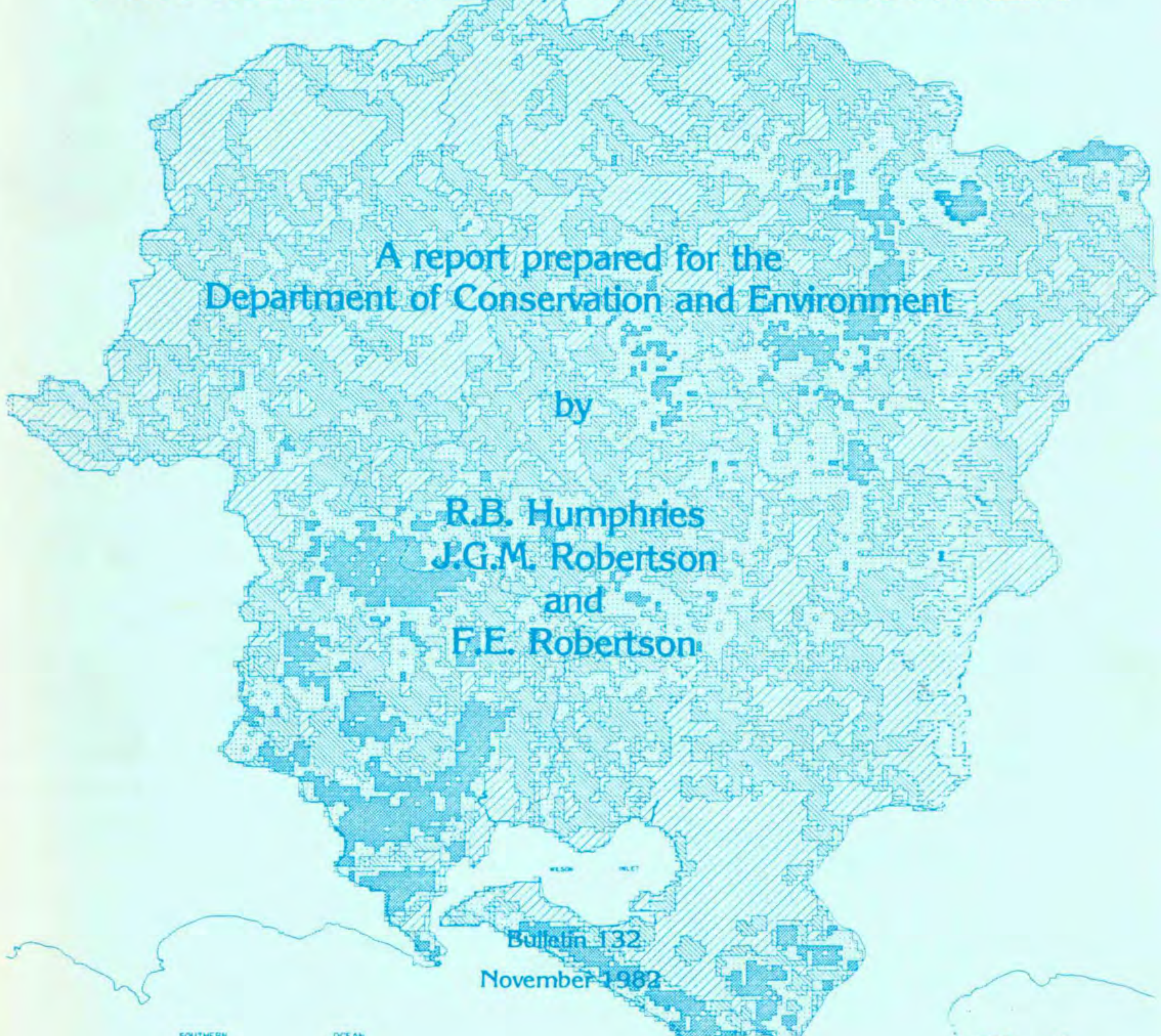
132

A RESOURCE INVENTORY AND MANAGEMENT INFORMATION SYSTEM FOR WILSON INLET, WESTERN AUSTRALIA



A report prepared for the
Department of Conservation and Environment

by

R.B. Humphries
J.G.M. Robertson
and
F.E. Robertson

Bulletin 132
November 1982

Department of Conservation and Environment
Western Australia

A RESOURCE INVENTORY AND MANAGEMENT INFORMATION SYSTEM FOR WILSON INLET, WESTERN AUSTRALIA

A report prepared for the

Department of Conservation and Environment

by

R.B. Humphries

J.G.M. Robertson

and

F.E. Robertson

November 1982

Ecosystem Analysis
7 Katrine Street
FLOREAT PARK WA 6014

Acknowledgements

Patrick Hesp, Department of Agriculture, Soils and Conservation
Colin Pearce, Forests Department
Nick Schofield, Western Australian Institute of Technology
Ian Eliot, Geography Department, University of Western Australia
Bill Collins, Water Resources Branch, Public Works Department
Paul Wilson, State Herbarium
Barry Smith, ESRI
Graham Chittleborough, Department of Conservation and Environment
Peter Birch " " "
Ernest Hodgkin " " "
Ian Parker " " "
Pauline Sawyer " " "
Brian Stewart " " "
Ross Field " " "
Tony Chiffings " " "
Rob Sippe " " "
Debra Totterdell " " "
Norm KcKenzie, W.A. Wildlife Research Centre
Neville McIntyre, Denmark Agriculture Research Station
Graham Sansom, Department of Conservation and Environment
Tony Berman " " "
Rex Spencer, Faculty of Agriculture, University of Western Australia

Abbreviations used in this report

ABS	-	Australian Bureau of Statistics
WA	-	Western Australia
PWD	-	Public Works Department
FMIS	-	Forest Management Information System (see FMIS code list (6.1.2) for FMIS abbreviations)
ESRI	-	Environmental Systems Research Investigations
UWA	-	University of Western Australia
WAIT	-	Western Australian Institute of Technology
GIS	-	Geographic Information System
DCE	-	Department of Conservation and Environment
CBM	-	Commonwealth Bureau of Meteorology
km	-	kilometre
m	-	metre
mg	-	milligram
ha	-	hectare

PREFACE

With a growing number of environmental studies at specific locations along the Western Australian coast, rapidly increasing quantities of data are being accumulated. The separate data bases assembled for each locality or specific problem are in various forms (maps, graphs, tables, computer files, etc.).

In some instances the original data are held by the Department of Conservation and Environment, but much use is also made of data held by other departments or institutions. So far there has been little effort to bring the various data from different coastal studies or from different sources into a common format. This would greatly enhance accessibility of information and ensure that hard-won data are not lost in the obscurity of individual files.

As a step towards establishing a better coordinated system for the storage and retrieval of information on our coastal resources and environmental quality, a resource inventory and management information system was developed for a specific area as a pilot operation. The area chosen (Wilson Inlet and its catchment) was selected partly on a basis of size and discreteness as a separate entity, but also because increasing conflicts between the various users make the assembling of a data base specific to this Inlet and its catchment a matter of priority.

While the inventory is a valuable summary of available data, the review of approaches is a sound step towards setting up a better integrated computer based data system.

C.F. Porter
DIRECTOR

TABLE OF CONTENTS

A RESOURCE INVENTORY AND MANAGEMENT INFORMATION SYSTEM FOR WILSON INLET, WESTERN AUSTRALIA

Page

1. INTRODUCTION

Wilson Inlet and some of the other estuaries in south western WA are beginning to show signs of deterioration from the human activities in their catchments. Land clearing, river bank erosion and increased sediment and nutrient runoff from the development of agricultural land have significantly affected the estuaries. Although there is a great deal of information available on these activities and their effects, the data are widely dispersed and are not readily available for manipulation and analysis. Much of the data are geographic in nature and could be conveniently displayed and stored as maps. This applies equally to attributes of the estuary, such as land use and vegetation cover, that vary with time.

The aims of this study were:

(1) To gather the existing data on Wilson Inlet and its catchment into an easily accessible and useable form.

(2) To store the geographically based data on computer so that they can be readily manipulated and modified as new data becomes available.

(3) To examine some of the various computer-based data management systems that are available in terms of:

- (i) the data base already stored in the system;
- (ii) requirements for additional data input to the computer system;
- (iii) the ease of data manipulation required for management decisions;
- (iv) suitability for storage of additional data for other estuaries; and

(v) cost-effectiveness

There are three computer-based systems that have been examined and used in this study. The systems are described in detail in section 6 but a brief description at this stage will clarify much of the description in the following sections.

The simplest system is the Geocoding System used by the Australian Bureau of Statistics. Data are stored as a single value for each attribute within a 10 x 10 km square. The Geocoding System was only used to provide data on the use of fertilisers and biocides (2.3). Its large grid size was considered inappropriate for data storage and manipulation for management purposes (see Figure 1).

The second system, FMIS (Forest Management Information System) (6.1.2) is used by the Forests Department, WA for the management of forestry activities. FMIS was a major source of data on tenure, land use, vegetation, etc., in the form of map plots and calculations of their areas in the different catchments. The resolution of FMIS is limited to the basic 2 ha cell which is appropriate for most management problems. Additional data can be coded and stored, and the system is easy to use and relatively inexpensive. The whole coverage of FMIS and an index to the FMIS squares is shown in Figure 2.

The third system is the GIS (Geographic Information System) produced and operated by Environmental Systems Research Investigations (ESRI). GIS is extremely flexible, and because it is not limited to grid cells of fixed size, like FMIS and Geocoding, it can accurately plot topography, bathymetry, rivers, roads, etc. It is capable of sophisticated analysis of the data and can produce maps of cartographic quality. All maps produced for this study were standardised at the scale of 1:100,000 Natmap sheets available commercially. A complete composite set of 1:100,000 maps, and all of the original computer-drawn maps reproduced in this report are lodged in the Library of the Department of Conservation and Environment, Perth.

The FMIS and ESRI systems are both able to produce maps at a wide range of scales on demand.

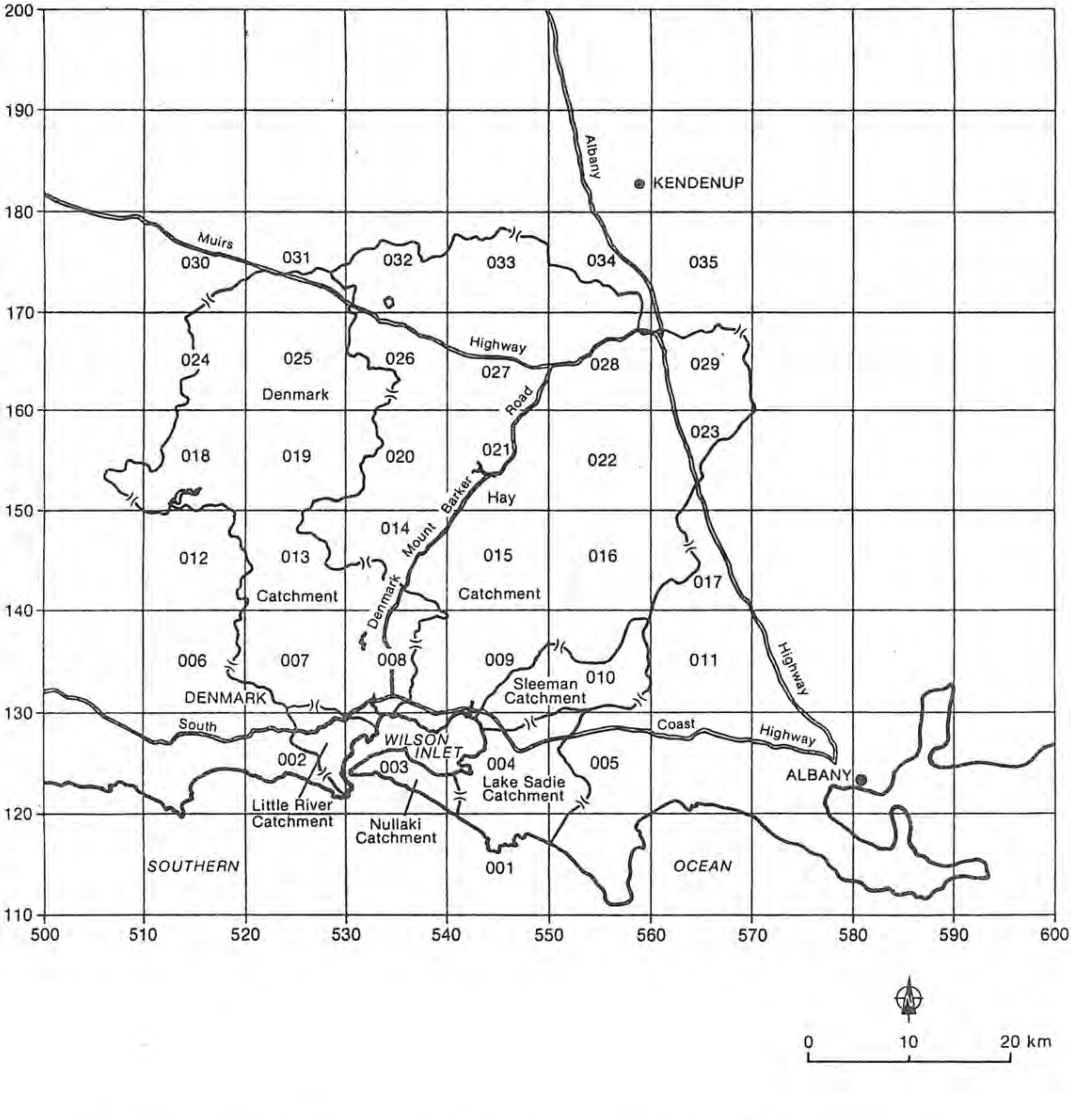
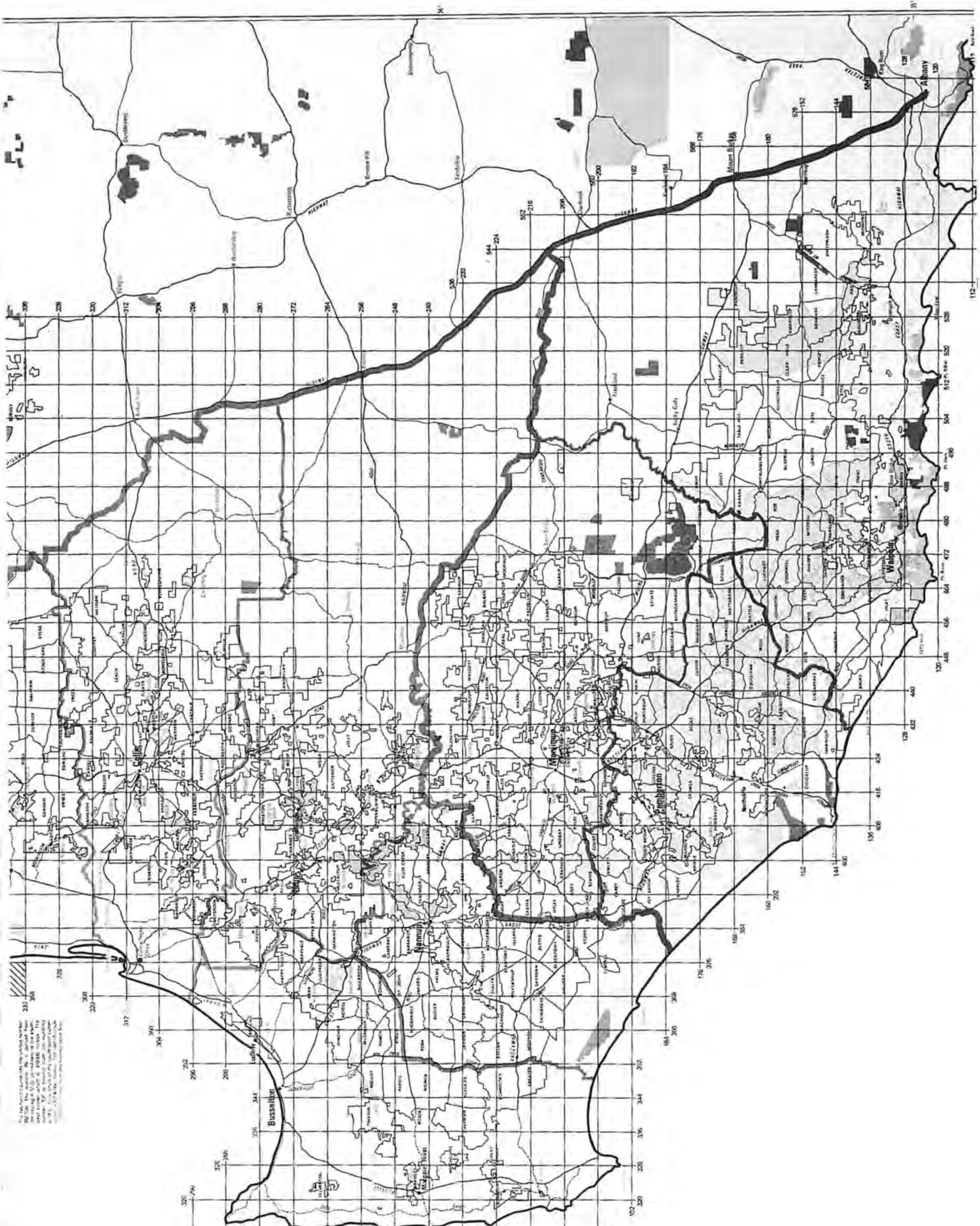


FIGURE 1. Geocoding squares from the Australian Bureau of Statistics and their relation to the Wilson Inlet catchment.


SOUTH-WEST OF WESTERN AUSTRALIA
FOREST AREAS
INDEX TO F.M.I.S. SQUARES
SCALE 1:500 000
Each F.M.I.S. square is an 8000 metre by 8000 metre area defined by the Australian Map Grid. It is identified at its south-west corner by the thousands value of the eastings and northings respectively. See example.
LEGEND
Forest Blocks
Pine Plantations
Karri Occurrence
State Forest, Timber Reserves (Forests Act) and other land under the control of the Conservator of Forests
National Parks
Flora and Fauna Reserves
Forest Regions
Forest Divisions
Forests Dept. Division Office
Forests Dept. Office
Towns
Northam
Mundaring
Kelmscott
Jarrahdale
Dwellingup
Narrogin
Harvey
Hamel
Como
Gnangara
Wanneroo
Yanchep


Albany
Mount Barker
Walpole
Pemberton
Manjimup
Nannup
Collie
Busselton
Margaret River

2. THE CATCHMENT

The catchment of Wilson Inlet includes the Denmark, Hay, Mitchell, Little and Sleeman rivers and their tributaries, the Lake Saide (or Sadie) Drain and Nullaki (Map 1, Table 1). The boundary of this drainage system was recently redefined from 1:50,000 contour map compilations (Collins and Fowlie 1981). This catchment was digitised by ESRI and is shown on the computer-drawn base maps for the catchment boundaries, the roads, rivers and coastline (Map 1 and 2). The Denmark, Hay (includes Mitchell) and Sleeman rivers are included in FMIS (FMIS RIV codes M, N and U), in addition to a catchment called Wilson Inlet (FMIS RIV code Z) which is a small drainage to the north of Wilson Inlet that apparently drains directly into the Inlet (Map 3). On the FMIS catchment map the Little River is incorrectly included in the drainage to William Bay (FMIS RIV code X) (Map 3). Another discrepancy between the FMIS and ESRI catchment boundary is due to the north east section of the Hay River being outside the area of FMIS coverage (section 6.1.2). Despite these discrepancies there is a reasonable agreement between the boundaries of the catchments (overlay Maps 1 and 3). However the discrepancies result in significantly different estimates of the areas of the subcatchments (Table 1).

2.1 Geology, Geomorphology and Topography

A preliminary uncoloured 1:250,000 geological map of the Albany/Mount Barker area was published in June 1982 by Geological Survey, WA. This map has been hand coloured for the catchment (Map 4), and was then digitised by ESRI at a scale of 1:100,000 (Map 5). The general geology of the area is outlined in "The Geology of Western Australia" (Geol. Surv. West. Aust. 1975). The area has a basement of Pre-Cambrian gneissic and granitic rocks dated

Table 1.

The areas of the subcatchments of Wilson Inlet calculated by ESRI and FMIS. The northeast corner of the Hay catchment falls outside the FMIS coverage (Map 3) and therefore has a substantially smaller area than the ESRI estimate. The Little River, Lake Saide (Sadie) and Nullaki catchments are also not included on FMIS. The Wilson Inlet subcatchment used by FMIS was included within the Denmark catchment by ESRI. If the FMIS estimates of the Denmark and Wilson Inlet subcatchments are summed, the area (70,626 ha) is very close to the ESRI estimate of the Denmark catchment.

Subcatchments of the Wilson Inlet	ESRI estimate of areas (ha)	FMIS estimate of areas (ha)
Denmark River	70,839	69 487
Hay River*	130,143	86,007
Sleeman River	8,830	8,431
Wilson Inlet (see Map 3)	-	1,139
Little River	1,751	-
Lake Saide (or Sadie)	11,931	-
Nullaki	2,839	-

*Note that the FMIS estimate is incorrect due to incomplete coverage of this catchment.

between 1300 and 1700 my. Younger porphyritic granite batholiths (11 my old) intrude through the basement and form the massive granite outcrops which dominate the landscape, especially near the coast where they form headlands with embayments of the lower country between them.

The coastal plains are underlain by a thin (<200 m) sequence of late Eocene Sedimentary rocks of the Plantagenet Group that mainly consist of siltstones and spongolite with some limestone. Climatic fluctuations in the Quaternary led to changes in the sea level with periodic deposition of beach sands, which formed dunes in low sections of the coastline and were blown inland. Most of the south coast is mantled with a belt of stabilised dunes that is usually 2 to 3 km wide but may reach a maximum of 6 km. The most recent sands are calcareous with up to 67 percent $CaCO_3$ (Enright 1978) and little consolidation. The dunes block drainage so there tends to be a belt of lakes and swamps behind them. Inland aeolian sand deposits may be recognised by their characteristic heath vegetation. The geomorphology of the inlet itself as inferred from 1977 aerial photography is reproduced from Treloar (1977), as Figure 3.

The catchment is in an area of high rainfall (2.2) and consequently the four main rivers, the Denmark, Hay, Mitchell and Sleeman, are close together and have an intense network of tributaries. Wilson Inlet is a drowned estuary of these rivers and is intermittently cut off from the sea by a sand bar (3.3)

A general soil map of the catchment can be obtained from sheet 5 of the Atlas of Australian Soils (Northcote *et al.* 1967). This map is extremely generalised as it is plotted at a scale of 1:2,000,000 and only shows the dominant soil in an association of soils. There are some detailed maps of small agricultural areas within the catchment Teakle and Southern 1937; Teakle 1938; Burville 1937; CSIRO 1943; Carroll 1945; Boehma and Pym 1950; Smith 1972a and b) but these have little applicability to the rest of the catchment. The soil types and their associated vegetation have been broadly classified into landform units and mapped for the catchment by Collins and Fowlie (1981).

On the coastal plain the soils are sands and podzols. Under the high rainfall at the coast the sandy soils form duplexes with a leached upper horizon that may be bleached pure white. The lower horizon contains the leached particles from the overlying sand and is usually a mottled clay that drains poorly. There may be a ferruginous hardpan formed between the two horizons. In the broad valleys where there are swampy depressions, the sandy soils commonly have peaty horizons. These soils are common near the coast and are extremely infertile. Most of the plateau consists of lateritic duricrust and

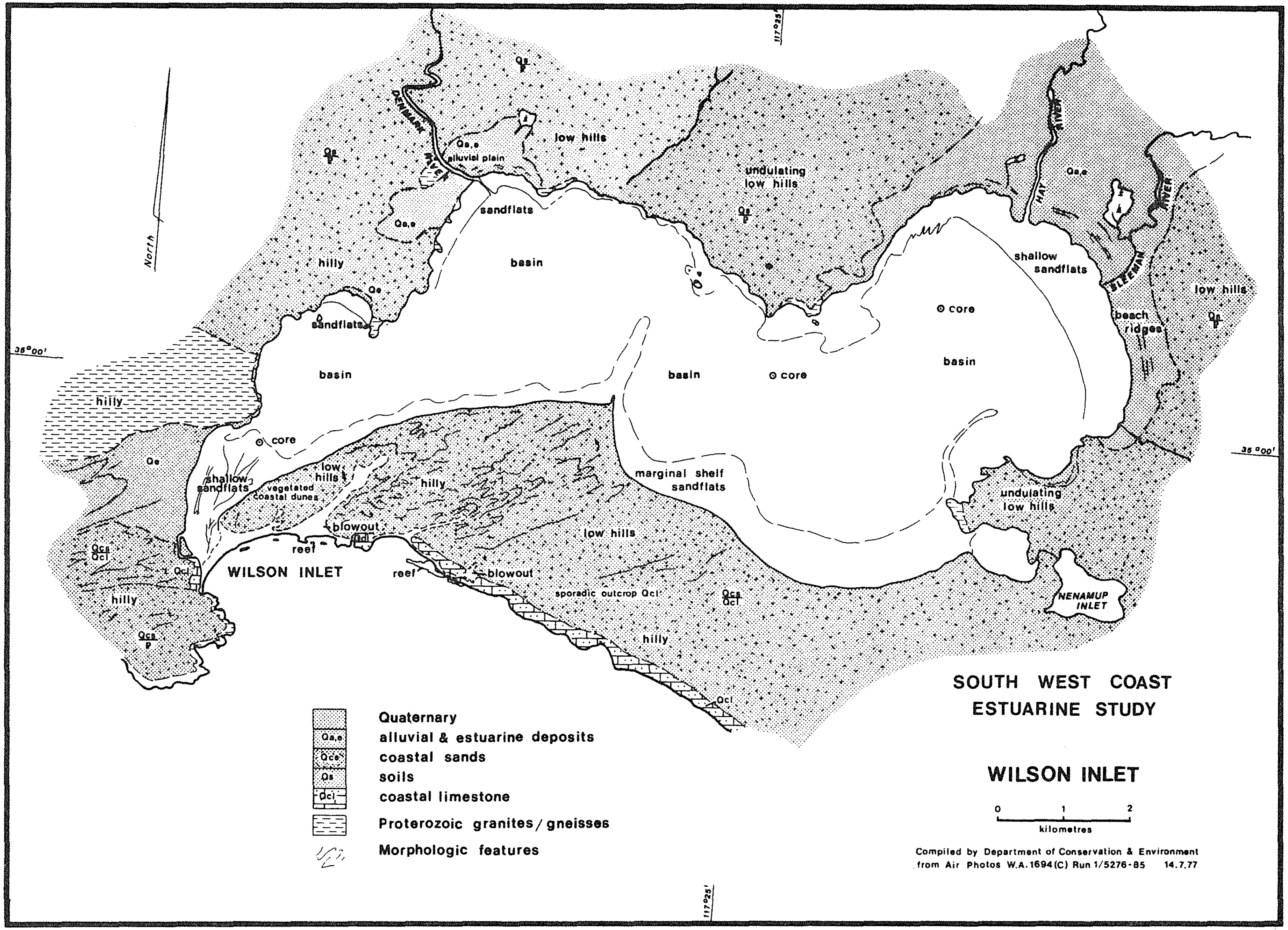


FIGURE 3. The geomorphology of Wilson Inlet (from Treloar, 1977).

gravels overlying kaolinitic clays. See Map 3 in Collins and Fowlie (1981) described in the Appendix of this report.

The topography of the catchment was digitised by ESRI from the Natmap 1:100,000 sheets covering the catchment. The slopes were classified into four classes, and are shown in Map 6.

2.2 Climate

There is a network of meteorological stations within the catchment which is operated by the Commonwealth Bureau of Meteorology, Public Works Department of Western Australia, and Dr. N. Schofield at the Western Australian Institute of Technology. All the stations and the records they collect are listed in Table 2, and the positions of the PWD and CBM stations are shown in Collins and Fowlie (1981) and those of Dr. N. Schofield on Map 2. The catchment has a Moderate Mediterranean Climate (UNESCO-FAO 1963), with rainfall maximal in winter and a dry season of less than four months. Average annual isohyets calculated by the Commonwealth Bureau of Meteorology are given in Beard (1979). There are also average annual isohyets that were calculated by PWD and stored on FMIS (Table 3, Map 7). More representative isohyets (Map 2) were produced by Collins and Fowlie (1981) using a more extensive network of meteorological stations than did the CBM estimate. There is a steep gradient for most climatic factors, including rainfall, as one moves inland from the coast (see Figure 1 in Collins and Fowlie 1981). Near the coast onshore winds produce a mild humid climate while inland the conditions are more extreme (Table 4), with lower rainfall and higher evaporation.

2.3 Land Use and Land Tenure

The catchment falls within the Shires of Plantagenet, Denmark and Albany. The original plot of the Shire boundaries within the catchment (Map 8) had some errors, which have now been corrected,

Table 2.

Meteorological and hydrological gauging stations and their records.

The positions of the CBM (Commonwealth Bureau of Meteorology) stations (009000 series) and PWD (Public Works Dept.) stations 509000 and 603000 series) are mapped in Collins and Fowlie (1981). N. Schofield's stations are shown on Map 2.
(note: Water Resources Branch, PWD have a 1:250,000 overlay showing all meteorological and hydrological stations for the Mt. Barker region. Contact Ross Sheridan)

009000 - CBM Rain Gauges

Number	Location	DATA
009581	Mt. Barker Post Office	Daily rainfall 1886 - present
009521	Narrikup (Carmendale)	Daily rainfall 1921 - present
009841	Binaburra	Daily rainfall 1974 - present *Not on Collins and Fowlie map
009591	Pardelup Prison Farm	Daily rainfall 1899 - present
009558	Mt. Barker (Iawakia)	Daily rainfall 1937 - present
009752	Denmark	Daily rainfall 1966 - present
009647	Denmark (4)	Daily rainfall 1966 - present
009531	Denmark Post Office	Daily rainfall 75 years complete daily record 1897 - present
009609	Youngs Siding	Daily rainfall 1905 - present
009599	Barrett Meadows	Daily rainfall 1914 - present
009523	Denmark River (Illalangi)	Daily rainfall 1912 - present
009637	Denmark Research Station	1951 - present Complete daily rainfall record Barometric pressure Dry, wet, max, min, temperature windrun, sunshine, daily pan evaporation *Not on Collins and Fowlie map
00974	Albany airport	Pluviograph 1942 - present

Table 2. (cont'd)

509000 - PWD Rain Gauges

Number	Location	Data
509230	Denmark (Riddlesden)	Daily rainfall Aug 1974 - July 1979
509175	Denmark River (Perillup)	Daily rainfall March 1973 - March 1974
509022	Yate Flat Creek (Woonanup)	Pluviograph 1972 - present *Same location as 603190
509228	Denmark River (Kompup)	Pluviograph 1974 - present *Same location as 603003
509018	Yate Flat Creek (Blue Peak)	Daily rainfall May 1970 - June 1979
509207	Denmark River (Blue Lake)	Pluviograph Sept 1973 - present
509183	Denmark River (Lindesay Gorge)	Pluviograph April 1973 - present *Same location as 603002
509017	Denmark River (Mt. Lindesay)	Storage gauge (monthly data only) May 1970 - Aug 1974
509020	Marbellup Brook (Athena)	Daily rainfall Oct 1970 - present
509023	Marbellup Brook	Daily rainfall Sept 1972 - present
509019	Marbellup Chorkerup	Daily rainfall Oct 1970 - present

Table 2. (cont'd)

603000 - PWD Gauging Station
Note that all stations measure streamflow, but that only at stations 603003 and 60316 are measures of water quality collected.

Number	Location	Data
603001	Marbellup Brook (Elleker)	Continuous streamflow Dec 1971 - present Note that this flows into Torbay Inlet
603002	Denmark River (Lindesay Gorge)	Continuous streamflow April 1973 - present
603003	Denmark River (Kompup)	Continuous streamflow, current metering April 1974 - present Daily pumped water samples since approx. 1978
603136	Denmark River (Mt. Lindesay)	Continuous streamflow, current metering June 1960 - present Daily pumped samples since approx. 1978
603190	Yate Flat Creek (Woonanup)	Continuous streamflow, current metering May 1963 - present
<u>CLOSED STATIONS</u>		
603014	Denmark River	June 1940 - June 1960 Replaced by 603136
603173	Denmark River (Clear Hills)	May 1962 - Jan 1978

Table 2. (cont'd)

N. Schofield's Hydrological Sampling Stations

Station Name	Location	Data
Nemanup/Lake Sadie Drain	Lake Sadie Road/ Road 5246	Daily stage reading Weekly water quality sampling
Cuppup River	Eden Road	Daily stage reading Weekly water quality sampling
Sleeman River	Sleeman Road	Daily PLI reading Weekly water quality sampling
Hay River (southern tributary)	Sunny Glen Road	Daily stage reading Weekly water quality sampling
Hay River	Site for future PWD gauging station	Daily PLI reading Weekly water quality sampling
Denmark Agricultural Research Station	Mt. Barker Road/ East River Road	Daily stage reading Weekly water quality sampling
Scotsdale Brook	Scotsdale Road/ Hamilton Road	Daily stage reading Weekly water quality sampling
Denmark River PWD gauging station 603136	Mt. Lindesay Road	Weekly water qualtiy sampling

Table 3.

The areas (ha) of the average annual isohyets within the Denmark, Hay*, Sleeman and Wilson Inlet catchments. Data derived from PWD and stored on FMIS (see Map 7)

Rainfall (mm)	Denmark River	Hay* River	Sleeman River	Wilson Inlet	Total
600-700	0	78.8	0	0	78.8
700-800	3,250.2	21,437.3	0	0	24,687.5
800-900	14,682.9	29.119.6	29.5	0	43,832.0
900-1000	18,539.8	27,063.1	5,960.6	0	51,563.5
1000-1100	24,983.0	8,283.0	2,434.7	880.5	36,581.9
1100-1200	8,009.2	0	0	0	8,009.2
Unclassified	21.7	25.6	5.9	258.0	311.2

*Note that coverage is incomplete, hence areas are incorrect.

Table 4.

Climatic gradients across the catchment of Wilson Inlet (after Collins and Fowlie 1981)

Climate Factor	Near Coast	At Inland Divide
Average Summer Max. Temperature (^oC)	24	27
Average Winter Min. Temperature (^oC)	9	< 6
Av. Days/Year with >32^{o}C Max. Temp.	5	20
Av. Days/Year with <2^o C Min. Temp.	2	12
Average Annual Evaporation (mm)	1200	1500
Average Summer Evaporation (Nov-Apr) (mm)	900	1150
Average Winter Evaporation (May-Oct) (mm)	300	350
Average Number Raindays/year	180	110
Average Annual Rainfall (mm)	1200	550
Average Summer Rainfall (Nov-Apr)(mm)	300	145
Average Winter Rainfall (May-Oct)(mm)	900	405

although the computer database itself is still in error. The areas of the Denmark, Hay, Sleeman and Wilson Inlet catchments within the Shires are given in Table 5. The table is wrong due to the errors in FMIS database, but it does give an indication of the areas controlled by the three Shires.

FMIS also provides a plot of the tenure of the land within the catchment (Maps 9 and 10) and the areas occupied by various landholders (Table 6). Note that the northeastern corner of the catchment is excluded from these figures. Maps 9 and 10 show the same information, and are both included to illustrate two of the different presentation modes available with FMIS. The areas of land cleared for pasture are highlighted in Map 11.

The quantities of nitrogeneous and phosphate fertilisers and quantities of various biocides applied on the farms in the catchment were obtained from the Australian Bureau of Statistics Geocoding System (Table 7). Geocoding data are gathered from questionnaires and stored as a mean value for a 10 x 10 km square. The resolution of the data can be improved 2.5 x 2.5 km square, but for reasons of confidentiality ABS will not release data on less than an aggregate of three farms, so in all cases the data have had to be released at the lower (10 x 10 km) resolution (Table 7). The large grid size of Geocoding leads to two other problems in interpreting the data. Firstly, the Geocoding grid does not include catchment boundaries and consequently the values for squares on the periphery of the Wilson Inlet catchment includes data from outside the catchment. Secondly, the data are geographically linked to the position of the farmhouse, not to where the fertilisers and biocides are applied. Some farms may have paddocks in two or more subcatchments feeding Wilson Inlet. These problems could be effectively overcome by overlaying a map of the quantities of fertilisers and biocides applied

Table 5.

The area (ha) of the Denmark, Hay, Sleeman and Wilson Inlet catchments within the Shires of Plantagenet, Denmark, and Albany, derived from the FMIS database, which is in error. The FMIS computer plot of the Shire boundaries (Map 8) has been corrected.

	Denmark River	Hay* River	Sleeman River	Wilson Inlet	Total
Plantagenet Shire	33,506.3	29,960.7	0	0	63,467.0
Denmark Shire	35,980.4	23,521.4	0	1138.5	60,640.3
Albany Shire	0	26,125.5	8430.7	0	34,556.2

*Incomplete estimates

Table 6.

Areas of land (ha) under different tenures in the Denmark, Hay, Sleeman and Wilson Inlet catchments.
Data derived from FMIS (see Maps 9 and 10)

Tenure	Denmark River	Hay* River	Sleeman River	Wilson Inlet	Total	%
Private property	23,001.4	45,498.4	6,916.0	892.3	76,308.1	46.23
Forest reserves	39,067.1	6,683.6	535.8	0	46,286.5	28.04
Crown land	5,822.7	29.127.4	953.4	108.3	36,011.8	21.82
Flora/fauna reserves	92.6	3,573.2	0	39.4	3,705.2	2.24
Other reserves (e.g. water)	616.5	449.1	17.7	0	1,083.3	0.66
Townsites	687.5	384.1	0	0	1,071.6	0.65
Recreation/camping reserves	198.9	289.6	7.9	98.5	594.9	0.36
				TOTAL	165,061.4	100.00

*Incomplete estimates

Table 7.

Wilson Inlet Catchment - Number and Area of Holdings. Artificial Fertiliser Used, 1981-1982
(data from the Australian Bureau of Statistics, Western Australian Office)

GRID NUMBER	ALL HOLDINGS		FERTILISED		SUPERPHOSPHATE			STRAIGHT NITROGENOUS TYPES – UREA		STRAIGHT NITROGENOUS TYPES – OTHER		OTHER NITROGENOUS		potash compounds and mixtures not containing N OTHER ARTIFICIAL	
			Holdings	Area	Holdings	Quantity		Holdings	Quantity	Holdings	Quantity	Holdings	Quantity	Holdings	Quantity
	No.	Ha	No.	Ha	No.	T	kg/ha	No.	T	No	T	No.	T	No.	T
001,002	19	4,148	14	1,229	10	210	169.5	-	-					7	147
003	5	1,213	3	452 } 2299	12	226	98.3	-	-	3	28	5	64	10	212
004	21	3,096	17	1,847				-	-						
005	41	8,563	36	6,051	30	997	164.8	-	-	3	14	5	38	13	317
006	27	6,286	22	3,322	21	643	193.6	-	-	-	-	5	39	7	88
007	39	4,538	31	2,306	26	432	187.3			3	4			5	50
008	39	6,165	33	3,361	30	547	167.7	3	3					19	209
009	14	3,335	13	2,406	10	286	118.9			3	5	3	43	8	158
010	23	6,177	21	3,683	19	594	161.3							8	129
011	35	8,434	31	6,034	26	923	153.0							11	323
012,013	6	915	5	654	5	145	221.7	3	9	5	13				
014	-	-	-	-	-	-	-					4	39	4	34
015,016	14	7,141	13	5,268	13	810	153.8								
017	26	10,042	24	7,905	21	1,255	158.8							10	132
018,019,020	11	6,402	11	4,306	8	522	121.2							4	124
021	5	5,281	4	3,767	4	449	119.2			5	27	3	32		
022	11	5,453	7	3,462	6	321	92.7	3	12					8	331
023	20	7,847	17	5,868	15	935	159.3					-	-		
024,025	4	4,098	3	827 } 6716	13	1,042	155.2			-	-			-	-
026	13	7,539	12	5,889						-	-	4	71	5	55
027	17	9,222	15	6,151	15	904	147.0	-	-					-	-
028	27	9,328	22	6,901	22	909	131.7	-	-			3	7	7	40
029	33	6,985	25	4,792	22	612	127.7							3	91
030	3	1,126	3	315	3	86	273.0					-	-	1	1
031	9	10,235	9	7,669	9	1,254	163.5			6	17	3	28		
032	6	4,424	6	1,781	6	252	141.5	3	8						
033	11	4,677	11	3,485	11	371	106.5							4	85
034	27	9,284	25	7,942	23	1,074	135.2					6	31		
035	17	7,396	17	5,116	17	756	147.8							3	4
TOTAL	523	168,350	450	112,789	397	16,555	146.8*	12	32	28	153	41	392	136	2.529

* mean application rate for catchment

on maps of tenure, topography and catchment boundaries to calculate the runoff into Wilson Inlet, although this has not yet been done. GIS (ESRI) would be an ideal system for combining all the existing data, plus data on soils as it becomes available, to provide information for a realistic model of the quantity and quality of agricultural runoff.

The present low resolution of the fertiliser and biocide data would best be improved by interviewing individual landholders.

2.4 Vegetation

There has been considerable human impact in the area. Aboriginals regularly burned the land before the arrival of Europeans (Stokes 1846; Hallam 1975). The arrival of Europeans marked the beginning of wholesale clearing of the land for agricultural purposes (Map 11). There are remnants of the original vegetation left along the road verges and there are still considerable areas of State forest and vacant Crown Land within the Wilson Inlet catchment (Beard 1979; Christensen 1980, Maps 9 and 10). The inferred original vegetation has been mapped by Beard (1979) at a scale of 1:250,000. This map was digitised by ESRI and plotted at 1:100,000 (Map 12). FMIS provides a map of the present cover of trees and pasture (Map 13) and the areas they cover in the subcatchments (Table 8).

An incomplete list of plant species from an area of vacant Crown Land east of the Denmark River, including the Mitchell River catchment is given in the Appendix (from Christensen 1980).

2.5 Fauna

An incomplete list of the terrestrial and aquatic vertebrates known from the estuary catchment is given in the Appendix. Species lists were compiled for the Denmark River catchments by Mr. N. McKenzie at the

Table 8.

Areas of various broad vegetation types (ha) in the Denmark, Hay, Sleeman and Wilson Inlet catchments. Data derived from FMIS (see map 13). Note that these data are not complete for the Hay River catchment (see Maps 11, 13).

	Denmark River	Hay* River	Sleeman River	Wilson Inlet	Total
Jarrah-marri	24,642.2	38,279.1	3,118.1	96.5	66,135.9
Non-forest, scrub	28,599.5	29,346.1	3,096.5	510.2	61,552.3
Pasture	15,622.5	17,891.7	2,216.0	531.8	36,262.0
Karri, karri-marri	581.1	0	0	0	581.1
Pine plantation	0	293.5	0	0	293.5

*Incomplete estimates

W.A. Wildlife Research Centre (personal communication) and supplemented by this study, but are largely based on the survey of Christensen (1980).

2.6 Hydrology

The flow characteristics and water quality of the Wilson Inlet catchment have recently been studied in relation to rainfall, landform and landuse (Collins and Fowlie 1981). ESRI digitised and plotted the river systems (Map 2) and calculated river lengths (Table 9). Dr. N. Schofield (WAIT) is currently working on a one year study of the hydrology and nutrient runoff of the Wilson Inlet catchment. The data from his study should be incorporated in the data base as they become available.

2.7 Water Quality

As mentioned above, Collins and Fowlie (1981) have studied the runoff and stream salinity in the Wilson Inlet catchment. Two of their original 1:250,000 maps of salt yield and total soluble salt concentrations in streams were digitised by ESRI and replotted at a scale of 1:100,000 (Maps 14 and 15). There is concern that further clearing of land for agriculture will lead to worsening salinisation of the streams, and so the Public Works Department is currently enforcing a total ban on the clearing of native vegetation on private land.

Loss of phosphorus and nitrogen fertilisers from agricultural land, particularly that in the areas of lighter soils is also of increasing concern. There is some evidence of eutrophication, leading to nuisance growths of aquatic plants in the estuary, although the rate of change of water quality and severity of the problems are not yet fully documented.

The current catchment studies by N.J. Schofield, and the estuary macrophyte and water quality surveys by I.N. Parker (DCE) and R.J. Lukatelich (Dept. of Botany, UWA) are now gathering data on these issues (see section 3.4).

Table 9.

Lengths (km) of main stream and total drainage networks for the main rivers draining into Wilson Inlet

	Length of main stream (km)	Total length of drainage (km)
Little	7.22	9.16
Denmark	59.50	205.69
Quickup	13.48	23.27
Total		228.96
Hay	78.86	410.58
Mitchell	23.14	40.25
Total		450.83
Sleeman	22.11	38.29
TOTAL (for whole Wilson Inlet Drainage)		727.24

3. THE ESTUARY

3.1 Geology and Geomorphology

The Inlet is included in the geology map digitised by ESRI (Map 5). The surface geology around Wilson Inlet was also broadly surveyed by Treloar (1977) who also took two cores in the basin of the Inlet and one on the bar (Figure 3). Treloar describes the basin cores at 0-50 cm as dark grey sandy silty mud that is sparsely fossiliferous. At 50-83 cm the cores are mottled, pale to dark grey muddy sand, a small proportion of which is skeletal fragments. The basal sediment type is a transgressive phase deposit, overlain by mud in the deeper parts of the basin.

Wilson Inlet - bar

A core from the Wilson Inlet bar, taken to 138 cm, is described as follows (Hodgkin m.s.): Skeletal-quartzose sand: percent skeletal fragments decreases upwards, becoming scarce in upper 35 cm; beneath upper zone there is a moderate percent of marine skeletal fragments (bryzoans, sponges, etc.). The sediment coarsens upwards reflecting shoaling, and skeletal fragments are derived from estuarine fauna mainly; the absence of marine fragments reflect a lower percent introduced, and reworking into deeper water.

The development in the core reflects typical development of a bar - high influx initially of marine sediment, decreasing as the mouth gets constricted/barred, shoaling facilitates re-working of finer-grained sediment and nett growth into the basin; however, the accretion rate over the Late Holocene has almost certainly decreased.

The geomorphology of the southwestern estuaries, including Wilson Inlet, are being surveyed by Dr. P.A. Hesp for the Department of Conservation and Environment (Hodgkin and Hesp, 1982). The western and northern margins of the inlet are mainly granite with some calcarenite at the mouth. The eastern and southern margins are sandy. There is an extensive shallow sandbar at the eastern end that may be exposed in late summer and block the mouths of the Hay and Sleeman rivers. A small subsurface sand bar forms at the mouth of the Denmark river and a boat channel is dredged through it.

3.2 Morphometry

The only data available on the bathymetry of the Inlet is a map prepared in 1980 and 1981 by third year geography students at UWA. This map was prepared from traverses (Figure 4) with a Furuno F6-11/200 echo sounder. The soundings were corrected in relation to PWD Survey Bench Mark (PWD BM Den 1). The accuracy of position fixing was better than $\pm$ 15 m and the depths are within $\pm$ 0.25 m. The map was digitised by ESRI, although not in metric units, and plotted at a scale of 1:25,000 to retain the detail (Map 16). The Inlet is closed by a bar for about six months of the year (3.3) and consequently the water level falls considerably due to evaporation during summer and rises with increased runoff in winter. The Inlet has an area of 50 km^2 and is about 14 km long and 4 km wide.

3.3 The Bar

The mouth of Wilson Inlet is completely blocked by a massive sand bar for about six months each year, usually from January until July. Some records suggest that the bar remained open permanently in the early nineteenth century, however other records suggest it was

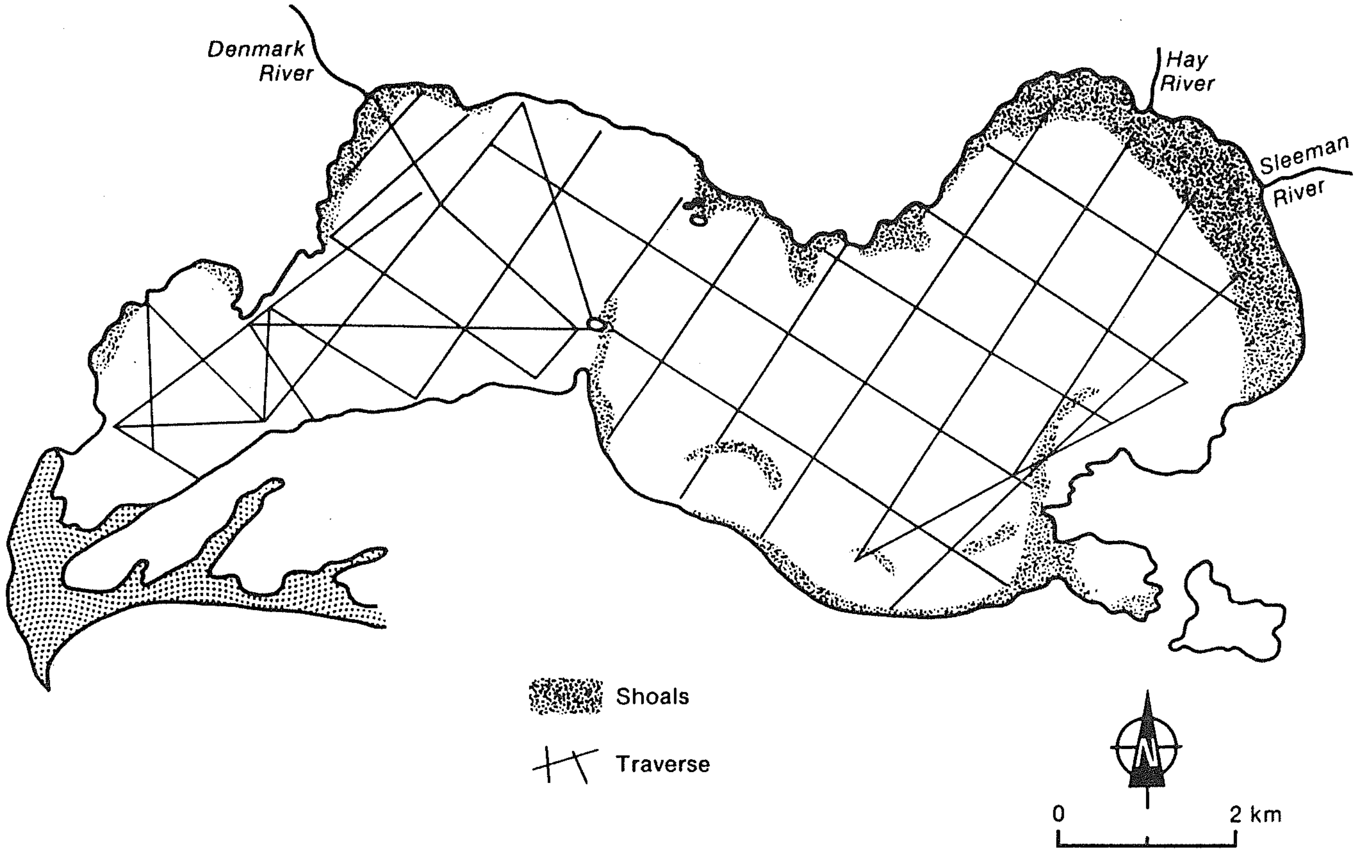


FIGURE 4. Map of traverses made to obtain bathymetric data for Wilson Inlet (from Conacher et al. 1981)

seasonally blocked (Hodgkin 1981). Before the 1930s the bar was allowed to break naturally when the accumulated winter runoff eventually ran over the top and scoured a channel to sea. In the 1930s the Elleker-Nornalup railway was realigned close to the shoreline of Wilson Inlet. It then became necessary to artificially open the sand bar each year to avoid flooding the railway line and the farms that were developed on the reclaimed land. The history of the opening of the bar is well-documented (Lenanton 1974b, Hodgkin 1981). The dates and positions of the opening of the bar from 1954 to the present are given in Table 10, and a summary of level variations in the Inlet between May and August for the years 1976-1980 in Figure 8.

3.4 Physico-chemical Characteristics and Water Quality

There are historic CSIRO records of water temperature, salinity, oxygen levels, pH, phosphate and nitrate levels from 1940-1956

WILSON INLET OCEAN BAR

YEAR	WHERE OPENED	DATE OPENED	DATE CLOSED	WIDTH & DEPTH OF CUT. WEEKS AFTER OPENING 0	1	2	4	8	16	32	DRIFTS IN METRES WEEKS AFTER OPENING 0	1	2	4	8	16	32	REMARKS .-
1954		N A																
1955	300m	15th JUNE '55																Dragline Channel First Opening By PWD
1956	340m	10th JUNE '56																
1957		8th AUGUST '57																
1958		7th AUGUST '58	28th DECEMBER '58															Denmark Shire Questioning Opening Control
1959	350m	6th OCTOBER '59	5th JANUARY '60		45/2							15W						Low WSL
1960	400m	12th JULY '60	24th DECEMBER '60															
1961	400m	4th JULY '60	JANUARY '61						23/1							NIL		Channel Serpentine Press Reports Denmark Shire Ratepayers Alteration Site of Opening
1962	360m	AUGUST '62	9th JANUARY '63															
1963	200m	4th JULY '63										100W						March Start Const Floodgates Marked Drift West.
1964	?	23rd JUNE '64																Feb Completed Const. Floodgates. Manual Opening After Abortive Attempt With Dozer
1965	?	24th AUGUST '65																
1966		27th JULY '66	14th JANUARY '67															
1967	200m	17th JULY '67	APRIL '68															
1968	200m	31st JULY 68	FEBRUARY '69								100W					CLIFF	200	
1969	442m	1st SEPTEMBER '69	22nd DECEMBER '69								NIL	NIL	NIL	NIL	NIL	NIL		July 69 Potatoe Farmers Urging For East Opening. Attempt To Cut Channel To Connect Pools. Good Channel Forming Into Inlet.
1970	442m	2nd August 70	27th FEBRUARY '72	100W	90						NIL	NIL	NIL	NIL	NIL	NIL	NIL	Mouth Slight Drift West Small Sand Bar Formed Channel Split East & West Good Outlet From Lake Saide
DENMARK COUNCIL OPENING. 1971	50m	16th JULY 71	4th MARCH '72			30	10/2	30	50/1.2		CLIFF	CLIFF	CLIFF	CLIFF	CLIFF	CLIFF	CLIFF	Poor Runoff From Lake Saide WSL In Inlet Average High Cut 240m Long.- 442m Bar Only 70m Council Cut Not Flowing, Also Flow From 442m
1972	100m	10th AUGUST '72	10th DECEMBER '72	100m -10 20m	20	20/1.5	20/1.5	20			-	CLIFF	CLIFF	CLIFF	CLIFF	CLIFF		Inlet Dirty Cut Drifted Hard On Cliff Exposing Limestone And Washed Away The Beach
1973	100m	13th AUGUST '73	14th FEBRUARY '74		50/2									CLIFF	CLIFF	CLIFF		Jan. Lot Of Weed Growing. Dozing Done By Denmark Council, In Inlet Has Silted Up No Interchange Of Water - Inlet Dirty. Oct. Complaints From LS Potato Farmers Re High WSL
1974	100m	5th AUGUST '74	NOVEMBER DECEMBER ?		100	40	40	30			CLIFF	CLIFF	CLIFF	CLIFF	CLIFF	CLIFF		
1975	100m	30th JULY '75	FEBRUARY '76		100	80	80	50			CLIFF	CLIFF	CLIFF	CLIFF	CLIFF	CLIFF		
1976	100m	6th JULY '76	FEBRUARY '77	60	60	40	60	100	70		CLIFF	CLIFF	CLIFF	CLIFF	CLIFF			Lake Saide Potato Farmers Pumping Again.
1977	100m	7th AUGUST '77	FEBRUARY '78	30				20			12m		CLIFF	CLIFF	CLIFF	CLIFF		Drift Along Beach Near Surf Club. No Interchange. Farmers Pumping. Opened On High Barometric Pressure 1008mb Started To Drift West When Only 30m Wide
1978	100m	30th JUNE '78	2nd MARCH '79					50							CLIFF			
1979	100m	16th JULY '79	FEBRUARY '80								CLIFF	CLIFF	CLIFF	CLIFF	CLIFF	CLIFF	CLIFF	Scour Along Beach Only 4m Beach At High Tide.
1980	100m	1st AUGUST '80	24th JANUARY '81								CLIFF	CLIFF	CLIFF	CLIFF	CLIFF	CLIFF		
1981	300m	3rd JULY '81																

FARMERS PUMPING 1971

TABLE 10. Summary of the history of bar opening, 1954-1981.

(Spencer 1952). These records were taken from eight sampling stations in the Inlet (Figure 6), and the data are reproduced in the Appendix because they are important baseline data, and the original publications are not readily available. There is also some data on salinity, temperature and dissolved oxygen in Lenanton (1974b) (Appendix and Figure 5) and other data collected by DCE in 1980 (Appendix). There is no information available on sewage, though some recordings of *E. coli* levels have been taken (DCE File 20/80). There is no information on the levels of biocides in the Inlet or its biota.

The Department of Conservation and Environment has initiated a study of the water quality, sediment distribution and aquatic plant standing crop of Wilson Inlet. I.N. Parker (DCE) and R.J. Lukatelich (Botany, UWA) initiated sampling this year in July.

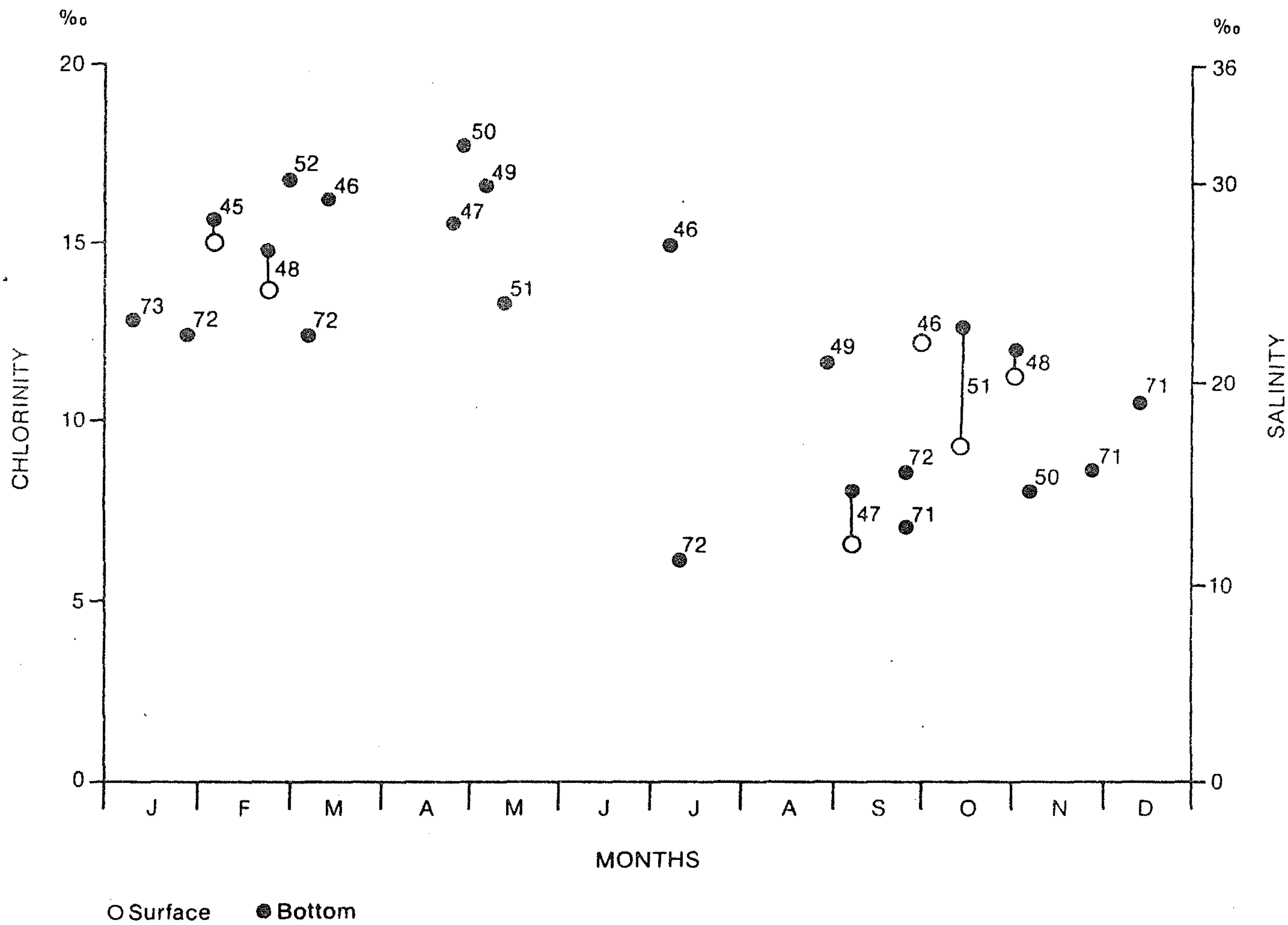


FIGURE 5. Seasonal variation of salinity in Wilson Inlet, based on Spencer (1952) and Lenanton (1974).

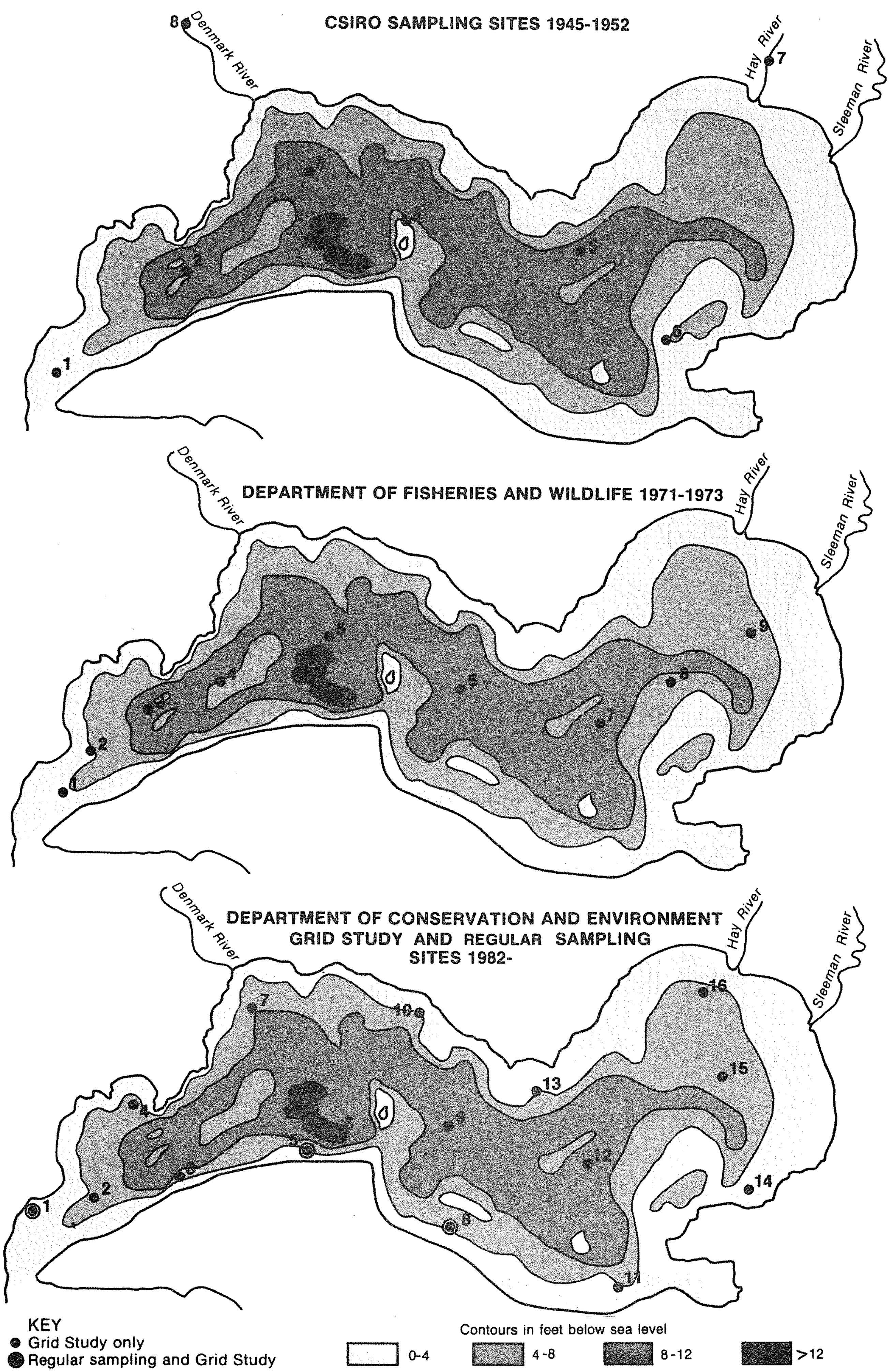


FIGURE 6. Composite of three maps showing water sampling locations - CSIRO (1946-1954) Lenanton (1971-1973) and DCE (1980-).

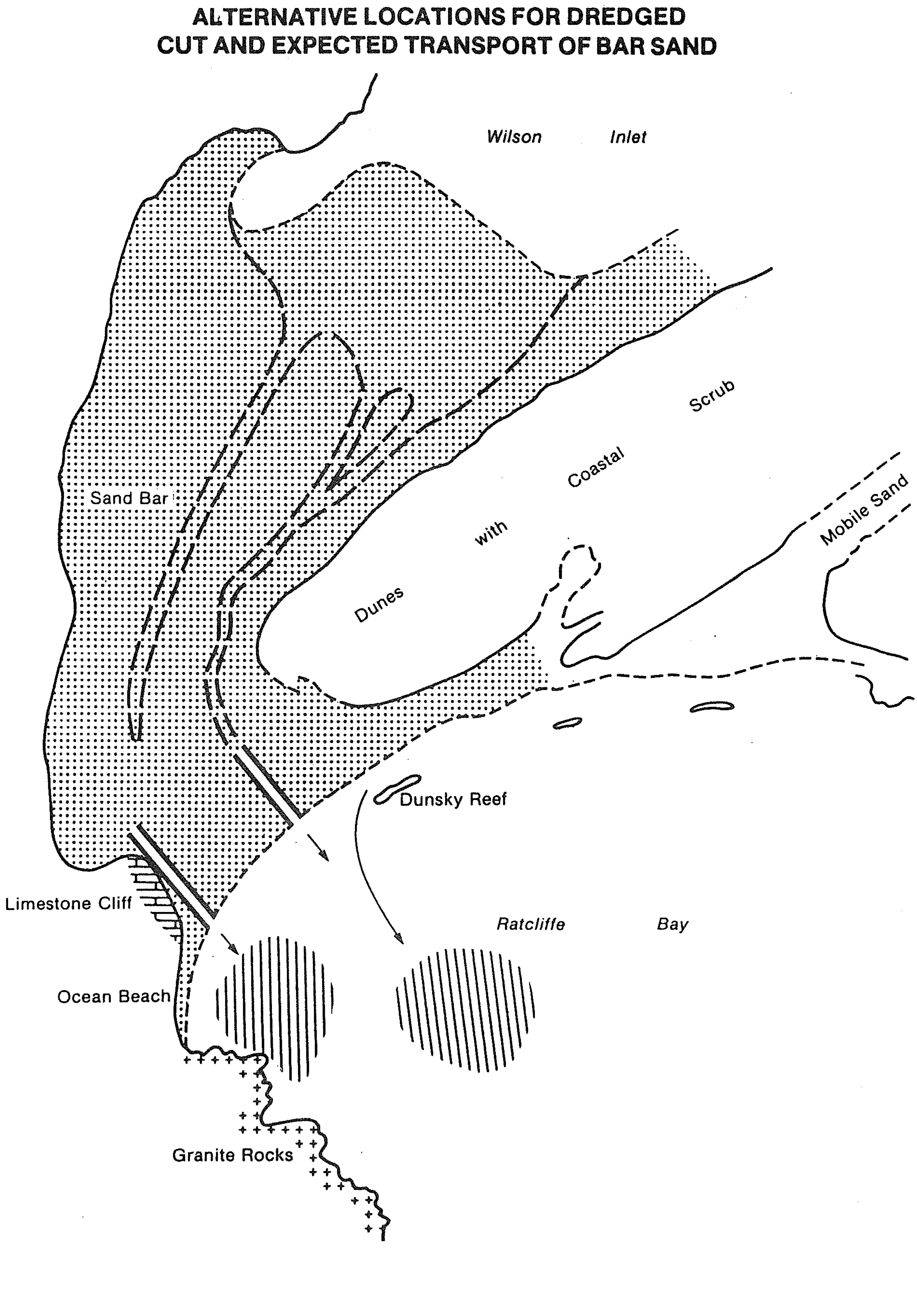


FIGURE 7. Diagrams of alternative bar openings.

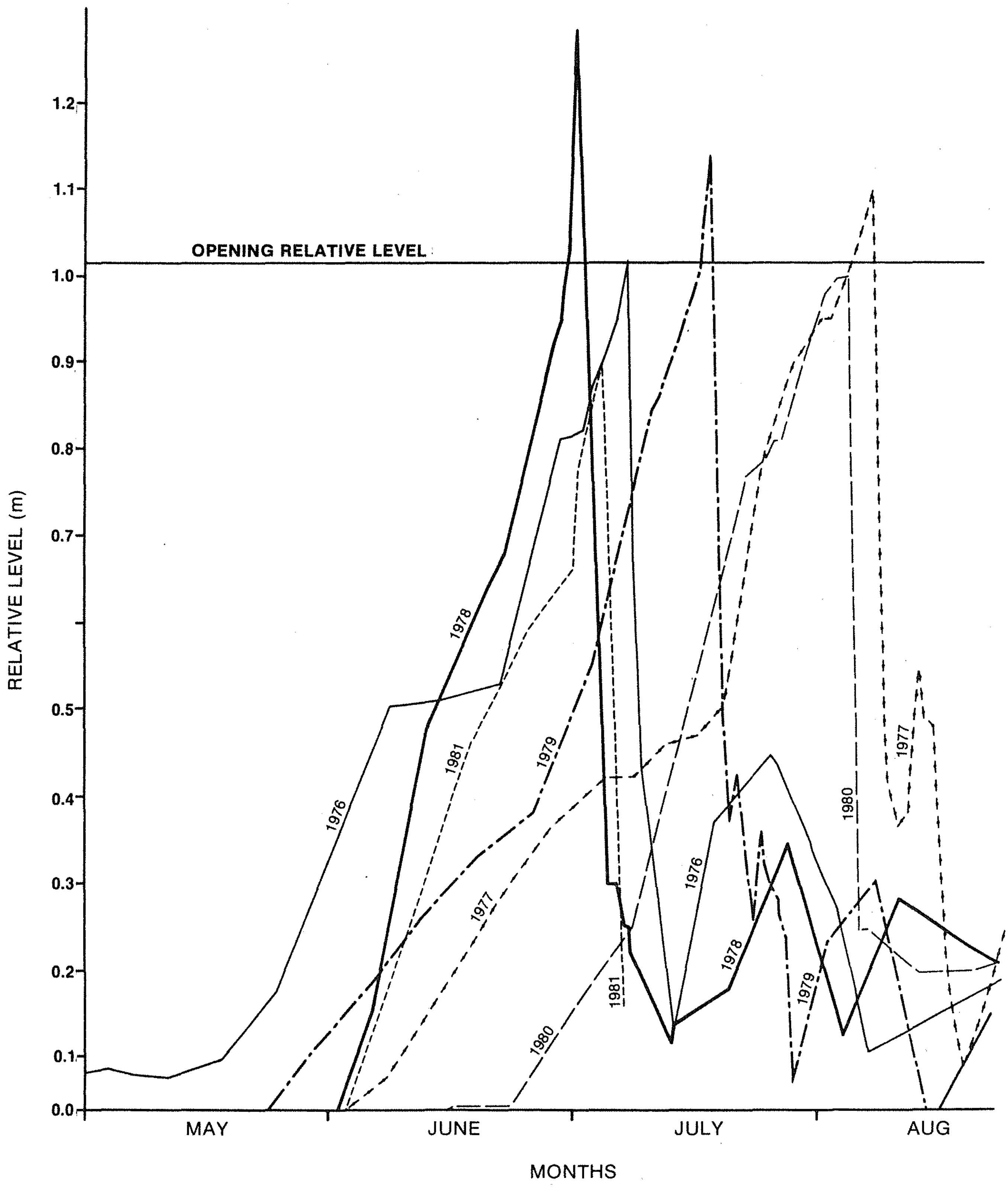


FIGURE 8. Inlet levels, winters 1976-1980.

A comprehensive range of physical and chemical properties of the Inlet's water, sediments and macrophytes is being sampled at quarterly intervals at sixteen stations. These data will be used in conjunction with the river nutrient loading and flow data being collected by PWD and N.J. Schofield to more precisely assess the level of nutrient enrichment in the estuary, its biological responses to enrichment and the sources and amounts of nutrient-enriched runoff from the catchment.

The data collected are still being analysed, and will form the subject of future reports.

3.5 Biology

Aquatic vegetation: The phytoplankton and macrophytes of the estuary are currently being studied by the joint DCE/UWA Botany Department monitoring survey. Table 11 contains an incomplete list of the macroalgae and aquatic angiosperms currently known from Wilson Inlet. Maps of the estimated distribution of the species found during the July 1982 survey of the estuary will be available soon. It is planned to resurvey the aquatic vegetation each three months for at least a year.

Littoral vegetation: The fringing vegetation was sampled during this study at Nenamup Inlet, Eden Road culvert, Winniston Park, and 500 m north of the west end of the bar. The fringing vegetation at these stations was a *Juncus* community (Bridgewater *et al.* 1981) with *Melaleuca cuticularis* and *Banksia littoralis* further inland. A species list is appended and a field herbarium was prepared for use in identifying saltmarsh plants in Wilson Inlet and other estuaries.

Table 11.

Aquatic angiosperms and macroalgae recorded from Wilson Inlet, May-June 1982 by R.J. Lukatelich and R.B. Humphries, and by Lenanton (1974b), indicated thus (*), and Hodgkin (m.s.), indicated thus (+).

AQUATIC ANGIOSPERMS	*Ruppia megacarpa*
CYANOPHYTA	*Lyngbya* sp. (+)
CHLOROPHYTA	*Acetabularia (Polyphysa) peniculus*
	Chaetomorpha linum
	Chaetomorpha aurea
	Cladophora sp.
	Enteromorpha intestinalis (and other species)
	Rhizoclonium sp.
CHAROPHYTA	*Nitella* sp. (*)
RHODOPHYTA	*Ceramium* sp.
	Polysiphonia sp.
	Chondria sp.
	Spyridia biannulata (*)
	Gracilaria verrucosa (*)
PHAEOPHYTA	Dictyotales (one unidentified species)

Note: The record of *Nitella* may be correct, although it is more likely that it has been confused with *Lamprothamium*, which typically occurs in euryhaline habitats.

Aquatic fauna: Regular zooplankton sampling was undertaken with 140 μm x 200 μm plankton net between May 1970 and May 1971 by E.P. Hodgkin, DCE. The three common estuarine copepods Gladioferens imparipes, Oithona nana and Acartia clausii were present throughout the year with Gladioferens particularly common in the rivers and Acartia dominant in the Inlet. Surprisingly the fourth estuarine copepod species, Sulcanus conflictus, was never taken, even though conditions appear ideal for this brackish water species.

Harpacticoid copepods, Ostracods, Cladocera and Halicyclops sp. were also present. The meroplankton included larvae of barnacles (presumably Balanus amphibrite sens. lat.), bivalve and gastropod molluscs, polychaetes, crabs, fish eggs and larvae. The benthic river fauna have not been studied systematically, however, the molluscs have been collected by Mr. R.P. McMillan (Table 12). The presence of the common mussel, Mytilus edulis is noteworthy, and is said to have been introduced by fishermen.

Fish: Thirty eight species of fish have been recorded in Wilson Inlet by Lenanton (1974b). Seventeen commercial fish are caught in the Inlet (Table 13), and the list of all known species of fish and commercial crustaceans is contained in the Appendix.

Table 12.

Molluscs collected in Wilson Inlet
(from R.P. McMillan, reported in Hodgkin m.s.)

BIVALVES	Family Mytilidae	*Mytilus edulis planulatus* Lamarck
		Xenostrobus securis Lamarck
	Family Lucinidae	*Wallucina icterica* Reeve (dead only)
	Family Erycinidae	*Arthritica helmsii* Hedley
	Family Mactridae	*Spisula (Notospisula) trigonella* Lamarck (mostly small)
	Family Tellinidae	*Tellina (Macomona) deltoidalis* Lamarck
	Family Psammobiidae	*Sanguinolaria (Psammotellina) biradiata* Wood
	Family Veneridae	*Katelysia scalaris* Lamarck
		Venerupis crenata Lamarck
GASTROPODS	Family Hydrobiidae	*Potamopyrgus* sp.
	Family Hydrococcidae	*Hydrococcus graniformis* Thiele
	Family Nassariidae	*Nassarius burchardi* Philippi
	Family Atyidae	*Haminoea brevis* Quoy and Gaipard
	Family Amphibolidae	*Salinator fragilis* Lamarck

Table 13.

Seasonal Records of Commercial Species of Fish Caught in Wilson Inlet
(from Lenanton 1974a)

FISH SPECIES		J	F	M	A	M	J	J	A	S	O	N	D
Yelloweye mullet	*Aldrichett forsteri*	x	x	x	x	x	x	x	x	x	x	x	x
Sea mullet	*Mugil cephalus*	x	x	x	x	x	x	x	x	x	x	x	x
King George Whiting	*Sillago punctata*	x	x	x	x	xx=	x	x	x	x	x	x	x
Western sand whiting	*S. schomburgkii*			x		x	x						x
Cobbler	*Cnidoglanis macrocephalus*	x	x	x	x	x	x	x	x	x	x	x	x
Ruff	*Arripis georgianus*	x	x	x	x	x	x	x	xx	x	x	x	x
Australian salmon	*A. trutta esper*		x		x	x	x	x			x	x	x
Dusky sea garfish	*Hyporhamphus melanochir*	x	x	x	x	x	x	x	x	x	x	x	x
Snapper	*Chrysophrys auratus*	x	x	x		x							
Black bream	*Acanthopagrus butcheri*							x					x
Tarwhine	*Rhabdosargus sarba*				x	x	x					x	x
Dusky flathead	*Platycephalus fuscus*	x	x	x	x	x	x	x	x	x	x	x	x
Trevally	*Caranx georgianus*	x	x	x	x	x	x						x
Tailor	*Pomatomus saltator*	x	x	x	x	x	x	x		x	x	x	x
Long snouted flounder	*Ammotretis rostratus*	x	x		x	x	x		x	x	x	x	x
Six spined leather jacket	*Navadon australis*			x	x			x	x		x	x	x
Blue groper	*Achoerodus gouldii*	x	x										x

4. OCEANOGRAPHY

Contact between the waters of Wilson Inlet with those of the Southern Ocean occurs for about three to five months each year (Table 10), during which time the estuary becomes tidal, and marine water intrudes and mixes with that of the estuary. The mouth of the estuary opens southeast into Ratcliffe Bay, which itself is sheltered from the southwest swell (Hodgkin, 1981) although high wave energy has formed the extensive barrier of Holocene sand dunes and mouth bar, occluding the estuary entrance from the sea (Lenanton 1974b, Section 3.1). Lenanton (1974b) states that wind waves produced by NE or SW winds blowing along the long axis of the Inlet may reach 0.9-1.2 m in height. The bar protects the estuary from the direct intrusion of ocean waves under most circumstances.

After closure of the bar, evaporation may reduce water levels considerably, so the annual variation in (non-tidal) water level may approach 2 m (Hodgkin 1981), with up to 1 m being lost by evaporation after bar closure (D.F. Wallace, pers. comm.).

There is no permanent marine tide gauge closer than Albany (about 40 km east of Wilson Inlet), so the ocean tidal regime must be inferred from analysis of these records, and those of the Augusta 220 km west, where a tide gauge was run in Flinders Bay during 1974 (Agnew *et al.* 1976).

Hodgkin and Di Lollo (1958) have published a detailed account of the tides in southwestern Western Australia. Of the tides in the Albany region, they said:

"Tides of daily type with high-water and low-water about 12 hours apart, occur near maximum lunar declination, and tides of semi daily type occur near zero declination with two high-waters and two low-waters at about six hour intervals. Between maximum and zero declination, the tides change progressively and there are tides of mixed type, transitional in form between the typical daily and typical semi daily types".

Marine astronomic tides have a small range (about 1.2 m maximum), and sea level changes due to longer-term forcing, such as changes of atmospheric pressure and shelf waves may be almost as great.

A tide gauge was operated at Poddyshot Point within the Inlet from 3 August 1975 until 21 November 1976, and in the ocean at Wilson Head for 41 days after 2 August 1975 by PWD, Harbours and Rivers Branch (D.F. Wallace, pers. comm.).

The diurnal tides within the Inlet are severely attenuated by the bar, and are mostly very small (< 10 cm). Seiching due to W to E wind stress causes greater level changes than do diurnal tides.

A full analysis and comparison of the tide records available for Albany, Peaceful Bay (1981), Wilson Head and Flinders Bay is yet to be done.

5. MANAGEMENT

5.1 Management Issues

There are five major estuary and catchment management issues in current debate. These are:

(i) The issue of artificial opening of the bar at the mouth once the water level at the Denmark bridge reaches 1.63 m (5ft 4 in). As this item has been thoroughly reviewed by Lenanton (1974b) and Hodgkin (1981), a brief statement of the ongoing debate will suffice.

Artificial opening had the benefit of prevention of flooding of the Elleker-Nornalup rail line (now removed), and of potato crops which were sown on land previously subject to saline inundation. Roads and permanent buildings have also been established in these areas. The disadvantages of artificial opening are stated to be (Lenanton 1974b, Hodgkin 1981):

(a) Increased marine sedimentation of the estuary due to decreased scouring of the bar by inlet water after its premature release, and subsequent progradation of marine sand into the estuary.

(b) A shortened period of contact between the estuary and the ocean, with the reduced dimensions of the channel adversely affecting colonisation of the estuary by valuable marine fishes.

(c) The reduced head difference between the estuary and the sea may lead to reduced penetration of marine water, causing greater retention of (relatively) nutrient-enriched estuary water, and higher levels of nuisance growth by aquatic plants.

(ii) The increased areas of land cleared for agriculture, combined with the use of artificial (particularly phosphate) fertilisers has led to increased rates of nutrient loss from the catchment soils, and consequent nutrient enrichment of the tributary streams and the estuary, leading to more aquatic plant growth. This issue is related to that of the artificial opening of the bar, as explained above.

(iii) Clearing of agricultural land has also led to increasing soil and river salinisation (section 2.7, Collins and Fowlie 1981). The Denmark River is used for urban water supply, the quality of which will suffer if salt concentrations increase.

(iv) Forestry management in lands controlled by the Forests Department is not yet in open contention, but there are published rumours of clearfelling for woodchips in the Albany-Denmark area (Sundstrom 1981), an issue certain to cause controversy, at least for the reasons of conservation of flora and fauna, salinisation and sedimentation of streams.

(v) Although burning is regulated by the Forests Department in the large areas of State Forest (Table 6), much uncontrolled firing of uncleared private and Crown land occurs. In many areas, particularly parts of the Nullaki peninsula, this has led to

> wind erosion of soils, and probably to significant changes in composition and abundance of the native biota.

Another more minor issue is the occasional high winter values of coliform bacteria in the Denmark River near the Town (DCE File 20/80), which was revealed by monthly sampling in 1980. Numbers of coliforms drop in summer, presumably due to increasing salinity of the river.

5.2 Current Practice

The Bar: The timing of the opening of the inlet bar is now the responsibility of the Public Works Department, and the bar has been surveyed annually by them since 1956 (Hodgkin 1981). These surveys have suggested that the bar may have built inwards about 2 km from the sea shore since the practice of artificial opening began 40 years ago, although the evidence is not conclusive.

The PWD has preferred to open the bar on the east side or middle while local opinion favours a western breach, close to the cliff, which is the "natural" position. The arguments in favour of the eastern opening are quoted below from Hodgkin (m.s.) and Lenanton (1974b), and illustrated diagramatically in Figure 7. The behaviour of Inlet levels before and after bar break during the winters of 1976-1980 are shown in Figure 8.

> "In the past, the channel cut through the eastern side of bar has been located at a point which is the shortest distance between the deep estuary water and the ocean, with a negative gradient from the estuary to the ocean.

When the bar was broken in this position, the trapped estuary water running into the ocean eroded a deep straight channel in the bar allowing rapid passage into the ocean. After several days, the estuary becomes tidal, and experiences a good water exchange with the ocean.

On most occasions, the point where the channel opened into the ocean was in line with an offshore "rip" over what is known locally as the "Dunsky Reef". This "rip" helps relocate the suspended material from the channel area into deeper water further offshore.

The deep channel allows for better recruitment of fish into, and quick release of accumulated fresh water from, the estuary.

In 1971 and 1972, the channel was cut through the western side of the bar, next to the cliffs. At this location, the distance between the deep estuary water and the ocean was greater, and the negative gradient between the estuary and the ocean less, than for the channel cut through the eastern side of the bar.

When the bar was broken, the trapped estuary water flowed into the ocean more slowly, forming a shallow meandering channel in the bar. Once the estuary became tidal, there was a poor water exchange between the ocean and the estuary. Suspended material from the channel area was relocated immediately offshore from the channel entrance forming a shallow bank ..."

The controversy over the bar is not limited to whether it should be artificially breached, but to where, and to a lesser extent when. The inlet falls to sea level within about 48 hours of bar break (Figure 8), after which the forcing variables available to transport sediment to sea are -

- Ocean waves and swells
- Additional freshwater inflow to the estuary
- Ocean tides.

Of these, ocean waves are by far the dominant process in most years, and hence whether or not the bar re-forms slowly or quickly is completely beyond human control, and far more dependent upon the sea state. It is dubious whether the position of the cut has any major effect on the rate of bar channel closure - certainly the durations of open periods (Table 10) appear unrelated to the position of the initial cut.

Eutrophication: There is no current management of agricultural lands to reduce nutrient loss, nor of the estuary to remove accumulations of weed when they occur. Work in progress to modify fertiliser types and application techniques on the coastal plain soils near Harvey Estuary will be of benefit in the future.

Clearing and Salinisation: The Public Works Department currently enforces a total ban on further clearing of Crown or Freehold land, and monitors water flow and salinity at the stations detailed in Table 2.

Forestry: The Forests Department has classified the areas of State Forest within the Wilson Inlet catchment as shown in Map 17, and has also defined cutting status within the catchment (Map 18). Forestry is a very significant land use within the estuary catchment (about 28 percent, Table 6), particularly within the catchment of the Denmark River (56 percent), and therefore contributes significantly to the minimisation of salinisation and other important problems associated with land clearing and agriculture.

Burning: Burning is controlled within State Forest by the Forests Department, and elsewhere by the Bush Fires Board. Management of the problem of deliberately set unauthorised fires appears to be ineffectual.

5.3 Suggestions for Further Research and Management of the Database

Two types of deficiency have emerged during the course of this work. The first concerns the quality or coverage of the data available for the Wilson Inlet catchment, and the second concerns the lack of personnel within DCE to curate environmental databases. The most obvious deficiences in data include:

- Incomplete coverage by the FMIS database of the Hay River catchment, which means that estimates of areas of various information categories maintained within the database (Table 15) pertaining to this catchment are inaccurate.

- The large scale of data available from the ABS Geocode database (10 x 10 km) is inadequate for any detailed analysis of fertiliser or biocide application rates, particularly as the Geocode square boundaries are unrelated to those of catchments or administrative units.

- The lack of a soils map of sufficient detail for the whole catchment, and inadequate detail for geology (1:250,000) and current patterns of land use.

- The lack of a detailed map of aquatic vegetation for the Inlet.

- The short record of water quality-related data presently available. These difficiences could be remedied by:

- More field mapping and data coding of the northeastern Hay River catchment, best done in association with Department of Forests personnel already familiar with the data gathering and coding requi rements of FMIS. Only a restricted selection of the FMIS code categories listed in Table 15 would be required.

- The large scale of the ABS Geocode coverage might be remedied by the release of existing, confidential information by ABS, or by field mapping and interview of landholders. Either the FMIS or ESRI systems would be appropriate to store and process these data.

- Soils and geological mapping at smaller scales and/or for larger areas would probably best be done after liaison with other State departments with interest in these areas. More detailed, unpublished material may already exist, and should obviously be sought out and assessed prior to any additional field mapping. Improvement of data coverage should first be concentrated in areas known or suspected to be the source(s) of problems, for example sediment and fertiliser loss to waterways.

- The biomass, species composition, distribution of aquatic macrophytes within the estuary provides an important and sensitive measure of the system's response to nutrient loading, and to other characteristics of the estuarine environment. Some effort and financial support should be devoted to continuing and expanding the current half-yearly survey of macrophytes done at 16 stations by the joint DCE and Botany UWA team. It is particularly important to relate the distribution of aquatic plants to the bathymetry of the Inlet (Map 16), which may in itself require improvement.

- The short record of most measures of water quality (except possibly salinity) in both the inlet and its catchment should be extended, so that calculations of catchment loss rates and inlet loading rates may be made. This will permit a more objective assessment of the apparent deterioration of inlet water quality to be made.

The second major concern is the lack of an officer within DCE to maintain a computer-based data archive, to process those data approximately, and to liaise with the Forests Department ADP section, ESRI, and any other supplier of data, or of data processing and storage services.

There is a rapidly increasing amount of data acquisition currently underway within DCE, particularly in the marine, estuarine and inland waters areas. A rational development of an archival, retrieval and processing system is required, together with the dedication of sufficient staff to manage the volume of incoming information.

It is beyond the scope of this report to examine this issue thoroughly, but other departments, notably Lands and Surveys, Forests and PWD already have made considerable investiments in this area, and their experience would be most valuable. Further, some consulting firms, such as ESRI Australia Pty Ltd specialise in the design and construction of data management systems, and are able to provide advice and specialised software for the various components of such a system. If DCE chooses not to establish a data processing and archive capability, it will, as in this study, be forced to employ outside consultants on a project-by-project basis, thus losing continuity of expertise and familiarity with the assembled data. The costs of data gathering are great, but costs rise even further if valuable data are not properly processed and interpreted, thus leading to misinformed or uninformed decision-making. In most cases, poor maintenance of a database leads to a decline in its usefulness to future, often unanticipated applications, since limitations of the data are not properly recorded and understood.

A report such as this is obviously a transient document, which will be superseded as more information becomes available, and clearer definition of issues evolves. The most economic means of updating such documents is to produce them on a suitable word-processing system, so that revision may be done piecemeal, where appropriate, rather than revising and retyping the whole text.

6. THE COMPUTER-BASED RESOURCE INVENTORY SYSTEMS

6.1 Geocoding - The Australian Bureau of Statistics

There is little technical information available for the ABS Geocoding system, and little more than the brief description below is necessary since extractions of information must be requested from ABS, and cannot be done by the user himself.

A very wide range of statistical information is contained in the system, but for reasons of confidentiality, resolution is usually limited to the basic 10 x 10 km square (Figure 1), although it may be improved to a resolution of 2.5 x 2.5 km. The Geocode squares are unrelated to any natural or man-made boundaries such as catchments or administrative units, and this usually leads to problems of partitioning information among segments of such areas which happen to fall inside a single square. For example, compare the relationships of subcatchment boundaries to Geocode square boundaries in Figure 1.

The ABS database is the least important source of information relating to land management, but at this stage must be used for data on fertiliser and biocide application rates until more precise information from other sources becomes available, for example by interview of individual landholders in the catchment.

6.2 FMIS - The Forest Management Information System*

The Forest Management Information System (FMIS) is a computer-based system for overlaying maps which describe the various characteristics of the forest, management activities and constraints on management. It locates areas which satisfy particular

*The text for this section was provided by Colin Pearce, Forests Department.

combinations of characteristics on several resource map overlays, determines areas, and prints or plots the resulting composite maps. It is also capable of comparing and calculating certain resource volume information. FMIS is a grid cell system with basic data being recorded for each separate overlay or attribute (see Figures 9 and 10).

The system was developed to cater for the constantly changing planning constraints in the Southern Region, brought about by the introduction of multiple-use management coinciding with an increase in wood production activity in the region, with the introduction of a wood chipping industry. The forest in this region is characterised by a mosaic of two major forest types, each of which requires a different management practice influenced by a large and growing number of constraints. Co-ordinated operational planning is required in considerable detail over a large area, as well as long range resource planning.

Manual techniques of manipulation and summarisation of the data required for this type of planning were inadequate - they were inconsistent, tedious and incapable of responding to rapid change and the demands of present day forest management.

Improvement in morale in the Inventory and Planning section was a major motivation for the development of the system. Once implemented, it does away with the drudgery of the manual extraction of enormous amounts of resource data required for forest management records and decision-making. A single alteration to the data frequently involved the frustration of repeating the whole extraction process, (sometimes months of work). The system will free staff from this mundane work and allow them to do the more challenging work for which they are trained.

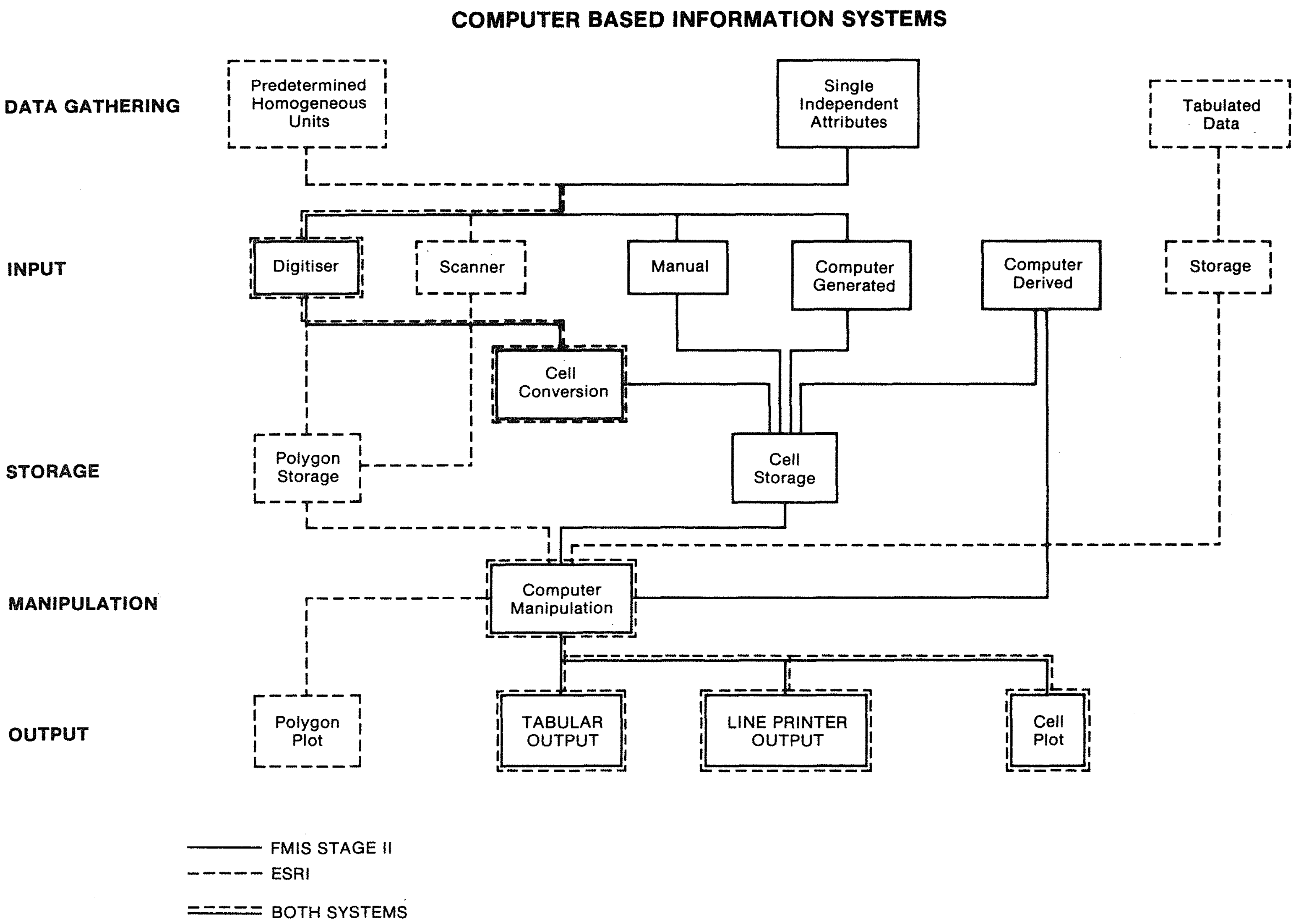


FIGURE 9. Structure of GIS systems.

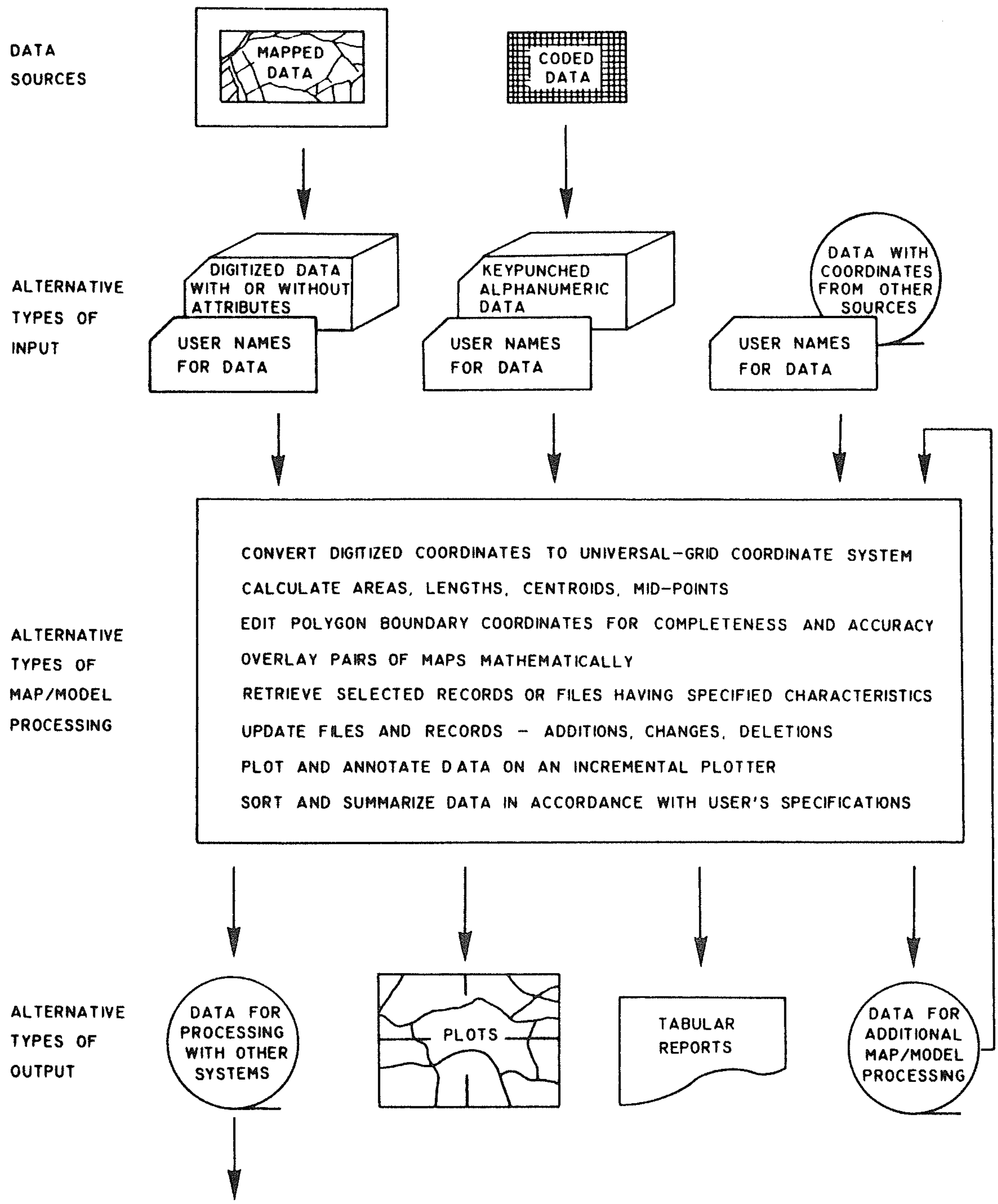


FIGURE 10. Summary of data entry, verification, manipulation, interrogation and output steps common to most Geographic Information Systems.

FMIS is an extension and modification of the earlier Map Display System (MDS) which is extremely versatile in its manipulation capacity, but was primarily designed for small projects. The central core of the programme has been retained, but peripheral programs have been added to provide broad area coverage on a recognised grid system, simplified input, extended output including volume calculations, and scale map plotting facilities.

The system is based on a Cyber computer at the WA Regional Computing Centre at the University of Western Australia.

At the present time there is no direct communication facility with the Cyber computer from field stations. For this reason the forest manager in the field must communicate his requirements to the ADP centre at the Forests Department State Headquarters in Como, which carries out all the computer functions. The structure of the manual reflects this method.

Figure 9 shows diagrammatic representation of FMIS in relation to information systems in general, and Figure 10 summaries the data entry, verification, manipulation, interrogation and output steps common to most geographic information systems.

FMIS will continue to be modified and upgraded in stages to increase its flexibility and capability. This edition represents stage II of the system.

<u>Data Structure</u>: This section explains the way in which the data is structured for its location and type. The structure of the computer files is covered in the Operators Manual.

The FMIS Square: The whole of the southwest area of the State covering State Forest and its surrounds has been divided into grid squares, 8000 x 8000 m in size, based on the Australian Map Grid (see Figure 2). Each square has a unique identification number, designated by the Easting and Northing at its southwest corner and read in thousands of metres, reading the Easting first and the Northing second. For example, the southwest corner of the square in which Manjimup is situated has an easting of 416,000 m and a Northing of 6,208,000 m. The FMIS square identification is therefore 416.208.

The whole of the State Forest area in Western Australia is contained within the AMG Zone 52.

An index to FMIS squares has been produced on transparent plans at 1:25,000 (the most common input scale) to facilitate precise registration for coding. The AMG grid is based on the Universal Transverse Mercator projection, while most of the imperial scale source plans used by the Forests Department are based on the Bonds projection. Because of this an exact match with Imperial Maps is not possible and the FMIS squares have been adjusted to best fit. The error, however, is within acceptable levels.

The FMIS square is the basis for data input and storage.

The FMIS Cell: Each FMIS square is divided into 57 x 57 (3249) cells, giving each cell an area of 1.9698 ha (140.35 m x 140.35 m). This is the smallest unit of data recording. This size was chosen as a compromise between the resolution required for management and the limitations of storage and manipulation. Given the precision of the basic information and the purpose for which it is used, this resolution is considered adequate.

At this size the output from one FMIS square can be accommodated on a conventional computer printer page using a two digit output code. Each cell within the square can be identified by its co-ordinates.

For more detailed information the reader is referred to the FMIS Manual, second edition, November 1981, a copy of which is lodged in the DCE Library, and to Colin Pearce, ADP Section, Forests Department, 50 Hayman Road, Como.

6.3 GIS - The Geographic Information System of ESRI*

ESRI (Environmental Systems Research Investigations) undertakes the development of automatic 'Geographic Information Systems' (GIS). Such a system uses a combination of hardware (computers, printers, plotters, digitisers) and software (standard program packages and custom-made programs for special jobs) to prepare data bases derived from maps, charts, tables, aerial photography, etc. This data base is then used to prepare selected maps of the geographic area under consideration and to model the area so that questions about the way the system behaves can be answered.

By using computer analysis coupled with a GIS, natural resource-related problems and theories can be tested quickly at low cost and without any threat to the environment under study. Testing can be

*The text for this section was provided by Barry Smith, of ESRI.

carried out quickly, and alternative theories tested against each other using real data. Promising ideas can be implemented quickly and unworkable ideas discarded, thus reducing field work to a minimum.

ESRI also provides expert staff when necessary to carry out monitoring of geographic areas once a management program is instituted, and has all the facilities necessary to prepare necessary maps and reports.

Essentially a GIS is an effective tool for:-

1. Inventory - organised data gathering and storage
2. Reporting - rapid response to user requests for information
3. Planning, Modelling - trying out ideas
4. Management and Policy Making.

For the Wilson Inlet Study only 1 and 2 above have been carried out, but this is sufficient to illustrate some of the powerful capabilities of ESRI processing. Specifically, the following processes were used.

(i) Data Automation

A variety of maps have been digitised. These were of different scales and different accuracies, and it is now possible to produce good quality maps, to a standard scale, and incorporating various combinations of factors. For example it was possible to plot a map showing catchment boundaries, rivers, roads and isohyets (Maps 1 and 2) even though the data for this were taken from several different maps (see Figures 9 and 10).

(ii) Gridfile Generation

One method of recording data for modelling is to enter the data into a grid format in which each row relates to an Australian Map Grid (AMG) Northing, each column an AMG Easting. The value at the intersection of a particular row and column is the corresponding attribute value (height ASL, vegetation or soil type, etc.) at those AMG coordinates. This is the method used to record FMIS data and has been used for geology, slopes, aspects and altitudes. The grid-cell size is exactly twice that used for the FMIS grid so the two systems are compatible. The grid method is used very often because although it can only approximate various map boundaries, it is easy to generate overlays and represent them as simple line-printer maps with associated statistical summaries. It is particularly suitable for Digital Elevation Models (height data) or spot values such as recordings of soil salt concentrations, rainfall data, etc., because the resulting grid file can be contoured at any selected contour interval. There are also cases where very poor maps do not give sufficiently accurate information to allow more sophisticated methods to be used. A case of this was the geology map for which the combination of small areas of categories and small scale made it necessary to use grid methods to reduce costs. (It would be desirable if money were available to develop an improved Geology map - ESRI can do this if required). Some of the disadvantages of the grid system is the difficulty of getting cartographic quality maps, and the loss of information because cell values are averages. Linear features are not easily represented in compatible form and curved boundaries are only approximated. Very small or very narrow polygons may have been considerably overstated.

(iii) Polygon Data

To overcome these deficiencies ESRI has developed software to map and model directly from the digitised polygon boundaries - the Polygon Information Overlay System (PIOS). This is the preferred system wherever data quality is adequate to allow its use. Most of the polygon data associated with Wilson Inlet - the vegetation, water classification, land use, salt yield, etc., was done in this way. If necessary, grid files can still be generated and these will be very accurate because of the high quality polygon files. In fact, different cell sizes for different purposes, and also different windowed areas, can be obtained. This points to a major deficiency of the FMIS data base which is held only as grid files and so is fixed in terms of cell size. This has the effect of limiting accuracy and also making the data less accessible to other users who are forced to use the FMIS cell size of 2 ha or perhaps a multiple of it. The PIOS system allows the creation of grid files to suit any user's requirements, so that even although the present study uses 8 ha cells it would be possible to regrid all or part of the area using, for example, 50 metre square cells.

In this particular study the most appropriate method given the available data, time and funds has been used to prepare a data base for the two major catchments of Wilson Inlet, and this is now readily available for many different purposes. At this stage, little modelling has been carried out apart from some simple overlays, but the quality of the data base apart from the lack of some essential information (soils, a more accurate geology map, more detailed landuse, especially agriculture) is of a standard more than satisfactory for further development.

This modelling process frequently involves the overlaying of several data sets, and the preparation of composite maps showing data relationships. As part of this process, some factors may be weighted at the expense of others in several different ways to test the affect of one factor on others. Such modelling frequently points to unsuspected relationships, which, if manual methods were used, would be prohibitively expensive to check and would probably not be done because of the time factors.

In particular, problems involving phosphates and soil salt need modelling in this area. For instance, overlays of salt concentration data versus vegetation, salt concentrations versus slope and salt concentration versus rainfall may allow the determination of areas within catchments where the most serious problems are likely to occur, and may also indicate a particular kind of plant association which is indicative of such problems developing. Overlays of slope, geology and land use with each other could identify major sources of phosphate pollution in the Inlet.

ESRI has the technical capability to carry out such modelling processes and is able to provide all the necessary ancillary services needed to extend the current study to a point where other important questions can be asked. The first need is for more data input, and some preliminary overlaying to establish which elements of the data base are the critical factors; to satisfy this need will require only a few weeks work and a few thousand dollars, but the results could lead to a sound monitoring and management program for the Inlet.

For more information on the services offered by ESRI, the reader is referred to Barry Smith, ESRI, telephone (09) 322-4955.

6.4 A Guide to the Databases Identified by this Study

Table 14 contains a summary of the sources of data used in this report, together with brief comments on their reliability. The majority of the information outlined in this Table is available in digitised form, and is accessible via the ABS Geocoding, ESRI or FMIS systems, which are discussed in greater detail below.

The literature, both published and unpublished relating to the management of Wilson Inlet and its catchment, is listed in the bibliography (Section 8) of this report. This listing is fairly comprehensive so far as can be determined, and certainly provides a sound basis for the future revision and updating of this listing of information resources contained in written form.

Three sources of quantitative, geographically based data were investigated or established during this study, namely the Geocoding System of the Australian Bureau of Statistics, the Forests Department FMIS System and the GIS of ESRI Australia Ltd.

The database maintained by ABS is very broadly based, but of relatively little use for management without great improvement of its geographic resolution, which for all practical purposes is limited to 10 x 10 km squares. For most purposes, improvement of the resolution of data available from ABS must be done by survey within the areas of interest.

FMIS contains information under 47 categories, listed in Table 15, many of which are obviously limited to forest management in a specific way. However, much of the FMIS database is of broader relevance to the management of the Wilson Inlet catchment and the estuary, and could, of course be expanded by the addition of other

Table 14.

The sources of data used in this report with comments on their reliability

Section	Section No.	Data	Source	Reliability
Geology and Geomorphology	2.1, 3.1	Geology	1:250,000 geological map replotted by ESRI at 1:100,000	Good considering scale of map. See note 1.
		Geomorphology	Treloar 1977	Inference from recent aerial photography.
			Collins and Fowlie 1981	Generalised, small scale.
			Hesp and Hodgkin, DCE	Data still being collected.
Climate	2.2	Rainfall, temperature, evaporation	CBM and PWD	Excellent
		Isohyets	Collins and Fowlie 1981	Very accurate, recalculated using more stations than CBM
Land Use	2.3	Land tenure	Collins and Fowlie 1981	Generalised, small scale.
			FMIS	Variable, see note 2.
Vegetation	2.4	Original vegetation	Beard 1979, 1:250,000 map	Speculative, small scale.
		Present vegetation	FMIS	Good for timber, see note 2.
		Species lists	Christensen 1980	Good quality, some names in need of revision, restricted to part of area.

Table 14. (Cont'd)

Section	Section No.	Data	Source	Reliability
Fauna	2.5	Amphibians, reptiles, birds, mammals	Christensen 1980	Confidential report with good fauna lists for part of catchment.
			CWR, DCE	Unpublished lists from Dr. N. Mckenzie, CWR, supplemented by our own field notes. Good data but more extensive field work is bound to add to the lists.
Hydrology	2.6	Catchment area, river lengths	ESRI	Very accurate though all the tributaries were not digitised. Overlay map 1 and Map 2. See note 1.
		Streamflow, runoff	Collier and Fowlie 1981	Reliable data though only collected over two years. Additional data being collected by N. Schofield (WAIT) for DCE.
Water Quality	2.7	Pesticides, herbicides	ABS	Limited data due to small scale (agricultural application rates only).
		Salinity, phosphorus, nitrogen	Spencer 1952	Reliable historical data (Appendix) within the limits of available techniques
			Collins & Fowlie 1981	Reliable data collected over two years.
			Hodgkin, DCE	Unpublished scattered data. Additional data being collected by N. Schofield for DCE

Table 14. (Cont'd)

Section	Section No.	Data	Source	Reliability
Water Quality (cont'd)	2.7	Sewage, bacteriology	DCE	No data for sewage, few unpublished counts of *E. coli* on file, DCE. Reliable but sparse data.
Morphometry of the Inlet	3.2	Area, shape	ESRI	Accurately digitised directly from available map.
		Bathymetry	Conacher *et al.* 1981 1:25,000 map	Data gathered by 3rd year geography students, UWA, with precision instruments. Replotted by ESRI on Map 16.
The Bar	3.3	Opening and closing dates PWD	Lenanton 1974	Excellent (Table 10), other observations more patchy.
Physico-chemical characteristics and water quality of the Inlet	3.4	Temperature, salinity, pH, dissolved O_2, phosphorus, nitrogen	Spencer 1952	Good historical data (Appendix).
			Lenanton 1974	Good recent data (Appendix)
			DCE	Some reliable unpublished data on file and being collected, 1980- (see Appendix)
		Sewage, pesticides, herbicides	No data	
Biology	3.5	Phytoplankton and aquatic macrophytes	DCE and Botany Dept. UWA	Reliable data being collected from 15 sample stations
		Fringing vegetation, especially samphire	DCE	Some reliable but incomplete data from five localities, may be extrapolated with aerial photographs. (Appendix)

Table 14. (cont'd)

Section	Section No.	Data	Source	Reliability
Biology (cont'd)		Benthic and planktonic fauna.	Lenanton 1974a and 1974b	Good data on molluscs and crustaceans.
			Hodgkin (R.P. McMillan)	Some unpublished data on file, DCE.
			DCE	Data being presently collected in same programme as aquatic vegetation.
Oceanography	4	Tides, wave energy	PWD	Short term reliable data
Management Issues	5.1	Agriculture	ABS	Small scale data on the use of chemicals.
			FMIS	Tenure and land use. See note 2.
		Fishing	Lenanton 1974a and 1974b	Good data on professional fishery. Amateur fishery likely to be at least equal to professional. Recent professional catches available from Owen McIntosh, Denmark.
		Recreational use	Caputi and Lenanton 1977	Questionnaire data from tourist and hotel trade. Not complete coverage but authors consider data is representative and reliable.
		Dredging and filling	PWD, Shire Councils	Some patchy data.

Note 1: The ESRI plots are of cartographic quality but their reliability obviously depends on the quality and resolution of the data that were digitised.

Note 2. FMIS data. The coverage of the FMIS Squares is variable for each attribute. The reliability of the data depends on how important the area is for forestry operations and how recently the data were coded. The reliability of each attribute for each FMIS square can be ascertained from the base maps at the Forest Department, Manjimup.

variables to the database.

The major limitations of FMIS relate to its dependence on a grid file structure, explained more fully in Sections 6.2 and 6.3, and this would limit the scope of data transfer from the newly digitised files provided by ESRI (Table 16). The possibility of adapting FMIS to cope with other forms of data, for example polygonal or linear is under current investigation, so that this assessment is not final.

Data not previously held in digital form on computer storage were digitised and subjected to limited processing by ESRI Australia Pty Ltd. Various geographical output is contained in the maps of this report, tabular data is given in the tables, and a directory to the magnetic tape files containing these data is given in Table 16.

6.5 Recommendations

Various suggestions for improving the database pertaining to the Wilson Inlet catchment were made in Section 5.3, and will not be repeated here. Further, the strengths and weaknesses of the three data management systems examined have been detailed in Sections 6.1 to 6.3, as have the scope of the data stored within each system.

The three aims of this work remaining to be treated (Section 1) are:

- the ease of data manipulation required for management decisions;
- the suitability (of the system) for storage of additional data for other estuaries; and
- cost-effectiveness.

Table 15.

Index to FMIS Codelist, with a guide to the acronyms for each category

DESCRIPTION	NAME
REGION BOUNDARY	REBY
TENURE	TENU
PROPOSED TENURE	PTEN
LAND SURVEYED FOR ALIENATION - 1927	PAL
SHIRES	SHIR
FOREST DIVISIONS	DIV
FOREST BLOCK WITHIN SECTION OF DIVISION	BLK
FOREST COUPES WITHIN A BLOCK	COUP
SAWMILLING AREAS	SMP
CHIPWOOD LICENCE AREA	WACP
GAZETTED WATER CATCHMENT	GWCA
RIVER WATERSHEDS	RIV
PROPOSED DAMSITES -MANJIMUP	PDAM
RAINFALL ISOHYETS	RAIN
FOREST MANAGEMENT PRIORITY	FMP
FOREST MANAGEMENT AREA	FMA
QUARANTINE	QT
FOREST/VEGETATION TYPE	TYPE
CLEARED LAND ORIGINALLY GROWING KARRI	PXK
BOUNDARY OF MAIN KARRI BELT	KZON
DIEBACK OCCURRENCE (70MM MAPPING)	DB70
DIEBACK OCCURRENCE (OLD DATA)	DB
CUTTING STATUS - SAWLOGS	CUTS
DECADE OF SAWLOG CUT	SLD
YEAR OF SAWLOG CUT	SLY
CUTTING STATUS AND HISTORY - CHIPWOOD	CUTC
EVEN-AGED REGENERATION (METHOD OF REGENERATION	MREG
EVEN-AGED REGENERATION (DECADE OF ESTABLISHMENT)	DREG
EVEN-AGED REGENERATION (YEAR OF ESTABLISHMENT IN DECADE)	REGY
1ST COMMERCIAL THINNING OF SECOND CROP	THIN
TYPE OF PLANNED CUT	TPC
YEAR OF PLANNED CUT	YPC
AVERAGE VOLUME JARRAH SAWLOGS PER HECTARE (MLI)	JVML
AVERAGE VOLUME JARRAH SAWLOGS FROM ACTUAL REMOVALS	JVAC
AVERAGE VOLUME KARRI SAWLOGS PER HECTARE (MLI)	KVML
AVERAGE VOLUME KARRI SAWLOGS FROM ACTUAL REMOVALS	KVAC
AVERAGE VOLUMES CHIPWOOD PER HECTARE (MLI)	CVML
AVERAGE VOLUMES CHIPWOOD FROM ACTUAL REMOVALS	CVAC
1ST COMMERCIAL THINNING OF SECOND CROP (KARRI S/LOGS PEELERS, MONIER) ACTUAL REMOVALS)	KSAC
1ST COMMERCIAL THINNING OF SECOND CROP (CHIPWOOD (KARRI AND MARRI) ACTUAL REMOVALS)	CHAC

Table 15. (Cont'd)

DESCRIPTION	NAME
BURNING BUFFERS	BURN
BURNING BUFFERS 1980 VERSION	BUFF
YEAR OF LAST BURN	YLB
BLOCK NAME	FBLK
REGENERATION HISTORY	RHIS
SAWLOG CUTTING HISTORY	CHIS
D'ENTRECASTEAUX AND WALPOLE/NORNALUP NATIONAL PARK	DENT

Table 16.

A guide to the file structure of the data tape produced for this study by ESRI Australia, 18 Prowse Street, West Perth WA 6005. A copy of this tape is lodged with DCE, and will be archived for two years by ESRI.

CATCHMENTS	NEW.DATA (DIG)
	CATCHMENT.AREA (Areas in hectares)
	NEW.CATCHMENTS (DIG)
	CATCHMENTS (DIG)
	CATCHMENT (DIG)
VEGETATION	TUCM10.VEG (PIOS)
	TUSG09.VEG (PIOS)
	TUBI11.VEG (PIOS)
	VEG.LIST (Areas of attributes)
LINEAR FEATURES	ROADS (DIG)
	COAST AND BOUND (DIG)
	RIVERS (DIG)
	GEOLOGY.DIG (DIG)
	ISOHYTES (DIG)
	EXTRA.ROADS (DIG)
	LAKES (DIG)
	GAUGE.STATIONS (DIG)
	BATHYMETRY.METRIC (DIG)
DIGITAL TERRAIN MODEL	DTM.DATA (DIG)
MAPS	MAP1.E (Salt yield)
	MAP2.E (Water quality)
	MAP3.E (Land forms)

As explained earlier, the Geocoding system of ABS suffers from major problems of geographic and temporal resolution, as well as seriously restricting the accessibility of users, and will not be discussed further.

Both the FMIS and ESRI Geographic Information Systems are highly developed, easy (with expert help) to interrogate and suitable for the storage of additional data for <u>any</u> terrestrial, estuarine or marine system.

The ESRI system is far more flexible than that of FMIS, and is able to cope with linear features, curved boundaries and topographic data at any level of precision. The minimum level of geographic resolution of the ESRI system is dictated only by the accuracy of the input data.

FMIS, on the other hand, is restricted to grid cell data input and handling. This restriction is not serious for many possible uses, but does limit its utility in the areas defined above. It should be noted, however, that the Forests Department data processing and storage system is currently under review, and that these limitations are unlikely to be permanent.

Both the ESRI and FMIS systems, as used in this study, are cost-effective, although a comparison is difficult, since the component of this work done by ESRI included data input, verification, manipulation and output as maps and line printer listings, while only the manipulation and output steps were performed with FMIS.

The costs of cartographic quality plots at a scale of 1:100,000 do vary considerably; about \$30 each from FMIS, and around \$200-\$300, depending on complexity, from ESRI.

The products, however, are not fully comparable, since all plotted FMIS output appears as grid cells, while grid cell plots are only one of a selection from ESRI (see Maps).

The incorporation of topographic, bathymetric and linear information (e.g. rivers, roads) into a computer database is currently best done by ESRI, and this capability may well dictate the use of this system.

If grid cells are suitable for the storage and manipulation of information, then FMIS is probably cheaper, although resolution is restricted to one cell size (2 ha) at present.

7. APPENDICES

7.1 Available aerial photography and topographic maps

OVERLAY MAPS produced for this report.

All maps were plotted at a scale of 1:100,000 except for the bathymetry of Wilson Inlet which was plotted at 1:25,000. The two base maps (Map 1 and Map 2) are plots of the catchment and subcatchment boundaries, the river network, roads, coastlines and a grid to match the FMIS maps. All the maps (except bathymetry) can also be overlain on a compilation of Natmap sheets 2327, 2328, 2427, 2428 lodged in the DCE Library.

MAPS available for Wilson Inlet and catchment

Scale	Date	Title	Sheet Code No.	Available From
1:250,000	1968	*Mt. Barker	SI 50-11	Lands and Surveys
"	1977	*Albany	SI 50-15	"
"	1981	*Pemberton	SI 50-10	"
"	1967	*Irwin Inlet	SI 50-14	"
1:100,000	1975	*Mt. Barker	2428	"
"	1976	*Denmark	2328	"
"	1975	*Parry Inlet	2327	"
"	1975	*Albany	2427	"
1:50,000	-	†Redmond	2428-III	"
"	1977	*Ratcliffe	2327-I	"
"	1976	*Kwornicup	2328-1	"
"	1976	*Rocky Gully	2328-IV	"
"	1980	*Mt. Barker	2428-IV	"
"	1981	*Denmark	2328-II	"
"	1976	*Owingup and Parry Inlet	2328-III and 2327-IV	"
1:50,000	1980	*Denmark	2328-III and 2328-II	Forests Dept.
"	1975	*Forest Hill	2328-I and 2328-IV	"
"	1975	*Mt. Barker	2328-I and 2328-IV	"
"	1975	*Mt. Barker	2428-IV	"
"	1975	*Redmond	2428-III and Pt.2427-IV	"
Geological map 1:250,000	1982	*Mt. Barker-Albany	SI 50-11	Geological Survey of WA
	(Preliminary printing)		SI 50-15-part	"

† This map is not available at present

* Stored in DCE

MAPS contained in reports

Collins, P.D.K. and Fowlie, W.G. (1981) Denmark and Kent River basins water resources study. Eng. Div. PWD, WA

Map 1. Denmark and Kent River basins - gauged catchments and hydrometric network.

Map 2. Annual average isohyets (mm) for Denmark and Kent river basins.

Map 3. Denmark and Kent River basins - generalised landform units.

Map 4. Denmark and Kent River basins - land tenure.

Map 5. Denmark and Kent River basins - water quality classification.

Map 6. Denmark and Kent River basins - catchment salt yield.

Beard, J.S. (1979) The vegetation of the Albany and Mt. Barker areas, Western Australia. Vegmap Publ., Perth.

Map - Albany and Mt. Barker 1:250,000. Vegetation Survey of W.A. (SI 50-11 15 Vegetation series)

Dept. of Geography, UWA (1981). Preliminary investigation of the Hay River catchment and Wilson Inlet, Denmark. Unpubl. report.

Map - Bathymetry of Wilson Inlet.

AERIAL PHOTOGRAPHY OF WILSON INLET
Unless noted, all photos are produced by
Department of Lands and Surveys

Date	Scale	Title	Job No.	Full or partial	Special Notes	B/W or Colour
Jan. 1959	-	Wilson Inlet to Duke of Orleans Bay	WA494	Full	Available from UWA Geog. Dept. Library	B/W
1970	1:40,000	Project K33	WA1303 Run 17/5040-44 WA1287 Run 17/5079-84	Full		
1971	1:15,840	Project L3	WA1307 Photos 5159-5219	Partial (coast of Wilson Inlet only)		
1972/73	1:40,000	Mt. Barker Albany	WA1443 Runs 17/5643-47 WA1443 Runs 1/5577-71	Full		
1973	1:15,000	Project P52	WA1489 Runs 1-4	Full		
1977	1:25,000	Job 770049	WA1666 WA1678	Partial		Colour
1980	1:10,000	Job 790106	WA1860 Run 3/5233-39 Run 4/5271-80 Run 5/5359-74 Run 6/5373-91 Run 7/5475-80	Partial		
Jan. 1981	1:15,000	Coast Run 800084	WA1965(15A) Photos 5128-51 WA1965(16)	Full	Currently only aerial photography available for sale at Lands Dept. Cathedral Av. Perth	B/W

AERIAL PHOTOGRAPHY OF WILSON INLET (Cont'd)

Date	Scale	Title	Job No.	Full or Partial	Special Notes	B/W or Colour
14.07.77	1:25,000	Bunbury to Israelite Bay (Wilson Inlet)	WA1694(c) Run 1 (5276-81) Run 1 (5282-88)	Full	Commissioned by DCE	Colour
06.02.81	1:25,000	Wilson Inlet	WA1973(c) Run 2 (5334-52)	Full	Commissioned by DCE	Colour
		Wilson Inlet	WA2038(c) Photos 5040-43		Commissioned by DCE	

7.2 A partial checklist of the terrestrial vegetation of the Wilson Inlet catchment

Plants collected or observed during the survey reported by Christensen 1980.

KEY

A - High Open Forest Karri

B - Open Forest Jarrah - Marri

C - Woodland Wandoo

D - Low Woodland Casuarina / *Banksia attenuata*

E - Low Woodland *Eucalyptus staeri*

F - Low Woodland *Eucalyptus occidentalis*

G - Low Open Woodland Jarrah, Blackbutt, Melaleuca

H - Mallee

I - Closed Scrub Jarrah / *Kunzea*

J - High Open Scrub Jarrah / *Kingia*

K - Open Heath *Melaleuca*

L - Sedgelands

M - Riverine

N - Granite Outcrop

Plant species not recognised were identified using Forests Department Herbarium specimens and Blackall, W.E. and Grieve, B.J. (1954-65).

APPENDIX 7.2 (Cont'd)

SPECIES	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Lindsaeaceae, Dennstaedtiaceae, Adiantaceae														
Lindsaya linearis		x												
Pteridium esculentum	x	x												
Cheilanthes tenuifolia														x
Zamiaceae														
Macrozamia riedlei		x		x										
Podocarpaceae														
Podocarpus drougyniana		x		x									x	
Juncaginaceae														
Triglochin sp.													x	
Poaceae														
Amphipogon sp.		x											x	
Cyperaceae														
Cyathochaete avenacea		x		x	x								x	
Lepidosperma effusum	x		x										x	
Lepidosperma tetraquetrum	x												x	
Lepidosperma longitudinale		x	x		x	x								
Lepidosperma angustatum		x												
Lepidosperma leptostachyum		x												
Mesomelaena tetragona		x			x	x								
Evandra aristata												x		
Gahnia trifida		x										x	x	
Restionaceae														
Anarthria scabra				x			x	x				x		
Loxocarya flexuosa			x											
Restio sp.			x											
Juncaceae														
Juncus acutus	x													
Liliaceae														
Dianella revoluta		x												
Agrostocrinum scabrum		x												
Borya nitida														x
Johnsonia lupulina		x		x	x									
Stypandra grandiflora													x	x
Kingia australis		x		x	x		x			x		x		
Dasypogon bromeliifolius	x	x		x	x							x		

APPENDIX 7.2 (Cont'd)

SPECIES	A	B	C	D	E	F	G	H	I	J	K	L	M	N
<u>Xanthorrhoeceae</u>														
Xanthorrhoea preissii		x	x	x	x					x		x		x
Xanthorrhoea gracilis		x		x	x									
<u>Haemodoraceae</u>														
Haemodorum spicatum		x												
Anigozanthos flavidus		x									x			
<u>Iridaceae</u>														
Patersonia sp.		x	x											
<u>Orchidaceae</u>														
Caladenia aphylla		x		x	x		x							
Eriochilus dilatatus		x		x	x		x							
Cryptostylis ovata														x
Pterostylis vittata														x
<u>Casuarinaceae</u>														
Casuarina humilis		x	x					x			x			
Casuarina fraserana		x		x	x						x			
Casuarina decussata	x												x	
<u>Proteaceae</u>														
Dryandra nivea		x	x											
Dryandra armata									x					
Dryandra carduacea		x												
Dryandra formosa														x
Grevillea occidentalis		x			x									x
Proteaceae sp.		x	x											
Hakea ruscifolia		x		x	x								x	
Hakea amplexicaulis		x	x	x	x									
Hakea ambigua		x												
Hakea varia		x	x											
Hakea oliefolia		x											x	
Hakea florida							x							
Hakea lissocarpha		x	x										x	
Hakea prostrata			x											
Hakea undulata			x											
Hakea ceratophylla											x	x		
Hakea lasiantha		x												
Petrophile diversifolia		x											x	
Banksia ilicifolia				x	x						x			
Banksia littoralis swamp form						x	x		x		x	x	x	
Banksia littoralis river form	x												x	
Banksia sphaerocarpa		x	x							x				
Banksia occidentalis												x		

APPENDIX 7.2 (Cont'd)

SPECIES	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Proteaceae (cont'd)														
Banksia prostrata		x		x	x					x			x	
Banksia attenuata				x	x									
Banksia quercifolia				x			x		x			x		
Adenanthos obovatus		x		x	x		x			x				
Persoonia microcarpa							x		x			x		
Persoonia longifolia		x		x	x									
Persoonia elliptica		x		x	x									
Synaphaea sp.		x		x	x									
Franklandia fucifolia		x												
Santalaceae														
Leptomeria cunninghamii		x	x											
Santalum spicatum			x											
Olacaceae														
Olax phyllanthi		x		x	x									
Loranthaceae														
Nuytsia floribunda		x		x	x	x			x			x		
Amyema sp.			x											
Lauraceae														
Cassytha sp.											x	x	x	
Pittosporaceae														
Billardiera sp.		x	x		x									
Leguminosae (subfamily Mimosoideae)														
Albizzia lophantha		x												
Acacia divergens	x	x	x							x			x	
Acacia extensa		x	x	x	x									
Acacia myrtifolia	x	x												
Acacia pentadenia									x					
Acacia pulchella	x	x	x	x	x					x			x	
Acacia drummondii		x											x	
Acacia browniana		x		x	x								x	
Acacia hastulata													x	
Leguminosae (subfamily Papilionoideae)														
Brachysema sericeum		x	x											
Brachysema sp.		x	x											
Oxylobium lanceolatum	x	x											x	
Burtonia sp.		x		x	x									
Jacksonia sp.		x		x	x									

APPENDIX 7.2 (Cont'd)

SPECIES	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Papilionoideae (cont'd)														
Viminaria juncea		x	x			x								
Daviesia sp.		x	x	x	x									
Pultenaea reticulata				x	x				x					
Hovea elliptica	x	x												
Bossiaea linophylla	x	x	x		x								x	
Bossiaea ornata														
Gastrolobium forrestii		x											x	
Gastrolobium bilobum		x											x	
Rutaceae														
Boronia sp.												x		
Crowea dentata (not in census of W.A. plants)														x
Tremandraceae														
Tremandra stelligera		x												
Polygalaceae														
Comesperma confertum									x			x	x	
Myrtaceae														
Actinodium cunninghamii												x		
Calytrix sp.		x												
Astartea fascicularis		x										x	x	
Hypocalymma strictum		x		x	x								x	
Hypocalymma angustifolium		x	x											
Hypocalymma cordifolium	x												x	
Agonis linearifolia	x	x											x	
Agonis juniperina													x	
Agonis parviceps		x										x		
Agonis undulata												x		
Leptospermum crassipes												x		
Leptospermum sp.		x												
Leptospermum firmum									x			x		
Darwinia citriodora													x	
Kunzea pulchella									x			x		
Callistemon speciosus												x		
Beaufortia decussata				x	x									
Beaufortia sparsa				x	x							x		
Beaufortia anisandra				x	x									
Calothamnus sp.												x		
Melaleuca cuticularis							x		x				x	
Melaleuca thymoides		x		x	x									
Melaleuca striata		x		x	x									
Melaleuca preissiana							x		x				x	
Melaleuca rhaphiophylla							x		x				x	
Melaleuca polygaloides			x											
Melaleuca viminea			x											
Melaleuca acerosa			x											
Eucalyptus marginata		x		x	x		x			x	x		x	
Eucalyptus staeri				x	x									

APPENDIX 7.2 (Cont'd)

SPECIES	A	B	C	D	E	F	G	H	I	J	K	L	M	N
<u>Myrtaceae</u> (cont'd)														
Eucalyptus patens		X					X						X	
Eucalyptus calophylla		X	X				X			X	X		X	
Eucalyptus wandoo			X					X						
Eucalyptus diversicolor	X												X	
Eucalyptus cornuta													X	
Eucalyptus occidentalis			X			X							X	
Eucalyptus rudis		X	X										X	
Eucalyptus decipiens		X	X					X						
Eucalyptus decurva		X												
Eucalyptus anceps								X						
Eucalyptus megacarpa		X											X	
Eucalyptus sp. (insufficient to identify)														
Eucalyptus doratoxylon		X												
Eucalyptus falcata														
<u>Sapindaceae</u>														
Dodonaea attenuata		X											X	
Dodonaea sp.		X								X				
<u>Rhamnaceae</u>														
Trymalium spathulatum	X	X											X	
Trymalium ledifolium		X	X											
<u>Sterculiaceae</u>														
Rulingia corylifolia	X													
Thomasia sp.		X	X											
<u>Dilleniaceae</u>														
Hibbertia amplexicaulis		X			X									
Hibbertia sp.	X													
<u>Thymelaeaceae</u>														
Pimelia sp.	X	X												
<u>Apiaceae</u>														
Xanthosia rotundifolia		X			X									
<u>Epacridaceae</u>														
Astroloma sp.		X	X							X				
Leucopogon australis	X	X										X	X	
Leucopogon oxycedrus		X												
Leucopogon sp.		X												
Lysinema ciliatum											X	X		
Andersonia sp.		X		X	X		X							
Cosmelia rubra												X		

APPENDIX 7.2 (Cont'd)

SPECIES	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Menyanthaceae														
Villarsia sp.													x	
Stylidiaceae														
Stylidium imbricatum					x									
Asteraceae														
Craspedia sp.		x											x	
Gnaphalium sp.				x	x									
TOTAL 170														

7.3 A partial checklist of terrestrial and aquatic vertebrates

	Open Forest	Woodland	Low Woodland	Closed Scrub	Sedgeland	Riverine
Western Grey Kangaroo (*Macropus fuliginosus*)	SO	SO	SO		SO	SO
Western Brush Wallaby (*Macropus irma*)			S			
Brush-tailed Possum (*Trichosurus vulpecula*)		O				
Ringtail Possum (*Pseudocheirus peregrinus*)	O					
Short-nosed Bandicoot (*Isoodon obesulus*)			O		O	TO
Soutern Bush Rat (*Rattus fuscipes*)	T		T	T	T	T
Common Dunnart (*Sminthopsis murina*)			O		SO	
Honey Possum (*Tarsipes spencerae*)			T		TS	
Little Bat (*Eptesicus regulus*)						T
Goulds Wattled Bat (*Chalinolobius gouldii*)						T
Tasmanian Pipestrelle (*Pipistrellus tasmaniensis*)						T
<u>Eutherian mammals</u>						
Fox (*Vulpes vulpes*)	O	O	O	O	O	O
Cat (*Felis catus*)	O	O			O	
Rabbit (*Oryctolagus cuniculus*)		O				O
Ship Rat (*Rattus rattus*)			T			T
House Mouse (*Mus musculus*)	T		T			

(After Ride (1970))

Native mammals not recorded on the survey, but almost certain to occur within the area.

Quokka (*Setonix brachyurus*)	M
Native Squirrel (*Phascogale tapoatafa*)	M
Mardo (*Antechinus flavipes*)	M
Pigmy Possum (*Cercartetus concinnus*)	M
Native Cat (*Dasyurus geoffroyi*)	M
Water Rat (*Hydromys chrysogaster*)	M
Lesser Long-eared Bat (*Nyctophilus geoffroyi*)	M
Great Long-eared Bat (*Nyctophilus timoriensis*)	M
Water-striped Bat (*Tadarida australis*)	

M - WA Museum records within 15 km of the area.

Native mammals which would possibly occur within the area, and for which there are limited areas of suitable habitat.

*Tammar Wallaby
(*Macropus eugenii*)

*Numbat
(*Myrmecobius fasciatus*)

Echidna
(*Tachyglossus aculeatus*)

*These two species were last collected to the east of the survey area in 1934-36.

T - Trapped or shot

S - Sighted (Daylight or spotlight, includes those caught while searching)

O - Other evidence (Scats, prints, nests, fur, etc)

APPENDIX 7.3 (Cont'd) Birds recorded by Christensen (1980)

SPECIES	Open Forest (Jarrah)	Woodland (Wandoo)	Low Woodland Banksia/Casuarina	Closed Shrub	Sedgeland	Riverine	Total
Emu (*Dromaius novaehollandiae*)	6	1			1	1	9
Little Pied Cormorant (*Phalacrocorax melanoleucos*)						2	2
White-faced Heron (*Ardea novaehollandiae*)					1		1
Pacific Heron (*Ardea pacifica*)					1		1
Pacific Black Duck (*Anas superciliosa*)						5	5
Brown Goshawk (*Accipiter fasciatus*)					1		1
Brown Falcon (*Falco berigora*)	1						1
Wedge-tailed Eagle (*Aquila audax*)	1						1
Whistling Kite (*Haliastur sphenurus*)	1						1
Nankeen Kestral (*Falco cenchroides*)					1		1
Collared Sparrowhawk (*Accipiter cirrhocephalus*)					1		1
Stubble Quail (*Coturnix novaezelandie*)	1					6	10
Painted Button-quail (*Turnix vaia*)				1			1
Brush Bronzewing (*Phaps elegans*)	8		4	1		1	14
Purple-crowned Lorikeet (*Glossopsitta porphyrocephala*)	10		15		35	21	81
White-tailed Black Cockatoo (*Calyptorhynchus baudini*)	50					140	190

APPENDIX 7.3 (Cont'd)

SPECIES	Open Forest (Jarrah)	Woodland (Wandoo)	Low Woodland Banksia/Casuarina	Closed Shrub	Sedgeland	Riverine	Total
Red-tailed Black Cockatoo (*Calyptorhynchus magnificus*)			2			6	8
Western Rosella (*Platycercus icterotis*)	8	8	8	1	2	5	32
Port Lincoln Ringneck (*Barnardius zonarius*)	2		2			2	6
Elegant Parrot (*Neophema elegans*)	30						30
Red-capped Parrot (*Purpureicephalus spurius*)	2						2
Pallid Cuckoo (*Cuculus pallidus*)			1				1
Tawny Frogmouth (*Podargus strigoides*)	7		1				8
Australian Owlet-nightjar (*Aegotheles cristatus*)	1					2	3
Laughing Kookaburra (*Dacelo novaeguinae*)	7	2	11		3	7	30
Welcome Swallow (*Hirundo neoxena*)					15		15
Richard's Pipit (*Anthus novaeseelandiae*)					1		1
Black-faced Cuckoo-shrike (*Coracina novaehollandiae*)		4	2		7		13
Splended Fairy-Wren (*Malurus splendens*)		3		4	7	6	20
Inland Thornbill (*Acanthiza apicalis*)		3	1			3	7
Western Thornbill (*Acanthiza inornata*)	8		11	2	5		26
Yellow-rumped Thornbill (*Acanthiza chrysorrhoa*)						4	4
White-browed Scrub-wren (*Sericornis frontalis*)						3	3

APPENDIX 7.3 (Cont'd)

SPECIES	Open Forest (Jarrah)	Woodland (Wandoo)	Low Woodland Banksia/Casuarina	Closed Shrub	Sedgeland	Riverine	Total
Scarlet Robin (*Petroica multicolor*)	12	3	12		8	7	42
Western Yellow Robin (*Eopsaltria griseogularis*)	5		1				6
White-breasted Robin (*Eopsaltria georgiana*)	3	2	2			4	11
Grey Fantail (*Rhipidura fuginosa*)	16	8	15	5	8	14	66
Willie Wagtail (*Rhipidura leucophrys*)						1	1
Restless Flycatcher (*Myiagra inquieta*)	1						1
Golden Whistler (*Pachycephala pectoralis*)	1	3			1	7	12
Rufous Whistler (*Pachycephala rufiventris*)			4				4
Grey Shrike-thrush (*Colluricincla harmonica*)						2	2
Varied Sittela (*Dapheonositta chrysoptera*)						12	12
Rufous Tree-creeper (*Climacteris rufa*)						3	3
Spotted Pardalote (*Pardolotus punctatus*)		3	3				6
Silvereye (*Zosterops lateralis*)			10	6	16	10	42
Brown Honeyeater (*Lichmera indistincta*)			2		2		4
White-naped Honeyeater (*Melithreptus lunatus*)		1				2	3
Western Spinebill (*Acanthorhynchus superciliosus*)			2		13		16
New Holland Honeyeater (*Phylidonyris novaehollandiae*)	4		22	10	55	24	115

APPENDIX 7.3 (Cont'd)

SPECIES	Open Forest (Jarrah)	Woodland (Wandoo)	Low Woodland Banksia/Casuarina	Closed Shrub	Sedgeland	Riverine	Total
Red Wattle Bird (*Anthochaera carunculata*)			6			5	11
Red-eared Firetail (*Emblema oculata*)			1	2			3
Australian Magpie-lark (*Grallina cyanoleuca*)	2				2		4
Dusky Woodswallow (*Artamus cyanopterus*)	4	18			41		63
Grey Currawong (*Strepera versicolor*)	5		11			5	21
Australian Magpie (*Gymnorhina tibicen*)	4				7	2	13
Australian Raven (*Corvus coronoides*)		1	3		2	6	12
No. Individual Species	27	14	25	9	26	30	57
Sighting TOTAL	203	60	153	32	237	317	1002

(After RAOU List)

APPENDIX 7.3 (Cont'd) Reptiles recorded on survey reported by Christensen (1980)

	Open Forest	Woodland	Low Woodland	Closed Scrub	Sedgeland	Riverine
<u>Goannas</u>						
Gould's goanna (*Varanus gouldii*)	S					
<u>Geckoes</u>						
Marbled Gecko (*Phyllodactylus marmoratus*)		S	S		S	
<u>Skinks</u>						
Bobtail (*Tiliqua rugosa*)			O			
Mourning Skink (*Egernia luctuosa*)						T
King Skink (*Egernia kingii*)						T
Smiths Skink (*Egernia napoleonis*)	T	S	TS	T	S	S
Frys Skink (*Egernia pulchra pulchra*)			T	T	S	
Red Legged Skink (*Ctenotus labillardieri*)	T	S	TS	T	TS	
(*Ctenotus catenifer*)		S	T		T	
Burrowing Skink** (*Hemiergis peronii peronii*)	T	S	TS		s	
New Holland Skink** (*Leiolopisma trilineatum*)			T			
(*Menetia greyi*)		S				
(*Morethia obscura*)			S			
<u>Snakes</u>						
Muellers Snake (*Rhinoplocephalus bicolor*)			S	T		

APPENDIX 7.3 (Cont'd)

	Open Forest	Woodland	Low Woodland	Closed Shrub	Sedgeland	Riverine
<u>Snakes</u> (cont'd)						
Crowned Snake (*Denisonia coronata*)			T		S	
Bardick * (*Denisonia curta*)			S			
Tiger Snake (*Notechis scutatus occidentalis*)			0			
Dugite (*Demansia nuchalis affinis*)			0			
Long-necked Tortoise (*Chelodina oblonga*)						0

*Collected in the area previously by Forests Department personnel

**Sighted in the Lake Saide/Nenamup area during June 1982 DCE survey

(After Storr, W.A. Museum identification)

APPENDIX 7.3 (Cont'd) Frogs recorded on survey reported by Christensen (1980)

	Open Forest	Woodland	Low Woodland	Closed Scrub	Sedgeland	Riverine
Guenthers toadlet (*Pseudophryne guentheri*)	S					
Moaning Frog ** (*Heleioporus eyrei*)	TS		TS	T	T	S
(*Heleioporus inornatus*)			T		T	
Banjo Frog ** (*Limnodynastes dorsalis*)	S		S			
Green and Gold Tree Frog ** (*Litoria moorei*)	S		S			
Slender Tree Frog (*Litoria adelaidensis*)	S		S			
(*Crinia georgiana*)	T		T	T	T	S
(*Crinia leai*)			T			
(*Ranidella* spp.)*						TS

*Probably *R. glauerti*, *R. subinsignifera*. *R. subinsignifera* occurs close to the coast, in the Neramup/Lake Saide area, and probably more widely.

**Sighted in the Lake Saide/Nenamup area, June 1982 DCE survey

(W.A. Museum identification)

FISHES

Striped Minnow
(*Galaxiella munda*)

Common Minnow
(*Galaxias occidentalis*)

Night Fish
(*Bostockia porosa*)

Western Pigmy Perch
(*Edelia vittata*)

Swan River Goby
(*Pseudogobius olorum*)

(W.A. Museum identification)

7.4 Listings of physico-chemical water quality data, over the period 1946-1980

APPENDIX 7.4

Surface and bottom physico-chemical data collected by CSIRO Division of Fisheries and Oceanography from Wilson Inlet, 1945-49.

Location: WILSON INLET

Date	Station	Depth	Temp. °C.	Cl °/oo	O_2	O_2 %	pH	PO_4-P	NO_3-N
1945									
6.ii	2	S	21.70	15.64	4.90	91		0	0
		D	21.30	.57	.76	87		0	0
	3	S	21.70	.62	.93	91		0	0
		D	20.50	.10	.93	89		0	0
	4	S	21.60	.58	.74	87		0	0
		D	21.75	.63	5.07	93		0	0
	5	S	21.50	.77	4.65	85		0	0
		D	21.70	.58	.26	78		0	0
	6	S	21.55	.47	5.23	96		0	0
		D	22.10	.58	.14	95		0	0
	7	S	23.90	13.82	4.97	93		0	0
		D	22.15	14.50	.17	76		0	29
	8	S	22.65	.89	3.45	64		0	0
		D	22.60	15.42	0.65	12		0	0
25.viii	3	S	11.90	0.08	5.23	68		0	0
26.viii	8	S	11.45	.09	6.25	81		0	0
		D	11.50	.07	4.50	58		0	0
27.viii	5	S	11.90	.91	5.40	71		0	0
		D	12.00	3.78	3.16	43		0	0
	6	S	12.90	0.11	.14	42		0	145
		D	12.40	8.74	1.53	22		0	0
	7	S	11.50	0.15	3.84	50		0	0
		D	11.50	1.41	2.50	35		0	0
1946									
13.iii	2	S	20.30	16.37	6.57	119		0	0
		D	20.05	.52	.27	114		2	0
	3	S	20.45	.20	5.90	107		20	0
		D	20.30	.23	3.36	61		20	0
	4	S	19.70	.18	6.42	115		9	0
		D	19.10	.15	.23	110		9	0
	5	S	19.50	.00	.30	112		0	337
		D	19.30	.16	5.65	101		9	450
	6	S	19.40	.03	6.88	122		6	530
		D	19.00	.35	2.92	52		0	60
	8	S	22.50	15.42	4.98	83		3	0
		D	20.00	.86	1.63	29		13	170
14.iii	7	S	19.40	14.83	6.23	109		0	0
		D	20.00	15.47	4.50	76		20	200
4.vii	3	S	11.30	14.85	5.90	89			5
		D	11.10	.90	4.33	65			13
	4	S	10.90	15.03	6.32	95			3
		D	10.80	14.95	.50	98			3
	5	S	11.50	.90	.80	104			5
		D	11.00	.75	.25	94			7
	6	S	11.00	.70	.51	98			8
		D	10.90	.60	7.44	111			11
5.vii	8	S	11.00	2.22	5.14	67			19
		D	11.90	15.15					15
6.vii	7	S	10.90	13.66	.40	67			150
		D	11.80	14.75	3.42	52			160
29.ix	1	S	20.20	13.38	5.10	89		2	5
	3	S	18.80	12.23	.07	86		1	11
	4	S	17.70	.23	.16	86		0	16
		D	16.60	.23	.32	87		0	10
	5	S	17.60	11.98	.32	88		0	9
		D	16.80	12.18	.03	82		0	5
	6	S	17.45	11.93	.42	89		1	9
		D	16.85	12.18	.30	87		1	7
	8	S	10.80	10.28	3.77	54		1	12
		D	9.90	11.78				0	16
1947									
23.iv	7	S	18.55	1.02	4.75	71		9	670
		D	18.70	13.01	0.00	0		4	410
24.iv	1	S	18.75	15.49	5.20	91		0	8
	2	S	19.20	.53	.65	100		1	46
		D	18.00	.56	.40	93		4	63
	3	S	19.70	.47	.40	96		5	26
		D	18.70	.53	.40	96		4	28
	4	S	18.30	.58	.46	95		1	28
		D	17.85	.58	.27	91		1	28
	5	S	18.30	.61	.20	91		1	43
		D	18.10	.63	.20	90		0	49
	6	S	18.30	.53	.52	96		0	43
		D	18.00	.53	.62	97		1	49
	8	S	20.90	12.96	.95	105		0	8
		D	19.00	14.95	2.75	48		0	11

Location: WILSON INLET

Date	Station	Depth	Temp. °C.	Cl °/oo	O_2	O_2 %	pH	PO_4-P	NO_3-N
1947									
7.ix	1	S	15.50	7.26	6.42	97		18	22
		D	16.00	18.16	4.88	75		11	6
	2	S	14.60	7.19	6.28	93		10	28
		D	14.50	14.23	4.15	59		8	28
	3	S	13.75	6.56	6.16	89		10	20
		D	13.80	8.16	5.73	84		10	30
	4	S	13.90	6.59	.65	82		18	28
		D	14.50	15.81	1.34	22		5	30
	5	S	14.00	7.14	6.16	90		12	11
		D	13.60	.61	5.88	86		11	28
	6	S	14.10	6.49	6.09	88		10	28
		D	13.40	9.30	5.82	86		10	28
	8	S	10.80	0.43	.82	74		37	3
		D	13.80	9.28	2.32	35		12	67
8.ix	7	S	11.30	0.56	5.73	74		20	3
		D	11.80	.97	.73	75		20	0
1948									
24.ii	1	S	23.00	15.39	5.42	102		24	3
		D	23.55	19.30	4.61	91		13	3
	2	S	22.50	14.90	5.12	95		14	3
		D	22.60	15.27	4.83	90		31	0
	3	S	22.40	13.64	.83	88		31	3
		D	22.50	14.72	.63	86		27	0
	4	S	23.00	.72	.81	90		13	3
		D	23.00	.72	.97	93		27	0
	5	S	22.60	.50	5.31	98		10	3
		D	22.70	.50	.30	98		12	3
	6	S	22.50	.50	.05	93		12	3
		D	22.60	.47	4.91	91		9	0
	7	S	24.20	13.73	5.03	95		6	3
		D	22.30	14.16	3.92	72		11	6
	8	S	24.40	12.61	4.44	83		31	3
		D	23.30	14.40	3.32	62		13	6
1948									
30-31.x	1	S	16.60	12.73	6.58	108		2	12
		D	16.30	16.78	4.46	76		12	9
	2	S	16.50	12.15	6.27	102		2	5
		D	16.20	.35	.27	101		1	9
	3	S	15.40	11.40	.27	99		2	0
		D	15.40	12.05	.27	100		2	2
	4	S	15.40	11.70	.39	101		1	2
		D	15.30	.82	.27	99		1	18
	5	S	15.30	.17	.39	100		0	15
		D	14.70	.12	.33	98		0	2
	6	S	15.40	.12	.44	101		1	9
		D	14.90	.12	.51	101		0	5
	7	S	14.90	7.25	.14	92			5
		D	16.60	10.32	4.87	78		0	12
	8	S	16.20	5.56	.81	72		0	5
		D	17.20	11.87	3.61	59		0	18
1949									
4.v	1	S	16.40	16.35	6.15	104		3	0
		D	16.10	.32	.10	103		5	0
	2	S	16.00	.58	.15	103		6	0
		D	16.00	.57	5.97	101		7	0
	3	S	16.00	.58	.72	98		8	0
		D	16.00	.58	.72	98		4	0
	4	S	15.80	.58	.80	98		6	0
		D	15.50	.60	6.03	101		7	0
	5	S	15.50	.56	5.65	95		8	0
		D	15.50	.55	.55	93		3	0
	6	S	15.80	.58	6.35	107		5	0
		D	15.50	.56	.15	103		0	0
	7	S	16.10	.01	4.60	77		5	0
		D	16.50	.06	.93	84		2	0
	8	S	17.30	.05	3.62	62		5	0
		D	16.70	.45	2.15	37		6	0

APPENDIX 7.4 (Cont'd)

Location: WILSON INLET

Date	Station	Depth	Temp. °C.	Cl °/oo	O_2	O_2 %	pH	PO_4-P	NO_3-N
1949									
25.viii	1	S	18.20	17.94	6.17	110		7	
		D	18.30	19.23	5.80	105		7	
	2	S	14.10	11.84	6.25	97		8	
		D	13.90	.92	.10	94		7	
	3	S	13.90	.69	.00	92		0	
		D	14.00	.74	.20	95		0	
	4	S	13.80	.79	.17	95		9	
		D	13.80	.82	.05	93		0	
	5	S	13.90	.69	.15	95		8	
		D	14.00	12.33	5.15	80		5	
	6	S	13.90		6.10				
		D	13.80	11.62	.10	94		0	
	7	S	12.00	0.97	5.75	77		2	
		D	13.50	12.53	1.16	18		4	
	8	S	13.20	7.13	5.40	78		3	
		D	12.90	13.23	0.50	8		2	
1950									
28.iv	1	S	17.10	17.82	5.89	103		8-10	0
		D	16.50	.84	.50	95		10-5	0
	2	S	17.70	.72	.38	95		5	0
		D	17.70	.74	.31	94		6	0
	3	S	17.50	.68	.13	90		6	0
		D	17.40	.69	.07	89		6	0
	4	S	17.90	.77	.34	95		6-11	0
		D	17.90	.82	.19	92		3-11	0
	5	S	17.20	.79	.55	97		7	0
		D	17.20	.84	.62	99		6	0
	6	S	17.40	.82	.41	95		6-12	0
		D	17.30	.87	.44	95		5-13	0
	7	S	17.00	16.79	4.77	82		7-8	0
		D	16.90	17.15	5.00	86		2-20	0
	8	S	18.80	.35	.37	96		6-28	0
		D	17.80	.54	4.06	79		9-11	0
1950									
3-4.xi	1	S	16.90	7.97	5.35	85	7.66	5	68
		D	17.10	12.90	4.25	71	.91	2	31
	2	S	16.80	7.51	5.50	85	.54	7-3	71
		D	16.70	8.09	.35	84	.55	4-24	130
	3	S	17.10	.16	.35	84	.51	7	77
		D	16.80	.10	.09	80	.52	5	115
	4	S	16.70	.07	.30	83	.58	6-6	45
		D	16.60	.06	.14	80	.59	6-8	53
	5	S	16.40	7.27	.05	78	.57	7	42
		D	16.30	.49	.35	82	.58	8	50
	6	S	16.70	.54	.61	86	.58	6-5	46
		D	17.30	14.14	3.32	56	.78	8-4	56
	7	S	18.30	4.49	4.18	65	.01	10-4	41
		D	16.50	6.45	5.21	78	.46	6-12	41
	8	S	16.40	0.77	4.25	61	6.23	11-4	72
		D	17.50	9.17	3.51	56	7.21	13-15	61

Location: WILSON INLET

Date	Station	Depth	Temp. °C.	Cl °/oo	O_2	O_2 %	pH	PO_4-P	NO_3-N
1951									
11.v	1	S	15.80	13.38	6.88	112	7.94	8-0	0
		D	15.70	13.38	6.88	112	7.92	5-0	0
	2	S	15.20	13.40	6.32	102	7.82	10	0
		D	15.20	13.40	6.35	103	8.02	11	0
	3	S	15.20	13.33	5.90	95	8.00	8	0
		D	15.20	13.37	5.38	87	7.90	10	0
	4	S	15.00	13.28	6.30	101	7.79	10-0	0
		D	14.90	13.27	5.88	94	7.77	9-0	0
	5	S	15.20	13.31	6.03	97	7.77	4	0
		D	15.20	13.32	6.50	105	7.80	7	0
	6	S	15.40	13.38	6.48	105	7.82	7-1	0
		D	15.10	13.38	6.67	106	7.82	3-5	0
	7	S	17.10	11.87	5.80	95	7.92	3-4	12
		D	15.90	12.68	5.60	90	7.92	5-3	14
	8	S	15.50	8.12	4.76	73	7.28	9-0	19
		D	15.50	13.25	4.13	67	7.45	9-16	14
12.x	1	S	17.30	8.37	5.32	84	7.72		17
		D	16.30	8.41	5.15	80	7.71		3
	2	S	17.20	14.10	5.21	87	7.67	12	13
		D	16.60	8.13	3.64	57	7.83	8	1
	3	S	16.60	9.42	3.22	51	7.82	2	7
		D	16.40	12.72	2.09	34	7.50	5	4
	4	S	16.40	8.03	4.67	73	7.59	5-9	0
		D	17.00	14.03	2.09	35	7.42	12-6	44
	5	S	17.10	7.81	4.56	71	7.68	3	7
		D	17.00	7.81	5.59	87	7.60	5	2
	6	S	16.80	7.84	4.75	74	7.74	2-9	4
		D	16.80	7.87	5.55	87	7.68	5-12	7
	7	S	15.90	0.50	3.34	47	6.44	2-14	5
		D	15.90	3.86	2.29	34	6.78	3-8	0
	8	S	15.80	7.14	2.02	31	7.10	51-14	0
		D	16.40	9.21	0.59	1	6.98	5-0	32
1952									
29.ii	1	S	22.30	17.20	4.83	92		20-0	0
		D	22.30	17.28	5.03	93		16-7	0
	2	S	22.30	16.99	4.55	86		20-7	0
		D	22.30	17.04	4.85	91		15-10	0
	3	S	22.30	16.78	5.14	97		5	0
		D	22.10	16.86	4.57	86		13	0
	4	S	22.00	16.83	4.79	90		11-3	0
		D	22.00	16.83	4.72	89		7-11	0
	5	S	22.00	16.76	4.79	90		11	0
		D	21.90	16.72	4.94	92		14	0
	6	S	22.00	16.71	4.97	92		3-12	0
		D	21.90	16.77	4.76	89		13-7	0
	7	S	22.80	15.80	4.20	79		6-4	0
		D	23.00	16.79	3.55	68		7-0	0
	8	S	24.50	14.83	3.60	69		27-7	0
		D	22.70	16.68	2.20	42		21-13	0

APPENDIX 7.4 (Cont'd)

Twenty-four hourly physico-chemical observations collected by CSIRO Division of Fisheries and Oceanography from the mouth of the Denmark River, Wilson Inlet, in 1948.

Location: WILSON INLET NO. 3 - MOUTH OF DENMARK RIVER

Date	Time	Tide (in.)	Air Temp. °C.	Water Temp. °C.	Cl °/oo	O_2	O_2 °/o	PO_4-P	NO_3-N
1948									
24.ii	4 pm	50	21.5	24.9	13.69	4.29	82	10	9
	5	50	19.3	.5					
	6	50	.0	.3	14.18	.72	89	17	0
	7	50	18.5	.1					
	8	50	.2	23.9	.15	.66	88	17	9
	9	50	17.0	.9					
	10	50	16.0	.7	.05	.26	80	17	9
	11	50	14.3	.5					
	12 m	50	12.0	.3	.00	.91	91	17	3
25.ii	1 am	50	.0	.1					
	2	50	11.2	22.3	13.64	.43	81	15	0
	3	50	10.5	21.5					
	4	50	9.2	.6	12.66	.55	81	15	3
	5	50	.0	22.3					
	6	50	8.2	.4	.45	.55	82	14	6
	7	50	.5	.3					
	8	50	12.7	.6	13.53	.29	78	15	3
	9	50	17.5	.8					
	10	50	20.5	.9	.49	.20	77	17	0
	11	50	22.5	23.1					
	12 n	50	23.7	.5	.36	.30	80	15	6
	1 pm	50	24.5	.6					
	2	50	.0	24.6	.87	.51	86	.18	3
	3	50	23.7	.3					
	4	50	22.8	.8	14.05	.58	87	24	6
30.x	8 am	22	12.2	16.9	2.80	5.41	80		15
	9	22	14.0	.8					
	10	22	.0	.7	3.42	.35	79		15
	11	22	13.8	.8					
	12 n	22	14.8	.5	.03	.35	79		15
	1 pm	22	15.5	.6					
	2	22	.0	.5	2.45	.47	80		12
	3	22	.0	.7					
	4	22	.2	.9	.06	.41	79		12
	5	22	14.5	.9					
	6	22	.0	.9	1.75	.53	81		15
	7	22	13.0	.7					
30.x	8 pm	22	13.0	16.8	1.57	5.53	81		12
	9	22	12.5	.7					
	10	22	.5	.9	.54	.47	80		12
	11	22	.5	.7					
	12 m	22	.5	.6	.49	.53	80		15
31.x	1 am	22	.5	.6					
	2	22	.8	.7	.59	.30	77		0
	3	22	.5	.7					
	4	22	.8	.6	.68	.35	78		9
	5	22	13.0	.4					
	6	22	.2	.4	.90	.35	78		12
	7	22	.8	.5					
	8	22	14.8	.4	2.24	.35	78		12

Analyses of sediment physical and chemical variables, made by CSIRO Division of Fisheries and Oceanography.

Location: WILSON INLET

Date	Station	Ins. P.	Ads. P.	Total P.	Total Fe	Org. C.	Total N.	°/o Silt
1946								
29.ix	1	8.0	45	945	7.0	39	3.4	18
	3	0	110	635	23.8	59	5.3	10
	4	0	122	675	41.2	64	5.4	63
	5	0	46	165	23.7	30	1.8	44
	6	0.4	114	590	29.4	44	4.4	10
	8	0	33	370	38.0	18	1.4	32
1948								
24.ii	1	2.0	35	525	18.2	52	5.2	10
	2	2.0	20	475	33.3	67	4.5	29
	3	0.4	135	545	47.6	83	4.6	8
	4	1.0	31	575	28.0	68	6.0	6
	5	0.5	94	375	22.5	26	3.1	3
	6	0	19	195	43.4	29	2.3	1
	7	6.0	24	265	39.6	67	2.9	69
	8	2.0	75	495	68.6	78	3.4	15
1950								
28.iv	1	1.0	18	680	14.0	48	5.0	3
	2	7.5	55	630	42.0	71	5.0	75
	3	1.0	60	500	62.0	71	3.8	3
	4	3.0	40	405	37.0	61	3.8	45
	5	0.2	18	160	16.0	53	2.5	9
	6	0	18	60	28.0	0	0	21
	7	0.2	59	330	45.0	66	4.2	5
	8	4.0	324	630	55.0	72	3.8	15
3-4.xi	1	5.0	0	880	17.0	62	6.7	8
	2	31.0	34	665	43.0	66	6.0	82
	3	3.0	62	765	40.0	70	6.2	6
	4	24.0	37	585	38.0	65	5.7	67
	5	0.5	72	600	77.0	75	5.2	2
	6	3.0	55	485	55.0	70	5.8	28
	7	0	16	230	54.0	48	2.8	23
	8	4.0	88	570	57.0	78	4.2	14

APPENDIX 7.4 (Cont'd)

SALINITY AND TEMPERATURE OBSERVATIONS AT GAUGING STATION 603136 ON THE DENMARK RIVER AT MOUNT LINDSAY.

DATE	SALINITY $^{o}/oo$	TEMPERATURE ^{o}C	DAILY FLOW RATE m^3/sec.
1/ 7/71	0.746	11.1	0.34546
21/ 7/71	0.580	11.1	0.89481
3/ 8/71	0.860	11.7	1.25727
11/ 8/71	1.140	11.1	1.01091
30/ 8/71	0.700	11.1	2.49189
5/10/71	0.225	13.9	4.58735
28/10/71	0.440	13.3	4.38913
27/11/71	0.220	16.7	5.04042
24/1 /72	0.700	21.1	0.02265
27/ 3/72	0.800	20.0	0.00028
9/ 5/72	0.920	13.3	0.02293
30/ 5/72	0.940	11.1	0.02038
39/ 6/72	0.620	9.4	0.60598

APPENDIX 7.4 (Cont'd)

MONTHLY MEANS OF DAILY MAXIMUM AND MINIMUM SURFACE WATER TEMPERATURES RECORDED FROM A JETTY ON THE WESTERN BANK OF WILSON INLET ADJACENT TO THE NUMBER 1 HYDROLOGICAL STATION, OVER THE PERIOD JULY 1971 TO MAY 1972

Month	Mean Temperature °C		Number of Observations
	Maximum	Minimum	
July	13	12	6
August	12	11	20
September	13	12	24
October	15	14	10
November	18	14	21
December	22	17	31
January	24	19	31
February	25	20	29
March	22	18	31
April	18	14	30
May	16	14	20
June	-	-	-

DISSOLVED OXYGEN RECORDED FROM THE WATERS OF WILSON INLET ON 11/1/1973

Station	Position	Temperature °C	Salinity ‰	O_2% saturation
1	Surface	23.4	20.3	87.44
	Bottom	23.2	20.3	72.13
2	Surface	23.5	20.4	95.00
	Bottom	23.5	20.4	105.84
4	Surface	23.3	20.1	98.92
	Bottom	23.3	20.1	98.88
6	Surface	23.3	20.1	99.50
	Bottom	23.3	20.0	101.55

SALINITIES ($^{o}/oo$) RECORDED FROM WILSON INLET

I Prior to the hydrological stations being established.

	Date	Position	Hay River	Denmark River	Wilson Inlet
*	11/1/71	Surface	25.4	24.0	-
		Bottom	26.9	27.7	-
	30/3/71	Surface	28.7	15.6	-
		Bottom	29.0	28.0	-
	29/6/71	Surface	16.1	11.2	23.3
		Bottom	-	26.0	23.3

II At Hydrological Stations

	Date	Position	Stations								
			1	2	3	4	5	6	7	8	9
*	22/9/71	Surface	17.7	17.7	31.8	17.2	16.3	16.4			
		Bottom	17.8	17.7	33.0	17.5	16.7	16.5			
*	20/11/71	Surface	11.7	11.4	10.9	10.3	10.5	10.0			
		Bottom	12.0	11.4	10.9	10.1	10.4	10.4			
*	11/12/71	Surface	11.5	11.0	10.8	10.7	10.6	10.7			
		Bottom	11.8	23.3	10.9	25.5	10.8	10.5			
*	29/1/72	Surface	17.9	16.7	16.5	16.3	16.0	16.1			
		Bottom	35.0	17.1	18.4	29.2	25.2	16.1			
	7/3/72	Surface	19.6	19.5	18.0	19.2	19.1	19.1			
		Bottom	19.5	19.5	19.1	19.1	19.1	19.1			
	6/3/72	Surface	17.3	17.3	17.5	17.4	17.5	17.6	17.6	17.7	17.8
		Bottom	17.3	17.3	17.6	17.6	17.9	17.8	17.8	17.9	17.8
*	27/9/72	Surface	13.9	13.7	13.5	13.3	13.0	13.1			
		Bottom	14.1	13.8	14.9	13.5	13.3	13.4			
	11/1/73	Surface	20.3	20.4	-	20.1	20.0	20.1			
		Bottom	20.3	20.4	-	20.1	20.0	20.0			
	Station Depth (ft) (Depth varies with tides and prevailing weather conditions)		4-5	12-15	12-15	18-20	18-20	18-20	16-17	10-11	8-9

* Indicates the estuary was open to the ocean.
N.B. Ocean salinity measured on the 7the July, 1971 was $35.653^{o}/oo$.

WATER TEMPERATURES (^{o}C) RECORDED FROM WILSON INLET

I Prior to the hydrological stations being established

	Date	Position	One mile east of the Denmark River mouth	Springdale
*	20/7/71	Surface	12.5	12.3
	20/7/71	Observed daily range		12.0 - 13.0

II At hydrological stations

	Date	Position	Stations								
			1	2	3	4	5	6	7	8	9
*	22/9/71	Surface	14.0	13.7	13.8	13.3	13.3	13.5			
		Bottom	14.2	13.7	13.4	12.8	12.7	12.7			
*	20/11/71	Surface	16.9	16.3	16.5	15.7	15.8	16.3			
		Bottom	16.6	16.1	16.5	14.8	14.4	15.3			
*	11/12/71	Surface	19.8	19.4	19.2	19.0	19.1	18.9			
		Bottom	19.5	18.5	19.1	18.2	19.2	18.7			
*	29/1/72	Surface	23.4	22.5	22.3	22.2	22.3	22.5			
		Bottom	21.2	22.3	22.7	22.3	21.7	22.4			
	7/3/72	Surface	21.9	22.6	22.4	21.9	22.0	22.0			
		Bottom	21.9	22.5	22.2	21.8	21.8	21.9			
	6/7/72	Surface	11.4	11.0	11.1	11.2	11.0	11.1	11.3	11.4	11.6
		Bottom	11.3	11.0	11.0	10.9	10.8	10.7	11.0	11.1	11.6
*	27/9/72	Surface	16.7	15.7	15.5	15.4	15.9	15.9			
		Bottom	16.5	15.4	14.4	14.8	14.9	14.8			
	11/1/73	Surface	23.4	23.5	-	23.3	23.3	23.3			
		Bottom	23.2	23.5	-	23.3	23.3	23.3			
	Station Depth (ft) (Station depth varies with tides and prevailing weather conditions)		4-5	12-15	12-15	18-20	18-20	18-20	16-17	10-11	8-9

* Indicates the estuary was open to the ocean.

APPENDIX 7.4 (Cont'd)

Surface water nutrients, chlorophyll a and phaeophytin concentrations for five sites on Wilson Inlet or its tributaries, collected by the Department of Conservation and Environment during 1980. All units are μg/L.

DENMARK 1. River - Railway Bridge

DATE	PO_4-P	ORG-P	TOT-P	NH_4-N	NO_3/NO_2	ORG-N	TOT-N	CHLORO-A	PHAEOPHYTIN
14.i	20	8	27	18	14	939	971	1.25	0.89
18.ii	16	24	40	19	4	1249	1271	0.00	0.00
23.iv	41	36	77	81	118	841	1040	0.00	11.21
25.v	7	127	134	30	42	284	356	0.00	0.48
02.vii	12	35	47	55	270	519	844	0.21	0.75
28.vii	31	34	65	30	149	747	925	0.39	0.49
19.viii	20	33	53	7	24	718	749	0.45	0.89
17.ix	28	31	59	28	30	605	663	1.10	0.83
23.x	20	14	34	19	15	537	571	0.00	0.00
17.xi	8	38	45	40	10	455	505	0.00	0.00
16.xii	6	-	-	2	4	-	-	0.00	0.00

DENMARK 4 Agricultural Drain

DATE	PO_4-P	ORG-P	TOT-P	NH_4-N	NO_3/NO_2	ORG-N	TOT-N	CHLORO-A	PHAEOPHYTIN
18.xi	37	74	111	19	4	1182	1204	0.00	0.00

APPENDIX 7.4 (Cont'd)

SLEEMAN RIVER

DATE	PO_4-P	ORG-P	TOT-P	NH_4-N	NO_3/NO_2	ORG-N	TOT-N	CHLORO-A	PHAEOPHYTIN
07.vi	96	58	154	28	63	1233	1324	0.00	0.00
02.vii	263	61	324	56	145	1703	1904	1.92	5.13
06.vii	103	78	181	63	193	1587	1842	0.00	0.00
18.vii	292	65	357	34	180	2177	2391	0.00	0.00
29.vii	266	61	327	42	50	1951	2043	1.66	4.03
01.ix	115	46	160	36	60	1594	1690	0.00	0.00
17.ix	174	104	278	35	20	1810	1865	0.00	0.00

95

HAY RIVER

DATE	PO_4-P	ORG-P	TOT-P	NH_4-N	NO_3/NO_2	ORG-N	TOT-N	CHLORO-A	PHAEOPHYTIN
02.vii	18	38	55	64	39	510	613	0.85	0.59
06.vii	20	5	25	13	150	710	952	0.00	0.00
18.vii	21	40	61	25	478	845	1348	0.00	0.00
29.vii	43	25	67	27	108	980	1024	0.45	0.90
01.ix	5	17	22	48	5	585	638	0.00	0.00
17.ix	87	78	165	41	15	1313	1369	0.00	0.00
23.x	-	-	-	23	11	763	797	0.00	0.00

APPENDIX 7.4 (Cont'd)

DENMARK 2. Sandflat in mouth of Denmark River

DATE	PO_4-P	ORG-P	TOT-P	NH_4-N	NO_3/NO_2	ORG-N	TOT-N	CHLORO-A	PHAEOPHYTIN
14.i	9	30	39	46	9	877	931	1.07	0.85
18.ii	7	19	26	18	5	846	869	0.00	0.00
23.iv	4	32	36	7	8	696	710	1.39	0.77
27.v	3	45	48	23	11	122	156	0.00	0.48
02.vii	-	-	-	-	-	-	-	-	-
28.vii	3	17	19	58	58	688	803	1.53	0.60
19.viii	6	21	27	1	36	662	699	10.94	0.00
17.ix	1	64	65	33	5	569	607	8.54	1.23
23.x	0	22	22	21	12	428	461	0.00	0.00
18.xi	-	-	-	-	-	-	-	-	-
16.xii	-	-	-	-	-	-	-	-	-

APPENDIX 7.4 (Cont'd)

DENMARK 3. Middle of Inlet

DATE	PO_4-P	ORG-P	TOT-P	NH_4-N	NO_3/NO_2	ORG-N	TOT-N	CHLORO-A	PHYAEOPHYTIN
14.i	4	22	26	19	2	938	958	0.75	0.45
18.ii	7	16	23	17	4	949	969	0.00	0.00
23.iv	3	9	12	13	4	690	707	1.50	1.39
27.v	1	26	27	21	5	344	369	0.22	-.11
02.vii	-	-	-	-	-	-	-	-	-
28.vii	0	27	27	66	45	539	650	0.81	0.10
19.viii	5	20	24	1	20	509	530	1.73	2.16
17.x	9	18	26	23	11	487	521	0.00	0.00
18.xi	-	-	-	-	-	-	-	-	-
16.xii	-	-	-	-	-	-	-	-	-

7.5 A checklist of saltmarsh plants collected during June 1982 at Wilson Inlet.

Bracketed numbers refer to pressed field specimens lodged at DCE.

Ruppiaceae

Ruppia megacarpa

Poaceae

Cynodon dactylon
Hemarthria uncinata
Paspalum distichum
Sporobolus virginicus

Cyperaceae

Baumea juncea
Lepidosperma gladiatum
Scirpus marginatus
Scirpus nodosus

Restionaceae

Restionaceae sp
Restionaceae sp

Juncaceae

Juncus kraussii

Proteaceae

Banksia littoralis

Olacaceae

Olax phyllanthi

Polygonaceae

Muehlenbeckia adpressa

Chenopodiaceae

Atriplex paludosa
Sarcocornia blackiana
Sarcocornia sp (3)

Aizoaceae

Carpobrotus sp (1)

Leguminosae subfam. Papilionoideae

Gastrolobium floribundum

Geraniaceae

**Pelargonium capitatum*

APPENDIX 7.5 (Cont'd)

Frankeniaceae

Frankenia pauciflora

Myrtaceae

Melaleuca cuticularis
Melaleuca raphiophylla

Apiaceae

Apium prostratum

Primulaceae

Samolus repens

Myoporaceae

Myoporum caprarioides

Goodeniaceae

Scaevola crassifolia

Asteraceae

**Arctotheca populifolia*
**Dittrichia graveolens*
Olearia axillaris

Unidentified specimens	4,5,6,11,12,17,55,74
Partially identified specimens	1,2,3,13,14,19,22,26,39,52,62, 64,68

*Denotes exotic species

7.6 A checklist of fishes and commercial crustaceans of Wilson Inlet. (Lennanton 1974a.)

Species	Type
PETROMYZONES	
MORDACIIDAE	
Geotria australis	
TELEOSTOMI-Commercial Species	
MUGILIDAE	
Aldrichetta forsteri	Estuarine-Marine
Mugil cephalus	Estuarine-Marine
SILLAGINIDAE	
Sillago punctata	Estuarine-Marine
PLOTOSIDAE	
Cnidoglanis macrocephalus	Estuarine-Marine
ARRIPIDAE	
Arripis georgianus	Marine
Arripis trutta esper	Marine
HEMIRAMPHIDAE	
Hemiramphus melanochir	Estuarine-Marine
Hemiramphus sp.	
SPARIDAE	
Chrysophrys unicolor	Estuarine-Marine
Rhabdosargus sarba	Estuarine-Marine
Mylio butcheri	Estuarine
PLATYCEPHALIDAE	
Platycephalus fuscus	Estuarine-Marine
Platycephalus bassensis westralie	Estuarine-Marine
CARANGIDAE	
Usacaranx georgianus	Estuarine-Marine
PLEURONECTIDAE	
Ammotretis rostratus	Estuarine-Marine
POMATOMIDAE	
Pomatomus saltator	Estuarine-Marine
ENGRAULIDAE	
Engraulis australis fraseri	Estuarine-Marine

APPENDIX 7.6 (Cont'd)

Species	Type
TELEOSTOMI-Commercial Species (Cont'd)	
BALISTIDAE	
Navodon multiradiatus	Estuarine-Marine
LABRIDAE	
Achoerodus gouldii	Estuarine-Marine
Pseudolabrus punctalatus	Estuarine-Marine
TELEOSTOMI-Non-Commercial Species	
KYPHOSIDAE	
Scorpis aequipinnis	
Kyphosus sydneyanus	
Melambaphes zebra	
TETRAODONTIDAE	
Contusus richei	
GOBIIDAE	
Pseudogobius olorum	
Glossogobius suppositus	
Callogobius mucosus	
ATHERINIDAE	
Atherinisoma sp.	
CLINIDAE	
Cristiceps australis	
GONORHYNCHIDAE	
Gonorhynchius greyi	
APLODACTYLIDAE	
Crinodus lophodon	
ENOPLOSIDAE	
Enoplosus armatus	
TRIGLIDAE	
Chelidonichthys kumu	
PEMPHERIDAE	
Schuetta woodwardi	
MORIDAE	
Physiculus barbatus	
URANOSCOPIDAE	
Ichthyscopus barbatus	

APPENDIX 7.6 (Cont'd)

Species	Type
TELEOSTOMI-Freshwater Introduced Species	
SALMONIDAE	
Salmo gairdneri	
CRUSTACEA	
PORTUNIDAE	
Portunus pelagicus	
Ovalipes australiensis	

8. BIBLIOGRAPHY

A community plan for Denmark (1980) A final honours School of Geog. Report, Dept. of Geog., University of Western Australia.

Adams, A.B. (1924) Clearing heavily timbered areas for pasture in the South-West. *J. Agric. West. Aust.* 1, (2nd Series), 182-188.

Anon. (1908) Westward of Albany. *J. Dept. Agric. West. Aust.* 16, (1st Series), 480-481.

Anon. (1909) The Denmark Estate. *J. Dept. Agric. West. Aust.* 18, (1st Series), 292-297.

Australia (1962) Climatological Survey Region 12 - Albany, Western Australia. Commonwealth Bureau of Meteorology, Melbourne.

Beard, J.S. (1979) The vegetation of the Albany and Mt. Barker areas. Vegmap Publ., Perth.

Birmingham, A., Packham, D.R. and R.G. Vines (1971) The age of the petrified forest near Denmark, Western Australia. *Search* 2, 11-12, 434-435.

Boehm, E.W., and Pym. L.W. (1950) The Denbarker reconnaissance. CSIRO Aust. Div. Soils divl Rep. No. 7/50.

Bridgewater, P.B., Rosser, C. and de Corona, A. (1981) The saltmarsh plants of southern Australia. Clayton, Vic., Botany Dept., Monash Univ.

Buchanan, G. (1902) Through the Gippsland of Western Australia. *J. Dept. Agric. West. Aust.* 6, (1st Series), 381-384.

Burvill, G.H. (1939) A soil survey of the Denmark Agricultural Research Station, Western Australia. *J. Dept. Agric. West. Aust.* 16, (2nd Series), 243-57.

Caputi, N.G. and Lenanton, R.C.J. (1977) A Survey of the Recreational Usage of South Coastal Estuaries of Western Australia. Report No. 27, Dept. of Fisheries and Wildlife, Western Australia.

Carroll, D. (1945) Mineralogy of some soils from Denmark, Western Australia. *Soil Sci.*, 60, 6, 413-426.

Chapman, V.J. (1960) Salt marshes and salt deserts of the world. Leonard Hill (Books) Ltd., London.

Chapman, V.J. (1977) Ecosystems of the world I. Wet coastal ecosystems. Elsevier Sci. Publ. Co., Amsterdam.

Christianson, I.G., Clayton, M.N., Allender, R.B. (1981) Seaweeds of Australia. Reed, Sydney.

Christensen, P. (1980) A forest worth preserving. A report on a biological survey of the area of Vacant Crown Land situated immediately to the east of the Denmark River Catchment. Confidential report of Forests Department, W.A.

Christensen, P. (1980) A Forest Worth Preserving. Forests Department of W.A. (Denbarker). Unpublished.

Clarke, E. de C., Phillips, H.T., and Prider, R.T. (1954) The Precambrian geology of part of the south coast of Western Australia. *J. Roy. Soc. West Aust.* 38, 1-64.

Clifford, P.J. (1977) The hydrologic behaviour of south west forested catchments. M.App. Sc. (Physics) Thesis, West. Aust. Inst. Tech.

Coastal Planning Steering Committee (1981) Coastal planning and management in Western Australia. A report to the Conservation and Environment Council.

Collins, P.D.K. and Fowlie, W.G. (1981) Denmark and Kent River basins water resources survey. Engineering Div., Public Works Dept., W.A. (Water Resources Branch).

Conacher, A,J. *et al.* (1981) Environmental studies of estuaries and their catchments in Western Australia. I. Preliminary investigation of the Hay River catchment and Wilson Inlet, Denmark: development of a methodology. Unpubl. report of Dept. Geog. UWA.

CSIRO Divisional Report No. 20. (1943) Report on soils and other agricultural features of certain areas in the south west of W.A.

Dairy Division (1969) More butterfat per acre at Denmark Research Station. *J. Agric. West. Aust.* 10, 11, 459-463.

Dakin, W.J. (1973) Australian seashores. Angus & Robertson, Sydney.

Enright, N.J. (1978) The interrelationship between plant species distribution and properties of soils undergoing podzolisation in a coastal area of SW Australia. *Aust. J. Ecol.* 3, 389-401.

Erickson, R., George, A.S. Marchant, N.G., Morcombe, M.K. (1973) Flowers and plants of Western Australia. Reed, Sydney.

Filmer, J.F. and Underwood, E.J. (1934) Denmark Wasting Disease. *J. Agric. West. Aust.* 11 (2nd Series), 24-28.

Filmer, J.F. and Underwood, E.J. (1934) Denmark Wasting Disease. *J. Agric. West. Aust.* 11 (2nd Series), 590-591.

Gardner, C.A. (1957) The Fire Factor in relation to the vegetation of Western Australia. W.A. Naturalist 5: 116-173.

Hallam, S.J. (1975) Fire and hearth. Aust. Aboriginal Studies No. 58. Aust. Inst. Abor. Studies, Canberra.

Harvey, R.J. (1937) The Denmark Wasting Disease. *J. Agric. West. Aust.* 14 (2nd Series), 386-393.

Hassell, C.W. (1962) Estuarine sedimentation on the south coast of Western Australia, with particular reference to Nornalup Inlet. Ph.D Thesis, Department of Geology, University of Western Australia (Unpublished).

Hirschberg, K.J.B. (1976) Geology and hydrology of the Albany-Mount Barker area. Record 1976/14. Geological Survey of Western Australia.

Hodgkin, E.P. and Sheard, K. (1959) Rottnest Island: the Rottnest biological station and recent scientific research. *J. Roy. Soc. W.A.* 42(3): 65-95.

Hodgkin, E.P. and Majer, K. (1978) An index to ecological information on estuaries and marine embayments in Western Australia. CSIRO Div. Fish. Oceanogr. Report 70.

Hodgkin, E.P. and Lenanton, R.C. (1981) Estuaries and coastal lagoons of south western Australia. Estuaries and nutrients. Eds. B.J. Neilson and L.E. Cronin. Humana Press, Clifton, N.J.

Hodgkin, E.P. (1981) The Wilson Inlet estuarine system. Unpublished report, Department of Conservation and Environment, W.A., 1981.

Hodgkin, E.P. & Hesp, P.A. (1982) A comparative study of the coastal lagoons of south western Austra. Department of Conservation and Environment, unpublished report.

Hosking, J.S. and Burvill, G.H. (1938) A soil survey of part of the Denmark Estate, Western Australia. Council for Sci. and Indus. Res. Bull. 115.

Hutchins, B. (1979) The fishes of Rottnest Island. Creative Research, Perth.

Johnson, W. (1950) Report on deposits containing concentrations of heavy minerals on D.C. 20H, near Denmark, W.A. West Australia Dept. Mines Ann. Rept. 1948, p. 96-97.

Kessell, S.R. (1981) Application of gradient analysis concepts to resource management modelling. *Proc. Ecol. Soc. Aust.* 11: 163-173.

Kowarsky, J. (1975) Strategy and zoogeographic Implications of the persistence of the estuarine catfish *Cnidoglanis macrocephalus* (Val) (Plotosidae) in estuaries of south western Australia. Ph.D Thesis, Zoology Dept. University of Western Australia (Unpublished).

Lake, J.S. (1971) Freshwater fishes and rivers of Western Australia. Thomas Nelson (Australia) Ltd.

Lenanton, R.C.J. (1972) Bibliography of information relating to the south western Australian estuarine environment. Fisheries Bull. 11. W.A. Dept. Fish. & Wildlife.

Lenanton, R.C.J. (1974) Fish and crustacea of the Western Australian south coast rivers and estuaries. Fisheries Research Bulletin No. 13, Department of Fisheries and Fauna, Western Australia.

Lenanton, R.C.J. (1974) Wilson Inlet - a seasonally closed Western Australian south coast estuary. Dept. Fish. and Fauna, W.A. Report 14.

Lenanton, R.C.J. 1974b) Wilson Inlet. A seasonally closed Western Australian south coast estuary. Report No. 14. Department of Fisheries and Fauna, Western Australia.

Lenanton, R.C.J. (1979) The inshore marine and estuarine licensed amateur fishery of Western Australia. Fisheries Research Bulletin No. 23, Western Australian Department of Fisheries and Wildlife.

Morris, P.D., Rosman, K.J.R. and de Laeter, J.R. (1978) Cadmium levels in coastal and estuarine waters of Western Australia. *J. Roy. Soc. West. Aust.* 61, 1, 19-23.

McArthur, W.M. and Clifton, A.L. (1975) Forestry and agriculture in relation to soils in the Pemberton area of Western Australia. Soils and Land Use Series 54, CSIRO, Melbourne.

Nind, S. (1831) Description of the natives of King George Sound (Swan River Colony) and adjoining country. *Journ. R. Geogr. Soc.* 1: 21-51.

Noldart, A.J. (1960) Report on heavy mineral concentrations on D.C. 66H, Wilson Inlet, S.W. Division. Western Australia Geol. Survey Bull. 114.

Northcote, K.H., Bettenay, E., McArthur, W.M. and Churchward, H.M. (1967) Dominant soils of the Perth-Albany-Esperance area. Atlas of Australian Soils Sheet 5. CSIRO, Melbourne.

Parry and Rosenthal (1979) Nullaki. Preliminary report for Palos Verdes Estates Pty. Ltd.

Radok, R. (1976) Australia's coast. An environmental atlas guide with baselines. Rigby Limited, Adelaide, 100p.

Samuel, L.W. (1951) The salinity and hardness of some rivers and streams in the south west of W.A. Annual report of the Government Chemical Laboratories for 1949, Agriculture, Forestry and Water Supply Div. Appendix pp 159-163.

Scott, T.D., Glover, C.J.M., Southcott, R.V. (1974) The marine and freshwater fishes of South Australia. Government printer, Adelaide.

Smith, G.G. (1973) A guide to the coastal flora of south western Australia. W.A. Naturalists' Handbook 10.

Smith, R. (1952a) The soils of the south west's agricultural region. B. Smity, Dublin.

Smith, R. (1952b) Soils of the south western agricultural region. Thesis, University of Western Australia. Unpublished.

Spencer, R.S. (1952) Oceanographical station list of investigations made by the Division of Fisheries, CSIRO, Australia, Vol. 8, CSIRO, Melbourne.

Sten, T. (1943) Agricultural development in the Hay River area of Western Australia. M.A. Thesis, University of Western Australia.

Stokes, J.L. (1846) Discoveries in Australia, 2 vols. T & W Boone, London.

Strickland, G.R. (1977) A study of the decline on dairy cattle numbers in the Denmark Shire. Unpublished field report, Department of Geography, University of W.A.

Sundstrom, P. (1981) Albany woodchipping: if they don't move, clearfell them. *Environment W.A.* 4(1): 46-49.

Teakle, L.J.H. (1938) Notes on potato and vegetable soils of the Albany District lying between Albany and Bornholm. Unpublished Ms.

Teakle, L.J.H. and Southern, B.L. (1937) The peat soils and related soils of Western Australia. *J. Ag. W.A.* 14, 332-352, 404-424.

The Geology of Western Australia (1974) W.A. Geol. Survey, Mem. 2.

Thompson, L. (1898) Report on the marine fisheries on the south and south western coasts of the colony of Western Australia. (Parl. Pap. 6 of 1898). Govt. Printer, Perth.

Treloar, J. (1977) Southwest Coast Estuarine Study. Unpublished, Department of Conservation and Environment, W.A.

UNESCO-FAO (1963) A bioclimatic map of the Mediterranean zone and its homologues. UNESCO Adv. Cttee. on Arid Zone Research 21: 7-58 UNESCO, Paris.

Western Australia (1923) The inlets and rivers of the south coast - a great national asset. Western Australian Tourists' guide and Hotel and Boarding House Directory.

Western Australia (1954) Opening of Wilson Inlet bar. *Mon. Serv. Bull. Fish. Dept. West. Aust.* 3, 1, 233.

Western Australia (1954) Seining at Wilson Inlet. *Mon. Serv. Bull. Fish. Dept. West Aust.* 3, 6, 196-197.

Western Australia (1956) Estuarine research programme. *Mon. Serv. Bull. Fish. Dept. West. Aust.* 5, 4, 45-46.

Western Australia (1956) Estuarine research programme ends. *Mon. Serv. Bull. Fish. Dept. West. Aust.* 5, 11, 151.

Western Australia (1963) Better opening at Wilson Inlet. *Mon. Serv. Bull. Fish. Dept. West. Aust.* 12, 9, 231-231.

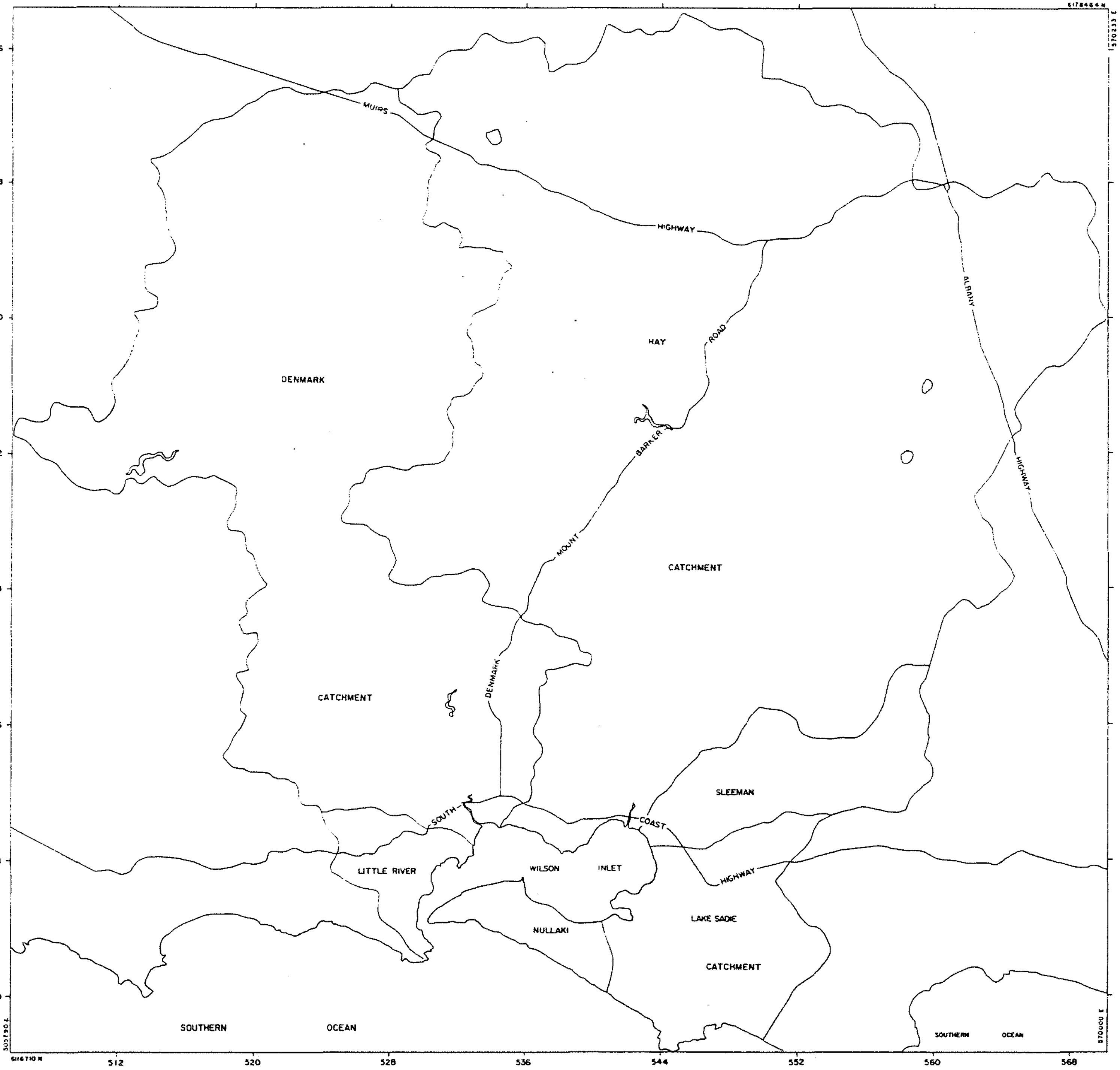
Western Australia (1972) Streamflow records of Western Australia 1934 to 1970. Vol. I. Basins 601-611. Water Resources Section, Planning Design and Investigation Branch, Public Works Department, Western Australia.

Western Australia (1978) South Coast Fisheries Parliamentary Study Committee.

Wright, P.B. (1971) Spatial and temporal variations in seasonal rainfall in south western Australia. Miscellaneous Publication 71/1 Agronomy Department, Institute of Agriculture, University of Western Australia.

Yale Dawson, E. (1956) The seaweeds. W.C. Brown Co. Publ, Dubuque, Iowa.

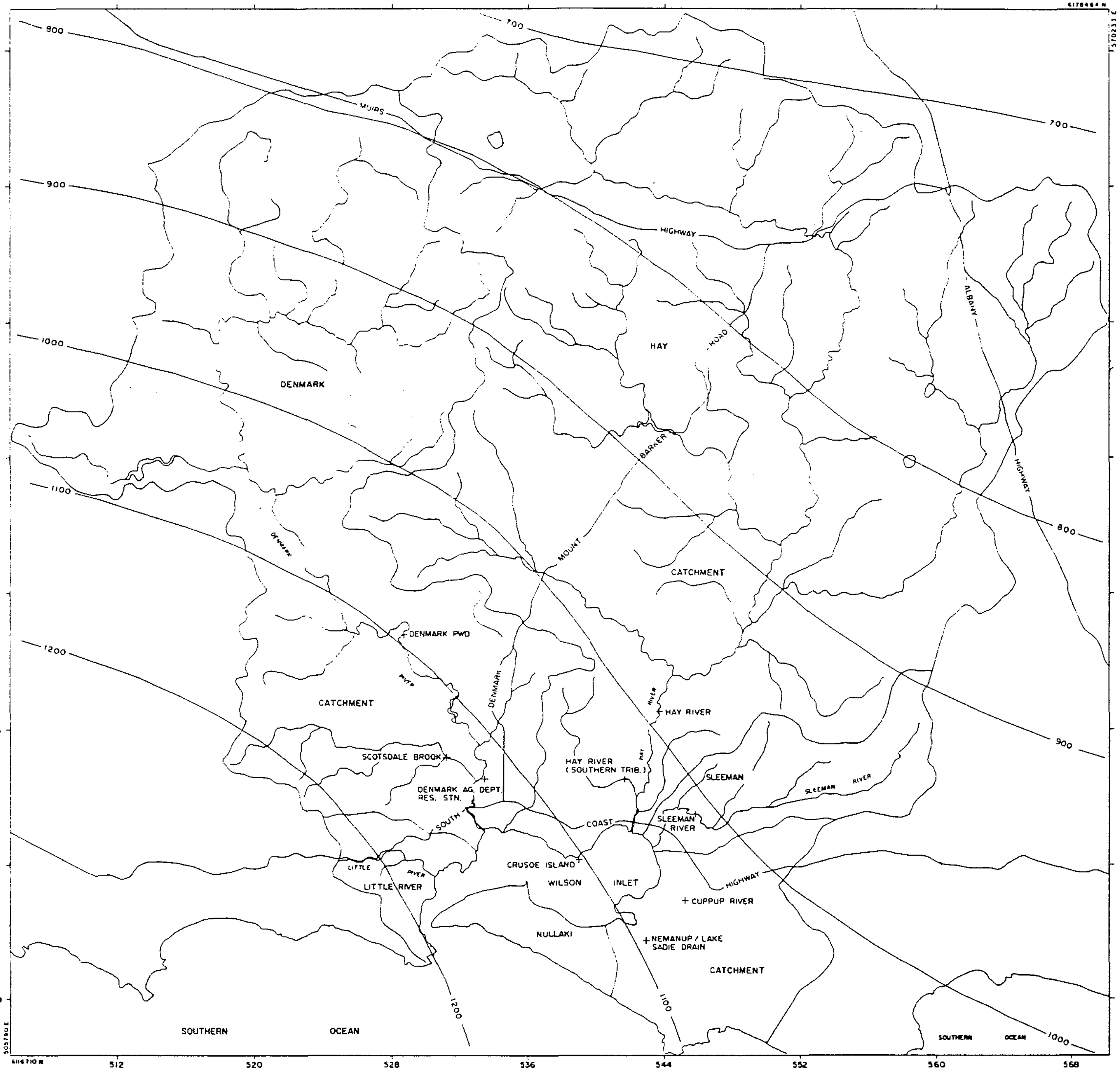
MAP 1. WILSON INLET RESOURCE INVENTORY - BASE MAP I



0 10 20 KM

ESRI-AUSTRALIA PTY. LTD.
18 PROWSE STREET, WEST PERTH, W.A. 6005
PHONE (09) 322 4866

MAP 2. WILSON INLET RESOURCE INVENTORY - BASE MAP 2

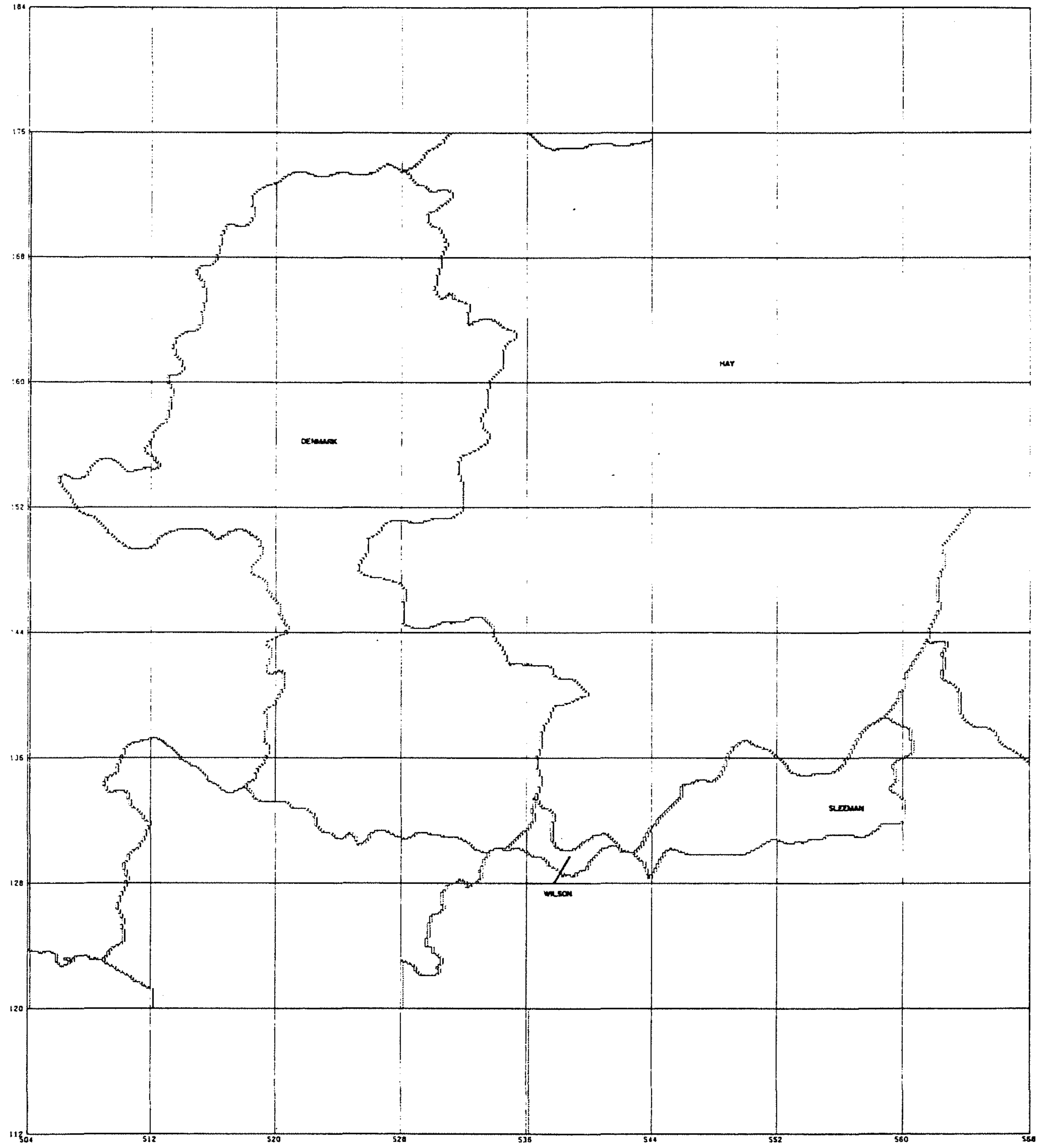


0 10 20 Km

+ GAUGING STATIONS

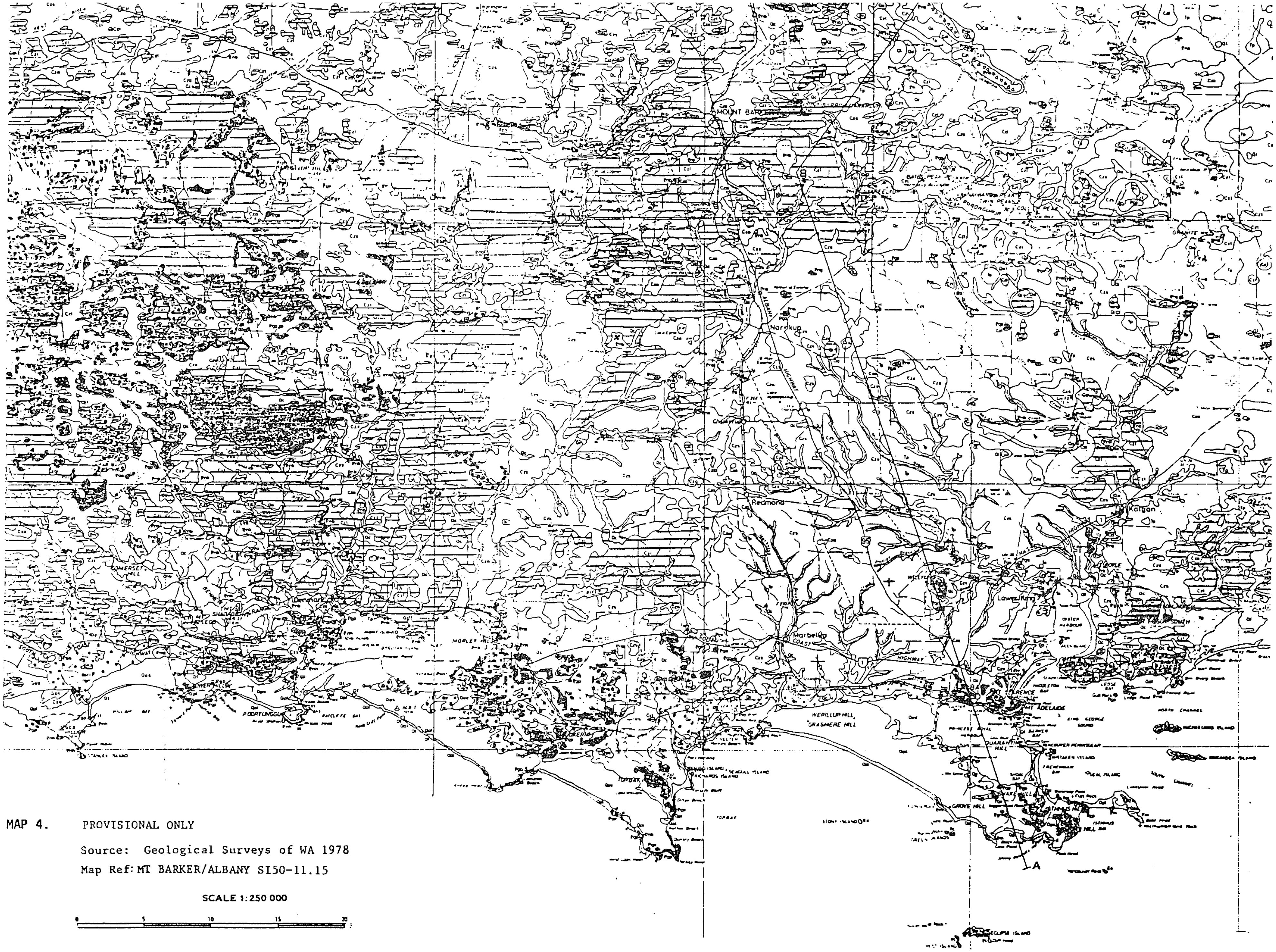
—700— ANNUAL AVERAGE ISOHYETS (mm)

ESRI-AUSTRALIA PTY. LTD.
18 PROWSE STREET, WEST PERTH, W.A. 6005
PHONE (09) 322 4955



MAP 3. DATE : 82/07/19 WILSON INLET RIVER CATCHMENTS

0 10 20Km



MAP 4. PROVISIONAL ONLY

Source: Geological Surveys of WA 1978

Map Ref: MT BARKER/ALBANY SI50-11.15

SCALE 1:250 000

0 5 10 15 20

REFERENCE

CAINOZOIC

QUATERNARY

Ql | Qe | Qed | Qpl | Qps | Qa | Ql | Qd | Qc

Ql Sand – beach and dune; unlithified mobile sand
Qe Estuarine and lagoonal deposits – clay, silt and sand
Qed Sand dunes on Qe – poorly lithified; vegetated
Qpl Limestone – cross-bedded calcareous sand in calcareous matrix
Qps White quartz sand on, and adjacent to, limestone

Qa Clay, silt, sand and gravel in watercourses
Ql Lake and swamp deposits – sand, silt, clay; may be saline and/or gypsiferous
Qd Mixed alluvium and lake deposits with sand dunes – marginal to lakes; gypsiferous in part
Qc Colluvium – sand, silt, clay

Cza | Czs | Czl | Czb

Cza Alluvium and colluvium – pebbles, sand, silt and clay; includes unlithified as well as lateritized lithified deposits present in old flat-bottomed valleys which contain lakes
Czs Sand – white, grey or brown; commonly contains iron pisoliths and overlies laterite
Czl Laterite – massive and pisolitic deposits; includes both in situ and clastic types interbedded with sandstone
Czb Silcrete – includes friable sandstone

TERTIARY

Ts Sandstone, medium-grained; friable

Tp PLANTAGENET GROUP : mostly PALLINUP SILTSTONE; spongolite with minor siltstone and sandstone; includes Nanarup Limestone Member of the WERILLUP FORMATION

PROTEROZOIC

d Dolerite and diorite dykes; dashed line indicates soil-covered dyke

q Quartz dykes and veins

Ᵽsa | Ᵽss

STIRLING RANGE FORMATION
Ᵽsa Sandstone, quartzite
Ᵽss Sandstone, shale (slate, phyllite)

Ᵽd Dolerite dykes and sills in the STIRLING RANGE FORMATION; variably deformed and recrystallized

Ᵽgh | Ᵽga | Ᵽgp | Ᵽge | Ᵽgm | Ᵽm

Ᵽgh Hornblende-bearing granite to quartz monzonite
Ᵽga Augen gneiss; developed from Ᵽgp
Ᵽgp Porphyritic biotite granite and adamellite
Ᵽge Medium even-grained biotite adamellite
Ᵽgm Mixed granitic rocks; mostly porphyritic and even-grained varieties
Ᵽm Migmatite; granoblastic or gneissic palaeosome (Ᵽnb, Ᵽna) and allotriomorphic granular neosome of Ᵽgp

Ᵽg Unassigned metamorphic and igneous rocks on islands

Ᵽn | Ᵽns | Ᵽna | Ᵽng | Ᵽnb | Ᵽnh

Ᵽn Gneiss; unassigned
Ᵽns Gneiss, granoblastic granite, adamellite with streaks of mafic minerals (biotite, hornblende or pyroxene) or magnetite, garnet common; includes minor layered and granofelsic rocks
Ᵽna Augen gneiss; coarse-grained with microcline augen
Ᵽng Granitic gneiss; fine to medium-grained with subordinate megacrystic varieties; weak foliation; granoblastic texture
Ᵽnb Quartz-feldspar-biotite (-garnet-hypersthene) gneiss; compositionally layered gneiss with subordinate Ᵽns and granofels; includes amphibolite and mafic granulite layers, granoblastic fabric
Ᵽnh Heterogeneous compositionally layered gneiss rich in enclaves; more than one period of migmatization and isoclinal folding

Ᵽa | Ᵽi | Ᵽq

Ᵽa Medium-grained mafic rock; amphibolite and granulite
Ᵽi Banded quartz-magnetite (hematite) (-chlorite-amphibole) rock; metamorphosed banded iron-formation
Ᵽq Quartzite

ARCHAEAN

Ag | Agv | Agp | Age | Agm

Ag Granitoid; unassigned
Agv Medium-grained adamellite; granite with scattered to locally abundant feldspar megacrysts
Agp Porphyritic adamellite and granite with microcline megacrysts
Age Medium even-grained biotite adamellite and granite
Agm Mixed porphyritic and even-grained biotite adamellite and granite

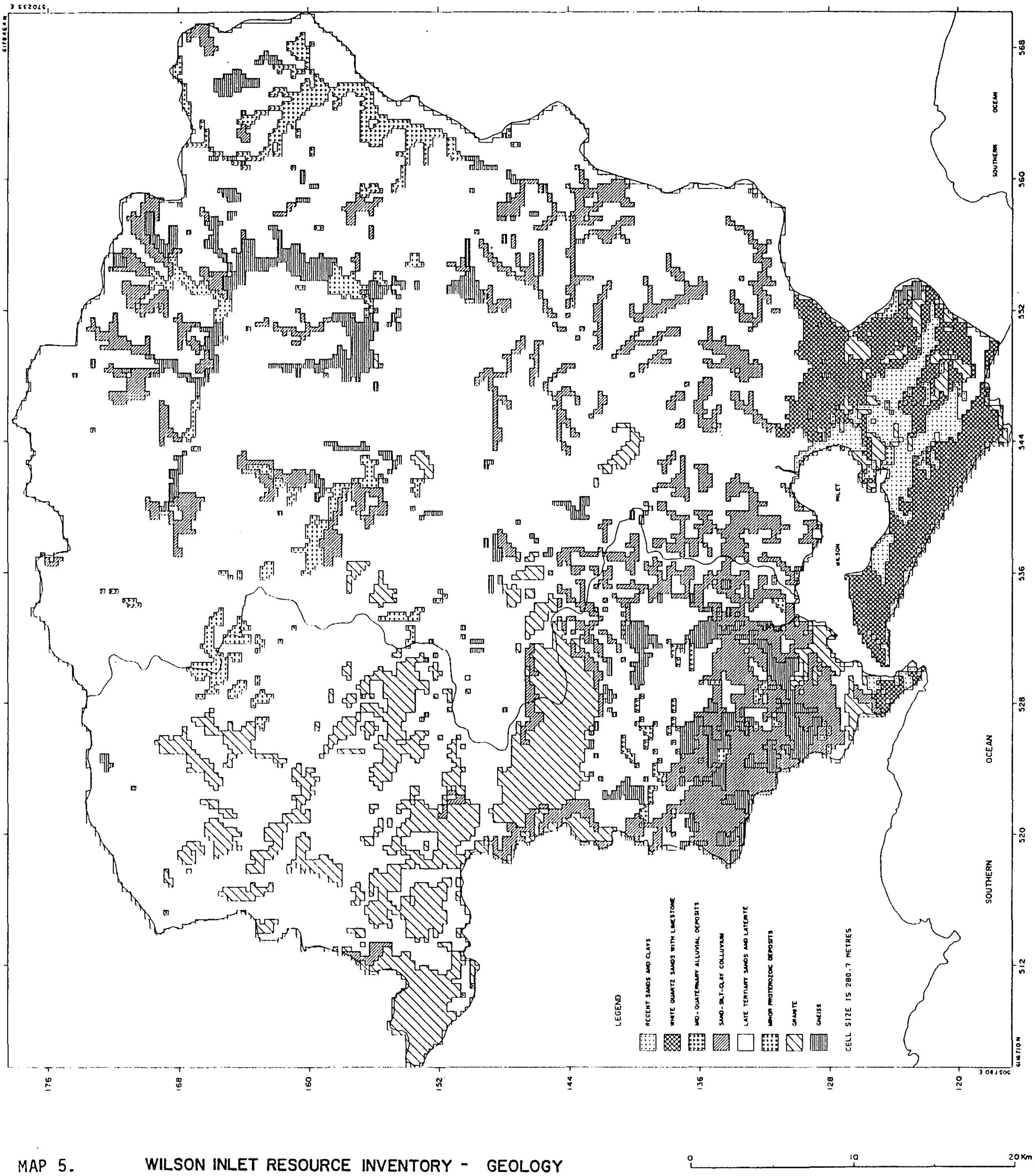
Ans | Am

Ans Gneiss; granoblastic adamellite, granodiorite and tonalite with streaks of biotite or hornblende, garnet common; includes minor banded and granofelsic rocks
Am Migmatite; granoblastic or gneissic palaeosome in allotriomorphic granular neosome of medium, even-grained biotite adamellite

Aa | Ai | Aq | Al

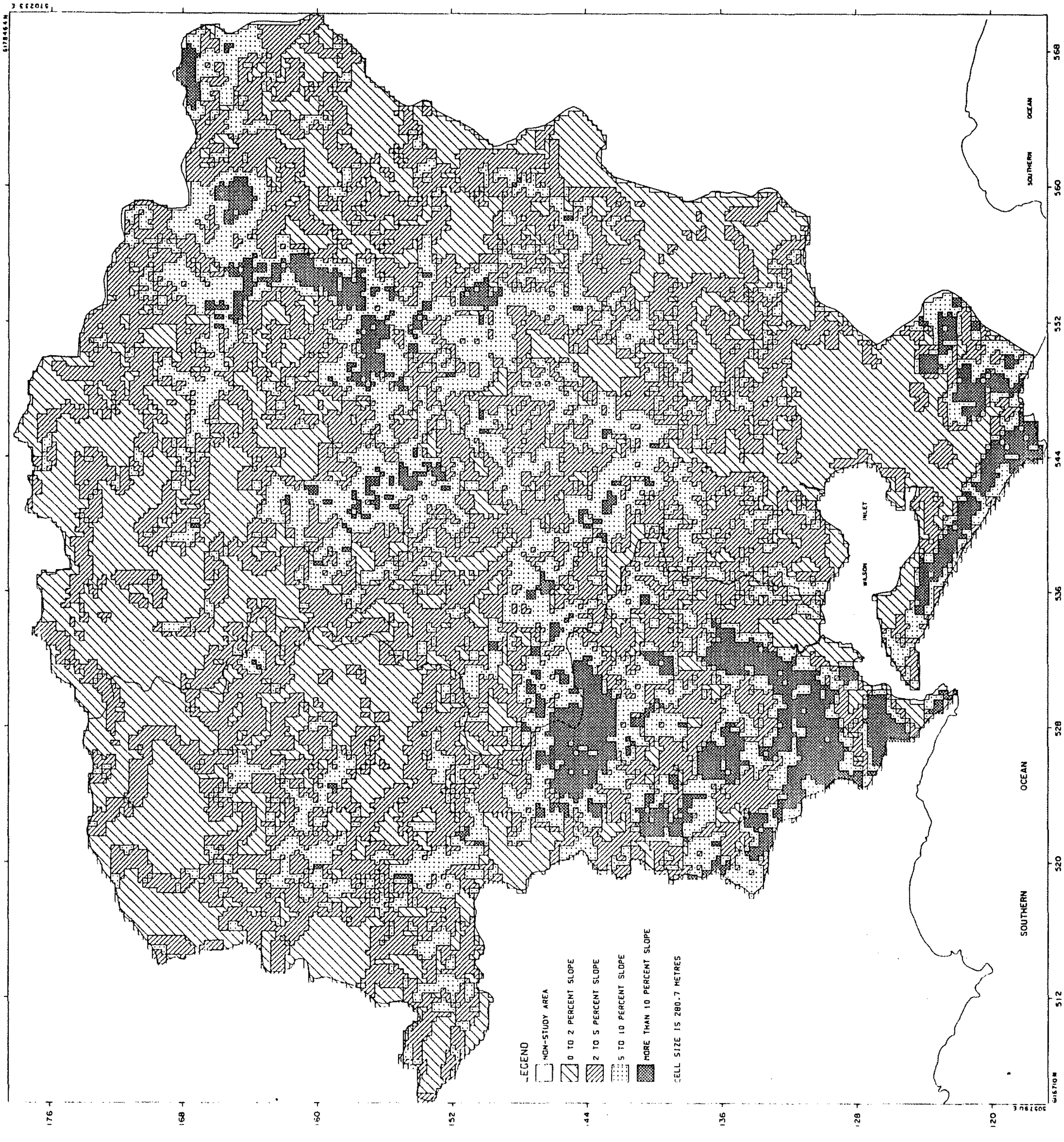
Aa Medium-grained mafic rock; plagioclase-hornblende
Ai Banded quartz-magnetite (hematite) rock; metamorphosed banded iron-formation
Aq Quartzite
Al Psammo-pelitic schist

Overprint indicating bedrock largely obscured by residual and colluvial deposits



MAP 5. WILSON INLET RESOURCE INVENTORY - GEOLOGY

ESRI-AUSTRALIA PTY. LTD.
18 PROWSE STREET, WEST PERTH, W.A. 6005
PHONE (09) 322 4856

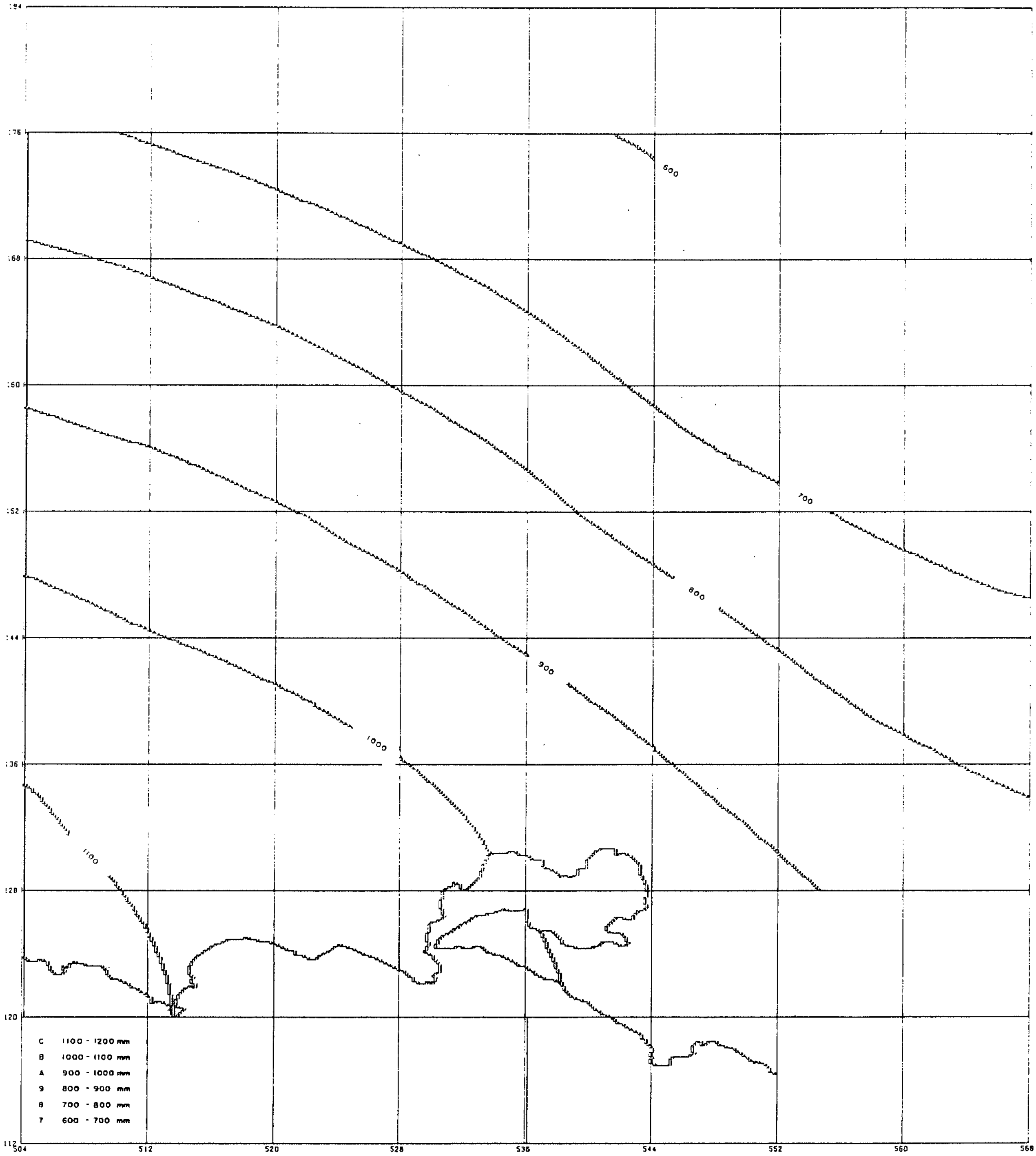


MAP 6. WILSON INLET RESOURCE INVENTORY - SLOPES

0 10 20 Km

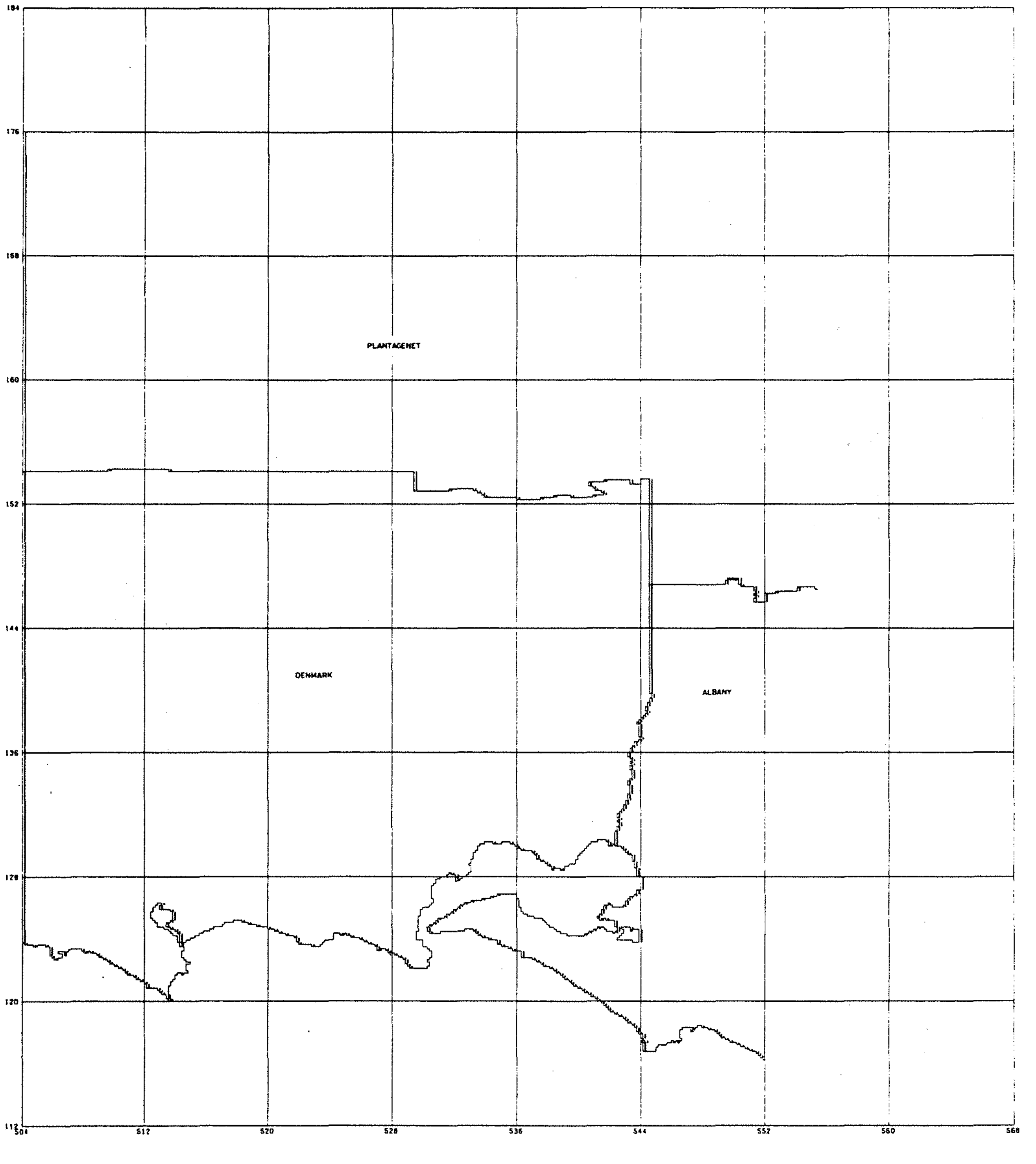
Checked B.D.S.K
10 - July - 1982

ESRI-AUSTRALIA PTY. LTD.
18 PROWSE STREET, WEST PERTH, W.A. 6005
PHONE (09) 322 4955

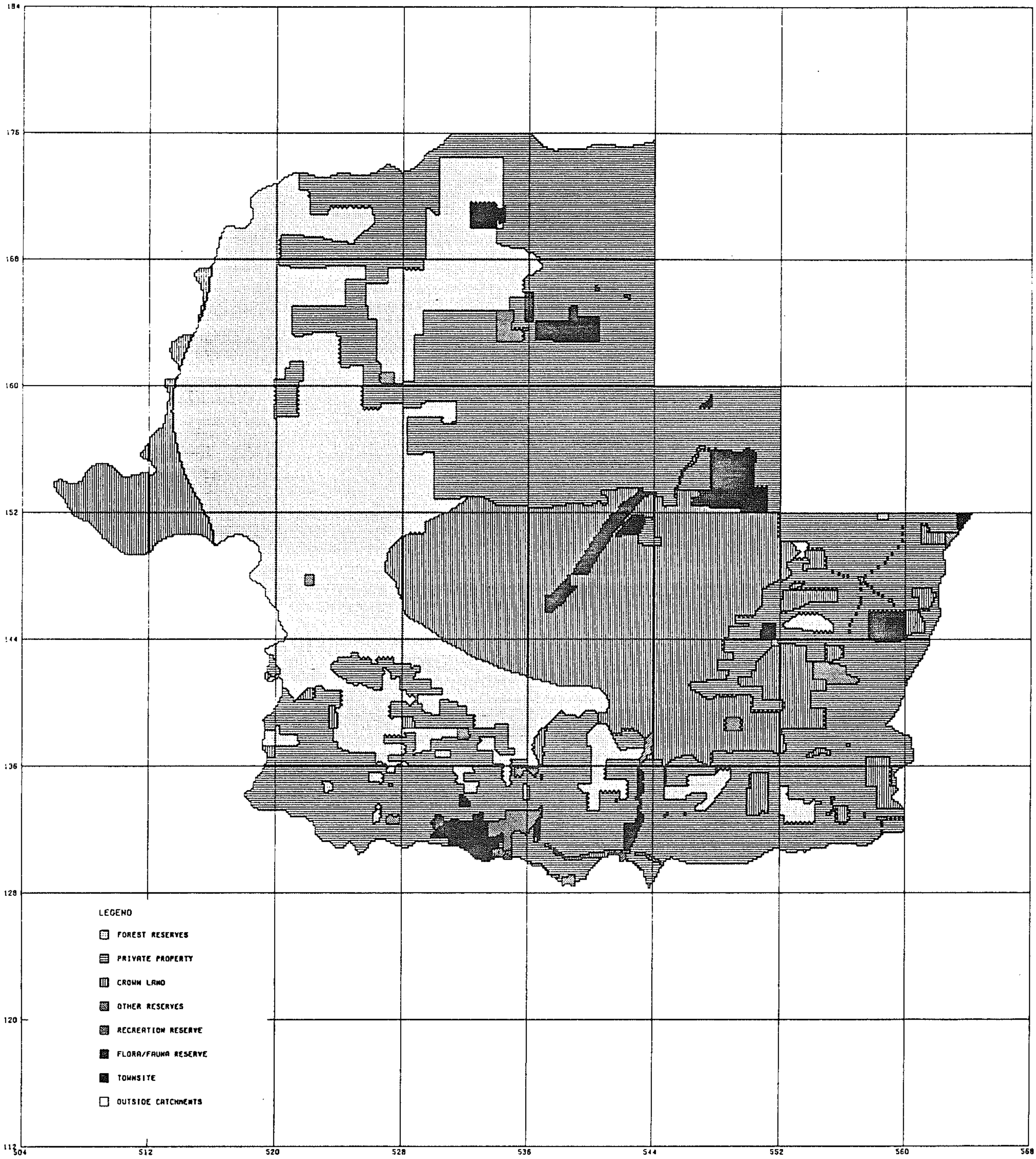


MAP 7. DATE : 82/07/23 ISOHYETS IN AREA OF WILSON CATCHMENTS

0 10 20Km

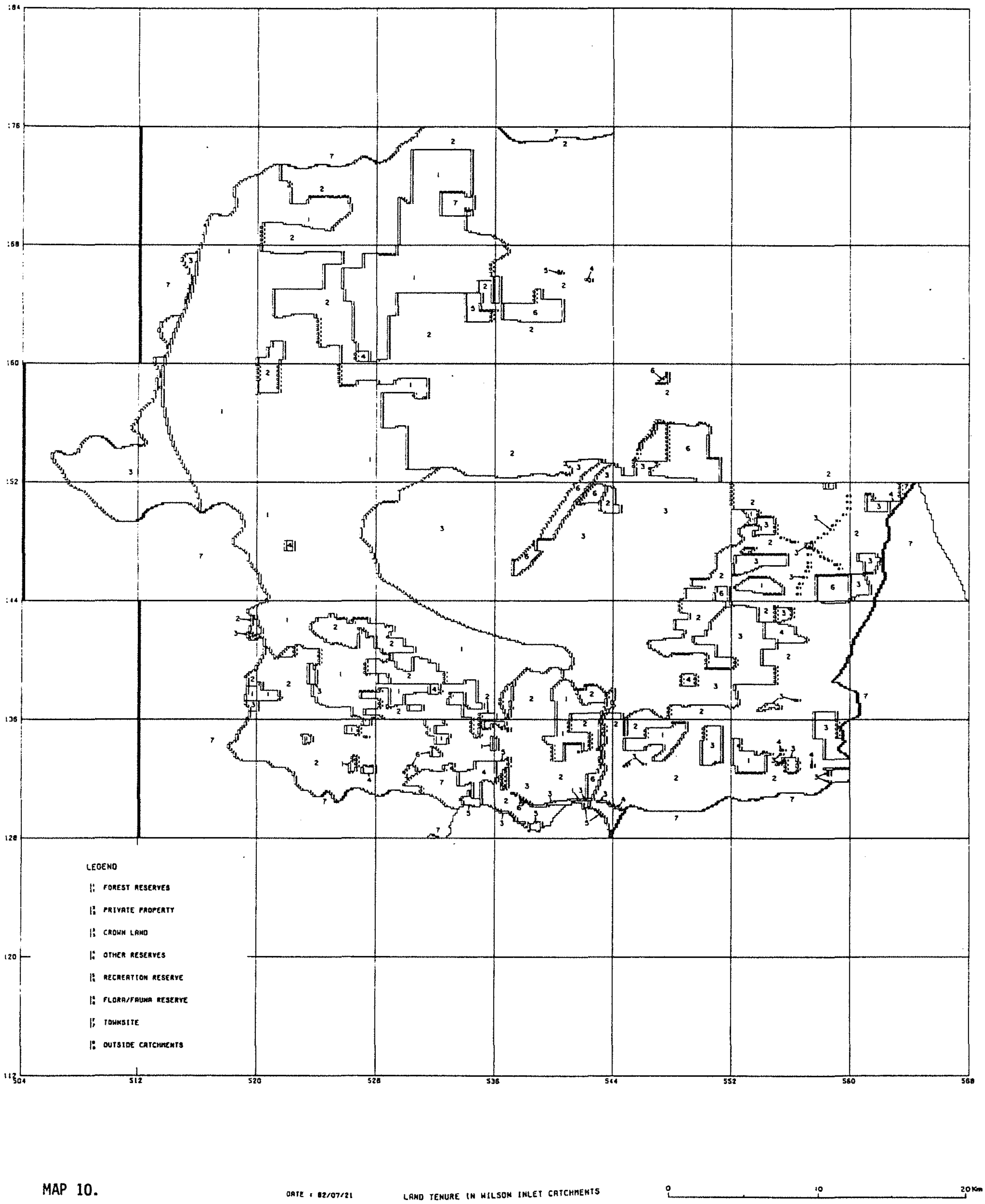


MAP 8. DATE : 82/07/23 SHIRES IN AREA OF WILSON CATCHMENTS

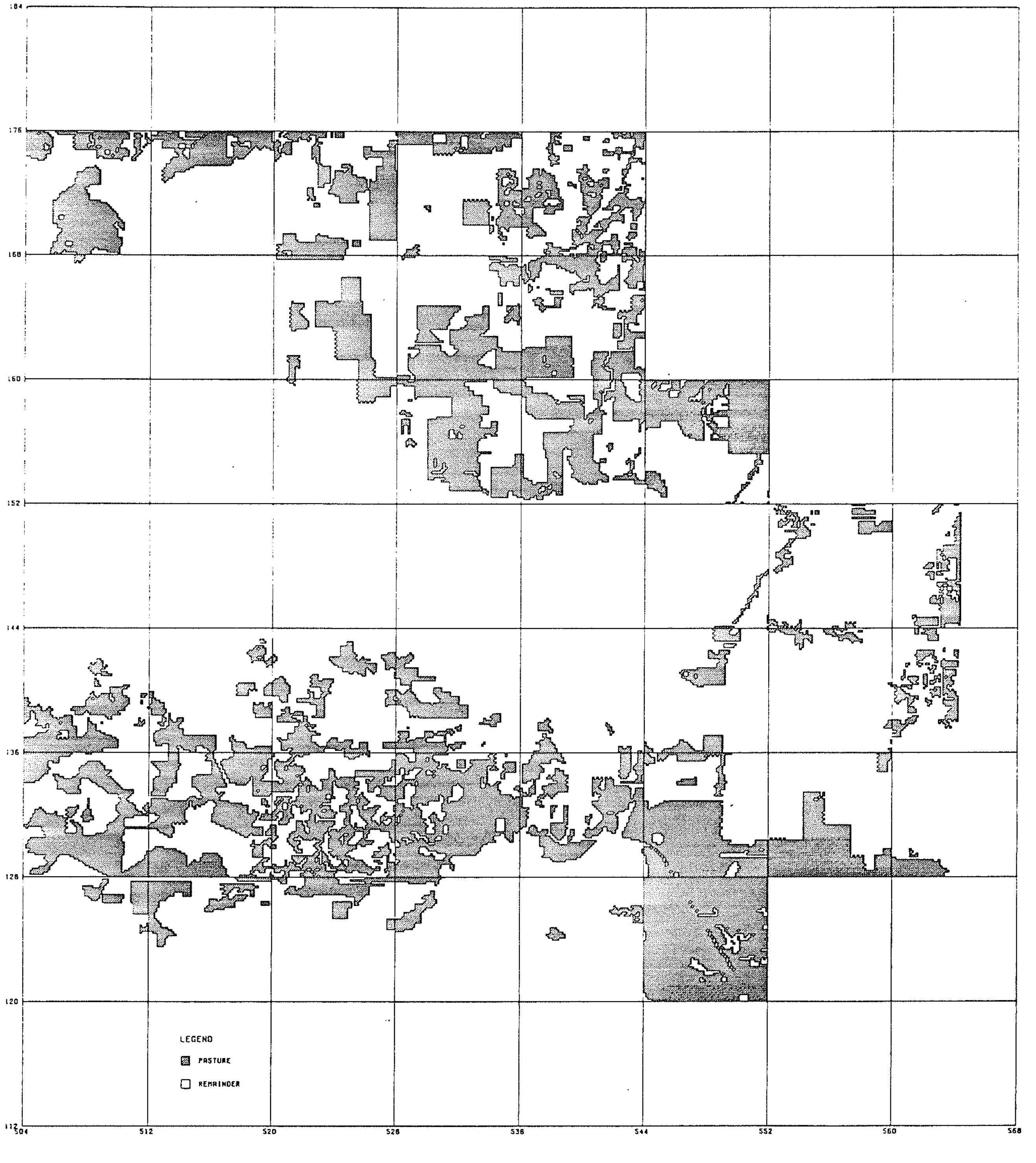


MAP 9. DATE : 82/07/20 LAND TENURE IN THE WILSON INLET CATCHMENTS

0 10 20Km

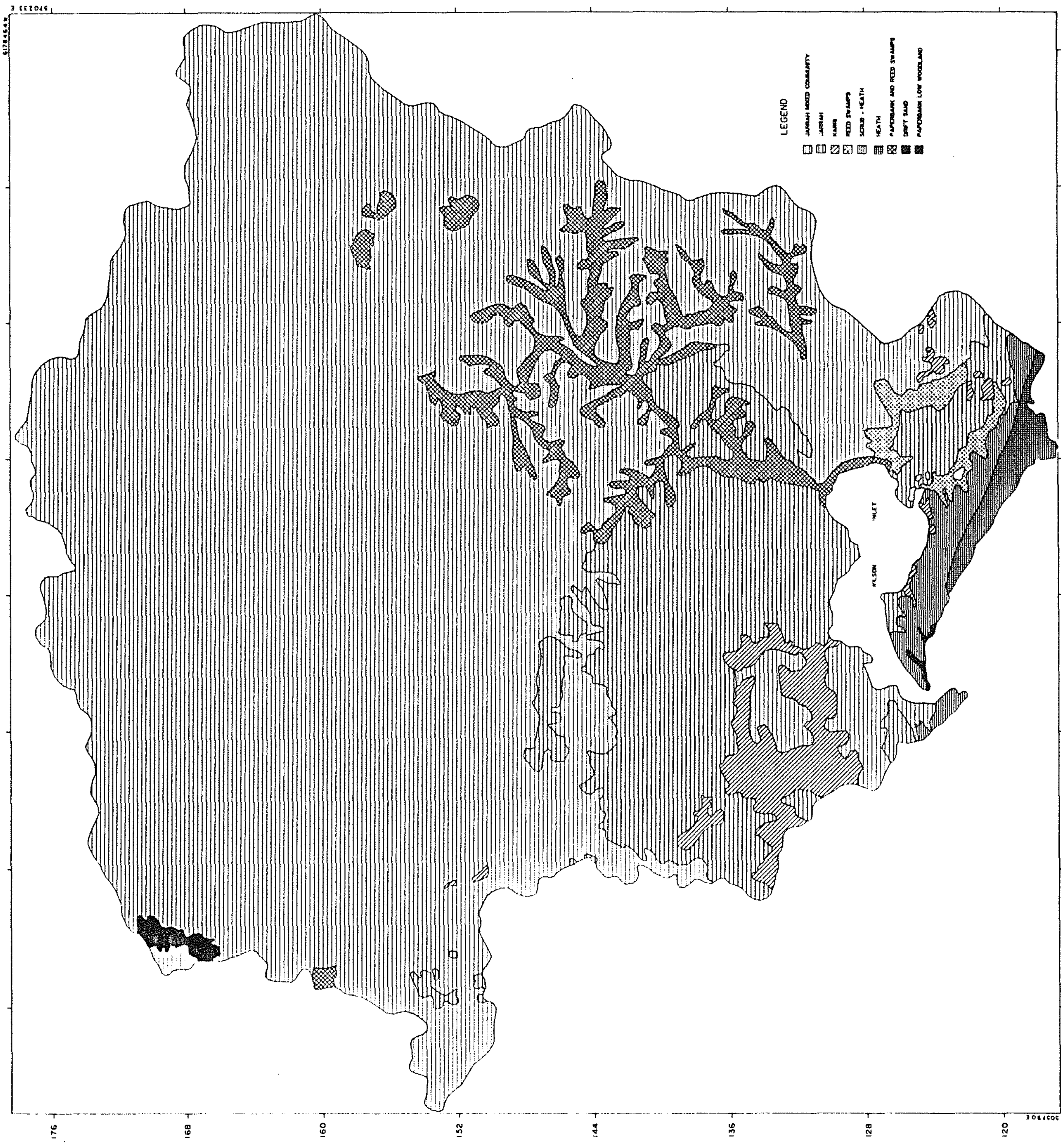


MAP 10. DATE : 82/07/21 LAND TENURE IN WILSON INLET CATCHMENTS



MAP 11. DATE : 82/07/19 PASTURE IN WILSON INLET HINTERLAND

0 10 20 Km

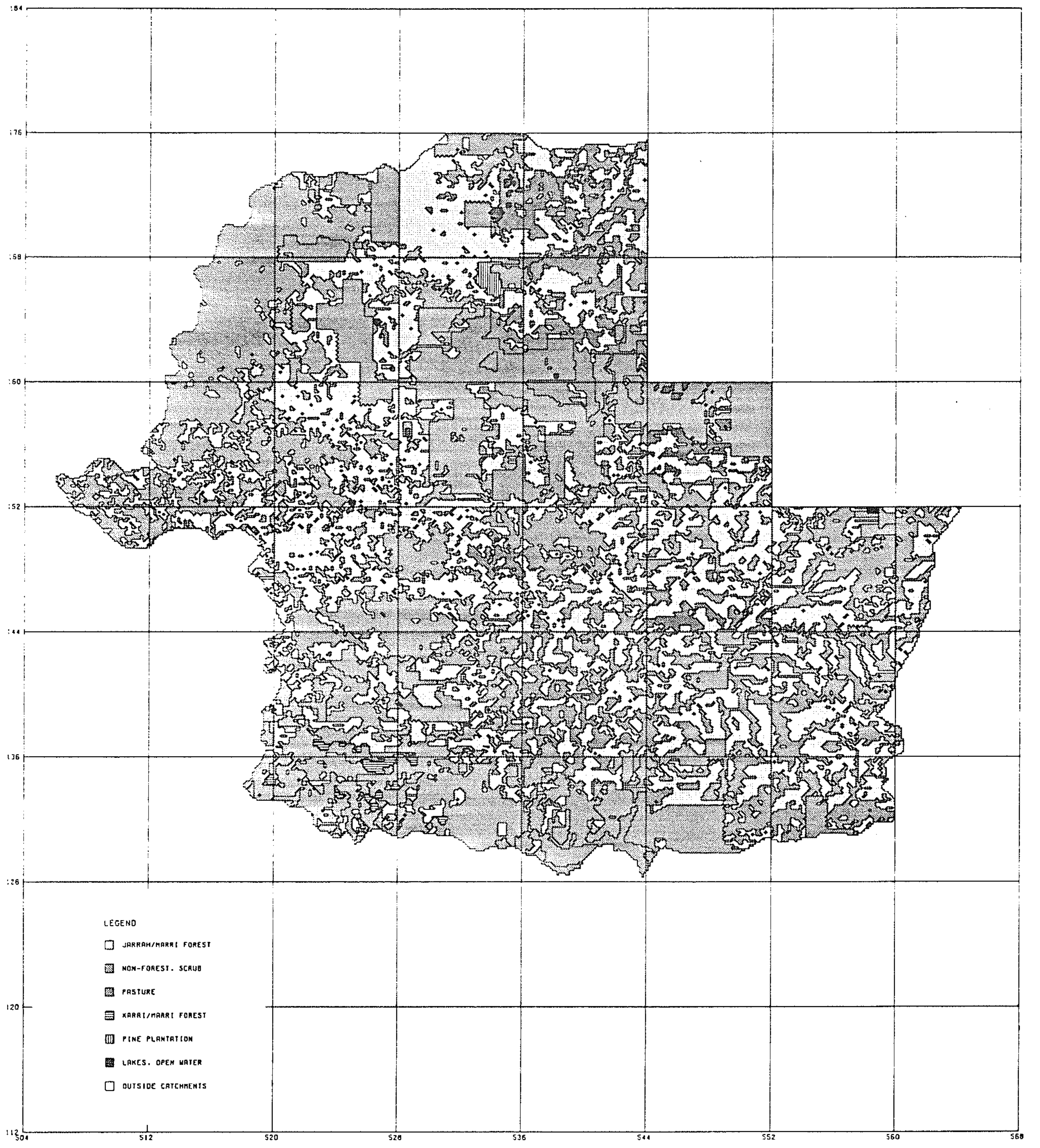


MAP 12. WILSON INLET RESOURCE INVENTORY - INFERRED ORIGINAL VEGETATION

0 10 20 Km

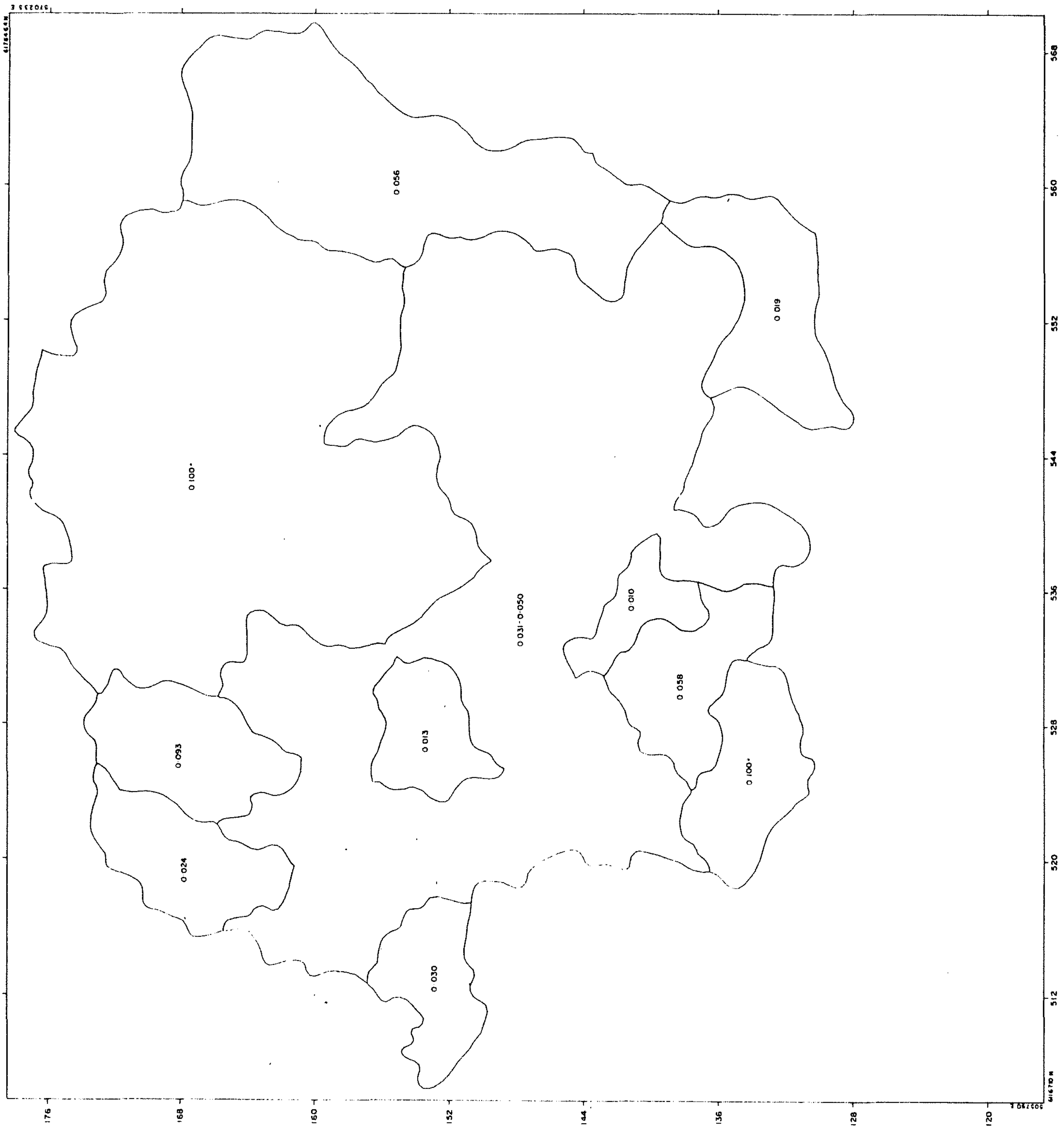
checked
10 - July - 1982

ESRI-AUSTRALIA PTY. LTD.
16 PROWSE STREET, WEST PERTH, W.A. 6005
PHONE (09) 322 4956



MAP 13. DATE : 82/07/23 VEGETATION TYPES IN THE WILSON CATCHMENTS

0 10 20Km

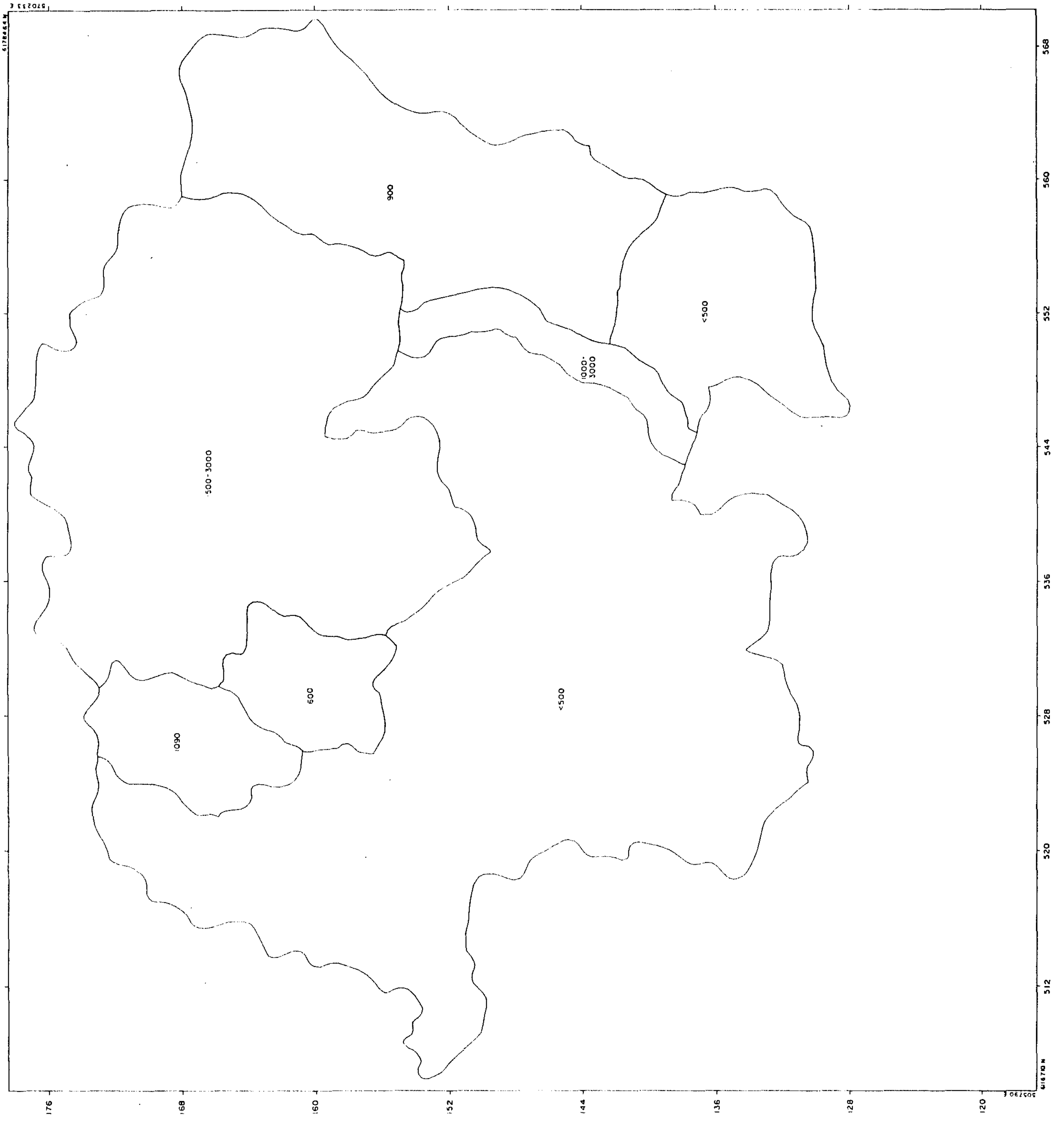


MAP 14. WILSON INLET RESOURCE INVENTORY - SALTYIELD

0 10 20 Km

1978-1979 SALT FLOW IN Kg/m²

ESRI-AUSTRALIA PTY. LTD.
16 PROWSE STREET, WEST PERTH, W.A.
PHONE (09) 322 4968



MAP 15. WILSON INLET RESOURCE INVENTORY - WATER QUALITY

0 10 20 Km

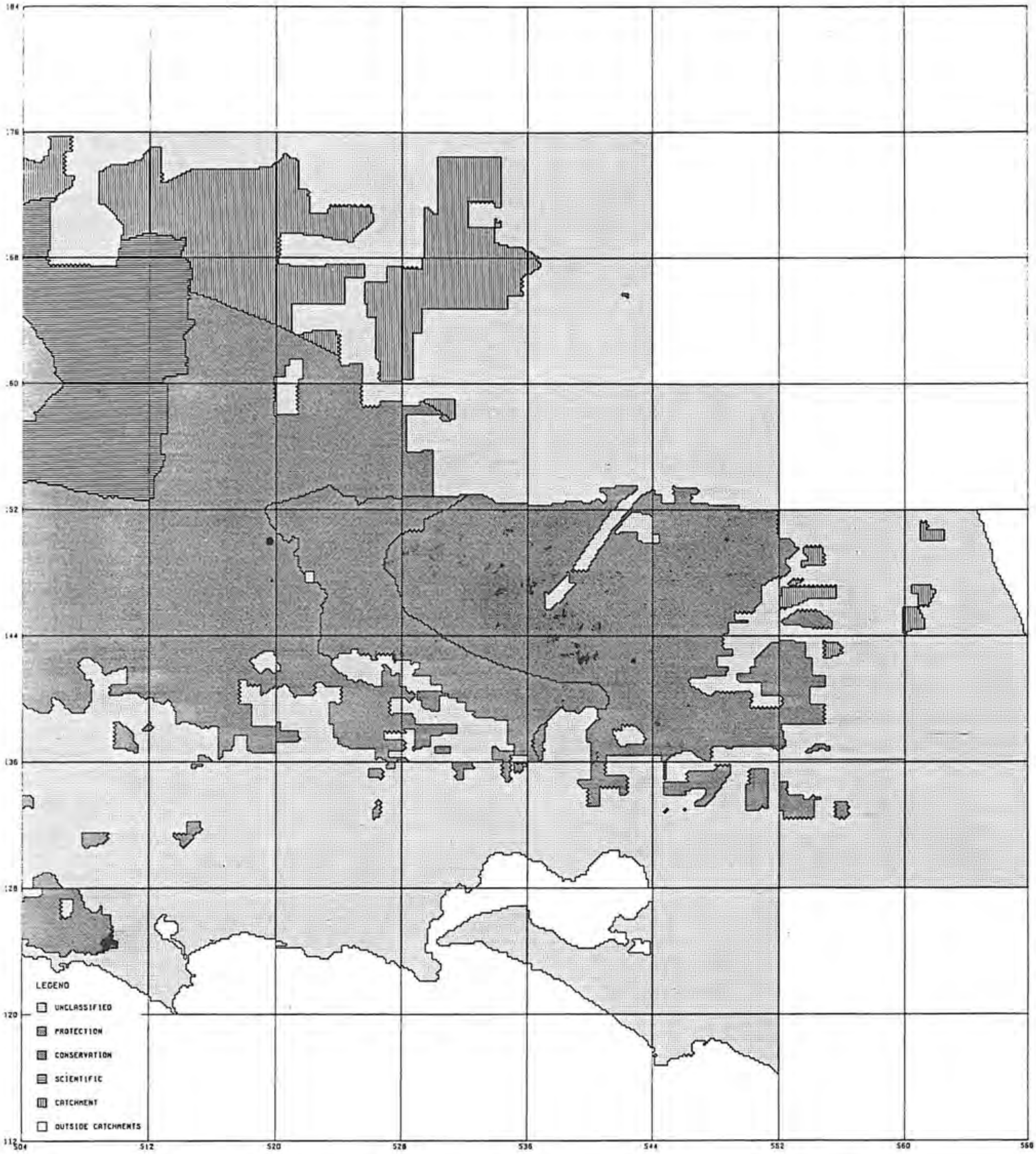
WEIGHTED MEAN TOTAL SOLUBLE SALTS Mg/L 1978-1980

ESRI-AUSTRALIA PTY. LTD.
18 PROWSE STREET, WEST PERTH, W.A.
PHONE (09) 322

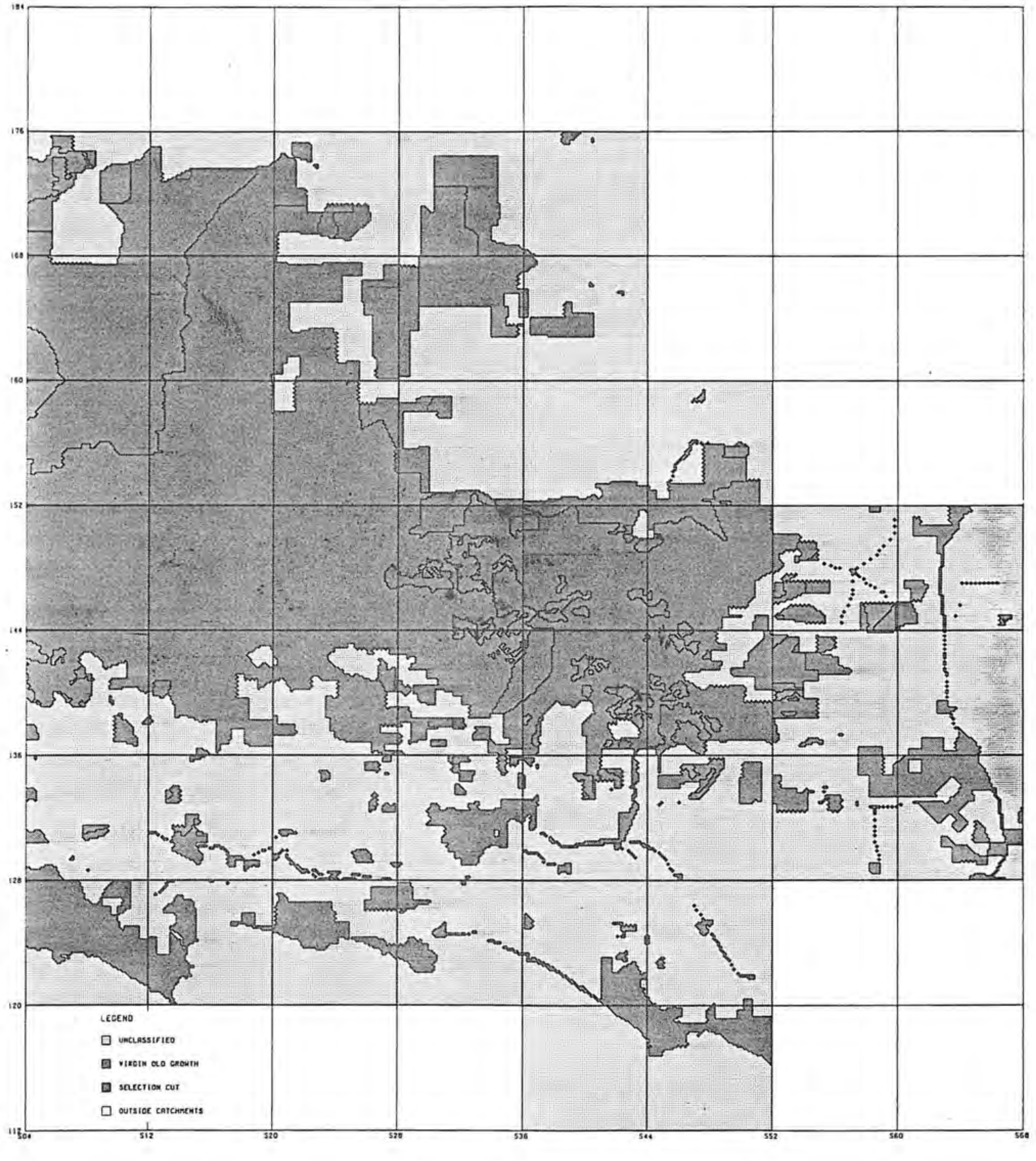
MAP 16. WILSON INLET RESOURCE INVENTORY - BATHYMETRY

0 5 Km

CONTOURS IN FEET BELOW SEA LEVEL



MAP 17. DATE : 82/07/23 FOREST MGMNT. PRIORITY IN THE WILSON CATCHMENTS 0 10 20 Km



MAP 18. DATE : 82/07/23 CUTTING STATUS IN THE WILSON CATCHMENTS

0 10 20Km