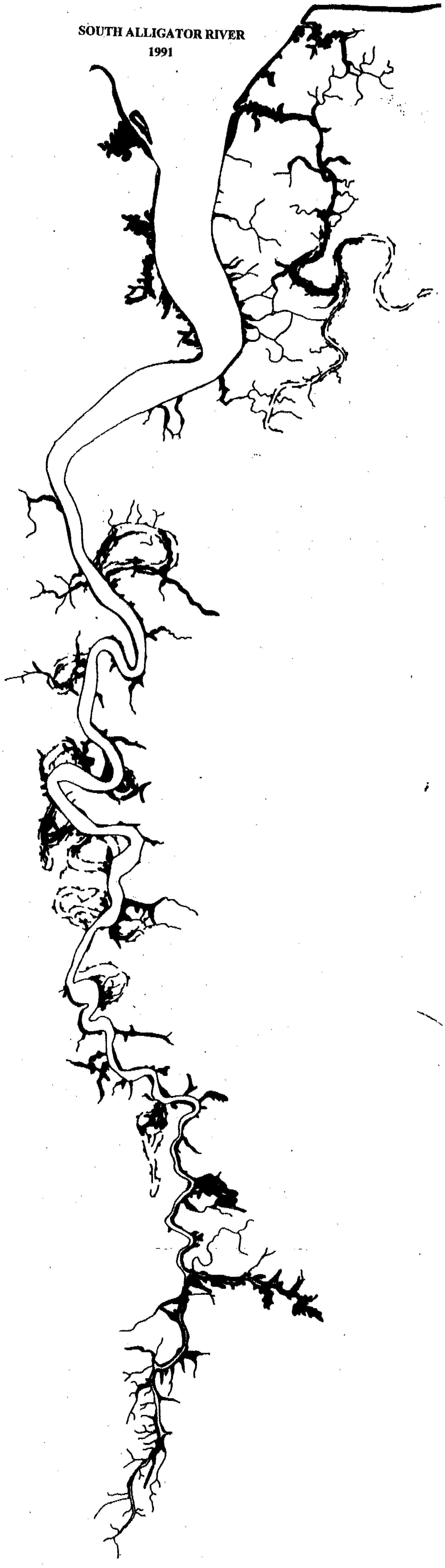
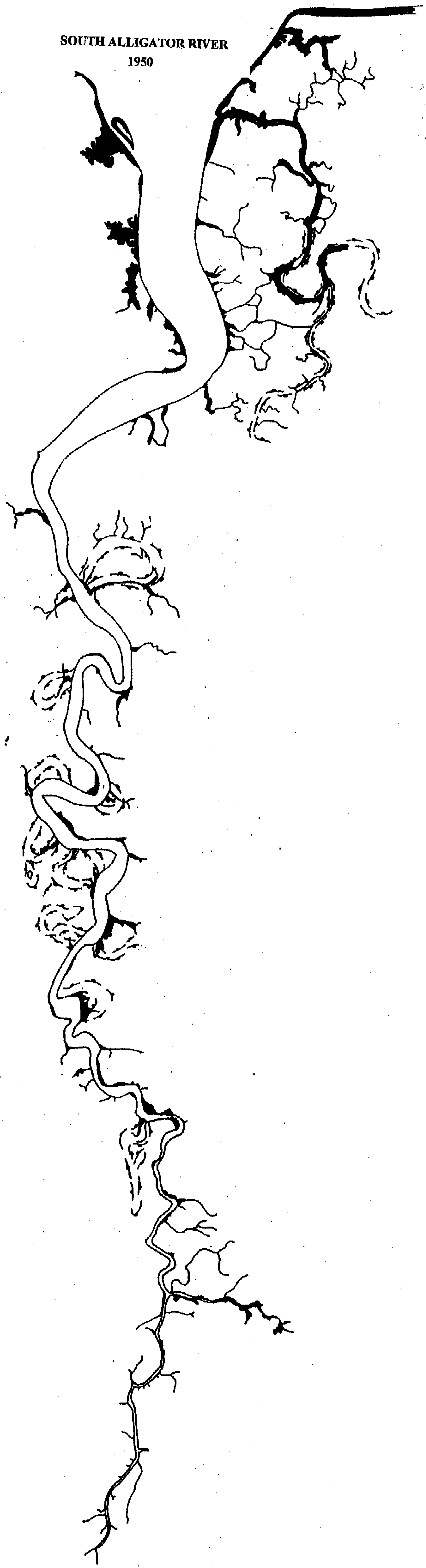
1991





SOUTH ALLIGATOR RIVER
1950