ENVIRONMENTAL STUDY OF THE LESCHENAULT INLET

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SCHOOL OF ENVIRONMENTAL AND LIFE SCIENCES
MURDOCH UNIVERSITY

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1.0 INTRODUCTION.

The Leschenault Inlet is situated on the southern section of the Swan Coastal Plain and like the other major inlets of the south west,(Peel Inlet and the Hardy Inlet) it runs in a north - south direction.The rivers entering the system,(Collie and Preston Rivers) flow in a east - west direction through the plain situated between the coast and the Collie escarpment.

The Leschenault Inlet is a shallow embayment approximately eleven kilometres long by two kilometres wide.It is bordered on the western side by coastal sand dunes of the quindalup system and on the eastern side by dunes of the older spearwood and bassendean systems.The northern and southern ends are of the vasse alluvial soil association.The substrate on the southern and eastern margins consists of shallow siliceous sands while the central and western sections consist of estuarine muds.

The Environmental Protection Authority (1977) has pointed out that wetlands(lakes,swamps,rivers and estuaries) are amongst the scarcest resources in Western Australia.They see these areas as important for:

(a) habitat for flora and fauna.

(b) areas for scientific research and education.

(c) areas of water balance and drainage and for maintenance of water quality.

(d) areas for recreation such as boating,swimming,fishing,water skiing,crabbing and prawning,all of which need open water of good quality.Other activities such as picnics,birdwatching, walking and photography are greatly enhanced by the presence of a water system.

(e) scenic landscape features which have economic value for locally based tourist facilities.

All these areas are coming under extreme pressure from increasing populations,greater recreational useage due to a more affluent society seeking a wider range of leisure activities,increased demand for housing near waterbodies,industry seeking easily accessible and cheap waste disposal areas,salination due to the clearing of large tracts of land for timber,agriculture and mining and eutrophication through an increase in nutrient imput from urban,industrial and agricultural areas.

1.1 The Leschenault Inlet Study.(October 1978 - October 1979)

The study of the Leschenault Inlet and its immediate environs was conducted over a twelve months period from October 1978 to October 1979. The study was carried out as part of the final assessment for a Batchelor of Science Degree at Murdoch University,Perth Western Australia. As this study was carried out concurrently with other required courses, time was a limiting factor.The study contract was conducted within the School of Environmental and Life Sciences under the supervision of Dr. B.Dell,(Lecturer in Botany) and Dr.P.Newman,(Lecturer in Synecology) Further assistance was given by the Leschenault Inlet Management Authority in the form of a grant of 600 dollars for the purpose of aerial photography to assist with the aquatic and terrestrial vegetation mapping.

The overall objectives of the study were to compile informarion regarding all aspects of the ecology,water quality,development and recreational useage of the area and to map the aquatic and terrestrial vegetation communities.And finally to make recommendations regarding the management of the region.

The areas of study were as follows:

(a) Historical,demographic and sociological factors.

(b) Land use,zoning,reserves and recreational useage.

(c) Water quality,physical features and geology.

(d) Fauna.

(e) Flora.

(f) Climatic conditions.

From the information gathered on the above mentioned areas,recommendations regarding the development,conservation and recreational useage of the inlet have been set out as management recommendations.

The final report is set out in the following way and is complimented by graphs,diagrams,photographs and maps.

(a) Summary of findings.

(b) Management recommendations.

(c) Historical,demographic and sociological factors.

(d) Land use,recreation,reserves and zoning.

(e) Water quality,physical features and geology.

(f) Fauna.

(g) Flora and plant communities.

(h) Climatic conditions.

(i) Control of waterways and adjacent land.

1.2 Acknowledgements

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Leschenault Inlet Management Authority	
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Prof.D.O'Connor	Murdoch University
Mr.P.Sanderson	Murdoch University
Mr.G.Smith	University of Western Australia

1.2 Summary of Findings and Recommendations

This section includes a discussion of the findings of the study and the conclusions and recommendations regarding the management of the Leschenault Inlet.For a more detailed account of the different facits of the study the main sections should be consulted.

1.2.1 Historical,Demographic and Sociological Factors.

Historically,the wetland areas in this region have been greatly reduced through draining and reclaimation for agricultural practices and in more recent years for urban development.The increasing population of the area and day and holiday visitors from other areas,especially Perth,are placing extreme pressure on the natural resources around the inlet.Because very little control is exercised over the use of the inlet and the surrounding shoreline,the banks in some areas are being eroded from the wave produced by speeding boats,sedges are being removed for access and the area is often littered by prawning and crabbing parties.From the results received in the public survey it would seem apparent that the local population are generally concerned with conservation and proper planning and management of the inlet.It is extensively used by a wide section of the community on a regular basis,mainly for crabbing,fishing and prawning,therefore it is important to maintain high water quality and maintain the surrounding areas in high quality condition.

1.2.2 Recreation,Reserves,Land Use and Zoning

Recreation

To protect the foreshore vegetation and hence maintain water quality recreational areas for boat launching,picnics and barbeques should be limited to restricted areas along the foreshore of the inlet and the Collie River.This practice localizes the problems and control over the use of the areas is more easily carried out.

Recommended areas for recreational reserves are the area around the Paris Road boat ramp,(partly developed at present)the small area by the boat ramp opposite the Laporte chemical plant,(popular for crabbing and prawning) the area to the south of the Collie River(combined with holiday chalets)and a small area to the northeast of the river and part of Alexander Island.The boat ramp to the north of the pipeline is partly developed and should be fully developed for recreational useage.The boat ramp at the junction of the scenic drive and the coast road and the area opposite Waterloo Head should be developed for recreation and a boat ramp to cater for the people who will be occupying homes in the areas presently under development along the scenic drive. Failure to provide adequate facilities could result in the destruction of the foreshore vegetation by removal of sedges for access and trampling down of other vegetation through over use.The area around the cut is extremely popular with shore fishermen and facilities should be provided.The area to the north of the cut is zoned recreational reserve but no development should take place until this fragile area has been stabilized.When this has been completed the area could be developed for limited recreational useage through proper planning.Access to the area would only be by boat.The areas for development should all have adequate brick B.B.Q. facilities,toilets,freshwater taps,adequate picnic tables and rubbish bins.The rubbish bins should be enclosed in a timber covered frame for aesthetic purposes.(for vegetation rehabilitation of these areas see section on flora)

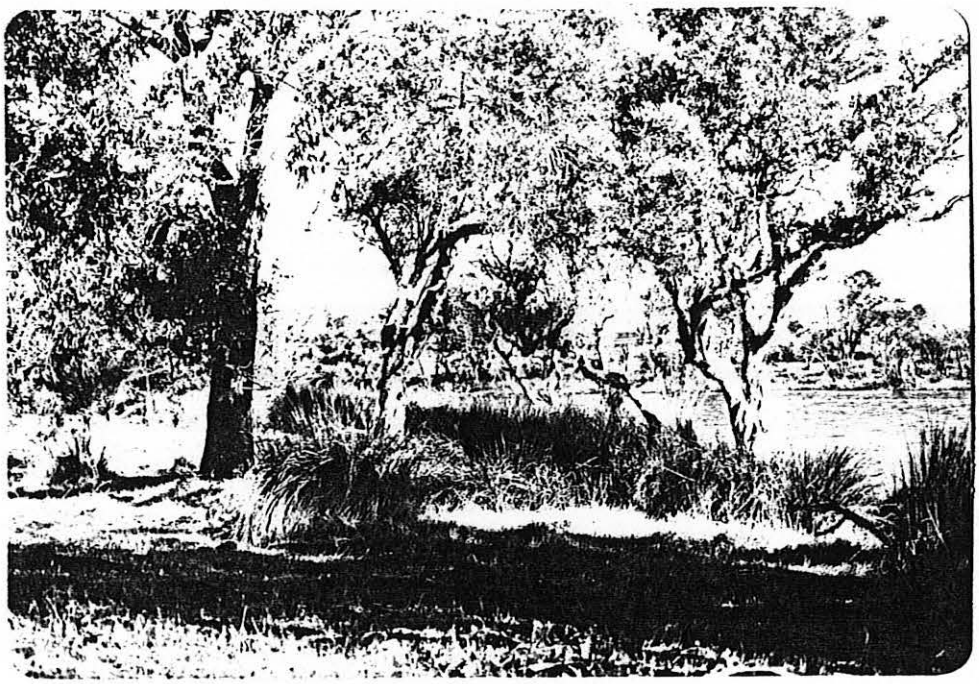
Development of Reserves and Area Around The Collie River

The area to the south of the Collie River is a wetland area and plays an important role in the ecology of the inlet.This area was originally put forward as a canals estate but this proposal was rejected.The land is now owned by the Bunbury council and they wish to develop the area and recoup

the money paid for the area.As the wetland is important for waterfowl it is proposed to retain this and incorporate some housing into the area.However,this would spoil the region so what has been proposed as a tentative plan is that the area be rehabilitated and holiday homes erected on a small area of the land.This has also been proposed for the northern side of the river.The homes would be small cottages or duplexes (as in the plan) of around seven squares each dwelling. (single) They should be built of materials that blend into the natural surroundings.The homes could either be sold or rented as holiday homes either by the local authority or by a private company.

The main water body which runs in a north south direction is approximately seventy centimetre deep and this area dries out over the summer perio It is highly productive and the sea grass Ruppia megacarpa grows in dense meadows over the substrate.(see section 6.0)The waterway running in a westerly direction at the northern end is at present a swamp of Melaleuca hamulosa,but because this section is water logged for most of the year these trees are nearly all dead.The area to the north of this is dry pasture land and the species growing are Eucalyptus rudis and Agonis flexuosa.(Peppermint) The other main species found in the area are Melaleuca rhaphiophylla and Melaleuca preissiana,Hakea prostrata and Jacksonia furcellata.The Flooded Gum,Eucalyptus rudis grow around the waters' edge and on the higher ground in association with the Paperbarks.The edges of the waterbodies are lined with the sedge, Juncus krausii and samphire.(see section 6.0)For a description of the waterbirds that utilize the area see section 5.0)

As the waterbody dries out during the summer and becomes aesthetically unpleasant it would be necessary to deepen the system so that a water level was maintained throughout the year.The water table during summer is approximately 30 centimetres below the substrate so it is anticipated that about a metre would have to be removed.This could be done with eart



The Collie River wetland area that is to be developed by the Bunbury Council to retreive the money paid for the area.The photo shows Eucalyptus rudis,Melaleuca rhaphiophylla and Juncus krausii.

Collie River wetlands showing Melaleuca sp and waterfowl

See figure 1.1

moving equipment during the dry season.The removal of the soil would also be recommended in the dead hamulosa swamp.Prior to the removal of the soil the dried out Ruppia should be collected so that the seeds can be replaced in the water system.The vegetation shown on the plan is mainly existing species but it would be necessary in some areas to plant trees and these should be of similar species to those that are already present.The plan incorporates a small boat ramp and jetty with a narrow channel dredged into the deeper water of Vittoria Bay.The area incorporates two car parks;one at the northern end and one at the southern end. The public recreational reserve by the Shoalhaven boat ramp should have facilities for B.B.Q.'s,picnic tables,freshwater taps,a toilet block,rubbish bins and a childrens playground.

A further recreational area has been proposed for the north eastern side of the river.This includes the small reserve on the western end of Alexander Island.The two are connected by a small foot bridge which spans the shallow part of the river.Both areas should have adequate picnic tables, rubbish bins and B.B.Q's,with fresh water taps and toilets situated on the 'mainland'reserve. Figure 1.1 shows the proposed plan.

The area to the east of the Collie wetland area is a samphire field(see map F 5) and this area contains some seasonally flooded areas.These could be deepened at the same time as the main waterbody and both these areas would then provide excellent summer refuges for the waterbirds for feeding and loafing.

Other Reserves

The boat ramp opposite Laporte should be properly constructed to prevent erosion of the foreshore and the undergrowth between the trees (mainly high grass) should be cut.The central part should be levelled,leaving the higher area near the road in its present condition.There are adequate shad trees in this area,therefore only minor landscaping would be necessary. The samphire swamp at the northern end of this area should be left in its

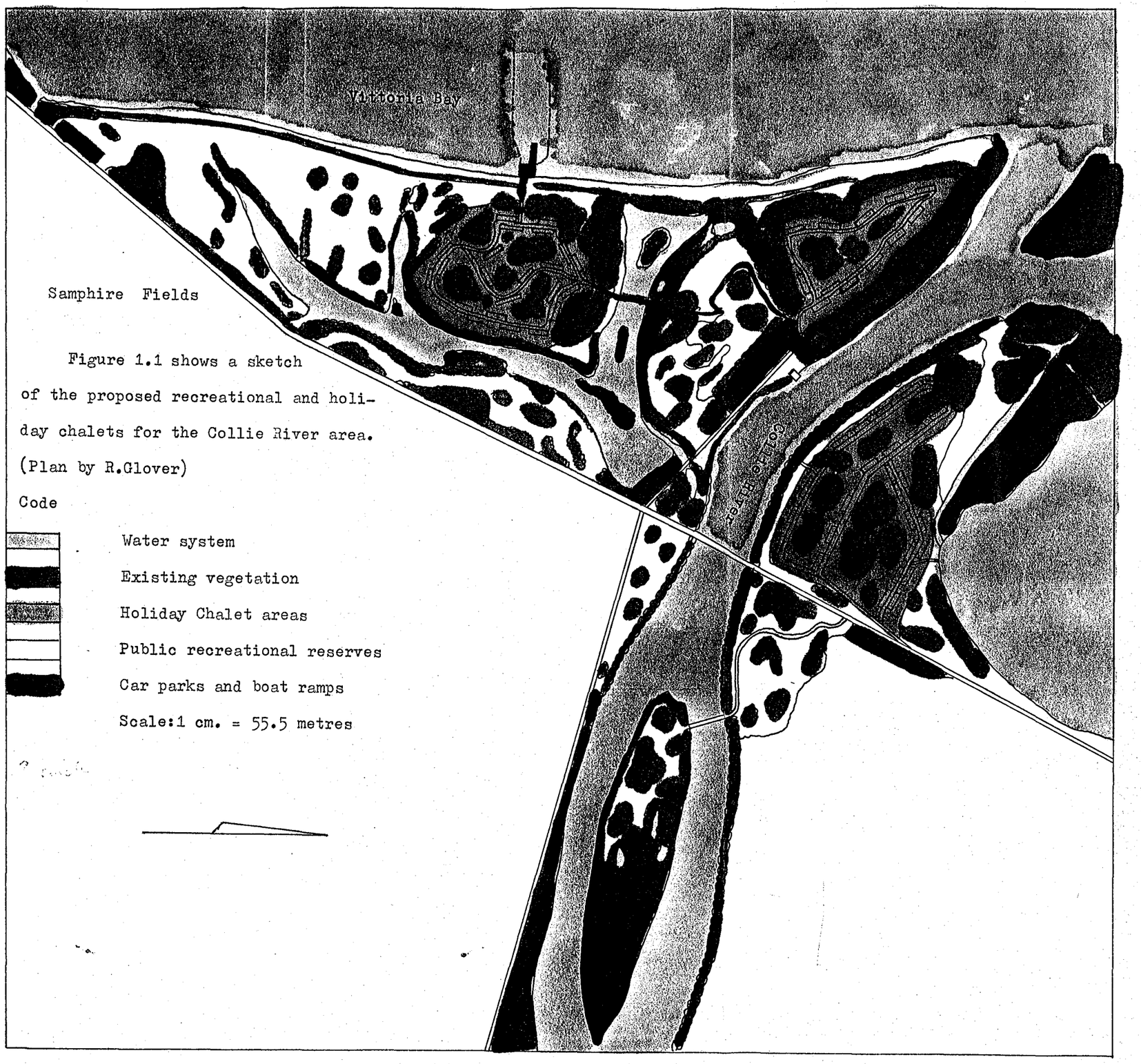


Figure 1.1 shows a sketch of the proposed recreational and holiday chalets for the Collie River area. (Plan by R.Glover)

present state as it provides a feeding area for the Egrets from the Laporte paperbark swamp.(see section 5.0)This area is also used by Grebes and a few ducks.

The Paris Road boat ramp should be concreted as access can be somewhat pecarious due to 'wheel slip' on the gravel surface.The area has requires more parking area during the summer,but toilet and shower facilities are adequate.The area to the north and east of the toilet block require landscaping and more shade trees are needed.B.B.Q. facilities, crab cooking facilities and picnic tables should be built in this popula area.A childrens playing area should also be contructed.The areas where sedges have been removed and trampled down should be restored by replanting and small,narrow,(about one metre wide) walkways should be construct over the sedges to allow free access to the water.

The reserve to the north of the pipeline and the reserve at the junction of the scenic drive and the coast road also require attention in a simil way.These areas are not excessively utilized,therefore two B.B.Q's and three picnic tables should be sufficient.The areas have toilet facilitie but a creeper such as Hardenbergia should be grown over the structures so that they blend into the natural scenery.Shade trees and some minor landscaping are required at both sites.

The area suggested for a northern reserve,opposite 'marina waters' estat will require full development.A boat ramp,access road and small car park would have to be constucted.Rehabilitation of cleared sedge areas would have to be carried out in the area to the north.Landscaping,shade trees and other facilities would be required and these could be blended in wit the small natural pool that exists in this area.(see map M 1)

This region is regularly used by people for crabbing and a great deal of damage has been done to the vegetation.All the other areas along the for shore of this region should be rehabilitated by replanting in the areas which have been cleared amongst the paperbarks for vehicle entry.

Western Foreshore Reserve.

This would be a long term project on the area to the north of the cut, but the area to the south could be developed when funds permit.This area is extremely popular with shore fishermen and up to 100 can be seen in the area when the fish are running,The area to the north is fragile sand dune with a small area of peppermint low open forest.The vegetation is restabilizing on the south eastern side of the dunes,but the remainder is barren.The dunes would have to be stabilized with grasses and large areas of natural vegetation planted on the eastern side.The Western Australian Peppermint,Agonis flexuosa and the Wattles,Acacia rostellifera,Acacia cochlearis and Acacia cyclops would be suitable for this purpose.Sedges should be planted along the margin with Casuarina obesa behind.There is some of this species established in the area.Access to the area would be by boat,therefore a small jetty would be required.A picnic,B.B.Q. and play ing area would have to be established with paths leading to points of inte est,such as the Peppermint forest and the cut.(for fishing)Platforms shoul be built over the sedges for access to the water.The foredunes area on the western side should be rehabilitated with low growing sub-shrubs such as Arctotheca populifolia,Salsola kali and Cakile maritima and the rhizomat- ous perennial Spinifex hirsutus.A pathway should be constructed to the bea area.(see figure 1.2)

1.2.3 Zoning

The zoning of land in the area comes under the Town Planning schemes for the Shires of Bunbury,Harvey and Dardunup.These are fully discussed in section 3.0.(see also map F 5 A)The area which comes under the greatest threat from development is the region along and to the east of the scenic drive.The northern part of the inlet faces the greatest threat from eutro- phication and unless proper management of this area is enforced serious problems in water quality may occur.Strict regulations on the clearing of

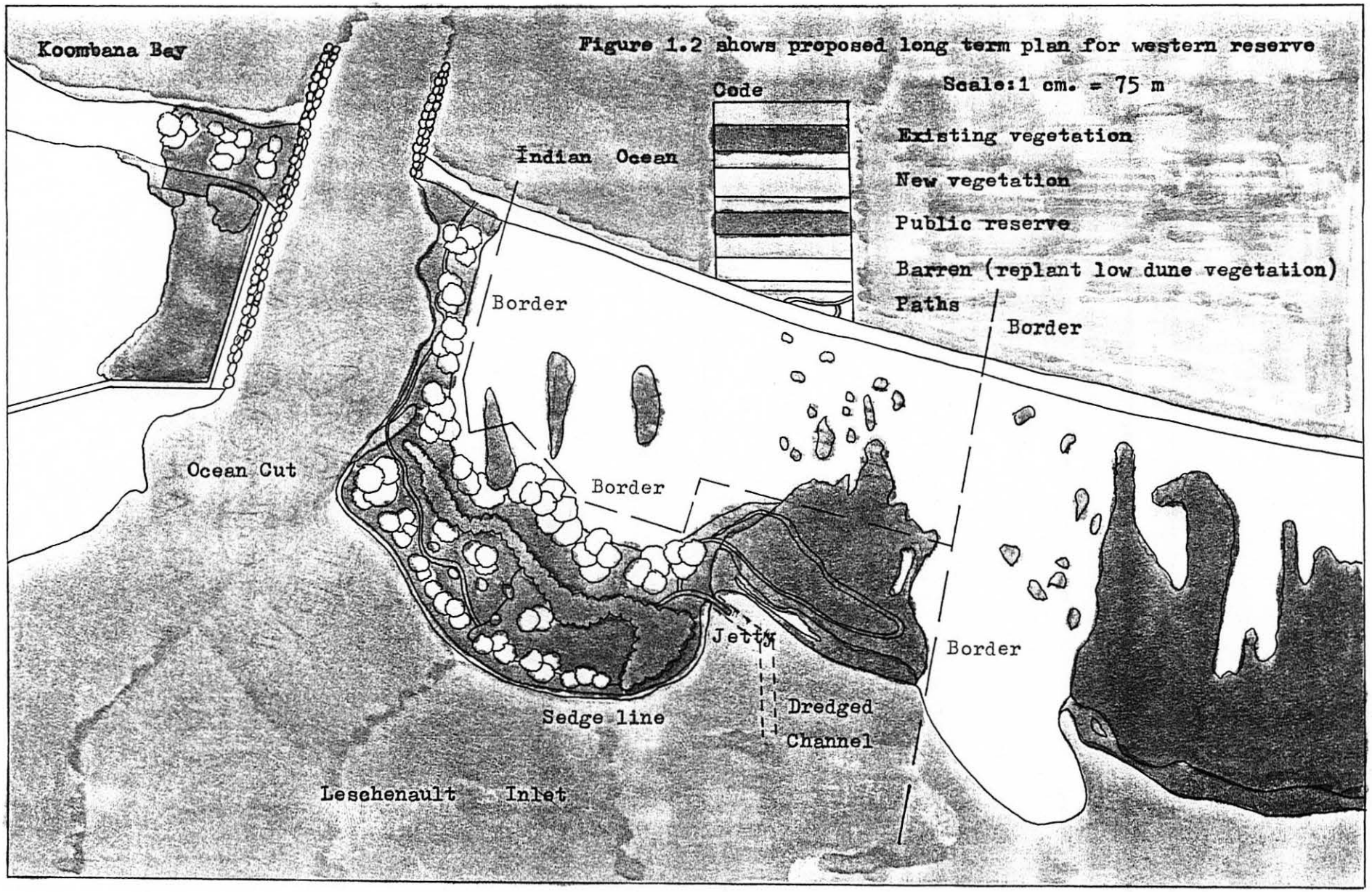


Figure 1.2 shows proposed long term plan for western reserve
Scale:1 cm. = 75 m
Code
Existing vegetation
New vegetation
Public reserve
Barren (replant low dune vegetation)
Paths
Koombana Bay
Indian Ocean
Border
Border
Border
Border
Ocean Cut
Jetty
Dredged Channel
Sedge line
Leschenault Inlet

of the forested region must be adherred to and movement in the marginal areas should be restricted until the area is rehabilitated and walkways are built across the sedges.There should be no more development on the north and north east sections of the inlet within 1.5 kilometres of the high water mark.There should be no development planning for the western side of the inlet and this area should be declared a nature reserve.This would be possible north of Waterloo point at present and the area which is used by LaPorte could be resumed and rehabilitated once a new disposal method has been successfully established.(see nature reserves and map M1) The area to the east of the inner harbour area,which is presently zoned rural,will eventually become industrial.A green belt area about 200 metres wide should be zoned in this region to form a barrier between the industrial area and the inlet.No further development should be carried out along the rivers and industrial areas should be limited to those already zoned and to areas to the south of Bunbury.

Once eutrophication occurs in a water system it is difficult to eradicate, therefore preventative measures should be taken by proper environmental studies being carried out prior to development zoning.(see also water quality recommendations)

1.2.4 Erosion

Erosion has occured in some areas through the removal of sedges for access to the water and from scouring along the banks of the rivers.Timber walls need to be constucted along the lower reaches of the Collie River to prevent further erosion of the banks by boats and water movement in the winter.The areas behind the walls should be filled and sedges and Casuarina and Eucalyptus rudis planted.The areas along the foreshore of the inlet that require rehabilitation should be replanted with sedges.Until these are established bags filled with a mixture of sand and cement should be placed along the foreshore.Once the sedges have become established,walk-

ways should be erected over the top for access to the water by people wishing to use the area for crabbing.Control should be exercised over speeding boats in the area as the bow waves cause erosion and the propellers churn up the sediment and damage the aquatic flora beds.

1.3 Water System Management

General

Overall,the quality of the water system is quite reasonable throughout the year,with the exception of some areas during the summer.(see section 6.0)Nutrients are carried into the inlet via the northern drainage channel,the river systems,ground water,runoff and to a lesser degree,from waterbird droppings.The northern end of the inlet receives the nutrients from the drainage channel which runs through the northern herbfields and drains water away from this area and the nearby agricultural lands.The nutrients enter the system during the winter and spring and are 'trapped' in the soft sediments.When the temperature of the water and the sediments increase during the late spring and early summer the nutrients are released into the main waterbody and this phenomenon greatly assists the rapid and dense growth of the macroscopic algae in the northern half of the inlet.The northern part of the inlet is very shallow (see map D 1) therefore dispersion of the nutrients is limited.The river systems carry large quantities of nutrients and herbicides and pesticides down into the inlet,but due to the high exchange of water and the depth of the water much of this is carried away.Nutrient levels near the housing area along the coast road are relatively high during the summer and this is probably due to septic tank seepage and runoff.

The Northern Drainage Channel

To assist in alleviating the amount of nutrients entering the system from this source a series of retention ponds should be constructed

along the channel.This would enable the nutrients to settle out during the winter period.The ponds should be about 50 centimetre deeper than the channel and the ponds could be constucted with simple earth moving equipment.If this does not reduce the problem significantly,additions of lime or alum (available from LaPorte) will precipitate the phosphorus out and seal it into the sediments. The addition of lime to the water will assist in the removal of nitrogen by increasing the amount of ammonia which bubbles out and is released into the atmosphere.The planting of sedges,paperbarks and samphires around the ponds would also assist.The ponds would serve a dual purpose;retention of nutrients and a resting,feeding,and transit area for the waterfowl in the inlet.

Other drainage channels entering the system from farms and stormwater should pass through a retention pond or canal and then enter the river or inlet by natural seepage.

Septic Tanks

Nitrates and phosphates are not easily removed by soil in comparison with other pollutants so that septic tanks placed near water bodies is asking for trouble.(Warnock,1976)With the increasing amount of urbanization along the eastern shoreline the problem associated with septic tanks will increase,therefore a sewerage system,incorporating tertiary treatment should be installed as soon as possible.

Forested Areas and Watersheds

By properly managing the forested areas around the inlet a reduction in the amount of nutrients entering the system from this source will eventuate.

When the forested areas are cleared for urbanization and agriculture it causes an increase in the transport of the nutrient rich sediments which then enter the system via runoff.Because of the high use of

fertilizers and watering on Australian domestic gardens, and the increasing urbanization along the eastern foreshore, this phenomenon could cause serious problems in relation to water quality in the near future. This is probably already adding to the nutrient budget in areas where housing is already established. Sediment traps should be constucted below the new housing areas to assist in alleviating the problem. Waste which enters the rivers from the industries upstream should be properly treated and cooled prior to discharge into the water systems.

Marginal foreshore vegetation should be maintained in all areas around the inlet as it stabilizes the foreshore and acts as a 'filter' for incoming nutrients. (see vegetation recommendations)

The application of fertilizers should be limited within the watershed because they form a substantial proportion of the nutrient inflow into water systems.

The algal growth did not appear to be excessive in the inlet, overall, but the area to the north should be regularly monitored.

1.4 Fauna

Waterbirds

The Leschenault Inlet is an extremely important area for avifauna, particularly waterbirds, and this can be borne out by observing the many species, both local and migrating, which occur in large numbers throughout the region. Forty six species were recorded during the study and a description of their habitats can be seen in section 5.0. Figure 5.2 shows the main waterbird areas. The most important area for the waterbirds is the north western region of the inlet and the birds gather here in large numbers during the spring and summer. Three areas should be set aside as reserves for the birds. The area in the north western section of the inlet, including the western section of the north-

ern herbland;the sand flats that surround Point Douro;the White Egret rookery in the LaPorte paperbark swamp and Anglesea Island. The old fence posts and other timber objects should be removed from the water and be replaced with artificial perches for species such as Cormorants.These should be placed in strategic locations around the sand flats adjacent to Point Douro,the Collie River(Pelican Point)to the north of the pipeline and on the Preston River Delta.(see map M 1)A count of the Swan population in October,1979, recorded 683 birds along the north east and north west shorelines. Ruppia,which constitutes about 90 percent of their diet occurs in this region.(see map F 3)However the plant growth appears to be very poor (see section 6.4.3 and 6.4.6)and may cause a problem in future years.Further studies should be carried out to determine the actual cause of the low productivity in this area (it is not believed to be overgrazing)and to determine if a transplanting program should be initiated.

Terrestrial Avifauna

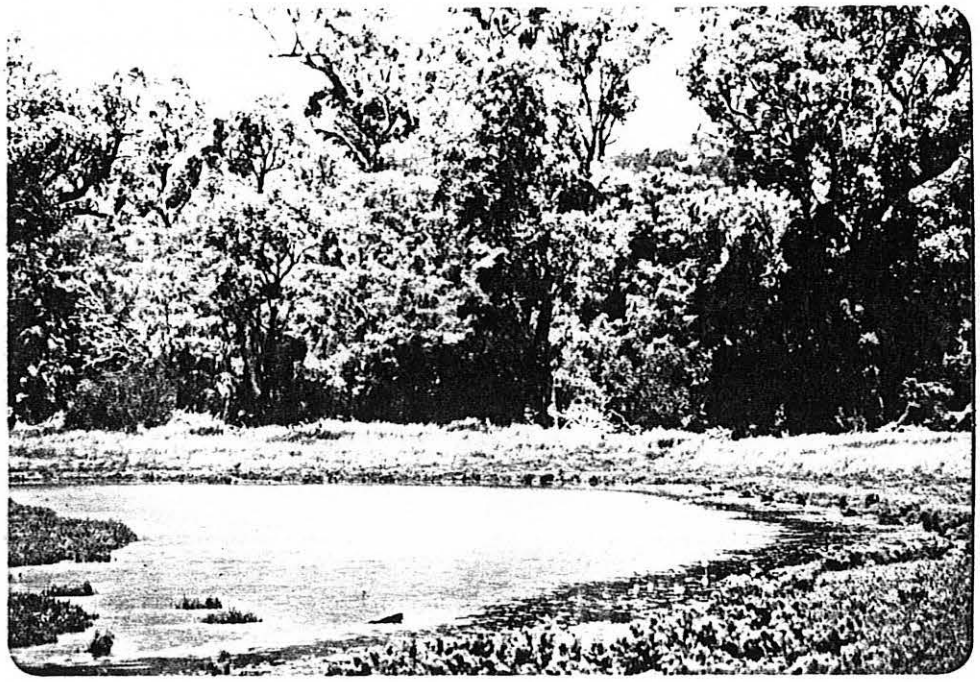
These species face a continuing threat from urbanization and many of their habitats have been destroyed in the region.The forest areas on the north western side of the inlet should be set aside as a reserve.

Other Fauna

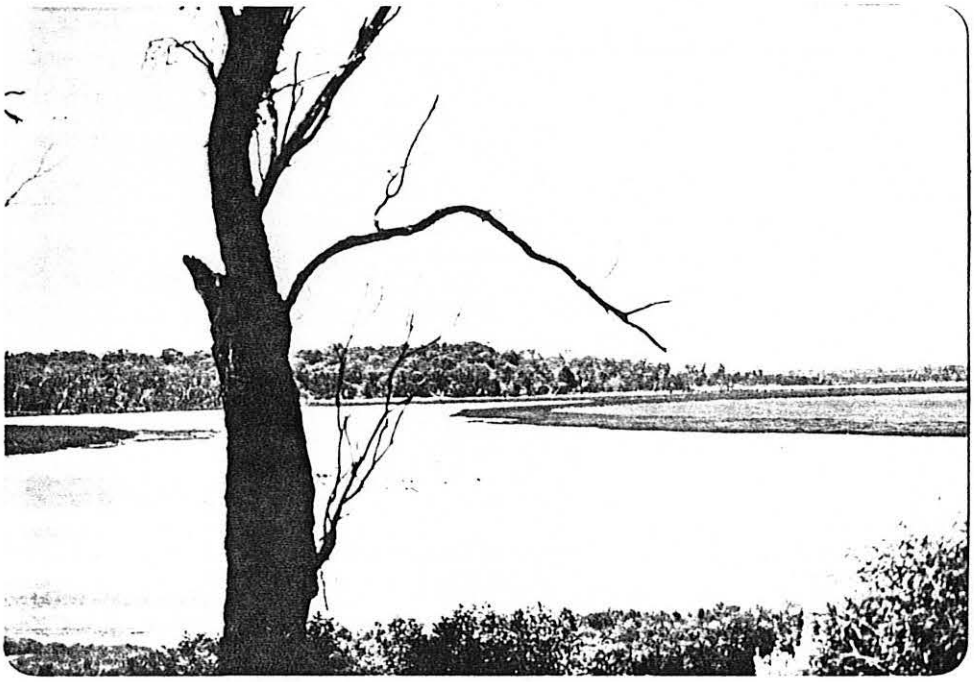
The area has an abundance of animal life,(see section 5.0)especially on the western side of the inlet where they are free from heavy traffic It is proposed to set the north western section aside as a reserve.

The North Western Reserve

The proposed reserve would encompass the region from the high water mark on the northern side of Waterloo Head to the north of the pools situated in the herbland,and west to the high water mark on the coast.



Seasonally flooded area on the north western shoreline that has been proposed as part of the fauna and flora reserve.



Seasonally flooded area to the north western section of the inlet

It is also proposed that this area should be set aside as a flora reserve because it contains a diversity of plant ecosystem that are unique in the region.The proposed fauna and flora reserve covers an area of 4.2 square kilometres.(see map M 1)The plant communities in this region are;woodland,low open forest,open scrub,herbfields,sedge-land and dune systems.The area has a number of seasonally flooded salt marshes.The area has an access road which leads to the Laporte disposal area to the south.(unsealed)The fauna is therefore used to a low level of noise from traffic.It is proposed that this area should be opened to the public for nature walks only.No vehicles should be allowed into the area.(with the exception of P.W.D. and LaPorte vehicles The existing road could be used for the inward journey and a path could be constucted through the varying vegetation communities for the outward journey.A small booklet could be produced depicting the flora and fauna that can be seen along the nature trail.Plants could either be numbered with a corresponding name in the booklet or the species name could be placed on a plaque near the species.The area should be strictly for nature walks and no other facilities should be provided.A car park would have to be built at the northern end. (see map M 1)and section 6.0;Vegetation communities)

Fish and Crustaceans.

The area supports a wide variety of fish and crustacean species that are valuable for both recreational and professional reasons.(see section 5.4)There does not appear to be any major problem associated with the fish as the water is well oxygenated throughout the year (see section 4.0) and the waters are not severely polluted.However,further research should be carried out on the effects of effluent pipeline breaks, which pour large amounts of effluent into the estuary at regular inter

vals.The waters of the inlet offer very limited shelter for the fish species as there are no rocky reefs in the area.It is therefore proposed to constuct an artificial reef in the deep water channel to the south of the pipeline.Once established this reef would provide shelter, food and probably increase the number of fish in the area.It would also be of educational value and tourist value as the reef and the fish could be viewed from a glass bottom boat which could be hired out by one of the local boat hiring firms.The reef could be constructed with some stone and old tyres partly filled with concrete and laid over the substrate.Fishing in this area would have to be prohibited.(see map M 1)

1.5 Flora and Vegetation rehabilitation.

The area surrounding the inlet offers a diversity of plant ecosystems, all of which are important in the overall ecology of the region.(see section 6.0)It has been proposed that a flora reserve be established on a 4.2 square kilometre area on the north western side of the inlet. (see section 1.4)However,all the vegetation communities on the western shoreline should be protected and once the disposal area is dispensed with the western side of the inlet should be set aside as reserve with limited access to the northern part by the nature trail.(no vehicles) The area at the extreme southern end would be established as a public reserve area with access by boat.(see section 1.2.2 and figure 1.2) The paperbarks along the scenic drive should be fully protected.The forest areas that are being developed along the eastern shoreline have limitations on the removal of vegetation,but how effective this will be in practice remains to be seen.There should be no more development in forested regions along the scenic drive or near the rivers.

Rehabilitation of Areas.

The foreshore areas opposite the Tavern,(near the Collie Bridge) should be replanted with sedges and a walkway constucted over the top once they are established.Paperbarks,sheoaks and flooded gum should be planted

behind the sedges.The area amongst the paperbarks along the scenic drive should be replanted with sedges (Juncus krausii)and samphire species so that the area can act as a filter for nutrients being brought into the system from nearby urban and agricultural holdings.

Green Belt

A green belt area should be established to the south of Eaton and along the coast road to the Preston River bridge.This would act as a barrier between the now rural area and the proposed industrial area.A green belt should be established between the inlet,(southern Vittoria Bay) and the inner harbour area.This would conceal the area from view and act as a barrier between the two zones.

Mangroves.

As this area has the only stand of mangroves between the Gascoyne River in Western Australia and the Spencer Gulf in south Australia they are of scientific and ecological importance and should be protected.(see map F 5)

Aquatic Vegetation

Most of the substrate of the inlet is covered by aquatic plants and so that adequate feeding grounds and substrate stabilization are maintained none of these areas should be cleared except where dredging is absolutely necessary to maintain depth in the inlet.The Ruppia beds on the north east and north western sides of the inlet (see map F 3)need further investigation to determine the exact reason for their low productivity.Experiments with transplanting should also be carried out. The area along the north section of the scenic drive is popular for horse riding and the animals are taken into the water.The area where they exercise has little aquatic vegetation but as the foreshore area is to be rehabilitated a path would be necessary for access to the water.

Conclusions

1.6 Conclusions

Although the region is under extreme and increasing pressure from increasing populations, urbanization, industrialization and recreation, the area, through proper environmental planning and management can be maintained in a stable state. Regular monitoring of the water for nutrients should be carried out on a seasonal basis and drains and rivers should be monitored to determine the sources of nutrient imput. The wetland areas around the inlet are in danger of extinction in many regions and reclaimation and filling of these areas should be stopped.

2.0 Historical,Demographic and Sociological Factors.

2.1 History of the wetlands - Swan Coastal Plain.

In 1845 the german physicist Julius Robert Mayer (1814 - 1878) said, ..."Nature set herself the task to catch in flight the light streaming towards the earth and to store this,the most evasive of all forces,by converting it into an immobile form.To achieve this,she convered the earth's crust with organisms which while living take up the sunlight and use its forces to add continuously to a sum of chemical differences.These organisms are the plants." Indeed these plants,through their conversion of the sun's radiant energy into chemical energy provide food,either directly or indirectly to all living forms that inhabit the wetlands of the Swan Coastal Plain.

With the arrival in Western Australia of the early European settlers came the need for the agricultural lands for grazing and crop planting.This ultimately led to the destruction of thousands of acres of the most biologically productive areas on the plain by massive drainage and reclaimation schemes to provide fertile land for these ventures.As time progressed,man required more land for housing,freeways and industrial sites near the coast and waterways, and in the process many valuable habitats were destroyed.

"This plain,only twenty five years ago,harboured one of the most stable populations of waterfowl in Western Australia" (Riggert 1966) but the destruction of its wetlands over the years has greatly reduced the number of waterfowl utilizing the region.By 1965 a total of 494,739 acres of wetlands had been drained on the Swan Coastal Plain.The following table lists the areas and acreage drained.(P.W.I annual report,1965)

Table 2.1 Known wetland drainage to 1965.

District	Total Acres
Harvey	65,608
Collie River	40,272
Waroona	69,569
Myalup	4,683
Pinjarra	66,540
Busselton	146,152
Stirling	6,726
Serpentine - Mundijong	95,189
Total Acres Drained	494,739

In the area from Yanchep to Rockingham,forty nine percent of the wetlands had been drained by 1966;between Rockingham and Harvey, thirty one percent;from Harvey to Dunsborough,ninety six percent and drainage and reclaimation in this area is still in progress. Wetland areas close to towns are being reclaimed for housing and light industrial projects.

In many areas the wetlands have not been drained or filled because they are too deep,are salt lakes or are in reserves.However,valuable feeding grounds for wildlife has been destroyed by the practice of clearing the vegetation around the lakes and waterways for housing and recreational developments.This practice can have serious consequences as it deprives some species of their main food sources,insects and spiders.

The most biologically productive part of the waterway is the shallo areas where sunlight can penetrate to enable photosynthesis to take place.It is these areas that face the greatest danger from dredging

which forces organic material that was below the level of the soil into suspension,making the water turbid and therefore allowing less sunlight to penetrate.This causes a substantial decline in productivity and the waterbody thereby supports less life.This practice is quite common in the Swan Estuary and although ..."the water is not significantly polluted it supports much less fish and birdlife than it used to do."(Riggert 1966)
There have been a number of areas dredged in the Leschenault Inlet over the past thirty years and these areas are discussed in sub - section 4.2.

During the winter the waterfowl seek out their preferred nesting areas - small isolated freshwater swamps that are high in food content and abundant with aquatic vegetation and hollow trees to hide their young from predators.The swamps that are seasonally flooded are usually very rich in plant and invertebrate life and therefore make excellent habitats during the breeding season.As these areas are usually the first to be drained for man's use,the migration of waterfowl is becoming more difficult,especially during dry seasons as the young birds are forced from their breeding grounds much earlier.When the young birds are able to fly they make their way to the permanent summer wetlands,feeding and loafing at the seasonally flooded areas on the way.Figures 2.1.1 and 2.1.2 show the main wetland areas and main waterbird habitats on the plain.The majority of freshwater breeding grounds are now situated on the Pinjarra Plain between Armadale and Harvey and only a few exist outside this area.The following table shows drainage of these wetlands between 1955 and 1966.

Table 2.2 Wetland drainage on the Pinjarra Plain,1955 - 1966.

Areas	1955	1966
Shallow inland fresh water marsh	19,697 acres	7,016 acres
Deep fresh water marsh	15,388 acres	3,622 acres

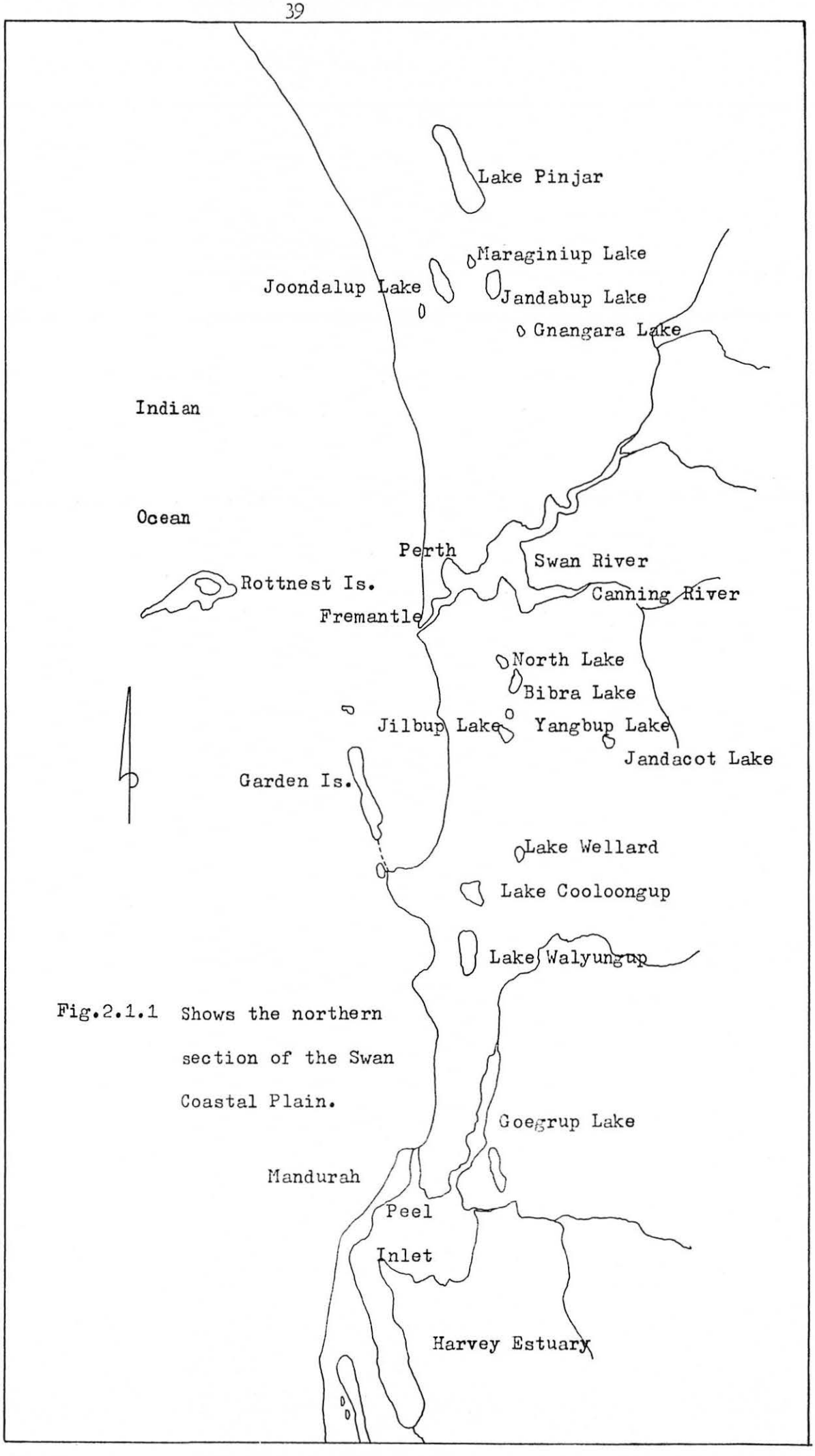


Fig.2.1.1 Shows the northern section of the Swan Coastal Plain.

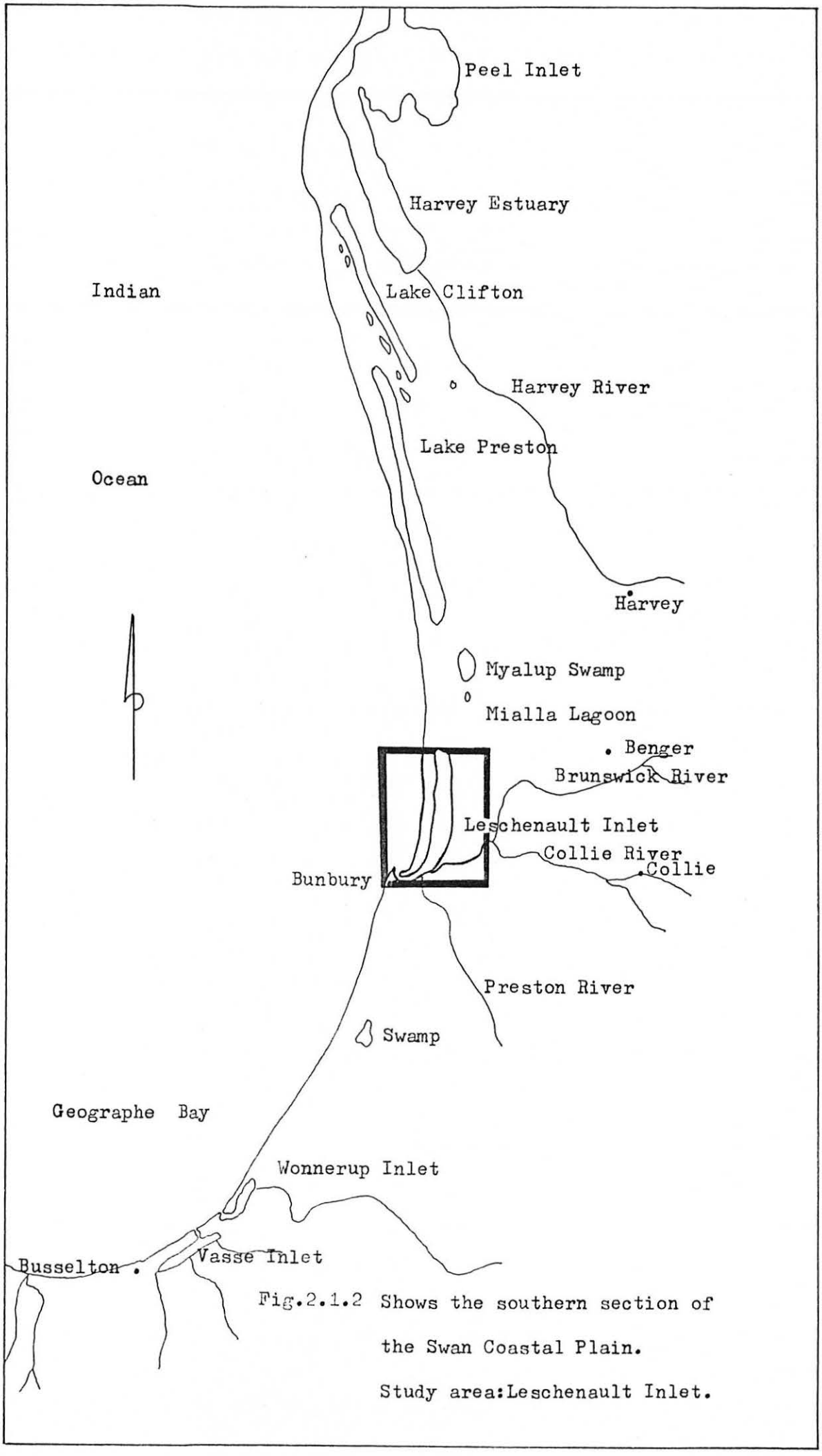


Fig.2.1.2 Shows the southern section of the Swan Coastal Plain.
Study area:Leschenault Inlet.

Further destruction of these wetland areas could cause serious problems for the waterfowl populations of the Swan Coastal Plain. Wetlands are classified into many different types,depending on the vegetation,salinity,depth and location.The following table which was developed by the Wetlands Classification Committee of the United States Fish and Wildlife Service (1953) gives a description of the varying wetland types.(* These types appear on the Swan Coastal Plain.)

Table 2.3. Wetland Classifications.

Wetland Type	Water Depth	Acres
Inland Fresh Water		
*Seasonally flooded basins	Few inches in upland	23,677
*Seasonally flooded flats	Few feet along rivers	
*Flooded agricultural land	Few inches in upland, few feet along rivers	36,990
*Inland fresh meadows	Few inches after rain	6,599
*Inland shallow fresh marsh	up to 6 inches	7,026
*Inland deep fresh marsh	up to 3 feet	3,442
*Inland open fresh water	upto 10 feet,marshy border maybe present	5,386
*Permanent open water	up to 10 feet	11,269
Shrub swamps	up to 6 inches	
Wooded swamps	up to 12 inches	
Bogs	Shallow ponds maybe present	
Inland Saline Areas		
Inland saline flats	Few inches after heavy rain	
Inland saline marsh	up to 2 feet	
*Inland open saline marsh	up to 10 feet,marsh around edges	10,554

Table 2.3 Cont.

Wetland Type	Water Depth	Acres
Coastal Fresh Areas		
*Coastal shallow fresh marsh	up to 6 inches at high tide.	3,290
*Coastal deep fresh marsh	up to 3 feet at high tide	1,669
*Coastal open fresh marsh	up to 10 feet,marshy borders often present	1,360
Coastal Saline Areas		
*Coastal salt flats	may have few inches at high tide	80
Coastal salt meadow	as above	
Irregularly flooded salt marsh	few inches at wind tide	
*Regularly flooded salt marsh	up to 1 foot at high tide	614
*Sounds and bays	up to 10 feet	47,321
*Mangrove swamps	up to 2 feet,Bunbury only	
Total area		159,757

2.2 Comparison of the Major Estuarine Systems of the South West.

This section has been included so that the reader can make a brief comparison of the four major estuarine systems in the south west of Western Australia.Three of these are located on the endangered Swan Coastal Plain.They are the Swan Estuary,the Peel Inlet - Harvey Estuary and the Leschenault Inlet - Collie Estuary.The fourth is situated near Cape Leeuwin;the Hardy Inlet - Blackwood Estuary.Figure 2.2.1 shows the locations of the above mentioned estuarine systems.

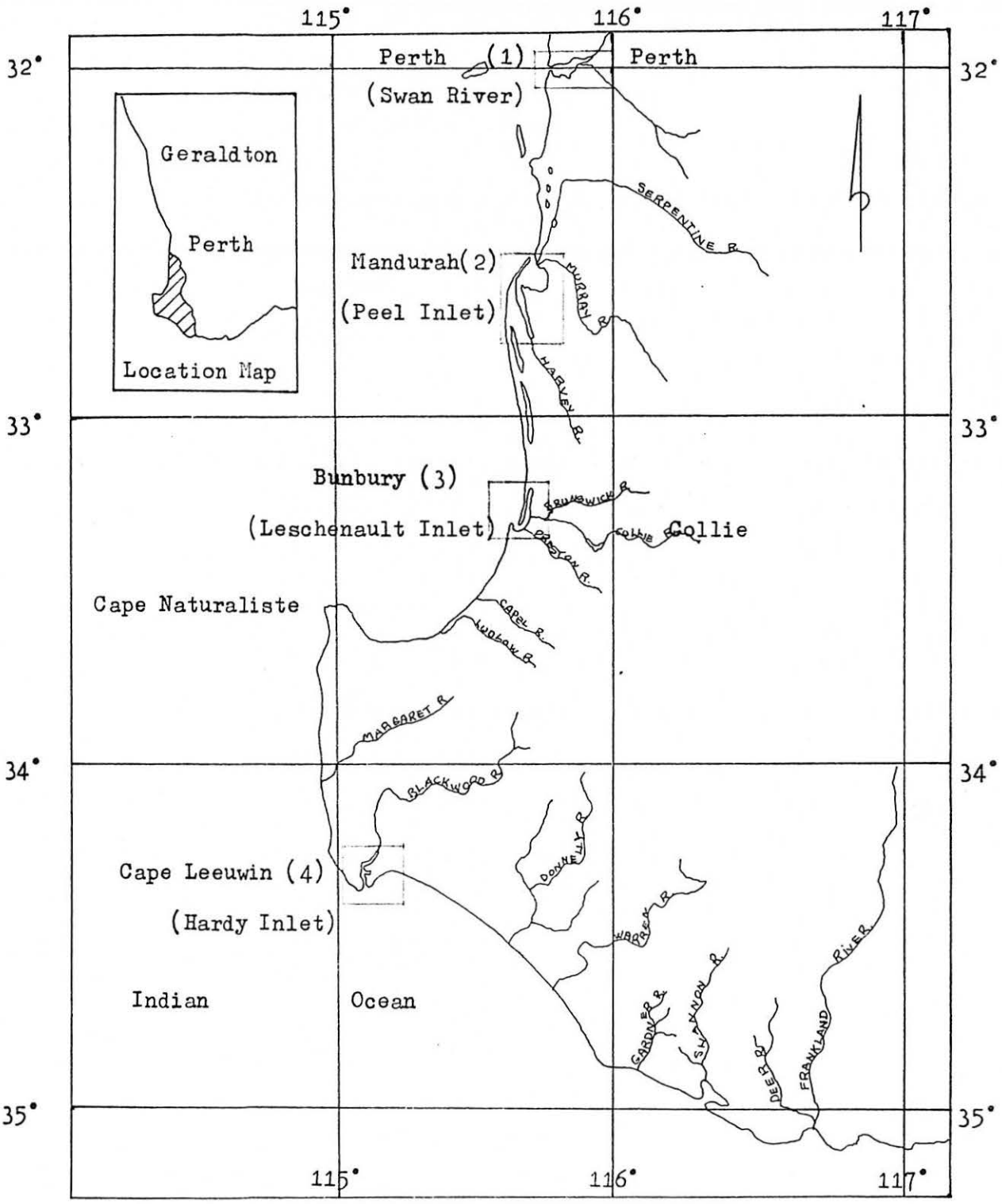


Fig. 2.2.1 Location map showing major south western estuaries.

(1) Swan-Canning Estuary.
(2) Peel Inlet-Harvey Estuary.
(3) Leschenault Inlet-Collie Estuary.
(4) Hardy Inlet-Blackwood Estuary.

2.2.1 The Swan Estuary.

This estuary, which has a total area of 5,300 hectares, is surrounded on all sides by the City of Perth and its adjoining suburbs. The Swan enters the Indian Ocean after winding through the City of Fremantle and its environs. The Swan has the largest catchment area of all the estuaries; a total area of 27,990 km^2. The population, as at the 1976 census, for the area was 820,100 persons. The geomorphology of the basin dates back to the pleistocene. The Canning River system enters the Swan River by what is now known as the Canning Bridge. The climate in this zone is largely controlled by the anticyclone belt and the area receives a hot dry summer and a cool wet winter.

The fish of the Swan estuarine system are comparable with those of the other systems and the species are similar. (see sub - section 5.5) The main species for commercial catches are: Perth herring, Sea mullet, Yelloweye mullet, Cobbler, Tailor, Whitebait, Flathead and Mulloway. The main crustaceans are crabs and prawns.

The main waterbirds seen on the estuary are divided into four categories (Lenanton 1973) and they total forty four common species. The four categories are: Ducks and Swans, Wading birds, Birds of the Reed Beds and the Fish - eating species.

The aquatic vegetation includes Halophila sp., Zostera sp., and a wide range of algae such as Gracilaria sp., Cystoseira sp. and Enteromorpha sp.

The terrestrial vegetation includes paperbarks, (Melaleuca rhaphiophylla) and the flooded gum, Eucalyptus rudis. Further upstream the Northern River Gum, Eucalyptus camaldulensis appears. The region has a wide variety of other trees and plants including banksia, dryandria and she - oak.

The area comes under the control of the Swan River Management Authority.

2.2.2 The Peel - Harvey Estuary.

This system is situated about sixty kilometres south of Perth and has a total area of 13,620 hectares, making it the largest of the south west estuarine systems. Its catchment area, however, ranks only third and is 12,000 km^2. The inlet is fed by the Harvey River, the Serpentine River and the Murray River. The inlet enters the ocean by the Town of Mandurah which has a population of 8,550. (1976 census) The area is very popular during the summer months because of its close proximity to Perth and because of this factor the water system is being exposed to increasing pressure from both people and development. The area enjoys a similar climate to Perth. (see section 7.0 for full details) The geomorphology of the basin is shallow pleistocene.

Fish species are similar to those of the other estuarine systems and the area is also popular for crabbing and prawning, especially the much sought after King Prawn.

Waterbirds are similar to those of the Leschenault Inlet and come under the same four categories as the waterbirds of the Swan Estuar However, the Peel Inlet is a breeding ground for the Australian Pelican and in January 1976 more than 1,000 of these birds were on the inlet. This is considered to be 60 percent of known pelicans on sout western estuaries at that time. (J. Lane, W.A. Fisheries and Wildlife.) In December 1976 there were some 2,100 of this species on the inlet Mr. Lane told me during a discussion that up to 100,000 birds are on this system during the summer peak. In the summer of 1976/77 there over 10,000 migratory waders present. There are about seventy specie that use the area. While the numbers are comparable with the Hardy-Blackwood system, they are far greater in species variety and number than the Leschenault and the Swan. Maximum population of the Lesche-

nault Inlet is around 7000 to 10,000 birds.

The aquatic flora is similar to other systems and includes the sea grasses Halophila ovalis, Ruppia megacarpa, Zostera muelleri, Heterozostem sp., Posidonea australis and Amphibolus antarctica. Algae include Chaetomorpha linum, Enteromorpha spp. and an algae which is causing great concern because of its profilic reproduction rate, Cladophora spp.

Shoreline vegetation includes Tuart woodland, with an understory of peppermint in some regions and Jarrah in others. There are areas of wattle and paperbarks border the inlet and swamp areas. Swamp sheoak is common near the water's edge in many places and where fresh water occurs there are large numbers of flooded gum.

The area has a much larger recreational useage than the Leschenault and this can be borne out by the results of a survey carried out by the Waterways Commission from the 26th to the 30th January 1978. The total number of boats on the estuary during this period was 4,900 compared to 1,771 on the Leschenault during the same period. (see sub - section 3.1.3) The area comes under the control of the Peel Inlet Management Authority.

2.2.3 The Hardy Inlet - Blackwood Estuary System.

This system is the most southerly of the four estuaries and while being the smallest in area, (890 hectares) has the second largest catchment area. (23,000 km^2) The inlet is fed by the Blackwood and Scott Rivers which have a mean annual runoff totalling about 2000 million cubic metres. The main population in the area is centred at Margaret River, (701) and Augusta, 464. (1976 census) The geomorphology of the inlet is of a shallow basin in Pleistocene sediments. The climatic conditions of the area can be seen in section 7.0. The fish species are predominantly the same as those found in the

other estuarine systems of the south west.

The bird species of the Hardy Inlet are comparable with those of the Leschenault Inlet,except for the Avoct which does not appear to extend its range this far south.(J.Lane,Fisheries and Wildlife) The area,however,supports a much larger population of waterbirds and in good years is comparable with the Peel Inlet.

Both the diversity and abundance of macro-algae in this region is less than the other estuaries and this is considered to be due to the lack of a holding substrate.The area contains filamentous algae such as Rhizoclonium riparium,Cladophora and Chaetomorpha species. The area has large meadows of Ruppia but Halophila ovalis,which once occured in the system has now disappeared.

The terrestrial vegetation is comprised of fringing sedges,paperbarks and salt marsh plants and in the fresh water areas,Melaleuca rhaphiophylla on the low ground and Eucalyptus rudis on the high ground.

The other main vegetation is generally comprised of open sclerophyll forest in the drier areas and heavy Jarrah-Marri forest in the areas of higher rainfall.

At present there is no management authority for the Hardy Inlet.

2.4 Present and Past Populations of the Region.

This section describes the population growth rates in the region since 1848.The population of Bunbury in 1848 was sixty six persons, while the overall population of the Wellington district totalled 358 Europeans plus an estimated 300 aborigines.The European population included 217 males and 141 females.Since this time the area has experienced a steady growth rate and the total estimated population for the Bunbury region today is 23,362.(including Australind and Eaton).Births in the region totalled 333 from June 30th 1977 to June 30th 1978.Deaths during this period totalled 158.Therefore the net increase is 175 persons.From the figures shown in table 2.4 it would appear that the region experiences a reasonably high immigration rate.In recent years this could probably be attributed to the downturn in the primary industries in the area.When Bunbury was originally planned for as major port the State Government estimated the population of the area would be 100,000 by the year 2000.The increase between the 1971 and the 1976 census was 2 percent and if this trend continues then the expected population by the year 2000 would be around 36,000. This could change slightly with the development of the Wagerup Bauxite and alumina industries.

The following table shows the population of the area from 1848 to 1978.

Table 2.4 Population since 1848.

Year	Males	Females	Total
1848	45	21	66
1881	-	-	583
1891	276	296	576
1901	1,773	1,658	2,455

Table 2.4 Cont.

Year	Males	Females	Total
1911	2,206	2,184	4,390
1921	2,145	2,330	4,475
1947	3,008	3,232	6,260
1954	4,929	4,940	9,869
1961	6,557	6,629	13,186
1966	7,789	7,670	15,459
1971	8,900	8,879	17,799
1976	9,686	9,827	19,513
1978 *	-	-	20,330

The above data was supplied by the Australian Bureau of Statistics.

* Estimated Population only.

Table 2.5 Australind and Eaton Figures for 1961 and 1976.

Year	Males	Females	Total
1961 (Australind)	104	103	207
1976	-	-	832
1961 (Eaton)	124	127	251
1976	-	-	1,423

From information received during the public survey(see 2.5.2 Question 1 (e) it would appear that the area has a large immigrant population. Of the 200 people interviewed the results show that59.4 percent of these families have lived in the area for less than eleven years.

2.5 Public Survey.

The aim of the survey was to gauge public reaction to several questions regarding the useage of the Leschenault Inlet.The information gathered during the survey should be of assistance in drawing up a management program for the area.The survey was carried out between the 21/10/79 and the 23/10/79 and a total of 200 people completed the questionaire.This represents about one percent of the total population of the region surrounding the Leschenault Inlet.Questionaires were distributed throughout all the suburbs of Bunbury and in the areas of Eaton,Clifton Park, and Australind,which are situated around the Inlet.The following is a sample of the questionaire.

2.5.1 Questionaire.

Question 1. (a) Area of residence----------

(b) Age (circle appropriate grouping)

20-25 26-31 32-37 38-43 44-49

50-55 56-61 62-67 over 67

(c) Sex - Male Female

(d) How many people in your immediate family --------

(e) How long have you resided in the Bunbury area (tick appropriate number of years)

1. less than one year
2. 1 - 5 years
3. 6 - 11 years
4. 12 - 17 years
5. 18 - 23 years
6. 24 - 29 years
7. 30 - 35 years
8. more than 35 years

Question 2. Recreation

(This refers to passive recreation such as fishing, crabbing, picnics, barbeques etc.)

(a) Do you own a boat? (tick appropriate) yes no

if so

(b) Do you use the boat on the Inlet or river (tick appropriate)

1. 2 - 15 times per year
2. 16 -27 times per year
3. 28 -39 times per year
4. 40 -50 times per year
5. over 50 times per year
6. less than 2 times per year

(c) How often do you or your family use the facilities in or around the Inlet.(tick appropriate answer)

1. Regularly
2. Occasionally
3. Rarely
4. Not at all

(d) What form of recreation does this usually take(list in order of useage,1 to 6.If you do not use for any of these reasons mark with a 0 and state any other uses)

1. Fishing ---------
2. Crabbing --------
3. Prawning --------
4. Pleasure boating --------
5. Picnics,B.B.Q. etc. ---------
6. Observing wildlife, scenery, vegetation etc. ---------

(e) Do you consider that fishing on the Inlet and river should be limited to (tick appropriate answer)

1. Amateur fishermen only
2. Professional fishermen only
3. Both amateur and professional fishermen

(f) Consider the following list of facilities in the recreational areas around the Inlet and river. How well have each of these been provided. (circle one number in each case)

		Very well provided	Reasonably provided	Better facilities needed
1.	Boat ramps	1	2	3
2.	Changing, showers, toilets	1	2	3
3.	Picnic tables	1	2	3
4.	B.B.Q. facilities	1	2	3
5.	Fresh water taps	1	2	3
6.	Rubbish bins	1	2	3
7.	Childrens playgrounds	1	2	3
8.	Access to water	1	2	3

(g) Do you consider that recreational areas should be (tick appropriate)

1. Landscaped
2. Left natural
3. Mixture of both

(h) Do you consider that the deep water channels in the Inlet are (tick appropriate)

1. Very satisfactory ------
2. Satisfactory ------
3. Do not know ------
4. Not satisfactory ------
5. Very unsatisfactory -----

(i) Would you approve of areas in and around the Inlet being proclaimed wildlife reserves.

yes -------- no ---------- do not know ----------

(j) Would you approve of areas around the Inlet being proclaimed native vegetation reserves.

yes --------- no ---------- do not know ----------

(k) Would you like to see some nature walks and trails constructed in the area.

yes --------- no ---------- do not know ----------

(l) If so,would you like to see a small booklet produced describing the birds and plants that can be seen in the area.

yes ---------- no ---------- do not know ----------

(m) Would you like to see some passive recreational areas developed on the western side of the Inlet.

yes ---------- no ---------- do not know ----------

Question 3. Land Useage.

(a) Do you consider that urban development should be allowed along the scenic drive area.

yes ---------- no ---------- some -------- do not know -----

(b) Do you consider that canal housing estates should be allowed around the edge of the Inlet.

yes -------- no --------- some -------- do not know -----

(c) Should further industrial development be allowed around the Inlet.(north of the Collie River)

yes --------- no -------- some --------- do not know ------

(d) Do you consider that the siting of the LaPorte factory was, (tick appropriate answer)

1. very satisfactory -------
2. satisfactory -------
3. do not know -------
4. not satisfactory -------
5. very unsatisfactory ------

(e) Do you consider that the effluent disposal system to be, (tick appropriate answer)

1. very satisfactory --------
2. satisfactory --------
3. do not know --------
4. not satisfactory --------
5. very unsatisfactory --------

(f) Do you consider that the companies attitude to the environment is, (tick appropriate answer)

1. very satisfactory ----------
2. satisfactory ----------
3. do not know ----------
4. not satisfactory ----------
5. very unsatisfactory ----------

(g) As a concluding comment what do you consider to be the best use for the inlet.(tick appropriate answer)

a. Primarily as a site for industry due to its close proximity to Bunbury and easy waste disposal. ---------

b. Primarily as a site for urban development around the foreshore and nearby forested regions. ----------

c. Primarily as a site for boating,fishing,crabbing,picnics,B.B.Q. etc., and as a nature reserve area. ----------

d. A mixture of b and c ----------

e. A mixture of a and b ----------

f. A mixture of a and b and c ----------

g. Do not know ----------

h. Any further comments.

2.5.2 Survey Results.

The following section shows the results of the public survey on an overall basis. This is followed by a general discussion of the results and a comparison is made between answers received in the Bunbury area and answers received in the urban areas adjacent to the Inlet.

Question 1. (b) Age Groupings of People Interviewed.

Age Grouping	Percentage
20 - 25	11.0
26 - 31	10.0
32 - 37	16.3
38 - 43	27.6
44 - 49	18.8
50 - 55	12.6
56 - 61	2.7
62 - 67	0
Over 67	1.0

Question 1. (c) Sex of the People Interviewed.

Sex	Percentage
Male	51.9
Female	48.1

Question 1. (d) How many people in your immediate family.

Number in Family	Percentage
1	2.4
2	8.4
3	9.6
4	25.3
5	27.7
6	14.5
7	7.2
8	3.7
9	0
10	1.2

Question 1. (e) Number of Years Resided in Bunbury Region

Year Groupings	Percentage
Less than one year	11.9
1 - 5 years	26.1
6 - 11 years	21.4
12 - 17 years	16.7
18 - 23 years	11.9
24 - 29 years	4.8
30 - 35 years	3.6
More than 35 years	3.6

Question 2.Recreation. (a) Do you own a boat.

Number who own a boat	45.5 %
Number who do not own a boat	54.5 %

Question 2 (b) Number of times boat used on estuary per year.

Useage Grouping	Australind%	Percentage Overall
2 - 15 times per year	18.1	33.3
16 - 27 times per year	54.5	22.2
28 - 39 times per year	9.0	16.7
40 - 50 times per year	18.4	11.1
Over 50 times per year	-	8.2
Less than 2 times per year	-	8.5

Question 2 (c) Use of facilities in or around the Inlet

Useage Grouping	Australind%	Percentage Overall
Regularly	47.4	24.4
Occasionally	42.1	37.8
Rarely	10.5	17.0
Not at all	nil	20.8

Question 2 (d) Primary use, secondary use and minor useage of Inlet.

Useage	Percentage		
	Primary Use	Secondary Use	Minor Use
Fishing	13.4	33.9	21.6
Crabbing	59.7	18.6	5.9
Prawning	7.5	15.3	27.5
Pleasure boating	6.3	11.9	11.8
Picnics, B.B.Q. etc.	6.3	8.5	21.6
Observing wildlife etc.	6.8	11.8	11.6

Question 2 (e) Fishing Restrictions.

Type of Fishing	Percentage
Amateur fishermen only	57.8
Professional fishermen only	1.2
Both professional and amateur fishermen	37.3
Do not know	3.7

Question 2 (f) Amenities provided in recreational areas.

Amenities	Very well provided	Reasonably provided	Better needed	Do not know
Boat ramps	20.5	36.2	26.5	16.8
Changing, showers, toilets	12.0	37.0	36.5	14.5
Picnic tables	3.6	29.0	49.4	18.0
B.B.Q. facilities	4.8	30.0	47.2	18.0
Fresh water taps	3.6	31.0	47.4	18.0
Rubbish bins	2.4	35.0	45.8	16.8
Childrens playgrounds	4.8	32.5	45.9	16.8
Access to water	9.6	50.6	25.3	14.5

Question 2 (g) Do you consider that recreational areas should be?

Form	Australind %	Percentage Overall
Landscaped	nil	1.2
Left natural	47.3	27.7
Mixture of both	47.3	63.9
Do not know	5.4	7.2

Question 2 (h) Deep water channels.

Grouping	Australind%	Percentage Overall
Very satisfactory	nil	2.4
Satisfactory	52.6	31.7
Do not know	26.3	46.1
Not satisfactory	15.7	13.9
Very unsatisfactory	5.2	5.9

Question 2 (i to m) Reserves etc. (in brackets refers to Australind)

(i) Would you approve of areas in and around the Inlet being proclaimed wildlife reserves?

Yes 87.8% (100) No 7.3% Do not know 4.9%

(j) Would you approve of areas around the Inlet being proclaimed native vegetation reserves?

Yes 89.0% (100) No 4.9% Do not know 6.1%

(k) Would you like to see some nature walks and trails constructed in the area?

Yes 80.5% (84.2) No 13.4% (15.8) Do not know 6.1%

(l) If so,would you like to see a small booklet produced describing the birds and plants that can be seen in the area?

Yes 82.9% (94.7) No 11.0% (5.3) Do not know 6.1%

(m) Would you like to see some passive recreational areas developed on the western side of the Inlet?

Yes 64.6% (47.4) No 26.9% (52.6) Do not know 8.5%

Question 3.Development.(a to c)

(a) Do you consider that urban development should be allowed along the scenic drive area?

Yes 0% (2.0) No 73.3% (89.0) Some 23.3%(9.0) Do not know 3.4%

(b) Do you consider that canal housing estates should be allowed around the edge of the Inlet?

Yes 3.5% No 84.9% (94.7) Some 5.8% (5.3) Do not know 5.8%

(c) Should further industrial development be allowed around the Inlet? (i.e. north of the Collie River)

Yes 1.2% No 87.8% (100) Some 7.3% Do not know 7.3%

Question 3. LaPorte Titanium Plant.

(d) Do you consider that the siting of the LaPorte factory was,

Grouping	Australind%	Percentage Overall
Very satisfactory	0	3.6
satisfactory	5.2	14.4
Do not know	5.2	7.2
Not satisfactory	10.5	22.9
Very unsatisfactory	80.1	51.9

(e) Do you consider the effluent disposal system to be,

Grouping	Australind %	Percentage Overall
Very satisfactory	0	4.8
satisfactory	5.2	10.8
Do not know	10.5	20.5
Not satisfactory	15.8	18.0
Very unsatisfactory	68.5	45.9

Question 3 Development Continued.

(f) Do you consider that the companies attitude to the environment is,

Grouping	Australind%	Percentage (overall)
Very satisfactory	0	9.6
Satisfactory	15.8	22.9
Do not know	5.2	22.9
Not satisfactory	31.6	21.7
Very unsatisfactory	47.7	22.9

(g) Best useage for the Inlet.	Overall Percentage	Aust.
(a) Primarily as a site for industry	0	0
(b) Primarily as a site for urban development	1.2	0
(c) Primarily as a site for boating, recreation etc.	74.7	84.2
(d) Mixture of b and c	18.0	15.8
(e) Mixture of a and b	0	0
(f) Mixture of a and b and c	4.8	0
(g) Do not know	1.3	0

2.5.3 Discussion of Results.

It can be seen, where recorded, that the people who live close to and around the Australind area are more concerned about the environment of the region than those who live in Bunbury. These people tend to utilize the facilities more often and would appear to be more concerned about further development around the Inlet, especially on the western side as many of the homes in this region would then lose their views of the natural bushland. (mainly Tuart - Peppermint forest)

The main recreational use for the Inlet would appear to be for crabbing and fishing.Most of the people who use the Inlet utilize this resource,while a smaller number enjoy the scenery and the wildlife.(see Question 2 (d).In most cases people tend to consider that better facilities are required in the recreational areas (see question 2 (f),and the general concensus is that the recreational areas should have a mixture of landscaping and natural vegetation.Although as the results show (Q2 (g) the people of Australind have a different opinion to those of Bunbury.A similar difference of opinion occurs in relation to reserves and development.(see Question 2 (i to m) and Question 3(a to g).

Further Comments.

The following are additional comments made during the survey and are taken directly from the questionaires.Many people commented,especially in the Australind area that they considered the survey was good and that it had made them aware of many things which they normally took for granted without considering the consequences to the environment.

1.Minimum building blocks no smaller than five hectares between scenic drive and highway with restriction on clearing.No clearing on the western side of the estuary.

2.There is more than enough cleared land to accomodate industry and housing and greater effort should be made to protect the last vestige of our natural heritage.

3. I would like to see the by-pass road started to take the heavy traffi away from Australind.More rubbish bins required during summer and holiday periods.More trees needed on the foreshore areas for protection and beauty.A great need for people in boats to bring back their rubbish with them and either take it home or put it in rubbish bins.During storms hundreds of plastic bags and bottles wash up on

the foreshore.Many other forms of rubbish probably litter the estuary floor.

4.No matter what we think the fools who are elected by the fools who elect them will do just what they wish until future generations will curse their names.

5.The Inlet and surrounds are unique and beautiful,rich in natural vegetation and wildlife and must be protected at all costs from encroaching industry, housing developments and trail bikes.W.A. is adequately provided with desert environments as it is.

6.I would like to see the LaPorte pipline removed or put underground.Also the factory itself hidden more by trees.If we can't get rid of the eyesore at least blend it into the environment.

7.Siting of LaPorte an environmental disaster.

8.LaPorte claims waste is a government responsibility.

9.I think that the Inlet is far too beautiful and unique for any other purpose than those mentioned in question 3 g (c)

10. I consider that the governments attitude to the Laporte effluent is also very poor.

11.I feel this is an emotive,biassed and loaded questionaire designed to give the answers required by the econuts who are deliberately trying to ruin our economy.

12.Something should be done to stop soil erosion on the western side of the Inlet.Develop it as a wildlife sanctuary.

13.I think that as much as can be preserved should be preserved for future generations to enjoy as we have done and hopefully will be able to keep on doing.

14.I feel that the western side of the inlet could provide the same close escape from the city life for Bunbury and districts as Kings Park does in Perth if left undeveloped.

15. Must be left in natural state for future generations.

16. I think the swampy parts of the inlet are not serving any purpose because they are not easily accessable.

17. Leave the Inlet alone.

18.It is only a matter of time before the Inlet will be so shallow that it will be impossible to use a boat.Similarly the damage being done by professional fishermen to young stocks and the depletion of fish has become more marked in the last three years

19.I enjoy walking and driving around the Inlet observing the birdlife.

20.Reference Q2(1) desperate need for this.Map and reference required as a matter of urgency.

21.Less questions more action.

3.0 RECREATION, LAND USE and ZONING.

3.1.1 Recreation.

The Leschenault Inlet provides an excellent recreational area for both local residents and visitors alike. The area provides good net and line fishing with many varieties of fish available in both the inlet and the rivers. Crabbing and prawning during the summer months draws large crowds, especially for the Blue Manna crab, which is a much sought after species by professional fishermen, local residents and visitors. The equipment required for this activity is inexpensive and because of the large areas of shallow water a boat is not required. (see fig. 4.3.1) Catches are limited to thirty crabs per day per person (non-professional) and this species occurs in large numbers from November through to late Febuary, early March. (see sub - section 5.4.16 and table 5.5) A popular recreational activity is crabbing and prawning parties. The water system and nearby bush has many fine scenic attractions for pleasure boating and bush walkers alike and for bird watchers the region provides reasonably large numbers and a good variety of avifauna, especially during the summer months when the northern hemisphere migratory species arrive in the region. (see sub - section 5.3)

3.1.2 Amenities.

(1) Toilet and shower blocks.

Paris Road boat launching ramp has toilet and shower facilitie available. The shoalhaven ramp has a toilet block and the Eaton ramp has a toilet and shower block adjacent to the launching ramp.

(2)Boat Launching Ramps.

(a) Paris Rd.This area has good car parking facilities and the ramp has a gentle but uncemented surface.This is the most popular launching ramp in the region.

(b) Shoalhaven.This area is situated just below the Collie Bridge and has two ramps;one cemented,one gravel.Present car and trailer parking facilities only cater for about eighteen vehicles.

(c) Eaton Ramp.This ramp is situated on the eastern side of the Collie Bridge and is very popular,especially for people using the Collie River and the cut area.This ramp is fairly steep,but cemented.

(d) The Elbow Ramp.This ramp is situated on the Collie River and because of its poor condition is very seldom used.

(e) Boat launching facilities are available on the southern end of the inlet,but as this area is cut off from the northern part of the inlet,boats launched here tend to head for Koombana Bay or the open sea.

(3)Picnic,Barbecue,and Rubbish Disposal.

The foreshores have many suitable grassed areas where picnic parties may enjoy a pleasant day by the water.The small park by the Collie Bridge has swings for children,as does the area near the Eaton ramp.Barbecue facilities are non-existant and make-shift barbecues from old bricks and stones can be seen scattered along the foreshore;among other litter as remnants of crabbing and prawning parties.Rubbish disposal facilities are placed at the most popular areas and consist of unsitely forty four gallon drums.

3.1.3 A Census of the Boat Population.

3.1.3 A Census of the Boat Population.

Data in this section is based directly on a census carried out by the Waterways Commission over a seven day period from the 24th of January to the 30th of January 1978, between the hours of 0500 and 1900. The areas surveyed included the main launching ramps at Paris Road, Shoalhaven and Eaton and areas along the foreshores of the inlet and the Collie River.

Table 3.1 Paris Rd. Ramp.

Boat Size(metres)		3.6	5.5	> 5.5
24th January	AM	18	26	2
	PM	4	27	2
25th January	AM	19	29	2
	PM	11	14	2
26th January	AM	11	30	1
	PM	5	30	0
27th January	AM	24	20	1
	PM	10	16	1
28th January	AM	40	48	3
	PM	12	54	3
29th January	AM	31	90	4
	PM	12	56	4
30th January	AM	23	66	2
	PM	7	38	1
Total Launchings	AM	166	309	15
	PM	61	235	13
Grand Total Number of Launchings			799	

Table 3.1 Cont.

Power of Engines (h.p.)	Number	Percentage
70	326	40
10	330	41
20	81	10
70 plus	62	9

Origin of Users	Number	Percentage
Local Residents	508	64
Holiday Makers	245	31
Day Visitors	46	5

Frequency of use per year	Number	Percentage
2 - 15 times	376	46
16 - 50 times	231	29
over 50 times	166	22
once	26	3

Purpose.Most of those using the ramp were going crabbing.

Public Comments.

Many boats were seriously overloaded and many people commented that this situation needs policing.

The eight Knot speed limit in the estuary was ignored.(note:almost half the boats launched had engines of 70 h.p. or more.)

There were numerous requests for a cement launching ramp.

There were complaints about congestion on the ramp when it was busy.

A rubbish bin is required on the waterfront.

The parking area should be extended.

The cement curbing at the north end of the car park should be removed to allow through-flow of traffic.

Footpaths are needed from the parking area to the toilet/shower block.

Table 3.2 Shoalhaven Ramp.

Boat Size (metres)		3.6	5.5	>5.5
24th January	AM	12	4	1
	PM	4	6	0
25th January	AM	9	5	0
	PM	4	5	0
26th January	AM	9	6	1
	PM	8	4	0
27th January	AM	5	6	0
	PM	7	7	1
28th January	AM	10	5	0
	PM	19	12	1
29th January	AM	13	22	2
	PM	9	9	2
30th January	AM	11	11	0
	PM	9	19	0
Total Launchings	AM	71	59	4
	PM	58	62	4
Grand Total Number of Launchings			258	

Table 3.2 Cont.

Power of Engine (h.p.)	Number	Percentage
10	120	47
70	88	34
70 plus	26	19
20	24	9
Origin of Users	**Number**	**Percentage**
Local Residents	154	60
Holiday Makers	79	30
Day Visitors	25	10
Frequency of Use Per Year	**Number**	**Percentage**
2 - 15 times	109	42
16 - 50 times	96	37
over 50 times	45	18
once	8	3
Purpose	**Number**	**Percentage**
Crabbing	166	64
Fishing	64	25
Pleasure	28	11

Public Comments.

A concrete launching ramp is needed as many cars have difficulty pulling the boats up the steep slope.

The area needs levelling and the parking area enlarged.

The rubbish bins need to be sited near the water,not in the car park.

The rotting remains of sunken boats and old jetties should be removed.

Parking should be encouraged on the south side of the road and not on the river bank.

An outside shower and fresh water tap is needed.The north east side of the toilet block was suggested.

Locals said that only about half the usual number of Perth visitors were crabbing and this was due to the good season being experienced on the Swan and the Peel Estuaries.

It was noted that a large proportion of the people crabbing were over sixty years of age.

Table 3.3 Eaton Ramp.

Boat Size (metres)		3.6	5.5	>5.5
24th January	AM	2	2	0
	PM	4	4	2
25th January	AM	4	2	0
	PM	6	5	1
26th January	AM	0	5	1
	PM	1	9	0
27th January	AM	0	6	2
	PM	4	1	0
28th January	AM	1	11	2
	PM	6	30	1

Table 3.3 Cont.

Boat Size (metres)		3.6	5.5	5.5
29th January	AM	5	27	6
	PM	3	28	4
30th January	AM	1	22	3
	PM	1	23	1
Total Number of Launchings	AM	13	75	14
	PM	25	100	9

Grand Total Number of Launchings 236

Power of Engine (h.p.)	Number	Percentage
70	96	41
10	65	28
70 plus	55	23
20	20	8

Origin of Users	Number	Percentage
Local Residents	172	74
Holiday Makers	53	22
Day Visitors	11	4

Table 3.3 Cont.

Frequency of Use Per Year	Number	Percentage
16 - 50 times	119	49
2 - 15 times	88	37
over 50 times	17	10
once	12	4
Purpose	**Number**	**Percentage**
Crabbing	117	50
Fishing	71	30
Pleasure	48	20
Destination	**Number**	**Percentage**
Estuary	140	60
River	67	28
Ocean	20	7
Cut Area	9	4

Table 3.4 Unofficial Launching Ramps.

Boat Size (metres)		3.6	5.5
Total over 7 days	AM	49	14
	PM	28	6
Grand Total Number of Launchings		97	

Table 3.4 Hire - Boat Launchings.

Boat Hiring Establishment	Motor Boats	Surfcats	Canoes
Shoalhaven Hire Boats	100	62	85
Derek Brown Hire Boats	25		
E.and B. Boat Hire	39		
Sail-a-Cat(J.and L.Gornall)		70	
Total Number of Launchings	164	132	85
Grand Total Number of Launchings		381	

Table 3.5 Summary of Boat Survey.

Ramp	Number of Boats
Paris Road	799
Hire - Boats	381
Shoalhaven	258
Eaton	236
Foreshores	97
Total Launchings	1,771

Purpose	Number
Crabbing	1,332
Pleasure	301
Fishing	134

3.1.4 Boat Hiring Facilities.

The following are details of boat hiring facilities which are available to local residents and visitors to the area.The majority of business comes from day visitors and holiday makers.

Table 3.5 Boat Hiring Details.

Establishment	No. of: Motor Boats	Canoes	Surf-Cats
Shoalhaven Hire Boats	10	8	4
D.Brown Hire Boats	3		
E.and B.Boat Hire	5 (6 h.p.)		
J.and L Gornall	2		3
Total Available	20	8	7

3.1.5 Caravan Parks and Camping Facilities.

Caravans and camping are restricted to licensed areas.There are three small caravan parks situated near the Collie Bridge in Australind.One park situated next to the Collie Bridge Tavern also offers chalets for hire.These buildings are small and in poor condition and can only be considered an eye-sore.There are three large caravan parks in Bunbury.These are situated in south Bunbury,'The Glades',which offers pleasant conditions and has good facilities;Koombana Park,which offers close access to the southern end of the inlet,a small par 27 golf course and due to recent industrialization of the area fine views of mounds of illmenite,wood chips and rusty and dirty old holding bins and old machinery.The third park is situated near the back beach and offe reasonable conditions in a reasonably unprotected area.

3.1.6 Partly Developed Recreational Reserves.

Areas such as the Paris Road launching ramp, the Eaton launching ramp and the Shoalhaven launching ramp are considered in other reports on the area to be fully developed recreational areas. However landscaping and facilities in these areas are only 'adequate' and further facilities are required to bring the reserves upto standard. These three areas are described in sub - section 3.1.2.

3.1.7 Undeveloped Recreational Areas.

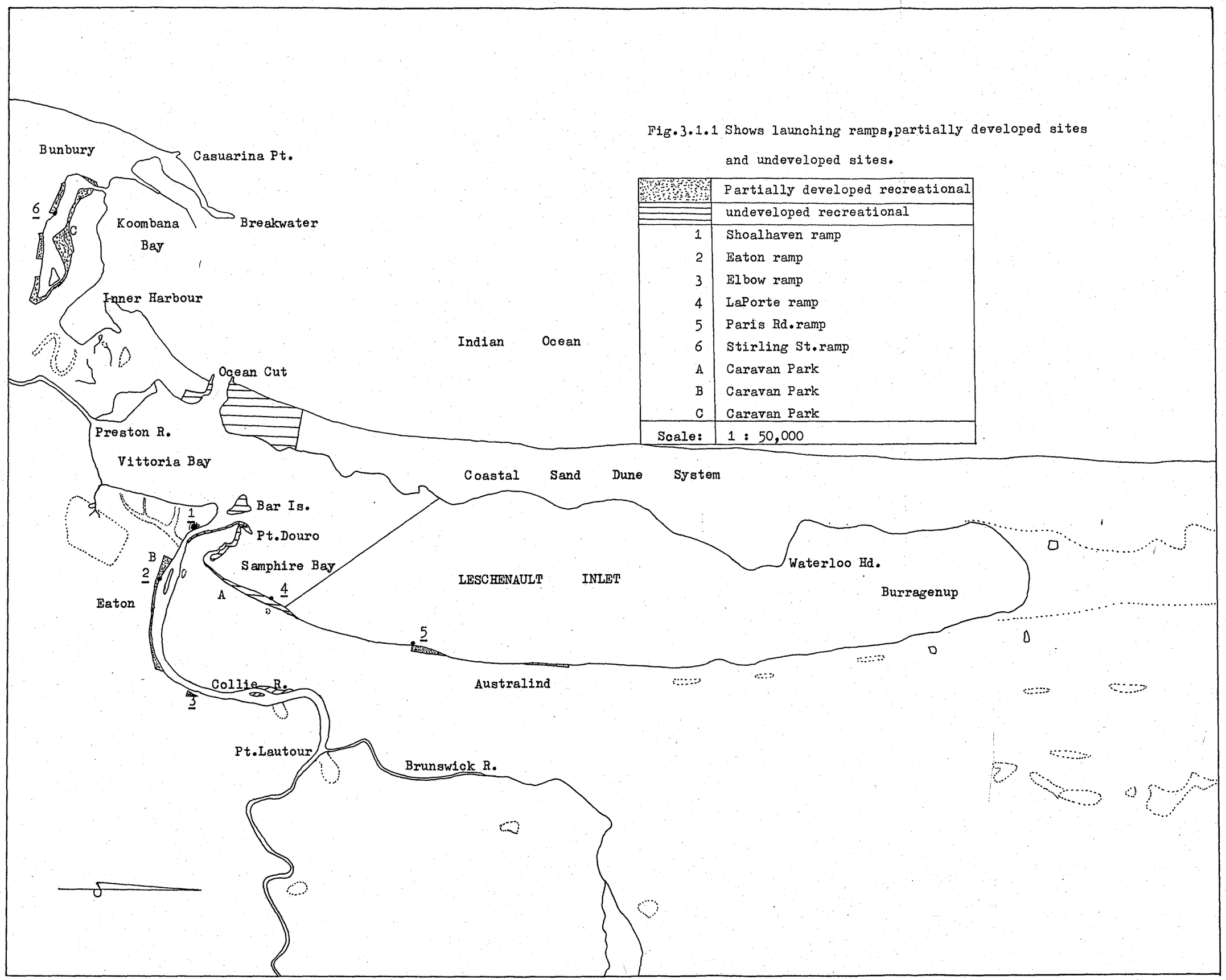
These areas are situated on the foreshore of the inlet from the Collie Bridge to the northern extremity. In several places the sedges have been removed to allow access to the water. In others, the sedges have been removed to allow gravel to be layed for car parking. The two sites which fit this category are opposite the LaPorte plant and just to the north of the pipeline. This area has a toilet block and some attempt has been made at development. Another is where the Old Coast Road and the Scenic Drive meet. Rubbish bins are provided in most of these locations. The area on the southern side of the cut is also an undeveloped recreational reserve. This area is particularly popular with beach fishermen as they can catch the fish as they enter or leave the inlet. Up to one hundred people can be seen in this region during the summer months. The dunes on the northern side of the cut are zoned as reserve, but lack any development at this stage. Bar Island is also set aside as recreational reserve, but to date has no facilities.

3.1.8 Flora and Fauna Reserves.

At present the area has no flora and fauna reserves, although many fine areas for this purpose exist within the bounds of the inlet.

Fig.3.1.1 Shows launching ramps, partially developed sites and undeveloped sites.

	Partially developed recreational
	undeveloped recreational
1	Shoalhaven ramp
2	Eaton ramp
3	Elbow ramp
4	LaPorte ramp
5	Paris Rd.ramp
6	Stirling St.ramp
A	Caravan Park
B	Caravan Park
C	Caravan Park
Scale:	1 : 50,000



3.1.9 Scenic Drives,Nature Trails.

A scenic drive exists along the north eastern foreshore.This road was the original coast road.There are some fine examples of paperbark trees along this road and they are protected.The road is sealed and although narrow,is in a reasonable condition. There are no set out nature trails in the region.

Figure 3.1.1 shows the launching ramps,reserves and caravan parks.

3.1.10 Problems Associated with Recreation in the Region.

Erosion.

This occurs in areas where sedges have been removed to allow for access to the water.The bow waves from speeding boats,wave action from westerly winds and general water movement erode the soft edges of the inlet.This is also occuring along the southern side of the Collie River where reeds have been removed and in areas where fishermen dig for polychaet worms.

Boats.

Apart from the damage caused to the shoreline by bow wave action, speeding boats churn up the soft sediment and send it into suspension.(see sub - section 4.2.3)In shallow areas the sea grass beds are damaged by boat propellers and this phenomenon can readily be seen from the air.Oil and petrol spillage and leaks affect the waterbirds and pollute the shoreline.This does not appear to be a major problem in the estuary.Speeding boats are a danger to other boats,crabbers and they disturb and frighten the waterbirds.

General Damage by People.

People tramp down and cut down sedges to gain access to the water' edge.This mainly occurs from residents who moor their boats in the water opposite their homes,along the coast road area in Australind

People leave large amounts of litter lying about,especially after crabbing and prawning parties along the north eastern shoreline.

3.1.11 Potential Recreational Reserves.

Eastern Shoreline.

The large wetland area which is bordered on the northern side by Collie River and on the western side by Vittoria Bay has excellent potential as a flora and fauna reserve and along the western shore for recreational development plus some possible housing or holiday home development.This region was originally zoned 'special development' (canals estate,see section 3.3),but is now owned by the Bunbury Town Council.Bar Island,is a recreation reserve as is the small island upstream from Alexander Island.Alexander Island is freehold land.The area between the Collie River and Samphire Bay is at present unzoned and this peninsula would make a fine recreational reserve.It is bordered on the southern side by the Collie River and Bar Island is situated off the western point.(Point Douro)The area opposite the Laporte plant has possibilities as a picnic and barbeque area as this region is a good crabbing and prawning area.Areas along the Collie River offer good flora reserve areas.The freehold forested areas on the north eastern shore offer excellent views of estuary and the diverse woodland in this region would make a good area for a nature trail.The swampland to the north should be left as a fauna reserve.

Western Shoreline.

The southern section of this area(lots 405 and 416) are owned by the State Energy Commission.The power station is situated on lot 416 (see sub - section 3.3)The cut area and lot 362 are zoned recreational as is the area to the north of the cut.(see map 3.1)Both these regions would be siutable for recreational development.The small bays on the northern side of the cut give good access and

provide sheltered waters during the summer months.The large area which constitutes the western dunes system is predominantly free-hold land.At the southern end 585 hectares of crown land are at present being used for effluent disposal and this rules out any options for development until at least 2011.(see sub - section 3.3) This peninsula is Tuart - Peppermint woodland and along with the unzoned north western section offers excellent areas for partial development as bushwalking and nature trail areas.The whole area offers a variety of plant ecosystems,(see section 6.0) a large variety of waterbirds(see section 5.2) which can be viewed with-out disturbance,and many other animals which can be readily seen at certain times of the day;especially kangaroos.(see section 5.6)

3.1.12 Damaged and Old Structures in the Inlet.

Old jetties.

There are twenty three private jetties along the southern side of the Collie River between the bridge and the Shoalhaven boat ramp. Of these seven are in poor condition,ten are badly in need of repair and five are in reasonable condition.This area also has many old and rotting boats,some of which have been sitting on the bottom for a number of years.

Old Fences and Posts.

There are many old posts in the water and an old fence runs out for a few hundred metres at the northern end of the inlet.These are of no use and should be removed.

3.2 Land Ownership and Development

3.2.1 Private Land Ownership and Development

With the exception of small,narrow road side reserves,all the land along the eastern shoreline of the inlet is privately owned. The land situated between the scenic drive and the coast road is privately owned,as is the area to the north of the inlet which is presently used for agriculture.(lay map F5A over map F5B)(Map F5A shows the urban and industrial areas)The forested region to the east of the scenic drive is presently being developed for small rural holdings and urban areas.These come under the Shire of Harvey Town Planning schemes,of which there are three in existance.One covers the Australind area,the second covers the Leschenault Parklands development and the third the whole of the Harvey Shire.The second scheme is presently being amended.The first allows for urban development in the Australind Townsite which extends along the coast road and along the first section of the scenic drive.Approximately sixty new blocks, serviced by septic tanks,are being developed in this region at present (see map F5A)These blocks will be in the Tuart - Marri woodland (see overlays F 5,F5A and F5B) and will be about 800 m^2 each.The Leschenault Parklands development which extends from the coast road to the scenic drive.However,no building is alowed below the escarpment and only land for the construction of dwellings can be cleared without 'approval' in this area,There are eighty blocks ranging in size from 39.6 hectares to 62.7 hectares.Along the scenic drive the blocks are 5.7 to 18.9 hectares in size.The marina waters development,which was originally to be a dredged canal and marina with motels,country club, holiday chalets and urban land has not been approved and this area will now be developed as 5000 m^2 blocks (50 in number) and come under similar regulations as Leschenault Parklands.

Other urban regions are Eaton,Clifton Park and the Australind Townsite. The main development plan for the overall region is in the form of a southern corridor which extends south along the coast from Bunbury and north along the eastern side of the inlet.The area to the south of the Collie River,bordered by Vittoria Bay on the west,was originally put forward as a canals estate.This,however,was rejected and the area,which is a highly productive wetland,is now owned by the Bunbury council and development proposals are being planned,but not known.The land which is situated around Glen Iris (see map F 5 A) is presently zoned rural but will eventually become industrial.

3.2.2 Vacant Crown Land

This comprises most of the western side of the inlet,with the exception of the area around Waterloo Head which is privately owned and used as a commune.The remainder is owned by the Public Works Department and is used for effluent disposal in the souther section.Small areas of crown land exist within the Bunbury Port Authority area to the south of Vittoria Bay.

3.2.3 Industrial Land and Development

This covers the inner harbour area,the Koombana Bay area and the Laporte Titanium plant at Australind.When referring to the disposal of LaPorte effluent,the senate select committee on water pollution said..."this is a classic case of industrial pollution.When a new industry is to be established in the state the government and the enterpreneur are naturally concerned primarily with the economic success of the industry.The judgements made about the side effects of pollution often receive rather less detailed consideration."

The Laporte titanium plant was established at Australind(see map F 5 A) in 1962 to covert ilmenite into titanium dioxide.During the process an effluent is produced (about 1.5×10^6 gallons per day) which consists of white titanium dioxide (2.0%),ferrous sulphate(44.0%),free sulphuric acid

(52.5%),unattached ilmenite (1.5%).Two constituents of the effluent are potentially dangerous to the environment;frrous sulphate and sulphuric acid.

Ferrous Sulphate

Ferrous sulphate is soluble in acid solution but precipitates out as ferric hydroxide in the presence of oxygen,forming a reddish floc slightly heavier than water.Seawater can provide the necessary oxygen and normally the precipitate would settle to the ocean floor,however,within the littoral zone,wave action tends to keep the floc in suspension.

Sulphuric Acid

Free acid in the effluent is concentrated,highly corrosive,and reacts with calcium carbonate in calcareous sands and limestone to form various hydrous forms of calcium sulphate.The sulphates are precipitated as a non-reactive,impervious cement in the sands and limestone and may to a large extent control further movement of the effluent within the system and tend to prevent continued chemical reaction and acid neutralization(R.Barnes,Geological Survey of W.A.On Laporte effluent disposal:not available)

Initially the effluent was dicharge into shallow lagoons situated in the foredunes.(1962-1968)The effluent seeped through the sand dunes and caused extensive staining of the ocean and beaches.It was found that suspended solids contained in the effluent eventually sealed the bottom of the lagoon.Following this discovery,lagoons were constucted on the ocean side of the dunes system.It was considered because of ground water flow,that the effluent would seep towards the ocean rather than the inlet.However,the effluent seeped towards the dunes area,caus- the destruction of the adjacent Tuart forest.In 1974,effluent was disposed of into natural vegetation hollows and after twelve months it

became apparent that the vegetation on the eastern side of the dunes was dying.The effluent at present is being dicharged into another hollow.Experiments are presently being carried out on submarine pipeline disposal six kilometres out to sea.Reports on this show that it is having little effect on the aquatic fauna and flora.The effect of this effluent on fish is not fully known but experiments have shown that fish avoid ferric hydroxide flocculate in sea water when the iron concentration was 0.5 mgl^{-1} or greater.A dose of the effluent at PH of 5.1 and iron concentration of 21 mgl^{-1} was found lethal for mullet. Whiting succumbed at PH 5.4 and iron concentration of 19 mgl^{-1}(preliminary information available on disposal systems)

Bunbury Power Station

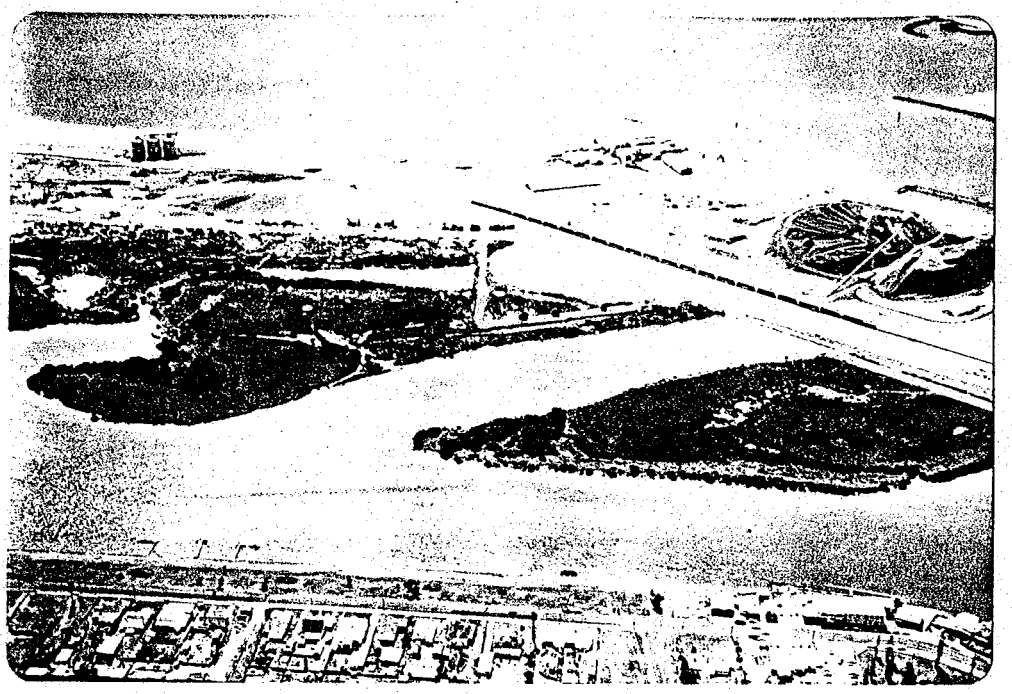
This is a coal fired station and discharges large quantities of fly ash over the Bunbury region.This problem is currently being rectified.

Cable Sands Limited

This plant is situated on the foreshore of the once popular,protected Koombana Bay.The process carried out is one of extracting ilmenite from sand and the waste product (sand)is discharged through tailing lines into the swamp adjacent to Anglesea Island.The filling of the swamp is resulting in the loss of a valuable wetland area,which is extensively used by waterfowl.

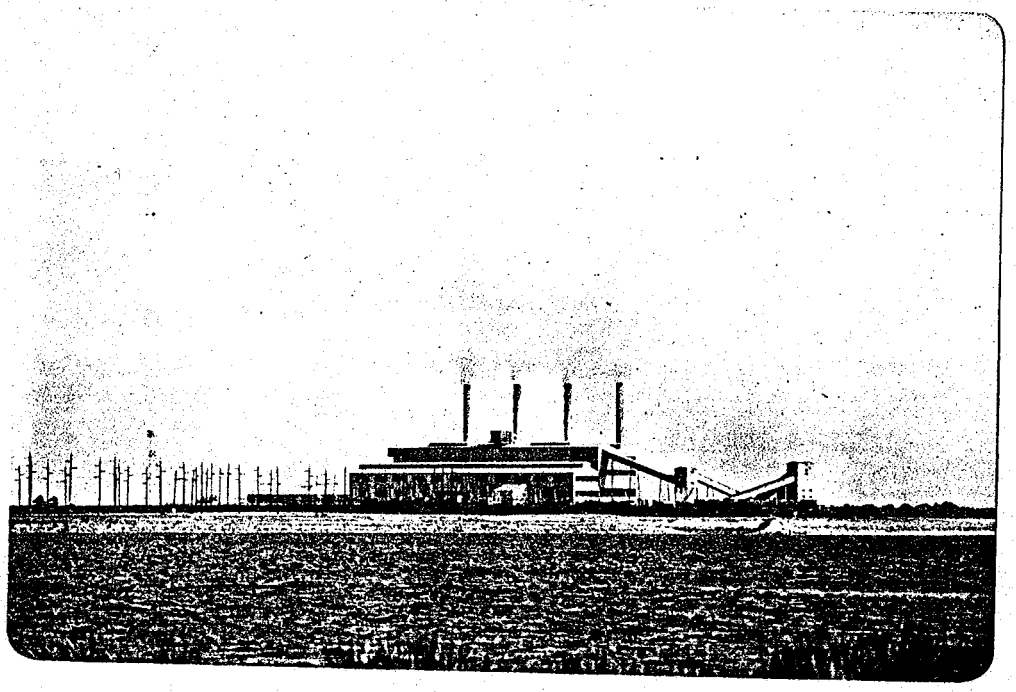
Inner Harbour Development.

This area now cuts off the southern end of the inlet from the northern end and has been partly responsible for flooding in the area.However a boom gate,costing about 250,000 dollars is to be constructed at the southern entrance near the Bunbury railway station.This area has the loading terminal and storage area for the woodchips and Alcoa alumina industries.It is eventually proposed to extend this harbour to the south east.

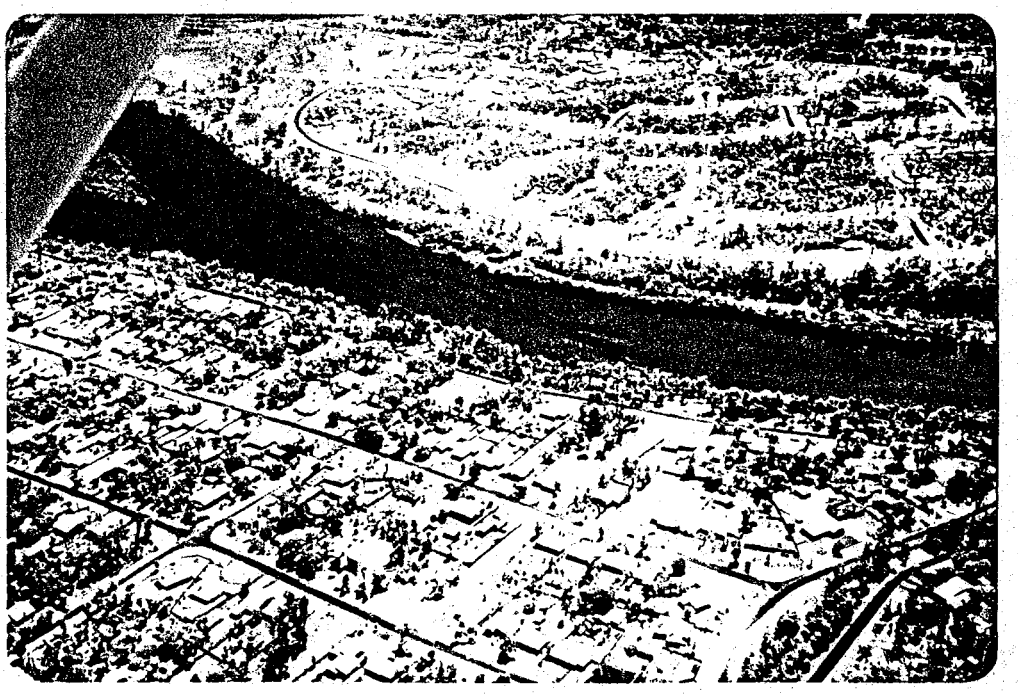


Aerial photograph showing inner harbour area with woodchip terminal and Cable Sands.The area behind Anglesea Island (Mangrove community) is the tailings disposal area for Cable Sands.

The Collie River wetlands that is to be developed to retreive the money paid for the area.See figure 1.1



The Bunbury Power Station



Infra-red photograph showing the Collie River and the urban areas of Eaton and Clifton Park. The marginal vegetation is Eucalyptus rudis on the far side and Eucalyptus rudis, Eucalyptus calophylla and Banksia grandis and Banksia attenuata on the near side. The housing in these areas are close to the river and stormwater and runoff enter the inlet via the river.

4.0 PHYSICAL FEATURES of the LESCHENAULT INLET.

4.0.1 Introduction.

This section describes the geology,soil distribution,hydrology, water depths,water quality,dredging and physical changes which have occured in the inlet.

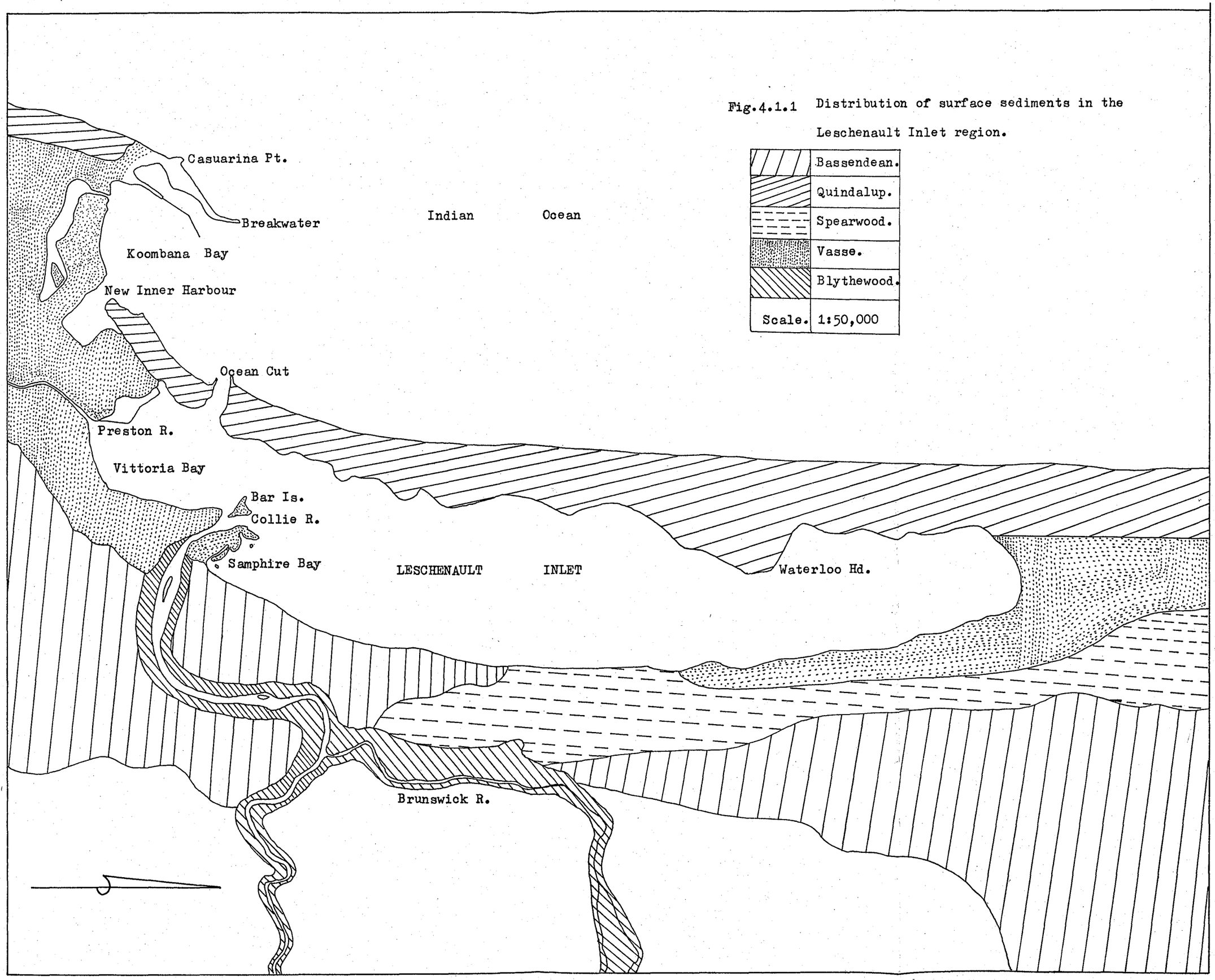
4.1 Geology and soil associations.

This sub-section has been included to give the reader a general outline of the geology and soil associations that exist in the study area.This is important because vegetation species can then be associated with the soil distribution.For a comparison of soil types and plant communities see section 6.0.Information on the geology and soil association was obtained from the Geological Survey of Western Australia and from field observations.

4.1.1 Surface sediment distribution.

Five main soil types occur within the study area;Bassendean,Vasse, Quindalup,Spearwood and Blythewood.Figure 4.1.1 shows the distribution of these surface sediments around the Leschenault Inlet.The coastal dunes system is predominantly quindalup with a small section of vasse in the vicinity of Anglesea Island.Vasse occurs on the southern portion of the inlet and is distributed along the north eastern shoreline.Bassendean is present along the eastern area from the Collie River to the scenic drive.It is also present to the south of the Collie River and on the western side it adjoin the vasse.Along the shores of the rivers,blythewood occurs.The north eastern section of the area is spearwood.This is situated between the vasse and the bassendean associations.For a cross section of the surface sediment see Figure 4.1.2.This diagram was drawn from information obtained from Figure 4.1.1.

Fig.4.1.1 Distribution of surface sediments in the Leschenault Inlet region.



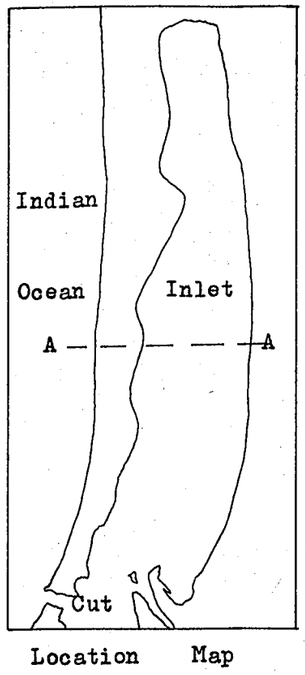
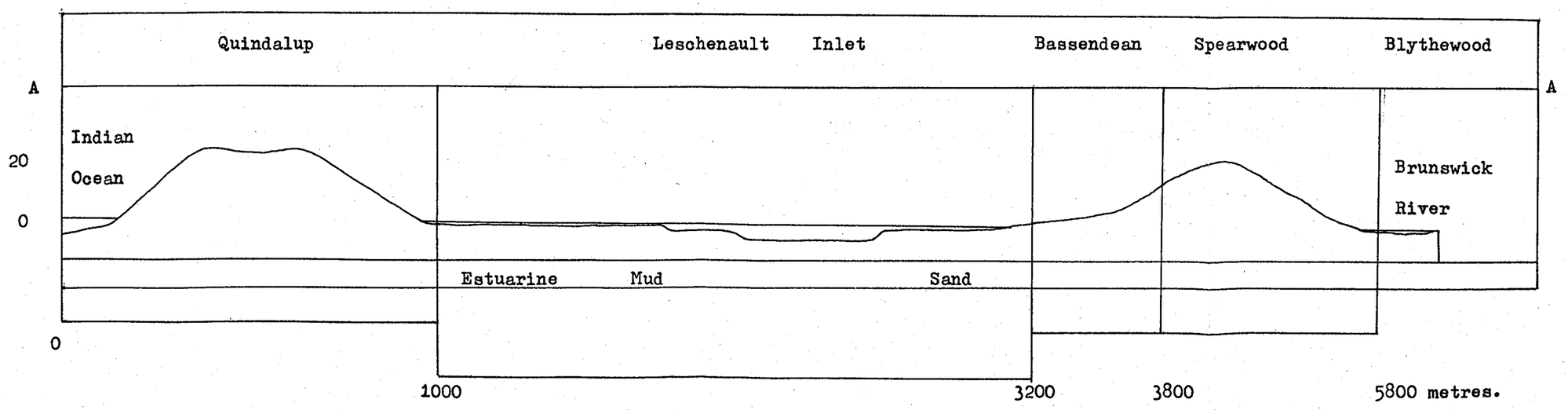


Fig. 4.1.2 Shows a cross section through the area surrounding the Leschenault Inlet.The diagram depicts the surface sediment as represented in Fig. 4.1.1 (The diagram is not to scale,)



4.1.2 Quindalup.

The sand dunes which form the coast line on the western side of the Leschenault Inlet were once connected to Bunbury,but because of the opening of the ocean cut,this area has become a 'peninsula. (see sub-section 4.2)These dunes form part of the quindalup dunes system that stretches along the coast from Geraldton in the north, to Dunsborough in the south.These dunes are composed of fine grain ed,slightly calcareous sands.

4.1.3 Vasse.

These soil areas are formed by the deposition of alluvial soils brought down by the river systems.Vasse is believed to be one of the youngest of the eight soils which fall into this category.It is a light soil,grey in colour, relatively fertile and well drain-ed.

4.1.4 Bassendean.

These soils were once an accumulation of beach sands along an old coastline and were probably, originally, calcareous sands,likened to the quindalup system.Over the years the carbonate has been leac ed out of these dunes by rainwater, leaving a grey-yellow infertil soil.The areas where these soils occur are usually rich in native plant species,but are poor areas for agriculture.

4.1.5 Spearwood.

These dunes are younger than the bassendean system and the soils are far less leached.They have a reasonably high iron content and this is reflected in their yellow-brown colouring.The surface lay-ers have been well leached by precipitation and the carbonate has been forced through the layers to form limestone deposits.Observ-ations in the area where this soil occurs show limestone in the surface layers where ploughing has been carried out to form fire-breaks.The area where spearwood occurs is well vegetated with marr tuart and banksia.

4.1.6 Geology of the Western 'Peninsula'.

A survey of the western sand dunes system was carried out in 1973/1974 by the Geological Survey of Western Australia and the following sub-section gives a summary of that survey.Figure 4.1.3 shows a cross section through the peninsula.The bottom layer which is approximately thirteen metres below the surface, consists of coarse sand and gravel, interbedded with thick clay. The surface is reasonably flat and the central section is overlain with green-grey clays,shelly mud, shell beds and black micritic limestone.Above this is a layer of coastal limestone which ranges in height from five to eight metres.The layer on top of the limestone is thick estuarine mud which is seven metres thick on the western side of the inlet.This mud thins out rapidly towards the eastern shoreline."The muds are of shallow marine origin,possibly representing a former tongue of water extending from the inlet to the coastline.Conversely,shallow marine conditions may have existe over the entire area.However,the presence of estuarine muds beneat the sand dunes indicates that the Leschenault Inlet was once larger than it is today." (Barnes 1974)On the western side is a thick area of calcareous,shelly,quartzose beach sands which were responsible for pushing the western shoreline into its present position. These areas push upwards into the finely grained,slightly calcareo quindalup dunes.A layer of fine to medium grained kankerised calcarenite precedes the dunes and according to the Geological Survey this indicates more recent rises in sea level.

4.1.7 Groundwater gradients.

The water table is highest 300 metres in from the eastern shoreline of the western dunes.(0.9 metres above the A.H.D.)and probably moves in a north-south line along the peninsula.On the eastern side of the dunes system the water discharges into the inlet

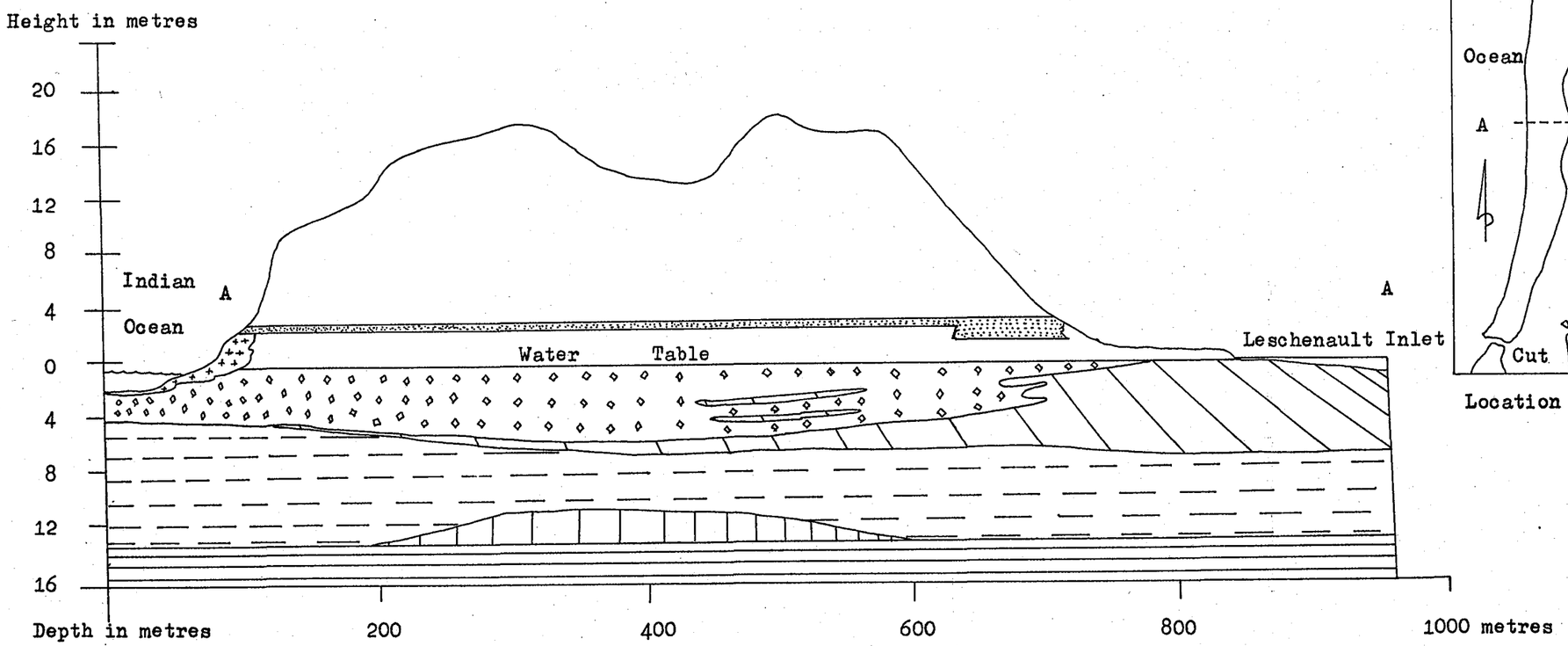


Fig.4.1.3 Shows a cross section through the coastal sand dunes.

	Medium grained littoral sand.
	Fined grained slightly calcareous dune sand.
	Fine to medium grained kankarised calcarenite.
	Fined grained littoral sand and shell beds.
	Slightly calcareous estuarine muds.
	Fine to medium grained calcilutite and calcarenite.
	Fine grained sand, clay, shell beds and micritic limestone.
	Medium to coarse grained sands interbedded with thick clay units.

between the dunes and the estuarine muds.On the ocean side this occurs between the low and high water marks.On the western border the superficial deposits pass under the ocean and become saturated with seawater.The mixing of freshwater and salt water occurs over an area of approximately 300 metres and the interface is gradual.In this region salinities of 27 ppt were recorded at depths between 12 and 18 metres below the surface.On the eastern section the estuarine muds increase in thickness and are about six metres thick beneath the inlet.A layer of limestone of about six metres underlays the estuarine mud and another freshwater-saltwater interface occurs where the limestone crops out within the inlet;to the west of the eastern shoreline.This situation allows seawater to move directly into the aquifer or freshwater to flow directly into the inlet!The salt water interfaces on the east and west sides of the dunes are not connected".(Barnes 1974)

4.1.8 Salinity.

Salinities increase with depth,ranging from 3 ppt to 30 ppt and groundwater on the eastern and western extremities has a higher salinity than that of the central section.Below the water table there is an increase in salinities from east to west and this is caused by the estuarine mud which creates a barrier to flowing water.Water flow into the inlet can only occur when the water table rises above the estuarine mud.The following table shows salinities recorded by R.G.Barnes during the survey.

Table 4.1 Salinities of the western sand dunes.

A. 100 metres from the eastern shoreline.

Depth (m)	Salinity (ppt)
3.0	2.0
3.6	1.65
9.8	1.28
12.0	.86
15.0	2.1
18.0	3.4
21.0	4.15

B. 250 metres from the eastern shoreline.

Depth (m)	Salinity (ppt)
18.0	3.5
24.0	1.19
26.8	2.8
30.0	1.67
33.0	1.12
36.0	.81
39.0	1.0

C. 550 metres from the eastern shoreline.

Depth (m)	Salinity (ppt)
16.4	1.57
20.4	1.5
22.0	1.33
24.0	2.1
26.0	2.4
27.0	2.75
30.5	8.9
31.6	5.7

D. 50 metres from the western shoreline.

Depth (m)	Salinity (ppt)
12.0	26.5
15.0	17.4
18.0	27.0
27.0	3.2
29.6	1.8

4.2 Physical changes to the Leschenault Inlet.

4.2.1 Introduction.

In its original configutation the Leschenault Inlet entered the sea at a point adjacent to the Bunbury townsite,at the extreme southern end of the inlet.In the early 1950's a cut was dredged through into the ocean opposite the entrance to the Collie River. This was to help alleviate flooding which occured in the region prior to the new opening being put through.This point was chosen because the land was narrow at this point,a sand dune 'blow-out' had broken through and, the new opening would be opposite the main water flow areas of the Collie and Preston Rivers.This feature,along with the daming of the Collie River and its tributaries has been most significant in changing the freshwater flows into the inlet.Prior to these developments there would have been a far greater flow of fresh water into the system and the surrounding wetland areas and the region was probably more important as a waterfowl refuge and breeding ground.With the opening of the cut a change occured in the aquatic flora of the inlet.Local fishermen say that prior to the opening of the ocean cut a Ruppia like species grew over the inlet.This can still be found in surrounding wetlands and in parts of the inlet,but its distribution is much less than it used to be.(see section 6.0)Within two years of the cut being opened the paddle weed,Halophila ovalis had invaded the area and now covers most of the inlet.Reclaimation for the inner harbour development has completely cut off the southern section of the inlet from the northern part and has resulted in the loss of a large salt marsh;the redirecting of the Preston River (1969 - 1970) and the loss of half of Anglesea Island and the loss of Gerrard Island.This has reduced the number of mangrove in the region and made less areas available for wading birds to

feed.Many acres of forest has been cleared for housing and agriculture in the vicinity of the inlet and this has resulted in a loss of wildlife habitats and has probably caused an increase in salinity of the freshwater entering the system. Figures 4.2.1 to 4.2.6 show the changes that have occured since 1895.These maps were redrawn from old maps of the area and were obtained from the Department of Lands and Survey.

4.2.2 Dredging.

The following table gives details of dredging that has taken place in the Leschenault Inlet and the amounts that were removed.

Table 4.2 Dredging in the Leschenault Estuary.*

1949/50/52. Bubury ocean cut,commenced on the 25/1/1950 and completed in 1952.The amount removed was 756,200 cubic yards.

1955.Two channels were dredged in the Collie River; a 900' channel at the mouth and a 350' channel at the southern end.These were completed in 1956.

1961/1963.This was a channel from the Collie mouth to Turkey point and a channel to the ocean cut.The length was 5,259' and 16,592 cubic yards of substrate were removed.

1969.Collie River dredging - upstream of the Collie Bridge.A channe 50' wide and 3,242' long was dredged.The mouth of the collie River was dredged at the same time.

11/1/69 to 1/12/69.During this period a 460 metre channel was dredged at Paris Road for boat access.A 1070 metre channel was dredged in the Collie River.Total amount removed was 76,823 cubic yards. At the same time another 7,962 cubic metres was removed from the Turkey Point channel.

10/3/75 to 7/7/75.During this period a channel 30 metres wide by 1.5 metres deep was dredged at the mouth of the Collie River.A tot-

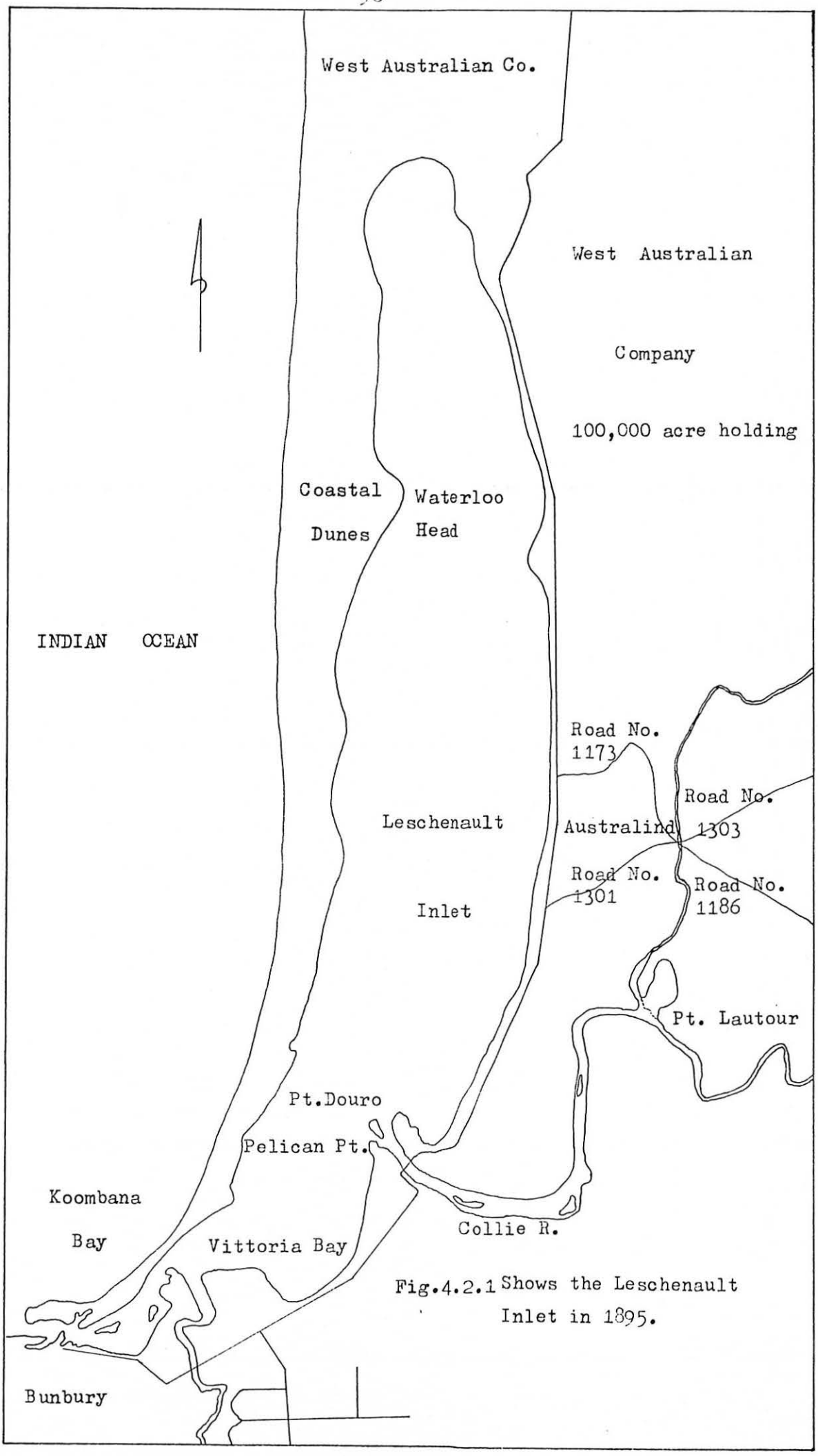


Fig.4.2.1 Shows the Leschenault Inlet in 1895.

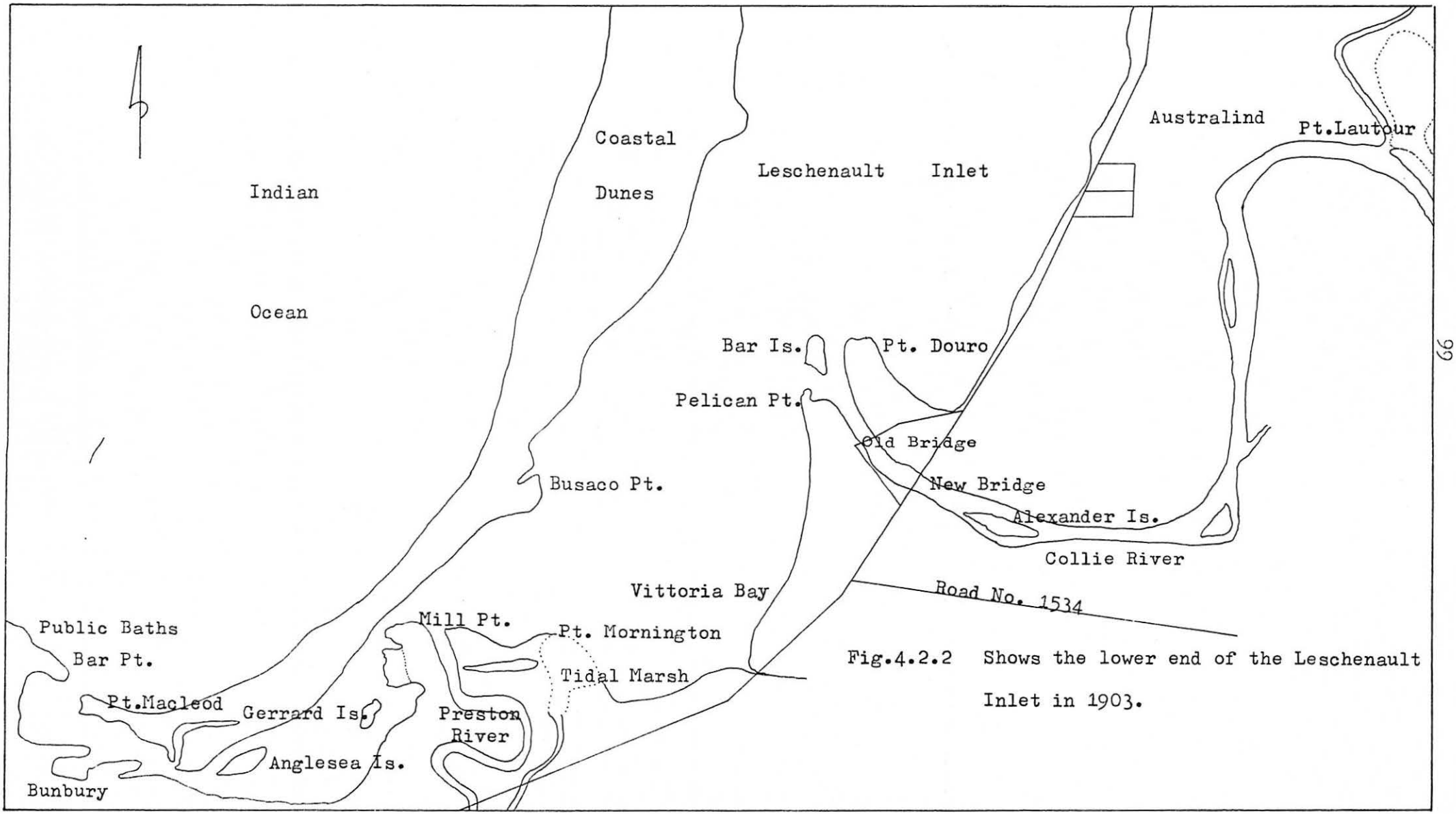


Fig.4.2.2 Shows the lower end of the Leschenault Inlet in 1903.

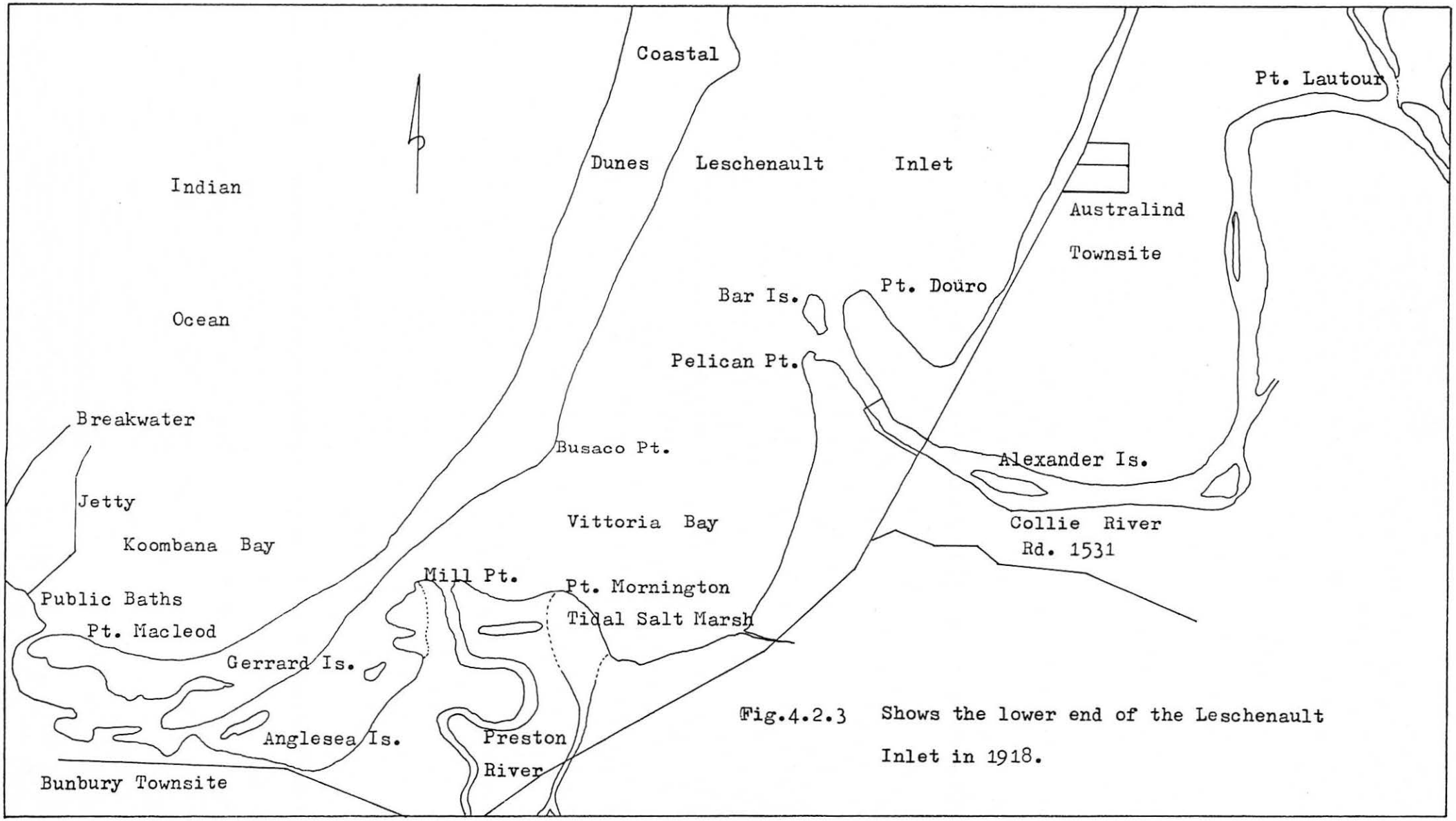


Fig.4.2.3 Shows the lower end of the Leschenault Inlet in 1918.

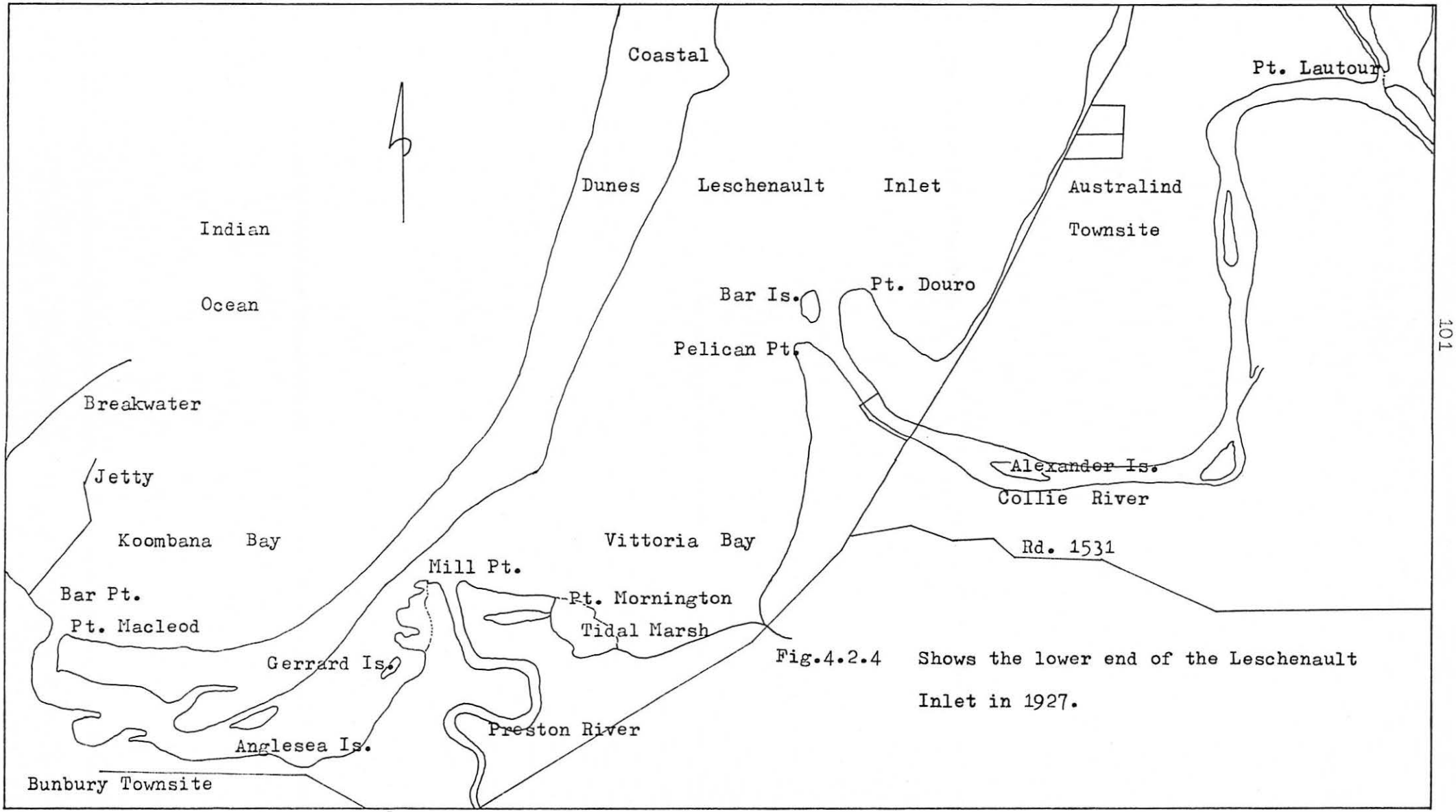


Fig.4.2.4 Shows the lower end of the Leschenault Inlet in 1927.

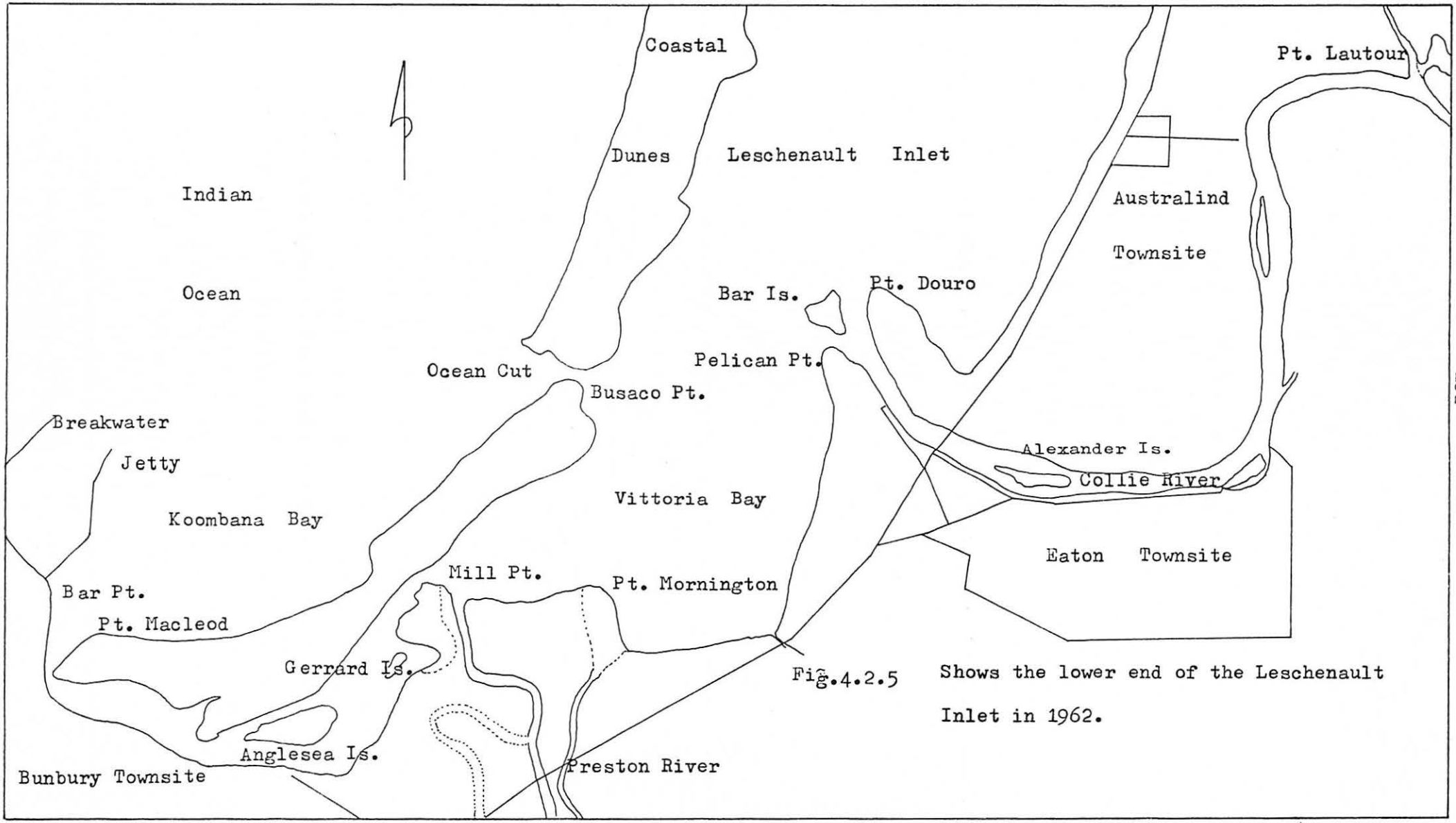


Fig.4.2.5 Shows the lower end of the Leschenault Inlet in 1962.

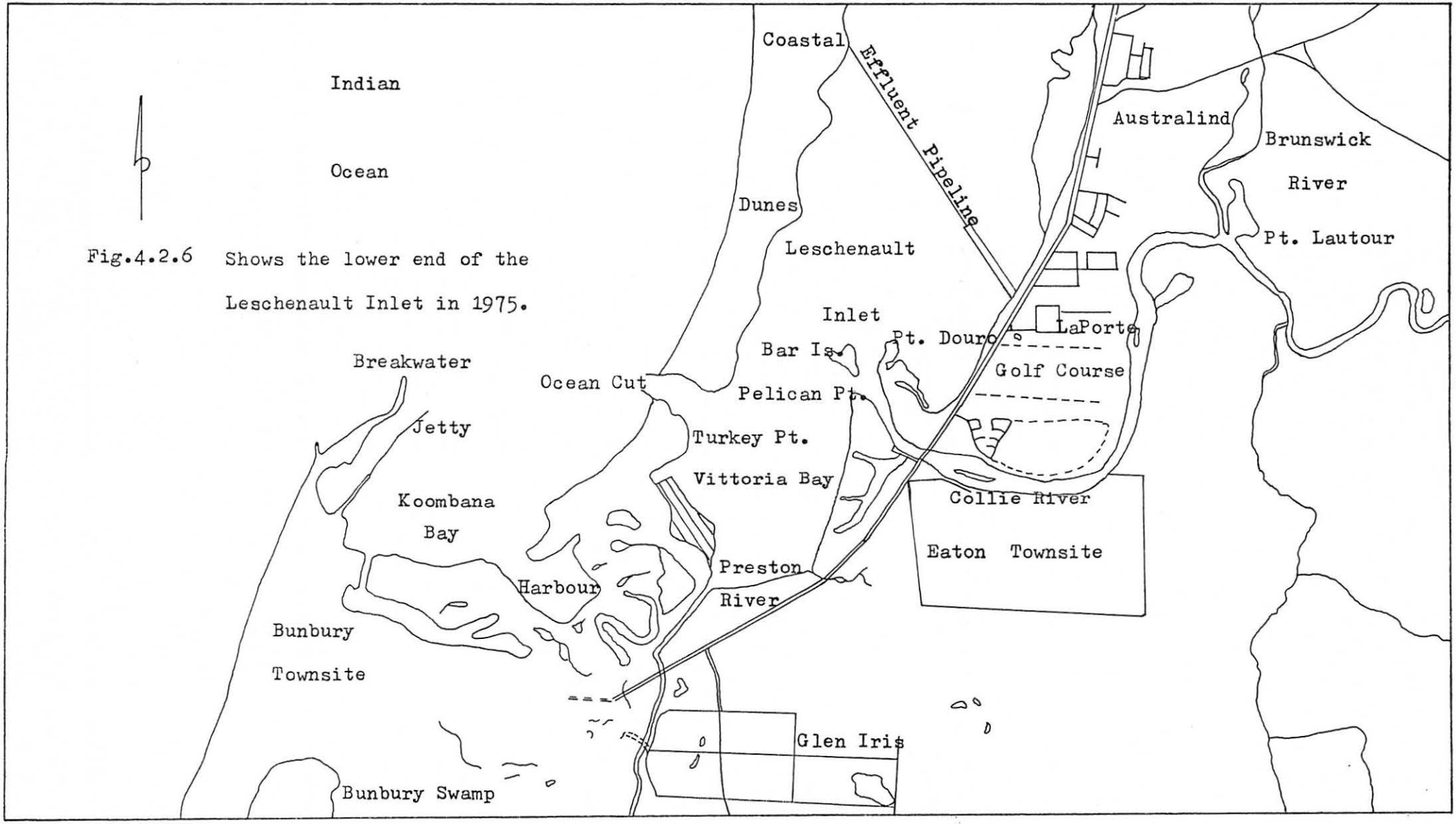


Fig.4.2.6 Shows the lower end of the Leschenault Inlet in 1975.

al of 7,466 cubic yards of material were removed.

* Information relating to dredging was obtained from the P.W.D.

4.2.3 Effects on dredged areas.

The most biological productive part of the estuary is the shallow areas where sunlight can penetrate to enable photosynthesis to take place.It is these areas that face the greatest danger from dredging which forces organic material that was below the level of the soil into suspension,making the water turbid and therefore allowing less sunlight to penetrate.This causes a substantial decline in productivity and the waterbody thereby supports less wildlife.When the Est-uary bed is dredged it results in the loss of its living biota, but the disturbed areas will eventually stabilize and become repopulated; the length of time this takes is unknown.Areas in Vittoria Bay that were dredged in the early 1950's, and have not been redredged since, have restabilized and have a good covering of aquatic plants on them.Another problem associated with dredged areas is that of filamentous algae build up.These algae tend to be carried into these areas by currents,wind,and tidal movement and become lodged in the deeper areas.This stops light penetration and other aquatic plants do not grow.

4.2.4 Sedimentation.

Sediment brought down by the river systems are deposited at the mouth of the Collie and Preston Rivers.These sediments form delta areas in these regions and therefore to keep the navigation channels open dredging is required.The sediments being brought down by the river systems make the area around Vittoria Bay and Samphire Bay extremely turbid during the winter.(see water quality) When westerly winds are prevailing,sands are brought in through the ocean cut and deposited in Vittoria Bay.

4.3 Physical features:waterbody.

The following table gives details of the main physical features of the Leschenault Inlet.(Table 4.3) To enable a comparison with the other major estuarine systems of the south west region,details of the main physical features are given.(see table 4.4,Swan;table 4.5,Peel - Harvey Estuary and table 4.6 for the Hardy Inlet - Blackwood Estuary.)

4.3.1 Physical features:Leschenault Inlet.

Table 4.3

Total Catchment Area	4,933 km^2	
River Runoff (Mean Annual)	300	(Collie)
in millions of cubic metres.	190	(Preston)
Salinity at mouth (ppt)	5	(Collie)
	5	(Preston)
Area of Dams on System	2,887 km^2	(Wellington)
	44 km^2	(Glen Merryn)
Tidal Rivers-length from mouth	4 km	(Collie)
	4 km	(Preston)
Total Area	2,540 ha	
Perimeter	33 km	
Greatest Depth	2 metres.	
Tidal Range (% of oceanic)	70%	
Barometric tide	undamped	
Length of inlet channel	0.4 km	
Depth at the mouth	2 metres	(dredged)

4.3.2 Physical features:Swan Estuary.

Table 4.4

Total Catchment Area	27,990 km^2
River Runoff(mean annual)	377 (Swan)
in millions of cubic metres.	300 (Canning)
Salinity at mouth (ppt)	10 - 30 (Swan)
	5 (Canning)
Area of Dams on System (km^2)	1,584 (Mundaring,Helena)
	784 (Canning)
	127 (Wungong)
	75 (Others)
Tidal Rivers-length from mouth(km)	60 (Swan)
	12.5 (Canning)
Total Area	5,300 ha
Greatest Depth	20 metres(Mosman Bay)
Tidal Range(% of oceanic)	80%
Barometric	undamped
Inlet channel-length	8 km
Depth at the mouth	11 metres (dredged)

4.3.3 Physical features: Peel - Harvey Estuary.

Table 4.5

Total Catchment Area	12,000 km^2
River Runoff (mean annual)	420 (Murray)
in millions of cubic metres.	62 (Serpentine)
	90 (Harvey)
	5 (Drains)
Salinity at mouth(ppt)	5 (Serpentine)
	5 - 30 (Murray)
	5 (Harvey)

Area of Dams on System(km^2)	Serpentine 635
Tidal Rivers-length from mouth (km)	Serpentine 10
	Murray 15
	Harvey 3.5
Total Area (km^2)	13,620 ha
Perimeter	94 km
Greatest Depth	2 metres
Tidal Range(% of oceanic)	1 - 10%
Barometric	undamped
Inlet channel - length	5 km
Depth at mouth	2 metres(dredged)

4.3.4 Physical features: Hardy Inlet - Blackwood Estuary.

Table 4.6

Total Catchment Area	23,000 km^2
River Runoff (mean annual)	1057 (Blackwood)
in millions of cubic metres.	1030 (Scott)
Salinity at mouth(ppt)	10 - 30 (Blackwood)
	5 (Scott)
Area of Dams	Not dammed
Tidal Rivers-length from mouth	42 km (Blackwood)
	4 km (Scott)
Total area	-
Perimeter	-
Greatest depth	2 metres
Tidal range(% of oceanic)	70%
Barometric	undamped
Length of inlet channel	2.5 km
Depth at mouth	2 metres

4.3.5 Waterflow into the Leschenault Inlet.

The following table shows estimates of inflow from river systems and drains into the inlet.They show mean annual flows.No details are available for the northern drain which drains away water from the northern wetland areas.This drain was completed in 1976.(Source: P.W.D.) Figures in millions of cubic metres.

Table 4.7 Freshwater Flows into the Leschenault Inlet.

Collie Catchment	
Wellington Dam capacity	200
Wellington Dam overflow	120
Brunswick and Collie Rivers	100
Wellesley Drain	80
Total	300
Preston Catchment	
Preston River	100
Preston River (lower)	50
Ferguson River	30
Joshua Creek	10
Total	190
Grand Total Inflow	$490 \times 10^6 \ m^3 \ year^{-1}$

4.3.6 Hydrology.

Because of the shallow depths of the Leschenault Inlet the water temperature reflects that of the ambient air temperature.This causes substantial changes in the diurnal water temperature with warm temperatures occuring during the day and cooler temperatures occuring during the night.During the summer water temperatures average 25°C

and during the winter, 14°C. The adjacent ocean has averages of 21°C and 16°C respectively. The highest water temperature recorded during the study period was 31°C at the northern end in late January. The coldest was 9°C recorded in early August 1979, on the central eastern shore at four o'clock in the morning. The depths of the inlet range from 0.3 metres on the shallow sand flats on the eastern side through to 2.0 metres in the deeper central channel. Depths on the western and northern margins reflect those of the eastern margin. (see Fig. 4.3.1 and Fig. 4.3.2) For more detailed analysis of the depths of the inlet and lower Collie River see map number 4. This shows soundings taken by the P.W.D. in 1979.

4.3.7 Salinity.

The salinity changes considerably throughout the year and varies from north to south. The area adjacent to the cut reflects the salinity of the ocean throughout the year. During the summer there is an increase in salinity from south to north and during the winter this trend is reversed. During the winter fresh water drains into the northern part of the inlet from the Parkfield drain which drains the northern wetland areas. During heavy rainfalls fresh water flows into the inlet from the Collie and Preston catchment areas and forms a layer over the salt water. The opposite occurs during summer when salt water penetrates into the river systems. (see water quality for salinities during study period.)

4.3.8 Oxygen Content.

A large diurnal change in oxygen content occurs in the inlet due to filamentous algae, aquatic plant photosynthesis and overnight cooling and daytime heating and respiration by plants at night. (see water quality for details)

4.3.9 Turbidity.

The water clarity varies throughout the inlet, according to the sea-

Fig.4.3.1 Shows water depths in the Leschenault Inlet.

	Depths shown at low water mark. ~~Tidal range 0.6 metres.~~
	Depths of 1.3 metres.
	Depths of 0.6 metres.
	Depths below 0.6 metres.
Scale.	1:50,000.

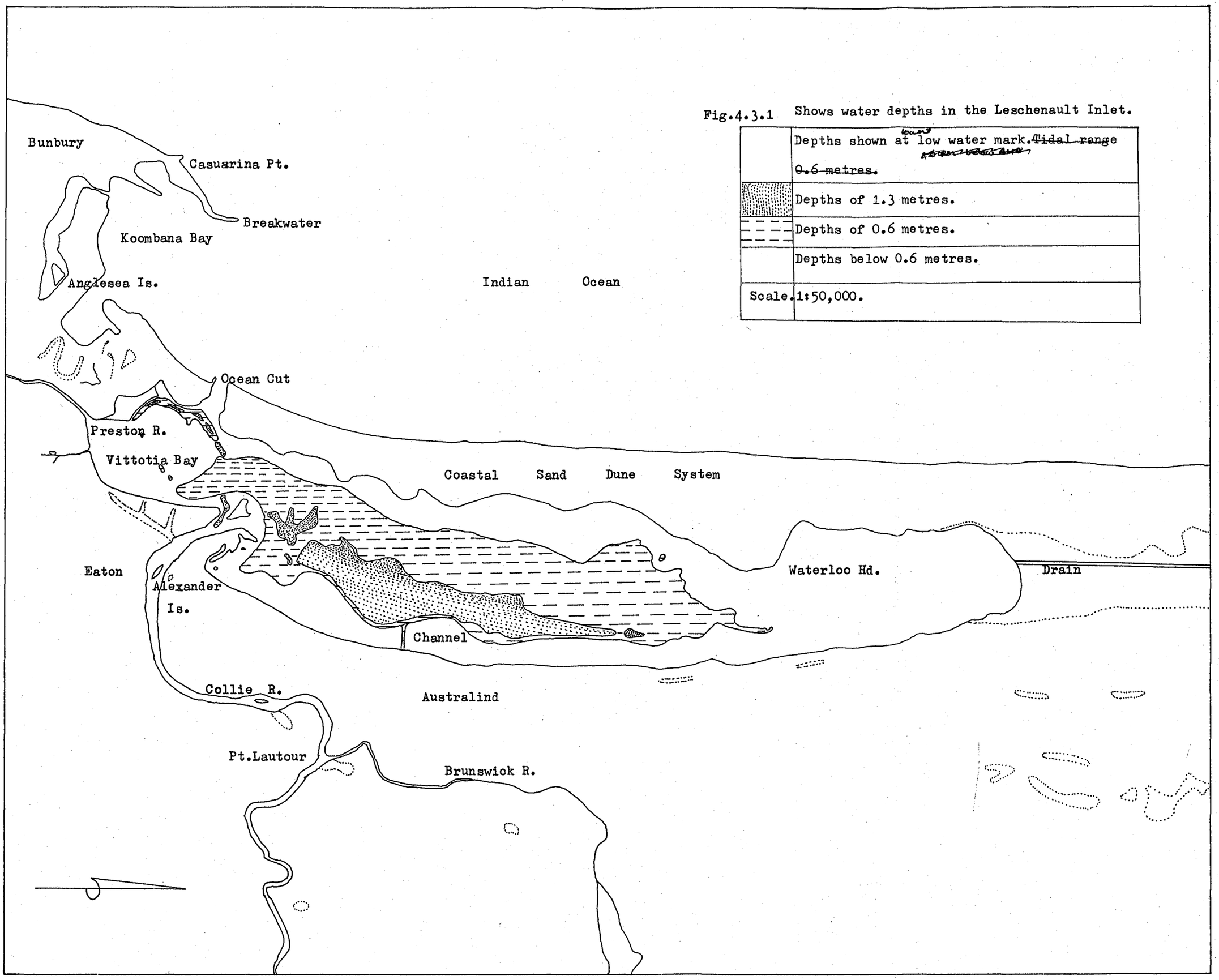
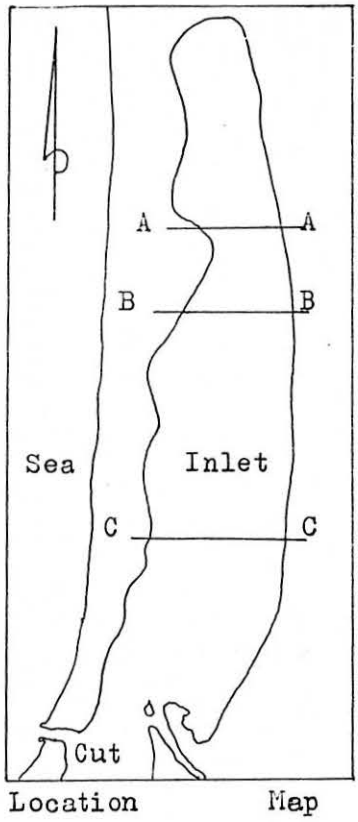
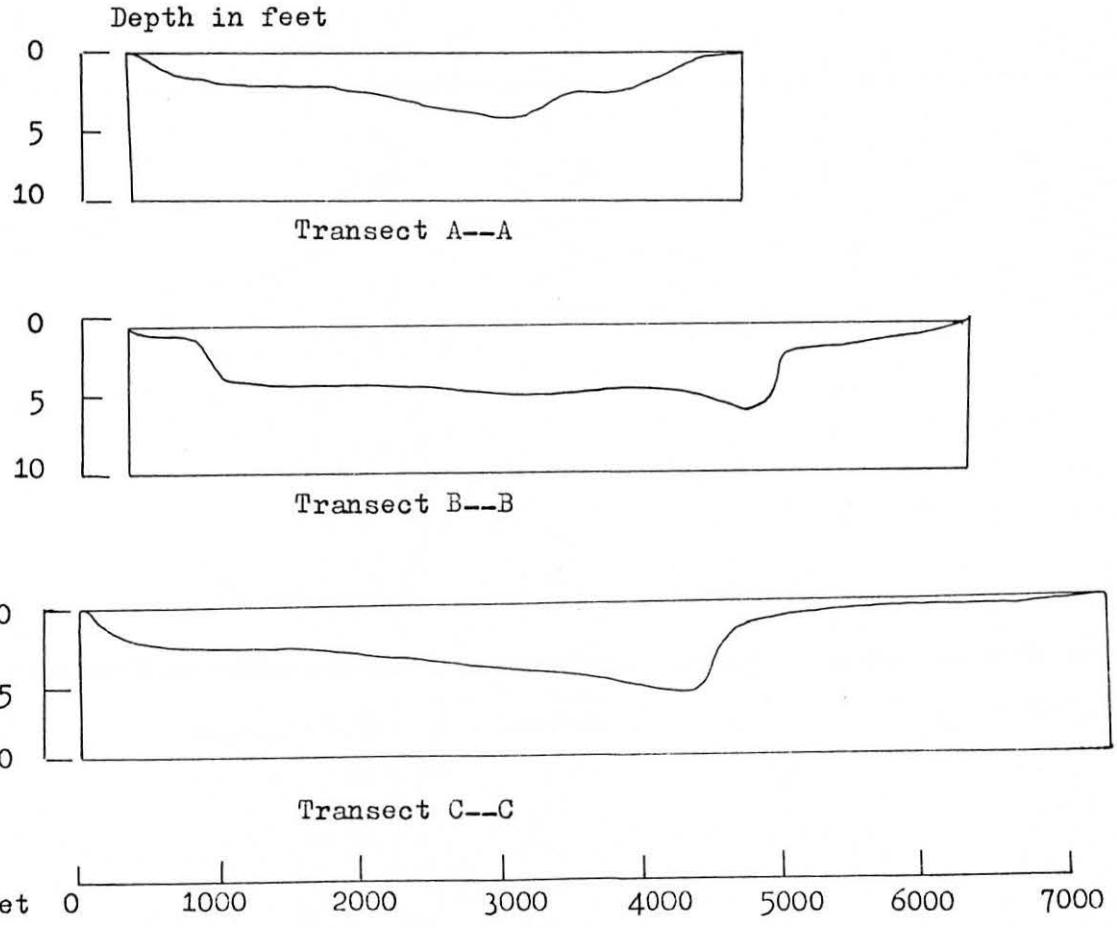


Fig.4.3.2 shows transects through three locations in the Leschenault Inlet for depths.





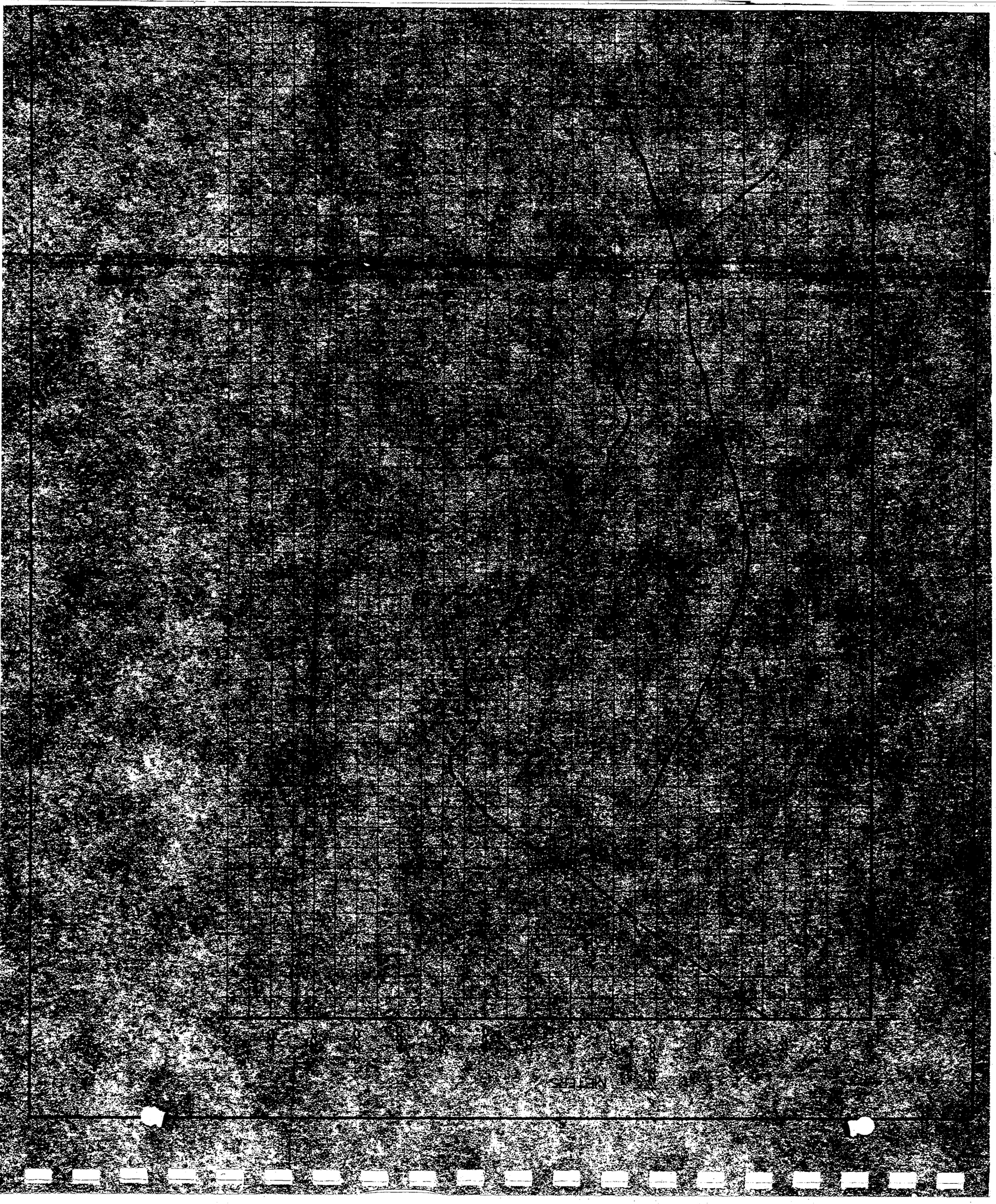
son and the prevailing winds.Strong winds tend to stir up the bottom sediment,especially in the central and western sections where the estuarine mud substrate occurs.The light penetration in the deep central channel is limited to about 170 centimetres during summer and about 100 centimetres during winter.(sechi disc readings) The shallow areas are reasonably clear during the summer, but the Vittoria Bay and Samphire Bay areas become quite turbid during winter because of the flows from the rivers.(see water quality for details)

4.3.10 Tides.

Because of the narrow entranee into the inlet the oceanic tide is dampened by some seventy percent.The Leschenault Inlet receives only one tide per day and this is of a relatively small amplitude.The average tide height in the inlet is o.5 metres with a range of about 0.3 metres below mean sea level to 2.1 metres above mean sea level. The lowest tides occur in late December,early January and during this period the sandy substrate on the eastern shoreline is exposed for 300 metres.The tidal lag which occurs in the inlet takes about one and a half hours to reach the pipeline and another twenty minutes to reach the northern end of the inlet.Because of the shallowness of the inlet a significant water exchange occurs.(approximately 40%)

4.3.11 Flooding.

With the construction of the Wellington Dam and the opening of the ocean cut,flooding in the region is very uncommon.The Preston River flooded in 1907,1926 and 1964.Extensive flooding of the region occure in 1978 during cyclone Alby.This was due to the surge of seawater into the inlet.To help alleviate this problem a storm surge gate is to be built at the southern end of the inlet.The cost is about a quarter of a million dollars and considering that the chances of this



values greater than 0.2 ppm* phosphorus are recorded then the water has a high potential for eutrophication."Evidence exists that a body of water is in danger with regard to its trophic level when its springtime concentration of assimilable phosphorus compounds and inorganic nitrogen compounds exceeds 10 mg P/m^3 and 200 - 300 mg N/m^3 respectively, and,or when the specific supply loading per unit area of water reaches 0.2 - 0.5 grams P/m^2 per year and 5 - 10 grams N/m^2 per year"(Vollenweider 1970) "Lakes with annual mean total nitrogen and phosphorus concentrations greater than 0.8 mgl^{-1}* and 0.1mgl^{-1} respectively,exhibit algal blooms and nuisance weed growths during most of the growing season."(Hammer 1977)Local studies carried out in the Peel Inlet on Cladophora sp. gave nitrogen levels of 10 - 30 mgl^{-1} and phosphate levels of 1 - 2 mgl^{-1} for rapid growth.(Pitcairn and Hawkes, 1973)Although nitrogen and phosphorus are the main causes of eutrophication,other substances such as sulphates,magnesium,potassium and trace elements such as cobalt, molybdenum,copper,zinc,boron,iron and manganese assist in the overall process.

U.S. studies

4.4.4 Nutrient sources.

Nutrients are derived from such sources as:natural sources,rainfall,aquatic birds,runoff from agricultural and other cleared areas, septic tanks and stormwater discharge,factory effluent discharge, abattoir effluent discharge,water treatment plant discharge and the intra - system cycle.

*ppm = parts per million. mgl^{-1} = milligrams per litre.

4.4.5 Natural sources.

The mechanical and chemical breakdown of rocks, the products of animal and plant decay and sediments brought down by the rivers and streams produce the soils of the region. During the rainy season the water percolates through the soil and dissolves the nutrients which then pass through to the ground water or nearby rivers and streams and then into the inlet.

4.4.6 Rainfall.

The nutrient loading in rainfalls vary greatly with climate, location, proximity to industry and the sea. "The nitrogen salt content per litre of rain varies between 1 mgl^{-1} and several mgl^{-1} In the tropics nitrogen and phosphorus loadings are generally low, so much so that it is not certain that they have any influence at all on agriculture. However, they can effect surface waters." (Menzel and Spaeth, 1962) Amounts recorded in temperate zones are 0.26 - 0.6 mgl^{-1} of organic nitrogen and 0.22 mgl^{-1} of $N(NO_3)$ in temperate regions of the United States of America. (Putman and Olsen, 1960) In the United States phosphate levels of 80 ugl^{-1} in Cincinnati rainwater were found. This represents 60 mg/m^2 of hydrolysable phosphorus for an annual mean rainfall of 750 milli - metres. (Weibel et al., 1966)

4.4.7 Aquatic birds.

When compared with other sources of nutrients, bird droppings probably contribute very little to the overall nutrient loading of the inlet. The nutrient imput of the waterbirds would vary from year to year due to fluctuations in the waterbird populations on the Lesch-

enault Inlet.However,due to the concentration of the waterbirds in particular areas,especially during the summer and early autumn periods,(see sub - section 5.2 and Figure 5.2) nutrient imput from waterbird droppings may contribute to the overall loading in that particular region.This shall be discussed in greater detail in the water analysis conclusions.

Paloumpis and Starret,(1960) give figures of 0.47 kg. of total Nitrogen per year and 0.20 kg. of total phosphorus per year per duck (wild) and this includes 0.10 kg. per year of soluble phosphorus.It is difficult to determine the imput from this source because of the annual fluctuation in duck populations on the inlet, but assuming some counts that were carried out figures maybe estimated.During a discussion with Mr.J.Lane,(W.A.Dept.Fisheries and Wildlife)he told me that the waterbird population of the Leschenault Inlet was far less than the other two major inlets.The population of the Leschenault would vary from 4000 to 10,000 birds of all species during the peak period.The Peel and Hardy Inlets have populations during this time of around 100,000 birds.Taking 2000 ducks as a peak over a year the imput would be 3.70 $gm^2\ year^{-1}$ and 1.57 $gm^2\ year^{-1}$ of nitrogen and phosphorus respectively.Soluble Phosphorus would account for about .80 $gm^2\ year^{-1}$ Duck counts during the study gave an average of 889 birds on a seasonal basis,therefore the above figures could be halved.These figures do not include the imput of nutrients from all the other species present.

Source of information

4.4.8 Forest clearing.

Clearing of forested land for housing,industry and agriculture results in an increase in the amount of runoff and sediment entering the water system.The plants which normally utilize the nutrients have been removed,hence more nitrogen and phosphorus enter the system via runoff and leaching or percolation of soluble nutrients into the groundwater.

4.4.9 The intra - system cycle.

The intra - system cycle is probably one of the main causes of nutrient loading in the Leschenault Inlet.The nutrients are products of the growth and decay process that takes place within the system.As the nutrients increase,so does the living matter; hence more nutrients.with decomposition.A large amount of these nutrients are cycled through the sediments.Sediment samples were taken during the study for nutrient analysis and these results shall be discussed in a later section.

4.4.10 Agricultural practices and fertilizers.

Clear felling of forested land for agricultural purposes results in a greater runoff of nutrients from the surface and via groundwater.Leaching occurs with nitrogen,especially if it is in the nitrate form,where as phosphorus tends to become bound to the soil particles and it therefore tends to be leached to lower levels,but not so readily into the ground water flows.After heavy rainfalls the water tends to flow over the surface and takes with it fertilizers,decaying debris and animal wastes."The quantities of nitrogen,phosphorus and potassium produced by cattle,expressed in terms of live weight,vary considerably from one species to another.Cows and pigs produce about 150kg N/100 kg live weight per year;horses,goats and sheep about 120 kg and poultry about 85 kg. Pigs produce the most phosphorus,with about 45 kg/1000 kg live weight per year.The amount for horses and cows is about 20 kg per year of phosphorus, while potassium is around 100 kg per 1000 kg live weight per year."(Vollenweider 1970)

4.4.11 Septic tanks.

The area near the southern end of the Leschenault Inlet,(East Bunbury) is sewered,but most of the areas around the main water body are served by septic tanks.According to results of work being carried out by the C.S.I.R.O. on the effects of septic tanks on the ground water of the Swan Coastal Plain they have come to the conclusion that the systems are reasonably effective.The sand is rich in iron and alumimium and tends to hold the phosphate as the effluent filters through the soil. However, once the soil is saturated with phosphate,the excess is free to flow into the ground water.Work also done at the C.S.I.R.O. shows that there may be a relationship between flow of nitrogen in ground water from residential areas into the Peel Inlet and the rapid growth rate of the algae Cladophora.Urban areas around the Leschenault Inlet are eithe situated on sloping country or on the low flat area opposite the inlet.Seepage from the houses would flow either into the Collie River or into the Inlet.Houses on the flat area are only a few feet above the water level and seepage here is quite probable.Taking Van Vurans(1948) figures for annual overall dry weight of human excrement as 34.4 kg per capita;and that it contains 5.2 kg of nitrogen and 0.52 kg of phosphorus, then from the 2,500 population in this area a total of 13000 kg of nitrogen and 1300 kg of phosphorus is being discharged into the sands from septic tanks each year from this source.

4.4.12 Stormwater.

Untreated urban stormwater may be a contributing factor to eutrophication.It contains significant quantities of nitrogen and phosphorus from gardens,industry and the streets.

4.4.13 Discharge from industry into the Collie River.

The industries are: Peters Factory,Brunswick;P.W.D.town water supply treatment plant,Brunswick and Fry and Son abattoir.These industries are operating under the rights in water and irrigation act,1974,and they are licenced by the Public Works Department.

(1) Peters Factory,Brunswick.

The liquid wastes from the factory are treated in a series of ponds before being discharged into the Brunswick River and then into the Collie River.During winter the purified effluent is diluted with natural runoff before entering the drains to the river.

(2) P.W.D.Brunswick.

Backwash water from the town water supply treatment plant is discharged and some of this enters the river.

(3) Fry and Son abottoirs.

The waste from this plant is treated in a series of ponds and the effluent finds its way into the drains and then into the river.

Figures 4.4.1 and 4.4.2 show annual monthly phosphorus, nitrogen,ammonia and nitrate levels for the upper Brunswick River and upper Collie River.(1978)

4.4.14 Agricultural Chemicals.

Agricultural chemicals such as herbicides,weedicides and pesticides are carried into rivers and streams by atmospheric transfer,biological transfer,groundwater,runoff and rainfall.These include chlorinated hydrocarbon pesticides,organophosphate and carbamate insecticides and herbicides such as xylene,copper sulphate 2,4-D, 2,4,5-T and diquat.The pesticides include D.D.T,H.C.H.,dieldrin, endrin,aldrin and endosulphan.The levels of D.D.T. and dieldrin in the Preston River are above the levels recommended by the United

States Environmental Protection Agency,1973.These chlorinated hydrocarbons are accumulated by aquatic organisms directly from the water and sediments and these are then accumulated by higher animals as they feed on them.In this way the pesticides are passed through the food chain to man.The concentration increases with each level of the food chain.Table 4.7 shows levels of pesticides and herbicides in the Preston River,Ferguson River,Brunswick River and Collie River.

These were taken and analysed by the Government Chemical Laboratories in 1977.The high levels of D.D.T and dieldrin in the Preston River are the rule rather than the exception. All quantities in ug l^{-1}

Table 4.7 Pesticide and herbicide levels of rivers entering the inlet.

River	D.D.T	Dieldrin	Amitole	Atrazine	Karbutilat
Preston	0.003	0.01			
Ferguson	< 0.001	0.004			
Collie	0.001	0.001	< 4	< 0.2	< 4
Brunswick	0.001	0.001	< 4	< 0.2	< 4

Sampling sites were:Preston River,(Glen Iris)* Ferguson River,(Picton Junction) Collie River,(Roelands) and the Brunswick River at Brunswick.*This sampling site is approximately 1000 metres from the mouth of the Preston River.The delta at the mouth is an important region for waterbirds.

The following table (4.8) shows the recommended working levels for pesticides in unfiltered waters as set down by the United States Environmental Protection Agency in 1973.

Table 4.8 Recommended Working Levels for Pesticides in Unfiltered Waters

Compound	R.W.L($ug\ l^{-1}$)*	Compound	R.W.L.($ug\ l^{-1}$
Clorinated Hydrocarbons			
Aldrin	0.01	**Carbamates**	
DDT	0.002**	Cararyl	0.02
Deildrin	0.005**	Zectran	0.1
DDE	0.006	**Herbicides**	
Chlordane	0.04	Aminotriazole	300.0
Endosulphan	0.003	Dalapon	110.0
Endrin	0.002	Dicamba	0.2
Heptachlor	0.01	Dicholbenil	37.0
Lindane	0.02	Dichlone	0.7
Methoxychlor	0.005	Diquat	0.5
Toxaphene	0.01	Diuron	1.6
Organophosphates		2,4-D (BEE)	4.0
Azinphosmethyl	0.001	Fenac(Sodium Salt)	45.0
Ciodrin	0.1	Silvex (BEE)	2.5
Coumaphas	0.001	Silvex (PGBE)	2.0
Diazinon	0.009	Simazine	10.0
Dichlorvos	0.001	**Botanicals**	
Dioxathion	0.09	Allethrin	0.002
Disulfonton	0.05	Pyrethrum	0.01
Dursban	0.001	Rotenone	10.0
Ethion	0.02		
EPN	0.06		
Fenthion	0.006		
Malthion	0.008		
Mevinphos	0.002		
Naled	0.004		
Oxydemeton Methyl	0.4		
Parathion	0.001		
Phosphamidon	0.03		
TEPP	0.3		
Trichlorophon	0.03		

* = Recommended working levels in micrograms per litre.

** See Table 4.7 and note level in the Preston River and location of sampling site.

4.4.15 Other water quality criteria.

Apart from nutrient analysis of water systems,other forms of analysing water quality are:fecal coliforms,dissolved oxygen, total dissolved salts and salinity, the PH,turbidity plus nutrients.

Fecal Coliforms.

This is a microbiological test which indicates the presence of human and animal wastes in water systems.The main coliform bacteria are Escherichia coli and fecal streptococci which can be found in the intestinal tracts of man and other warm blooded animals and these are excreted in large amounts.Untreated domestic water usually contains about three million coliforms per 100 ml.Therefore water containing 200 fecal coliforms per 100 ml and 2000 total coliforms per 100 ml are considered unfit for recreational purposes.The main danger of this type of contamination could come from septic tank overflow during years of heavy rainfall.Prior to the sewerage system being installed in East Bunbury raw sewerage from nearby homes used to enter the inlet during times of high rainfall.

Dissolved Oxygen.

This gives an indication of how much organic matter is present in the waterbody.There is a direct relationship between dissolved oxygen and temperature.If the water temperature rises then the amount of oxygen available to the fauna decreases.When the water temperature decreases the oxygen content increases.The solubility of oxygen is also affected slightly by the salinity of the water. If the waterbody is highly eutrophic then areas may become anerobic,especially at night when the plants are utilizing the oxygen. The deoxygenization of the waterbody can kill the living fauna

or drive them away to more aerated waters outside the system. Values of around 8 ppm indicate saturation of the water and when values of less than 2 ppm are recorded it means that the system is nearing an anaerobic state.

Total dissolved salts.

This measures the amount of dissolved salts present in the system. It can be measured directly as salinity or by conductivity and then converted on a chart to the salinity.The following shows the criter for salinity in waterbodies.

0 to 500 ppm : fresh water

500 to 1000 ppm : marginal water

1000 to 3000 ppm : brackish water

greater than 3000 ppm : saline water

35,000 ppm : seawater

greater than 35,000 ppm : hypersaline water

PH

The PH of the waterbody indicates whether it is alkaline or acidic. Water that originates from limestone areas is usually alkaline in nature while swampy areas tend to be acidic.The criteria set down for the PH of recreational areas is 6.3 to 8.5.

Turbidity.

This is caused by the presence of insoluble particles of soil, micro-organisms,other organisms,and organic material in the water system.These particles scatter and absorb the light and therefore impede its penetration.This has a serious effect on the amount of light reaching the aquatic green plants.which form the base of the food chain.

4.4.16 Parameters measured during the study.

(1) Dissolved oxygen

(2) Salinity

(3) PH

(4) Water temperature

(5) Turbidity

(6) Chlorophyll'a'

(7) Phaedphytin

(8) Phosphorus (orthophosphate, organic and total phosphorus)

(9) Nitrogen (ammoniacal, organic, NO_3 + NO_2 and total nitrogen)

(10) Conductivity

(11) Substrate samples were taken from selected sites and analysed for nutrients.

Water analysis for chlorophyll'a', phaedphytin, phosphorus and nitrogen were carried out by the Botany Department, University of Western Australia by arrangement with the Department of Conservation and Environment.

4.4.17 Methods and times of sampling.

Nutrient analysis.

Fourteen sampling sites were chosen at different locations around the inlet, Collie River and the Vittoria Bay swamp for the analysis of nutrients and chlorophyll'a' and phaedphytin. The PH and the salinity were also taken at these points concurrently with the water samples. (see Fig. 4.4.1) To enable an overall annual analysis of the water quality sampling was done on a seasonal basis. Although this form of sampling only shows the conditions for particular times of the season, it gives a reasonable picture of the overall seasonal variations that occur within the system. Samples were taken in the spring, (1978) summer, (1979) autumn, (1979) and the winter (1979). The results of the analysis are shown in the tables and graphs that accompany this section. A discussion of the results is also included; summary and recommendations are discussed in section 1.0.

Fig.4.4.1 Shows water sampling points.

	Main wetland areas.
	Man made dams.
Scale.	1 : 50,000

Bunbury
Casuarina Pt.
Breakwater
Koombana Bay
Inner Harbour
Ocean Cut
Preston R.
1 Vittoria Bay
14
Indian Ocean
Coastal Sand Dune System
13
Bar Is.
2
3
Pt.Douro
12
4 Samphire Bay
11
10
Drain
Waterloo Hd.
5
Eaton
6
Burragenup
LaPorte
9
7
8
Australind
Collie R.
Pt.Lautour
Brunswick R.

4.4.18 Diurnal Analysis.

Two diurnal analysis were carried out during the course of the survey.The first being on the 28th of Febuary (1979) and the second being on the 29th of July (1979).The Febuary analysis was taken over eleven sites around the inlet and the July analysis was taken at site 7,along with a diurnal nutrient and chlorophyll 'a' analysis.This site was chosen because of its proximity to the housing areas situated on the inlet.These homes have septic tank waste water disposal systems.

The sites chosen for the Febuary diurnal analysis were site numbers:1,3,4,5,6,7,8,9,10 and 11.Site 2, which is a seasonally flooded zone was still dry at this time.

Measurements taken were,PH,conductivity,dissolved oxygen and water temperature.The measurements are in;water temperature,(°C) PH,

4.4.18 Tables of Results.

The following tables show the results of the two diurnal analysis carried out for dissolved oxygen.

Table 4.9 Site Number 1.(Febuary,1979)

Time	1200	1400	1600	2000	2400	0400	0800
Water temp.	28.7	30.0	28.6	26.4	24.3	21.2	21.0
D.O.	9.8	7.2	8.0	9.6	7.5	6.6	7.5
PH	7.9	8.0	8.1	7.8	7.9	7.8	7.9
Conductivity	62.0	69.7	68.3	65.4	63.8	58.9	59.2

Table 4.10 Site Number 3.(Febuary,1979)

Time	1200	1400	1600	2000	2400	0400	0800
Water temp.	27.0	27.0	26.9	24.0	23.5	21.7	22.9
D.O.	5.8	6.0	7.5	9.9	9.5	8.8	8.5
PH	7.8	7.8	7.9	7.9	7.8	7.8	7.8
Conductivity	55.6	56.6	61.3	60.8	49.6	44.5	49.7

Table 4.11 Site Number 4.(Febuary,1979)

Time	1200	1400	1600	2000	2400	0400	0800
Water temp.	28.9	30.4	27.2	25.1	23.0	21.8	21.2
D.O.	7.9	8.0	7.4	8.4	8.1	6.5	7.2
PH	7.8	7.9	8.0	7.9	7.8	7.7	7.8
Conductivity	69.7	71.2	67.1	64.6	60.9	60.1	59.9

Table 4.12 Site Number 5.(Febuary,1979)

Time	1200	1400	1600	2000	2400	0400	0800
Water temp.	29.8	30.5	29.5	26.1	23.5	22.4	21.7
D.O.	8.2	7.5	7.6	9.1	8.7	5.1	6.8
PH	7.9	7.9	7.9	7.9	7.8	7.6	7.6
Conductivity	68.7	70.8	69.8	65.8	61.8	61.1	60.3

Table 4.13 Site Number 6.(Febuary,1979)

Time	1200	1400	1600	2000	2400	0400	0800
Water temp.	28.2	30.0	28.5	25.5	24.1	23.0	22.1
D.O.	7.3	7.9	8.3	9.2	6.3	5.4	5.7
PH	7.7	7.8	7.9	7.7	7.7	7.6	7.5
Conductivity	70.0	71.0	70.0	69.3	65.8	64.5	63.8

Table 4.14 Site Number 7.(Febuary,1979)

Time	1200	1400	1600	2000	2400	0400	0800
Water temp.	28.3	29.3	28.9	25.6	24.6	22.6	21.9
D.O.	7.1	7.5	7.8	9.5	9.2	6.4	7.2
PH	7.7	7.8	7.9	7.8	7.8	7.7	7.5
Conductivity	70.5	71.6	71.0	67.5	66.9	64.2	63.1

Table 4.15 Site Number 8.(Febuary,1979)

Time	1200	1400	1600	2000	2400	0400	0800
Water temp.	28.7	31.1	29.6	26.4	24.9	22.3	21.9
D.O.	8.0	9.4	9.2	8.6	8.4	6.9	7.5
PH	7.8	7.9	8.0	7.8	7.9	7.8	7.8
Conductivity	72.1	72.8	70.8	69.1	68.4	65.3	65.2

Table 4.16 Site Number 9.(Febuary,1979)

Time	1200	1400	1600	2000	2400	0400	0800
Water temp.	28.1	34.3	30.1	26.0	24.1	22.4	21.4
D.O.	7.6	7.8	8.8	9.1	7.0	5.9	6.9
PH	7.9	7.9	8.1	7.9	7.8	7.7	7.8
Conductivity	74.7	73.6	72.9	72.6	70.6	69.8	67.0

Table 4.17 Site Number 10.(Febuary,1979)

Time	1200	1400	1600	2000	2400	0400	0800
Water temp.	31.8	32.7	30.4	25.7	24.2	22.4	22.5
D.O.	9.5	8.2	7.8	7.9	6.7	5.8	7.4
PH	8.4	8.5	8.7	8.1	7.9	7.8	7.8
Conductivity	84.2	88.0	87.2	85.0	83.1	82.3	80.2

Table 4.18 Site Number 11.(Febuary,1979)

Time	1200	1400	1600	2000	2400	0400	0800
Water temp.	29.8	30.2	28.5	26.5	24.0	23.5	23.1
D.O.	7.1	8.1	8.2	10.7	6.5	5.4	7.5
PH	8.2	8.2	8.1	8.2	8.1	8.2	8.2
Conductivity	82.0	83.5	82.0	75.1	73.2	71.7	71.0

Table 4.19 Site 11.Mangroves.(Febuary,1979)(Time,1400)

Distance from Mangroves.	Water temp.	D.O.	PH.	Conductivity.
20 metres	30.3	10.4	8.1	78.4
10 metres	29.8	11.8	8.0	78.6
Under Mangroves	29.2	13.6	8.1	78.4
0200 reading under.	23.6	4.7	8.1	70.9

Table 4.20 Site 7 Diurnal Analysis.(July,1979)

Time	Water temp.	D.O.	PH.	Conductivity.
0800	11.2	8.9	8.1	38.0
1000	11.3	9.1	7.9	37.9
1200	14.6	9.2	7.8	41.4
1400	16.0	9.7	7.8	42.3
1600	16.4	10.1	7.8	42.0
1800	15.1	9.6	7.9	41.7
2000	13.5	9.4	7.9	40.5
2200	12.2	9.2	8.0	39.5
2400	11.3	9.0	7.9	38.2
0200	10.6	8.9	7.9	37.5
0400	9.7	8.9	7.9	37.0
0600	9.1	9.0	7.9	36.3

Table 4.21 Site Number 2.(Vittoria Bay Swamp)(July,1979)

Time	Water temp.	D.O.	PH.	Conductivity.
1400	16.6	16.4	9.0	21.2
0400	9.8	8.1	8.7	18.3

4.4.20 Tables of Results, Nutrient Analysis.

The tables in this section show the results of the nutrient analysis for each season. They show phosphorus, (ortho, organic and total) and nitrogen, (ammoniacal, NO_3 + NO_2, organic and total nitrogen). All measurements are in mgl^{-1} (milligrams per litre). Results are shown for sites 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 and for site 2 during times when the area was flooded. (for sampling sites see figure 4.4.1)

Table 4.22 Nutrient Analysis for the Spring. (November, 1978)

	Phosphorus - P (mg/l)			Nitrogen - N (mg/l)			
Site	Ortho	Organic	Total	Ammoniacal	NO_3+NO_2	Organic	Total
1	.008	.018	.026	.036	.004	.068	.108
2	.063	-	-	.077	.002	2.372	2.451
3	.007	.020	.027	.039	.004	.089	.132
4	.000	.043	.043	.032	.004	.131	.167
5	.009	.012	.021	.031	.003	.079	.113
6	.008	.016	.024	.034	.009	.198	.241
7	.009	.024	.033	.037	.011	.230	.278
8	.003	.013	.016	.036	.008	.321	.365
9	.004	.015	.019	.038	.010	.396	.444
10	.008	.016	.024	.047	.003	.435	.485
11	.009	.032	.041	.039	.005	.499	.543
12	.006	.017	.023	.028	.004	.317	.349
13	.008	.014	.022	.031	.007	.176	.214
14	.007	.018	.025	.036	.005	.079	.120

Table 4.23 Nutrient Analysis for the Summer.(January,1979)

	Phosphorus - P (mg/l)			Nitrogen - N (mg/l)			
Site	Ortho	Organic	Total	Ammoniacal	NO_3+NO_2	Organic	Total
1	.065	.247	.312	.043	.002	.961	1.006
2	-	-	-	-	-	-	-
3	.053	.377	.430	.029	.002	1.239	1.270
4	.052	.053	.105	.033	.002	1.046	1.081
5	.013	.259	.272	.023	.002	1.037	1.062
6	.007	.126	.133	.025	.002	.771	.798
7	.017	.494	.511	.027	.003	.996	1.026
8	.013	1.693	1.706	.030	.002	.898	.930
9	.023	.428	.451	.058	.002	1.172	1.232
10	.081	.098	.179	.248	.010	5.933	6.191
11	.018	.068	.086	.027	.005	1.052	1.084
12	.030	.1	.130	.030	.005	1.200	1.235
13	.018	.184	.202	.030	.003	.834	.867
14	.019	.067	.086	.017	.003	.741	.761

Table 4.24 Nutrient Analysis for Autumn.(April,1979)

	Phosphorus - P (mg/l)			Nitrogen - N (mg/l)			
Site	Ortho	Organic	Total	Ammoniacal	NO_3+NO_2	Organic	Total
1	.006	.015	.035	.038	.005	.380	.423
2	-	-	-	-	-	-	-
3	.060	.035	.095	.042	.003	.420	.465
4	.015	.030	.045	.039	.005	.281	.325
5	.013	.026	.039	.035	.008	.310	.353

Table 4.24 Cont.

	Phosphorus - P (mg/l)			Nitrogen - N (mg/l)			
Site	Ortho	Organic	Total	Ammoniacal	NO_3+NO_2	Organic	Total
6	.010	.032	.042	.035	.005	.405	.445
7	.008	.016	.024	.038	.007	.441	.486
8	.013	.020	.030	.039	.008	.780	.827
9	.020	.028	.048	.041	.005	.820	.866
10	.022	.028	.050	.048	.007	1.260	1.315
11	.026	.036	.062	.038	.005	.998	1.041
12	.024	.034	.058	.031	.003	.638	.672
13	.020	.032	.052	.029	.005	.483	.517
14	.009	.018	.027	.031	.006	.238	.275

Table 4.25 Nutrient Analysis for Winter.(July,1979)

	Phosphorus - P (mg/l)			Nitrogen - N (mg/l)			
Site	Ortho	Organic	Total	Ammoniacal	NO_3+NO_2	Organic	Total
1	.005	.015	.020	.017	.007	.438	.462
2	.010	.026	.035	.026	.002	1.863	1.890
3	.055	.031	.086	.095	.350	.782	1.227
4	.010	.015	.025	.036	.008	.428	.472
5	.015	.013	.028	.032	.009	.457	.498
6		.017		.025	.004	.515	.543
7	.015	.020	.035	.040	.009	.812	.861
8		.018		.042	.009	.802	.852
9	.009	.036	.044	.073	.003	.804	.880
10	.018	.019	.037	.053	.008	1.381	1.441
11	.024	.019	.043	.031	.006	1.048	1.085

Table 4.25 Cont.

	Phosphorus - P (mg/l)			Nitrogen - N (mg/l)			
Site	Ortho	Organic	Total	Ammoniacal	NO_3+NO_2	Organic	Total
12	.020	.018	.038	.030	.005	.998	1.033
13	.015	.020	.035	.028	.006	.890	.924
14	.010	.013	.023	.030	.008	.418	.456

4.4.21 Tables of Results.Chlorophyll'a',Phaedphytin,Salinity,PH.

The tables in this section show the results of the above.These were taken at the same time and same locations as the nutrients.(see Fig. 4.4.1)

Table 4.26 Spring Results.(November,1978)

Site	Chlorophyll'a'(ugl^{-1})	Phaedphytin (ugl^{-1})	Salinity (ppt)	PH
1	1.64	.83	34.6	8.0
2	6.41	9.29	28.8	9.1
3			32.4	
4	1.60	.80	34.8	8.0
5	1.87	.93	34.4	8.0
6	4.81	2.60	35.1	8.1
7	1.34	.87	36.5	8.3
8	.27	1.13	37.5	8.3
9	1.07	.73	34.2	8.4
10	1.98	.96	34.2	8.0
11	3.98	2.35	34.1	8.0
12	.26	.97	34.0	8.1
13	.76	.84	34.4	8.0
14				

Table 4.27 Summer Results.(January,1979)

Site	Chlorophyll'a'(ugl^{-1})	Phaedphytin (ugl^{-1})	Salinity(ppt)	PH
1	1.28	1.24	40.3	8.1
2	-	-	-	-
3	14.03	2.44	21.8	7.7
4	11.10	5.23	37.9	8.1
5	3.82	2.25	41.5	8.1
6	1.19	.65	41.9	8.1
7	6.55	7.33	36.9	8.1
8	1.66	1.36	49.2	8.1
9	1.90	1.66	52.9	7.7
10	5.80	5.42	62.2	7.8
11	2.85	.07	40.4	8.1
12	9.04	2.83	35.7	8.1
13	.95	.65	36.2	8.1
14	1.14	1.21	31.8	8.2

Table 4.28 Autumn Results.(April,1979)

Site	Chlorophyll'a'(ugl^{-1})	Phaedphytin (ugl^{-1})	Salinity (ppt)	PH
1	2.21	1.73	36.5	8.0
2	-	-	-	-
3	6.45	5.48	14.7	7.9
4	7.81	4.85	34.0	8.0
5	2.08	1.23	36.8	8.1
6	1.00	.53	37.0	8.1
7	4.04	2.07	35.3	8.0
8	1.53	.58	34.0	8.0
9	.90	.63	30.0	7.9

Table 4.28 Cont.

Site	Chlorophyll'a'(ugl^{-1})	Phaedphytin (ugl^{-1})	Salinity (ppt)	PH
10	4.85	2.53	23.0	7.9
11	3.08	1.73	31.5	8.0
12	6.56	4.83	30.3	8.0
13	1.05	.73	31.6	8.1
14	1.23	.95	29.9	7.9

Table 4.29 Winter Results.(July,1979)

Site	Chlorophyll'a' (ugl^{-1})	Phaedphytin (ugl^{-1})	Salinity (ppt)	PH
1	4.06	2.19	32.4	8.0
2	.24	1.19	16.05	9.2
3	1.07	1.50	4.85	8.2
4	1.61	.63	30.2	7.9
5	1.71	.53	29.6	8.0
6	.85	.27	29.0	8.1
7	2.81	1.89	30.1	8.0
8	1.71	.69	27.5	8.0
9	.85	.59	18.5	8.1
10	4.05	1.69	3.5	8.1
11	3.42	2.03	24.8	8.0
12	3.05	1.91	28.5	8.1
13	1.81	.71	29.2	8.0
14	.85	.50	29.5	8.0

4.4.21 Diurnal Nutrient Analysis.

The diurnal nutrient analysis was carried out over the twenty four hour period commencing at 0800 on the 29th. July,1979 to 0600 on the 30th.July,1979.The site chosen was site number seven as this area had shown high chlorophyll 'a' readings and also because it was opposite the main urban area.(see Fig.4.4.1)A twenty four hour dissolved oxygen analysis was carried out concurrently and the results of this are shown in table 4.20

Table 4.30 Results of Diurnal Nutrient Analysis (Site 7)

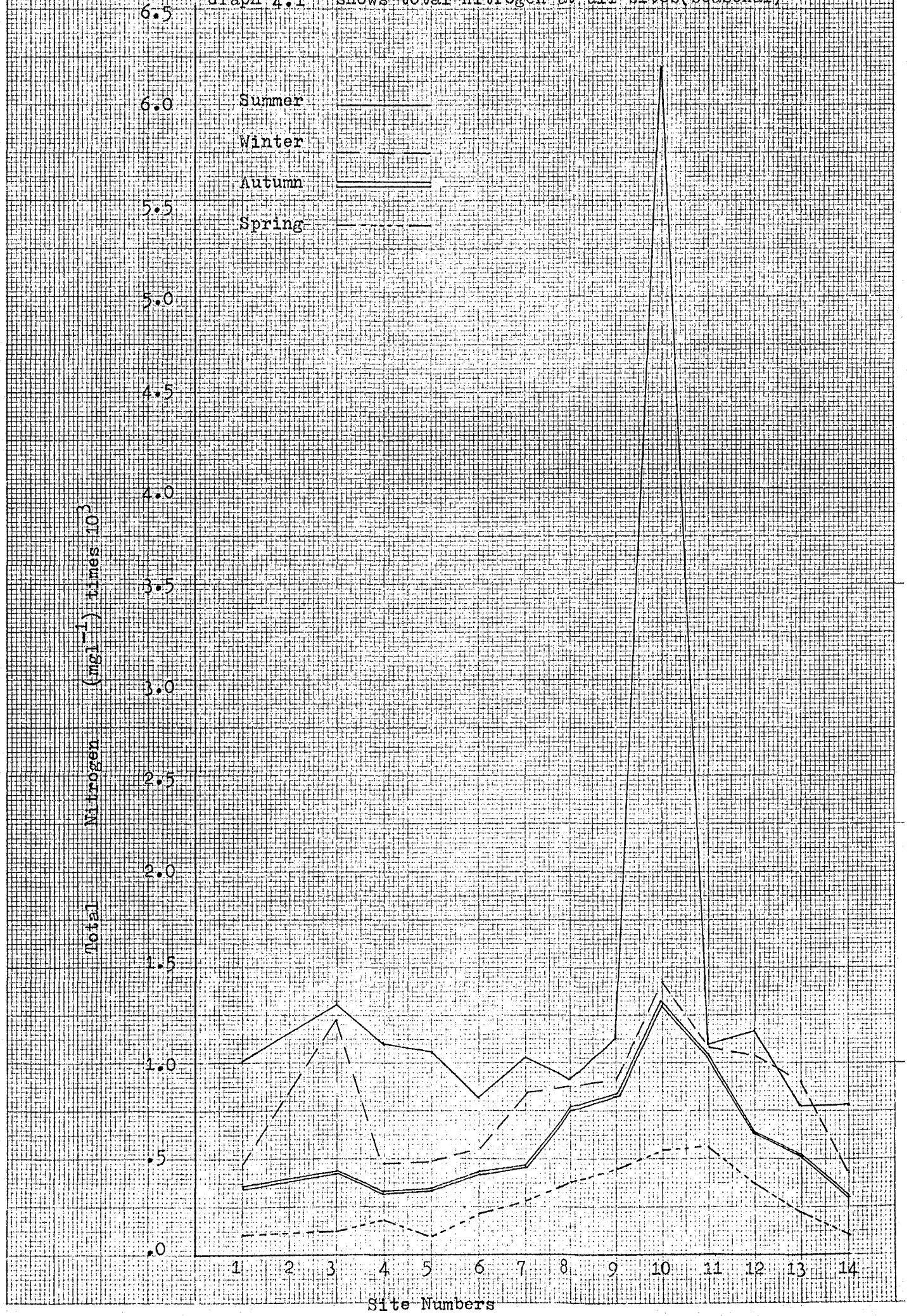
	Phosphorus - P (mg/l)			Nitrogen - N (mg/l)			
Time	Ortho	Organic	Total	Ammoniacal	NO_3+NO_2	Organic	Total
0800	.008	.004	.012	.024	.001	.736	.760
1200	.004	.010	.014	.026	.001	.752	.779
1600	.008	.008	.016	.027	.001	.770	.797
2000	.005	.009	.014	.028	.003	.806	.837
2400	.006	.025	.030	.030	.003	.972	1.004
0400	.006	.000	.006	.030	.004	.767	.801
0600	.007	.002	.009	.021	.003	.739	.762

4.4.22 Discussion of Results.

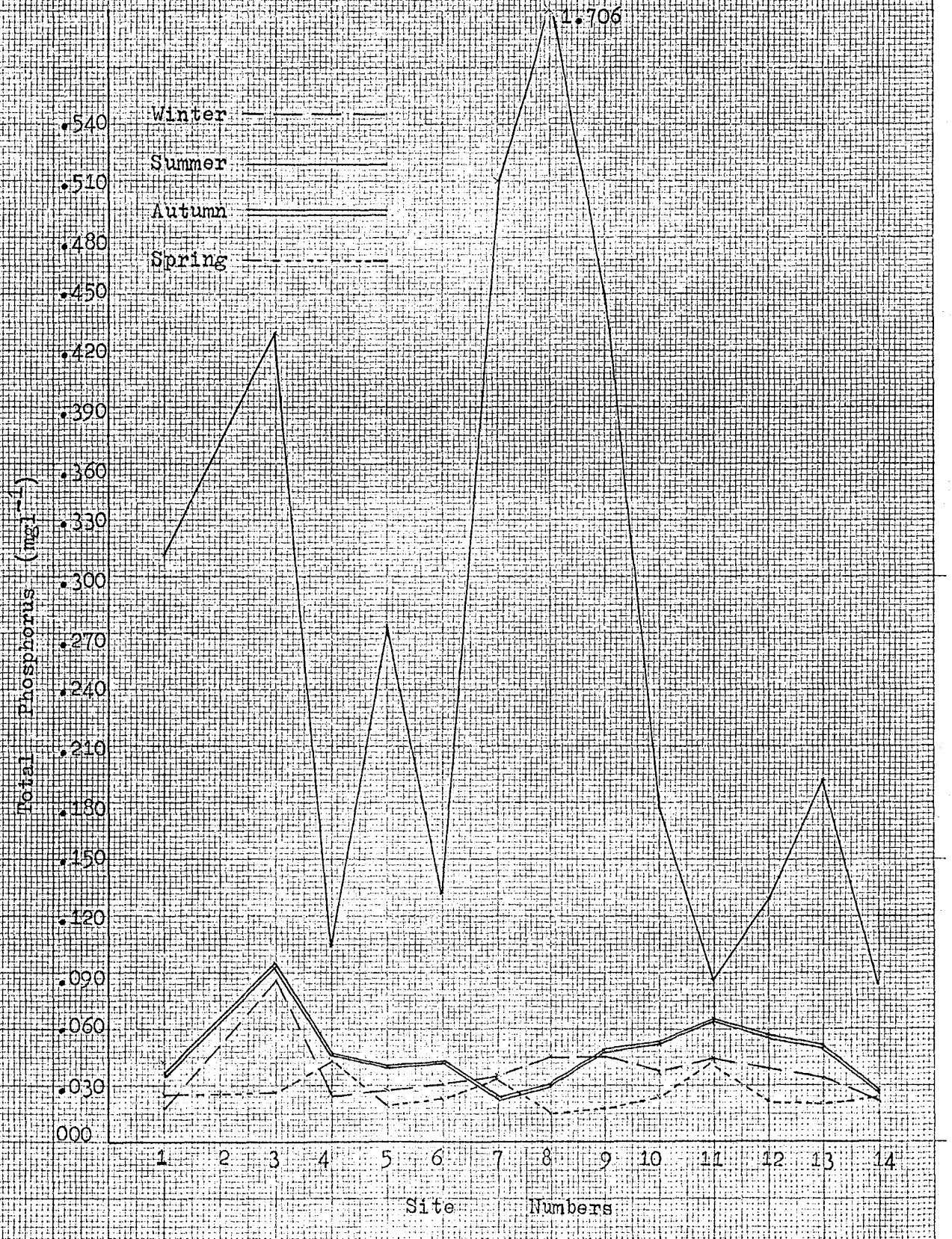
4.4.23 Nitrogen.

The water samples were analysed for the common forms of nitrogen which are found in estuarine systems:organic,ammonia,nitrite and nitrate.The highest total nitrogen levels recorded in

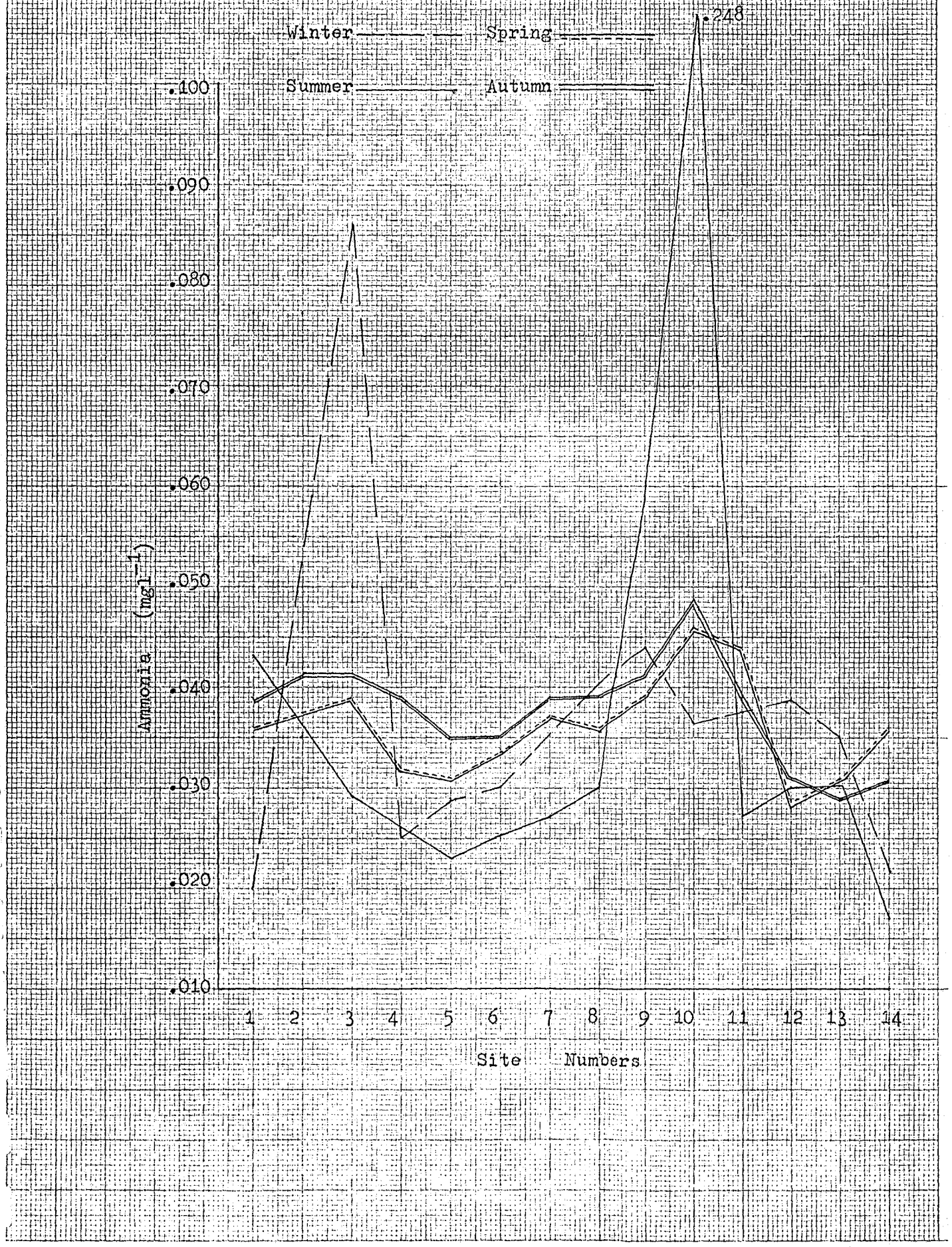
Graph 4.1 shows total nitrogen at all sites(seasonal)



Graph 4.2 shows total phosphorus.All sites(seasonal)

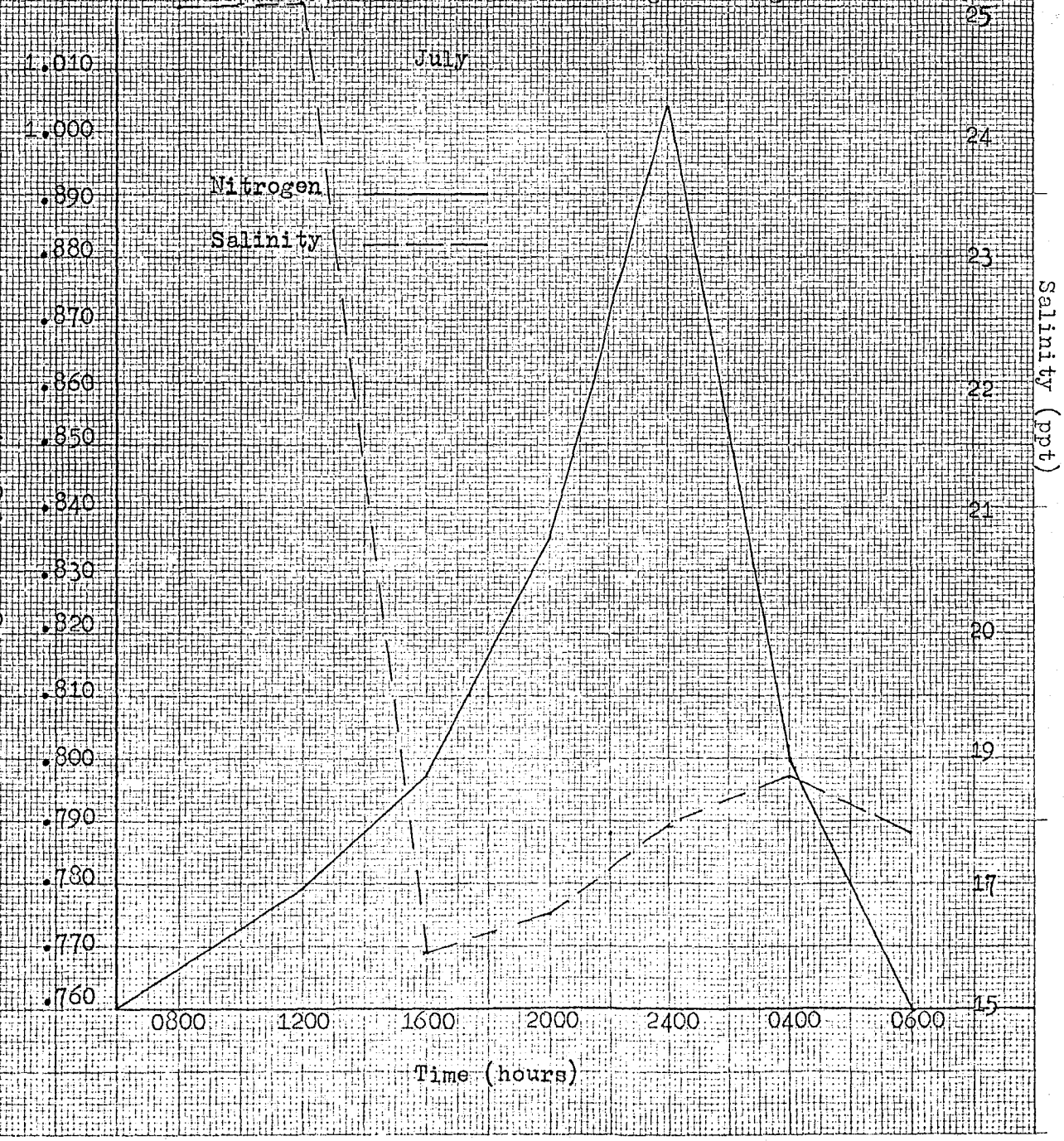


Graph 4.3 shows ammonia levels. All sites. (seasonal)

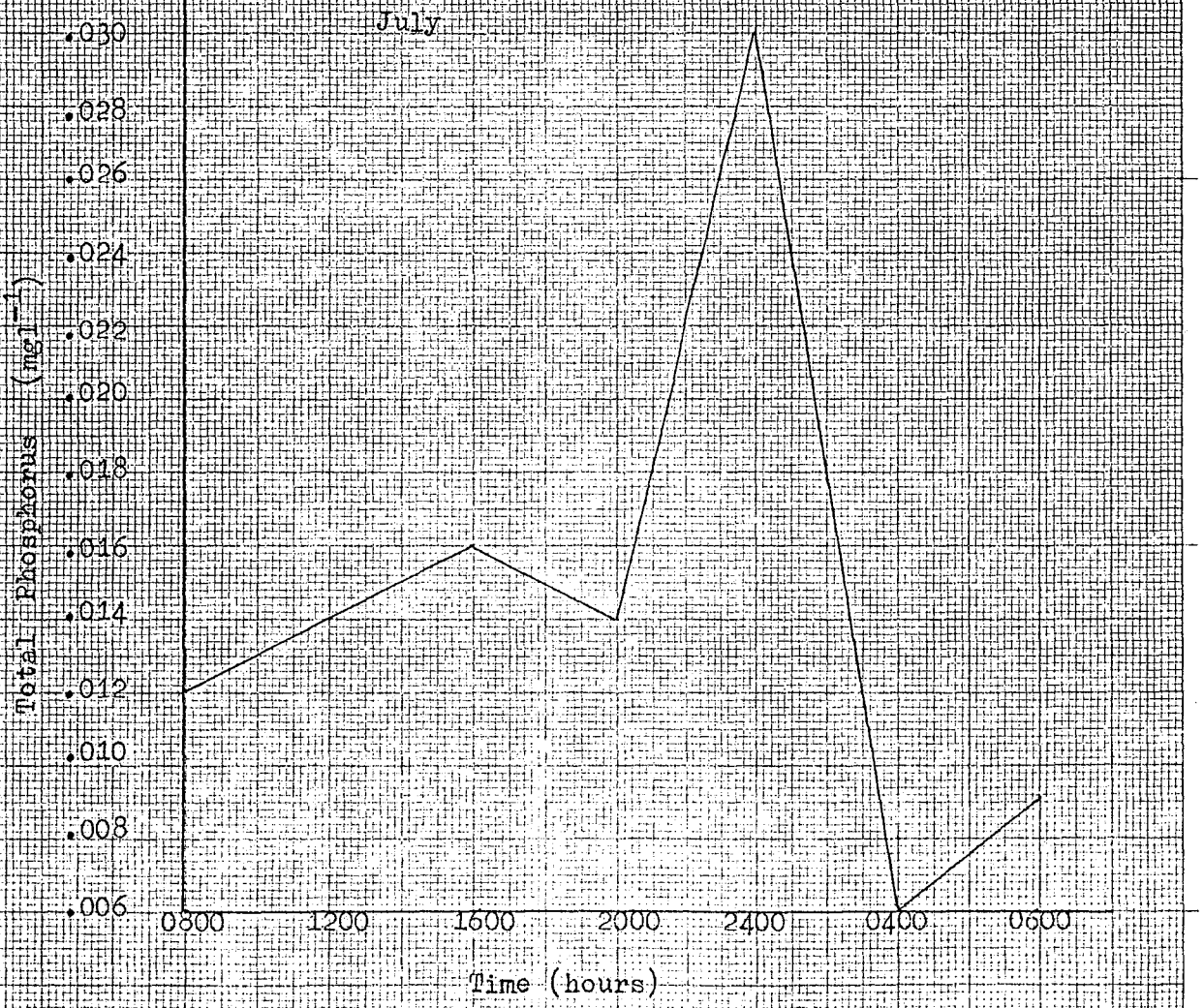


Shows salinity change during diurnal analysis

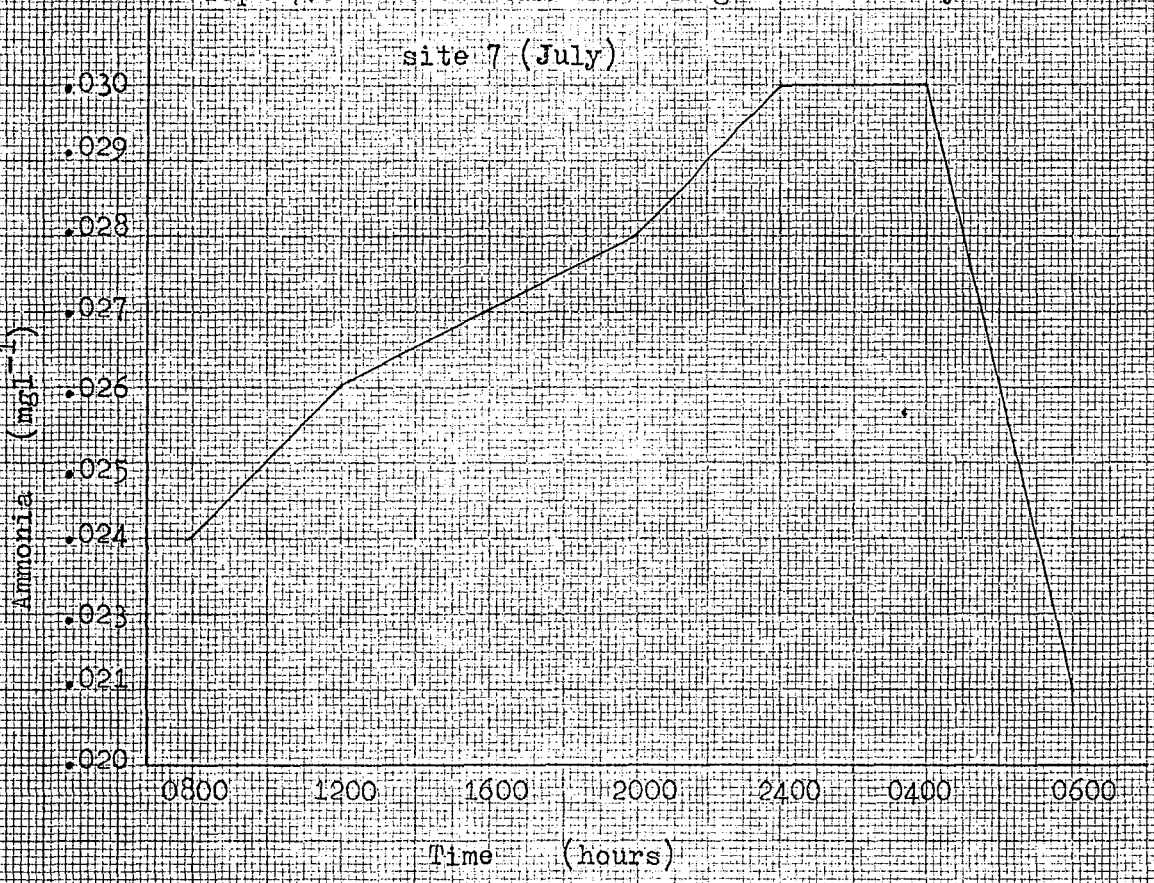
Graph 4.4 shows total nitrogen during diurnal analysis



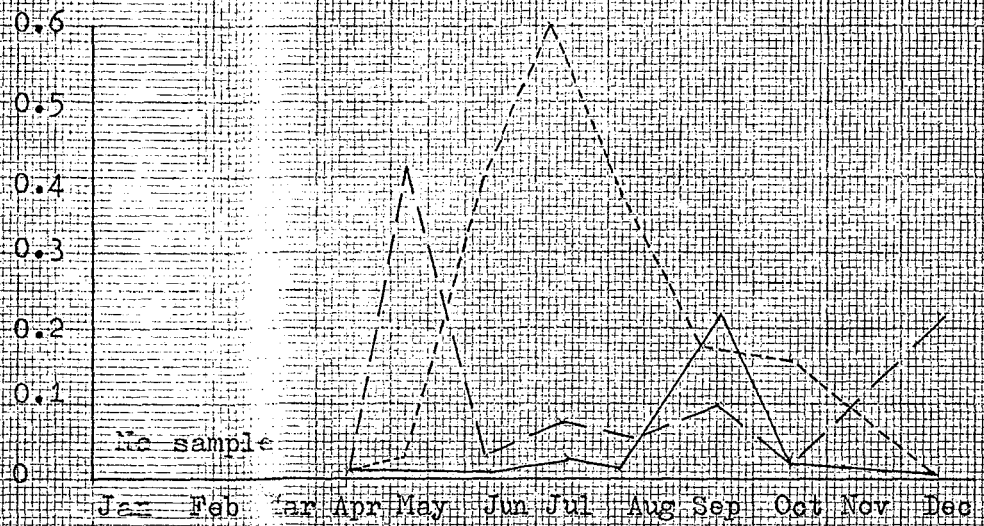
Graph 4.5 Total phosphorus during diurnal analysis



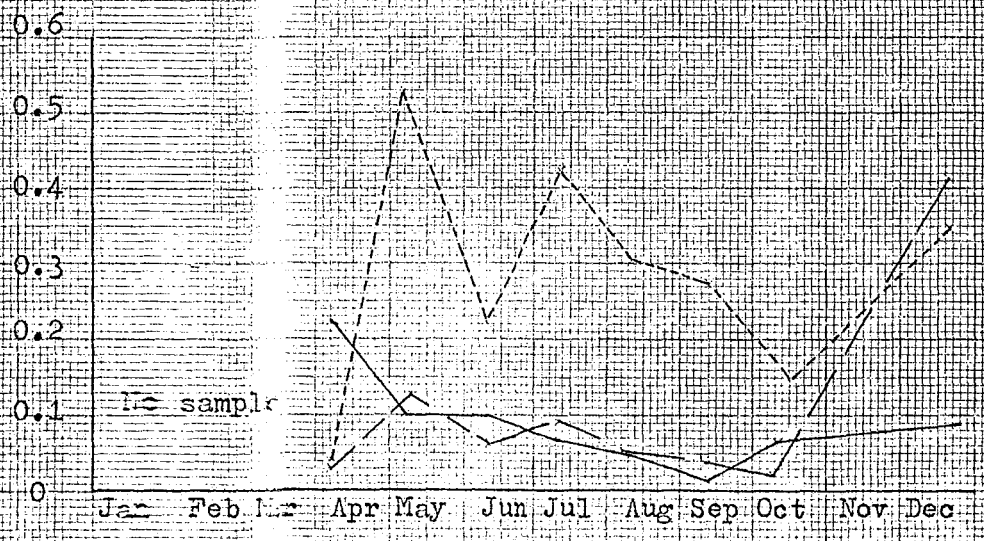
Graph 4.6 shows ammonia during diurnal analysis site 7 (July)



Graph 4.2 Collie River - Roelands



Graph 4.3 Brunswick River - Brunswick



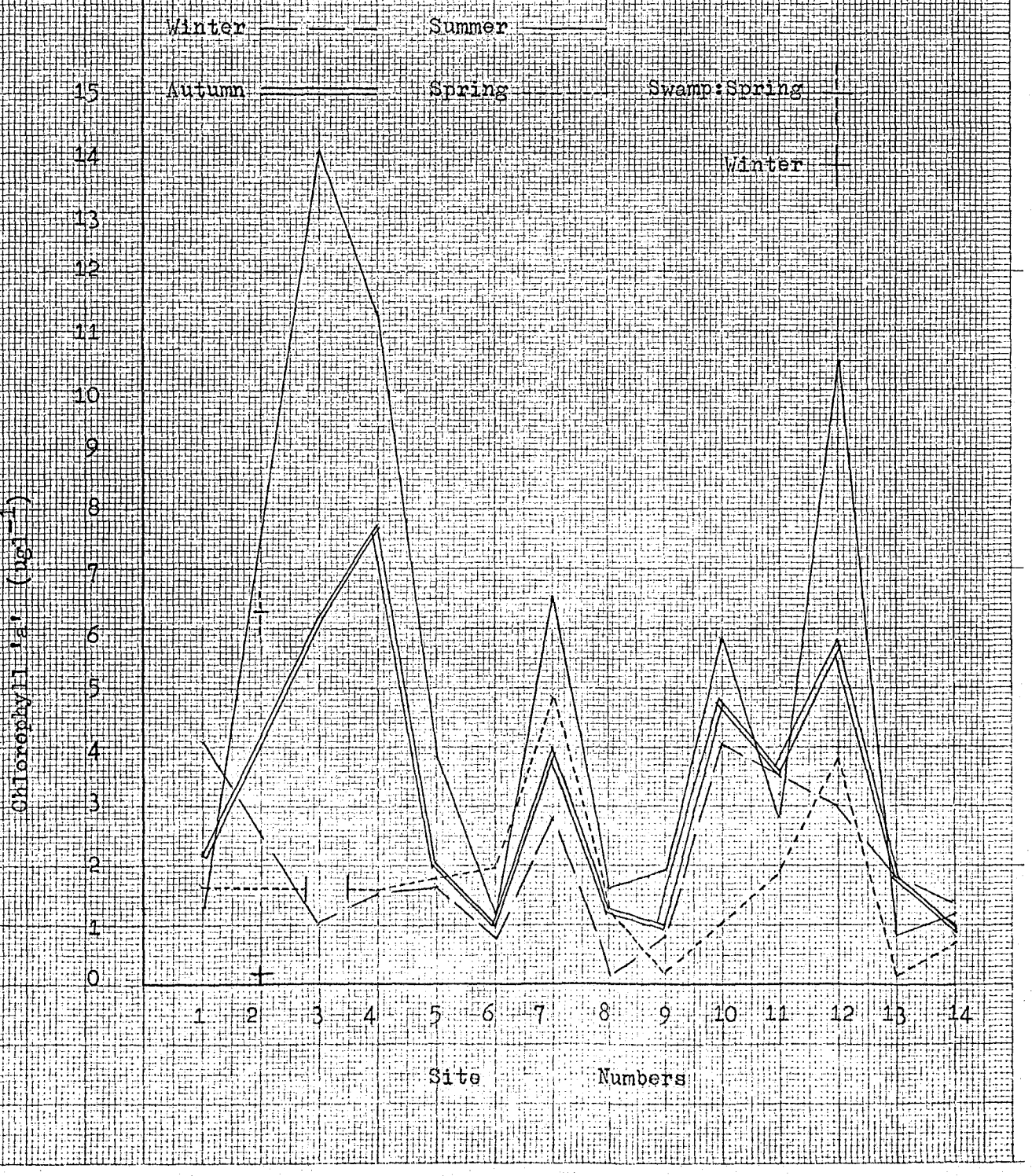
These are readings taken by the Dept. of Health in 1978

Phosphorus ——————

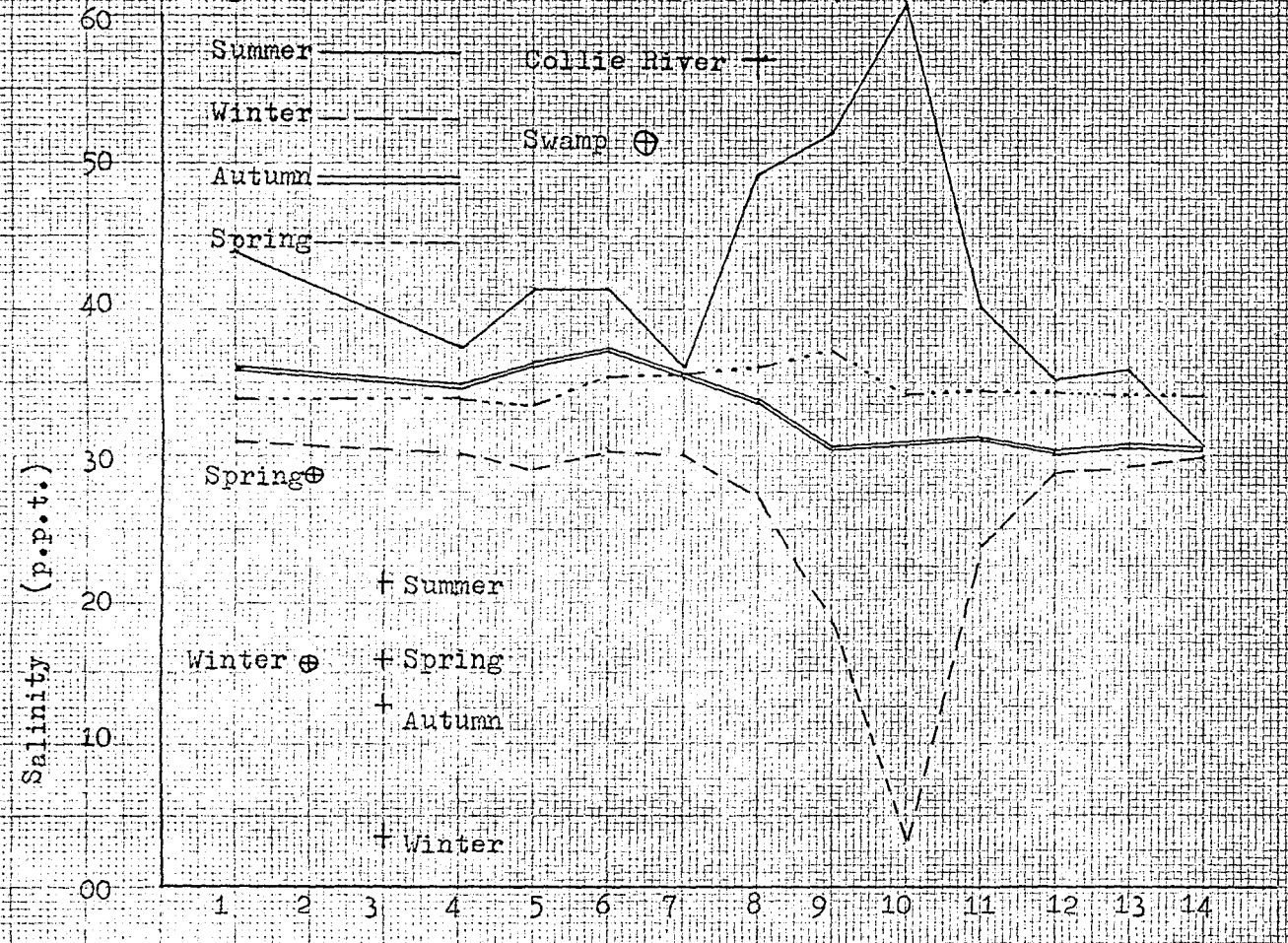
Nitrogen — — — —

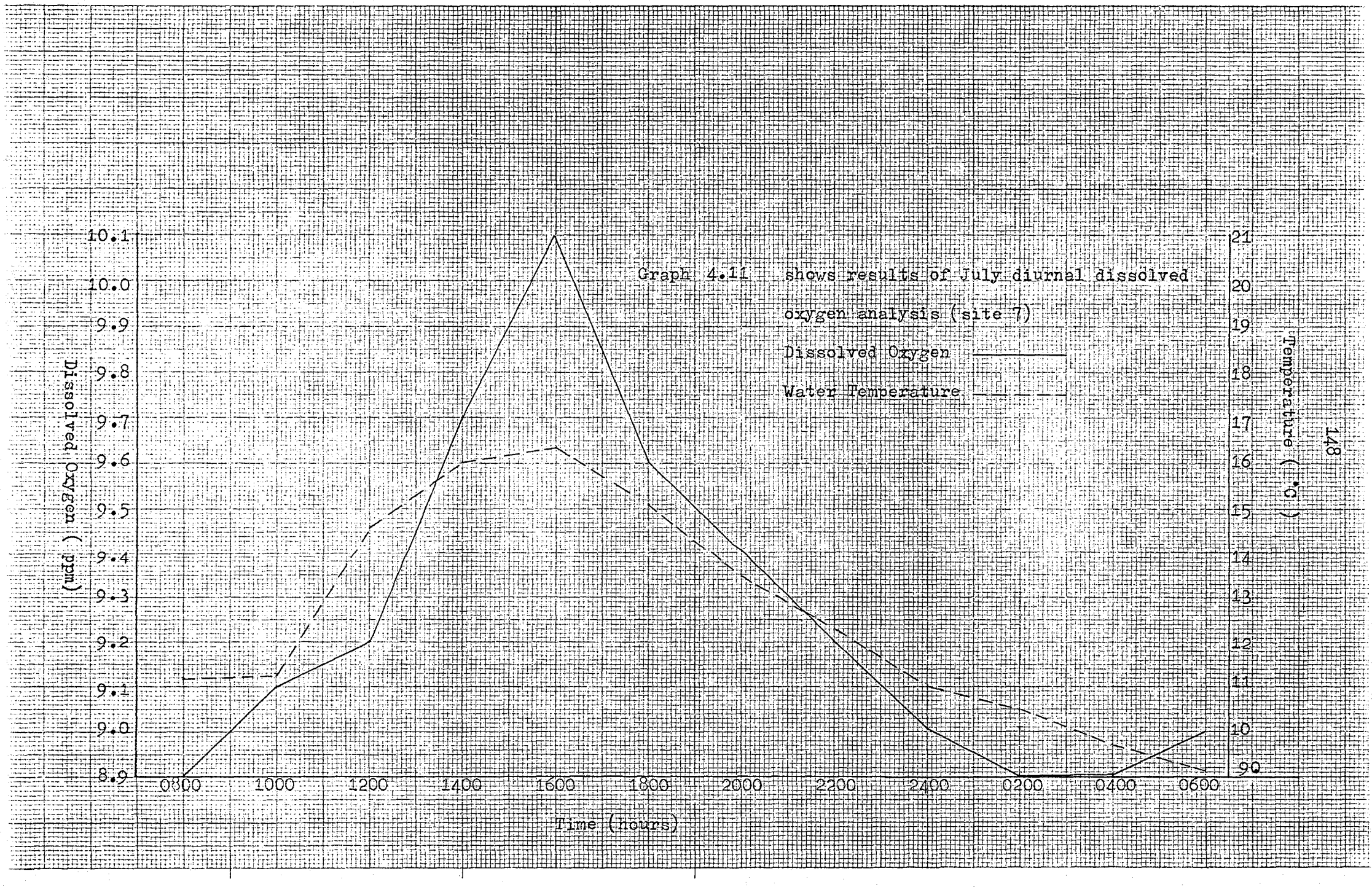
Ammonia ----------

Graph 4.9 shows Chlorophyll 'a' all sites (seasonal)

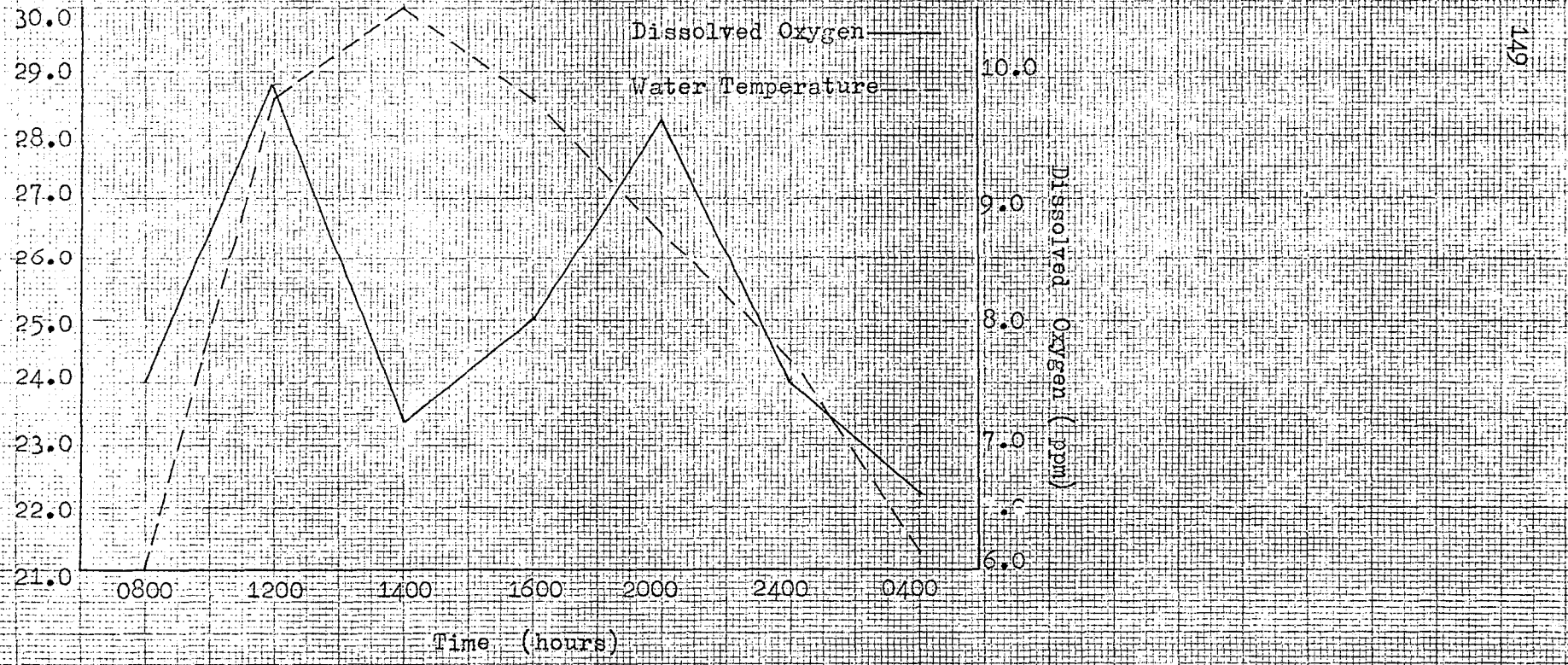


Graph 4.10 shows salinity at all sites(seasonal)



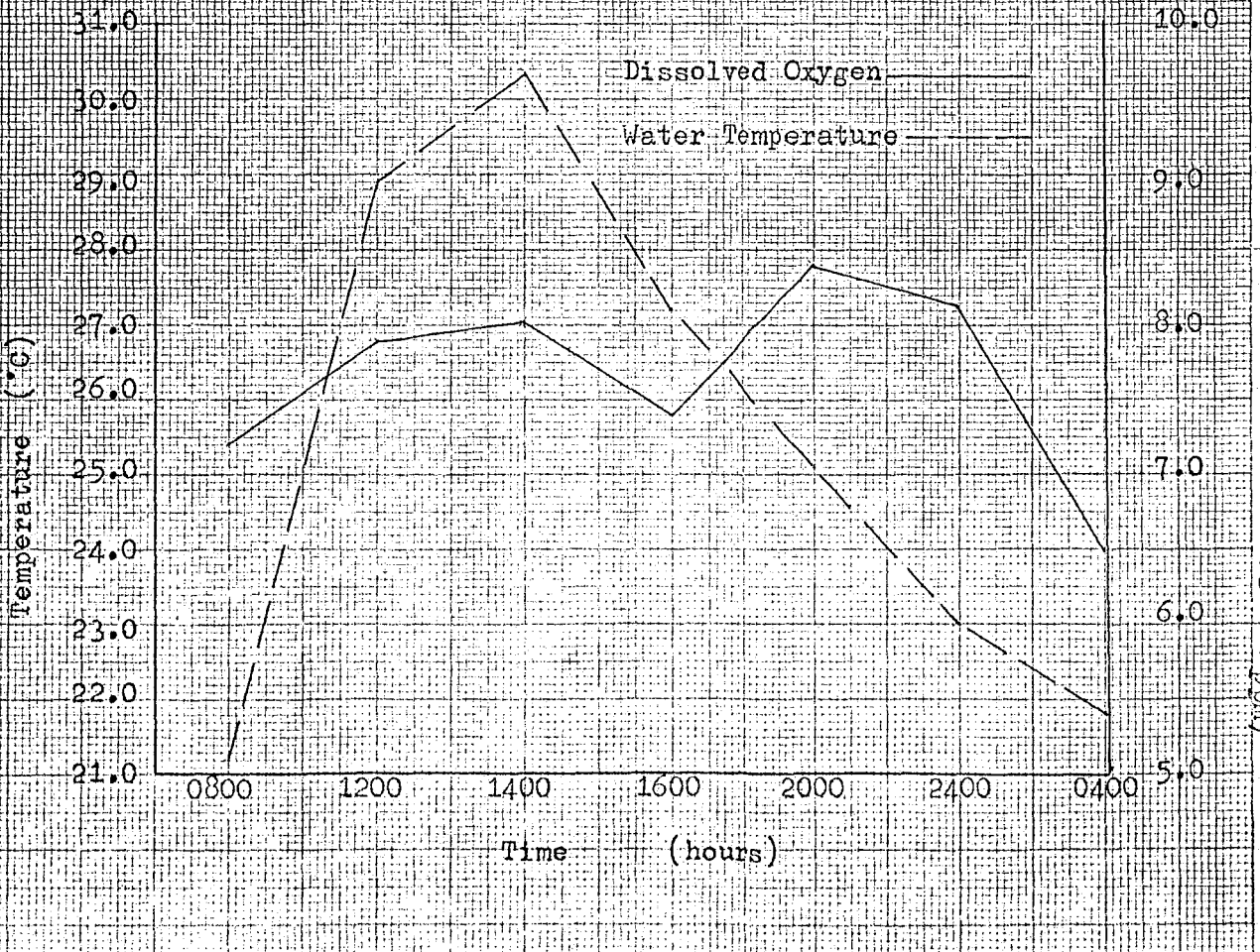

Graph 4.11 shows results of July diurnal dissolved oxygen analysis (site 7)
Dissolved Oxygen
Water Temperature
Dissolved Oxygen (ppm)
Temperature (°C)
10.1
10.0
9.9
9.8
9.7
9.6
9.5
9.4
9.3
9.2
9.1
9.0
8.9
21
20
19
18
17
16
15
14
13
12
11
10
90
0800
1000
1200
1400
1600
1800
2000
2200
2400
0200
0400
0600
Time (hours)

Graph 4.12 shows Febuary diurnal dissolved oxygen(site 1)

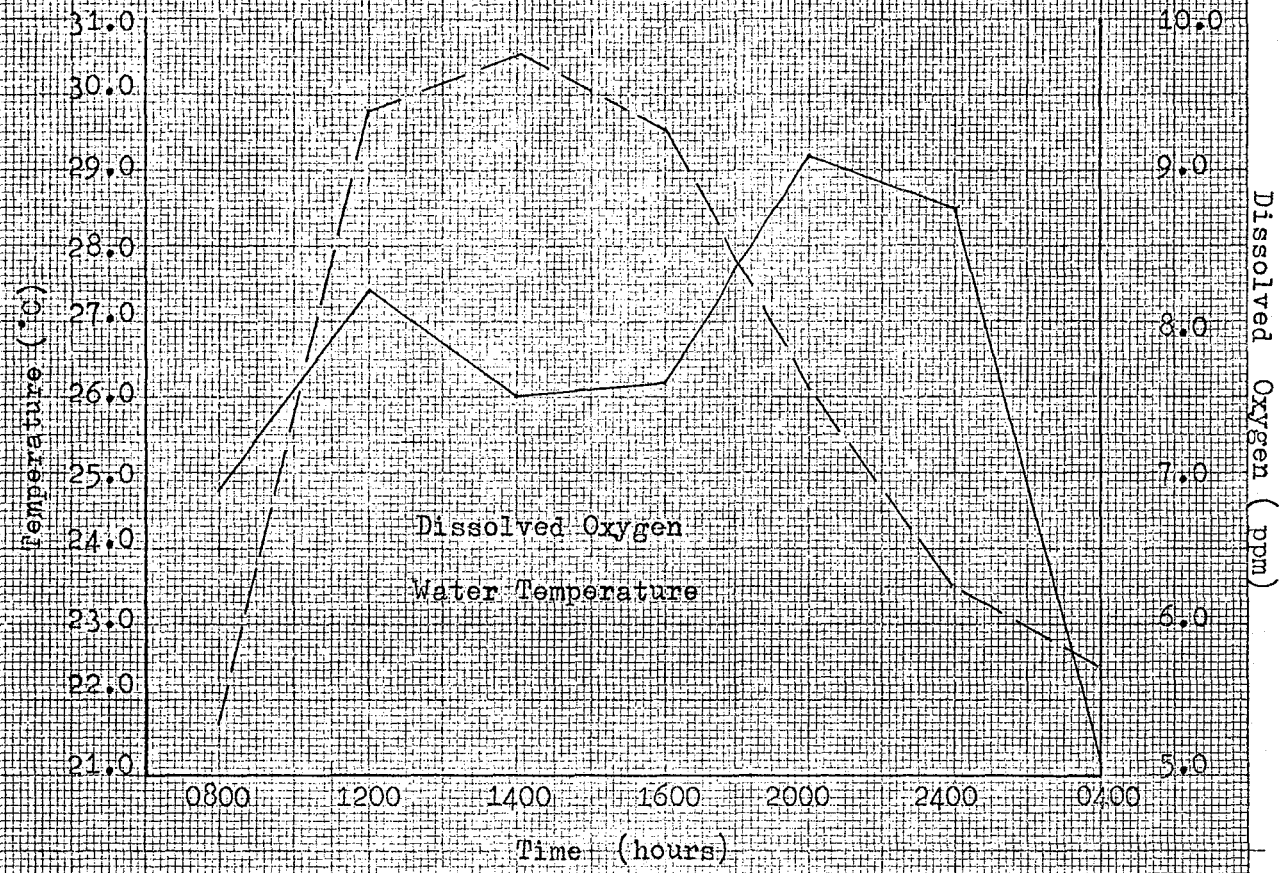


Graph 4.13 shows Febuary diurnal D.O.(site 3)

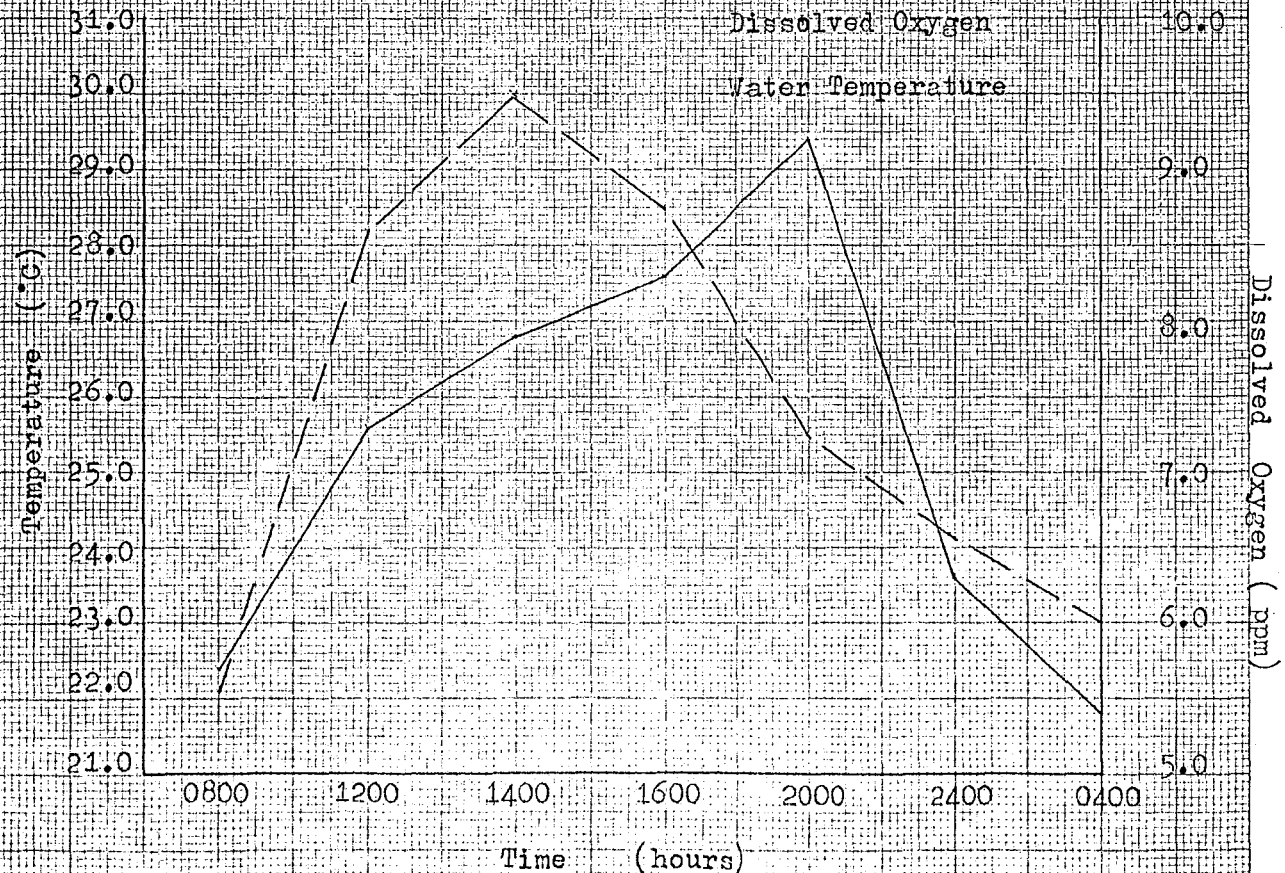
Graph 4.14 shows Febuary diurnal D.O.(site 4)



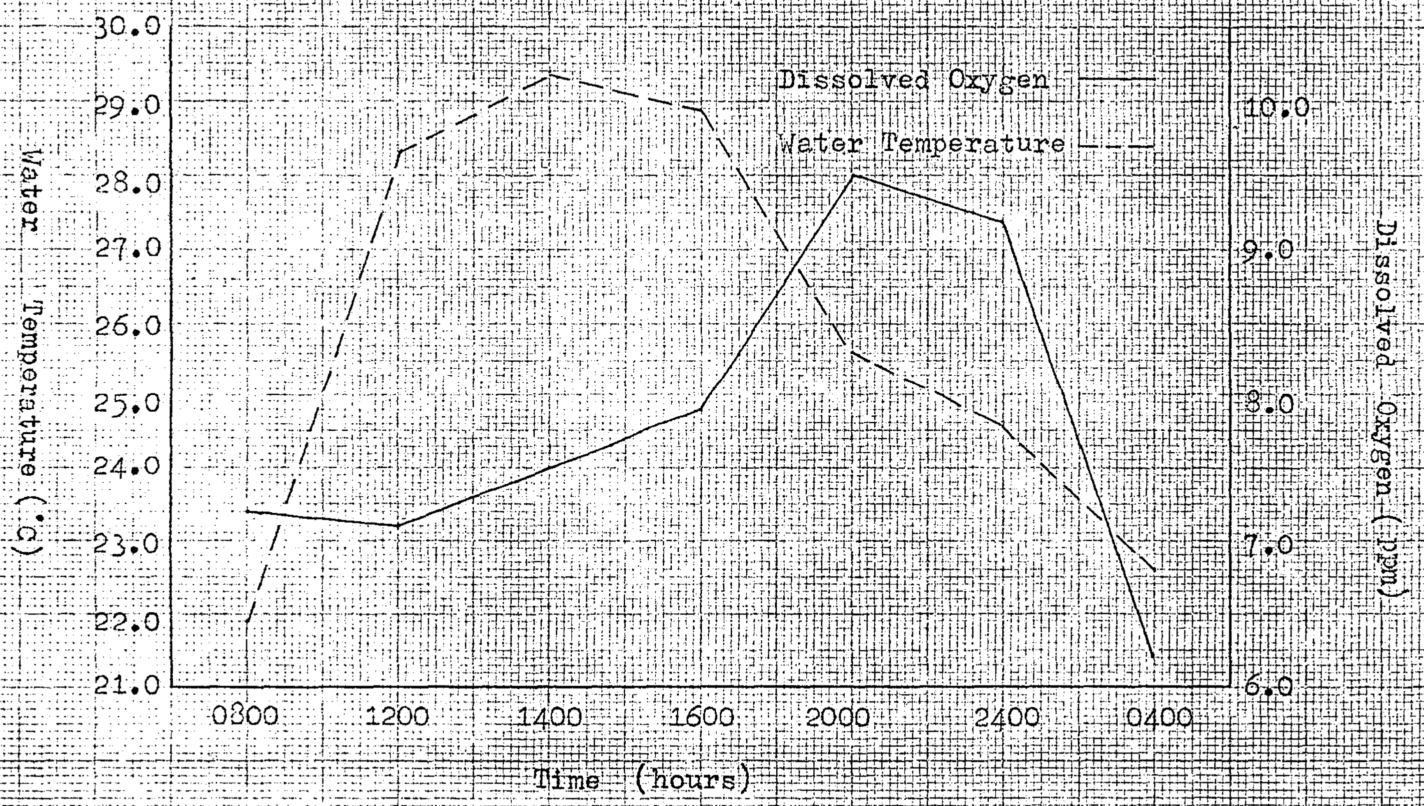
Graph 4.15 Feb. diurnal D.O. (site 5)



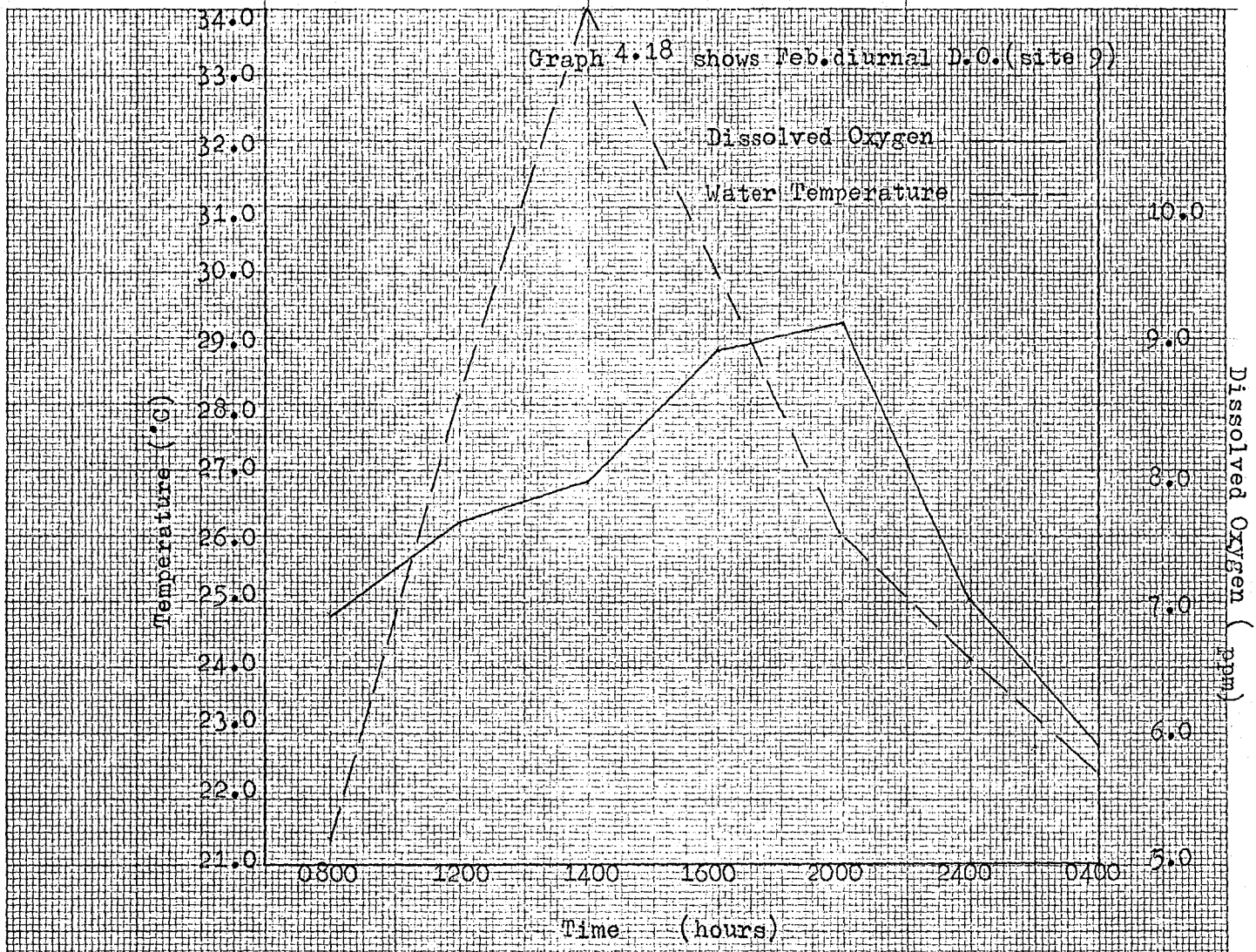
Graph 4.16 Feb.diurnal D.O. (site 6)



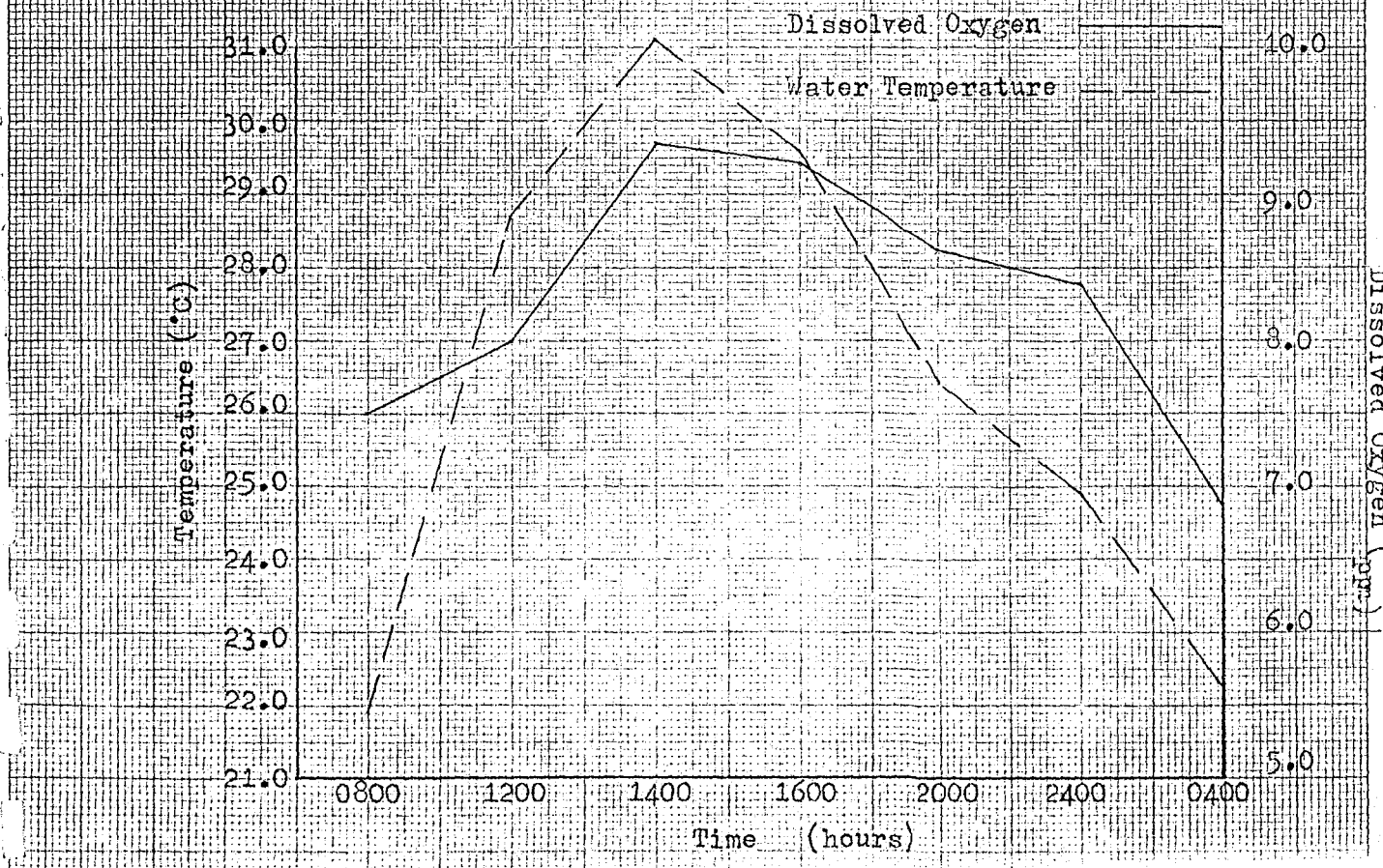
Graph 4.17 shows Febuary diurnal dissolved oxygen (site 7)



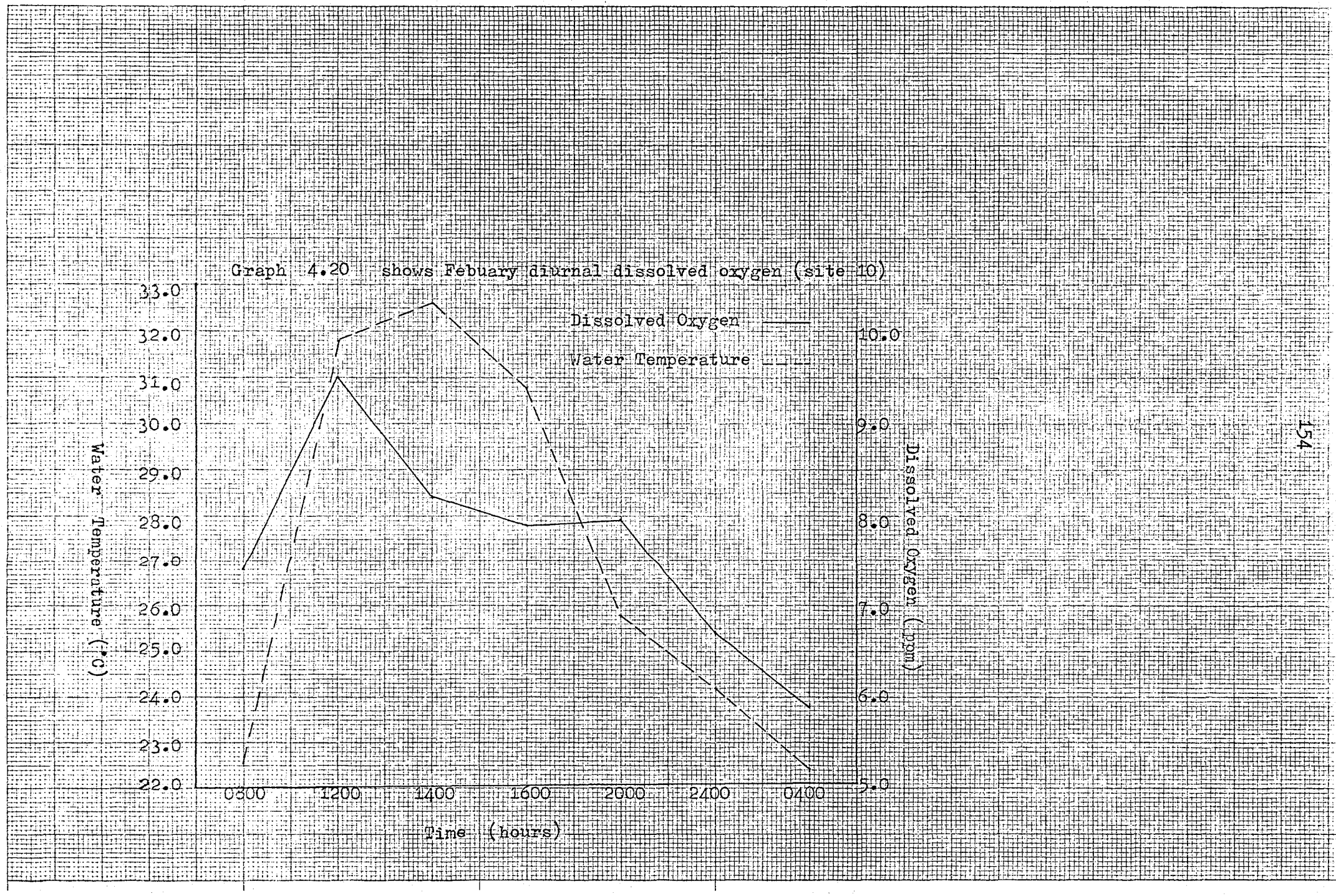
Graph 4.18 shows Feb.diurnal D.O.(site 9)



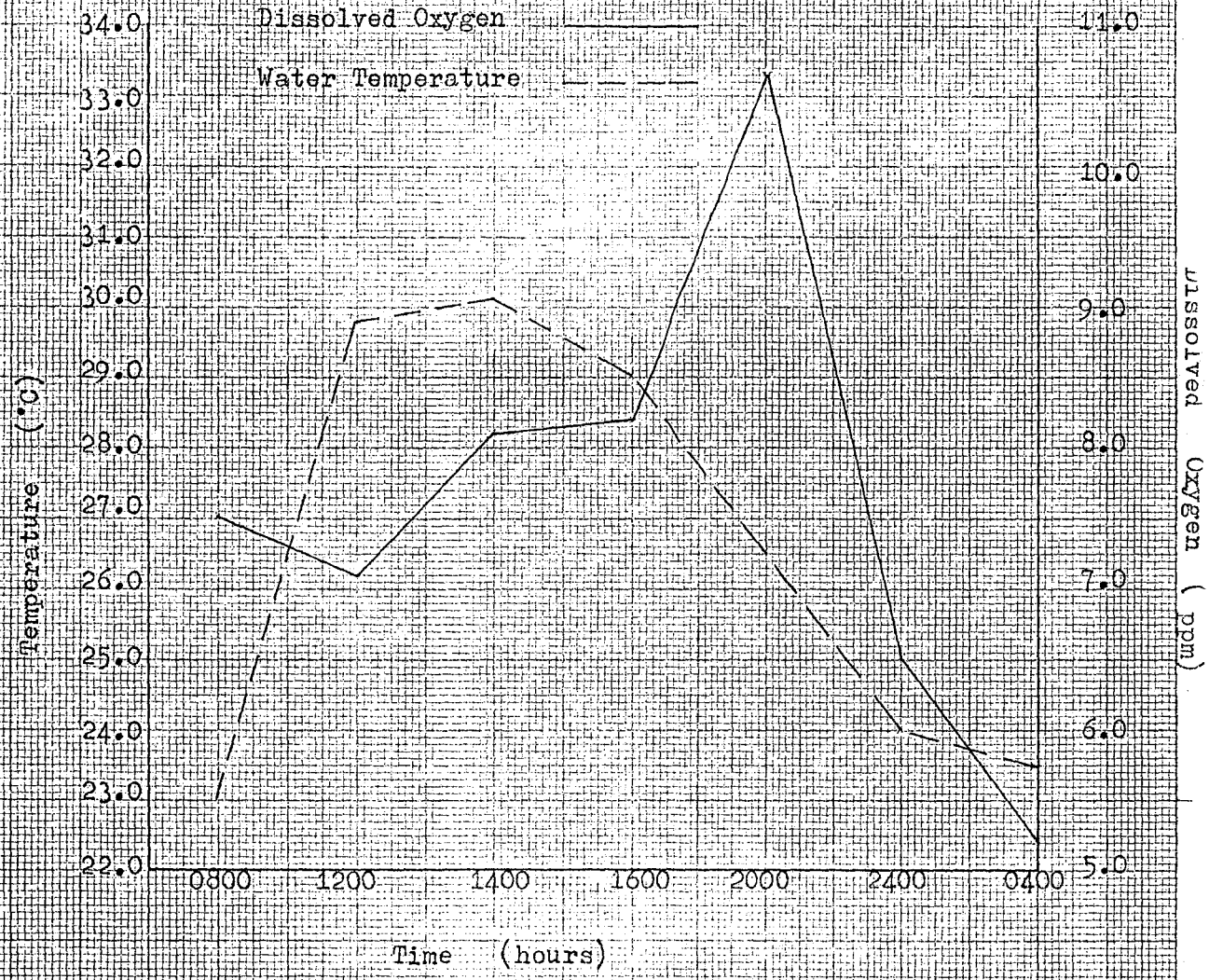
Graph 4.19 shows Feb.diurnal D.O. (site8)



Graph 4.20 shows Febuary diurnal dissolved oxygen (site 10)



Graph 4.21 shows Feb. D.O. (site 11)



the Leschenault Inlet occured during the late summer months (see table 4.23) and of these the highest recorded levels occured at the extreme northern end (site 10)where values of 6.191 mgl^{-1} were found and at the mouth of the Collie River where the summer reading was 1.270 mgl^{-1} (site 3)With the exception of sites 6,8,13 and 14 all total nitrogen levels recorded were above 1.0 mgl^{-1} and the other sites were around 0.8 mgl^{-1} (see table 4.23) According to Hammer (see 4.4.3) these levels constitute a danger in regards to algal blooms.Of the nitrogen forms present,organic nitrogen was the most prevalent at all sites,followed by the ammonia form.It can be seen from graph 4.1 that sites 3 and 10 have the highest overall readings and this is probably due to the nutrients being brought down by the winter and spring rains.Site 3 is served by the river systems and site 10 by a large drainage channel which enters the inlet at the northern end.This channel drains water away from the surrounding wetlands and farms.Discharge from effluents and stormwater enter the Collie system and nutrient levels taken at Brunswick and Roelands show the nutrient concentration to be close to 0.8 mgl^{-1} during certain times of the year.(see graphs 4.7 and 4.8)It would appear from graph 4.1 that a build up of nitrogen occurs during the winter and spring from drain,river and runoff and that the nitrogen is 'locked' into the soft sediments of the substrate,especially at the northern end of the inlet.The graph shows a steady increase from south to north and then a decrease from north to south along the western side of the inlet.(sites 11, 12,13 and 14)Because of the high temperature of the water at the northern and north eastern section of the inlet during summer,(30°C and above during mid afternoon)(see tables 4.9 to 4.19)and because of the shallowness of these regions,(see depth map)and the prevailing winds,there is a release of the stored nutrients from the sed-

iments.Housing blocks situated along the eastern side of the inlet either slope towards the inlet or towards the Collie River and as they are serviced by septic tanks,and because the water table is relatively high in winter and spring,organic matter is probably brought into the inlet via the groundwater.Because of the high nutrient levels occuring in the northern sector blooms of filamentous algae flourish during the late spring and early summer (see section 6.0)and when these algae decay large amounts of organic matter are deposited on the inlet floor.The diurnal nutrient analysis carried out at site seven in July (1979) shows a steady increase in total nitrogen levels up to 2000 hours and then a 'burst' at midnight,followed by a steady decline until 0600 hours.With the exception of the northern and north eastern section it would appear that total nitrogen levels in the waterbody are reasonable.Recommendations regarding the northern area can be seen in section 1.0.

4.4.24 Ammonia.

Inorganic nitrogen in the form of ammonia and nitrate is utilized by green plants in the photosynthetic process by uptake through the root systems in attached marine plants and from the water by the filamentous algae.Reasonable levels of ammonia occur in the inlet,with high levels at the northern end.(see graph 4.3)As with the total nitrogen there is an increase from south to north and a decrease from north to south along the western bank.Ammonia is produced by the bacterial decomposition of protein,amino acids and excretion.The high readings along the north and north eastern sections are probably due to the decomposition of the algae and to a lesser degree,waterbird droppings.This area is one of the main bird areas and in october 1979,700 swans were counted in this region.(see section 5.0 and 4.4.7)

4.4.25 Phosphorus.

The common compounds measured were orthophosphate,organic phosphate and

total phosphorus.Levels above .1 mgl^{-1} are considered a danger in regards to eutrophication and algal blooms.Levels between 1 and 2 mgl^{-1} were found to cause rapid growth in the algae,Cladophora,in the Peel Inlet.(Pitcairn and Hawkes,1973)Sources of phosphates are mainly from detergents,runoff from agricultural areas and from decaying organic matter.The highest levels recorded were at the mouth of the Collie River,(.430 mgl^{-1}) during the summer and at site 8, (1.706 mgl^{-1})also during the summer.Phosphate entering the river systems from effluents,farms and stormwater is probably the main cause of these high levels,while at site 8 a drain enters the inlet from a nearby farm.Large amounts of decaying algae were also present in this region at the time of sampling.Like the nitrogen,the phosphate probably becomes trapped in the sediment during the late summer,early autumn,from decaying organic matter and from water brought down during the winter and spring.During the summer months the sediment heats up and releases the trapped phosphorus.Phosphorus levels during the other seasons are below danger levels.(see graph 4.2)Site 7 also recorded high phosphorus levels,(.511mgl^{-1}) and high nitrogen levels,(1.026 mgl^{-1}).This site is opposite the main housing area along the shore of the inlet and seepage from septic tanks maybe occuring during the winter and spring.Overall,the high phosphorus levels,along with the nitrogen are causing problems in the inlet in regards to algal blooms during the late spring and early summer.The diurnal analysis at site seven(July 1979) showed a gradual increase until 1600 hours,followed by a slight decline to 2000 hours,followed by a 'burst' at midnight and a decline till 0400 hours.(see graph 4.5)

4.4.26 Dissolved Oxygen.

Graphs 4.12 to 4.19 show the dissolved oxygen at all sites over a twenty four hour period in Febuary 1979.Graph 4.11 shows the diss-

olved oxygen over a twenty four hour period at site seven in July 1979.It can be seen from the Febuary diurnal analysis that the dissolved oxygen begins to decline in all cases at 2000 hours.This would be due to respiration taking over.This phenomenon occurs at about 1600 hours during the winter months.(see graph 4.11)The waterbody becomes saturated during the day and drops to low levels in some areas towards morning.Sites 1 and 7 appear to be mainly temperature dependant while sites 9 and 10,although reacting to the temperature would appear to be influenced greatly by biological factors.When the dissolved oxygen is low there is a tendancy for the orthophosphate to rise as anaerobic conditions favour this release.This can be seen by comparing the July phosphorus and dissolved oxygen diurnal analysis. (graphs 4.5 and 4.11)Oxygen levels during the cooler months are quite adequate and because of the shallow depths which occur in the inlet, there is a sufficient transfer of oxygen and mixing through wind and wave action.However,due to the algal growth,less wind and wave action, the large fish population and sea grass growth during the warmer months,the oxygen levels become low towards morning and during a year of excessive algal bloom could become critical in some areas and cause deoxygenation.

4.4.27 Chlorophyll 'a'

In comparison to the Peel Inlet the Chlorophyll 'a' levels are reasonably low.Peel Inlet levels are as high as 99 ugl^{-1}The Chlorophyll 'a' peaks tend to follow the peaks of the nitrogen and the phosphorus levels with the highest levels being recorded at the mouth of the Collie River.(14 ugl^{-1}) Sites 7,10 and 12 also show reasonably high levels compared with the rest of the inlet.(see graph 4.8 and tables 4.26 to 4.29)These areas also reflect the greatest depletion of dissolved oxygen during the summer.

4.4.28 Salinity.

Salinity,in the Leschenault Inlet,causes extreme environmental stress for the flora and fauna that inhabit the water system. This physical feature is one of the prime factors in determining the species and distribution of species in the inlet.It is common knowledge amongst local professional fishermen that the blue manna crab moves south as the salinity increases in the north and although the aquatic flora that grow in the inlet can sustain extremes of salinity,there distribution is directly related to this phenomenon.(see section 6.0)Graph 4.10 shows the seasonal variations in salinity from the spring of 1978 to the winter of 1979.(Note:this was a season of relatively low rainfall.see section 7.0)During the summer the salinity varies from 40.3 ppt* at the southern end to 62.2 ppt at the northern end of the inlet.(see tables 4.26 to 4.29)The northern end changes from hypersaline in the summer to hyposaline in the winter when fresh water enters the system from the northern drainage channel(3.5 ppt.)The southern end,Vittoria Bay,has salinities close to those of the adjacent ocean during this period.(32.0 ppt and 35.0 ppt respectively)During winter and spring,especially in years of heavy rainfall,fresh water flows out into the inlet from the Collie and Preston River systems and forms a layer over the salt water.During the summer months the salt water penetrates into the river systems.Summer salinity levels at the mouth of the Collie River were 21.8 ppt and the winter levels were 4.85 ppt.(see graph 4.10)It would appear that the main problem associated with the high salinities is the shallow depths in most parts of the inlet, especially in the northern end,and because of the high evaporation

*ppt = parts per thousand.

rates,the salts accumulate in the sediment and are released during the warm weather.Salts also accumulate in the nearby seasonally flooded zones and these are washed into the inlet with the first rains and because there is little water movement at the northern end,tend to accumulate.

4.4.29 Turbidity.

The water clarity varies greatly throughout out the inlet and throughout the various seasons.During the summer the shallow areas are relatively clear,but in the deeper central section dechi disc reading showed that light penetration ceased at approximately 154 centimetres in areas north of the pipeline and at 174 centimetres south of the pipeline.Strong winds tend to stir up the sediment,especially in the areas where estuarine mud is present.The areas near the river exits become very turbid during the winter due to the depositing of sediments brought down by the systems.

4.4.30 PH

The PH in the inlet comes within the range for safe recreational use. The PH is influenced by the conductivity and tends to drop to around 7.7 in areas of high salinity.During the winter the PH averages around 8.1.The changing temperatures effect the PH,which in turn effect the nutrient release,especially phosphorus.Overall,the PH of the inlet reflects an alkaline system,which in part,maybe due to the limestone which is present under the inlet.

4.4.31 Substrate Soil Analysis.

Substrate soil samples were taken from various location during the summer and winter.Both nitrogen and phosphorus seem to be limited during both the winter and the summer seasons. However,overall the winter nutrient content of the substrate is generally higher than the summer levels and this could support the hypothesis that the nutrients become 'locked' in the sediments during the winter and spring and are released into the waterbody during the summer period when warmer water temperatures prevail.

Table 4.31 Substrate Soil Nutrients(mg g^{-1} dry weight soil)

	Winter		Summer	
Site	Kjeldahl N	Total P	Kjeldahl N	Total P
4	0.30	0.09	-	-
7	0.26	0.50	0.10	0.17
9	0.38	0.05	0.10	0.39
10	4.23	0.13	0.14	0.02
11	3.93	0.11	0.12	0.02
(2)	8.21	0.03	-	-

5. FAUNA OF THE LESCHENAULT INLET.

5.1.1 Introduction.

The Leschenault Inlet is an extremely important area for avifauna, particularly waterbirds, and this can be borne out by observing the many species, both local and migrating, which occur in large numbers throughout the region. Because of the wide diversity of plant ecosystems, which occur throughout the region, the area is also important to terrestrial bird species. Grazing and carnivorous animals occur throughout the region, but their habitats are mainly restricted to the diminishing forested areas, especially those of the western sand dunes system.

5.1.2 Waterbirds.

Observations of the waterbird populations were made at regular intervals throughout the study and a total of fifty species was recorded. Twenty six of these are considered to be common, while the remainder are either uncommon or rare. In comparison to the Peel-Harvey Estuary it would appear that the Leschenault Inlet supports smaller populatior and varieties of waterbirds. The difference in species and numbers may be due to the smaller size and more southerly location of the Leschenault Inlet.Apart from being aesthetically important to the estuary, the waterbirds help to maintain aquatic plant growth at a reasonable level in this highly productive waterbody.

5.1.2 Feeding.

Because of the high produstivity of the Inlet and the surrounding wetland areas, this region offers excellent feeding grounds for many species.Because they have a high metabolic rate, large amounts of foo are consumed by some species and in the Blackwood Estuary ...."Black Swans have consumed 230 tonnes of sea grass during a year" ..... which represents ..... " a significant part of an estimated standing

crop of some 650 tonnes growing in Swan Lake." (Lane 1976). "Waterbirds have also been shown to cosume a large part of the production of estuarine molluscs and worms." (Milne and Dunnet,1971.) Black Duck, Musk Duck, Grey Teal, Mountain Duck and Coot appear in large numbers throughout the area and it was found on the Coorong of South Australia ....."that over ninety percent of the food of these birds consisted of the tubers and seeds of Ruppia and Lamprothamnium." (Delroy 1974.)Both these species occur in the region and the seeds of Ruppia megacarpa are abundant in the seasonally flooded zones which surround the Inlet. The main diet of the Western Australian Black Swan is also Ruppia and the swans tend to 'screw' the plants from the substrate. This can readily be seen by observing the swans and the areas in which this species grows.The area is very rich in crustacean amphipods, isopods, small bivalve molluscs and polychaete worms which form the diet for many species such as Herons and Egrets. As the Leschenault Inlet is a nursery ground for many fish species, (see sub-section 5.5) it offers an excellent habitat for fish - eating waterbirds such as Pelicans and Cormorants.

5.1.3 Breeding.

Little is known about breeding in this region and it has been pointed out that...." coastal inlets and estuaries are of minimal value for large-scale breeding of ducks."(Riggert 1966.) However, because of the favourable conditions which occur in this region, and the fairly stable duck and swan populations that occur throughout the year,it is most likely that some breeding takes place during the spring and winter seasons.Possible breeding species are the Mountain Duck, Black Duck, Grey Teal, Wood Duck, Musk Duck, Coot and the Black Swan.The White Egret, White-faced Heron and the White-headed stilt are all nesting species.The Egrets nest in a colony situated next to the LaPorte Titanium Plant; as do Nankeen Night-Herons, Pied Cormorants and Black Cormorants. The White-faced Heron nests in trees which

overhang the rivers and nearby wetlands.Many nests can be observed in the Eucalyptus rudis which overhang the watercourse in the wetland adjacent to Vittoria Bay.

5.1.4 Waterbird localities.

Observations were made throughout the study period of the habitats of the different species which occur on the Leschenault Inlet.The following is a discussion of the findings. The inlet has been divided into five areas. (see Fig. 5.1)

Area 1: northern section of the inlet.

Area 2: eastern shore as far south as the Collie River.

Area 3: Vittoria Bay, wetlands adjacent to Vittoria Bay, Preston River and Preston River delta.

Area 4: western shore as far south as the ocean cut.

Area 5: Koombana Bay and Anglesea Island region.

5.1.5 Area 1: northern section.

This area is very important as a spring and summer refuge for ducks an swans who congregate in this region in large numbers.The sea grasses and filamentous algae provide good feeding for these species.The most common species seen in this area were: Mountain Duck (Tadorna tadornoides), Black Duck (Anas superciliosa),Grey Teal (Anas gibberifrons), Wood Duck (Chenonetta jubata),Musk Duck(Biziura lobata),Coot (Fulica octra), and the Western Australian Black Swan, (Cygnus atratus).The Ducks mainly congregate along the western shore and occur in large numbers as far south as Waterloo Head. The northern drainage system also offers a refuge for the ducks during the summer period; as does the dam which is situated on the western side of the northern samphire flats.During the winter and spring large numbers of ducks utilize this area!In november 1974 there were approximately 2000 ducks in this area (Lane 1976)" In November,1973, 860 swans, were sighted in this region. (Lane 1976) This represents approximately ninety five percent of the inlet's swan population.The northern region is also a popular area

Fig.5.1 Shows waterbird observation areas.

	Main wetland areas.
	Man made dams.
Scale.	1:50,000.

Bunbury
Casuarina Pt.
Breakwater
Area 5
Koombana Bay
Anglesea Is.
Inner Harbour
Area 5
Ocean Cut
Indian Ocean
Preston R.
Area 3
Area 3
Vittoria Bay
Area 4
Coastal Sand Dune System
Bar Is.
Area 4
Area 3
Pt. Douro
Samphire Bay
Area 2
Area 2
LESCHENAULT INLET
Waterloo Hd.
Drain
Area 1
Burragenup
Area 1
Eaton
LaPorte Swamp
Channel
Area 2
Collie R.
Australind
Pt.Lautour
Brunswick R.

for the inlet's Pelican population (Pelecanus conspicillatus).These birds,which comprise the second largest population of Pelicans south of Perth,tend to congregate along the eastern shoreline. This area is abundant with small fish during the summer season.In Febuary 1979 a total of 68 Pelicans were observed in this area.A total of nine Pelicans were sighted just to the north of Waterloo Head.No nesting sites for this species have been recorded in the Leschenault Inlet and as far as it's known the nearest colonies occur at Mandurah.The seasonally flooded pools and marshes on the northwest section of the Inlet are important for migrating birds such as the Greenshank (Tringa nebularis) and wading species such as the White - headed stilt (Himantopus himantopus)and the Pied Stilt.All these birds occur in large numbers in this region during the summer and autumn seasons.The mud substrate offers good feeding grounds for these species because of the abundance of worms and molluscs. The area surrounding the mangroves, (Avicennia marina)Which are situated on the north west shoreline, is rich with crustacean amphipods.A small number of White Egret (Egretta alba)and White - faced Heron (Ardea novoehollandioe)can be seen in this area, particularly along the drainage channel.

5.1.6 Area 2:South eastern shore.

On the shallow, sedged lined eastern shoreline, many species can be seen resting and feeding. Pelicans (Pelecanus conspicillatus) occur at the extreme northern part of this section and as many as ten birds can be seen congregating around the areas where local professional fishermen anchor their boats.(Between LaPorte pipeline and the access channel)The Black Cormorant (Phalacrocorax carbo), Little Black Cormorant (Phalacrocorax sulcirostris)and Little Pied Cormorant (Phalacrocoax melanoleucos)are common in this area and can be readily seen

diving for small fish which are abundant in this region. They are a common sight on the pipeline, rock outcrops and in open water. According to Lane, these species,(Phalacrocorax)are more abundant on the Leschenault Inlet than they are on the Blackwood Estuary. A small Paperbark swamp (Melaleuca rhaphiophylla)is situated on the southern side of the LaPorte Titanium plant and is a rookery for the White Egret (Egretta alba). This is one of only three White Egret colonies known to exist in the south west.The Nankeen Night-Heron(Nycticorax caledonicus) Little Pied Cormorant (Phalacrocorax melanoleucos)and the Little Black Cormorant (Phalacrocorax sulcirostris)also nest in this swamp.This species (White Egret) can be seen feeding in the shallows adjacent to the plant, in shallows in Samphire Bay and in the wetland areas to the south of the Collie River.The White - faced Heron (Ardea novoehollandioe)can be observed feeding near the sedges that line the foreshore; the wader, Tringa nebularia (Greenshank) can also be seen in this area , but their numbers are far less than in the nort west part of the inlet.The Grey Plover (Pluvialis squatarola)and the Bar-tailed Godwit (Limosa lapponica) were also observed in this area. However,these species are not a common sight around the inlet. On the sand flats adjoining Point Douro, Pelican Point and Bar Island, many species can be observed resting and feeding. They form important areas for Swans,Pelicans, Cormorants and waders. During the summer months there is a steady population of about ten Pelicans in this area.The delta region at the mouth of the Collie River is important to waders and other species. Those species recorded in this region were: Bar-tailed Godwit(Limosa lapponica), Greenshank (Tringa nebularia), Grey Plover (Pluvialis squatarola), Red-necked Avocet (Recuruirostra novae-hollandiae), Silver Gull (Larus novae-hollandiae), Red-capped Dotterel (Charadrius alexandrinus), Red-necked Stint (Calidris ruficollis),

White-headed Stilt (Himantopus himantopus), Caspian Tern (Hydroprogne caspia), Crested Tern (Sterna bergii)and the Darter, (Anlings rufa). A White-necked Heron was also sighted in this area in July (1979). The White-necked Heron (Ardea pacifica)is an uncommon species in this regior and their presence was probably due to the dry winters which Western Australia has been experiencing over the last few years.

5.1.7 Area 3: Vittoria Bay.

This area is comprised of : the Collie River, Vittoria Bay, the Preston River and the Preston River delta and the wetlands to the east of Vittoria Bay.Species feeding along the Collie River are Herons, Egrets and Darters.The swamp to the east of Vittoria Bay is an important feeding and resting area for many species.The waterbirds utilize these protected waters during the autumn, winter and spring.During early morning large numbers of waterbirds can be seen congregating along the watercourse. The lower salinity (14 ppt) and fresh water pools provide relief for the waterfowl from the higher salinities of the adjacent inlet.(35 ppt) The large samphire flats to the east provide food and refuge for many waterbirds. Species sighted in the wetland area were: Little Grebe (Podiceps noval-hollandiae), Hoary-headed Grebe (Podiceps poliocephalus) Black Cormorant (Phalacrocorax carbo), Little Pied Cormorant (Phalacrocorax melanoleucos), White-faced Heron (Ardea nocal-hollandiae), White Egret (Egretta alba), Black Swan (Cygnus atratus), Mountain Duck (Tadorna tadornoides) , Black Duck (Anas superciliosa), Grey Teal (Anas gibberifrons), Musk Duck (Bizuira lobata), Swamp Hen (Porphyrio porphurio), Coot (Fulica atra), Black-fronted Dotterel (Charadruis melanops) and the white-headed Stilt (Himantopus himantopus). The Little Grebe and the Hoary-headed Grebe appear to restrict their habitat to the main watercourse,especially the northern end.They can be seen diving in this area, staying submerged for periods up to eight seconds. The overhanging branches of the marginal vegetation is favoured as a resting place by

Cormorants.Large numbers of these can be seen, especially at the southern end of the watercourse.This species is an 'open' water bird and it is unlikely that they feed in the swamp. However the adjacent Vittoria Bay offers excellent feeding grounds for this species.The samphire flats and rush beds are favoured by the White -faced Heron and White Egret. These two species feed mainly on semi-aquatic invertebrates which occupy these flats. The Egrets come to this area from the nearby colony.Black Swan use the main watercourse and would find an abundance of food because the area has large beds of Ruppia and Lamprothamnium.The waterbody is very rich in diatoms and small macro-fauna.The waders tend to congregate at the shallow northern end.The delta of the Preston River is an important area for the migratory birds (waders) which come to the region in the spring and summer months,Lane estimates the migratory population at around 2000 birds.Other species which use this area are mainly ducks. Herons are common along the banks of the Preston River.

5.1.8 Area 4: South western shore.

The shallow western shoreline of the Leschenault Inlet is rich in small estuarine fish and is an important feeding ground for species whose diet depends on this fauna.The estuarine muds of this region are rich in worms and crustacean amphipods and the swamp areas are abundant with Ruppia.The area opposite the Australind Townsite has naturally occuring fresh water soaks and seepage and this offers the waterbirds good drinking areas. Species recorded along this section included Little Grebe, Hoary-headed Grebe, Pelicans, and Terns. Towards the end of summer most of the swan and duck populations move from the north of the inlet to this region."In March 1974, approximately seventy percent (680) of the inlet's swan population were concentrated in this area".(Lane 1976)This area offers the waterbirds a relatively undisturbed region as access is difficult due to the

estuarine mud and the marshy fringing areas along the western shoreline.

5.1.9 Area 5: Koombana Bay and Anglesea Island.

This area comprises the extreme southern end of the inlet, now divided from the northern section by the reclaiming of land for the construction of the new inner harbour.Although Anglesea Island is now half its original size its samphire flats and mangrove community offer excellent feeding and protection for many waterbirds, especially the migratory waders from the northern hemisphere.To the west of the island are more mangroves and a large section of rushes.The area contains many fresh water pools. The area is rich in molluscs, worms and crustacea amphipods which are an important source of food to the wading species.Species recorded in this area are: Black Swan (Cygnus stratus),Pelican (Pelecanus conspicillatus), White Egret (Egretta alba) White-faced Heron (Ardea novaehollandiae),Little Grassbird (Megalurus gramineus), Sacred Kingfisher (Halycon sancta), Little Pied Cormorant (Phalacrocorax melanoleucos), Black Cormorant (P. carbo), Pied Cormorant (P. varius), Black Duck (Anas superciliosa)Grey Teal (A. gibberifrons) and the migratory waders Greenshank (Tringa nebularia), Common sandpiper (Tringa hypoleucos)and Sharp-tailed Sandpiper (Calidris acuminata).

5.1.10 List of species recorded during study period. (Table 5.1)

Common Name	Scientific Name
Little Grebe	Podiceps noval-hollandiae
Hoary-headed Grebe	Podiceps poliocephalus
Black Cormorant	Phalacrorax carbo
Little Pied Cormorant	Phalacrocorax melanoleucos
Pied Cormorant	Phalacrocorax varius
Little Black Cormorant	Phalacrocorax sulcirostris
Black Swan	Cygnus atratus
Mountain Duck	Tadorna tadornoides

Table 5.1 cont.

Common Name	Scientific Name
Black Duck	Anas superciliosa
Grey Teal	Anas gibberifrons
Musk Duck	Bizuira lobata
Chestnut Teal	Anas castanea
Blue - Winged Shoveller	Anas rhynchotis
Coot	Fulica atra
Swamphen	Porphyrio porphyrio
Moorhen	Gallinula tenebrosa
Black Fronted Dotterel	Charadruis melanops
White Headed Stilt	Himantopus himantopus
Red - Capped Dotterel	Charadrius ruficapillus
Pied Oystercatcher	Hoematopus longirostris
Avocet	Recurvirostra novoehollandioe
Wood Duck	Chenonetta jubata
Caspian Tern	Hydroprogne caspia
Crested Tern	Sterna bergii
Darter	Anlings rufa
Kelp Gull	Larus dominicanus
Marsh Tern	Chlidonias hybrida
Sacred Kingfisher	Halcyon sancta
White-fronted Chat	Ephthianura albifrons
Little Grassbird	Megalurus gramineus
Swamp Harrier	Circus approximans
Osprey	Pandion halioetus
Silver Gull	Larus novoehollandioe
Pelican	Pelecanus conspicillatus
White Egret	Egretta alba
White-faced Heron	Ardea novaehollandiae

Table 5.1 cont.

Common name	Scientific Name
Nankeen Night Heron	Nycticorax caledonicus
White - necked Heron	Ardea pacifica
Straw - necked Ibis	Threskiornis spinicollis
Summer Migrants	
Common Name	**Scientific Name**
Large - sand Dotterel	Charadrius leschenaultii
Grey Plover	Pluvialis squatarola
Turnstone	Arenaria interpres
Whimbrel	Numenius phaeopus
Bar - tailed Godwit	Limosa lapponica
Eastern Curlew	Numenius madagascariensis
Greenshank	Tringa nebularia
Common Sandpiper	Tringa hypoleucos
Grey - tailed Tattler	Tringa brevipes
Terek Sandpiper	Xenus cinereus
Knot	Calidris canutus
Great Knot	Calidris tenuirostris
Sharped - tailed Sandpiper	Calidris acuminata
Red - necked Stint	Calidris ruficollis
Curlew Sandpiper	Calidris ferruginea

5.1.11 Areas of importance to waterbirds.

Figure 5.2 shows the areas that are of greatest importance to the waterbird populations that inhabit the Leschenault Inlet.

1. North and north western shoreline.
2. Central western shoreline.
3. LaPorte swamp.
4. Collie River delta, Point Douro, Bar Island, adjacent wetlands.
5. Preston River delta.
6. Anglesea Island and Koombana Bay area.

5.2 Terrestrial avifauna around the Leschenault Inlet.

The terrestrial vegetation surrounding the Leschenault Inlet offers a good variety of plant communities, all of which are important to the local bird populations.Plant communities include:

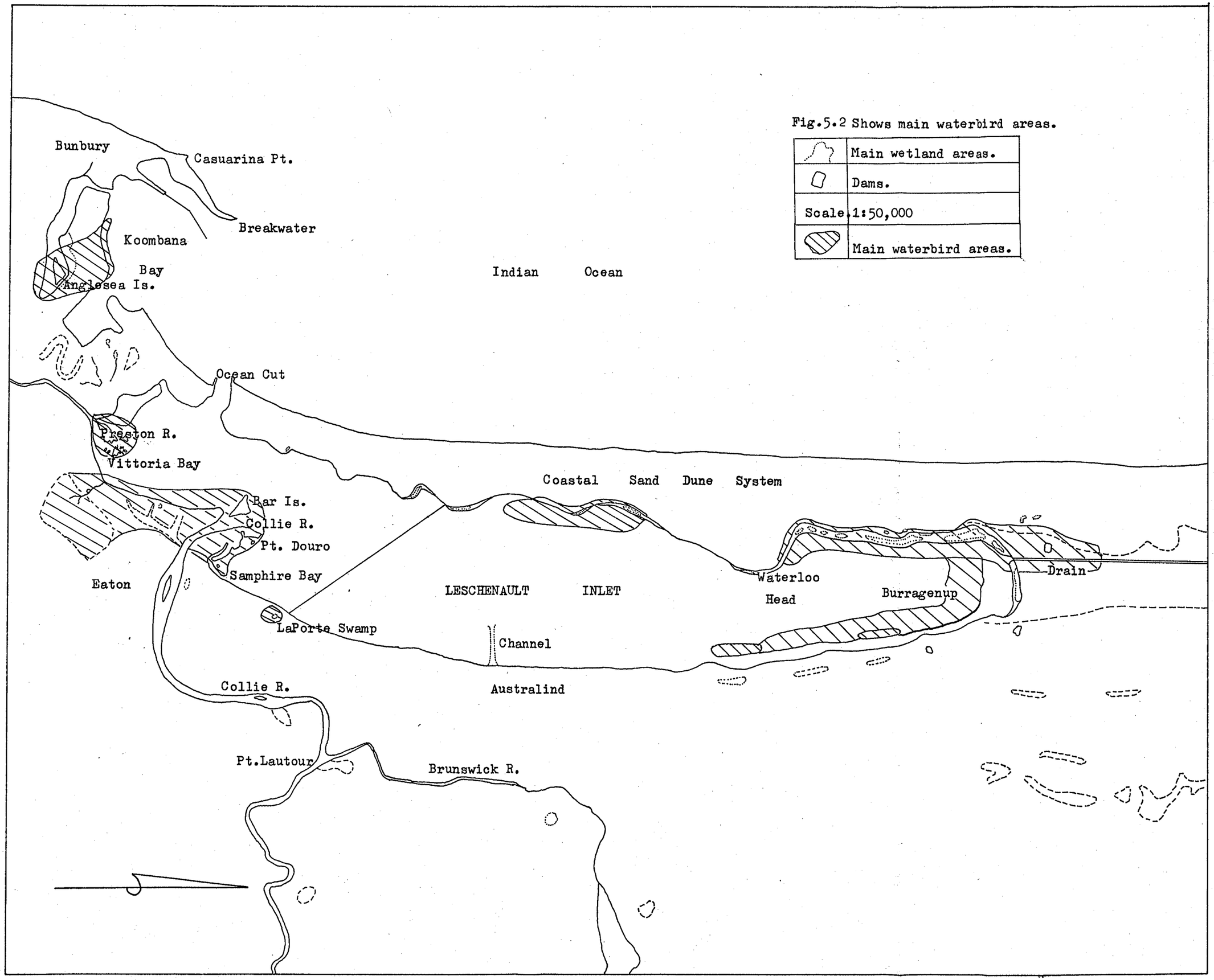
1. Tuart - Peppermint forest.
2. Jarrah - Banksia forest.
3. Marri - Banksia forest.
4. Marri - Tuart - Banksia forest.
5. Melaleuca - Juncus swamps.
6. Flooded Gum - Melaleuca systems.
7. Samphire Flats.
8. Mangrove communities.
9. Open and closed heath.
10. Open dry and wet pasture.

5.2.1 Feeding.

Because of the variety of plant communities readily available in this region a wide variety of foods are available to the bird populations. Birds of prey, such as the Australian Goshawk (Accipiten fasciatus) and the Brown Hawk (Falco berigora)will find an abundance of grasshoppers, beetles,, snakes, lizards, rabbits and other small animals, while the Red-tailed Black Cockatoo (Calyptorhynchus magnificus)feeds

Fig.5.2 Shows main waterbird areas.

	Main wetland areas.
	Dams.
Scale	1:50,000
	Main waterbird areas.



upon the matured Marri capsules.The flowering gums provide food for the honey-eaters and a variety of seeds are available for the parrots.

5.2.2 Breeding.

The area provides a wide range of nesting sights and many nests can be observed in the trees of the western and eastern forested areas.It is probable that most of the species found in the region breed near or within short distances of the inlet.

5.2.3 List of species recorded during the study period. Table 5.2

Common Name	Scientific Name
Grass Parrot	Neophema elegans
Western Rosella	Platycercus icterotis
Red-tailed Black Cockatoo	Calyptorhynchus magnificus
Rock Parrot	Neophema petrophila
Kookaburra (Laughing)*	Dacelo gigas
Whistling Eagle	Haliastur sphenurus
Australian Goshawk	Accipiten fasciatus
Osprey	Pandion halioetus
Brown Hawk	Falco berigora
Yellow-plumed Honeyeater	Meliphaga ornata
Banded Blue Wren	Malurus splendens
Southern Emu-Wren	Stipiturus malachurus
Western Warbler	Gerygone fusca
Western thornbill	Acanthiza inornata
White-fronted Chat	Ephthianura albifrons

* This species was introduced to Western Australia from Victoria in 1897.

Table 5.2 Cont.

Common Name	Scientific Name
Weebill	Smicrornis brevirostris
Scarlet Robin	Petroica multicolor
White-breasted Robin	Eopsalthia georgiana
Grey Fantail	Rhipidura fuliginosa
Willy Wagtail	Rhipidura leucophrys
Rufous Whistler	Pachycephala rufiventris
Red-tipped Diamond-bird	Pardalotus substriatus
Brown Honeyeater	Lichmera indistincta
White-cheeked Honeyeater	Phylidonyns nigra
Yellow-throated Miner	Manorina flavigula
Little Wattle Bird	Anthochoera chrysoptera
Magpie-lark	Grallina cyanoleuca
Western Magpie	Gymnorhina dorsalis
Narrow-billed Bronze Cuckoo	Chrysococcyx basalis
Golden Bronzed Cuckoo	Chrysococcyx lucidus
Tree-martin	Petrochelidon nigricans
Black-faced Cuckoo	Coracina novoehollandioe
White-winged Triller	Lalage sueunii
Reed Warbler	Acrocephalus stentoreus
Brown Songlark	Cinclorhanphus cruralis
Rufous Songlark	Cinclorhanphus mathewsi

5.3 Important invertebrates of the Leshenault Inlet.

5.3.1 Introduction.

The Leschenault Inlet is very rich in small and larger benthic, sessile and free swimming invertebrates.These form an integral part of the overall ecology of the inlet and constitute a major portion of the diet of many fish and waterbird species found in the region.Substrate and water samples were taken at various points throughout the inlet to ascertain the different types present.

5.3.2 Invertebrates recorded.

The invertebrates recorded during the study period included: the Blue Crab (Portunas pelagicus), the shrimp (Palaemonetes australis), the Greasyback Prawn (Metapenaeus mastersii),bivalve molluscs, univalves, crustacean amphipods, mysids,isopods, ostracods,copepods, polychaete worms, nematodes, foraminifera, and chironomids.

5.3.3 Distribution.

The Blue Manna Crab (see sub-section 5.5) is distributed throughout the inlet but tends to move to the southern areas as the salinity increases in the summer months.Shrimps and Greasyback prawns tend to favour the sandy substrate regions on the eastern shoreline.Substrate samples taken on the western shoreline showed large amounts of crustacean amphipods, isopods, small bivalve molluscs and polychaete worms. These specimens were most abundant in the vicinity of the mangrove community(Avicennia marina)situated to the north of Waterloo Head.Polychaete worms are reasonably abundant on the eastern shoreline, especially on the sand flats in Samphire Bay and at Point Douro. The area around Anglesea Island

is also very rich with worms,molluscs and crustacean amphipods. This could account for the large number of migratory waders that gather in this region.Chironomids, (midge larvae) were found around the algae and sea grasses on the eastern shoreline. These sandy subsrates also contained large quantities of Foraminifera and bivalve molluscs.The only location in which mussels were found was on the pylons of the effluent pipeline.Copepods occur throughout the inlet and in the seasonally flooded wetland areas adjoining the estuary.

5.4 Fish of the Leschenault Inlet.

5.4.1 Introduction.

The Leschenault Inlet is an important area for both professional and amateur fishing and with the abundance of crustaceans that are present, it provides an excellent commercial and recreational facility for the many people who utilize its natural resources each year.(see section 3.0 for boat population)Information on fisheries was obtained from the Bureau of Statistics, Western Australian Department of Fisheries, personal observation and from discussions with local professional fisherman, Mr.D.Brown.Mr. Brown restricts his catch to the confines of the Leschenault Inlet.Much information on species,seasons,abundancy,food and distribution was obtained from this source. Mr.Brown checks the stomachs of the fish when cleaning them to assess their feeding habits.The estuarine environment is one of continual change throughout the different seasons (see section 4.0 for data on the Leschenault Inlet) and because of the changing salinity,temperature,turbidity and dissolved oxygen, the utilization of this environment,and distribution within the estuary, of fish species, changes throughout the year.Mr. Brown indicated that the fish population is highest during years

when turbulent winter conditions occur in the open sea.The fish tend to migrate into the inlet where calmer conditions provide shelter and allow easier feeding.The abundance and diversity of species in the estuary vary from year to year.

5.4.2 Species occurring in the Leschenault Inlet.

Table 5.3 shows the main fish species that occur throughout the year.

Table 5.3

Common Name	Scientific Name
Sea Mullet	Mugil cephalus
Sand Mullet	Myxus elongatus
Yellow-eye Mullet	Aldrichetta forsteri
Western Sand Whiting	Sillago ciliata
King George Whiting(or spotted)	Sillaginodes punctatus
Silver Whiting	Sillago schomburgkii
Blue Mackerel	Pneumatophorus australasicus
Silver Bream (Tarwhine)	Rhabdosargus sarba
Black Bream	Acanthopagrus australis
Cobbler (Cat-fish)	Cnidoglanis macrocephalus
Perth Herring	Fluvialosa viaminghito
Leather Jacket	Monacanthus macrolepis
Southern Trevally(skipjack)	Usacaranx nobilis
Flounder	Ammotretis rostratus
Tailor	Pomatomus saltator
Buffalo Bream	
Australian Salmon	Arripis trutta
Ruff	Arripis georgianus
Yellowtail Kingfish	Seriola grandis
Trumpeter Whiting	Sillago maculata

Table 5.3 Cont.

Common Name	Scientific Name
Mulloway (River Kingfish)	Sciaena antarctica
Dusky Flathead	Planiprora fusca
Sea Garfish	Hemirhamphus ardelio
Yellowtail Perch	
Sea Kingfish (Samson-fish)	Seriola hippos
Scaly Mackerel	
Cod	
Anchovy	Engraulis australis
Sandy Sprat	Stolephorus robustus
Blowfish	
Pike*	
Tuna*	
Fiddler Sharks*	
Black and Brown Stingrays*	
Dolphins*	

* These fish are occasionally found in the inlet,but not on a regular basis.(Seedistribution)

5.4.3 Breeding.

No information is available on which species,if any, actually breed in the inlet. However,species such as the black bream, cobbler,herring,flathead,flounder, hardyheads and gobies are known to breed in some estuarine systems.(Roughley 1971)All these species are capable of breeding outside the estuaries in the ocean or embayments."Hardyheads,gobies and cobbler, have rather specialised breeding habits which help to make them well adapted to living in such extreme environments.They produce relatively few eggs, but take rather better care of them

than most fish. Hardyheads attach their eggs to sea-grass leaves, and gobies actually build nests under stones and other objects, attaching their eggs to the inner surface of their nests". (Lenanton 1977)

5.4.4 Nursery habitat.

The Leschenault Inlet is used extensively as a nursery ground for many fish species.Juveniles netted during the study period included, garfish,whiting,tailor,blowfish,mullet,sprats and anchovy.Other likely juveniles include, bream,flounder,flathead,mulloway,trumpeter, perch and cobbler.The inlet offers the fish an abundance of food and shelter from the harsh ocean environment, especially during their early life stages.Observations at night along the eastern shoreline gave a good indication of the abundance of small fish in the inlet.The water vertually 'boiled' all along this part of the estuary.This area is shallow, sandy, and covered with the sea-grass, Halophila ovalis.The area is rich in small invertebrates and filamentous algae, both of which form the main diet for many species. The fish enter the system when the salinity is comparable to that of the adjacent ocean.They move all over the inlet, but as the salinity increases towards the north during the summer months, they move towards the south where the salinity levels are lower. With the coming of the winter rains, many fish are forced from the inlet and back into the open sea.During years of low rainfall many species may remain in the system throughout the entire year.

5.4.5 Distribution.

The yellow-eyed mullet (Aldrichetta forsteri)appears in the inlet all year round, but is most predominant during the autumn and spring. It can be found in schools of up to 1000 kilograms throughout the inlet, but mainly occurs in the southern regions as it comes in and out on the tide.The sea mullet (Mugil cephalus) occurs in the same

regions as the yellow-eyed mullet, but enters the system during early winter to early summer when freshwater is running.It tends to congregate around sandy areas where freshwater seepage is occurring. It appears in schools of upto 700 Kilograms.King George whiting (Sillaginodes punctatus)occur in the inlet from March to June, with a short run in October. They appear in scattered schools of up to 20 Kilograms, usually along the edges of sand banks where Halophila ovalis grows.The silver whiting (Sillago schomburgkii) enter the estuary in late spring and are usually heavy in spawn. They appear in schools of around 20 Kilograms and congregate on the surf line. During light winters they congregate around the cut area, and do not often venture north of the pipeline; definitely not in the last three years.Tailor (Pomatomus saltator)are in the estuary from November to Febuary and appear in large schools.The fish are usually well undersize and are not fished commercially.This could indicate that they utilize the inlet for feeding while they are still juveniles.They occur all over the inlet.The river kingfish,mulloway (Sciaena antarctica)is present from September through to the end of December and appears in large schools which break up on entering the inlet.The fish range in weight from .75 to 20 Kilograms.They occur all over the inlet, but are mainly restricted to the Collie River. The cobbler (Cnidoglanis macrocephalus)appears from June to August and can be found in mud holes. Local fishermen believe that this species has increased in numbers in the last few years.The black bream (Acanthopagrus australis)occurs from July to September in the Collie and Preston Rivers, but moves towards the mouth after this time. The dusky flathead (Planiprora fusca)Appears in small amounts around the sandy areas, especially near the mouth of the Collie and Preston River.The Australian salmon (Arripis trutta) occurs from

May to July and only occurs around the southern half of the inlet. It does not move north of the pipeline.The salmon appear in 20 to 30 Kilogram schools.Trumpeter are in the system from December to April and occur in schools upto 500 Kilograms. They appear all over the inlet and are mainly used for cray bait as their flesh has an iodine flavour.The Perth herring (Nematalosa come) appear all over the inlet and are in schools of upto 500 Kilograms. They are in the estuary from June to August and from October to November.It was observed during the study period that as the freshwater entered the system from the northern channel the juvenile fish moved south. There appeared to be relatively few juveniles in the inlet during the winter season.

5.4.6 Feeding.

The feeding habits of estuarine fish can be classed into four categories; carnivorous,omnivorous,herbivorous and iliophagus.The carnivorous species consist of,flathead,kingfish,salmon,tailor,ruffs and whiting, while bream, skipjack, and cobbler are mainly omnivorous.The herring is a mud-digesting species,oliophagus, and the garfish and mullet are mainly herbivorous.The following table shows the main diets of fourteen fish species found in the Leschenault Inlet.The table is based on information from the work done on estuarine fish by J.M.Thompson between November 1954 and November 1955. A total of 2,298 fish were sampled from the Leschenault Inlet during the study.This formed part of the 5,053 samples which were taken from twelve estueries and semi-enclosed bays around south western Australia.

5.4.7 Main diet of fourteen Western Australian estuarine fish.

Table 5.4

Name	Food	Percentage
Bream	Bivalves	29
	Polychaets	23
	Zostera	10
	Amphipods	8
	other	30
Flathead	Fish	51
	Shrimp	46
	Other	3
Kingfish	Fish	31
	Shrimp	69
Skip-jack	Amphipods	17
	Polychaets	17
	univalves	12
	Bivalves	11
	Other Crustacea	15
	Other	28
Cobbler	Bivalves	24
	Algae	23
	Polychaets	19
	Univalves	14
	Other	20
Herring	Organic Debris	93
	Other	7
Tailor	Fish	90
	Shrimp	9
	Other	1

***See also Figures 5.4.1 and 5.4.2.These were drawn from information available.

Table 5.4 Cont.

Name	Food	Percentage
Garfish	Zostera	49
	Algae	25
	Diatoms	17
	Other	9
Ruffs	Fish	67
	Shrimp	27
	Other	6
Sand Whiting	Polychaets	81
	Amphipods	13
	Other	6
Yellow Tail Perch	Polychaets	32
	Amphipods	23
	Shrimp	16
	Fish	15
	Other	14
King George Whiting	Polychaets	56
	Shrimp	21
	Molluscs	15
	Other	8
Yellow-eyed Mullet	Algae	22
	Amphipods	14
	Univalves	14
	Bivalves	11
	Chironomids	9
	Other	30
Salmon	Fish	80
	Zostera	12
	Shrimps	8

*** See also Figures 5.4.1 and 5.4.2

5.4.8 Main food sources.

The following sub-sections give a description of the main food sources available in the inlet and directly relate the distribution of the fish species to the availability of the main food types.It can readily be seen from table 5.4 that the diets of the major fish species are predominantly made up of bivalves, univalves,polychaets,molluscs,fish,shrimps,amphipods,algae,diatoms, Zostera, organic debris and other sources.

5.4.9 Fish as a food source.

Thompson points out that the commercial fish species form only a minor part of the carnivorous and omnivorous species diets.The bulk of the diet of these species(kingfish,ruffs,flathead,salmon,bream and cobbler)was non-commercial species such as gobies,hardyheads and gudgeons.

5.4.10 Polychaet worms.

There are many species of Polychaet worms and the habitat of these invertebrates ranges from sandy substrates for the larger varieties; muddy substrates for the smaller variety,(western shoreline) and the tubiculous types are found on the filamentous algae of such species as Chaetomorpha valida, Chaetomorpha linum and Enteromorpha sp., all of which appear in large quantities in the Leschenault Inlet during the late spring,summer and early autumn.(see section 6.0)Table 5.4 shows that these worms form a substantial part of the diet of bream, cobblers,skip-jack,yellow tail, sand whiting and King George whiting.

5.4.11 Crustacea.

This class includes the crabs,prawns,shrimps,amphipods,copepods and ostracods.The main species which utilize crustacea are ruffs, King George whiting,sand whiting,yellow-eye mullet,salmon,yellow-tail,tailor,skipjack,kingfish,flathead,andabream.The greasyback or

green-tailed prawn,Metapenaeus mastersii,and the shrimp,Palaemonete australis form a major part of the diet of crustacean-eating fish. The ..."amphipod Corophium minor rivals or exceeds the shrimp in numbers, though it is small and therefore not so important in bulk" (Thompson 1957)This species build tubes on the algae of the Chaetomorpha sp. and the Enteromorpha species.Small crabs form a part of the diet of these fish; they also take the limbs of the larger crabs.

5.4.12 Molluscs.

The molluscs consumers include King George whiting,cobbler,bream, yelloweye mullet and skipjack.The cobblers are distributed throughout the muddy areas of the inlet and tend to consume shellfish such as mussels and cockles, while species such as whiting tend to consume the molluscs of the sandy areas and those which are attached to the filamentous algae and seagrasses.Many small crustaceans can be seen attached to seagrasses, especially Halophila ovalis.However these appear to be restricted to the seagrass beds situated on the sandy eastern shore.

5.4.12 Chironomids.

Midge larvae is mainly found amongst the algae which accumulates on the sandy substrate of the eastern shore."The yellow-eye mullet in particular seem to relish this food." (Thompson 1957)

5.4.13 Seagrass,algae and microflora.

The sea grass Zostera is described as a major food source for garfish.The species occuring in the Leschenault Inlet is Zostera muelleri, but investigations have shown that the distribution of this species is limited.(see section 6.0) While the area contains this species, the dominant seagrasses of similar appearance are Ruppia megacarpa and some small areas of Lepilaena cylindrocarpa. These grow along the sandy eastern shores and many small garfish can be sighted amongst them.A Spirorbis species of polychaet worm

attaches itself to these seagrasses and according to Thompson cobbler eat the seagrass (Zostera)to obtain these small invertebrates."Cobbler,yellow-eye mullet and garfish frequently have nothing but masses of algal filaments in the gut, sometimes mixed with polychaets or chironomids." (Thompson 1957)The Leschenault Inlet is very rich in diatoms,(see section 6.0)especially in areas where the algae is prevalent.Table 5.4 shows that garfish and yellow-eye mullet consume large quantities of these, while cobbler and bream take lesser amounts.Thompson points out that the major species are Melosira and cosinodiscus.

5.4.14 Organic debris consumers.

The main consumer of this type of food is the Perth herring.A small amount of organic debris is found in..."yellow-eye mullet stomachs, usually in association with algal filaments on which the debris has probably settled." (Thompson 1957)

5.4.15 Major crustaceans of the Leschenault Inlet.

The major crustaceans of the inlet are crabs,shrimps and prawns, all of which are taken by both commercial and amateur fishermen. These larger invertebrates form a major part of the recreational fishing that takes place in the inlet.Other species which occur from time to time are hermit prawns and butterfly crayfish.

5.4.16 Blue Manna crab. (Portunus pelagicus)

The inlet is rich in this species and they occur mainly between October and March;December being the height of the season.The Blue Manna crab does not breed within the confines of the inlet, but ventures well out to sea to spawn.The main diet of this species is small fish,prawns,shrimp,worms and some detritus and grasses.

5.4.17 Greasyback prawn or Green-tailed prawn.

The greasyback prawn,Metapenaeus mastersii,occurs mainly along the sandy eastern area of the inlet and feeds amongst the seagrasses

and filamentous algae that occur in this region.This is a possible breeding species in the inlet as they spawn inside estuaries and coastal lakes."The mating and spawning grounds of this species are the shallow mud flats of the estuaries."(Roughley 1971)During the study period three sweeps,each of twenty minutes duration, were carried out to assess the abundancy of this species.An average of 193 prawns were caught.

5.4.18 Shrimp.

The main species of shrimp occuring in the inlet are Palaemonetes australis.This species also occurs along the eastern sand flats amongst the seagrasses and algae.It is a favourite food of many fish species.

5.4.19 King prawn.

The king prawn,Penaeus plobejus occurs in the inlet for brief periods during the summer months.They tend to migrate from the system from January onwards.They spawn at sea and use the estuaries as a nursery ground.They are omnivorous in nature.

5.4.20 Observations of rare species in the Leschenault Inlet.

During late January 1979, two dolphins entered the inlet and ventured well north of the pipeline.They could be seen feeding on the small fish in this region.A large black stingray, approximately one metre across was sighted at the same time in shallow water about 500 metres from the shore and slightly to the north of the pipeline.

5.4.21 Fisheries production of the Leschenault Inlet.

The following tables show the fish production of the Leschenault Inlet from 1966 to 1975 in respect to wetfish and from 1959 to 1975 for crustaceans.Reference:Australian Bureau of Statistics.

Table 5.5: Weight of Blue Manna crabs taken by commercial fishermen.

Year	Weight (Kg)	Months
1959	3,400	Jan,Feb,Mar,Apr.
1960	2,800	Jan,Feb,Mar.
1961	6,000	Jan,Feb,Mar,Apr.
1962	3,600	Feb,Mar.
1963	3,400	Jan,Feb,Mar,Apr.
1964	6,000	Feb,Mar.
1965	4,100	Jan,Feb,Mar.
1966	11,810	Jan,Feb,Mar,Apr.
1967	15,921	Jan,Feb,Mar,Apr.
1968	8,549	Jan,Feb,Mar,Apr.
1969	8,925	Jan,Feb,Mar.
1970	7,987	Jan,Feb,Mar.
1971	9,967	Jan,Feb,Mar,Apr.
1972	13,097	Jan,Feb,Mar,Apr.
1973	22,141	Jan,Feb,Mar,Apr.
1974	26,392	Jan,Feb,Mar,Apr.
1975	25,150	----------

Table 5.6:Weight of prawns taken by commercial fishermen.

Year	Weight(Kg)
1969	363
1971	850
1972	4,473
1975	545

Table 5.7 Fisheries Production of the Leschenault Inlet.

Name	1967	1968	1969
Sea Mullet	13,829	5,704	7,206
Sand Mullet	-	-	-
Yelloweye Mullet	39,463	31,177	24,093
Western Sand Whiting	5,911	4,469	1,001
Blue Mackerel	-	-	-
King George Whiting	1,273	1,583	367
Tarwhine	-	-	67
Cobbler	1,324	888	1,635
Black Bream	-	-	-
Perth Herring	4,789	9,017	1,887
Leather jacket	-	-	-
Southern Trevally	5,292	132	1,001
Flounder	-	-	-
Tailor	2,346	1,044	1,534
Buffalo Bream	-	-	-
Salmon	412	-	4,815
Yellowtail Kingfish	-	-	-
Ruff	470	-	583
Trumpeter Whiting	-	-	-
Mulloway	512	1,172	259
Dusky Flathead	-	-	-
Garfish	-	3	-
Yellowtail Perch	-	-	-
Samson Fish	8	-	-
Scaly Mackerel	-	-	-
Other Wetfish	185	12	-
Cod	-	-	-
Sharks and Rays	1,166	-	212
Pilchard	-	-	-
Total	76,972	55,201	44,702

* All weights in Kilograms.

Table 5.7 Cont. Weights In Kilograms.

Name	1970	1971	1972
Sea Mullet	8,174	7,226	16,340
Sand Mullet	-	-	-
Yelloweye Mullet	25,946	13,900	38,469
Weatern Sand Whiting	5,238	2,959	6,165
Blue Mackerel	-	-	-
King George Whiting	3,820	13,544	6,223
Tarwhine	-	-	166
Cobbler	1,934	9,284	5,539
Black Bream	-	14	-
Perth Herring	1,411	2,650	6,753
Leather Jacket	-	-	-
Southern Trevally	6	-	222
Flounder	-	-	7
Tailor	986	2,432	7,589
Buffalo Bream	-	3,946	-
Salmon	848	20	6,885
Yellowtail Kingfish	-	45	-
Ruff	425	105	415
Trumpeter Whiting	-	181	-
Mulloway	35	148	131
Dusky Flathead	6	20	-
Garfish	23	-	670
Yellowtail Perch	30	21	-
Samson Fish	-	42	-
Scaly Mackerel	1,218	-	-
Other Wetfish	-	5	25
Cod	1,178	-	-
Sharks and Rays	153	1,354	551
Pilchard	-	719	304
Total	51,431	58,615	96,454

Table 5.7 Cont. Weights in Kilograms.

Name	1973	1974	1975
Sea Mullet	19,416	38,792	36,167
Sand Mullet	2,705	-	23
Yelloweye Mullet	44,082	43,300	77,095
Western Sand Whiting	6,027	4,165	14,326
Blue Mackerel	-	-	83
King George Whiting	5,749	9,213	10,615
Tarwhine	-	17	582
Cobbler	9,189	14,767	20,072
Black Bream	768	1,710	238
Perth Herring	4,306	22,600	8,947
Leather Jacket	7	136	10
Southern Trevally	176	-	1,817
Flounder	-	-	3
Tailor	5,194	2,577	24,115
Buffalo Bream	-	-	-
Salmon	4,521	565	45
Yellowtail Kingfish	-	25	-
Ruff	654	85	5,304
Trumpeter Whiting	-	-	-
Mulloway	179	354	180
Dusky Flathead	-	11	-
Garfish	470	1,538	869
Yellowtail Perch	-	-	-
Samson Fish	-	380	-
Scaly Mackerel	-	-	-
Other Wetfish	1,877	192	5,896
Cod	-	-	-
Sharks and Rays	375	976	223
Pilchard	22	113	-
Total	105,717	141,516	206,610

Fig.5.4.1 shows the main foods of the carnivorous and iliophagus species.

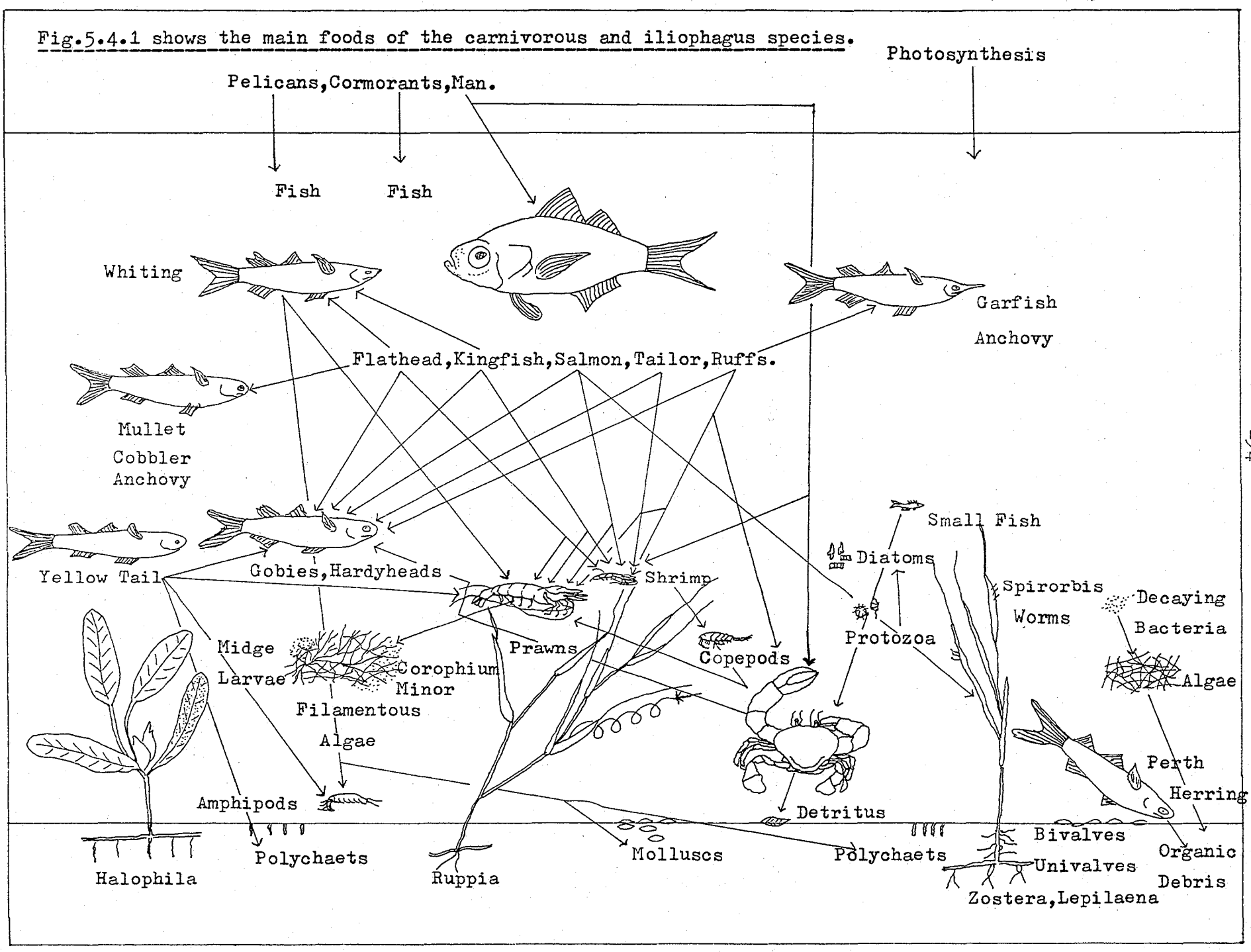
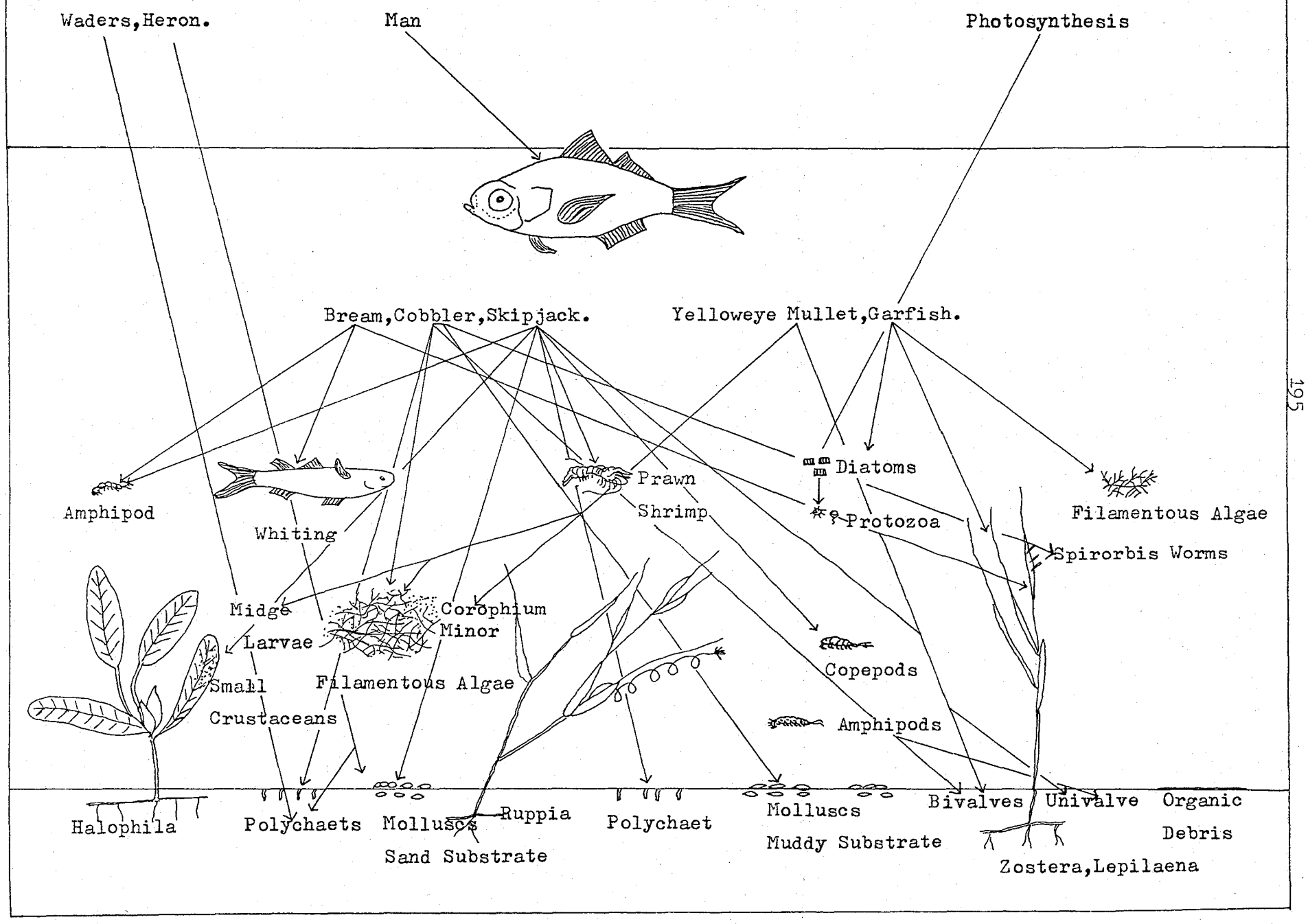


Fig.5.4.2 Shows the main foods of the omnivorous and herbivorous species.



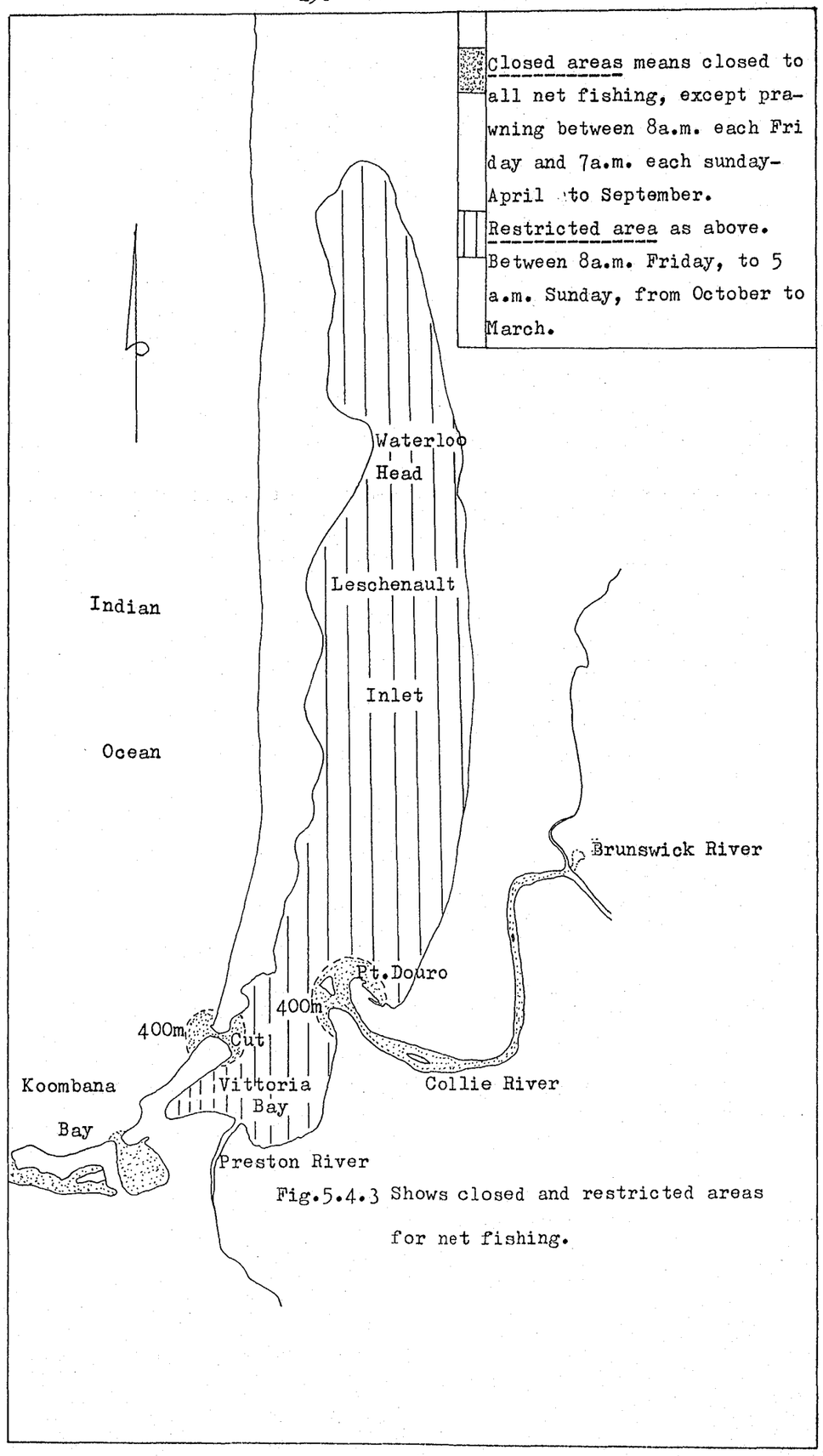


Fig.5.4.3 Shows closed and restricted areas for net fishing.

5.5 Terrestrial fauna of the area.

The forested zones on the eastern and western sides of the inlet form important habitats for many species.These include, Kangaroos, Emu,Foxes,Possums,Rabbits,Skinks and reptiles.Species such as the Grey Kangaroo,Macropus major, can be seen on the eastern hills,especially behind the Laporte Titanium plant.On the western sand dunes many of this species can be seen,especially in the early morning.On two occasions during the study a group of four were sighted on the edge of the samphire flats at the north western end.They were some 90 metres from the nearest bush and what they were actually doing in this area is not known.The Bobtailed Skink,Trachysaurus rugosus, is a common sight throughout the region.The sand hills offer a good habitat for snakes such as the Dugite and this species is fairly common in the region,especially on the western dune system.The Tiger Snake,Notechis scutatus,frequents the swampy areas and feeds on the large numbers of frogs that are present.A large number of water rats also inhabit the freshwater swamp areas.The area probably once supported a much larger animal population,but due to extensive urban development in this area,much of the forest has been lost to the bulldozer.

6.0 AQUATIC and TERRESTRIAL VEGETATION

6.1 Terrestrial Vegetation

This section describes the terrestrial vegetation which surrounds the Leschenault Inlet.The distribution and species present are directly related to salinity tolerance,geology and soil associations of the region.(see section 4.1)The climatic conditions of the region also play an important role in determining the distribution and species present,especially in relation to the rainfall,evaporation and the humidity.The plant ecosystems range from salt tolerant marginal plants to brackish water plant systems,forested regions and wind pruned dune systems.The different communities which occur in the area have been divided into vegetation formations by using the tallest stratum and the foliage cover of the tallest stratum. The following plant formations occur in the region of the study area.

Formation	Tallest Stratum	Foliage Cover (%)
Woodland	Trees 10 - 30 m	10 - 30
Open Woodland	Trees 10 - 30 m	below 10
Low Open Forest	Trees 5 - 10 m	30 - 70
Low Open Woodland	Trees 5 - 10 m	below 10
Open Scrub	Shrubs 2 - 8 m	30 - 70
Open Shrubland	Shrubs 0 - 4 m	30 - 70
Low Open Shrubland	Shrubs 0 - 2 m	below 10
Open Heath	Shrubs 0 - 2 m	30 - 70
Herbfield	Herbs	30 - 70
Sedgeland	Sedges	30 - 70
Barren	Low sand dune species	scattered
Cleared Land	Scattered Remnants	Varying

6.2 Method Used For Survey

The vegetation survey was carried out by field observation and by utilizing aerial photography. The main vegetation distribution was mapped from vertical aerial photographs taken by the Department of Lands and Survey. (scale 1 : 25000) To obtain more detailed information of the vegetation formations a series of low level(500') oblique photographs were taken using both 35mm colour and 35mm infra - red film. When projected on to a screen detailed information of the major plants, distribution and coverage was obtained. The infra-red photographs also gave an indication of the condition of the plants and highlighted areas where the vegetation was either dead or in poor condition. Field observations were then carried out to determine the accuracy of the method used and to collect data and species identification of the plants in the region. It would appear from the results that this method of vegetation mapping is reasonably accurate.

6.3 Plant Communities and Maps

The following sections give a detailed description of the different species growing in each community. Maps F5, F5A and F5B show the vegetation communities described in 6.1. They can be used separately, but to achieve an overall appreciation of the region the maps should be used as overlays. Map F5 (coloured) should be placed on the bottom, followed by map F5A (urban, industrial and roads) and then map F5B which shows the coding system for the different communities. A black and white map (F5 black and white) has also been provided, but using a slightly different coding system. The maps are scaled 1 : 25000.

The following table shows the coding system used to describe the plant communities using the tallest stratum.

Table 6.1. Coding System For Plant Communities

Common Name	Scientific Name	Code
Tuart	Eucalyptus gomphocephala	E 1
Flooded Gum	Eucalyptus rudis	E 2
Marri	Eucalyptus calophylla	E 3
Jarrah	Eucalyptus marginata	E 4
Peppermint	Agonis flexuosa	A 1
Paperbark	Melaleuca species	M
Sheoak	Casuarina obesa	C
Wattle	Acacia species	A 2
Banksia	Banksia species	B
Sea Rush	Juncus krausii	J
Samphire	Arthrocnemum bidens	
	Arthrocnemum haloenemoides	? probably same
	Salicornia australis	A 3
Mangroves	Avicennia marina	A 4

6.3.1 Woodland

This formation comprises trees between ten and thirty metres in height with a foliage cover of between ten and thirty percent.Woodland areas cover small sections of the western dunes system on the inlet side and most of the eastern region of the inlet.However,due to clearing practices for agriculture and urban development much of this vegetation has now disappeared leaving only small areas of scattered remnants.This practice is still continuing along the eastern area,mainly for urbanization and

and small 'hobby' farms.

(a)Western Woodland Areas

The woodland areas on the western side of the inlet are dominated by Tuart (Eucalyptus gomphocephala)which range in height from two metres to twenty metres.The southern stand of Tuarts,adjacent to the LaPorte pipline,has a number of young trees which range in height from two metres to five metres.It was not established whether these were planted or had germinated from seed but judging from their location the latter is more probable.The Tuarts in this area grow almost to the edge of the inlet and are restricted to the flat area between the inlet and the sand dunes.This area has limestone just beneath the surface and this phenomenon is probably directly related to the growth pattern of these trees.The western Australian Peppermint,Agonis flexuosa, forms the main understory in this region,but this species is limited compared with other areas.Most of the peppermint present is young trees ranging in height upwards to four metres.The Sword Sedge, Lepidosperma gladiatum, grows in the low depressions in this section, while on the higher ground the wattle,Acacia cyclops is common and grows to a height of around one metre.The herb,Senecia lautus,is widespread throughout the area and in the higher sandy areas Jacksonia furcellata grows to a height of two metres.Other plants which occur infrequently in this area are the shrub,Olearis axillaris,the liane,Clematis microphyla (old man's beard) and the introduced species,Asphodelus fistulosus (onion weed) and the arum lily,Zantedeschia aethiopica.

One kilometre to the north of the pipeline another large stand of Tuart forest occurs with trees growing upwards to fifteen metres in height. This area also contains young trees which range in height from three to five metres and they are all growing in the damper low depressions.

The Tuarts,Eucalyptus gomphocephala,grow to the edge of the inlet on the point and to the edge of the marginal vegetation in the other areas of this region.The main understory species is the Peppermint,Agonis flexuosa, which,like the southern stand,is only present in limited numbers.They grow in height upwards to five metres.Other species present in this area are the wattle,Acacia cyclops, the sword sedge,Lepidosperma gladiatum,the salt bush,Rhagodia radiata,the shrub,Olearia axillaris,the two creepers,Clematis microphylla and Hardenbergia comptoniana,the herb, Senecia lautus,the wild geranium,Pelargonium capitatum,the shrub,Spyridium globulosum,the introduced species,Zantedeschia aethiopica (Arum Lily) and Asphodelus fistulosus (onion weed).Towards the western side of this area the wattles,Acacia rostellifera and Acacia cochlearis grow in amongst the Tuarts and Peppermints and these shrubs range in height upwards to one and a half metres.The thistle,Sonchus oleraceus is quite common in the disturbed areas along side the road.

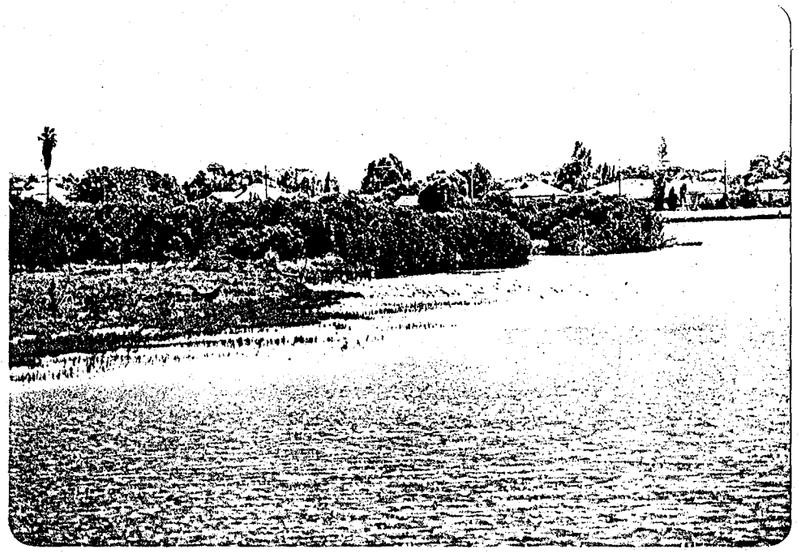
Five hundred metres to the north of this area there is a large area of Tuart forest which covers the area around Waterloo Head.This point used to be a market gardening area and therefore contains many introduced species.However,these are mainly restricted to within a few hundred metres of the shoreline.(in the area coloured yellow on map F5)They include the Olive,Olea europea,which are present in large numbers,Date Palms,Mulberry trees and Arum Lilies,(Zantedeschia aethiopica)onion weed,(Asphodelus fistulosus)False Bamboo,(Arundo donax)thistles,(Sonchus oleraceus)Fennel weed,(Foeniculum vulgare)and the daisy Aster subulatus.The Tuarts in this area range in height upwards to fifteen metres and one very large specimen,twenty metres by fifteen metres occurs in the north eastern part of this region.The main understory is the Western Australian Peppermint,Agonis flexuosa, and these trees grow to a height of seven metres in this zone. Overall they are more abundant than the Tuart and form a dense understory over most of the area,especially in the region to the east of the road.

The wattle,Acacia rosteffifera grows in large numbers on the northern side of this area and this species,along with Acacia cochlearis grow in areas where the Tuart and Peppermint trees are less abundant.These species,along with Hakea prostrata form the main understory beneath the Peppermints.The strata beneath this comprises mainly Hibertia cuneiformis and Hibertia cuneifolia with large numbers of Jacksonia furcellata growing in the more open areas.The story beneath this is comprised mainly of Olearia axillaris with large masses of Aster subulatus and Senecia lautus covering the forest floor.On the western side of the road Spyridium globulosum and the occasional Diplolaena dampieri grow on the crests beneath the Peppermints.Growing amongst these species is Acanthocapus preissii.

The Tuart forest to the north of this area forms a narrow strip between the foreshore vegetation and the sand dunes to the west.Like the other areas where the Tuarts occur the limestone is close to the surface and in some areas protrudes through the soil into small outcrops.The species occuring in the southern section of this area are similar to those appearing in the previous section but without the introduced species.The area adjacent to the northern end of the water body contains a few specimens of Melaleuca rhaphiophylla which occur in damp depressions amongst the Tuarts and Peppermints.To the north of this area the Tuarts become far less dense and occur once again with an understory of Peppermint and to the west the wattles occur.The woodland here forms a border on the eastern side with Melaleuca species and the northern herbfields.

(b) Eastern Woodland Areas

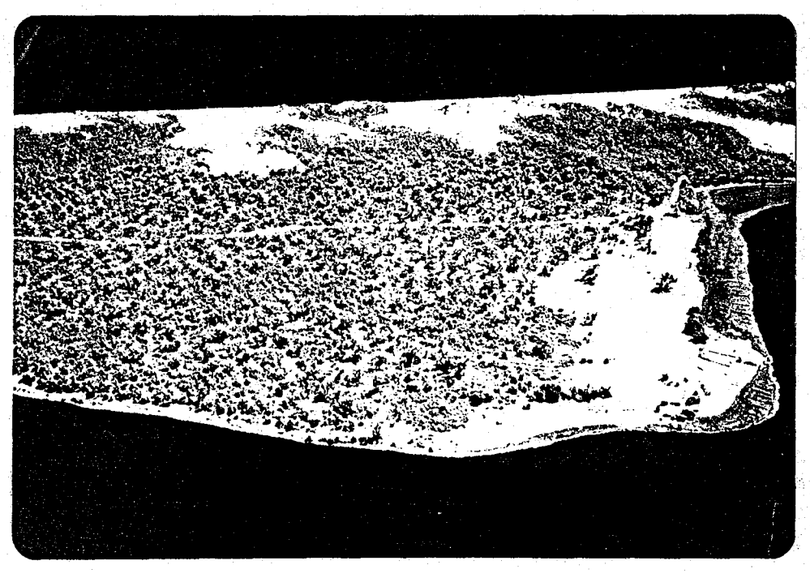
Between the inlet and the main road much of the woodland has been cleared for agriculture and at present other areas are being cleared for new roads for housing.The region between the scenic drive and the coast road is a mixture of Tuart,Eucalyptus gomphocephala and Marri, Eucalyptus calophylla.



Mangrove stand growing on Anglesea Island at the extreme southern section of the inlet.

Eucalyptus rudis (Flooded Gum) growing along the banks of the Collie River.

Tuarts, Eucalyptus gomphocephala, and the sedge, Juncus krausii growing along the scenic drive on the central eastern shoreline



Tuarts growing near Waterloo Head on the western shoreline

The north eastern section has been completely cleared for agriculture, but the area to the south still has a relatively good section of woodland.Most of this area,however,is presently being sub-divided for small holdings and if the trees are cleared to any great extent,water quality and animal life in this area will suffer considerably.Between the foreshore and the wooded area is a strip of wet pasture land with scattered Tuarts,mainly along the road side.To the east of the wet pasture land the woodland area is comprised of Tuarts,which grow upwards to about twenty metres and Marri,Eucalyptus calophylla,which grow to a height of around ten metres.These become more dominant towards the east.The western part of this area has limestone close to the surface and where fire breaks have been cleared the limestone protrudes through the surface soils. The understory species is Agonis flexuosa (Peppermint) and the sub - stratum is Banksia attenuata and Banksia grandis.The shrub layer consists mainly of Hibertia cuneiformis, Dryandra sessilis,Leptomeria empetriformis,Templetonia retusa and the small shrub Acanthocarpus preissii. The creepers Hardenbergia comptoniana ,Clematis microphylla and Kennedia prostrata.also occur throughout this area.There is no evidence of Tuart regeneration taking place in this area but there are large numbers of young Marri and Banksia throughout the area and it would appear that these species are becoming more dominant.The cleared area to the east of this region has many young Banksia species and some Jacksonia furcellata,both of which appear to be revegetating the area.

To the east of the coast road the region is predominantly Jarrah,Eucalyptus marginata and Eucalyptus calophylla (Marri) woodland.This forested area encompasses the whole of the region from north east of the inlet to the Preston River.It is interspersed by urban areas and other small communities dominated by Banksia species,Eucalyptus species and Melaleuca species.The main understory is Banksia attenuata and Banksia grandis with

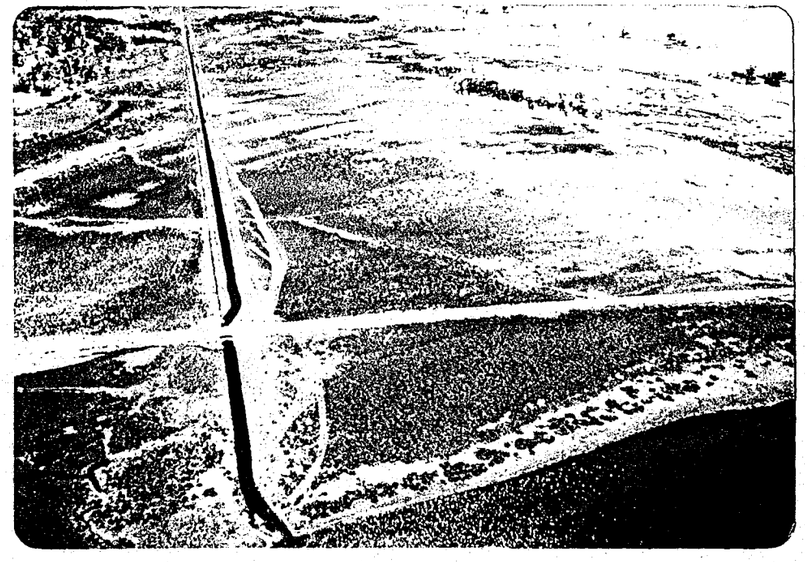
the occasional Peppermint occuring on the higher ground.The Black-boy,Xanthorrhoea preissii and the Palm,Macrozamia reidlei grow throughout this area.Further to the south the Jarrah - Marri woodland borders the Collie River,and to the east,the Brunswick River,and throughout this area the two Banksia species,Banksia attenuata and Banksia grandis form the main understory,growing to about five metres in most parts.Other species found in the area include Nuytsia floribunda,(Western Australian Christmas Tree)Agonis flexuosa,(Peppermint) Jacksonia furcellata,Acacia cyclops,the sheoak,Casuarina humilis,Cassytha sp.,(a parasite)Anigozanthos sp.,(Kangaroo Paw)the woody pear, Xylomelum occidentale,Hardenbergia comptoniana,(False Sarsaparilla) Clematis microphylla,(Old Mans Beard)Kennedia prostrata,Templetonia retusa,(Cockies Tongue) Hakea prostrata,Pteridium aquilinum,(Bracken Fern)Oxylobium capitatum,(Bacon and Eggs)Hibertia cuneiformis and Hibertia cuneifolia.The area also has a wide variety of native orchards.

Where the woodland borders the rivers the Flooded Gum,Eucalyptus rudis occurs in large numbers and this is associated with an understory of Melaleuca rhaphiophylla in some areas and with the swamp sheoak,Casuarina obesa in other areas.

6.3.2 Open Woodland.

Open woodland is comprised of trees ranging in height from ten to thirty metres and having a foliage cover of less than ten percent.A small area of this formation occurs to the south of the Collie River.(see map F5) The most southern section is comprised of Jarrah,Eucalyptus marginata and Marri,Eucalyptus calophylla with an understory of Melaleuca rhaphio phylla.Towards the north of this area the Jarrah and Marri give way to the Paperbarks as the area becomes wet towards the river.This is the only natural vegetation in the area that could be described as open wood

The LaPorte effluent pipeline on the western side of the inlet. The area to the left is low open forest (Peppermint) and the area to the right is woodland.(Tuart)Halophila ovalis can be seen growing in the water in the foreground.



land.

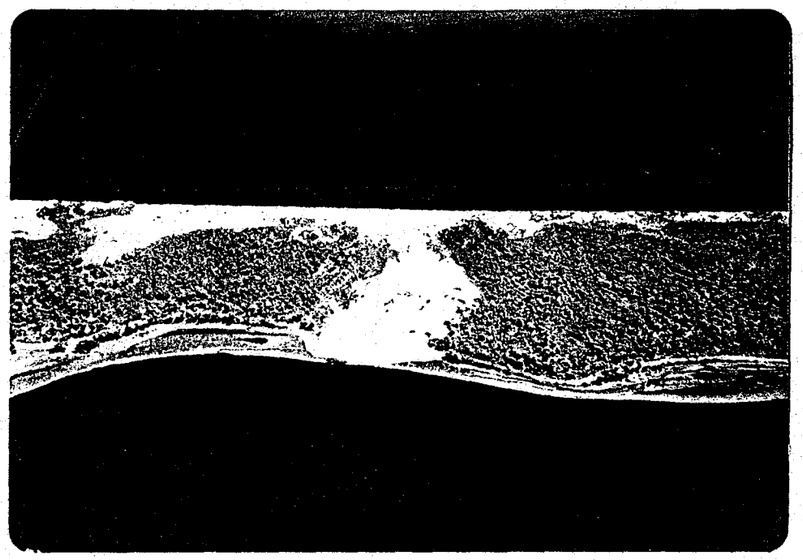
6.3.3 Low Open Forest

Low open forest consists of trees ranging in height from five to ten metres and having a foliage cover of thirty to seventy percent.Areas which come into this category are mainly comprised of Agonis flexuosa (Peppermint) and Melaleuca rhaphiophylla (Paperbark) as the tallest stratum.One small area to the south of the Collie River has Casuarina obesa (Swamp Sheoak)as the tallest stratum.

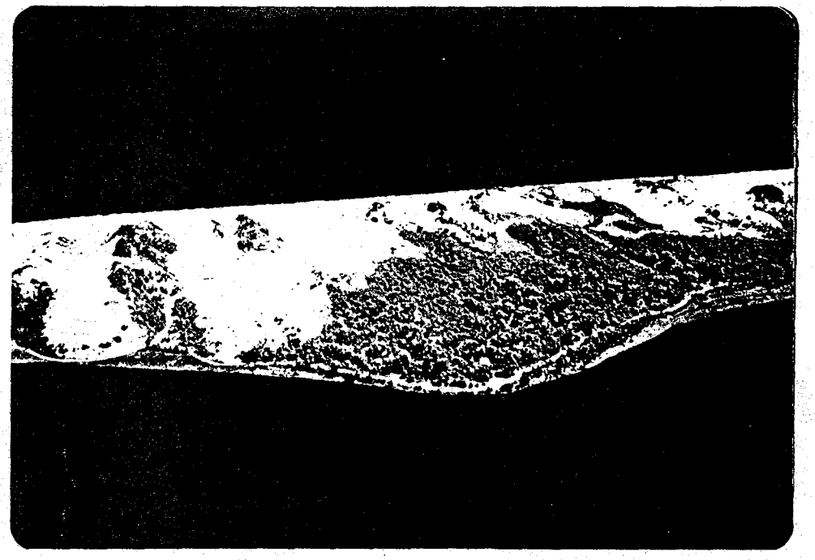
(a) Low Open Forest:Peppermint.

These formations occur along the western side of the inlet and are interspersed by the Tuart woodland.To the south of the pipeline the Peppermints grow to a height of about seven metres in the protected gullies and to a height of around four metres on the crest of the dunes where the prevailing winds tend to 'prune'them.The main understory species are the Wattles,Acacia rostellifera,Acacia cochlearis ,Acacia cyclops.The Kangaroo Apple Solanum laciniatum and the Apple of Sodom,Solanum sodomaeum,are present in reasonably large numbers in this area.Other shrubs present include Olearis axillaris,(smoke bush),Jacksonia furcellata, Spyridium globulosum,Leucopogan parviflorus,Lepidosperma gladiatum,(Swor Sedge)Templetonia retusa(Cockies Tongue),and the sub - shrub layer consists mainly of Phyllanthus calycinus.Hardenbergia comptoniana and Clematis microphylla are both present in the lower regions. The herb layer consists predominantly of Senecia lautus and Pelargonium capitatum,(Native Geranium).Exocarpas spartens and Acanthocarpus pressii grow in the more sheltered areas between the crests.The foliage cover of the understory in this region is between fifty and seventy percent. Towards the crests the main species is Acacia cyclops with Scaevola crassifolia, Spinifex longifolius,Olearia axillaris and Jacksonia furcellata.

The Peppermint forest situated between the Tuart woodland has a mixture



Mobile dune near Waterloo Head.The dune is being restabilized with Marram grass and a small stand of mangroves are in the foreground of the dune.



The Laporte effluent disposal area on the western side of the inlet. The green areas on the photograph are dead vegetation.

of species from both systems with the main understory consisting of the three Wattles,Acacia rostellifera,Acacia cochlearis and Acacia cyclops. Diplolaena dampieri,Acanthocarpus preissii and Spyridium globulosum grow on the sides of the higher ground while introduced species such as onion weed,Asphodelus fistulosus and False Bamboo,Arundo donax grow around the base.

The northern Peppermint forest has a line of Acacia saligna bordering the eastern section and these grow to a height of about three metres.Directly behind these is a large area of the Bracken Fern,Pteridium esculentum and to the west of this species is the Peppermint forest with understory of Acacia rotellifera and Acacia cochlearis.Towards the western crest the main understory becomes Acacia cyclops.Other species occuring in this area are similar to the southern Peppermint forest.The Peppermint in this region grows upwards to a height of seven metres.The area also has a large amount of Blind Weed,(Cassytha sp.)growing over the trees.Where this area borders the Tuart woodland Hakea prostrata and Hibertia cuneifolia occur.

(b)Low Open Forest:Paperbark.

These areas form a border between the northern Tuart woodland and the herb-field which is situated at the extreme northern end of the inlet.The tallest stratum is Melaleuca rhaphiophylla with some Melaleuca cuticularis and Melaleuca preissiana forming the understory.Juncus krausii,Arthrocnemum bidens,Arthrocnemum haloenemoides and Salicornia australis form the layer beneath these.On the eastern side of the coast road Melaleuca rhaphiophylla and Melaleuca preissiana form the main vegetation around the fresh water swamps.

A large stand of Paperbarks border the scenic drive and these are protected by law from people removing the bark.The species is Melaleuca rhaphiophylla and they grow to a height of about six metres.

(c)Low Open Forest:Casuarina.

This stand occurs at the southern end of the wetland area to the south of the Collie River.The stand borders on to Vittoria Bay and grow to a height of seven metres.The species present is the Swamp Sheoak,Casuarina obesa.

6.3.4 Low Open Woodland.

Low open woodland is comprised of trees ranging in height from five to ten metres and having a foliage cover of less than ten percent.This is comprised of three different species forming the tallest stratum.They are Eucalyptus rudis,Melaleuca rhaphiophylla and Banksia attenuata.

(a) Low Open Woodland:Flooded Gum

This occurs in three areas;at the junction of the scenic drive and the coast road;on the north western and north eastern side of the Collie River and in the wetland area to the south of the Collie River.The areas on the old coast road and the Collie River have Eucalyptus rudis as the tallest stratum and the main understory is comprised of Acacia cyclops and Acacia saligna,accompanied by Jacksonia furcellata and the occasional Casuarina obesa.The low open woodland region in the wetland area has an understory of Melaleuca preissiana, in the low depressions and Hakea prostrata on the higher dry areas.Jacksonia furcellata is also common in this area.The other species occuring are Hibertia cuneiformis,Gahnia trifida,Dampiera sacculata, Samolus repens,Sowerbaea multicaulis,Vicia sativa,Templetonia retusa and Parentucellia latifolia.The occasional Casuarina obesa and Agonis flexuosa also occur.

(b) Low Open Woodland:Melaleuca

This formation occurs along the north eastern side of the inlet and between the wetland area to the south of the Collie River and the herb-field to the west.The main species occuring is Melaleuca rhaphiophylla with the samphires,Arthrocnemum bidens,Arthrocnemum haloenemoides and

Salicornia australis.In the area to the north east of the inlet Juncus krausii is present and in the area to the south of the Collie River the semi - aquatic plant,Cotula coronopitolia is present.

Two small areas of low open woodland occur near the 'cut' area.The tallest stratum in this region is Casuarina obesa.

6.3.5 Open Scrub

Open scrub is comprised of shrubs between two and eight metres in height with a foliage cover of between thirty and seventy percent.These areas occur between the foredunes and the woodland and low open forest regions on the western side of the inlet.The tallest stratum consists of the wattles,Acacia rostellifera,Acacia cochlearis and Acacia cyclops.These species grow in this region to about one and a half metres in the sheltered areas and to two metre in the exposed regions.The understory consists of Olearia axillaris,Rhagodia radiata,Hibertia cuneifolia,Spinifex longifolius,Scaevola crassifolia and Olearia axillaris.Overall,this area is of one story formation.However,some of the shrubs grow to heights of three metres and a few wind 'pruned' Peppermints occur in this area.

6.3.6 Low Open Shrubland

Low open shrubland is comprised of shrubs ranging in height upwards to two metres and having a foliage cover of less than ten percent.There are two main areas in this category.The area between the inner harbour and Vittoria Bay and a small area adjacent to samphire Bay.Other small areas occur between the inlet and the main forested areas on the western shore but they are to small to map at this scale.The largest area,between the harbour and the bay is a reclaimed salt marsh and the area is revegetating.The main species present are Olearia axillaris,Solanum sodomaeum, Acacia rostellifera and Jacksonia furcellata.The area adjacent to Samphire Bay is mainly Jacksonia furcellata and small areas of Acacia cyclops.

6.3.7 Open Shrubland

Open shrubland is comprised of shrubs growing to a height of four metres and having a foliage cover of between thirty and seventy percent.This formation occurs on Anglesea Island at the extreme southern end of the inlet and in the area just to the north of Waterloo Head on the western side of the inlet.The tallest stratum in these areas is the Mangrove,Avicennia marina.These Mangroves are the only specimens between the Gascoyne River and the Spencer Gulf in South Australia.They are believed to be very important in the overall system and according to Lear and Turner (1977) ...."the greater the supply of mangrove detritus,the greater is the mass of fish,prawns and crabs which can be supported.In Westernport Bay in Victoria,mangroves have been found so productive,that four times as much nitrogen and half as much phosphorus is cycled in one year as there is in the Bay itself".

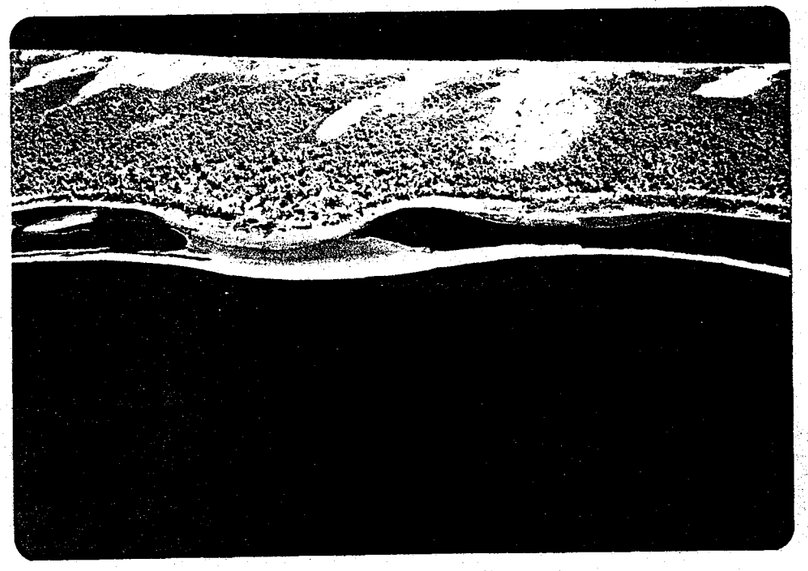
6.3.8 Open Heath

Open heath is comprised of shrubs ranging in height upwards to two metres and having a foliage cover of thirty to seventy percent.A smal area occurs at the extreme north western side of the inlet and is comprised of low growing Acacia cyclops,Scaevola crassifolia,Olearia axillaris and Spinifex longifolia.

6.3.9 Herbfields

Herbfields are comprised of small herbaceous plants having a foliage cover of thirty to seventy percent.The main areas where these occur around the inlet are to the extreme north,the western seasonally flooded zones and to the south of the Collie River.The main species growing in these areas are the samphires,Arthrocnemum bidens,Arthrocnemum haloenemoides and Salicornia australis.

The northern herbfield with the drainage system in the centre.This drain carries large quantities of nutrients into the inlet.See section 1.1 and section 4.0 and section 6.0



Seasonally flooded area to the north western side of the inlet. Ruppia megacarpa and Lepelaena bilocularis grow in this zone. Samphires form a border between the inlet and the marsh.

The Salicornia grows to a height of about ten to twenty centimetres while the Arthrocnemum grows to a height of between ten and thirty centimetres.Areas of these species were cut and dried to determine the standing crop per metre squared.These were taken in the spring at the height of the growing season and the Salicornia cut recorded was 637 grams per metre squared dry weight and the Arthrocnemum was 723 grams per metre squared dry weight.(above ground)Much of this weight,however,was in the woody stems.These plants are extremely salt tolerant and can grow in hypersaline conditions. In the area to the south of the Collie River an understory of the semi-aquatic plant,Cotula coronopitolia occurs and the standing crop in October 1979 was 422 grams per metre squared.This plant dies off during the summer period and a cut taken in April gave a dry weight of 23 grams per metre squared.(above ground)This means that over the twenty five week period the plant increase in dry weight by 399 grams per metre squared.A rate of around 15.9 grams per week per metre squared dry weight.

6.3.10 Sedgeland

This formation is comprised of sedges with a foliage cover of thirty to seventy percent.The main sedge growing around the inlet is Juncus krausii This occurs along both the western and eastern shorelines,along the low-banks of the Collie and Preston Rivers and around seasonally flooded wetland areas on the western side of the inlet and in the area to the south of the Collie River.They grow upwards to about seventy centimetres and form broad areas of up to ten metres in some areas.They act as a stabilizers for the shoreline soils and protect the banks from erosion.They als form an integral part of the nutrient 'filter' system between the land an the waterbody.Other sedge in the area is the Bulrush,Typha domingensis. This grows mainly in a small area to the north east.Other species assoc-

iated with the sedgelands are the Samphires, Arthrocnemum bidens, Arthrocnemum haloenemoides and Salicornia australis and the sea rocket, Cakile maritima, the sea blite, Suaeda australis, Centella asiatica and Scirpus maritimus.

6.3.11 Dune Vegetation.

This occurs in scattered areas of the foredunes and the mobile dunes on the western side of the inlet. Spinifex hirsutus occurs in large clumps in these areas as does the Marram Grass, Ammophila arenaria, which is planted to assist in dune stabilization, especially on the mobile dune systems. Other species occuring are Cakile maritima, Arctotheca populifolia, Salsola kali and the introduced species Asphodelus fistulosus, (onion weed) and the tangle daisy, Helichrysun cordatum. The dune systems on the eastern side of the western 'peninsula' (mobile dunes) are vegetated with Marram Grass, Ammophila arenaria, Pelargonium capitatium, Scirpus nodosus, Carpobrotus aequilaterus, (Pig Face) Lepidosperma gladiatum and on the lower sides by Acacia cyclops, Olearia axillaris , Jacksonia furcellata and on the crest by Scaevola crassifolia, Acacia cyclops and Spinifex longifolius.

6.4 Aquatic Vegetation

This section describes the aquatic vascular plants and the microscopic filamentous algae which are present in the Leschenault Inlet. These plants and algae form an important part of the overall ecology of the inlet as their presence, abundance and distribution determine the amount of aquatic fauna that the waterbody can support. They also play an important role in the overall chemical cycle of the water system and the vascular plants assist in stabilizing the substrate. Man-made changes to the inlet have altered greatly the species and distribution of the aquatic plants in the inlet. The opening of the 'ocean cut' in the early 1950s changed the adjac-

area from a estuarine system to a system that is more representive of a marine environment.The construction of the Wellington Dam has greatly reduced the flow of freshwater into the system,thereby causing changes in the salinity gradients of the inlet.The construction of the northern drainage channel,in its present form,has increased the flow of freshwater into the northern part of the inlet,thereby altering considerably the annual salinity variations in this region. This drain also brings down large amounts of nutrients during the winter and spring from nearby wetlands and farms.These nutrients are 'trapped' in the substrate and released into the water system as the water heats up,assisting greatly in the abundance and rapid growth of the filamentous algae in the northern part of the inlet.The decaying algae increase the organic content of the substrate,thereby creating a 'vicious' circle.Man-made changes to the inlet have altered the floral composition of the water system and according to local fishermen Ruppia species covered the substrate of the inlet prior to the opening of the 'ocean cut!Within two years of this being opened most of the Ruppia had disappeared from the inlet and had been replaced by the paddleweed,Halophila ovalis.

6.4.1 Objectives of the Study and Metods Used

The main objectives of the study were to classify the vascular aquatic plant species that grow in the inlet and map their distribution.To classify the macroscopic filamentous algae that occurs in the system and map its main distribution during the summer.To assess the standing crop of the different vascular species and to assess some growth rates of the varying species.This was carried out mainly on Ruppia and Halophila species.

Aerial photography was used to map the initial outlines of the various sea grass beds and the algal distribution.The two could be readily identified from the photographs.The sea grass beds appeared as light areas, while the algal areas appeared as heavy dark areas on the photographs. Three types of film was used;infra-red,(35mm)colour,(35mm)and colour(70mm). The colour (35mm)and the colour (70mm) were used in association with both yellow and green filters to assess which gave the better water penetration. The end result was that the best film and filter to use for this type of survey was the 70mm fitted with a yellow filter.The infra-red film,while being excellent for terrestrial photography,tended to make the aquatic vegetation blend in with the water and both appeared dark green.The green filter gave a similar result.A series of 35mm and 70mm colour photographic runs were made over the area from a height of 500 feet and 3000 feet.The photographs were projected onto a screen and from these the outlines of the sea grass beds were mapped.This was followed up by field trips to collect samples for classification from all areas of the inlet.From this information the distribution of the various sea grasses were mapped.A similar process was carried out for the macroscopic filamentous algae.The map was then taken into the field and the sea grass beds and main algal areas were traversed from a boat in the deeper water and by foot in the shallow regions.Compass bearings were taken from the edges of the beds to strategic points around the inlet and then converted to true bearings and plotted on the map.Although this method is time consuming it is reasonably inexpensive and quite accurate.

The sites used for the vegetation cuts were the same points as those used for the water quality samples.A series of quadrats were established at the various stations around the inlet to assess the biomass and growth rates of the various vascular plants which occur in the inlet.One problem with this method in an area which is extensively used for recreational activities is that people tend to remove the quadrat markers and this makes it difficult

to relocate the position, especially in areas where algae has formed. Nutrient and salinity levels were taken during each season to compare the plant distribution and algal distribution with these factors.

Table 6.2 Aquatic Sea Grasses of the Leschenault Inlet

Family	Genus	Species
Hydrocharitaceae	Halophila	ovalis
Ruppiaceae	Ruppia	megacarpa
Zosteraceae	Zostera	muelleri
Zanichelliaceae	Lepilaena	bilocularis
Zanichelliaceae	Lepilaena	cylindrocarpa
Zanichelliaceae	Amphibolis	antarctica
Posidonaceae	Posidonia	australis

Table 6.3.Macroscopic Algae of the Leschenault Inlet

Genus	Species
Chondria	-
Gracilaria	vemicosa
Dictyota	-
Enteromorpha	-
Enteromorpha	intestinales
Hormophysa	triquetra
Chaetomorpha	valida
Chaetomorpha	linum
Spyridia	spinella
Lamprothamnum	paludosum
Rhizoclonium	riparium

6.4.2 Distribution Maps

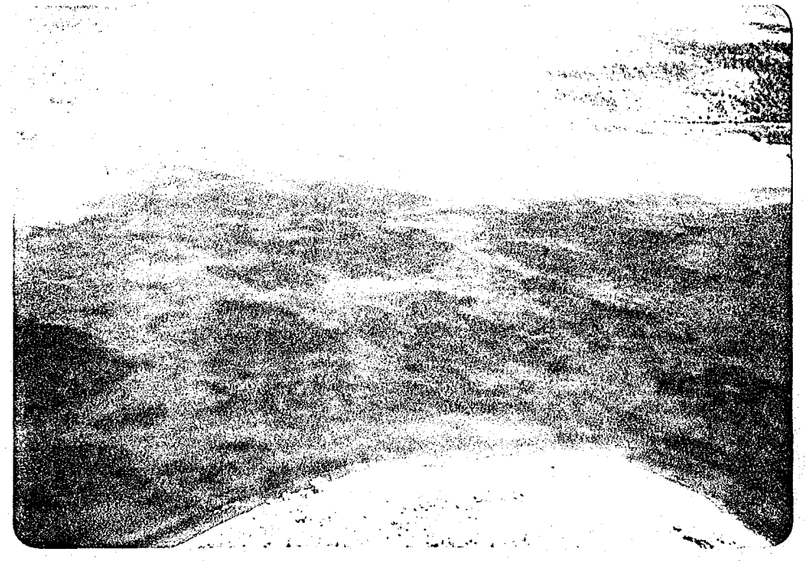
Maps showing the distribution of the plants and algae have been produced in both black and white and transparencies. The latter are for use as overlays on the depth map(map F 1) and the former for individual species observation.The maps show the distribution of Halophila ovalis,(map F 2) Zostera muelleri, Ruppia megacarpa,Lepilaena bilocularis,Lepilaena cylindrocarpa and Lamprothamnum paludosum (map F 3)The algae are shown on map F 4.(map F 4)

6,4.3 Description and Distribution of Species

Halophila ovalis

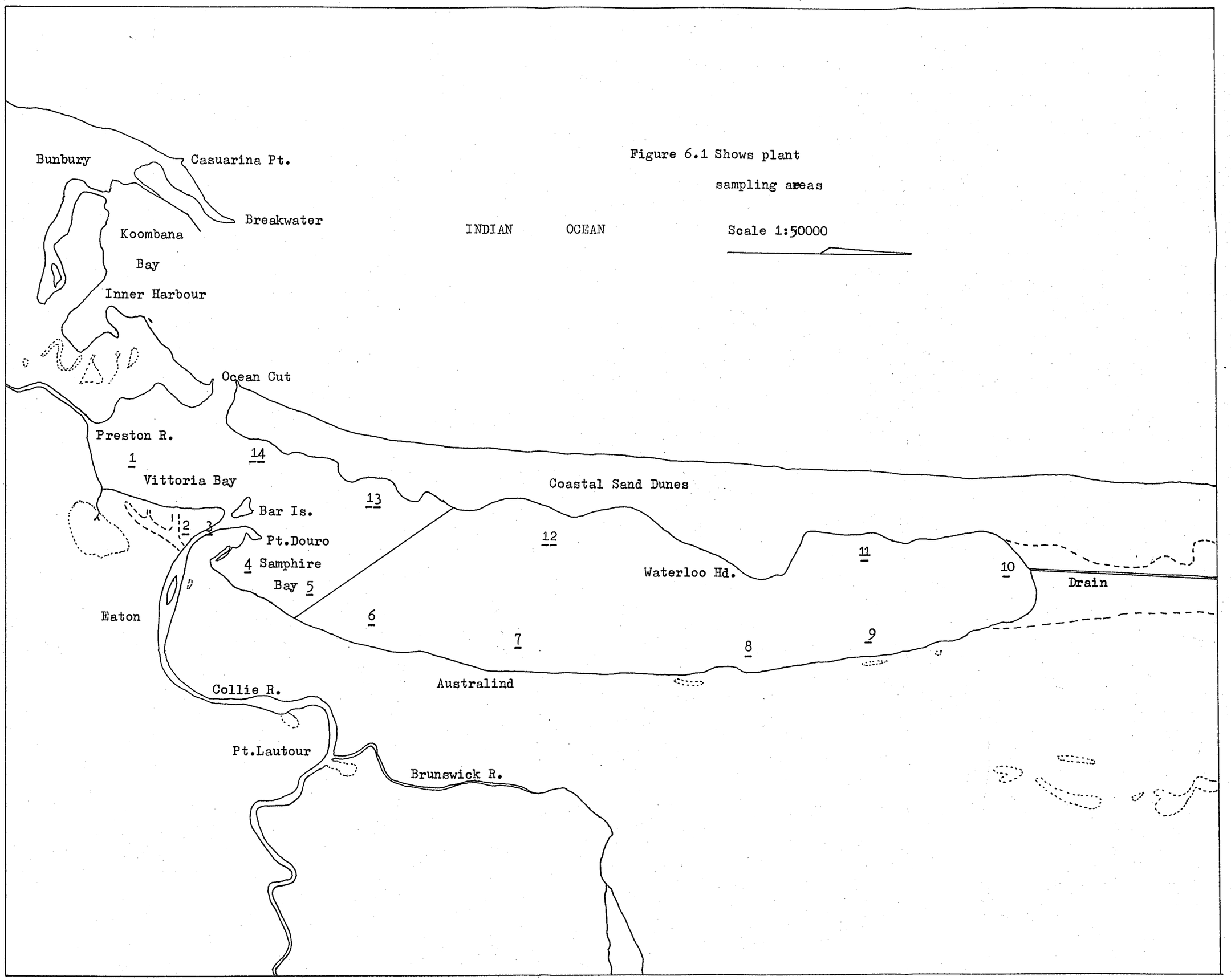
This species is a monocotyledon and grows in submerged form on sandy and muddy bottoms.The plants have creeping root systems which grow out to a radius of two to three metres and to a depth of about ten centimetres.The glabrous leaves are paired at each node and rise from a side stem and vary in length from one centimetre to six centimetres in length and three millimetres to one and a half centimetres in width.This species flowers in early summer in the inlet (December)and fruit occurs on the plants in late January to early Febuary.The size of the plant appears to be environmentally dependent with the larger plants growing on the muddy substrate of the north western shoreline.(Waterloo Hd.) This species is extremely abundant in the Leschenault Inlet and grows over most of the substrate below the low water mark.A few specimens can be found growing in the intertidal zone but this is not common.Areas where this occurs is in the vicinity of station seven.(See Figure 6.1)Halophila ovalis can be found growing from the low tide zone out to the deep water areas in the centre of the inlet and it would appear that the restriction of light is

Aerial photograph 35 mm yellow filter:shows Halophila ovalis,Ruppia megacarpa and Zostera muelleri growing to the north of the junction of the coast road and the scenic drive.



Aerial photograph 35 mm yellow filter:Algae between Waterloo Head and eastern shoreline.

Figure 6.1 Shows plant sampling areas

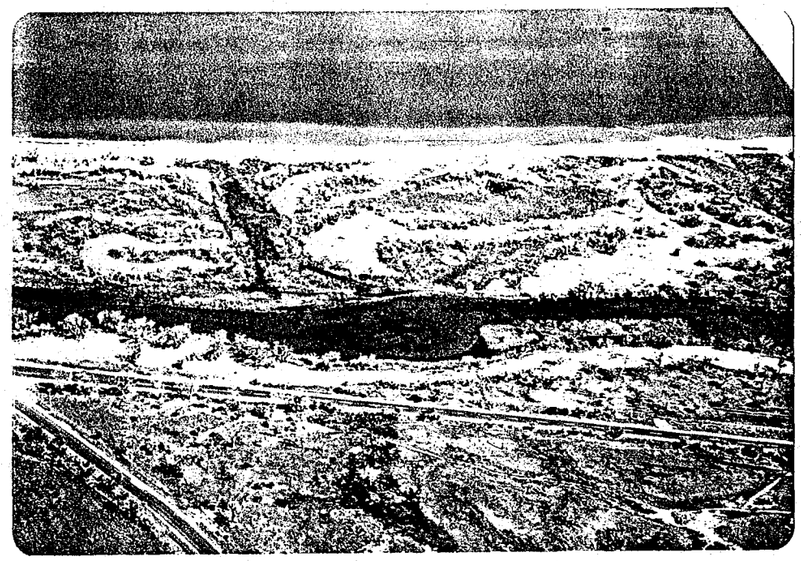


Aerial photograph 70 mm yellow filter: shows Halophila ovalis, Zostera muelleri and Ruppia megacarpa meadows to the north of the junction of the coast road and the scenic drive.(site 8)

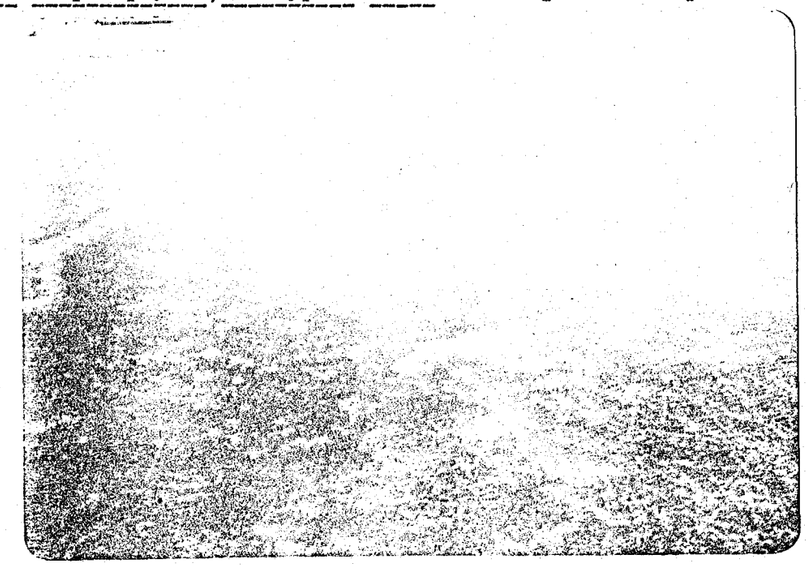
the limiting factor which prohibits its growth in this region.This species covers the entire western shore as far north as the 'mobile dune' to the north of Waterloo Head.Much of Vittoria Bay is covered with Halophila ovalis but no growth occurs in the vicinity of the Collie River mouth.This is probably due to either the low salinity, (ranging from 5 ppt in the winter to 24 ppt in the summer)the low light penetration in the dredged channel or in the case of the shallow areas to the north of and east of Bar Island the continuous build up of sediment being brought down by the river system which prohibits the plants from becoming established.The prohibiting factor at the northern end of the inlet is probably the extremes in salinity ranges that this area experiences.They vary from 62 ppt in the summer to 3.5 ppt in the winter and show a gradual decrease towards Waterloo Head in the summer and a gradual increase in the winter.(see section 4.0)It would appear from the results that this species favours salinity levels of between 24 ppt and 45 ppt.

Ruppia megacarpa

This species is often confused with Ruppia maritima in the estuaries of the south west.The plant is a monocotyledon and grows submerged in water up to one metre in depth in the inlet.This attached perennial also grows abundantly in many wetland areas and seasonally flooded salt marshes around the inlet.The specimens in the inlet range in height from six centimetres on the north west muddy areas to fifteen centimetres below the pipeline on the eastern sand banks to forty centimetres in the wetland to the south of the Collie River.The Ruppia flowers in late September and fruit appear in late October in this region.This species dies off in the winter and regrowth starts around July in the inlet, while in the wetland areas,which are seasonally flooded,growth commences soon after the first heavy rains in late April.This is probably because these areas are small in comparison with the inlet and the temperature



Infra-red aerial photograph showing the Ruppia megacarpa growing in the Collie Wetlands area.Note poor condition of Melaleuca hamulosa swamp on the right of the photograph.Other main vegetation is Melaleuca rhaphiophylla,Eucalyptus rudis and sedges and samphire.



Aerial photograph 35 mm yellow filter:shows Halophila ovalis growing to the north east of the pipeline.

of the water and the substrate are higher, therefore this type of environment is more inducive to growth. During the summer period the Ruppia dies of and forms a thick mat over the surface of the dry wetland areas. A count of the seeds in the area to the south of the Collie River gave a result of about 7,500 per square metre. In the inlet Ruppia megacarpa distribution is limited to small areas in Samphire Bay, the area near the south eastern side of the pipeline, adjacent to the Paris Road boat ramp and along the eastern shoreline to the north of the inlet and down the western shoreline to the mobile dune. In most areas this species grows in the intertidal zone. (see map F 3) The seasonally flooded salt marshes on the north west side of the inlet are generally covered with Ruppia but due to the low rainfall and extremely low tides over the period of the study, growth in this area has been very poor and the area dried out in spring. The northern herbfield used to have a reasonable growth of this species but due to drainage practices it now only occurs in the deeper sections. Ruppia also occurs in small brackish pools along the western side of the inlet and the growth is quite dense in these pools which range in depth up to one metre. In the wetland to the south of the Collie River the growth is extremely dense and the biomass in this region is the largest in the area. This is probably due to the rich substrate and the calm waters that occur here, coupled with warm temperatures and an optimum salinity range. Studies in the United States have shown that flowering in Ruppia is influenced by salinity and studies carried out in Florida indicate that flowering is confined to lower salinities and that seed set occurs at a salinity of 28 ppt or less. This would correspond with data collected from the Collie wetland area and salinities in this region range from 15 ppt in the winter (1979) and 28 ppt (1979) in the spring. While the Ruppia would appear to regenerate from rhizomes in most parts of the inlet, it appears to regenerate from both rhizomes and seed in the Collie wetland and the small pools to the north west of the inlet. Results have shown

that the higher the salinity,the lower the growth rate.It was found in the Peel Inlet,(S.Carstaires,uncompleted study for Masters Degree,U.W.A.) that the start of the growing season was temperature dependant and that two species occured in the region.Ruppia megacarpa in the inlet and Ruppia polycarpa in the marginal wetland areas.This does not occur in the Leschenault Inlet and only Ruppia megacarpa is present.The limiting factor in distribution appears to be salinity,available light,water flow and soil nutrients,coupled with heavy grazing by Swans.Both nitrogen and phosphorus are limited in the substrate,except in the Collie wetlands where nitrogen is high during the winter,(8.21 mg g^{-1} dry weight of soil) but phosphorus is low,(0.03 mg g^{-1} dry weight of soil) (site 2)The spring results here are 1.78 and 0.04 respectively.At site 9 where the growth is poor the nutrients in the substrate are 0.38 mg g^{-1} dry weight of soil (nitrogen) and 0.05 mg g^{-1} dry weight of soil(phosphorus)Similar results occur on the western side of the inlet,(0.12 mg g^{-1} and 0.02 mg g^{-1} dry weight of soil,respectively)but in the region of the Mangrove community the content is higher,3.93 mg g^{-1} (nitrogen) and 0.11 mg g^{-1} d.w.s.(phosphorus)(Spring results)Another limiting factor would appear to be the macroscopic algal growth which occurs in the northern,north western and north eastern part of the inlet.This algae initially attaches to the Halophila ovalis and forms dense mats over the surface.This covers the Ruppia beds and because they require more light than Halophila,die. The wind then moves the algae away from the Halophila and growth continues The algae moves into the intertidal zone and once again covers the Ruppia beds,restricting light penetration and prohibiting growth.Because of this and the other limiting factors,the Ruppia species in the inlet appear to be in danger.The loss or reduction of this species could have an adverse effect on the Swan population of the inlet as Ruppia constitutes about

eighty percent of their diet.(see section 5.0)

Zostera muelleri

This species is a monocotyledon and grows to about five centimetres in height in the Leschenault Inlet.Like most of the other sea grasses that are present in the Inlet,with the exception of Ruppia,the greatest part of the plant grows beneath the substrate.This species is considered important in the overall ecology of herbivorous fish species(see section 5.0) and forms beds over sandy areas of the inlet between the low and high water marks,but is more dense in the intertidal zone.This species can be left exposed during low tides and this occurs in the Samphire Bay area.Zostera occurs in Vittoria Bay,along the south western foreshore, in Samphire Bay and extends along the eastern foreshore as far north as site eight.This species is restricted to shallow water and as with the Ruppia is covered with algae in the northern areas during the spring and the summer,thereby restricting the growth.This species tends to favour salinity levels comparable with the ocean (35 ppt) but grows over a range of 30 ppt to 46 ppt in the Leschenault Inlet.Zostera flowers in the late spring to early summer in this region and fruit appears during the latter part of the summer period.

Lepilaena species.

There are two species of this sea grass growing in the Leschenault Inlet, Lepilaena cylindrocarpa,which grows in the main waterbody and Lepilaena bilocularis,which grows in the seasonally flooded areas to the north west Both these species are monocotyledons and grow to a height of about five centimetres in this region.Lepilaena cylindrocarpa appears to favour the more saline conditions while Lepilaena bilocularis tends to favour the brackish regions.Neither are very abundant in the area and only small beds are present.(see map F 3)In the locations where these species grow they are in association with Ruppia.

The salinity range where this species grow in the inlet is between 30 ppt and 36 ppt, therefore it would appear that this species favours lower salinity levels from brackish to saline conditions.

Amphibolis antarctica

This species is a submerged, dioecious marine perennial, monocotyledon in form, and only occurs in small areas around the cut in Vittoria Bay. Only a few specimens were found and this plant probably did not occur in the inlet prior to the opening of the 'cut! It favours salinity levels that are comparable with the adjacent ocean. (35 ppt) It grows in the deep-water below the low tidal zone.

Posidonia australis

This species, like Amphibolis antarctica, is a submerged perennial which favours the marine habitat. It occurs in small areas around the 'cut' and only occurs below the low tide mark. This species is an 'invader' from the nearby ocean and probably did not occur prior to the opening of the 'ocean cut!

6.4.4 Distribution of Macroscopic Algae

Lamprothamnum paludosum

This species of algae is easily mistaken for a flowering plant and it is distributed throughout the brackish and freshwater wetland areas which border the inlet. It usually grows in association with Ruppia megacarpa and forms a dense mat over the substrate of the brackish pools and wetlands. It occurs in depths up to one metre in this region. On the western side of the inlet this species was found growing as a single species in two small fresh water ponds. (see map F 3) In this area the plant were, on average, ten centimetres in height, while in areas where Ruppia grows the plants were only about six centimetres in height. It appears to favour fresh to brackish water with muddy organic substrates. This species was not found in areas where the salinity exceeded 28 ppt.

Chaetomorpha species

This species is a benthic green algae and grows in large quantities in the northern half of the inlet.(see map F 4)The growing season starts in late September to late October,depending on the temperature,and the algae grows attached to Halophila leaves and small stones on the inlet floor.When the summer winds blow,the algae is detached and moves around the inlet with the wind and current flows. This species takes its nutrient suuply from the surrounding water and growth is by reproduction of multinucleate cells which are arranged in branch form.There are two species present in the inlet;Chaetomorpha valida and Chaetomorpha linum.Nutrients brought down by the northern drainage channel are released from the sediments when the water temperature begins to rise in the spring and because of this phenomenon the algal growth in the northern part of the inlet is rapid and large areas are covered by dense growth up to fifteen centimetres thick.When the algae leave the Halophila beds it moves into the shallow intertidal zones and covers the Ruppia and Zostera beds.

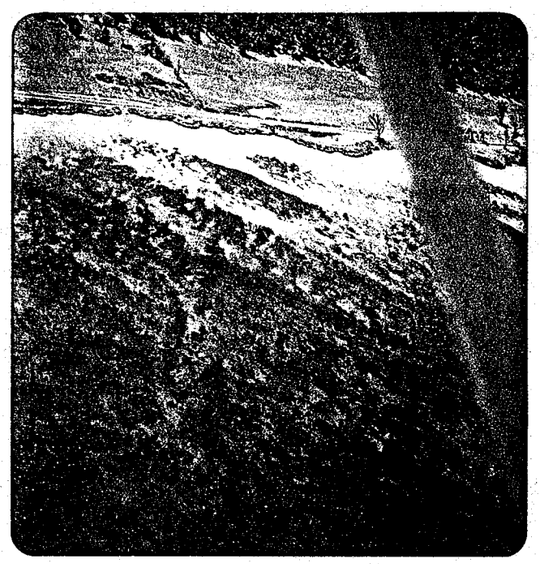
This species can be found over a broad salinity range of between 30 ppt and 55 ppt,with optimum growth occuring around 40 to 45 ppt.

Rhizoclonium riparium

This species also occurs in the northern region of the inlet and is associated with the Chaetomorpha species.It is a benthic green algae and grows in filamentous form with an unbranched stucture.

Enteromorpha species.

Two species of this green algae occur in the inlet;Enteromorpha species (unclassified) which grows attached to the substrate by rhizoidal outgrowths,breaking free with wind and water movement and Enteromorpha intestinales which is a green 'lettuce like' slime which grows attached to rocks and the sedges which line the foreshore.Enteromorpha is most common in the area to the south of the pipeline where the



aerial photograph 70 mm yellow filter:shows algae growing at site 9 on the north eastern side of the inlet.

salinity is comparable with that of the ocean.(35 ppt)The salinity range in which this species grows is between 32 ppt and 46 ppt.

Chondria (so called)

Chondria is a benthic red algae and grows in free form and attached, mainly to Halophila ovalis leaves.It is distributed throughout the inlet with the densest growth occuring in Vittoria Bay and Samphire Bay and along the southwestern shoreline.In most areas it is only about six centimetres in length.

Glacilaria vemicosa

This species is a benthic red algae and grows attached to the substrate in Vittoria Bay and along the south western shoreline.The species is variable in estuarine systems and the colouring ranges from bleached white to red.It only occurs below the low tide mark in Samphire Bay and Vittoria Bay but on the south western shoreline it grows,in smaller form,in the intertidal zone.The filaments grow in length up to about twelve centimetres in the deeper water and about five centimetres in the shallows.Glacilaria is mainly distributed in the southern section of the inlet where the salinity range is between 33 ppt and 46 ppt. Specimens collected north of the pipeline were in the free floating form.

Dictyota species

This algae is a benthic brown algae and has a dichotomous branching system.This species attaches to the Halophila leaves by a sreies of branched rhizoids and its distribution is generally restricted to the Samphire Bay area.

6.4.5 Algal Epiphytes

These occur mainly during the summer when the water temperature is at its highest peak.(see section 4.0)The epiphytes are attached to the sea grasses,especially Halophila ovalis,which has larger leaves than the other species.Species of algal epiphytes occuring in the inlet include Ectocarpus sp.,Acrothaetium thuretti,Ceramium sp. and Callithamnion sp.

6.4.6 Productivity Rates and Biomass

Halophila ovalis

To determine the time taken for this species to recolonize an area of cleared substrate all the rhizomes were removed from an area of one square metre.Three quadrats were established so that biomass cuts could be taken at intervals throughout the year.Another quadrat was established to determine the growth over a set period of time.This was cleared in June 1978 and the other three in January 1979.The standing crop of the June '78 area was 86 grams per metre squared dry weight(above and below ground)in January 1979.This is a growth rate of 10.75 grams per square metre per month.The standing crop at the time of the January '79 cut was 153 grams per metre squared dry weight.(above and below ground)Plant growth had started entering the quadrats by Febuary and a cut taken in April gave a dry weight of 30 grams per metre squared.The July cut was 45 gram per metre squared and by October this had reached 92 grams per metre squared.This gave a productivity rate of 10.22 grams per metre squared,overall.The growth commences in september and in the period July to October the productivity rate was 15.6 grams per metre squared per month and assuming that the area stabilized to its original standing crop of around 153 grams then the growth rate

between October and January would be 20.3 grams per metre squared.(site Other cuts taken in the area showed similar standing crops at the height of the growing season.Site 11 gave a standing crop of 163 grams per metre squared dry weight in late January,and a cut at site 1 gave a standing crop of 143 grams per square metre.Approximately ninety percent of this species grows below the substrate.

Ruppia megacarpa

The growth rate and annual productivity of this species was only established in the wetland to the south of the Collie River.Standing crops were obtained from other areas around the inlet at the height of the growing season.Water first entered the wetland in early April,1979, and a cut taken in late July (10 weeks period)and this yielded 55.8 grams per square metre dry weight(above ground).This is 4.65 grams per square metre per week.Another cut was taken at the end of October (12 week period) and the yield was 446.3 grams per metre squared dry weight above ground.This represents a productivity rate of 32.5 grams dry weight per metre squared above ground.per week.The Ruppia bed to the south east of the pipeline yielded a standing crop of 8.2 grams per metre squared in July and 71.6 grams per metre squared in October. This represents a productivity rate of 5.28 grams per square metre dry weight above ground per week.The Ruppia was in flower at all sites in October.Cuts taken in October on the north west and north east shoreline of the inlet yielded 6.3 and 8.2 grams per square metre dry weight above ground.

Algae Standing Crop

Algae was collected from one metre square areas at three sites in the inlet in January,1979,and the dry weight from site eight was 738 grams per metre squared (all species) and at site seven 528 grams per metre squared and site one 127 grams per metre squared.The algae tends to be carried into dredged areas in the inlet and the weight at the site seven boat channel was 800 grams per square metre.

6.4.8 Importance of Sea Grasses in the inlet

The sea grasses act as a 'baffle'and increase the rate of sedimentation within the inlet.Research in the United States shows that the sea grasses "preferentially concentrate the finer particle sizes and stabilize the underlying sedimentary deposits.This occurs through the entrapment of water-borne particles by the leaf blades,the formation and retention of particles produced within the meadows,and the binding and stabilization of the substrate by the rhizome and root systems." (Phillips 1978)The sea grasses provide shelter and food for many fish and other aquatic fauna and assist in the overall chemical cycle which occurs within the system.by using nutrients for growth and replenishing the system with detritus and organic nutrients upon decomposition.(see also section 5.0)

7. CIMATIC FEATURES.

7.1 Introduction.

The Leschenault Inlet is on the centre of the western seaboard of climatic survey area number sixteen-South West, Western Australia and is situated in low lying land (below 220 metres) at the southern end of the Swan Coastal Plain. (see Fig.7.1: location map and Fig. 7.2: topographic map.) All data relating to the immediate area was recorded over a period of eighty three years at Bunbury which is situated at the extreme southern end of the Leschenault Inlet. Maps showing the whole of the south west region have been included so that climatic conditions can be compared with the two other major inlets in the region; Peel Inlet and Hardy Inlet. (see Fig.7.1)
All data relating to climatic conditions for the area was obtained from the records of the Bureau of Meteorology, and where necessary, converted to metric scales.

7.2 General

The Bunbury region is dominated primarily by two seasons: winter, which takes in the months from May to October when the area comes under the influence of the westerly and north westerly winds giving the region a fairly reliable rainfall.Whilst the winter is mild but wet, the summer months (November to March) are usually hot and dry and long periods can be experienced without rain.
The southward movement of the thermal equator causes the area to be dominated by anticyclones and as these atmospheric highs move across the state they create south easterly winds which veer around to easterlies and finally to north easterlies which bring hot, dry air to the area during the summer months. These usually persist for a few days until there is an increase in the humidity and a new anticyclone brings cool air in from the sea.

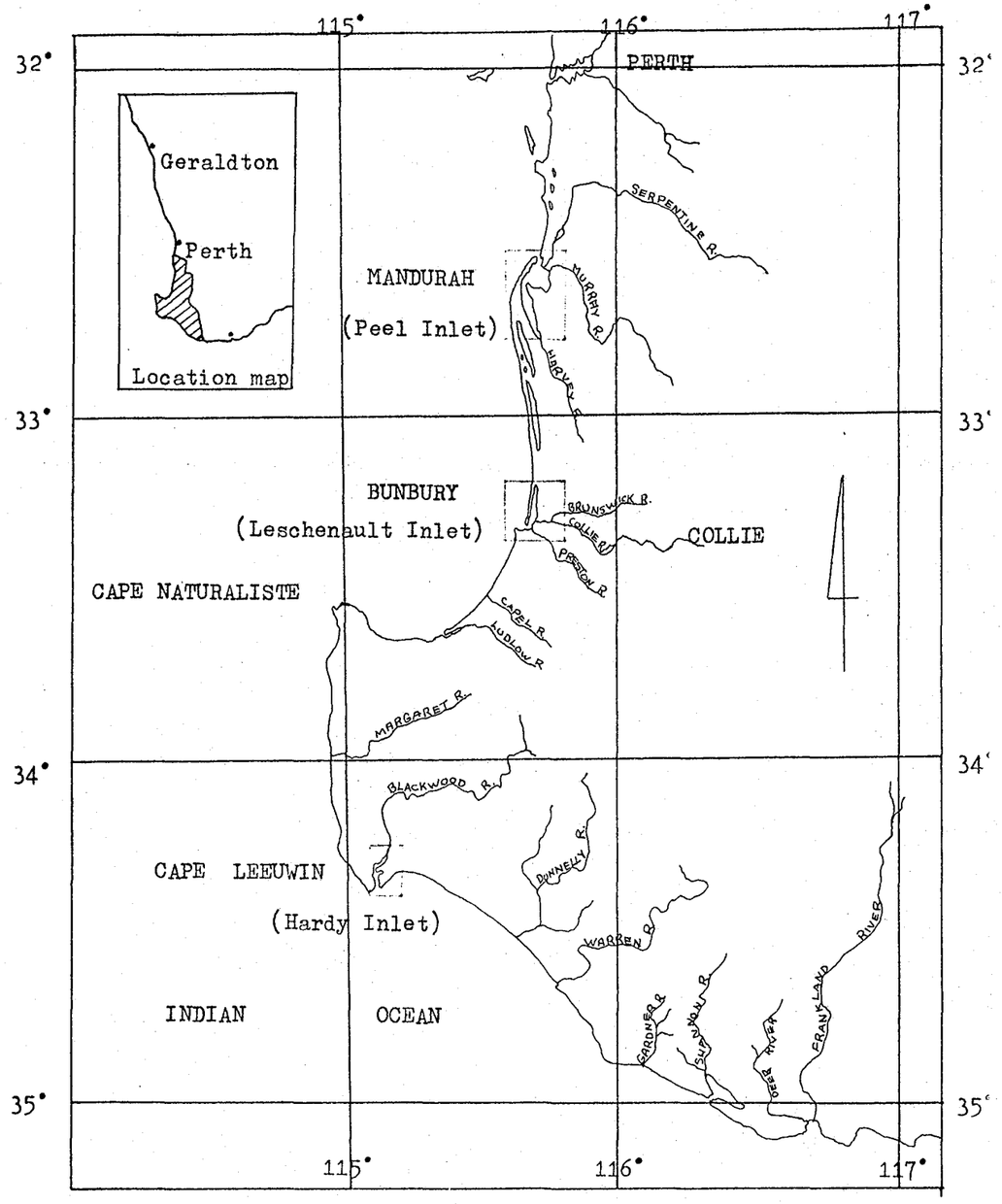


Fig. 7.1 Map Showing Major Inlets and Rivers of the S.W. Climatic Region.

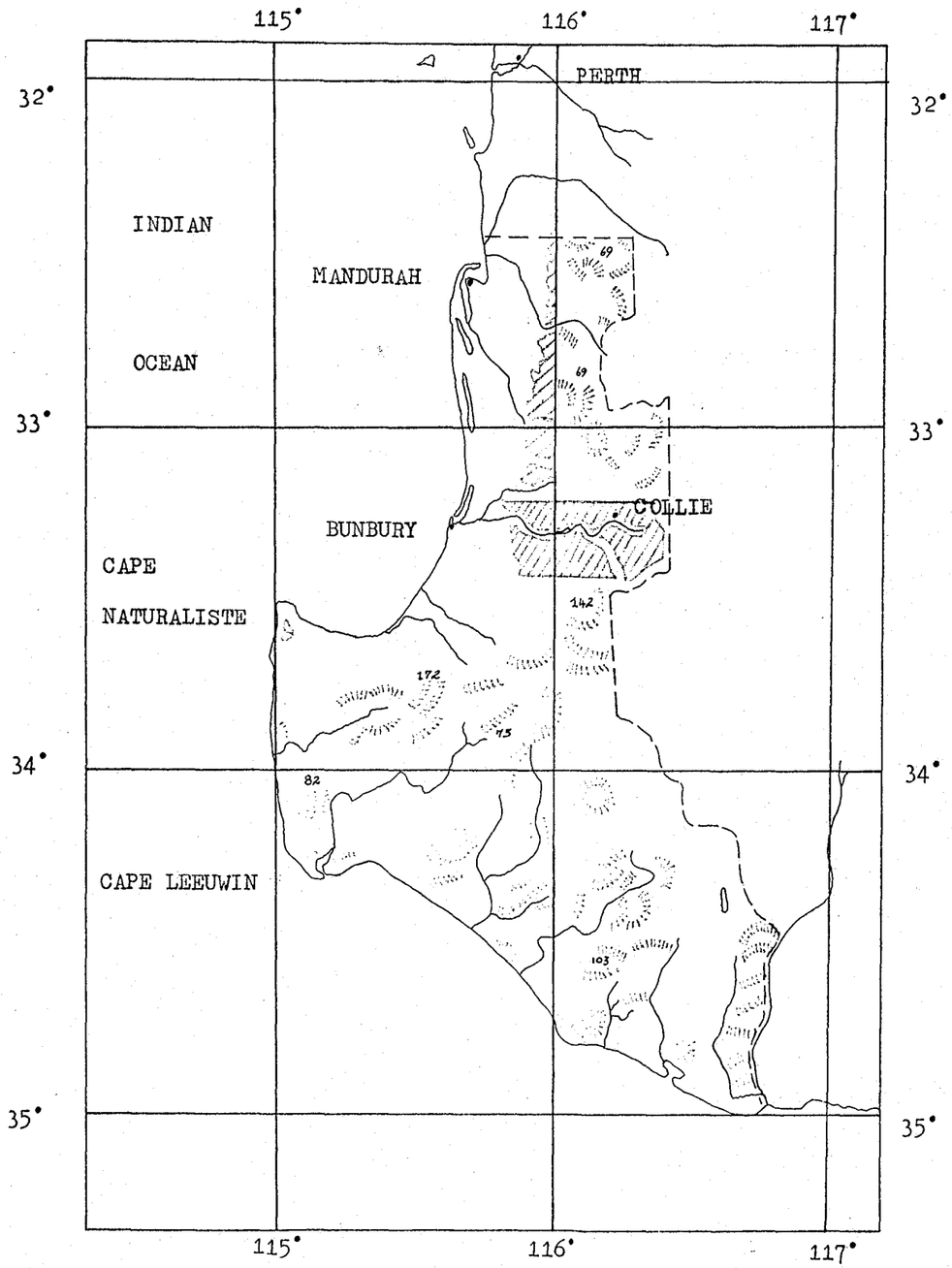


Fig.7.2Topographic and Location Map of South West Climatic Region.

0 - 220 metres.

Above 220 metres.

7.3 Rainfall.

The majority of rain falling in this region occurs during the winter months (May to October - see Fig. 7.4.) and can be seen to closely resemble that of the average annual rainfall. (see Fig. 7.3.)This can be borne out by comparing Figures 7.3,7.4and7.5 which show that during the winter months the 750 mm isohyet runs through Bunbury while during summer an average rainfall of 125 mm is recorded slightly west of Bunbury. The average annual rainfall isohyet which runs through Bunbury shows a reading of 875 mm which is only 125 mm more than the average winter rainfall. The broad ranging effects this has on the area shall be discussed in greater detail in the sections on water quality and flora.The following table shows average monthly and annual rainfall in mm recorded over a period of 83 years at Bunbury.

Table 7.1

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
9	12	22	44	128	185	165	125	83	56	24	16	875

A comparison between the total monthly rainfall during the study period (October 1978 to October 1979) and the average monthly rainfall (over 83 years) and the average annual rainfall(over 83 years) can be seen in Figure 7.3.1.

7.4 Rainfall Reliability.

Rainfall reliability is obtained by analysing monthly rainfall data and obtaining median and quartile values for the area.The Bureau of Meteorology use the following system for obtaining these results. " All totals of a specific month are arranged in ascending order. The series is then divided into four parts, each containing an equal number of totals. The values which separate these parts are called first quartile, median and third quartile. So, one quarter of all monthly totals are less than or

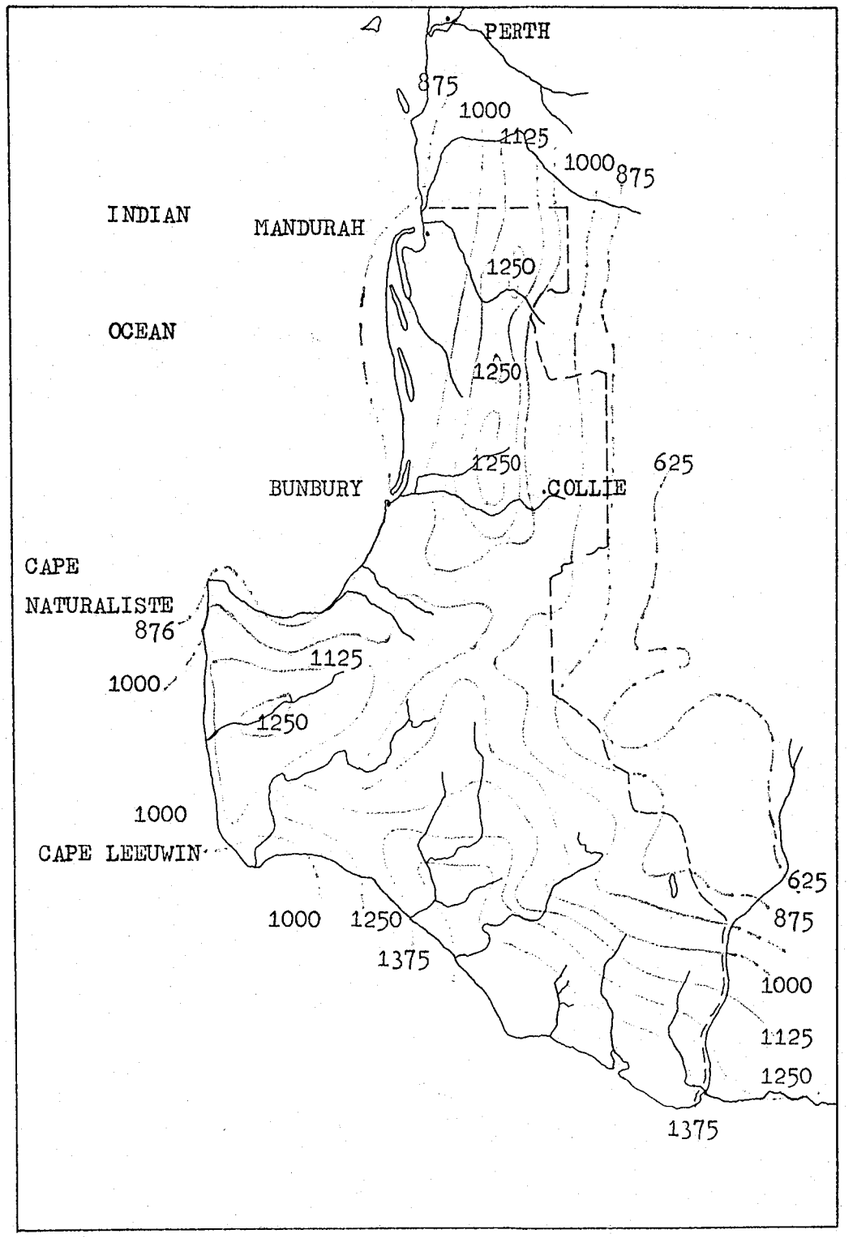


Fig. 7.3 Average annual rainfall (mm)

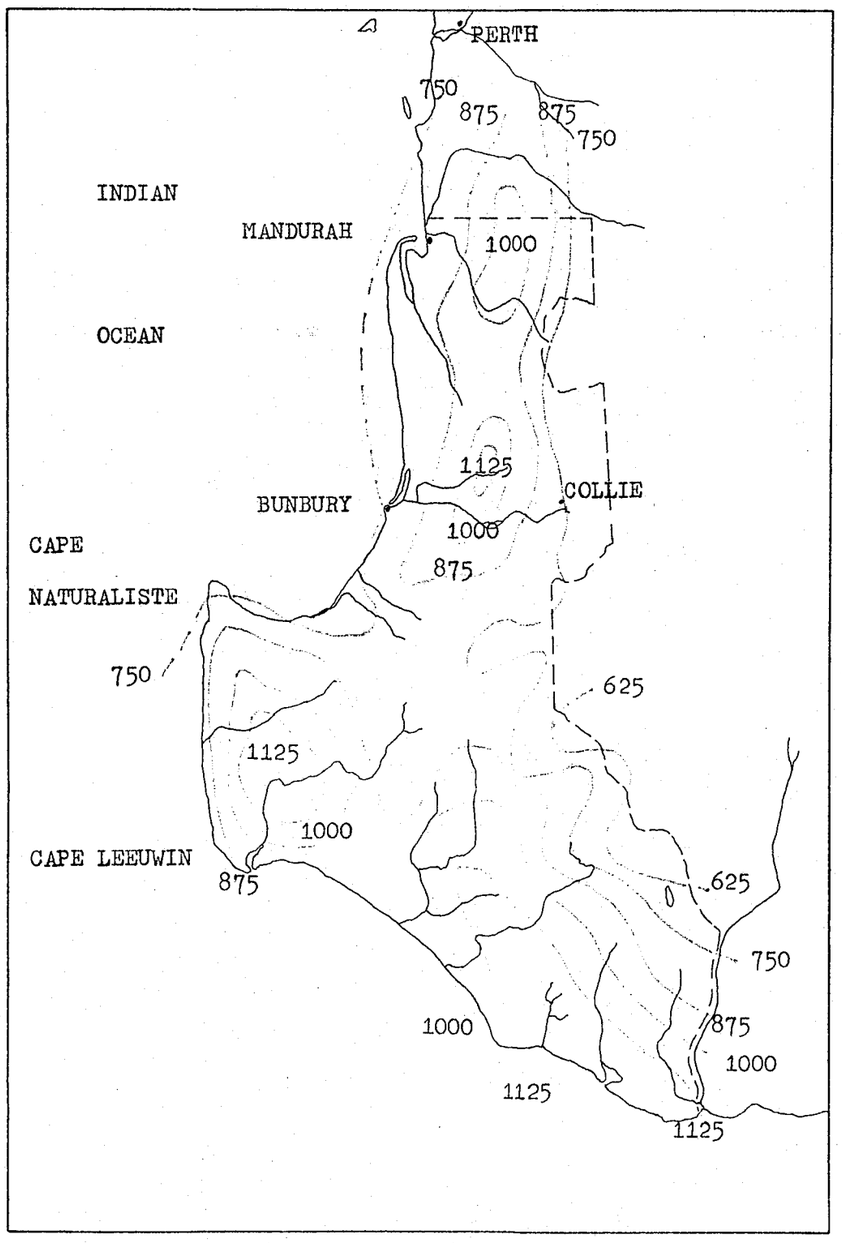


Fig. 7.4 Average Winter Rainfall. (mm)

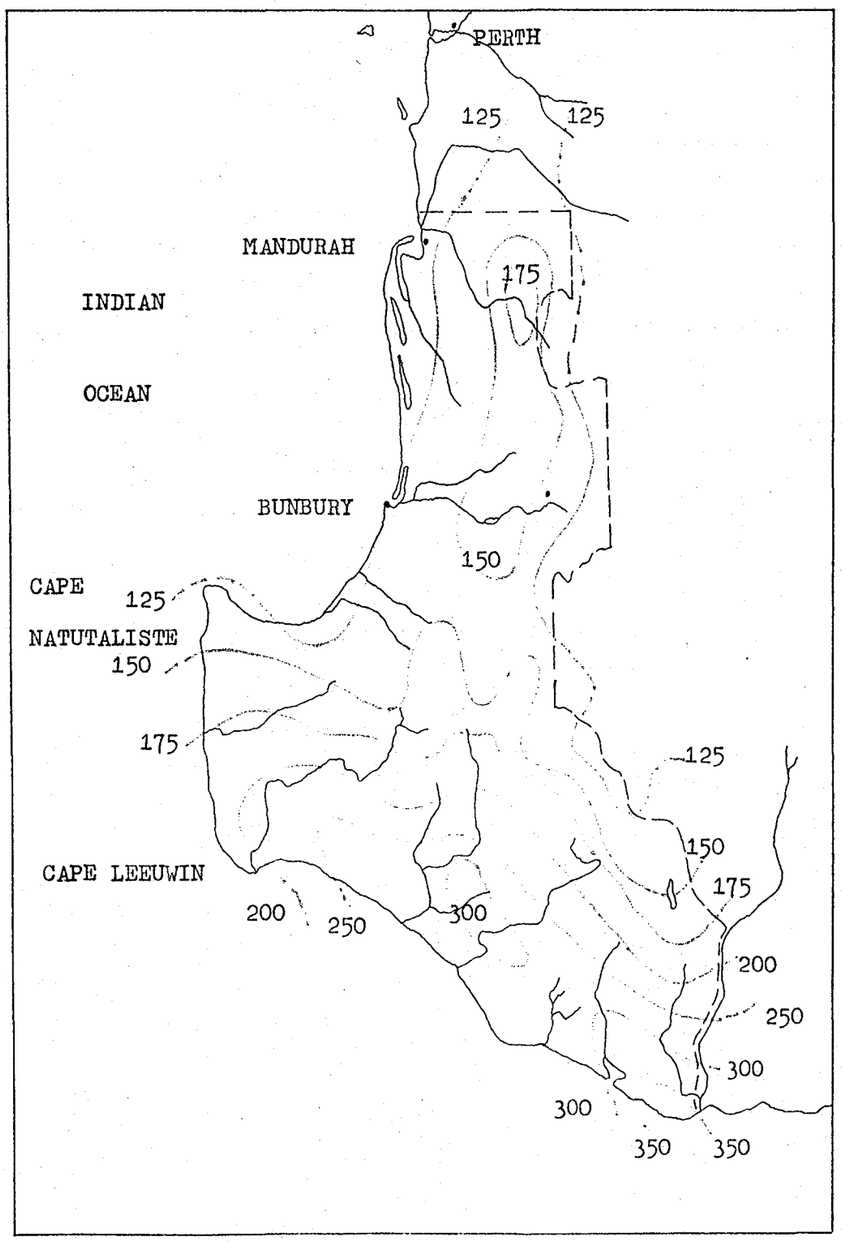


Fig. 7.5 Average Summer Rainfall. (mm)

equal to the median and three quarters of them are less than or equal to the third quartile. Finally, half of the monthly totals have values between the first and third quartiles." ( )

TABLE 7.2

Bunbury Rainfall Quartiles (in mm)

Line 1 : First Quartile

Line 2 : Median

Line 3 : Third Quartile

Line	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	1.25	1.0	4.7	20	89	125	137	86	46	36	11	4
2	4.20	4.5	14.7	35	125	153	156	120	75	50	19	8
3	11.3	13	38	62	159	227	222	160	112	63	39	19

Table 7.3 shows the percentage probability of receiving specific totals of rainfall and by examining this table it can be seen that the frequency of light and heavy rainfalls are greatest during the months of June and July. They reach their minimum during the summer months.

TABLE 7.3

Percentage probability for Bunbury

Line 1 : Effective Rainfall

Line 2 : 12.5 mm

Line 3 : 25.0 mm

Line 4 : 50.0 mm

Line	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	2	6	20	53	99	100	100	99	92	84	17	4
2	23	27	52	85	100	100	100	100	96	95	68	37
3	10	14	31	67	99	100	100	99	92	88	40	19
4	3	6	15	30	96	100	100	93	73	48	10	3

7.5 Effective Rainfall.

The 'effective rainfall' is the amount of rain required to initiate and maintain the growth of plants above their wilting point. To obtain the mean effective rainfall for any one month the following formula is used: $P/E^{0.7} = 0.54$; where P equals the effective rainfall and E equals the amount of evaporation from a free water surface. Figure 7.3.2 gives a comparison of effective monthly rainfall against average monthly rainfall for the study area.

7.6 Rainfall Intensity.

Rainfall intensity is defined as the highest falls recorded in a twenty four hour period ending at 9 a.m. Table 7.4 shows the highest daily rainfalls recorded in Bunbury. The Bureau of Meteorology defines heavy falls as: 2.5 mm or more in 5 minutes.

3.8 mm or more in 10 minutes.

5.0 mm or more in 15 minutes.

6.25 mm or more in 20 minutes.

7.5 mm or more in 30 minutes.

10 mm or more in 1 hour.

12.5 mm or more in 2 hours.

15.4 mm or more in 4 hours.

16.3 mm or more in 6 hours.

17.8 mm or more in 8 hours.

20.0 mm or more in 12 hours.

25.0 mm or more in 24 hours.

TABLE 7.4

Highest Daily Rainfall at Bunbury (In mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
55	84	64	47	79	122	93	66	56	38	51	26

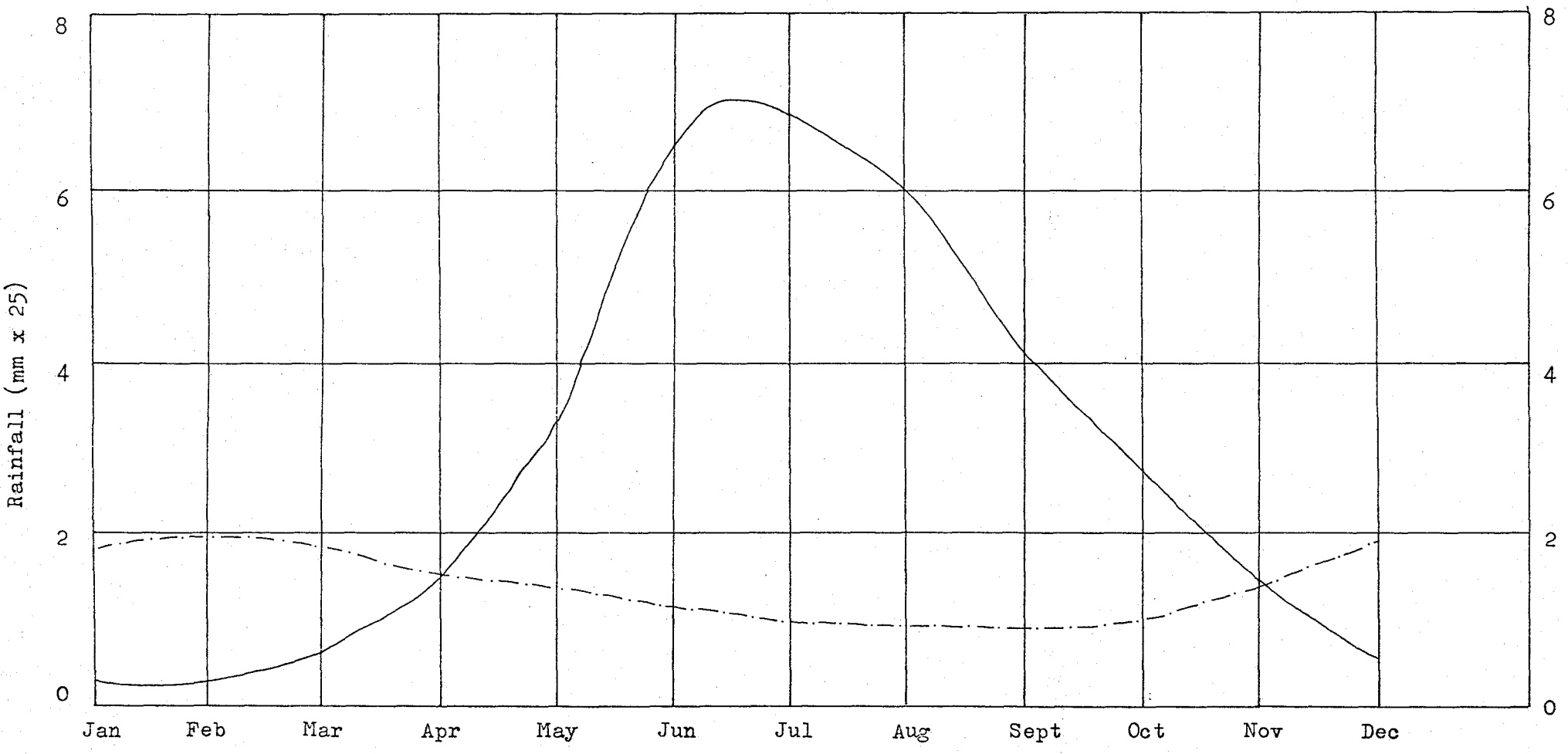


Fig. 7.3.2 Shows effective and average monthly rainfall for the study area.

Average Rainfall ———— Effective Rainfall—·—·—·—

7.7 Thunder Days..

The average number of thunder days has been plotted in Figure7.6. The data is from charts published by the State Electricity Commission of Western Australia and the Bureau of Meteorology. It can readily be seen that the study area receives an annual average of fifteen thunder days.

7.8 Temperature.

After rainfall, the temperature is probably the most important factor influencing the Leschenault Inlet, its flora and fauna. The hottest mean maximum occurs at Bunbury during Febuary and the area has a mean average temperature of twenty one degrees celsius during the summer months of December through to Febuary.(see Fig. 7.7)During spring (see Fig. 7.8) there is a general weakening of the temperature gradient in the south west region and there is little difference between the isotherms with the study area having an average temperature of 15.5°C. During the winter (see Fig.7.9) the isotherms form a similar pattern to the Autumn isotherms (see Fig. 7.10) but with lower average temperatures. Bunbury receives a mean temperature of 12°C during this season compared with 18°C during the Autumn. The Bunbury region, being on the coast, receives a higher average temperature during the three cooler seasons, but because of coastal winds the mean maximum temperature is slightly lower than areas further inland.(see Fig. 7.11)The area also receives less days per annum with temperatures of 32°C or above.(see Fig. 7.12) In contrast, Bunbury receives a higher mean minimum temperature than areas further inland(see Fig. 7.13) for the coldest month which is usually July.

The following table shows average and extreme temperatures recorded in Bunbury. The unit is degrees celsius.

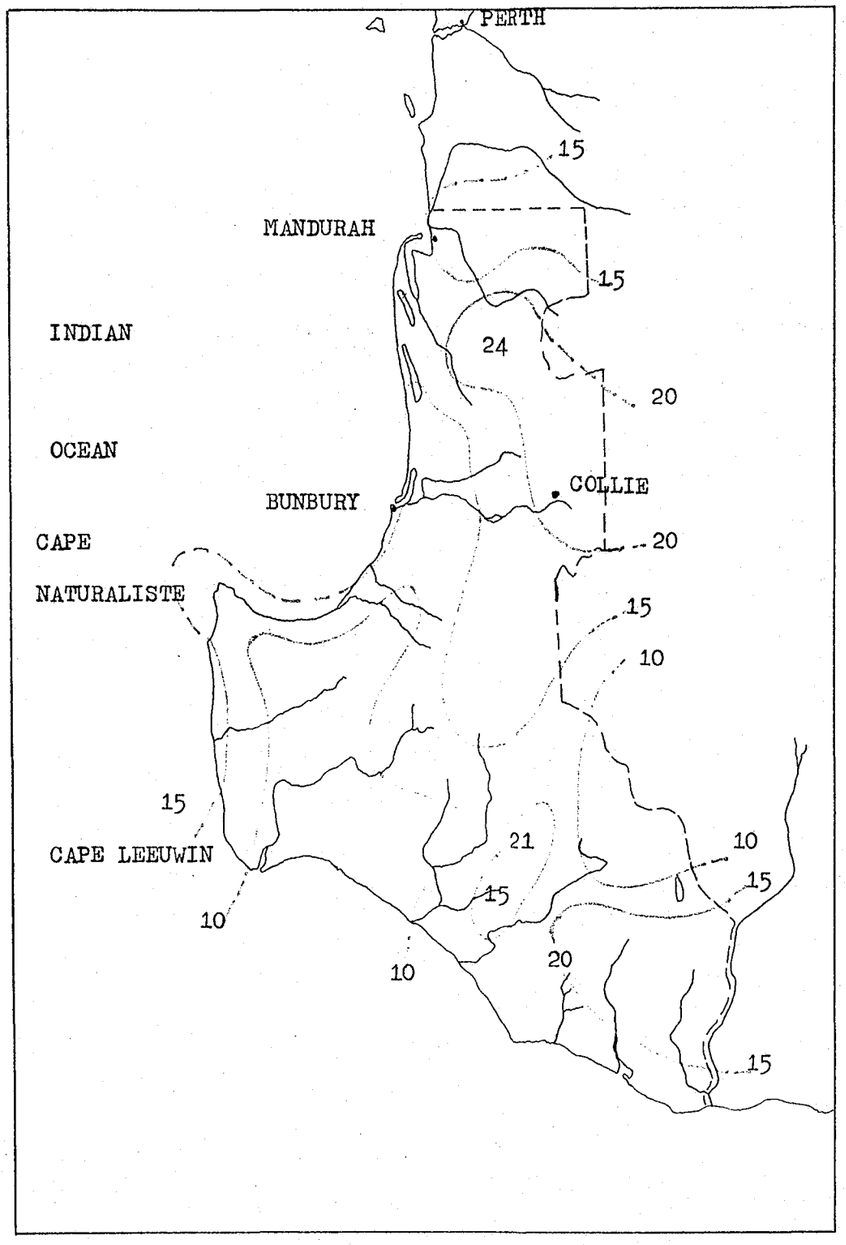


Fig. 7.6 Average Annual Number of Thunder Days.

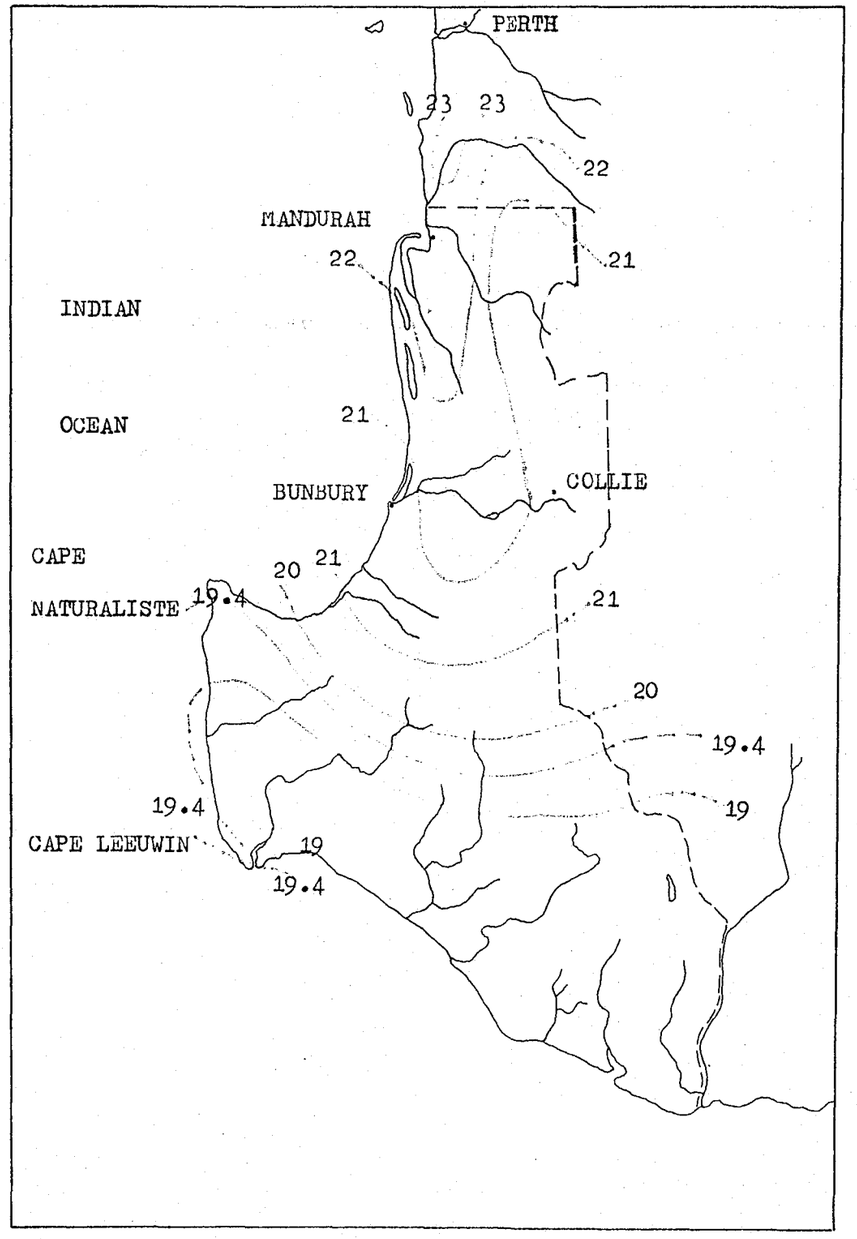


Fig. 7.7 Mean Temperature in Summer. (°C)

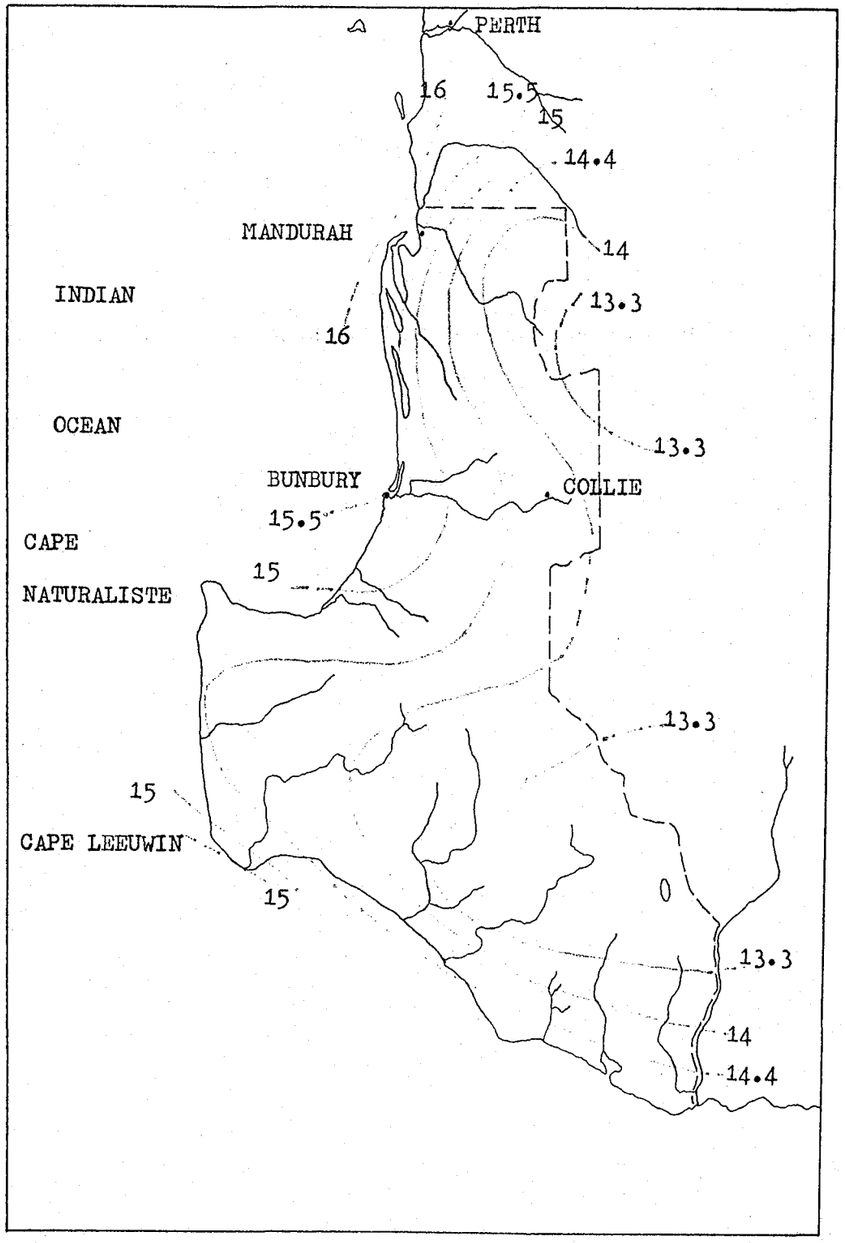


Fig. 7.8 Mean Temperature in Spring. (°C)

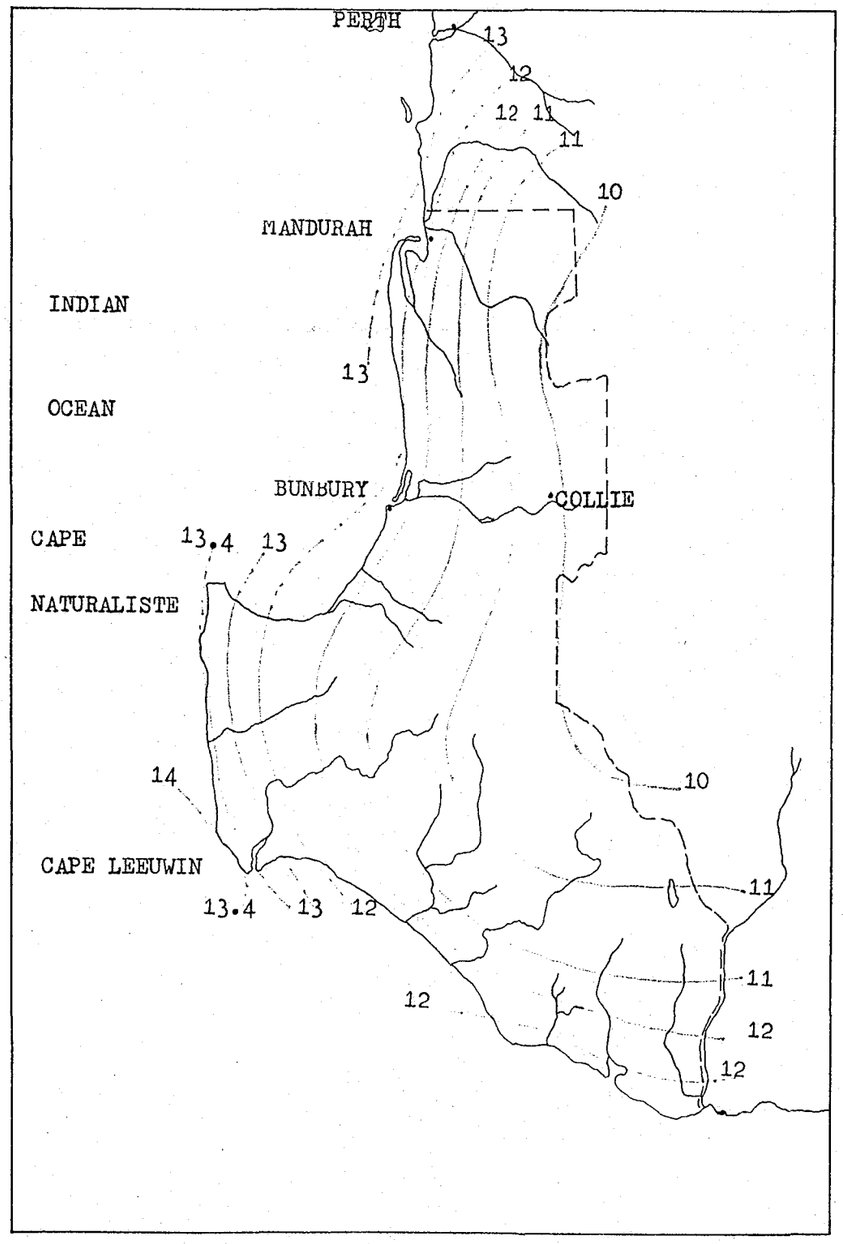


Fig. 7.9 Mean Temperature in Winter. (°C)

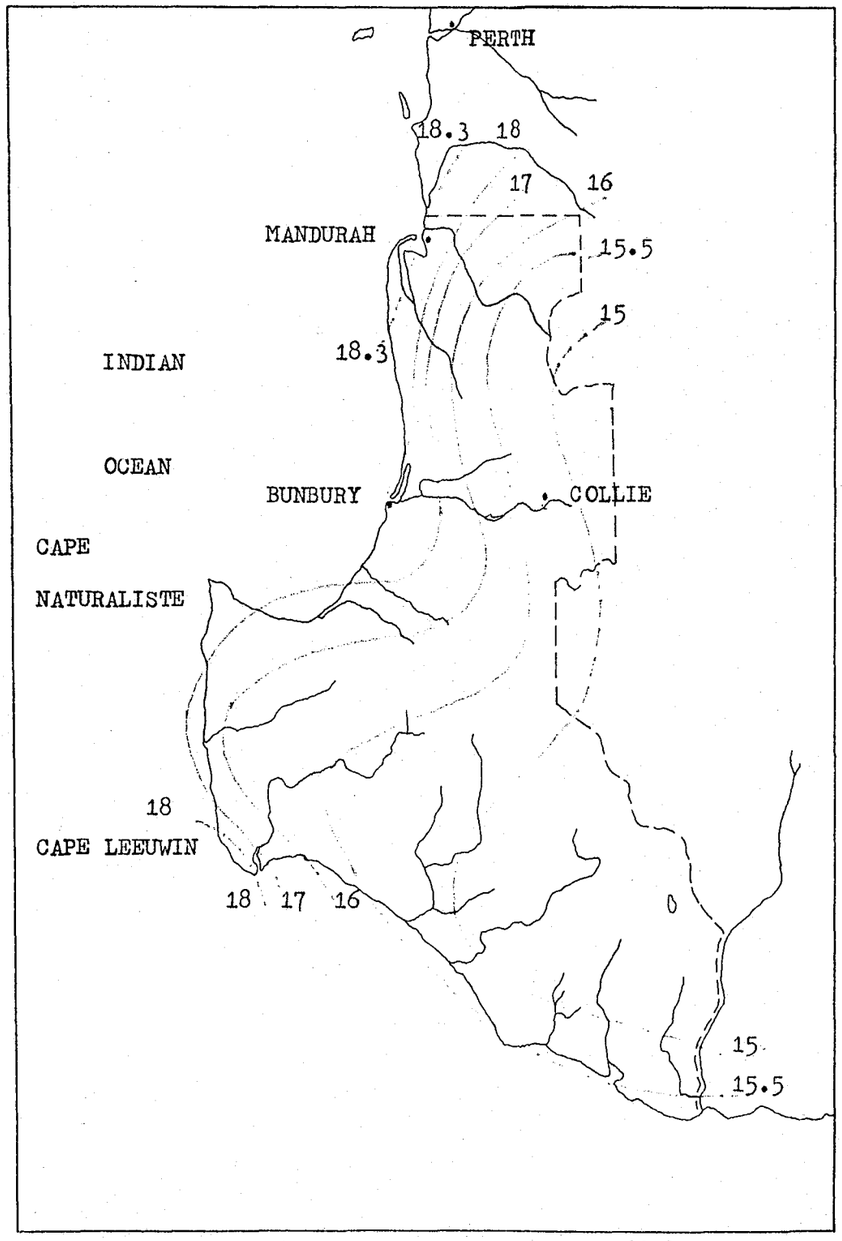


Fig. 7.10 Mean Temperature in Autumn. (°C)

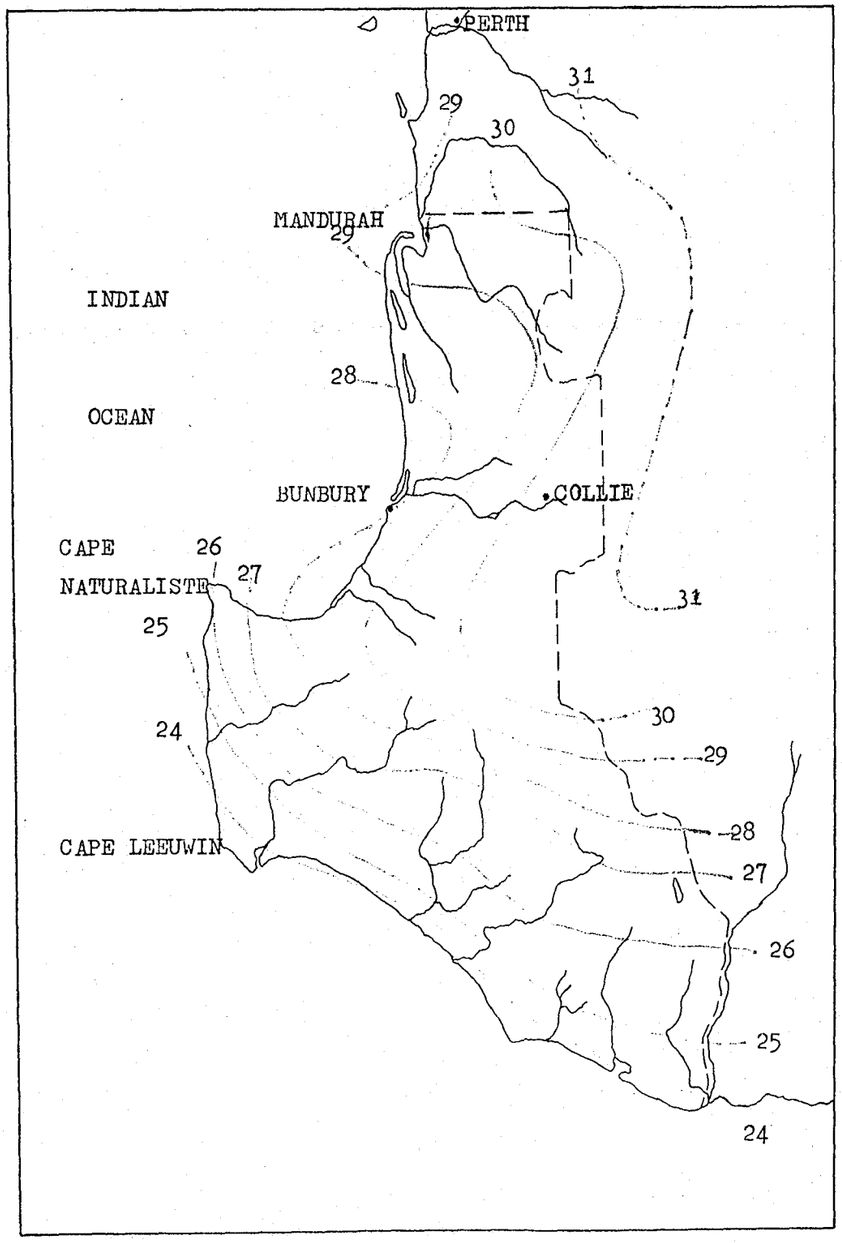


Fig. 7.11 Mean Maximum Temperature for Hottest Month.(°C)

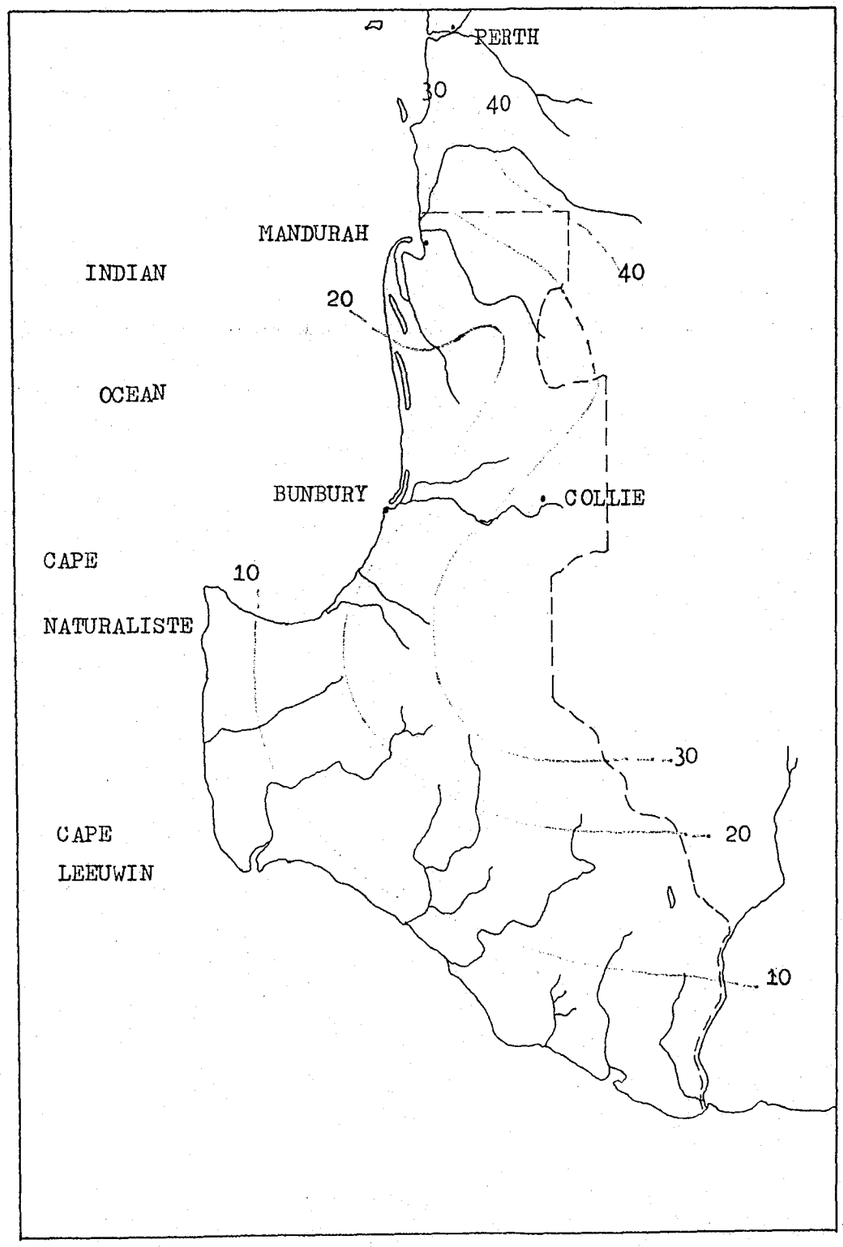


Fig. 7.12 Average Number of Days Per Annum with Temperatures of 32° C. or Above.

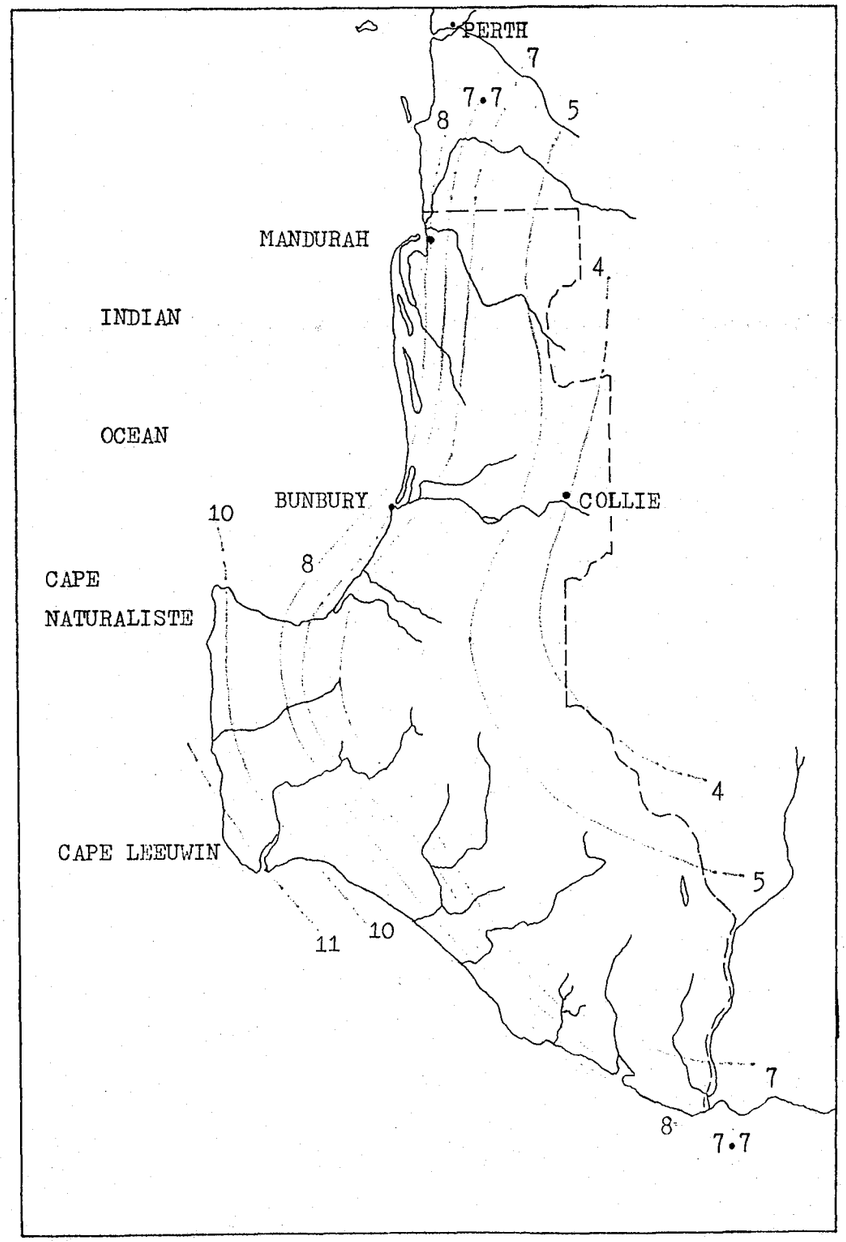


Fig. 7.13 Mean Minimum Temperature for Coldest Month. (°C)

TABLE 7.5 Average and Extreme Temperatures in Bunbury.

Line 1 : Average Maximum (over 56 years)

Line 2 : Average Minimum (over 56 years)

Line 3 : Highest Recorded(over 40 years)

Line 4 : Lowest Recorded (over 65 years)

Line	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	27	28	26	23	20	18	17	17	18	20	23	25
2	14	15	14	12	10	9	8	8	9	10	12	13
3	41	40	38	34	28	25	22	25	29	34	38	39
4	6	5	4	3	0	.5	0	.5	0	.5	4	3

7.9 Frosts.

The study area receives only small amounts of frosts and Table 7.6 shows the average frequencies of frosts for the region.(see also Fig.7.14)

TABLE 7.6 Average Frequencies of Frosts.

Years of Record	Apr	May	June	July	Aug	Sept	Oct	Nov
23	0	0	1	1	0	0	0	0

7.10 Humidity.

Humidity is expressed in percentage relative humidity (R.H.) and is directly related to the amount of water vapour in the air at a specific time. If the air is completely saturated this means it cannot contain any more vapour unless the temperature increases.(100% R.H.) If the temperature should decrease whilst the air is saturated this will result in condensation, giving dew, fog or clouds.Table 7.8 shows the relative humidity in percentages for the Bunbury region at 3 p.m.

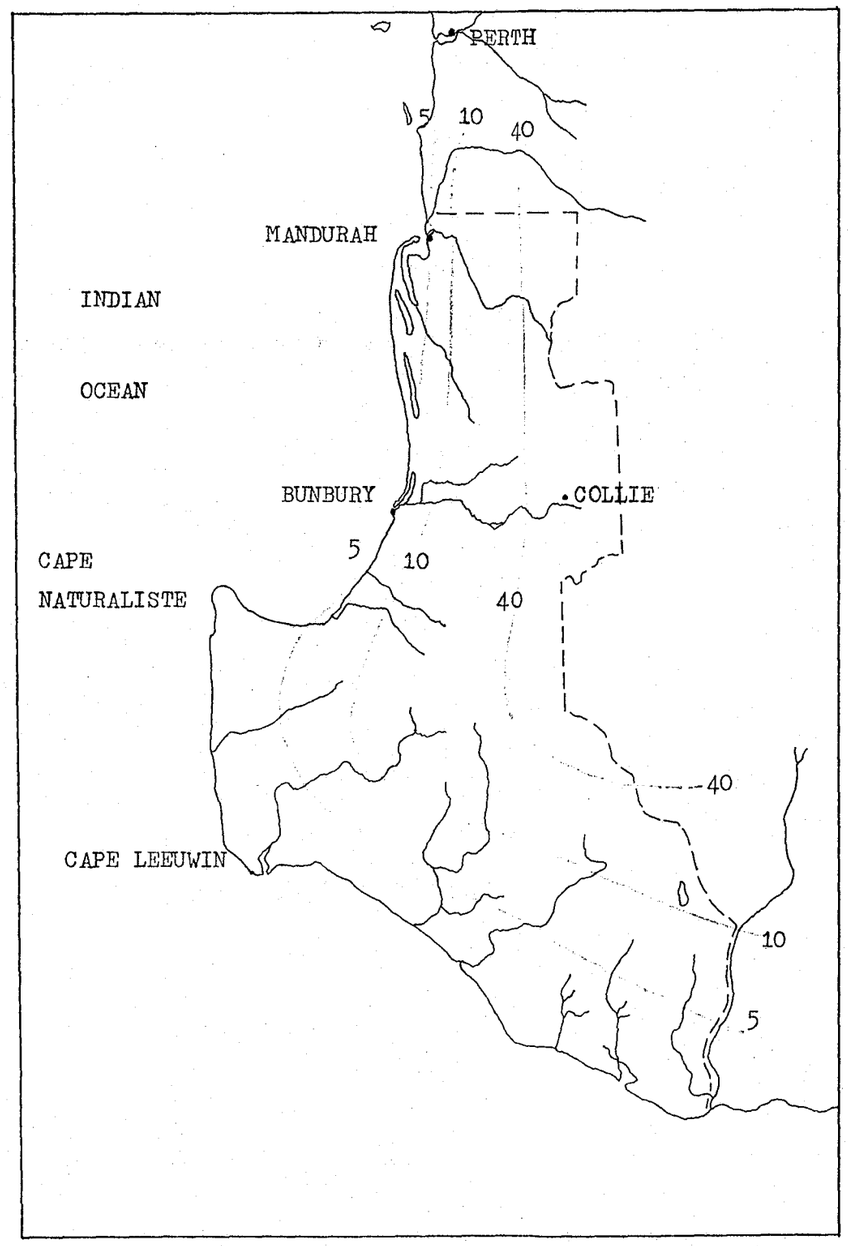


Fig.7.14 Average Frequency of Frosts. (Screen temperature of 2.3 °C or less.)

TABLE 7.8

Line 1 : Average Relative Humidity at 3 p.m. (over 44 years)

Line 2 : Average Index of Mean Relative Humidity (over 30 years)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
57	56	58	63	68	70	71	69	67	65	60	59
66	67	71	74	78	78	77	78	75	72	69	74

7.11 Evaporation.

The annual evaporation (see Fig. 7.15)for the study area is approximately 1200 mm per annum and the importance of this climatic condition on the estuary shall be discussed in more detail in other relevant sections.

7.12 Growing Season.

The length of the growing season is determined by the amount of rainfall received and the effective rainfall. This season occurs during the year when the rainfall received is greater than the effective rainfall.(for effective rainfall see sub-section 7.5) The opening dates for this season vary throughout the south west region, starting in Febuary in the south and April in the north. The average date of the beginning of the growing season for the study area is the seventh of April.(see Fig.7.17) The length of the growing season follows a similar pattern with a longer season in the southern areas.(see Fig. 7.16)The length of the growing season for the three major inlets in the south west are: Peel Inlet,(6.5 months) Leschenault Inlet, (7.0 months) and Hardy Inlet, (8.0 months).The variation is due to a more constant rainfall over a longer period in the more southerly regions.The Bureau of Meteorology uses the following criteria for determining this data.

(a) "Rainfall totalling at least 12.5 mm was received on one day or during a number of almost consecutive days"

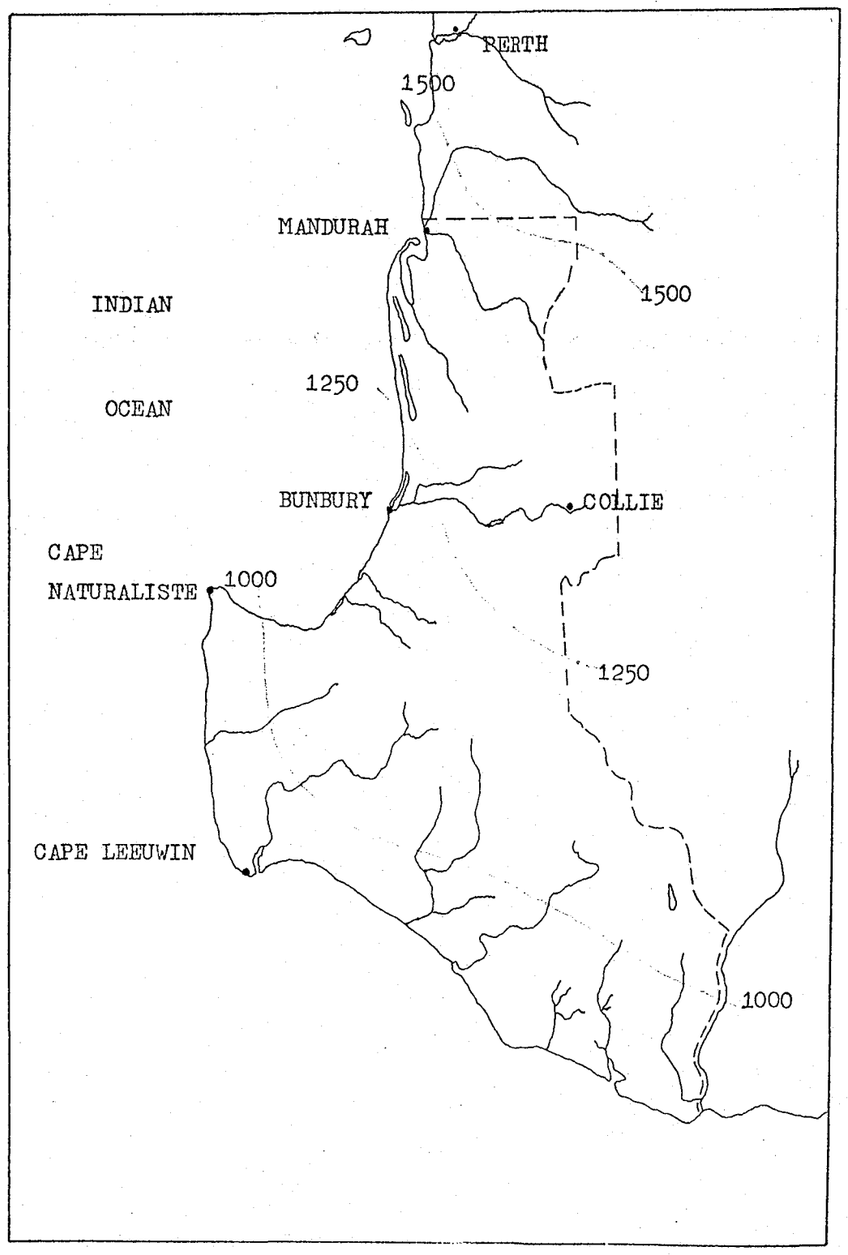


Fig. 7.15 Average Annual Evaporation in mm.

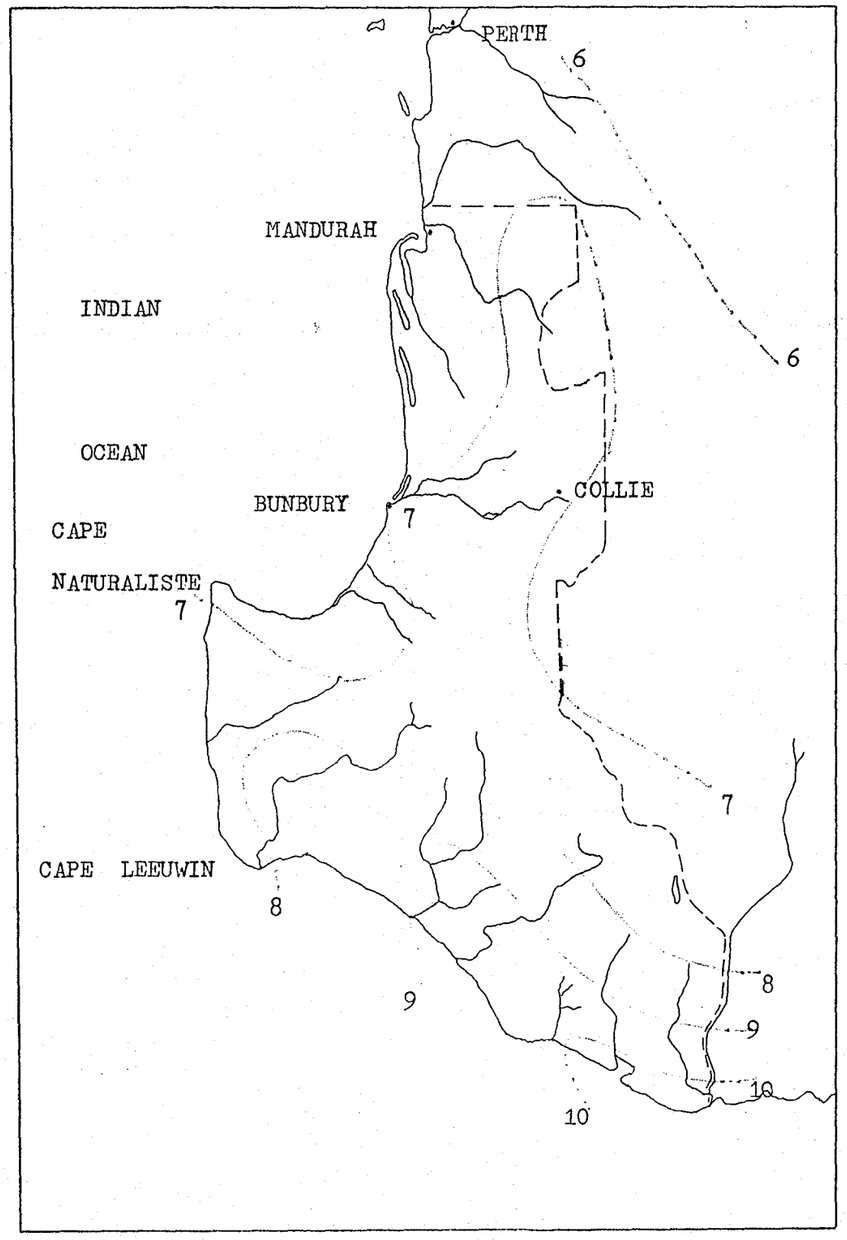


Fig. 7.16 Length of Growing Season in Months.

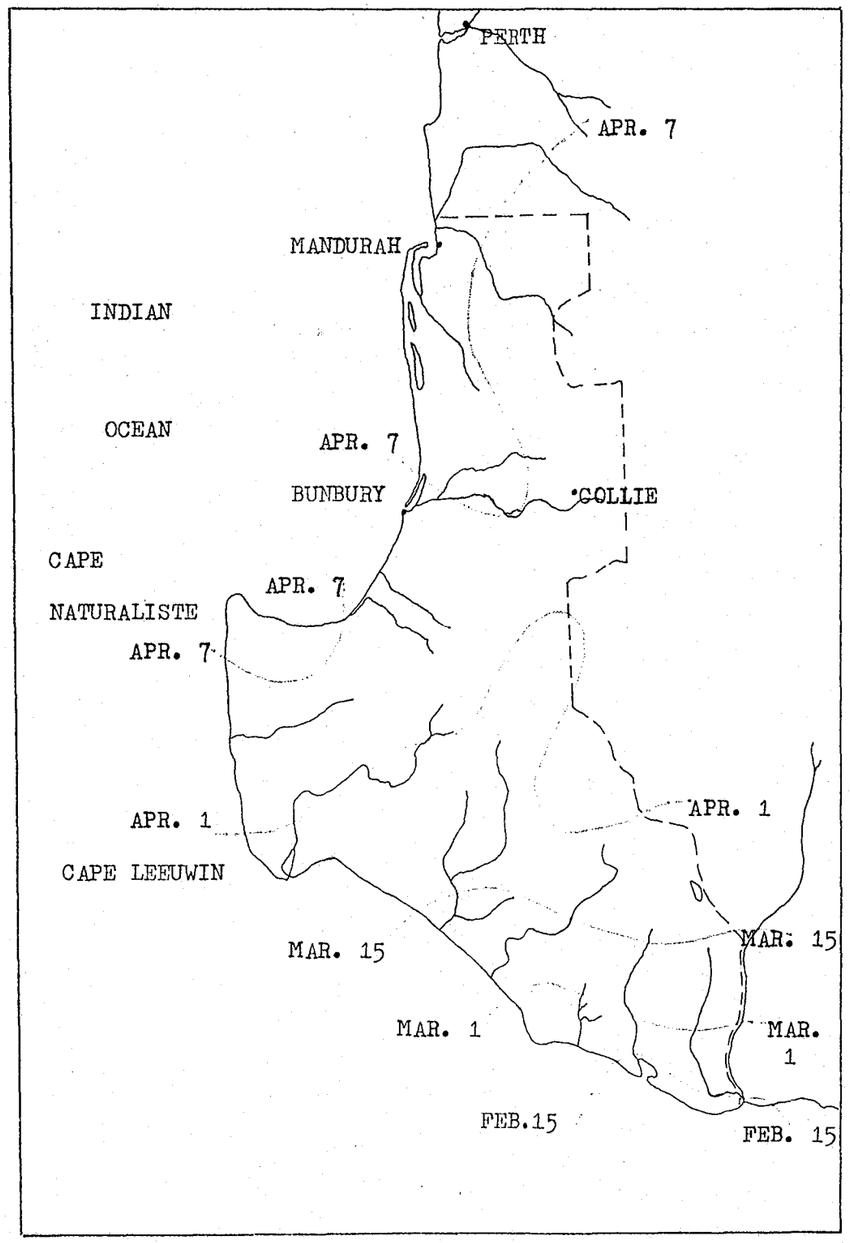


Fig. 7.17 Average Date of Beginning of Growing Season.

(b) "The effective rainfall was exceeded continually during the following thirty days." ( )

This criteria is used because light falls of rain after a period of drought do not penetrate the soil to any great depth, evaporate quickly and therefore have little effect on germination. Germination is produced by heavier falls of rain but these are of little value if they are not followed by more showers.

7.13 Drought

Following the winter rains in the study area a dry spell usually occurs, intermitently broken by light summer showers. A dry spell is defined as a season in which all months receive less than the effective rainfall.In the following table for the Bunbury region it can be seen that in sixty five percent of the years, dry spells have lasted for at least five months; eighty six percent of the years it has lasted for at least four months and ninety three percent of years for three months.The length of these dry seasons has a broad and varying effect on the water Quality and flora in the study area and this shall be expanded on in the relevant sections

TABLE 7.9

Recorded Dry Spells in the Study Area.

Line 1 : Length of dry spells in months.

Line 2 : Percentage of years.

1	2	3	4	5	6	7	8	9	10	11	12
100	100	93	86	65	33	4	1	0	0	0	0

8.0 Control of Waterways and Adjacent Land.

This section outlines the legislation of the Waterways Conservation Act,1976,associated with the control of waterways and adjacent land. Information was supplied by the Waterways Commission of Western Australia.

8.1 Recreational Activities.

All activities such as boating,water - skiing and swimming and private and public jetties are controlled by the composite Navigable Waters Regulations under the Shipping and Pilotage Act,1967,Jetties Act,1926 and the Western Australian Marine Act,1948.

8.1.1 Private Pleasure Boats.

All matters concerning registration,equipment to be carried,speed limits etc., are covered by regulations 45a to 45f,48,51,51a,51b and 52a to 53 inclusive.

8.1.2 Water Skiing.

Areas to be set aside for this sport,control of speed limits,manning of boats etc., are covered by regulations 46 to 50 inclusive.

8.1.3 Organised Races and Regattas.

The control of these activities are covered by regulation 12 and 51c.

8.1.4 Swimming.

The areas to be set aside for this activity and the conduct of swimmers near public jetties and bridges are covered by regulations 10 t
11 inclusive.

8.1.5 Public Jetties.

Regulations 22 to 36 inclusive,cover use and control of public jetties generally.Most of these concern commercial cargo or ferry jettie
however,some are applicable to small public jetties within the area

under the Waterways Commission.

8.1.6 Private Jetties.

These are defined under Section 3 of the Jetties Act,1926 and the requirements that they be licensed by the Harbour and Lights Department is covered by Section 8 of that Act.Parts of the waters are within the boundaries of the Bunbury Port Authority and registration and licensing of jetties is carried out by that Authority.

8.1.7 Rubbish.

Regulation 8 prohibits the throwing of rubbish or any other matter into the waters without approval.

8.2 Dredging.

Regulation 9 of the Navigable Waters Regulations prohibit removal of sand or other material from below high water mark without the permission of the Lands Department.

Sub - Section 2 (i) of section 5 of the Waterways Conservation Act, 1976, retains ownership of the bed of the waters with the Crown,(under section 6 of the Lands Act,1933) hence approval must be obtained from the Lands Department before dredging work can be carried out. Any royalties that may be charged for the removal of sand by any person must be remitted to the Lands Department.

8.3 Control of Discharges into the Waters.

The rights in the Water and Irrigation Act,1974,gives the Minister for Water Supply,Sewerage and Drainage rights to grant or refuse disposal licenses.Under sections 7 to 11 inclusive, of the 1974 amendment to that Act the terms and conditions of these sections are similar and in some portions identical,with those in section 47 of the Waterways Conservation Act.

Under section 3 of the Waterways Conservation Act 'wate
the rivers,inlets and estuaries within the gazetted boun
the Rights in Water and Irrigation Act,1974,under sectio
to discharges into the waters of any watercourse,lake,lag
marsh or subterranean water system.

8.4 Controls by Local Government Authorities under Local Gover

All these regulations come under the Local Government Act,1

8.4.1. Jetties.

Under section 301 (a) of this Act a council may make by - la
ulating the management and use of jetties - and shall cause a
these by - laws to be conspicuously displayed on the jetties.

8.4.2 Foreshores.

Under section 214 a council may make by - laws for regulating
of the foreshores of the sea and of the rivers,of watercourses
tidal and non - tidal waters.

8.5 Limitations of the Waterways Conservation Act,1976.

The Waterways Conservation Act does not give the Waterways Commi
or the appointed management authority exclusive control of all a
ities or matters within the gazetted boundaries of the authority.
Many of these are covered by existing legislation administered b
relevant department.In the event of a disagreement the decision
department under its legislative power must prevail.

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