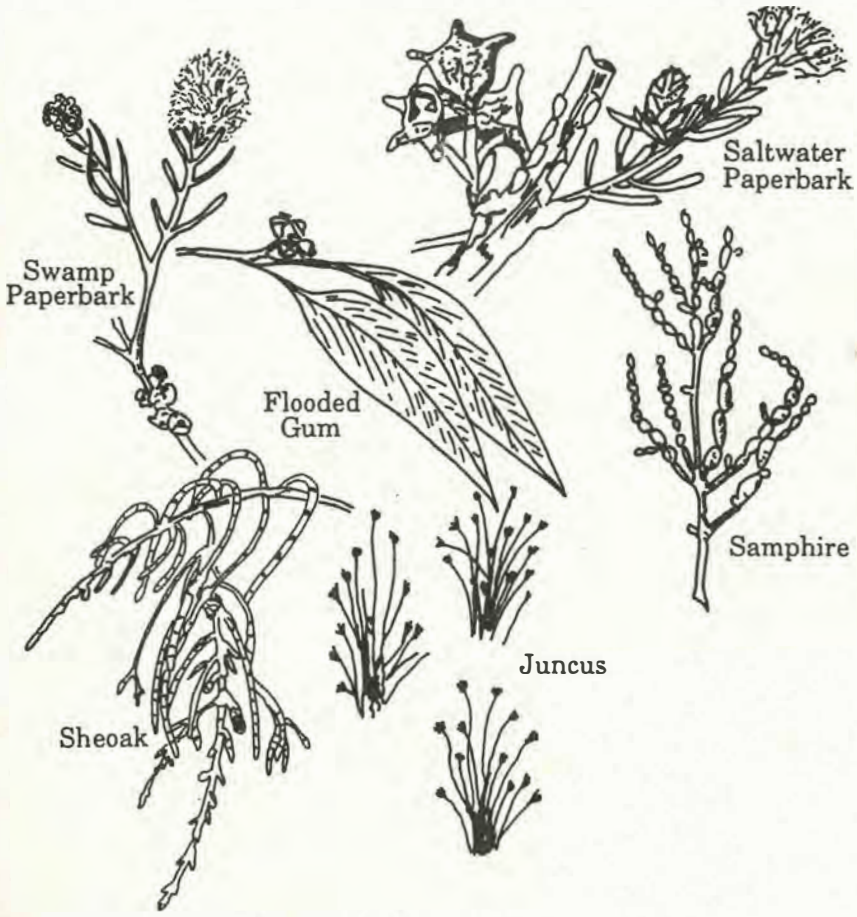
LESCHENAULT INLET MANAGEMENT AUTHORITY

Fringing estuarine vegetation of the Leschenault Estuary 1941 - 1991



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FRINGING ESTUARINE VEGETATION OF THE LESCHENAULT ESTUARY 1941-1991

Report to the Leschenault Inlet Management Authority

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FOREWORD

The Leschenault Estuary supports 28 plant communities which are divided into salt-marsh (13), fringing vegetation (3), fringing estuarine forest (5), freshwater vegetation (3) and sandy rise vegetation (4). In addition there are eight vegetation types which are characterised by a high degree of replacement of native species by weeds, particularly grasses.

Vegetation changes were documented between 1941 and 1989 using aerial photographs. The main changes are a decline of estuarine fringing forest, the encroachment of the estuary by the shore-rush *Juncus kraussii*, colonisation of sandy river deltas by native vegetation and the formation of a vegetated tidal lagoon.

Between 1941 and 1989 about 346 ha (approximately half) of the fringing vegetation has been lost through clearing, chiefly in the northern and southern regions of the estuary. Degradation of the remaining native vegetation is occurring through invasion by mainly introduced species. A variety of grasses are invading the *Juncus kraussii* (shore-rush) closed rushland along the eastern foreshore and there are local infestations of Port Jackson (*Acacia saligna*), bulrush (*Typha orientalis*), club-rush (*Bolboschoenus caldwellii*), water couch (*Paspalum distichum*) and bridle creeper (*Asparagus asparagoides*).

Changes to the drainage regime in the north-eastern corner of the estuary foreshore are thought to have had only very localised effect on the native vegetation in that region. Major issues relevant to the management and conservation of the fringing plant communities of the estuary are discussed. Plant species suitable for vegetation rehabilitation works are listed and categorised into various zones of the estuary foreshore and associated land.

TERMS OF REFERENCE

This report was prepared by Dr Luke Pen under contract to the Waterways Commission. The findings of the report will assist in the preparation of a management plan for the Cathedral Avenue and northern Leschenault Estuary. This plan is being prepared jointly by the Leschenault Inlet Management Authority and the Shire of Harvey. It is proposed to undertake a further two studies in the region one for the Brunswick/Collie River system and another for the Preston/Ferguson River system.

Since completing the report Dr. Pen has been employed by the Waterways Commission at the Albany Waterways Management Authority.

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The author expresses his gratitude to Bev Thurlow, Caroline Seal, Colin Chalmers and Eric Wright and other officers of the Waterways Commission. Thanks also to Greg Baxter for the preparation of maps and figures in the document and Monique Jose for her assistance in collating maps and aerial photographs.

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1. INTRODUCTION

The Leschenault Estuary is located immediately north of the city of Bunbury some 200 km south of Perth. It is an elongate cigar shaped estuary lying in an approximate north-south direction having a length of about 13.5 km and a width of between 2.5 and 1.5 km. The Collie and the Preston Rivers enter the estuary in the lower 3 km section and the mouths of both rivers are bordered by extensive vegetated deltas. The location of the Preston River mouth has been moved about 800 m to the east as part of harbour developments which have been ongoing since the 1950s.

Prior to the 1950s the estuary was connected to the ocean via a narrow channel of about 3 km in length located at its southern end. The effect of such a narrow channel would have been to dampen tidal oscillations inside the estuary and therefore to limit the exchange of saline ocean water and fresh river water between the inlet and the sea throughout the year. As a result, in the winter the estuary was probably quite fresh, following the flushing of saline estuarine water, while in summer, due to evaporation, it would have been hypersaline. In 1951 a portion of the Leschenault Peninsula opposite the mouth of the Collie River was excavated, increasing the exchange of ocean and estuarine water (Schwinghammer, 1982). The effect would have been to reduce the extreme summer salinities and increase the winter salinities. Furthermore, the old connection to the ocean most probably formed a bottleneck causing the winter flood waters, coming down the rivers, to swell the estuary in the winter period which means that the estuary water levels were probably much higher in the winter/spring periods of the past than they are today. Should the original estuary mouth have had a sand bar then the initial winter water levels, prior to the breaching of the bar, would have been much greater than today. Therefore, after the creation of what is known as the Cut, mean water level of the estuary has probably decreased significantly.

In 1960 the Wellington Dam on the Collie River was completed. This dam has decreased both the duration of flow and magnitude of freshwater input to the estuary from the river (Schwinghammer, 1982).

Such environmental changes, should they have occurred, would be reflected in vegetation changes evident over the last 40 years.

2. THE STUDY AREA AND AIMS OF THE STUDY

The study area consists of the land along the estuary which supports fringing vegetation (Fig 2.1). Generally it includes all the land north-east of the harbour facilities, west of Cathedral Ave and Old Coast Rd and south of Buffalo Rd and the eastern foreshore of the Leschenault Peninsula. Although little fringing vegetation lies to the east of Cathedral Ave on the low floodplain which extends to a low ridge from 170 m in the south to 1500 m in the north, it was also examined.

The aims of the study were as follows:

1. To map the fringing estuarine vegetation of the estuary,
2. To compare the existing vegetation with that of the past as visualised using aerial photographs dating back to 1941,

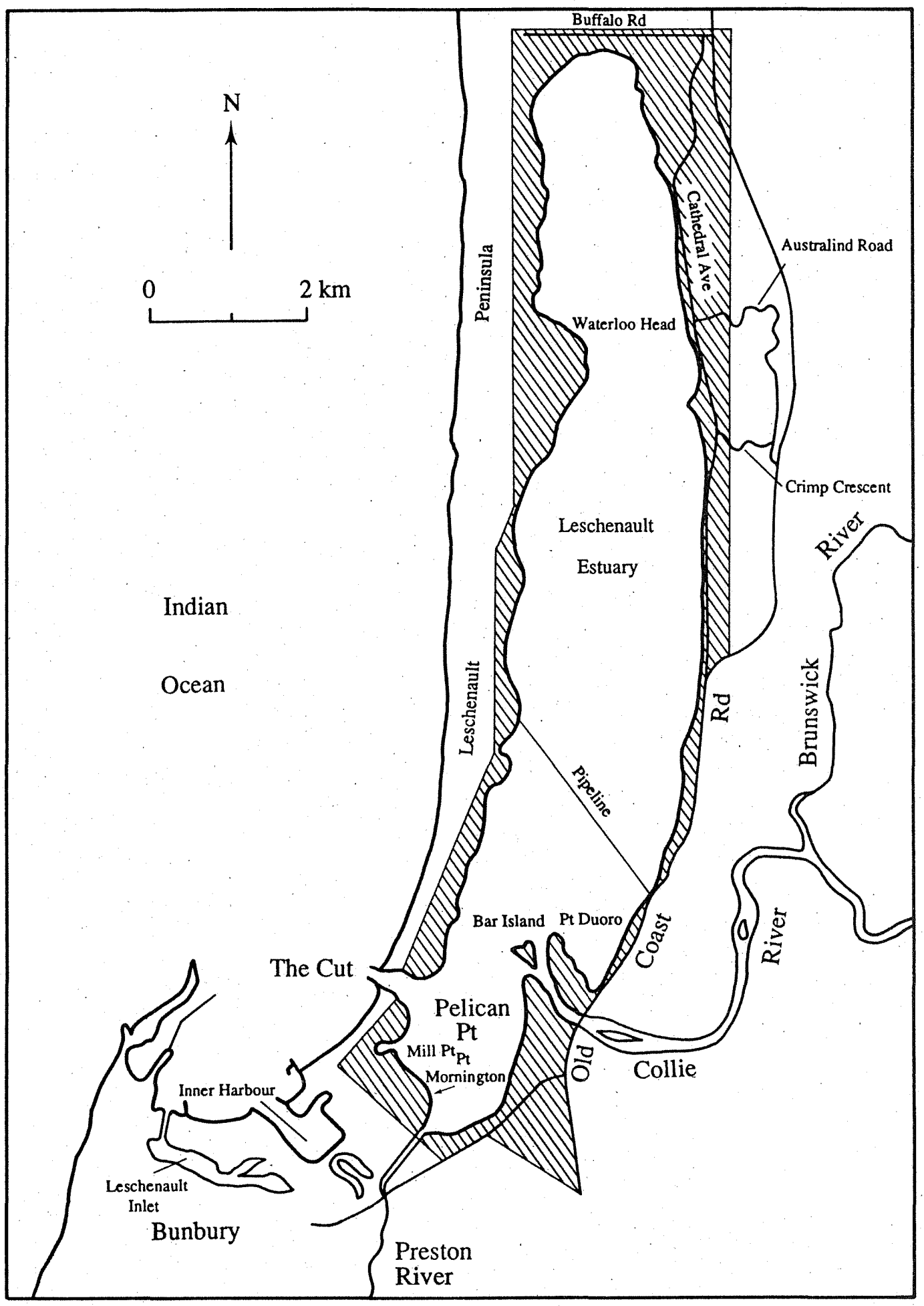

Figure 2.1: Leschenault Estuary Study Area. [2]

3. To identify the drainage network which may be responsible for vegetation changes over the last 50 years, and
4. To consider the quality of the vegetation and to make recommendations for conservation and rehabilitation.

3. MATERIALS AND METHODS

3.1 Vegetation description and mapping

Colour aerial photographs at 1:10 000 scale from the Department of Land Administration were obtained for the study area in 1989 (see Appendix 1) and sketchmaps were produced using a Ziess Aerosketchmaster to a 1: 5 000 scale. The sketchmaps were drawn up to convey information on the distribution of vegetation and vegetation type, standing water and landuse (e.g. pasture or urban).

The sketchmaps were then taken into the field on the May 24 and June 8 and 21, 1991 and annotated with relevant information on plant community composition and structure and weed infestations.

Unknown plant species were submitted to the WA Herbarium for identification.

Plant communities were identified and described on the same structural and dominant species basis as that used by Trudgen (1984) for his description of the Leschenault Peninsula vegetation. This was done to create a continuity of the description of the vegetation of the region.

3.2 Vegetation change

Vegetation changes over time were observed by comparing the present situation with that of the past utilising aerial photographs from 1941, 1966, 1975, 1977, 1982, 1986 and 1989 (see Appendix 1). Examples of such changes were documented by reducing vegetation maps of the distribution of the plant communities at particular places and times to the same scale using the Ziess Aerosketchmaster.

4. VEGETATION OF THE LESCHENAULT ESTUARY

The environmental relationships of the various estuarine plant communities have been investigated in the Swan and Peel-Harvey estuaries (Backshall, 1977; Pen, 1981). The plant communities of the Leschenault Estuary are very similar, and their distribution in relation to environmental factors, such as salinity, ground level (which largely determines tidal inundation) and freshwater flushing, can be inferred from observations of local conditions.

Fringing vegetation can be broken up into five categories: salt-marsh, estuarine fringing forest, fringing vegetation, sandy rise vegetation, freshwater vegetation including forest and disturbance related plant species assemblages.

Salt-marshes develop in areas which are saline either through tidal inundation directly or as a result of tidal inundation followed by evaporation of water trapped on the marsh by a shoreline levee. The latter effect seems more common along river channels where peripheral sediment deposition is greater (Pers. obs.). Estuarine fringing forest, typically of the small saltwater sheaok (*Casuarina obesa)*, saltwater paperbark (*Melaleuca cuticularis)*, paperbark (*M. viminea)* and swamp paperbark (*M. rhaphiophylla)*, occurs as the ground level increases and salinity levels, although high at times of the year, are not extreme. Fringing vegetation consists of those emergent species which live more or less permanently in shallow water. On the Swan the tall sedge, lake club-rush (*Schoenoplectus validus)* is an excellent example, where it forms 1-3 m bands 1-2 m from the shoreline. Sandy rise vegetation occurs on the margins of high coastal sand dunes or low estuarine beach dunes. Freshwater fringing vegetation occurs close to the estuary in areas receiving substantial freshwater input, either from surface inputs (i.e. drains, creeks) or from groundwater seepage which typically occurs at the base of a ridge or sand dune.

In areas subject to frequent disturbance plant assemblages may develop which are marked by an absence of native plant regeneration or a high degree of weed infestation and heterogeneity. For example, relic trees over parkland or pasture are largely prevented from regenerating because of continuous physical disturbance including grazing and therefore the population becomes increasingly aged. Another example of a disturbance related plant assemblage is an area where environmental conditions have not been allowed to reach an equilibrium because of changing land use over a period of many years. In this case, at any time, some native plant species are undergoing decline while others are becoming established or are enjoying great success and at the same time ephemeral weeds exploit opportunities for invasion, which may in the long term retard the regeneration of native species. Such assemblages of plants appear chaotic and contrast greatly with the homogeneity of native plant communities and the continuums which exist between them.

4.1 Salt-marsh vegetation

Bolboschoenus caldwellii closed sedgeland

The introduced club-rush (*Bolboschoenus caldwellii)*, is an ephemeral species which grows from rhizomes over the winter/spring period when salinities are low, and then subsequently senesces as salinities increase over summer and autumn (Brock and Pen, 1984). Small stands of this community are found along the Leschenault Peninsula (Trudgen, 1984), on the edge of pools or tidal lagoons. These stands were not of sufficient size for them to be properly mapped, although minor infestations of the species are marked on the maps.

Juncus kraussii closed rushland

Much of the southern half of the estuary is fringed at the water's edge with a dense band of shore-rush (*Juncus kraussii)* which grows to about 1.5 m in height. The samphires, *Sarcocornia quinqueflora* and *Suaeda australis* , are often found amongst it and sometimes the small saltwater sheoak (*Casuarina obesa)*, saltwater paperbark (*Melaleuca cuticularis*) and the shrub seaheath (*Frankenia pauciflora)* are found scattered across it.

This plant community also fringes salt-marshes on the landward side, a feature particularly apparent along the western foreshore. On the landward side bandsof shore-rush *(Juncus kraussii)* are often fringed with the sedges knotted club-rush *(Isolepis nodosa)* (see Section 4.5) or twig-rush (*Baumea juncea)* (see Section 4.4) and the herb, marsh saltbush (*Atriplex hastata).* Along the water's edge along the lower southern foreshore fringing bands of water couch (*Paspalum distichum*) are common.

Along the eastern foreshore, particularly in the middle region, the community is being invaded by the grasses *Cynodon dactylon* (couch) and *Pennisetum clandestinum* (kikuyu) and *Carpobrotus edulis* (pigface) (see Section 6.1).

Sarcocornia quinqueflora salt-marsh complex

This category contains four communities which are often impossible to delineate in the field as they merge over broad areas. The one feature which is common to all four communities is the present of the low decumbent samphire herb *S. quinqueflora.* These communities are:

> *Sarcocornia quinqueflora* closed herbland. This community is widely distributed around the estuary and basically takes the form of extensive mats of samphire (*S. quinqueflora),* either fringing the shoreline or behind a shoreline strip of shore-rush (*Juncus kraussii* closed rushland). The species seablite (*Suaeda australis),* seaheath (*Frankenia pauciflora),* streaked arrowgrass (*Triglochin striata), Samolus repens* (a perennial small herb with no common name), glasswort (*Halosarcia halocnemoides),* annual beardgrass (*Polypogon monspelliensis),* saltwater couch (*Sporobolus virginicus),* shore-rush (*J. kraussii)* can be common to sparse.
> *Suaeda australis - S. quinqueflora* closed herbland. The only difference between this community and the *S. quinqueflora* low closed herbland is that seablite (*S. australis)* is dominant.
> *Samolus repens - S. quinqueflora* closed herbland. In this case the small herb, *S. repens* dominates. This community is found fringing with the *S. repens* closed herbland.
> *Sarcocornia quinqueflora - B. caldwellii* closed herbland. In a few localities the seasonal sedge club-rush (*B. caldwellii)* grows through samphire (*S. quinqueflora)* mats over the winter/spring period and then senesces. At this time it forms the *S.quinqueflora - B. caldwellii* closed herbland.

Frankenia pauciflora - S. quinqueflora - S. australis low closed heath

Near the mouths of the Preston and Collie Rivers seablite (*Suaeda australis*) and the samphire (*S. quinqueflora)* form a heath of about 0.5 - 1 m high with the shrub seaheath (*F. pauciflora).* Curiously a similar association occurs on the Swan estuary near the mouth of the Swan River at Maylands (Pen, 1981). Other species present include marsh saltbush (*A. hastata)* and saltwater couch (*S. virginicus).*

Triglochin striata closed herbland

This community, consisting of a monospecific stand of the perennial herb streaked arrowgrass (*Triglochin striata),* was not observed by the author, however Trudgen (1984) noted its presence along the Leschenault Peninsula.

Samolus repens closed herbland

This community consists of monospecific stands of the perennial herb *S. repens* and is found in small areas near the mouth of the Preston River (Map 18) and in large patches along the western foreshore (Maps 4 and 6).

Sporobolus virginicus grassland

The perennial creeping grass saltwater couch (*Sporobolus virginicus)* sometimes forms extensive mats, occasionally with the samphire *S. quinqueflora* and water couch (*P. distichum).* Examples are to be found at the north-eastern corner of the estuary (Map 8) and at Pelican Point (Map 17).

Halosarcia halocnemoides low open heath

The shrubby samphire glasswort (*Halosarcia halocnemoides)* is a small shrub rarely reaching 1 m in height. It forms a low open heath in the most saline regions of the salt-marsh (see Pen, 1981), growing over the samphire *S. quinqueflora*, seablite (*S. australis)* and saltwater couch (*S. virginicus).* Large stands of this community are found at the northern end of the estuary (Map 8) and south of Old Coast Rd near Pelican Point (Map 17).

Halosarcia indica bidens low open heath.

The shrubby glasswort *(Halosarcia indica bidens)* is a large shrub, reaching 2 m in height, which forms an open heath in high but saline regions of the salt-marsh (Pen, 1981). On the Leschenault Estuary this community also consists of the herbs seablite (*S. australis)*, marsh saltbush (*A. hastata)* and the samphire *S. quinqueflora* and the shrub seaheath (*Frankenia pauciflora).* On Pelican Point its understorey also includes another samphire (*Sarcocornia blackiana)* and glasswort (*Halosarcia syncarpa).* The latter species is found nowhere else in the study area and the former only occasionally in other areas of the southern half of the estuary.

Gahnia trifida open sedgeland

Coastal saw sedge is a large tufted sedge, which grows to 1.5 m, forms narrow bands on the fringe of salt-marsh bordering between saline and relatively freshwater soils. As such it could well be considered a marginal freshwater vegetation type. However, this species is also found as part of plant communities associated with more saline conditions and so this community has been identified as a marginal salt-marsh component. Stands are found at the north-eastern point of the estuary and at Pelican Point (see Maps 8 and 17).

4.2 Fringing vegetation

Schoenoplectus validus closed sedgeland

This tall weeping sedge, which reaches 2 m, forms a small narrow monospecific stand near the north - eastern end of the estuary (Map 9). Lake club-rush (*Schoenoplectus validus*) is often found growing in shallow water and for this reason is referred to as emergent.

Paspalum distichum low closed grassland

The introduced creeping grass water couch (*Paspalum distichum)* occasionally forms monospecific low grassy mats on beaches (Maps 1 and 2) and even more occasionally it forms extensive mats near salt-marsh or fringing forest vegetation where the soil is waterlogged (Maps 3 and 17). The species appears quite capable of tolerating the high salinities characteristic of the estuary.

Paspalum distichum - Bolboschoenus caldwellii close grass and sedgeland

A significant stand of club-rush (*Bolboschoenus caldwellii)* is present along the southern periphery of the Preston River mouth growing over a partially floating mat of water couch (*Paspalum distichum).*

4.3 Fringing estuarine forest vegetation

Avicennia marina closed scrub

The white mangrove *Avicennia marina* forms considerable stands of fringing forest in the nearby Leschenault Inlet which was once part of the narrow channel which connected the estuary to the ocean. On the estuary today the mangrove has only a very occasional presence and in only one site does it form anything like a fringing forest or as Trudgen(1984) recognised it, a scrub (see Map 6). Isolated mangrove trees are marked on the vegetation maps.

Melaleuca cuticularis low open-closed forest

The small saltwater paperbark *Melaleuca cuticularis* is typically found on the saline soils bordering estuaries (Marchant et al, 1987) and on the Leschenault estuary is mainly restricted to the northern part of the eastern foreshore (Maps 10 and 11). Here it forms long bands of forest mostly to the landward of salt-marsh or fringing shoreline rushes. Only a small stand is found on the north-western corner. The understorey mostly consists of shore-rush (*Juncus kraussii),* shrubby glasswort (*H. indica bidens),* samphire (*S. quinqueflora),* seablite (*S. australis),* saltwater couch (*S. virginicus)* and the tufted coastal saw sedge *G. trifida* are often present as are the introduced species wild aster (*Aster subulatus),* marsh saltbush (*A. hastata),* couch (*Cynodon dactylon),* water couch (*P. distichum)* and dock (*Rumex crispus*). The other small trees of the estuary, saltwater paperbark (*M. rhaphiophylla)* and saltwater sheoak (*Casuarina obesa),* are sometimes members of the upper storey, as is the large weed Port Jackson (*Acacia saligna).*

Melaleuca rhaphiophylla - M. cuticularis low open forest

In one locality near Crimp Cr on the eastern foreshore the small swamp paperbark (*Melaleuca rhaphiophylla)* shares the upperstorey with saltwater paperbark (*M. cuticularis)* forming a low open forest between shore-rush (*Juncus kraussii)* and landward pasture. Understorey species are essentially the same as the *M. cuticularis* low open - closed forest.

Melaleuca viminea low open forest

In saline sandy areas adjacent to salt-marsh or close to the foreshore the small paperbark (*Melaleuca viminea)* forms a community with a number of salt-marsh species which occupy the understorey. They include shrubby glasswort (*H. indica bidens)*, samphire (*S. quinqueflora)*, seablite (*S. australis)*, shore-rush (*J. kraussii)* and saltwater couch (*Sporobolus virginicus)* and sometimes seaheath (*F. pauciflora)*. Coastal saw sedge (*Gahnia trifida)* is also commonly present.

Melaleuca viminea low open - closed forest is found on the Collie River delta and near Crimp Cr (Maps 11, 16 and 17).

Casuarina obesa low open - closed forest

The small saltwater sheoak (*Casuarina obesa)* forms a low open - closed forest over seablite (*S. australis)*, samphire (*S. quinqueflora)* and shore-rush (*J. kraussii)* mostly, in areas of the southern quarter of the estuary especially along the river deltas and near the Cut. Other species in the understorey include coastal saw sedge (*G. trifida)*, water couch (*P. distichum)* and seaheath (*F. pauciflora)*. This forest is often found along the shoreline (see Maps 1,2,16,17 and 18).

4.4 Freshwater vegetation

Baumea juncea sedgeland

To the landward of the *J. kraussii* closed sedgeland, which fringes the shoreline along most of the south-eastern shoreline between Cathedral Ave and Point Douro, twig-rush (*B. juncea)* can be found fringing between the rush stand and the parkland grasses. Only seldomly does it form a band of sufficient depth to enable its recognition as a separate community. Unlike knotted club-rush (*Isolepis nodosa)* which is associated with sandy rises, twig-rush (*B. juncea)* is found in low lying areas apparently prone to freshwater flushing. Such areas were probably favoured for clearing and pasture development in past years, and as a consequence little of the *B. juncea* closed sedgeland remains today.

Melaleuca rhaphiophylla - Agonis flexuosa low open - closed forest

M. rhaphiophylla - A. flexuosa low open - closed forest (swamp paperbark and peppermint respectively) is found astride Cathedral Ave in the vicinity of Crimp Cr, either between high dry pasture or sandy rise vegetation and water logged pasture or between salt-marsh and the latter (Maps 10, 11 and 12). This situation suggests that this community is strongly associated with freshwater flushing from the landward side. Native understorey species such as Port Jackson (*A. saligna)*, mat grass (*Hemarthria uncinata)*, jointed twig-rush (*B. articulata)*, common sword sedge (*L. lcngitudinale)*, another tall sedge *L. angustatum*, giant rush (*Juncus pallidus)* and twig-rush (*B. juncea)* which are typical of freshwater conditions, strongly support this hypothesis, but fringing estuarine species, including shore-rush (*J. kraussii)*, knob sedge (*Carex inversa)* and coastal saw sedge (*Gahnia trifida)* are also present.

Numerous freshwater weeds are also present including bridle creeper (*Asparagus asparagoides)*, coast daisy bush (*Oxalsi pes-caprae)*, braken fern (*Pteridium aquilinum*), kikuyu (*Pennisetum clandestinum)*, an *Irridaceae* sp., arum lily (*Zantedeschia aethiopica)* and buffalo grass (*Stenotaphrum secundatum)*.

This community is also found between salt-marsh, mainly *J. kraussii* closed sedgeland, and sand dune vegetation, chiefly *Agonis flexuosa* woodland to low open - closed forest, along the north-western foreshore (Maps 6 and 7). Here, members of the dunal vegetation such as the shrubs basket fern (*Spyridium globulosum)*, *Acacia cochlearis* and cutleaf hibbertia (*Hibbertia cuneiformis)*, are occasionally present, and weeds are far less common than on the eastern foreshore.

Along the Leschenault Peninsula *M. rhaphiophylla - A. flexuosa* low open - closed forest is probably supported by freshwater flushing arising from the base of the sand dunes.

Melaleuca rhaphiophylla low open - closed forest

In some regions of the Swan River estuary where freshwater flushing is moderate swamp paperbark (*Melaleuca rhaphiophylla)* grows over dense shore-rush (*J. kraussii)*. Similarly on the Leschenault, *Melaleuca rhaphiophylla* low open - closed forest with a shore-rush (*J. kraussii)* understorey is found landward of the *J. kraussii* closed sedgeland, samphire communities or *M. cuticularis* low open - closed forest on the north-western foreshore (Maps 7 and 8). A small strip of this plant community is found along the north-western foreshore along Cathedral Ave.

4.5 Sandy rise vegetation

Jacksonia furcellata open - closed scrub

This plant community, which is dominated by the large shrub grey stinkwood (*Jacksonia furcellata)*, is found on sandy rises or small sand dunes located either along the beach front, as it is in the Pelican Point area, (Map 17) or behind a band of fringing rushes of shore-rush (*J. kraussii),* as it is just south the pipeline on the eastern foreshore (Map 15). Common understorey species included pigface (*Carpobrotus edulis)* and couch (*Cynodon dactylon)*. Less common species are the herb *Trachyandra divaricata*, harsh hakea (*Hakea prostrata)*, Port Jackson (*A. saligna)*, golden spray (*Viminaria juncea)*, saltwater couch (*Sporobolus virginicus)*, swamp paperbark (*M. rhaphiophylla)* and saltwater sheoak (*C. obesa)*.

Eucalyptus rudis - Melaleuca rhaphiophylla woodland

In the highest parts of Point Douro and Pelican Point and in some areas north and south the flooded gum (*Eucalyptus rudis)* forms a woodland with swamp paperbark (*M. rhaphiophylla)* (see Maps 16 and 17). The understorey of this vegetation type has been depleted of native species, probably as a result of the ravages of frequent fire and weed invasion. Mostly it consists of perennial veldt grass (*Ehrharta calycina)* and the herb *Trachyandra divaricata* along with a plethora of other weeds. Only some native species, including grey stinkwood (*Jacksonia furcellata)*, common sword sedge (*Lepidosperma longitudinale)*, shore-rush (*J.kraussii)* and knotted club-rush (*I. nodosa)*, remain today.

In some adjacent areas the understorey has been completely replaced by lawn for parkland development and only the relic flooded gum (*E. rudis)* trees remain (see Section 4.6).

Acacia saligna low closed forest

Along the north-eastern foreshore the small tree Port Jackson (*Acacia saligna)* is very common. Here it infests the native plant communities, pasture and road verges, probably as a result of frequent fires which favour many *Acacia* species, and in places these infestations are so severe that the species form a low closed forest. The best example occurs just north of Crimp Cr on the eastern foreshore (Map 11).

Juncus kraussii - Isolepis nodosa low closed sedgeland

Where the foreshore abutts a sand dune, as is often the case along the south - western side of the estuary, or a sandy rise, which is more commonly the case along the eastern foreshore, the knotted club-rush (*Isolepis nodosa)* is often found to the landward side of the *Juncus kraussii* closed rushland and along the western foreshore often merging with sand dune species such as red-eyed wattle (*Acacia cyclops)*, the large shrub *A. cochlearis*, coast daisy bush (*Olearia axilaris)* and cutleaf hibbertia (*Hibbertia cuneiformis).* Along the eastern foreshore much of the native vegetation on the landward side of the shore-rush (*Juncus kraussii)* has been cleared and replaced with parkland and as a consequence the *J. kraussii - I. nodosa* low closed sedgeland is often only present as a remnant narrow strip bordering lawn.

4.6 Other plant communities and vegetation types

The chaotic plant assemblage

Over large areas of Pelican Point the vegetation is too heterogeneous to enable the recognition of definite plant communities (see Map 17). A wide area of native and introduced species typical of saline and freshwater environments and a huge range of weeds are present. The more successful species include swamp paperbark (*M. rhaphiophylla)*, paperbark (*M. viminea)*, shore-rush (*J. kraussii)*, samphire (*S. quinqueflora)*, seablite (*S. australis)*, coastal saw sedge (*G. trifida)*, flooded gum (*E. rudis)*, marsh saltbush (*A. hastata)*, rye grass species (*Lolium* spp.), water couch (*P. distichum)* and couch (*C. dactylon).* It would appear that these areas are in a state of flux, probably brought about by a combination of factors including frequent fires, physical disturbance (as indicated by the irregularity of the ground surface) and frequent alteration to the salinity/freshwater flushing regime caused by the Cut, drains, nearby reclamation and the construction of Taylor Rd.

Melaleuca rhaphiophylla low closed (swamp) forest

Swamp paperbark *(Melaleuca rhaphiophylla)* forms patchy stands of closed forest over small lakes in the most north-eastern region of the study area (see Map 19).

Pastured woodlands

In some areas of the eastern and southern foreshores relic trees from past stands of forest and woodland communities remain over parkland or pasture grasses. A small stand of saltwater paperbark (*C. obesa)* trees over parkland can be found near Mill Point where it abutts a stand of *C. obesa* low open forest (Map 18). A large area of *M. rhaphiophylla - A. flexuosa* pastured woodland is found on the central eastern foreshore from Australind Road to the base of the ridgeline (Map 10). This suggests that the *M. rhaphiophylla - A. flexuosa* low open-closed forest was once far more extensive along the Leschenault Estuary than it is today. Peppermint (*Agonis flexuosa)* woodland is also found in the area but only in small patches (Map 15). Flooded gum (*Eucalyptus rudis)* pastured woodland probably representing the relic trees of the *E. rudis - M. rhaphiophylla* woodland, is found on Point Douro and to the north of the pipeline (see Maps 14 and 16). In the most north-eastern corner of the study area *Eucalyptus gomphocephala* (tuart) - *A. flexuosa and E. gomphocephala* pastured woodlands are found over relatively broad pastured areas.

5. VEGETATION CHANGES SINCE 1941

Figure 5.1 shows the location of sites where vegetation changes and one landform change have been documented in Figures 5.3 to 5.11.

5.1 Clearing of fringing vegetation

Figure 5.2 shows the approximate extent of fringing vegetation in 1941 (about 700 ha) and that which remains today (about 350 ha). The most substantial losses have occurred to the north of Buffalo Rd through clearing and drainage for agriculture and to the south where large areas, including much of the original estuary mouth have been reclaimed for harbour construction. Substantial stands of the glasswort (*H. halocnemoides)* low closed heath and fringing forests of most probably saltwater paperbark (*M. cuticularis)*, swamp paperbark (*M. rhaphiophylla)* and peppermint (*Agonis flexuosa)* have been lost north of Buffalo Rd. Much of the narrow strip of fringing vegetation along the eastern foreshore has been cleared on the landward side leaving an even more narrow strip today. However, on the Leschenault Peninsula the narrow band of fringing vegetation of the western foreshore remains largely intact.

Relic trees present over pastured floodplain along Cathedral Ave and south of Buffalo Rd, which falls within the study area, indicate that this area once supported swamp paperbark (*Melaleuca rhaphiophylla)* low closed forest, *M. rhaphiophylla - A. flexuosa* low closed forest, and forests and woodlands dominated by tuart (*E. gomphocephala)* and/or peppermint (*A. flexuosa)*. The parkland areas near Australind and Point Douro today support relic flooded gum (*E. rudis)*, strongly suggesting that these areas once supported small stands of *E. rudis - M. rhaphiophylla* forest.

5.2 Decline of estuarine fringing forest

A decline in fringing forest, particularly of saltwater paperbark (*M. cuticularis*) and swamp paperbark (*M. rhaphiophylla)* has occurred since before 1941. This can be seen quite clearly in the aerial photographs and confirmed by the observations of dead and dying trees in the field. In the north-western most corner of the study area the reduction in fringing forest has been

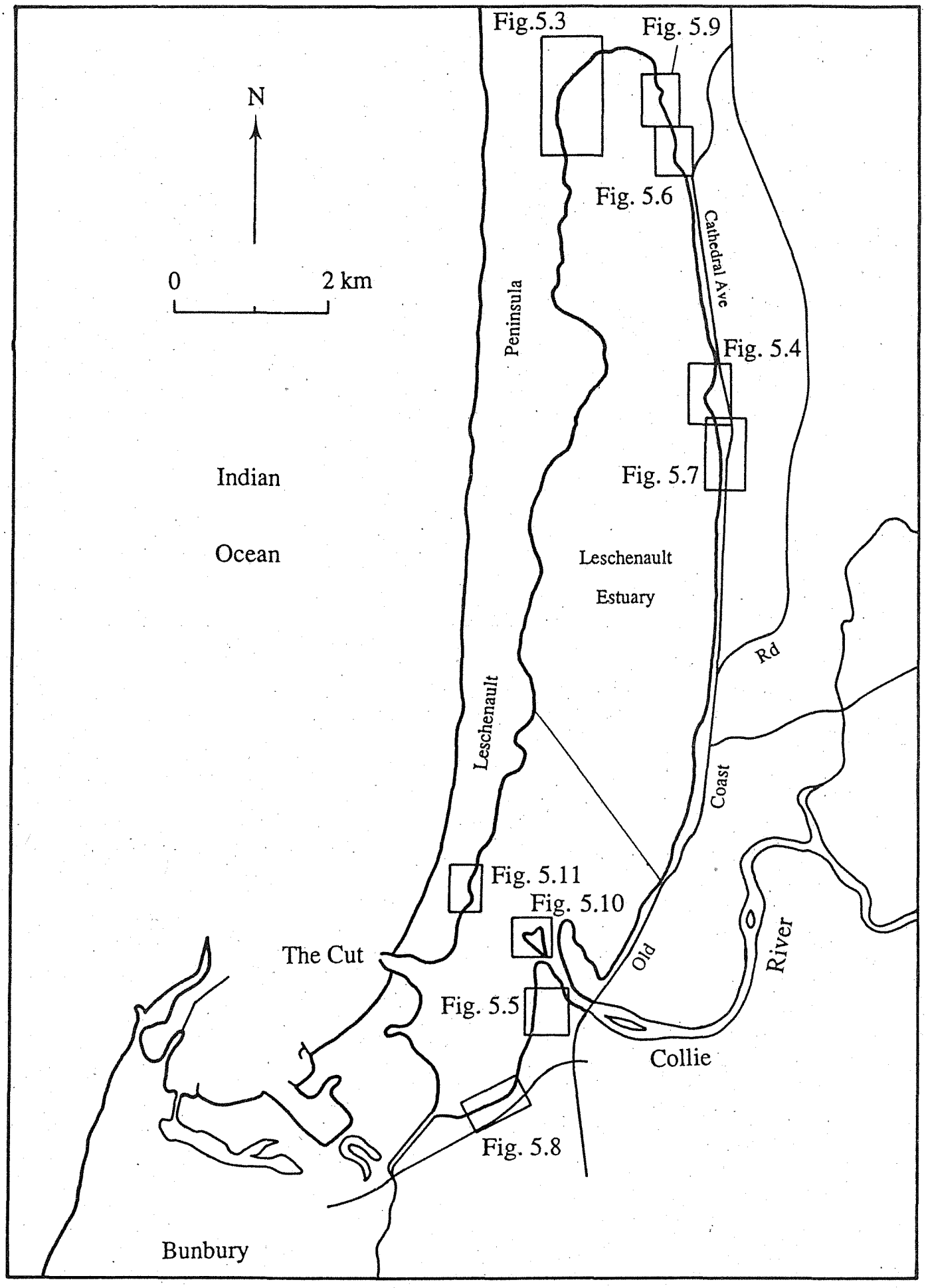

Figure 5.1: Location of sites where vegetation changes and one landform change have been documented.

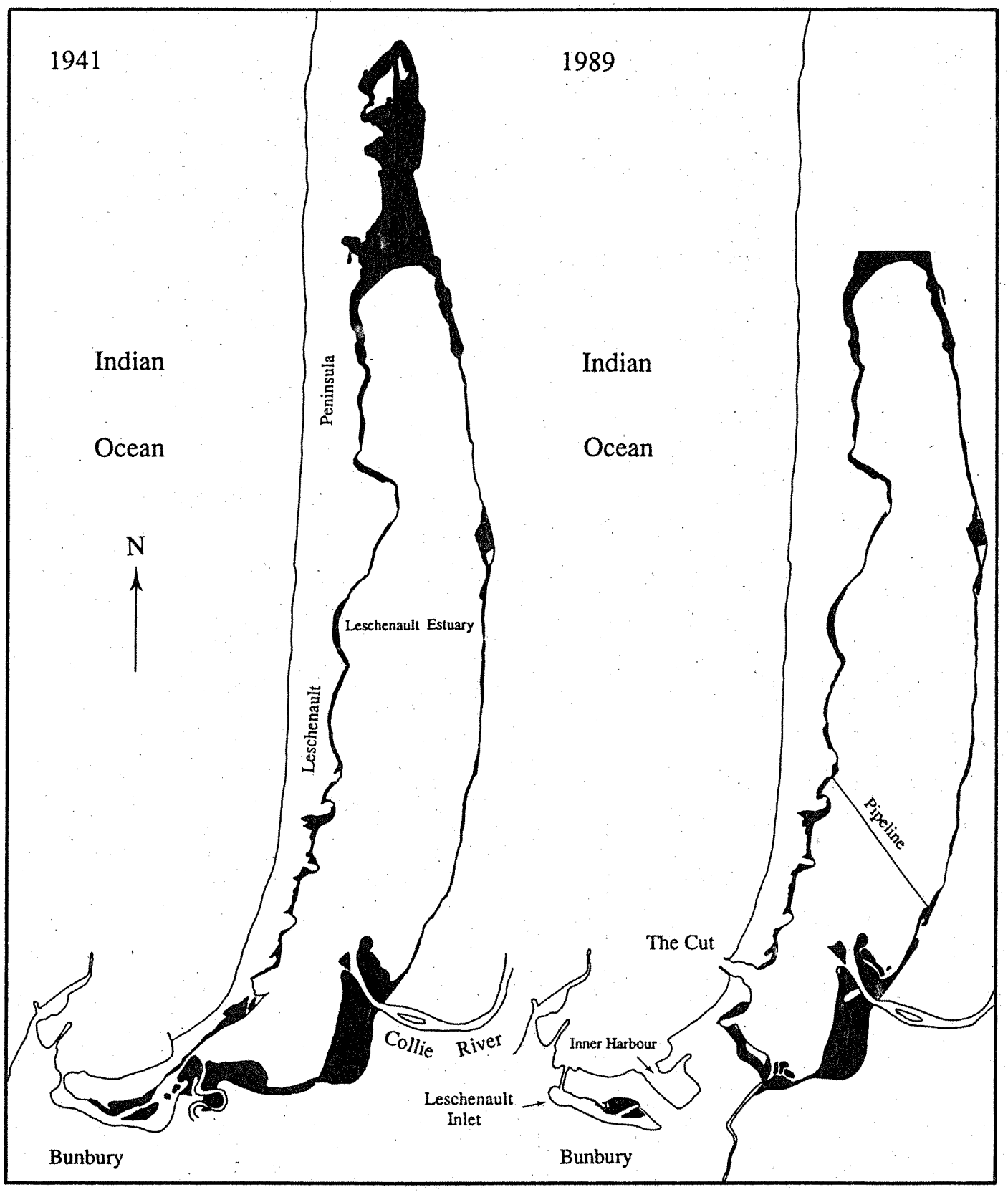

Figure 5.2: Extent of fringing vegetation along the Leschenault Estuary and the later Leschenault Inlet in 1941 and 1989.

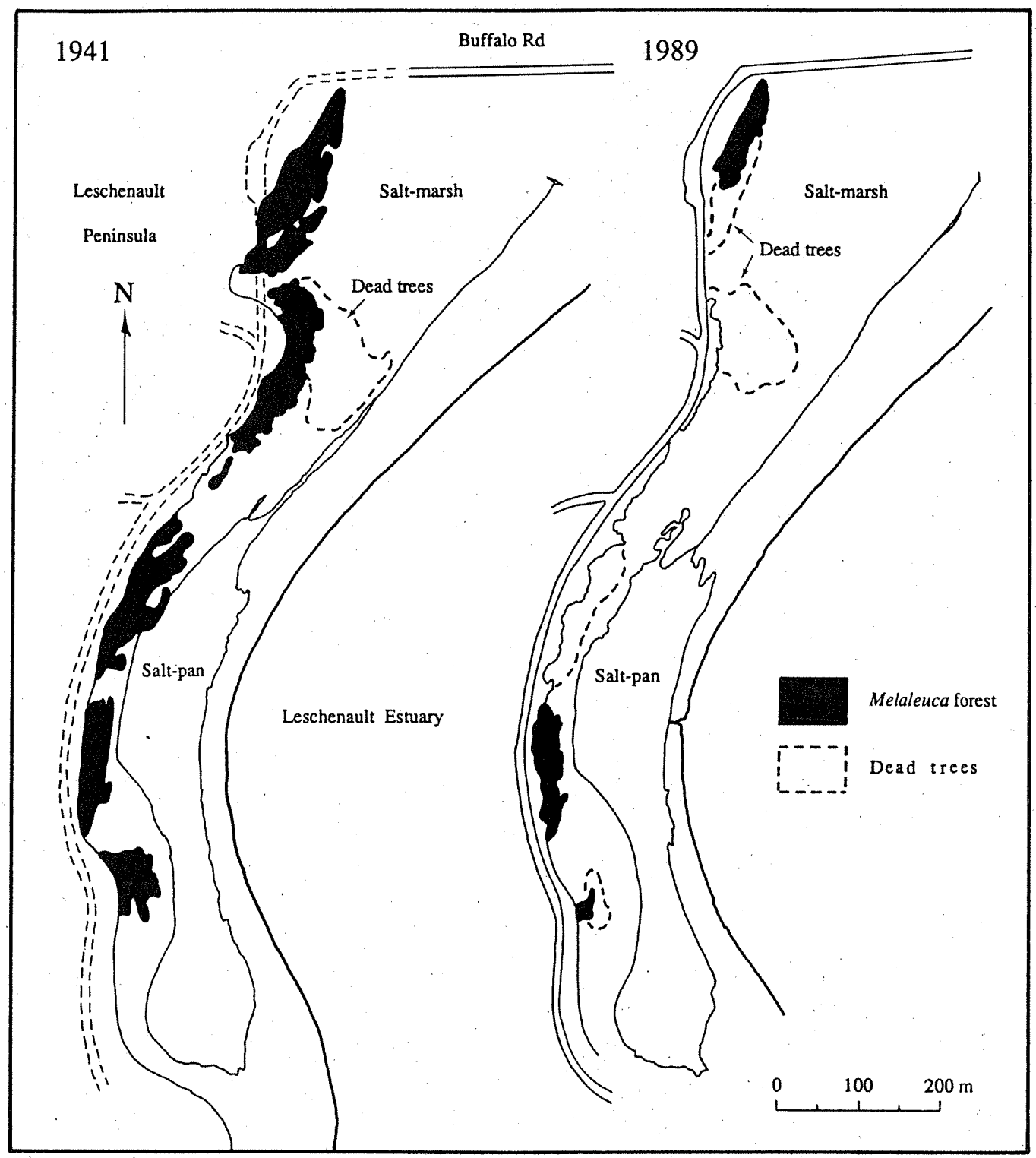

Figure 5.3: The extent of *Melaleuca* dominated forest in 1941 and 1989 in the north-western corner of the Leschenault Estuary (see Fig. 5.1).

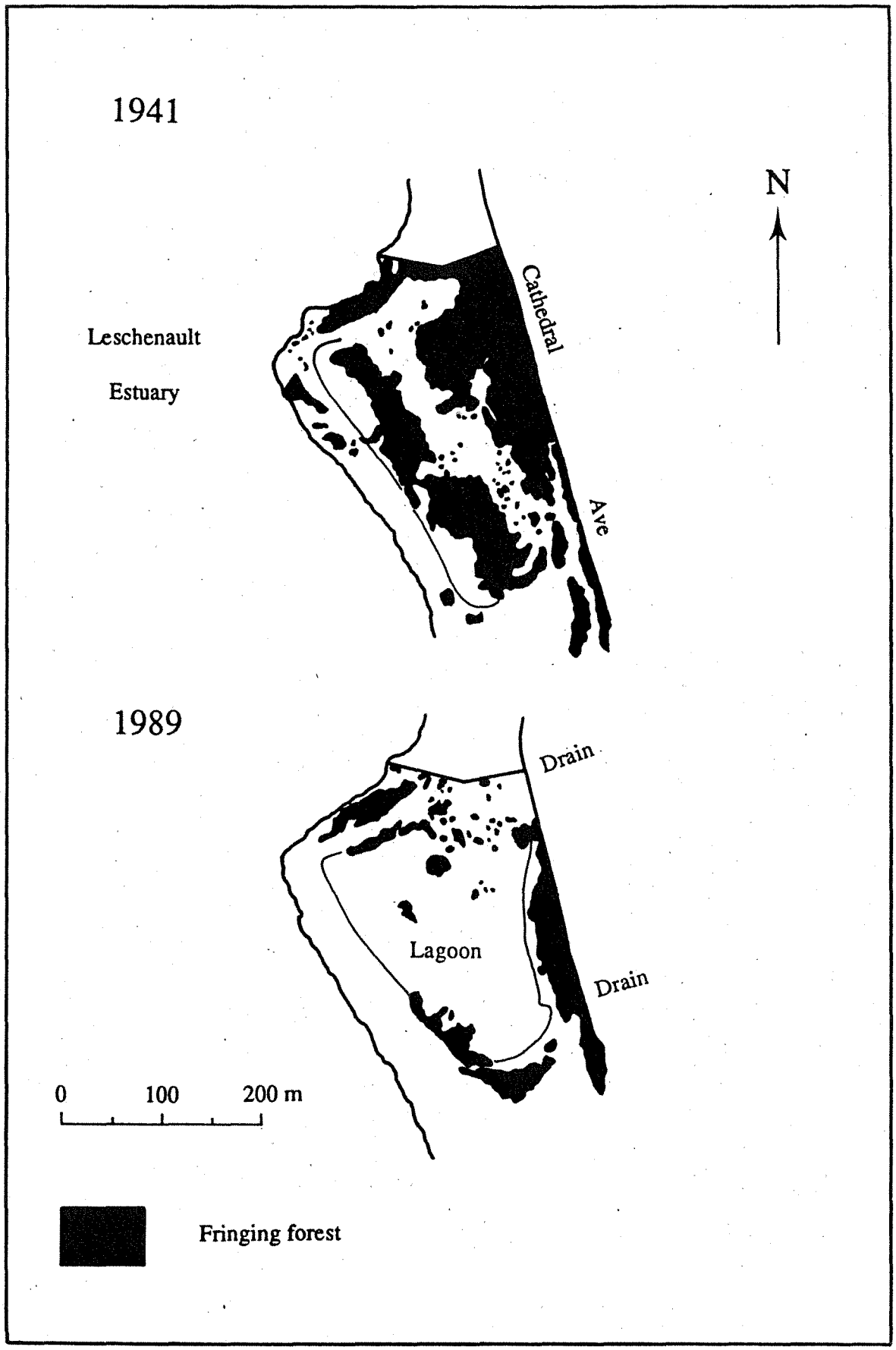

Figure 5.4: The extent of fringing forest in 1941 and 1989 around and on a tidal lagoon on the eastern foreshore of the Leschenault Estuary (see Fig. 5.1).

occurring since before 1941 as white tree stems are clearly evident in the photographs of that year (Fig 5.3). As this predates the Cut and no alteration to the drainage regime of the area is obvious, it is difficult to explain the decline of the forest. If it had been caused by a local increase in salinity, the neighbouring salt-pans, where salinity levels are at their most extreme and preclude all fringing plant growth, would have increased in size. However, they have largely remained unaltered since 1941.

The death of fringing forest in the lagoon area north of Crimp Cr is almost certainly due to a general increase in salinity brought about by artificial drainage (Fig. 5.4). This is also indicated by the death of shore-rush (*J. kraussii)* which very probably once formed the understorey of the forest, and its replacement by samphire species and by a stand of bulrush (*Typha)* in one corner of the lagoon. The replacement of shore-rush (*Juncus)* by samphire indicates a recent increase in salinity while the bulrush infestation suggests strong localised flushing caused by artificial drainage of the adjacent waterlogged pastures (see Map 11 for the location of the drains). In other words a steady year long flushing of the lagoon area by groundwater has been replaced by more centralised drainage, causing an increase in salinity over most of the area and a decrease in salinity in specific areas, probably at certain times of the year only.

The most dramatic decline in fringing forest has occurred in the central area of Pelican Point (Fig. 5.5). Here fringing forest of paperbarks (*Melaleucas)* has been replaced by salt-marsh and the chaotic plant assemblage (see Section 4.1). Once again this change has probably been brought about by alterations to drainage patterns in the area as part of urban development. The effect has been to shift the salinity/freshwater balance in the direction of increasing salinity, favouring salt-marsh at the expense of fringing forest.

There is some evidence of recent fringing forest regeneration. A small stand near Crimp Cr of paperbark (*M. viminea)* (Map 11) low open - closed forest, which is associated with very saline conditions, has been slowly growing in size since at least 1941. Furthermore, the presence of young trees of swamp paperbark (*M. rhaphiophylla)*, paperbark (*M. viminea)* and saltwater paperbark (*M. cuticularis)* indicate a resurgence of fringing forest in some parts of Pelican Point.

5.3 Encroachment of *Juncus kraussii* closed rushland upon the estuary

In most areas of the estuary where the foreshore is fringed with shore-rush (*J. kraussii)*, the species is growing into the estuary, moving across the samphire (*Sarcocornia quinqueflora)* complex beach sands or the sandy estuarine substrate. This can be seen clearly by the growth of rhizomes with tapering leaf height; the smaller leaves being present at the growing end of the rhizome. This pattern is repeated over and over again across the estuary. Figures 5.6 to 5.9 show considerable encroachment of shore-rush (*J. kraussii)* upon the estuary at four locations. Photographic evidence suggests a rate of growth into the estuary of the order of 5-20 m over the last 50 years.

This encroachment of fringing sedges and rushes may be caused by a reduction in mean water level over the winter months as a result of the Cut. This explanation is supported by further field observations. The first is that the rushes nearest the estuarine waters reside at a much lower level than those to

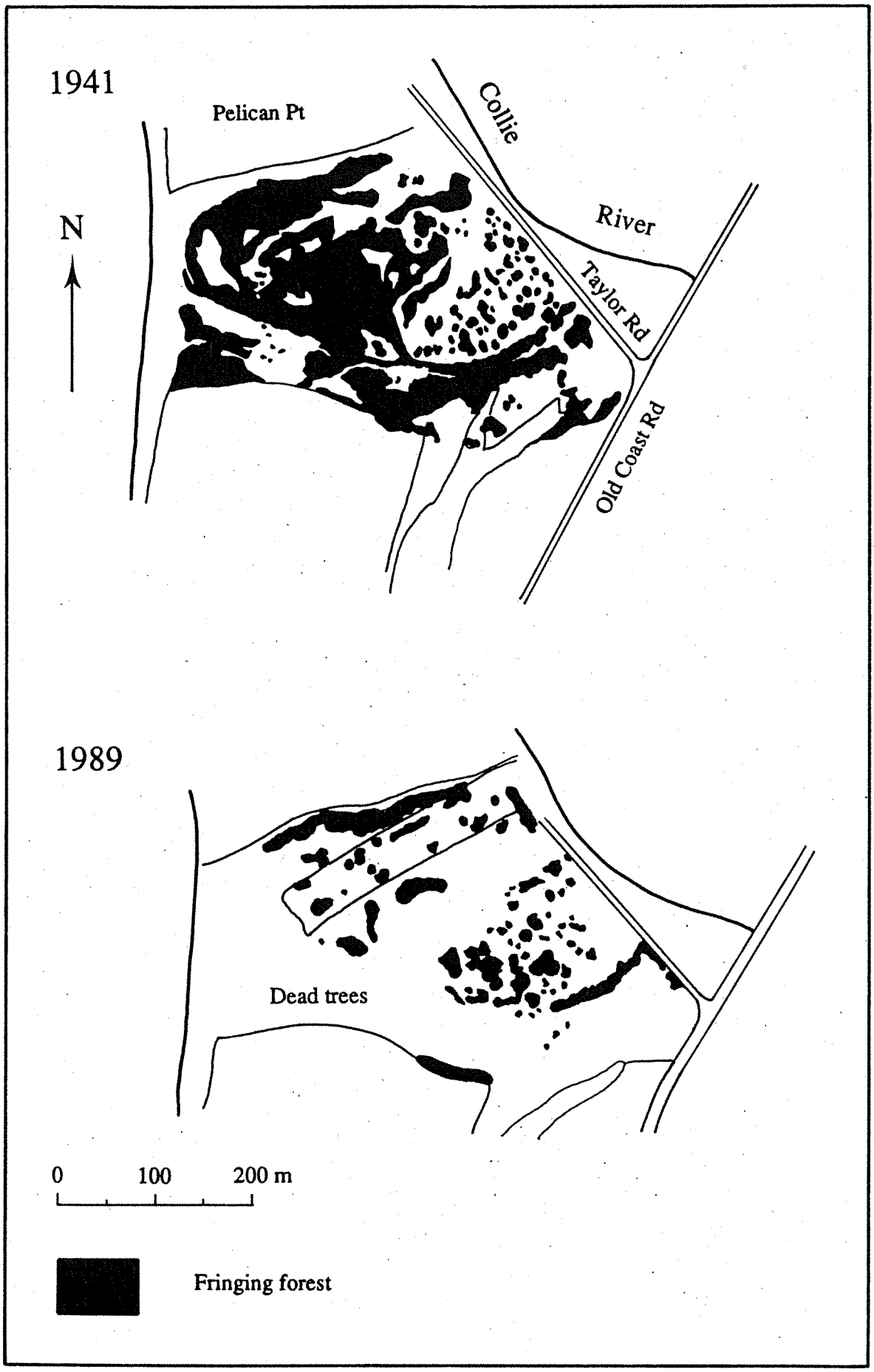

Figure 5.5: The extent of fringing forest in 1941 and 1989 in a small section of Pelican Point (see Fig. 5.1).

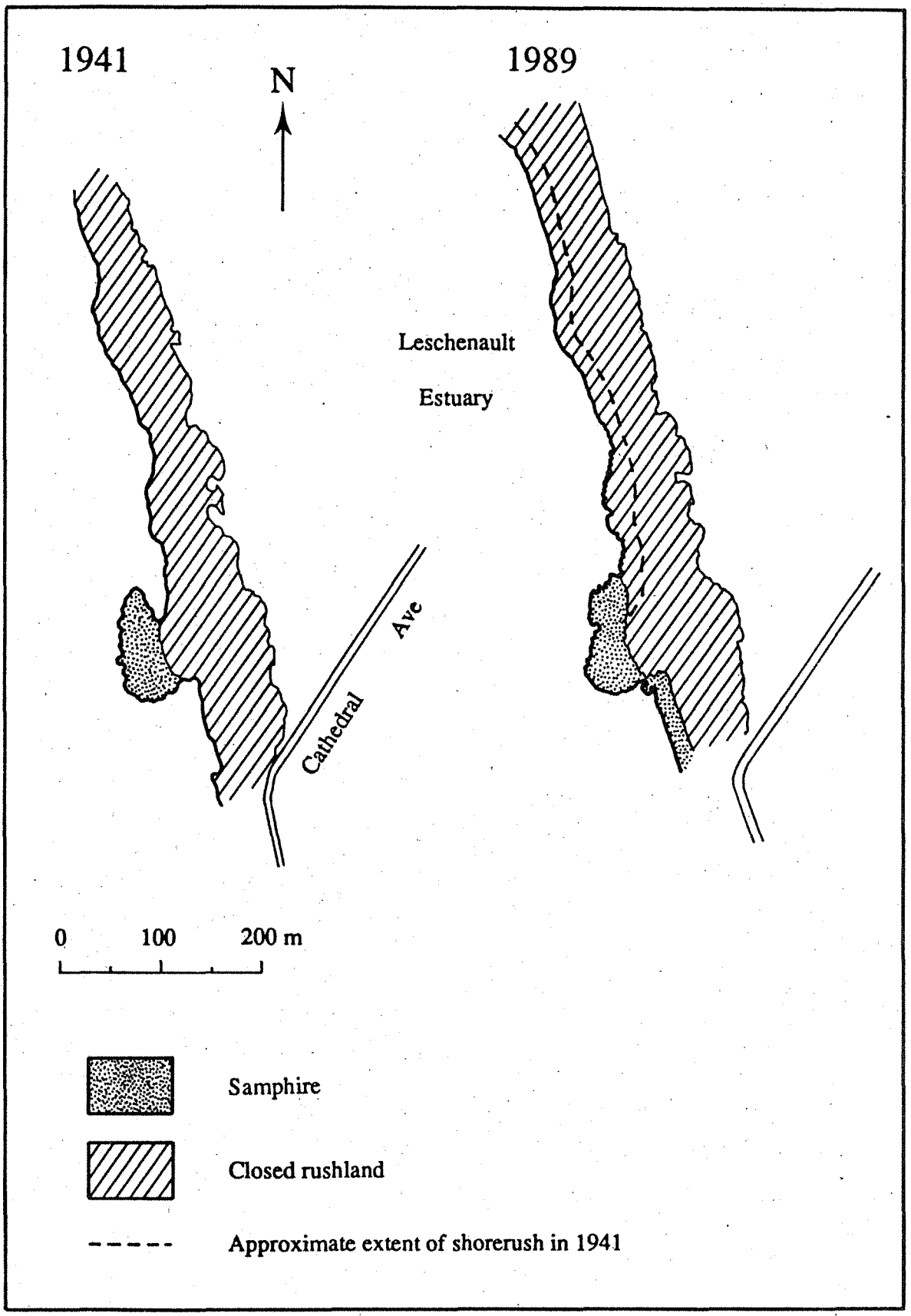

Figure 5.6: Extent of samphire and closed rushland in 1941 and 1989 along a region of the north-eastern foreshore of the Leschenault Estuary (see Fig 5.1).

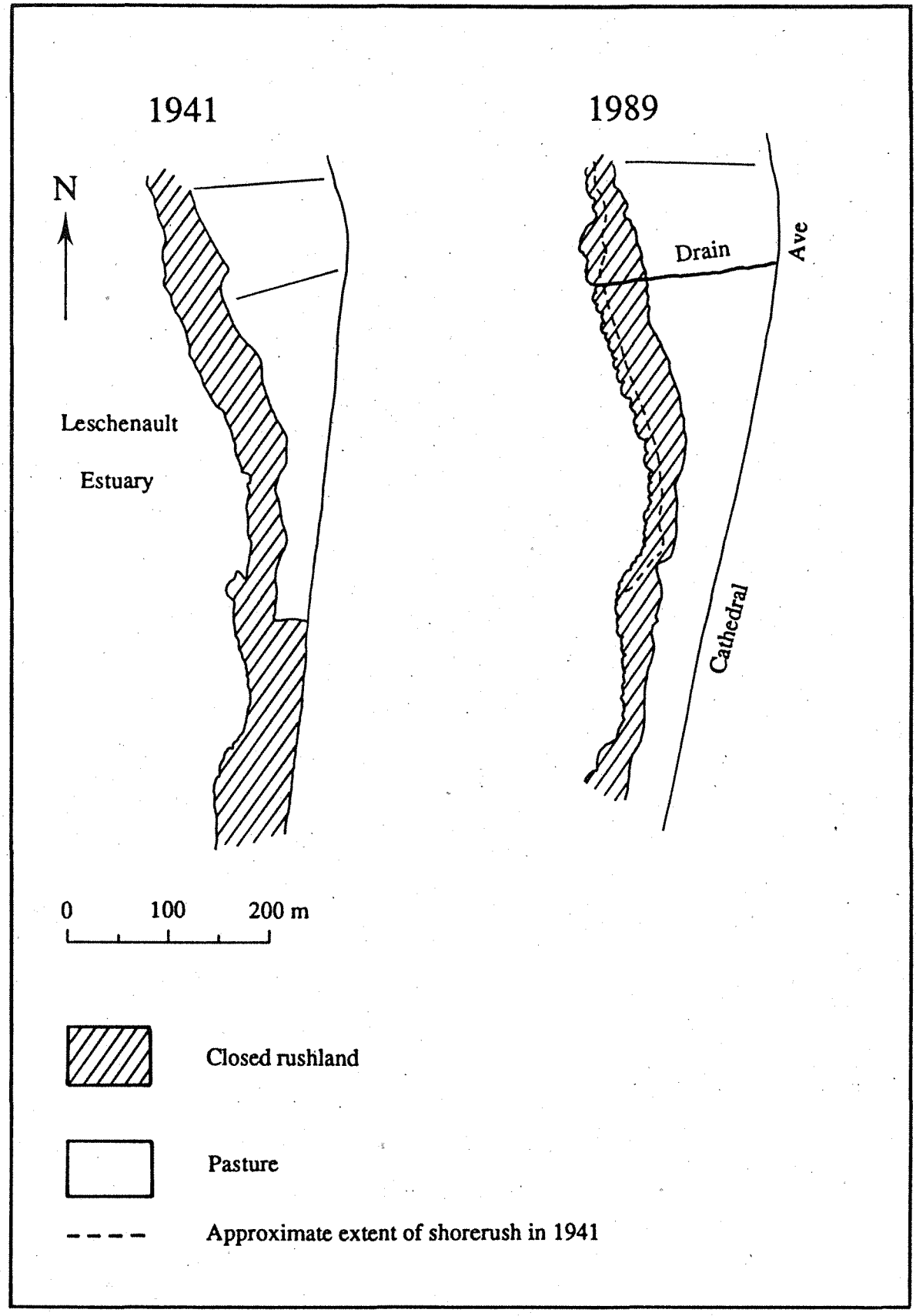

Figure 5.7: Extent of closed rushland in 1941 and 1989 in a region of the north-eastern foreshore of the Leschenault Estuary (see Fig. 5.1).

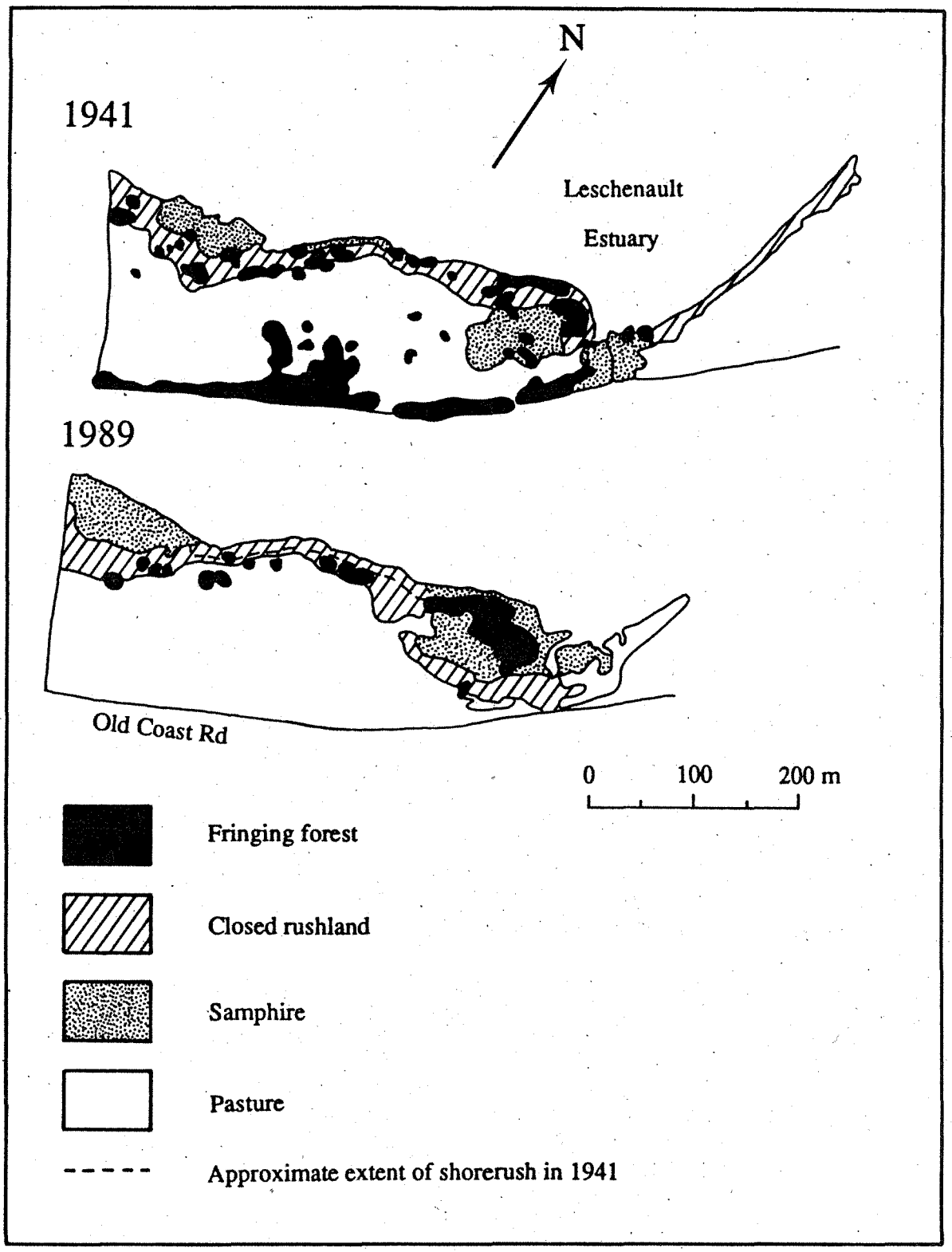

Figure 5.8: The extent of different plant communities in 1941 and 1989 in a region of the south-eastern foreshore (see Fig. 5.1).

the landward, indicating together with other observations, recent rush growth at a significantly lower level. The second observation is that of erosion and subsequent undermining of shore-rush (*J. kraussii)* along the south-western foreshore above the Cut. Here the 10-20 cm deep peat layer which supports the shore-rush (*Juncus*) is being undermined as waves or currents wash away the sandy substrate. Curiously in some areas shore-rush (*J. krausii)* has established in front of the erosion. A plausible explanation may be the following series of events. The reduction in mean estuarine water level increased the exposure of an area of sandy substrate which was until then relatively unexposed. Subsequently waves at low tide and possibly currents at high tide eroded the substrate eventually exposing and undermining the peat layer of the sedgeland. At the same time the reduced water level enabled shore-rush (*J. kraussii)* to become established, probably vegetatively, at a lower level of the estuary in front of the site of erosion. In other parts of the estuary, free of erosion, the shore-rush (*J. kraussii)* could simply colonise the new sites which had become favourable for growth by direct rhizome growth and indeed this would appear to be occurring.

Note that if the encroachment is due to the effects of the Cut that growth has occurred since 1951 and puts the growth rate at 5-20 m over the past 40 years.

Section 6.1 deals further with the possible consequences of the Cut and reduced mean water level of the estuary.

5.4 Colonisation of river deltas

Pen (1981) showed that the colonisation of recently deposited river sediments by fringing estuarine vegetation can be rapid. Figure 5.10 documents the colonisation by samphire of the sandy deposits at the north-western end of Bar Island, which has largely occurred since 1975. However, far more impressive colonisation by fringing vegetation has occurred on the recently formed Preston River delta and the enclosed mud-flats at Point Mornington. In these areas *Sarcocornia quinqueflora* complex and *J. kraussii* closed sedgeland completely colonised the low-lying mud flats over a ten year period since 1977 and presently *Casuarina obesa* low open forest is developing on the high central area on the east bank.

5.5 Formation of tidal lagoons or pools along the Leschenault Peninsula.

Along the southern foreshore of the Leschenault Peninsula there are a number of small tidal lagoons or pools. Figure 5.11 documents the process by which they are formed. Initially a blowout in a sand dune causes sand to be deposited in the estuary which is washed by a current moving in a north by north west direction causing the formation of a sand bar which entraps a body of water within a roughly triangular shaped area. Slowly over the years the fringing vegetation colonises this area and gradually encroaches upon the pool. Eventually, through the accretion of organic matter, the fringing vegetation colonises the entire area, forming a small triangular shaped salt-marsh of which there are many examples along the southern half of the Leschenault Peninsula.

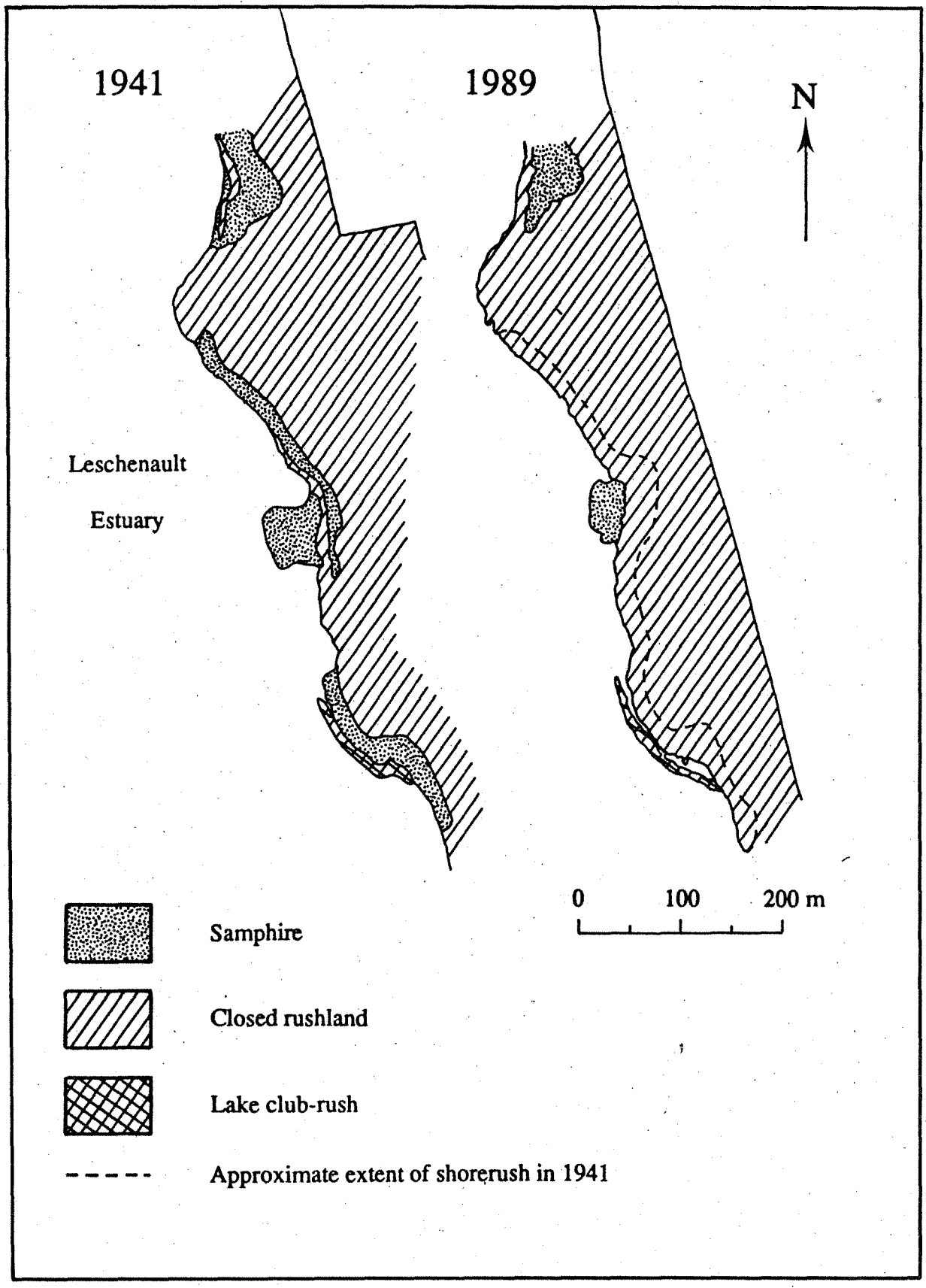

Figure 5.9: Extent of closed rushland and lake club-rush (*Schoenoplectus validus*) in 1941 and 1989 in a region of the north-eastern foreshore (see Fig. 5.1).

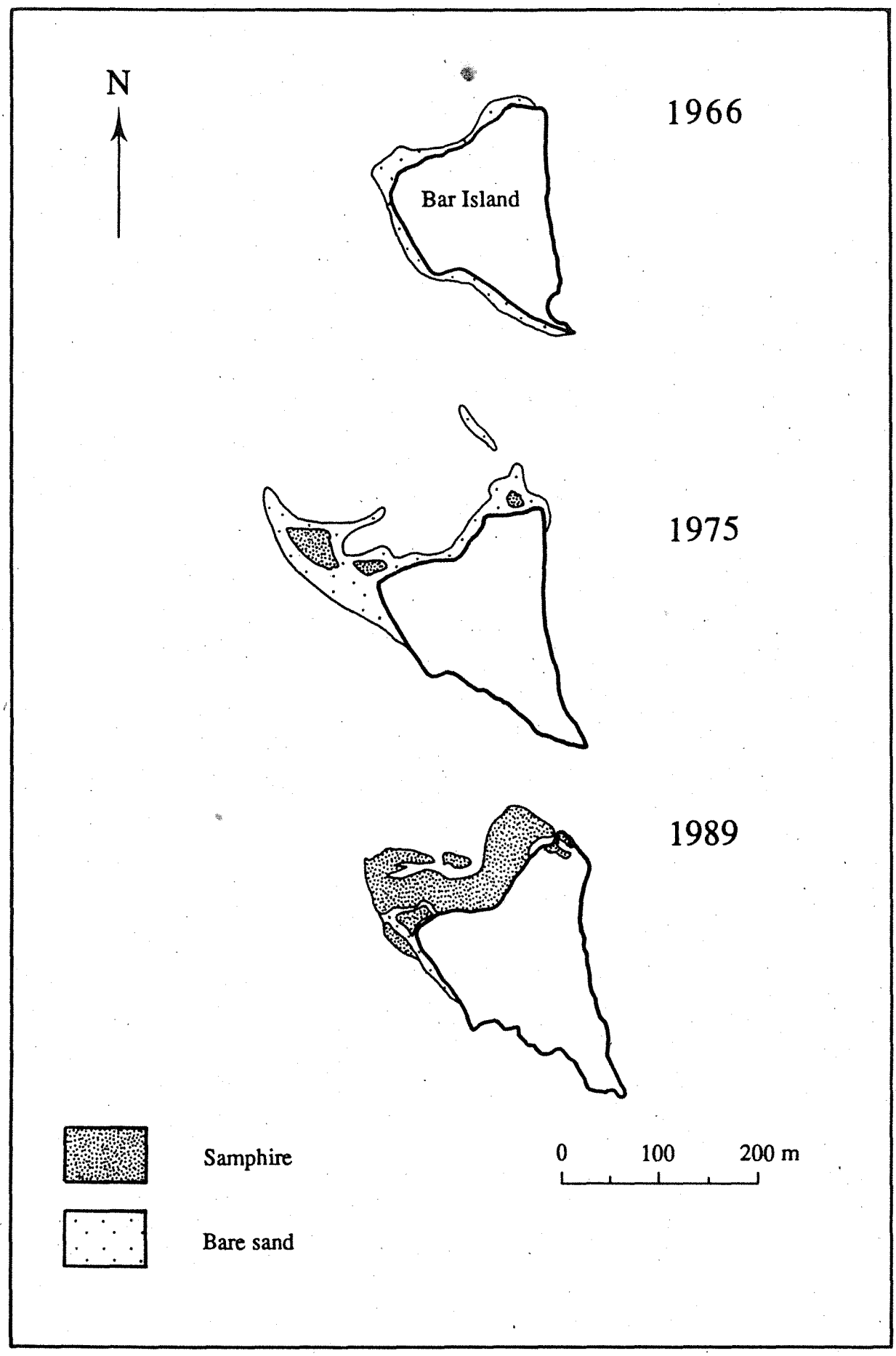

Figure 5.10: Colonisation of bare sand by samphire from 1966 to 1989 on Bar Island (see Fig. 5.1).

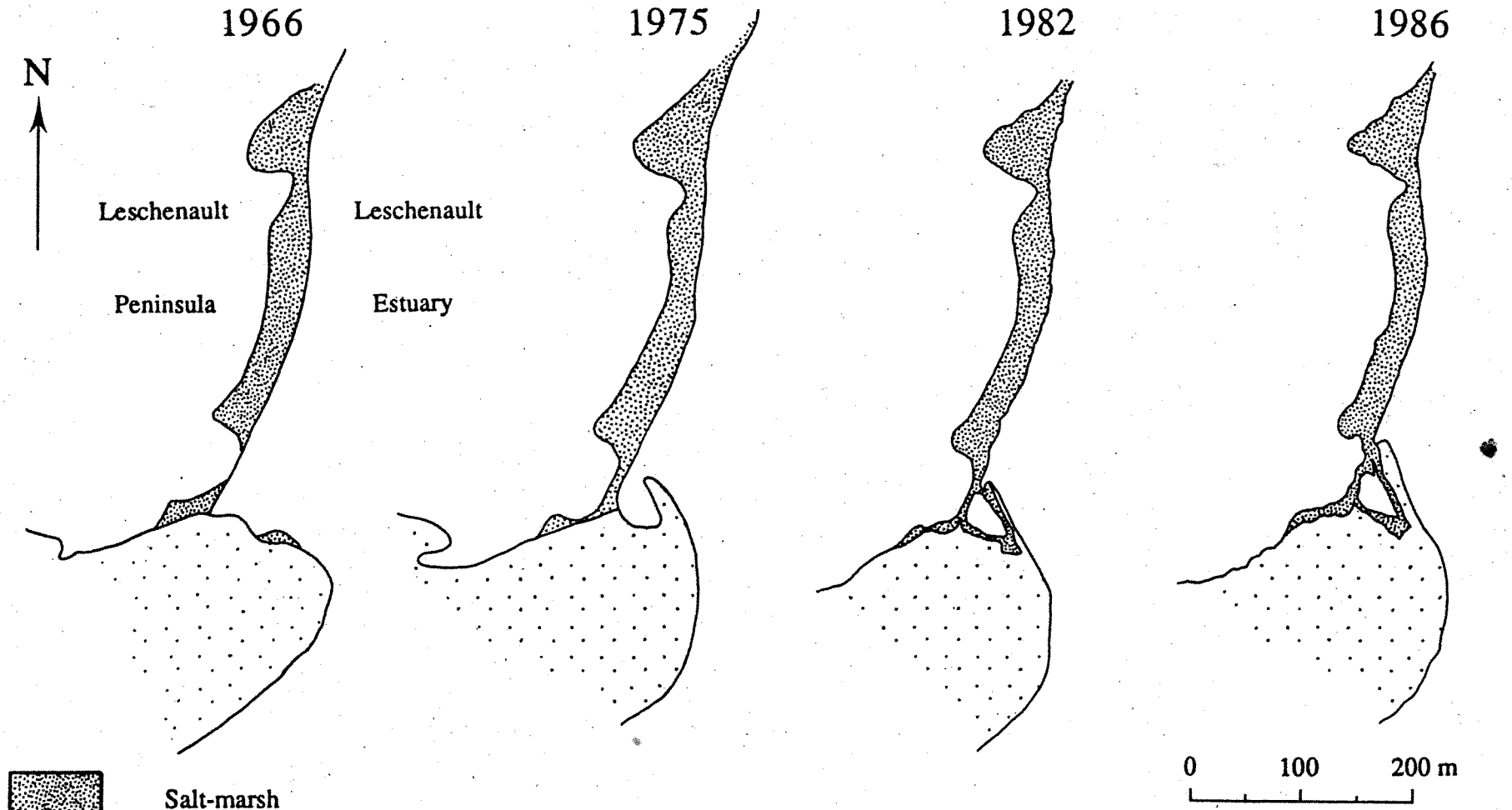

Figure 5.11: Formation of a tidal lagoon and subsequent colonisation by salt-marsh species in a region of the southern part of the Leschenault Peninsula (see Fig. 5.1).

6. WEED INVASIONS AND INFESTATIONS

6.1 Weed invasion of the *Juncus kraussii* closed rushland

Along the south-eastern foreshore grasses and other weeds are invading from the adjacent parkland into the landward side of the narrow shoreline strip of *J. kraussii* closed sedgeland. Chief among the weeds are couch (*Cynodon dactylon)*, kikuyu (*Pennisetum clandestinum)*, water couch (*P. distichum)*, buffalo grass (*Stenotaphrum secundatum)* and pigface (*Carpobrotus edulis)*. The shoreward side of the shore-rush (*J. kraussii)* sedgeland remains relatively free of weeds although water couch (*P. distichum)* often forms mats on areas of exposed sand.

A reduction in mean water level brought about by the Cut together with the clearing of the native vegetation behind the shore-rush (*Juncus)* strip and its subsequent replacement by grasses and other weeds provides an explanation for this weed invasion. A reduction in mean water level would not only mean that shore-rush (*J. kraussii)* could encroach upon the estuary but that the plant communities behind the shore-rush (*Juncus)*, probably dominated by twig-rush (*B. juncea)*, knotted club-rush (*I. nodosa)* and swamp paperbark (*M. rhaphiophylla)* could have encroached upon it. However, these communities, having been replaced by grasses and other weeds, have not been present to respond to the change in environmental conditions. Instead the weeds have responded and are slowly invading and replacing the shore-rush (*Juncus)*.

6.2 Local infestations

6.2.1 *Acacia saligna*

The small tree and native weed Port Jackson (*Acacia saligna)* is enjoying considerable success along the north-eastern foreshore where it is favoured by frequent fires (Wright, Pers. Comm.). It is a common member of freshwater fringing forest communities and has formed its own fringing forest in some areas (see Section 4.5).

6.2.2 *Typha orientalis* and *Bolboschoenus caldwellii*

On the Swan Estuary these two species are abundant, either fringing the rivers or invading salt-marshes receiving stormwater input. On the Leschenault their presence is as yet marginal. Bulrush (*Typha)* is present in some localities receiving freshwater input via drains or freshwater seepage at the base of sand dunes. Club-rush (*Bolboschoenus)* is found in a few localities fringing tidal pools and the Preston River. The distribution of these two species is limited to localised reductions in salinity and as such neither represents a major threat to the native plant communities at present.

Local infestations of these two species are shown on the vegetation maps.

6.2.3 *Paspalum distichum*

This species forms extensive grassy mats on beach sand and narrow mats in and about shore-rush (*Juncus kraussii)* on the immediate foreshore in some areas. Along the Preston River it forms dense partially floating mats and may be found in association with club-rush (*Bolboschoenus)* (see Section 4.2). In these forms it is a useful and complementary member of the estuarine fringing vegetation, as it helps to stabilise foreshore and does not appear to prevent the colonisation or regeneration of native species. However, further away from the foreshore it can be an invasive species contributing to the replacement of shore-rush (*Juncus)* on higher and dryer ground. It can also form dense mats in areas of salt-marsh receiving freshwater input, but its status as an invader in these circumstances is uncertain and requires further observations.

6.2.4 *Asparagus asparagoides*

The climber bridle creeper (*Asparagus asparagoides)* is abundant in the *M. rhaphiophylla-A. flexuosa* low open-closed forest north of Crimp Cr. On the Canning River this species is a troublesome weed and has the capacity to smother native shrubs and juvenile trees and could become a problem in this community.

7. DRAINAGE NETWORK - NORTH-EASTERN SIDE OF LESCHENAULT ESTUARY

The low-lying areas of pastured floodplain along Cathedral Ave north of Crimp Cr are drained by numerous ditches which, in most cases, run straight through to the estuary. Before the drains were dug the fringing vegetation would have presumably been flushed by the fresh water passing from this area. Today much of this water would be conveyed straight out to the estuary, but despite this change in the salinity/freshwater flushing regime there has been only one major change in the vegetation along the foreshore over the last 50 years. This vegetation change is, not surprisingly, of fringing forest to salt-marsh (see Section 5.2). The otherwise apparent absence of major change is probably because the volume of water which once passed through the area was at that time insufficient to reduce the highly saline conditions characteristic of most of the northern estuary (Glover, 1979), and thereby support plant communities associated with less saline conditions. As a result no general major increase in salinity brought about by the drains, through reducing freshwater flushing, has occurred. More minor changes, such as the replacement of *Juncus kraussii* closed rushland by *Sarcocornia quinqueflora* complex cannot be ruled out, but nothing significant was evident in the aerial photographs.

Local reductions in salinity along the periphery of the drains in the salt-marsh areas do not appear to have been sufficient to enable the establishment of aquatic weeds associated with freshwater conditions. Rather the salt-marsh species themselves have colonised them near the foreshore.

8. MANAGEMENT

8.1 Weed invasion of the *Juncus kraussii* closed rushland

The probable cause of the weed invasion of the *Juncus kraussii* closed rushland has been a reduction in tidal inundation of the foreshore since the construction of the Cut. This has probably rendered shore-rush (*Juncus kraussii)* less competitive against the abundant and vigorous invasive weeds of the neighbouring parklands. The solution in this situation is to plant those species which once occupied the conditions now favouring the weed invasion. Relic plants indicate that those species most suitable for planting include twig-rush (*Baumea juncea)*, knotted club-rush (*Isolepis nodosa)*, swamp paperbark (*Melaleuca rhaphiophylla)*, peppermint (*Agonis flexuosa)*, *golden spray (Viminaria juncea)* and flooded gum (*Eucalyptus rudis)*. Most important is the planting of trees which will preclude the establishment of many weeds through shading, while still enabling the native species to thrive. Short term weed control can be used to encourage the native species. A further breakdown of what species to plant and where to plant them is given in Section 8.4.

8.2 Maintenance of the existing drainage network along the north-eastern foreshore

The network of drains which now drain the area of floodplain along Cathedral Ave do not at the present time represent a major problem in terms of weed invasion (see Section 7). No significant invasion of fringing salt-marsh vegetation by weeds such as bulrush (*Typha)*, club-rush (*Bolboschoenus)*, wild aster (*Aster subulatus)*, rye grass (*Lolium multiflorum)* and annual beardgrass (*Polypogon monspelliensis)*, which are typical invaders along the Swan Estuary, has occurred along the foreshore in this area. Careful management of these drains will be needed to prevent any weed invasions arising from increases in discharge or from changes in the pattern of discharge.

Clearing drains of obstructions such as aquatic weed infestations or accumulations of sediment will ensure that stormwater is discharged directly to the estuary. While this will largely prevent the flushing of saline foreshore zones supporting salt-marsh or saline fringing forest and thus prevent weed invasions, it will also have the effect of maximising the nutrient loss from the pastured areas of the estuary which may contribute towards problematic algae growth. The establishment of native plant species along the peripheries of the drains and the creation of nutrient traps of aquatic plant species in pastured areas will cause a proportion of the nutrients to be taken up in plant growth and then, through the senescence of plant material, held for a time as peat or detritus.

Furthermore, the presence of native species will stabilise the peripheries of the drains and create wetland habitat.

The appropriate plant species for drain peripheries and nutrient traps are given in Section 8.4.

8.3 Considerations for conservation

8.3.1 Distribution of plant communities

All the plant communities and their species are not distributed across the whole estuary. For example fringing forests dominated by saltwater paperbark (*Melaleuca cuticularis)* and peppermint (*Agonis flexuosa)* are restricted to the north-eastern half of the estuary while forest or woodlands dominated by saltwater sheoak (*Casuarina obesa)* and flooded gum (*Eucalyptus rudis)* are restricted to the southern half. More importantly the samphire species *Sarcocornia blackiana* and glasswort (*Halosarcia syncarpa)* are best represented on the estuary at Pelican Point, although stands may be present on salt-marshes along the Collie River. Again the best stands of *Samolus repens* closed herbland are found along the Leschenault Peninsula.

The point to be made of the variation in the distribution of plant communities about the estuary is that the reservation of large areas in one region of the estuary only will not serve to conserve all the components of the estuarine fringing vegetation system. Today all the components of the system appear to be present on the estuary, although some, such as the mangrove (see Section 8.3.3), are in an extremely precarious position. Should any of the components disappear then the spatial and temporal system, by which one plant community replaces another over environmental gradients, will begin to breakdown. This occurs because the reduction or loss of a species on the estuary also reduces its capacity for regeneration through a decrease in the production of seed and vegetative material which enable colonisation. Two of the consequences of this, which are most troublesome to human activities, are weed invasion and soil erosion. Conservation, therefore, should aim to maintain representative stands of the various elements of the fringing vegetation.

8.3.2 Weed invasion and plant community replacement

In plant communities associated with freshwater conditions weeds are a serious problem and can only be dealt with by stabilising environmental conditions and encouraging native species by weed eradication and suitable plantings. On salt-marsh and in estuarine fringing forest weeds are less of a problem, their success being generally precluded by the saline conditions, and where they are successful their presence tend to be highly localised, as is the case with water couch (*Paspalum distichum)*, club-rush (*Bolboschoenus caldwellii)* and bulrush (*Typha orientalis)*. However, major reductions in the salinity of a salt-marsh can be brought about by increased freshwater flushing. On the Swan this has occurred where stormwater drains are allowed to empty into the vegetation rather than to run through it. At present the latter situation largely occurs on the Leschenault Estuary and there is little degradation of the salt-marshes. Conversely drains placed through the vegetation can replace freshwater flushing with the consequence that the previously flushed area experiences an increase in salinity, and at its most extreme results in a replacement of freshwater vegetation by salt-marsh. An example may be the decline of fringing forest and its replacement by samphire in the lagoon area north of Crimp Cr.

Replacement of plant communities through environmental change can also threaten the loss of components of the estuarine fringing vegetation.

8.3.3 Mangroves

The white mangrove (*Avicennia marina)* was once a conspicuous element of the estuarine fringing vegetation of the Leschenault Estuary. Today that section of the estuary which supports nearly all the mangrove stands has been separated from the estuary by the harbour development. Given that the species was favoured by the conditions present at the old mouth of the estuary there may be potential for the establishment of stands in the vicinity of the Cut, where similar conditions to that of the old mouth may exist. But today only a few trees are found on the estuary and they would only provide a tiny and probably inadequate amount of seed for further colonisation.

Consideration should be given to facilitating the establishment of the mangrove in the estuary. This could be done by collecting seed from the Inlet population and releasing it near the Cut over the long term. This would provide the opportunity for colonisation and for species to become a component of a functioning estuary.

8.4 Vegetation rehabilitation

The following is a list of the native plant species recommended for rehabilitation of the native vegetation, broken down into the various zones of the estuary foreshore and associated land. Those species which are rare or restricted in distribution should receive special attention. These species are denoted by the asterisk (*).

Immediate foreshore or beach

Juncus kraussii	shore-rush
Schoenoplectus validus *	lake club-rush
Sarcocornia quinqueflora	samphire
Avicennia marina * - especially near the Cut	white mangrove
Casuarina obesa - especially along rivers	saltwater sheoak

Salt-marsh - often inundated by the tide and fringing the estuary waters

Sarcocornia quinqueflora	samphire
Suaeda australis	seablite
Samolus repens	
Sporobolis virginicus	saltwater couch
Halosarcia halocnemoides	glasswort
Frankenia pauciflora	seaheath

High salt-marsh - only inundated at high tide but very saline

Halosarcia halocnemoides	glasswort
Halosarcia indica bidens	shrubby glasswort
Halosarcia syncarpa *	glasswort
Sarcocornia blackiana *	samphire
Melaleuca viminea	paperbark

Landward periphery of saltmarsh - receiving small freshwater input

Juncus kraussii	shore-rush
Gahnia trifida	coastal saw sedge
Melaleuca cuticularis	saltwater paperbark

Land adjacent to the saltmarsh or estuarine fringing forest - receiving considerable freshwater input

Melaleuca rhaphiophylla	swamp paperbark
Agonis flexuosa	peppermint
Viminaria juncea	golden spray
Juncus kraussii	shore-rush
Baumea juncea	twig-rush
Lepidosperma longitudinale	common sword edge
Lepidosperm angustatum	tall sedge

Small permanent freshwater pools

Baumea articulata	jointed twig-rush
Melaleuca rhaphiophylla	swamp paperbark

Sandy rises

Isolepis nodosa	knotted club-rush
Jacksonia furcellata	grey stinkwood
Jacksonia sternbergiana	green stinkwood
Hakea prostata	harsh hakea
Viminaria juncea	golden spray
Eucalyptus rudis - moist soils only	flooded gum

Base of the dunes along the Peninsula

Isolepis nodosa	knotted club-rush
Lepidosperma angustatum	tall sedge
Spyridium globulosum	basket brush
Acacia cochlearis	
Hibbertia cuneiformis	cutleaf hibbertia
Agonis linearifolia	swamp peppermint
Melaleuca rhaphiophylla - damp conditions only	swamp paperbark

Winterwet pastured floodplain - i.e. area along Cathedral Ave north of Crimp Cr

Melaleuca rhaphiophylla	swamp paperbark
Melaleuca preissiana	moonah paperbark
Agonis flexuosa	peppermint

High pastured floodplain - i.e. north-east area cornered by Buffalo Rd and Old Coast Rd

Eucalyptus gomphocephala	tuart
Agonis linearifolia	swamp peppermint

The periphery of the freshwater sections of drains

Melaleuca rhaphiophylla	swamp paperbark
Agonis flexuosa	peppermint
Baumea juncea	twig-rush
Lepidosperma angustatum	tall sedge

The periphery of the saline sections of drains

Melaleuca cuticularis	saltwater paperbark
Casuarina obesa	saltwater sheoak
Sarcocornia quinqueflora	samphire
Juncus kraussii	shore-rush

Nutrient traps in pastured areas

Typha orientalis	bulrush
Typha domingensis - on the edge of very wet areas	native bulrush

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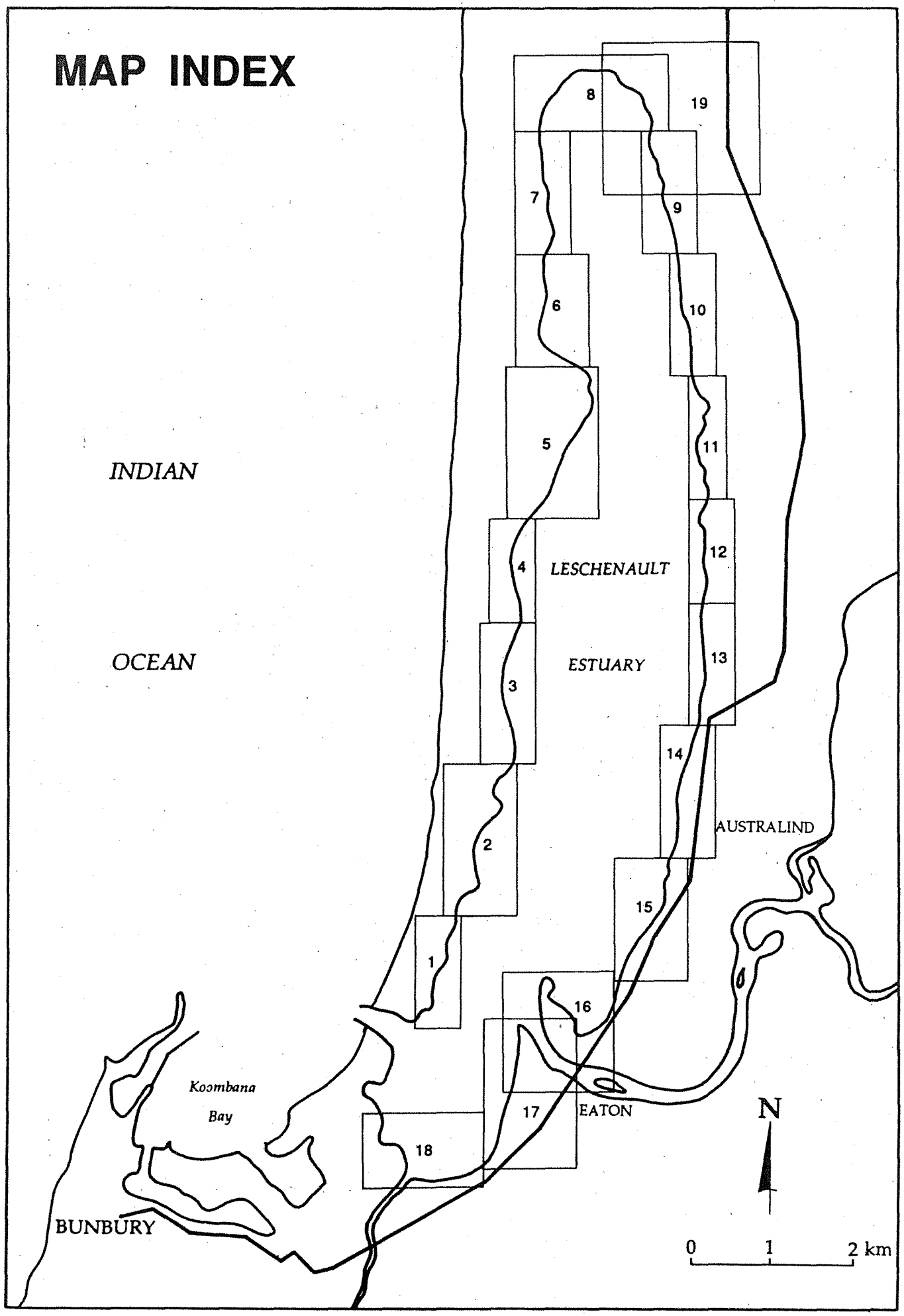
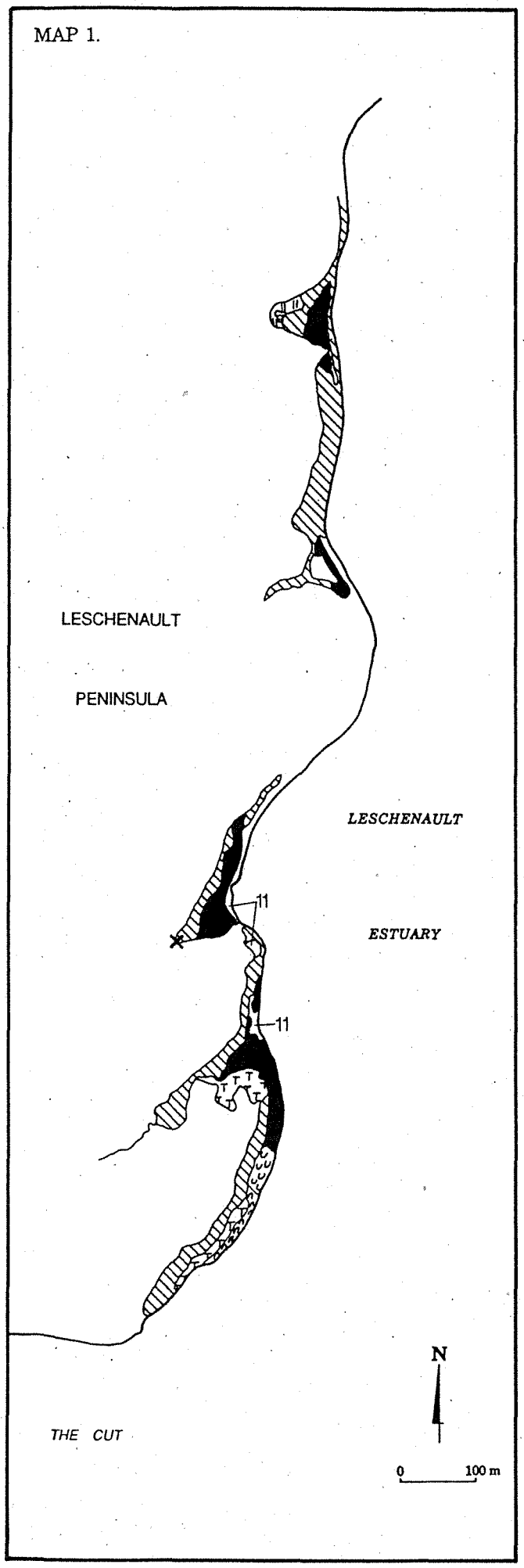
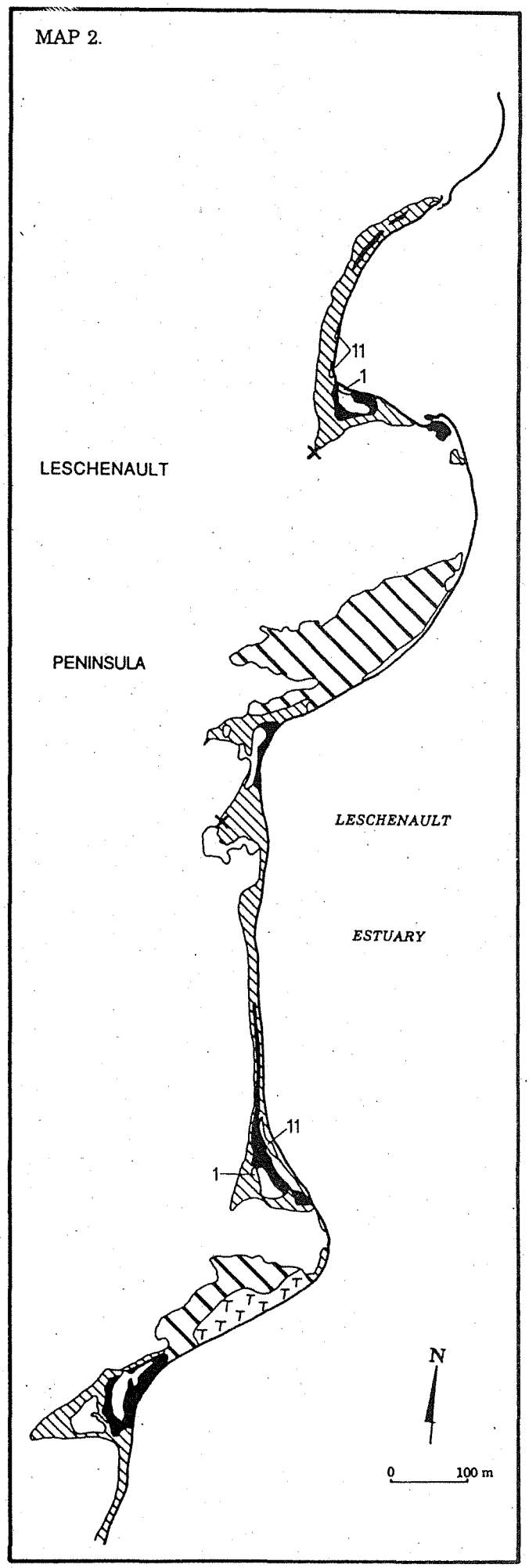

MAP INDEX
INDIAN
OCEAN
LESCHENAULT
ESTUARY
AUSTRALIND
EATON
Koombana
Bay
BUNBURY
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
N
0
1
2 km


MAP 1.
LESCHENAULT
PENINSULA
LESCHENAULT
ESTUARY
11
11
N
THE CUT
0
100 m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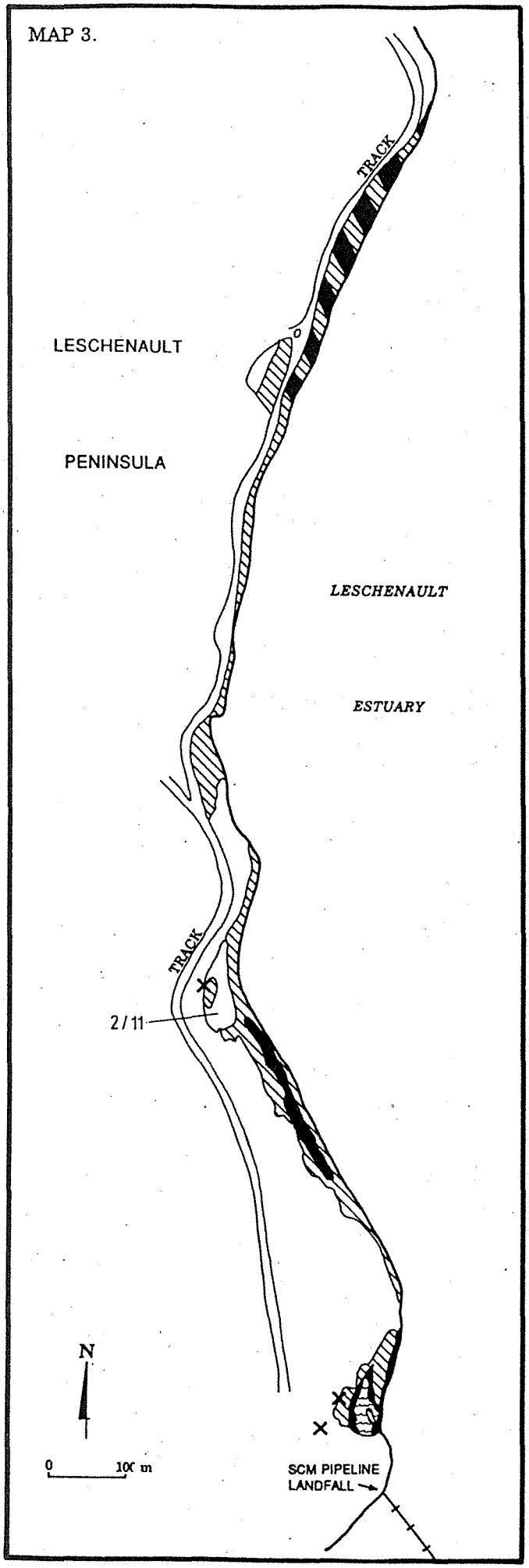
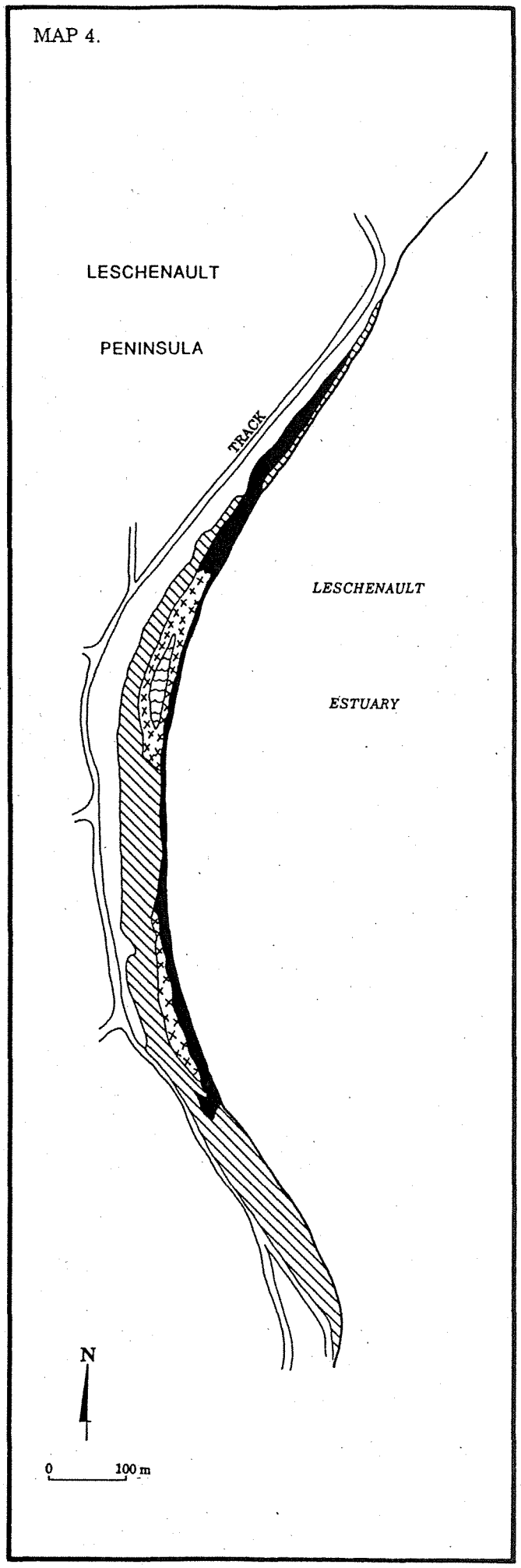
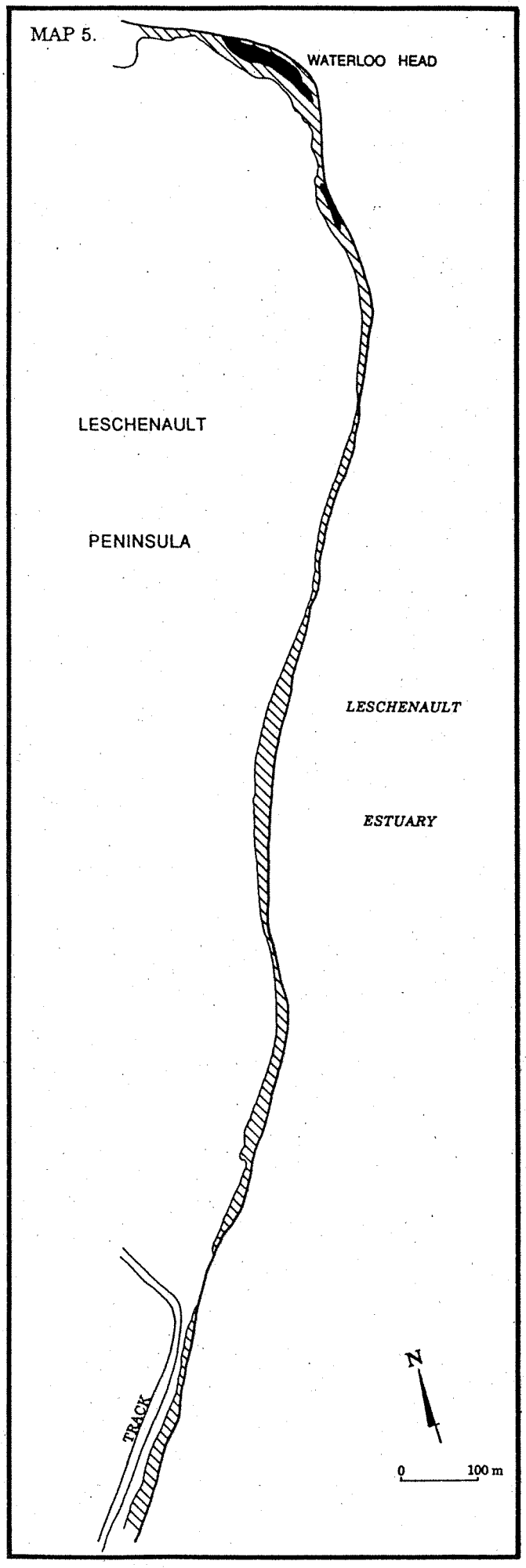
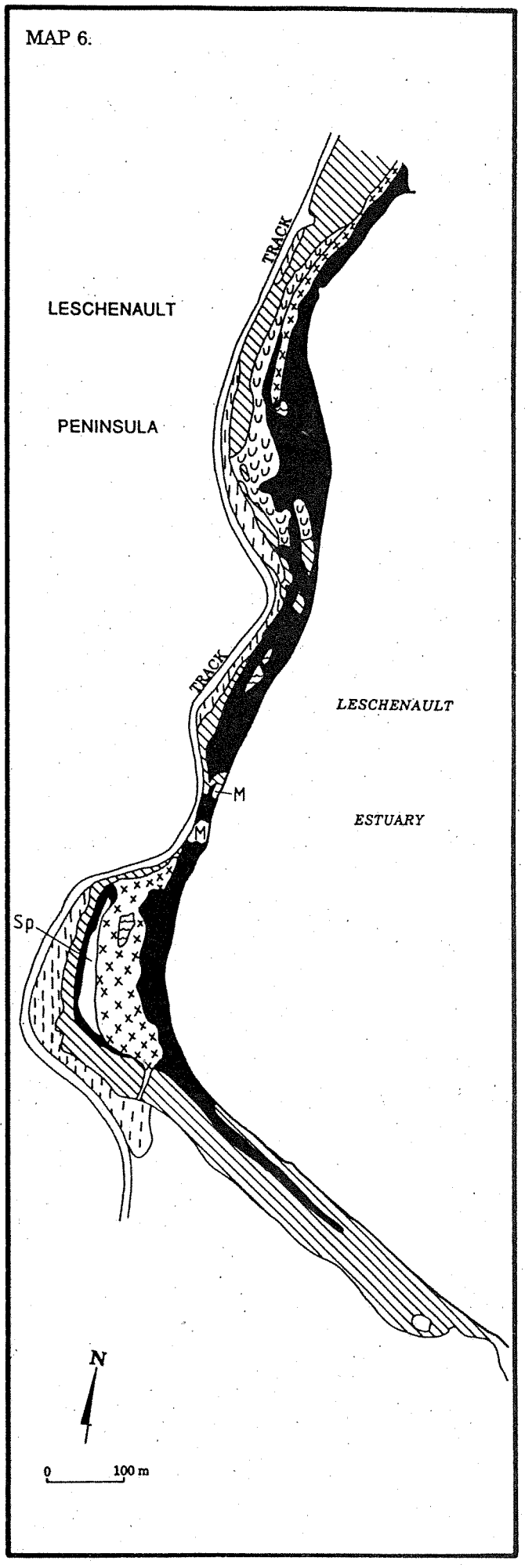
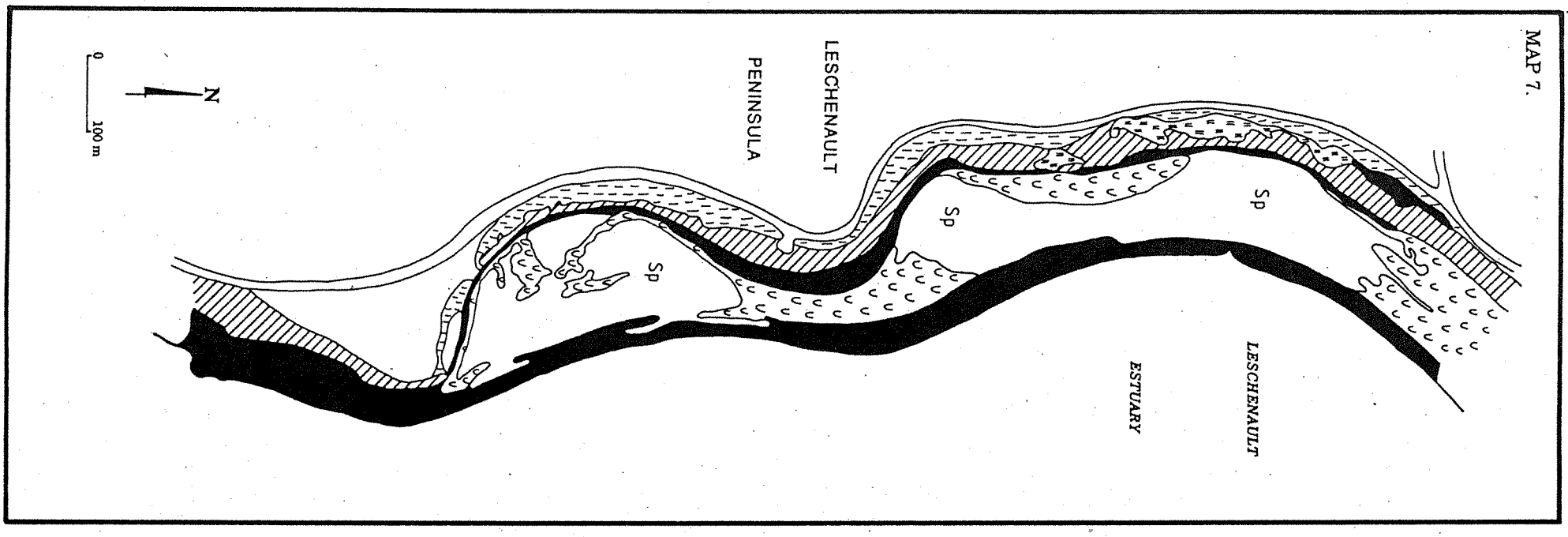
11
1
LESCHENAULT
PENINSULA
LESCHENAULT
ESTUARY
11
1
N
0
100 m

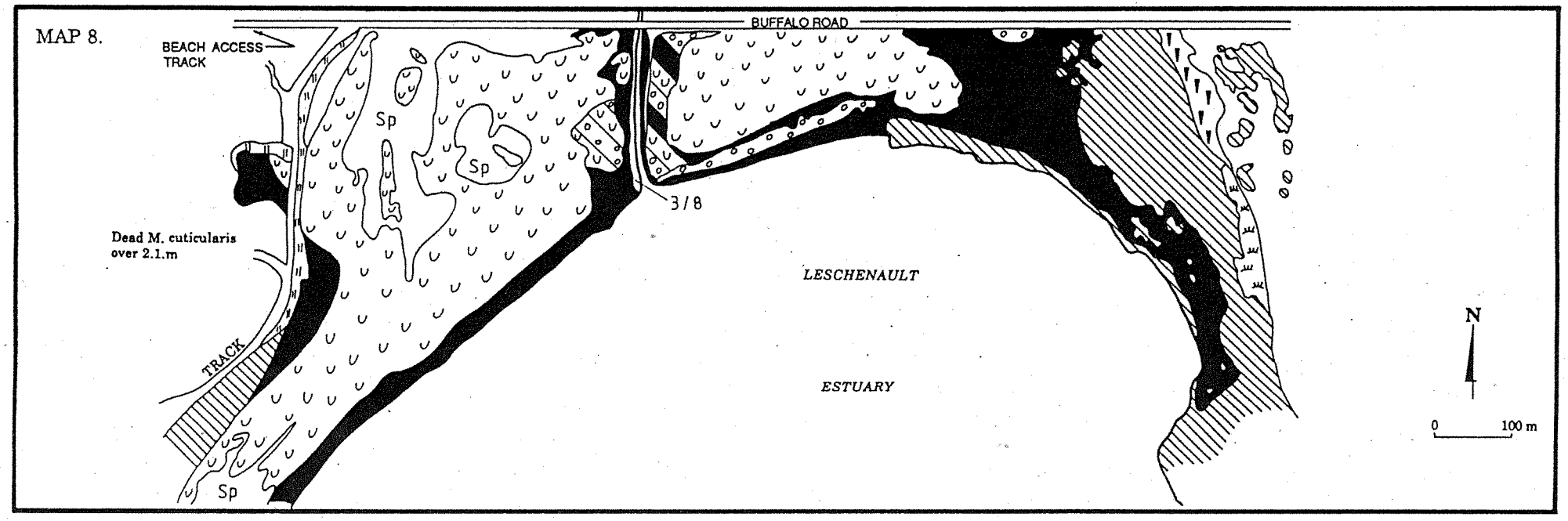

MAP 3.
TRACK
LESCHENAULT
PENINSULA
LESCHENAULT
ESTUARY
TRACK
2/11
N
0
100 m
SCM PIPELINE
LANDFALL

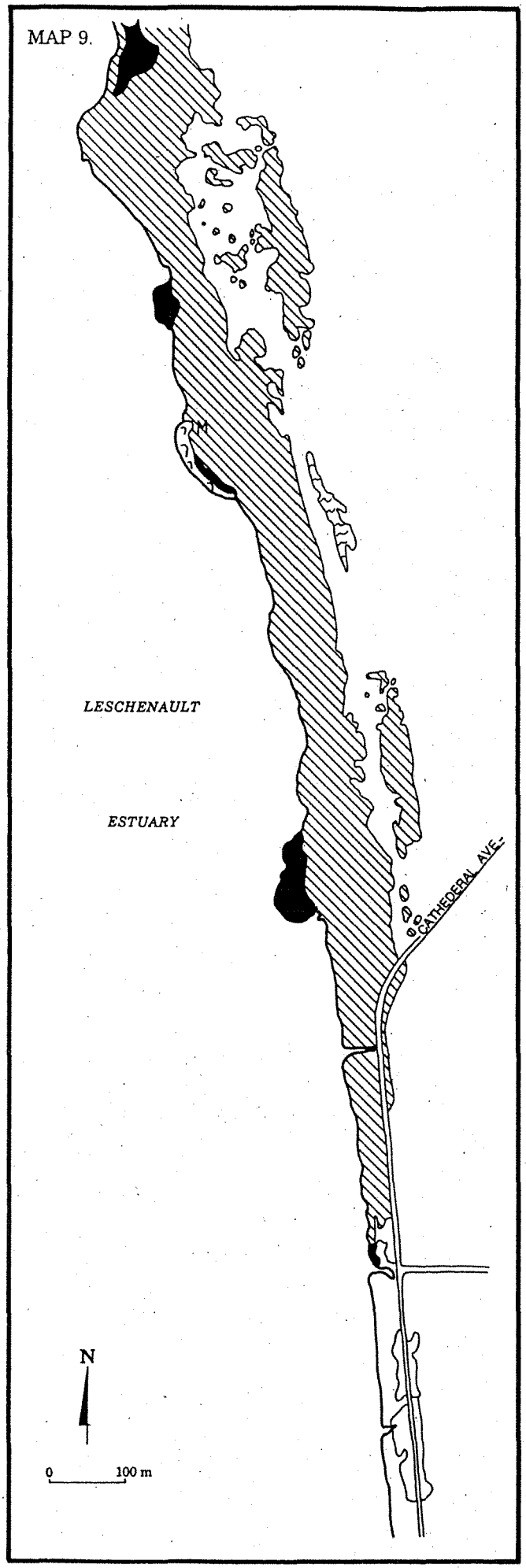

MAP 4.
LESCHENAULT
PENINSULA
TRACK
LESCHENAULT
ESTUARY
N
0
100 m

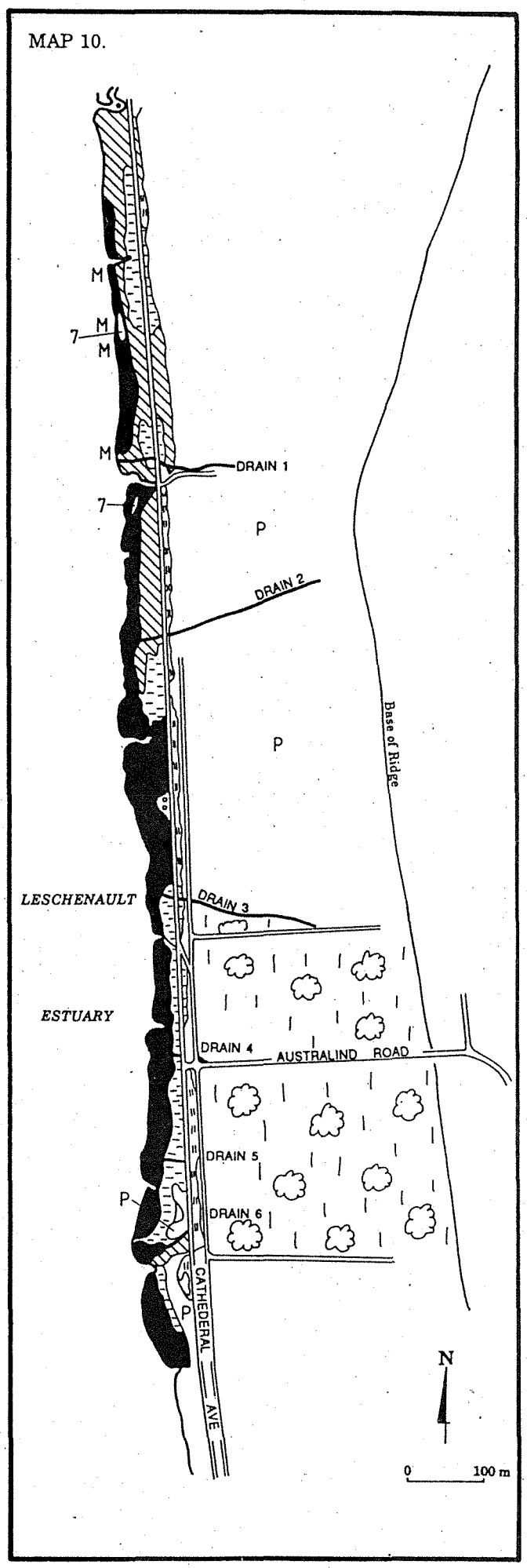

MAP 5.
WATERLOO HEAD
LESCHENAULT
PENINSULA
LESCHENAULT
ESTUARY
TRACK
N
0
100 m


MAP 6.
TRACK
LESCHENAULT
PENINSULA
TRACK
LESCHENAULT
ESTUARY
M
M
Sp
N
0
100 m

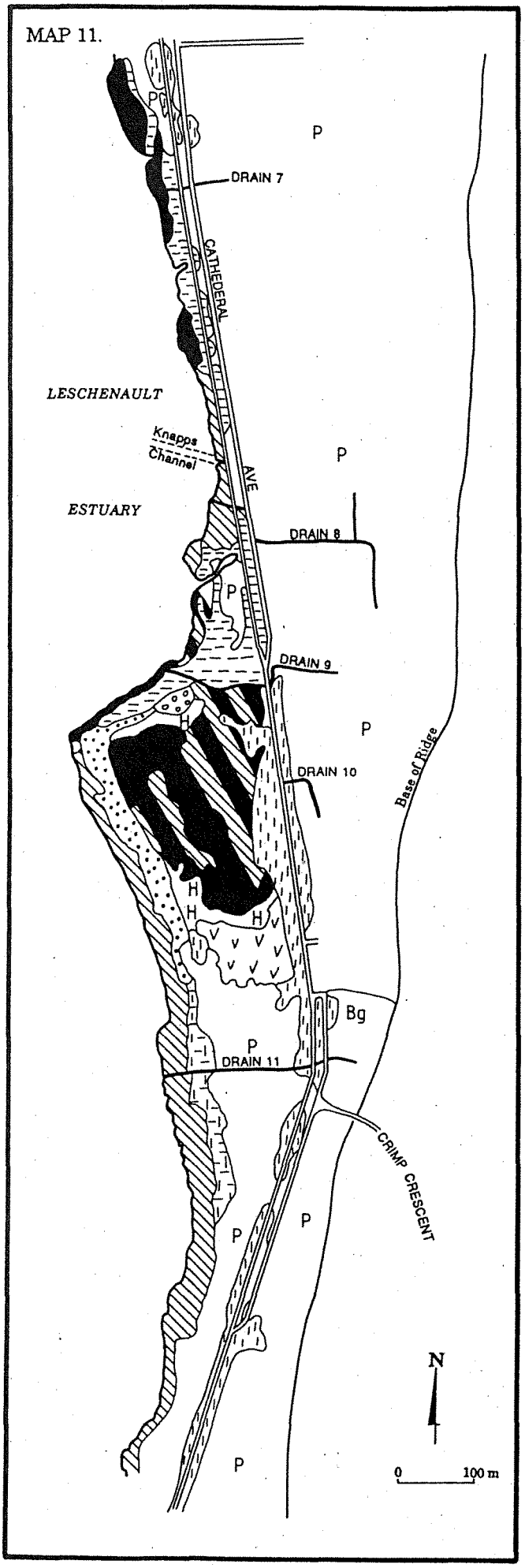

MAP 7.
0
100 m
N
PENINSULA
LESCHENAULT
Sp
Sp
Sp
ESTUARY
LESCHENAULT


MAP 8.
BEACH ACCESS TRACK
BUFFALO ROAD
Sp
Sp
3/8
Dead M. cuticularis over 2.1.m
TRACK
Sp
LESCHENAULT
ESTUARY
N
0
100 m

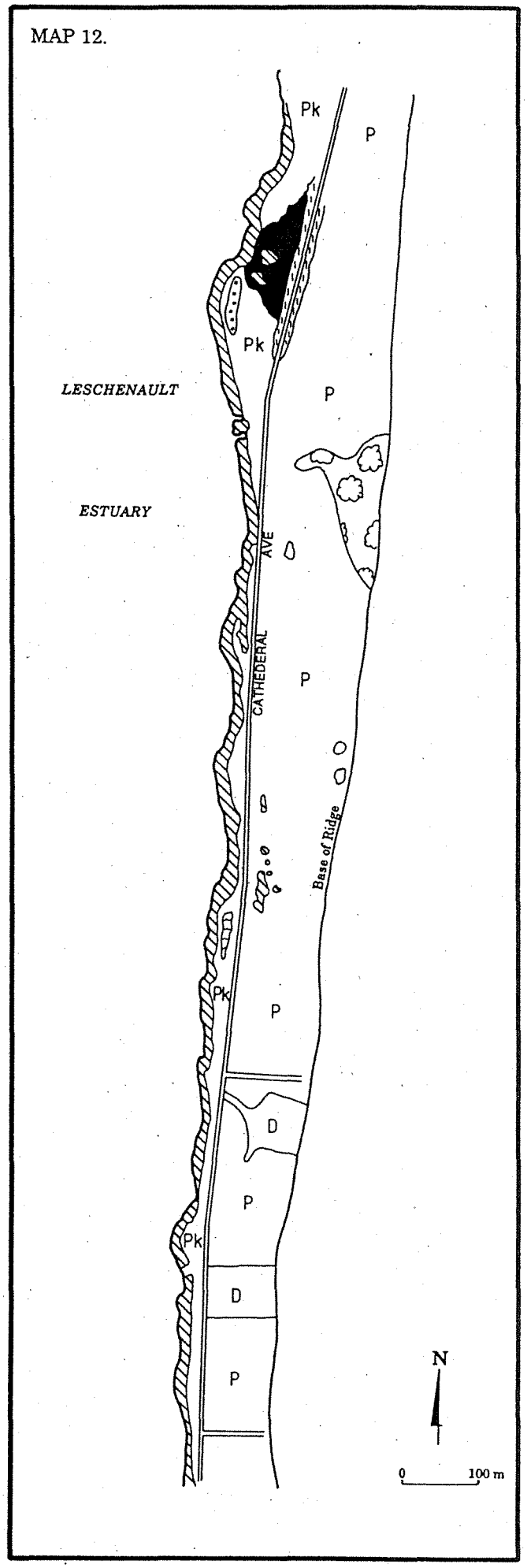

MAP 9.
M
LESCHENAULT
ESTUARY
CATHEDERAL AVE
N
0
100 m

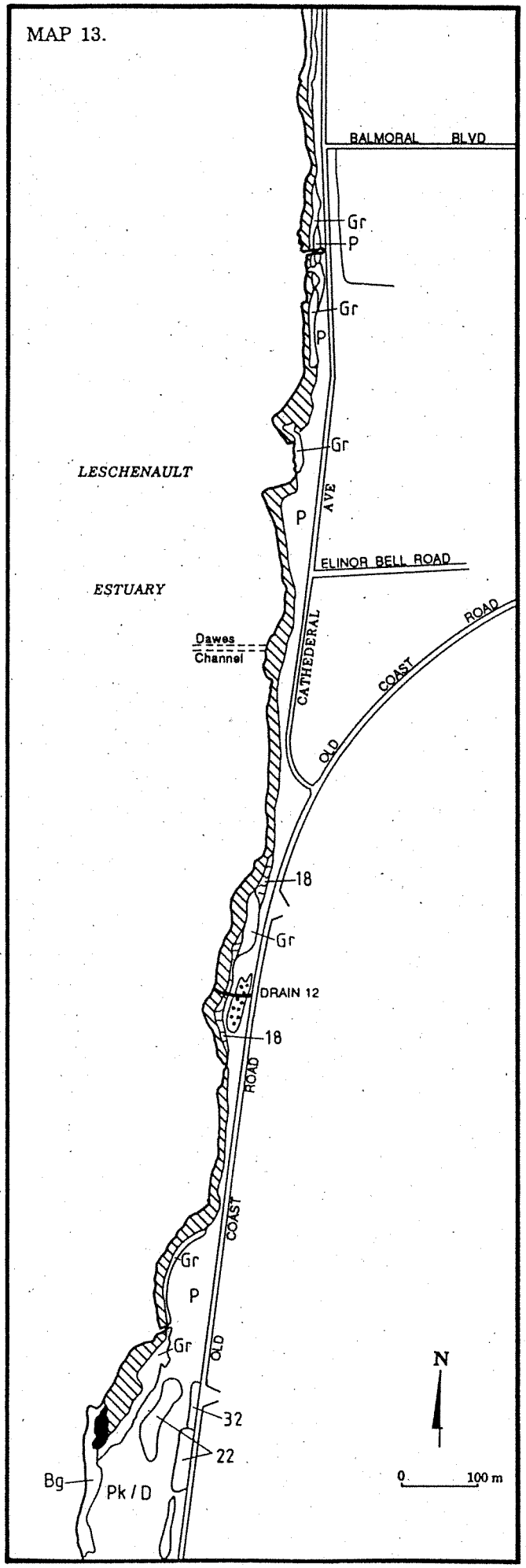

MAP 10.
M
M
7
M
7
DRAIN 1
P
DRAIN 2
P
Base of Ridge
LESCHENAULT
DRAIN 3
ESTUARY
DRAIN 4
AUSTRALIND ROAD
DRAIN 5
P
DRAIN 6
P
CATHEDERAL AVE
N
0
100 m

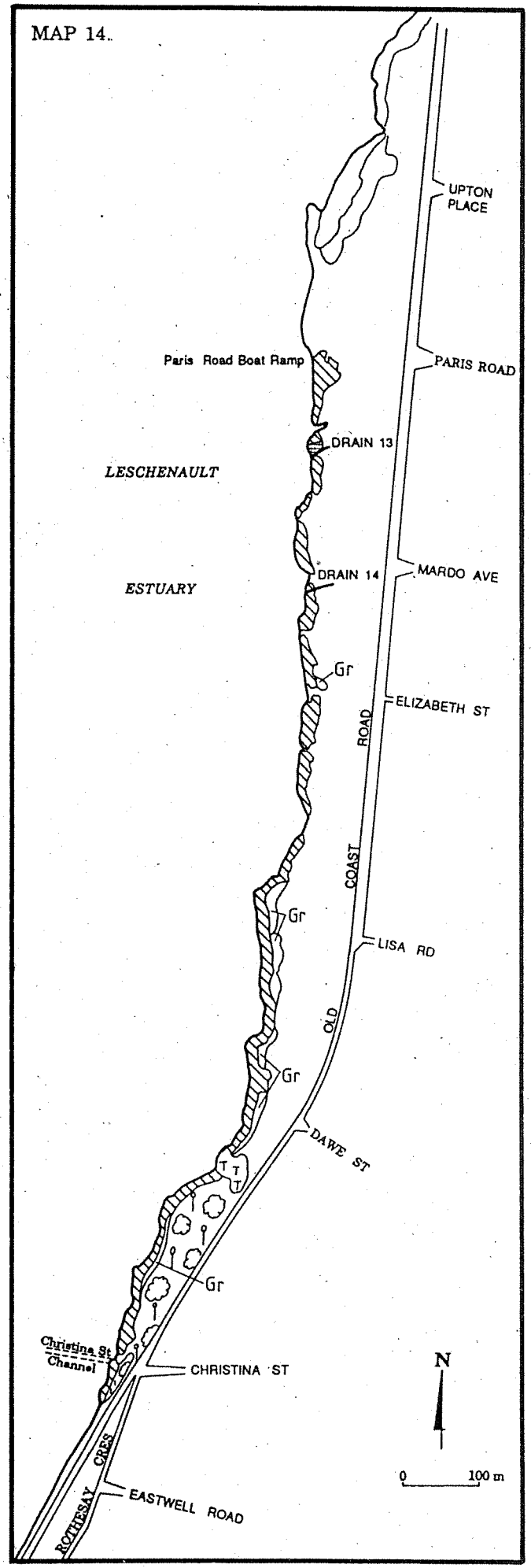
MAP 11.

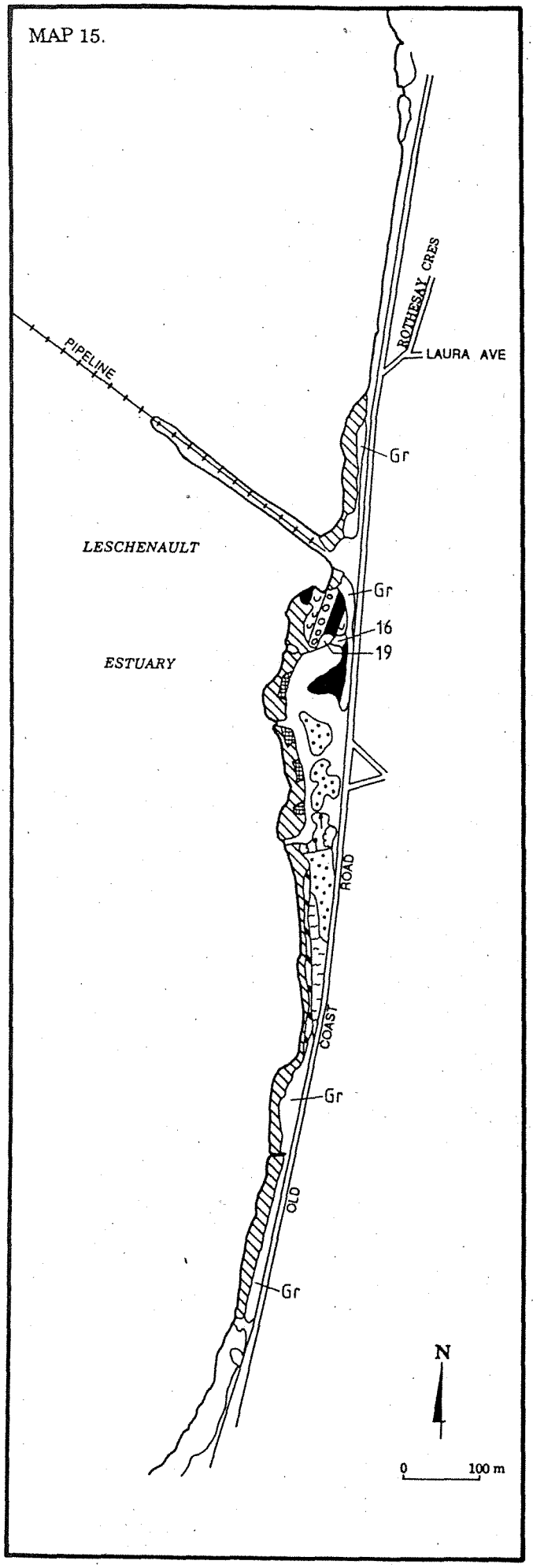

P
DRAIN 7
CATHEDERAL AVE
LESCHENAULT
ESTUARY
Knapps Channel
DRAIN 8
DRAIN 9
DRAIN 10
Base of Ridge
H
V
Bg
DRAIN 11
CRIMP CRESCENT
N
0
100 m

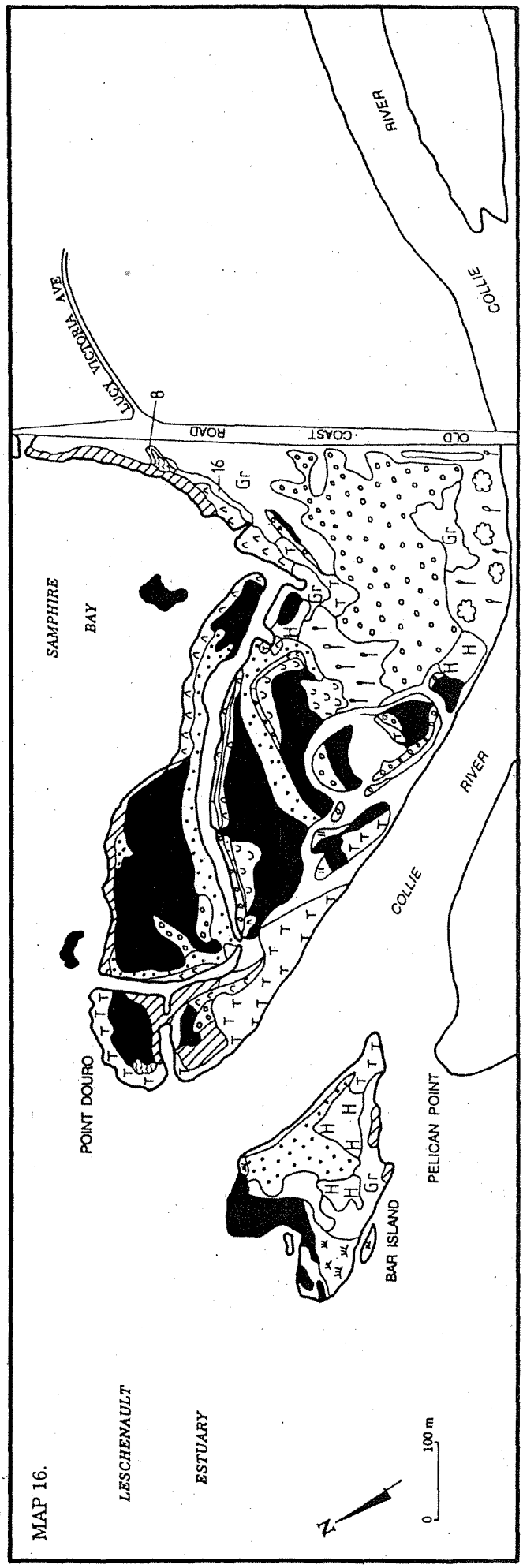
MAP 12.

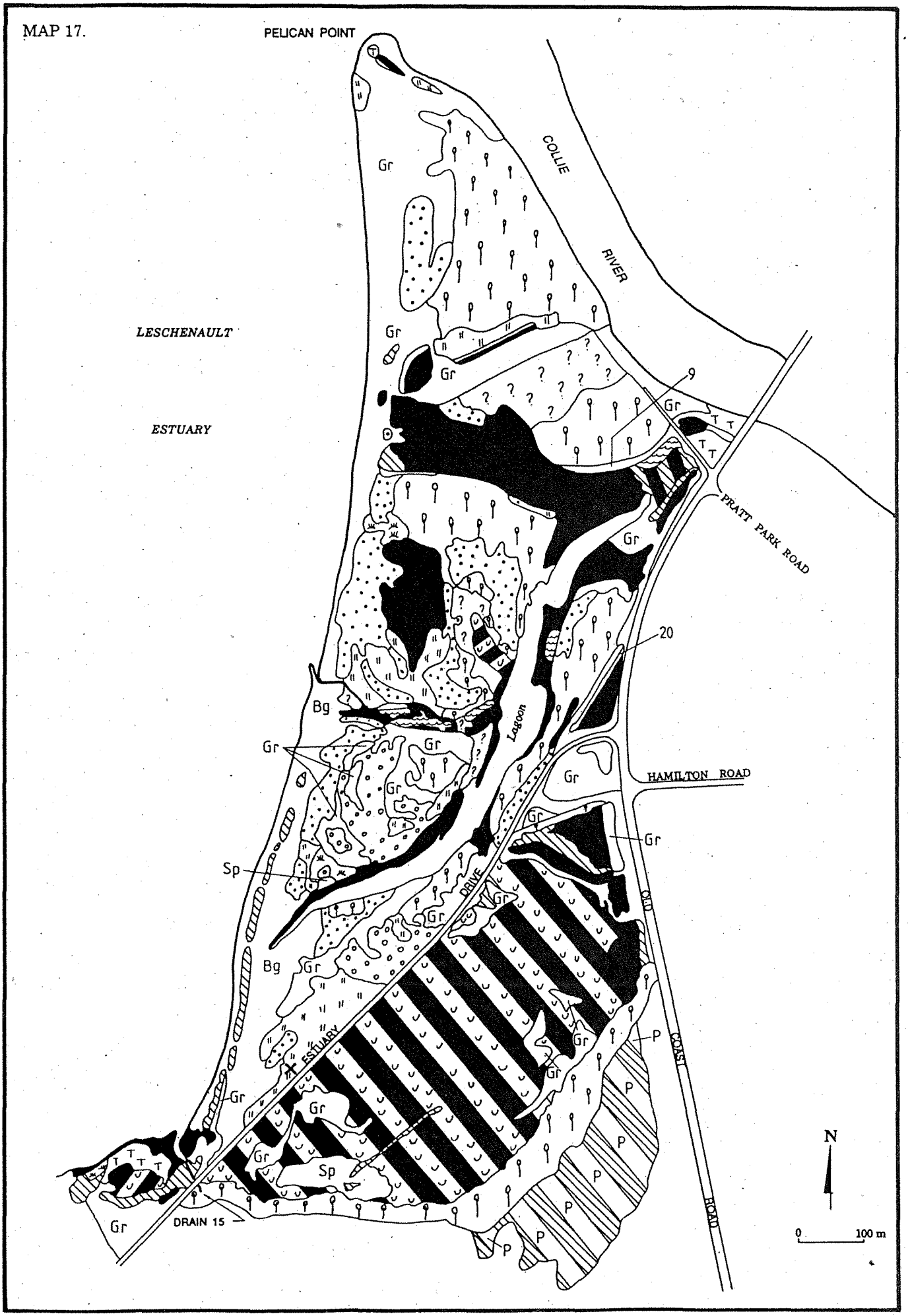

Pk
P
LESCHENAULT
ESTUARY
CATHEDERAL AVE
Base of Ridge
D
N
0
100 m


MAP 13.
BALMORAL BLVD
Gr
P
Gr
P
Gr
LESCHENAULT
ESTUARY
P
CATHEDERAL AVE
ELINOR BELL ROAD
Dawes Channel
OLD COAST ROAD
18
Gr
DRAIN 12
18
OLD COAST ROAD
Gr
P
Gr
32
22
Bg
Pk / D
N
0 100 m

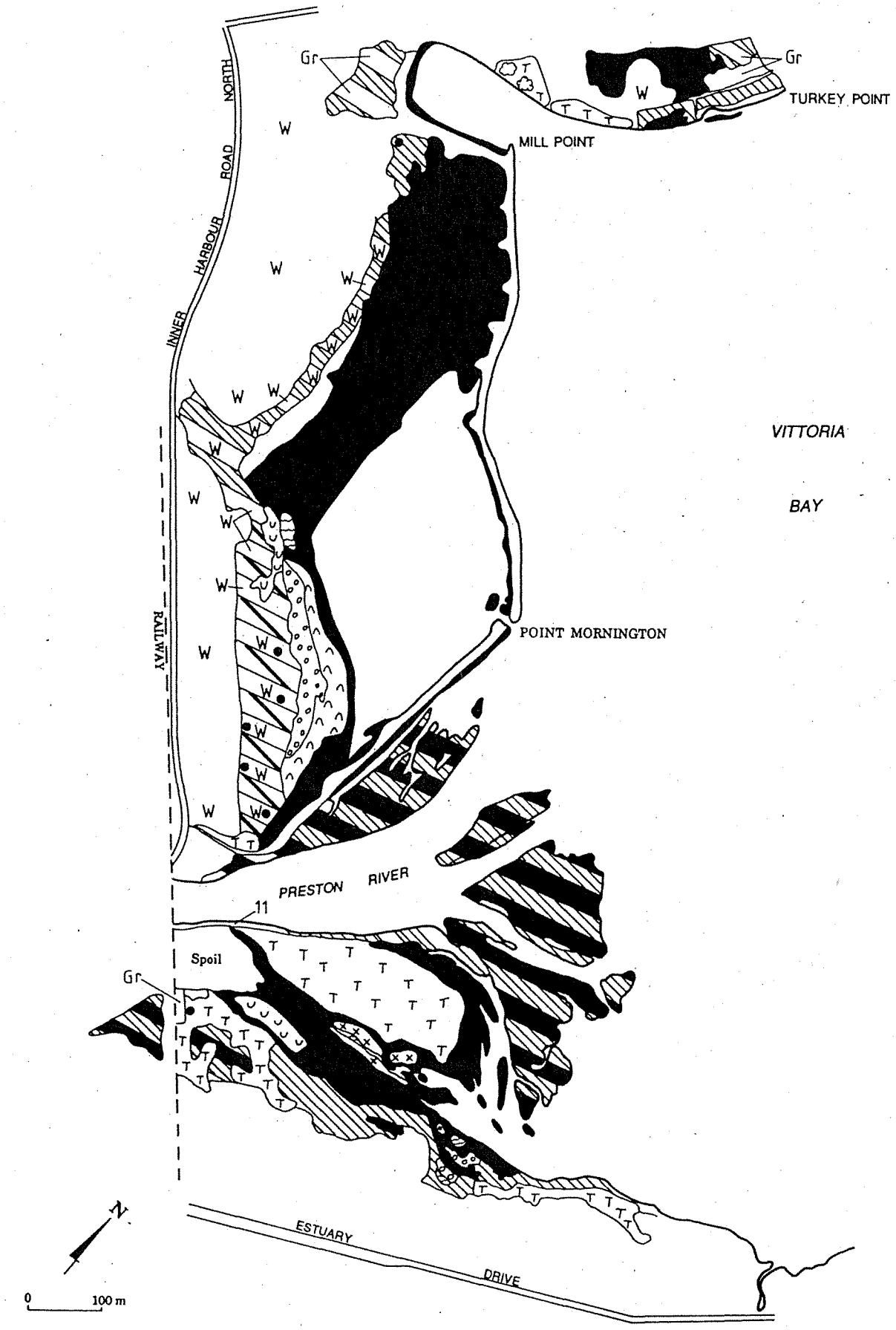

MAP 14.
UPTON PLACE
Paris Road Boat Ramp
PARIS ROAD
DRAIN 13
LESCHENAULT
ESTUARY
DRAIN 14
MARDO AVE
Gr
ELIZABETH ST
OLD COAST ROAD
Gr
LISA RD
Gr
DAWE ST
Gr
Christina St Channel
CHRISTINA ST
ROTHESAY CRES
EASTWELL ROAD
N
0 100 m


MAP 15.
PIPELINE
ROTHESAY CRES
LAURA AVE
Gr
LESCHENAULT
ESTUARY
16
19
OLD COAST ROAD
N
0
100 m

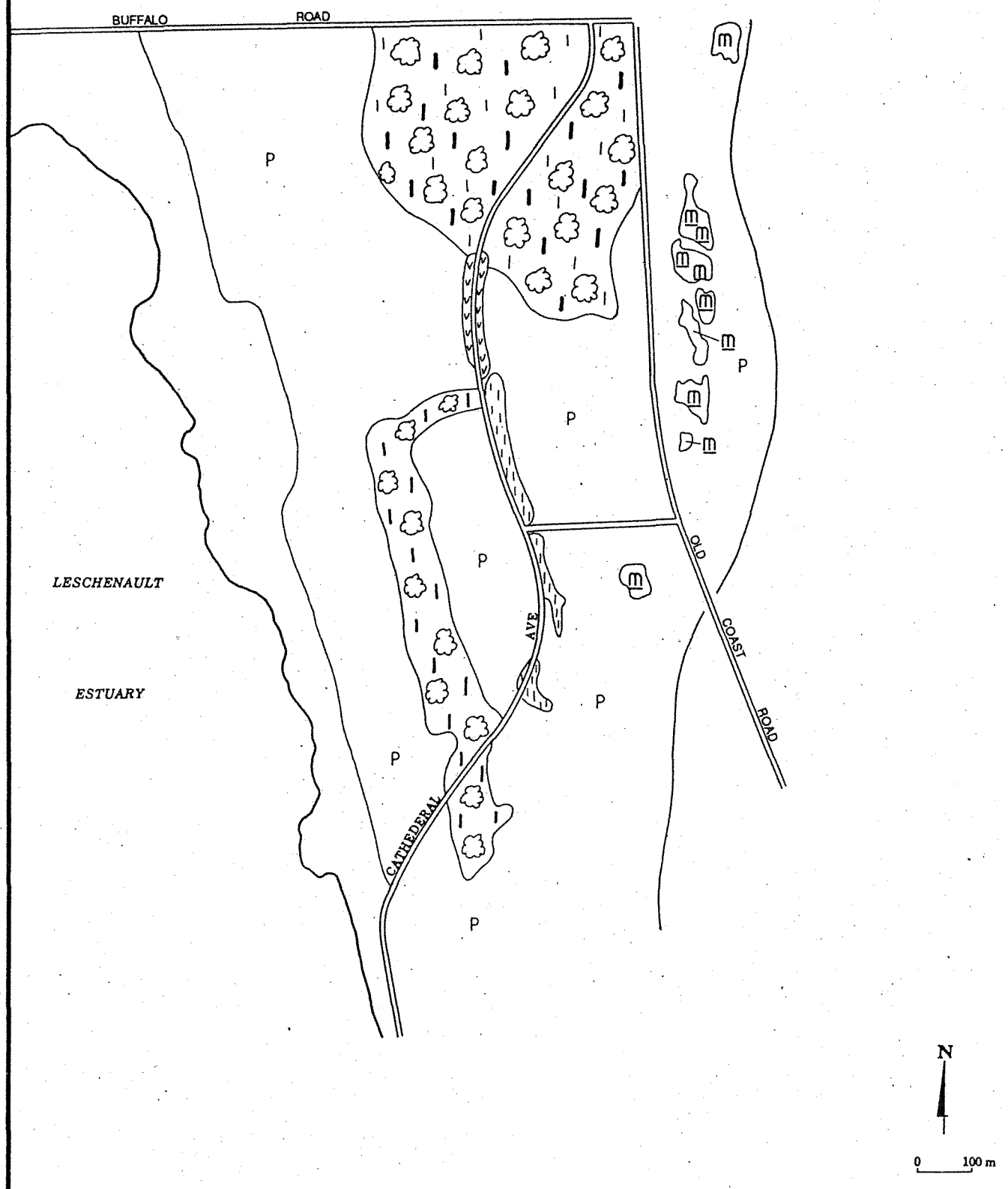

RIVER
COLLIE
LUCY VICTORIA AVE
8
OLD COAST ROAD
16
Gr
SAMPHIRE BAY
H
T
RIVER
COLLIE
POINT DOURO
PELICAN POINT
BAR ISLAND
LESCHENAULT
ESTUARY
MAP 16.
N
0
100 m


MAP 17.
PELICAN POINT
COLLIE
RIVER
LESCHENAULT
ESTUARY
PRATT PARK ROAD
HAMILTON ROAD
Lagoon
DRIVE
OLD
COAST
ROAD
ESTUARY
DRAIN 15
Gr
Bg
Sp
P
T
9
20
N
0
100 m

MAP 18.

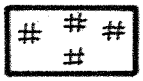

NORTH
ROAD
INNER HARBOUR
RAILWAY
Gr
Gr
TURKEY POINT
MILL POINT
VITTORIA
BAY
POINT MORNINGTON
PRESTON RIVER
11
Spoil
Gr
ESTUARY
DRIVE
N
0
100 m

MAP 19.


BUFFALO ROAD
P
P
P
P
P
P
LESCHENAULT
ESTUARY
AVE
CATHEDERAL
OLD COAST ROAD
N
0 100 m

LEGEND

SALT-MARSH VEGETATION

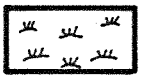

1. *Bolboschoenus caldwellii*
closed sedgeland

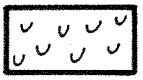

2. *Juncus krausii*
closed sedgeland

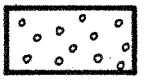

3. *Sarcocornia quinqueflora*
salt-marsh complex


4. *Frankenia pauciflora* - *S. quinqueflora*
low closed heath - *Suaeda australis*


5. *Samolus repens*
closed herbland

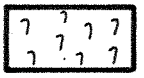

6. *Sporobolus virginicus*
grassland

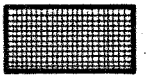

7. *Halosarcia halocnemoides*
low open heath

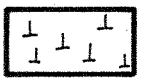

8. *Halosarcia indica bidens*
low open heath


9. *Gahnia trifida*
open sedgeland

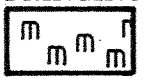
FRINGING VEGETATION


10. *Schoenoplectus validus*
closed sedgeland


11. *Paspalum distichum*
low closed grassland

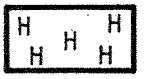

12. *Paspalum distichum* - *Bolboschoenus caldwellii*
closed grass and sedgeland

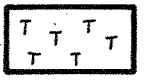
FRINGING ESTUARINE FOREST VEGETATION


13. *Avicennia marina*
closed scrub

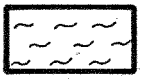

14. *Melaleuca cuticularis*
low open - closed forest


15. *Melaleuca rhaphiophylla* - *M. cuticularis*
low open forest


16. *Melaleuca viminea*
low open - closed forest


17. *Casuarina obesa*
low open - closed forest

FRESHWATER VEGETATION


18. *Baumea juncea*
sedgeland


19. *Melaleuca rhaphiophylla* - *Agonis flexuosa*
low open - closed forest

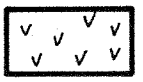

20. *Melaleuca rhaphiophylla*
low open - closed forest

SANDY RISE VEGETATION

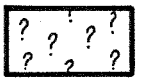

21. *Jacksonia furcellata*
open - closed forest


22. *Eucalyptus rudis* - *M. rhaphiophylla*
woodland


23. *Juncus kraussii* - *Isolepis nodosa*
low closed sedgeland


24. *Acacia saligna*
low closed forest

OTHER PLANT COMMUNITIES

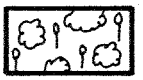

25. The chaotic plant assemblage


26. *Melaleuca rhaphylla*
low closed (swamp) forest


27. *Casuarina obesa*
pastured woodland


28. *Melaleuca rhaphiophylla* - *A. flexuosa*
pastured woodland

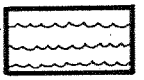

29. *Agonis flexuosa*
pastured woodland


30. *Eucalyptus rudis*
pastured woodland


31. *E. gomphocephala* - *A. flexuosa*
pastured woodland


32. *Eucalyptus gomphocephala*
pastured woodland

SYMBOLS


Standing water

×	*Typha orientalis* bulrush infestation
M	*Avicennia marina* mangrove
Bg	Bare ground
Sp	Salt-pan
P	Pasture
Pk	Parkland
Gr	Scattered grasses
W	Weeds
D	Developed land
●	*Cortaderia selloana* pampas grass infestation
■	*Bolboschoenus caldwellii* clubrush infestation

Appendix 1

Aerial photographs used to document vegetation changes on the foreshore of the Leschenault Estuary

1941	Bunbury 30.9.1941	Map 1341 Run 1 No 3107 Map 1342 Run 2 Nos 2864, 2866 Map 1341 Run 3 Nos 3025, 3027, 3029 Map 1342 Run 4 Nos 2854, 2856, 2857
	Harvey 15.9.1941	Map 1475 Run 12 No 2396 Map 1475 Run 13 No 2283 Map 1476 Run 14 No 2536 Map 1456 Run 15 Nos 2466, 2467 Map 1476 Run 16W Nos 2392, 3107
1966	Collie 17.1.1966	WA945 1:20 000 Run 6 No 5227
1975	Leschenault Inlet 10.4.1975	WA1565 (C) 1:20 000 Nos 5001-5010 (Every second)
1977	La Porte Effluent 15.12.1977	WA1723 (C) 1: 32 000 Run 2 Nos 5061-5069
1982	La Porte Effluent 7.9.1982	WA2089 (C) 1:8 000 Run 1 Nos 5330-5350
1986	La Porte Effluent 29.1.1986	WA2381 (C) 1:8 000 Nos 5079-5097 (Every second)
1989	Myalup-Ludlow 25.9.1989	WA2780 (C) 1:10 000 Run 14A 5032, 5034 WA2777 (C) 1:10 000 Run 15 5167-5185 (Every second) WA 2777 (C) 1:10 000 Run 16 5093-5106 (Every second)

Appendix 2

Scientific names, vernacular names and short description of the fringing plant species of the Leschenault Estuary

Scientific name	Common name	Description
Acacia cochlearis		large shrub
Acacia cyclops	Red-eyed wattle	large shrub
Acacia saligna	Port Jackson	small tree
Agonis flexuosa	Peppermint	small tree
Agonis linearifolia	Swamp peppermint	small tree
Asparagus asparagoides *	Bridle creeper	creeper
Aster subulatus *	Wild aster	annual herb
Atriplex hastata *	Marsh saltbush	annual herb
Avicennia marina	White mangrove	small mangrove tree
Baumea articulata	Jointed twig-rush	tall sedge
Baumea juncea	Twig-rush	sedge
Bolboschoenus caldwellii	Club-rush	sedge
Carex inversa	Knob sedge	sedge
Carpobrotus edulis *	Pigface	creeping herb
Casuarina obesa	Saltwater sheoak	small tree
Cortaderia selloana	Pampas grass	tall grass
Cynodon dactylon *	Couch	perennial creeping grass
Ehrharta calycina *	Perennial Veldt grass	tufted grass
Eucalyptus gomphocephala	Tuart	large tree
Eucalyptus rudis	Flooded gum	medium to large tree
Frankenia pauciflora	Seaheath	medium shrub
Gahnia trifida	Coastal saw sedge	tall sedge
Hakea prostrata	Harsh hakea	large shrub - small tree
Halosarcia halocnemoides	Glasswort	small shrub
Halosarcia indica bidens	Shrubby glasswort	medium shrub
Halosarcia syncarpa	Glasswort	small shrub
Hemarthria uncinata	Mat grass	creeping grass
Hibbertia cuneiformis	Cutleaf hibbertia	medium shrub
Isolepis nodosa	Knotted club-rush	sedge
Jacksonia furcellata	Grey stinkwood	large shrub
Jacksonia sternbergiana	Green stinkwood	large shrub
Juncus kraussii	Shore-rush	rush
Juncus pallidus	Giant rush	rush
Lepidosperma angustatum		tall sedge
Lepidosperma longitudinale	Common sword sedge	sedge
Lolium sp. *	Rye grass	annual grass

Melaleuca cuticularis	Saltwater paperbark	large shrub - small tree
Melaleuca preissiana	Moonah paperbark	medium tree
Melaleuca rhaphiophylla	Swamp paperbark	small - medium tree
Melaleuca viminea	Paperbark	small tree
Oleria axillaris	Coast daisy bush	medium shrub
Oxalis pes-caprae *	Soursob	perennial herb
Paspalum distichum *	Water couch	perennial creeping grass
Pennisetum clandestinum *	Kikuyu	perennial creeping grass
Polypogon monspelliensis *	Annual beardgrass	annual grass
Pteriduim aquilinum	Braken fern	small shrub
Rumex crispus *	Dock	perennial herb
Samolus repens		perennial small herb
Sarcocornia blackiana	samphire	decumbent small shrub
Sarcocornia quinqueflora	samphire	decumbent small shrub
Schoenoplectus validus	Lake club-rush	tall sedge
Sporobolus virginicus	Saltwater couch	perennial creeping grass
Spyridium globulosum	Basket bush	large shrub
Stenotaphrum secundatum *	Buffalo grass	perennial creeping grass
Suaeda australis	Seablite	small succulent shrub
Trachyandra divaricata *		herb
Triglochin striata	Streaked arrowgrass	small herb
Typha orientalis *	Bulrush	large sedge
Typha dominigensis	Native bulrush	large sedge
Viminaria juncea	Golden spray	large shrub
Zantedeschia aethiopica *	Arum lily	herb

* **Denotes exotic species**