AERIAL PHOTOGRAPHY AND ENVIRONMENTAL IMPACT ANALYSIS:

The potential contribution of comparative interpretation

of multi-temporal aerial photographs

to Environmental Impact Analysis.

by

Sandra Bayne

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ABSTRACT

The hypothesis was advanced that comparative interpretation of multi-temporal aerial photographs can be used as a tool in Environmental Impact Analysis (EIA). To test this hypothesis a site, Silwerstroomstrand, approximately 40 kilometres north of Cape Town on the West coast was chosen.

An analysis of the site was carried out using aerial photographs taken in 1938, 1960, 1968, 1971, 1977, 1981 and 1983 at scales ranging from 1:7 000 to 1:50 000.

Development of the site for recreation began in 1972 and in 1976, for water extraction. Pre-development photographs, 1938, 1960, 1968 and 1971, were stereoscopically compared and the observations were interpreted using a systems approach. From the analysis of the photographs and information on past landuse, the dynamics of the site were described with particular attention to the response of that environment to perturbations such as fire and removal of vegetation.

Development actions were analysed to establish any similarity to past perturbations and on the basis of similarities, predictions of probable future responses of the site (and hence impacts) were made.

The predicted impacts were compared with:

1. the interpretation of post-development photographs.
2. impacts identified by a multi-disciplinary panel after a visit to the site

It was found that the major limitation of multi-temporal aerial photographs was the spatial resolution of the early (pre 1970) photographs. However, the capabilities of the tool for-

quantitative and semi-quantitative data gathering;
promoting an understanding of spatial and temporal relationships;
monitoring change;
communicating information and
the fact that it is economical

means that it has a postive contribution to make to Environmental Impact Analysis. It is suggested that the optimal use of the tool of comparative interpretation of multi-temporal aerial photographs is to combine it with other tools such as site visits and multi-disciplinary panels.

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PREFACE

Although the findings of this study are based on aerial photographs and an essential part of interpretation is stereoscopic viewing, it is unfortunately prohibitively expensive to furnish each copy of the report with stereopairs of all the pictures used. Consequently only single copies of the earliest and most recent aerial photographs are included in the report.

These two photographs represent a good and worst case, for the 1938 picture is of a good quality whereas the 1983 picture is of poor quality, limited cover and the area on which this study is focussed, lies on the edge of the picture where maximum distortion occurs. In spite of these limitations comparison of these two photographs taken forty-five years apart gives the reader a good indication of the changes that have occurred within that timespan. Because of the limited area of the study site covered and the distortion the 1983 photographs have not been included in the quantitative analysis of the site.

Full details of all the aerial photographs used are given in Table 4 on page 35, including the individual sources of these photographs.

INTRODUCTION

"The aim of scientific explanation is to establish a general statement which covers the behaviour of the objects or events with which the science in question is concerned, thereby enabling a connection to be made between separate known events and to make reliable predictions of events as yet unknown" (Goudie 1981:3).

Based on Goudie's statement above, Environmental Impact Analysis (hereafter abbreviated to EIA) is a form of scientific explanation for it is a process aimed at recognising cause and effect; where the cause is any action of a proposed project which has an effect upon the environment. (Fuggle 1983:488)

The usual way in which the scientific analytical method would establish cause and effect would be to conduct experiments under controlled conditions. But, because of the complexity of components and interactions that make up even the simplest natural environment, it is seldom feasible or even possible to set up a controlled experiment to investigate the behaviour of the whole system. Thus this approach has severe limitations when applied to any complex system. Methods other than the analytical experiment must therefore be sought to investigate the behaviour of such systems.

Erickson, (1979:360) describing the current evolutionary stage of Environmental Impact Assessment (a process of which Environmental Impact Analysis is an important part) comments that "at this time the need of assessment is for experimentation with different approaches (and) with different analytical and integrative tools".
This study, therefore, explores the use of a series of aerial photographs taken at different times over a period of decades (multi-temporal aerial photographs) as a tool for providing insights into the process of recognising cause and effect within an environment and predicting environmental impacts within that same environment.

Multi-temporal aerial photographs provide "frozen models" of the environment at different points along a time continuum. The changes in elements of the environment observed through comparative interpretation can be regarded as the 'effects' of previous events. If these effects can be linked with known perturbations within the site (established by interviewing previous landowners and managers, exploring relevant research and from interpretation of aerial photographs) a model can be developed on which to base predictions of future change. The accuracy of these predictions will depend on the similarity in nature of the past and future perturbations. Even if there is little or no similarity it is suggested that the insights into the dynamics of the area will make a valuable contribution to the EIA process.

The hypothesis advanced is that the comparative interpretation of multi-temporal aerial photographs is a viable tool for use in Environmental Impact Analysis.

As Talkenberg (1982:6) has indicated, holistic studies are too wide-ranging to lend themselves to the strict scientific approach of hypothesis, test and conclusion. However this study attempts to evaluate on an objective qualititative basis, the hypothesis stated above.

THE APPROACH TO THE STUDY

In the knowledge that major infrastructural changes had taken place in 1972 at the chosen site, Silwerstroomstrand, a series of panchromatic black and white aerial photographs taken between 1938 and 1983 were acquired.

The study was then approached in three phases:
In the first phase, photographs taken prior to the infrastructural development, namely in March 1938, December 1960, April 1968 and December 1971, were examined stereoscopically. Photographic cover from the different years was compared and changes noted. The photographs were interpreted using a systems approach, paying particular attention to the observed changes. Possible causes for the changes were sought in:

1 Natural processes occurring at the site

2 Human actions within the boundaries of the area or its surroundings.

The proposed actions of the infrastructural development projects commencing in 1972, were examined and grouped according to similarity or dissimilarity with past perturbations. Predictions of the impacts likely to result from project actions comparable with past perturbations were made on the basis of the postulated cause and effect links derived from the comparative interpretation of the aerial photographs.

In the second phase, post-development photographs, taken in March 1977, April 1981 and March 1983, were examined, compared and changes noted. The predictions of impacts from the first phase were evaluated against the interpretation of the post-development photographs. This evaluation acted as an internal check on the validity of the predictions made in the first phase.

In the third phase the current impacts at the chosen site were identified and rated by a group of experts who undertook a field visit to the study site. The results of this exercise were compared with the impacts predicted from the first phase.

The study is presented in two parts.
Part One, encompassing Chapters 1, 2 and 3, gives background information on the concepts used and reviews the literature. Part Two describes the site and the methods used, sets out and evaluates the results and finally, draws conclusions.

PART ONE - BACKGROUND

CHAPTER ONE

ENVIRONMENTAL IMPACT ANALYSIS

The inter-relatedness of all the facets - physical, biological and social - of any environment means that no powerful external action can be expected to have only one consequence which is confined to the facet at which it was primarily directed. The action is bound to affect other facets as well. "Our old-fashioned common sense has not had to face such situations before and is not well adapted to doing so. We need nowadays to be able to think not just about simple processes but about complex systems" (Waddington 1977 : xii). It is in response to this need and the increasing pressures of expanding world population on finite natural resources that Environmental Impact Analysis (EIA) and Environmental Impact Assessment, of which broader field EIA is a part, have come into being.

Environmental Impact Assessment received considerable impetus with the passing into law of the National Environmental Policy Act (NEPA) in the United States of America on 1 January 1970. This Act required that an evaluation be undertaken of the potential environmental impacts of all projects, laws and actions proposed by Federal agencies. Methodologies and techniques were rapidly developed to meet the new legal requirements and research and experimentation burgeoned. New terminology also proliferated with resulting confusion. Fuggle (1983:488) has clarified the definition of the various terms and has indicated the relationship of one term to another. environmental impact analysis has been described as "a process contained in environmental impact assessment by which the environmental effects of a project are analysed". environmental impact assessment is "the administrative process by which the environmental impact of a project is determined".

A number of authors have pointed out that because EIA concerns itself with complex systems and their even more complex interactions, it has limited predictive power. Considering only the biological aspects of the environment, Moss (1976:84) states that "in perhaps more than 99% of species, the detailed significance (of those species within their ecosystem) is completely unknown, simply because the system is too complex for our present abilities to investigate it. Hence our abilities to predict the future of current ecosystems are very limited".

Add to this the fact that interactions occur between our social and physical environments and that we simply do not know what all these relationships and interactions are (Erickson 1979:14), and the result is a further dimension of complexity. Confronted with this considerable challenge EIA faces a basic problem - whether to proceed more in the direction of analysis or more in the direction of integration (Erickson 1979:89).

There are many indications of a move in the direction of integration. Gutkind (1956:1) describes a general trend away from an over emphasis on the purely analytical approach toward synthesis and unitary ideas. However he indicates that both analysis and synthesis are needed and should be applied to every problem on equal terms.

Comparative interpretation of aerial photographs is a potential tool for both analytical and integrative insights. The integrative potential lies not only in the spatial dimension it presents or in the use as an interdisciplinary tool, (see fuller discussion in Chapter 2) but also in its unique ability to encompass the dimension of time through comparison of multi-temporal aerial photographs of a particular area.

"The conquest of the air enables mankind for the first time in its history to experience (the) interaction (of man and nature shaping the face of the earth) in all its innumerable ramifications. A new scale in time and space has been added to our mental and material equipment" (Gutkind 1956:1).

One of the responses to dealing with the problem of complexity has been to draw heavily on the insights of past experience. Moss (1976:87) comments that the only predictions that can be made about ecosystems are broad ones based on previous experience. Against this background comparative interpretation of aerial photographs may have a unique contribution to make to EIA.

CHAPTER TWO

AERIAL PHOTOGRAPHY

Whenever there is no physical contact between an object and a sensor the process of remote sensing occurs. The simplest form of remote sensing is merely looking at an object. Basic to the process is that some form of energy must be reflected by, or transmitted from, an object to a sensor. Aerial photography is but one small section in the broad topic of Remote Sensing.

Information can be derived from all parts of the electro-magnetic spectrum, with each wavelength furnishing different data. In this study only information from the visible portion of the spectrum has been considered. Whilst this represents a small fraction of the total range of wavelengths of radiation that can be remotely sensed it is the portion that is most easily captured in a permanent form as a panchromatic black and white photograph.

The greater the distance between object and sensor the more information that is generally included in a scene, but the smaller the scale of the resulting image. A sensor on the platform provided by an aircraft observing the ground normally depicts a view of smaller scale and greater regional perspective than a sensor on the ground, whilst a spacecraft-borne sensor gives information at an even smaller scale and with a broader perspective than the aircraft-borne sensor.

2.1 Choice of aerial photography for this study

Many human activies create change on a measurable scale and add new components to existing natural processes. As a result new interactions are generated which result in environmental effects and potentially in environmental impacts. To understand environmental impacts it is necessary to detect, and where possible measure, changes that occur in the environment. Multi-temporal photographs lend themselves to detection of a wide range of change and hence offer a means of detecting environmental impacts.

Of the various types of sequential remote sensing imagery that are available aerial photography was chosen because it provides the most retrospective view of the South African environment. Aerial photography began on a regular basis in South Africa in the 1930's, at a point in the development of the country when many of the major environmental changes of today had not yet manifested themselves. The early photographs can thus often provide baseline data against which to measure subsequent change. As all the early photographs were panchromatic black and white this was the imagery chosen for this study.

2.2 The holistic nature of aerial photography

The analytical approach that has characterised the scientific method has been responsible for many of the insights and achievements of science and technology. Nevertheless, a narrow focus on a single aspect of a problem has not, on its own, proved a satisfactory means of approaching environmental problems. The interrelatedness of the components of a single system e.g. rainfall and vegetation as components of the ecosystem, and the interrelationship between different systems e.g. physical and social systems, requires the addition of a broader integrative view to complement the analytical approach (Gutkind 1956:1). Such an holistic approach which aggregates the results of analysis, seeks for patterns and interprets them within the context of a broad system, is the goal of ecologists and environmentalists.

The synoptic view offered by an airborne platform is a major contributor to the holistic nature of aerial photographs (Gutkind 1956:1. Weisser 1979:70). This is because patternings and interfaces are more readily apparent (Edwards 1972:100), and because it is often easier to appreciate the significance of system components from the wider perspective lent by distance. For example stream valleys may appear as relatively insignificant irregular depressions between rolling hills when viewed from the ground but their structure and function, and hence their significance within the landscape, readily become apparent on an aerial photograph. Furthermore, the range of information that can be collected from aerial photographs promotes an holistic approach. An example of this is that Archaeology, the epitome of an integrative discipline, is increasingly using them to gather information about the distribution of resources and other environmental properties

(Ebert 1980:1). A measure of the growing importance of aerial photographs in this context is the appearance in 1977 of a journal entitled Aerial Archaelogy.

It is because aerial photography is an holistic tool that it opens a broader view on the relations between various large scale natural phenomena (Schanda 1976:1). In addition to the spatial perspective offered, a sequence of images of the same area at different times offers a temporal perspective which is an important ingredient in the holistic viewpoint. The slow steady incremental changes which insidiously escape detection on the ground are unambiguously evident on sequential aerial photographs of the same area. Repetitive observation gives an overview of earth dynamics previously difficult or impossible to obtain.

The broad spatial and temporal perspectives of aerial photographs make them an eminently holistic tool which should have a valuable contribution to make to any attempt to understand the dynamics of the environment.

2.3 Aerial photography and environmental impact studies.

Appendix A gives a review of the use of aerial photography in South Africa. From this review, it is apparent that in the past decade a considerable body of information has been established from research involving air photos.
Although there is a clearly identifiable trend towards greater use of aerial photographs in monitoring studies,

there is no evidence from the research proposals for 1984 and the research register of the National Programmes for Remote Sensing that any attention is as yet being focussed on research into the contribution of Remote Sensing to Environmental Impact Studies in South Africa. This is in contrast to the situation internationally where an indication of this trend is shown in a recent issue, March 1981, of the journal "Remote Sensing of the Environment" in which an advertisment appeared for a book on "Remote Sensing and Land Use Planning and Environmental Impact Assessment."

Multi-temporal studies have furnished valuable information on the dynamics of processes operating in the area photographed. Not only is information available on the processes operating but it is also possible to deduce the rates of change at which they operate. The information that is being accumulated about changes in the environment being induced by human activities has an important contribution to make to planning and management as well as to case studies of how the South African environment has changed. Overall the insights afforded by the use of aerial photographs are providing environmental perspectives that would not otherwise be available.

CHAPTER THREE

COMPARATIVE INTERPRETATION AND THE SYSTEM APPROACH

Image interpretation is "the act of detecting, recognizing and classifying the Earth's surface and subsurface characteristics using remotely sensed data" (Townshend 1981:80). The way in which the data are classified depends on the theoretical constructs of the particular discipline from which the data are being analysed. Thus a botanist may interpret vegetation quite differently than a geologist.

The environmentalist should have an holistic outlook and approach problem solving with the insights of numerous disciplines. Thus the theoretical constructs against which an environmentalist would interpret data requires an overarching theoretical base to unify the insights of the diverse contributing disciplines. The Systems Approach holds promise for achieving this. Chorley (1971:1) states that "Systems can be identified at all scales of magnitude and with all degrees of complexity... reality is a hierarchy of organised systems. Indeed, it may be that such a view of the real world - as an interlocking set of systems - will provide a greater impetus to the unification of all sciences than will their analysis in terms of physical and chemical attributes."

3.1 Systems and the Systems Approach

The formal definition of a system is - "a set of objects together with relationships between the objects and between their attributes."The definition fails to give the slightest hint that the system itself is relative to the viewpoint of some observer. The idea of set is very common in mathematics, but contrary to the impression of precision it gives, it is one of the undefined primitives in most theories" (Weinberg 1975;63). In essence, a system is a way of looking at the world. The consequence of this is that "Sytems are thoroughly man-made...When we include a given relation in a system, or omit it, we may do well or ill; but such an inclusion creates no truth, and such omission indicates no falsity. The justification for one's procedure, in this respect, is purely pragmatic; it depends upon the relevance of what is included or omitted to the purposes which the system is designed to satisfy." (Lewis and Langford, quoted in Weinberg 1975:61)

The systems approach is an aid to thinking. it is a much needed aid when thinking holistically about complex systems. It is significant that much of the Systems literature cites environmental problems as an example of an area where the conventional analysis that "a causes b, b then causes c, then c causes d", is quite inadequate (Waddington 1977:xi. Dury 1981).

Lilienfeld (1978:10) points to one of the powerful attributes of the systems approach when he comments "What is relevant to the development of systems theory is the 'organizing' property of contextualism. The world of experience is seen as a chaos of potentialities that spring into a meaningful form only under an organizing context. Parts are meaningless when detached from a whole; more than that, they are not only meaningless but often simply unperceived or unperceiveable."

Odum (quoted by Erickson 1979:88) points to new insights resulting from the use of a systems approach when he says that science should not only be reductionist in the sense of seeking to understand phenomena by detailed study of smaller and smaller components, but also synthetic and holistic in the sense of seeking to understand larger components as functional wholes. Odum also indicates that an important consequence of hierarchical organization is that as components are combined to produce larger functional wholes new properties emerge that were either not present or not evident at lower levels.

The systems approach is certainly not without its critics. Lilienfeld's view (1978:249) is that the system is, like the experiment, an arbitrary way of organizing a small aspect of phenomena; at best it is an analogy with which one can perform no operations. He states that systems theorists have shown an ecumenical bent, claiming significance for their work beyond the limits of any one specific discipline. (Lilienfeld 1978:159).

Whatever its limitations, the systems approach offers sufficient insights to be used in this study as a theoretical basis for interpretation of data extracted from aerial photographs.

3.2. Comparative interpretation and change.

The specific concern of environmentalists is the change induced within an environment and whether this change will remain within the range which can be accomodated by that particular environment. Comparative interpretation of successive aerial photographs of an area is particularly well suited to the detection of change and is thus of use to environmentalists.

Change is an alteration in state or quality. Within any environment there is change which may be due to cyclical variations -diurnal, seasonal, successional, erosional, tectonic. Thus any environment fluctuates within certain limits as part of its normal functioning. Materials and energy flow through the system interacting with the processes of that system. When human actions remove material or energy, or introduce material or energy of a different nature or of a different order to that which is the norm in an environment, changes occur if the system is unable to accomodate the alteration. Some of these changes will manifest themselves visibly and can be captured on aerial photographs.

Comparative interpretation adds a time dimension to the picture that it builds of an area. In the case where the earliest cover is decades before the present it is unlikely that any other source can furnish this invaluable data. From this time dimension an idea of the dynamics of the site can be obtained.

However in comparing aerial photographs there are sources of change that are extrinsic to the environment which is remotely sensed, for example: scale of photograph, film type, time of day and season of data capture, type of photographic paper, distortion due to position of the feature relative to the principal point of the photograph. It is important to appreciate the presence of these extrinsic changes so that variations due to extrinsic factors can be screened out as far as possible when using comparative interpretation.

For those involved with EIA, and thus seeking cause and effect relationships, comparative interpretation of multi-temporal air cover can add valuable insights.

PART TWO - THE STUDY

CHAPTER FOUR

THE STUDY AREA

4.1 Criteria for site selection

The selection of the study site was based on the following criteria:

i The existence of impact inducing activities upon the site.

ii The availability of adequate aerial cover before and after the onset of the impact inducing activities.

iii Relative isolation from influences exerted by impact inducing activities other than those occurring on the site.

iv Accessibility for field visits.

4.2 Natural features of the site chosen.

The site chosen was Silwerstroomstrand, located at 18 21 East and 33 36 South on the farm Buffels Rivier. The location and boundaries of the study area are indicated on Figure 1.

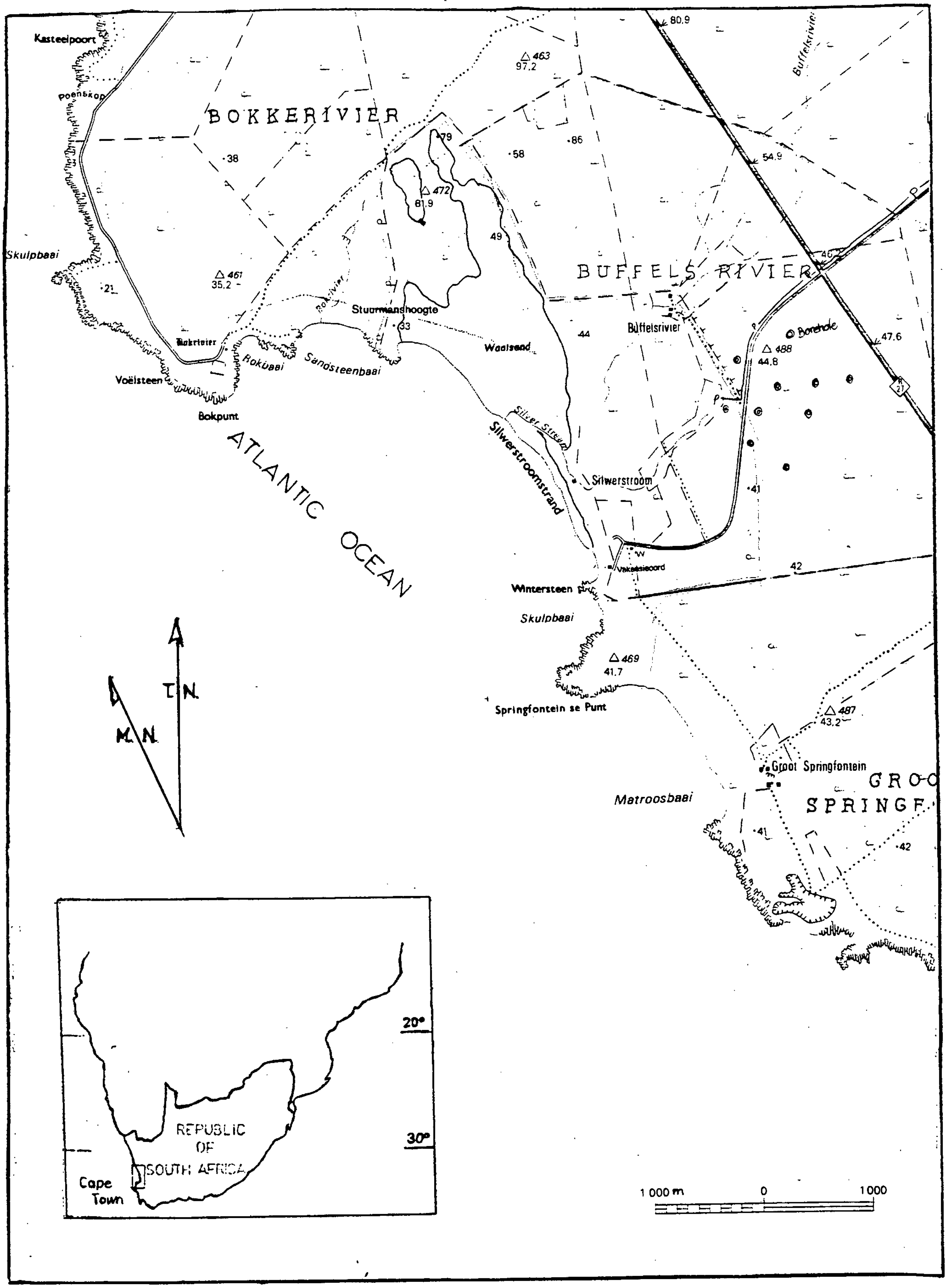


FIGURE 1 LOCATION MAP

The boundaries were selected to include representative areas of the two major development activities, recreation and water extraction. The whole dune plume was also included to obtain a more complete understanding of the processes acting within this system.

Geology and Physiography

The study area is part of a coastal lowland in which Tertiary to Recent marine and aeolian sands are underlain by rocks of the Malmesbury series. Slates of the Malmesbury series outcrop along the coast giving rise to bays and inlets (Bredenkamp 1982:3-4). Dunes and occasional outcrops of limestone provide relief in the coastal plain (Callaghan 1973:11). To the north of the site there is an extensive triangular "dune plume" and linear dunes parallel the coastline to the south.

Climate

The average annual rainfall is 350 - 400 mm and occurs mainly during the winter months (W Duckitt pers. comm. 1983). A detailed monthly record of rainfall at the Atlantis Electricity depot from October 1976 to December 1983 is given in Appendix B. Summers are hot with strong prevailing southerly winds whilst during winter months northerly winds prevail with speeds noticeably lower than the summer winds (Fuggle 1976 : 35).

Vegetation

The vegetation forms part of Acocks Veld type 34, Strandveld. Moll calls this form West Coast Strandveld and describes it as open to closed (40-90%) canopy cover, usually high and rarely tall communities, with a mixture of broad-leafed, evergreen deciduous and succulent elements. The understorey has a perennial graminoid component, as well as a large annual component, consisting of annual herbs, including succulents and geophytes (Moll in press). There are noticeable variations within the area such as the riverine vegetation and the limestone outcrop communities.

4.3 Past landuse

Hunting, gathering and pastoral use

The fynbos region in which the study site occurs has been inhabited for hundreds of millennia before the present, (Deacon 1983 : 183) with the early inhabitants using the environment as hunter-gatherers. Two thousand years ago pastoralist Khoisan tribes emigrated from the north and followed a pattern of seasonal migration through the area. Although they used fire to improve the grazing for their sheep and cattle, Avery (1981:65) states that the impact of indigenous people was nowhere near that which the establishment and subsequent expansion of permanent European settlements initiated thereafter.

Middens left by the early inhabitants have been discovered in the dunes. The University of Cape Town Archaeology Field Club, working in the Silwerstroomstrand area in 1978, observed that noticeably high dunes often contained shell middens and suggested that the middens might stabilise the dunes (Tim Robey personal communication 1983).

Settled Farming

(All information on landuse under settled farming has come from Mr. Wilfred Duckitt, who farmed the area from 1946 to 1964).

The earliest record of settled European agriculture dates back to the mid eighteen hundreds when "Kockie" Duckitt obtained the farm, Buffels Rivier. The area has been used primarily for grazing of sheep and cattle. Management practices have involved regular patch burning "to keep the veld young all the time" and "dragging" (pulling a six metre rail behind a tractor) to enable cattle to utilise the vegetation which was otherwise too dense for grazing.

To encourage vegetation growth on the dunes and the growth of "buffelsgras", a favourite grazing grass of stock, a canal, parallel to the shore and north of the river mouth, was dug between 1948 and 1956 .(This is marked as 'Silver Stream' on the map, Figure 1). Marram grass, Ammophila arenaria, was planted on the northern part of the dunes in the 1930's. Concurrent with the digging of the canal, four rows of marram were planted across the path of the prevailing southerly winds at the southern, end of the dune plume to further aid growth of vegetation on the dunes. (One of the rows is clearly visible on the 1960 and 1968 aerial photographs.)
Between 1962 and 1964 the unstabilised dunes were fenced to exclude stock which it was appreciated would impede plant growth. The rest of the farm was also fenced into camps to better control stock and grazing.

4.4 Present Landuse.

With increasing pressure on the resources of the Cape Town metropolitan area for industrial and recreational development, other foci were sought for future expansion. Attention was directed to the West Coast and in 1974 the "Report on planning policy WEST COAST" was produced, followed by the "Atlantis-West Coast Draft Guide Plan" in 1978. These reports formed the basis for the development of the decentralized growth point at Atlantis which in turn necessitated the developments in the study area.

As a result of this the Department of Community Development bought Buffels Rivier and several surrounding farms in 1975 (Divisional Council of the Cape, property record NA 60). Pastoral use of the area continues as grazing is leased to local farmers. However, other uses are now superseding this.

Recreation

Initial development at Silwerstroomstrand began in December 1972 (Callaghan 1973 : 5). An access road was built, parking and camping sites cleared and ablution blocks and water points provided (Callaghan 1973:25). Currently the facilites include four ablution blocks, a shop, further cleared picnic and camping sites with water points, refuse bins and braai sites.

No reliable records of visitor numbers are available prior to 1982. From February 1982, however, an individual entry charge has been levied and it is possible to obtain an indication of visitor numbers from that time.

Table 1 gives a monthly breakdown of visitor numbers and when plotted, the broad pattern, shown in Figure 2, is of summer usage with peaks at the Easter and Christmas holiday periods.

MONTH	ADULTS note 1	CHILDREN note 2	CAMPERS note 3	TOTAL VIS-DAYS
February 82	1365	445	12	1822
March 82	1527	611	92	2230
April 82	2150	650	1424	4224
May 82	477	125	26	628
June 82	1187	184	28	1399
July 82	635	46		681
August 82	392	156	46	594
September 82	1310	372	68	1750
October 82	2057	479		2536
November 82	2240	761	10	3011
December 82	4611	1478	2152	8241
January 83	8604	2348	3098	14050
TOTALS	26555	7655	6956	41166

MONTH	ADULTS	CHILDREN	CAMPERS	TOTAL VIS-DAYS
February 83	1140	202		1342
March 83	1909	342	14	2265
April 83	3821	1126	908	5855
May 83	464	102		566
June 83	206	25		231
July 83	227	30		257
August 83	589	71		660
September 83	701	131		832
October 83	1870	1385	268	3523
November 83	1896	534		2430
December 83	4870	1970	4668	11508
January 84	4164	4324	2446	10934
TOTALS	21857	10242	8304	40403

note 1 An "adult" is anyone over the age of twelve.
note 2 A "child" is anyone between the ages of twelve and five.
note 3 "Campers" are calculated as number of people x 2 to give visitor-days (VIS-DAYS)

TABLE 1 : SILWERSTROOMSTRAND VISITOR NUMBERS Feb.82 - Jan.84

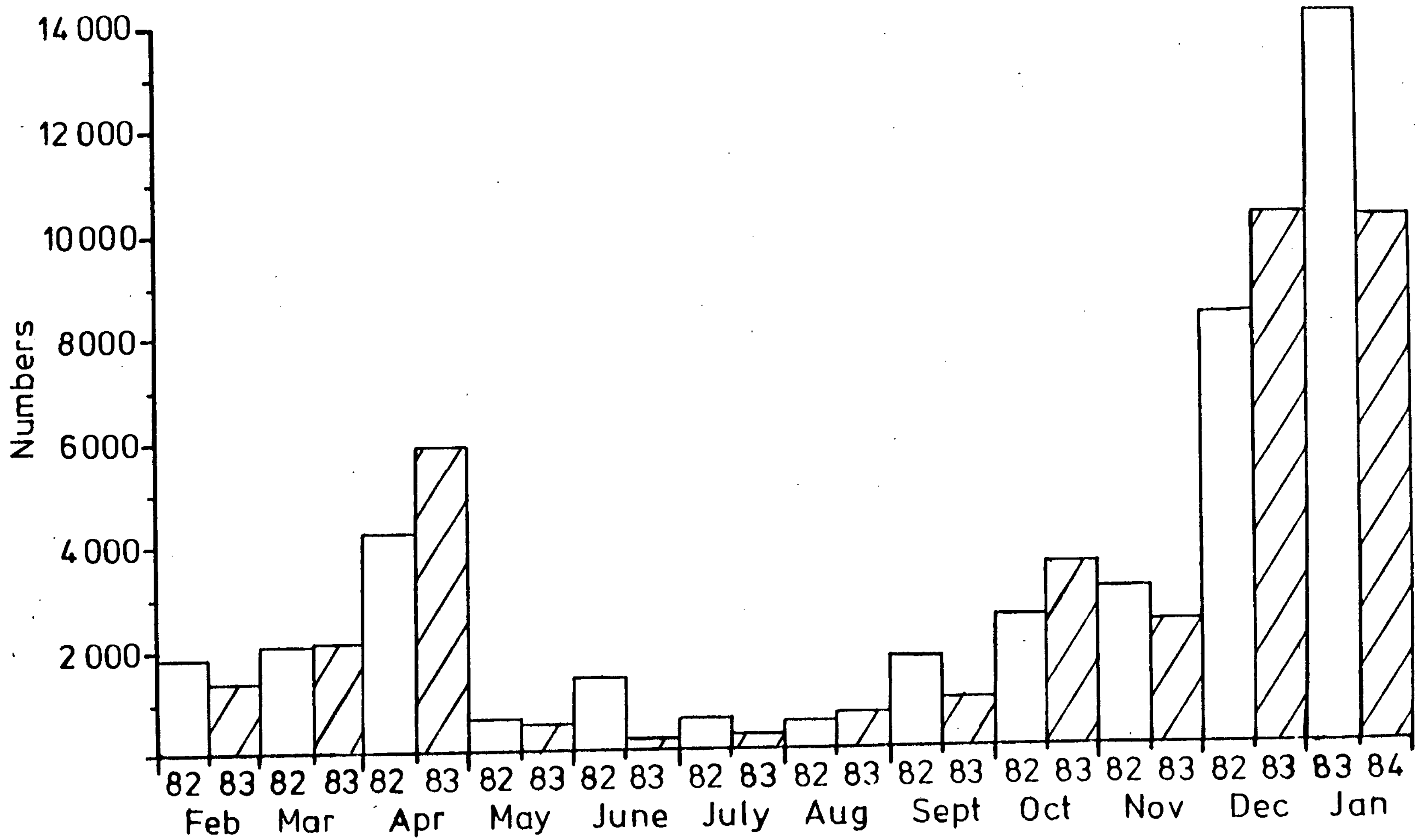


FIGURE 2 MONTHLY VISITOR NUMBERS - FEBRUARY 1982 to JANUARY 1984

Water Extraction

A perennial natural spring is one of the features of the site. Whilst initially, the intention had been to pipe water for the Atlantis development from the Berg river, investigation of the spring revealed that the area was underlain by an aquifer with considerable potential for water extraction. The use of the underground store of water was therefore initiated to provide water for the planned Atlantis complex.

Consequently a second focus of development was initiated. The Silwerstroomstrand aquifer is 52.58 km^2 in extent and estimated to contain 71×10^6 m^3 of water (Bredenkamp 1982:18). This aquifer is one of three units comprising the Atlantis aquifer system which in turn forms part of the vast primary aquifer which stretches from the Peninsula to the Olifants river. (See Figure 3.)

The existence of the aquifer is due to the presence of extensive deposits of poròus and permeable sediments underlain by the virtually impermeable rocks of the Malmesbury series. The effect of this combination is that rainfall passes through the sediments to be trapped at the interface with the Malmesbury shales forming a vast underground dam .

By 1976 the infrastructure needed for the removal of water was complete. The height of an existing weir below the natural spring was raised slightly. A treatment

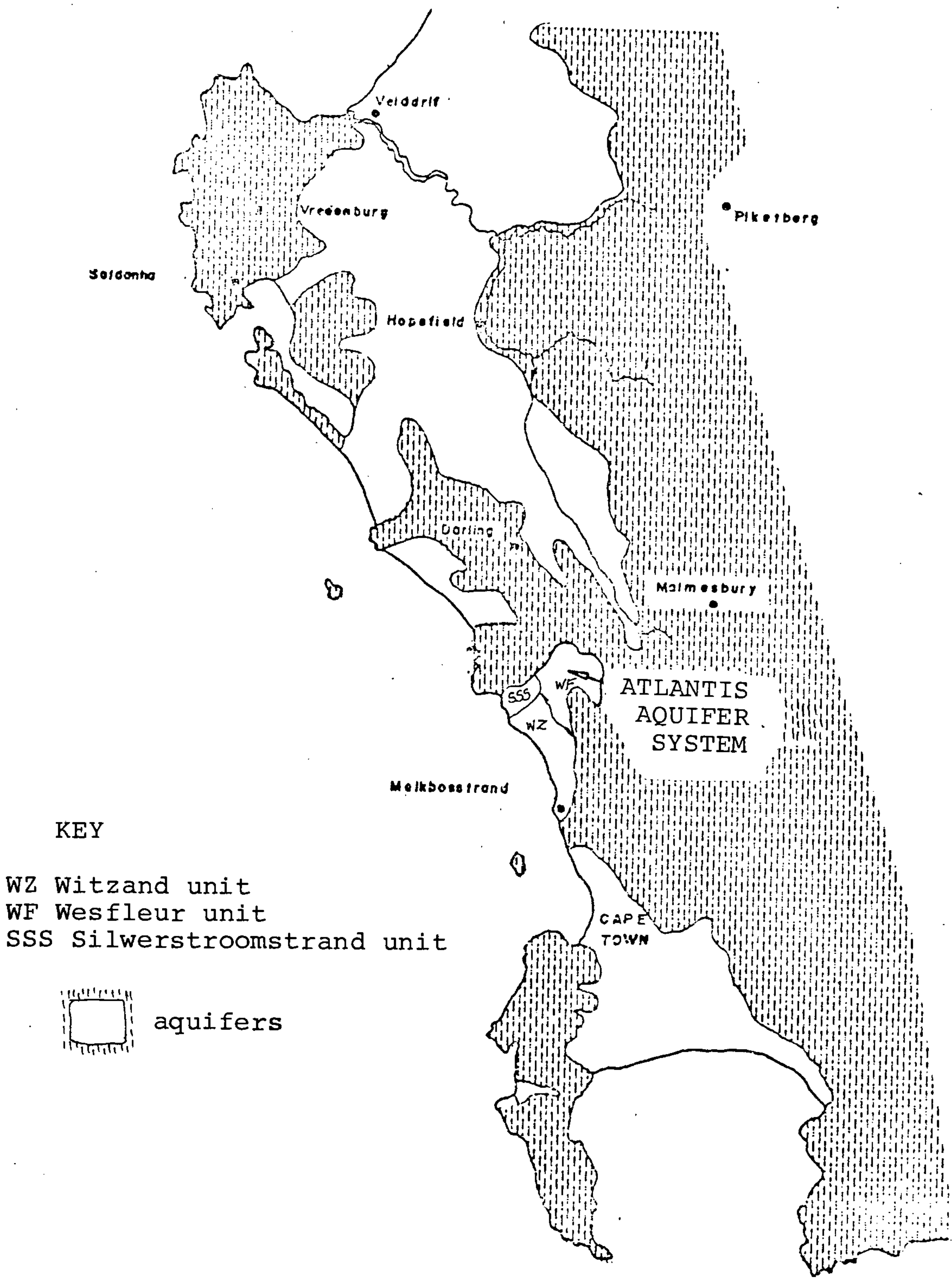


FIGURE 3 POSITION OF WEST COAST AQUIFERS
(From Bredenkamp 1982)

plant consisting of sand filters, chlorination and pH adjustment facilities was built, as well as a reservoir, pipeline and pumps (Mr Gordon Stewart of Liebenberg and Stander Consulting Engineers; personal communication 1983). From 1976 to 1978 water was removed from the spring only. In 1979 three boreholes were brought into production, followed by two more in 1980 and a further two in 1983. The location of the structures and the first five boreholes is shown on Figure 4. As the seven boreholes produce more water than can be transported by the pipeline to the reservoirs at Pella, which is 18 km to the East of Silwerstroomstrand, the further three boreholes on the site are used in a standby capacity only.

Initially the water from Silwerstroomstrand was adequate for both the industrial and residential needs of Atlantis. However, by 1980 demand had exceeded supply and development of the other two units of the Atlantis system, the Witzand and Wesfleur units, was initiated. The location of these units is shown on Figure 3. By 1983 Silwerstroomstrand was providing water for residential needs only and it is estimated that this unit will continue to be able to supply the domestic water requirements until summer 1985 (Bredenkamp 1982).

Table 2 indicates the amount of water removed from Silwerstroomstrand from September 1976 to December 1983. Table 3 gives the Annual water extraction from the whole Atlantis aquifer system for the same period.

The effect of the water extraction is monitored by the Directorate of Water Affairs of the Department of the

	1976	1977	1978	1979	1980	1981	1982	1983	TOTAL
Spring	99 878	428 212	699 796	619 604	709 505	863 842	466 970	318 418	4 206 225
G29757 [1]				82 096	100 333	89 692	228 702	141 054	641 877
G29794				138 711	163 488	221 251	346 876	339 872	1 210 198
G30865				118 211	131 423	182 666	230 891	195 495	858 686
G30991					30 666	100 511	210 300	71 520	412 997
G30999					41 965	188 495	152 456	205 443	588 359
G32952								182 594	182 594
G32954								278 673	278 673
Total	99 878	428 212	699 796	958 622	1 177 380	1 646 457	1 636 195	1 733 069	8 379 609

TABLE 2 : ANNUAL WATER EXTRACTION IN M^3 FROM THE SILWERSTROOMSTRAND UNIT OF THE ATLANTIS AQUIFER

note 1-G29757 to G32954 refer to the individual production boreholes

	1976	1977	1978	1979	1980	1981	1982	1983	TOTAL
	99 878	428 212	699 796	993 849	1 275 322	1 783 693	2 433 435	2 945 546	10 659 731

TABLE 3 : ANNUAL WATER EXTRACTION IN M^3 FROM THE TOTAL ATLANTIS AQUIFER

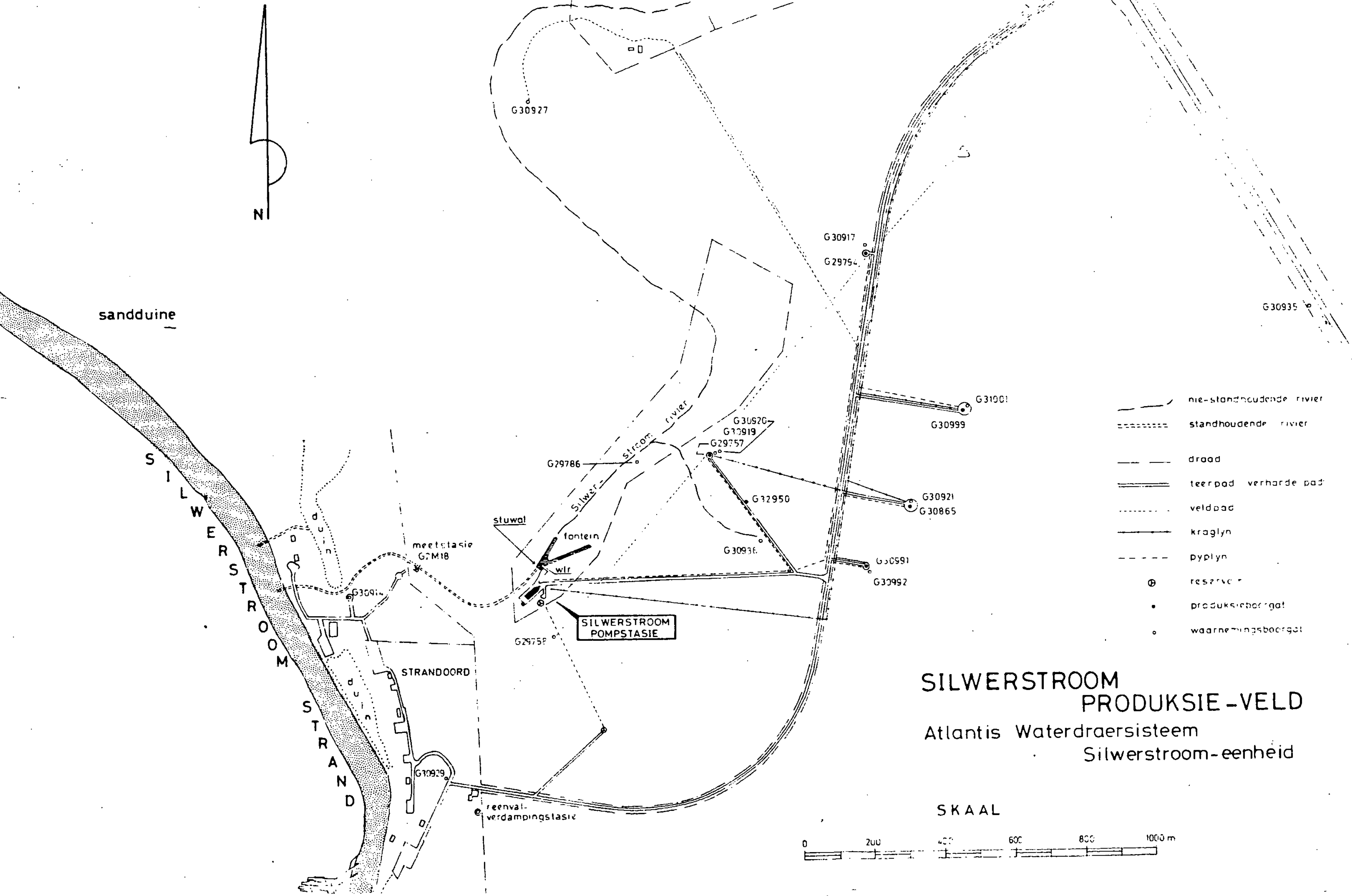


FIGURE 4 SILWERSTROOMSTRAND WATER EXTRACTION INFRASTRUCTURE
(From Bredenkamp 1982)

Environment. A network of 81 observation boreholes is distributed throughout the Atlantis system. Although there has been little change in the overall pattern of the water table, water extraction is certainly resulting in a drop in the level of the water table. Maximum drop has been of the order of 5m and predictably this has occurred where pumping takes place. Figure 5 shows the drop in water table from April 1978 to March 1982.

4.5. Silwerstroomstrand's suitability as a study site.

The site satisfied the criteria specified at the beginning of Chapter 4 in that:

1 Two major types of development occurred from the mid 1970's - recreation with formal amenities and extraction of above and under-ground water.

2 Pre-development aerial photographs had been taken in 1938, 1960, 1968 and 1971. Post-development photographs from 1977, 1981 and 1983 were available.

3 Up to 1972 the Silwerstroomstrand area had remained relatively isolated from impact inducing activities other than farming. This was because undeveloped land still existed in nearby urban areas. By 1972 the pressure on these areas was such that other foci of development had to be sought.

4 The site was accessible in terms of distance from Cape Town and the responsible local authority, the Divisional Council, readily gave permission for visits to the area.

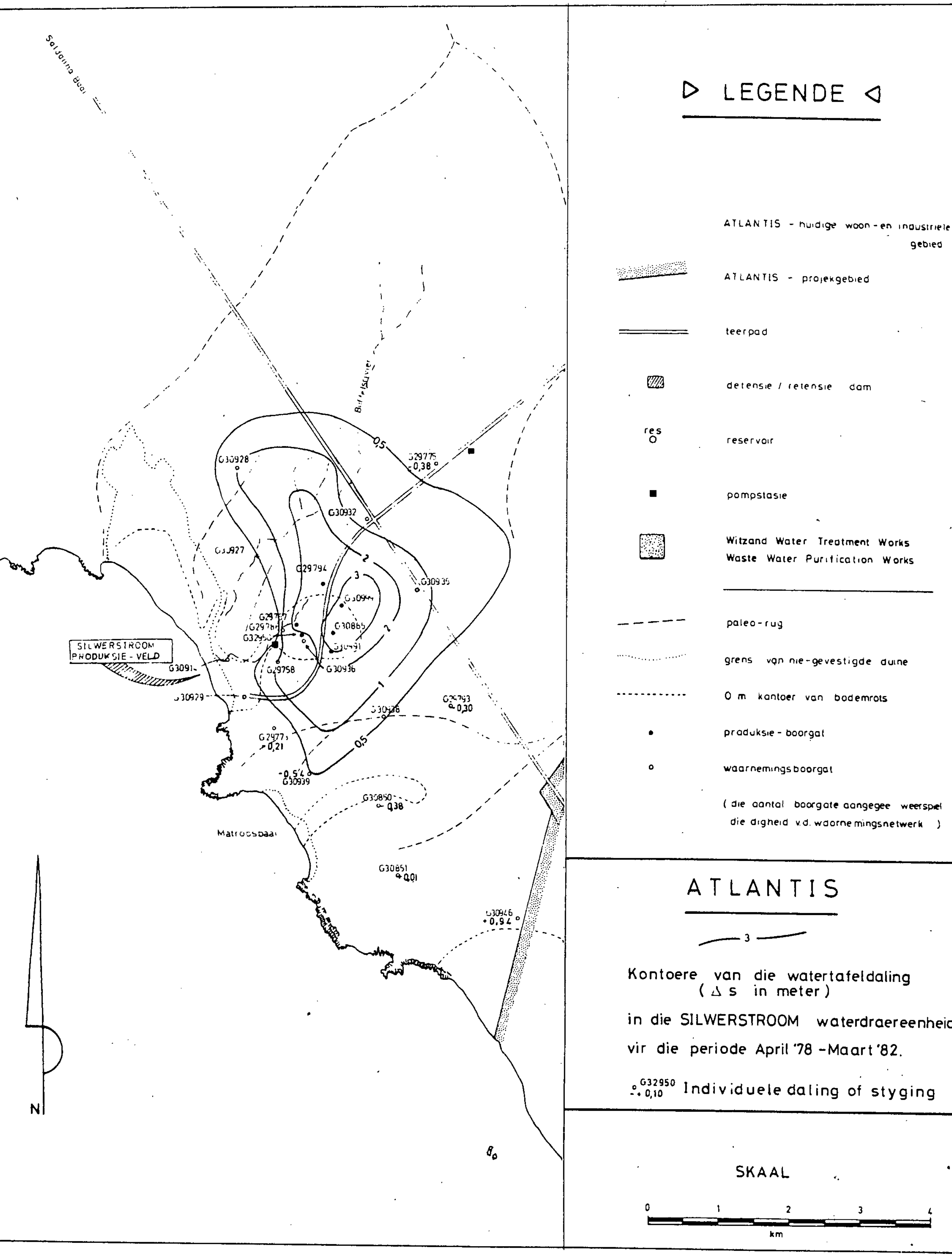


FIGURE 5 DROP IN WATER TABLE
(From Bredenkamp 1982)

CHAPTER 5

METHODS

The data for the study were obtained from three sources

Aerial photographs

Interviews

A site visit by experts

5.1 Aerial photographs

Obtaining cover. The prime source of aerial photographs is the Surveys and Mapping Branch of the Department of Community Development, Mowbray, Cape. Further cover is frequently available from sources such as the local administrative authority, universities, state departments, research bodies or consulting engineers associated with any projects undertaken at the site.

In the case of Silwerstroomstrand, cover was available from the Surveys and Mapping Branch as well as the Data Bank of the local authority, The Divisional Council of the Cape, The Fisheries Development Corporation, Viskor, a quasi-government body responsible for the planning of harbour facilities, and The Institute for Remote Sensing and Photogrammetry at the University of Cape Town . For reasons discussed in Chapter 2, only panchromatic black and white cover was selected, consequently the colour and infra red cover held by the University of Cape Town was not used.

As the site lies on the coast, the aerial photographs are classified and permission for their use had to be obtained from the Defence Force.

Job	Strip	Number	Scale (approx.)	Date	Time	Source
126	60	10528/9	1:25 000	03/1938	10h55	Trig[1]
126	60	10523/4	1:25 000	03/1938	10h50	Trig
454	23	8036/7	1:36 000	12/1960	10h25	Trig
619	11	340/1	1:36 000	04/1968	11h47	Trig
	15	1085-9	1:10 000	11/1971	09h12	D C C
	18	2523-5	1: 7 000	12/1971	16h30	D C C
786	6	403	1:50 000	03/1977	11h30	Trig
	3	948-53	1: 8 000	04/1981	12h25	D C C
	4	965-9	1: 8 000	04/1981	12h30	D C C
871	46	1-6	1:13 000	03/1983	13h35	Visk[2]

1 = Survey and Mapping Branch, Department of Community Development
2 = Viskor photos available through source 1.

TABLE 4 DETAILS OF AERIAL PHOTOGRAPHS USED

Orthophotos 3318CB 8 BUFFELSRIVIER and 3318CB 7 BOKRIVIER were used to produce a base map. The control points chosen are shown in Figure 8.

<u>Qualitative analysis</u>. Successive covers were examined and compared using a Topcon mirror stereoscope and changes were noted.

Aerial photographs contain considerable amounts of information which may not be readily perceived. It was found that each successive viewing revealed further information. Lilienfeld's comment (1978:10) "that parts are meaningless when detached from a whole; more than that they are not only meaningless but often simply unperceived or unperceivable" is particularly apt and highlights the need to interpret aerial photographs in the framework of a conceptual context. Use of a systems approach was found to satisfy this need.

Quantitative analysis. For any comparative quantitative analysis, distortions in the photographs must be removed as far as possible and the data brought to a common scale. There were three possible methods by which this could be achieved.

1 Rephotographing each photograph and adjusting it to the scale of a base map drawn from orthophoto maps.

2 Tracing off the desired features and photographically adjusting these to the scale of the base map.

3 Using a Zoom transferscope (such as the one at the Estuarine and Coastal Research Unit, Stellenbosch) to transfer features onto a base map.

All three methods were explored and the first and second were used in the course of the study. Although the Zoom transferscope is an extremely useful tool for transfering information of one scale onto a base map of a different scale, the field of view is limited and unless there are adequate reference points to ensure an accurate match, the error factor can be significant (Perry personal communication 1983).

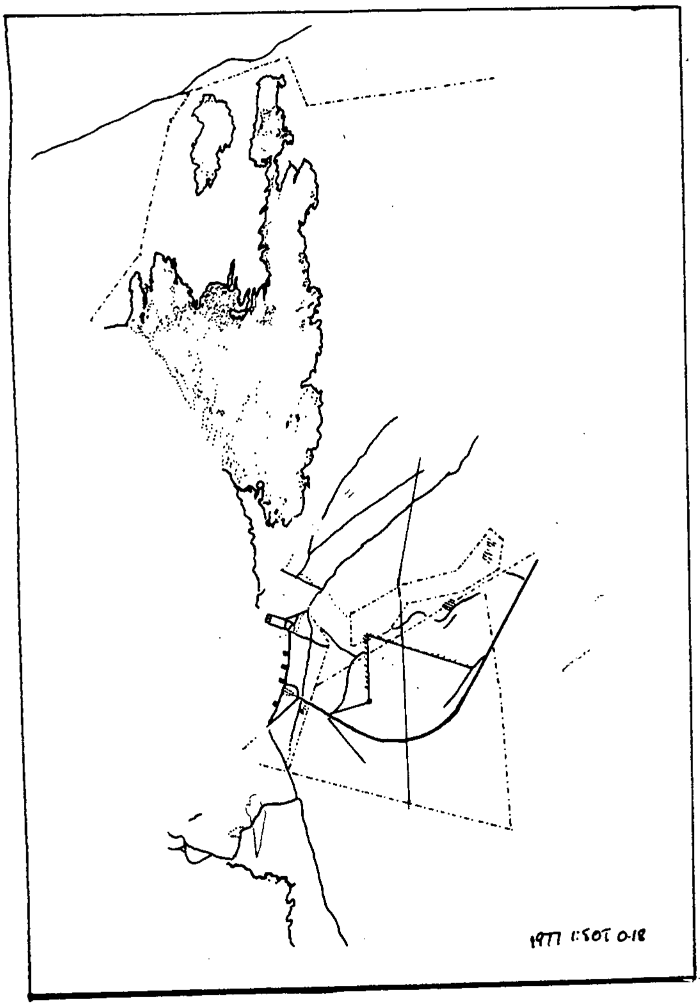
The first method offers the most flexibility in data collection. The disadvantage, if the original photograph is poor, is the loss of quality in the scale-adjusted copy.

This loss of quality can be seen by comparing the original 1983 photograph in Figure 11 with the scale-adjusted copy in Figure 18. If the technical problems can be solved, this is certainly felt to be the preferable method.

The second method was used most extensively in the study. Figure 6 shows the steps in the process. The figure also illustrates a 'worst case', where a considerable scale adjustment, from 1:50 000 to 1:20 000, is made. The thickening of the outline obliterates detail and necessitates redrawing the map after it has been enlarged.

Once the data from all the covers were at a common scale (the base map with its reference points is shown in Figure 7) measurements could be made. Length was measured using a digital map reader developed by Flepp in the School of Environmental Studies, University of Cape Town. Measurement of areas of unvegetated mobile dunes posed a challenge as very small non-contiguous areas had to be measured. The solution employed was to use a light table to transfer the areas onto graph paper and to then count the squares.

Step 1.
Data traced directly from the photograph



Step 2.
Tracing enlarged to the scale of the base map.

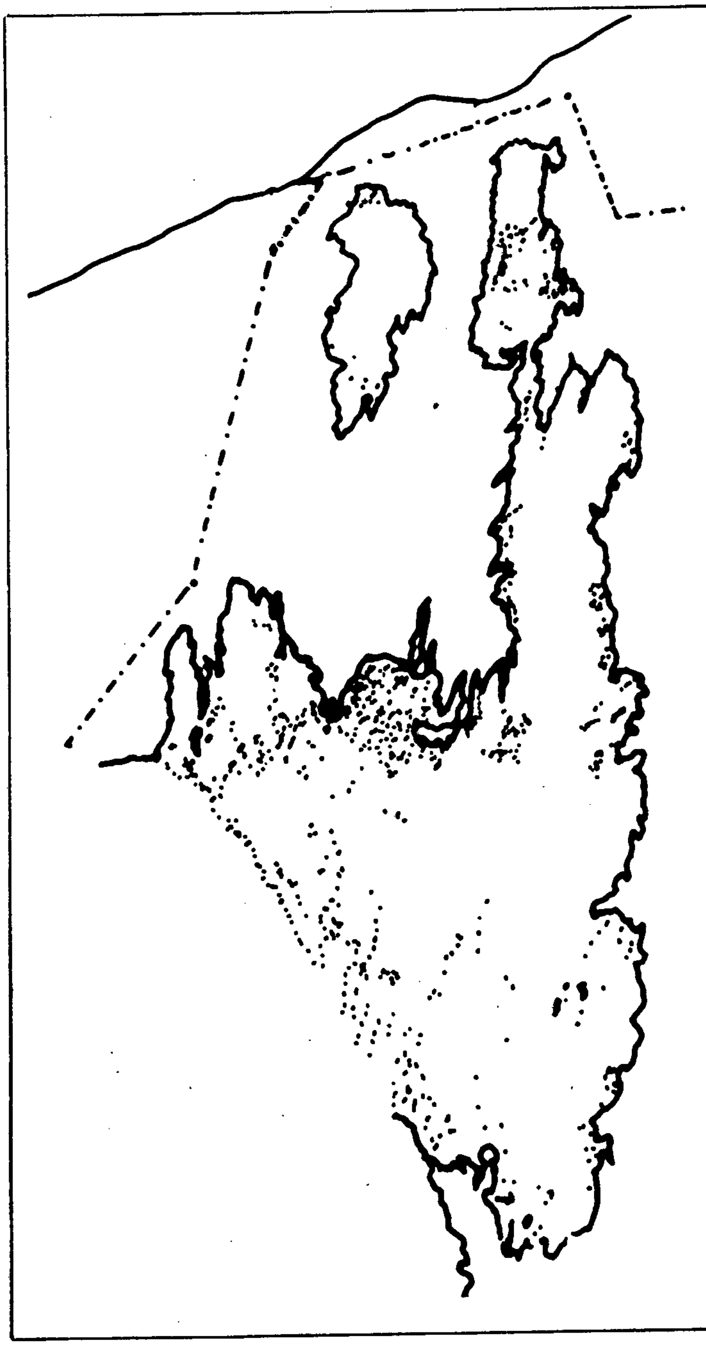


FIGURE 6 STEPS IN DATA EXTRACTION FROM PHOTOGRAPHS

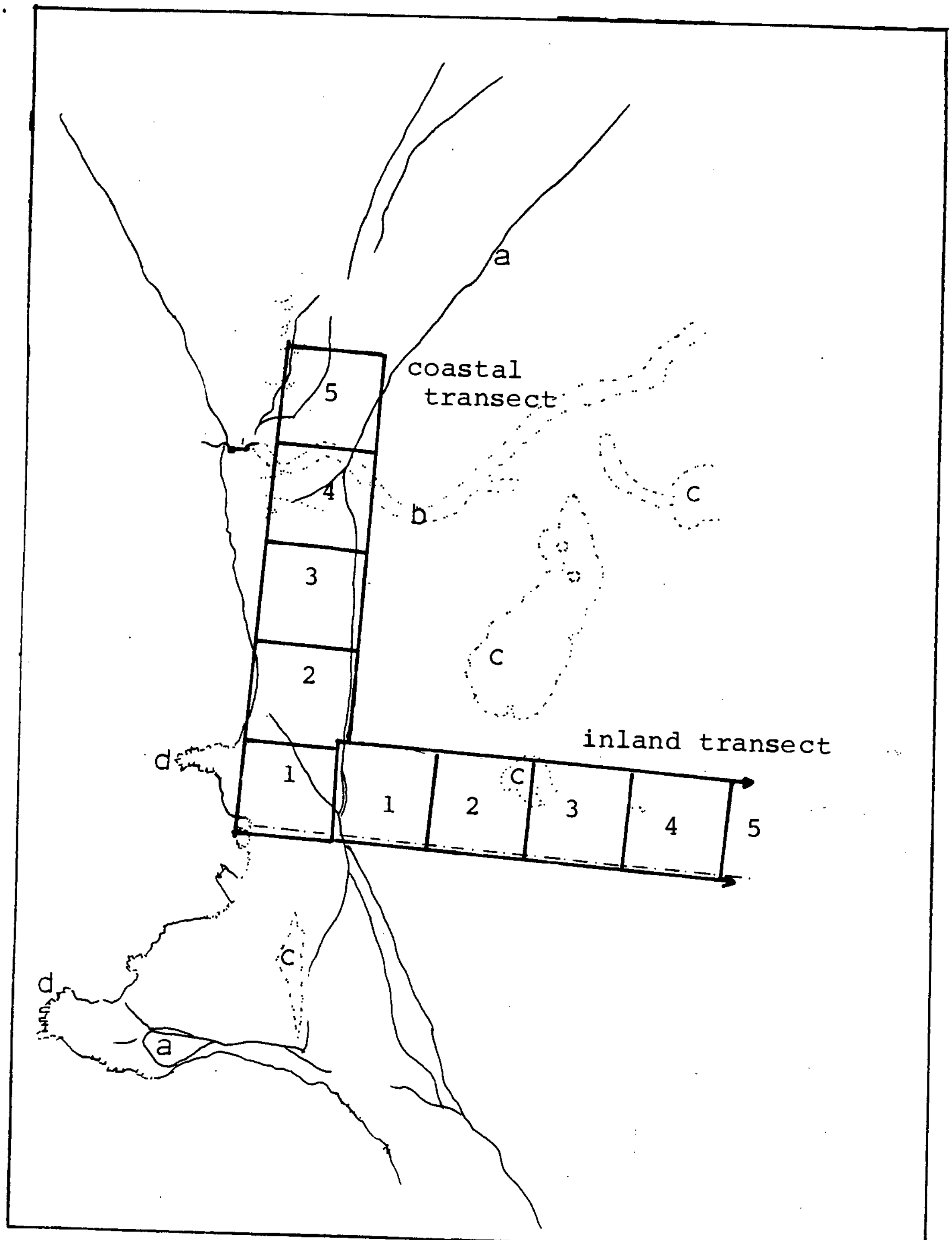
Transparent overlays were made of the data extracted from each different cover. (These are to be found in the plastic sleeve at the back of the thesis.) These significantly assist comparative interpretation. They also reveal a problem in this method, in that whilst the adjusted maps of 1938, 1960, 1968 and 1971 registered satisfactorily with the base map drawn from the orthophotos, the 1977 and 1981 maps do not register consistently over the whole area. However, by moving the transparencies relative to one another small areas can be registered and so compared.

By making a mosaic of the larger scale photographs (1981) the registration with the ortho-photo derived base map could be improved. This solution was not used as the 1981 photographs were on loan and could not, therefore, be cut.

Semi-quantitative analysis.

Vegetation condition is less amenable to objective measurement than is area or distance. However, it is possible to give a semi-quantitative evaluation of the state of the vegetation.

Two transects were taken, one from the coast inland and one along the coast. The position of the transects is shown in Figure 7. Transparent overlays with grid squares approximately 9 ha each, adjusted to the scale of the different photographs, were prepared and placed over the photographs of the same scale.



Reference points
a = vehicle tracks
b = river course
c = limestone outcrop vegetation
d = rocky outcrop

FIGURE 7 LOCATION OF REFERENCE POINTS & TRANSECTS

To rate the condition of the vegetation in each grid square a seven point scale was used:-

1 No disturbance
2 Minimal disturbance
3 Noticeable disturbance
4 Moderate disturbance
5 Marked disturbance
6 Severe disturbance
7 Gross disturbance

5.2 Interviews

To obtain background information on-

i the natural features of the area

ii the past landuse and tenure

iii the present landuse

interviews were conducted with researchers, managers, engineers and planners involved with the area and with a previous owner of the farm Buffels Rivier.

5.3 Site visit by experts.

A panel of experts, representing a range of disciplines, each with some knowledge of the area or of the type of projects undertaken there, was taken on a field visit on 12 March 1984 to identify impacts. (Appendix C gives details of the panel members.)

The impacts to be identified were either

1 directly observable, or

2 could be inferred i.e. they were not themselves visible but could be deduced from direct observations.

Thus the inferred impacts could be:

2.1 presently occurring but not visible

2.2 likely to occur in the future

2.3 the result of erstwhile actions no longer occurring.

The impacts were then rated in terms of the degree to which each was accommodated by the environment. Because of the multi-disciplinary nature of any EIA panel, there should be a range of opinions in rating impacts and there are no 'right' answers. Consequently reliance is placed on the experience and insights of the panel members to reach a satisfactory conclusion. Thus the exercise of rating the impacts so that reflects the considered opinions of the group of experts is reflected, can be regarded as a decision making exercise which is undertaken under conditions of uncertainty. Research has shown that decision making under conditions of uncertainty is more accurately done by groups and that the most accurate group judgements are made using a technique involving iteration with controlled feedback (Stauth 1983 :160-165).

For this reason the Delphi technique, which seeks the insights of generally knowledgeable and respected persons and uses their judgements as systematically as possible, was selected to rate (and therefore rank) the impacts.

The data from the three sources, aerial photographs, interviews and the site visit by experts, was then correlated and evaluated.

CHAPTER 6

INTERPRETATION OF PRE-1972 AERIAL PHOTOGRAPHS

Introduction

The systems approach was the framework used for comparative interpretation of the aerial photographs taken before the onset of infrastructural development in 1972. Environmental systems and their constituent elements were thus identified. Descriptions of human actions within the study area were derived from analysis of the photographs and from information from interviews. Comparison of sequential photographs showed the changes in both the environmental elements and human actions. These changes were interpreted as indicators of the sensitivity of the various elements identified. The changes also revealed possible cause and effect links from which an understanding of the dynamics of the area could be derived.

6.1 Identification of Environmental Systems

As discussed in Chapter 3, systems are man-made and the purpose of the systems approach is to aid thinking. Thus the definition of the systems used will depend on the purposes to be served by the exercise. As this study investigates the use of panchromatic black and white photographs one of the parameters for definition of the systems is that the elements should be visible. The concern with EIA determines that the systems should include the geographical areas in which the infrastructural developments occur and areas where possible resultant visible impacts might be manifested. Thus use of general physiographic units visible on the aerial photographs seems applicable.

It must be noted that systems are undefined primitives (see discussion on page 14) and that it is appreciated that there are many other ways of delineating systems at the study site. For example, a "Sand system" and its elements would be defined quite differently if the primary purpose was to consider sediment transport. In that instance consideration of the bathymetry, ocean substrate, sources of sediment, water movement and the subsystems which in turn influence water movement, namely currents, wind and shape of coastline, would need to be included.

One of the advantages of the use of a systems approach for the holistic outlook required by environmentalists is shown in the above example of system delineation. When it is appreciated that setting the boundary of the system is dependent on the aims of the exercise, it encourages far more flexible and lateral thinking. The system is not an unvarying entity but a working tool to be adapted and modified until it attains a form that is best suited to the purpose for which it is to be used.

It must further be noted that a very superficial use of systems theory has been made in this study. The potential of the approach merits wider and more detailed investigation of its applicability.

Against the background given above the following systems and their elements were delineated:

A. SAND SYSTEMS	A.a Matroosbaai dune plume A.b Beach A.c Linear dunes A.d Silwerstroomstrand dune plume
B. VEGETATION	B.a Lowland B.b Limestone outcrops B.c Riverine B.d Linear dunes B.e Dune plumes
C. RIVER COURSES	
D. ROCKY OUTCROPS	

An overlay indicating the position and extent of these systems is provided as Figure 9.(This is superimposed upon Figure 10, the 1938 photograph.)

6.2 Changes in the systems and identification of sensitive environmental elements

In discussing the changes and constancies noted, frequent reference will be made to Figures 12 to 15 and to the transparent overlays of these figures which are contained in the plastic sleeve at the back of this report. On the basis of the changes observed on the aerial photographs, the environmental elements most sensitive to human actions will be identified.

In the case of the elements A.a-Matroosbaai dune plume, A.d-Silwerstroom dune plume and B.e-vegetation of the dune plumes, changes occurring after 1972 have been included in the in this section to prevent unnecessary repetition in the discussion of interpretation of post-1972 photographs which is to be found in chapter 9.

A. SAND SYSTEMS

A.a Matroosbaai dune plume.

The trend visible from sequential aerial photographs is one of a decreasing area of unvegetated mobile sand. The area changed from 28 ha in 1938 to 9 ha in 1981 and the decrease is clearly shown by comparison of the 1938 and 1981 overlays.

There is an indication of a 'pulse' of sand prior to 1938. (A full discussion of the possible causes is given under the heading 'Dynamics of the sand system' in Chapter 7.) Whatever the cause/s, the invading sand spread northwards. By 1938 it had covered a pre-existing track and it is suggested that this sandblow prevented further use of the track so enabling vegetation to re-establish. There is no further sign of the track on the 1971 photograph.

From the above observations of the photographs it is inferred that the environmental element, Matroosbaai dune plume, would be sensitive to anything which disturbed the present vegetation cover on a large enough scale to give rise to a contiguous area of unstabilised sand. The sequence of photographs gives some indication of the threshold value of contiguous area at which a sand blow can occur. There are obviously many factors other than area involved in the initiation of a sand blow. Orientation of the area to prevailing wind; degree of exposure; nature of substrate; depth of disturbance; strength of prevailing winds are all contributing factors. Talkenberg (1982:128) has discussed some of these factors in greater detail and has shown that wind erosion significantly magnifies the primary impact of mining on the West coast by creating sandblows which then destroy the vegetation over which sand is blown.

Under the particular combination of factors acting at Silwerstroomstrand the threshold is suggested to lie between twenty and thirty hectares, where the length and width dimensions of the area are of the same order. (This proviso is added as twenty hectares of road, where length is of a quite different order to width, would not normally give rise to a sand blow.) Although this threshold value cannot be calculated with great accuracy, it is suggested that even an approximate value contributes some further refinement to the prediction process.

In the past an ingress of a large volume of sand appears to have changed the equilibrium of the system. In the future, another pulse of sand as well as actions such as severe burning or scraping, could generate a similar effect and give rise to a sandblow.

A.b Beach.

Detection of any change in the beach is problematical as the photographs were not taken at similar times in the tide cycle. In addition, beaches are among the most high energy and mobile of land forms and any changes noted may be due to natural tidal and/or seasonal cycles. Photographs separated by intervals longer than seasonal or tidal cycles, such as those available for this study, are not suitable for detailed beach process interpretation or measurement.

The high energy nature of the beach element makes it particularly vulnerable to some changes and able to reverse the impacts of others. In Heydorn and Tinley's words (1980:48) "despite their vulnerability to disturbance, sand coasts have a high durability afforded by their malleability." The beach would be particularly sensitive to any changes in systems associated with transport of sediment such as interference with longshore drift by groynes, berms or harbours.

A.c Linear dunes.

Heydorn and Tinley (1980) infer whether a sandy coastline is eroding, homeostatic or prograding by looking at the age and density gradation of plant cover on foredunes. Mature cover abutting the beach is taken as a sign of a homeostatic coast; denser cover landwards fronted by a series of hummocks indicates a prograding coast and undercutting of dunes shows an eroding coast.

The southern 500m of the linear dunes show mature vegetation abutting the beach in all photographs. Using the above argument this indicates homeostasis and consequently an area of lower sensitivity than the northern section where hummocks develop progressively seawards. This development can be seen by comparing the 1938 to 1971 overlays. The seaward extension of hummock dunes suggests a prograding coastline, thus an influx of sediment and consequently a node of greater change and higher sensitivity than the southern section.

Measurements indicating the advance of the vegetation, and thus it is suggested of the dunes, are given in Table 8 and further discussion occurs under section B.d of this chapter.

A.d Silwerstroomstrand dune plume.

The decrease in area of bare sand (shown in Table 5) is one of the most noticeable changes in the study area. An inverse measure of the changing area of sand is given by the increase in area of vegetation cover. A major part of the vegetation expansion in the dune plume occurred around a diversion of the Silwerstroom into a canal parallel to the coast. This change is discussed fully in section B.e of this chapter.

The prograding shoreline indicates a regular influx of sand to the northern section of the linear dunes and probably to the dune plume with vegetation serving to stabilise this incoming sand. Thus it is suggested that the environmental element, Silwerstroomstrand dune plume, would be very sensitive to any disturbance of the plant cover, such as fire or scraping.

1938	1960	1968	1971	1977	1981
45.0	40.5	37.7	36.4	37.0	18.3

TABLE 5 - Area of unvegetated sand in hectares

Although it is suggested that there is a constant influx of sand there is no indication that the dune plume is migrating inland. Any addition of sand must therefore give rise to higher dunes. Although it is possible to measure heights from stereo pairs of aerial photographs, it is a more advanced technique than the techniques used in this study which study is focussed on generalised use of the tool, thus the more specialised extraction of data was not included.

The pre-1938 'pulse' of sand mentioned in connection with the Matroosbaai dune plume, also manifests itself on the inland margin of this dune plume, for there is a clear boundary between sand and vegetation suggesting recent movement of sand over the plants. No subsequent photographs show so clear a boundary. This either indicates that no further pulses have occurred or that increasing vegetation cover has trapped and stabilised such pulses of sand. If the latter is the case, it makes it even more important that vegetation cover within the dune plume is not disturbed as the vegetation stabilises not only the regular influx but also large irregular pulses of sand.

Changes in the aspect of the dune crests could be seen on some of the photographs and this reflected seasonal climatic changes. The 1981 photograph, taken in April at a scale of 1:8 000, shows the slip face of the crest of the dune facing south indicating a northerly prevailing wind at this time of year. In contrast, the 1971 photograph taken in December at a scale of 1:10 000, shows northerly facing slip faces indicating that the prevailing wind was from a southerly direction.

The crests also indicate a difference in the summer and winter prevailing winds, for the winter winds rework only a small portion of the mobile sand resulting in small crests topping the larger southerly aspect dunes. This is in part due to the fact that the study area receives most of its rain in winter (see Appendix B) wetting the sand particles and making them less easily transportable by the less persistent and lower velocity winds typical at this time.

B VEGETATION SYSTEMS

B.a Lowland Vegetation

The 1938 aerial photograph in Figure 12 shows the almost 'pristine' condition of the lowland vegetation. The semi-quantitative rating of the condition of the vegetation in two transects (location shown in Figure 7) and around one of the boreholes (location shown in Figure 4 on page 31) is shown in Tables 6 and 7. The 7 point scale used in the rating represents:

1 No disturbance
2 Minimal disturbance
3 Noticeable disturbance
4 Moderate disturbance
5 Marked disturbance
6 Severe disturbance
7 Gross disturbance

Grid square number	1	2	3	4	5
INLAND TRANSECT					
1938	1	1	1	1	2
1960	1	2	4	3	2
1968	2	3	4	3	2
1971	2	3	4	3	3
COASTAL TRANSECT					
1938	2	1	1	2	2+
1960	2+	1+	1+	2+	2+
1968	2+	1+	1+	2+	2+
1971	2+	1+	1+	3	2+

TABLE 6 CONDITION OF VEGETATION ON TRANSECTS

1938	1
1960	2
1968	2
1971	1+

TABLE 7 CONDITION OF VEGETATION AROUND BOREHOLE G29757

To establish if there was any variation in vegetation due to seasonal factors the following photographs of similar scale taken in different seasons were compared-

December 1960 and April 1968 at a scale of ±1:36 000

November 1971 and April 1981 at a scale of ±1:10 000

No marked differences were discernible thus it is unlikely that the condition of the vegetation reflected in the semi-quantitative measures was influenced by seasonal variations.

The semi-quantitative measures reveal a slow incremental deterioration in the condition of the vegetation in the transects. On the inland transect, patch burning and tracks were the main cause of the decline while on the coastal transect an increasing number of paths disturbed the vegetation.

The single semi-quantitative value for a 9ha grid square is too gross a measure to highlight small isolated changes which changes nevertheless contribute to an understanding of the dynamics of the area. The revegetation of the track which was isolated from continued use by the blowout from the Matroosbaai dune plume shows that there is some elasticity in the system in that the vegetation has returned to its former state following a perturbation. Similarly, areas of patch burns showed recovery on sucessive photographs. A fuller discussion of this is given in the section on patch burning in this chapter and under the section Dynamics of the vegetation system in chapter 7.

The lowland vegetation is thus seen to be sensitive to fire and pressure from stock, people and vehicles. This vegetation element has a measure of elasticity in that after some time, it returns to its former state.

B.b Vegetation of the limestone outcrops

Throughout the forty five years from the earliest to the most recent photographs there has been remarkably little change in the vegetation of the limestone outcrops. The constancy and distinctive pattern of these areas made them ideal for use as reference points. Their resistance to burning was specifically noted by Duckitt and this fire resistance is borne out by the lack of change even when patch burning effected significant alterations in the surrounding vegetation.

During visits to the site it was found that the limestone outcrop plants were thick, impenetrable shrubs 1-2m high. Unless the vegetation is specifically removed it is unlikely that paths would be forced through it. The overall picture of this element is that it is one of the least sensitive in the study area.

B.c Riverine vegetation

The major changes in this system appeared to be caused by deliberate removal of riverine vegetation. This is shown on the 1960 and 1971 photographs. When there was no active removal the vegetation appears constant in extent and density and it was used as a reference point for this reason.

Plants requiring a high water table grow within this element so it is likely that this would be the area most sensitive to any changes in water table. The reeds that grow near the stream are used for thatching and it is possible that reed cutting is the major source of disturbance to the riverine vegetation. Generally, regrowth of reeds occurs within a few seasons so recovery after cutting should be fairly rapid.

B.d Linear dune vegetation

The vegetation on the southern extremity changed little in density or extent and this can be seen on Figures 12 to 15. The fence erected in 1948 excluded stock from the dune vegetation. There was at this time only one beach access point situated near Wintersteen. No fires appear to have occurred in the area in recent times.

At the northern end there was an increase in the area covered by vegetation and hummock dunes developed seaward of the position of the 1938 vegetation. A useful indicator of the change is the position of the cottage (marked in blue on the Figures) relative to the edge of the vegetation. A measure of the seaward advance of the vegetation is given below.

1938	1960	1968	1971
-40m[a]	-10m[a]	+10m[b]	+40m[b]

note a - distance is landward from the building
note b - distance is seaward from the building

TABLE 8 - Distance from building to vegetation

An access track to the northern section of the linear dunes was situated about 100 m south of the river mouth. A network of paths in this area can be seen on the 1938 photograph in Figure 10. Although the vegetation is disturbed there is no sign of sand blows or deflation suggesting that the impact is limited and contained. The paths are aligned across the direction of the major prevailing wind thus perhaps mitigating against wind exacerbation. By 1960 the paths had been overgrown and the vegetation had spread noticeably seaward. The cause of this effect was the exclusion of sheep by the fence erected in 1948. Duckitt stated that "the seekoring was loved by the animals and that as a result of fencing out the sheep, seekoring grew almost to the sea."

The interpretation of these observations is that the linear dune vegetation is sensitive in two ways to the presence of stock. Firstly their movement creates paths which within a maximum period of twelve years (from 1948 to 1960) revegetate where pressure is excluded. Secondly their grazing removes the seekoring which grows back strongly when grazing is stopped.

Linear dune vegetation is able to tolerate windblown sand. The presence of this element therefore serves as a buffer zone protecting vegetation more sensitive to the impact of sand scouring. Thus any impacts that affect this element are likely to generate secondary effects on inland vegetation as well as the primary impact on the linear dune vegetation.

B.e Dune plume vegetation

Both the small Matroosbaai plume and the far larger Silwerstroomstrand plume showed an increase in the area of vegetation cover. An inverse measure of this is the area of unvegetated mobile sand shown in Table 5. A detailed analysis of the vegetation change around the canal is given in Table 9.

The patches of plant growth in the body of the plume developed on the northern slopes of the dunes probably because this was in the lee of the wind for most of the year. Isolated patches of vegetation served to interupt the previously contiguous areas of unvegetated sand and this decreased the likelihood of sand blows.

The presence of the canal initiated an exponential increase in vegetation growth, as can be seen from Table 9 and the graph below.

1938	1960	1968	1971	1977	1981
0	0.64	1	1.2	1.7	2.6

TABLE 9 - Area of canal vegetation in hectares

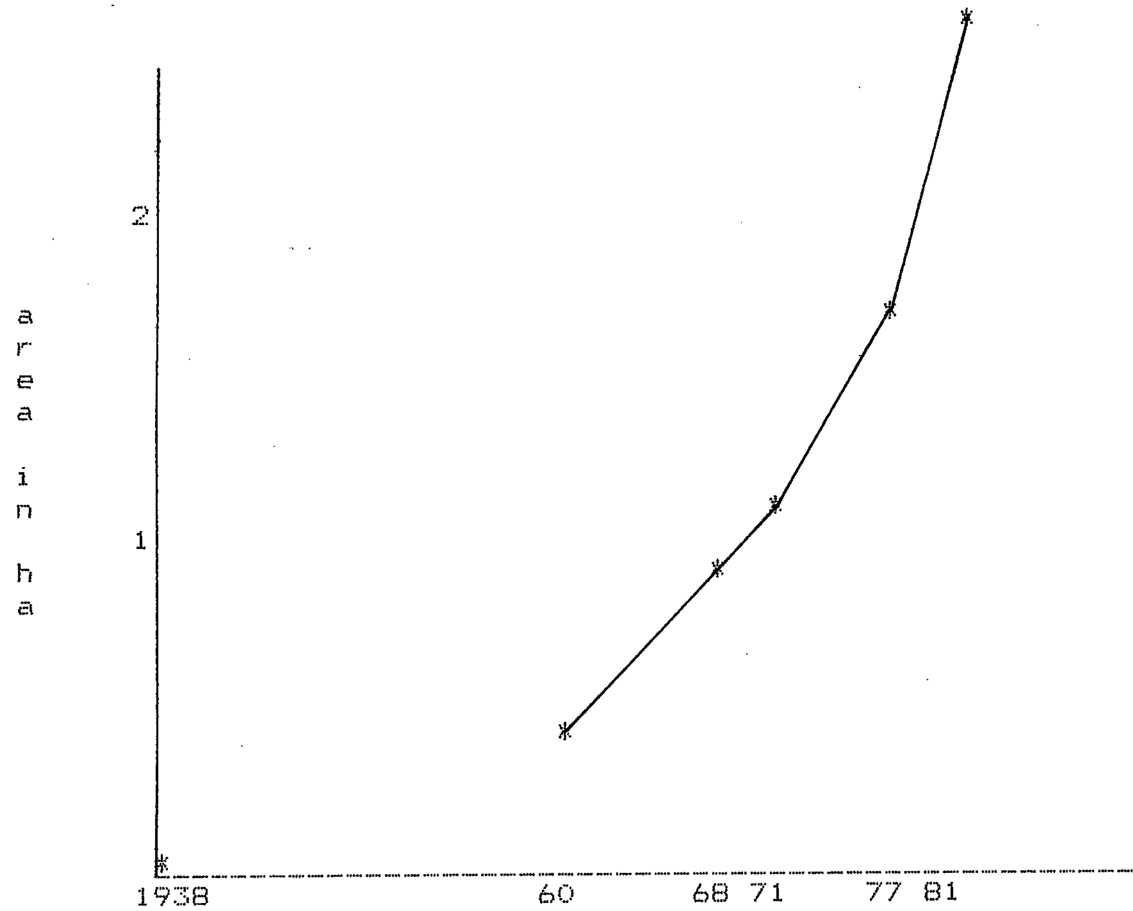


FIGURE 8 GRAPH SHOWING RATE OF CHANGE OF CANAL VEGETATION

The vegetation that developed around the canal trapped the sand introduced into the southern end of the dune plume. Under these changed conditions the vegetation on the inland margin of the dune plume flourished and expanded onto the unvegetated sand. The nett result of vegetation growth on seaward and inland margins is the exponential increase in area of plant cover.

The dune vegetation is thus very responsive to the provision of surface water and to the reduction of windblown sand. Any action that would remove vegetation cover especially along the seaward margin of the dune plume would give rise to unstable mobile sand. It is possible that the threshold value at which sand blows would start is of a similar order to that suggested for the Matroosbaai dune plume, namely between twenty and thirty contiguous hectares.

C RIVER COURSE

Silwerstroom is more correctly a series of springs than a river. Tracing its course landwards, it disappears underground to reappear further inland. The flow of water appears not to effect any changes in the river course. The constancy of the position, size and shape of the stream and its vegetation made it suitable as a reference point on all photographs and indicated the low sensitivity of this element. The change in the position of the mouth is due to human intervention and is discussed in the next section.

D ROCKY OUTCROPS

The resistance of the rocky outcrops to change made them suitable as reference points and also indicated their low sensitivity to any of the human actions or natural processes acting within the site during the forty five years spanned by this study. Changes within this system are certainly occurring but at a rate and on a scale that cannot be detected on the photographs available and with the techniques used.

6.3 Human actions within the study area

For the purposes of this study human actions can be considered as perturbations in the natural environment which

i introduce new types of material or energy

ii remove existing material and/or energy

iii change the flow of material and/or energy.

The location, extent and change over time of each type of action is discussed. Where possible the link between cause and effect is made by showing what changes occurred as a result of the perturbations.
There were seven types of human actions visible on the pre-development aerial photographs - Provision of paths, tracks and fences; alteration of the river mouth; patch burning; grazing of stock; cutting of reeds; planting of marram grass; recreation activities.

1 Provision of paths, tracks, and fences.

The density and location of paths provide an indicator of the use and management of the area. Paths were made by both stock - mainly sheep - and humans. Although it was not always easy to distinguish between stock and human paths on the aerial photographs, stock paths were generally noticeably narrower and were usually visible only with the aid of magnification. Many of the small stock paths were not drawn on to Figures 12 to 17. In the 1938 photograph the stock paths were concentrated around the northern end of the linear dunes. Fencing undertaken in 1948 excluded stock from this area and the stock paths were then confined to inland camps. The increase in paths in 1960 was a reflection of the more intense pastoral use made of Buffels rivier. The increase in fencing and also in patch burning which can be seen on the photographs support this interpretation.

Tracks remained fairly constant until 1971 when 'doubling' of tracks occurred on slopes. The "doubling" effect shows areas which are sensitive to the presence of tracks. The decrease in length of tracks when comparing 1938 and 1960 is due to the Matroosbaai sand blow which has been more fully discussed in section A.a of this chapter.

The extent and location of fencing is another useful indicator of landuse. In 1938 the only fence within the boundaries of the study area was the boundary between the farms Buffels Rivier and Groot Springfontein. Thereafter the marked increase in length of fences reflected the more active use of Buffels Rivier when fences were used to manage stock, excluding them from the dunes and confining them to inland camps. The effect of this has already been noted in the description of paths and linear dune vegetation. It should be noted that the figures given in the Table 10 are approximate as it was frequently difficult to distinguish fences unambiguously.

	1938	1960	1968	1971
Paths	0.7	4.4	0.7	0.5
Tracks	8.7	8.4	8.7	9.5
Fences	1.4	8.5	7.5	7.0

TABLE 10 Length of paths,tracks,fences in km

2 Alteration of the stream mouth

Measurements were taken of the straight line distance between the mouth of the stream relative to its position in 1938. The results are given in Table 11. The relative positions can also be seen by comparing the overlays.

1960	1968	1971	1977	1981
900m N	860m N	240mN	200mN	100m N
		140mN		
		40m S		

TABLE 11 Position of stream mouth/s relative to 1938

After maintenance of the canal ceased in 1968, the stream broke back to the coast, reverting closer to the original mouth position. Although no mouth as such was visible at the original position in the 1968 and 1971 photographs, a moist patch could be seen on the beach indicating underground wetness even though there was no surface flow. It was also observed that in the 1981 and 1983 photographs the beach south of the dune plume was darker - perhaps indicating more moisture - than the northern section of the beach.

3 Patch burning

Apart from the burns at the head of the Silwerstroom, there is no sign of recent burns on the 1938 photograph. By 1960, extensive patch burning of the inland coastal vegetation had occurred. Some of the '1960' burn patterns are still clearly visible on the 1968 and 1971 photographs whereas others have returned to their pre-burn state. By 1977 there are no further signs of the '1960' burnt patches. Some further burning occurred between 1960 and 1968 but thereafter there appear to have been no fires, accidental or intentional.

4 Stock grazing

Although this is not directly visible on the photographs, if path density in areas of low recreation appeal is accepted as a reasonable indicator of stocking levels, the highest stocking rate can thus be inferred to be pre-1960 and to have decreased thereafter. Duckitt said that on average 600 sheep were pastured on the area in summer and about 1100 in winter.

5 Reed cutting

Duckitt reported that during 1950 to 1954 extensive rethatching of the Bokbaai buildings was carried out and that some of the reeds used came from the Silwerstroom. Reed regrowth is usually accomplished within one or two seasons thus it is not likely that the cleared areas seen on the 1960 photograph are the result of the reed cutting mentioned by Mr Duckitt but may possibly be reed cutting for a similar purpose.

6 Marram grass planting

As mentioned in chapter 4 page 22, one of the four rows of marram planted in 1948 is visible on the 1960, 1968 and 1971 photographs. In 1981 it is barely discernible as a profusion of other vegetation has developed around it. The length of the row in 1960 was approximately 80m, in 1968 110m and in 1971 160m.

7 Recreation

The only building visible on the photographs was the one at the original mouth of the river. According to Mr Duckitt this was a holiday cottage belonging to the van Reenen family.

6.4 Summary

From the interpretation of the pre-development aerial photographs the most sensitive elements of the Silwerstroomstrand environment are suggested to be the vegetation of the dune plumes and vegetation of the linear dunes. The least sensitive elements are the rocky outcrops and the vegetation of the limestone outcrops. The rest of the vegetation shows varying amounts of elasticity to fire, grazing, movement of stock, people and vehicles and reed cutting.

The human actions having the longest acting impact were patch burning and stock movement. Stock grazing effected marked changes on the vegetation of the northern linear dunes. There are indications that all the impacts of the human actions before 1972 are reversible with time and cessation of the causative action. Recreation impacts visible on aerial photographs were confined to the area around the cottage and were minimal.

Having described the changes and constancies noted on the aerial photographs some understanding of the dynamics of the area can be gained and this is discussed in the next chapter.

FIGURE 9 LOCATION AND EXTENT OF SYSTEMS

FIGURE 10 1938 AERIAL PHOTOGRAPH (scale ±1:25 000)

Note the difference in scale when comparing Figures 10 and 11.

FIGURE 11 1983 AERIAL PHOTOGRAPH(scale±1:13 000)

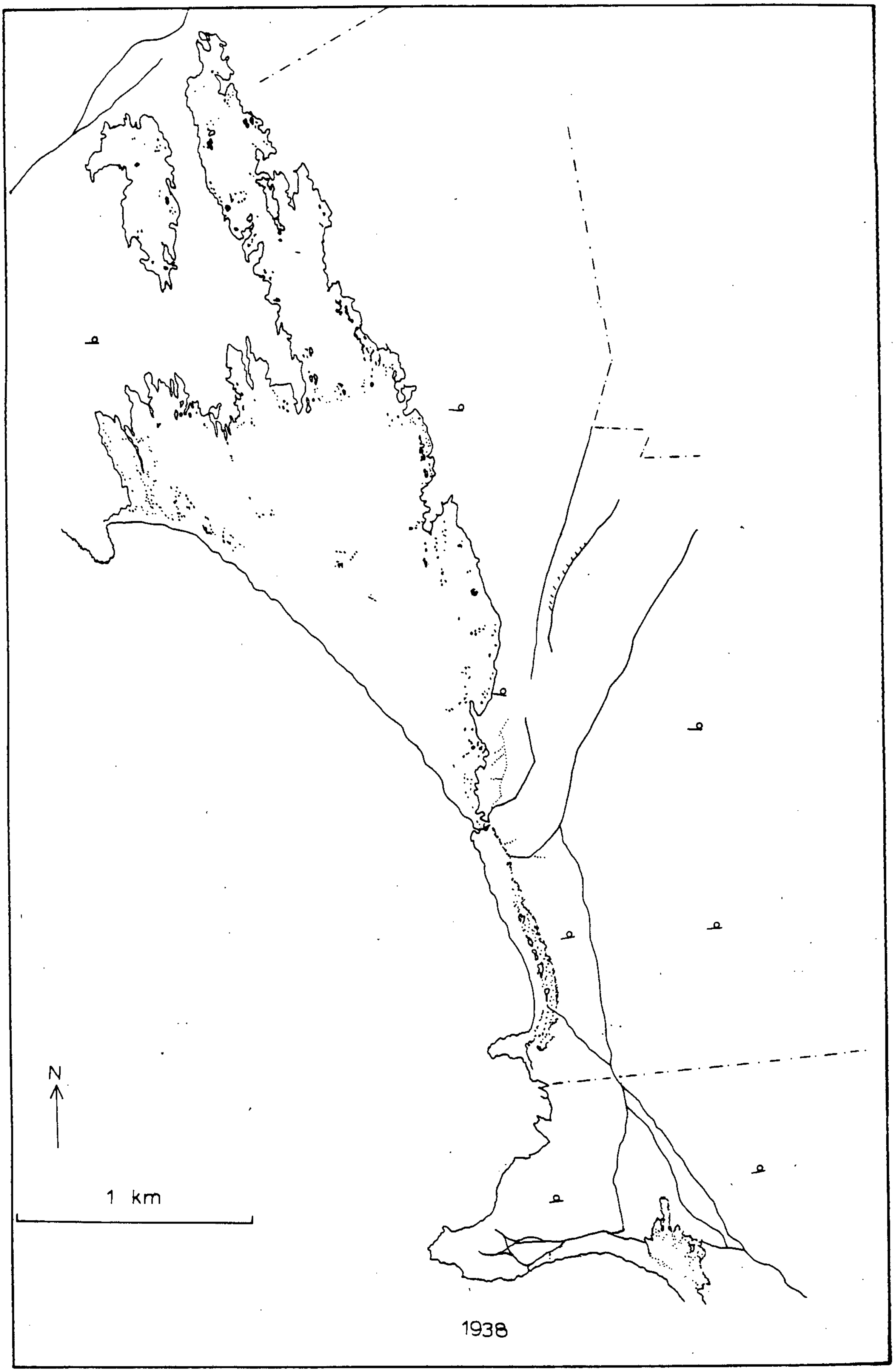


FIGURE 12
For key see foldout behind Figure 17

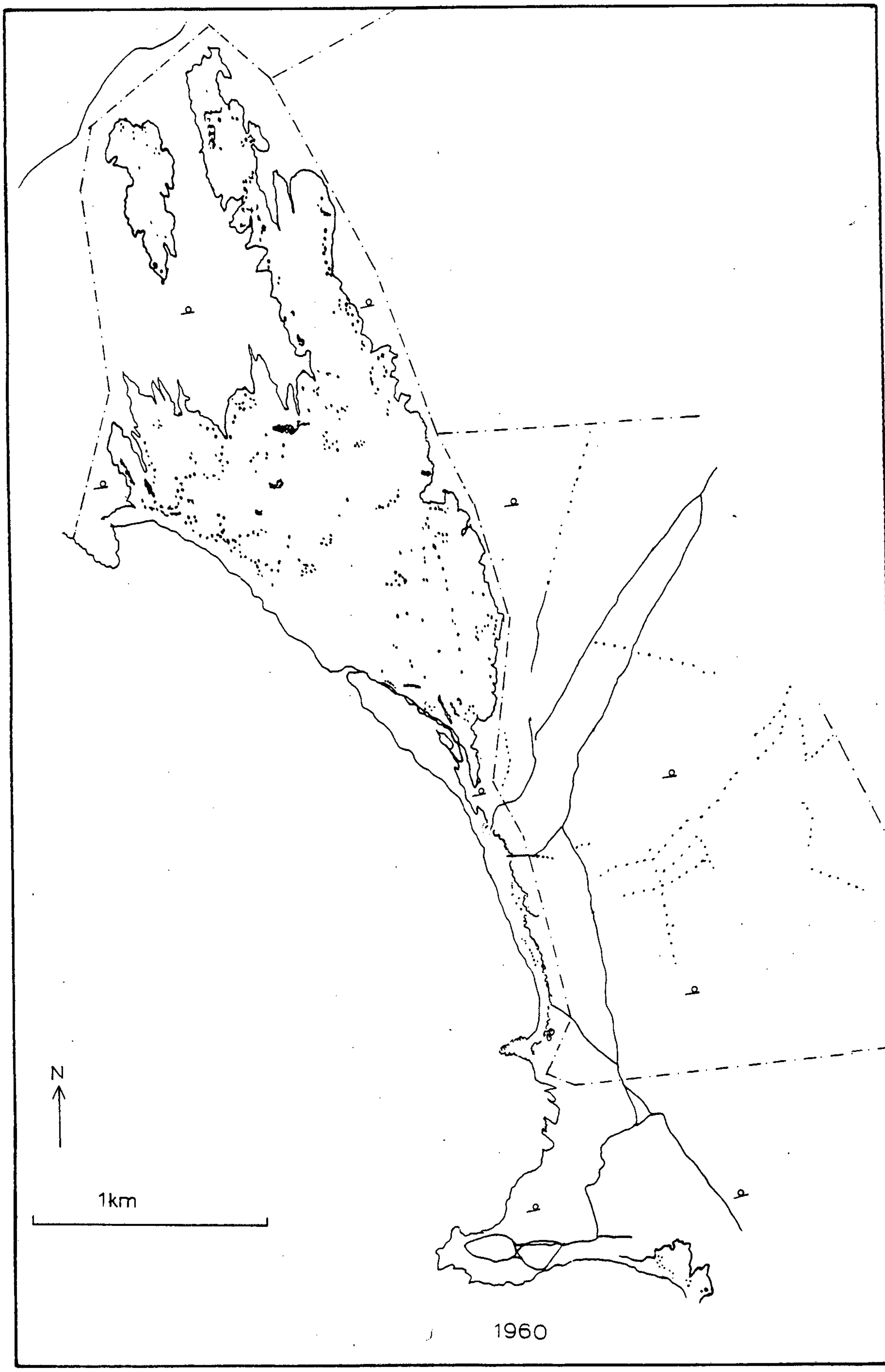


FIGURE 13
For key see foldout behind Figure 17

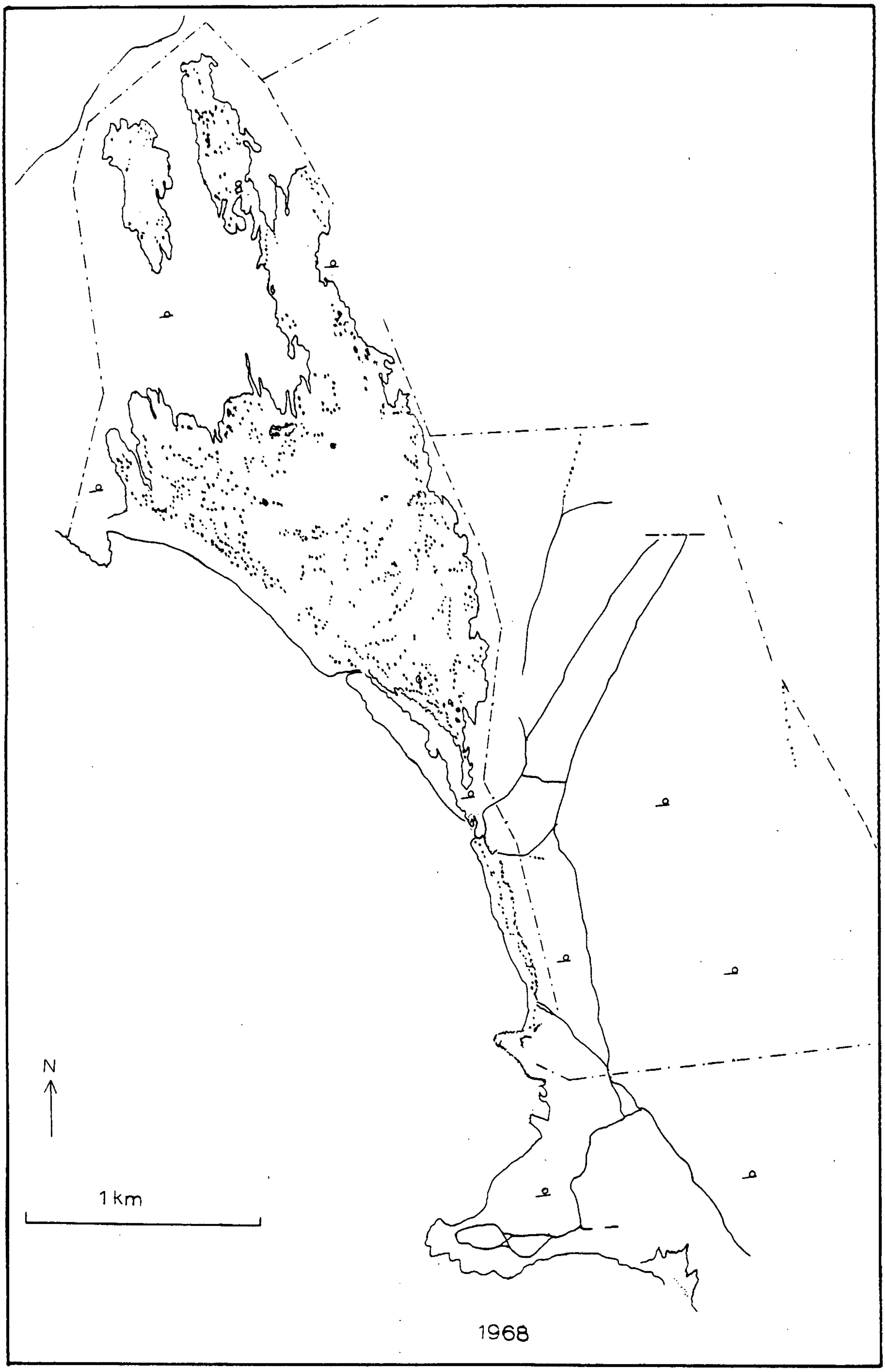


FIGURE 14
For key see foldout behind Figure 17

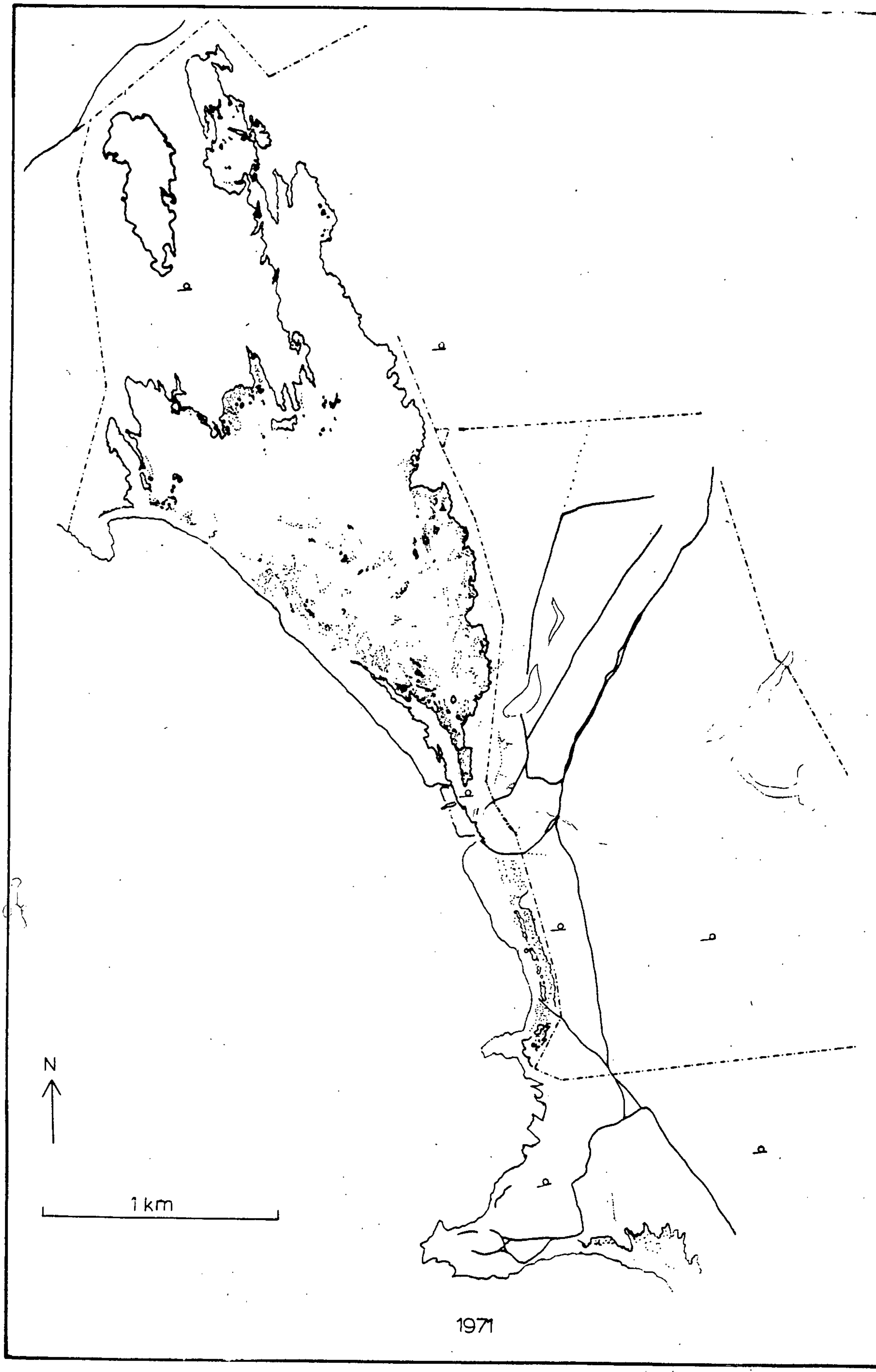


FIGURE 15

For key see foldout behind Figure 17

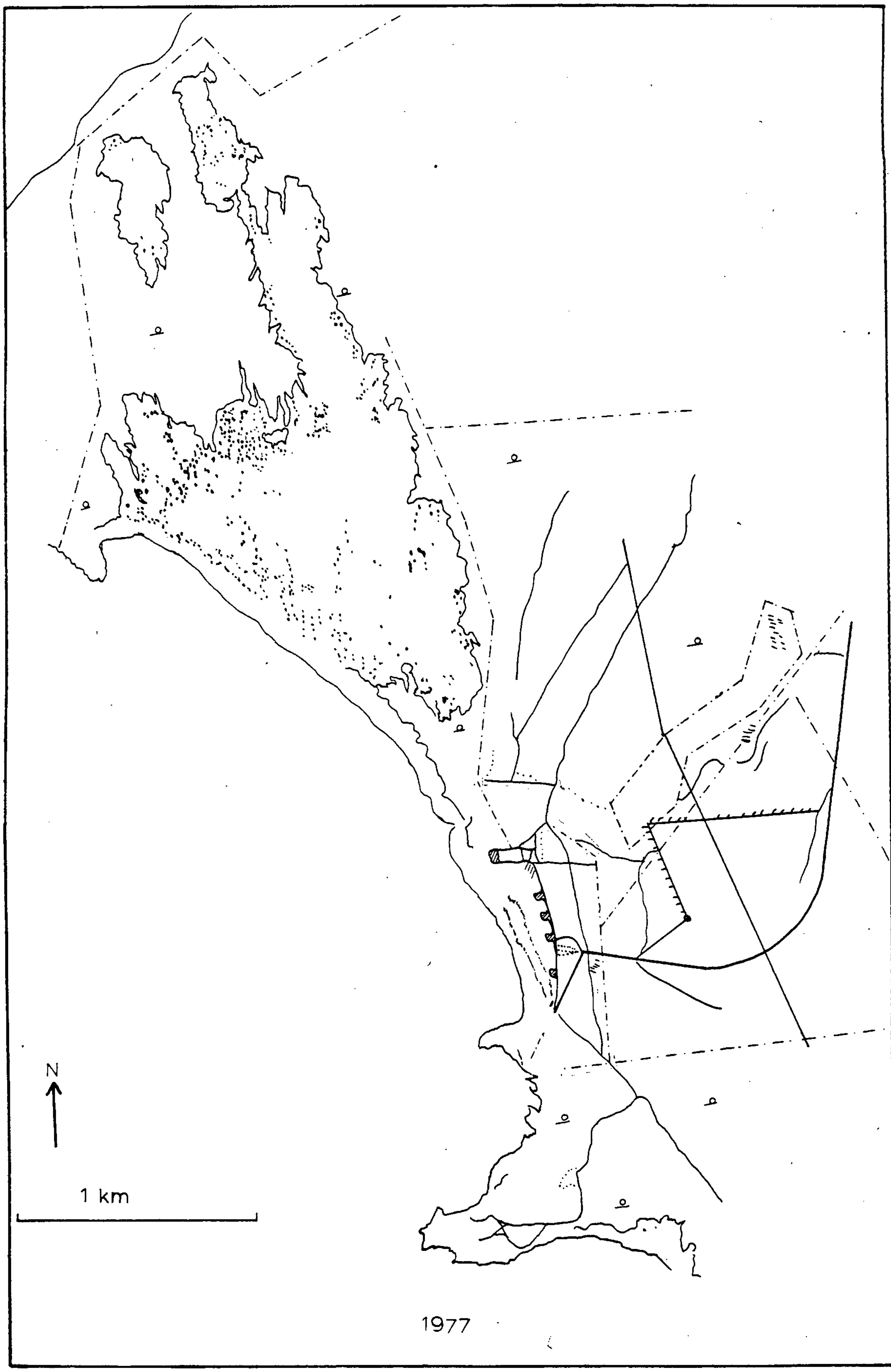


FIGURE 16

For key see foldout behind Figure 17

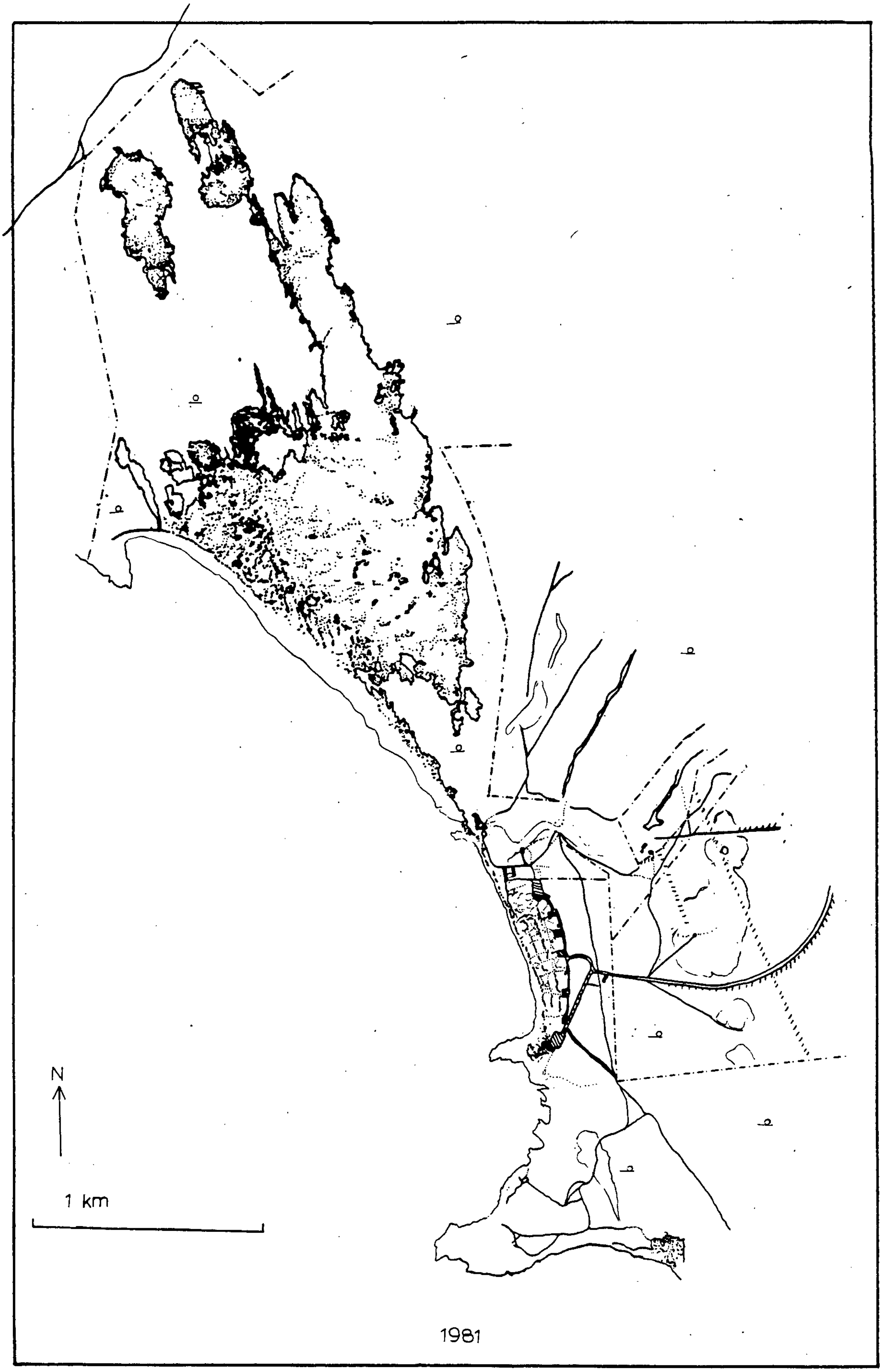
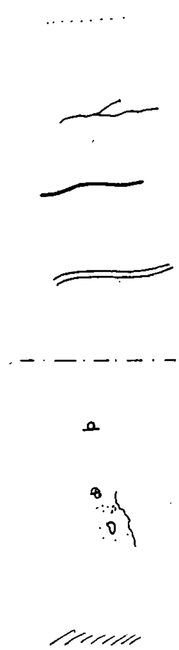


FIGURE 17

For key see foldout behind Figure 17

KEY TO FIGURES 12 to 17



Paths

Tracks

Gravel road

Tarred road

Fence line

Bush

Vegetation in dunes

Scraped areas

CHAPTER SEVEN

THE DYNAMICS OF SILWERSTROOMSTRAND

Introduction

Building on the comparative interpretation described in the preceding chapter, the dynamics of each of the four major systems delineated at Silwerstroomstrand are outlined.

Dynamics of the site.

Attempting to link cause and effect by observing the response of the environment to perturbations resembles a 'black box' situation. The internal workings of the system are opaque and the visible response gives a 'summarised' view of the processes operating within that environment. Thus, encapsulated in the changes described in the preceding section, are the dynamics of the site. Causes of the visible effects and effects of the visible actions can be surmised but not easily proven. It is suggested, however, that even the surmised cause and effect links offer a useful view of the dynamics of the area.

7.1 Dynamics of the sand system

Insights into the dynamics of the sand system came firstly from changes observed in the vegetation on the Matroosbaai dune plume. There is an increase in vegetation cover which has not been initiated by provision of surface water nor were animals excluded by fences as in the case of the Silwerstroomstrand dune plume. Thus it appears that a steady background process of vegetation expansion has been in progress since 1938.

A second contribution to understanding the dynamics of the sand system is obtained by analysing the changes in the sand content of the Matroosbaai dune plume. Figure 12 shows that prior to the 1938 photograph the Matroosbaai dune plume had covered a track running along the southern end of the Springfontein point. It can be seen in Figure 13 that by 1960 the landward portion of the track had been partially revegetated. It is suggested that as a track existed prior to 1938, there was no obstruction to the passage of vehicles but the sand blow covered the track making it impassable and so allowing revegetation. The sand blow reflected some change in sediment inflow which is also reflected in the inland margin of the Silwerstroom dune plume. The 1938 photograph in Figure 10 shows the sharply defined boundary between dune and adjacent vegetation suggesting a recent movement of sand over the vegetation.

The cause of this incoming 'pulse' might lie in increasing storm episodes. Dury (1981:165) describes how the greatly increased storminess of the Middle Ages drove Atlantic beachsand as far as 100 km inland in southwest France.

There is supplementary evidence of the influence of storm episodes on the sand systems within the area. Duckitt (personal communication 1983) described the uncovering on two occasions of an old sailing ship buried under the sand at the northern end of Silwerstroomstrand, first in the 1920's and again in 1964. He also stated that winter storms twice washed away the canal.

Against this background it is probable that weather phenomena are a contributory cause to any variation in the volume of sand within the mobile dunes and consequently the varying area of unvegetated sand.

A possibility to be considered is that the construction of the Duncan dock in 1936, which significantly affected the sediment dynamics at Milnerton beach (Impey personal communication 1984) might have produced secondary impacts at some distance and might have been responsbile for the pulse of sand seen in the 1938 photograph. If this is in fact the case it has implications for the future of Silwerstroomstrand. Construction of a harbour has begun at Koeberg, some 10 km south of the site. In addition it is plannned that a small boat harbour will be built at Silwerstroomstrand. Both of these activities will affect sediment transport and will consequently have an impact on the sand system at Silwerstroomstrand.

A third contribution, the change noted in the development of hummock dunes in front of the northern portion of the linear dunes is suggestive of a prograding coastline and thus of a regular continuing input of sand.

The fourth contribution to understanding the dynamics of the sand system is the rapid and extensive growth of vegetation along the canal. Any increasing area of vegetation serves to trap wind-blown sand. A secondary impact of this will be to lessen the amount of sand reaching the inland margin of the dune plume, thus creating conditions in which vegetation can spread, consequently decreasing the area of unvegetated sand. Comparison of Figures 12 to 17, Table 9 and Figure 8 show the increasing vegetation of the canal area and eastern margin of the Silwerstroomstrand dune plume. It is suggested that the canal was a major contributing cause of the decrease in bare sand. (This was the intended outcome of the action initiated by the Duckitt family.)

The dynamics of the sand system are clearly influenced by the sediment transport system. Although many elements of this system cannot be seen directly on aerial photographs some inferences about the operation of the system can be made.

On many photographs a band of foam appears about 800m offshore opposite Wintersteen. This was variously interpreted as foam from waves breaking on the rocks of Springfontein point and trapped by an eddy circulation caused by refraction of waves around the point; or as an indication of a shallow area possibly a reef or cluster of rocks which may be an extension of the outcrop of Malmesbury shales of Wintersteen and Springfontein point. Whichever was the case, the direction of flow and energy of incident waves would determine where sediments would be deposited.

Gunn (1977) carried out an extensive study of the dynamics of Matroosbaai, which is just south of Springfontein point and Buffelsbaai, the main bay of the study site. The bathymetry of Buffelsbaai was investigated as part of his study and the bathymetric map, reproduced in Appendix D, shows two shallow areas off Wintersteen and Springfontein point.

Gunn found that water movement in Buffelsbaai is driven by both wind and waves as opposed to Matroosbaai where waves are the dominant forcing mechanism of water movement. During moderate or stong southerly winds the flow in Buffelsbaai was found to be from south to north. During light winds this reversed and was interpreted as a downwelling to balance the reduced wind stress. The significance of this is that as the prevailing winds for eight months of the year are moderate to strong southerly, water generally moves from the south to the north. When this incident water strikes the shallows off Wintersteen it is refracted and generates a small eddy circulation isolated from the overall water movement. The incoming water carries less sediment having lost energy in breaking on the shallows, consequently the southern portion of the linear dunes is fed with less sand than the northern section. This line of reasoning is supported by the observations from the aerial photographs that the southern portion of the linear dunes remained constant in extent in contrast to the prograding northern section.

The presence of dunes 10 to 15m high at the southern end of the linear dunes indicates that there has been an influx of significant volumes of sand in the past. It is suggested that any sand input to this area might currently be transported by winter storms driven by northerly winds.

In summary, analysis of the comparative interpretation of the aerial photographs indicates a range of cause and effect within the sand system. It is argued that:

i regular and episodic natural processes as well as

ii human intervention

are involved in the dynamics of the sand system. It is suggested that the greatest change in the sand system in the forty five years of aerial cover, was effected by provision of surface water which stimulated plant growth and so stabilised 60% of the dune area within three decades.

7.2 Dynamics of the vegetation system

Understanding of the dynamics of the vegetation system was inferred from changes observed in plant growth in response to the human actions of burning, running domestic stock, vehicle movement, recreation and provision of surface water by diverting the Silwerstroom into a canal.

Recovery from burning depended on the time of year when the burn occurred and there is clear evidence on the photographs of the variability of regeneration time. The length of time between successive photographs placed a constraint on the accuracy with which recovery rates could be determined.

Whilst some '1960' burns had regenerated by 1971, some were still visible in 1977 but had regenerated by 1981. From these observations a rough estimate of recovery rates can be made.

Brownlie (1982:16), working at Pella (18km east of the study site) gives a tentative relationship between time after burning and appearance on aerial photographs of shades of grey as well as vegetation density suggesting that:

Grey-cream and bare ground = 0-2 years post-fire

grey and medium cover = 2-5 years post-fire

dark-grey and dense cover > 5 years post-fire

She indicates that burn intensity and soil colour will modify the relationship but states that this proposed relationship is the best available tool to trace the fire history of an area. Brownlies's study was undertaken in the coastal fynbos vegetation type whereas the vegetation type of the study area is strandveld, thus whilst the relationship given above is used, it is appreciated that there are limitations imposed by soil colour, vegetation type and burn intensity.

Using Brownlie's tentative relationship it is estimated that the 1960 photograph was taken 0-2 years after the areas had been burnt. The burns were still visible on the 1968 photographs but no longer visible on the 1971 pictures. Thus it can be calculated that the recovery rate of these patches was between a minimum time of nine years (1960 to just after the 1968 photograph) and a maximum time of thirteen years (two years before 1960 to 1971). Similar calculations for burns visible on the 1960 and 1977 photographs but not on those of 1981, gives a minimum recovery time of eighteen years and a maximum of twenty two years. Thus recovery rates from burning appear typically to vary from nine to twenty two years.

Duckitt (personal communication 1983) estimated that recovery from a burn in February or March would take twelve years whereas a summer burn driven by a strong wind could take over twenty years to recover fully. His practical experience and the calculations based on the observations from the aerial photographs are in close agreement.

Revegetation of paths and tracks which had fallen into disuse was observed on the photographs. The same problem of estimating recovery rates applies for this revegetation as for burn recovery. Nevertheless, an estimate of the maximum recovery time can be made. Animal tracks on the inland camps are visible on 1960 photographs but absent by 1968. This suggests that the the longest time for recovery of lowland vegetation from small paths is eight years whilst it is possible that it is shorter.

Stock paths on the northern portion of the linear dunes were present on the 1938 pictures and absent on those of 1960. Because it is known that a fence was erected in 1948 and that this action led to recovery of the vegetation, it is possible to state that the longest time for recovery of dune vegetation from the impact of small paths is twelve years.

The track on the Springfontein point, which was covered by the sand blow, is visible on the 1960 picture. By 1968 regrowth has begun and by 1971 has almost covered the entire track. Thus the vegetation of the point which includes limestone outcrop and linear dune elements, regenerates over unused tracks in a minimum time of eleven years.

The response of dune vegetation to the provision of surface water can be analysed in some detail as it is known when the canal (which provided the water) was started. Figure 8 shows the exponential spread of the plant growth. The provision of surface water initiated a chain of changes and the extent and rate of change reveal that the action had been started at a 'responsive' point, one which was very susceptible to the introduction of water.

The vegetation of the limestone outcrops is resistant to fire and grazing and regenerates rather more quickly than Lowland vegetation over disused tracks.

7.3 <u>Dynamics of the river course and rocky outcrops</u>

The river course and the rocky outcrops remained very constant. The dynamics of these elements of the site are probably governed by long term cycles and the rates of change are therefore too small to be detected on the spatial and temporal scale of the photographs available or with the techniques used for this study.

The dynamics of the site described above can now form the basis for the following chapter in which predictions of the probable and potential impacts of the planned project actions are made.

CHAPTER EIGHT

PREDICTION OF IMPACTS

Introduction

Predictions of the impact of actions on an environment are based firstly on an informed understanding of the dynamics of the environment concerned and secondly on an analysis of the interaction of planned actions and exisiting dynamics. Chapter 7, gave an outline of the dynamics of Silwerstroomstrand and this chapter analyses how actions at the site between 1972 and April 1981 (the time of the last photograph from which measurements were taken) compare with past actions. On the basis of the response of the environment to past actions, predictions of the probable and potential impacts are made.

8.1 Analysis of actions at the site from 1972 to 1981

The actions at the site, information about which was obtained from interviews with the consulting engineers, Liebenberg and Stander, the Directorate of Water Affairs, Divisional Council of the Cape and from aerial photographs, are considered in three broad groupings

- actions associated with recreation
- actions associated with water extraction and
- other actions which include the construction phase of recreation and water extraction infrastructure.

The actions were analysed to see if they resembled any of the previous human actions within the study area. This analysis is summarised in Table 12. They were also arranged in a matrix to show in which environmental elements each action was located and this matrix is presented as Table 13. The siting of the recreation and water extraction infrastructure is shown on the map in Figure 5, page 31.

ACTIONS	COMPARABLE PAST ACTIONS
RECREATION	
Buildings*	
office and house	holiday cottage
ablution blocks	holiday cottage
shop and kiosk	holiday cottage
Cleared areas	
camping and picnic spots	burning/trampling
hardened for parking	none comparable
Gravel road	track (note 1)
Visitors	visitors & stock
WATER EXTRACTION	
Treatment plant*	none comparable
Raised weir	none comparable
Buried pipelines*	none comparable
Boreholes*	none comparable
Powerlines	none comparable
Reservoir*	none comparable
Water extraction	none comparable
Gravel road	track (note 1)
OTHER	
Fencing	fencing
Grazing	previous grazing
* Vegetation removal	burns/tracks(note 1)
Tarred road	track(note 1)
Halt in canal maintenance	none comparable

TABLE 12 FUTURE ACTIONS & COMPARABLE PAST ACTIONS

* Indicates actions which in the construction phase involve removal of vegetation

Note 1: "tracks" refer to vehicle tracks

SYSTEM ELEMENTS	A.a	A.b	A.c	A.d	B.a	B.b	B.c	B.d	B.e	C	D
ACTIONS											
RECREATION											
Buildings											
office and house	-	-	-	-	*	-	-	-	-	-	-
ablution blocks	-	-	-	-	-	-	-	*	-	-	-
shop & kiosk	-	-	*	-	-	-	-	*	-	-	-
Cleared areas											
camping & picnic	-	-	*	-	-	-	-	*	-	-	-
hardened for parking	-	-	-	-	*	-	-	-	-	-	-
Gravel road	-	-	-	-	*	*	-	-	-	-	-
Visitors	-	*	*	*	-	-	-	*	*	-	*
WATER EXTRACTION											
Treatment plant	-	-	-	-	*	-	*	-	-	-	-
Raised weir	-	-	-	-	-	-	*	-	-	*	-
Buried pipelines	-	-	-	-	*	*	-	-	-	-	-
Boreholes	-	-	-	-	*	*	-	-	-	-	-
Gravel road	-	-	-	-	*	*	-	-	-	-	-
Powerlines	-	-	-	-	*	*	-	-	-	*	-
Reservoir	-	-	-	-	-	*	-	-	-	-	-
Water extraction	-	-	-	-	*	*	-	-	-	-	-
OTHER											
Fencing	-	-	*	-	*	*	-	*	*	*	-
Grazing	-	-	-	-	*	-	-	-	-	-	-
Vegetation removal	-	-	-	-	*	*	-	*	-	-	-
Tarred road	-	-	-	-	*	*	-	-	-	-	-
Halt in maintenance of canal	-	-	-	*	-	-	-	-	*	-	-

TABLE 13 MATRIX SHOWING ELEMENTS IN WHICH ACTIONS OCCUR

A.a=Matroosbaai dune plume
A.b=Beach
A.c=Linear dunes
A.d=Silwerstroom dune plume

B.a=Lowland vegetation
B.b=Limestone outcrop veg.
B.c=Riverine vegetation
B.d=Linear dune vegetation
B.e=Dune plume vegetation

C = River course
D = Rocky outcrops

Post-1972 actions comparable to past actions

It is considered that the buildings in themselves will make little impact as the holiday cottage made no visible primary impact (on aerial photographs) on any element of the site. It should be noted that once a certain threshold concentration of buildings is reached, this will change and will certainly interfere with many natural processes. However, in the density currently planned this will not occur.

Areas to be cleared for camping and picnic sites were considered comparable to the areas that had been burnt or trampled by stock in the past. Such areas recovered with time and diminished pressure.

Vehicle tracks, to which gravel and tarred roads are comparable, at the low density of the period prior to 1972, made little visible impact on aerial photographs other than the obvious one of removal of vegetation within the area of the track. The only other impact was on slopes where it appeared that erosion caused surface deterioration necessitating a new track. It is therefore suggested that gravel and tarred roads at the density planned, will have little impact and because of better construction methods, will not erode as badly on slopes as do the old vehicle tracks. Although gravel roads and tarred roads are considered comparable to tracks, they have no past precedents in the sense that they introduce new materials into the area.

The visible impact from visitors before 1972 was limited to paths concentrated around the cottage. It would appear that there was no great press of visitors and certainly the poor roads would not have encouraged large numbers.
The prime purpose of the current recreation development is to increase the number of visitors. A comparable action in the past is thus suggested to be stocking density which resulted in a proliferation of paths.

Construction activities involving initial removal of vegetation are comparable to burnt areas and disused tracks. In the past, vegetation regenerated following burning or disuse of paths and tracks.

Fencing serves either to exclude or to concentrate use of an area. Where exclusion has occurred as within the inland section of the Divisional Council property and in the and Silwerstroom dune plume, there has been an improvement in the condition of the vegetation. Where concentrated use was the outcome, as on the inland stock camps in 1960, an increasing number of paths occurred.
In the past the impact of grazing was masked by the patch burning that usually preceded it. However, in 1938 the grazing on the linear dunes and around the stream mouth was not preceded by burning and the impact visible on aerial photographs, was reduction in the canopy cover of the vegetation.

The actions for which no comparable past actions occurred, were gravel and tarred roads and hardened parking areas (in the context of introduction of new materials), all the water extraction infrastructure and a dropping water table.

8.2 Predictions

In making predictions of the effects of the project actions a distinction can be drawn between potential effects and probable effects. Erickson (1979:128) states that "potential effects are those effects that are reasonable in light of theory or general understanding: probable effects are those effects that are reasonable in light of both theory and actual fact (for probable effects can only be estimated in terms of the data that are specific to the proposed project and to the project site). The identification of both the potential and the probable effects on abiotic and biotic systems depends upon an informed understanding of specific dynamic processes."

The comparative interpretation of the aerial photographs and the analysis of the actions have provided data specific to the project and the site and can be used as the basis for predicting probable impacts.

Prediction 1. Buildings will make no significant impact.

Prediction 2. Vegetation will regenerate within the areas cleared for camping and picnic sites.

Prediction 3. Gravel and tarred roads will make little impact.

Prediction 4. Informal paths will increase markedly as soon as good roads provide access to the site. The paths will be concentrated along the coastline. Because of the resistance of the rocky outcrops to change and the malleability of the beach, the paths will be visible mainly in the linear dunes. The highest density of paths will be around access points. This impact will remain as long as the paths continue to be used. Should use cease they would be revegetated within one to two decades.

Prediction 5. The positioning of the camping and picnic sites will be one factor determining the pattern of informal paths.

Prediction 6. Construction actions removing small areas of vegetation and where no further disturbance occurs, will be fully revegetated after one or two decades. Where large areas are disturbed, i.e. about twenty hectares and where the shape is such that length and width dimensions are of the same order (in other words, not twenty hectares of road) - sand blows will occur similar to that seen in the dune plumes. If no further disturbance occurs these too will revegetate as did the Matroosbaai dune plume, but will take longer, probably thirty years.

Prediction 7 Fencing will improve the quality of the vegetation where it excludes entry of stock and people. Where it concentrates people and stock, pressure on the vegetation can be expected to increase. This will be expressed as decreased canopy cover and increased paths.

Prediction 8 Because of the on-going pressure, recreation will give rise to longer acting impacts than will water extraction and the area of greatest impact will be in the linear dunes.(The orientation of paths across the line of the prevailing winds may well mitigate against wind erosion of the paths.)

Prediction 9 Uncontrolled fires will damage vegetation. If they occur during dry summer months revegetation will take at least two decades. If more than twenty hectares of dune plume or linear dune vegetation is affected it will give rise to a secondary impact of sandblows.

The following are predictions of potential impacts.

Prediction 10 Continued grazing could be a source of paths and decreasing vegetation quality as overstocking could result from farmers hiring grazing. This is an example of the "tragedy of the commons" phenomenon where absence of property rights leads to poor management.

Prediction 11 Water extraction has no comparable past action on the site and thus predicting its impact on the basis of past behaviour of the system is not possible. Theory would lead to the prediction that lowered water table would affect plant growth.

Past behaviour of the system does provide an insight into the relationship of the water table level and initiation of plant growth. A high water table does not appear to be the factor that initiates plant growth in the dunes as, if this were the case, vegetation cover would have been expected in the dunes prior to 1976, the year when water extraction began, but the early photographs show no vegetation within the dunes. Surface water appears to have been far more

important in initiating growth. It is also possible that the mists and fogs which are a feature of the West coast may make a greater contribution to the plant water relations of the area than does the underground water.
The height of the water table might be far more significant in sustaining growth and determining the species compostion of the vegetation. Thus it is predicted that the potential exists for growth rates of existing species and species composition to change.

Prediction 12 The non-maintenance of the canal will lessen the availability of surface water in the dunes. This will affect some of the vegetation. It is possible that plant succession has progressed to a point where the community will continue to grow provided there is no major perturbation such as heavy grazing or fire. Thus the prediction is that vegetation cover will remain constant or continue to expand.

Prediction 13 does not arise out of analysis of the actions but of the dynamics and is added as it is felt that it could provide a significant insight into potential future impacts at Silwerstroomstrand.

The construction of the harbour at Koeberg, initiated in mid-1981 (Cook personal communication 1984) will affect sediment transport. This may give rise to a greater influx of sand to all parts of the Silwerstroom coastline although less will reach the southern 500m of the linear dunes.

8.3 Summary

Overall, it is predicted that there will be an initial surge of impacts following the construction of the water extraction and recreation infrastructure. Thereafter, revegetation will occur where there is no further disturbance. Recreation activities will be a more important source of impacts than water extraction activities but will be concentrated on a narrow belt along the coastline. Its major expression will be in the form of informal footpaths concentrated around access points such as parking areas and camping and picnic sites. The potential exists for water extraction to affect vegetation growth rates and species composition.

CHAPTER 9

EVALUATION OF PREDICTIONS

Introduction

The results of the interpretation of the post-1972 photographs and the results of the field visit and Delphi session are discussed. This provides a background against which the validity of the predictions that were made as a result of comparative interpretation of aerial photographs are evaluated.

9.1 Interpretation of the post-1972 photographs

Figures 16 and 17 on pages 70 and 71 show the extent of dune vegetation, paths, tracks, fences and scraped areas in 1977 and 1981.

In all the elements of the sand system the trends observed in the pre-1972 photographs continue i.e. the area of bare sand in the two dune plumes continues to reduce, there are no marked long-term changes in the beach, the southern portion of the linear dunes remains constant in extent and the northern portion progrades. (The original discussion of these results is on pages 45 to 49.)

Overall the elements of the vegetation show more marked changes than the elements of the sand system. In some instances vegetation condition deteriorated and in others, improved.

Table 14 repeats the semi-quantitative evaluation of two transects through the vegetation before 1972 and adds post-1972 evaluations to complete the picture of the changes. The same is done in Table 15 for the area around borehole G29757.

Grid square number	1	2	3	4	5
INLAND TRANSECT					
1938	1	1	1	1	2
1960	1	2	4	3	2
1968	2	3	4	3	2
1971	2	3	4	3	3
1977	2	3	4	2	2
1981	1	2	2	1	no photo
COASTAL TRANSECT					
1938	2	1	1	2	2+
1960	2+	1+	1+	2+	2+
1968	2+	1+	1+	2+	2+
1971	2+	1+	1+	3	2+
1977	5	6	5	3	3
1981	5	6	5	3	3
1983	5	6	5	3	3

TABLE 14 CONDITION OF VEGETATION ON TRANSECTS 1938-83

1938	1
1960	2
1968	2
1971	1+
1977	5
1981	4

TABLE 15
CONDITION OF VEGETATION AROUND BOREHOLE G29757

Key for seven-point scale in tables 14 and 15
1=no disturbance
2=minimal disturbance
3=noticeable disturbance
4=moderate disturbance
5=marked disturbance
6=severe disturbance
7=gross disturbance

Looking at individual elements in more detail, parts of the element B.a Lowland vegetation, have improved in condition whilst other parts still show the impact of grazing.
The Department of Community Development rents out grazing to farmers on its property whereas no grazing is rented out on Divisional Council property. (The boundary between the land owned by the Divisional Council of the Cape and the Department of Community Development is shown in green on Figure 17.) The difference in the density of the vegetation on either side of the boundary fence is noticeable and is denser where there has been no grazing.

The element B.b, Limestone outcrop vegetation, remains unchanged except for the area where it has been cleared to build a reservoir.

The element B.c, Riverine vegetation, has regrown along the lower section of the Silwerstroom following the removal of vegetation as seen on the 1971 photographs. By the time of the 1981 photograph there has been extensive clearing of riverine vegetation around the site of the water treament plant.

The Linear dune vegetation, element B.d, has borne the major impact of the increased visitor numbers. This is reflected in Table 13 where grid squares 1, 2 and 3 of the coastal transect show a sudden marked deterioration in condition. (The coastal transect lies along the linear dunes. See Figure 7 on page 40.)

Within the dune plumes the vegetation, element B.e, continues to cover further areas of sand. This trend is shown in Figure 8 and Figure 9 on pages 56 and 57.

The River course and the Rocky outcrops, systems C and D, remain unchanged on the aerial photographs.

The major changes after 1972 were manifested in the human actions. Table 16 shows the length of paths, tracks, fences and roads. As in the example of vegetation condition, the results prior to 1972 are included to give a full picture of the trends.

	1938	1960	1968	1971	1977	1981
Paths	0.7	4.4	0.7	0.5	a	±3 b
Tracks	8.7	8.4	8.7	9.5	10.8	>7.6c
Fences	1.4	8.5	7.5	7.0	±11.4	c
Gravel-roads	nil	nil	nil	nil	1.7	1.8

TABLE 16 Length of paths, tracks, fences and gravel roads

a scale too small to extract data for measurement
b estimated as too numerous to measure accurately
c incomplete cover
All lengths measured in kilometres.

Although it is difficult to measure the lengths of paths accurately, the increase is quite clearly visible. Most paths are concentrated within the linear dunes but paths can also be seen around the water treatment plant and the reservoir. The distribution of paths is shown on Figure 17 and in the photographs in Figure 18. The length of tracks continued to increase. (Note that the apparent decrease in 1981 is due to the fact that cover was not available for the easterly section.)

There was a nett increase in the length of fences. The gross figure shown in the table masks the fact that fences on the inland border of the dunes appeared to deteriorate whereas

March 1983 (scale photographically adjusted to ± 1:8 000)

April 1981 (scale ± 1:8 000)

FIGURE 18 COMPARISON OF VISITOR IMPACT

many new fences were erected around the water treatment works and along the boundary between Divisional Council and Department of Community Development property.

By 1981 the recreation infrastructure included the ablution blocks, parking areas, camping and picnic sites, roads, office and house, and a shop. The water extraction infrastructure of the water treatment plant, reservoir, boreholes, underground pipelines and raised weir had also been completed. The location of these can be seen on Figures 4 and 17 on pages 31 and 71 respectively. By the time of the 1983 photographs, a tidal pool and grassed areas had been added to the recreation infrastructure. These can be seen on the copy of the photograph in Figure 11 on page 65.
(Note - because of the limited cover and distortion of the 1983 photograph, it was not included in the series of photographs from which measurements were taken. Thus no mention was made of the tidal pool and the gardens in the list of actions from which the predictions were derived.)

9.2 Results of the site visit and Delphi session

During the site visit, the panel members individually listed the impacts which they observed. This was followed by a Delphi group exercise in which a final list of impacts, agreed upon by all panel members, was drawn up and this list is reproduced below. At the end of the field visit and Delphi session, panel members were asked to give a personal summary of their overall impression of the exercise. (The panel was not given information about the predictions made on the basis of the photographic evaluation).

LIST OF IMPACTS IDENTIFIED AFTER THE SITE VISIT

RECREATION IMPACTS

<u>People pressure giving rise to</u>

A denuded vegetation around picnic and braai sites
B footpaths
C deflation of sand surface
D human defecation in bushes
E increasing numbers increasing A to D

<u>Tourist infrastructure</u>

F roads and parking areas
G gardens and buildings
H aesthetic impact

<u>Secondary impacts of tourism</u>

I erosion around parking areas & roads
J unmade footpaths
K vehicle tracks across dunes
L wind erosion & dust deposition from roads
M increased establishment of alien vegetation
N planted alien vegetation e.g.eucalyptus,kikuyu, marram
O invasive acacias
P removal of dead firewood causing change in nutrient flows
Q removal of intertidal fauna
R fewer animal tracks in tourist areas

WATER EXTRACTION IMPACTS

<u>Water supply infrastructure</u>

S powerlines
T derelict construction camps
U removal of indigenous vegetation
V increased establishment of aliens

<u>Water extraction</u>

W increase in sea water influx
X change in total dissolved solids (TDS)
Y change in plant communities

MANAGEMENT IMPACTS

Z no maintenance of canal
AA new fencing
AB possible changes in beach management
AC decrease in alien control
AD use of area by domestic stock

<u>Ranking of the impacts</u>

Panel members were asked to rate the extent to which each of the listed impacts was accommodated by the natural ecosystem. A seven-point scale was used :

1 = full accommodation
4 = moderate accommodation
7 = complete disruption

The final rating is shown in Figure 19 with the impacts arranged in rank order from the most disruptive to the best accomodated.

The computer program for Delphi meetings (Stauth 1983:329) gives an output of histograms showing the distribution of voting for each impact. This information ensures that the opinion of each member of the panel is reflected and can be communicated to fellow panel members without identifying who holds what opinion. Any impact with a mean rating of 4 or more was considered significant. The histograms of voting on all significant impacts are shown in Figure 20.

Mean Rating	Impact Letter and Statment	
6.44	E	INCREASING NOS INCREASING A-D
5.67	AC	DECREASE IN ALIEN CONTROL
5.56	M	INCREASE IN ALIENS IN RECREATION AREA
5.33	A	DENUDED VEGETATION (PICNIC & BRAAI SITES)
5.00	F	ROADS AND PARKING AREAS
4.78	C	DEFLATION OF SAND SURFACE
4.67	B	FOOTPATHS
4.56	O	INVASIVE ACACIAS
4.56	V	INCREASE IN ALIENS AROUND WATER INFRASTRUCTURE
4.22	K	VEHICLE TRACKS ACROSS DUNES
4.11	H	AESTHETIC IMPACT
4.11	AD	USE BY DOMESTIC STOCK
4.00	G	GARDENS AND BUILDINGS
4.00	Y	CHANGE IN PLANT COMMUNITIES
3.89	I	EROSION OF PARKING AREAS & ROADS
3.89	J	UNMADE FOOTPATHS
3.67	P	REMOVAL OF DEAD WOOD AFFECTING NUTRIENT FLOWS
3.67	Q	REMOVAL OF INTERTIDAL FAUNA
3.67	X	CHANGE IN TOTAL DISSOLOVED SOLIDS
3.56	U	REMOVAL OF INDIGENOUS VEGETATION
3.56	W	INCREASE IN SEA WATER INFLUX
3.33	AA	NEW FENCING
3.22	D	HUMAN DEFECATION IN BUSHES
3.11	N	PLANTED ALIENS
2.89	L	WIND EROSION & DUST DEPOSTION FROM ROADS
2.78	AB	POSSIBLE CHANGES IN BEACH MANAGEMENT
2.67	R	FEWER ANIMAL TRACKS IN TOURIST AREAS
2.67	Z	NO MAINTENANCE OF CANAL
2.56	S	POWERLINES
2.44	T	DERELICT CONSTRUCTION CAMPS

FIGURE 19 FINAL LIST OF IMPACTS SHOWING RANKING

```
VOTING FOR E
INCREASING NOS INCREASING A - D

         7 :****
         6 :*****
         5 :
  IMPACT 4 :
         3 :
         2 :
         1 :
       ---------------------
          9  VOTES

MEAN VALUE IS      6.44
```

```
VOTING FOR AC
DECREASE IN ALIEN CONTROL

         7 :***
         6 :
         5 :******
  IMPACT 4 :
         3 :
         2 :
         1 :
       ------------------------
          9  VOTES

MEAN VALUE IS      5.67
```

```
VOTING FOR M
INCREASED ESTABLISHMENT OF ALIENS

         7 :**
         6 :**
         5 :****
  IMPACT 4 :*
         3 :
         2 :
         1 :
       --------------------------
          9  VOTES

MEAN VALUE IS      5.56
```

```
VOTING FOR A
DENUDED VEGETATION (PICNIC & BRAAI SITES)

         7 :***
         6 :***
         5 :
  IMPACT 4 :*
         3 :*
         2 :*
         1 :
       ----------------------------
          9  VOTES

MEAN VALUE IS      5.33
```

```
VOTING FOR F
ROADS AND PARKING AREAS

         7 :*
         6 :***
         5 :*
  IMPACT 4 :***
         3 :*
         2 :
         1 :
       -----------------
          9  VOTES

MEAN VALUE IS      5.00
```

```
VOTING FOR C
DEFLATION OF SAND SURFACE

         7 :
         6 :**
         5 :****
  IMPACT 4 :**
         3 :*
         2 :
         1 :
       ------------------------
          9  VOTES

MEAN VALUE IS      4.78
```

```
VOTING FOR B
FOOTPATHS

         7 :
         6 :****
         5 :*
  IMPACT 4 :*
         3 :***
         2 :
         1 :
       ----------------------
          9  VOTES

MEAN VALUE IS      4.67
```

```
VOTING FOR O
ACACIAS

         7 :
         6 :*
         5 :*****
  IMPACT 4 :*
         3 :**
         2 :
         1 :
       ----------------------
          9  VOTES

MEAN VALUE IS      4.56
```

```
VOTING FOR V
INCREASED ALIENS

         7 :
         6 :**
         5 :***
  IMPACT 4 :**
         3 :**
         2 :
         1 :
       ------------------------
          9  VOTES

MEAN VALUE IS      4.56
```

```
VOTING FOR K
VEHICLE TRACKS ACROSS DUNES

         7 :
         6 :*
         5 :**
  IMPACT 4 :****
         3 :**
         2 :
         1 :
       ---------------------
          9  VOTES

MEAN VALUE IS      4.22
```

```
VOTING FOR H
AESTHETIC IMPACT

         7 :
         6 :**
         5 :*
  IMPACT 4 :***
         3 :**
         2 :*
         1 :
       ----------------------
          9  VOTES

MEAN VALUE IS      4.11
```

```
VOTING FOR AD
USE BY DOMESTIC STOCK

         7 :*
         6 :
         5 :**
  IMPACT 4 :***
         3 :**
         2 :*
         1 :
       -----------------------
          9  VOTES

MEAN VALUE IS      4.11
```

FIGURE 20 VOTING HISTOGRAMS FOR SIGNIFICANT IMPACTS

9.3 Comparison of predictions with results of photographic interpretation and site visit

Prediction 1 **Buildings will make no significant impact.**

From the photographs. The total area covered by buildings is so small that it cannot be measured accurately at scales smaller than 1:10000.

From the site visit. Impact G -'gardens and buildings as part of tourist infrastructure' - relates to this prediction. (See previous note on omission of gardens and tidal pool from analysis of photographs).

The mean rating for impact G was 4 indicating that the panel considered gardens and buildings to be moderately accommodated by the site and therefore not a significant impact.

Both site visit and photographs confirm prediction 1.

Prediction 2 **Vegetation will regenerate in the site cleared for camping and picnic sites.**

From the photographs. Regrowth of vegetation in camping and picnic sites was not observed on the photographs nor was it mentioned by the resort manager.

From the site visit. No mention was made of the regeneration of vegetation within the picnic and camping sites, in either the list of impacts or in the summarising comments.

Prediction 2 is not confirmed by the photographs nor commented upon by the panel.

Prediction 3 **Gravel and tarred roads and parking areas will make little primary impact.**

From the photographs. There is no evidence that roads and parking areas have reached the threshold at which they are not accommodated by the environment.

From the site visit. Impact F - 'roads and parking areas as part of tourist infrastructure', was given a mean rating of 5.00. The voting distribution is shown in Figure 20 and a clear division of opinion can be seen. The cause of the divergence may lie in ambiguous definition of the impact. It is possible that there is confusion between the primary and secondary impact of the presence of roads and parking areas. The secondary impact of facilitating high density recreation is considerable but this is not the case with the primary impact which is limited to the mere presence of the road. The focus of prediction 3 is the primary and not the secondary impact.

The photographs support the prediction. The results from the panel are equivocal.

Prediction 4 **Informal paths will increase with improved**

access to the site. Paths will be concentrated around access points along the linear dunes.

From the photographs. Analysis has shown the deterioration in condition of the vegetation due to the prescence of paths in grid squares 1, 2 and 3 of the coastal transect (location shown in Figure 7 on page 40). Figure 17 also shows the marked increase in paths in the linear dunes.

From the site visit. Three impacts relevant to this prediction were identified by the experts, B - people pressure giving rise to footpaths; E - increasing people pressure giving rise to increasing footpaths (and associated other impacts - denuded vegetation, sand surface deflation and human defecation) and J - unmade footpaths as a secondary impact of tourism.

Impact E was ranked the most disruptive impact and the histogram in Figure 19 shows the distribution of the voting which can be regarded as virtually unanimous which supports the prediction.

However, there is some confusion in the definition of impacts B and J. Both appear to say the same thing but have been rated quite differently. The confusion is also reflected in the histogram which shows the voting distribution for impact B. There are two opposing schools of thought, the one indicating that the footpaths are accommodated by the natural system and the other expressing the view that footpaths create a serious disruption. Thus there is no clear agreement from this part of the Delphi procedure. It is suggested that the problem may lie in the ambiguous definition of the impact and the rating of impacts

B and J should be interpreted with caution.

The photographs confirm the prediction and the panel gives partial confirmation.

Prediction 5 The positioning of the camping and picnic sites will be one factor determining the pattern of informal paths.

From the photographs. The network of paths through the linear dunes shown in Figure 17, suggests that the position of the camping sites behind the primary dune was significant in determining the pattern of paths. (The 1983 photograph in Figure 11 on page 65 shows the clear link between paths and camping sites.)

From the site visit. Although there was no specific mention in any impact definition or comment that pointed to a link between the pattern of informal paths and access points, mention was made in the personal summaries of 3 of the panel members of the fact that visitor pressure was confined to the linear dunes.

Prediction 5 is confirmed by the photographs, no comment is offered by the panel.

Prediction 6 Vegetation removed in the course of construction activities will regenerate. Large areas will take longer than smaller areas.

From the photographs. By 1981 revegetation of the areas scraped in the construction phase, had begun. This is reflected in the semi-quantitative measure of vegetation condition around borehole G29757 and on the 1981 photograph which is unfortunately not reproduced in this report.(See explanation in the Preface.)

In the 1977 photograph there is evidence that in some of the areas where vegetation was removed, sand blows have occurred. This is particularly noticeable where a pipeline was laid on an east-west orientation, across the path of the prevailing winds.

The evidence of sand blows in an area smaller than twenty hectares means that prediction 6 should be modified to incorporate the factor of the orientation of the disturbed area to the direction of the prevailing wind.

There were no areas of more than twenty hectares disturbed so this part of the prediction could not be tested.

From the site visit Panel members identified that there was an impact created by removal of indigenous vegetation for the water supply infrastructure - impact U. The mean rating of the panel for this impact was 3.56 (see Figure 19) and the histogram showed 5 members giving a rating of 3 whilst the remaining four members distributed one vote each for ratings of 2,4,5 and 6. Thus there was agreement within the panel that this impact was not significant. This is interpreted as supporting the prediction that construction scars revegetate with time. The photographs also support this prediction.

Prediction 7 Fencing will improve the condition of vegetation where it excludes people and stock and worsen the condition where people and stock are concentrated.

From the photographs. The fence between the Divisional Council property and that belonging to the Department of Community Development has excluded stock and the vegetation condition has improved in the former property. It should be noted that fences have been unsuccessful in excluding people from the dunes. The fence behind the linear dunes was erected to exclude sheep, which it did successfully. It has not excluded people who have taken the shortest straight line distance from the camping site to the beach. This is further evidence of the key importance of the positioning of camping and picnic sites.

From the site visit. Impact AA - new fencing as part of a management impact was listed by the panel. The mean rating was 3.33 with the histogram indicating agreement among the panel. No direct mention was made either in the definition of the impact or in the final summaries of panel members of the role of fencing in controlling the quality of the vegetation. The implication of its role lies in the heading of "Management impacts" under which it is subsumed but there is no clear indication from the panel members that this prediction is supported or contradicted.

Prediction 8 Recreation impacts will be longer acting than impacts associated with water extraction and its supporting infrastructure and will be concentrated within the linear dunes.

From the photographs. Recovery of the vegetation on the construction scars of the water extraction infrastructure contrasts with the constancy of the paths that resulted from recreational use of the area.

From the site visit. Although the issues raised in this prediction were not directly addressed in the list of impacts drawn up by the panel, 3 members commented that most of the noticeable damage to the area is from tourism and not obviously from water extraction. Another comment was that the water extraction infrastructure made a greater impact than the water extraction itself. A further three comments noted that recreational impacts were severe but limited to a narrow belt along the coast. Thus the prediction can be considerd to be confirmed.

<u>Prediction 9</u> Uncontrolled fires will damage vegetation.

No fires have occurred so this prediction is neither confirmed nor contradicted by the photographs. No mention of potential fire damage was made in the list of impacts or in the comments of the panel.

N.B. Predictions 9 - 12 are "Potential" as opposed to "Probable" impacts.

Prediction 10 **Grazing could adversely affect the condition of the vegetation.**

From the photographs. The difference in vegetation quality in grazed and un-grazed areas has been noted. However, although there was decreased canopy cover there was no increase in stock paths visible on the aerial photographs.

From the site visit. Impact AD - 'use of the area by domestic stock' had a mean rating of 4.11 and the distribution of the votes is shown in Figure 20. It was considered a significant impact by the panel but not of major importance.

Both photographs and site visit confirm the prediction.

Prediction 11 **Water extraction could change growth rates of existing species of plants and change the species composition of the Lowland vegetation. The dune vegetation will not be affected.**

From the photographs. The condition of the vegetation around borehole G29757 which had pumped continuously from 1979, did not show any marked deterioration. Vegetation cover appeared as dense as it had been in the past. Thus it would appear that by 1981 the Lowland vegetation had not been affected by the dropping water table.

The overall area of dune vegetation continued to expand suggesting that water extraction was not having any negative impact on plant growth within the dunes.

From the site visit. The relevant impacts identified were-

W increase in sea water influx - mean rating 3.56

X change in total dissolved solids - mean rating 3.67

Y change in plant communities - mean rating 4.0

The histograms shown below reflect the lack of unanimity within the group as to the significance of the impact.

```
 VOTING FOR W         VOTING FOR X          VOTING FOR Y
7:                    :*                    :*
6:*                   :*                    :*
5:***                 :*                    :*
4:                    :                     :*
3:**                  :****                 :****
2:**                  :*                    :*
1:*___________       _:*___________        _:__________
```

Botanists who had prevously worked at the site commented on the lack of change in the Lowland vegetation and in the dune vegetation.

Prediction 12 **Non-maintenance of the canal will not affect the area of dune vegetation but may change the species composition.**

From the photographs. The vegetation around the canal in the Silwerstroomstrand dune plume continued to expand in area. (See Figure 8 and Table 9). However, some changes were observed. The dense plant growth visible within the canal on the 1971 photograph in dark grey tones, appears as a light background with dark dots in the 1981 photograph. This suggests that most of the vegetation in the erstwhile main channel has died.

From the site visit. Impact Z – 'no maintenance of the canal' had a mean rating of 2.67 and only one panel member considered that this would in any way disrupt the existing system.

Prediction 13 is not open to either photographic confirmation or rejection as no measurements have been made on photographs taken subsequent to the start of construction of Koeberg harbour. No mention of the harbour was made in the briefing given to panel members so no comments on this aspect were expected or received.

The evaluation of the predictions is summarised below.

PREDICTION	PHOTOGRAPHS	PANEL-SITE VISIT
PROBABLE IMPACTS		
1. Buildings – little impact	confirmed	confirmed
2. Revegetation in camp/picnic sites	do not confirm	no comment
3. Roads & parking– low primary impact	confirm	equivocal opinion
4. More paths with better access	confirmed	partially confirm
5. Camp position fixes path pattern	confirmed	no comment
6. Revegetation of construction scars	confirmed	partially confirm
7. Fencing's role in vegetation condition	confirmed	no comment
8. Recreation impacts longer acting	confirmed	confirmed
POTENTIAL IMPACTS		
9. Fires damage vegetation	———	no comment
10. Grazing damages Vegetation	some indication	confirms
11. Change in plant growth & species composition	confirm (dune vege.) do not confirm (Low-land vegetation)	confirm (dune vege) do not confirm (Low land vegetation)
12. Veg. unaffected by absence of canal	confirmed	confirmed

There is very close correspondence between the predictions and the post-1972 photographs. This is hardly surprising as the impacts are perceived using the same 'instrument' and the same interpreter. However, it did reveal that prediction 2 'the probable impact of revegetation of camping and picnic sites', was not confirmed and may not be a valid prediction.

The panel undertaking the site visit not only perceived impacts differently to those identified from the aerial photographs but also perceived different impacts. In spite of the differences, five of eight predicted probable impacts were identified by the panel, four of them were confirmed (two of them partially) and an equivocal opinion expressed on the fifth. No comments were offered on the remaining three, one of which may not be valid. The other two concern temporal and spatial relationships. The potential impacts were confirmed in three out of four cases which may only indicate that the same theoretical basis (or bias) was used to derive the predictions.

It seems significant that no mention was made by the panel of the potential impact of fire whereas the potential impact of alien invasion was heavily emphasised. Alien invasives were not identified as an impact by the photographic analysis whereas the fire sensitivity of the vegetation is striking on photographs. This is one of the examples of the different perception offered by a site visit and analysis of a series of aerial photographs.

9.4 Additional insights from the post-1972 photographs and the field visit

Only the data relevant to the predictions have been considered so far. However, there were further insights from both the photographic analysis and the field visit that contribute to the evaluation of aerial photography as a tool in EIA.

Post-1972 photographs

Comparison of the photographs of the linear dunes in 1981 and 1983, shown in Figure 18 reveals that in the two years between the photographs, there has been no discernible change in the area of vegetation cleared for picnic and camp sites, nor is there any visible difference in the footpaths through the dunes. The only noticeable changes are the addition of a semi-circular road at the northern end of the Wintersteen parking area, the tidal pool and the grassing and tree planting adjacent to the parking area.

It is possible to obtain some indication of the visitor pressure during this period. Unfortunately detailed records of visitor numbers are only available from February 1982. However, between February 1982 and March 1983 44 773 visitor-days were spent at the site. It seems a reasonable estimate that in the intervening time between the two photographs some 80 000 visitor-days were spent at Silwerstroomstrand. It is perhaps unexpected that visitor pressure of this order would have no incremental impact.

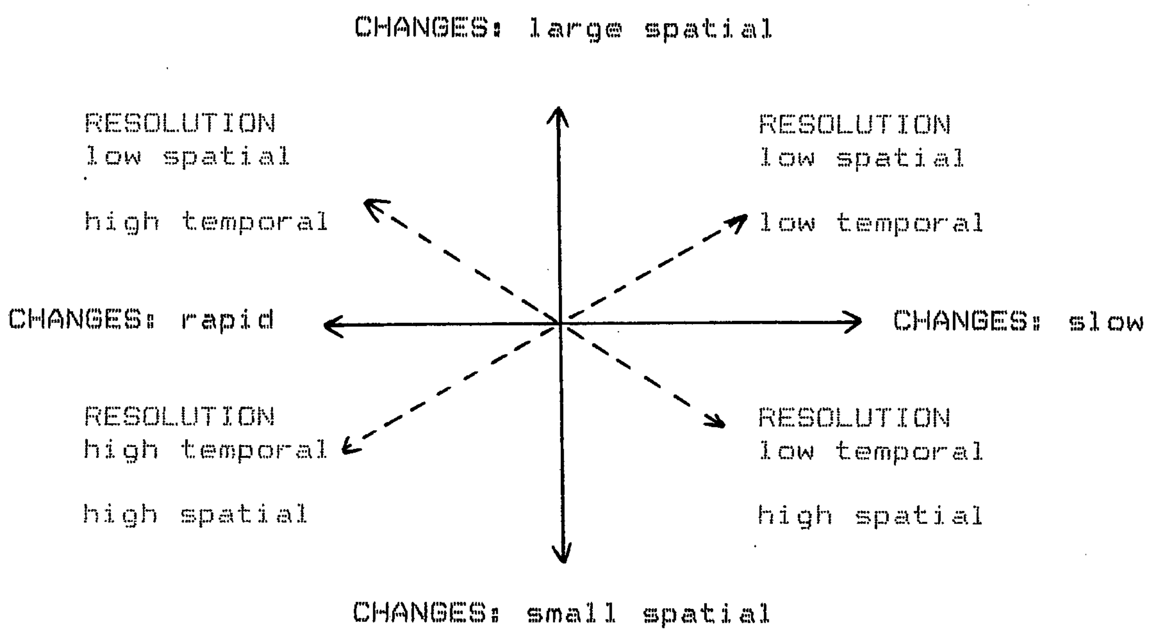
This finding draws attention to the need to refine descriptions of impacts possibly by attempting to indicate a semi-quantitative graphic relationship showing thresholds of increased sensitivity and plateaux of stability in contrast to the implied straight line relationship that 'increased numbers of visitors imply increased lengths of paths or any other measure of recreation impact, such as deflation of sand surfaces etc.

The finding also indicates that comparative analysis of aerial photography can contribute to the statement of such relationships. It shows too, the value of on-going monitoring. It is a shortcoming of much current EIA that monitoring is apparently seldom undertaken. The feedback provided in the above example would help to formulate far more accurate statements of impacts in future EIA's.

Panel's site visit

Analysis of the list of impacts produced by the panel revealed some of the limitations of the particular aerial photographs used in this study. Data on impacts like deflation of sand surfaces, removal of firewood, animal tracks, removal of intertidal fauna, erosion from roads and parking areas, are not visible on the photographs because they are localised impacts on a small scale. Although wind erosion was seen on some construction scars it was not seen on roads or tracks in the photographs.

Powerlines, single vehicle tracks on the beach and alien vegetation are distinguishable on photographs of 1:10 000 and larger. The early photographs are of too small a scale to build a sequential picture (assuming the presence of these types of impact at the time of earlier cover). The reasons for the limits to the spatial resolution can be seen in Figure 21.



KEY: PHENONMENA'S PROPERTIES / PHOTOGRAPHIC CAPABILITIES

FIGURE 21 Relationship between the capabilities of aerial photographs and properties of the phenomena observed (After Townshend 1981:98)

The 1938 to 1977 photographs used in the study had low spatial and low temporal resolution. The predictions resulting from comparative interpretation of these photographs are thus only able to address phenomena that change slowly and are spatially large.

Localised impacts, such as removal of firewood, deflation of sand surfaces, removal of intertidal fauna, were neither detected nor predicted. Increase in alien vegetation was not predicted as detection of aliens is not only beyond the spatial resolution of the early photographs but also beyond their spectral resolution. For reliable detection of aliens on aerial photographs, colour photography of a large scale is desirable. (Boucher personal communication 1984; Brownlie 1982:183).

After 1977 the photographs used, had higher spatial and temporal resolution and using these, it was possible to obtain insights on a level detailed enough to reveal the unexpected constancy in the level of visitor impact.

Lack of spatial resolution in the pre-1972 photographs was obviously a major source of the difference between the impacts listed by the panel and those predicted. If this source of variation is removed, the following short list of impacts identified by the panel is derived. Those marked by an asterisk denote impacts that were not mentioned in any predictions.

SHORT LIST OF IMPACTS IDENTIFIED BY THE PANEL

RECREATION IMPACTS

People pressure giving rise to
A denuded vegetation around picnic and braai sites
B footpaths
E increasing numbers increasing A and B

Tourist infrastructure
F roads and parking areas
G gardens and buildings
* H aesthetic impact

Secondary impacts of tourism
J unmade footpaths
* K vehicle tracks across dunes

WATER EXTRACTION IMPACTS
Water supply infrastructure
* S powerlines
* T derelict construction camps
U removal of indigenous vegetation

Water extraction
* W increase in sea water influx
* X change in total dissolved solids (TDS)
Y change in plant communities

MANAGEMENT IMPACTS
Z no maintenance of canal
AA new fencing
* AB possible changes in beach management
AD use of area by domestic stock

If the impacts that were not mentioned in any predictions are considered, it is seen that -

H is not a technical impact, open to objective evaluation but requires the subjective value judgement appropriate for social impacts. The panel was selected to look at technical not social impacts and so this impact should be omitted from the list.

Other than the single access track at the northern end of the linear dune, no vehicle tracks were observed on any dunes on the 1983 photographs. The panel members were in agreement on impact K (see Figure 20) which had a mean rating of 4.22 and was thus considered significant. The difference of opinion between panel and photograph may lie in the limitation of temporal resolution in that the most recent photograph was taken almost exactly a year before the site visit.

Impact S was ranked very low with a mean rating of 2.56 and a histogram indicating general agreement among panel members. It is suggested that its absence from the predicted impacts is therefore not significant.

Similarly, the mean rating of impacts W, X and AB was below 4. In each of these cases there was no unanimity within the panel (histograms for impacts W and X are shown on page 106) but the majority considered the impacts to be insignificant. Issues where such division of professional opinion exist may indicate the need for further briefing to better define the impacts and obviate any ambiguities.

Impact T, the derelict construction camp was considered part of the overall construction activities.

Thus of all the impacts identified by the panel impact K was the only significant one not supported by the predictions made as a result of comparative interpretation of aerial photographs.

The site visit also showed how a more detailed definition of elements in the framework used for interpretation could produce a more sensitive analysis. In the course of the visit botanists identified the die-back of Psoralea aphylla in the riverine vegetation. This had not been detected on the photographs initially but subsequent stereo viewing confirmed that a change could be seen when comparing large scale photographs from 1971 and 1981. As Psoralea aphylla is a distinctively tall plant requiring a high water table, the significance of monitoring change in the plant is its indication of the state of the water table. This is an example of the limitations imposed by scale and lack of specialist insight on the indicators that can be monitored on aerial photographs.

In general terms, it was observed that the site visit and the photographic analysis gave very different perceptions of the impacts at Silwerstroomstrand. The site visit tended to identify more localised and detailed individual phenomena whereas the comparative interpretation of multi-temporal aerial photographs tended to focus more on spatial and temporal relationships. Neither perception is adequate on its own. The two are very complementary and suggest the potential of a powerful interdisciplinary synergy focussed through the medium of aerial photographs. Beaumont (personal communication 1983) uses aerial photographs for preliminary assessments of all studies undertaken and finds multi-temporal photography "extremely important, in fact almost critical for assessing the stability or rate of change of an area."

CHAPTER TEN

CONCLUSIONS

The hypothesis on which the study was based is that comparative interpretation of multi-temporal aerial photographs is a viable tool for use in Environmental Impact Analysis. This was tested against another tool commonly used for EIA's - the site visit by a multi-disciplinary panel who list impacts and rate them.

Every tool has inherent capabilities and limitations as well as limitations imposed by the way in which it is used and the skills of the user. This must be appreciated when evaluating the results produced by that tool. It is particularly important to appreciate the limitations when the tool is to be used as a standard against which a comparison is made.

The site visit was planned for a panel composed of members representing a wide range of disciplines. The disciplinary composition of the actual panel that visited the site was however, unbalanced. (Comments to this effect were made by the panel members themselves). A further limitation was that the tight schedule planned for the exercise was unexpectedly overextended by delays caused by technical problems. Although these limitations might have lessened the detailed output of the exercise it was not considered that they affected its overall validity.

From phase one (see page 3) predictions were made by using the tool of comparative interpretation of pre-development aerial photographs. Eight probable and four potential impacts were predicted.

From phase two, one of the eight probable impacts was assessed as invalid by the 'internal' check applied, whereby the predictions were compared with the interpretation of the post-development photographs.

From phase three, a list of thirty impacts was drawn up by the panel and the interpretation of phase one were compared with these impacts. Of the remaining seven probable impacts predicted in phase one, five were identified by the panel and four of the seven were confirmed in whole or part.

The major limitation of the tool when evaluated against the results of the panel, was the spatial resolution of the early photographs. Thirteen of the thirty impacts could not be seen on photographs of scales smaller than 1:10 000. When impacts not visible because of the limits of the spatial resolution of the early photographs are removed from this list of impacts, seventeen remain. Only one significant impact, 'vehicle tracks across the dunes as a secondary impact of tourism', was not predicted by the tool being evaluated.

Thus the tool, comparative interpretation of aerial photographs, perceives a sufficiently similar core of impacts to that perceived by a different commonly used tool, to justify being considered as a viable tool for EIA.

The strengths of the tool were in the following contributions that it made to the environmental impact analysis of the site:

- it aided in gathering both quantitative and semi-quantitative information about the site (changing areas of sand and vegetation, lengths of tracks, paths and roads, condition of vegetation)

- it promoted an understanding of the site by furnishing firstly, a regional perspective so showing the spatial relationships of the systems within that environment (position of camping/picnic sites and pattern of paths, position of submerged rocks and unchanging sections of linear dunes, orientation of disturbed surfaces and wind erosion) and,

  secondly, a temporal perspective which enabled the interpreter to detect constancies, changes and rates of change (recovery of vegetation after burning or scraping). This gave the basic information for some understanding of the natural dynamics of the site and the way in which the environment responded to perturbations.

- it monitored changes in the physical environment and this monitoring function refined the prediction of the impacts indicating, even very roughly, threshhold values and stable plateaux within that site (area and orientation of disturbed surface and probability of sand blows, visitor numbers and formation of paths, season of burning and time for regeneration).

- it was relatively inexpensive and is therefore an economical way in which to gather preliminary data. (It is however, no substitute for site visits but should be used as a complement to this source of data.)

- the overlays produced through use of the tool are a communicating device (and also contribute to the process of informing readers of this report.)

In addition

- it can aid organisation of EIA's by directing attention to the priorities in information gathering. Priorities are significant because holistic studies can draw on a plethora of information and it is important to direct the resources of the impact study team to essential information as opposed to peripheral information.

- multi-temporal photographs enable the interpreter to telescope time, so experiencing change vicariously. This feature suggests that there might be considerable scope for the use of case studies based on multi-temporal photographs as a means of training all who would benefit from an understanding of the dynamics of an environment.

The limitations of spatial resolution can be lessened in some measure by supplementing the data from aerial photographs with

- i site visits
- ii reliable data from other sources e.g. interviews, previous reports, etc.,
- iii using some framework against which to interpret the data.e.g. a systems approach, the theoretical constructs of a discipline.

As has been mentioned previously the potential for synergy in combining the insights afforded by interpretation of multi-temporal aerial photographs with other sources of data is considerable.

From this study it is concluded that comparative interpretation of multi-temporal aerial photographs is a viable tool for use in Environmental Impact Analysis and the hypothesis is accepted.

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A review of aerial photographic research and use in South Africa.

The earliest major use of aerial photographs in South Africa was in 1929 for mapping purposes (Cloete personal communication 1983). These early aerial photographs were flown by the South African Air Force. The commercial potential of aerial surveys in Africa was appreciated by a British company which, in 1931, established a local enterprise, Aircraft Operating Company of Africa. The company's first contract was a survey of the Durban Municipal area for town planning purposes. By 1934 the company had been awarded a contract by the Union government for the first of the photographs that were to form the basis for the 1:50 000 topographic map series (Clegg 1981: 1-3). With expanding use of aerial photography, a South African Association of Air Survey Companies was formed and this now has twenty members.

The holistic nature of aerial photography makes it a tool with a very broad range of applications. An overview of its initial uses in South Africa is given in the Proceedings of the Symposium on Remote Sensing held in Pretoria in May 1972 (Malan, 1972).

The Symposium Proceedings indicate that prior to 1972 the major use of aerial photographs was for cartographic purposes. The then equivalent of today's Mapping and Survey Branch of the Department of Community Development, used aerial photographs to compile topographic and other maps. De Villers (1972: 201) considers that after cartographic uses, the second major application was in agriculture where it was used in farm planning, soil, botanical and landuse surveys, and for irrigation development.

Aerial photography played - and continues to play - an important role in planning. For instance, the Town and Regional Planning Commission of Natal has carried out parking and traffic surveys, spot counts of people on beaches as well as rural land use surveys with the aid of aerial photographs. Other local authorities such as Cape Town and Johannesburg also make extensive use of aerial photography in their planning. The National Institute for Road Research has established a Data Bank which has a collection of the photographs used in planning road networks. The Fisheries Develpment Corporation, which is involved in the planning and development of new harbours, maintains its own aircraft to undertake aerial surveys of areas where harbours are planned and to help solve any problems associated with their maintenance (Savage personal communication 1983).

Whilst there is a definite use of aerial photography in geological application, the degree of utilisation is difficult to assess. Newton (1972: 193) points to the absence of published material on this topic and suggests that this might be due to the secrecy involved in studies which have considerable economic ramifications. A similar constraint applies in assessing the contribution that aerial photography makes to engineering and construction activities. One example of the use of aerial photography in this field is the land use evaluation system described by Beaumont et al (1975).

What is notable is that aerial photographs were little used in environmental monitoring studies prior to 1972. Edwards (1972:101) has identified the only work of this nature - the monitoring of the coastal dune and estuarine ecology of Isipingo beach by Ward, submitted as a Master's thesis at Natal University in 1971. Other early uses of specialised aerial photography for environmental monitoring involved the detection of Phytophthora rot in avocado pears using multispectral imagery and use of image intensifiers to record biolumninesence of plankton from which tonnages of fish were inferred. (Cram in Malan 1974:129)

Research into the application of remote sensing for environmental problems received considerable impetus with the launching on 23 July 1972 of the earth resources satellite ERTS. Although much subsequent research effort has been directed at satellite digital imagery, aerial photography seems also to have been more widely used and researched in South Africa since that time.

Since the initial multi-temporal work done by Ward, Weisser appears to have been the major South African researcher in this field. He has, in particular, investigated the gross vegetation changes in the dune area between Richards Bay and the Mfolozi River. By comparing photographs from 1937 and 1977 he was able to identify successional trends as well as indicate the possible rate of succession (Weisser 1982:127 - 130). In work on the aerial photographs of the Siyai lagoon in Natal he has traced the increase of _Phragmites australis_ reeds from 1937 to 1976 (Weisser 1981:553). Weisser has also investigated the suitability of aerial photographs to measure foredune advancement and has found photographs of a scale of 1:30 000 or larger adequate for this purpose (Weisser 1982:127).

Watson and MacDonald (1983: 265-269) have used aerial photographs to monitor the effectiveness of two methods used to control bush encroachment. MacDonald (personal communication 1983) has also indicated the value of aerial photographs in monitoring gully erosion, the extent of fire damage, reed cutting in nature reserves and invasion of alien species.

Breen, (1971:223-234) working on 1942 and 1964 air photos of Sibayi, has shown how the control of agriculture has resulted in considerable improvment in dune forest vegetation. Brownlie (1982) has used a multi temporal study as a tool to contribute to an investigation of possible causal relationships between land use and management practices and the resultant ecosystem.

Multi temporal study of aerial photographs is an important tool in the work of the National Research Institute for Oceanology. The Coastal Engineering and Hydraulics Division, of this Institute, is working on hydrologial and hydraulic studies of Natal and Cape estuaries. The aerial photographs are analysed to reveal changes in features such as channel widths, sand spits, open water areas, and surrounding landuse. From this information a description of the condition of the rivers and estuaries can be produced, interpreted and evaluated against the background of simulated run-off data, marine processes and changing land use in the catchment area.

The Estuarine and Coastal Research Unit made extensive use of air surveys to produce Part 1 of the reports "Estuaries of the Cape". Comparison of aerial photographs also contributes to the individual estuary reports which form Part 2 of the overall work of the unit (Heydorn and Tinley 1980).

Huntley (1977) reviewing terrestrial ecology in South Africa, indicated that whilst considerable progress has been made in mapping this country's vegetation, very little effort has been expended in monitoring the rates and kinds of change that are taking place within it, or the processes accounting for these changes.

This observation is certainly less true today, but it nevertheless highlights the need for the multi-temporal type of investigation.

MONTH	1976	1977	1978	1979	1980	1981	1982	1983
JAN		8	4	18	24	50	24	6,2
FEB		41	0	14	7	0	0	31,6
MAR		21	48	10	0	0	4	26,7
APR		53	0	4	48,5	37	49	6,5
MAY		75	8	69	74	12	44	90,7
JUN		123	17	57	66	37	58	94,2
JUL		124	12	29	30	88		62,5
AUG		80	79	30	44	102	63,3	26,0
SEP		27,5	68	12	13	41	33,3	36,4
OCT	10	11	4	43	48	12	37,1	14,4
NOV	61	3	17	21	46	12	21,5	7,6
DEC	45	44	14	0	42	0	12,2	13,2
TOTAL		610,5	271	307	442,5	391	407,8	416

APPENDIX B: ATLANTIS RAINFALL (ELECTRICITY DEPOT)

APPENDIX C

LIST OF PANEL MEMBERS

The field visit was organised under the auspices of the Hydrology working group of the Fynbos Biome Project, Cooperative Scientific Programmes of the Council for Scientific and Industrial Research (CSIR).

Mr G Boddington of the Town Planning Branch, Cape Town City Council

Mr J Bosch of Jonkershoek Forestry Research Station

Mr C Boucher of Botanical Research Unit

Prof R F Fuggle of School of Environmen al Studies, University of Cape Town

Mrs M Jarman of Co-operative Scientific Programmes, CSIR

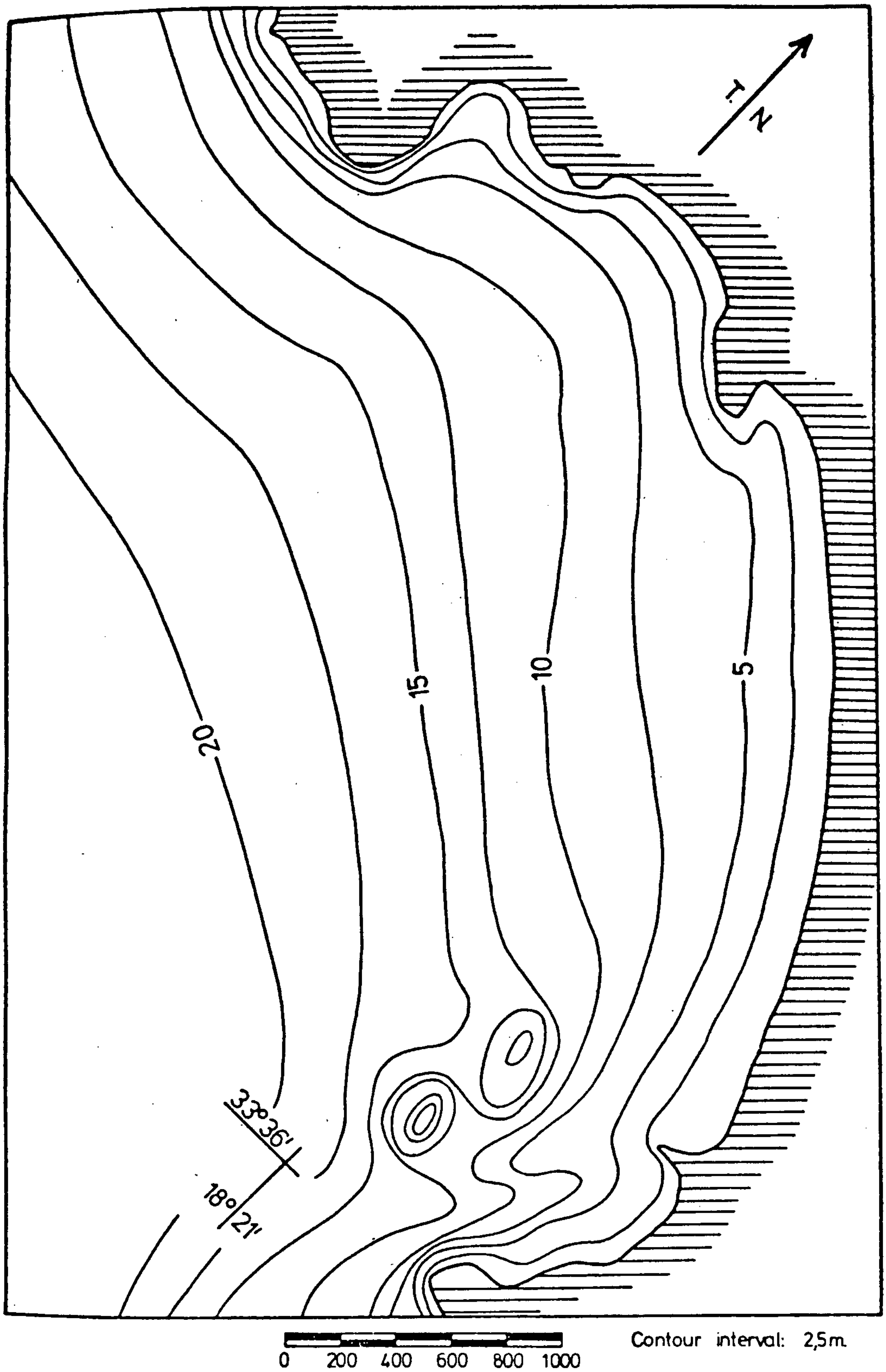
Mr I McDonald of Percy Fitspatrick Institute of African Ornithology, University of Cape Town

Mr J Miller of Jonkershoek Forestry Research Station

Prof E Moll of Department of Botany, University of Cape Town

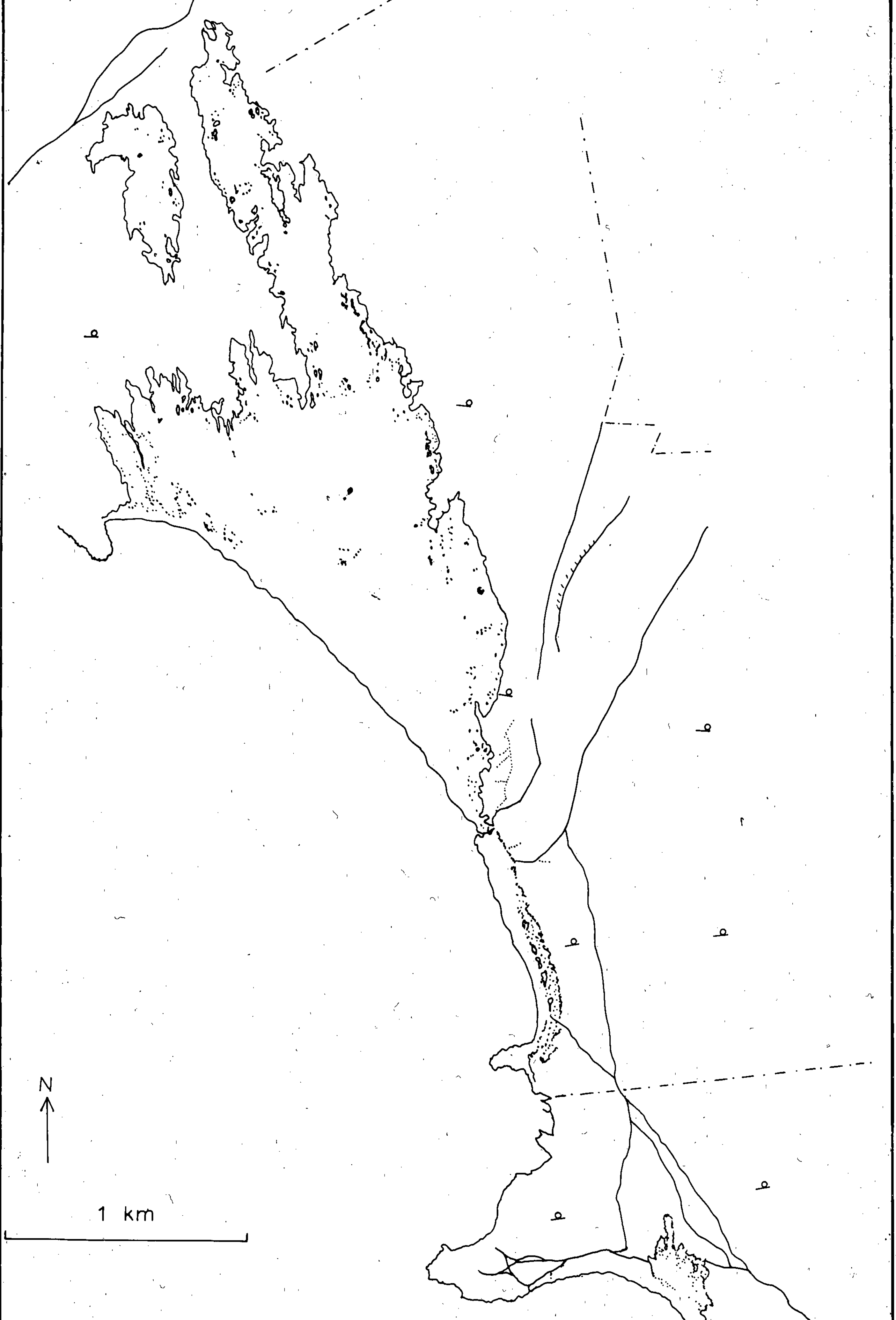
Mr D B van Wyk of Jonkershoek Forestry Research Station

APPENDIX D

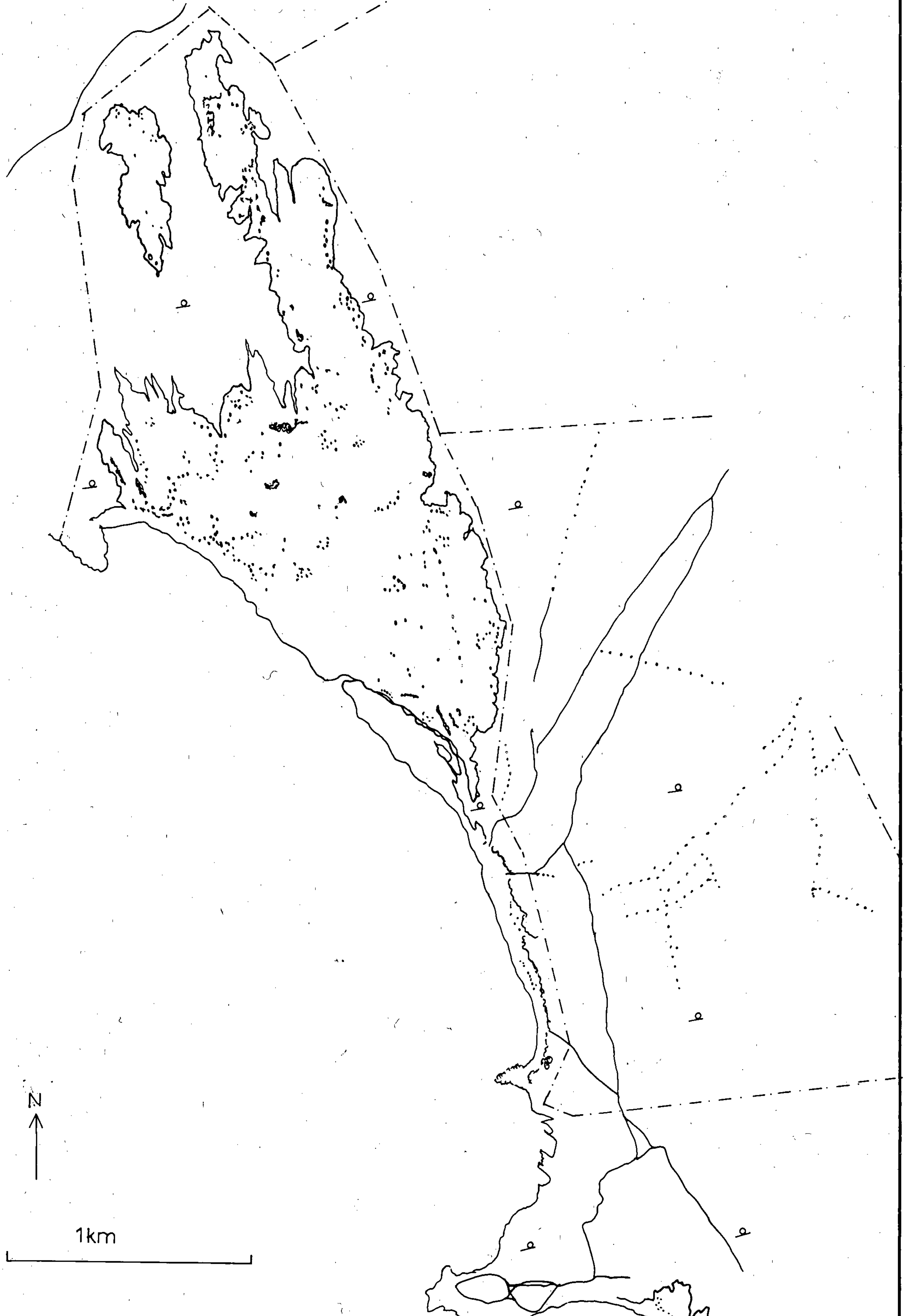


Bathymetric map of Buffels Bay.

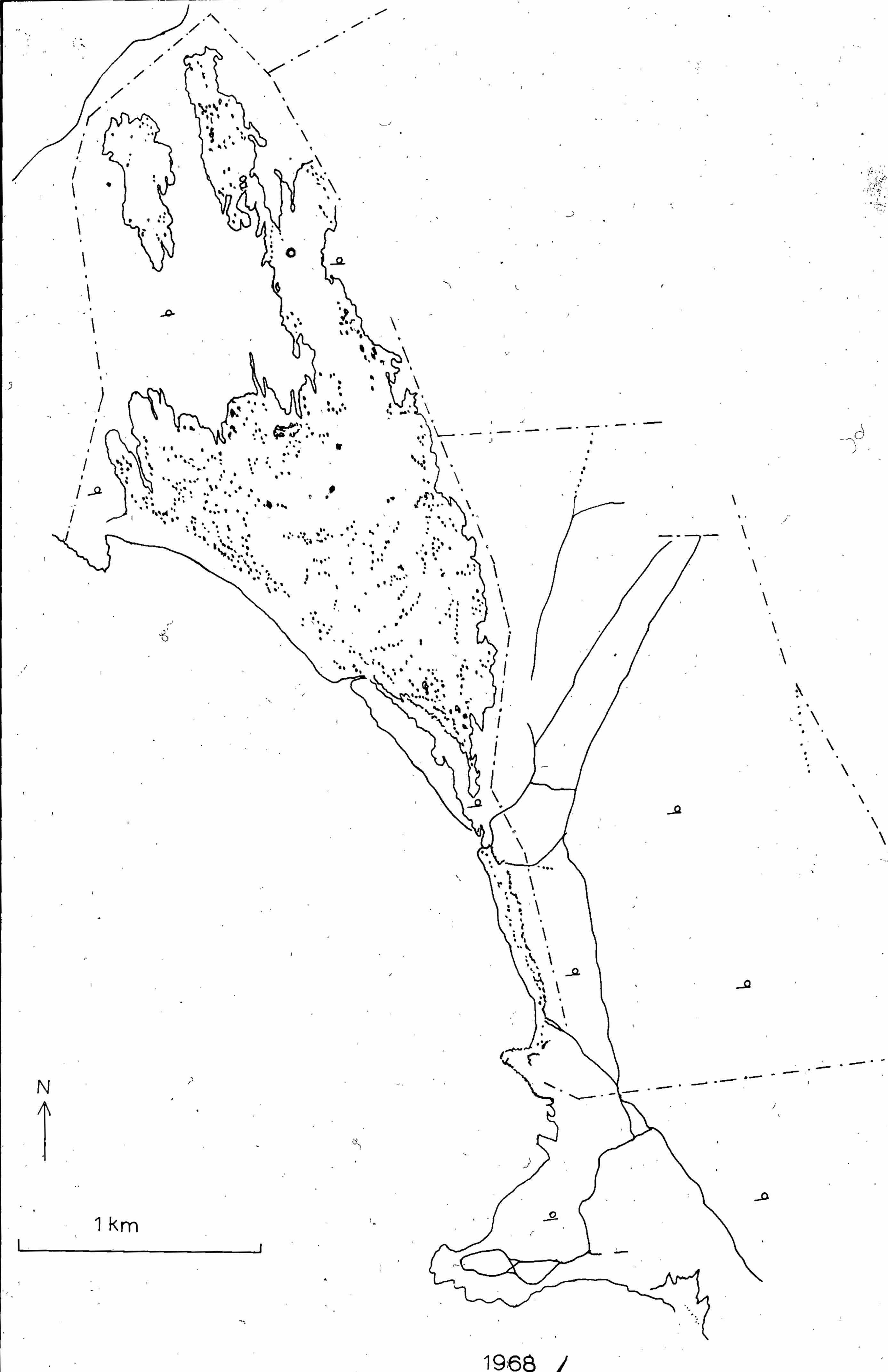
(From Gunn 1977)



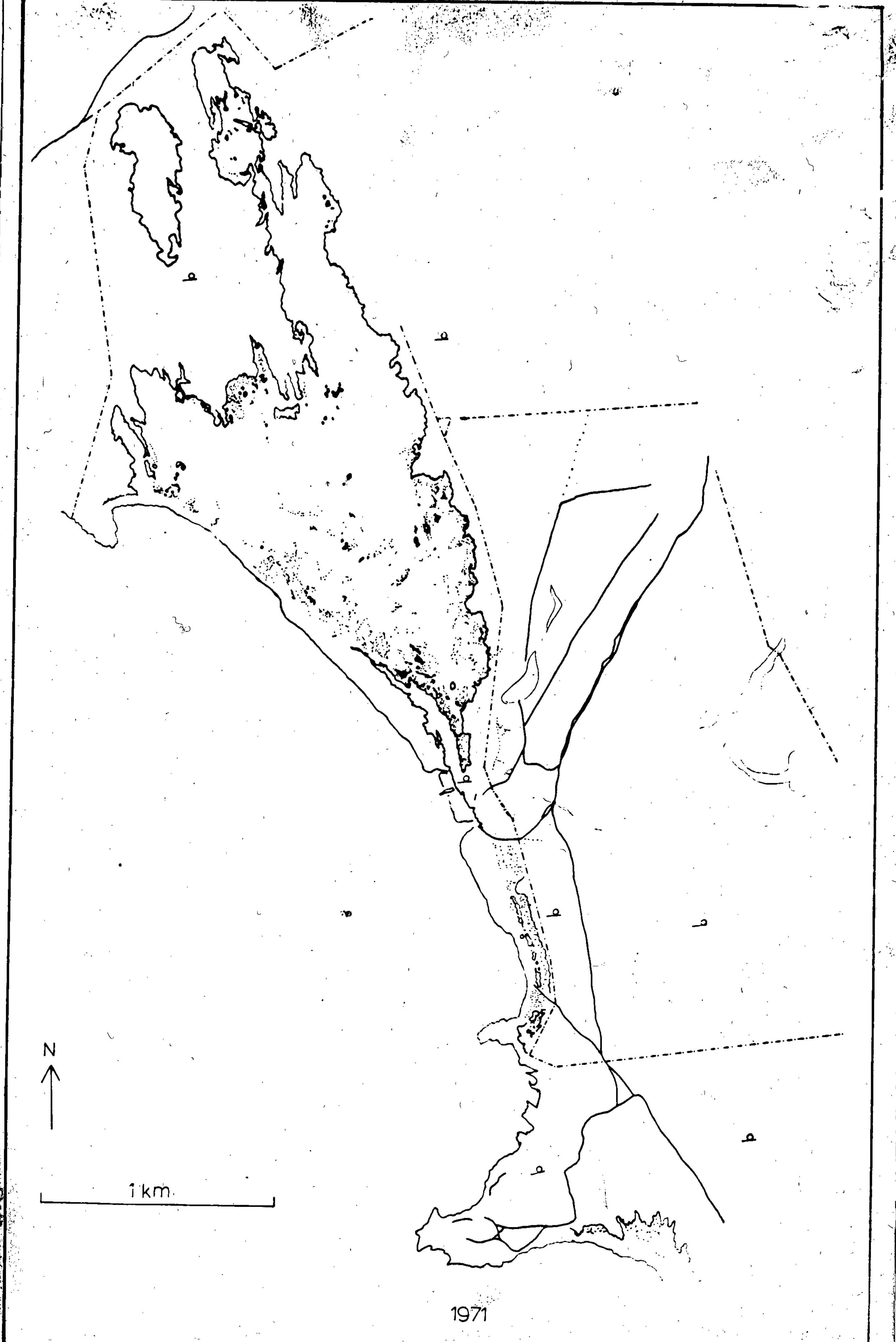
1938

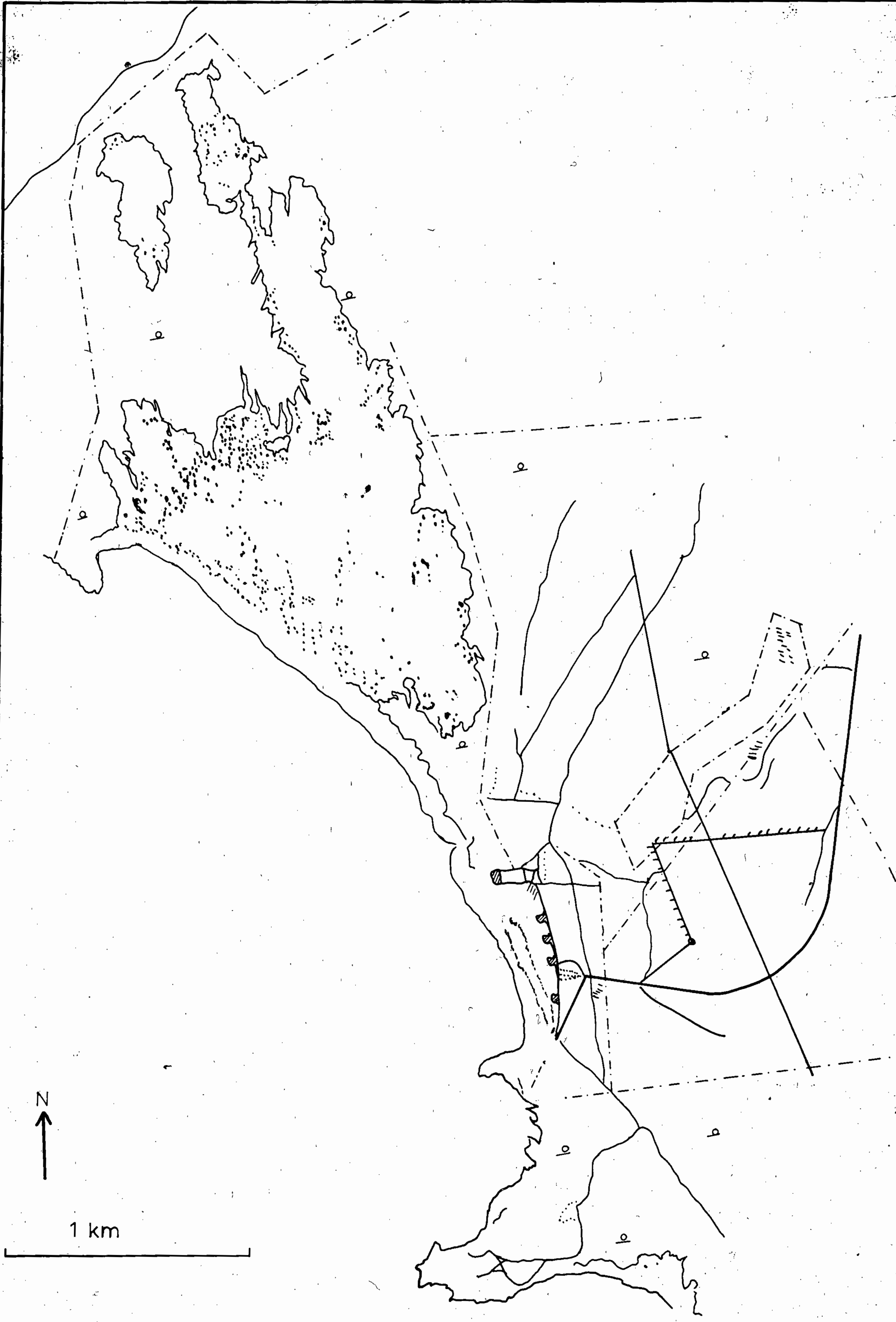


1960

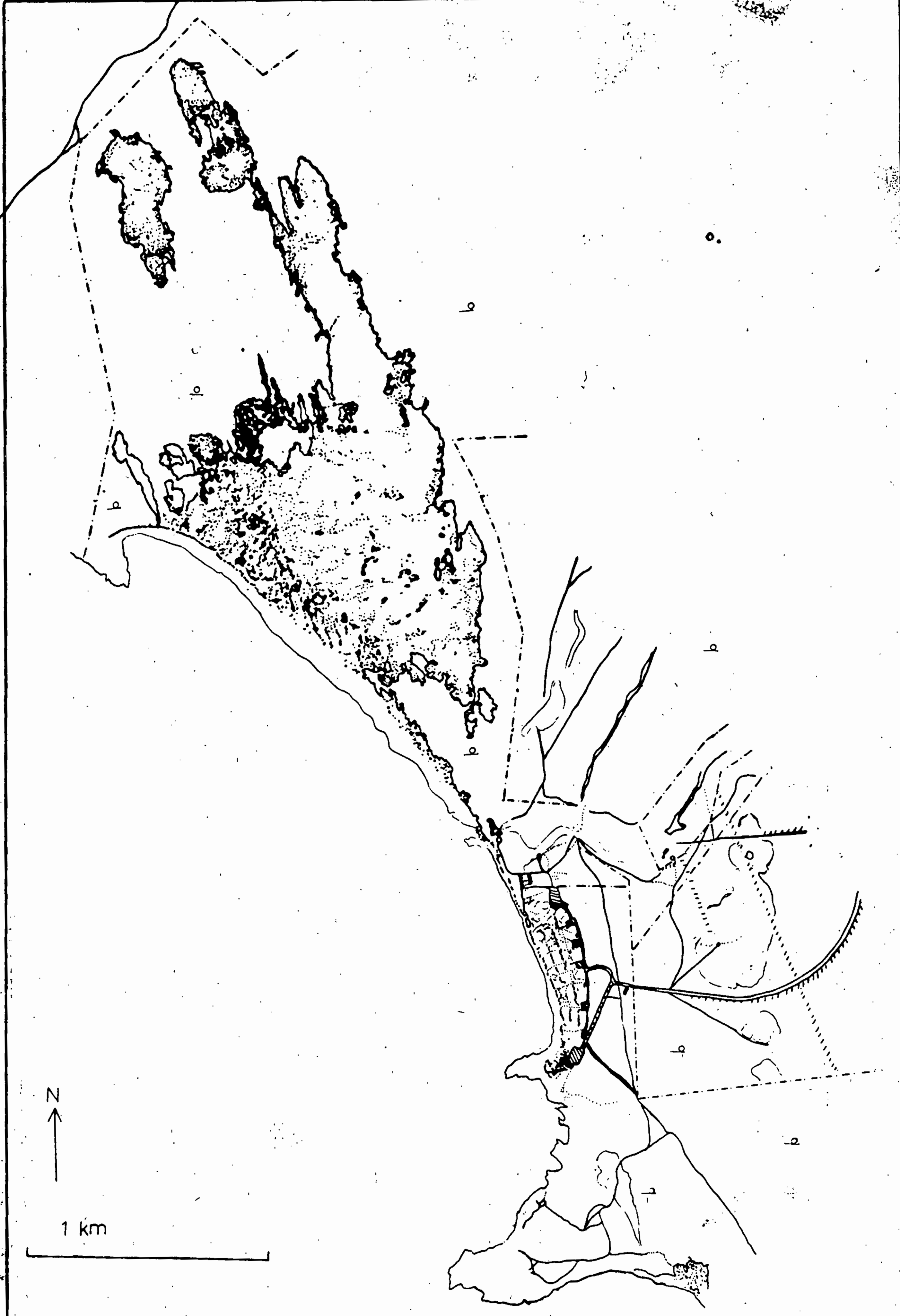


1968


N
1 km
1971



1977



1981