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29 January 2010

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Dear Alister

Re: Fern Bay Seaside Village

As requested we have reviewed the matters raised in Pauline Hon (Department of Planning – DoP) email of 11 December 2009 and updated the information contained in our November 2007 letter report accordingly.

To do this we have compared the January 2007 LiDAR data obtained for the Central Coast including the southern section of Stockton Bight with the aerial photogrammetry assessment of available photography from 1954 to 1994 that was undertaken by DLWC and discussed in our letter of November 2007. The results of this comparative analysis are shown in plan view on **Figure 1** and as a typical elevation on **Figure 2**. The implications of the analysis and relevance to matters raised by DoP are discussed below.

Responses to each of the matters raised in the DoP email of 11 December 2009 are provided below:

1) Further work to be undertaken on **Coastal Hazards** with particular reference to sea level rise predictions in NSW Government's 'NSW Sea Level Rise Policy Statement' (October 2009) and Department of Planning's recently released draft 'NSW Coastal Planning Guideline: Adapting to Sea Level Rise' (October 2009).

   The results of the AWACS (1992) studies in regard to delineation of the Coastal Hazard Zone are summarised in Table 1.

Table 1 – Coastal Hazard Zone Widths (AWACS 1992)

Hazard Zone Component	Coastal Hazard Zone Widths (m)	
	30 Year Return Period	100 Year Return Period
Beach Recession	36	120
Storm Cut	20	20
Greenhouse Effect	14	60
Total	70	200

   Since the AWACS report was prepared sea level rise predictions by 2100, have increased from 0.6 metres to 0.9 metres. Using the Bruun Rule and a bed slope of 1 in 100 as used by AWACS (1992), the 100 year hazard component due to Greenhouse Effect in Table 1 would increase from 60 metres to 90 metres i.e. an increase of 30 metres.

2) A response to concerns raised by the Department in letter dated 9 July 2009 (as outlined in report by Cardno Lawson Treloar dated 2 July 2009) including:

a) The following documents to be submitted:

- AWACS (1992a) *Fern Bay Development Dune Stabilisation Study*, Australian Water and Coastal Studies Report No 92/05, March.
- AWACS (1992b) *Fern Bay Coastal Region Beach Plan of Management*, Australian Water and Coastal Studies Report No 92/19, September.

A copy of AWACS (1992a) is included with this response. We do not have a copy of AWACS (1992b) and have not relied on it for this report.

b) Provide an assessment (as a minimum in the form of a comparison of available aerial photography over this time from either DECC or Department of Lands) of whether there has been further progradation or recession over the most recent period to support the argument that recession is substantially reduced from that assumed in AWACS (1992a, b and 1993).

The analysis of available topographic data shown on Figures 1 and 2 shows that the shoreline has aggraded (i.e. moved seaward) between 1954 and 1994 and remained in approximately the same location between 1994 and 2007. Analysis (see Figure 2) shows that the current 2007 shoreline at 1.5 mAHD (approximately high water mark) is shoreward of the 1954 location by approximately 20 to 50 metres indicating the beach has aggraded over the 53 year period at an average rate of approximately 0.4 to 1 metre per year compared to the 1.2 metre per year beach recession rate predicted in the AWACS 1992 report. Analysis indicates that between 1994 and 2007 beach aggradation and beach recession have been negligible. Based on this analysis the 100 year beach recession component set out in Table 1 could be reduced to between 0 metres and -20 to -50 metres rather than the +120 metres used by AWACS (1992).

The updated elevation plan of dune transgression provided in Figure 2 shows Cross-Section 50 of DLWC photogrammetry updated to include the 2007 LiDAR data. The typical cross-section shows that the 2007 4.0 mAHD foredune contour used by AWACS as a reference point for determining the coastal hazard zone is approximately 30 metres seaward of the 1954 4.0 mAHD contour location and in a similar position to the 1994 4.0 mAHD contour location again indicating that between 1954 and 2007 the beach has aggraded with the foredune location remaining in approximately the same position between 1994 and 2007.

c) After 100 years it could be expected that the development will have issues with inundation by dune sands if the dune system is not stabilised. Provide comment on this longer term issue and the management of this matter.

The analysis provided on Figure 1 shows that the rate of landward dune transgression has reduced with the current landward edge of the unvegetated mobile dune system in approximately the same location as plotted by AWACS in 1992. In addition to this, as shown on Figure 2 heavy mineral sand mining activities that occurred between 1994 and 2007 survey periods moved the mobile dune mass seaward of its 1994 location lowering the height of the major hind dune system by approximately 2 to 3 metres and lowering the height of the small dune system between the hind dune and the Fern Bay Seaside Village site by approximately 5 metres. As a result of the seaward sand movement that was undertaken as part of the heavy mineral sand mining activities, the amount of sand available to be transported onto the Fern Bay Seaside Village site has been substantially reduced.

The results of the AWACS (1992) studies in regard to Hind Dune Hazard Zone Width are summarised in Table 2 and shown in Attachment 1 of Umwelt 2007.

Table 2 – Hind Dune Hazard Zone Widths

Hazard Zone Component	Hind Dune Hazard Zone Widths (m)		
	0 year	30 Year Development Period	100 Year Planning Period
Historic Transgression	0	95	320
Long Term Wind Climate	0	15	50
Nuisance Inundation/Safety Zone	50	50	50
Total	50	160	420

The historic transgression component of the Hind Dune Hazard Zone width determined by AWACS (1992) was based on an average dune transgression rate adjacent to the Fern Bay Seaside Village land between 1951 and 1983 of 3.2 m/year.

Analysis of DLWC detailed photogrammetry of the dune transgression between 1954 and 1994 indicates that the average rate of landward progression of the mobile dune system adjacent to Fern Bay Seaside Village land (i.e. between Cross-section 25 and Cross-section 50 of the DLWC analysis) for the period 1954 to 1994 was approximately 3 metres per year with the average rate of landward progression between 1983 and 1994 reducing to approximately 2.3 metres per year. Further analysis based on the January 2007 LiDAR data indicates that the rate of landward mobile dune progression between 1994 and 2007 was negligible with part of this reduction in dune transgression rate being a direct result of heavy mineral sand mining.

Detailed photogrammatic analysis by DLWC (1995) indicates that the landward toe of the mobile dune system in 1994 was at the eastern corner of the Pt Lot 5 DP 270466 (i.e. Fern Bay Seaside Village land). Analysis of available LiDAR data shows that in January 2007 the unvegetated section of the dune was approximately in the same location as in 1994 with the edge of the transgressive mobile dune being seaward of this location as a result of previous mining operations as discussed.

Survey undertaken by Fagan Mather Duggan Surveyors on 16 November 2007 as referenced in our November 2007 report (i.e. Attachment 3 of Umwelt 2007) shows the landward toe of the mobile dune system approximately 20 metres to east of the corner of Pt Lot 5 DP 270466 indicating that the edge of the mobile dune system is now approximately 20 metres seaward of its 1994 position. This indicates that the landward progression of the mobile dune system at this location has stopped or has been effectively managed by the previous mining operations.

Combining the detailed DLWC 1995 photogrammetry, the 2007 LiDAR data and the November 2007 Fagan Mather Duggan Surveyors survey, the average landward rate of dune transgression between 1954 and 2007 is approximately 2 metres per year. On this basis the AWACS (1992) Historic Transgression component of the Hind Dune Hazard Zone width set out in Table 2 would reduce by 120 metres from 320 metres to approximately 200 metres. As a result the total 100 year Planning Period Hind Dune Hazard Zone width would reduce from 420 metres as determined by AWACS in 1992 to 300 metres.

The analysis of the combined topographic and photogrammatic data sets discussed in this report indicates that the rate of landward transgression of the mobile dune system is less than predicted by AWACS in 1992 and will be less than the predicted rates considered when approval for the Seaside village subdivision was approved. The analysis indicates that shoreline recession is considerably less than was predicted by AWACS 1992 as is the rate of landward dune transgression. On this basis it is considered that the subdivision may not be affected by the inundation of dune sand within the 100 year planning timeframe that was considered at the time the development was approved.

It is our understanding that there are no proposals for further stabilisation of the mobile dune system to the east of Fern Bay Seaside Village site.

If in the longer term management of the mobile dune system on the Fern Bay Seaside Village site was required, it could be readily achieved through selective harvesting and subsequent removal of sand as it moves onto the Fern Bay Seaside Village site. The harvested sand could be used for landscaping, dune restoration of sale as a sand product. A range of other control measures could also be considered if required.

d) The matter of sea level rise is not dealt with in a manner that is consistent with the Draft NSW Sea Level Rise Policy (DECC, 2009) and this should be resolved with the provision of revised information. The Draft Sea Level Rise Policy requires consideration of sea level rise to **0.9 m by 2100.**

See response to Point 1 above.

Conclusion

Based on the above analysis it is considered that the 30 year and 100 year return period Coastal Hazard Lines would be seaward of the respective lines shown on Figure 4.2 of AWACS 1992 (see Attachment 1 of the Umwelt November 2007 letter). It is considered that if any mobile dune sand moved onto the Fern Bay Seaside Village site, it could be readily managed through a range of measures including sand harvesting with the sand subsequently being used for a range of beneficial uses.

If you require any further information in regard to this matter, please don't hesitate to contact Peter Jamieson on (02)4950 5322.

Yours faithfully

Peter Jamieson (BE Civil) CPeng
Director

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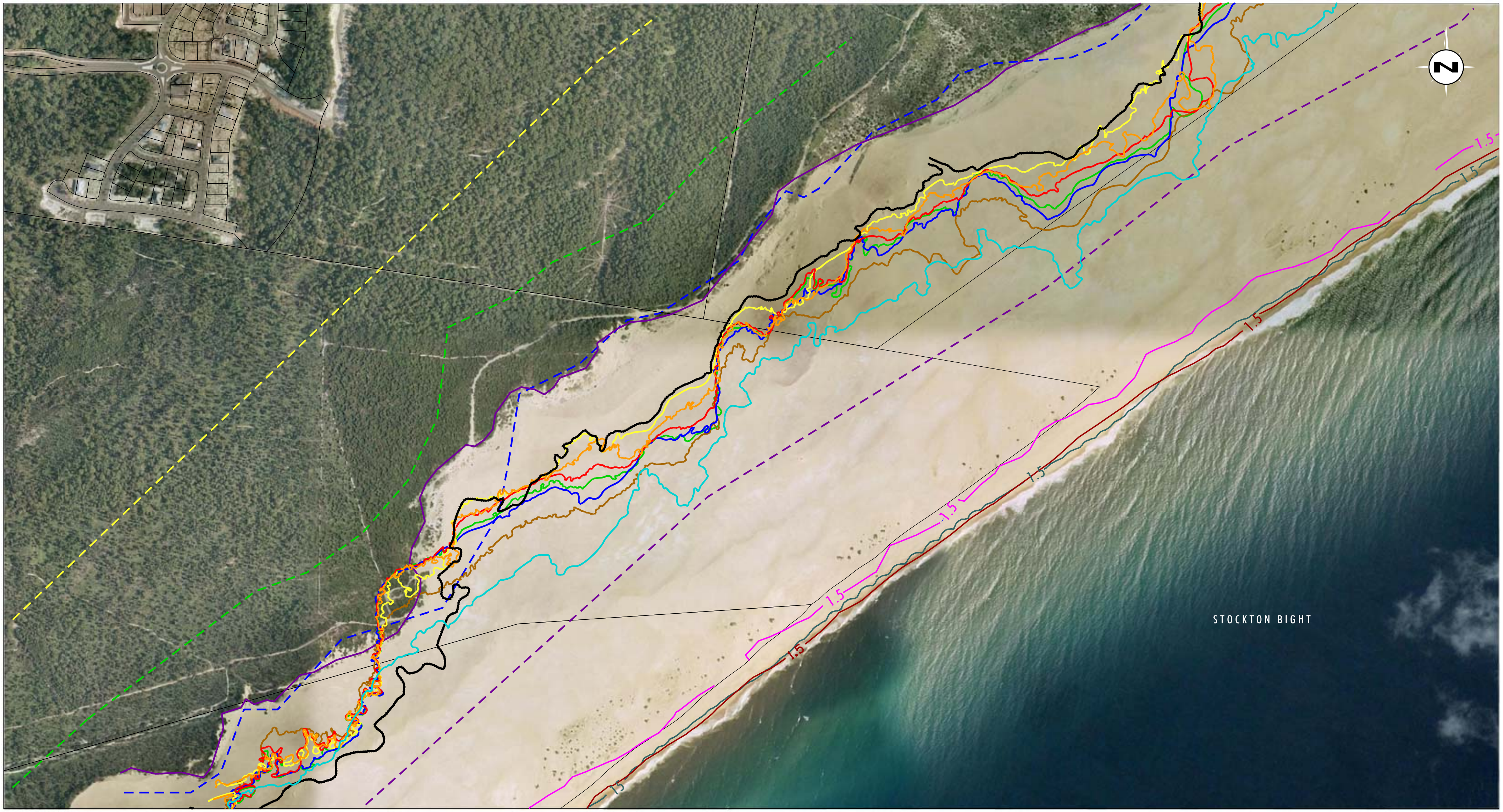
Umwelt
Environmental Consultants



Source: Aerial Google Image Dec 2006

Legend

Dune Progression:
- 1954
- 1965
- 1972
- 1975
- 1977
- 1983
- 1990
- 1994
- 2007

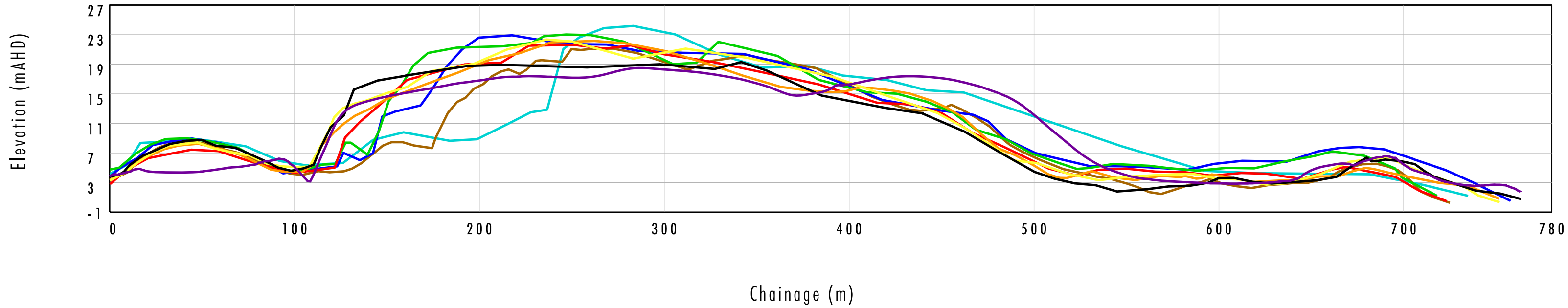
Shoreline Progression:
1.5mAHD Contour line -
- 1954
- 1994
- 2007

- AWACS approx edge of transgrassive dune (aerial photo Aug 1991)
- AWACS 30 year hind dune hazard line
- AWACS 100 year hind dune hazard line
- AWACS 100 year coastal hazard line

FIGURE 1

Historic Dune and Shoreline Progession

File Name (A4): N:\ 2518\Figures\ 2518_003.dgn



Cross Section 50

Legend

- 1954
- 1965
- 1972
- 1975
- 1977
- 1983
- 1990
- 1994
- 2007

0 12.5 25 50m
Vertical Scale 1:1000

0 50 100 200m
Horizontal Scale 1:4000

FIGURE 2

Typical Dune Cross Section

AUSTRALIAN WATER AND
COASTAL STUDIES PTY LTD

FERN BAY DEVELOPMENT
DUNE STABILISATION STUDY

REPORT 92/05 MARCH 1992

Prepared by:

R T Jacobs
J R Wilson
A D Gordon

Foreword

This study was carried out by Australian Water and Coastal Studies Pty Ltd (AWACS) who were contracted by Coffey Partners International Pty Ltd acting on behalf of Port Stephens Shire Council.

Table of Contents

List of Figures

List of Plates

1. Introduction

1.1 Background

The Department of Housing and Howship Holdings has applied to Port Stephens Shire Council for the preparation of a revised Local Environment Plan (LEP) associated with the proposed rezoning of coastal lands in the Fern Bay area (Gardner Browne 1991). The site originally comprised four lots individually held by the Department of Housing, the Department of Conservation and Land Management (Crown Land), Howship Holdings and Boral. Boral chose not to be involved in the rezoning proposal. The locality of the site is shown in Figure 1.1 and the individual holdings are shown in Figure 1.2. The proposed rezoning of the site would provide the opportunity for mainly urban development in accordance with planning controls and engineering requirements.

1.2 Scope of Investigation

As part of a broad planning strategy and structure plan for the area, Australian Water and Coastal Studies Pty Ltd (AWACS) were contracted by Coffey and Partners, acting on behalf of Port Stephens Shire Council, to undertake a dune stabilisation study. The aim of the study was to enhance the understanding of coastal processes within and surrounding the proposed development site. Further, to facilitate the formulation of strategies for dealing with the problems of coastal erosion and dune mobility, including the determination of appropriate buffer zones and how they should be managed.

During consultation with the Development Review Committee (which comprised representatives from Council and the land owners), AWACS were advised that the following planning periods were to be considered in the determination of coastal hazards and in the formulation of management measures:

- 100 years for the assessment of beach and dune movements; and
- 30 years (or less) for complete development of the site.

The Review Committee also stipulated that, at this stage of planning strategy formation, the recession rates on the foredune and the transgression rates on the hind dune were to be based on existing information.

1.3 Investigation Methodology

The investigation involved the following major work components:

- An inspection of the development site.

This provided an assessment of the site and surrounding area. It also allowed the study team to update its knowledge of the area gained through involvement in previous local studies in the 1970s and 1980s.

- A review of existing information on the processes affecting the site.
  Information relating to Stockton Beach, both published and unpublished reports, historical photographs, letters of advice on coastal hazards and plans of foreshore protection measures and dune restoration/stabilisation works were reviewed . This established an information base for other work components.

- Consultation with relevant authorities, landowners and developers.
  This comprised meetings with the Review Committee (comprising Council staff and the landowners or their representative) and discussions with the Soil Conservation Service and the Public Works Department in both Newcastle and Sydney.

- An assessment of the hazards affecting the site.
  The hazards associated with open coast processes such as beach movements (short term fluctuations and longer term recessional trends), mobile sand dunes and the possible future impacts of global warming (the Greenhouse Effect) were assessed.

- Determination of options to best manage the site.
  The broad options for dune management were examined in terms of benefits, costs and implementation.

- Reporting.
  This report documents the investigations and findings of the study.

2. Previous Relevant Reports

Reports from the Public Works Department and Soil Conservation Service provided the base data for assessing the coastal recession and transgression rates at the study site. The Gardner Browne report provided the existing concept plan for the development. The relevant documents are described below.

2.1 Public Works Department 1977

In the early 1970's the Fern Bay region was being examined as a possible site for a second port within the Newcastle area . The Public Works Department (PWD) 1977 report documents the sediment movement study conducted as part of the port investigation. The report presents the nature and quantity of onshore and offshore sediment movements in Newcastle Bight and provides estimates of the beach and dune transgression rates.

The investigation involved significant data collection and analysis and an examination of the sediment transport mechanisms. The second port proposal was withdrawn prior to finalisation of the report and as such the report is in restricted draft form.

2.2 Soil Conservation Service 1985

The Soil Conservation Service (SCS) 1985 report examines the geology, geomorphology, climate, ecology, land use and topographic changes of the Stockton Beach region. Of particular interest are the estimates of beach and dune movements, the assessment of future impacts of these processes on private and government interests in the area, and the assessed feasibility of initiating dune stabilisation programs in sand drift areas.

The SCS report was in a preliminary (incomplete) draft stage at the time of reporting of the present study.

2.3 Public Works Department 1985 and 1987

Two studies were conducted by PWD to assess the nature and extent of the coastal hazards around the township of Stockton. The 1985 report documented the storm history and beach fluctuations, the beach processes and oceanic factors, assessed the coastal hazards and determined structural management options for this area. Photogrammetry was used to determine shoreline movements since 1959 for 1.25 km of Stockton Beach in the vicinity of the township.

The 1987 study was undertaken to extend the earlier work and provide further information on beach changes and an update on the beach state.

2.4 Gardner Browne 1991

The Gardner Browne 1991 report was prepared as a supporting document to an application, recently submitted to Council, for the rezoning of land at Fern Bay. The majority of the land is currently zoned Rural 1(a) under Port Stephens Local Environmental Plan 1987. The beach and part of the dune is zoned Public Recreation 6(a) and an area of Crown Land is zoned Environmental Protection 7(c) - Water Catchment Area. The report proposed that the land be rezoned to Residential 2(d), Business General 3(a) and Special Uses 5(a) Sewerage Treatment Works (STW).

The total area comprised by three lots (Dept Housing, Howship Holdings and Crown) was stated as 482 ha (more recent surveys put this at 480 ha) of which 331ha was determined to be potentially developable. The report presents a development structure plan (i.e. a concept plan) for the location of residential development, recreation areas, schools, sewerage works, commercial centre, roads and conservation areas. This plan is shown as Figure 2.1.

The report also identified the following areas of further specialist studies to be undertaken and included in an environmental study:

- geotechnical and dune stabilisation
- traffic and noise
- engineering (site engineering and drainage)
- archaeological
- resources and soil conservation
- town planning and
- sewerage works

3. Locality and Site Description

3.1 Location Description

Fern Bay is situated between Newcastle and Port Stephens approximately 95 kilometres north of Sydney. It is a small township with surrounding areas of undeveloped land. Immediately to the east of the township is Stockton Beach which extends some 30 km from Stockton township in the south to Anna Bay in the north. The regional setting is shown in Figure 1.1.

The study area extends from north of the Stockton Rifle Range (just north of the Port Stephens Shire Council boundary) to some 3.5 kilometres north (to about the Signa wreck) and is bounded by Nelson Bay road to the west and the ocean to the east. The site location and the property boundaries of land holdings in the study area are shown in Figure 1.2. The areas of the land holdings are as follows:

Department of Housing	168.6 ha
Howship Holdings	205.9 ha
Crown	105.5 ha
Total	480 ha

In plan view, the study area is broadly characterised by the beach, backed by a unvegetated, transgressive dune field of some 500 metres width which in turn is backed by vegetated, stable dunes extending some 1.5 kilometres to Nelson Bay Road. In terms of morphology, the sub-aerial beach face slopes upward at about 1:20 (vertical:horizontal) and, above about 3m Australian Height Datum (AHD), gives way to the foredune which, while being discontinuous along the length of the beach, rises in places to about 8m AHD. Behind the foredune the sand levels dip to about 4m AHD forming a swale. Further west the dune field rises, typically to about 20m AHD, and undulates to its western edge. There is a sharp interface between the western edge of the present transgressive dune and the vegetated dunal areas further landward as shown in Plate 1. The vegetated dunal areas, between the transgressive dune edge and the western boundary of the site, are of Holocene age, having been formed within the last 10,000 years. They are characterised by sand ridges extending north-east/south-west. The elevation of the ridge crests reach up to 30m AHD with low lying depressions between them dipping to a minimum of 3m AHD.

Sand mining has been carried out to the north of the Fern Bay study area on the hind dunes of Stockton Beach.

3.2 Regional Processes

PWD (1977) found a noticeable trend in the sand grain size variation along Stockton Beach. The trend was evident in samples from all sections of the swash zone, foredunes and backdunes (shown in Figure 3.1). The implications of this grain size variation trend are that no significant nett littoral drift can exist on Stockton Beach.

Considerable movement of sediments within Newcastle Bight were found by PWD (1977) to be in the form of large onshore/offshore movements, longshore transport and wind blown transport. PWD (1977) concluded that:

> *"the compartment of Newcastle Bight is fairly stable with regard to sediment movements. The only movement out of the compartment is by wind losses along the western face of the active dunes. Any longshore movement is balanced in a north south direction."*

Sand transported over western face of the active dune interface was found to be permanently moved into the rear vegetated areas. This was termed the 'sand diode' effect (by Gordon and Roy 1977) which explained why the nett direction of movement of sand was better correlated to measured data when the westerly wind components were reduced. The rates of encroachment of sand to the west were found to be higher in the northern part of the dunal area. A schematic representation of PWD (1977) report findings is shown in Figure 3.2.

After reviewing available literature the SCS (1985) report concluded that:

> *"the most important aspect of this closed water-borne sediment budget ...... is the fact that sand moved inland from the beach and frontal dune system by wind is not only lost to the beach system but will not be replaced by waterborne sediment. Such windborne sand movements not only aggravate the sand drift problems of the hinterland but by virtue of the volume lost to the immediate beach system, have aggravated the problem of shoreline recession."*

The SCS report then went on to estimate the rate of movement of both the shoreline/foredune and the transgressive hind dune. This is summarised for the study area in Section 4.

SCS (1985) also highlighted the importance of the foredune stability to the amount of sand available to the inland transgressive dune. Wave erosion or damage to the foredune can destroy the vegetative cover and the continuity of the foredune allowing increased wind erosion. The continuity of the foredune was found to be interrupted in many places along Stockton Beach. The report concluded that the dune migration could be slowed if the frontal dune was reconstituted over the full length of the beach. Further, the report recommended that the stable vegetated dunes be maintained in their present condition to preserve the flora, fauna and landforms and to act as a buffer between developed land and the encroaching sand dunes.

3.3 Site Specific Processes

PWD (1977) and SCS (1985) determined recession rates for the foredune and transgression rates for the hind dune in the development study area. The actual rates of recession and transgression for the study area are discussed in Sections 4.1.1 and 4.2.1.

SCS (1985) considered Stockton Beach in four areas and found the study area to have the lowest percent continuity of the foredune. They assessed that some 56% of the foredune within the study area was not well formed. The SCS report concluded that :

> *" it is believed that dune migration can be slowed, in the long term, if the frontal dune were reconstituted over the full length of the beach".*

The study area is currently used as a primary access point to the beach for 4WD and other off road vehicles. SCS (1985) reports that it is not uncommon to have up to 50 buggies using the area on the weekends.

3.4 Historical Information

Nineteen dates of vertical aerial photography were obtained of the study area. These covered the period from 1940 to 1991 and were used to assess qualitative changes in the study area over this period of time. The photos and a summary of the changes are presented in Appendix A.

To the south of the study area, a number of investigations have been undertaken to examine beach movements in the area of Stockton township, namely, Jacobs and Gordon (1989), Lawson and Treloar (1988) and PWD (1985, 1987, 1988a and 1988b).

Examination of the effluent ponds at Stockton provide an illustration of the dramatic movements in this area. The Stockton STW has effluent holding ponds on the back of the beach north of the township. In the 1974 storms (May and July) one of the four ponds was lost due to the recession at that location. Plate 2 shows photographs of the ponds in June and October of 1974.

4. Hazards Assessment

4.1 Beach and Frontal Dune Movement

A shift in location of the beach and frontal dune can be the result of various factors, namely; beach recession, storm cut and climate change. Each of these are discussed below in relation to the proposed development site.

4.1.1 Beach Recession

Shoreline recession is the progressive landward shift of the average long-term position of the coastline. It results from an ongoing loss of sand from the active beach system. The process is schematically shown in Figure 4.1.

From aerial photograph interpretation, PWD (1977) established the average annual recession rate for Stockton Beach to be about 1 to 5 metres between 1938 and 1976. The accuracy in locating features from the photography and comparing them was given as ± 20 metres. Other analyses undertaken involved the comparison of recorded depths from hydrosurveys between 1878 and 1976. The movement of the low water mark was assessed to be between 1 and 2 metres per year (m/yr) on average by this latter method.

SCS (1985) investigated the beach movements using aerial photography zoom transferring techniques. Mention was made in the report about the difficulty in locating the frontal dune and shoreline. Beach movement rates along Stockton Beach varied in location and time and, overall, were concluded to range between 2.2 m/yr recession and 1.2 m/yr accretion. It was also assessed that between 1975 and 1983 all beach areas had accreted. However, within the Fern Bay study area over the longer period of 1966 to 1983, the assessed trend was one of beach recession at an average rate of 1.2 metres between 1966 and 1983.

More recently, PWD (1985 and 1987) undertook precise photogrammetric measurements and examined land survey records of Stockton Beach south from the existing Stockton Sewerage Treatment Works. These analyses revealed that the southern end of the beach, while having undergone considerable fluctuations in the sand reserves held on the beach at any point in time, had not, over the length of survey records (1959 to 1986) undergone any significant beach recession. Indeed the highest average annual recession rate over the 27 year period was determined as 0.3cubic metres per metre of beach length (m^3/m) adjacent to the Treatment Works.

Following consideration of the available information a beach recession rate of 1.2m/yr has been adopted for the coastline fronting the proposed development site. This is the rate assessed by SCS (1985) and is within the PWD (1977) range of values. Over a planning period of 100 years the allowance for beach recession would therefore be 120 metres (assuming no beach protection measures are undertaken in the future in which case this value may reduce). These adopted values could be refined by precise photogrammetric mapping of the study site and analysis of the data thus obtained.

4.1.2 Storm Cut

During any individual storm event or closely linked storm events there is a redistribution of sand from the sub-aerial beach face (that part of the beach above water) to the offshore bar. During subsequent periods of fine weather the sand from the bar migrates shoreward and re-establishes the sub-aerial beach. The overall effect can be one of considerable fluctuation in sub-aerial sand reserves (as distinct from nett beach recession). These storm induced fluctuations of the beach and frontal dune need to be allowed for when planning the development locality. The process is schematically shown in Figure 4.1.

Some field data is available on the statistical occurrence of storm cut volumes at New South Wales (NSW) beaches (Gordon, 1987) while for several east coast beach locations a predictive model has been used to simulate extreme storm cut profiles (Couriel and Wilson, 1991). These studies indicate that severe storms can remove some 200 m^3/m and erode the face of the foredune by some 20 metres.

PWD (1977) measured storm cuts after a storm on 5 March 1976 at six locations along Stockton Beach. The maximum cut was 40 metres and the average was 35 metres. These measurements were of the beach movement at the waterline and represent a larger variation than those which would have occurred along the seaward face of the foredune.

The May/June 1974 storms impacted severely on beaches of the central NSW coast. For example, at Nine Mile Beach, Belmont the foredune was eroded by up to 20 metres (Wilson, 1990). Also the frontal dune of Newcastle Bight was severely eroded (SCS, 1985); loss of one of the effluent ponds at the Stockton STW (Plate 2) is a clear example of potential storm damage.

Given the above available information a design storm cut value of 20 metres has been adopted for the coastline fronting the proposed development site. It applies to the potential storm cut at the face of the foredune.

4.1.3 Climate Change

There is current scientific evidence to suggest that the world is experiencing a period of warming that is widely believed to be a long term trend associated with the Greenhouse Effect (GHE). The GHE would result in a change in climatic regimes that may bring about many changes in the coastal zone. One of these changes is a rise in the mean global sea level which is expected to cause a landward movement of the shoreline.

GHE induced sea level rise scenarios were considered by the United Nations Inter-Governmental Panel on Climate Change (IPCC-WG1-1990) and are shown in Table 4.1.

Table 4.1 Global Sea Level Rise Scenarios

Year	2030	2050	2100
Low Scenario	0.08m	0.15m	0.31m
Medium Scenario	0.18m	0.30m	0.66m
High Scenario	0.29m	0.49m	1.10m

Gordon (1989b) suggests it is important to evaluate both the risk of climatic trends eventuating and the consequences should they occur. For the proposed urban development at Fern Bay the risk/consequence would seem to warrant consideration of the medium scenario for a 100 year planning period. That is, adoption of 0.6 metres sea level rise. Using a representative offshore slope of 1:100 and a sea level rise of 0.6 metres, and applying the Bruun rule for coastline response (Bruun, 1962), the adopted GHE component of frontal dune recession is 60 metres.

4.1.4 Total

Combining the above components, gives the following coastal hazard zone width for 30 and100 year planning periods:

Table 4.2 Coastal Hazard Zone Widths

Return Period	30 years	100 years
Beach Recession	36 m	120 m
Storm Cut	20 m	20 m
GHE	14 m	60 m
TOTAL	70 m	200m

These zones are measured landward from the seaward face of the frontal dune (about the 4m AHD beach contour). The location of the 100 year coastal hazard zone is shown in Figure 4.2 along with typical locations of existing water line and foredune. It can be noted that at other open coast locations, where little or no information is available on shoreline movement, the PWD have often advised that a prudent coastal hazard zone would extent to 200 metre landward of the frontal dune.

4.2 Hind Dune Movement

In determining a setback for the long term total hind dune movement consideration needs to be given to a number of factors, namely; the historical transgressive movement, long term wind change and nuisance inundation. These are discussed below.

4.2.1 Historical Transgression

The hind dune transgression rate has previously been examined by PWD(1977) and SCS(1985). PWD established the transgression rate for the period 1878 to 1976 to be between 5 m/yr and 10 m/yr. SCS examinations for the period 1951 to 1983 put the average annual rate at 3.2 metres for both the entire beach length and a sector adjacent to the proposed development site (SCS Sector 1B as shown in Figure 1.1). SCS also determined that the range of overall rates of transgressive dune encroachment was from 0.7 m/yr to 8.4 m/yr between 1951 and 1983 within Newcastle Bight area.

Given these values a transgression rate of 3.2 m/yr has been adopted. Over a planning period of 100 years the allowance for inland dune progradation would be 320 metres. For the development period of 30 years this transgression zone is 96 metres. These values are determined on the basis that no future stabilisation or sand extraction measures are undertaken.

4.2.2 Long Term Wind Climate Change

The GHE described in Section 4.1.3 will also cause a variation in the wind climate. One scenario is that the qualitative effects will be weaker trade winds, westerly wind stream moving further south, tropical cyclones moving further south, and stronger squalls associated with more severe weather events.

There are no quantitative scenarios available for long term variation in wind climate. However, the movement of the transgressive dune at Fern Bay is wind dependent and any change in wind climate may have a significant influence on the transgression rate and direction. As such, an allowance of 50 metres has been adopted to take into account variation of wind climate due to GHE for a 100 year planning period. For a development period of 30 years this allowance would be reduced to 15 metres.

4.2.3 Nuisance Inundation/Safety Zone

In addition to the historical transgression and the long term wind climate allowance, a zone must also be defined to allow for nuisance wind blown sand inundation and accelerated, short term progradation of the transgressive dune field.

PWD (1977) recorded a maximum landward progradation of the hind dune area (within Newcastle Bight) of about 80m over a 3 year period (PWD Line D as shown in Figure 1.1). Gordon and Roy (1977) found that the maximum movement of the transgressive dune was in the order of 80 m/yr (at a location north of the Fern Bay area). SCS (1985) examined this information and following further analyses determined that rates up to 30 m/yr to 40 m/yr could have occurred.

Given these encroachment rates in areas along Stockton Beach and the need to provide a zone that is clear of impacts of wind blown sand and accelerated dune progradation, an additional safety zone of 50 metre width is considered prudent. The value is applicable to all planning periods and applies from the commencement of development.

4.2.4 Total

Combining the above components for the hind dune transgression gives the following hind dune hazard zone widths:

Table 4.3 Hind Dune Hazard Zone Widths

Return Period	0 year (Initial)	30 year (Development Period)	100 year (Planning Period)
Historical Transgression	0 m	95 m	320 m
Long Term Wind Climate	0 m	15 m	50 m
Nuisance Inundation/Safety Zone	50 m	50 m	50 m
TOTAL	50 m	160 m	420 m

Figure 4.2 shows the location of the hind dune hazard lines for the 0, 30 and 100 year periods for the situation where no works are undertaken to stabilise the transgressive dune field. These lines show the present dune edge moved 50, 160 and 420 metres back (parallel to the current shoreline). This is a representation only, the exact location of the line will vary depending on the inland topography (sand will take longer to encroach up hills and less time to encroach into valleys) and the exact direction of movement of the dune face at different locations (not determined by the SCS (1985) report).

The planning period adopted for this study is 100 years. The 0 and 30 year periods are included as they indicate the progressive encroachment that is likely to occur. These shorter time frames do not represent possible alternatives to the 100 year planning period. Rather, they are indications of the buffers necessary over the given time frames for development if stabilisation procedures are adopted.

The area between the present landward edge of the transgressive dune and the 100 year planning line is a hazard zone which excludes development of a permanent nature. This zone need not be a sterile area but rather one that could be used for recreation or other uses that can accept inundation.

4.3 Future Perspective

There is at present no substantial development within the area of the three land holdings. The preliminary Structure Plan (in Gardner Browne, 1991 and presented here as Figure 2.1) provides for future development of a permanent nature (as opposed to temporary or relocatable development) to be setback outside the 100 year hazard zone. The exception to this is the STW which was proposed to be located on the trangressive dune field (Figure 2.1) and protected by stabilising the surrounding mobile dunes.

Hence, the main asset at risk would seem to be land area which could be impacted upon in the future by beach/foredune recession and landward movement of the transgressive dune field. The 100 year line shown in Figure 4.2 represents the best estimate of the distance to which the transgressive dune will encroach by the year 2092 if no dune stabilisation measures are undertaken. It corresponds to a reduction from 480 ha, being the total land area comprised by the three lots, to a developable land area of 260 ha, being the land landward of the transgressive dune after 100 years.

Adjacent to the proposed development site, the rifle range and the Commonwealth land which it occupies would seem to be at low risk of being significantly impacted on in the immediate future. In the medium to longer term, and in the absence of dune stabilisation or dune sand extraction operations, substantial areas of this facility could be inundated with wind blown sand.

5. Dune Management Options

Three broad options have been formulated for managing the dunes in the terms of the current development concept. The description, preliminary costing and evaluation of the options, referred to as Options A, B and C, are presented below.

5.1 Description of Options

5.1.1 Option A

This option is shown in Figure 5.1(a,b) and provides buffer zones for the transgression of the hind dune into the development areas. The area between the 100 year hind dune hazard line and Nelson Bay Road represents the developable area for this option. The area between this hazard line and the present landward extent of the transgressive dune would form the buffer zone. The presence of the buffer zone is not intended to sterilise land use. Rather, it is aimed at providing the opportunity for inclusion of development which is commensurate with the hazard. For example, the buffer zones could be used as recreation areas and include temporary/relocatable buildings.

Figure 5.2 shows the land areas that would likely fall within the hazard area over three time periods. It can be seen from the figure that some 212 hectares, out of a total of 480 hectares for the three lots, is projected to be unavailable for permanent development for the 100 year planning period.

For the STW location as proposed in the Structure Plan (Figure 2.1), dune stabilisation works would be necessary in order to protect it from sand inundation. The degree of protection required is somewhat uncertain. In recognition of this two protection alternatives with different degrees of dune stabilisation, have been examined:

(i) The first alternative is referred to as Option A1 and shown in Figure 5.1a. This approach is inferred in the Structure Plan (Figure 2.1) and involves the stabilisation of 42 hectare area within some 400 metre of the STW site. Given the dynamics of the surrounding dunes, the 400 metre buffer is considered to be a minimum requirement.

(ii) The second alternative is referred to as Option A2 and shown in Figure 5.1b. It involves the more conservative approach of stabilising 101 hectares of surrounding Crown Land.

These alternative areas would both require the shaping and stabilisation of the foredune and hind dune areas. The foredune stabilisation would be some 200 metres wide and include a swale area on the landward side of the dune.

5.1.1 Option B

A second option would involve maintaining the edge of the hind dune in approximately its existing location. This could be done by establishing a stabilised 150m wide strip of the transgressive dune at the landward edge of the dune, and by reserving a 50m wide strip on the landward side of this edge as a maintenance/safety inundation area. These areas are represented by Zones 1 and 2 respectively as shown in Figure 5.3.

Initially, major reshaping of the edge of the landward edge of the transgressive dune would be necessary to produce a slope more applicable to stabilisation. Stabilisation could then proceed using brush matting and primary and secondary grass and shrub plantings. This initial vegetation establishment would have to be completed quickly to prevent sand inundation during this period.

Of the 480 hectares total land in the three lots, 110 hectares would be unavailable for permanent development under Option B.

5.1.2 Option C

A third option is shown in Figure 5.4 and involves the initial shaping and stabilisation of the foredune/swale and stabilisation of the hind dune areas in later stages. By reducing the wind blown sand in this way the transgression of the hind dune would be slowed and eventually cease when all of the site is stabilised by a combination of dune planting and development. Similarly, the recession of the foredune would dramatically decrease and likely halt once stabilisation had taken hold.

A schematic sectional representation of Option C is shown in Figure 5.5. Significant earthworks would be required in some site locations to relate the schematic section to specific site conditions. The swale area, although within the coastal impact zone, could be used for temporary or relocatable development such as surf club facilities and also for open space recreation.

The option allows a much greater area of land to be used for permanent development but would require an initial input of funds and a period of time to allow the foredune/swale and hind dune areas to stabilise. There would be some maintenance costs which can be expected to reduce as the stabilisation takes hold (such as the costs associated with the replanting of degraded dune paddock areas). A buffer zone on the north east end of the development would likely be necessary to intercept wind blown sand from the north. An appropriate area for this purpose is considered to be Zone 4 shown in Figure 5.4.

Option C provides the opportunity for beach side and ocean view development. It would also facilitate usage of the beach by the wider community if such facilities as surf clubs were constructed. The first stage of development is planned to be within the western portion of the site, may take some 10 to 30 years to complete and could extend to the 30 year hind dune hazard line shown in Figure 5.4. Within this time frame there would need to be a plan of action implemented to stabilise the transgressive dune field.

That is, stabilisation either wholly by dune planting or by a combination of dune planting and development.

As previously mentioned, stabilisation of the transgressive dune field (the eastern portion of the site) would initially involve planting of the foredune/swale and subsequent stabilisation of the hind dune (probably in staged manner). The eastern limit of permanent development would be the 100 year coastal impact line shown in Figure 5.4.

The amount of developable land would be further increased if a land swap could be arranged such that the Dept of Housing land between the 100 year coastal impact line and the water line was exchanged for land on the seaward side of the Crown land; shown in Figure 5.4. Were this done, 100% of the available land within the three holdings would be usable for development.

5.2 Costing of Options

Costs for dune stabilisation were determined through consultations with the SCS and PWD in both Newcastle and Sydney and previous AWACS experience. Costs were obtained for past dune works undertaken at Stockton Beach, Caves/Hams Beach and Bate Bay (Kurnell). These works are of relevance since they are both local to the study area and involve large stabilisation areas. The individual project costs were brought to 1992 values using a 10% per annum CPI adjustment and appropriate values adopted for the study area.

5.2.1 Basis of Establishment Costs

The figures used to estimate the establishment costs for dune stabilisation are as follows:

Options A and C

- $60,000 per hectare for foredune stabilisation. This includes bitou bush removal, major dune reshaping, dune and access way fencing, board/chain walkways, primary grasses and secondary shrub planting.
- $16,000 per hectare for hind dune stabilisation. This includes reshaping, bitou bush control, fencing and grass/cover crop planting.

Option B

- $100,000 per hectare for stabilisation of the western edge of the hind dune when done in the absence of any stabilisation of dunal areas to the east. The high cost reflects the massive dune reshaping required, extensive use of sand catching fences, dune and access way fencing, intensive planting and possible other measures such as brush matting.

5.2.2 Basis of Maintenance Costs

Three levels of dune stabilisation maintenance costs have been estimated. These are described below:

High Maintenance Area
A vegetated area immediately adjacent to a highly mobile dune field can be expected to require a high level of maintenance to prevent inundation. Such areas are defined here as "high maintenance areas" and comprise a 50 metre strip at selected locations along the perimeter of the stabilised dune areas. The estimated maintenance costs for this level allows for complete re-establishment of a stabilised boundary strip each year:

Medium Maintenance Area
This is applicable to areas of medium to high exposure to sand drift once vegetation is established. The estimated maintenance costs for this level allows for 20% re-establishment of a 50m stabilised strip each year and are:

Low Maintenance Area
This applies to areas of low to moderate exposure to sand drift once vegetation is established. Depending on the success of the stabilisation in general (and the high and medium maintenance areas in particular) it may be that this level of maintenance is only required for period of about 2 years. The estimated maintenance costs for this level allows for 5% re-establishment of stabilised areas each year:

5.2.3 Option A

Costs involved for Option A are only those concerned with the protection of the STW located on the north east corner of the development in the concept plan. As outlined previously two alternatives for protection of the STW are provided, these being referred to as; A1 (stabilisation of a 400m area around the STW) and A2 (stabilisation of most of the Crown Land).

For Options A1 and A2 the maintenance areas are nominated as follows:

- High Maintenance - a 50m wide strip at the both the northern and southern boundaries adjacent to the mobile dune field.
- Medium Maintenance - a 50m wide strip on the northern and southern sides adjoining the high maintenance areas above.
- Low Maintenance - the remaining area of both options not included as high or medium maintenance areas.

Estimated costs for these two alternatives would be:

Option A1

(i)	establishment - stabilise 42 hectares (16 foredune, 26 hind dune, Zones 1 & 2 shown in Figure 5.1a)	\$1.4 M
(ii)	annual maintenance High Maintenance (2Ha foredune + 4Ha hind dune), Medium Maintenance (2 ha foredune + 4 ha hind dune) Low Maintenance (12 ha foredune + 18 ha hind dune)	\$0.3 M

Option A2

(i)	establishment - stabilise 101 hectares (41 ha foredune, 60 ha hind dune, Zones 1 & 2 shown in Figure 5.1b)	\$3.4 M
(ii)	annual maintenance High Maintenance (3 ha foredune + 5 ha hind dune), Medium Maintenance (3 ha foredune + 5 ha hind dune) Low Maintenance (35 ha foredune + 50 ha hind dune)	\$0.5 M

Should the STW be relocated, there would be no costs associated with Option A (within the 100 year planning period) for dune stabilisation.

If development proceeds as per Option A it is probable that after 100 years (the planning period) the hind dune may be close to houses at the edge of the development putting them at risk of inundation. If this were to happen there would be high costs associated with protecting the development.

5.2.4 Option B

The costs associated with Option B are those of stabilising a 150m wide strip along the landward edge of the transgressive dune. Further, maintaining this area and an adjacent 50m wide strip (Zones 1 and 2 shown in Figure 5.3).

The maintenance areas for this option are nominated as follows.

- High Maintenance - a 50m wide strip at the eastern boundary adjacent to the mobile dune field.
- Medium Maintenance - a 50m wide strip landward the high maintenance area above.

- Low Maintenance - a 100m wide strip landward of the medium maintenance area, shown as Zone 2 shown in Figure 5.3.

The estimated costs for this option are:

(i)	establishment - stabilise 54 hectares (54 ha @ $100,000 per hectare, Zone 1 shown in Figure 5.3)	$5.4 M
(ii)	annual maintenance High Maintenance (18 ha @ foredune rate) Medium Maintenance (18 ha @ foredune rate) Low Maintenance (36 ha @ foredune rate)	$2.3 M

5.2.5 Option C

The costs associated with Option C are those of stabilising the foredune and hind dune over a period of time. It could take up to several years to establish a stabilised foredune.

The maintenance areas for this option are nominated as follows.

- High Maintenance - a 50m wide strip at the both the northern and southern boundaries adjacent to the mobile dune field.
- Medium Maintenance - a 50m wide strip on the northern and southern sides adjoining the high maintenance areas above.
- Low Maintenance - the remaining area of both options not included as high or medium maintenance areas.

The estimated costs for this option are:

(i)	establishment - stabilise 219 hectares (86 ha foredune, 133 ha hind dune, Zones 1,2 & 4 shown in Figure 5.4)	$7.3 M
(ii)	annual maintenance High Maintenance (1 ha foredune + 2 ha hind dune) Medium Maintenance (3 ha foredune + 4 ha hind dune) Low Maintenance (82 ha foredune + 127 ha hind dune)	$0.5 M

If the hind dunes are not stabilised within the 30 year development period then, at the end of this period, stabilisation would need to extend over a larger area further 62 ha would need to be stabilised. That is, if the transgressive dune face has moved from its present position to that line on Figure 5.4 (Zone 3) marked as the 30 year line, a further

62 ha will need to be stabilised. This would appear to be an unlikely scenario. It is more likely that rapid development into the eastern portion of the site would negate the need for some hind dune stabilisation and as such significantly reduce the cost of Option C.

5.2.6 Funding Assistance

The Coastal Hazard Program (CHP) provides funds to Councils and Government Departments for coastal hazard protection works up to a maximum of 50% of the project. The program is administered by the Public Works Department, NSW (PWD).

Options A and B appear to be within the CHP guidelines but it is anticipated that the priority for funding assistance would be low.

Option C is within the CHP guidelines and, since it involves a complete approach to dune management, is more likely to attract state government financial support through the CHP.

Federal government funding (or assistance) may also be available to do the stabilisation works on the rifle range property currently held by Department of Defence.

5.3 Comparison of Dune Stabilisation Options

5.3.1 Option A

The advantages of Option A are :

- lower establishment costs than for Options B and C and varying from $1.4 M to $3.4 m depending on the dune area stabilised;
- dune stabilisation costs would be negligible if the STW were relocated landward of the 100 year hind dune hazard line.

The disadvantages of Option A are :

- loss of 56% of developable area under Option C (212 ha unavailable from total of 480 ha);
- building restricted to western portion of the site and the opportunity forgone of beachside and oceanview development;
- beach usage would continue to be restricted to off-road vehicles and hardy walkers;
- sewerage works located in NE corner of site, needs to be protected from sand inundation by major dune stabilisation works;

- vehicular access across dunes in a haphazard method would be likely to continue along with foredune degradation.

5.3.2 Option B

The advantages of Option B are:

- provides the opportunity to develop up to an additional 160 ha compared to that available under Option A;

- establishment cost of $ 5.4 M is less than that for Option C;

The disadvantages of Option B are:

- higher establishment cost than Option A

- annual maintenance costs are the highest of the three options at $2.3 M and are unlikely to reduce with time;

- loss of 23% of developable area under Option C (110 ha unavailable from a total of 480);

- building restricted to western portion of the site and the opportunity forgone of beachside and oceanview development;

5.3.3 Option C

The advantages of Option C are:

- dune maintenance costs, although initially high at 0.5m/yr, can be expected to reduce in time as the vegetation cover consolidates;

- provides the opportunity to develop up to an additional 212 ha compared to that available under Option A and an additional 110 ha compared to that available under Option B, i.e. 100% of lots potentially developable (480 hectares);

- beach amenity would be available to community via car-park and walking tracks through vegetated backbeach with surf clubs and other amenities used to provide a focus;

- vehicular access tracks can be constructed to allow entry only at specific locations to protect the foredune;

- possible funding assistance under the PWD Coastal Hazard Program.

The disadvantages of Option C are:

- high initial establishment cost of $7.3 M;

- high initial maintenance cost of $0.5 M annually (albeit decreasing after say 2 years).

5.4 Implementation of Options

5.4.1 Option A and C

Stabilisation and works of Options A and C would be staged in the following manner:

- Remove bitou bush.
- Re-build and shape the foredune/swale starting from the south and working to the north. Sand from the rear of the transgressive dune could be used as fill if required.
- Plant the foredune with primary grasses and secondary scrubs.
- Establish board/chain walkways and access paths.
- Monitor and maintain the foredune during the continuation of works.
- Shape hind dune areas.
- Plant primary grasses or crop cover on the hind dunes. The extent of hind dune planting will be dependent on the timing of urban development and a program of works will be necessary to coordinate these aspects.
- Fencing and possibly landscape planting in the hind dunes.
- Maintenance of the foredune and hind dune plantings and additional tertiary shrub/tree plantings where appropriate.
- Building of roads/car parks and temporary/relocatable buildings (surf clubs, playing fields, conservation areas for walking, cycling and disabled access, community halls etc.) in the swale areas behind the foredune (Option C only).
- Urban development in the form of housing, roads, schools, sewerage works etc.

5.4.2 Option B

Stabilisation of Option B would be staged in the following manner:

- Reshape the sloping edge of the transgressive dune to a profile suitable for stabilisation.

- Stabilise with primary grasses, secondary shrubs and tertiary tree plantings together with brush matting and other sand drift prevention measures. This would need to be done in a lesser time frame than for Options A and C as the risk of inundation is higher whilst the stabilisation works are in progress.

- Establish board/chain walkways and access paths.

- Maintenance/re-establishment of the stabilisation zone.

- Urban development in the form of housing, roads, schools, sewerage works etc.

The dune stabilisation works should be managed by or carried out in close consultation with the Department of Conservation and Land Management NSW (CaLM), formerly the Soil Conservation Service.

6. Discussion

The development concept plan put forward by Gardner Browne (1991) recommended a program for stabilising the dunes so as to significantly increase the area available for urban development. This is indeed the case. By stabilisation of some 219 hectares of mobile sand dunes 100% (480 ha) of the land in the three lots is potentially developable. This approach is referred to in the previous section as Option C. Two other approaches, Options A and B, stabilising lesser areas of the mobile dune fields have also been considered.

The approach referred to as Option A in the previous section, is to allow for the ongoing progradation of the transgressive dune and accommodation of this by establishing buffer zones which preclude development of a permanent nature. Option A would seem to under utilise the potential coastal amenity of the area. By defining buffer zones to allow transgression of the hind dune the development area available in Option A is restricted to the western ends of the lots. This removes the site from the beach environ which may otherwise be a primary focus for residential development and community leisure activity.

Gardner Browne (1991) notes that the study area enjoys proximity to the beach and its microclimatic benefits. The STW, which is currently proposed to be located at the north east corner of the development site, is considered to restrict the potential benefits. In the framework of the current Structure Plan (Figure 2.1) the STW would have several obvious problems, namely:

- In order to prevent the STW from being inundated with dune sand the plant area will need to be protected by a surrounding stabilised dune field requiring relatively high maintenance. The cost of the dune stabilisation measures is estimated to be between \$1.4 M (plus \$0.3 M per annum) and \$3.4 M (plus \$0.5 M per annum).

- The plant and surrounding stabilisation area occupies land which could potentially be used for prime urban development.

- The north east coastal sea-breezes that prevails in the warmer summer months will transmit any odour from the works over a high proportion of the proposed development area.

- The access to the beach will be restricted and the general beach amenity diminished.

For the above reasons it would seem appropriate that the location of the STW be revised. For example, it may be feasible to locate the plant adjacent to the golf course or on the western side of Nelson Bay Road. Whatever the location of sewage processing, the effluent, once having undergone an appropriate level of treatment, would be suitable for watering of the planted dune fields. This procedure, if properly managed, would enhance the growth of stabilising vegetation and significantly reduce the dune maintenance costs.

The approach referred to as Option B in the previous section, is to attempt to hold the edge of the mobile dunes in approximately its present location. This option allows an increase in usable land of some 102 ha over Option A. The cost of this stabilisation is estimated at $5.4 M plus $2.3 M annually. Further, the annual maintenance cost of this option is unlikely to reduce in time.

Due to the fact that no foredune stabilisation would be done under Option B the dune field to the east of the stabilised area would still be highly mobile and present a high inundation risk. Therefore, the dune stabilisation under Option B would need to proceed quickly once begun, to avoid sand inundation from the eastern side. This would require a high initial injection of funds to bring the stabilisation to completion in as short period of time as possible. Further, the constant risk of this inundation will require a high annual maintenance cost of $2.3 M.

The viability of Option B is uncertain given there is little or no experience with this type of stabilisation on the central east coast of NSW. If this option is to be pursued, further consultation would be required with CaLM and PWD.

The approach referred to as Option C allows for stabilisation of some 219 hectares of mobile sand dunes and potential development of 100% of the land in the three lots. This is an increase in developable land of 212 ha over Option A and 110 ha over Option B. Weighed against this increase in usable land area is the cost of stabilisation which is estimated at $7.3 M plus $0.5 M per annum. This cost estimate is somewhat conservative as it is based on 'up front' stabilisation cost for the entire foredune/swale and hind dune areas, whereas it is more likely that the stabilisation works will be staged and a proportion of the hind dune stabilisation will result from urban development over the transgressive dunes. Further, the maintenance would likely reduce in time as the dune vegetation cover consolidates.

Option C would require an initial injection of funds to shape, plant and control access over the foredune and swale. A period of 5 to 10 years of maintenance and plant growth would then be needed to consolidate the foredune/swale stabilisation works. However, the required level of maintenance can be expected to reduce after the second year. Following the establishment of a stabilised foredune and the initiation of a programme of hind dune stabilisation, urban development could proceed into the eastern portion of the site. As such Option C facilitates the opportunity to develop all the available land and utilises the beach and coastal amenity to the fullest.

The stabilisation of large dune areas on the New South Wales coastline has been previously undertaken and proved very successful. Areas such as Caves/Hams Beach in Lake Macquarie Shire and Bate Bay in Sutherland Shire involved large stabilisation works to transform the areas of coastal land from barren mobile dunes to landscaped and stable dune paddocks. On completion of such projects, the beach and surrounds tend to become a focus for open space recreation. Plates 3 and 4 show examples of completed stabilisation works at Wanda and Elouera Beaches (Bate Bay) and Palm Beach respectively. Further to these examples, the mining areas to the north of the proposed development site have been successfully stabilised in the past.

The area of foredune and swale created in Option C (Figure 5.5) could be used in a number of different manners. Areas could be devoted to community uses, conservation and combinations of both. Community uses such as playing fields, temporary buildings (surf clubs and community halls), parkland, access and car parking areas would provide beach access and usability together with community resources. Areas could also be set aside as nature conservation areas or as community education zones where limited access and documented walks and nature trails could be incorporated.

Option C would need to be completed within the guidelines of an overall Beach Management program for the Stockton Beach/Newcastle Bight area. A management strategy and works program should be formulated and administered by Council, CaLM, PWD and other relevant bodies.

7. Conclusions and Recommendations

7.01 This study was based on the use of existing data and hence photogrammetry was not carried out as part of the project. The dune movement figures were therefore based on existing data sets. More detailed photogrammetric analysis would undoubtedly refine the figures for long term beach recession. Further, should Option C be adopted and particularly if this option is progressively extended throughout the embayment it can be anticipated that the recession rate will be substantially reduced.

7.02 Following examination of available information the following beach movement parameters have been adopted for the study area:

Long Term Beach Recession	1.2 m/yr
Storm Cut	20 m
Climate Change (sea level rise)	60 m

It follows then that for a planning period of 100 years, the coastal hazard zone extends for some 200 m inland from the present location of the foredune. It should be noted that these figures do not include any allowance for the foredune width. Rather, they indicate the possible location of the front face of the foredune in 100 years time given that an extreme storm cut occurs at that time. Hence consideration should be given to further setback to provide for a viable foredune in 100 years time.

7.03 Similarly, the following hind dune movement parameters have been adopted for the study area:

Long Term Transgression	3.2 m/yr
Short Term Inundation/Safety Zone	50 m
Climate Change (wind climate)	50 m

For a 100 year planning period, the hind dune hazard zone extends some 420m inland from the present location of the landward edge of the transgressive dune. Again, these figures could be refined with more detailed photogrammetric analysis.

7.04 Three broad options have been formulated for managing the dunes in terms of the current Structure Plan (Figure 2.1)

7.05 Table 7.1 presents an estimate of the initial and annual maintenance costs for each option. Also included is the potential lot yield associated with each option, which has been based on an average lot yield of 10 lots/hectare (Gardner Browne 1991).

Table 7.1 Estimated Cost of Options

Option	Dune Stabilisation Establishment Costs	Annual Dune Stabilisation Maintenance Costs	Potential Lot Yield (No. of lots)
A (Sewerage treatment works (STW) relocated)	$0	$0	2,700
A1 (stabilise 400m zone around STW, see Figure 5.1a)	$1.4 M	$0.3 M	2,700
A2 (stabilise most of the Crown Land around the STW, Figure 5.1b)	$3.4 M	$0.5 M	2,700
B (stabilise eastern edge of transgressive dune only, see Figure 5.3)	$5.4 M	$2.3 M	3,720
C (stabilise foredune and hind dune, see Figure 5.4)	$7.3 M	$0.5 M	4,820

7.06 Although the capital outlay for Options B and C is substantially more than for Option A, this would be offset by the increased lot yield. That is, for Option B some 1020 extra lots could be developed (compared to Option A) at an average incremental cost per extra lot of $5300 plus $2300 per annum. For Option C, some 2120 extra lots could be developed at an average incremental cost per extra lot of $3500 plus $240 per annum. In regard to the annual maintenance cost for Option C, these can be expected to reduce over time as the dune vegetation cover consolidates and as the hind dune paddock areas give way to the residential development.

7.07 Option C provides for initial shaping and stabilisation of the foredune/swale and stabilisation of the hind dune in later stages. Out of the total land-holding of 480ha, all land has the potential to be developed. This option is shown in Figure 5.4.

7.08 The Coastal Management Committee, comprising representatives of Port Stephens Shire Council, Newcastle City Council, Department of Conservation and Land Management (formerly the Soil Conservation Service), Public Works Department, Department of Mineral Resources, Hunter Water Corporation and other relevant bodies, should give consideration to formulating a coastal management strategy for Newcastle Bight. Of particular focus should be the area comprising the proposed development site and adjacent coastline.

7.09 Any future dune stabilisation works should be managed by, or carried out in close consultation with the Department of Conservation and Land Management, NSW.

7.10 There are several problems associated with the proposed Sewerage Treatment Works being sited at the north east corner of the development site (as per the Structure Plan). The problems relate to the need for costly (sand inundation) protection measures, sterilisation of land which could potentially be used for housing estate development at some future time, odour from the treatment plant, and restricted beach access. As such, further consideration should be given to alternate sites.

7.11 The Public Works Department, NSW should be 'formally' approached as to whether Options A, B and C fall within the guidelines for funding assistance under the Coastal Hazard Program and, further, to obtain advice on the likelihood of funding levels and timing.

8. Glossary of Terms

Australian Height Datum (AHD) — a survey height datum approximately equal to mean sea level.

Beach — the zone of unconsolidated material that extends from the low water line to the place where there is a marked change in material or physiographic form (e.g.: erosion escarpment), or to the line of permanent vegetation (usually the landward limit of storm wave impact)

Dune Crest — a nearly continuous mound of beach material that has been shaped up by wave and/or wind action.

Dune Swale — the depression between two dune crests.

Foredune — the front dune immediately behind the beach face and acted upon by waves only during severe storms.

Greenhouse Effect — predicted global climate change (global warming) associated with the build up of certain gases in the atmosphere and in particular carbon dioxide from the burning of fossil fuels.

Holocene — the most recent time interval recognised in the geological time scale, approximately 10,000 years ago to present.

Littoral Drift — the sedimentary material (typically sand) moved by waves and currents in the zone between the shoreline to just beyond the breaker zone. Net littoral drift is the resultant of up coast and down coast drift, also explained as the time averaged littoral transport.

Photogrammetry — the science of measurement and data acquisition from photographic or remotely sensed images.

Recession — the net landward movement of the beach profile and shoreline over a period of time.

Sediments	unconsolidated material of which the composition and textural characteristics (e.g.: gravel, sand or mud) vary with the sediment source (e.g.: local, fluvial, marine) and the transporting process (e.g.: currents, waves).
Shoreline	the intersection of a specified plane of water with the shore or beach, the location of which can be highly variable in time.
Storm Cut	the volume of unconsolidated sediment temporarily removed from the sub-aerial (above water) part of the beach to the offshore bar during a single storm or series of storms occurring over a short duration (of say 1 to 2 months). Normally measured as the volume of beach sand removed above 0m AHD. During subsequent fair weather conditions the beach tends to recover as sand from the offshore bar migrates onshore.
Transgressive Dune	an unstable hind dune moving landward under the action of wind.

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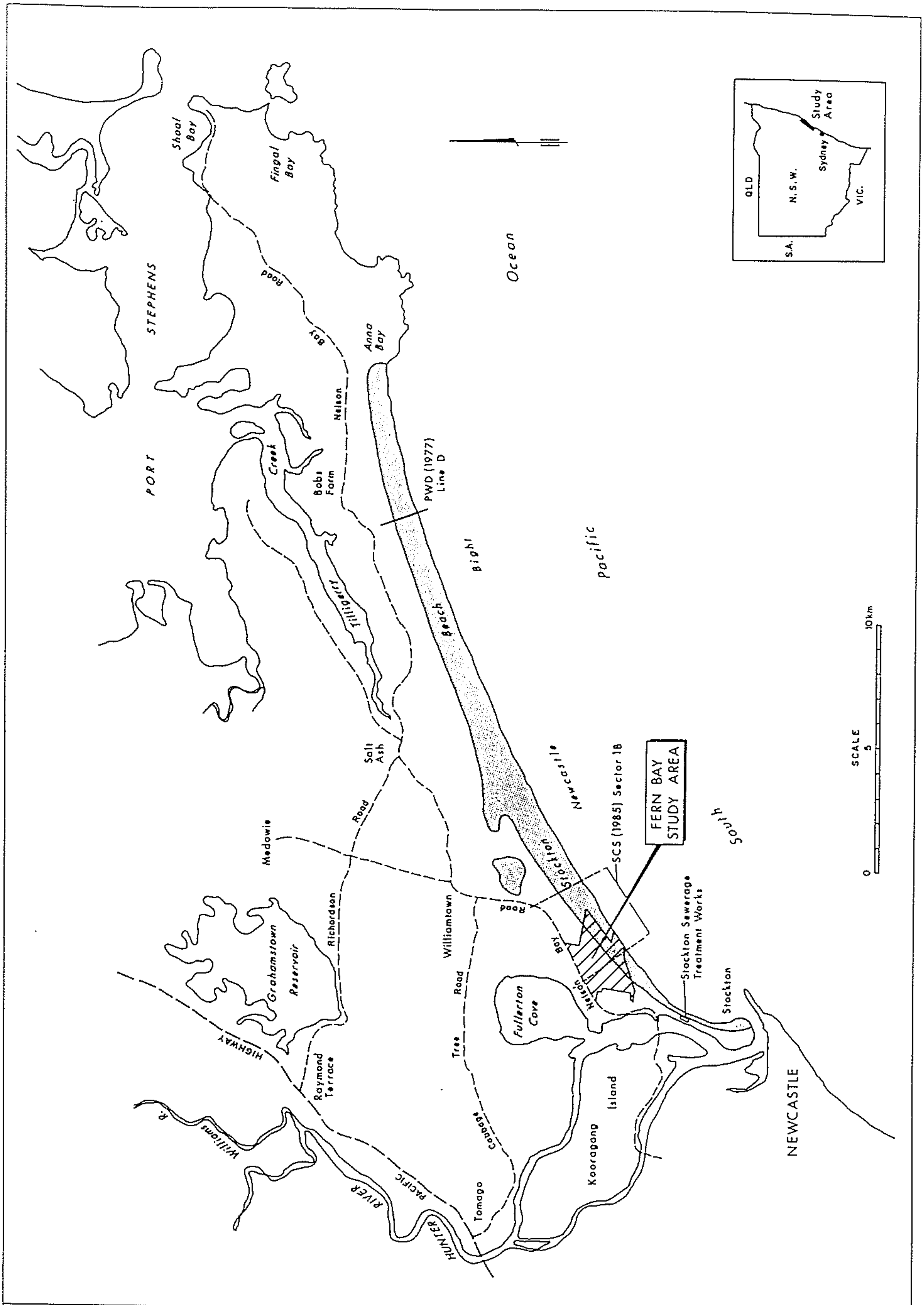
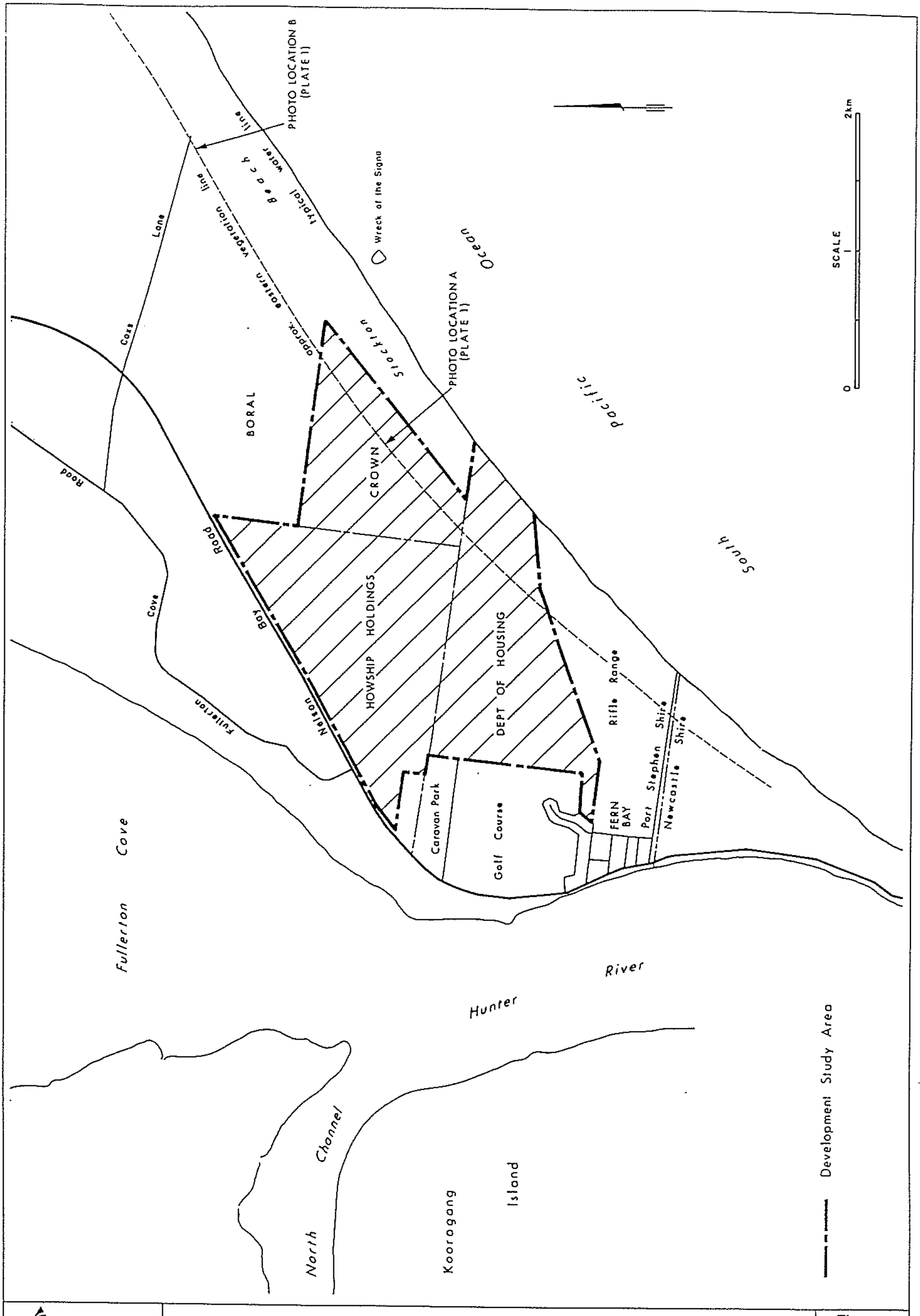


AWACS
Report No. 92/05

LOCALITY PLAN

Figure 1.1



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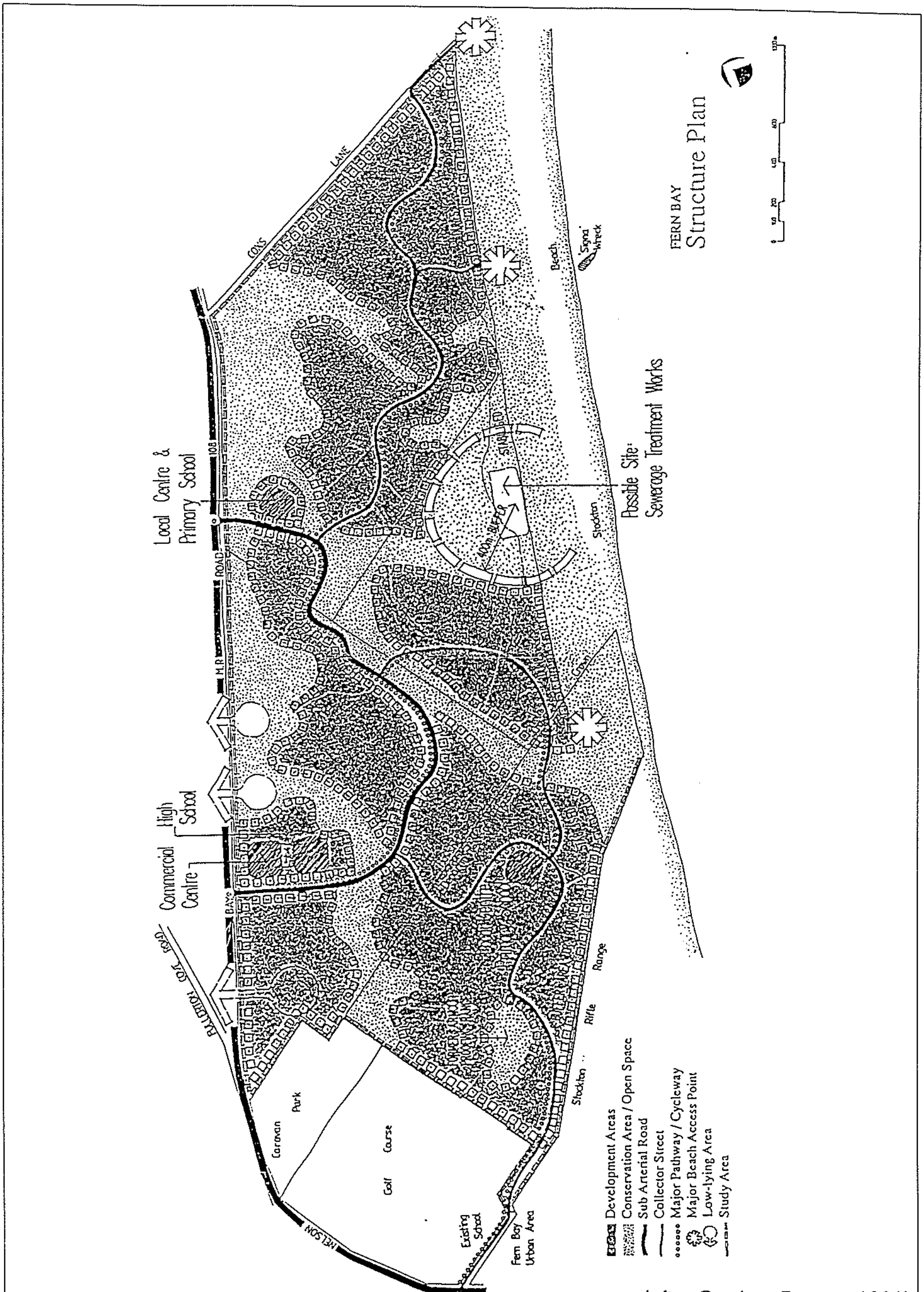
Report No. 92/05

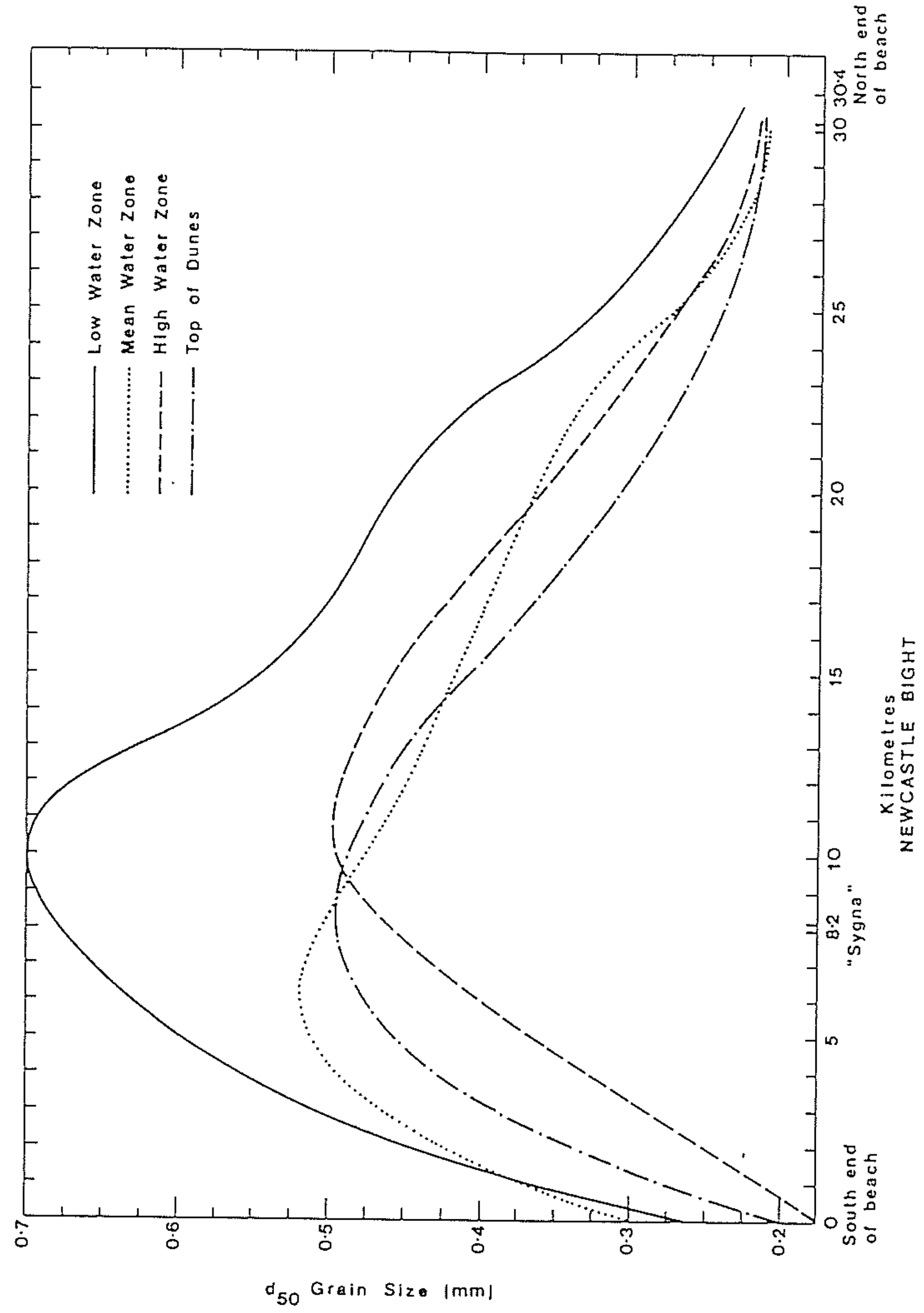
DEVELOPMENT STUDY AREA PLAN

Figure 1.2



(after Gardner Browne 1991)

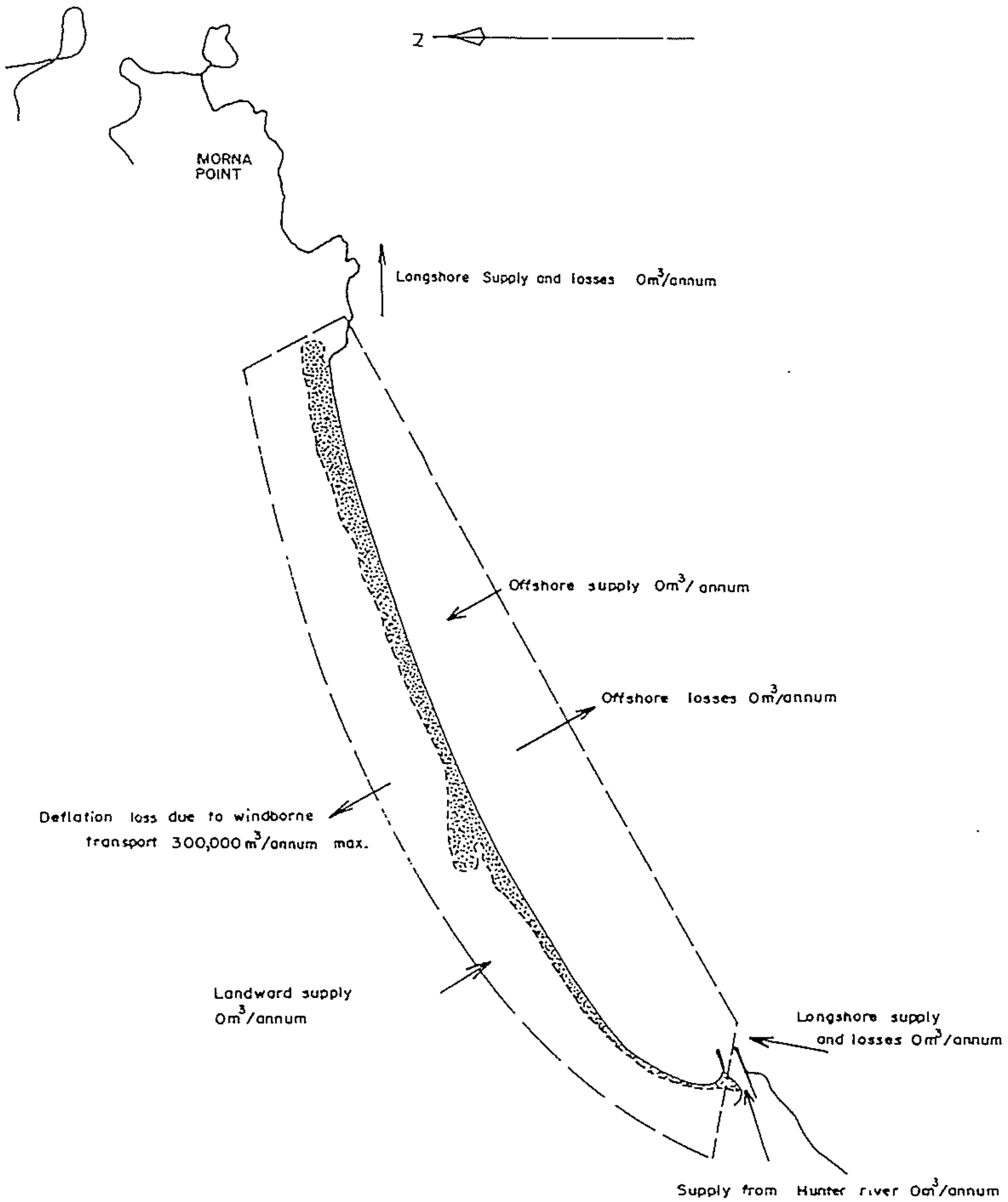
AWACS Report No. 92/05	FERN BAY EXISTING CONCEPT DEVELOPMENT STRUCTURE PLAN	Figure 2.1



d_{50} = Median diameter of sediment sample

(after PWD 1977)

AWACS Report No. 92/05	NEWCASTLE BIGHT SAND GRAIN SIZE DISTRIBUTION	Figure 3.1



(after PWD 1977)

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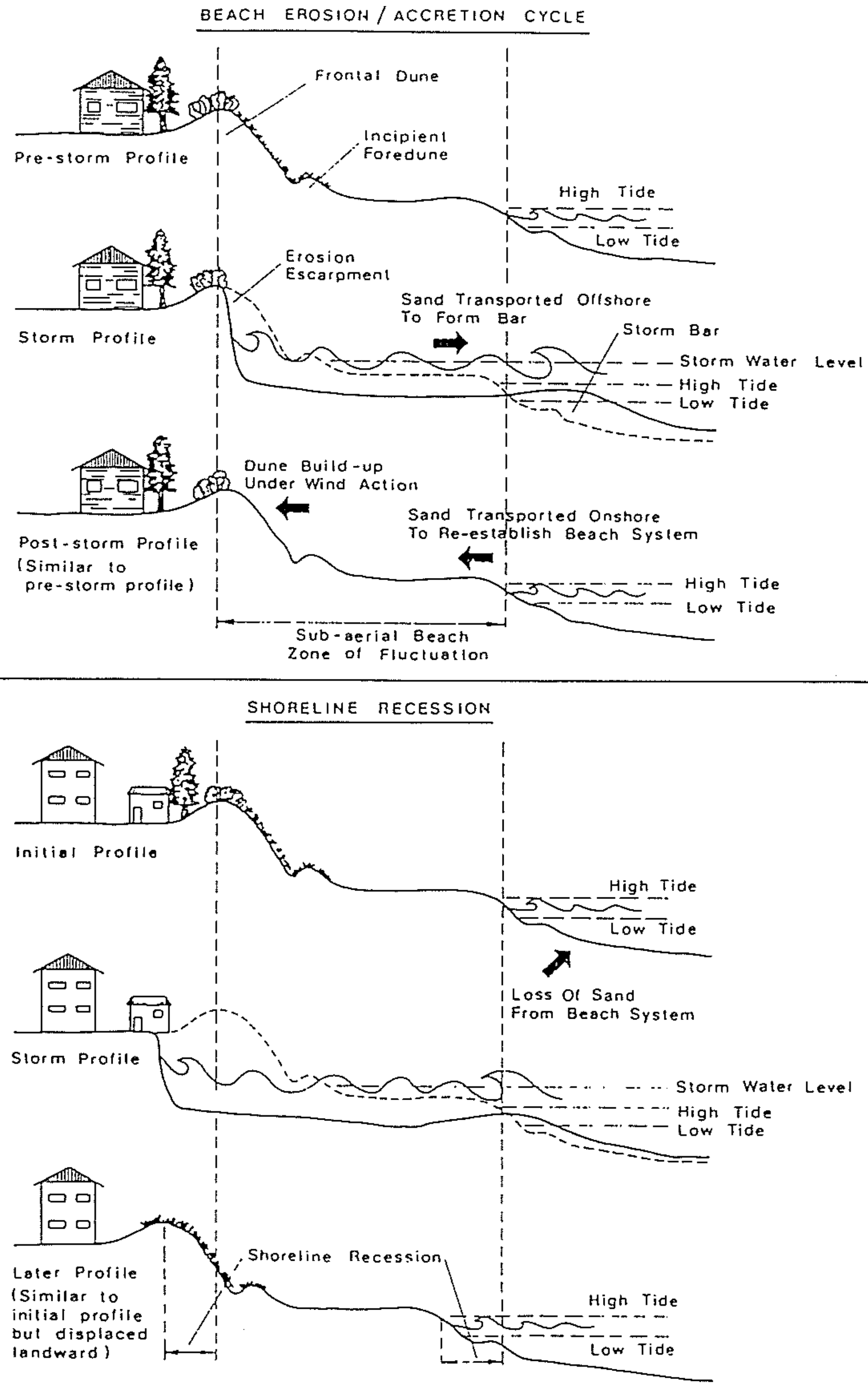
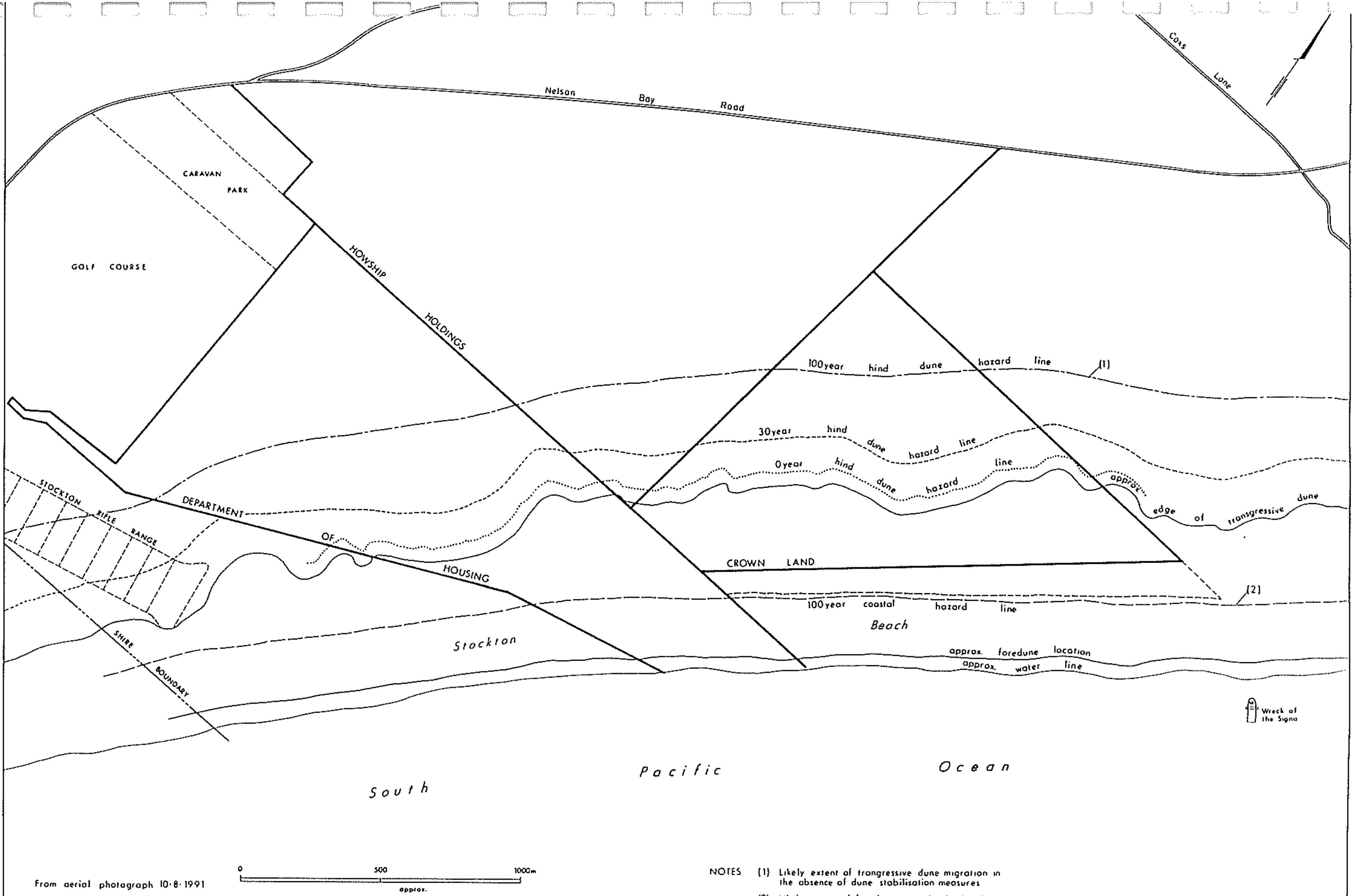
SCHEMATIC REPRESENTATION OF BEACH SAND SEDIMENT BUDGET IN NEWCASTLE BIGHT

Figure 3.2



(after PWD 1985)

AWACS Report No. 92/05	SHORT TERM BEACH FLUCTUATIONS AND LONG TERM BEACH RECESSION	Figure 4.1



From aerial photograph 10·8·1991

NOTES (1) Likely extent of trangressive dune migration in the absence of dune stabilisation measures

(2) Likely extent of foredune recession in the absence of any beach protection measures

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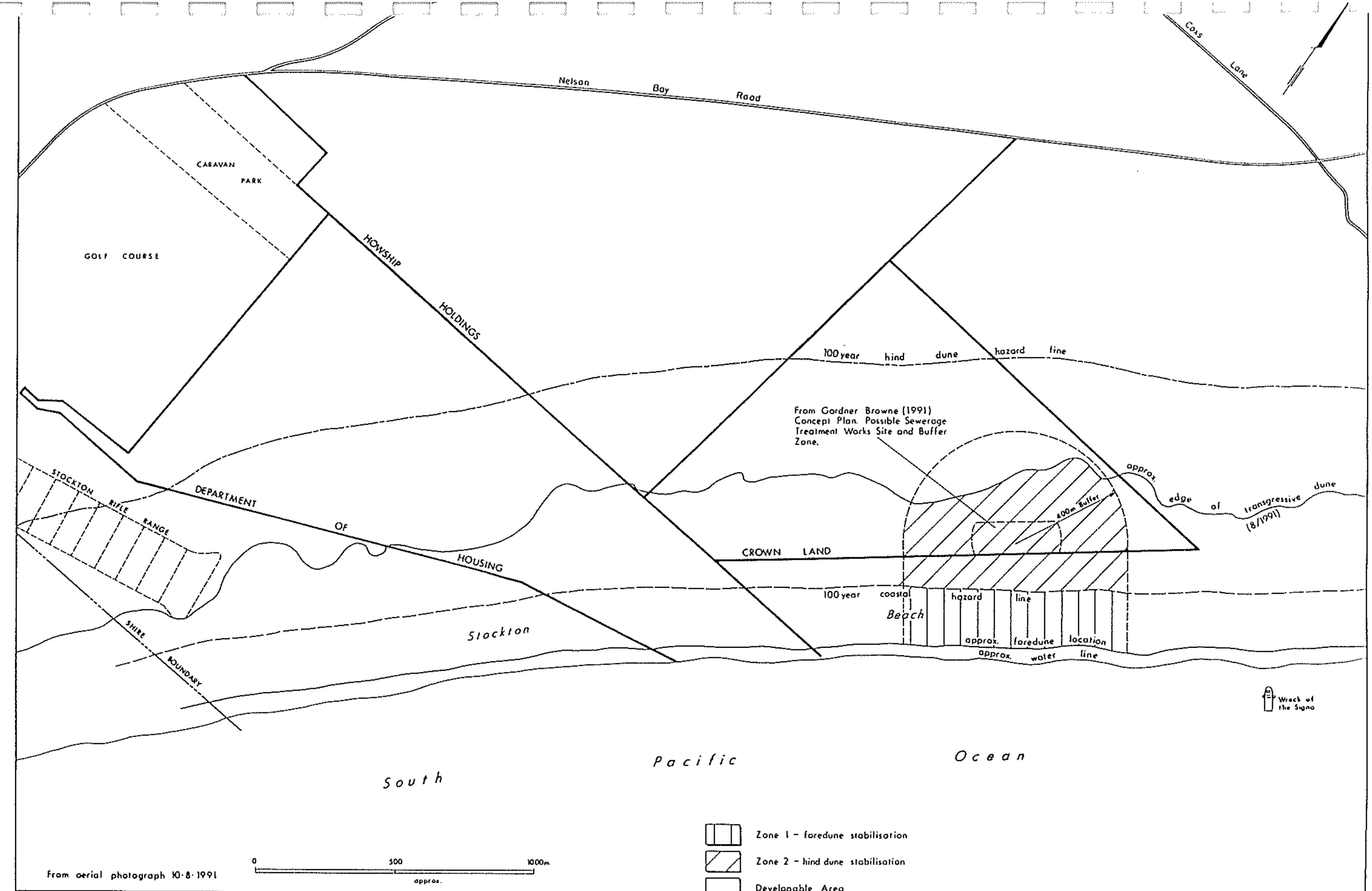
DEVELOPMENT AND PLANNING PERIOD BOUNDARIES

Figure 4.2



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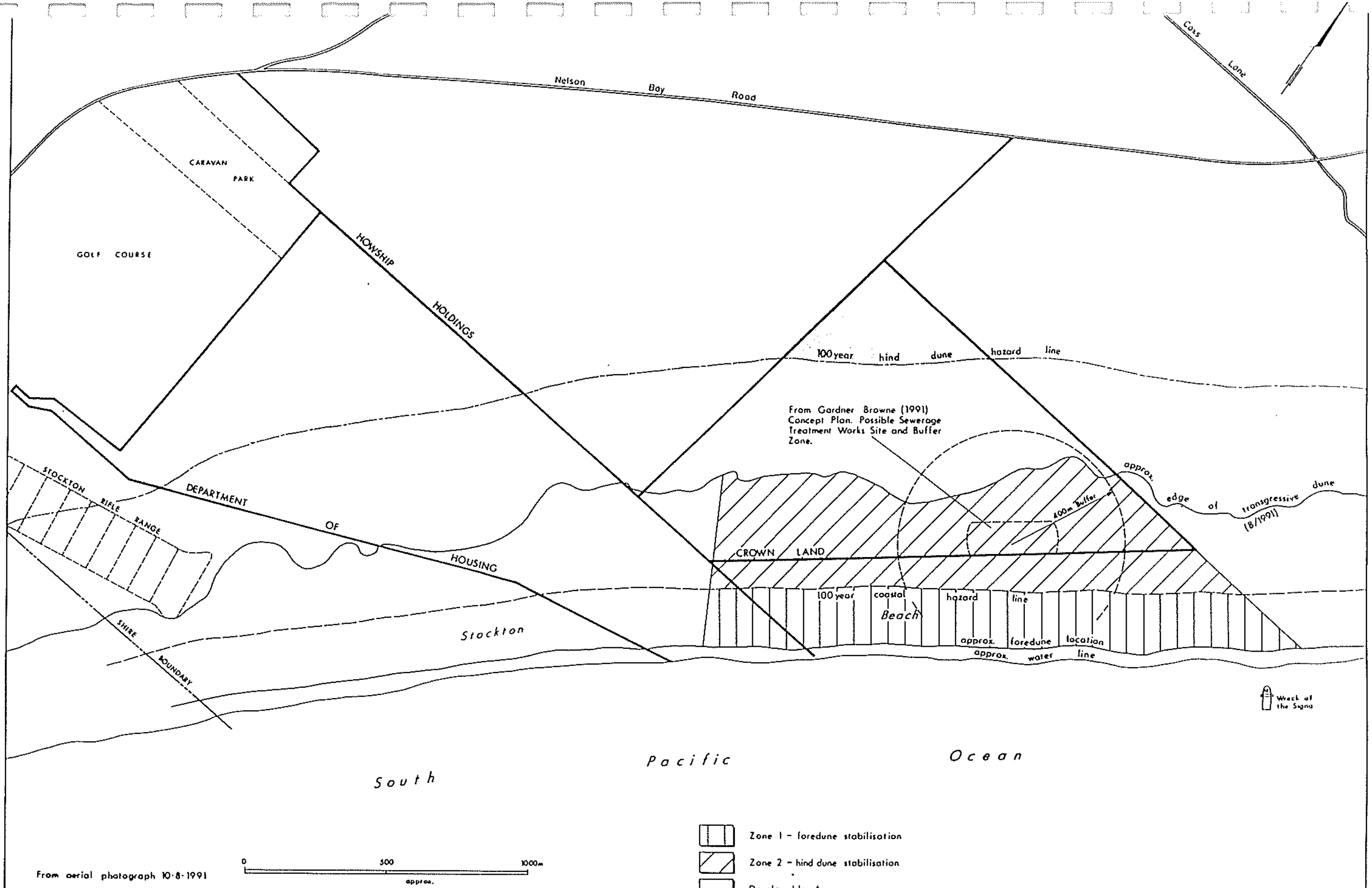
CONCEPT PLAN FERN BAY DEVELOPMENT OPTION A1

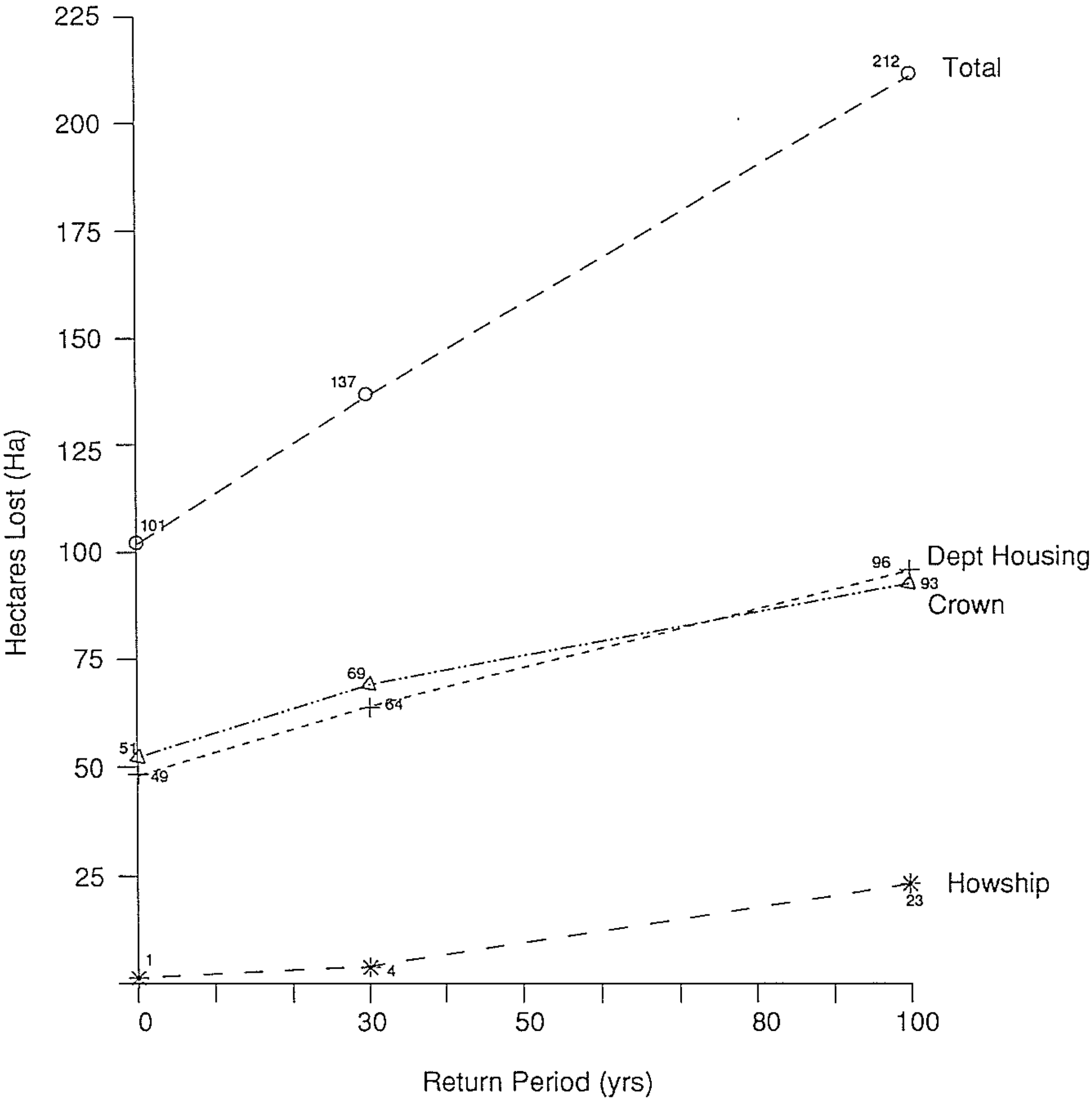
Figure 5.1a



AWACS Report No. 92/05

CONCEPT PLAN FERN BAY DEVELOPMENT OPTION A2

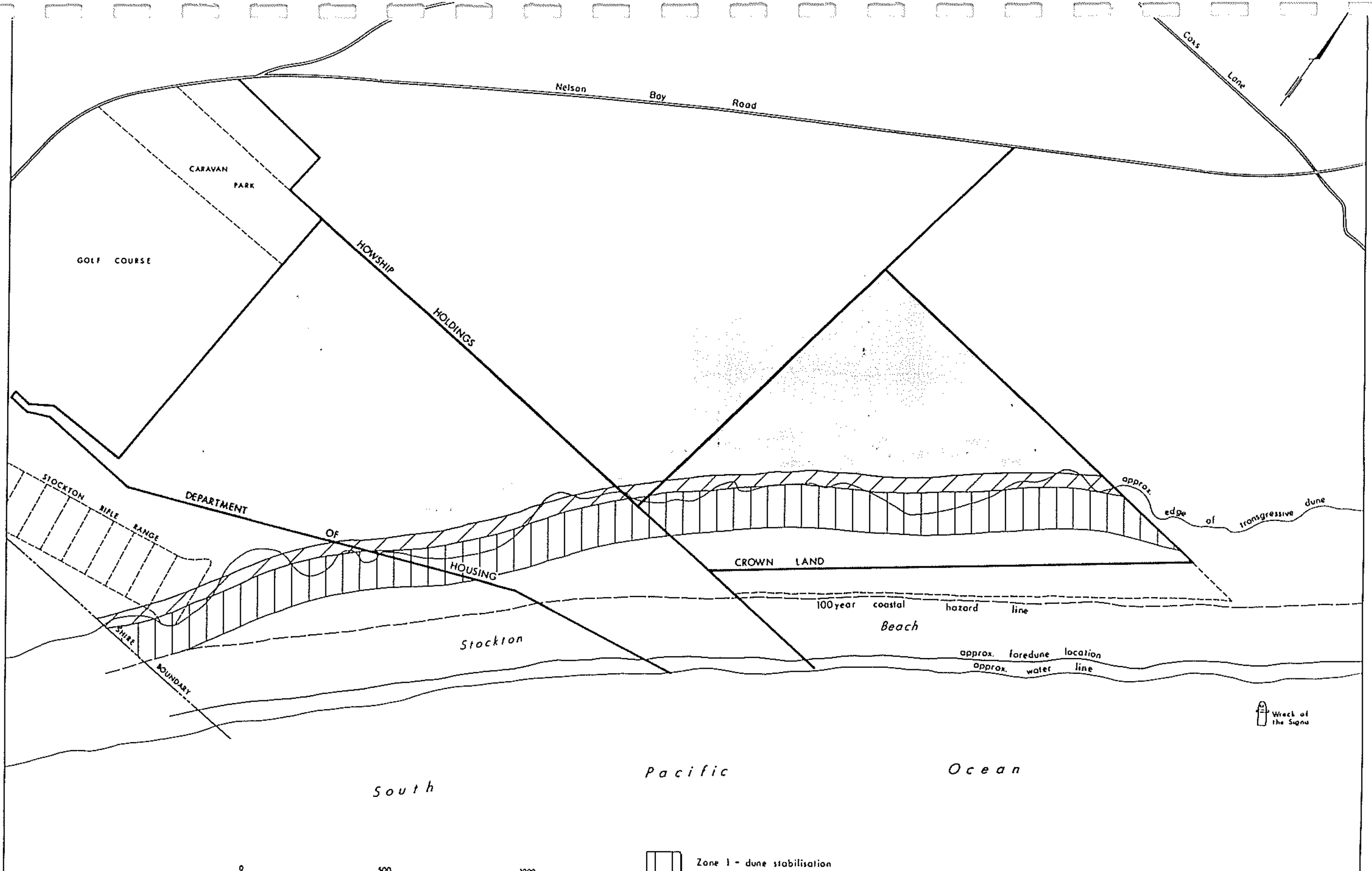
Figure 5.1b



AWACS
Report No. 92/05

LAND LOST FOR DEVELOPMENT OVER TIME OPTION A

Figure 5.2



From aerial photograph 10·8·1991

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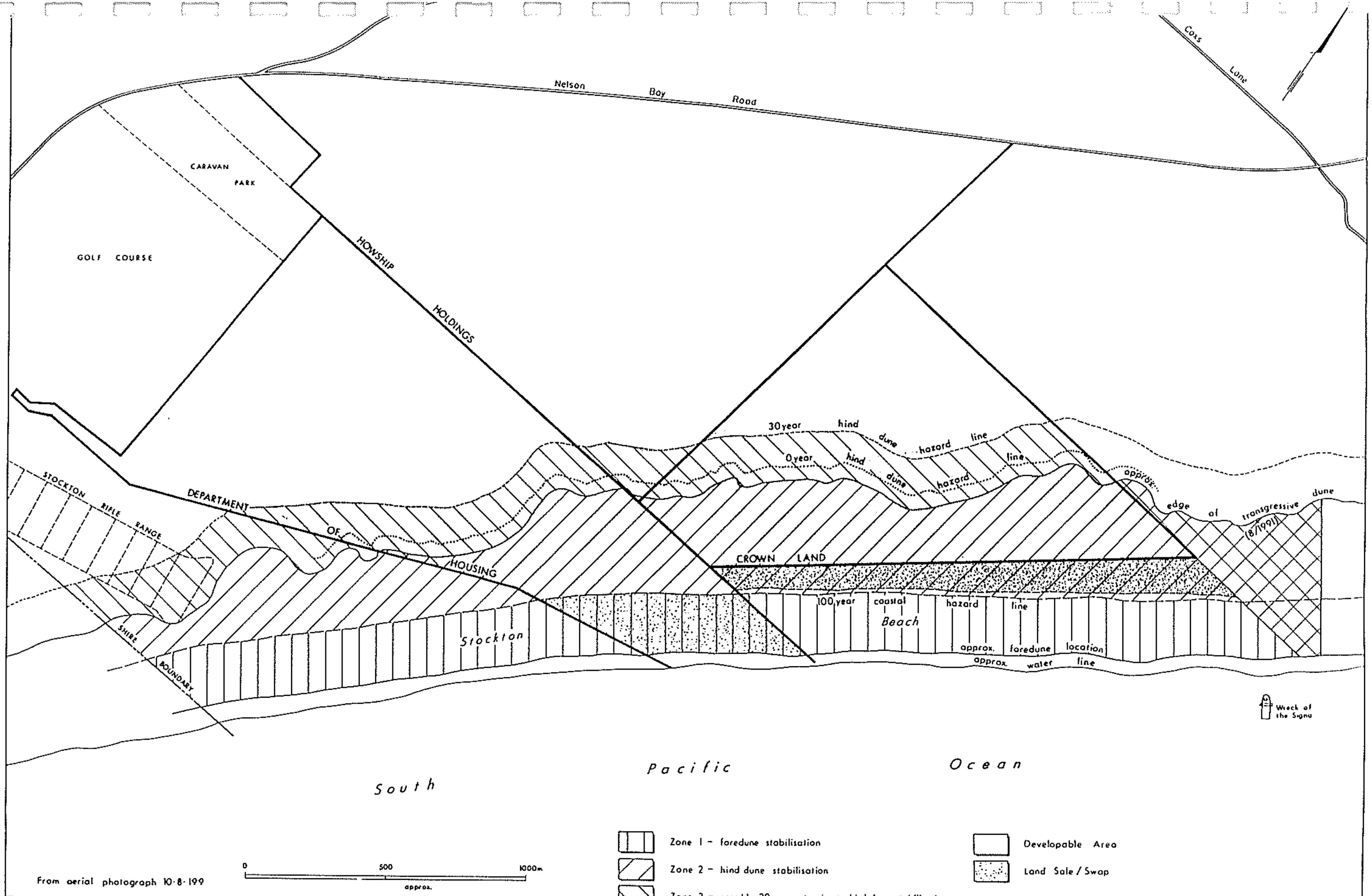
CONCEPT PLAN FERN BAY DEVELOPMENT OPTION B

Figure 5.3



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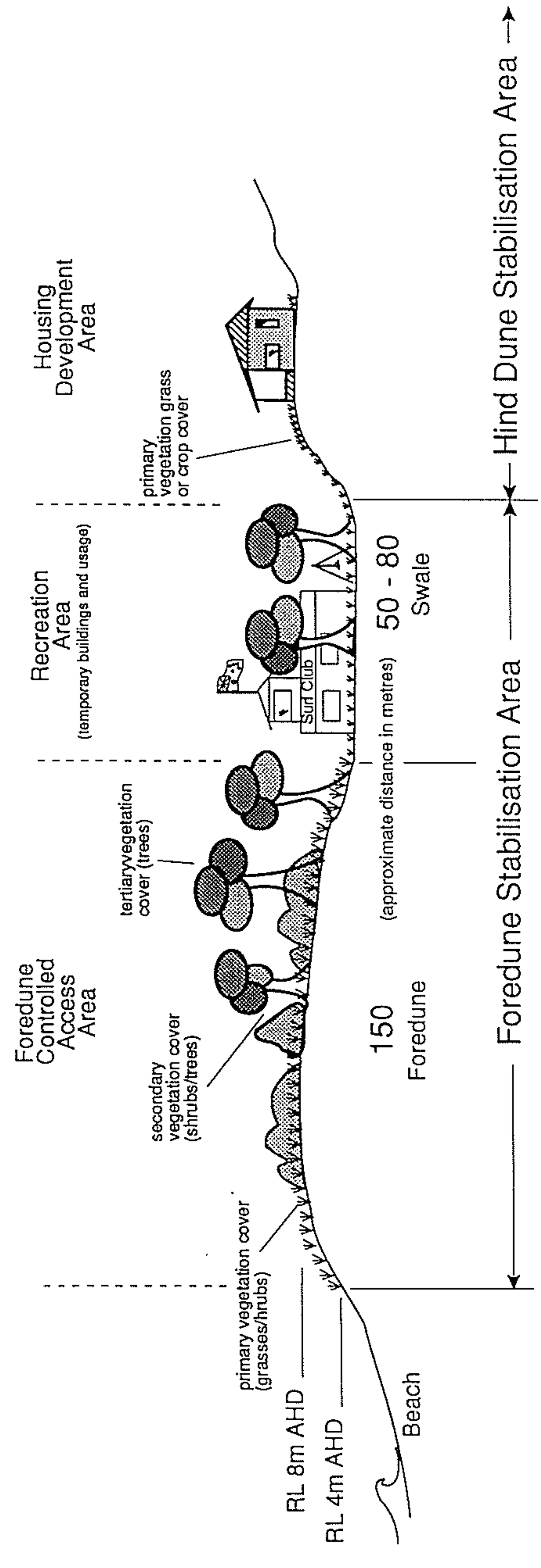
CONCEPT PLAN FERN BAY DEVELOPMENT OPTION C

Figure 5.4



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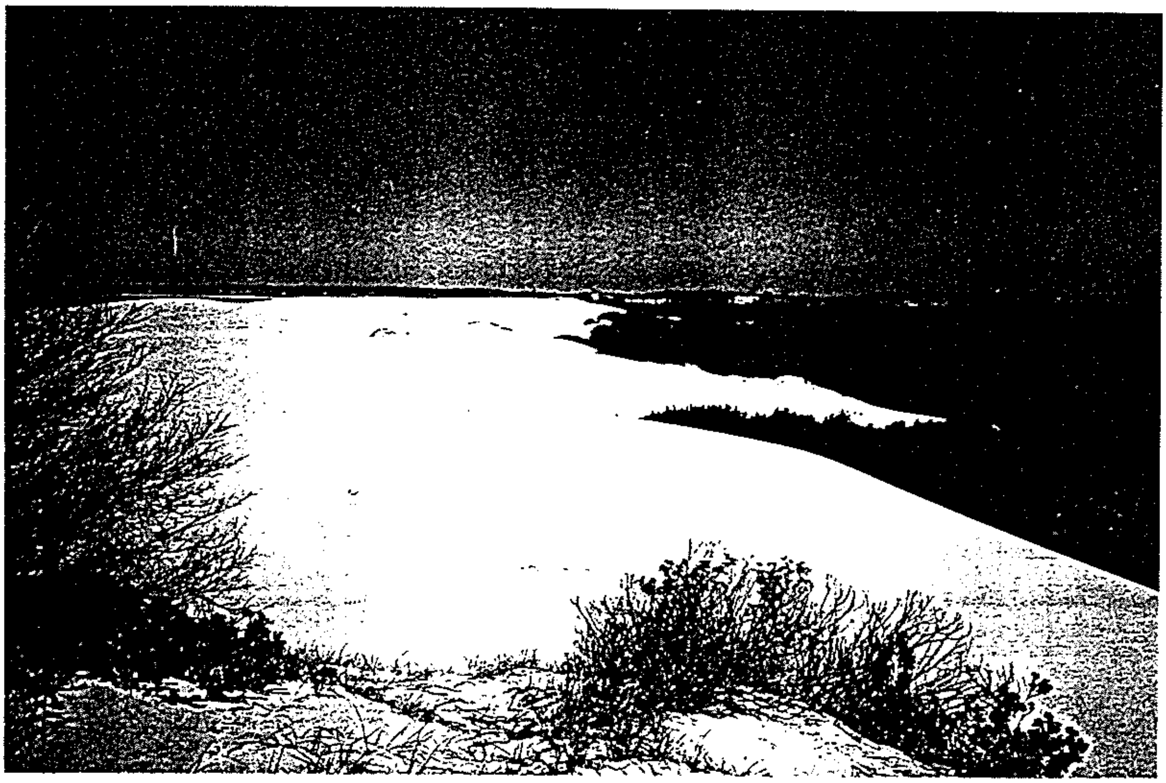
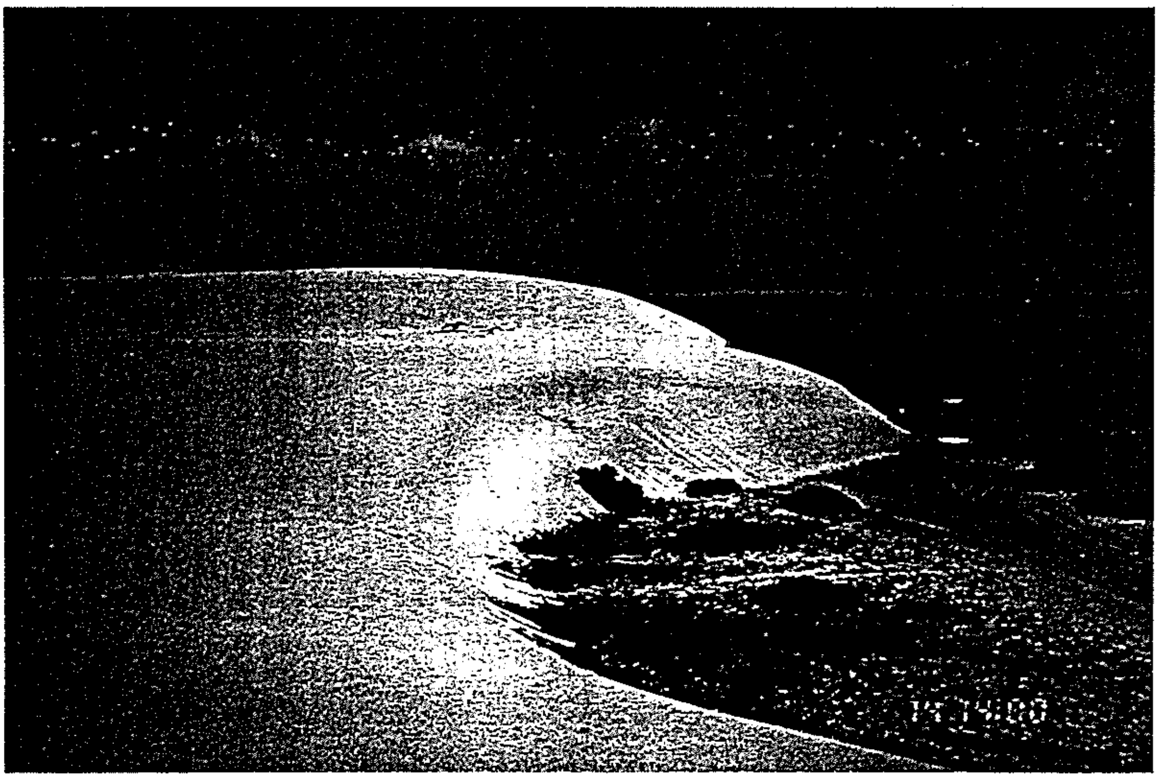
Report No. 92/05

SCHEMATIC REPRESENTATIVE SECTION
OPTION C

Figure
5.5

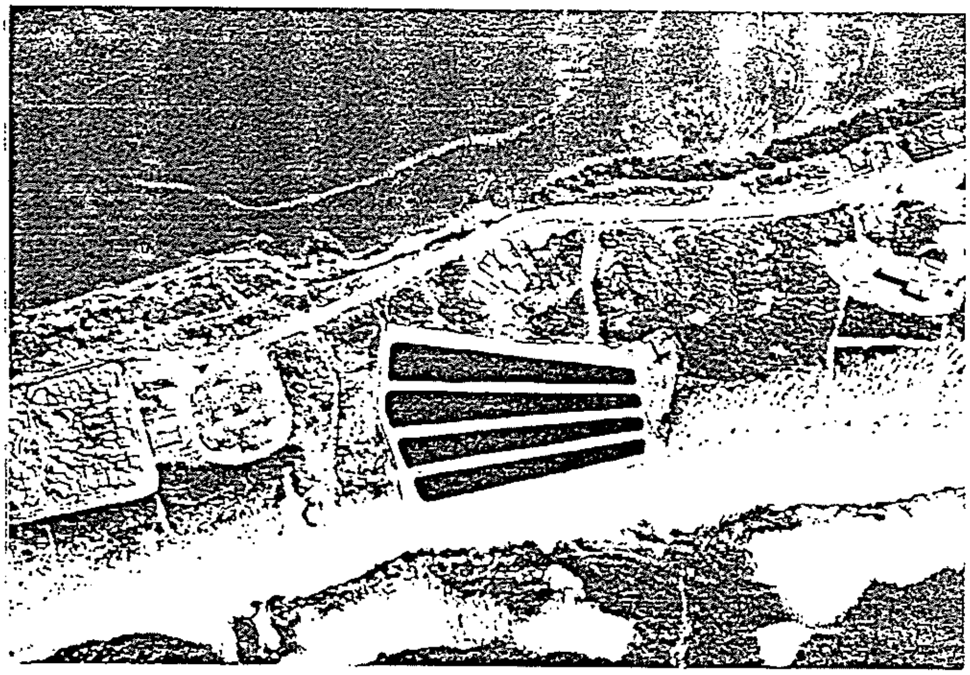


View to the south from within the Crown Land Holding
(Location A Figure 1.2)

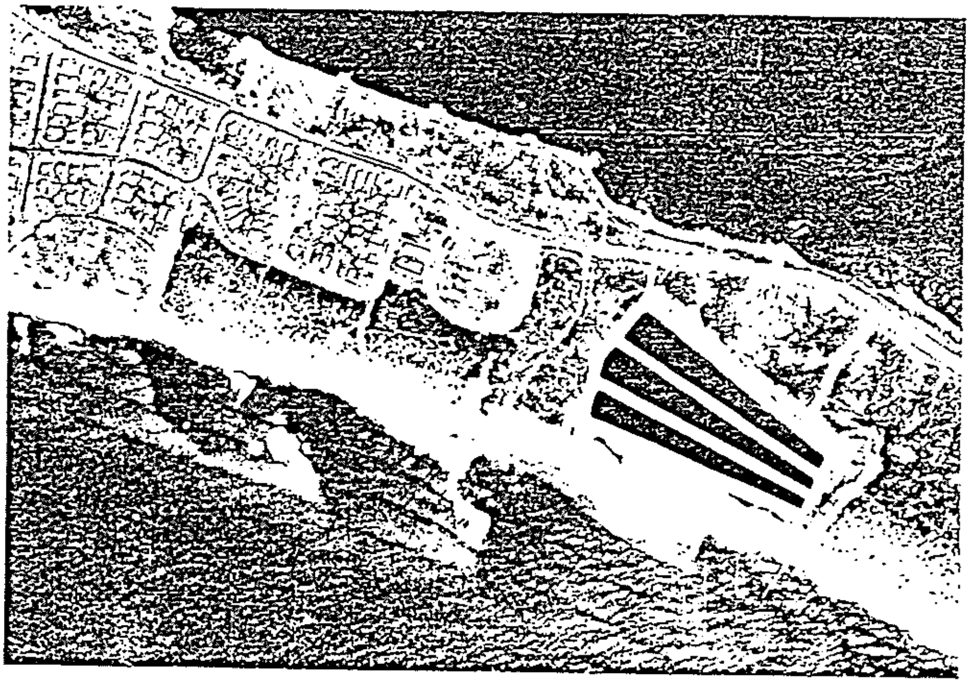


View to the south from the eastern end of Coxs Lane
(Location B Figure 1.2)

AWACS Report No. 92/05	WESTERN EDGE OF THE TRANSGRESSIVE DUNE IN THE STUDY AREA VICINITY 14 JANUARY 1992	Plate 1



JUNE 1974



OCTOBER 1974

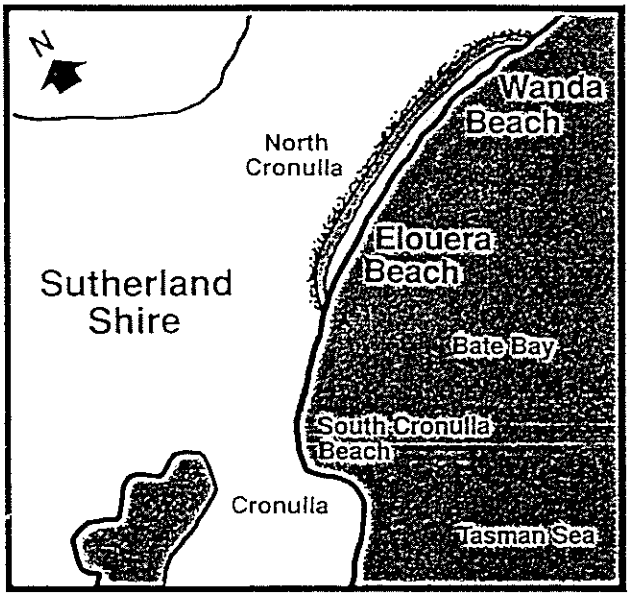
(after PWD 1985)

AWACS Report No. 92/05	1974 STORM DAMAGE TO STOCKTON BEACH EFFLUENT PONDS	Plate 2

COASTAL PROJECT SHEET 11

WANDA & ELOUERA BEACHES REVIVED

This foreshore is the longest expanse of beach (11.25km) in Sydney. Being within the metropolitan area, the Bate Bay beaches - Cronulla, Wanda and Elouera - are well serviced by public transport and are extremely popular.



By 1977 the popularity of Wanda and Elouera Beaches had taken its toll. The beach had become destabilised and the loss of sand was so severe that the entire beach around the Bay was receding. The worst affected area was in the south of the Bay where the prevailing winds had moved large amounts of sand inland.

In 1977, a beach nourishment program was implemented at South Cronulla. This included an allowance to increase the width of Wanda and Elouera Beaches by the natural movement of sand.

The beach stabilisation program began in 1978. It was a two stage program, with Stage 1 being dune formation and stabilisation of the area between the surf clubs and in front of Wanda Surf Club. Stage 2 commenced in 1983 and included extension of the sealed parking area at Wanda Beach and landscaping of the back beach area.

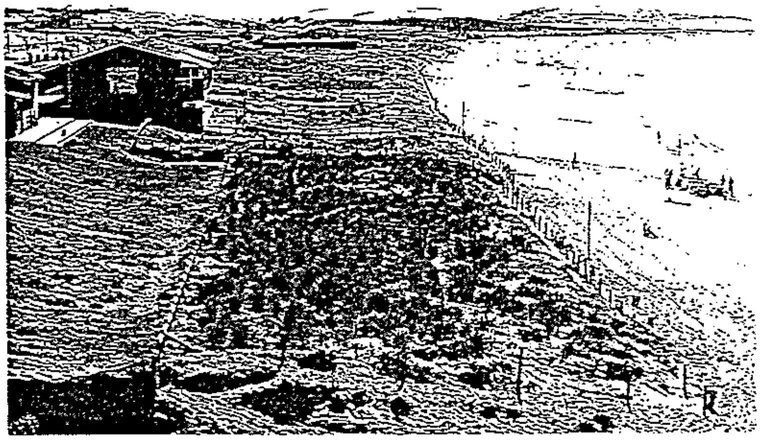
While these works were in progress, the Soil Conservation Service stabilised the dune in the north of the Bay.

Wanda and Elouera Beaches.

The effects of the dune stabilisation have been to halt the major loss of sand which was causing recession of the beach and to restore the natural balance of the Bay. Fluctuations will occur from time to time but there will be little further permanent loss of sand.

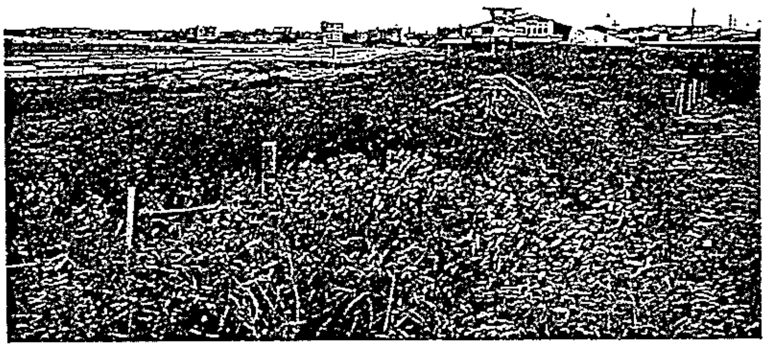
In the future, minor maintenance involving fertilisation of dune vegetation and raising fences and accessways will be necessary.

(Courtesy PWD)



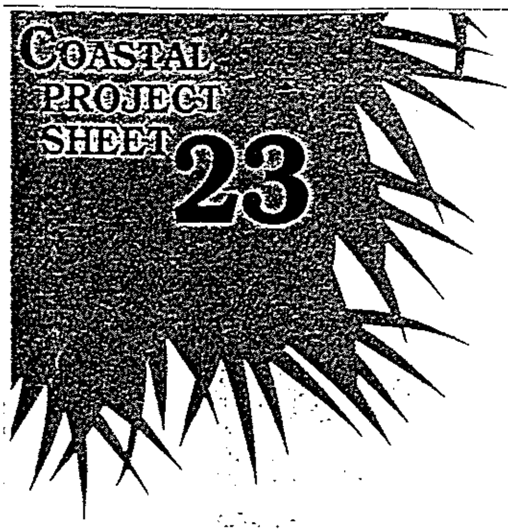
Wanda and Elouera Beaches before and after the beach improvement program.

Wanda Surf Club after dune stabilisation works.



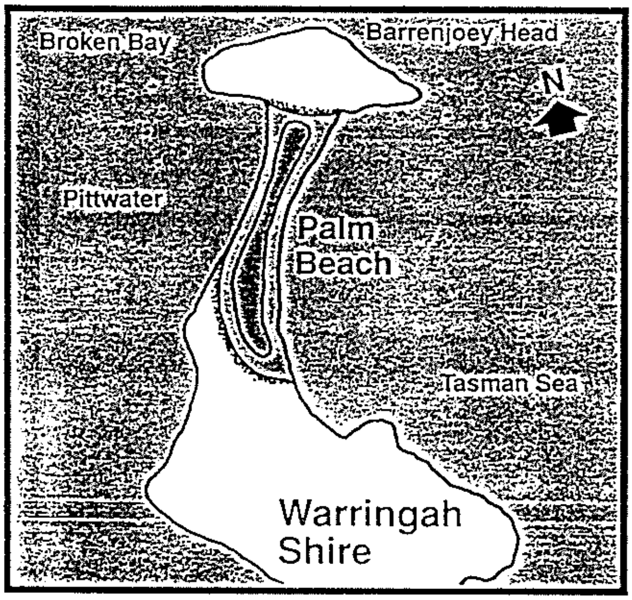
Location:	Wanda and Elouera Beaches, Sutherland Shire
Type of Works:	Dune stabilisation through planting; fencing; provision of accessways; extension of car park at Wanda Beach; and landscaping back beach
Technical Advice:	Public Works Department and Soil Conservation Service of New South Wales
Constructed by:	Sutherland Shire Council
Date of Works:	1978/1985
Funded by:	State Government Beach Improvement Grant
Cost:	$74,100

(Courtesy PWD)



PALM BEACH RENEWED

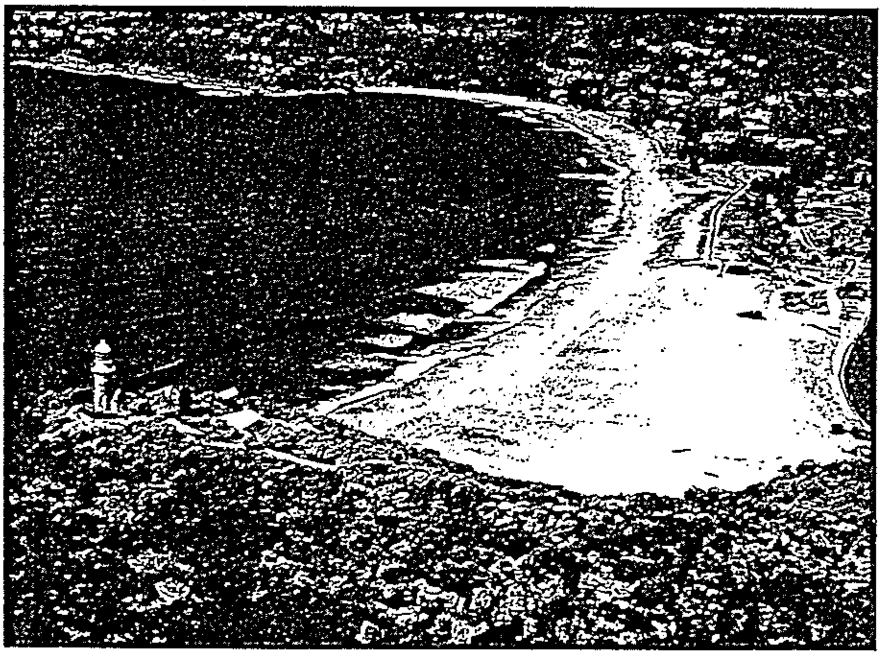
Barrenjoey Peninsula is two kilometres long and is divided into Palm Beach and North Palm Beach on the ocean and Barrenjoey Beach on Pittwater.



It encompasses an area of park and sand dunes, a golf course, surf beach and a sheltered estuarine beach. Its great scenic beauty and range of recreational opportunities attract tourists and residents alike.

Upgrading of the Barrenjoey Peninsula commenced with Govenor Phillip Park car park near North Palm Beach Surf Club. The car park, sited on top of the dune, was barren and unattractive and had inadequate drainage. In the absence of vegetation on the foredune, windblown sand was a problem. To improve the situation, the car park was grassed and the drainage was diverted inland; the dune was vegetated; pedestrian and vehicular access controlled through fencing and the entire area landscaped.

While this work was in progress, Warringah Shire Council requested the Public Works Department undertake a study of beach erosion at Palm Beach to enable them to develop an overall beach management plan. The study, completed in 1982, concluded that erosion of the beach was caused by wind blown sand losses from the northern part of the beach on to Barrenjoey Headland and offshore around the headland by wave and current action.



Palm Beach, 1984

(Courtesy PWD)

In 1983 work commenced at North Palm Beach (stretching northward from Govenor Phillip Park to the southern escarpment of Barrenjoey Headland) It included:

- formation of a frontal dune utilising sand adjacent to the Barrenjoey Headland;
- planting vegetation; and
- installing fences to protect the vegetation.

Works were suspended when it became known that there were aboriginal relics in the area. An archeological study was commissioned which located 11 aboriginal middens, three of which were rated as significant. All of the sites were protected to the satisfaction of the National Park and Wildlife Service and the aboriginal community.

The program includes a two year maintenance scheme which involves replanting and fertilising of the grasses and shrubs, raising of walkways and fences. Given time for the vegetation to mature, Palm Beach will be restored to its natural beauty and be a great asset to the Shire.

Barrenjoey Peninsula after reshaping and planting

The native grasses will prevent windblown sand losses which leads to erosion.

Location:	Palm Beach, Warringah Shire
Type of Works:	Upgrading the car park; landscaping; dune stabilisation, fertilising, fencing, provision of accessways, maintenance
Technical Advice:	Public Works Department and Soil Conservation Service of New South Wales
Constructed By:	Warringah Shire Council
Date of Works:	1983-1987
Funded By:	State Government's Beach Improvement Program
Cost:	Govenor Phillip Car Park - $84,500 North Palm Beach - $328,473

(Courtesy PWD)

Appendix A

Aerial Photography Summary

Photographs of the study area were obtained from the PWD Coast and Rivers Branch air photograph library for the period 1940 to 1991. These were examined for quantitative changes in the study area over the period of the photographs. A summary of the photographs obtained and comments relating to the site are given in Table A1. The photographs have been reproduced as photocopies at approximately the same scale (1:12,000) in Figures A1 to A19.

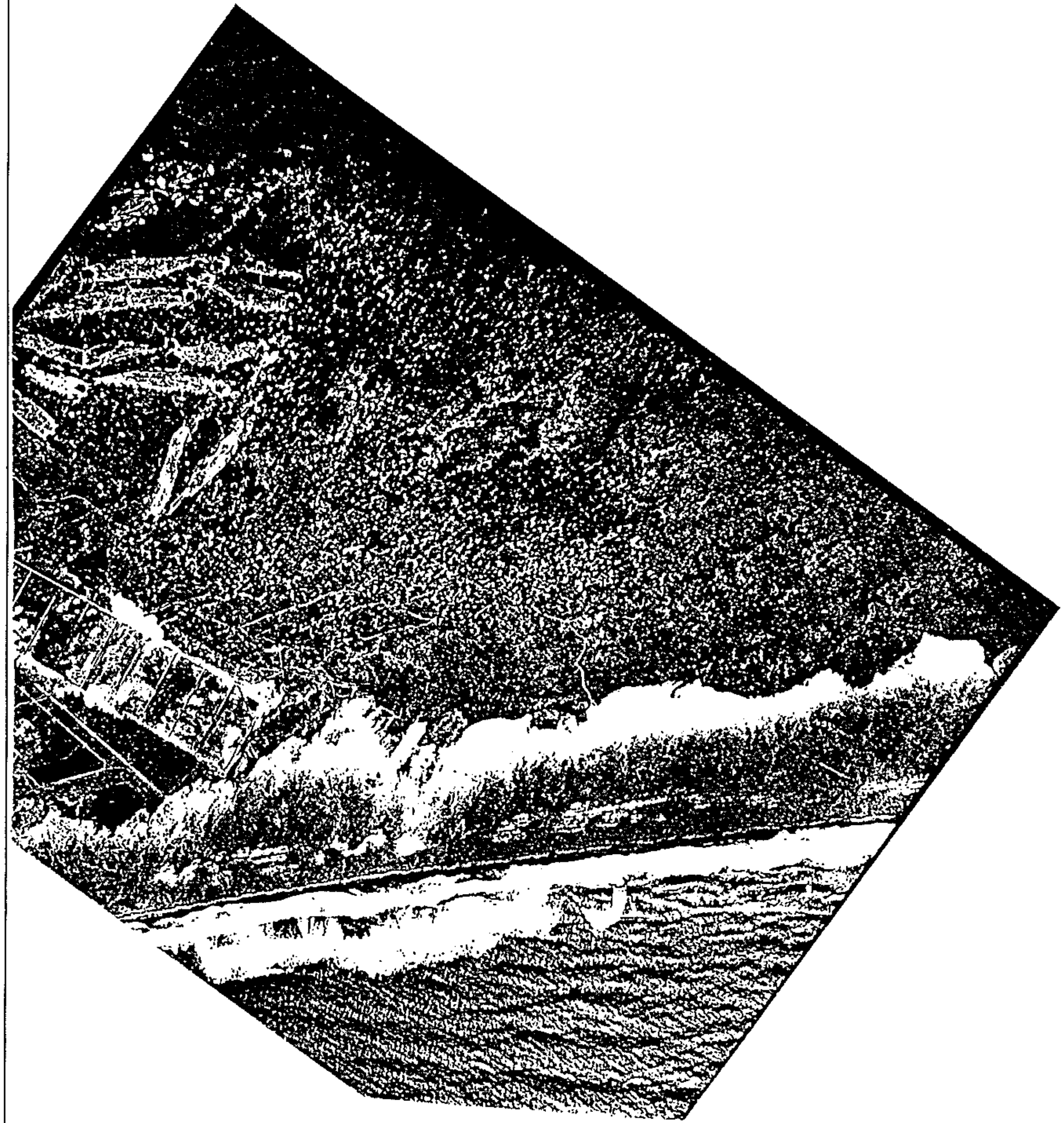
Table A1 - Aerial Photograph Summary

Date	Film No.	Flying Height	Frame	Figure No.	Comments
11-40	SVV 3080	Sc 1:26800	28102	A1	Few access tracks, good vegetation cover. Not full coverage of the area.
28-8-52	RAAF V87 294	7500 ft (2286m) Sc 1:15000	5045, 5046, 5047, 5048, 5049	A2	Vegetation cover sparse in low lying areas to the west of present day Nelson Bay Rd. Cleared area for the ammunition depot near the Rifle Range. More access tracks in this southern area also.
11-59	Lands Newcastle Project NSW 477	5950 ft (1814m) Sc 1:15850	5028, 5029, 5030, 5070, 5186	A3	Some growth back in cleared ammunition area, good vegetation cover over rest of area.
26-9-65	Lands North Land Project NSW 1410	5950 ft (1814m) Sc 1:15850	5154, 5155, 5156	A4	Establishment of wide track along the edge of the golf course toward the main road. Vegetated area to the south of the rifle range has been reduced by beach inundation/erosion. Track into the hind dune area at southern end.
11-3-72	RAAF V2 7176	21000 ft (6400m) Sc 1:25200	210,213	A5	Tracks in last photo now have some regrowth. Nelson Bay Rd established and areas to the west now more vegetated.
1-7-72	Lands NSW 2020	2000ft (6096m) Sc 1:40000	5025	A6	Tracks established north end boundary. Cloud over part of study area.
9-9-72	Lands NSW 2035	20000 ft (6096m) Sc 1:40000	5002	A7	Regrowth on tracks at north boundary. Little change in vegetation cover.
27-5-75	Lands NSW 2314	6401 m Sc 1:42260	89, 135	A8	Little change in vegetation coverage. wreck of the Signa (1974) appears at north end of study area. Stockton STW now has only 3 ponds.
21-5-76	CMA NSW 2388	3658m Sc 1:24150	12,13, 15,16, 17	A9	Little change in vegetation coverage. Excavation road into southern area similar to that in photo 9/65
17-11-76	CMA NSW 2418	1219m Sc 1:8000	168,169 170,171 172	A10	Possible sand removal from road at end of hind dune southern end.

Table A1 - Aerial Photograph Summary (continued)

19-8-77	CMA NSW 2460	6096m Sc 1:40000	91,92	A11	Cleared area on northern boundary on the Boral land, possible mining operation.
23-5-79	CMA NSW 2775	610m Sc 1:4000	104	A12	Only small part of the study area shown in photo. Tracks on the dune indicate usage by recreational vehicles.
18-3-81	Qasco NSW 3035	10000 ft Sc 1:20000	717,718	A13	Area revegetated at northern boundary on the Boral land (that was cleared in 19/8/77 photo series).
27-11-81	CMA NSW 2955	3028m Sc 1:20000	140,141 146,148	A14	Large track made near the rifle range to access area at rear of the hind dunes. Similar sand removal area at the rear of the hind dune on the Boral land.
18-1-84	CMA NSW 3362	3048m Sc 1:20000	5,6,7 15,16, 17	A15	Vegetation cover still good, no distinct areas of significant change.
22-5-86	CMA NSW 3520	2452m Sc 1:16000	66,68	A16	Little change since last photo series.
10-8-91	Lands LIC NSW 4027	2515m Sc 1:16000	4,5,6, 7,9	A17	Cleared area to the north of Coxs Lane being revegetated. Vegetation in Dept Housing land appears sparser than some earlier photos (may be the exposure of the contact print).
11-8-91	Lands LIC NSW 4027	1265m Sc 1:8000	156-158	A18	Only small portion of the study area shown in the photo series.
16-9-91	Qasco Qas2740c	3,500ft (1067m) Sc 1:12000	9305, 9309, 9313	A19	Dept Housing lot appears more sparsely vegetated than some previous photos (may be the exposure of the contact print). Revegetation of mining area to north of Coxs Lane progressing.

From these photographs it can be seen that little overall significant change in the quality and coverage of the vegetation coverage has taken place since 1940. This indicates that vegetation coverage can be stable in this area over a period of at least 50 years. A few instances of cleared areas being revegetated are apparent and seem to have been successful. No attempt has been made to determine recession or transgression rates from these photographs but rather the available results from SCS (1985) and PWD (1977) have been used.



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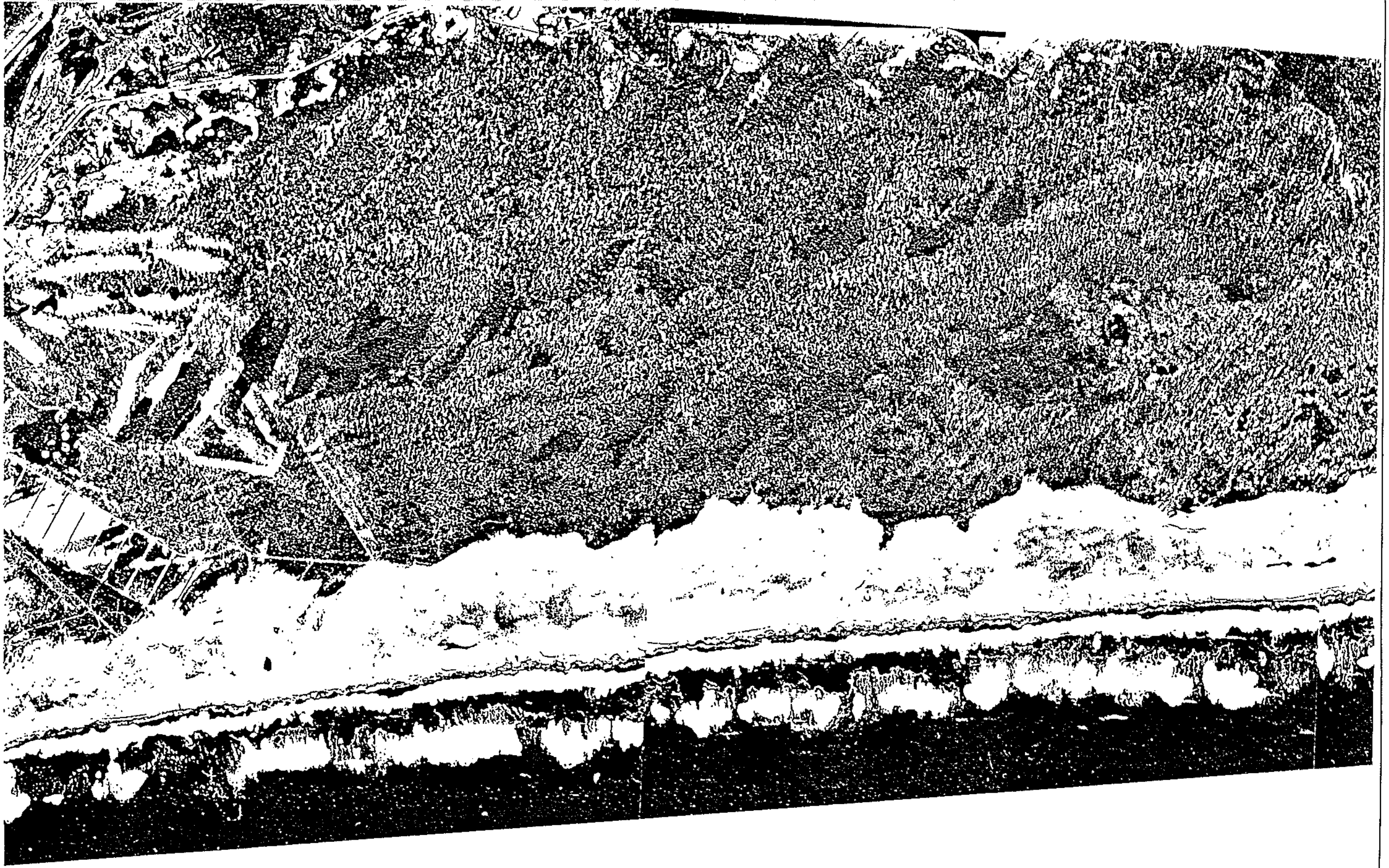
Report No. 92/05

AERIAL PHOTOGRAPHY MOSAIC 11-1940

Figure
A1



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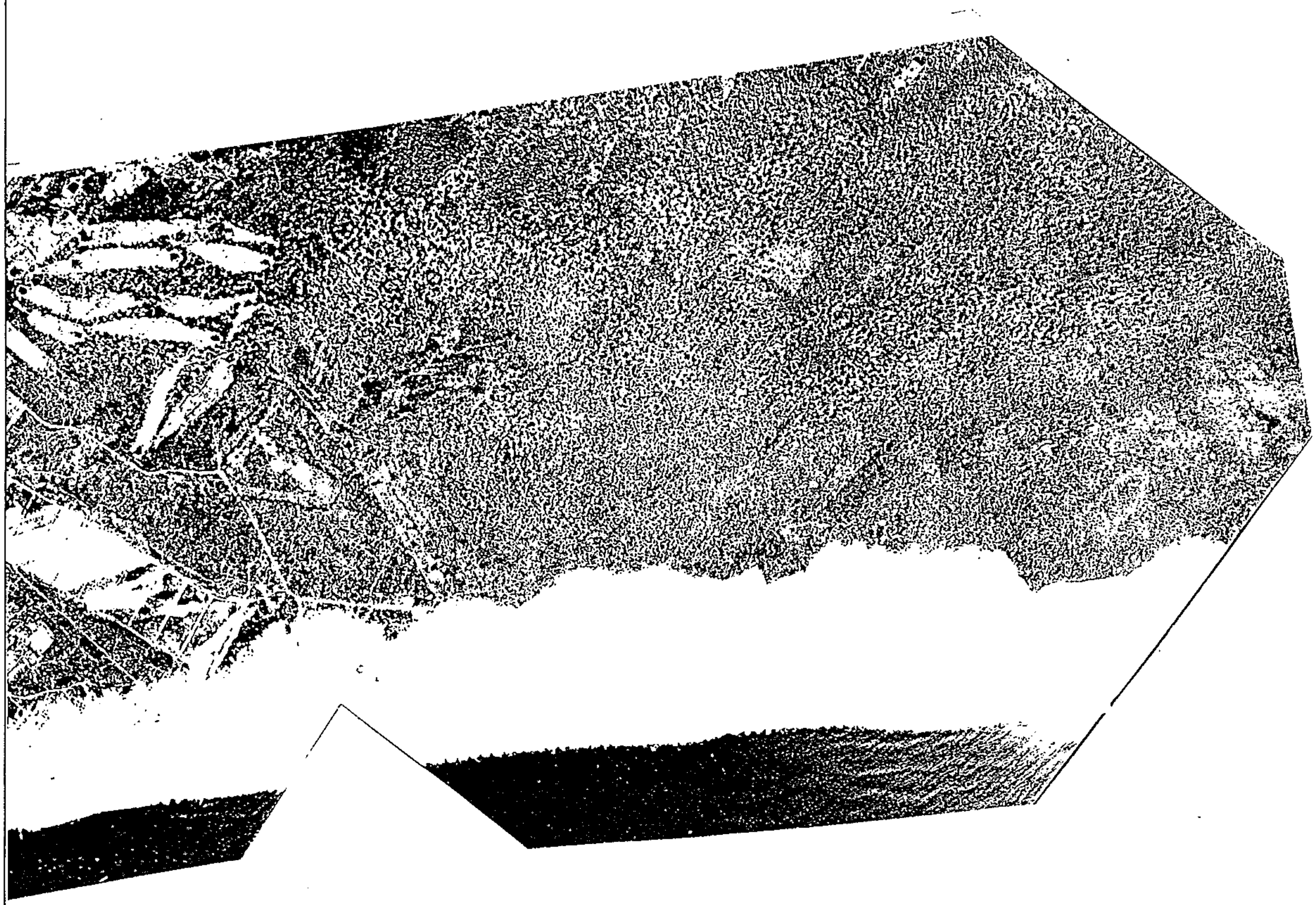
AERIAL PHOTOGRAPHY MOSAIC 28-8-52

Figure
A2



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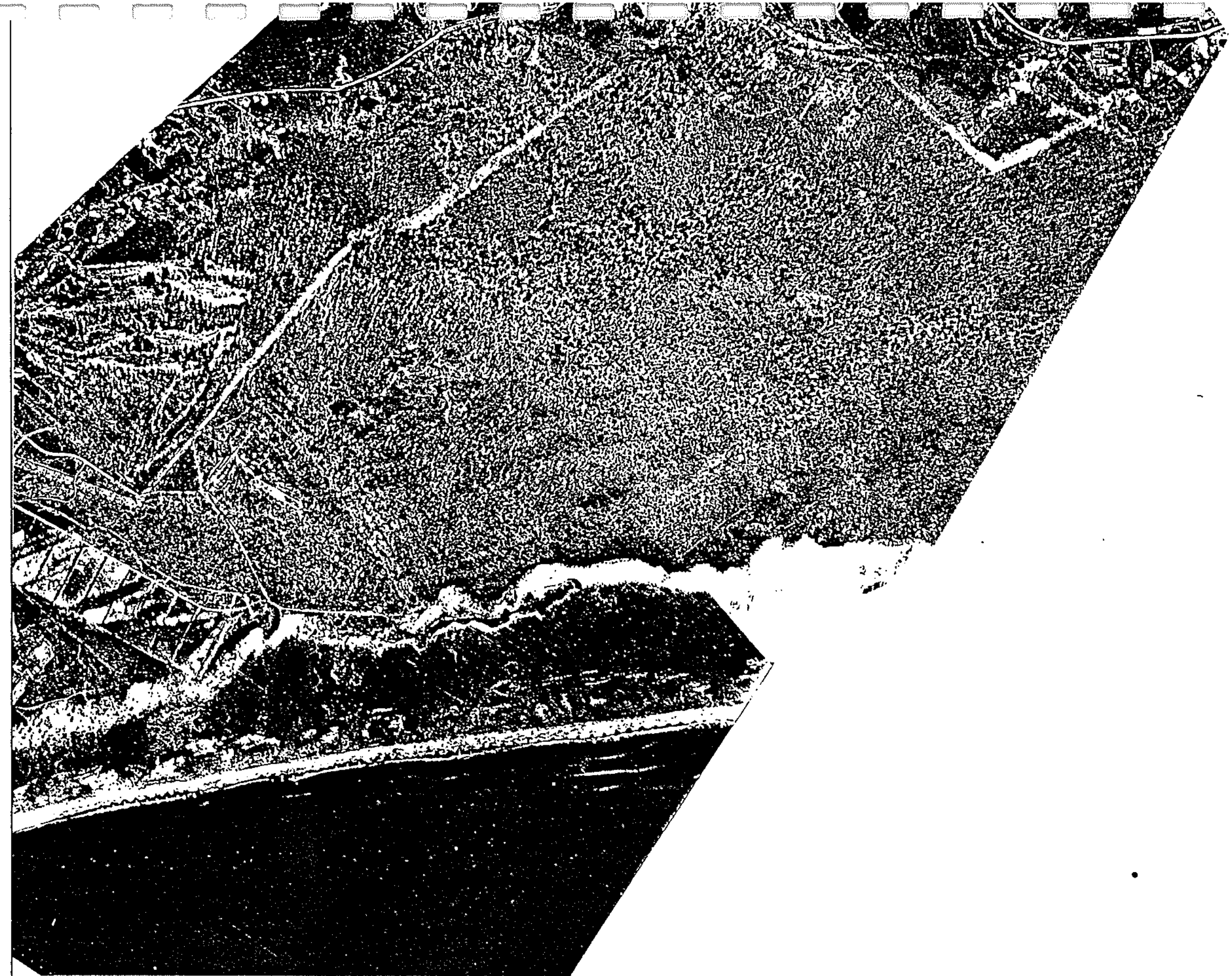
AERIAL PHOTOGRAPHY MOSAIC 11-1959

Figure A3



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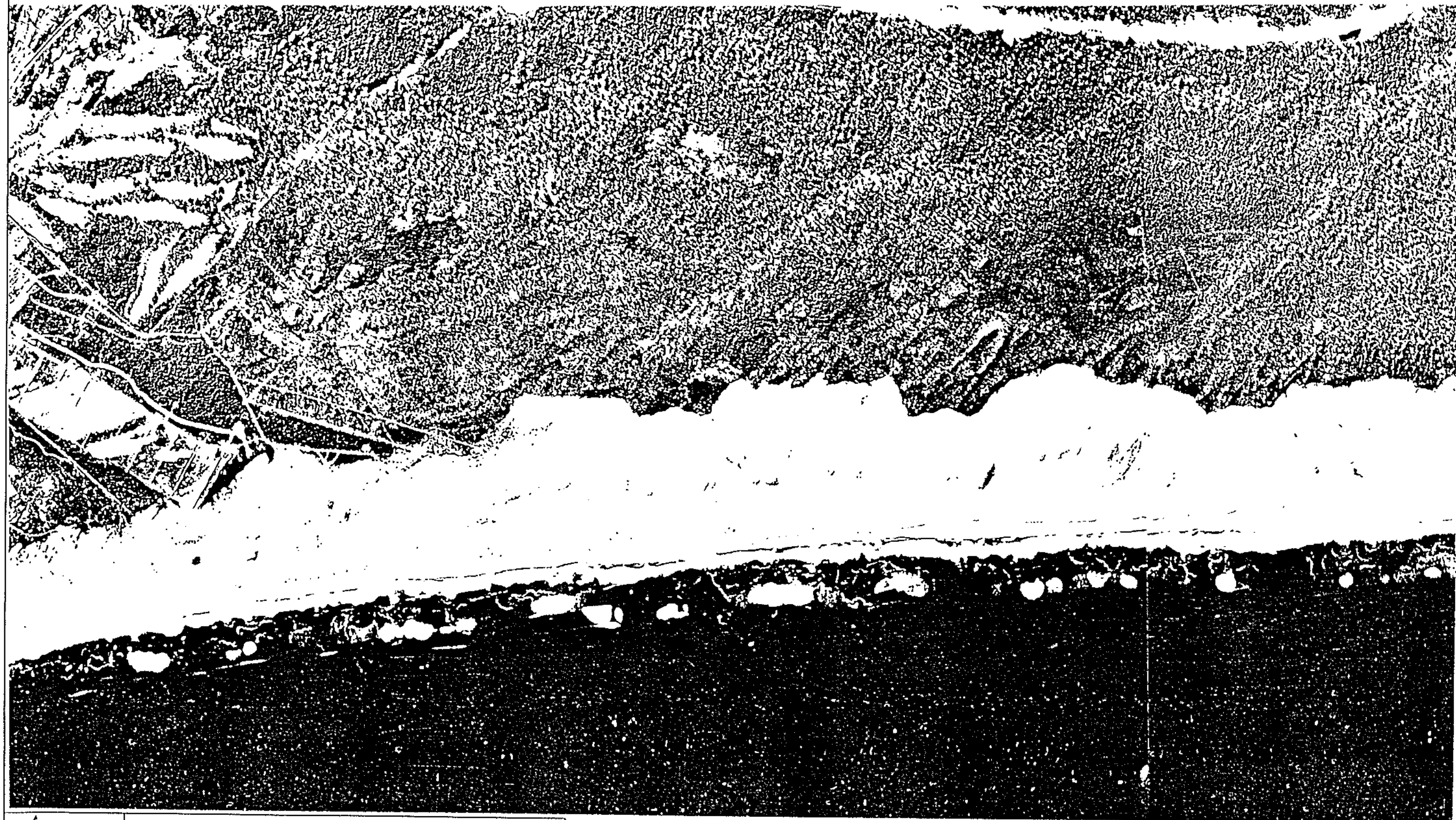
AERIAL PHOTOGRAPHY MOSAIC 26-9-65

Figure A4



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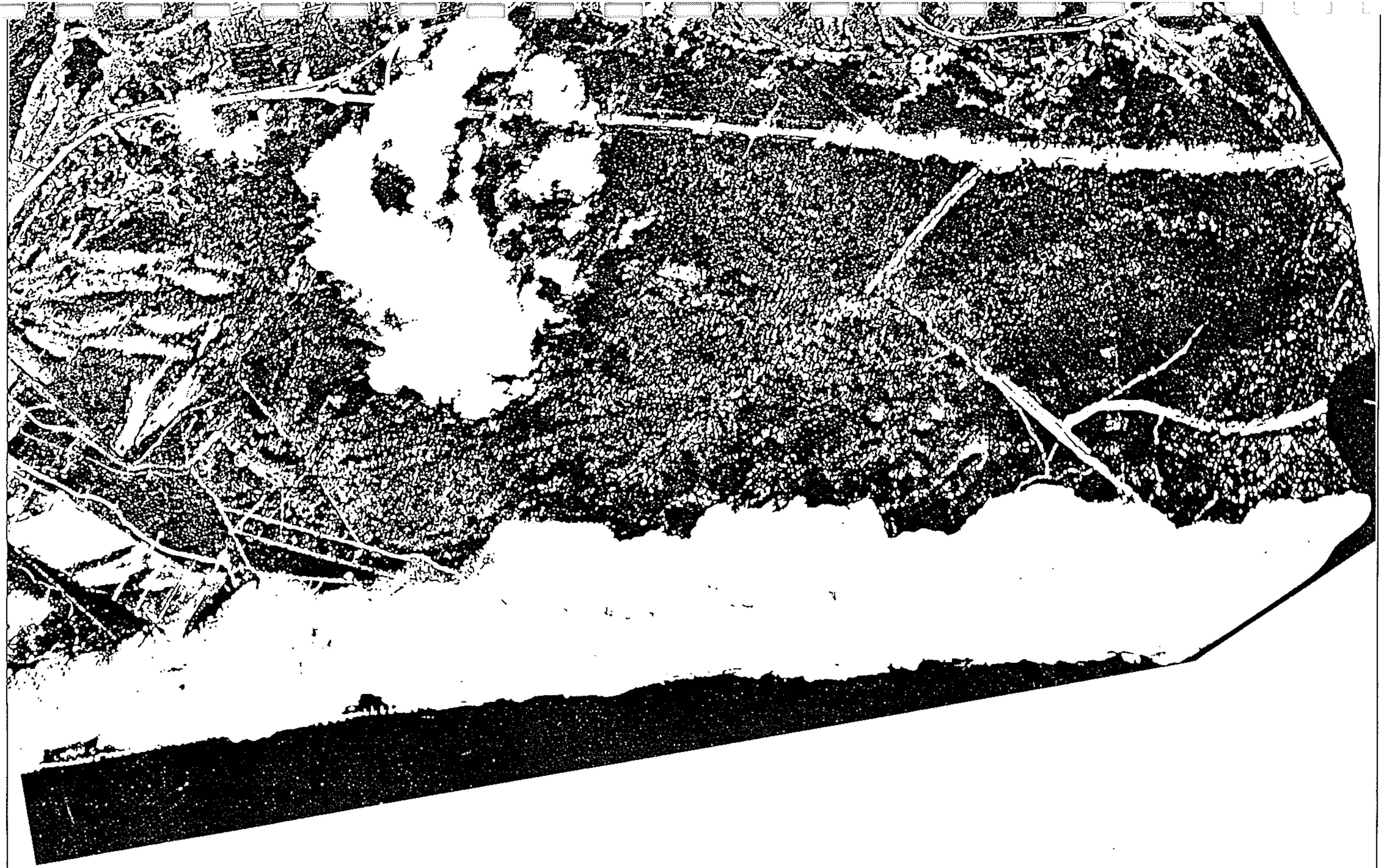
AERIAL PHOTOGRAPHY MOSAIC 11-3-72

Figure A5



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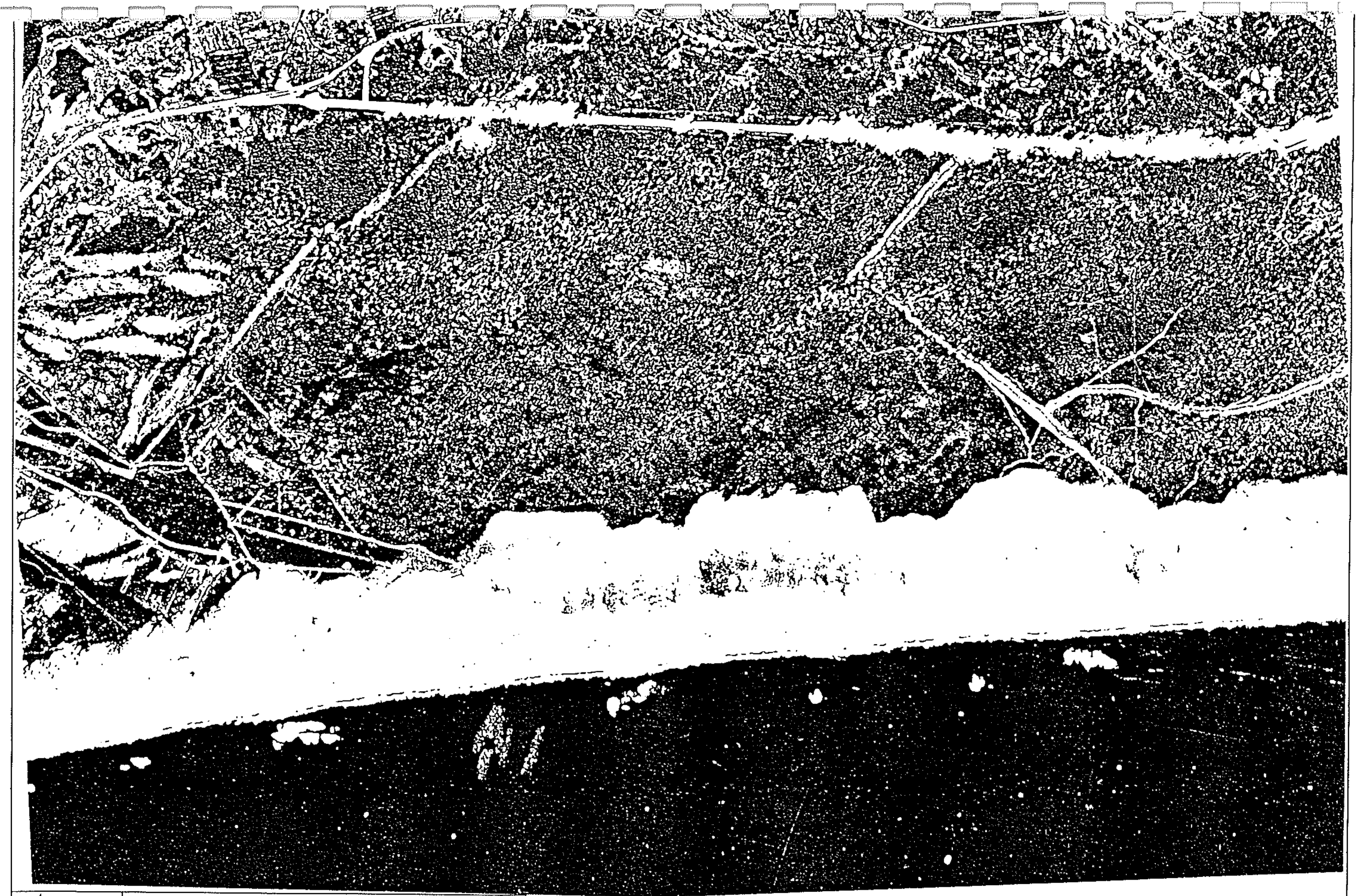
AERIAL PHOTOGRAPHY MOSAIC 1-7-72

Figure A6



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AERIAL PHOTOGRAPHY MOSAIC 9-9-72

Figure A7

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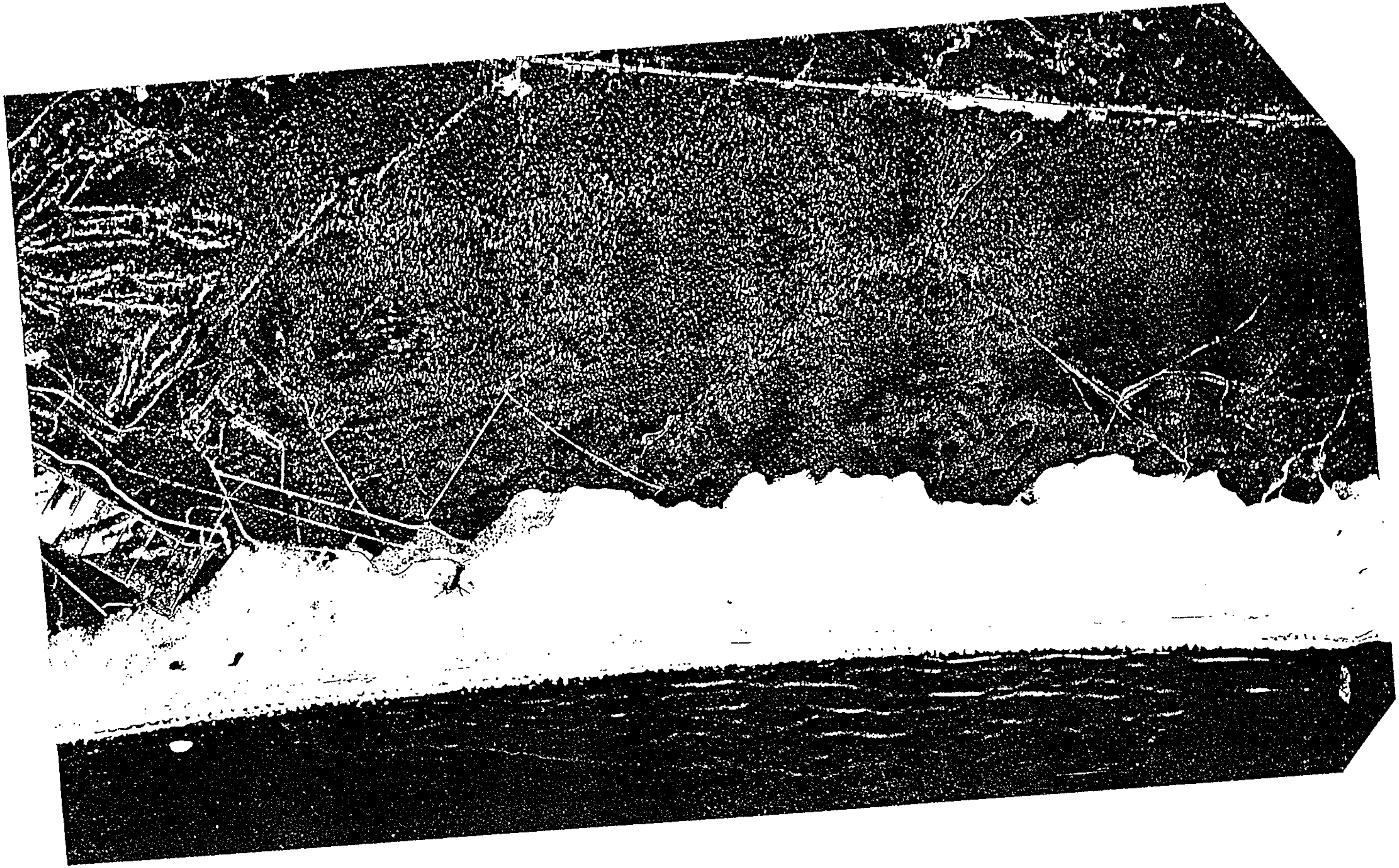
AERIAL PHOTOGRAPHY MOSAIC 27-5-75

Figure A8



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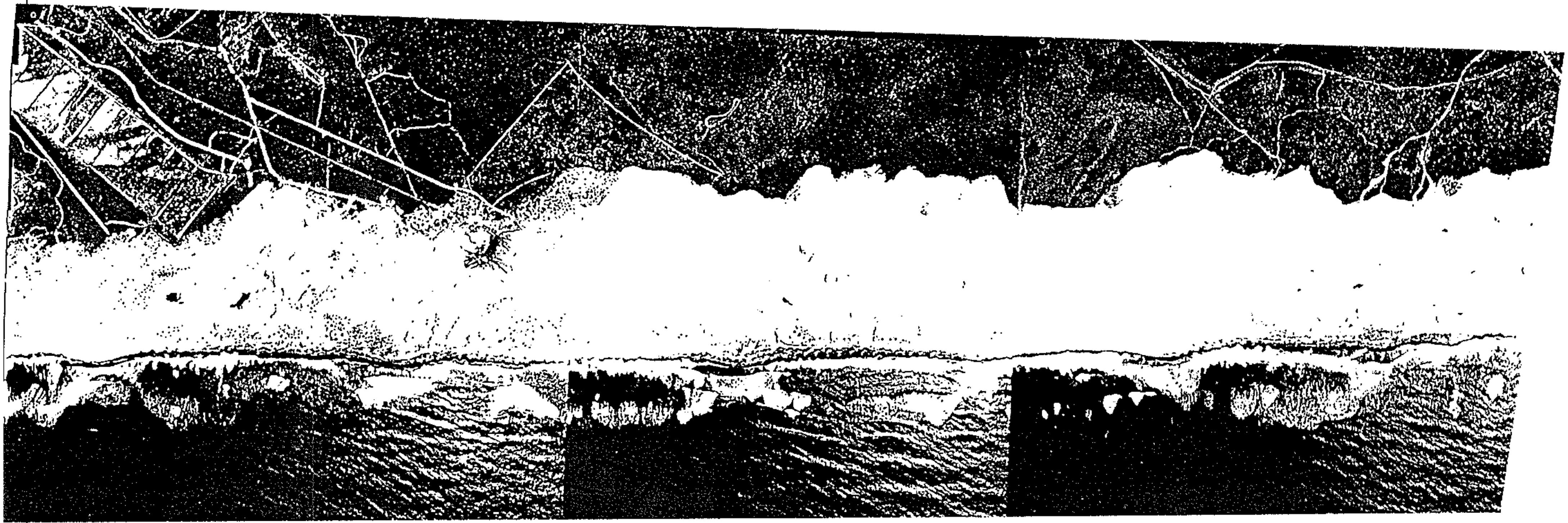
AERIAL PHOTOGRAPHY MOSAIC 21-5-76

Figure A9



AWACS Report No. 92/05

AERIAL PHOTOGRAPHY MOSAIC 17-11-76

Figure A10

AWACS
Report No. 92/05

AERIAL PHOTOGRAPHY MOSAIC 19-8-77

Figure
A11

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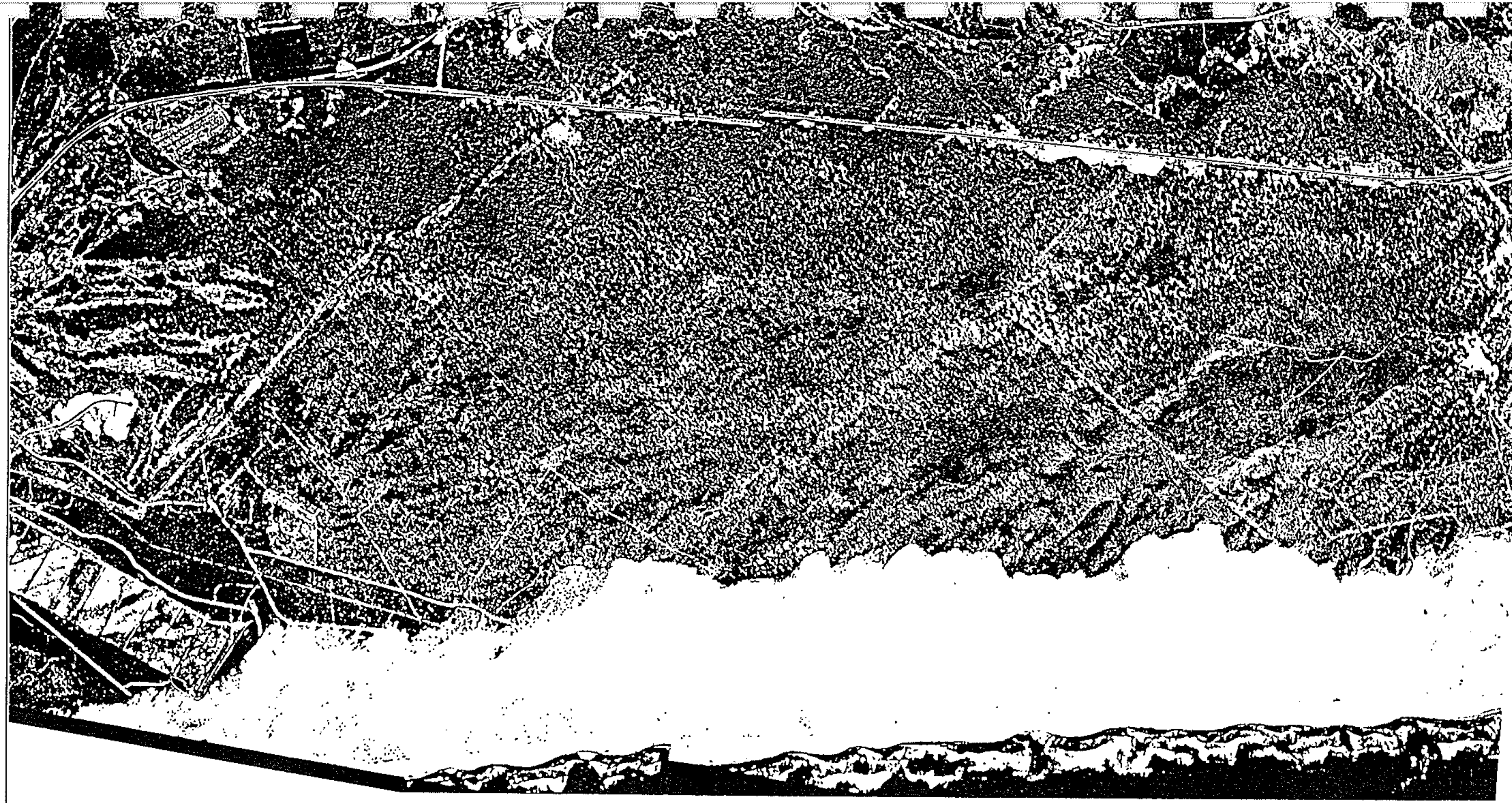
Report No. 92/05

AERIAL PHOTOGRAPHY MOSAIC 23-5-79

Figure
A12



AWACS Report No. 92/05

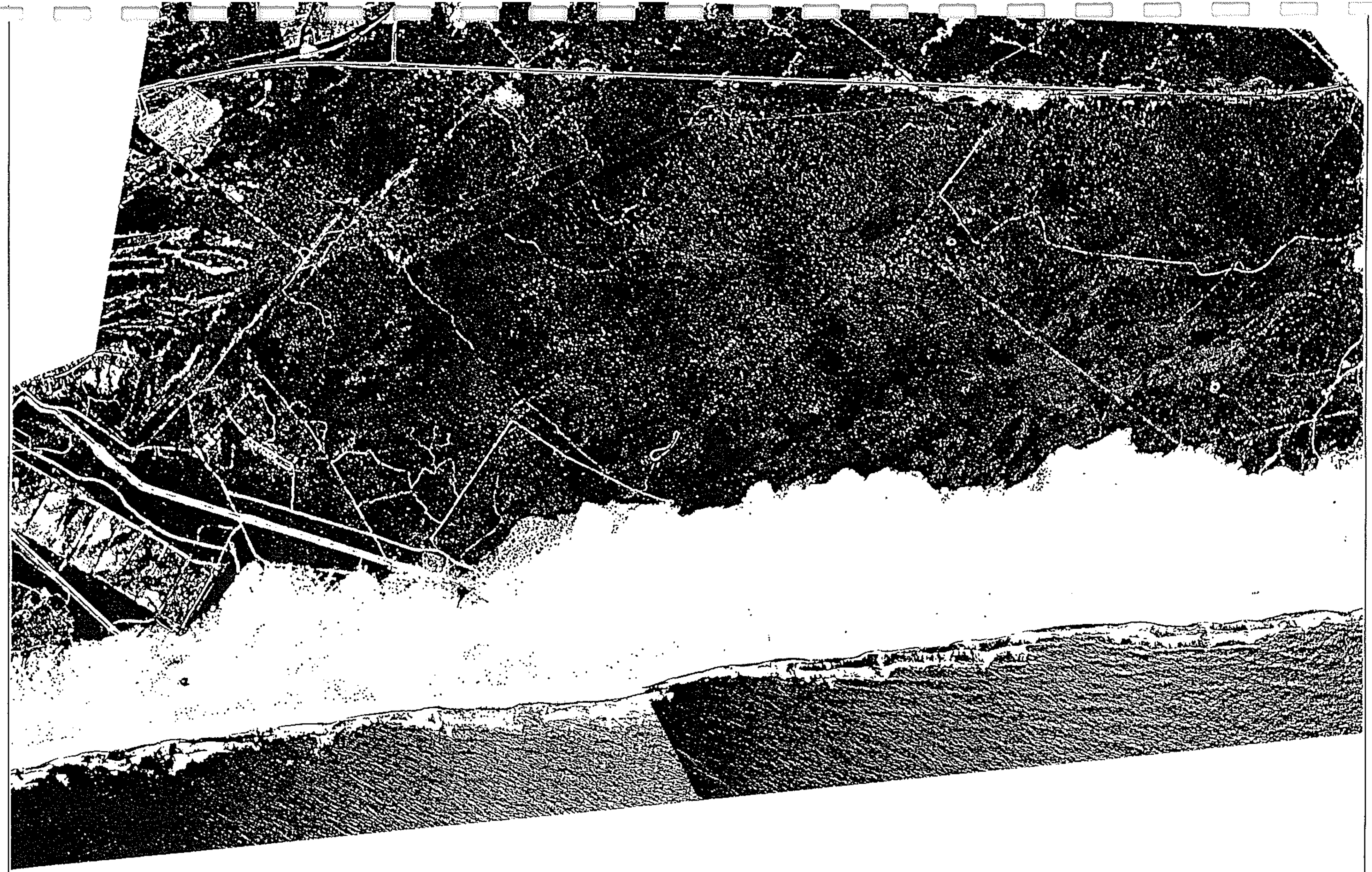
AERIAL PHOTOGRAPHY MOSAIC 18-3-81

Figure A13

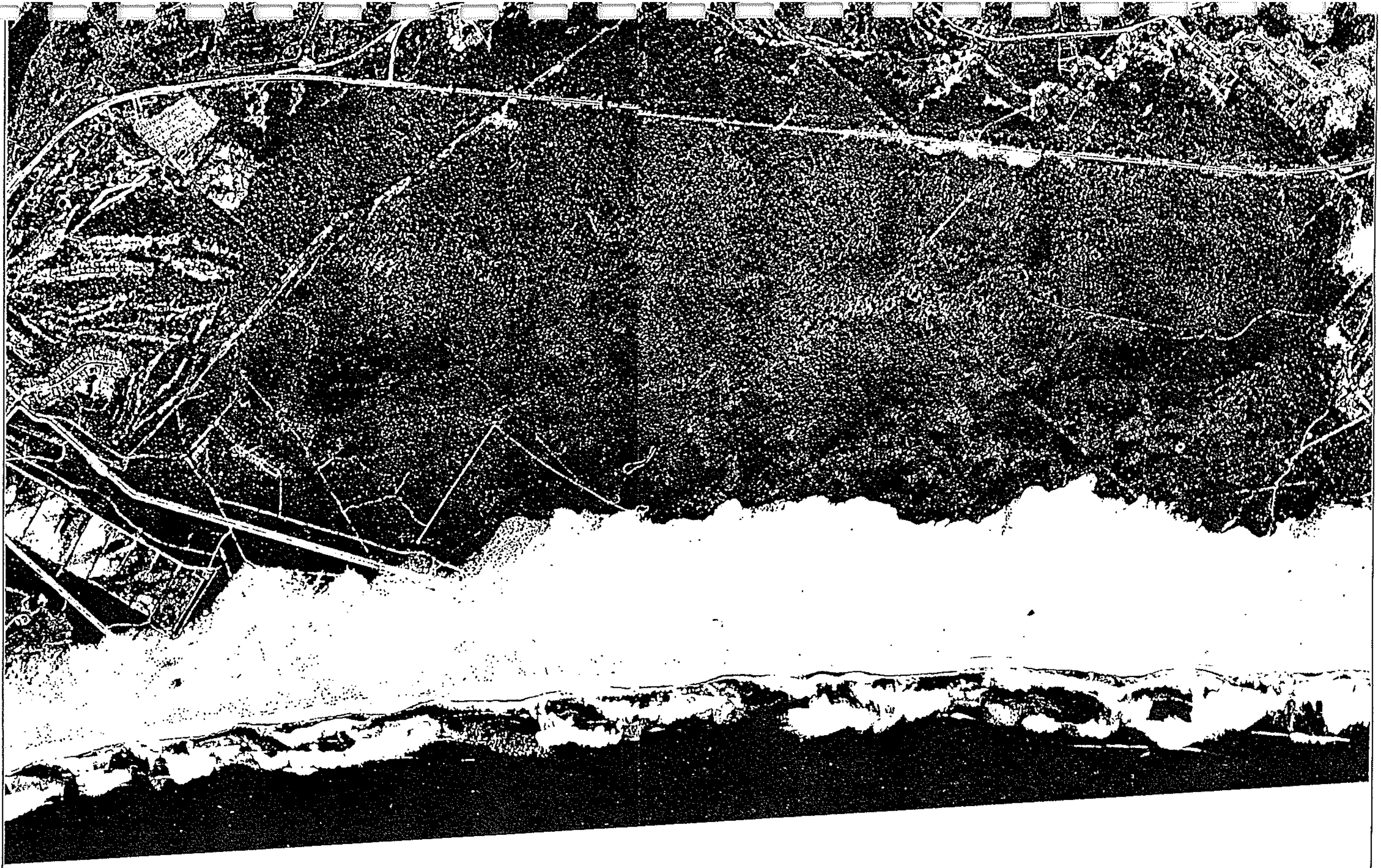
AWACS Report No. 92/05

AERIAL PHOTOGRAPHY MOSAIC 27-11-81

Figure A14



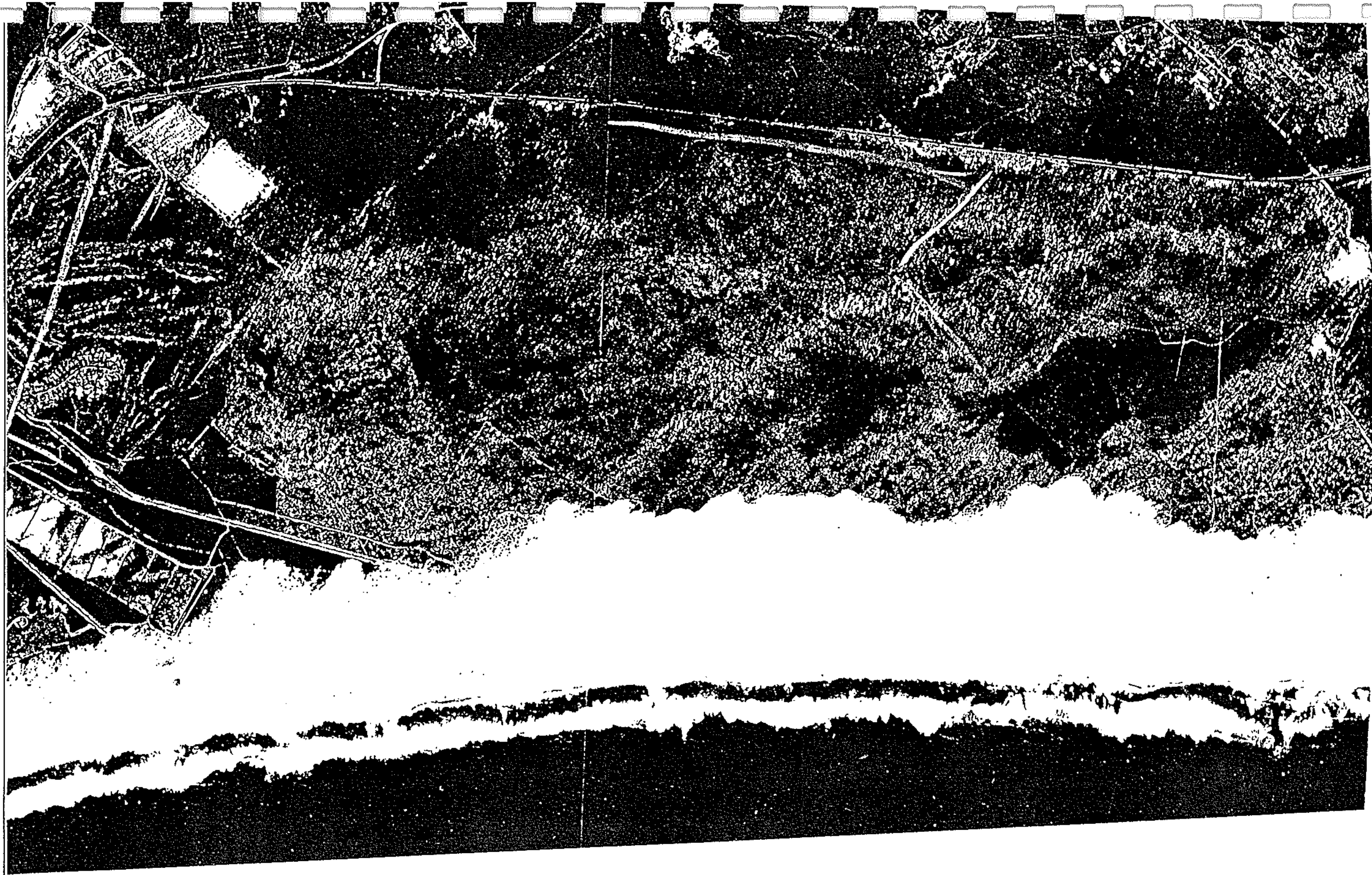
AWACS Report No. 92/05	AERIAL PHOTOGRAPHY MOSAIC 18-1-84	Figure A15



AWACS Report No. 92/05

AERIAL PHOTOGRAPHY MOSAIC 22-5-86

Figure A16



AWACS Report No. 92/05

AERIAL PHOTOGRAPHY MOSAIC 10-8-91

Figure A17

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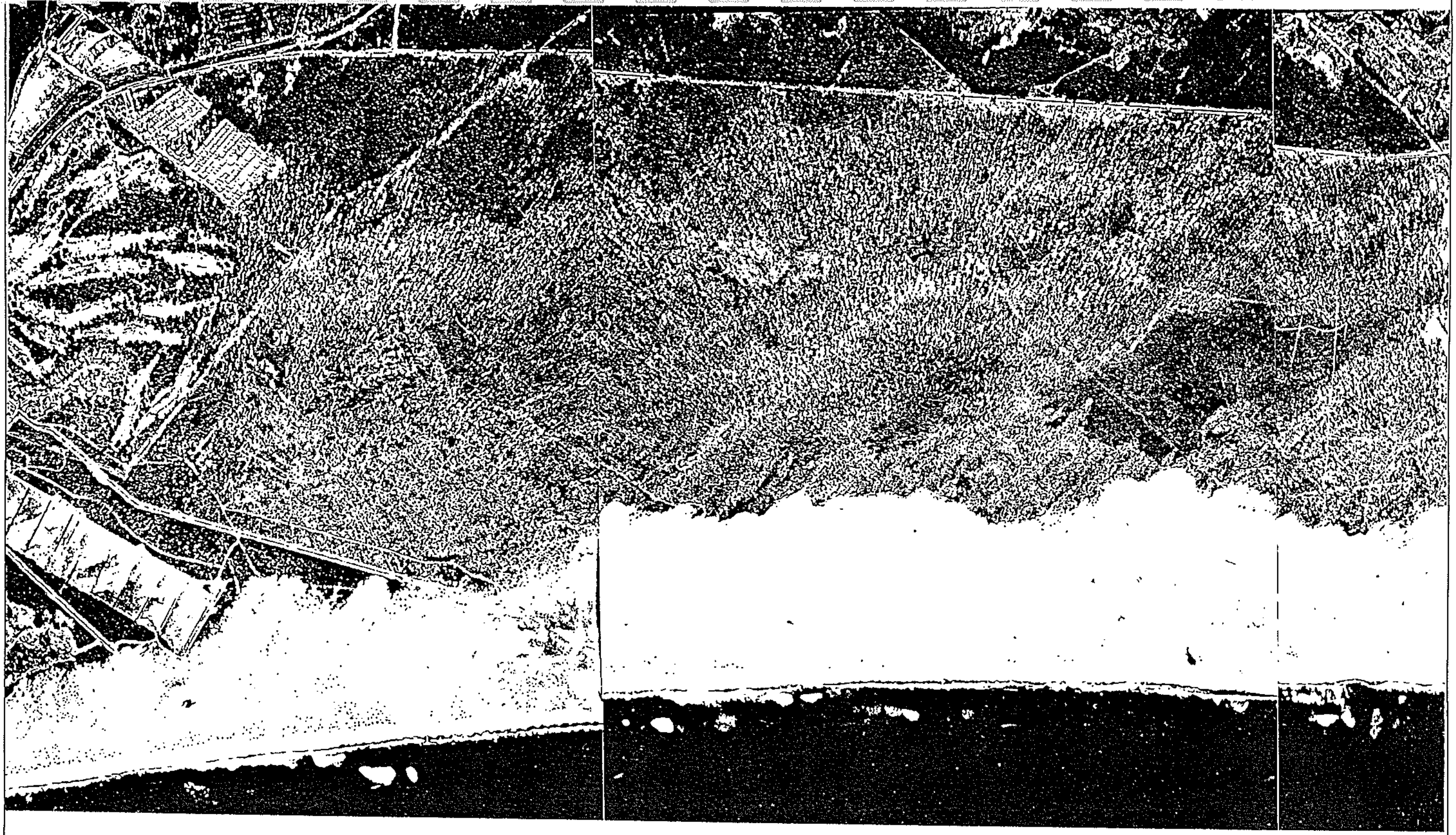
Report No. 92/05

AERIAL PHOTOGRAPHY MOSAIC 11-8-91

Figure
A18



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Report No. 92/05

AERIAL PHOTOGRAPHY MOSAIC 16-9-91

Figure
A19