COASTAL REGION ENVIRONMENTAL ASSESSMENT AND MANAGEMENT

TECHNICAL REPORT 1: LAND SYSTEMS AND USE WITHIN THE CAMDEN HAVEN.
COASTAL REGION ENVIRONMENTAL ASSESSMENT AND MANAGEMENT

PILOT STUDY: CAMDEN HAVEN CATCHMENT

TECHNICAL REPORT 1.

LAND SYSTEMS AND USE WITHIN THE CAMDEN HAVEN CATCHMENT

Camden Haven, 1971 (Photo courtesy of Hastings Shire Gazette, Wauchope).

A report to the Coastal Council of N.S.W.
Colin Creighton and Gethin Morgan
the climbers were high enough to see Lost Haven below at a dizzy tilt; the grey estuary coiling; the bewildering mixture of moor and swamp and waterway; the Hope; the dark patches in the sea that were the snapper grounds. Space seemed to curve up so that a wall of ocean lay on a level with their eyes. To the south, the Nine Mile Beach slanted away at an unfamiliar angle. North, the coast swelled and receded and tied itself up with Limeburners' Lake and the forests behind.

From the roaring white bar the sea flowed in up-channel, past the mile-long walls of oyster-bitten rock, to lap round the funnel of the sunken tug-boat. Innumerable ditches and dykes drank in the cold, salt water and drew it inland through the grass. There was a stirring and burrowing of red-nippered crabs in the mangrove swamps, a rustling of millions of tiny lives adjusting themselves to one more great thud of the earth's pulse. All the enormous stretch of marsh and sand-dune, swamp and forest, listened to the whisper of the tide, as it came lapping about the fins of black shadow on which the mountain reared its bulk above Abraham's Bosom.
SUMMARY

CHAPTER 1: LAND USE PLANNING AND THE COASTAL REGION

An overview of coastal region land use may be best achieved through the workings of the Coastal Council of N.S.W. as established by the Coastal Protection Act, 1979. One of the foremost requirements of this overview of coastal region land use is the provision of a suitable map base, detailing the biophysical components of the coastal region.

In the absence of a specific definition of the coastal region and in recognition of the biophysical linkages between land areas of a water catchment, the coastal water catchments are taken as being the 'coastal region' of N.S.W.

This report through general discussion and detailed research of the Camden Haven catchment describes one methodology which provides a suitable map base for resource allocation and management of lands of the coastal catchments that compose the coastal region of N.S.W.

N.S.W. coastal catchments present a series of landform similarities as a function of similar prior and contemporary processes. At best, the methodology is applicable to all coastal catchments of the east coast of Australia. At least, the methodology evolved by this study is relevant to the barrier estuary type of catchment (Roy 1982 - Type 2). Further research is progressing towards adapting the methodology to the 'saline coastal lake with ephemeral entrance' type catchment (Roy, 1982 - Type 3).

Land use development and future options may be spatially related to the land system types that characterize coastal catchments. Central to both land use and coastal region management is the estuary and its attendant land areas. Mapping scale adopted within the genetic landscape based methodology allows for the disaggregation of land systems into functional areas of direct applicability to resource allocation and management.

Lands within a coastal catchment may be defined as either coastal or uplands. Coastal lands are sustained by and sustain the subaqueous environments of estuary and nearshore marine zone.
Uplands may provide input to the subaqueous environments but are sustained in turn by the coastal waters only through the circuitous processes of evaporation and precipitation.

The delineation of coastal and upland areas within a catchment provides for description of impact processes and pathways. Within the framework of coastal region management, coastal lands must be assessed with respect to both resource allocation and management. Mapping of coastal lands within discrete vegetation communities provides for the functional analysis of the component parts of the coastal ecosystems. This information defines a basis for decisions concerning both resource allocation and management.

Uplands, with their 'one-way impact paths' require management to control impacts attendant with land use type that are transferred to the coastal environment. Impacts from upland areas will be a function of both the land use type and the biophysical attributes of the land area. Mapping of uplands within functional management areas provides a basis for evaluation of impact and the generation of land use management strategies.

State Government mechanisms incorporated within various agency functions provide a basis for the effective allocation and management of use within the coastal region. The Coastal Council through its role as defined by the Coastal Protection Act, 1979 may coordinate the activities of the various governmental agencies to ensure the establishment of an effective coastal region environmental management strategy.

Methodology adopted by this study is displayed within Figure 1.4 (over page).
Apply D.E.P. Guidelines, Environmental Protection Zones 7a. All development consents to be considered within a catchment perspective.

Coastal lands
Apply D.E.P. Guidelines, Environmental Protection Zones 7b, 7c. All development consents to be considered within a catchment perspective.
CHAPTER 2: LAND SYSTEMS AND LAND UNITS OF THE CAMDEN HAVEN

Climatic and hydrologic data including temperature, frosts, evaporation, winds, rainfall, storm events, runoff and tidal hydrodynamics is presented to provide a context for further biophysical description of the catchment. A lack of site-specific climatic data and a concurrent lack of knowledge of the correlation between catchment lands, their soils and vegetation, and the influence of climate precludes further evaluation of the climatic and hydrologic data.

Geology influences landform and soils and hence vegetation and some land uses. General relationships between lithology and other biophysical components of the catchment can be described.

A review of relevant geomorphological data assists in defining prior and contemporary processes and demonstrating the linkage between geology and biophysical information such as regional climate and soils.

The genetic landscape approach to the mapping of catchments exploits the geologic and geomorphic interrelationship provided by the catchment lands. Mapping of the catchment into defined land systems utilizes these relationships.

Soil type reflects parent material, topography, climate, biotic factors and age. Of these factors parent material and their geomorphic history dominate. Soil type is not a workable divisive factor in the delineation of land systems and units, but rather, soil type is implied through the application of the genetic landscape approach.

Vegetation type as discernable from aerial photographs provides the primary divisive factor in the disaggregation of land systems to land units. Plant communities are the best available surrogates for ecosystems and thus provide a definition of land unit function and relation to associated units within the designated land systems.

Faunal communities are inferred from the description and mapping of vegetation type.
Within the Camden Haven catchment twenty land systems are mapped and described. Within each land system a recurring pattern of topography, soils and vegetation is exhibited. This recurring pattern of biophysical attributes provides a basis for the formulation and implementation of a strategy of resource management.

Selected delineation of land units within the land systems provides a map base of those lands that are ecologically defined as coastal lands. This map base provides sufficient information for the implementation of specific resource allocation guidelines.

CHAPTER 3: LAND USE PLANNING AND THE CAMDEN HAVEN

The mapping methodology detailed within this study provides sufficient detail to define the extent of all estuarine wetlands of the Camden Haven (Zone 7b - Department of Environment and Planning Land Evaluation Guidelines). Departmental guidelines suggest that within estuarine wetlands agriculture (not involving buildings, clearing, filling or alteration to landform) would be the only likely use.

The provision of a map base detailing estuarine wetland areas of coastal catchments provides a context for the overview of local environmental plans and development proposals within the coastal region. Further, if development consent is to be considered for any alternative use, the provision of the map base for the entire catchment facilitates the site-specific evaluation of a proposal within a catchment context.

Shoreline processes and the extent of Holocene and Pleistocene barrier development within the Camden Haven are detailed. Of particular significance is the variation in Holocene barrier development. The mapping program adopted by this study may provide a basis for the State-wide investigation of compartmentization and littoral drift patterns as reflected by contemporary landforms. Use options and management strategies for the barrier systems could be varied in response to this data.
The mapping methodology provides a basis for foreshore definition, utilizing the specific biophysical characteristics of the lands which compose foreshore areas. This data is applicable to the formulation of use capability and management constraints suitable to specific foreshore types, thus facilitating the allocation of conforming uses within those lands denoted 7f) - Foreshore (Department of Environment and Planning Land Evaluation Guidelines).

Application of the genetic landscape approach facilitates the mapping of all flood prone lands of the Camden Haven catchment. Flood event hydrological data is required to precisely define floodways.

Formulation and implementation of specific land use and management guidelines for flood prone lands could utilize the map base provided. Preferably, these use control mechanisms would recognize the varying biophysical characteristics of the land areas comprising the discrete land units, with and as a subset to, general guidelines for use allocation and management of flood-prone lands.

The mapping of coastal catchments into discrete land systems provides a 'first-order sieve' for further studies pertaining to the management of coastal lands. Brief discussion of the applicability of the land systems approach to use capability, soil erosion and nature conservation is contained within the text.
The Coastal Protection Act of 1979 established the Coastal Council of N.S.W. The Coastal Council has, as its primary functions:

a) The protection and maintenance and, where practicable, the enhancement and restoration of the environment of the coastal region and its natural and man-made resources;

b) The orderly and balanced utilization and conservation of the coastal region and its resources, having regard to the financial resources of the State and the social and economic needs of the people of the State.

The need for fulfilment of these functions provides impetus for the establishment of a overview approach to the environmental management of the coastal region of NSW. In March 1980, through the University of New England the present project was initiated. The project has as its principle objective, the definition and application of a methodology for coastal region environmental assessment and management.

During 1980 the project developed through discussions with other research workers, the collection of available data on the Camden Haven catchment and the establishment of a field work program. In January 1981, a research grant was obtained from the Coastal Council of NSW. This grant enabled the purchase of necessary equipment and instruments to complete the field work program. The provision of the grant is gratefully acknowledged. Field work for the project was completed late December, 1981.

The results of the project together with a defined methodology for coastal region environmental assessment and management are presented within four technical reports. Regionally, the water catchment is the most logical unit for the assessment and management of coastal lands and waters. Technical Report 1 details the catchment approach to land use planning and management. Land areas of the Camden Haven catchment are mapped within land systems and units applicable to the establishment of use allocation and management guidelines.

Central to the catchment approach is the estuarine area. Technical Report 2 examines the physical and biological characteristics of the Camden Haven estuary. This report details both the natural resources of the estuary as are presently exhibited and the historical changes to the estuary as a result of man's interaction with the coastal region environment.

To attain the future protection and maintenance of environmental
quality within the coastal region monitoring and management of man's present and future actions is essential. The estuarine area provides the central unit for this monitoring. Technical Report 3 details present water quality within the Camden Haven estuary.

Man's dependence on the estuarine area provides one rationale for the establishment of coastal region management guidelines. Man's actions within the coastal region manifest themselves through varied impacts upon the estuarine environment. Final expression of impacts is biological. Technical Report 4 details both man's dependence (the oyster growing and fishing industries) and, man's sum total ecological impact (estuarine condition, through analysis of individual and community structure).

In summary, four technical reports have resulted from this investigation of one coastal catchment. The four Technical Reports are entitled:

Technical Report 1: Land systems and use within the Camden Haven catchment.


Associated with these technical reports are a series of recommendations pertaining to the formulation of specific policies for the coastal region, and where necessary, recommendations for further research of specific problems. These recommendations may lead to the establishment of policies that may or should be adopted by the Government and public authorities concerning the planning and management of the coastal region.

To satisfy the primary objective of this study a methodology for coastal region environmental assessment and management is detailed. This methodology is based upon the catchment approach to land use planning and the utilization of available data. This available data is collected by a number of Government authorities. Adoption of the methodology would assist the coordination of the policies and activities of the Government and public authorities relating to the coastal region. Methodology detail, concluding comments and specific recommendations will be withheld until the completion of the four technical reports.
During the course of the project many people, organizations and government bodies gave their time, assistance and knowledge. Among those that come foremost to mind are:-

Forestry Commission - Kendall District
Public Works Department - Coffs Harbour, Sydney
Soil Conservation Service - Kempsey, Sydney.
National Parks and Wildlife Service - Taree
N.S.W. State Fisheries - Taree, Sydney
Health Commission of NSW - Lismore, Port Macquarie
Hastings Municipal Council.
Laurieton Fishing Coop.
Camden Haven Oyster Growers Assoc.
Faculty of Resource Management, University of New England.

During the field work for the project assistance and expertise were provided by Gethin Morgan (Aerial photograph interpretation), John Urquhart (Physical chemistry), Roger Buttermore (Benthos) and Reginald Dog (general assistance). John Duggin and Steve Perrens of the University of New England supervised the project.

To all of the above, and to any I have inadvertently forgotten to mention, thank you.

# LAND SYSTEMS AND USE WITHIN THE CAMDEN HAVEN CATCHMENT

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CHAPTER 1: LAND USE PLANNING AND THE COASTAL REGION

1.1 INTRODUCTORY COMMENTS

1.2 LAND USE PLANNING, ENVIRONMENTAL MANAGEMENT AND COASTAL CATCHMENTS

1.3 COASTAL CATCHMENTS AND LAND USE
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Camden Haven entrance, 1971 (Photo courtesy of Hastings Shire Gazette, Wauchope).
1.1: INTRODUCTORY COMMENTS

Cronin (1967) discussing the role of man in estuarine environments stated:

"Man's past effects on estuaries have been poorly and incompletely planned, unimaginative, and frequently destructive. In view of the many important uses served by these waters, and the size of the growing pressures on them, it is imperative that a new major force be utilized in the future - the force of intelligent management".

Within N.S.W. change from circumstances similar to that described by Cronin has been slow. Man's actions within the coastal region affecting estuaries and shorelines are often poorly and incompletely planned. Often action is taken with no regard to the consequences. Decisions have generally been made subjectively without the benefit of adequate scientific knowledge. This lack of planning and subsequent results can be attributed in part to the traditionally parochial attitude displayed to land use planning and management - management in the past being wholly within "the hands of local government authorities" (Gilmour, Owen and Collett 1979). In essence, the problem of the lack of adequate planning stems from a lack of management overview, a lack of institutions for bridging the gap between existing knowledge and contemplated action.

Concern that there is a need for an overview approach, the need for State and National policies, whether they be for coastal or inland lands is not new. There has been a continual and growing awareness of the need to coordinate land use planning, long-term conservation programs and a wide spectrum of environmental aspects. The House of Representatives Standing Committee on Environment and Conservation (1980) stated that this "inter-relation is most apparent in the coastal zone - where land, sea and air meet". That coastal zone management, as it is entitled, should develop within the last decade reflects in part the increasing land use conflicts being experienced within the coastal region. Couple this with the inherent fragility of coastal ecosystems, the dynamic and often unstable interface between land and water and the problems become apparent.

This research project was initiated in recognition of the need for an overview approach to coastal region land use. The primary objective and specific aims of the study have been outlined in the general introduction.
This technical report is one of a series detailing aspects of the research program. Field work for the project was carried out in 1980 and 1981. All aspects of the program were designed as integral parts of a coastal land use overview, so defining one methodology for the environmental assessment and management of the coastal region.

1.2: LAND USE PLANNING, ENVIRONMENTAL MANAGEMENT AND COASTAL CATCHMENTS

Burton (1979) defined environmental management as being "inseparable from natural resources management". Both environmental management and natural resources management need to be undertaken within the context of overall land use planning and management. Burton continues with: "Effective environmental management depends upon an understanding of and appreciation for the nature of land-resource-environment interactions".

An understanding of and appreciation for, the nature of land-resource-environment interactions calls for the application of the ecosystems approach to the definition of regional context within which planning and management may be effected. Aquatic and terrestrial ecosystems are linked directly by water moving in the hydrologic cycle. Both functional and impact use analysis of land areas within the theme of environmental management calls for the definition of linkages and interactions between terrestrial and aquatic ecosystems. Water is the common denominator. In recognition of these concepts, to understand or at least to provide a preliminary basis for ecosystem function analysis regional context should be based upon the water catchment.

Ecologically, systems analysis defined how the natural system operates as a catchment through description of the storages, inter-linkages, control systems and flow pathways of materials, biota and energy (e.g. Odum, H.T. 1967,1971; Odum, E.P. 1971). Figure 1.1, after Loucks (1975) provides an illustration of the relationships within ecosystems on the land and in the water, and of these ecosystems to the land-water interactions that bind the two together in a drainage basin.

Loucks (1975) discussing the applicability of Figure 1.1 to ecological systems analysis states:
"Implicit (in the figure) is a systems approach to the relationships between the trophic levels in subsystems and the environmental control of the whole system. The systems approach allows quantitative study of the entire complex of biological and physical entities, and interactions as a functional unit".

FIGURE 1.1: DRAINAGE BASIN INTERLINKAGE (after Loucks, 1975).

Loucks (1975) in a further discussion of these concepts defines the method and application of the systems approach to catchments:

"Systems models ..... should by design, elucidate the effect of terrestrial ecosystems on the water system and of hydrologic manipulation on the primary production of the deep-rooted plant system ..... Human activity exerts some of its greatest effects on the processes that link the terrestrial and aquatic systems, and therefore models of these interactions contribute means for identifying control strategies to ameliorate human impacts".
The study of drainage basins as a linked combination of a series of ecosystems offers possibilities for integrated research which have to date been neglected or viewed too narrowly (Creighton, 1982b), despite their relevance to man's use of his environment. Human activities cause environmental impacts by altering storages, control systems and flow pathways in ecological systems. A recognition of the ecological systems and linkages which constitute the drainage basin provides the basis for impact assessment. Applying these concepts to site-specific and use-specific conditions allows reliable predictions of primary and secondary impacts, short-term and long-term impacts, incremental impacts as well as direct and indirect impacts, any one of which may in turn be adverse to the natural environment.

Recognising the applicability of these concepts within the theme of environmental management, this study adopts the water catchment as being the basic delineator of regional context. The catchment provides a basis for the investigation of land use planning mechanisms applicable to the environmental management of the drainage basin and more specifically to those lands within the drainage basin that may be denoted as 'coastal'.

Precedent for such an approach towards land use planning and regional boundaries does exist within Australia. For example, the CSIRO South Coast Study utilized a river catchment approach for data collection. Practical limitations of the approach were however recognized in terms of the area of responsibility of the Shire of Eurobodalla not conforming to the defined data collection area. Similar problems of lack of correlation of Local Government boundaries and State Government Departmental management boundaries with water catchments exist throughout N.S.W. Often, Departmental boundaries do not coincide with Local Government Areas, or even with the boundaries of other Government Departments. Resulting problems in data collection are immense. Rationalization of organizational boundaries for both Local and State agencies is both necessary and long overdue. Problems associated with the implementation of such a proposal have to date been parochial but insurmountable.

While recognizing the problems associated with the catchment approach and data collection, the catchment approach is inherently capable of providing a basis for management overview under the Coastal Protection Act.
of 1979. As Cocks (1979) stated, "planning is a decision aid, hence planning regions must be defined largely in terms of the areas for which decision-makers are responsible". The Coastal Council is defined as having two principal functions, viz:

a) the protection and maintenance and, where practicable, the enhancement and restoration of the environment of the coastal region and its natural and man-made resources; and

b) the orderly and balanced utilisation and conservation of the coastal region and its resources, having regard to the financial resources of the State and the social and economic needs of the people of the State.

(Coastal Protection Act, 1979)

While no precise definition of the coastal region is contained within the Act the drainage basins of the coastal rivers and lakes do provide a logical definition of the coastal region for the fulfilment of the Council's functions. Ecologically, this 'coastal region' is defined by the hydrologic system of ocean, estuaries and coastal catchments bound by a close network of ecological relationships (Sorenson, 1974).

1.3: COASTAL CATCHMENTS AND LAND USE

a) The Land-Resource-Use-Environment Interaction

In 'An Introduction to the New Environmental Planning Legislation (PEC, 1979) environmental planning is defined as the process under which decisions on land use and resources management, are made within the physical capacity of the environment in order to promote the economic and social welfare of the people. Any evaluation of the relationships between land use and environmental quality requires the identification, location and quantification of land use and environmental features, and, an assessment of environmental processes. Determination of environmental features and processes provide the basis for assessment of the "physical capacity of the environment". Identification, location and quantification of present land use provides a socio-economic context within which this "physical capacity of the environment" may be examined and management alternatives evaluated.
Burton (1979) discussing this land-resource-use-environment interaction stated:

"The nature and availability of land-based resources is a function of the nature and characteristics of the land itself. These vary from place to place and result from a long period of evolution and development under the influence of a variety of climatic, topographical, geological, hydrological, biological and cultural factors. These factors combine to produce a wide range of land patterns or units having vastly different characteristics and providing widely differing groupings of available resources, each of which is closely related to the characteristics of the land unit from which it derives".

Each of Burton's "units" constitutes a dynamic ecological system. The characteristics and functions of these units together with their interaction with associated "units" must be understood prior to determination of the nature and optimal use of the resources of a particular unit. In essence, the nature of the land units, the processes which formed them and are presently operating within them provides the basis for the effective management of these units and the wise utilization of the resources which they provide. Prior to examining the geomorphological basis of the present land characteristics exhibited by coastal catchments some brief mention of land use and land evaluation is required.

With regard to a particular land use it is usual to denote the environmental features and processes of a unit with respect to the use being considered as the unit's capability (e.g. Baird, Cocks and Campagnoni, 1980). Land capability under these terms can be equated to a measure of the potential of the unit to fulfil a use function based upon the inherent biophysical characteristics of the unit (Duggin, 1981).

To determine the inherent biophysical characteristics of a unit or series of units some form of evaluation is necessary. Land resources surveys evaluate and map natural landscapes using concepts and information relating to geology, climate, landform, soils and vegetation. Speight (1977) considers that: "the systems on which such surveys have been based are very largely implicit concerning both the specific attributes of the landscape constituents that are to be evaluated and the procedures
by which landscape maps and descriptions are to be derived from them. Progress in landscape science depends on more explicit statements of both attributes and methods without which no objective assessment of the validity of a landscape survey is possible.

One of the primary objectives of this Technical Report is to detail explicitly one method of mapping and land evaluation for the coastal catchments of N.S.W. This methodology provides a basis for the establishment of a method of environmental assessment and management of the coastal region. Particularly, the following discussion provides evidence of the basic uniformity of the coastal catchments within N.S.W. This uniformity is predominantly a function of the coastal region's geomorphological evolution. Obviously departures from the pattern of uniformity exist, and obviously varied landscapes reflect the presence of individual disparities. These disparities may still be accounted for within the genetic landscape based methodology adopted by this study.

b) The Geomorphic Base

Jennings and Bird (1967) within a discussion of the geomorphological evolution of the Australian coast and estuaries defined a series of factors of particular relevance to the N.S.W. coastal environment. Briefly:-

- Australian rivers have low runoff coefficients and few have perennial flow. Perennial rivers exist particularly on the East coast of Australia and these rivers do show marked seasonal variations. Spasmodic flooding is characteristic throughout Australia. These conditions affect the geomorphology and hydrology of estuaries; they weaken the ability of rivers to prevent barrier formation by marine action, and they limit the yield of fluvial sediment for delta and barrier construction.

- The East coast is subjected to the effects of long period (12-16 seconds) high energy swell. Because of this high wave energy extensive barriers have been built up by the action of the ocean swell, and many of the river mouths are partially to wholly cut off from the sea. Estuarine lagoons are therefore more common than simple estuaries.
Few river mouths are completely and permanently enclosed by barriers. Usually there is a natural outlet which may be sealed off by marine deposition when the river discharge is low, and reopened by augmented outflow after heavy rainfall within the catchment. (Most estuaries throughout N.S.W. now have training walls to offset shoaling associated with this phenomena). The position of estuarine outlets is often related to patterns of refraction of ocean swell. The outlets occur where the swell is strongly refracted, and therefore weakened, in the vicinity of rocky headlands, or where there are islands or shoals immediately offshore (Bascom 1954). Littoral drift patterns are also affected by headlands and shoals, complementing the wave refraction pattern.

Tidal conditions generally show a complementary pattern to wave energy. The high wave energy east coast has a low to moderate tidal range. As the morphological effects of waves and tides are often opposed, this complementary distribution has a strengthened significance on the formation of barrier systems.

Sedimentation within estuaries is influenced by biotic factors where salt marsh, mangrove swamp, or reed swamp develop on their margins. If the tidal range is large, mangroves form broad zones of swamp vegetation on intertidal land, but, mangroves are restricted or absent in estuarine lagoons where the tidal range is reduced. Reed swamp encroachment is restricted to relatively fresh water and becomes more important where the enclosure of estuaries by barriers permits reduction of salinity by inflowing rivers.

Along the east coast of Australia quartzose beach sands predominate and dunes and barriers derived from them remain relatively unconsolidated. (Compare the more calcarenite depositional forms on the western and southern coasts of Australia).

Neotectonic effects cannot be excluded from consideration of present-day estuaries, many of which inherit morphological features from estuarine phases prior to the recent (Holocene) marine transgression.
The proceeding dynamic factors work within the more static framework of the geological structure and geomorphological evolution of the coastal hinterland.

Jennings and Bird (1967) conclude this discussion of coastal geomorphological processes with the following comments:-

This coast (N.S.W.) possesses a basic uniformity: it is straight; it is subject to a powerful wave attack and to a small tidal range; and it also has the "geographical unity" (Andrews, 1910) of its hinterland of high plateaus with rather uniform geological strike and dissected coastal slope. The prevailing characteristics of this coast is the existence of substantial quartz sand barriers and dunes along zeta-curve bays (Halligan, 1906; Jennings, 1955; Davies, 1959) fashioned by refracted southeasterly swell and breached most frequently at the southern side of the bays where the swell has been most weakened by refraction. Nevertheless, within this broad canvas there are innumerable contrasts and departures at all levels of magnitude, and each present different research problems.

Within this geomorphologically similar base and while recognizing that as Jennings and Bird stated "there are innumerable contrasts and departures" further similarities can be highlighted. Roy (1982) discussing the evolution of N.S.W. estuary types stated:

"It is hypothesised that, in the early Holocene, marine processes interacted with coastal topography and river discharge to produce three distinct types of estuaries with characteristic entrance conditions:

1. Drowned river valley estuaries with full tidal exchange
2. Barrier estuaries with attenuated tides
3. Saline coastal lakes with ephemeral entrances and no tides.

Of Roy's three estuary types, the Camden Haven can be classified as type 2. The methodology developed within this study is applicable to at least all estuaries of the N.S.W. coastal region of this type. Further research is presently progressing with the aim of adapting the methodology to Roy's type 3. The Lake Cathie - Innes catchment, adjacent to the Camden Haven catchment was chosen as the study area. Limited funding has to date restricted the research program, however it is expected preliminary results will be published in 1983.
Providing a more specific framework to the hypothesis of geomorphological similarities and thus further illustrating the applicability of a generalized coastal region environmental assessment methodology, Gordon and Lord (1980) developed a specific model for contemporary coastal processes. The methodology adopted by Gordon and Lord for evaluation of further research on coastal processes is displayed in Figure 1.2. The concepts denoted by the figure are also applicable to this study.

FIGURE 1.2: GENERALIZED COASTAL MODEL (after Gordon and Lord, 1980).

Gordon and Lord's discussion of contemporary coastal processes is detailed below to provide a basis for later discussion of coastal processes within the Camden Haven region (chapter 3).

In simplistic terms the model for the N.S.W. coastline can be presented as follows:

Three major natural features have contributed to the present day coastal morphology:

i) Bedrock outcrops and sediment deposits which pre-date the Holocene sea level rise

ii) The onshore movement of sand which accompanied the Holocene sea level rise
iii) The alongshore and onshore/offshore reworking of coastal deposits by wind wave and current action

...... the generalized coastal model predicts that at the present time, where there is no new source of suitable sediments, the beaches will be either:

i) In a state of dynamic equilibrium where no longshore or aeolian losses occur

ii) undergoing long term erosion where either aeolian and/or long-shore losses occur.

Obviously, as Gorden and Lord later in the paper state, this general coastal model must be adapted to site specific cases. However, the model of formation and of contemporary processes remains as a basis for further detailed, site-specific investigation. Similarities also exist within the sediment types displayed by the estuaries of N.S.W. and, the adjoining floodplain land areas, both estuarine and riverine. Roy and Crawford (1977) discussing sediment distribution in coastal rivers of northern N.S.W.

All the major rivers on the north coast of N.S.W. show a similar pattern of sediment distribution in which three main sediment types are clearly distinguished. River sediments of terrestrial origin occur in the upper and central reaches of the rivers; beach and nearshore sands of marine origin occur in their mouths and on the adjacent ocean beaches; and sands reworked from coastal barriers occupy an intermediate position (except in the Hawkesbury) [Roy's type 1] between the river sediments and the marine deposits. These sediment types generally occupy discrete zones although limited mixing occurs at zone boundaries.

The concepts and delineation of sedimentary types within N.S.W. estuaries of type 2 (Roy 1982) is utilized within Chapter 2 of this report to delineate between riverine and estuarine alluvium land systems (Section 2.7).

The similar geomorphic base, that exists within the catchments of the coastal region of N.S.W. provides a rationale for the application of the genetic landscape approach to the mapping of land areas of the coastal catchments. This geomorphic base is further reflected by the resource
pattern and thus land use pattern exhibited by the coastal catchments. One example of the resource base accompanying the geomorphic character of the coastal region is the pattern of heavy mineral distribution within the barrier systems of the coastal areas. Winward and Nicholson (1975) detail the mode of formation and hence distribution of heavy mineral deposits within the N.S.W. Quaternary sediments. Further examples abound. The correlation of soil type with land systems and thus land-use and land systems is discussed within Chapter 2. The applicability of the genetic landscape approach to the definition of resource pattern is not confined to coastal areas. Creighton (1980) utilized the genetic landscape approach to map and define mineral distribution within the Binghi area, west of Glen Innes.

To provide further evidence of the applicability of the genetic landscape approach the following section details the resource and land use development of the Camden Haven catchment. The discussion is historically based, defining the pattern of settlement and land use. Parallel examples from other northern N.S.W. coastal catchments are discussed briefly.

c) **Land Use Development, Camden Haven Catchment**

Central to any concern for prior and contemporary processes within a drainage basin is the river. The assemblage of characteristics of a river is both a function and component of the geomorphic base of the catchment. Water can be seen as both the primary driving force of contemporary processes and the linkage inter-catchment between land units. With respect to land use, water has been and still is the most important physical factor influencing the land use patterns within the coastal region of N.S.W.

The Camden Haven and Stewards rivers and surrounding catchment lands conform with the above general comments. Historically development centred on the use of the rivers for transport. The township of Laurieton was the area's port for coastal steamer trade. The townships of Johns River and Kendall are at the navigable limits and hence, almost the tidal limits of the Stewarts and Camden Haven rivers. This pattern of settlement is replicated throughout the coastal catchments of N.S.W.

Within the Camden Haven catchment, as within other N.S.W. coastal catchments, this pattern of development, or, of land use, replicates not only the early transport patterns but also the spatial arrangement of natural
resources around the riverine environment. First to the area were the 'cedar-getters' who came by boat to take advantage of the red cedar which grew along the upriver alluvium fringes of the Camden Haven and Stewarts Rivers. By the 1880's migrants or free settlers were arriving by steamer to foster the agricultural development of the Camden Haven. Agriculturally the land areas associated with the various sectors of the rivers provide differing capabilities and constraints for cropping, grazing and irrigation. First areas settled were the deeper soil, fertile river flats which because of the proceeding timber interests (note site quality plus proximity to river for transport of logs) could soon be converted into productive farms. Principal agricultural activity in this period was the growing of corn, with, as population increased, the establishment of dairy farms.

By the 1890's men and companies with capital (e.g. Laurie, Dunn and Bogan) began to build sawmills and exploit the extensive areas of hardwood forests within the catchment. Principal species were blackbutt (E. pilularis) flooded gum (E. grandis) and tallowwood (E. microcarpa). Logging proceeded inland from the more accessible river flat areas to the hinterland, with transport by river, bullock team and in some forests in the early 1900's by tramways.

This historical land use base of the rivers being both the spatial centre of the natural resource pattern of the catchment and the centre of transportation was altered with the development of the North Coast Railway, in the period 1911 to 1915. The provision of railheads to the established towns at the navigable (and tidal) limits of the rivers did however reinforce the position of these towns as the centre of commerce for the catchment. Again, similar comments are applicable to other north coast catchments (e.g. Grafton, Clarence catchment; Wauchope, Hastings catchment; Taree, Manning catchment).

The distribution of development has altered with recent changes in transport patterns, road transport changing the emphasis on locational attributes as seen from a riverine perspective. Log punts on the Camden Haven ceased operation in the late 1950's. Similarly transport of sugar cane on the Clarence, Richmond and Tweed was by river until the early 1970's. During the same post World War II period, urbanization of the lower catchment areas has increased. Developers and planners have
recognised the recreational and aesthetic value water provides. Present and future growth of urbanized areas is firmly centred on the immediate coastal sector - the land areas associated with the lower estuarine and ocean beach environments. Towns like Laurieton (or Port Macquarie) are now developing at a higher rate than towns like Kendall (or Wauchope). Facilities associated with urban environments are also shifting to the immediate coastal sector.

Recognition of these patterns of development emphasizes the relevance of the catchment approach to land use planning within the coastal region. Recognition of the central role of the estuarine environment in this pattern of development reinforces the need for land use planning to account for and incorporate the estuarine environment within and as a central part of any land assessment and management plan for the coastal region. Sorenson (1974) on the subject of planning and land use within the coastal environment and, the role of estuaries stated:

The planning regimes that have formed around estuaries are a recognition of their natural unity. Estuaries, because of their natural enclosure, do exhibit stronger geophysical, hydrologic and ecologic relations between use and the resource base than an open coastal environment. Also the bounded geographic setting would appear to give estuaries a stronger image as a plannable unit than a continuous strip of coastline.

If it is assumed that the estuary and associated land areas are central to concerns of planning and management within the coastal region, questions of mapping scale must be resolved. Water-caused interrelationships do provide the strongest argument for recognizing the coastal catchment and its resources as a system. However, within this system issues of concern vary, and the mapping scale adopted should reflect these variations. The following section provides a discussion of coastal boundary types that have been utilized within specific coastal management programs as the basis for land evaluation and subsequent management. This discussion, together with the accompanying discussion on land use issues pertinent to the coastal region provides a basis for the definition of mapping scale adopted within this study.

d) Coastal Management Boundaries and Land Use Issues

Cullen (1978) presents three main approaches used to define the inland boundary of the 'coastal zone'; viz:
Biophysical - features such as altitude, vegetation, geomorphological or ecosystem boundaries

Administrative - local government boundaries, roads, planning areas or census districts

Linear - a set distance from a feature such as the Mean High Water Mark.

Cullen in subsequent discussion suggests that the best approach may be "to identify the issues leading to a coastal management program and ensure that sufficient area is included to allow their resolution". What Cullen fails to suggest is that all lands on which activities may adversely affect any defined coastal zone and hence, all lands that may present issues of concern are in effect, the coastal water catchments. This catchment approach, as already outlined, is particularly applicable to the Coastal Council of N.S.W. under the terms of the Coastal Protection Act (1979). However it should be recognised that within catchments issues of concern will vary. What is required is a spatial disaggregation of coastal catchments into as Cocks (1977) terms 'functional areas'. These 'functional areas' should exhibit significant differences in possible functions between areas yet still provide considerable similarity in functional possibilities within areas. Cocks (1977) states that "this disaggregation should be consistent with the availability of resources and the range of possible land uses identified". Further, this delineation of functional areas should provide a basis within which particular issues of pertinence to coastal region environmental assessment and management may be examined.

Woodruff, Longley and Reed (1978) provide an ecological systems approach to the delineation of boundaries applicable to coastal management. With respect to the immediate coastal area they state:

An analysis of ecological systems that both sustain and are sustained by coastal waters provides the key to a biophysical procedure for delineating inland coastal management boundaries. This analysis entails two basic tasks: (1) mapping the ecosystems that compose coastal waters and adjacent areas, and (2) charting sustaining flows among these systems. The resulting boundary encompasses all environments of coastal waters (subaqueous areas containing a measurable quantity of seawater) and all shorelands (either emergent of submergent environments that interchange sustaining materials, energy, or biota
with coastal waters). As this biophysical procedure depends on the precise location of, and functional transfers among coastal ecosystems, it provides a means both for assessing the consequences of human actions and for establishing a landward boundary for a management program.

Woodruff, Longley and Reed proceed to define four component systems within coastal catchments. Briefly these are:

**Coastal waters:** Coastal waters being that subset of the coastal area that includes only subaqueous environments containing a measurable amount of seawater. Coastal waters extend inshore or upstream to the farthest extent of subaqueous environments defined by measurable seawater content (i.e. the tidal limit).

**Shorelands:** Shorelands are defined in a functional manner. This is interpreted in an ecological context to denote two-way flows of energy or sustaining materials between shorelands and coastal waters. Shorelands are thus:

(i) adjacent to coastal waters
(ii) strongly influence coastal waters (e.g. through the contribution of organic and inorganic materials)
(iii) are dependent upon coastal waters for any one of a combination of sustaining materials, biota or energetic processes.

**Non-coastal waters:** Non coastal waters are defined as those subaqueous environments without a measurable amount of seawater (i.e. fresh water portions of rivers and creeks and isolated freshwater wetlands).

**Uplands:** Uplands are those land areas within a catchment that while they may provide sustaining components to the coastal waters, are sustained in turn by the coastal waters only through the circuituous processes of evaporation and precipitation.

Using the concepts and definitions as detailed by Woodruff, Longley and Reed it is possible to delineate land areas within coastal catchments as being of two broad classes - coastal (or shorelands) and non-coastal (or uplands). In actuality, as denoted by the mapping process in Chapter 2 there is an abrupt discontinuity between uplands and coastal lands. These two
major sub-components of a catchment are composed of mappable environments, each with its own distinctive suite of biological, geological, topographic and process characteristics. Application of the genetic landscape approach provides for the mapping of these sub-components of a catchment.

The delineation of coastal and upland areas under these terms provides a basis for definition of mapping scale. Inherent within the delineation of coastal and upland areas is a definition of impact processes and pathways. Land use within uplands may result in impact upon the subaqueous environments of the estuary and nearshore marine zone (e.g. land clearing → soil erosion (runoff-freshwater transferred to estuary) → turbidity/siltation). There is no concurrent impact upon the uplands from the subaqueous environments. The specific units mapped within uplands should therefore reflect the biophysical capabilities of the lands in terms of their management to provide for minimal impact upon the coastal resources i.e. land areas should be mapped as functional management areas. Under this premise, with respect to coastal region environmental assessment and management emphasis within uplands is placed upon resource management rather than resource allocation.

Within lands defined as coastal, by their definition as being sustained by and as sustaining the subaqueous environments (e.g. materials, biota or energetic processes) mapping must account for mutual interaction. Woodruff Longley and Reed (1978) discuss the mutual interaction between estuary and marsh as an example of the two-way flow processes operating:

Between the estuary and marsh systems, the flows are direct, mutual and essential to ecosystem maintenance. The marsh and estuary share many of the same consumer species which migrate between the two systems. There are also interchanges of organic detritus, inorganic sediment, nutrients, and other salts, all of which are intimately associated with water (tidal) exchanges between the two systems. These flows and migrations sustain the basal as well as higher trophic levels for both systems. Moreover, the interchanges physically sustain each of the two systems through the water budget, the sediment budget, and the processes of erosion and compaction. These interactions document the interdependence of the estuary (part of the coastal waters) and the marsh.

Similar examples could be described for mangrove, swamp oak forest and foredune. Because of this interaction functional areas within coastal
lands must define both the linkage of the area to the subsqueous environment and, the capabilities of these land areas to sustain some form of land use. Thus, the mapped functional areas of the coastal lands must provide information relevant to both resource allocation and resource management. The mapping of coastal lands within vegetation communities allows for such an analysis.

Chapter 2 provides further detail of this mapping approach together with descriptions of the land units delineated within the Camden Haven catchment. To provide a basis for the allocation and management strategy adopted by this study and detailed within Chapter 3, the following section provides a review of State Government planning and management mechanisms applicable to the coastal region.

1.4: STATE GOVERNMENT LAND USE PLANNING AND MANAGEMENT MECHANISMS

a) Available Land Use Planning Instruments

Within Notes on the Coastal Protection Act, 1979 coastal management is defined as requiring: an integrated approach to the many and varied coastal problems and issues ...... at this stage, the primary problems of the coastal region relate to land use controls and the effects of land development on biological conditions of coastal environments. Specifically, for the development of this discussion these "problems" can be accounted for within the two separate but interlinked themes of resource allocation and resource management.

Resource allocation calls for the provision of a detailed catchment map-base within which specific biophysical aggregations are presented, as a basis and a primary input to the implementation of any planning scheme. With regard to planning schemes, their implementation and the role of the Coastal Council, the Notes on the Coastal Protection Act, 1979 state:

The Coastal Council will provide specialist input and advice into planning schemes and interim development orders prepared by the N.S.W. Planning and Environment Commission (now the Department of Environment and Planning) which affect the coastal region. Planning instruments will be the major vehicle whereby the policies recommended by the Coastal Council will receive implementation.
Land use planning in N.S.W. is a responsibility which falls primarily to the local Councils. Under the Environmental Planning and Assessment Act, (1979) however, this responsibility is shared with local government by the Department of Environment and Planning. In particular, the provision of local and regional environmental plans is now regarded as mandatory. To facilitate the development of these environmental plans the Department of Environment and Planning has produced a series of circulars and guidelines. Of particular importance to land use planning and the implementation of land zoning is the recently published 'Rural Land Evaluation Manual (DEP, 1981). The primary aim of this manual is the delineation of areas to assist the refinement of rural zonings. Specific rural zonings are described within the manual. Of these zones, the denoted Environmental Protection Zones are as follows:–

7(a) Wetlands
7(b) Estuarine Wetlands
7(c) Water Catchment Areas
7(d) Scenic
7(e) Escarpment
7(f) Foreshore Protection
7(g) Archaeological Site
7(h) Historic Site
7(i) Scientific Site
7(j) Wildlife Refuge

Development controls which should be applied to these zonings are contained within the Guide to Rural Zoning (DEP, 1981b). Specific zones of interest to the Coastal Council in the fulfilment of its functions and of concern to resource allocation include: 7(a) - Wetlands, 7(b) - Estuarine Wetlands and 7(f) - Foreshore Zone. The genetic landscape approach adopted by this study provides for the mapping and description of these units. Detail of these units within the Camden Haven is contained in Chapter 2. Chapter 3 provides recommendations for the allocation and management of these units.

If the genetic landscape approach was adopted by the Coastal Council as the basis for the mapping of all N.S.W. coastal catchments an inventory of these land areas could be provided to all Local Government bodies and to the Department of Environment and Planning. Such an inventory would provide a basis upon which environmental protection and management of these areas
may be achieved within the framework of present Department of Environment and Planning policies. Further, such an inventory could provide a catchment perspective for any proposed development within these land areas. This 'catchment perspective' would assist the quantification of impact of a particular project (Creighton, 1982b).

b) The Land Ethic and Land Use Management

Johnstone (1981) discussing the present Australia-wide trend for a proliferation of Acts concerning environmental issues contends that there has been a shift in man's place in nature. The shift has been for man to share the centre place with all other living things. Johnstone (1981) sites Leopold (1949) who denoted this 'new' relationship between man and nature as the "land ethic". To quote Leopold (1949) from his A Sand County Almanac:

*All ethics so far evolved rest upon a single premise: that the individual is a member of a community of interdependent parts ..... The land ethic simply enlarges the boundaries of the community to include soils, waters, plants and animals, or collectively the land ..... In short, a land ethic changes the role of Homo Sapiens from conqueror of the land-community to plain member and citizen of it.*

In essence, the 'newness' of this ethic may relate more particularly to man's awareness and appreciation for his surrounds. The early days of white settlement in Australia when all things European were revered, has been replaced by a recognition of the qualities of the Australian environment. Perhaps, Australia is finally coming of age!

Application of this 'land ethic' to the coastal region is well accounted for within the Coastal Protection Act, 1979. One of the primary functions of the Coastal Council, as defined by the Act, is to coordinate policies and activities of public agencies relating to the coastal region. Within N.S.W. there is a complex of regulating powers spread throughout many agencies which are of direct relevance to coastal region land use management. Figure 1.3 depicts the agencies and their responsibilities within the coastal region. To provide for the coordination of these agencies and their regulatory powers, the Coastal Council includes representatives of six government agencies together with a representative of local government and two members of the community who possess qualifications.
### Agency and Ministerial Responsibility Within the Coastal Region

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<tr>
<th>Agency</th>
<th>Responsibility</th>
<th>Ministry</th>
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<tr>
<td>Public Works (e.g., Coastal Engineering Branch)</td>
<td>Public Works</td>
<td>Public Works and Ports (Ferguson)</td>
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<td>Maritime Services Board</td>
<td>Ports, Harbours and Waterways</td>
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<tr>
<td>Soil Conservation Service</td>
<td>Erosion protection and control</td>
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<tr>
<td>Catchment Areas Protection Board</td>
<td>Regulation of use of classified lands</td>
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<tr>
<td>Lands Department</td>
<td>Crown Lands - management/retention; drainage</td>
<td>Local Government and Lands (Gordon)</td>
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<td>Forestry Commission</td>
<td>State Forests</td>
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<td>Department of Local Government</td>
<td>Local Government liaison</td>
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<td>Water resources - allocation/management</td>
<td>Energy and Water Resources (Lands)</td>
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<td>Energy regulation and control</td>
<td>Mineral Resources (Wran)</td>
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<td>Consumer Affairs and Roads (Momcil)</td>
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<td>Promotion of development</td>
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<td>Environment and Planning (Bedford)</td>
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<td>State Pollution Control Commission</td>
<td>Regulation of Air/Water/Noise pollution</td>
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<td>Health Commission</td>
<td>Regulation of Public Health (e.g., oysters)</td>
<td>Health (Herston)</td>
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</tbody>
</table>
relating to coastal protection. This organizational structure of the Coastal Council provides a framework within which specific issues concerning land use management of the coastal region may be approached.

Issues pertaining to the environmental management of the coastal region are many and varied. Cocks and Arman (1980) provide a listing of some two hundred issues of relevance to the coastal region. Cullen (1978) discussing the issues in Australia which a coastal management program must incorporate, stated:

"..... the Australian coastal zone is an extensive and valuable resource capable of meeting a wide variety of the needs of the Australian public. This diversity of uses is the cause of many of the resource outcome issues evident in Australia. Not only are some sections of the coast highly valued for a number of competing uses, but many of the uses are not compatible with one another.

Under the heading of "Resource Outcome Problems" Cullen (1978) lists the following general topics within which specific issues may be categorized:

- Intense competition between alternative uses
- Increasing population growth with consequent development pressures
- Water Pollution
- Dredging and Filling
- Coastal Erosion
- Destruction of Coastal habitats
- Recreation access and facilities
- Degradation of coastal crown lands.

Sorenson (1974) approaches the problem of land use management within the coastal region by an analysis of 'cause-condition-effect' of a series of specific land uses and their attendant impacts. Such an approach does provide a listing of possible impacts of a particular development project, thereby providing a basis upon which strategies may be defined for the amelioration of impacts.

This study adopts the approach of categorizing lands of the catchment within specific functional areas thereby defining a land capability upon which impact analysis such as that described by Sorenson (1974) may be imposed. The genetic landscape method by which the Camden Haven catchment
is mapped into functional units provides the series of units described in Chapter 2. Within these functional units considerable similarity is exhibited, in terms of their biophysical characteristics, the processes which formed them and the processes presently operating within them.

The characteristics of each functional unit defines the scope of environmental management required to ensure the orderly and balanced utilization of the unit and its resources. Thus, the mapping of the coastal catchments by the method adopted within this study would provide a basis upon which an overview of agency function by the Coastal Council may be achieved. Chapter 3 describes some particular management issues and their relation to functional units and agency regulation within the Camden Haven catchment.
Camden Haven river delta, Watson Taylor Lake from North Brother. Stewarts River entrance and South Brother in the background.

Sedimentary forms, Camden Haven.

Dunbogan embayment and Camden Head, north to Grants and Rainbow Beach embayments. Note offshore sand patterns extending north past Perpendicular Point (Photo - NPWS, Taree circa 1980).

Stingray Creek, river entrance channel and Gogleys Lagoon from North Brother.

Stingray Creek and Queens Lake. Rainbow beach embayment, Lake Cathie and Lake Innes in the background.
CHAPTER 2: LAND SYSTEMS AND UNITS OF THE CAMDEN HAVEN

2.1 THE CAMDEN HAVEN CATCHMENT
   a) Boundary Description
   b) Sub-catchments

2.2 CLIMATIC AND HYDROLOGICAL DATA
   a) Temperature, Frosts and Evaporation
   b) Winds
   c) Rainfall and Storm Events
   d) Runoff and Discharge Characteristics
   e) Estuarine Hydrodynamics

2.3 GEOLOGY AND GEOMORPHOLOGY

2.4 SOILS

2.5 VEGETATION

2.6 FAUNA

2.7 LAND SYSTEMS OF THE CAMDEN HAVEN

2.8 DESCRIPTIONS OF LAND UNITS MAPPED
   a) Coastal Sands
      CS-1: Present Barrier
      CS-2,3: Dry and Wet Heath
      CS-4: Eucalypt Dominated Dunes
   b) Estuarine Alluvium
      ES-1: Mangrove Dominated Intertidal Flats
      ES-2: Salt Marsh
      ES-3: Swamp Oak - Open to Closed Forest
      ES-4: Estuarine Connected Fresh to Brackish Wetlands
      ES-5: Eucalypt Dominated Alluvium
   c) Fluvatile Alluvium
      -A : Alluvium (above tidal limit)
      -As : Alluvium (below tidal limit)
      -AT : Alluvial Terraces
      -FW : Isolated Floodplain Wetlands
      -EW : Estuarine Connected Fresh to Brackish Wetlands on Riverine Alluvium
2.1 THE CAMDEN HAVEN CATCHMENT

a) Boundary Description: The headwaters of the Stewarts and Camden Haven rivers rise near Mount Gibraltar and are separated from the Hastings Catchment by the Broken Bago Range. This range varies in elevation from about 600 metres near the Comboyne Plateau (Mount Comboyne 668 metres) to about 300 metres above sea level near Wauchope (Bago Lookout 358 metres). The headwaters of Herons Creek rise near Bago Lookout. Between Bago Lookout and the coast the Camden Haven catchment and the small coastal catchment of Bonny Hills are separated from the Lake Innes - Lake Cathie catchment by a series of ridges generally less than 200 metres elevation (Jolly Nose 248 metres).

On the north-western edge of the catchment lies the Comboyne Plateau. Proceeding westward then southeast from the Comboyne Plateau a range between Mt. Gibraltar and South Brother (494 metres) divides the Camden Haven catchment from tributaries of the Manning River. This range varies in elevation from 150 metres to 600 metres. East of South Brother the catchment boundary is defined by a low coastal sedimentary range before becoming ill-defined in the complex of swamps and lagoons below Watson Taylor lake. This complex of coastal swamps extend from behind Diamond Head to the Manning River and are a geomorphic function of prior barriers.

b) Sub-catchments: The study area can be delineated initially into ten sub-catchments. Details of catchment area and parameters are provided in Table 2.1.

The location of each of these sub-catchments is mapped in Figure 2.1. Herons, Bobs, Waterloo and Limeburners Creek catchments drain to Queens Lake. The Camden Haven and Stewarts rivers together with the smaller Stoney Creek catchment drain to Watson Taylor Lake. Below Watson Taylor Lake the estuary, denoted in this report as the entrance channel, receives waters from the land areas described in Table 2.1 as "Watson Taylor - Entrance Channel Coastal Lands". Full definition of water movement from these lands cannot be achieved without the detailed mapping of coastal land units (refer to later discussion and Maps 2 and 3B). Stingray Creek connects Queens Lake and associated catchments to the entrance channel.

Duchess - Vinegar Creek and Grants Beach catchments are small coastal catchments draining the north-easternmost sector of the study area. Duchess
FIGURE 2-1: CAMDEN HAVEN CATCHMENT, INCLUDING SUB-CATCHMENTS.

CATCHMENT BOUNDARY

SUB-CATCHMENT BOUNDARY

HASTINGS CATCHMENT
HERONS CREEK CATCHMENT
CAMDEN HAVEN RIVER CATCHMENT
CAMDEN HAVEN RIVER CATCHMENT
BOBS CREEK CATCHMENT
DUCHESS CREEK CATCHMENT
QUEENS LAKE CATCHMENT
STONEY CREEK CATCHMENT
STEWARTS RIVER CATCHMENT

LAKE CATHIE- INNES CATCHMENT
GRANTS BEACH CATCHMENT
WATSON TAYLORS ENTRANCE CHANNEL CATCHMENT

SCALE 1:100,000.
TABLE 2.1 CATCHMENT PARAMETERS

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Catchment Area (km²)</th>
<th>Main Stream Length (km)</th>
<th>Average Main Stream Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camden Haven River</td>
<td>240.0</td>
<td>47.0</td>
<td>0.0034</td>
</tr>
<tr>
<td>Stewarts River</td>
<td>107.0</td>
<td>32.0</td>
<td>0.0029</td>
</tr>
<tr>
<td>Herons Creek</td>
<td>133.0</td>
<td>21.0</td>
<td>0.0033</td>
</tr>
<tr>
<td>Stoney Creek</td>
<td>18.0</td>
<td>7.1</td>
<td>0.0282</td>
</tr>
<tr>
<td>Bobs Creek</td>
<td>13.1</td>
<td>6.2</td>
<td>0.0020</td>
</tr>
<tr>
<td>Waterloo Creek</td>
<td>5.6</td>
<td>3.5</td>
<td>0.0086</td>
</tr>
<tr>
<td>Limeburners Creek</td>
<td>7.5</td>
<td>3.1</td>
<td>0.0020</td>
</tr>
<tr>
<td>Duchess and Vinegar Creek</td>
<td>9.4</td>
<td>2.3</td>
<td>&lt; 0.0020</td>
</tr>
<tr>
<td>Grants Beach</td>
<td>5.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Watson Taylor - Entrance</td>
<td>31.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Channel Coastal Lands</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

and Vinegar Creeks provide intermittent openings to the ocean during and immediately after storm events. Grants Beach catchment drains to a dune swale area westward of the present barrier system.

2.2 CLIMATIC AND HYDROLOGICAL DATA

a) Temperature, Frosts and Evaporation. The temperature regime of the Camden Haven is illustrated by Table 2.2, displaying average temperatures at Laurieton. No temperature records are available for the upland areas of the catchment.

TABLE 2.2: AVERAGE TEMPERATURE °C, LAURIETON

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Max.</td>
<td>25.4</td>
<td>25.4</td>
<td>24.2</td>
<td>22.2</td>
<td>18.9</td>
<td>16.8</td>
<td>16.1</td>
<td>17.3</td>
<td>19.4</td>
<td>22.0</td>
<td>23.5</td>
<td>24.5</td>
<td>21.</td>
</tr>
<tr>
<td>Average Min.</td>
<td>16.5</td>
<td>16.6</td>
<td>15.3</td>
<td>12.5</td>
<td>8.8</td>
<td>6.4</td>
<td>5.5</td>
<td>6.2</td>
<td>8.4</td>
<td>11.0</td>
<td>13.9</td>
<td>14.9</td>
<td>11</td>
</tr>
<tr>
<td>Average Daily</td>
<td>20.9</td>
<td>21.0</td>
<td>19.5</td>
<td>17.4</td>
<td>13.8</td>
<td>11.6</td>
<td>10.8</td>
<td>11.7</td>
<td>13.9</td>
<td>16.5</td>
<td>18.7</td>
<td>19.7</td>
<td>16</td>
</tr>
</tbody>
</table>

Highest on Record: 37.8 Lowest on record: -5.6

Warm to hot weather is experienced from October to April, with average maxima varying from 22°C to 26°C. Temperatures exceeding 32°C occur frequently while temperatures exceeding 37°C occur on the average 1 day/year. During
the remainder of the year conditions can be classified as cool to mild. On occasions of clear skies and light winds very low overnight temperatures occur. Extreme minima as low as -5°C have been recorded. Frosts on the coastal fringe are rare. Inland from the coast at Kendall about six frosts per year are experienced. Approximately forty frosts per year can be experienced in the higher parts of the catchment (Pers. Comm. 1981a).

No evaporation data for the Camden Haven is available. Table 2.3 presents estimates of average monthly and annual evaporation from a sunken pan for the Hastings Valley (Water Conservation and Irrigation Commission, 1968).

TABLE 2.3: ESTIMATED AVERAGE MONTHLY AND ANNUAL EVAPORATION IN MILLIMETRES FOR THE HASTINGS VALLEY (after WCIC, 1968)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaporation</td>
<td>134.6</td>
<td>86.4</td>
<td>83.8</td>
<td>60.9</td>
<td>60.9</td>
<td>43.2</td>
<td>35.6</td>
<td>60.9</td>
<td>76.2</td>
<td>109.2</td>
<td>121.9</td>
<td>139.7101</td>
<td></td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.5</td>
<td>0.6</td>
<td>0.9</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b) Winds: Strong winds may occur in association with one of the following meteorological conditions:–

- Strong east to south east winds associated with depressions off the northern N.S.W. coast. The depressions often originate as tropical cyclones and may still be of cyclonic intensity when they affect the region. Wind speeds under these conditions may exceed 100 km/hour on the coast.
- Violent squalls associated with severe local storms such as thunderstorms or frontal squalls. Gusts under these conditions can be of the order of 160 km/hr.

Table 2.4 gives the extreme wind gusts likely to be experienced at a point in the catchment for various return periods.

TABLE 2.4: ESTIMATED EXTREME WIND GUSTS WITH GIVEN RETURN PERIODS (after WCIC, 1968)

<table>
<thead>
<tr>
<th>Return Period (Years)</th>
<th>10</th>
<th>20</th>
<th>50</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind gust (km/hr)</td>
<td>140</td>
<td>150</td>
<td>170</td>
<td>180</td>
</tr>
</tbody>
</table>
c) Rainfall and Storm Events: The highest annual rainfall for the catchment occurs on the Comboyne Plateau where the annual median exceeds 1700 mm. All of the Camden Haven catchment receives annual median falls exceeding 1200 mm. Table 2.5 provides data of the monthly median rainfall at Comboyne, Kendall and Laurieton.

**TABLE 2-5 MEDIAN RAINFALL - COMBOYNE, KENDALL AND LAURIE TON**

<table>
<thead>
<tr>
<th>STATION</th>
<th>MONTHLY MEDIAN RAINFALL (mm)</th>
<th>YEAR (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>J</td>
<td>F</td>
</tr>
<tr>
<td>COMBOYNE</td>
<td>177</td>
<td>185</td>
</tr>
<tr>
<td>KENDALL</td>
<td>110</td>
<td>132</td>
</tr>
<tr>
<td>LAURIE TON</td>
<td>121</td>
<td>143</td>
</tr>
</tbody>
</table>

(Data adapted from Water Resources Commission, 1968; and recent records).

The five months December to April are relatively wet, receiving approximately 55% of the annual rainfall for all stations. On the coastal fringe (e.g. Laurieton) the wet period generally extends to include May. The months July to November, which receive approximately 30% of the annual rainfall are relatively dry. The driest month is scattered between July and September for the three stations. Figure 2.2 depicts graphically monthly rainfall for Comboyne, Kendall and Laurieton for the period 1976 to 1981 inclusive.

Very heavy rain may occur over the catchment as a function of depressions off the N.S.W. coast. The highest total recorded in the catchment in a twenty-four hour period is 448 mm on 29 April, 1963 at Laurieton. This rainfall coincided with a major flood for the catchment. Sinclair Knight and Partners (1980) during a flood study of the catchment derived the following data on storm intensity and volume for differing return periods. Station used was Laurieton.

**TABLE 2-6: STORM INTENSITIES AND VOLUMES.**

<table>
<thead>
<tr>
<th>RETURN PERIOD (years)</th>
<th>STORM INTENSITY (mm/hr)</th>
<th>STORM VOLUME (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DURATION (Hours)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>20</td>
<td>18.6</td>
<td>14.7</td>
</tr>
<tr>
<td>50</td>
<td>21.2</td>
<td>17.0</td>
</tr>
<tr>
<td>100</td>
<td>23.8</td>
<td>19.0</td>
</tr>
</tbody>
</table>

(After Sinclair Knight and Partners, 1980).
FIGURE 2-2: MONTHLY RAINFALL, 1976-1981

Laurieton

Kendall

Tomboyne
d) Runoff and Discharge Characteristics: Runoff is a function of rainfall, vegetation, topography, geology and catchment area. Because of the complexity of these relationships continuous stream gauging records provide the most suitable data for determination of water yield and runoff characteristics of the catchment. Stream gauge data also provides information on the magnitude of fresh water entering the estuary. Stream-gauging has occurred for the Camden Haven and Stewarts Rivers from 1970 to the present. This monitoring of stream flow is supervised by the Water Resources Commission of N.S.W. No stream gauging has been carried out on any of the other sub-catchments.

Details of all monthly discharges exceeding 20,000 megalitres for the Camden Haven and Stewarts rivers together with daily maximums for both rivers are contained within Table 2.7. Since 1970, on an additional sixteen occasions monthly discharge for the Camden Haven river exceeded 10,000 megalitres. Figure 2.3 presents graphically all monthly discharge data for the two rivers.

The magnitude of daily maximum flows for each significant discharge event are indicative of the 'peakiness' of the discharge. A large proportion of this discharge may be accounted for by surface runoff during and to a lesser extent following storm events. For the discharge events detailed in Table 2.7, flow during the maximum day of discharge accounts for a significant proportion of total monthly flow. For the Camden Haven river the proportion of monthly discharge occurring during the day of maximum flow ranges between 18% and 46%, with a mean value of 25%. For the Stewarts River the range is between 14% and 56% with a mean value of 30%. Slightly higher values for the Stewarts River may be accounted for by the reduction in upper catchment area.

Subsurface runoff and groundwater flow may contribute to the initial discharge peak. Soil and groundwater recharge will lessen this contribution. Subsurface runoff and groundwater flow are of more importance in determining the shape of recession curve following the peak. In the case of groundwater flow, the predominant influence is associated with stream flow persistence between rain events.

As an indication of stream flow persistence and variability within stream flow an arbitrary figure of 2,000 megalitres per month has been chosen as indicative of low flow for the Camden Haven river. Flows below this level occurred on a total of 58 miles between 1970 and 1981. Table 2.8 presents this data on a monthly basis. Low discharges are clustered around September. The period of low discharges extends from August through to January. This pattern of low discharge is mirrored by the Stewarts River.
TABLE 2-7: DISCHARGES EXCEEDING 20,000 MEGALITRES/MONTH

<table>
<thead>
<tr>
<th>MONTH</th>
<th>CAMDEN HAVEN RIVER</th>
<th>STEWARTS RIVER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MONTHLY TOTAL</td>
<td>DAILY MAX.</td>
</tr>
<tr>
<td>March 1972</td>
<td>20,300</td>
<td>4,058</td>
</tr>
<tr>
<td>April 1972</td>
<td>25,300</td>
<td>11,900</td>
</tr>
<tr>
<td>October 1972</td>
<td>43,200</td>
<td>11,100</td>
</tr>
<tr>
<td>February 1973</td>
<td>28,000</td>
<td>5,100</td>
</tr>
<tr>
<td>January 1974</td>
<td>64,200</td>
<td>13,700</td>
</tr>
<tr>
<td>March 1974</td>
<td>70,900</td>
<td>18,800</td>
</tr>
<tr>
<td>June 1974</td>
<td>33,200</td>
<td>13,200</td>
</tr>
<tr>
<td>February 1975</td>
<td>22,500</td>
<td>10,400</td>
</tr>
<tr>
<td>November 1975</td>
<td>47,300</td>
<td>9,250</td>
</tr>
<tr>
<td>January 1976</td>
<td>37,000</td>
<td>5,490</td>
</tr>
<tr>
<td>February 1976</td>
<td>38,400</td>
<td>7,040</td>
</tr>
<tr>
<td>March 1976</td>
<td>71,200</td>
<td>8,860</td>
</tr>
<tr>
<td>March 1977</td>
<td>38,400</td>
<td>5,900</td>
</tr>
<tr>
<td>March 1978</td>
<td>60,200</td>
<td>17,500</td>
</tr>
<tr>
<td>May 1980</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>May 1981</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

TABLE 2-8. TEMPORAL PATTERN OF LOW DISCHARGE
(< 2,000 Megalitres/Month) FOR THE CAMDEN HAVEN RIVER, 1970-1981.

<table>
<thead>
<tr>
<th>MONTH</th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>FREQUENCY</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>9</td>
<td>12</td>
<td>9</td>
<td>8</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Stream flow persistence, as already noted, is in part a measure of the groundwater flow which is able to sustain flow in the stream channels for extended periods of time after cessation of rainfall. Low gradients in the middle reaches of the Camden Haven and Stewarts Rivers provide good development of narrow alluvial flats of fluvatile origin. These unconsolidated sediments while not large enough to provide extensive ground water storage are of significance to the persistence of stream flows. No other groundwater reserves are known to occur within the upper catchment.

e) Estuarine Hydrodynamics: The hydraulics, bathymetry, salinity, temperature and turbidity variation within the Camden Haven estuary is documented in detail within Technical Report 2. A brief summary of data relevant to this report is presented below.

All fresh water from the Camden Haven and Stewarts rivers flows through the entrance channel after mixing with the waters contained within Watson...
Taylor Lake (12.7 sq. km, average depth < 1.5 metres). Tidal flow of water to Watson Taylor Lake is of the order of $6.5 \times 10^6$ cubic metres (PWD 1978, 1979). Entrance channel width below Watson Taylor Lake varies from 750 to 1400 metres, with Sinclair Knight and Partners (1981) estimating an effective channel width of between 250 and 350 metres.

Queens Lake (12.1 sq. km, average depth < 2.0 metres) is fed by Herons Creek catchment and three smaller, largely forested catchments (Waterloo, Bobs and Limeburners Creek catchments). Stingray Creek joins Queens Lake to the entrance channel approximately three kilometres above the ocean entrance and approximately five kilometres below Watson Taylor Lake. Tidal flow of water to Queens Lake is of the order of $2 \times 10^6$ cubic metres (PWD 1978, 1979). Maximum velocity of tidal flow recorded at Stingray Creek entrance to the entrance channel is 0.9 metres per second (PWD, 1979). Within Queens Lake itself velocities are much reduced. Channel configuration is similarly reduced. Sinclair Knight and Partners (1981) define a storage area between Herons Creek entrance and Stingray Creek ranging between 2.91 and 2.11 kilometres width. Associated effective channel width varies. Sinclair Knight and Partners (1981) define the width of conveyance area as 230 metres at Herons Creek entrance, 900 metres adjacent to Christmas Cove Caravan Park and 169 metres within Stingray Creek proper, below Cemetery Bay.

Gogleys Lagoon was formed in 1902 when the construction of the southern training wall isolated a section of the lower reaches of the Camden Haven. Prior to construction of the training wall the main river entrance channel swept around the base of Camden Head, past Dicks Hill and Dunbogan. The main entrance channel to the present Gogleys Lagoon is at the western end of the lagoon between Dunbogan and Gogleys Island. The southern training wall separating Gogleys Lagoon from the entrance channel has been breached during flood events on several occasions.

Tidal flow into and out of the lagoon now occurs at the western and eastern entrances and at several points along the training wall. Total tidal flow is of the order of $1.3 \times 10^5$ cubic metres, with water within the lagoon exchanged in two tidal cycles (PWD, 1977). Of this flow, the Department of Public Works estimated that 69% entered through the western entrance, 16% through the eastern entrance and 15% through training wall breaches. Analysis of circulation patterns within Gogleys Lagoon (PWD, 1977) has indicated that a nett circulation of 12% occurs, the waters being well
mixed during a tidal cycle. During the flood tide approximately 10% of the water entering the lagoon from the western entrance is river water from the preceding ebb tide.

Climatic and hydrological data are of relevance to a wide range of land characteristics, functions and contemporary processes (e.g. soil formation, coastal dune formation and erosion, floodplain formation, vegetation species and structure and land uses such as forestry and agriculture). Data presented in the proceeding sections is a summary of that available. The linkage between these data and the land systems and units of the catchment can only be displayed through detail such as the listing of rainfall for a number of sites within the catchment. Turner (1976) discussing the role of climatic data within the CSIRO South Coast study stated:

"The question of scale, both in the level of data available, and its application, is an issue that haunts a project such as this, and is particularly troublesome to the study of climate. Little has been done in Australia in regional climatology, although it is known that attributes can vary widely over short distances due to local topographic influences".

These comments are also relevant to this project. Where necessary, (e.g. within the discussion of contemporary coastal processes - Appendix 2), further data of direct applicability is presented.

2.3 GEOLOGY AND GEOMORPHOLOGY

Generalized geology of the Camden Haven catchment is presented in Figure 2.4 (after Herbert, 1974). Age sequence is illustrated in Figure 2.5.

Phyllites, greywackes, slates and tuffs of Lower Palaeozoic age are found to the north of Queens Lake through to above Bonny Hills. These rocks weather readily to form soft clays and thus are largely absent at the coast and are of low relief inland. At Middle Rock, Bonny Hills embayment these rocks are presently exposed to wave attack. No major headlands of this rock-type exist.

The Byabbara beds of Carboniferous age extend from west of Queens Lake through Kendall - Herons Creek area to the north-western catchment boundary. These lithic sandstone, siltstone, tuff shale and limestone beds underlie the Triassic deposits of the Lorne Basin. Minor areas of serpentinite
FIGURE 2-4: GENERALISED GEOLOGY OF THE CAMDEN HAVEN CATCHMENT
(After Herbert, 1974)

REFERENCE

QUATERNARY
Sand, silt, clay and gravel

TERTIARY
Comboyne Basalt

JURASSIC
Microgranite

TRIASSIC
Grants Head Formation

CAMDEN HAVEN GROUP
Laurieon Conglomerate
Camden Head Claystone

Undifferentiated Palaeozoic

Fault - position approximate
ultrabasic intrusives of upper Permian age are found within Limeburners and Waterloo Creek subcatchments.

The Lorne Basin is a small, intramontane Triassic basin formed on the cratonized New England Fold Belt. Herbert (1974) suggests that terrestrial sedimentation into this basin was "probably initiated by further activity along surrounding major faults and serpentinite beds". Described as a roughly circular basin by Packham (1969) the basin is, in more detail, a double structure with a north and south lobe, the overall dimensions being approximately 20 kilometres in a east-west direction and 35 kilometres in a north-south direction (Herbert, 1974).

Pratt and Herbert (1973) have defined three formations within the Camden Haven beds. These are, from the top of the sequence:-

- Grants Head formation 75 metres
- Laurieton Conglomerate 45-210 metres
- Camden Head Claystone 0-75 metres

Herbert (1974) discussing these formations states: -

"The Camden Head Claystone is a sequence of red-brown claystone and siltstone with minor amounts of grey plant-bearing siltstone, sandstone and conglomerate. Overlying and interfingering with
with the Camden Head Claystone is the Laurieton Conglomerate, a red jasper and quartzite pebble to cobble conglomerate which is over 200 metres thick along the western margin of the basin and rapidly wedges out towards the east. Spectacular cuestas and cliff escarpments of the basin rim are formed by this conglomerate. Grading upwards, the overlying Grants Head Formation comprises laminated fine sandstone and siltstone with cross-bedded channel sandstone.

During the Tertiary a series of intrusives altered the proceeding sedimentary pattern. Volcanic activity was responsible for the outpouring of the basalts of the Comboyne Plateau. These basalts are pyroxene bearing trachytes (Stewart in Packham 1969) which flowed from the plugs located at Mt. Gibraltar and Mt. Bulli. Porphyritic rhyolite plugs such as Big Nellie, Little Nellie and Lorne Peak intrude the western part of the Lorne Basin. Rhyolite intrusives are also found at Diamond Head and within the coastal barrier system of the Diamond Head embayment. Large alkaline intrusives form the topographic feature of the Three Brothers and Mount Juhle, along the eastern part of the Lorne Basin. These intrusives are probably laccolithic structures (Chestnut 1968) which vary in lithology from hornblende - biotite granodiorite to riebeckite and pyroxene-bearing porphyritic microgranite (Herbert 1974). The Three Brothers and Mount Juhle are of similar age and mode of occurrence as the Valla and Yarrahanpinni Adamellites (Thompson 1974).

The Quaternary coastal sediments consist of beach deposited quartzose sand, with variable quantities of fluvial, paludal, estuarine and lagoonal sediments. These Quaternary sediments are bounded to the west by bedrock outcrop and to the east by the present beach lines of the embayments between the Triassic and Tertiary headlands.

The contemporary beach and foredune is backed in the Dunbogan and Grants Beach embayments by a series of parallel ridges. In total this formation has been denoted the outer barrier (e.g. Bird 1965, 1978; Thom 1965; Thom, Polack and Bowman 1978). The sands of this feature are not indurated. Further landward sands of the inner barrier are found. This formation is characterized by low ridges and depressions with indurate layer at depth. Remnants of an additional barrier are found within the catchment
(e.g. Johns River State Forest - Den Exter, 1975). Within this report the terms 'present barrier' and 'prior barriers' are used to denote the barrier formations.

Modifications of the barrier systems by fluvial and aeolian activity has masked their identification on morphological grounds. Much of the prior barrier system, particularly in the Dunbogan Beach embayment has been subjected to reworking. The barrier has been eroded and overlain by estuarine and paludal sediments associated with Watson Taylor Lake. Similar barrier alteration is evident within Grants Beach embayment over an area which may have been a prior entrance channel to Queens Lake. Aeolian processes are also evident, with transgressive dunes overtopping the prior barrier in the central to northern areas of the Dunbogan embayment. Geomorphologically Den Exter (1975) has detailed the sequence of barrier formation and alteration as follows:-

- Draining of subaerial landscape, last Pleistocene submergence, development of gravel prior barriers.
- Initiation and progradation of prior barrier with concurrent fluvial and estuarine sedimentation of lagoons
- Prior barrier dissection during the last Glacial emergence
- Holocene transgression and submergence of dissected inner barrier; initiation of present barrier
- Recent sea level still-stand; present barrier progradation and sedimentation of coastal lagoons.

Explanatory figures taken from Den Exter (1975) are presented in Figures 2.6 to 2.8.

Contemporary aeolian, fluvial and estuarine processes continue to alter the landforms of the catchment. Taylor (1972) defined the depositional environment of the Camden Haven estuary as being "a shallow water marginal marine system possessing many of the attributes of both a lagoon and an estuary". Roy and Crawford (1977) recognized four sediment types and hence sources of sediment within coastal rivers of northern N.S.W. The sediment types are as follows:

- Terrestrial river sediment
- Reworked coastal sand
- Beach and nearshore marine sand
- Offshore sand.
FIGURE 2.6: GEOMORPHOLOGICAL SEQUENCE OF BARRIER FORMATION - PLEISTOCENE SUBMERGENCE AND INNER BARRIER INITIATION (after Den Exter, 1975).
FIGURE 2.7: GEOMORPHOLOGICAL SEQUENCE OF BARRIER FORMATION - INNER BARRIER PROGRADATION AND LATER DISSECTION DURING THE LAST GLACIAL EMERGENCE (after Den Exter, 1975).
FIGURE 2.8: GEOMORPHOLOGICAL SEQUENCE OF BARRIER FORMATION - HOLOCENE TRANSGRESSION, INITIATION AND PROGRADATION OF PRESENT BARRIER (after Den Exter, 1975).
Terrestrial river sediment within the Camden Haven catchment derived from the Palaeozoic, Triassic and Tertiary hinterland is poorly sorted and immature. Taylor (1972) found the sediments in Herons Creek to be of arkosic greywacke composition while the sediments of the Camden Haven and Stewarts rivers varied from a lithic arkose to a arkosic greywacke. This variation in sediment type reflects the higher proportion of Tertiary intrusives within the Camden Haven and Stewarts river subcatchments.

Roy and Crawford (1977) define variability within barrier, coastal and offshore sands as follows:

"Beach and nearshore marine sand is more shelly than reworked coastal sand; shell fragments are mainly of open ocean, rather than estuarine, species. It also contains numerous ironstained grains of well-rounded shell and quartz.

Reworked coastal sand has a leached appearance and commonly contains grains with brown organic coatings. The degree of rounding is similar to that of the beach and nearshore sand, but ironstained grains are absent and shell content is lower.

Offshore sand is finer grained, more lithic and more angular than either the reworked coastal or the beach and nearshore sands".

Within the Camden Haven terrestrial river sediment is deposited in the lakes resulting in the formation of subaqueous and subaerial delta deposits. The distribution of lithofacies in Queens Lake is considerably simpler than that within Watson Taylors Lake. This reflects the greater sediment input into Watson Taylors Lake resulting in the extension of the Camden Haven river delta into the lake. As a consequence of the delta building processes sandy fluvial facies are prograding over muddy lake bottom facies.

Sediment derived from the beaches and nearshore zone by wave action and longshore drift is moved into the estuary by flood tide currents and mixed with sands from the prior barrier systems. These sands are transported into the lakes resulting in the formation of sandy tidal reverse deltas at the entrances of both lakes. Note: Construction of training walls may have increased the inshore movement of sands (e.g. Druery and Neilson 1979; McLean and Burgess 1975; Neilson and Gordon 1980). Taylor (1972) recognised a zone of mixing of sediment derived from the inlet area with that derived from the rivers draining the hinterland. Taylor’s investigation
was based upon the heavy mineral content and the grain size of the sand fraction of the sediments. Further research and mapping of estuarine sediments based upon Taylors investigation is presented within Technical Report 2. Recognition of these processes is inherent within the mapping of associated land areas in the latter sections of this chapter. Contemporary marine and nearshore processes acting on the present barrier system are detailed within Appendix 2 of this report.

The assembly and interpretation of existing geological information provides a basis for the delineation of land systems within the catchment. Geology influences landform and soils and hence vegetation and land uses such as forestry and agriculture. The broad nature of the geologic mapping available implies that only general relationships between lithology and other biophysical components can be described. It is apparent for example that the variety of landscapes within the sediments or the quaternary deposits reflect at least in part differences in lithology. However, further biophysical data is required to define the aggregation of land units that compose a land system.

Similarly, a review of geomorphology provides direct input to the delineation of land systems, defining prior and contemporary processes and demonstrating the linkage between geology and additional biophysical data such as climate. Exhibited soil types for example, are directly related to the lithology of the underlying rocks and their geomorphic history. The definition of prior and contemporary processes also provides input to the establishment of a management strategy for land systems and units of the catchment. For example, the recognition and detailing of contemporary processes may impose constraints on land use type deemed to be compatible with a specific land unit. In particular, knowledge is required of contemporary processes which define the environmental hazards of coastal erosion and floods. The location of the land areas affected by these hazards is defined by the land system and land unit mapping through the recognition and inclusion of geomorphic factors within the mapping base.

2.4 **SOILS**

No detailed mapping and definition of soils of the Camden Haven catchment is available. Of the soils within the catchment the most ferrile are those based on the porphyritic rhyolite intrusions of the upper catchment
(e.g. Forest Preserve, Kerewong State Forest Pers. Comm. 1981a). These soils are followed in a fertility gradient by those based on the micro-granites (red podzolics). Soils derived from the sediments (usually yellow to red podzolics) are less fertile. Within this group there is a fertility gradient from shale through conglomerate to sandstone. The coastal sediments of the Johns River State Forest area, being predominantly sandstone derived with no associated conglomerates and shales are amongst the poorest within the catchment (Pers. Comm. 1981a).

The environmental features interacting with soil formation include parent material, topography, climate, biotic factors and age. Of these, parent material, reflecting the complex lithology of the underlying rocks and their geomorphic history are the dominant factors. Relationships between soil and vegetation are obscured by the complexity of microclimates controlled by variations in altitude, aspect and distance from the coast.

For the above reasons soil type is not considered relevant as a workable divisive factor in the delineation of land systems and units. Rather, through the aerial photographic interpretation of geologic, geomorphic and vegetative factors soil type is implied, at least in general terms. General descriptions only of soil type was obtained during field inspection of land systems. These general descriptions are contained within later discussion of land systems and land units.

It must be noted however, that the evaluation of soil limitations for various forms of land use is important within any consideration of use allocation and management. For example, the generation of exclusion criteria for uses would require data on such aspects as profile, moisture and erosability. The definition of land systems and units provides a initial sieve for further data collection. Further detail of these concepts and the methodology adopted within this study are contained within Chapter 3.

2.5 VEGETATION

Naturally occurring vegetation covers a large proportion of the catchment (≈ 65%). Few of the existing or potential land uses are dependent on the indigenous species cover. Forestry and conservation are the obvious exceptions. The incorporation of vegetation within the mapping program has emphasis on the application of vegetation as an indicator of particular functional environments. Generalized vegetation type with reference to
structure, function, environmental and geographic relationships was thus deemed to be more important than detailed vegetation lists. Indicative species lists rather than complete species lists are presented for land systems and units. Data for these lists was obtained during the field work program together with reference to prior studies and assistance from informed personnel (Forestry Commission, Kendall; National Parks and Wildlife Service, Taree).

Milledge (1979) defined the following broad vegetation classification for the Camden Haven:-

<table>
<thead>
<tr>
<th>Classification</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td></td>
</tr>
<tr>
<td>Estuarine</td>
<td>5%</td>
</tr>
<tr>
<td>Wetlands</td>
<td>1%</td>
</tr>
<tr>
<td>Disturbed</td>
<td></td>
</tr>
<tr>
<td>Pastoral</td>
<td>32%</td>
</tr>
<tr>
<td>Crops and Grasses</td>
<td>0.25%</td>
</tr>
<tr>
<td>Rural/Town Gardens</td>
<td>0.25%</td>
</tr>
<tr>
<td>Coastal Complex</td>
<td></td>
</tr>
<tr>
<td>Rocky Areas</td>
<td>0.25%</td>
</tr>
<tr>
<td>Dunes</td>
<td>0.25%</td>
</tr>
<tr>
<td>Heaths</td>
<td>5%</td>
</tr>
<tr>
<td>Forest</td>
<td></td>
</tr>
<tr>
<td>Low Open/Open Forest</td>
<td></td>
</tr>
<tr>
<td>Tall Open Forest</td>
<td>56%</td>
</tr>
<tr>
<td>Tall Closed/Closed Forest</td>
<td></td>
</tr>
<tr>
<td>Low Closed Forest</td>
<td></td>
</tr>
</tbody>
</table>

Within the mapping program vegetation type as discernable from aerial photographs was used as the primary divisive factor in the disaggregation of land systems to land units. This not only because the vegetation types present indications of environmental conditions and primary producers, but also because vegetation largely infers the ecosystem structure, including the species composition of all the other biotic communities (UNESCO, 1979). Plant communities can be seen as the best available surrogates for ecosystems and thus provide a definition of land unit function and relation to associated units within the designated land systems.
2.6 FAUNA

Turner (1976) discussing faunal surveys and resource inventories stated:

"Animals play a vital role in the variation and maintenance of natural and man-modified systems. They are thus an integral component of the biophysical environment but because they present special problems of variation in both time and space, resource inventories have seldom involved fauna as a component element".

No survey of land-based fauna was included within this study. Aspects of estuarine fauna are discussed within Technical Reports 2 and 4.

Milledge (1979) detailed land-based fauna of the Camden Haven catchment. As already stated, the delineation of land units on a primarily vegetative base does infer ecosystem structure and the species composition of the faunal communities. For further information on land-based fauna reference to Milledge (1979) should be made in the context of the land systems and land units described within this study. Refer to Heyligers, Myers, Scott and Walker (1981) for further discussion of the applicability of the land systems approach to faunal surveys.

2.7: LAND SYSTEMS OF THE CAMDEN HAVEN

The preceding sections have detailed the biophysical background data relevant to the study area. Methodology utilized to define the land systems and units is summarized by figure 2.9.

Map 1 (1:100,000) details the location of all land systems. Maps 3A and 3B provide this information together with the location of all land units mapped (1:25,000 - CMA Map Coverage: Comboyne 9334-1-N, Byabarra 9434-1V-N, Grants Head 9434-1-N, Bobin 9334-1-S, Lorne 9434-1V-S, Laurieton 9434-1-S, Coopernook 9434-111-S).

The following notes detail occurrence, landform, geology, soils, vegetation, land use and tenure for all land systems. The landform notes describe the topography, typical slopes and slope lengths, elevation and dissection of the land systems. Soils are described within Greater Soil Groups and represent dominant soil types. Vegetation provides information
FIGURE 2.9: MAPPING METHODOLOGY (GENETIC LANDSCAPE APPROACH)

CLIMATE

CATCHMENT DELINEATION

HYDROLOGY

GEOLOGY

GEOMORPHOLOGY

LANDFORM

API

LAND FORMATION

LAND SYSTEMS

CLIMATE

CATCHMENT

HYDROLOGY

ALL OTHER
LAND SYSTEMS

ESTUARINE ALLUVIUM
COASTAL SANDS

LAND SYSTEMS

RIVERINE-FLOODPLAIN ALLUVIUM
UNITS DELINEATED

VARIATIONS WITHIN MAPPED
LAND SYSTEMS NOTED

FIELD SURVEY

(LAND UNITS
(Detailed mapping to define
ecologically functional
areas)

(FORMALIZE BOUNDARIES, COLLECT INFORMATION ON
VEGETATION FLORISTICS AND STRUCTURE, SOIL TYPE
AND LAND USE. REMAP WHERE NECESSARY).
MAP: KEY TO THE LAND SYSTEMS.

- Estuarine Alluvium
- Coastal Sands
- Ross Glen Intrusion
- North Brother Intrusion
- Middle Brother Intrusion
- South Brother Intrusion
- Black Creek Intrusion
- Stewarts River Intrusion
- Upper Catchment Intrusions
- Diamond Head Intrusions
- Comboyne Plateau
- Stewarts River Sediments
- Johns River Sediments
- Herons Creek Sediments
- Comboyne Rim
- Bago Bluff Conglomerate
- Jolly Nose - Bonny Hills Sediments
- Camden Haven River Sediments
- Limburners Creek Sediments
- Lake Cathie Sediments
MAP I: LAND SYSTEMS OF THE CAMDEN HAVEN.
on the naturally occurring floristics and structure of the land systems. Wherever possible vegetation types are defined in terms of the forest types and associations utilized by the N.S.W. Forestry Commission. Species lists are provided to further define the vegetation associations. Land use and tenure notes provide general information on use and tenure status within each land system. The location and management strata of all State Forests is listed together with areas of urban development, agricultural and pastoral activity, and areas reserved for conservation purposes.

ESTUARINE ALLUVIUM

**Occurrence:** Lower floodplain of Stewarts and Camden Haven rivers with extensive areas surrounding Watson Taylor Lake; Lower Herons, Waterloo, Bobs and Limeburners Creeks with fringing elements to Queens Lake; land areas and islands associated with entrance channel and Stingray Creek; wetland areas of Duchess and Vinegar Creek.

**Landform:** Generally flat, minimal dissection, levee formation adjacent to major watercourses; inundation varies from tidal to major flood events only.

**Geology:** Unconsolidated Quaternary sediments of fluviatile and marine origin.

**Soils:** Humic podsols of varying lithofacies.

**Vegetation:** Estuarine alluvium areas were mapped within the following vegetative types: mangroves, salt marsh, swamp oak forest, fresh to brackish estuarine connected wetlands and eucalypt dominated closed to open forest. Refer to Section 2.8 for further discussion of these land units.

**Land Use and Tenure:** Well-drained areas cleared for urban development (e.g. North Haven, Dunbogan); limited grazing and agricultural development; portions of the system contained within Crowdy Bay National Park, the remainder predominantly freehold.

COASTAL SANDS

**Occurrence:** Extensive development in the southern areas of the catchment (Dunbogan embayment) grading to moderate development within the Grants Head embayment to minimal within the Rainbow Beach Embayment.
Landform: Present and prior barrier formation with associated landforms, often reworked by fluvial and aeolian processes (e.g., transgressive dunes);

Geology: Unconsolidated quaternary sediments of beach deposited quartzose; indurate layer present beneath Pleistocene formations.

Soils: Where well-drained a humic A horizon (< 0.3 metres depth) overlies unconsolidated sands, while in poorly drained areas soils are generally humic podzolics, humic gleys and acid peats.

Vegetation: The coastal sands land system was mapped at the land unit level within the following vegetative types: Present barrier complex, dry and wet heaths, eucalypt dominated woodland to low forest; refer to Section 2.8 for further detail and species occurrence within this land system.

Land Use and Tenure: Limited urban development (e.g., Camden Head, Bonny Hills); heavy mineral mining (refer to Appendix 2, section 4), recreation; portions of this land system within Crowdy Bay National Park; remainder crown land or freehold.

COMBOYNE PLATEAU

Occurrence: A portion of the Comboyne Plateau forms the central area of the western catchment boundary.

Landform: Elevation greater than 450 metres, rolling low hills, moderate dissection, long ridges and consistently moderate slopes (Ave: 6°); The Comboyne Plateau falls sharply away to the east with dissection increasing adjacent to the Comboyne Rim land system.

Geology: Tertiary pyroxene bearing trachytes generally known as Comboyne basalt.

Soils: Krasnozems.

Vegetation: Extensively cleared, some remnant depauperate rainforest pockets around creeks.

Land Use and Tenure: Predominantly freehold; agriculture - cropping and improved pasture.
UPPER CATCHMENT INTRUSIVES

Occurrence: Upper catchment within Comboyne Rim, Stewards River Sediments and Camden Haven River Sediments land systems.

Landform: Two landform types are present - the topographically significant plugs (Big Nellie, Little Nellie, Lorne Peak) and the remainder (6 occurrences), being rounded, moderately dissected hills with moderate slope lengths (0.75 km) and convex to low moderate slopes (Ave: 10°).

Geology: Tertiary porphyritic rhyolite plugs and intrusives.

Vegetation: Open to closed forest, blackbutt and moist hardwoods on ridges and upper slopes (> 40 m) flooded gum association within valleys and low slopes (> 50 m). Species within these associations are as follows: i) Blackbutt and moist hardwoods: Eucalyptus pilularis, E. propinqua, E. microcorys, E. paniculata, E. maculata, E. amenodes, E. gummifera, E. resinifera, E. grandis, Syncarpia glomulifera, Tristania conferta, Casuarina torulosa, Acacia floribunda, Ceratopetalum apetalum, Archontophoenix cunninghamiana; ii) Flooded Gum Association: Eucalyptus grandis, E. microcorys, E. propinqua, E. gummifera, E. pilularis, Syncarpia glomulifera, Tristania conferta, Acacia floribunda, A. mearnsii, A. elata, Casuarina torulosa, Archontophoenix cunninghamiana, Aokama paniculata, Doryphora sassafras, Laportea gigas (the listed rainforest species being of limited occurrence).

Land Use and Tenure: Predominantly State Forest (Kerewong, Comboyne and Landsdowne) intensively logged, generally regrowth with some scattered veterans.

DIAMOND HEAD INTRUSIVES

Occurrence: Diamond Head and an associated outcrop within the Coastal Sands land system.

Landform: Diamond Head is a topographically significant headland (113 metres) with moderate dissection, moderate length ridges (0.7 km) and some shorter side slopes (0.3 km). The outlier is a low rounded hill, less than 20 metres elevation, with moderate ridge lengths and convex slopes.
Geology: Triassic sediments intruded and overcapped by rhyolitic larva of tertiary age; Quaternary coastal sands overlie the system along the southern margins.

Soils: Generally shallow gleyed podzolics overlying bedrock; Humic sand podzolics and yellow podzolics where overlying coastal sands predominate.

Vegetation: Coastal heath complex of less than 0.5 metres, species similar to the heaths of the Triassic sedimentary headlands (Camden Head, Grants Head); where overlying sand present the unit exhibits a closed to open woodland with the following species dominating: Eucalyptus intermedia, E. planchoniana, E. signata, Angophora costata, Casuarina littoralis, Banksia integrifolia, with a grassy understorey (e.g.: Themeda australis, Lomandra sp.). Melaleuca quinquenervia dominates in lower poorly drained areas.

Land Use and Tenure: Within Crowdy Bay National Park; recreation and camping area developed on northern side of Diamond Head, adjacent to beach.

NORTH BROTHER INTRUSION

Occurrence: North Brother, behind Laurieton.

Landform: Mountainous (maximum elevation 487 metres) with long (1.5 km) radial ridges, moderate to coarsely dissected with concave slopes, dominant slopes 17°-30°; Colluvium fans associated with major watercourses, feetloope areas (4°-8°) around perimeter.

Geology: Microgranitic intrusion of Tertiary age.

Soils: Generally fine-grained yellow to brown podzolics.

Vegetation: Strong aspectral differences - northern faces and western ridges dry blackbutt - mixed hardwoods; southern faces exhibit blackbutt with moist hardwoods, rainforest pockets in sheltered valleys and valley sides, (refer to Lee, 1975 for a detailed species list including monocots, ferns, fungi and orchids).

Land Use and Tenure: More than half of the land system is contained within Camden Haven State Forest and is presently reserved from logging. The remainder is generally freehold, including on the eastern foothloope the township of Laurieton. Lower slopes of the south-eastern face have recently been logged by private forestry.
MIDDLE BROTHER INTRUSION

Occurrence: Middle Brother, west of Kendall.

Landform: Mountainous (maximum elevation 556 metres), with hilly summit area; moderate to coarsely dissected, long central ridges (1.5 km) with steep moderate length spurs; straight to concave slopes (16°-25°); colluvial fans associated with major watercourses. Associated areas of the Camden Haven River Sediments are hilly to mountainous, fine to moderately dissected with long ridges.

Geology: Microgranitic intrusion of Tertiary age.

Soils: Yellow podzolics, fine grained.

Vegetation: Blackbutt and mixed hardwoods on ridges; blackbutt and moist hardwoods dominating lower slope and valley locations; some rainforest and palm forest elements present in sheltered locations including Arthropitcollix cunninghamiana, Gmelina leichhardtii, Heritiera actinophylla, Sloanea woolii.

Land Use and Tenure: The majority of the system is contained within Middle Brother State Forest, comprising regrowth sawlogs and scattered veterans, older regeneration with some seed trees and areas presently reserved from logging. Freehold lower slope and colluvium areas on the southern fringe of the system, within the Stewarts River valley have been cleared for grazing and cropping.

SOUTH BROTHER INTRUSION

Occurrence: Southern catchment boundary, west of Johns River township.

Landform: Mountainous (maximum elevation 444 metres), rocky central core with radiating steep short spurs, coarsely dissected; very minor lower slope component.

Geology: Microgranitic intrusion of Tertiary age.

Soils: Shallow yellow podzolics.

Vegetation: Blackbutt with mixed hardwoods in lower areas.

Land Use and Tenure: Crown land.

ROSSGLEN INTRUSIONS

Occurrence: Fringing the Camden Haven River upstream from Rossglen.

Landform: Hilly (maximum elevations 103 metres, 52 metres), concave slopes (8°-26°) with short ridges, coarse to moderate dissection.
. Geology : Microgranitic intrusion of Tertiary age.
. Soils : Yellow podzolics.
. Vegetation: Blackbutt with mixed hardwoods, partially cleared.
. Land Use and: Freehold with limited clearing for grazing.

BLACK CREEK INTRUSION

. Occurrence: North west of Kendall, within the Camden Haven river catchment.
. Landform : The system is dissected by Black Creek, with alluvium and lower rolling areas in the Creek valley. The remainder is hilly to mountainous (maximum elevation 247 metres), with straight to concave slopes (Ave: 16°). Moderate length ridges (0.75 km) with short steep spurs characterize the system. Dissection is moderate to coarse throughout.
. Geology : Microgranitic intrusion of Tertiary age.
. Soils : Yellow to red podzolics.
. Vegetation: Predominantly flooded gum association with restricted pockets of rainforest (e.g. Black Creek Forest Reserve); Drier exposed ridges develop a mahogany association - species within this association are as follows:
Dominant: Eucalyptus propinqua, E. amentioides, E. Paniculata.

. Land Use and: Predominantly freehold, grazing and agriculture within lower slopes and alluvium areas; Northern portions of the system lie within Lorne State Forest.

STEWARTS RIVER INTRUSION

. Occurrence: Catchment boundary west of South Brother, extending northwards to enclose the Stewarts River valley.
. Landform : Hilly to mountainous along catchment boundary (maximum elevation 300 metres) with a hilly tableland moderately to finely dissected; Central areas are undulating, moderately dissected with short slopes and ridges. The northern rim area comprised of a virtually continuous steep (Ave: 35°) moderately dissected ridge. The northern rim is a continuously steep (Ave. 35°), moderately dissected ridge.
Microgranitic intrusion of Tertiary age.

Red to yellow podzolics.

Dominated by blackbutt with mixed hardwoods; Limited occurrence of blackbutt with moist hardwoods within valleys and lower slopes.

The higher catchment boundary areas are contained within Landsdowne State Forest. The remainder of the system is predominately freehold, with grazing on the lower slopes and cropping within the alluvial flats.

North western catchment boundary extending south adjacent to the Comboyne Plateau, thence the southwestern catchment boundary and upper portions of the southern catchment boundary.

Long even ridges with no real dissection, dipping generally to the east; Steeper western aspects and escarpment; Where underlying sediments are exposed the system displays short, often strongly dissected spurs with perpendicular strongly parallel steep-sided ridges.

Herbert (1974) described the Laurieton conglomerate as being "a red jasper and quartzite pebble to cobble conglomerate over two hundred metres thick along the western margin, wedging out towards the east". This conglomerate overlies the finer sediments of the Lorne Basin.

Yellow podzolics, coarse to fine grained as a function of bedrock.

Predominantly dry blackbutt and mixed hardwoods (less than 40 metres) in the exposed, shallow soil areas; Lower ridges to mid-slope are dominated by blackbutt with moist hardwoods (greater than 40 metres), which is replaced further downslope by a Tallowwood - Sydney Blue Gum association (40 to 60 metres); Valley floors are dominated by subtropical, dry and depauperate rainforest; Species typical of the dry blackbutt and mixed hardwoods association are as follows:-

Eucalyptus pilularis, E. maculata, E. microcorys, E. paniculata, E. propinqua, E. acomenioides, E. globoidea, Syncarpia glomulifera, Casuarina torulosa. Rainforest species include:-
Archontophoenix cunninghamiana, Aokama paniculata, Doryphora sassafras, Laportea gigas, Tristania conferta, Syncarpia glomulifera, Acacia floribunda, A. meareii, A. elata.

- **Land Use and Tenure**: The system is predominantly State Forest (Kerewong, Comboyne and Landsdowne), with logging intensive to extensive as a function of species and local topography.

**STEWARTS RIVER SEDIMENTS**

- **Occurrence**: Stewarts river valley together with portions of the upper Camden Haven river valley, bounded to the west of the Comboyne rim.

- **Landform**: Low undulating to hilly, moderate to fine dissection with alluvial areas adjacent to major watercourses; scattered plateau areas, as a function of harder sediments; plateau areas are shortly undulating, of moderate to fine dissection with short ridges and rounded spurs.

- **Geology**: Lorne Basin sediments, particularly the Camden Haven claystone formation (red-brown claystone and siltstone with minor amounts of grey plant-bearing siltstone, sandstone and conglomerate); Sandstones and conglomerates dominate in the plateau areas.

- **Soils**: Red and yellow podzolics.

- **Vegetation**: Largely cleared; remnant areas within State Forests display blackbutt and mixed hardwoods association on ridges and plateau areas, blackbutt with moist hardwoods on valley sides and slopes, flooded gum association within valley floors with small remnant pockets of rainforest in sheltered, low slope locations.

- **Land Use and Tenure**: Predominantly freehold, agricultural cropping and grazing; portion within Kerewong State Forest generally young regrowth and regrowth sawlogs with few veterans.

**CAMDEN HAVEN RIVER SEDIMENTS**

- **Occurrence**: West of Watson Taylors and Queens Lakes, including Kendall area then north to northwest to the catchment boundary; An outlier of this system lies further to the west on the catchment boundary and surrounded by the Comboyne Rim land system.

- **Landform**: Hilly, moderate to coarsely dissected, long ridges, moderate length spurs, convex to straight slopes (1.5°-9°); Scattered rounded hills display coarse dissection and shorter ridges.
Geology: Byabbarra beds of Carboniferous age—lithic sandstone, siltstone, tuff, shale and limestone beds; Triassic capping of fine conglomerates and lithic sandstones, particularly in the upper catchment areas.

Soils: Yellow to red podzolics, coarse to medium grained.

Vegetation: White Mahogany association on plateaus and ridges, often less than 30 metres; blackbutt and mixed hardwoods association on deeper soil areas of ridges and valley sides, with blackbutt and moist hardwoods association within valleys; limited occurrence of flooded gum association.

Land Use and Tenure: Catchment boundary areas lie within Broken Bago and Lorne State Forest. Areas of Camden Haven River Sediments adjacent to the Middle Brother Intrusion are contained within Middle Brother State Forest. Apart from Kendall State Forest, the remainder which accounts for most the lower slope areas is freehold. Freehold lands are generally used for grazing with agricultural cropping in alluvial areas.

BAGO BLUFF CONGLOMERATES

Occurrence: Northern catchment boundary, headwaters of Herons Creek.

Landform: The land system generally dips south from the northern escarpment. Dissection is parallel, fine to moderate—in the west and coarser, less controlled in the east. Generally steep, slopes range from 14° to 22°.

Geology: Triassic conglomerate to depth.

Soils: Coarse yellow podzolics.

Vegetation: Blackbutt and mixed hardwoods association; 6B's Forest Reserve includes E. pyrocarpa (southern limit) with an understorey of Hakea trineura, Callistemon acuminatus.

Land Use and Tenure: The system is contained within Broken Bago State Forest. Apart from the 6B's forest preserve the State Forest has been extensively logged, and is presently composed of young regeneration with few seed trees.

HERONS CREEK SEDIMENTS

Occurrence: North eastern catchment boundary through to Queens Lake, comprising most of the Herons Creek catchment.

Landform: Rolling, moderately to coarsely dissected with long ridges and convex slopes (1.5-5.5°).
**Geology**  : Triassic sediments.

**Soils**  : Medium grained yellow to red podzolics.

**Vegetation**  : Dominated by blackbutt and mixed hardwoods association with blackbutt and moist hardwoods and flooded gum associations in valley floors. Limited occurrence of white mahogany association in upper catchment, shallow soil areas.

**Land Use and Tenure**  : Upper Herons Creek catchment within Burrawan and Broken Bago State Forests; intensively logged, displaying regrowth sawlogs and young regeneration; The remainder is predominately freehold and cleared for grazing with some cropping in lower and alluvial areas.

**JOLLY NOSE - BONNY HILLS SEDIMENTS**

**Occurrence**  : The land system is found in the following locations: - north of Queens Lake to the catchment boundary (including Jolly Nose) - east of Queens Lake, south of Limeburners Creek - Grants Head - Perpendicular Point and Camden Head - North Haven.

**Landform**  : The Queens Lake occurrences are steep to rounded, moderately dissected with moderate length ridges. Slopes are convex ranging from 11° to 27°. Camden Head (elevation 64 metres) and Grants Head (elevation 60 metres) display similar landforms. The North Haven occurrence is low and rounded but of sufficient elevation to be above maximum flood levels.

**Geology**  : Fine conglomerates, sandstones and shales of Triassic age.

**Soils**  : Yellow to red podzolics, medium grained.

**Vegetation**  : Vegetation is strongly related to aspect and location, varying from coastal heaths and Banksia woodlands on the headlands to blackbutt and mixed hardwoods within the Queens Lake area. Ridges and exposed, shallow soil areas in the Jolly Nose occurrence exhibit a white mahogany association. Valleys associated with major creeks exhibit a limited extent of blackbutt and moist hardwood association.
Land Use and Tenure: Portions of the system are contained within Queens Lake State Forest (regrowth sawlogs and areas of young regeneration with few seed trees). The remainder of the system is predominately freehold, with urban development at Grants Head and North Haven.

**JOHNS RIVER SEDIMENTS**

- **Occurrence:** West of Watson Taylors Lake to the southern catchment boundary.
- **Landform:** The system is low and rolling, displaying moderate dissection. Slopes range from 1° to 8°.
- **Geology:** Triassic sediments, predominantly sandstones.
- **Soils:** Yellow podzolics with a poorly structured grey sand upper horizon.
- **Vegetation:** Tall open forest to woodland of the blackbutt and mixed hardwoods association; Dominant species are as follows: *Eucalyptus pilularis*, *E. Signata*, *E. intermedia*, *E. gummiifera*, *E. aemerioides*, *E. resinifera*, *E. robustus*, *E. micrantha*, *Angophora costata*; Valley floors are dominated by *Melaleuca quinquenervia*.

- **Land Use and Tenure:** The land system is almost wholly contained within Johns River State Forest. The system has been intensively logged and presently exhibits young regeneration with few seed trees and plantation blackbutt.

**LIMEBURNERS CREEK SEDIMENTS**

- **Occurrence:** North of Queens Lake incorporating most of the Limeburners Creek catchment.
- **Landform:** Low rolling to slightly hilly, moderate to coarsely dissected with convex slopes (2° to 8°).
- **Geology:** Schist, phylite, greywacke and slate of Devonian age.
- **Soils:** Yellow podzolics and lithosols on rises, gleyed podzolics in lower slopes and valleys.
- **Vegetation:** Dry sclerophyll open forest to 30 metres on ridges and side slopes; Dominant species: *Eucalyptus propinquua*, *E. globoidea*, *E. intermedia*, *E. microcorys*, *E. creba* and *E. pilularis*; Valleys are dominated by *Melaleuca* sp.

- **Land Use and Tenure:** Apart from Diggers Hill Flora reserve and a adjacent portion of Crown land the system is freehold.
LAKE CATHIE SEDIMENTS

- **Occurrence:** To the north and east of the Limeburners Creek Sediments comprising the uplands of the Duchess-Vinegar Creek catchment.

- **Landform:** The system is of higher relief than the Limeburners Creek System, is rolling to low hilly, coarsely dissected and of slopes ranging from $1^\circ$ to $9^\circ$.

- **Geology:** Schist, phylite, greywacke and slate of Devonian age.

- **Soils:** Red, medium to fine grained podzolics.

- **Vegetation:** The system displays a blackbutt with mixed hardwoods association on ridges and upper slopes with a blackbutt and moist hardwoods association in valleys and lower slope locations.

- **Land Use and Tenure:** The system is predominantly freehold, with grazing, private forestry and hobby farm development being the major activities.

Within the Coastal Sands and Estuarine Alluvium land systems component land units were mapped. Within all other land systems aerial photographic interpretation was utilized to delineate alluvium areas associated with major creeks and rivers (refer to Figure 2.9). The following section provides data on all land units mapped. Refer to Map 2 (Coastal Lands) and Maps 3A, B for the location of these units.
2.8 DESCRIPITIONS OF LAND UNITS MAPPED

a) COASTAL SANDS

CS-1: Present Barrier

The vegetation transition found within this unit is represented by the following list of dominant species and notes on location:

- Festuca littoralis
- Senecio spathulatus
- Spinifex hirsutus
- Carpobrotus aequilaterus
- Leptospermum laevigatum
- Leucopogon richel
- Scaevola calcarulacea
- Cupaniopsis anacardioides
- Acacia longifolia var. sophora
- Scirpus nodosus
- Banksia integrifolia
- Banksia serratifolia
- Angopnera lanceolata
- Monotoca elliptica
- Breynia oblongifolia
- Notolaea Longifolia
- Pteridium esculentum
- Imperata cylindrica

Note: Bitou bush (Chrysanthsoides monilifera) is present in all areas of this unit except the incipient foredune. In disturbed areas growth is very dense (e.g.: sand mining rehabilitation areas, public access points). Colonization of undisturbed areas is evident (e.g. within the Banksia woodland of the landward beach ridges). Bitou bush has also been observed within Camden Haven and Queens Lake State Forests. Classification as a noxious weed and control of this species is necessary.

The present barrier occurs in varied extent within all embayments of the study area, viz:

- Dunbogan Beach - Diamond Head to Camden Head
- Pilot Beach - Perpendicular Head to Southern Training Wall
- Grants Beach - Training Wall to Grants Head
- Rainbow Beach - Grants Head to Middle Rock Point.
In the classification system adopted by this study this land unit is comprised of the beach zone or zone of contemporary swash action, the fixed foredune, where aeolian processes dominate and the associated present barrier ridges. This unit represents the contemporary active zone of aeolian and marine processes thereby defining a management unit.

The fixed foredune on Dunbogan and Grants beaches comprises a single ridge, with an elevation of 6 to 10 metres above mean high water aligned parallel to the shore. Incipient foredunes develop at the toe of the fixed foredune during short-term periods of beach progradation, wind blown sand being trapped by *Pestaca littoralis* and *Spinifex hirsutus*. During short term periods of beach erosion the incipient foredune is removed and reworked exposing the toe of the fixed foredune to wave attack.

Landward of the fixed foredune on Dunbogan and Grants beaches the present barrier comprises a series of beach ridges occupying the zones of recent marine and aeolian deposition. Vegetative components are as noted within the species list. Between one and three ridges are present landward of the beaches. These ridges abut the prior barrier system from which they are readily distinguished by marked differences in morphology, soils and vegetation. The contact between the beach ridges and the foredune is marked by a swale or depression, except in those areas where transgressive dunes have encroached upon and often buried both present barrier ridges and foredune swale. Contemporary transgressive dunes are present on the northern end of Dunbogan Beach. In this case the dune is migrating landward in the direction of effective onshore winds (Den Exter 1975).

Conditions differ in the Rainbow Beach - Cathie embayment to those described in the preceeding discussion of the Camden Haven embayments. Within the Cathie embayment the prior barrier of Pleistocene age lies adjacent to the beach zone and incipient foredune. The prior barrier comprises a series of one to three generally ill-defined ridges over a width of 300 metres. The barrier is interrupted by the outlets of Duchess Creek in the southern corner of Rainbow Beach and by Lake Cathie to the north of the study area. The barrier attains an elevation varying between 6 and 9 metres, with local relief of the landward ridges not exceeding 1 metre except where the stream course of Duchess Creek follows a swale between the two ridges comprising the unit. Indurated sand of Pleistocene age is exposed on the beach throughout the Cathie embayment during periods
of short-term beach erosion.

Roy and Stephens (1981) define five factors of relevance to beach formation and erosion. Briefly these are:

- Degree of compartmentization and sand by-passing
- Incident wave energy
- Offshore sand losses to deep water sinks
- Inherited sediment characteristics
- Substrate control.

It is suggested that the absence of a significant barrier of Holocene age within the Cathie embayment may be attributed at least in part, to changes in the littoral drift pattern associated with changes in sea level. For further discussion on barrier formation and the significance and mode of formation of indurated sand refer to Thom 1978; Thom, Polack and Bowman 1978, and Winward and Nicholson 1974.

CS-2,3: Dry and Wet Heath

The vegetation transition found within these units is represented by the following list of dominant species and notes on location:-

- Banksia serratfolia
- Banksia aspleniifolia
- Banksia ericifolia
- Leptospermum flavescens
- Boronia pinnata
- Ricinocarpus pinifolius
- Goodenia stelligera
- Eriostemon lanceolatus
- Hypolaena fastigiata
- Actinotus helianthi
- Lomandra glauca
- Isopogon anemonifolius
- Eucris pulchella
- Eucalyptus robusta
- Gahnia sieberana
- Xanthorrhoea
- Leptospermum livessidgei
- Leptospermum juniperinum

Dry Heath

Wet Heath
Heath units occur in all embayments of the study area landward of the present barrier. In several cases (for example, Dunbogan Beach) aeolian processes have created extensive areas of Eucalypt dominated transgressive dunes, land unit CS-4. These transgressive dunes alter the geomorphic pattern of present and prior barrier, thereby disrupting the continuity of units CS-2 and CS-3 landward of CS-1. Further disruption of continuity may be the result of recent fluvial process. Within the northern extremity of the Dunbogan Beach embayment prior barrier and flats have been eroded so that the prior barrier is no longer joined to the Triassic bedrock of Camden Head.

Specht (1970) structurally classified heaths as being vegetation communities dominated by shrubs of less than 2 metres in height having a projected foliage cover of 30-70% (mid-dense) to 70-100% (dense heaths).

With respect to heath type Specht (1981) defined two general types, dry and wet heathlands (land units CS-2 and CS-3 respectively). Specht (1981) provided the following definitions:

- **Dry heathlands** occur on well-drained but seasonally droughted, infertile soils where fungal mycorrhizas usually fail to inoculate tree seedlings.
- **Wet heathlands** occur on seasonally waterlogged soils where tree seedlings fail to survive during the long period of poor aeration.

In effect, Specht's two heath types represent two modes in a continuum of soil profiles (Groves 1981). Wet heath in the Camden Haven catchment occurs on humic podzolics, humic gleys and acid peats with soil depth being generally
shallow underlain by impermeable indurate. The indurate aids in retention of local runoff, producing a relatively high to surface water table. On a gradation from these conditions with increasing soil depth dry heath occurs, the depth of sand implying increased drainage of the upper horizons. An organic rich A horizon is usually present (< 0.3 metres depth) underlain by a leached horizon of sand which extends at depth to the indurate layer. Vegetation variation reflects the continuum of soil type. The species list provided with these notes illustrates the vegetation variation within this complex.

During mapping of the catchment, while recognizing the distinction between wet and dry heaths, the continuum of vegetation and soil variation was also recognized. Variation in microrelief further complicates the vegetation patterns. For these reasons, where the continuum of wet and dry heath is present units have been identified as CS-2,3. Variation in vegetation is also found where the units abut bedrock. For example, adjacent to the Diamond Head rhyolite poorly drained sites display Melaleuca quinquenervia woodland. These minor variations are recognized but not mapped.

Generally the landward margin of units CS-2 and CS-3 is defined by topographical variation and transition to land unit CS-4, Eucalypt dominated dune complex. The landward boundary in several isolated cases is defined by what has been denoted by Thom (1965) and Bird (1965,1978) as a prior barrier, separating CS-2,3 from the Estuarine Alluvium land system. For example, within the Johns River State Forest below Watson Taylors Lake a prior barrier composed predominantly of gravel is evident. Den Exter (1975) comments that this prior barrier is orientated in the expected pattern of refracted south east swell entering the Crowdy embayment and, is similar in plan to the southern curves of the present beaches. Seaward boundary of CS-2,3 is defined by the beach ridges of land unit CS-1. Differences in morphology, soils and
vegetation are well discernable.

CS-4: Eucalypt Dominated Dunes

The vegetation type found within this unit is represented by the following list of dominant species and notes on location:

- *Eucalyptus micrantha*
- *Eucalyptus pilularis*
- *Eucalyptus gumifera*
- *Eucalyptus intermedia*
- *Eucalyptus planchoniana*
- *Angophora costata*
- *Banksia integrifolia*
- *Banksia serratifolia*
- *Imperata cylindrica*
- *Pteridium esculentum* (plus Dry Heath species)
- *Eucalyptus robusta*
- *Melaleuca quinquervia*

Open to Closed Woodland, < 20 metres
Sparse to moderate tree understorey
Understorey, < 1 metre
Poorly drained areas as a function of microrelief

Specht (1981) discussing vegetation transitions and heath communities states:

"The habitats on which true heathlands survive are very restricted. The landscape changes rapidly to produce habitats in which seedlings of trees and tall shrubs can survive to overtop the heathland vegetation. The resultant vegetations show an environmental sequence of increasing complexity (density and height) of trees/shrubs over a heathland understorey. The heathland flora is present throughout the sequence, usually becoming less rich in species diversity as the overstorey becomes more complex."

Specht's environmental sequence of vegetation is given in Table 2.10.

Within the classification system adopted by this study the unit CS-4 delineates dry sclerophyll woodland as distinct from dry heath (CS-2). Intermediate between these units is shrub-heathland, as defined by Specht. Shrub heathlands have not been delineated within this mapping program because of the complexities of variation in microrelief and areas of vegetation transition. In general however, within unit CS-4 small pockets of shrub-heathland exist. Shrub-heathland is also evident in the transition zone
TABLE 2.9: ENVIRONMENTAL SEQUENCE OF VEGETATION (After Specht, 1981)

Heathland (trees and shrubs absent)

Shrub-Heathland (with scattered shrubs)

Tree-Heathland (with scattered trees)

Dry-Sclerophyll Woodland (woodland over heath)

Dry-Sclerophyll Forest (open-forest over heath)

Wet-Sclerophyll Forest (tall open-forest over heath)

between units CS-2 and CS-4 or CS-1 and CS-4. Geomorphologically this unit represents elevated prior transgressive dunes formed as a function of aeolian processes together with higher elevations of the Prior Barrier (Pleistocene). Elevation in all cases is less than 30 metres. Soil is similar to that of the dry heathland, consisting of a organic rich A horizon underlain by a leached horizon of white sand which continues to the indurate layer. The A horizon within this unit is generally deeper than within dry heaths, often to a depth of 0.5 to 0.8 metres.

b) ESTUARINE ALLUVIUM

ES-1: Mangrove Dominated Intertidal Flats

Species are as follows:

- *Aegiceras corniculatum*
- *Avicennia marina*
- *Exocoetaria agallocha*

With associated algae species, e.g. *Enteromorpha intestinalis*

Note: Watson Taylor Lake is thought to support the southern-most occurrence of *Exocoetaria agallocha*, the Milky Mangrove (Pers. Comm. 1981b). Leer and Turner (1977) and Jones (1971) define the limit of the Milky Mangrove as being the Coffs Harbour area. Paijmans (1978) during a reconnaissance study of estuarine wetlands in northern N.S.W. and southern Queensland found that *E. agallocha* was most abundant near the limit of tidal influence, mixed with *Casuarina glauca*. Such an occurrence is evident within Bensons Inlet, Watson Taylor Lake.
Where well developed, *Aegiceras corniculatum* is present as a dense belt landward of which *Avicennia marina* is present. Mangrove inter-tidal flat sediments range from muddy sands to pure muds depending on the width of the mangrove flat. Where mangroves are extensively developed the mud content increases landward of the inlet.

Walsh (1974) defines five factors of importance to mangrove development. Briefly these are: temperature, sediment character, wave and tidal action, salinity and tidal range. These factors are evident in varying degrees with the Camden Haven estuary distribution. Of particular importance in distribution is the action of tide and wave. For example, within Watson Taylor Lake, the extended Camden Haven River delta, the deltaic islands associated with the entrance channel and the deltaic islands of the Stewarts River entrance create wave shadow areas where fine sediments are prograding and thus providing substrate for extensive mangrove development. Away from these wave shadow areas the mangroves develop as fringes only on a steep-sided erosional shoreline. This pattern is replicated within Stringray Creek and Gogleys Lagoon.

Mangrove distribution throughout the estuary can be summarized by the following notes:

- **Watson Taylor Lake**: Fringes, sheltered bays and inlets; low deltaic islands of Stewarts and Camden Haven River inlets; islands and sheltered areas of the reverse delta associated with the entrance channel.

- **Queens Lake**: Minor occurrence only; some fringe areas associated with inlets and Herons Creek entrance; sheltered areas of reverse delta islands of Stingray Creek inlet.

- **Stingray Creek Channel**: Islands, fringes and sheltered bays.
- **Entrance Channel**: Limited occurrence, some fringe areas and sheltered inlets.
- **Gogleys Lagoon**: Islands and sheltered fringe areas.
- **ES-2**: Salt Marsh

Wiegert (1980) discussing the position and function of salt marshes states:-
"..... salt marshes are tightly coupled to the boundary communities; ground and nutrient water flows from the land may affect the productivity. The marsh may in turn export organisms, detrius or nutrients to the estuary. The surplus of net primary production and the heavy sediment accumulation means that micro-organismal degradation of energy and release of nutrients will be important regulators of the community".

In effect, the vegetation of salt marshes may be interpreted as zones topographically spaced from the shoreline, thus exhibiting a mosaic pattern of communities as a function of microrelief. Adams (1981) states that this pattern does not necessarily represent an active succession from mangrove to saltmarsh, but should be regarded as a "static zonation of a complex environmental gradient". The most important factors in species distribution would seem to be soil salinity and its variation in response to tidal, climatic and drainage influences. Refer to Clarke and Hannon (1967,1969,1970,1971) for further detail of these concepts.

Vegetation transitions and species occurrence for the salt marshes of the Camden Haven estuary is detailed by the following species list and location notes:

- Casuarina glauca - Shore levee, areas of high microrelief
- Sporobolus virginicus var. minor
- Sarcocornia quinguelora
- Triglochin striata
- Suaeda australis
- Samolus repens
- Juncus krauseii
- Bauhinia junca
- Cyperus spp.
- Scirpus spp.

Landward brackish to fresh water fringing elements include Phragmites australis and Melaleuca quinquenervia. Where freshwater swamps are present of significant areal extent, freshwater swamps are classified as a separate unit ES-4. Salt marsh vegetation may also be associated as a landward fringe to mangrove inter-tidal flats or, as an understorey within unit ES-3. These areas are recognised but not mapped as separate units.
Salt marsh has a limited distribution within the Camden Haven estuary. The following notes summarize the location of salt marsh areas mapped.

**Watson Taylor Lake:** Mud Bay and some fringing areas (e.g. Bensons Inlet)

**Queens Lake**
- Limeburners Creek entrance, Lake margins north of Stingray Creek entrance delta.

**Stingray Creek**
- Isolated fringing elements and inlets.

**Entrance Creek**
- Dunbogan, Hanley Point Flat, Moores Island.

**ES-3: Swamp Oak - Open to Closed Forest**

This unit defines extensive stands of *Casuarina glauca* forest on sites that are subject to seasonal fresh to brackish short-term flooding. The soil is saline and waterlogged. After spring tides, freshes or periods of rain lower areas often hold standing water for extended periods. Within Watson Taylor Lake the elevation of this unit above the mangrove intertidal flats is generally less than 30 centimetres. Principal species found within this unit are as follows:

- *Casuarina glauca* - Forest < 25 metres
- *Sporobolus virginicus var. minor*
- *Juncus kraussii*
- *Scirpus sp.*
- *Eleocharis sp.*

Dominant elements of the understorey.
Variation is a function of microrelief.

Where stands of *Casuarina glauca* have been cleared for grazing and are presently exhibiting a mosaic pattern of regrowth the unit may support grasses such as *Paspalum orbiculare* and *Imperata cylindrica*. Distribution within the Camden Haven lower catchment is summarized by the following notes:

**Queens Lake:** Lake fringes, extensive development adjacent to major creeks - Herons, Bobs, Limeburners.

**Entrance Channel:** Extensive areas adjacent to estuary from Dunbogan/Laurieton to Watson Taylor Lake entrance.

**Watson Taylor Lake:** Lake fringes, landward of inlets and adjacent to Camden Haven and Stewarts River entrances.

**Camden Haven and Stewarts Rivers**
- Fringing elements on suitable substrate to the tidal limit.
ES-4: Estuarine Connected Fresh to Brackish Wetlands

Within the classification system used by this study a distinction is made between those wetlands linked to the estuary by vegetative transitions and those wetlands isolated from the estuarine environment by such as flood plain levees. Connection of these latter wetlands to the estuary only occurs during major flood events.

A definition for those areas mapped as ES-4 could be as follows:- wetlands of the present barrier estuary floodplain subject to inundation by fresh to saline water and linked to the estuarine environment by vegetative transitions (viz: units ES-1,2 and 3).

The boundaries of the wetlands of this unit tend to be vague as a consequence of water fluctuation, vegetation zonation and microrelief variation (Paijmans 1978b). Species mix is a mosaic pattern reflecting microrelief and hydrology and thus duration of submergence. Further delineation of vegetative patterns is also possible, for example as a function of salinity of soil and water. Goodrick (1970) on the basis of depth and duration of submergence and salinity of soil and water defined specific wetland types within the floodplain environment. Briefly these are:-

- Teatree swamps
- Fresh meadows
- Seasonal fresh swamps
- Semipermanent fresh swamps
- Open Fresh waters
- Reed swamp.

In smaller swamps the wetland type of greatest areal extent was used by Goodrick to categorize the swamp, while larger swamps were subdivided into their different wetland types. Goodrick's categorization of wetlands can be seen to be based on vegetative dominance rather than linkage with the estuarine environment through vegetation transition and water movement. The concept of estuarine linkage through vegetation transition and water movement must be considered within any management strata proposed for the coastal region.

Further complications with Goodrick's system arise because of the complexity of vegetation patterns. While vegetative patterns exist, sufficient
information is not available to precisely infer the hydrologic regime from the mosaic pattern of vegetation exhibited by the wetlands. For example, consider the species *Melaleuca quinquenervia*. This species, while readily identifiable from aerial photographs, has a wide tolerance to varying degrees of inundation and salinity. *Melaleuca quinquenervia* may dominate under conditions ranging from temporary waterlogging to almost permanent water, both fresh and brackish (Paijmans 1978a). Within the areas defined as ES-4 for the Camden Haven, *Melaleuca quinquenervia* occurrence varies from fringing elements to extensive monospecific swamp forests to isolated pockets within a mosaic pattern of wetland vegetation.

For the above reasons the estuarine linked fresh to brackish wetlands have been mapped as a single unit, while recognizing that within this unit specific vegetative patterns exist as a function of hydrologic regime and microrelief. The following species list and notes on location defines the wetland character of areas agglomerated within the unit denoted "estuarine connected fresh to brackish wetlands."

- **Casuarina glauca** — Fringing brackish areas
- **Phragmites communis**
- **Eragrostis pubescens**
- **Juncus kraussii**
- **Scirpus validus**
- **Typha sp.**
- **Cladium sp.**
- **Najas marina**
- **Potamageton tricarinatus**
- **Myriophyllum sp.**
- **Melaleuca quinquenervia** — Extensive, often monospecific forest
- **Melaleuca viridiflora**
- **Eucalyptus robusta**
- **Tristalia suavolens** — Fringing fresh areas

Occurrence of this unit within the Camden Haven is as follows:

- **Queens Lake**: Adjacent to creek inlets - Limeburners, Bobs and Herons Creek. Eastern side of lake, extending to behind North Haven.
- **Entrance Channel**: Dunbogan area in mosaic pattern with units ES-2 and 3. Restricted tidal flow following road construction is leading to development of this unit in previous areas of ES-2 and 3.
Watson Taylor Lake: Eastern side of lake between prior barrier and units ES-1, 2 and 3. Extensive development south of lake behind Bensons and Washtub Inlets.

ES-5: Eucalypt Dominated Alluvium

This unit defines in microrelief the highest areas of the estuarine alluvium land system. Soils are a sand/alluvium mix depending on position of unit with respect to contemporary sedimentation processes, barrier development and barrier reworking processes. Species present and pattern of distribution varies with microrelief within units. Large areas of this unit have been cleared and developed (e.g. North Haven and Dunbogan, for urban development; Camden Haven and Stewarts River units, for agriculture). Inundation of the unit is restricted to flood events. In the Camden Haven and Stewarts River units landward boundaries are defined by bedrock or eustatic terraces. Alluvium levee formation is evident adjacent to rivers. Species mix is represented by the following list of dominant species and accompanying notes:

- Casuarina glauca
- Melaleuca quinquenervia
- Eucalyptus robusta
- Eucalyptus tereticornis
- Eucalyptus intermedia
- Tristania suaveolens
- Casuarina teretifolia
- Eucalyptus pilularis
- Acacia sp.
- Banksia spp.
- Leptospermum sp.

Lower relief, poorly drained areas

Lower tree storey.

The occurrence of this unit within the Camden Haven is as follows:

Queens Lake: Henry Kendall Reserve, associated with units ES-3 and 4 on lake margins, creek inlets.

Entrance Channel: North Haven, Dunbogan, Hanley Point.

Watson Taylor Lake: Associated with barrier formation on eastern side of Lake, Camden Haven and Stewarts River entrances plus associated with units ES-3 and 4.

Camden Haven and: Associated with unit ES-3 within the lower estuarine Stewarts Rivers reaches of both rivers.
c) FLUVATILE ALLUVIUM

Stream characteristics including bathymetry, stream gradient and bank contours are a function of the land systems in which they are contained. Similarly, formation and extent of fluvatile alluvium areas will reflect land system type. Fluvatile alluvium areas were thus mapped as units within the land systems in which they occur. The following discussion provides detail of the four alluvial landform types observed within the Camden Haven catchment.

-A: Alluvium (Above Tidal Limit)

The alluvial soil areas of the Camden Haven and Stewarts rivers above their tidal limits are small in extent. These small areas adjacent to creeks and rivers are generally cleared and often utilized for irrigated small cropping. This unit is distinctive to the alluvial areas below the tidal limit. Alluvium areas above the tidal limit are within a erosional/depositional environment during flood events. Levee formation is limited. Groundwater at all depths within this unit is fresh. Vegetative differences reflect the fresh/saline influences of the adjacent river/estuary.

Extensive clearing of this unit prohibits accurate definition of species mix. Rainforest species may have been present in some areas. Uncleared areas examined could be classified as Wet Sclerophyll forest including the following species:

- *Eucalyptus grandis*
- *Eucalyptus saligna*
- *Eucalyptus microcorys*
- *Eucalyptus pilularis*
- *Tristonia conferta*
- *Casuarina torulosa*

Open to closed forest, > 30 metres

Within the Stewarts River valley (land systems: Stewarts River Sediments and Stewarts River Intrusion) contemporary alluvium areas are restricted in extent. Most of the unconsolidated sediments within the valley are terraced and above contemporary flood levels. Occurrences of contemporary alluvium are generally too small to be mapped at 1:25 000 scale. Similar comments apply to the upper reaches of the Camden Haven River. The lower reaches of the Camden Haven, (including Black, Batar and Upsells Creeks) and Herons Creek exhibit extensive areas of contemporary alluvium (refer to Map 3A,B).
-As: Alluvium (below tidal limit)

Extensive areas of this unit are cleared and utilized for agriculture. Species observed include:

- Casuarina glauca
- Eucalyptus pilularis
- Eucalyptus resinifera
- Eucalyptus robustus

Closed to open forest < 30 metres with Casuarina glauca dominating estuarine fringes. Cleared areas support grasses, e.g. Paspalum obiculare, Imperata cylindrica.

The unit is found adjacent to the estuarine reaches of the Camden Haven and Stewarts rivers and, adjacent to Herons Creek. Inundation occurs during flood events. Alluvium levees are well defined. Small fresh groundwater reserves may occur within the unconsolidated sediments. Alluvium deposition is over bedrock as compared to prior barrier flats for the unit ES-5 (Eucalypt dominated estuarine alluvium). The unit is bounded on the landward side by floodplain wetlands, terraces or bedrock.

-AT: Alluvial Terraces

The terraces are remnants of flats of fluvial origin associated with prior barrier formation. These units are now terraces above inundation but adjacent to the contemporary floodplain. The units are cleared and utilized for agriculture. Major occurrences for all river valleys are mapped. Note: For a detailed discussion of mode of formation and present topographical profiles of these terraces refer to Den Exter (1975).

-FW: Isolated Floodplain Wetlands

Within this unit vegetative patterns and species mix have been altered by clearing, grazing and drainage. Species observed include:

- Melaleuca quinquenervia
- Phragmites communis
- Juncus sp.
- Scirpus sp.
- Typha sp.

The unit has a limited occurrence on the floodplains of Herons Creek, Camden Haven and Stewarts Rivers. The Herons Creek unit (three occurrences) are all associated with levee formation. Bedrock and terraces define the landward boundaries of these wetlands. Smaller occurrences (not mapped) are
present above the tidal limit, being generally ponded tributaries and local
run-on areas associated with terrace and levee formation. Several small
ponded tributaries are present on the Camden Haven floodplain. The large
unit adjacent to the Pacific Highway at Rossglen is bounded by terraces,
bedrock and contemporary levee, thus forming a back swamp or flood basin
wetland (Pressey, 1981). Clearing and drainage of this unit is proceeding.
A number of small backswamps occur on the Camden Haven floodplain close to
the tidal limit (e.g. adjacent to Kendall). The two floodplain wetlands
mapped within the Stewarts river valley are bounded by terrace and levee
formations.

- EW: Estuarine Connected Fresh to Brackish Wetlands on Riverine
  Alluvium

This unit displays a similar vegetative pattern and function as the
units denoted ES-4. Soils vary with alluvium type. No coastal sand component
is present. Occurrences mapped are as follows:-

Heron Creek - Melaleuca sp. dominated with Casuarina glauca fringe
Bobs Creek - Melaleuca sp. dominated with Casuarina glauca fringe
Limeburners Creek - Melaleuca sp. dominated with Casuarina glauca fringe
Camden Haven River - Melaleuca sp. dominated with Phragmites communis
Stewarts River - Juncus and Scirpus sp. with Melaleuca sp. along
  landward fringe.
CHAPTER 3: LAND USE PLANNING AND THE CAMDEN HAVEN

3.1 COASTAL LANDS AND UPLANDS

3.2 COASTAL LANDS - ALLOCATION AND MANAGEMENT
   a) Estuarine Wetlands
   b) Present Barrier

3.3 FLOOD LIABLE AREAS OF THE CAMDEN HAVEN

3.4 RESOURCE MANAGEMENT - APPLICATION OF THE MAP BASE
   a) Land units and Capability
   b) Soil Erosion in the Camden Haven
   c) Land Systems and Nature Conservation

Bonny Hills, 1971 (Photo courtesy of Hastings Shire Gazette, Wauchope).
3.1: COASTAL LANDS AND UPLANDS

Within Section 1.3d) 'coastal lands' were defined as being those lands sustained by and sustaining the subaqueous environments (e.g. materials, biota or energetic processes). 'Uplands' were defined as those land areas within a catchment that while they may provide sustaining components to the coastal waters, are sustained in turn by the coastal waters only through the circuituous processes of evaporation and precipitation.

Chapter 2 provided a map base upon which these definitions may be further refined for the Camden Haven catchment. The description of functional land units provides a basis for the delineation of coastal and uplands. Coastal functional land units are as follows:

<table>
<thead>
<tr>
<th>MAP NOMENCLATURE</th>
<th>FUNCTIONAL LAND UNIT</th>
<th>LAND SYSTEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cs-1</td>
<td>Present Barrier</td>
<td>Coastal Sands</td>
</tr>
<tr>
<td>Es-1</td>
<td>Mangrove Dominated Inter-Tidal Flats</td>
<td>Estuarine Alluvium</td>
</tr>
<tr>
<td>Es-2</td>
<td>Salt Marsh</td>
<td>Estuarine Alluvium</td>
</tr>
<tr>
<td>Es-3</td>
<td>Swamp Oak Forest</td>
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</tr>
<tr>
<td>Es-4</td>
<td>Estuarine Connected Fresh to Brackish Wetlands</td>
<td>Estuarine Alluvium</td>
</tr>
<tr>
<td>Es-5</td>
<td>Eucalypt Dominated Alluvium</td>
<td>Estuarine Alluvium</td>
</tr>
</tbody>
</table>

-EW: Estuarine Connected Fresh to Brackish Wetlands on Riverine Alluvium

All remaining land units are defined as uplands. The biophysical and locational attributes of the upland units vary. Concurrently, any management strategy adopted for the uplands must recognize this variability. Further discussion of uplands and their management is contained within sections 3.3 and 3.4. Because of the interrelation between coastal lands and waters, any land use planning overview of coastal functional land units, suitable for implementation by the Coastal Council, needs to be defined in terms relevant to both resource allocation and management. The following sections provides data and discussion of specific issues relevant to coastal lands together with recommendations for use allocation and management.

3.2: COASTAL LANDS - ALLOCATION AND MANAGEMENT

a) Estuarine Wetlands

The Department of Environment and Planning (1981a) define estuarine wetlands (zone 7b) as:
predominantly brackish or marine, and tidal or occasionally tidal or submerged beneath a tidal waterway. Vegetation develops in response to regular or irregular tidal inundation and consist of plants like seagrasses, mangroves, samphire, rushes and trees (e.g. Casuarinas).

Wetland systems comprising an intermixture of both fresh and saline components are probably best zoned completely ?(a) or ?(b) or even as ?(a,b).

This definition covers all areas of functional land units of this study denoted Es-1, 2,3 and 4. Maps 2 and 3A,B detail the location of all estuarine wetlands within the Camden Haven. Description of these units is contained within section 2.8. Plate 2 documents some aspects of improper use and management of wetlands. Photos 2.1 and 2.2 are of the Dunbogan wetland - saltmarsh and mangrove components. During road construction little regard was given to tidal ventilation and flushing aspects. Residents have complained of 'smells' and the backing up of runoff waters. Plate 2.3 illustrates drainage and land clearing (under the guise of flood mitigation) of estuarine - connected Melaleuca swamp forest (Corraville area - Manning river catchment). Drainage and land clearing of freshwater wetlands for agricultural purposes is depicted in plate 2.4. This flood basin wetland, adjacent to the Pacific Highway (Ross Glen) was cleared and drained during the abnormally dry period of late 1980. Rains prohibited the completion of drainage. The area one year after the photo was taken displayed a good crop of weeds together with some Melaleuca and sedge regrowth.

Available land use planning mechanisms, if enforced, could ensure the protection and management of wetland areas. With respect to the implementation of nominated zonings, Department of Environment and Planning guidelines for estuarine wetlands are detailed within Appendix 1. Discussing land use for this zone, the Guidelines state:

If it is possible to confine the zone to the actual wetland area, then agriculture (not involving buildings, clearing, filling or alteration to landform) would be the only likely use.

The mapping methodology adopted within this study does provide sufficient detail to confine the denoted zone 7b to the actual extent of the estuarine wetlands. Thus, the Department of Environment and Planning recommendation for permissive use being confined to "agriculture (not including
Road causeway, Dunbogan. The 15" diameter pipe is inadequate for both tidal ventilation and runoff following rain events.

Drainage and land clearing of Melaleuca forest, Coralville. Peaty soils have minimal agricultural potential.

Drainage and land clearing of freshwater wetland, Ross Glen. No further agricultural development of this area has occurred to date.
buildings, clearing, filling or alteration to landform" is applicable to the functional land units denoted Es-1, 2, 3 and 4 within this study.

If development consent is to be considered for any other use, the provision of the map base for the entire catchment allows for the site-specific evaluation of a proposal within a catchment context (Creighton, 1982b). The protection and maintenance of estuarine wetland areas is an essential part of any overall concern for the "orderly and balanced utilization of the coastal region and its resources". The provision of maps for all N.S.W. coastal catchments based upon the methodology evolved and described during this study would assist the Coastal Council in the protection and maintenance of these estuarine associated land areas.

b) Present Barrier

The examination of shoreline processes as a prelude to the determination of use allocation and management for the present barrier includes the following aspects:

- wave and wind climate, storm surge and wave set-up,
  nearshore and offshore currents, littoral drift and
  onshore sand losses
- onshore and offshore geology
- review of historical records of shoreline movement,
  including available aerial photographs
- man-induced changes (e.g. breakwater construction, urban-
  ization, provision for access, devegetation associated with
  use and heavy mineral mining).

Appendix 2 provides detail on these aspects together with data from other studies which may assist in defining the shoreline processes within the Camden Haven. To summarize this data:

- Wave climate is dominated by storm events from the south east.
  Severe storm events from the north to north east occur at longer intervals
- Wind climate is affected by the coastal configuration and sheltering effects of headlands. The formation of transgressive dunes replicates this wind pattern
- Maximum combined storm surge and wave set-up is estimated to be 2.6 metres AHD. Overtapping of the barrier system under these
conditions occurs in the southern corners of Grants Beach and Rainbow Beach embayments.

Current direction and velocity varies with storm events. Under the prevailing south easterly wave climate northward drift dominates.

Sand transport has been observed to occur both to the north and to the south, however under the prevailing wave and current conditions a nett drift to the north is postulated. Further sand losses from the present barrier occur as a result of aeolian processes. With the data available no precise definition of the sediment budget is possible.

Holocene barrier development within the study area varies from extensive in the south to minimal in the north. The mapping program adopted by this study may provide a basis for the State-wide investigation of compartmentization and littoral drift patterns as reflected by contemporary landforms. Management strategies and use options for the barrier systems could be varied in response to this data.

Changes to the natural coastal configuration are primarily a function of use. Control over use of the barrier system together with the implementation of management strategies is necessary.

To illustrate use patterns and the need for both wise use allocation and management three key areas are detailed by a series of photographs. All photographs dated prior to 1980 were provided by the Soil Conservation Service, Kempsey.

Department of Environment and Planning guidelines for the planning zone denoted Environmental Protection (f) - Foreshore are detailed within Appendix I. These guidelines lack direct applicability to the present barrier - foredune landforms in that 'foreshore' under the definition and use constraints presented applies equally to ocean, river and lake adjacent areas. Use and management options for these foreshore types vary. A more precise definition of use as a function of the varying capabilities of the foreshore zone is attempted within the notes accompanying the Department of Environment and Planning classification. For example, Note 4 states:
Vinegar Creek. Losses of onshore sand resulted when flood waters banked up behind the causeway, washed out both causeway and beach berm. Rain event mid 1981.

Indurate exposed after rain event, late 1981 - Duchess Creek. Use allocation and management within this embayment should recognize the limited extent of Holocene barrier development as being indicative of contemporary processes. (Note beach erosion - Lake Cathie township).

S SERIES 3: RAINBOW BEACH EMBAYMENT

Loss of sand from the onshore zone in an area already subject to erosion and high use. Vinegar Creek, the natural outlet is 300 metres to the north. Rain event 1981.

Vinegar Creek. Bridge span is less than natural waterway. Muddy sediments are the result of bridge construction and urban development upstream. Rain event late 1981.
Area being stabilized is the incipient foredune. Clubhouse carpark and amenities blocks are located on the leveled barrier.

Spinifex hirsutus/Acacia longifolia circa 1978. Stabilized sand has since been removed and partially replaced by littoral and aeolian processes. Further beach recession is expected.

Rehabilitated sand mining area, northern end of Grants Head embayment. Onshore and offshore sand losses during period of disturbance may have affected the sediment budget.
Dunbogan beach from Camden Head, 1955. Note lack of stabilizing vegetation accompanied by aeolian transport of sand onshore.

Dunbogan beach 1966, prior to sand mining.

Sand mining, Associated Minerals Ltd. 1967. Gravel quarry on headland denotes the location from which the other photographs were taken.

Dunbogan beach late 1981. Following sandmining profile is reduced and vegetation cover dominated by Bitou Bush. Onshore losses associated with aeolian processes continue.
Generally, buildings should not be permitted on frontal dunes (with the possible exception of surf life saving clubs, and some structures associated with fishing, oyster farming and boating or sailing). Plans should contain provisions compatible with any restrictions under the Coastal Protection Act.

However, to assist local government agencies in the formulation of site-specific plans (e.g. Local Environmental Plans), a more precise definition of foreshore types is required. The formulation of guidelines for use capability and management constraints applicable to specific foreshore types would facilitate the allocation of conforming uses. The mapping methodology displayed by this study provides one basis for foreshore definition, utilizing the specific biophysical characteristics of the lands which compose foreshore areas. For example, as already stated, the mapping of Holocene barriers may provide a basis for the State-wide investigation of contemporary compartmentization and littoral drift patterns. Management strategies and use options for the foredune and adjacent areas could be varied in response to this data. With respect to river and lake foreshore areas the mapping methodology adopted within this study precisely defines the biophysical capabilities of all areas. Estuarine wetland areas are detailed previously. Technical Report 3, chapter 3, detailed one management concern - the effective disposal of human waste. The following section illustrates one further application of the genetic landscape approach, the delineation of flood liable areas.

3.3: FLOOD LIABLE AREAS OF THE CAMDEN HAVEN

Land use planning techniques can help lessen the impact of flood events by: reducing the population and economic investment at risk; reducing the public cost of subsequent evacuation, relief and rehabilitation, and decreasing dependance upon costly protection works requiring public investment.

Two studies have been directed at determining flood liable lands of the Camden Haven and measures for flood protection. The Department of Public Works (1977) detailed a proposed flood mitigation works for the lower coastal areas of the Camden Haven, particularly North Haven and Dunbogan, concluding that:-
If construction of flood mitigation works is undertaken, then it is considered that the only effective works which could be justified, are those to protect mainly the North Haven residential area west of the Port Macquarie road, to a flood level of approximately RL 101.85 m. Works in Dunbogan cannot be justified economically and would not conform to the Government’s flood plain policy.....

..... Further development should follow a careful assessment of the existing and potential problems and should not be encouraged where it could be avoided e.g. contour plans indicate that some ground within the strip development in Dunbogan could be subject to tidal flooding in the event of an extreme high tide. It should be realised that public funds cannot be expected to be used to alleviate problems brought on by careless and unwise development. Property owners, developers and prospective buyers must be made aware of the flood hazard in quantitative terms such as level, frequency and duration of flooding.

To date, no levee construction has occurred within the Camden Haven. Sinclair Knight and Partners (1980) in accordance with Department of Public Works undertakings to provide flood plain mapping of all coastal rivers, investigated and mapped the lower floodplain area of the Camden Haven. Figure 3.1 presents this information, defining the 1 in 100 year flood levels. Following the release of this report Hastings Municipal Council adopted an interim policy for development of flood prone lands. This policy is detailed within Figure 3.2.

The mapping methodology adopted by this study provides for the mapping of all flood prone lands of the Camden Haven catchment. Functional units which comprise the flood prone lands of the Camden Haven are as follows:

- A Alluvium (above tidal limit)
- As Alluvium (below tidal limit)
- FW Isolated Floodplain Wetlands
Es-1 Mangrove dominated inter-tidal flats
Es-2 Salt Marsh
Es-3 Swamp Oak Forest
Es-4 Estuarine connected fresh to brackish wetlands
Es-5 Eucalypt dominated alluvium.
-EW Estuarine connected fresh to brackish wetlands on riverine alluvium
LEGEND
ESTIMATED FLOOD LIABILITY:

\[
\begin{align*}
\text{AREA INUNDATED BY 1 IN 100 YEAR FLOOD} & : \text{Shaded Area} \\
\text{ADDITIONAL AREA OF INUNDATION, APRIL 1983 FLOOD} & : \text{Striped Area} \\
\text{INDICATES ACTUAL EXTENT OF FLOODING IS UNKNOWN} & : \text{Dashed Line}
\end{align*}
\]

NOTE:
Flooding are defined by probabilities of occurrence in any one year. e. 1 in 100 year flood has a 1 in 100 chance of occurring in any one year. Flood levels for the 1 in 100 year flood were derived from hydrologic and hydraulic analysis. Due to the lack of suitable survey information outside of the urban area it is only possible to show an estimated extent of flood and these can only be confirmed by further survey of the floodplain. The pattern of flooding varies from one flood to another. The flow of floodwater is affected by many factors including natural and man-made obstructions, but the principal factor is the prevailing tidal pattern and storm surge at the ocean entrance.

Figure 3.1:
PRELIMINARY FLOOD PLAIN MAP
— CAMDEN HAVEN
CAMDEN HAVEN FLOOD STUDY
(Sinclair Knight and Partners 1983)
Interim policy on flood land development

Hastings Municipal Council, following a public meeting on Tuesday night, has adopted an interim policy for development of flood prone lands.

The policy is:

Flood prone lands are those covered by a 1 in 100 year flood unless otherwise determined by the Public Works Department.

Floodways are those areas covered by a 1 in 20 year flood unless otherwise determined by the Public Works Department. The Department would generally determine floodways to be the areas where a substantial amount of floodwater flows and which should therefore be kept open in order to not unduly restrict the passage of large floods. Shallow backwater areas within the area covered by a 1 in 20 year flood would generally not be determined as floodway.

1. Applications for rezoning of land to permit a higher level of development in flood prone areas will not be considered.

2. No development of any kind will be permitted in the determined floodways at Settlement Point, Kings Point, Dumbogans and North Haven, between Ocean Drive and Stingray Creek, and in any other floodway advised by the Department of Public Works or the Water Resources Commission from time to time.

3. (a) The subdivision of flood prone urban lands, other than boundary adjustments, will not be permitted; (b) Subdivisions of rural properties, part of which are flood prone, shall not be allowed unless, in council's opinion there are adequate flood-free homestead and stock-holding areas as well as access to higher ground, each case to be treated on its merits.

4. Building development will not be permitted on flood prone areas where the lowest natural level at the building site is more than one metre below the 100 year flood level where known, or where not known, below such other flood level as advised at the time by the relevant authority (PWD or WRC).

5. Building development in flood prone areas shall generally be restricted to single dwelling or non-residential development permissible within the zone.

6. Each application for development in flood prone areas shall be considered on its merits taking into account the advice of the PWD or WRC on the application.

7. Filling or raising the site levels will only be permitted with the concurrence of the PWD or the WRC. Such filling will be restricted to locations where the effect on flooding is considered to be minimal and—
   - Where the site abuts flood free land, or
   - Where in rural areas provision is being sought—for the floodproofing of a dwelling, sheds and outbuildings necessary to the operation of the property (only one dwelling on each holding will be permitted; for provision of a flood refuge for stock machinery, materials and produce.

8. Where land is flood prone but not in a floodway no building shall be erected unless the following design criteria are adhered to—
   - (a) buildings shall be flood proofed in a manner acceptable to council.

(b) the furnished floor levels of habitable rooms shall be at least five hundred millimetres above the one hundred year flood level where known, or where not known, above such other level as advised at the time by the relevant authority (PWD or WRC).

(c) where it is intended to carry out additions to an existing building such increase will be restricted to a floor area not exceeding twenty per cent of the ground floor area of the existing building. The first floor additions will be unrestricted provided that the site is not situated within the floodway.

(d) yard gullies are to be raised to a level of at least one hundred and fifty millimetres above the 100 year flood level where known or above such other level as advised by the relevant authority (PWD or WRC).

(e) renovations including recladding, brick veneering or re-roofing may be carried out subject to council's consideration.

9. In each case where council approved development in flood prone areas the owner of the properties shall be required to indemnify the council against any claim which may arise.

10. (1) Renovations to existing buildings in floodways may be considered provided that no extension to the floor area will be permitted and the building is to be lifted so that the floor level of habitable rooms is at least five hundred millimetres above the one hundred year flood level where known, or where not known, above such other level as advised at the time by the relevant authority (PWD or WRC).
The mapping program does not provide sufficient information to define what has been classified as floodways. Floodways are presently defined as those areas covered by a 1 in 20 year flood, unless otherwise determined by the Department of Public Works. It should be noted however, that inherent within this definition of floodways, shallow backwater areas, where floodwater flows are not substantial, may be classified as flood-prone. Drainage patterns and hence the location of backwater areas can be inferred from the map base. Further, flood-event hydrological data is required to specifically define floodways.

Provision of such a map-base as developed within this study, for all coastal catchments of N.S.W. would provide a basis for the formulation and implementation of specific land use and management guidelines for flood-prone and floodway lands. Preferably these use control mechanisms would recognize the varying biophysical characteristics of the land areas comprising the discrete functional land units, with and as a subset to, general guidelines for use allocation and management of flood-prone and floodway lands.

3.4: RESOURCE MANAGEMENT - APPLICATION OF THE MAP BASE

a) Land Units and Capability

The map base presented in Chapter 2 of this report describes the areal distribution of the type and number of major environments defined by dominant geologic-biologic assemblages. In short, the map base outlines the natural condition of the Camden Haven catchment. Particularly important to the maintenance of environmental quality within the catchment are those properties and characteristics of the natural resource land systems that limit their use for specific purposes or activities. Examples could include:-

- flood liable lands (as previously detailed)
- engineering properties (e.g. shrink-swell characteristics)
- degree of permeability (e.g. human waste disposal)
- erosional susceptibility of various soils.

Land systems provide an agglomeration of a series of similar characteristics or inherent properties. These inherent properties comprise the biophysical data relevant to the determination of capability for a particular use. In terms of use, differing human activities imply differing capabilities and tolerances for the same land system. For example, a highly permeable sand is a very poor host for human waste disposal. Wastes are rapidly transported
into ground water reserves and nearby surface water bodies. However, the same sand provides an excellent foundation for urban-associated construction. Land systems therefore, must be evaluated in terms of each land use activity. To provide examples of the application of these concepts, Table 3.1 presents a matrix utilized within the Bay and Estuarine System Management Program, Texas, (Division of Natural Resources and the Environment, University of Texas, 1973). Table 3.2 displays the evaluation of 'physical properties groups' for various land uses (Brown, 1976).

Management of use will vary with both use type and the inherent properties of the systems. For any particular use within a specific land system properties will be predictable. These properties will differ to those exhibited by another land system. It has been previously suggested (Chapter 1) that upland areas mapped as functional management areas could provide a basis for management overview of uses and activities within the coastal catchments that may affect the coastal environments. To provide one example of these concepts the following discussion details briefly the varied erosive characteristics displayed by the upland management systems. Appendix 3 details some of the agencies and their activities related to soil erosion control. Overview of agency function in relation to specific issues affecting the coastal environment may lead to improved coordination of the policies and activities of public agencies. The provision of a land resource map as developed within this study provides a basis for both the direction of agency activity and, the evaluation of agency function.

b) Soil Erosion in the Camden Haven

Technical Report 3 (Chapter 2) details turbidity and suspended solids data available for the Camden Haven catchment. Briefly, both suspended solids load and turbidity at Logans Crossing were found to vary as a function of discharge. Maximum turbidity for the period 1977-1980 was in March 1980, a value of 40 units on a day of discharge of 15,400 megalitres. Highest daily suspended solids loading recorded was 45 mg/l at a daily discharge of 2,350 megalitres. For the Camden Haven river catchment above Logans Crossing, estimated annual loading was calculated to be of the order of 540 tonnes. Photo series 6 displays agricultural and forestry practices within the Camden Haven uplands.

To provide a frame of reference for discussion of soil erosion and control practices the following list of possible impacts upon estuarine
TABLE 3.1: RESOURCE CAPABILITY UNITS AND LAND USE
(Texas Bay and Estuarine System Management, Division of Natural Resources and the Environment, University of Texas, 1973).

<table>
<thead>
<tr>
<th>ACTIVITIES</th>
<th>Land Use (Affordable)</th>
<th>Land Use (Developable)</th>
<th>Land Use (Commercial)</th>
<th>Land Use (Residential)</th>
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</table>

*Affordable* =-capable of being developed at a low cost
*Developable* =capable of being developed at a reasonable cost
*Public* =capable of being developed at a high cost
*Commercial* =capable of being developed for commercial purposes
*Residential* =capable of being developed for residential purposes
*Affordable* =capable of being developed at a very low cost
*Developable* =capable of being developed at a very low cost
*Public* =capable of being developed at a very high cost
*Commercial* =capable of being developed for commercial purposes
*Residential* =capable of being developed for residential purposes

---

Note: The table continues with similar entries for other resource capability units and land use categories.
biota associated with the transport of suspended material to coastal waterbodies is presented (SPCC, 1979). Suspended materials:

- cause mechanical damage such as clogging of fish gills or irritation of tissues, resulting in the death of the organism or a reduction in its growth rate and resistance to disease.
- cause blanketing of areas as a result of sedimentation - thus smothering non-tolerant sessile flora and fauna or creating habitats unsuitable for some species.
- settle on seagrass leaves in areas of low current velocities and inhibit photosynthetic activity even though the overlying waters allow adequate light penetration.
- result in a change in species composition to those more tolerant of higher suspended solids loads.
- reduce light penetration - affecting the efficiencies of predatory species which rely on sight and decreasing the euphistic zone, and thus, indirectly, influencing the available food supply.
- provide surfaces for the growth of micro-organisms or for the absorption of various chemicals.
- increase work for filter feeders such as oysters and mussels, leading to a decline in condition.
- settle on oysters resulting in infestation of the oysters with a parasitic mudworm causing loss of condition and mortality.
- alter the temperature of different water layers and thus the associated species distribution.
- change natural movements, spawning behaviour and migration of fish.

Associated with soil transport to waterbodies is the transport of nutrients such as phosphates and nitrates. Phosphorus applied to agricultural lands is lost primarily by erosion because phosphate absorbs strongly on soil particles. Fertilizer phosphorus applied in soluble orthophosphate form soon converts to insoluble forms in the soil (Agricultural Research Service, 1975). Phosphate concentration has been reported to be higher in sediment than in original soil because phosphorus is absorbed more readily by the finer soil particles (OECD, 1972). Only a small fraction of the phosphate moved with the sediment is immediately available
to aquatic organisms. Biophysicochemical reactions on the sediments slowly release the remaining phosphorus (Cullen and Rosich, 1979). Watson Taylor and Queens Lake perform as sediment sinks for the Camden Haven catchment. Presumably most of the monitored phosphate loading at Logans Crossing is later found within sediments in Watson Taylor lake. Phosphate loading from the Camden Haven river catchment above Logans Crossing has been estimated at 12.5 tonnes/annum. Total loading on the Camden Haven estuary is expected to be at least double this figure. (Refer to Technical Report 3 for further detail). Nitrates from agricultural lands behave in a similar manner to phosphates. Transport to the aquatic system is similar, erosion accounting for a large proportion of total nitrogen loading. Improved techniques for erosion control and mitigation would reduce both phosphate and nitrate inputs to coastal waters.

The Soil Conservation Service of NSW (1978) define three soil properties that need to be assessed with regard to erodability. These are as follows:-

. Soil structure
. Soil texture
. Soil dispersibility

The environmental features interacting with soil formation include parent material, topography, climate, biotic factors and age. Of these, parent material, reflecting the complex lithology of the underlying rocks and their geomorphic history are the dominant factors. These factors were utilized to delineate specific land systems. Each land system displays specific soil characteristics similar within the system but differing to those characteristics displayed by other systems. Personal communications with relevant agencies (Soil Conservation Service, Forestry Commission) indicate that in respect to soil properties, erosion potential within the upland systems delineated for the Camden Haven catchment is as follows:-

Johns River Sediments, Herons Creek Sediments
Stewarts River Sediments, Camden Haven River Sediments, Bogo Bluff Conglomerates, Comboyne Plateau

High to moderate erosion potential
Land improvement for agriculture, Stewarts River catchment. All vegetation cleared and dumped into watercourse.

Wet weather logging - Snig track blocks drainage line, Burrawan State Forest. Logging is now planned in response to weather conditions. (Photo - Forestry Commission, Kendall).

Land cleared for grazing during the same land improvement program as the above photo.
Limeburners Creek Sediments, Lake Cathie Sediments
Comboyne Rim, Jolly Nose - Bonny Hills Sediments
All Microgranitic Intrusions, Upper Catchment Intrusions

With regard to this classification it must be noted that basic erodability of soils is only one component of a complex set of interactions which actually cause erosion. Precise definition of erosion potential must relate to a further series of factors, for example, as denoted by the Universal Soil Loss Equation. Factors incorporated within this formation are as follows:

- Rainfall and runoff erosivity index
- Soil erodability factor (function of soil properties, as above)
- Topographic factors incorporating slope length and steepness
- Cover and management factors - Function of land use
- Supporting practices

Land system mapping, as well as providing general information on soil erodability, also provides information on such aspects as topographic factors and land use. Thus, the map base developed by this study provides a frame of reference for further site-specific and use-specific studies by the responsible agencies. For discussion of control and management practices pertaining to specific use types refer to such publications as: Agricultural Research Service (1975), Soil Conservation Service of N.S.W. (1977, 1978(a)(b)), Cameron and Henderson (1979) and OECD (1972, 1973).

Ecological conservation, usually through the declaration of suitable areas of land as nature reserves, national parks or flora and fauna reserves, is a land use that ensures the long-term preservation of natural diversity and natural processes. Ecological conservation by necessity is a non-exploitive land use. The benefits are economically intangible, being both infinite in time and insufficiently known to be assessed.

Effective nature conservation relies upon the identification of suitable areas and their successful management. The following criteria need to be considered when selecting nature conservation areas:
I. Degree of disturbance of the natural communities

- The regional significance of the natural communities, and their present distribution and conservation status.
- Adequacy of reserve design, including such variables as internal diversity of vegetation and landform, shape, size, the nature of adjacent land uses, and existing uses and management constraints.

The use of aerial photographs, field work and literature review involved in land system mapping, together with the broad perspective the method provides, satisfies the information requirements for the above selection criteria. The use of land systems and units as indicators of ecological differences allows accurate definition of variations, and ensures accurate extrapolation of field data. This land system and unit data in turn ensures that research into the management of particular ecological reserves is stratified to maintain consistency and allows management policies to be effectively implemented and monitored. Land system mapping thus provides a basis both for the identification of ecosystem types within particular areas or regions, and for the location, design and management of ecological reserves.

Twenty land systems have been mapped and described for the Camden Haven region. Of these land systems three are contained within Crowdy Bay National Park. The Diamond Head intrusion is wholly contained within the National Park. All land units of the Coastal Sands land system are well represented. All units of the Estuarine Alluvium land system are represented within the park however mangrove and salt marsh communities (land units ES-1,2) are of very limited extent. While, as previously outlined, development consent is required for these land units, selected areas of the Estuarine Alluvium land system throughout the estuary may warrant dedication and management under some form of secure tenure.

Of the remaining seventeen land systems within the Camden Haven, several are represented within small State Forest reserves, preserves and informal reserves. Informal reserves are areas set aside from logging under the management plan and are areas generally inaccessible or unsuited to logging. These informal reserves amount to some 1340 hectares of the total Kendall management area of 22,720 hectares. Details of all reserves, preserves and informal reserves are as follows:
<table>
<thead>
<tr>
<th>State Forest</th>
<th>Reserve type</th>
<th>Land System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lorne</td>
<td>Lorne Flora Reserve, 54 ha</td>
<td>Camden Haven River Sediments</td>
</tr>
<tr>
<td>Queens Lake</td>
<td>Diggers Hill Flora Reserve, Limeburners Creek Sediments</td>
<td>40 ha</td>
</tr>
<tr>
<td>Broken Bago</td>
<td>6 B's Forest Preserve, 32 ha</td>
<td>Broken Bago Conglomerates</td>
</tr>
<tr>
<td>Kerewong</td>
<td>Black Creek Forest Preserve, Black Creek Intrusion</td>
<td>26 ha</td>
</tr>
<tr>
<td>Johns River</td>
<td>Informal Reserve</td>
<td>Estuarine Alluvium (ES-4), Johns River Sediments</td>
</tr>
<tr>
<td>Middle Brother</td>
<td>&quot;</td>
<td>Middle Brother Intrusion, Camden Haven River Sediments</td>
</tr>
<tr>
<td>North Brother</td>
<td>&quot;</td>
<td>North Brother Intrusion</td>
</tr>
<tr>
<td>Lorne</td>
<td>&quot;</td>
<td>Camden Haven River Sediments</td>
</tr>
<tr>
<td>Kerewong</td>
<td>&quot;</td>
<td>Comboyne River, Upper Catchment Intrusion</td>
</tr>
</tbody>
</table>

These reserves are essentially the main forested areas within the catchment that have not been subject to land use disturbance. Dedication of all informal reserves as flora reserves is recommended, thereby providing at least some ecological conservation of several land systems.

Vacant Crown Lands within the Camden Haven are limited in extent. Significant areas largely undisturbed are as follows:

<table>
<thead>
<tr>
<th>Location</th>
<th>Land System</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Brother</td>
<td>South Brother Intrusion</td>
</tr>
<tr>
<td>Perpendicular Point (presently a Nature Reserve proposal)</td>
<td>Jolly Nose - Bonny Hills Sediments</td>
</tr>
<tr>
<td>Eastern shore of Queens Lake to Grants Beach</td>
<td>Estuarine Alluvium (ES-4), Coastal Sands (CS-1,2,3,4)</td>
</tr>
<tr>
<td>Adjacent to Diggers Hill Flora Reserve</td>
<td>Limeburners Creek Sediments</td>
</tr>
</tbody>
</table>

It is recommended that these lands be investigated under the Crown land evaluation procedures currently being developed by the Department of Lands with a view to retention within the Crown Estate.
LIST OF APPENDICES

APPENDIX 1: DEPARTMENT OF ENVIRONMENT AND PLANNING GUIDELINES

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- 7f) Foreshore

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A2-2. Onshore and Offshore Geology
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- Designated protected land, Camden Haven catchment (Catchment Areas Protection Board)
- Restrictions on destruction of trees growing on protected lands and along prescribed streams (Catchment Areas Protection Board)
- Standard erosion mitigation conditions for logging in N.S.W. (Catchment Areas Protection Board)
- Data for Logging Plan (Kendall District, Forestry Commission)
APPENDIX 1: DEPARTMENT OF ENVIRONMENT AND PLANNING GUIDELINES

ZONE No. 7 - ENVIRONMENT PROTECTION

ENVIRONMENT PROTECTION 7b) - Estuarine Wetlands

<table>
<thead>
<tr>
<th>Zone</th>
<th>Purposes for which development may be carried out only with development consent</th>
<th>Purposes for which development is prohibited</th>
</tr>
</thead>
<tbody>
<tr>
<td>7b) Environment Protection (Estuarine Wetlands)</td>
<td>Agriculture; Dwelling-houses; Fishing; Open Space; Oyster Farming; Roads; Subdivision; Utility installations other than gas holders or generating works</td>
<td>Any purpose other than those permitted by the proceeding column</td>
</tr>
</tbody>
</table>

Notes:

2. It may be impractical to confine this zone to wetland areas as such. Probably the hinterland or drainage system would need to be included. Therefore, the zone should recognise limited land uses that could be carried out on these other areas.

If it is possible to confine the zone to the actual wetland area, then agriculture (not involving buildings, clearing, filling or alteration to land form) would be the only likely use.

3. Special provisions in this zone would control:
   . alterations to the landform (filling, excavation, etc.);
   . drainage;
   . waste and effluent disposal (particularly related to intensive animal production - feed lots etc.);
   . clearing of trees and vegetation;
   . soil erosion;
   . cultivation (including the use of pesticides, etc.)

Consultation with, and/or the concurrence of specialist government agencies, may also be necessary.

4. If the general objective that wetlands not be alienated is to be met, it may be necessary for them to be brought into public ownership. This would not obviate the need for strict controls on surrounding land.
5. Home industries and research establishments could also be allowed if there was a need.

ENVIRONMENT PROTECTION 7f) - Foreshore

<table>
<thead>
<tr>
<th>Zone</th>
<th>Purposes for which development may be carried out only with development consent</th>
<th>Purposes for which development is prohibited</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment Protection Foreshore 7f)</td>
<td>Agriculture; Dwelling-houses; Fishing; Home Industries; Open Space; Oyster Farming; Roads; Subdivision, Utility installation other than gas holders or generating works</td>
<td>Any purpose other than those permitted by Column IV</td>
</tr>
<tr>
<td>Others (see Note 1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ENVIRONMENT PROTECTION 7f) - NOTES

1. Whether other uses are permitted depends largely on how far inland the zone extends. If it covers more than dune systems, then the following uses could also be permitted in appropriate circumstances:

- uses associated with boating/sailing
- camping grounds
- caravan parks
- extractive industries
- mines
- picnic grounds
- plant nurseries
- recreation establishments
- research establishments
- roadside stalls
- stables
- workers' dwelling-houses.

Surf life saving clubs could be permitted, subject to consideration of the following:

(a) the facilities should be those required for efficient beach patrolling, life saving and first aid;
(b) recreational amenities should be permitted to promote fitness and to encourage membership;

(a) public amenities and community services should, where practicable, be integrated to assist economic financing and to encourage community involvement;

(d) in considering the scale of development, regard should be had to:

(i) minimising the impact on the existing environments;

(ii) the area and length of the beach and public reserves;

(iii) the popularity of the beach and public reserves;

(iv) car parking facilities;

(v) the stability of the foreshore and/or dune system; and

(vi) the aesthetic quality and enjoyment of the beach and public reserves.

2. (i) The aim should be to create minimum disturbance of the landscape, to conserve existing vegetation, and to conserve the natural shoreline.

(ii) The main controls on development would be similar to those in Zones 7(d) and 7(e). For dwelling-houses, these are covered in Technical Bulletin No. 11, "Guidelines for Siting Rural Dwellings in Coastal Areas".

(iii) Development should:

. be in scale with the topography;
. respect site contours and natural features;
. avoid cut and fill;
. avoid conspicuous elevated platforms or stilts;
. be below ridges and the skyline.

(iv) Landscaping should be sympathetic to existing vegetation and should act to soften development, e.g. by breaking the roof line with trees of an appropriate scale.

(v) Construction of sea walls and realcimation should only be allowed in exceptional cases.
(vi) Roads, driveways, paths and walkways should be sited so that they are as inconspicuous as possible.

(vii) Boatsheds should be strictly controlled as to their location, size, height, use, materials and interference with tidal flows.

3. Special controls would apply to any of the additional uses in Note 1, particularly concurrence for mineral sand mining.

4. Generally, buildings should not be permitted on frontal dunes (with the possible exception of surf life saving clubs, and some structures associated with fishing, oyster farming and boating or sailing). Plans should contain provisions compatible with any restrictions under the Coastal Protection Act.

5. Where land is proposed to be acquired or otherwise protected under the Coastal Lands Protection Scheme, the zoning should be quite restrictive. The following tables (from I.D.O. 100, Gosford) should be numbered as sub-zones of the 7(f) zone. Uses requiring consent will also usually be subject to the Department's concurrence.

<table>
<thead>
<tr>
<th>COLUMN I</th>
<th>COLUMN II</th>
<th>COLUMN III</th>
<th>COLUMN IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone and colour indication on Map</td>
<td>Development which may be carried out without the consent of the Council</td>
<td>Development which may be carried out only with the consent of the Council</td>
<td></td>
</tr>
<tr>
<td>(d) Coastal Lands Protection Orange with dark red edging and lettered 7(d)</td>
<td>The use of land for agriculture ....</td>
<td>Camping; Caravan Parks; Dams; Drainage; Dwelling houses; Forestry; Golf courses; Home industries; Mining; Roads; Subdivision; The erection or use of buildings in conjunction with agriculture; The quarrying of sand; Utility installations (other than gas holders or generating works)</td>
<td></td>
</tr>
<tr>
<td>Coastal Lands Acquisition Orange with dark red edging and lettered 7(e)</td>
<td>The use of land for agriculture ....</td>
<td>Dams; Drainage; Dwelling-houses; Roads; The erection or use of buildings in conjunction with agriculture</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX 2: COASTAL PROCESSES - BACKGROUND DATA

A2.1. WAVE AND WIND CLIMATE, STORM SURGE AND WAVE SET-UP, NEARSHORE AND OFFSHORE CURRENTS AND LITTORAL DRIFT.

a) Wave Climate

Wave data has not been collected offshore from the study area. Data is available for Coffs Harbour, Newcastle and Botany Bay. Riedel and Byrne (1981) discuss and display available data from these three locations. All data has been collected and interpreted by the Coastal Engineering Branch, Department of Public Works, together with the Maritime Services Board of NSW. Tables A2.1, 2 and 3 and Figures A2.1, 2 and 3 are reproduced from Riedel and Byrne (1981) to provide a context for this report. Table A2.1 presents wave height exceedence for Coffs Harbour. Table A2.2 presents analysis of wave direction for Coffs Harbour. Table A2.3 compares Coffs Harbour data with that available for Botany Bay and Newcastle. Figures A2.1, 2 and 3 present wave height exceedence data for Coffs Harbour, Newcastle and Botany Bay. All information sources are noted on the figures and tables.

Riedel and Byrne (1981) discuss the absence of recorded swell from north of NE at Coffs Harbour, concluding that Coffs Harbour directional data may not be representative. For these reasons Riedel and Byrne utilize Botany Bay data in further calculations relevant to the Diamond Beach area. Wave refraction analysis of wave climate for the Camden Haven bathymetry and coastal configuration is beyond this authors capability.

b) Wind Climate

General climatic data for the Camden Haven is presented within section 2.2 of this report. Further site-specific data is relevant to the definition of coastal processes. For example, transgressive dunes are driven in the direction of effective winds, or those winds which can supply new material to the dunes to continue their growth and migration. The direction of the effective winds for linear transgressive dunes is denoted by the alignment of the dune ridges normal to wind direction (eg; Langsford-Smith and Thom, 1969). In the case of parabolic dunes and blowouts direction of effective winds is denoted by the dune axis (eg; Landsberg, 1956; Jennings, 1957; Den Exter (1975) evaluated the impact of the Camden Haven coastal configuration and the sheltering effects of headlands on wind direction, concluding that close correlation exists between resultant local wind direction and landward sand movement.
TABLE A2.1: WAVE HEIGHT EXCEEDENCE - COFFS HARBOUR
(Data presented in Riedel and Byrne, 1981 from Coastal Engineering Branch, DPW records).

<table>
<thead>
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<th>YEAR</th>
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<th>1.5-2</th>
<th>2-2.5</th>
<th>2.5-3</th>
<th>3-3.5</th>
<th>3.5-4</th>
<th>4-4.5</th>
<th>4.5-5</th>
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<td>0.11</td>
<td>0.04</td>
<td></td>
</tr>
</tbody>
</table>

**For each year: Row 1 - shows the number of wave observations
Row 2 - shows the cumulative number of wave observations
Row 3 - shows the percentage exceedence.**

FIGURE A2.5: AUTUMN CIRCULATION IN THE AUSTRALIAN REGION
(after Hamon and Golding, 1980).
WAVE HEIGHT EXCEEDENCE CURVES - COFFS HARBOUR, NEWCASTLE AND BOTANY BAY (after Riedel and Byrne, 1981).

A2-1 WAVE-HEIGHT EXCEEDENCE CURVE
DEEP WATER, COFF'S HARBOUR

A2-2 WAVE-HEIGHT EXCEEDENCE CURVE
DEEP WATER, NEWCASTLE

A2-3 WAVE-HEIGHT EXCEEDENCE CURVE
DEEP WATER, BOTANY BAY

Source: Data supplied by D.P.W. (Coastal Eng Branch)

Source: Unpublished data obtained directly from Maritime Services Board of N.S.W.

Source: Lawson and Abernathy, 1975
TABLE A2.2: DIRECTIONAL WAVE FREQUENCIES - COFFS HARBOUR
(Data presented in Riedel and Byrne, 1981 from Coastal Engineering Branch, DPW records).

<table>
<thead>
<tr>
<th>Direction</th>
<th>1979</th>
<th>1978</th>
<th>1977</th>
<th>1976</th>
<th>Average All years (Probability)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NNE</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>0.009</td>
</tr>
<tr>
<td>NE</td>
<td>12</td>
<td>27</td>
<td>22</td>
<td>8</td>
<td>0.066</td>
</tr>
<tr>
<td>ENE</td>
<td>42</td>
<td>76</td>
<td>63</td>
<td>10</td>
<td>0.181</td>
</tr>
<tr>
<td>E</td>
<td>35</td>
<td>82</td>
<td>113</td>
<td>43</td>
<td>0.259</td>
</tr>
<tr>
<td>ESE</td>
<td>41</td>
<td>71</td>
<td>44</td>
<td>19</td>
<td>0.166</td>
</tr>
<tr>
<td>SE</td>
<td>35</td>
<td>63</td>
<td>75</td>
<td>61</td>
<td>0.222</td>
</tr>
<tr>
<td>SSE</td>
<td>16</td>
<td>11</td>
<td>28</td>
<td>43</td>
<td>0.093</td>
</tr>
<tr>
<td>S</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td>0.004</td>
</tr>
<tr>
<td>SSW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE A2.3: DIRECTIONAL WAVE FREQUENCIES - COMPARISON
(after Riedel and Byrne, 1981)

<table>
<thead>
<tr>
<th>Direction</th>
<th>% Botany Bay</th>
<th>Location % Newcastle</th>
<th>% Coff's Harbour</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>0.2</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>NNE</td>
<td>2.1</td>
<td>5.0</td>
<td>0</td>
</tr>
<tr>
<td>NE</td>
<td>13.1</td>
<td>9.5</td>
<td>0.9</td>
</tr>
<tr>
<td>ENE</td>
<td>12.9</td>
<td>10.8</td>
<td>6.6</td>
</tr>
<tr>
<td>E</td>
<td>11.2</td>
<td>12.5</td>
<td>18.1</td>
</tr>
<tr>
<td>ESE</td>
<td>10.0</td>
<td>11.1</td>
<td>25.9</td>
</tr>
<tr>
<td>SE</td>
<td>14.1</td>
<td>12.7</td>
<td>16.6</td>
</tr>
<tr>
<td>SSE</td>
<td>14.7</td>
<td>16.1</td>
<td>22.2</td>
</tr>
<tr>
<td>S</td>
<td>20.6</td>
<td>21.3</td>
<td>9.3</td>
</tr>
<tr>
<td>SSW</td>
<td>0</td>
<td>0</td>
<td>0.4</td>
</tr>
</tbody>
</table>
Transgressive dunes in the northern ends of the Camden Haven embayments were found to be aligned in the direction of dominant south-easterly winds. The occasional and smaller scale blowouts occurring in the southern sections of the embayments were found to be aligned in the direction of locally dominant north-easterly winds. Figure A2.4 presents Den Exter's findings for the Dunbogan blowout area and the North Haven area adjacent to the northern breakwater (Photograph series 4 and 5).

FIGURE A2.4: RELATIONSHIP BETWEEN DUNE ORIENTATION AND EFFECTIVE ONSHORE WIND RESULTANT (after Den Exter, 1975).
c) Storm Surge and Wave Set-up

Silvester and Mitchell (1977) suggest a maximum storm surge component of 0.3 metres for the mid-north coast of N.S.W. Riedel and Byrne (1981) using Queensland cyclone data estimate a storm surge of 0.6 metres for Diamond Beach, south of the study area. Further analysis of available meteorological data for the N.S.W. coast is presently being prepared by the Coastal Engineering Branch, Department of Public Works (Refer to Kemp and Douglas 1981 and McMonagle and Fidge 1981). For the purposes of this study Silvester and Mitchell's figure of 0.3 metres is adopted.

Sinclair Knight and Partners (1980) utilizing 1963 recorded flood data calculated a peak ocean level of RL 2.4 m AHD, being composed of a 1.3 metre wave set-up component on top of the historical high tide level. Storm surge during this period was assumed to be negligible. Meteorological data for the 1963 flood event notes that the heavy seas approached from a ENE direction and thus directly entered the estuary with minimal wave shadow effects from Camden Head - Point Perpendicular. As stated by Sinclair Knight and Partners, and as detailed in Tables A2-2 and 3, the most common direction for heavy seas along the N.S.W. coast is from the south east. From this direction the Camden Haven river mouth is partially protected by Camden Head and the breakwaters. Thus, Sinclair Knight and Partners consider the figure of RL 2.4 metres AHD, given the critical direction of the approaching waves, presents the expected maximum wave set-up for the Camden Haven river entrance. Table A2-4 (after Sinclair, Knight and Partners 1980) presents wave set-up at the Camden Haven estuary for a range of wave heights and periods.

<table>
<thead>
<tr>
<th>TABLE A2.4: WAVE SET UP AT SHORE, CAMDEN HAVEN</th>
<th>(after Sinclair Knight and Partners, 1980).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave Period</td>
<td>8 Secs 10 Secs 12 Secs 14 Secs 16 Secs 18 Secs 20 Secs</td>
</tr>
<tr>
<td>Incoming Wave Ht (metres)</td>
<td></td>
</tr>
<tr>
<td>3.7 m</td>
<td>0.66 0.70 0.77 0.85 0.92 1.00 1.07</td>
</tr>
<tr>
<td>4.6 m</td>
<td>0.71 0.80 0.90 1.00 1.08 1.16 1.23</td>
</tr>
<tr>
<td>5.5 m</td>
<td>0.80 0.91 1.01 1.11 1.22 1.32</td>
</tr>
<tr>
<td>6.1 m</td>
<td>0.86 0.99 1.10 1.20 1.30</td>
</tr>
</tbody>
</table>
Sinclair Knight and Partners calculation is primarily concerned with wave set-up influencing flood levels at the Camden Haven river entrance. While this calculated wave set-up of 1.3 metres has been the subject of some discussion (e.g. Pers Comm. - S. Perrens, Faculty of Resource Management, UNE), documentary evidence available on Lake Cathie bridge approach erosion on two occasions would seem to support a wave set-up component of at least 1.3 metres. Also, calculations from other N.S.W. north coast locations present similar results. For example, calculations of wave set-up for Coffs Harbour utilizing the Department of Public Works waverider buoy data and the method described in U.S. Army CERC (1977) are outlined by Van Kervoot (1980). Using a design wave of 10 metres height and 10 second period Van Kervoot defined a wave set-up for Coffs Harbour region of 1.2 metres. Riedel and Byrne (1981) using Botany Bay wave data calculated a wave set-up of 1.8 metres for Diamond Beach.

With these comments providing a context, figures adopted for this study are as follows:

- Estimated Storm Surge: 0.3 metres
- Estimated Wave Set-up: 1.3 metres
- Estimated Spring Tide Allowance: 1.0 metres

Thus, a maximum still water level of 2.6 metres AHD during an extreme event is postulated for the Camden Haven. Orthophotomaps North Haven ZB292-1,2 and 4 cover the northern end of Dunbogan embayment, the Camden Haven River entrance and the southern end of Grants Head embayment. Data presented indicates that during an extreme storm event overtopping of the barrier system would occur adjacent to the Camden Haven northern breakwater. This occurred during a storm event, 1978, associated with a winter low depression. No further records are available. No orthophotomap data is available for the remainder of the study area however, overtopping has been reported in the southern corner of the Rainbow Beach embayment, affecting the developed car park and amenities block area, and the house closest to the Creek (Pers. Comm. - Local Residents).

d) Local and Offshore Currents

Local and offshore currents are associated with phenomena having a wide range of time scales. One example of this is as follows, (source unknown):

<table>
<thead>
<tr>
<th>Wave Induced Currents</th>
<th>seconds</th>
<th>months</th>
<th>years</th>
</tr>
</thead>
<tbody>
<tr>
<td>variation over a wave period</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>seasonal variation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>storm variation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Tide Induced Currents
- daily
- monthly
- long term

### Wind Induced Currents
- daily
- seasonal
- storm

### Oceanic Currents
- short-term variation
- long-term variation

### River Discharge
- daily
- floods

### Density Currents
- seasonal
- long-term

The complex oceanic circulation patterns of the east coast of Australia have been grouped together and termed the East Australian Current (EAC). Figure A2-5 (after Hamon and Golding 1980) presents a model structure for the EAC. This model is confined to deep ocean waters beyond the continental shelf (> 200 metres). These offshore currents influence continental shelf or inshore currents (Greig, 1974). Inshore currents are allied to the topography of the continental shelf and inshore zone (Jacobs 1980) and probably have a more dominant effect than the 'pure' EAC component on coastal processes.

Den Exter (1975) cites Chan (1957) who reported the dominant current direction in the Port Macquarie area as being offshore, with an onshore movement occurring only during January. Chan related these current patterns to seasonal changes of the coastal wind systems, the effect of migrating tropical water masses, and upwelling of bottom waters. Chan considered the upwelling of bottom waters to be the dominant factor influencing local current patterns. Hamon and Tranter (1971) noted a strong upwelling adjacent to Laurieton from August to October 1971. This upwelling has been further
researched by Rochford (1982). Algal blooms (red weed - *Ceramium* sp.) observed in the study area during the spring of 1980 and 1981 may be associated with this upwelling.

Nearshore currents of varying directions associated with storm events were observed during field work for the project. For example, during September 1980, associated with a north easterly swell of approximately two to three metres, a month to south nearshore current flow was observed from Tacking Point south to Diamond Head. At North-Haven extensive reworking of onshore and offshore bar formations accompanied this event with sand being deposited in an extended lobe off the northern breakwater southwards to the centre of the estuary entrance channel. Similar sand formations have been reported within Hydrographic surveys of the entrance bar (e.g. 1957 to 1958 - Dept. Public Works records). South east swells during the winters of 1980 and 1981 were observed to generate a strong northerly drift, interrupted at intervals by rip currents oblique to the shore. Sand transport northwards accompanied these storm events.

e) Littoral Drift and Onshore Sand Losses

Gordon and Lord (1981) develop a generalized coastal model for N.S.W. which predicts that at the present time, where there is no new source of suitable sediments, beaches will be either:

- In a state of dynamic equilibrium where no longshore or aeolian losses occur
- Undergoing long-term erosion where aeolian and/or longshore losses occur.

Roy and Stephens (1981) discussing coastal evolution in the past and contemporary processes list five factors of relevance in the determination of coastal sediment budgets. These factors are as follows:

- degree of compartmentisation and sand bypassing
- incident wave energy
- onshore sand losses to deep water sinks
- inherited sediment characteristics
- substrate control.

With respect to the Camden Haven area it has been suggested that the coastal zone be treated as an open compartment (Pers. Comm. Peter Roy, Geological Survey of N.S.W.). Geomorphologically the study area presents a transitional variation from south to north. Holocene barrier development varies from extensive in the Crowdy Head embayment (just south of the study
area) to moderate within the Dunbogan and Grants Head embayments to minimal in the Rainbow Beach to Tacking Point embayment. Further detail is contained within the following section providing data on onshore and offshore geology and within Chapter 2, sections 2.3 and 2.8.

There has been to date, no site-specific investigation of littoral and aeolian processes of the Camden Haven. To provide a context for this discussion several site-specific studies to the south and north of the Camden Haven are detailed in the following discussion. It must be noted however, that it could be quite erroneous to infer specific quantitative conclusions for the Camden Haven from this data.

Diamond Beach, south of the Camden Haven is detailed within Riedel and Byrne (1981). Diamond Beach was found to receive a negligible sand supply from the south and that under normal conditions movement to the north was also negligible. During southerly storm events associated with Khappinghat Creek floods, sediment of the order of 50,000 m³ may be transferred northwards. Riedel and Byrne suggest that such a storm event would occur on average every five years, thus establishing a possible annual loss of 10,000 m³. Rates of erosion over the last forty three years varied from up to 0.4 metres/year at the north and south of the beach to less than 0.1 metres/year in the central part of the beach. Duchess Creek, Rainbow Beach embayment may perform in a similar fashion to Khappinghat Creek (refer to Photograph Series 3).

Druery and Neilson (1980) detail research on the Hastings River entrance associated with breakwater construction. Druery and Neilson nominated four cells within which sedimentary processes were described. The 'southern coast cell' comprising small beaches north of Tacking Point was found to exhibit a weak intermittent littoral transport pattern thought to be associated with temporary development of offshore bars during major storms. Transport was estimated to be 20,000 m³/year northwards. While this 'southern coast cell' is just to the north of the Camden Haven, the coastal configuration of Tacking Point area precludes any quantification of northward movement from the study area to this 'southern coast cell'. It must be noted however, that onshore heavy mineral composition as defined by Hails (1969) for the Port Macquarie - Grassy Head area could possibly be explained by northward littoral drift from the Camden Haven catchment.
Further north, several studies have detailed recession rates and estimated northward littoral drift rates. Wong (1979) details the Hat Head area, predicting the following recession rates:

<table>
<thead>
<tr>
<th>Average Maximum Recession Rate</th>
<th>1.3 metres/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Minimum Recession Rate</td>
<td>0.1 metres/year</td>
</tr>
<tr>
<td>Mean Recession Rate</td>
<td>0.5 metres/year</td>
</tr>
</tbody>
</table>

Wong noted that actual recession is primarily a function of storm events with short-term changes of both recession and accretion of up to 10 metres recorded.

Van Kervoort (1980) within a investigation of Myleston Beach, south of Coffs Harbour, cites a preliminary DPW investigation which indicated a nett northerly littoral drift at Coffs Harbour of 30,000 to 100,000 m$^3$/year. Similar northward littoral drift patterns are experienced at Smokey Cape (Pers. Comm. DPW). Northward littoral drift in the Tweed region has been estimated at 300,000 m$^3$/year (Pers. Comm. DPW).

With this background data providing a context, and noting the wave climate, onshore currents and beach shape of the study area, it is postulated that the Camden Haven is subject to a northward littoral drift pattern. However, no quantitative assessment of the littoral drift is possible with the data available.

Losses of sand from the onshore zone by aeolian processes must be accounted for within any sediment budget. The significance of aeolian processes will vary. For example, a sediment budget based on a closed offshore compartment with net onshore losses by aeolian processes is proposed for the Newcastle Bight (e.g. Depart. Public Works. 1977; Roy 1980; Roy and Crawford 1980). Site-specific wind climate associated with transgressive dune formation within the Camden Haven is detailed previously within this discussion. Presently active transgressive dunes occur at the northern end of Dunbogan embayment (refer to Photograph Series 5), and to a much lesser extent within the Grants Head embayment. To the north of the study area but still within the Rainbow Beach - Tacking Point embayment, further active blowouts are found. As for the littoral drift, no quantitative assessment of onshore losses is possible with the data available.

If, as postulated, the Camden Haven area is subject to northward littoral drift together with onshore losses, allocation of use and management
of the barriers systems should account for these presently active processes. Van Kervoort (1980) on this subject stated:

Any beach/dune system located on a high nett littoral drift section of coastline must be considered in a delicate state of balance. For the beach to be maintained in its present condition at a given location the quantity of sand reaching that location from updrift must balance the quantity of sand leaving downdrift. Should any imbalance occur to the littoral supply (e.g. construction of groyne fields, training walls, sand extraction, localized storm erosion etc.) this can result in immediate and irreversible loss of sediment from the beach face, manifested as a landward movement of the shoreline.

To provide a further basis for the effective use allocation and management of the present barrier system the following sections detail onshore and offshore geology, observed changes to beaches over the time scale of available aerial photography, and detail of man’s use and attendant impacts upon the barrier systems.

A2.2. ONSHORE AND OFFSHORE GEOLOGY

Onshore geology is detailed within Chapter 2, sections 2.3 and 2.8. The extent of the Holocene present barrier varies within the study area. The barrier is well developed within Dunbogan and Grants Head embayments comprising incipient foredune, foredune and a series of barrier ridges which abut the prior barrier system. Transgressive dunes and disturbance associated with sand mining have altered the landform pattern, particularly in the northern end of both embayments.

Within the Rainbow Beach embayment the prior barrier of Pleistocene age lies adjacent to the beach zone and incipient foredune. Indurated sand of Pleistocene age is exposed throughout the Rainbow Beach embayment during periods of short-term beach erosion (refer to Series 3). It is suggested that the absence of a significant barrier of Holocene age within the Rainbow Beach embayment may be attributed at least in part, to changes in the littoral drift pattern associated with changes in sea level. Recent erosion, as discernable from aerial photographs interpretation and historical records has further reduced the extent of the Holocene barrier, particularly in the southern
Limited Holocene development of barrier systems is not confined to the Rainbow Beach embayment. Other examples on the N.S.W. north coast include Diamond Beach (Riedel and Byrne, 1981) and Angourie Backbeach (south of Yamba). Mapping using the methodology adopted within this study of the entire N.S.W. coast may provide further data of relevance to the definition of prior and contemporary coastal processes. It is suggested that such a map base may particularly provide further data on the compartmentalization and littoral drift patterns presently exhibited throughout the N.S.W. coast. Management strategies and use options for the barrier systems could be varied in response to this data.

No investigation of offshore geology was carried out during the study. Figure A2-6 presents data on offshore contours taken from RAN Chart AUS 811. Figure A2-7 presents profiles at locations marked on figure A2-6. Den Exter (1975) cites Phipps (1966) who described the area offshore of the Camden Haven as being located in a shelf rise zone, with greater depths recorded to the south and north of the study area. This warping of the continental shelf has been used by Phipps to demonstrate earth movements along the N.S.W. coastline during the Pleistocene. Den Exter (1975) cites Thorn et al. (1972) who presented data on the existence of an undeformed terrace at approximately 200 metres depth, thus displaying that the earth movements described by Phipps did not continue into the last phase of glacially lowered sea level.

Offshore sediments of N.S.W. south of the study area have been described in general terms by Shirley (1964) who delineated three specific zones:

- Nearshore - beach sands and shell debris
- Central Terrigenous sediments - fine sands, muds and very few shells
- Outer Coarse Belt - shells and older consolidated sediments.

Planet Metals Ltd. (Brown and MacCulloch, 1970) during offshore exploration noted the presence of low grade deposits of rutile, zircon and ilmenite. These deposits were found in 15-18 fathoms water depth on what is described as a inner fossil strand line and has all the characteristics of a preserved beach, similar to modern beaches along the east coast of Australia. Planet Metals Ltd. from investigations of sub-bottom profiles suggest the
FIGURE A2.6: OFFSHORE CONTOURS, CAMDEN HAVEN (after RAN chart AUS 811)

Tacking Point

Lake Innes

Lake Cathie

Grants Head

Queens Lake

Watson Taylor Lake

Diamond Head

Profile 1

Profile 2

Profile 3

Profile 4

Profile 5

Scale 1:150 000 Offshore Contours in Fathoms
FIGURE A2-7: OFFSHORE PROFILES, CAMDEN HAVEN (after RAN chart AUS 811).

Profile 1: Flat Rock

Profile 2: Grants Head

Profile 3: Point Perpendicular

Profile 4: Diamond Head embayment

Profile 5: Diamond Head
presence of a second fossil beach line occurring between 35 and 40 fathoms water depth.

Riedel and Byrne (1981) described and mapped offshore sediments of Diamond Beach, south of the study area. Components described were: rock reefs, inner nearshore sand, outer nearshore sand, inner shelf sand, inner shelf sand-mud sub-facies and muddy shelf sand. All these components may be also present within the study area.

A2-3 BEACH CHANGES DISCERNABLE FROM AVAILABLE AERIAL PHOTOGRAPHY

Aerial photographic coverage for the Camden Haven is available from 1940 onwards. Available photographic coverage includes:

- 1940: KD508 SVY H56-14-354 Camden Haven
- October 1960: N.S.W. 570, Kendall Group
- August 1963 : N.S.W. 1188, Camden Haven
- November 1965: N.S.W. 1368, 5144
- December 1976: N.S.W. Coastline N.S.W. 2421 (Colour)
- July, 1979 : Camden Haven N.S.W. 2790.

Factors relevant to past and contemporary processes have been listed previously (Roy and Stephens, 1981). These factors are influenced by man's use of the onshore and nearshore zone (e.g. breakwater construction, landform change associated with sand mining, urban development and access; vegetation change associated with use, fire and introduced species and so on). Time scales will vary. Natural processes vary both in the short term and the long term, (e.g. Wearne, 1977; Thom Polach and Bowman 1978). Long term changes associated with man's use may be masked by short-term changes of greater magnitude. Changes associated with breakwater construction are a good example. Druery and Nielsen (1980) detail short term and long term changes observed and expected for the breakwater extensions at Hastings River entrance. Nielsen and Gordon (1980) detail changes associated with breakwater construction at Wallis Lake. Floyd and Druery (1976) document changes to the Clarence river entrance associated with breakwater construction.

In total, river entrance works throughout N.S.W. have a long history of changes, modifications and extensions. To what extent these alterations reflect past inadequacies in design and to what extent alterations reflect long term and short term changes in sediment budgets associated with entrance works has yet to be fully investigated.
It may be concluded however that any erosion or accretion rates predicted by photogrammetric methods are at best the combination of that portion of short term and long term changes accounted for within the time scale of photographic coverage available. For these reasons no detailed photogrammetric analysis has been attempted for the Camden Haven. The following discussion presents a qualitative description of the changes observable from the available aerial photographs for each embayment of the study area.

- **Rainbow Beach** (Flat Rock south to Bonny Hills)
  1940: Entire foredune vegetated, no disturbance observable. Vegetated foredune limited but present in southern corner of the beach. Most of the rock reef areas in the southern corner covered by sand.
  1975: Increased urbanization and use with attendant changes to foredune. Devegetation and erosion of southern corner. Several access paths along the beach marked by devegetation and profile change (refer to Photograph Series 3 for recent photographs).

- **Grants Beach** (Bonny Hills to northern breakwall, North Haven)
  1940: Acretion of sand against northern breakwater extending the barrier seawards. Remainder of foredune largely undisturbed, some disturbance associated with localized access points, open sand areas.
  1960: Mining and rehabilitation in progress.
  1965: Rehabilitation progressing with further mining proceeding in the northern end of the embayment.
  1975: Rehabilitation completed. Bare sand patches minimal except at access points.
  1976: Loss of sand associated with breakwater. Extension of southern breakwaters may have influenced sediment budget. Increased number of access paths, erosion at southern end of embayment prompting sand stabilization works by the Soil Conservation Service (refer to Photograph Series 4 for recent photographs).

- **Pilots Beach** (Southern breakwall to Camden Head)
  1940: Sand accretion occurring, limited vegetation between southern training wall, Gogleys Lagoon and Camden Head.
1975: Vegetation well developed through to Gogleys Lagoon. Small vegetated foredune formed. Increased accretion may be associated with breakwall modifications.

1979: Further accretion of sand however use of beach has reduced foredune vegetation.

Dunbogan Beach (Camden Head to Diamond Head)

1940: Series of blowouts at the northern end of the embayment. Lack of vegetation cover on the coastal face of the barrier extending to the road in several areas. Remainder of the barrier extending southwards to Diamond Head vegetated except for isolated access points. Dunbogan blowout reported but not detailed by Hewitt (1954). Sless (1957) noted that the Dunbogan sand drift was then drifting onto the road over a distance of 800 yards. Sless defined the cause of the drift as being grazing by stock, destruction of timber and wave action. During this period Hastings Shire Council initiated a sand stabilization program.

1965: Three main sand drifts at the northern end of the embayment. Revegetation by Hastings Shire Council largely unsuccessful. Increased access paths the length of the beach. Sand mining and rehabilitation programs carried out from 1967 to 1971. Watt (1972) noted the Dunbogan blowout within a list of N.S.W. sand drift areas. The blowout was defined as being of 29 hectares over a length of 3,821 metres.

1976: Rehabilitation after mining partially established. Increased number of access paths the length of the beach. Adjacent to the blowout areas houses established in a small subdivision.

1980: Rehabilitation has improved sand stability. Fewer open sand areas the length of the beach. Use associated with Crowdy Head National Park causing localized erosion points at the southern end of the embayment. Dunbogan blowout reduced in extent but still drifting onto the road at three points (Photograph Series 5 presents further detail on the blowout area).

From these brief notes it is apparent that changes in beach profile, erosion, accretion and sand drift, while being associated with natural processes, are primarily a function of use. Control over use of the barrier system together
with the implementation of management strategies is necessary. Management strategies implemented must account for the natural processes previously detailed, together with the variation in use functions presently imposed upon the barrier system. To complete the review of background data the following section details heavy mineral deposits and mining within the Camden Haven.

A2-4 HEAVY MINERAL DEPOSITS AND MINING WITHIN THE CAMDEN HAVEN

The source or sources of heavy mineral concentrations along the coast of northern N.S.W. and southern Queensland has been the subject of much discussion (e.g. Beasley, 1948, 1950; Gardner, 1955, Whitworth, 1959). To date no general agreement exists as to whether the Pre-Cambrian Shield, or the New England Granite formation (Gardner, 1955) is the provenance of the heavy minerals along the coastline. A consensus of opinion does exist however, in that erosion of secondary deposits occurring as units of the sedimentary basins of the N.S.W.-Queensland coast (e.g. Sydney, Lorne, Clarence and Moreton Basins) has contributed the bulk of heavy minerals of economic significance to the coastal zone. Coastal processes including deposition, erosion, reworking, transport and redeposition have assisted in obscuring the origins of the present heavy mineral concentrations.

Winward and Nicholson (1974) cite Hails (1969) who, although not entering into the controversy of the origin of the major heavy minerals, noted the presence of accessory heavy minerals in the Port Macquarie - Grassy Head area. Minerals present reflected a medium grade metamorphic source not present within the Hastings catchment. Their presence could be explained by the complete removal of the source rock, either by erosion or submergence during the last transgression or, a source outside the Hastings catchment, such as associated with the microgranitic intrusives of the Camden Haven catchment. Northward littoral drift together with gravity separation may account for Hail's findings.

Economic deposits of heavy minerals within the Camden Haven are predominantly of the beach placer type. No data is available to determine the occurrence and distribution of wind blown deposits. Figure A2-8 displays the location of the major economic deposits within the study area. Winward and Nicholson (1974) describe beach placer deposits as follows:
Beach placer deposits are found where wave action has concentrated the heavy mineral fraction with respect to the quartz fraction, and this concentrate has been preserved. As the deposits form on the sloping surface of beaches, they are usually elongate (up to several kilometres long and 100 metres wide) and lens or wedge shaped (tapering and sloping seaward). The deposits may vary from a few millimetres to several metres in thickness. The thickest accumulations are normally in the northern part of the beach (i.e. adjacent to the southern side of the headland terminating the beach) ..............

To preserve the heavy mineral deposits requires that either the shoreline progrades because of a more abundant sediment supply (Halls 1964, Halls and Hoyt 1968, Langford-Smith and Thom in Packham, 1968), or that the sea level falls, removing heavy mineral accumulations from the province of wave activity (Jones 1946; Gardner 1958).

Beach placer type deposits are found well developed within the prior barrier south of the Camden Haven river entrance (Dunbogan embayment) and to a lesser extent northward of the river entrance (Grants Head embayment). Den Exter (1975) suggests that these deposits indicate that the Camden Haven river contributed a significant amount, if not all the heavy minerals to the shore zone during the period of prior barrier formation.

Present barrier deposits are found within all embayments. Deposits are generally most extensive at the northern end of the embayments. Smaller deposits are located at the southern ends of the embayments. Details of all sand mining carried out to date within the study area are as follows -

**Dunbogan Embayment**

1. Southernmost section of present barrier adjacent to Diamond Head - AMA Sept. 1967 to May 1968
2. Northernmost section of present barrier adjacent to Camden Head - AMA Oct. 1966 to Aug. 1967
3. Prior barrier, adjacent to and extending southwards from the northern present barrier deposit - AMA July 1969 to June 1971

**Grants Head Embayment**

1. Present Barrier, Mid Beach to northern end adjacent to Grants Head - M.D. 1969 to 1970
. Smaller Inner Barrier deposits also mined, no detail available

Rainbow Beach Embayment

. Prior Barrier westward of Duchess Creek - AMA July 1971 to Nov. 1971

Note: All data supplied by Associated Minerals Ltd. and Mineral Deposits Ltd.

All mining operations within the study area were with dredges and floating concentration plants. While no precise data on recovery from past operations is available, remining may be economically warranted at a later date.

The rehabilitation of the areas mined was carried out in accordance with the requirements of the Department of Mines at that time. The emphasis was on stabilization of the sand mass with plants such as spinifex grass (Spinifex hirsutus) acacia spp. (e.g. Acacia longifolia) and bitou bush (Chrysanthemeoides monilifera). No emphasis was given to restoration of topography and naturally occurring vegetative species. Photographs of revegetating mined areas are included within plates 4 and 5.
FIGURE A2.8: HEAVY MINERAL SAND MINING AREAS - BONNY HILLS TO HARRINGTON (after Winward and Nicholson, 1974).
APPENDIX 3: SOIL EROSION - SOME ASPECTS OF AGENCY REGULATION

This appendix provides some of the data relevant to agency regulation of land use to control and mitigate soil erosion. Information presented is as follows:-


2. Restrictions on destruction of trees growing on protected lands and along prescribed streams (Catchment Areas Protection Board).

Provisions of section 26D of the Water Act, 1912-1972 apply to the following watercourses within the Camden Haven catchment: Camden Haven river and southern branch, Upsalls Creek (northern branch), Stewarts River, Herons Creek. Enforcement of these regulations is presently minimal. This lack of enforcement is attributed by Catchment Areas Protection Board officers to a lack of public awareness together with a lack of staffing. Reassessment of the manner of implementation of these regulations may be required. Further, it is suggested that relevant regulations should be altered to include all significant watercourses and lakes within any catchment. Watercourse catchment areas may provide a basis for the definition of "significant watercourses". Lakes such as Queens and Watson Taylor should obviously be included within the regulations.

3. Standard Erosion Mitigation Conditions for Logging in N.S.W. (Catchment Areas Protection Board). Erosion mitigation conditions for permanent and temporary clearing of lands under the control of the Board are of similar format. The Forestry Commission of N.S.W. adopts these erosion control principles to all lands under their control. Controls over private forestry operations are limited. Assessment and regulation of private forestry operations is long overdue (Pers. Comm. Forestry Commission).

4. Data for Logging Plan (Forestry Commission, Kendall Management Area). This prescription for logging plans is included to display the planning implemented by the Forestry Commission prior to logging within a specific compartment. Similar planning and control mechanisms should be applied to private forestry operations.

Note: Forest management practices to control and mitigate soil erosion within the Kendall Management area have increased over the last eight years. Forestry operations have been planned to utilize existing roads,
rather than construct further roads. While road grading remains essential, in order to minimize erosion, wherever possible (e.g. fire trails), a farm tractor and flail mower are used. The clearing of trees during silvicultural treatment has been reduced. Additionally an attempt has been made to minimize wet weather logging problems. Herons Creek Mill has agreed to maintain an increased log inventory against the possibility of a prolonged spell of wet weather. In planning the logging order, the Forestry Commission has attempted to schedule difficult blocks for the drier months. The logging plan for each compartment is also used to hold suitable wet weather sections until they are required. It is suggested the concept of scheduling difficult blocks for the drier months and of holding suitable wet weather sections within compartments until required could be adopted by the Forestry Commission throughout N.S.W.
APPENDIX 3.1:

MAP OF
"PROTECTED LAND"
CAMDEN HAVEN RIVER
CATCHMENT AREA
AS SET OUT IN SECTION 21
SOIL CONSERVATION ACT 1938-72
Date of map 2nd July 1975

Protected Land
Catchment Area Boundary
State Forest, National Forest, Timber Reserve or Flora Reserve
National Park, State Park or Historic Site

S.C.S. 10059
APPENDIX 3.2:

CATCHMENT AREAS PROTECTION BOARD

RESTRICTIONS ON DESTRUCTION OF TREES GROWING ON PROTECTED LANDS AND ALONG PRESCRIBED STREAMS

1. The Soil Conservation Act, 1938, and Water Act, 1912, require owners, occupiers or holders of timber rights, to make application to the Catchment Areas Protection Board, for an authority before destroying or injuring trees growing on PROTECTED LANDS or along PRESCRIBED STREAMS.

2. Protected lands are those lands within catchment areas notified under the Soil Conservation Act, 1938, which are shown on a map as having slopes generally in excess of 18 degrees from the horizontal, i.e. where slopes are steeper than one vertically in three horizontally.

3. Prescribed streams are those rivers, creeks, effluents or lakes which are listed as 'prescribed' within provisions of Section 26D of the Water Act, 1912. Many streams in New South Wales have been prescribed.

4. Why is it necessary?

Silt in rivers is the main form of pollution throughout rural areas of New South Wales, as it is in other States and countries with large areas of eroded and erodible lands. It can render costly works entirely ineffective and seriously degrade waterways to the general disadvantage of the community.

Generally a vigorous tree cover is recognised as the most effective control of erosion on steep lands and is of major importance along river banks.

The overriding consideration, therefore, is that the preservation of suitable tree cover on steeply sloping lands, and of trees along the rivers, is essential to protect the water and soil resources of New South Wales.

5. What lands are affected?

These provisions of the Soil Conservation Act and Water Act apply to all lands mapped as 'protected lands' or along streams listed as 'prescribed', irrespective of tenure.

That is to say, private property (freehold) lands are included as well as lands held under tenures from the Crown.

6. What are the restrictions relating to 'protected lands'?

The Soil Conservation Act provides that, unless the authority of the Catchment Areas Protection Board has been secured, a person shall not -

(a) ringbark, cut down, fell, poison or otherwise destroy, or cause to be destroyed; or

(b) top, lop, remove or injure or cause to be injured; any tree ('tree' includes 'sapling') on protected lands.
7. How are Protected Lands identified?

Protected lands are those mapped as having slopes generally in excess of 18° from the horizontal within catchment areas notified under the Soil Conservation Act.

The majority of the lands east of the Great Dividing Range are already within notified catchment areas and action is being taken to extend this west of the range.

These maps are deposited in the office of the District Soil Conservationist which is nearest to the land to which the map relates, and may be inspected by any person during normal office hours without payment of any fee.

Protected land maps are also available for inspection at a number of local Soil Conservation Service, Lands Department and Forestry Commission offices.

8. Where are applications concerning Protected Lands lodged?

The application form can be secured from any Soil Conservation Service office, which will accept the completed application on behalf of the Catchment Areas Protection Board.

9. Procedures - Protected Lands

As soon as possible after receiving an application to cut or destroy trees on protected lands, the District Soil Conservationist will arrange for an inspection of the area affected and will report to the Catchment Areas Protection Board. The Board, if it approves of the application, will issue an Authority under Section 21D of the Act subject to conditions considered necessary to control erosion and siltation.

In certain cases, the District Soil Conservationist is authorised to issue an interim authority to proceed with the proposed operation pending the granting of authority by the Board.

10. Exemptions from Protected Lands provisions

An owner or occupier of protected lands need not apply for an Authority should he wish to cut or destroy in any period of one year:

(a) no more than 7 trees per hectare; or

(b) the trees growing on no more than one quarter - up to a maximum of 2 hectares - of the area, of each portion of protected land contained within his holding.

Operations normal to the harvesting and management of banana plantations and orchards are exempt, except that an Authority is required if the operations result in the complete destruction of the plantation or orchard.

PRESCRIBED STREAMS

11. What are the restrictions concerning Prescribed Streams?

The Water Act requires that, unless the authority of the Catchment Areas Protection Board has been secured, a person shall not -
(a) ringbark, cut down, fell, poison or otherwise destroy, or cause to be destroyed; or

(b) top, lop, remove or injure, or cause to be injured, any tree within the bed or within 20 metres of the banks of a prescribed river or lake.

12. How are Prescribed Streams identified?

Rivers, streams or lakes prescribed under the Water Act, 1912, are listed in a publication - "Restrictions on the Removal of Trees on New South Wales Watercourses" - published by the Water Resources Commission.

Copies of this publication are available for inspection at all Soil Conservation Service and Water Resources Commission offices. It can also be inspected in some Department of Public Works, Forestry Commission and Lands Department offices.

13. Where are applications concerning Prescribed Streams lodged?

The application form can be secured from offices of the Soil Conservation Service, the Water Resources Commission and coastal offices of the Department of Public Works, each of which will accept applications on behalf of the Catchment Areas Protection Board.

14. Procedures - Prescribed Streams

As soon as possible after receipt of an application to destroy trees along a prescribed stream, the Catchment Areas Protection Board will arrange for an inspection and report to be made by -

(a) The Water Resources Commission in the case of non-tidal waters; or

(b) the Department of Public Works in the case of tidal waters.

The Board, if it approves of the application, will issue a Permit under Section 260 of the Water Act, subject to such conditions it sees as necessary to control erosion and siltation.

15. Exemptions concerning Prescribed Streams

There are no exemptions from the restrictions concerning destruction of trees along prescribed streams.

16. Penalties

Any person who contravenes these provisions of these Sections of the Soil Conservation Act or Water Act is liable to a fine not exceeding $500 for each offence.

17. Remedial Measures

If a person contravenes these provisions of the Acts and, if the operations have resulted in or are liable to result in erosion or siltation, the Catchment Areas Protection Board can require that person to carry out remedial measures to its satisfaction.
18. Get expert advice

The Catchment Areas Protection Board is conscious of the Government's wish that - "the provisions work in the interests of the whole of the State, as well as in the interests of the individual landholder."

Before destroying trees on steep land, consult any office of the Soil Conservation Service and obtain free advice. These local officers understand your problems of land use and know how to deal with them.

For your enquiries regarding destruction of trees along river banks, consult the Rivers and Foreshores Improvement Branch of the Water Resources Commission or the District Engineer, Public Works Department.

All correspondence to the Catchment Areas Protection Board should be addressed -

The Secretary,
Catchment Areas Protection Board,
Box R201 Royal Exchange P.O.,
SYDNEY. 2000
APPENDIX 3.3:

CATCHMENT AREAS PROTECTION BOARD

STANDARD EROSION MITIGATION CONDITIONS FOR LOGGING IN NEW SOUTH WALES

1. GENERAL

(a) These conditions for mitigation of erosion shall apply to all logging and forest operations controlled by the Catchment Areas Protection Board and the Forestry Commission of N.S.W. The Catchment Areas Protection Board authorises these operations under provisions of Section 21 of the Soil Conservation Act, 1938, as amended. The Forestry Commission of N.S.W. exercises control of these operations on Crown timber lands under provisions of the Forestry Act, 1916, as amended.

(b) The person authorised by the Catchment Areas Protection Board shall ensure that all activities connected with the logging operations on the authorised area shall be conducted in such a manner that erosion is not aggravated and shall carry out any instructions given by the Catchment Areas Protection Board or its nominee with a view to minimising or preventing erosion.

(c) Notwithstanding the following conditions, in catchments of major water storages and in areas where the erosion hazard so warrants, restrictions on the method and intensity of all forest operations may be imposed by the Catchment Areas Protection Board or the Forestry Commission of N.S.W.

2. CONDITIONS FOR LOGGING

(a) Roads

Roads shall be located where practicable on ridges. They shall not intrude into filter strips beside streams except where the road crosses the stream.

Roads (i) are defined as those maintained on some regular basis so that they are generally available for use.

A minor road (ii) is defined as one that is constructed for a short term specific purpose, e.g. for timber haulage from log dump or for access during clearing and is used at most intermittently.

(i) Roads

Roads shall be properly formed, and they shall be gravelled if the density of traffic so warrants, and this is specified.

All batters shall be constructed to a stable slope. Positive consolidation may be necessary on fills to minimise subsequent slumping and erosion of fill batters. Revegetation of batters may be required on some roads, and this shall be carried out when specified.

Adequate pipe drainage shall be provided in roads consistent with sound engineering practice so that erosion of the road surface and table drains is minimised. Pipes should discharge water onto undisturbed vegetation.

The use of borrow pits for the provision of extra material during road construction should be kept to an absolute minimum. Where use of a borrow pit is unavoidable topsoil shall be stockpiled and subsequently replaced to aid revegetation.

The bottom of pits should be graded and levelled, sides should be battered and shaped to conform to the surrounds and the
replaced topsoil fertilized and seeded where necessary to establish a vegetative cover.

Maximum grades on roads shall be kept below $10^5$.

Bridges and culverts on roads shall be designed to transmit peak discharges consistent with the standard of road. Bridge approaches shall be stabilized and revegetated where necessary following construction. Culvert outlets should be located or designed to minimise scour and erosion.

Maintenance grading shall be carried out only where necessary and disturbance to vegetation should be minimised.

(ii) Minor Roads and Logging Tracks

Wherever the type of operations permit and as far as practicable, minor roads and tracks shall be constructed with cross fall drainage.

Immediately after the logging operation has ceased (even if it is planned to use the road any time in the future) the road or logging track shall be drained by cross banks where necessary. The channels of these banks must be constructed with a minimum gradient to ensure that there is positive lateral drainage onto the surrounding vegetation. Cross banks must not direct water directly onto other tracks or roads. The exits of these banks must allow water to escape readily from the track or road. The cross bank spacings and height to be employed are those listed in the table under "(d) Snigging".

Immediately after operations have ceased on minor roads and logging tracks, the surface material shall be replaced as far as practicable and they shall be drained by banks unless otherwise specified. Seeding and/or fertilizing shall be specified where necessary.

The use of borrow pits should be kept to an absolute minimum, and if employed, should be dealt with as under "(i) Roads".

Minor roads and logging tracks shall not cross running streams unless a causeway, bridge or pipe culvert designed to transmit peak flows has been provided. They may cross dry stream beds via causeways, temporary culverts or log crossings provided there is minimum disturbance to the surroundings.

"Blading-off" on minor roads and logging tracks shall be permitted only where track damage is minimal and subsequent drainage and repair is possible.

Each "blading-off" operation must be specifically approved.

The use of minor roads should be minimised during wet weather. They should carry no traffic at times when there is runoff from the road surface.

(b) Filter Strips

(i) A filter strip is defined as a strip of existing vegetation retained along both sides of a stream.

(ii) A filter strip of existing vegetation shall be retained to extend at least 20 metres on each side of a stream or drainage line where its catchment area exceeds 100 hectares unless otherwise specified by the Catchment Areas Protection Board.
(c) Felling

(i) No tree shall be felled into a watercourse within a filter strip.

(ii) Trees may be felled into or within a filter strip. Tractors shall not enter the filter strip to remove logs.

(iii) No logging operations shall take place within 100 metres of the top water level of any major water storage.

(iv) No tree shall be felled within 20 metres of a prescribed stream as defined under the Water Act, 1912, without prior authority of the Catchment Areas Protection Board.

(v) Logging operations should be carried out so that there is a minimum disturbance within any watercourse.

(d) Snigging

(i) As far as is practicable snigging should be uphill. Downhill snigging should not be practised in areas of more erodible soils or where specified.

(ii) The drainage of snig tracks shall be carried out in the same way as for minor roads. Cross banks shall be constructed with the heights and maximum spacings as follows:

<table>
<thead>
<tr>
<th>Grade of Snig Track or Road</th>
<th>Height</th>
<th>Maximum Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degrees</td>
<td>Percentage</td>
<td></td>
</tr>
<tr>
<td>&lt;10°</td>
<td>18</td>
<td>0.5</td>
</tr>
<tr>
<td>10°-15°</td>
<td>27</td>
<td>6.0</td>
</tr>
<tr>
<td>15°-20°</td>
<td>27-37</td>
<td>4.0</td>
</tr>
<tr>
<td>20°-25°</td>
<td>37-47</td>
<td>3.0</td>
</tr>
<tr>
<td>25°-30°</td>
<td>47-57</td>
<td>2.5</td>
</tr>
</tbody>
</table>

In the case of "outrow" extraction tracks in plantations drainage shall be carried out when necessary and as specified.

(iii) Snig tracks shall not cross the beds of defined streams without application of the same conditions which apply to minor roads and logging tracks.

(iv) Snig tracks shall not intrude into filter strips, except in (iii) above.

(v) A tractor blade should not be used to remove soil from a snig track except during initial track construction and during track drainage. "Blading-off" of snig tracks shall be permitted only where subsequent track drainage is possible. Each "blading-off" operation must be specifically approved.

(vi) The use of snig tracks in wet conditions shall be minimised.

(vii) As far as practicable surface material should be returned to the track immediately after logging ceases on that track to aid in revegetation, and at the same time to re-establish crossfall drainage. In circumstances where it is considered necessary, the method of revegetation shall be specified.
(e) Log Dumps

(i) Log dumps should be located as far as practicable in accordance with an uphill extraction pattern. In any case they shall not be located closer than 10 metres from a filter strip or drainage line.

(ii) When ungravelled dumps are constructed and unless otherwise specified, topsoil is to be stockpiled in a recoverable position. Upon completion of logging (even if further logging is contemplated in the near future) dumps are to be levelled where necessary, drained so that runoff is directed onto surrounding vegetation, and the topsoil spread evenly out over the dump. The dump shall be revegetated and/or ripped where specified.

(iii) Gravelled dumps shall be drained upon completion of logging, so that runoff is directed onto surrounding vegetation.

(f) Burning

Any burning associated with logging operations shall be carried out only in accordance with the provisions of the Bush Fire Act, 1949.
APPENDIX 3.4

DATA FOR LOGGING PLAN.

State Forest:
Compartment No. (as on appraisal):
Compartment History Unit Number:
Data collected by:
Date:

Approximate date of expected commencement of logging:

This data will lead to the preparation of a formal logging plan. Some questions may be answered by reference to an attached sketch plan where appropriate. Some form of notation should appear against every question to show it has been considered.

1. **Product mix for this operation** (rough outline of proportions).
   - Logs under 40cm centre diameter
   - Logs over 40cm centre diameter
   - Poles
   - Mining timber
   - Other
   Comments

2. **Type of operation**
   - Final felling of mature crop
   - Selection of more defective stems including scattered veterans
   - Thinning
   - Recovery of seed trees
   - Other
   Comments

3. **Forest types** (brief description to give principal species and distribution)

4. **Boundaries**
   Are the logging unit boundaries (particularly any PF boundary) clearly defined in the field?
   If not, what additional marking is required?

5. **Reservations from logging (any applicable?)**
   a) Streamside protection areas
   b) Species preservation areas (e.g. brush gullies)
   c) Special scenic protection zones (tourist roads, prominent skyline etc)
   d) Areas excluded on slope
   e) Areas excluded on rock


f) Areas excluded on low volume


g) Preservation of outstanding individual trees (indicate on sketch)


h) Is any marking of reservation areas necessary in the field?


6. Plots

Continuous Forest Inventory plot numbers:


Research Plots (numbers if known)

Any restrictions on logging?


Are boundaries of buffer areas well defined?

7. Creek crossings

Are there likely to be any problems in meeting the erosion control specifications for creek crossings during logging


8. Sawmiller road

Is there any reasonable opportunity for construction of sawmiller rebate roads to improve the appraisal?


9. Dump site locations

Indicate locations on sketch

Are any dump site restoration works likely to be necessary? Specify


10. Wet weather contingency arrangements


11. Road maintenance needed before logging (including gravel)


12. Pre-logging burning requirements


13. Silvicultural treatment likely to be needed after logging


14. Workability

Enough timber:
Wet weather relief areas:
Best tractor size:

15. Any other items of special interest
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