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South Pacific Regional Environment Programme

Implications of Climate Change and Sea Level Rise for Tuvalu

Report of a Preparatory Mission

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many benefits. However, where expertise is insufficient the Group will make use of external assistance, preferably from regional organizations such as SPREP, SOPAC and the Forum Secretariat and increasingly less on individual consultants from overseas.

B. SPREP has plans for 2 week workshops in Tuvalu on environmental impact assessment (EIA) procedures for:
   i) planners and others involved in undertaking EIAs (e.g. those who would be members of TEAG)
   ii) for permanent secretaries and others involved in receiving environmental impact assessments and making decisions based on them (e.g. members of NDSC)

C. The broad terms of reference and job description of the Environmental Officer have already been prepared, but specific responsibilities should include:
   i) development and implementation of the National Environmental Management Strategy, including the development of strategies to address the likely impacts of CC/SLR, as detailed in this report
   ii) supervision of the collation, analysis, interpretation and dissemination of environmental and resource data, including information on sites of cultural significance and including liaison with regional and international organizations.
   iii) to develop procedures to ensure that environmental concerns are taken into account in proposals for new development and for ongoing works
   iv) to assist in the development of curriculum on environmental management in consultation with others locally (e.g. the Climate Change Officer) and in the region (e.g. SPREP and USP). The curriculum would cover primary, secondary and adult education needs

D. External organizations which are undertaking environmental monitoring in Tuvalu should be responsible for training a Tuvaluan officer in the related data collection, analysis and interpretation methods so that the information is available locally for incorporation in local planning and decision making.

E. It is imperative that all Ministries retain expertise and responsibility for environmental monitoring and management within their sphere of operations rather than pass all these obligations and commitments to an environmental management unit. All government officials, and indeed the population as a whole, have a responsibility for maintaining environmental quality, rather than abdicating this obligation to a central organization.

F. Environmental impact assessments should be mandatory for all new

South Pacific Regional Environment Programme

IMPLICATIONS OF CLIMATE CHANGE AND SEA LEVEL RISE FOR TUVALU

REPORT OF A PREPARATORY MISSION

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to the
Government of Tuvalu
and to the
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The person filling a recommended new position, that of Environmental Monitoring Officer, would also be a member of the Group. The function of the Group would be to provide assessments on environmental issues and development projects to the National Development Strategy Committee.

National Development Strategy Committee (NDSC)

This existing Committee, which consists of permanent secretaries of government departments, could have its functions broadened to include a specific responsibility for establishing and implementing environmental management policies. The Committee should incorporate in its decisions related to development projects and other activities, environmental considerations using, amongst other information, the results of environmental assessments and recommendations provided by the Environmental Assessment Group.

We recommend establishment of the following position:

Environmental Monitoring Officer

Appointment of an Environmental Monitoring Officer, funded by SPREP, with responsibility to increase local knowledge and understanding regarding the state of the Tuvaluan environment by:

i) local monitoring of environmental conditions and resource use
ii) achieving familiarity with environmental information from local, regional and international sources and dissemination of such information to appropriate government departments and other groups
iii) liaison with SPREP and other regional organizations regarding regional projects which require the involvement of Tuvalu and which will provide results of relevance to Tuvalu and its people.

The Environmental Monitoring Officer would be responsible to the Environmental Officer. Tasks will include collection of data on sea level, climate (in conjunction with the Climate Change Officer), lagoon shoreline profiles, state of underground water lenses; new data which are required include salinity and water levels in pulaka pits and wells, coastal erosion rates using aerial photographs, survey data and satellite data. The Climate Change Officer is ideally placed to assist the proposed Environmental Monitoring Officer in acquiring meteorological and related data.

5.1.1.1 COMMENTARY

A. It is intended that members of the Environmental Assessment Group will gain expertise and confidence by working collectively and with a continuing involvement in environmental management. The multidisciplinary membership of the group will also bring about

5. RECOMMENDATIONS AND IMPLEMENTATION

The following recommendations and implementation plans are based on personal observations, wide-ranging discussions with residents of Tuvalu (including government officials, politicians, representatives of non-governmental organisations and the public at large) and on the results of consulting a large body of literature some of which has been reviewed in the preceding sections. While the main incentive for making the recommendations has been provided by concerns related to climate change and sea level rise, the proposals also arise from concerns related to maintenance of environmental quality and the sustainable use of natural resources.

5.1 RECOMMENDATIONS

The recommendations are presented in three categories: those related to personnel and institutional arrangements, proposals on general environmental management issues and climate change/sea level rise in particular and, finally, recommendations regarding specific needs or activities.

5.1.1 PERSONNEL AND INSTITUTIONAL ARRANGEMENTS

The Government of Tuvalu has shown considerable foresight in its decision to appoint both an Environmental Officer and a Climate Change (Scientific) Officer. As a result, Tuvalu is well placed to respond to the challenges of climate change and sea level rise (CC/SLR); these officers form the basis of a sound programme to meet the needs we have identified. It is imperative that these people receive additional training and appropriate support and encouragement to ensure that they have access to relevant information, possess the appropriate skills and participate in the planning, development and conservation decisions facing Tuvalu.

Given the context of the existing appointments and given the environmental and resource management challenges facing the country, we propose a two level policy/management system:

Tuvalu Environmental Assessment Group (TEAG)

The membership of the Group would consist of at least one representative from each Ministry, this being the person(s) within that Ministry with responsibility for environmental planning/management. Such people would be familiar with the relevant environmental issues and preferred management practices. The group would be chaired by the proposed Environmental Officer. It would also include the Climate Change Officer who would bring to the group's attention issues related to climate change.

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critical to successfully deal with the problems of climate change and sea level rise. Ultimately environmental protection cannot be achieved without the support of the people. Simple material, printed in the Tuvalu language, needs to be developed. This should explain the main environmental problems of Tuvalu and what needs to be done to solve them.

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forwarded or not received at all. We propose the appointment of an Environmental Monitoring Officer whose job it would be to assemble, store and distribute to all relevant personnel local monitoring results and up-to-date environmental data and information of relevance to Tuvalu.

In 1991 a Climate Change Officer was appointed as a member of the Meteorological Service. In early 1992 an Environmental Officer will be appointed. The appointee will be responsible for formulating a State of the Environment Report for Tuvalu and a National Environment Management Strategy. In association with an Environmental Monitoring Officer these personnel form a basis to direct the further development of environmental management in Tuvalu. It is critical, however, that the environmental planning process originates in the department initiating the project. The SPREP programme to strengthen environmental impact assessment capabilities by holding workshops in each SPREP country for members of all relevant government departments should assist this process.

Awareness of climate change and sea level rise is high in Tuvalu. This is likely to be due to radio broadcasts by the Climate Change Officer and other news broadcasts. Climate change is an accepted fact, although the local evidence cited by people that convinces them of this often is unrelated to climate change.

Attitudes regarding possible responses seem to be influenced by the strong religious nature of the people. Many feel that climate change should be accepted as the will of God or dealt with by prayer. It was also questioned whether it would not be easier and cheaper for the entire population to migrate rather than pursue all the measures necessary to maintain the viability of Tuvalu. Overall, however, it is expected that the strong attachment to the land of their ancestors will be the dominant sentiment, especially for people not already displaced to Funafuti. The attitudes of the people toward relocation should be formally canvassed, perhaps by way of a survey organised by the Climate Change Officer.

The logistics of moving Tuvalu's relatively small population are not insuperable. In fact due to population pressures on Vaitupu after World War II, the Fijian island of Kioa was bought and a group resettled there. Such movement is not uncommon in the Pacific. Indeed, the peopling of the islands of the Pacific grew out of mass migrations. Lessons to be drawn from some of the more recent relocations are noted in studies such as those by O'Collins (1990a, 1990b) and Connell and Roy (1990). Although we do not expect Tuvalu to be uninhabitable by the year 2050 due to climate change (especially if population growth is contained), there are many uncertainties in the magnitude of climate change. The Government of Tuvalu would be remiss in not holding preliminary discussions both internally and regionally on this issue.

Environmental education at all levels of formal and informal schooling are

EXECUTIVE SUMMARY

A two person task team, operating under the auspices of the South Pacific Regional Environment Programme and the Association of South Pacific Environmental Institutions and working with national counterparts, has identified the components of the natural environment, society, culture and economy of Tuvalu which are vulnerable to expected changes in both climate and sea level. Due to the strong relationships between the environment and socio-economic conditions the study has also addressed the broad range of environmental, natural resources and human health issues that face Tuvalu, either now or in the immediate future.

The current report is the outcome of extensive interviews conducted in Tuvalu and a study of the relevant international, regional and local literature, including scientific papers and consultant reports. The recent reports of the Intergovernmental Panel on Climate Change provided an international context for the mission while the numerous studies by consultants provided locally focused information related to the many issues addressed in the study.

The Government of Tuvalu has shown considerable foresight in its decision to appoint both an Environmental Officer and a Climate Change (Scientific) Officer and as a result Tuvalu is somewhat prepared to respond to the diverse challenges of climate change and sea level rise. But in Tuvalu the high vulnerability of both natural and human systems to such environmental changes means that considerable additional effort is required if the country is to be spared the hardship associated with environmental degradation and drastic reductions in the quality of life.

It is recommended that environmental and resource management in Tuvalu incorporate a two level policy/management system based on a new Environmental Assessment Group and the National Development Strategy Committee. The latter would extend its current functions to include a specific responsibility for environmental policy with the former Group would providing advice on environmental and resource development issues. The structure relies on personnel being well informed. Consequently emphasis is placed on increasing expertise and confidence by way of training programmes and on the establishment of a comprehensive environmental monitoring programme involving a new Environmental Monitoring Officer.

Such an approach will mean that Tuvalu can reduce its reliance on advice from overseas consultants while the preservation of a quality environment and the sustainable management of local resources will remain the responsibility of all sectors of Government rather than one department. The obligations and needs of the public are also recognised through proposals for public information and education programmes.

Coastal erosion, reclamation and construction activities are recognised as

encouraged.

4.7 ENERGY

Tuvalu relies heavily on imported fuel for transport and electricity generation. The use of solar power for lighting in the outer islands has been promoted by the Tuvalu Solar Electric Cooperative Society Ltd. The interisland telecommunication system also uses solar power. Government plans to provide electricity to outer islands should build on the success of the lighting project. Small island nations have the moral high ground in the climate change debates and this can be reinforced if they lead the way by using renewable energy sources which do not produce greenhouse gases.

4.8 ENVIRONMENTAL AWARENESS AND EDUCATION

The basis of environmental action is environmental awareness. This applies at both the Governmental and public level. We were impressed by the interest and willingness of a large majority of government officials to incorporate environmental concerns, especially those related to climate change, into their planning process. Most officials acknowledged the fact that the environmental issues which Tuvalu is facing or is expected to face in the foreseeable future will be exacerbated by climate chnage and or sea level rise. An active precautionary approach is therefore imperative. The evolving National Environmental Management Strategy for Tuvalu is an appropriate mechanism for ensuring that the desired environmental management goals are achieved.

A major constraint to environmental management in Tuvalu is a lack of information. A large amount of environmental data is currently being acquired by regional and international agencies operating in Tuvalu. Much of this information is generated by monitoring climate change or parameters that may be affected by it. Although in most cases annual reports on the data are sent to the relevant government department, seldom is there much explanation of their significance. In most cases it is filed away, and sometimes misplaced, without much notice taken. Such data include information on sea level, wave heights, wind speed and direction, rainfall, Funafuti lagoon profiles, island profiles dating back to World War II and fresh ground water resources. These available data, along with a few additional monitoring programmes, would provide information that could form the basis of intelligent environmental management decisions. Besides collecting and interpreting these data, it is critical that such information be passed on to other appropriate sections within both the government and the private sector. In addition, reports relevant to environmental management and climatic change from a number of regional conferences and organisations are often not accessible to the appropriate departments. It is unclear as to whether these have been sent to a focal point and not

issues requiring the development of appropriate policies and programmes as are water supply, energy utilization, landuse and population planning, fisheries and waste management, transport and communications. There is a need to increase production of local food crops and reduce the vulnerability to adverse environmental conditions, both now and in the foreseeable future.

Specific proposals relate to the need to enhance the ability to monitor and predict weather conditions, especially those likely to cause damage and bring hardship to Tuvalu. The health of Tuvaluans and the ability to provide appropriate health care are likely to be impaired if the anticipated changes in climate do occur. Early consideration should be given to enhancing health care services and reducing their vulnerability to projected environmental change.

Education, both formal and informal and for governmental and non-governmental groups, and information acquisition and sharing are fundamental cornerstones to a successful response to the environmental problems which Tuvalu faces now and may well face in the future.

information arising from these studies be made widely available and that regular monitoring of water levels and salinity be performed.

4.5 MARINE RESOURCES

Major problems related to marine resources are overexploitation or destruction. Some reef and lagoon resources such as giant clams have been overexploited. The Government of Tuvalu has an active restocking programme for giant clam as well as trochus. Sea weed culture has been attempted but faces many problems. The skipjack tuna resource is underexploited and needs to be further developed for the benefit of the nation. Tuvalu requires assistance in policing its EEZ to stop poaching by foreign vessels which could severely deplete this resource.

Reef passage construction changes lagoon circulation patterns and is also a potential cause of cigutera fish poisoning. The latter is currently a serious problem on Niutao island. Marine pollution, especially from human waste, is a localised problem. In the face of higher temperature and rising sea level it will be particularly important to adopt practices that protect healthy coral reefs.

4.6 WASTE MANAGEMENT

Many of the health problems in Tuvalu stem from contamination of water supplies through poor disposal of human and animal waste. A cholera epidemic in 1990, although apparently started from a boat passenger from Nauru, led to large scale testing of water which revealed high levels of contamination. Because of the limited area of land and the susceptibility of ground water to pollution, waste disposal is a considerable problem. Liquid wastes and sewage are dumped into the sea by sludge tankers or disposed of in septic tanks, soak pits, or pit latrines. There are no sewage systems or treatment facilities in Tuvalu although there are plans for primary treatment in open tanks at the southern tip of Fongafale islet. Systems which recycle waste, such as integrated pig/tilapia fish ponds or using treated human waste as fertiliser, make sense in a resource poor environment.

Solid waste is also a problem since there is little land available for its disposal. Burying increases the possibility of ground water and marine resources being contaminated through leaching. The amount of nonbiodegradable products and packaging is increasing. In Funafuti the borrow pits are common dumping grounds. Perhaps if the waste had toxic materials removed and was compacted its use as controlled fill might be a sensible proposal. Such a prospect should be explored for Funafuti. A major waste product, aluminium cans, is compacted and shipped to Australia for recycling. A similar approach for other appropriate materials should be

1. INTRODUCTION

1.1 BACKGROUND

The authoritative Intergovernmental Panel on Climate Change (IPCC)* concluded that global mean sea level will likely rise, with best estimate predictions of 18 cm by 2030 and 44 cm by 2070 (Houghton et al., 1990). It showed that, even with substantial reductions in future emissions of the major greenhouse gases, such increases in sea level are unavoidable due to lag effects in the climate system - the thermal inertia of the oceans and the ongoing response of land ice to climate changes. Such revelations led Working Group II (IPCC, 1991a) to decide that the most significant consequence of rising sea level is likely to be the potential destruction of coral atolls. These provide no opportunity for landward retreat of people in the face of increased sea level and they serve as important ecological habitats contributing to regional and global biodiversity.

Despite the benefit of nearly three decades of scientific study, the views of the IPCC working groups on the vulnerability of coral atolls are essentially the same as those expressed by Wiens (1962), although the causes and rates of sea level rise he considered did not reflect anthropogenic factors. Over the subsequent decades the growing recognition of accelerated rates of sea level rise induced by enhanced greenhouse effects raised the degree of concern regarding the future habitability of coral atolls. Nevertheless, as late as 1982 a review (Fawcett and Partners, 1982) of coastal protection requirements for Tuvalu did not consider the possibility of a systematic rise in sea level.

For the South Pacific much of the work on climate change and sea level rise undertaken in the late 1980s was pursued as part of the South Pacific Regional Environment Programme (SPREP) Action Plan (SPREP, 1988). This followed a request from the United Nations Environment Programme (UNEP), through its Regional Seas Programme, to assess the potential impacts of greenhouse-induced climatic and sea level changes on Pacific island cohas been assisted in this work by the Association of South Pacific Environmental Institutions (ASPEI) with the main results presented as a series of case studies and review papers (Pernetta and Hughes, 1990; Hughes and McGregor, 1990) and in a popular booklet (Hulm, 1989).

Much of this and other work conducted during the 1980s was influenced by assumptions of a 1 m rise in sea level by 2050 and accelerated increases beyond that date (the scenario was the basis of the various ASPEI assessments - ASPEI, 1990), by uncertainty as to the ability of coral reef systems to keep pace with rising sea level (ASPEI, 1990), and by "the cataclysmic events forecast by the prophets of doom" (Connell and Roy,

* A list of acronyms appears in Appendix I.

4.3 AGRICULTURE

Some of the major issues concerning agriculture have been discussed under food supply in Chapter 3. Ultimately it is likely to be the ability of maintaining agricultural systems that will have the greatest influence on the will and ability of the Tuvalu people to remain on their islands in the face of significant changes in climate and/or a rise in sea level. Agricultural research has recently focused on tropical crops such as sweet potato that could expand the variety of foods grown in Tuvalu. The continued decline in the price or copra, traditionally the major source of income for island dwellers, has redirected policy regarding coconut planting to merely meeting subsistence needs. Research on high-yielding coconut varieties is well advanced at the Vaitupu Agricultural Research station. We believe a major effort is needed to improve the potential yield and salt tolerance of other traditional atoll staples such as pulaka. This will need to be a regional programme, perhaps organised by the Agricultural School of the University of the South Pacific.

Planting programmes are also likely to be of assistance in protecting shorelines from erosion. It should also be recognized that traditional agricultural systems produce a wide range of useful products such as firewood, beverages, medicines, animal feed, mulch, dyes, cordage, canoes, oils, perfumes, fences and body decorations. The value of these and the need for their protection should not be underestimated.

4.4 WATER

Problems regarding water and climate change have been outlined in Section 3. It is likely that the water supply provided by the UNDP project will prove insufficient during extended drought periods. In fact the Government of Tuvalu originally requested a larger storage capacity. Although water conservation should certainly be encouraged, it is unlikely in a country accustomed to high rainfall that conservation will be practised before water supplies are already low. Expansion of the rainwater catchment system should be encouraged with soft government loans. Building codes already require tank construction with all new structures. Their capacity should be above the minimum used by the UNDP project. The importance of the maintenance of the catchment system should be a priority. Desalination equipment was imported during the last drought in Funafuti. The maintenance of this equipment and the use and cost effectiveness of such equipment on the lower rainfall northern islands will increase the ability of Tuvaluans to maintain domestic water supply under changing climatic conditions.

Ground water sources have been partially surveyed as part of the land resources survey (McLean and Hosking, 1991b) and are being further studied as part of the UNDP water project. It is important that full

1990). In contrast, very few studies were influenced by the more cautious and optimistic views as typified by McLean (1989).

This demonstrates that in a period as short as five years there have been fundamental changes in assumptions and attitudes regarding the impact of climate change on coral atolls. Many of the refinements in estimates of significant changes in natural factors influencing atoll environments in the coming decades (i.e. air and ocean temperatures, precipitation, sea level, wind regimes and tropical storms) arise from recent improvements in our understanding of the climate (atmosphere-ocean) system at the global scale. But even at this scale considerable uncertainty remains - the sources, sinks and ambient concentrations of greenhouse gases in the future; the effects of clouds, especially in terms of their ability to enhance or suppress greenhouse gas-induced global warming; the ways in which the oceans influence the timing and patterns of climate change particularly through thermal inertia and changes in circulation; and the manner in which the polar ice sheets will influence future sea levels (IPCC, 1992).

At the regional scale of the South Pacific the situation is even more complex and the future fundamentally less certain. As Basher et al. (1990) demonstrate, current climate models do not simulate well a number of features of the present climate of the South Pacific (e.g. the position and intensity of major convergence zones and tropical cyclone intensities). While there is some consistency between models in estimates of predicted temperature changes, rainfall estimates as a consequence of doubling atmospheric CO_2 concentration show little agreement for the South Pacific. Improvements must await higher resolution models of both the ocean and atmospheric circulations. Predictions of systematic changes in climate resulting from anthropogenic influences are difficult to discern in an environment such as the South Pacific where there are large interannual variations and regional anomalies - especially in the present day patterns of precipitation, sea level, wind and tropical cyclone frequency. For example, McLean (1989) has highlighted the very great differences between the global and tropical Pacific sea level records over the past few decades and hence questioned the appropriateness of directly applying global trends in sea level to the tropical Pacific. Furthermore, he concluded that the high variability in local sea level rather than a global sea level rise is likely to continue to dominate the record of sea level change over the next few decades. With annual extremes in sea level in the tropical Pacific region (sometimes as much as 40 cm) being of similar magnitude to the systematic changes predicted to occur in global sea level by 2050, McLean also acknowledged that it will be difficult to discern any enhanced greenhouse related change in the observed sea level record.

Finally, in identifying the likely present and future environmental threats for coral reef and related ecosystems, a recent workshop report on coral reef ecosystems (D'Elia et al., 1991) found that although global climate change represents an important long-term challenge, the most immediate concerns

during powerful storms. The hurricane bank is an extremely valuable resource whose importance will increase as sea levels rise. To build it as a sea wall would cost tens of millions of dollars. Its removal below the high tide level should only be considered in places where it does not protect any significant resources. Much of the recent bank removal occurred when materials were needed for tar sealing the main Funafuti road. The new surface has seriously deteriorated in a short time and has been the scene of Tuvalu's first recorded road death. The advisability of such projects with high environment costs needs to be carefully evaluated before implementation.

Another potential source of material is the lagoon or ocean floor (Figure 4.2). Experience has shown that creation of lagoon borrow pits alters sediment flow and often increases coastal erosion. The effects of the pilot project to dredge for fill in the lagoon to fill a pond near the airport will need to be carefully evaluated before any further such work is performed. This SOPAC project has clear monitoring requirements written into it. Careful consideration will be required when assessing any environmental effects identified in the pilot study. Impacts on both the lagoon and the pond and its environs should be assessed. Alternative uses for the area intended for reclamation must also be considered. Such environmental checks must be an integral part of any new or ongoing project.

Channel blasting is another atoll activity that may lead to ecosystem disturbance and coastal modification. The lagoon blasting in Funafuti during World War II has likely contributed to removal of sand from the lagoon shoreline. Aerial surveys show trails of sand leading to and filling the blasted areas. Kaly and Jones (1991b) have studied the environmental changes associated with boat channel construction. Effects were assessed using abundance of marine organisms and physical variables such as beach width, sediments and substratum complexity. They concluded that such channels do not have widespread detrimental effects on the ecology of coral reefs. Provided that appropriate restrictions are placed on the number and type of channels the ecological costs are outweighed by the benefits of the channels. A major anchorage project for Vaitupu is in the late stages of planning. Environment impact advice received from the Japanese who are funding the project has not totally reassured the government that serious erosion will not result. They have sought the advice of a New Zealand firm. A useful role for SPREP would be providing assistance in obtaining and interpreting such advice for major projects in the region.

A complicating feature in any modification of land use is the land tenure arrangement with traditional land owners. Although environmentally it may make more sense to remove material from an unproductive extremity of an island or from an uninhabitated island, the interests of land owners makes dredging offshore or removing the hurricane bank <u>appear</u> to be a preferable short-term solution. Erosion or creation of new land are other processes which are complicated by land tenure arrangements.

and the strongest stresses and environmental "signals" arise from local and regional anthropogenic sources as the result of such factors as human population growth, land use, resource exploitation and waste disposal.

This latter point was one that had a marked influence on the breadth of the first country report (Sullivan and Gibson, 1991) prepared by SPREP, in association with ASPEI, on projected specific impacts of greenhouse-induced climate change for Kiribati. At the South Pacific Commission/UNEP/ASPEI Intergovernmental Meeting on Climate Change and Sea Level Rise in the South Pacific held in Majuro, Marshall Islands in July 1989 six small island states from the South Pacific requested SPREP to organise teams of ASPEI scientists to visit each country and work with designated government officials to produce a preliminary report on projected specific impacts of greenhouse-induced climate change for each country and to suggest appropriate activities which could be undertaken to alleviate the impacts.

The present report is the result of the study requested by Tuvalu, an independent state of 9 coral atolls located slightly south of the equator and just to the west of the international date line. Pernetta (1990) calculated an index of island susceptability to sea level rise. By this measure Tuvalu ranked third (after Tokelau and the Marshall Islands) out of 26 small South Pacific countries or territories. Tuvalu was assigned a category meaning that it would be "devastated if projected rises (in sea level) occur and such states may cease to contain habitable islands". Kiribati was also assigned to this category and so too would be the Maldive Islands of the Indian Ocean, had Pernetta's analysis extended to that region. Consequently the reports on similar studies for Kiribati (Sullivan and Gibson, 1991) and the Maldives (Pernetta and Sestini, 1989) provide a useful background as to the issues to be addressed and methods to be used in the current study of Tuvalu. But naturally we were very aware of the uniqueness of the Tuvaluan nation, in terms of its physical setting and character, its ecology and its history, society and culture. A useful background for the mission was provided by South Pacific Commission (1981). The present study updates much of that material.

1.2 TERMS OF REFERENCE

The terms of reference under which this study operated where established by Dr. V. Fuavao, Director of the South Pacific Regional Environment Programme. They were as follows:

1. Under the general supervision and guidance of the Chairman of the Association of South Pacific Environmental Institutions (ASPEI) a two/three person mission will visit the host country for approximately 7 days. The main purpose of the mission is to prepare, in close consultation with national counterparts identified by the host

of the issue. Demand for construction materials may come from fouractivities - new construction, reclamation, protection and upgrading of the infrastructure. Material can be removed from the lagoon, other land areas or it can come from offshore. In all cases there are significant adverse effects on the environment although, as shown in Fig. 4.1, the effects vary somewhat between source areas. Fig. 4.2 provides a detailed assessment of possible environmental impacts associated with an activity such as upgrading (increasing height and sealing) of an airport runway. There is an overwhemling bias towards negative environmental impacts which include such diverse effects as loss of playing fields to the modification of surface and sub-surface water conditions. The current airport runway at Fongafale provides an extensive cleared, flat and grassed area that serves as a playing field for football and cricket (Plate 4.2).

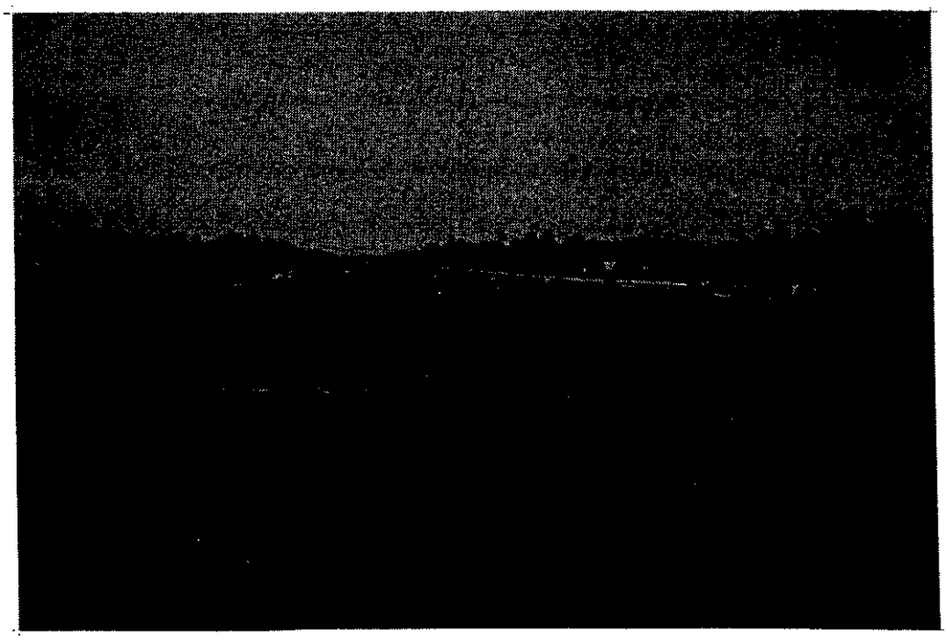

Plate 4.2 The airport runway at Fongafale, with a game of cricket in progress shortly before the arrival of an aircraft.

In Funafuti a major source of land material in recent years has been the hurricane bank itself. Removal of rock (along with rock compaction and movement inland and seaward, all by wave action) has lowered the hurricane bank to the present high water sea level. This is likely to expose the airfield, which will be upgraded in 1992, to damage by wave action

Government, a proposal for a programme of assistance to undertake an in-depth study of the potential impact of expected climatic changes (primarily sea level and temperature rise) on the natural environment and the socio-economic structure and activities of the host country, including the identification of response options which may be suitable and available to avoid or mitigate the expected negative impact of climatic changes.

2. Specifically, while in the host country, the mission, consisting of two/three senior experts from the ASPEI/UNEP/SPREP Task Team on climatic change will:

(a) examine and evaluate the available information affecting the physical and biological environment (terrestrial and marine) of the islands comprising the country;

(b) examine and carry out a preliminary assessment of the available demographic, social (including archaeological and cultural) and economic data;

(c) present, via a public lecture or radio broadcast as appropriate, an overview of the current state of knowledge concerning the greenhouse effect and its possible consequences for Pacific Island nations;

(d) present to the national authorities, organisations, institutions and experts the results of UNEP-sponsored studies, specifically those conducted in the South Pacific (e.g. Kiribati) and South Asian Seas areas outlining the potential applicability of these studies to the host country;

(e) discuss with the national authorities; organisations, institutions and experts their perceptions of the consequences of the potential impacts of climatic change and seek their views on the suitable response options; and

(f) identify national authorities, organisations, institutions and experts which may participate in the in-depth study expected to follow the mission, and determine the modalities of co-operation between the legal and administrative structures of the country with the team which will assist in the implementation of the in-depth study.

3. On the basis of the activities referred to in paragraph 2 above, as well as information collected by the experts prior to their mission to the host country, the experts will prepare a joint report containing:

(a) a general overview of the climatological, oceanographic,

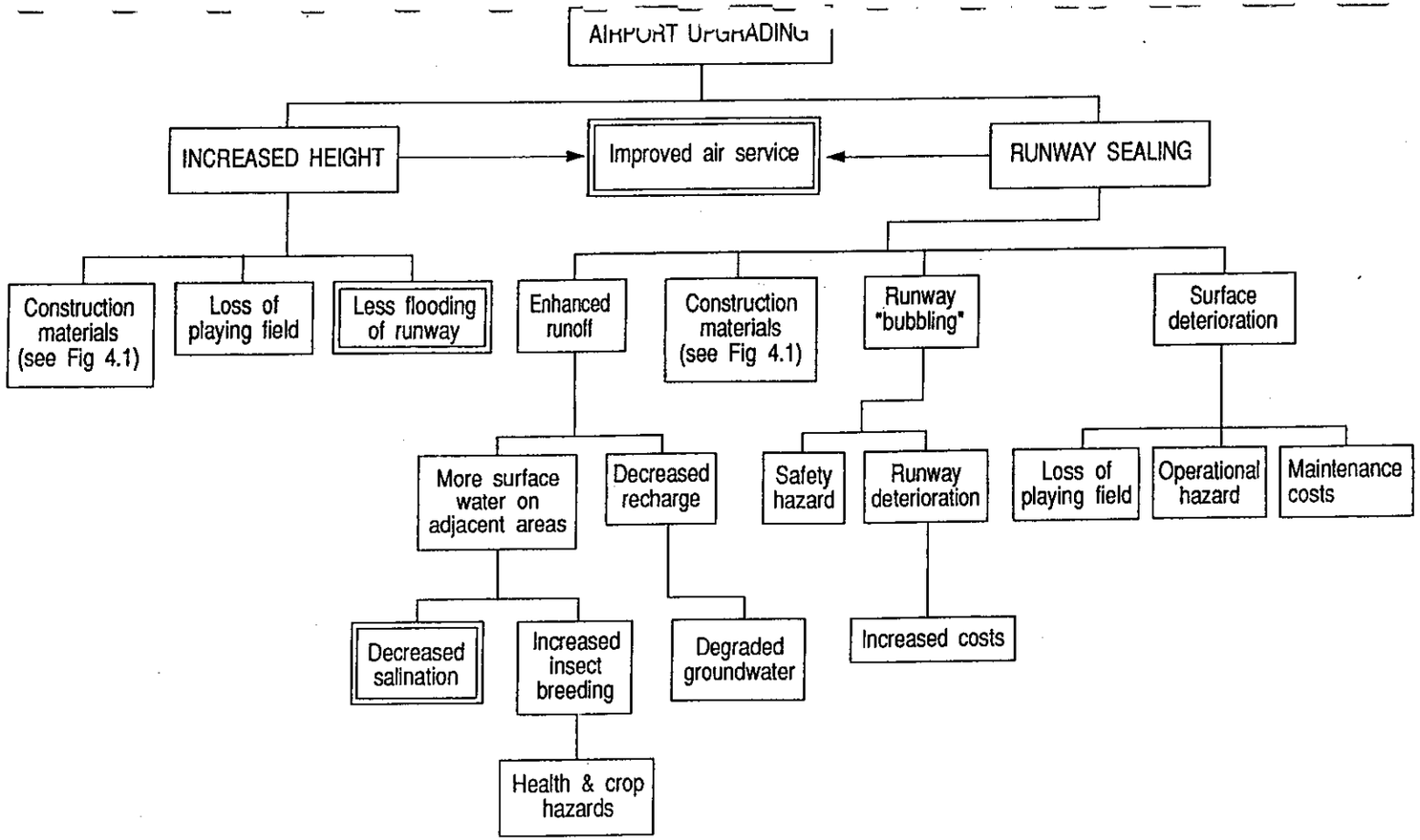

Fig. 4.2 The possible environmental impacts of airport runway upgrading (raising the level and sealing the runway). Positive impacts have a double border; negative impacts a single border.

geological, biological and socio-economic factors which may be relevant to or affected by the potential impacts of expected climatic changes;

(b) a preliminary identification of the most vulnerable components and sites of the natural environment, as well as the socio-economic structures and activities which may be most critically affected by expected climatic changes;

(c) an overview of current environmental management problems in the country and an assessment of how such problems may be exacerbated by climatic changes;

(d) a detailed proposal for a joint programme of assistance to the host country for the in-depth evaluation of potential impacts of expected climatic changes on the natural environment and the socio-economic structures and activities of the country including the identification of policy or management options suitable to avoid or mitigate the impact of climatic changes; the proposal should identify the workplan, timetable and financial requirements of the in-depth evaluation as well as the possible institutional arrangements for carrying out the evaluation.

4. Prior to leaving the host country, the mission will present to and discuss with the authorities identified by the Government of the country, the outline of the proposed programme, as well as the major findings of the mission. The comments and suggestions of the authorities identified by the Government of the host country will be duly taken into account in preparing the final report of the mission.

5. The final report of the mission, prepared as the experts joint report and as specified in paragraph above, will be simultaneously submitted to the Chairman of ASPEI, the Director of OCA/PAC and the SPREP Director of clearance. Submission of the report will be made no later than 30 days following the completion of the visit.

6. The final report of the mission will be transmitted by SPREP to the Government of the host country together with the comments of SPREP, UNEP and ASPEI and will be used as the basis for subsequent assistance to the Government of the country in formulation and implementing suitable response options to the expected impacts of climatic change.

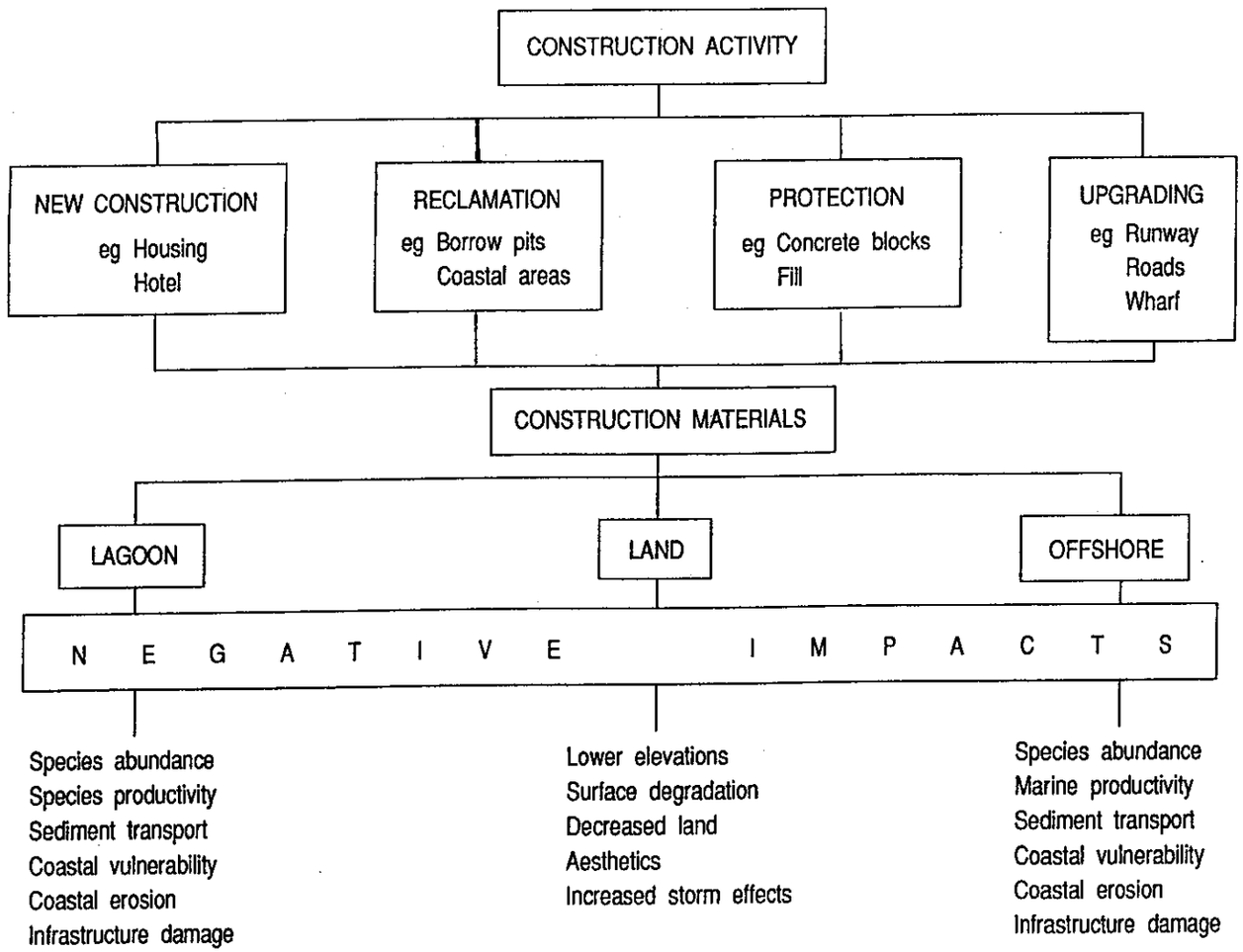

Fig. 4.1 The sources of construction material for new construction, land reclamation, coastal protection and upgrading of roads, airport runway and other facilities. The likely negative impacts of obtaining these materials from land areas, within the lagoon and from offshore are indicated.

1.3 PROGRAMME OF THE VISIT TO TUVALU

The visit to Tuvalu took place between January 17 and 24, 1992. The itinerary was coordinated by the Office of the Prime Minister with the assistance of Mr Fakavae Taomia, Scientific officer of the Tuvalu Meteorological Service. Details of the programme are presented in Appendix II.

A secondary school on Funafuti has recently opened and a second school is under construction. Previously the only secondary school was located on Vaitupu and this had done much to maintain the population there. Although having secondary schools on Funafuti may be more convenient they can only further imbalance the population distribution. It would be preferable to locate such institutions on outer islands where the potential for students to raise their own food and learn by this process is much greater. But such plans are contingent upon there being a more reliable inter-island transportation service.

4.2 LAND ISSUES

Given its limited extent as well as its cultural significance, land is a major environmental issue. Erosion is a perennial problem in coastal ecosystems and it is likely that this will increase as sea levels and storminess increase. Walls of coral stone and coconut palm trunks have traditionally been used for coastal protection. In 1982 a major report was prepared (Fawcett, 1982) to address this problem. Since then the European Community has funded a variety of measures to protect the coast with limited success. A report on those efforts and further proposals was made by Reynolds (1988). SOPAC has recently been active in assessing coastal erosion in Tuvalu (Rearic, 1991). Effective , low-cost measures are a priority for Tuvalu and other nations (see Appendix III for a review of current practices and protection options) and SPREP should seek state-of-the-art advice on this issue.

Identifying a source of material for coastal protection is a major problem in Tuvalu. Increasing the height in one area typically means reducing the height somewhere else. The materials are also in demand for home building, road and airfield construction and, in Funafuti, for the reclamation of borrow pits excavated during World War II (Plate 4.1) and ponds enclosed by the hurricane bank. Figures 4.1 and 4.2 highlight the complex nature

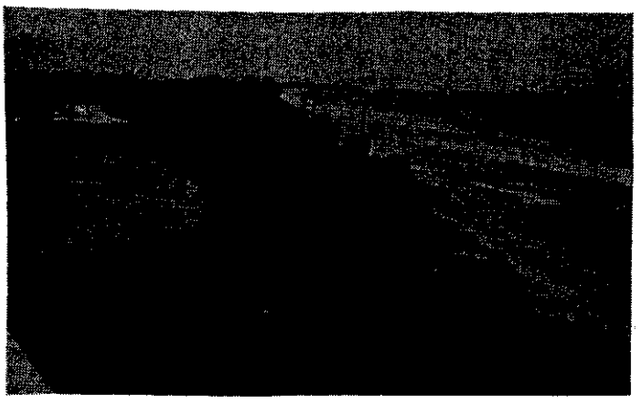

Plate 4.1 A borrow pit on Fongafale.

2. THE ENVIRONMENT OF TUVALU

2.1 Geographical Setting

Tuvalu has been an independent state, within the British Commonwealth, since 1 October, 1978. Three years earlier the country separated from the Gilbert Islands (now Kiribati) and adopted the name Tuvalu ("Eight Standing Together"). Previously the group of 9 atolls (one had no permanent habitation - hence the name Tuvalu) had been known as the Ellice Islands, forming part of the British Colony of the Gilbert and Ellice Islands. The archipelago of Tuvalu extends over approximately 670 km with a general northwest-southeast orientation between 5 and 10°S latitude and 176 and 179°E longitude covering an area of 750,000 km^2 (Fig. 2.1). This positioning provides Tuvalu with an Exclusive Economic Zone (EEZ) of 1.3 million km^2. Funafuti, the capital and port of entry, is in the southern group of islands, 587 km from the northernmost island of Nanumea and 158 km from the most southern island of Niulakita (Fig. 2.2).

The archipelago is part of the Austral-Gilbert-Marshall chain and is the surface expression of thick carbonate deposits draped over extinct volcanic mounds. Interpretation of a seismic refraction profile of Funafuti (Locke, 1991) shows that there is at least 550 m of coral immediately below the lagoon and overlying 3650 m of either consolidated or dolomitised limestone or volcanic rocks. Below this basic igneous rocks occur, typical of the ocean floor west of Funafuti and elsewhere in the Pacific.

All nine islands (Fig. 2.3) of the archipelago are built of unconsolidated coralline sands and gravels derived from the adjacent reefs and lagoons. Five (Nanumea, Nui, Nukufetau, Funafuti and Nukulaelae) can be classed as true atolls given their more or less continuous rim of reef, at or near the surface of the sea and surrounding a distinct and deeper lagoon (McLean and Hosking, 1991a). Three islands (Nanumaga, Niutao and Niulakita) occupy the flat tops of table reefs and there are no surface draining lagoons. Rather they have a continuous land margin that completely encircles a shallow mangrove-fringed and enclosed lagoon or pond. Vaitupu, by far the largest island at 530 hectares, has the composite characteristics of the atoll and table reef forms. Its two small lagoons are almost occluded by land and reef flat, filling through shallow channels at only the higher stages of the tide (McLean and Hosking, 1991a).

McLean (1991) discusses the formation, persistence and evolution of reef islands and atoll motu in Tuvalu while McLean and Hosking (1991a; 1991b) provide a detailed description of the contrasting characteristics of the reef islands associated with the smaller table reefs and of the motu (islets) which form part of the larger atolls (Table 2.1). In the case of the table reefs over two-thirds of each reef top is occupied by a single island centrally located on the reef platform while on the atolls the motu are unevenly distributed around the reef rim, with greater concentrations along the

4. ENVIRONMENTAL PROBLEMS, THE EFFECT OF CLIMATE CHANGE AND MANAGEMENT OPPORTUNITIES

Environmental issues related to climate change are often problems that exist even without climate change. The added stress merely makes the problem more pressing. Thus some of the topics in this section will already have been discussed in section 3. These and other environmental concerns will be considered in more detail in the Tuvaluan context and possible positive responses discussed.

4.1 POPULATION GROWTH AND DISTRIBUTION

The root of many environmental problems lies in population growth in excess of available resources. This is especially true in Tuvalu with such extremely limited land area. The moderate natural population growth of around two per cent is being increased by phosphate workers from Kiribati returning home. It is expected that by the end of the century, as mining ceases, an additional 1000 Tuvaluans now in Nauru will return to Tuvalu. This repatriation of overseas workers not only adds to population pressure but can also cause economic hardship as an important income source is lost. There are a large number of sailors trained at the Maritime School to work on foreign vessels and the demand for these sailors is increasing. The government is aware of the importance of finding overseas employment for its excess labour supply and has negotiated for 90 workers to be employed annually in New Zealand. Such agreements are difficult to obtain especially at times of high overseas unemployment rates.

Family planning is encouraged by the dispensaries and the hospital and also by non-governmental organisations. The main resistance comes from the idea that a family needs at least two sons, one to work overseas to provide monetary support for parents and the other to stay home to provide for day to day living.

A related problem is urban drift. In the last five years the population of Funafuti has increased by about 35% and now contains 43% of the total population (Government of Tuvalu 1991a). There is thus a great deal of reliance on imported food. In addition, the increased population on Funafuti aggravates the waste disposal problem.

The Government has a stated policy of outer island economic development but a recent government report (Government of Tuvalu 1991b) admits that most of these projects have not been implemented. The fact that there is only one interisland vessel makes any such project much more difficult than one implemented on Funafuti. Past experience has shown that hurricanes will often affect only a few islands and it is therefore important to disperse the resources base as much as possible.

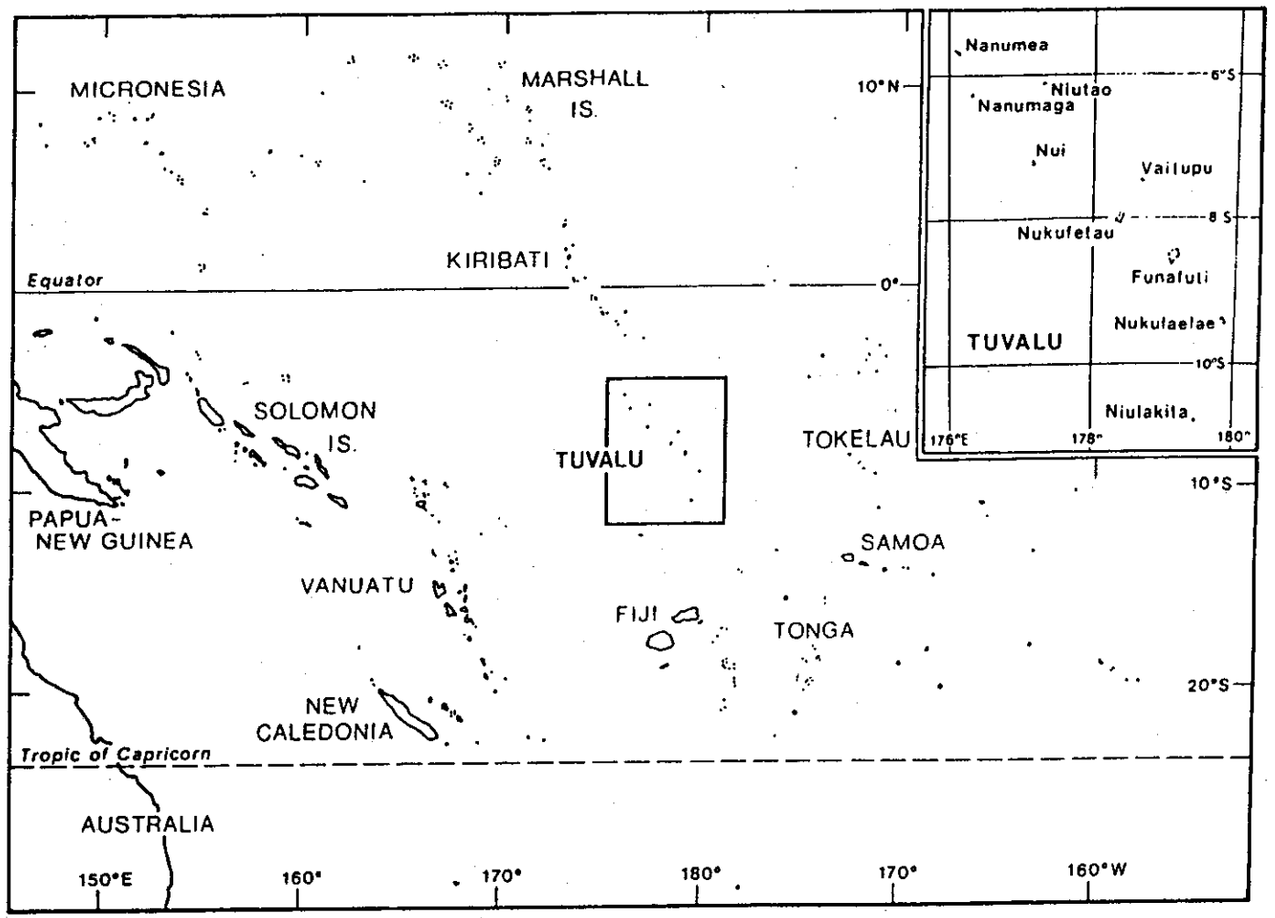

Fig. 2.1 Location of Tuvalu within the Pacific Basin (from McLean and Hosking, 1991b).

other structures built at or near sea level. Increased storminess could increase this effect. The extended Vaiaku Lagi hotel is being built at the lagoon edge since no other land is available. Structures such as these would be especially threatened by increased tropical cyclones.

As water levels increase underground facilities such as septic tanks and latrines could be affected. In Funafuti utility wiring is underground and it is possible that these could be affected as water levels rise, especially if saline.

Preparation of a national draft building code for Tuvalu was begun in response to the high risk of injury and damage that cyclones pose for the people and facilities of Tuvalu. In the code no provision is made to meet the diverse impacts (e.g rising ground water table and flooding) of climate change and sea-level rise on building design and construction practices. Given that an incentive for preparing the code was to mitigate the damage of cyclones, a design wind speed of 45 m s^{-1} leaves little margin beyond the maximum gust observed at Funafuti (73 kts; 38 m s^{-1}). The code has yet to be formally adopted and there may well be an opportunity to incorporate more provisions related to climate change and sea level rise.

3.4.7 Transport and Communications

A single airline with one aircraft services Tuvalu (Funafuti) on a regular basis. An internal air service was terminated in 1983. A single ship provides the normal interisland transport for passengers and cargo. Interisland voice communications rely on high frequency radio transmissions and there is only one satellite earth station for international telecommunications. Transport and communication systems are therefore exceedingly vulnerable to extreme events and the ability to provide adequate services at the time of a national disaster is in doubt.

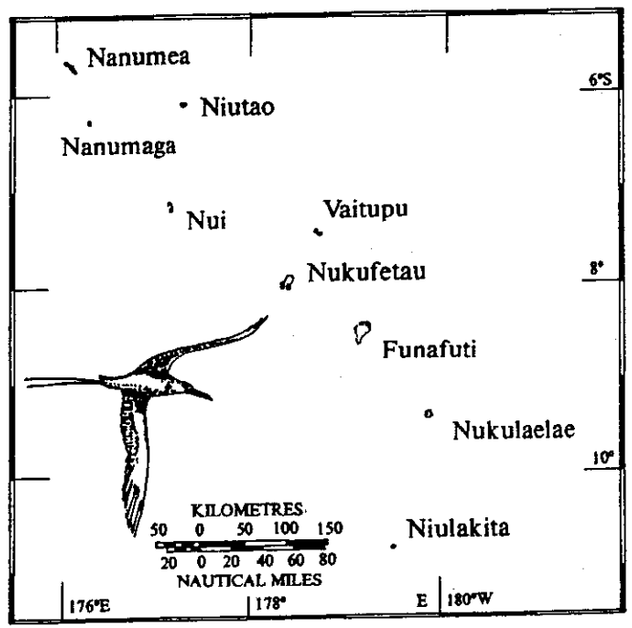

Fig. 2.2 The islands of Tuvalu (from Rogers, 1991).

It is difficult at this point to predict changes in rainfall patterns for individual islands of Tuvalu. One view is that wet periods may get wetter and dry periods drier. Droughts (less than 100 mm total rainfall) of two or three months are experienced, especially in the northern islands. With more evaporation and the possibility of less dry season rain, drought could become more serious, especially since tank water is unlikely to be conserved until the drought is in full force. Traditionally drinking coconuts are used as a source of liquid and salt water (or well water if available) for other purposes during droughts. Well water is nominally used for agriculture, washing and other purposes.

3.4.5 Food Supply

The atoll agricultural system is fairly simple. Giant swamp taro (pulaka) is grown in pits dug down to the fresh water lens and filled with refuse to produce humus. Bananas and taro plants are sometimes also grown in these pits. Pandanus, breadfruit, bananas and coconuts are grown at ground level. Fig trees are grown on some islands. Fruits such as papaya and some exotic vegetables are increasingly grown but the poor soils limit agricultural development. Imported foods are increasingly consumed, especially in Funafuti.

Plant growth is expected to increase as a result of increased carbon dioxide concentration in the atmosphere (Jacobs, 1990). Increased temperature, however, will lead to added heat stress in some plants. A major factor that will affect agriculture is the ground water availability. In Nanumea, in the north, ground water deficiency reaches 35 mm by the end of the dry season in an average year (Thompson, 1987). (In the southern islands the deficiency only reaches 5 mm.) Higher temperatures would increase this. Salt water intrusion into pulaka pits has traditionally been a problem, especially during droughts. Higher sea levels and waves are likely to cause more salt mixing in the lens. Storm wave overwash and salt spray are also more likely, which would damage crops. Increases in water level will lead to increased flooding of low-lying inland areas which would then reduce area available for agriculture.

Fish, especially skipjack tuna, forms the other major part of the Tuvaluan diet. Supply does not totally meet demand, especially during stormy periods when no tuna fishing is possible. Although Tuvalu licenses foreign vessels to fish their EEZ, there is no evidence of depletion of the tuna resource (Government of Tuvalu, 1990). The effects of potential changes in current systems and upwelling zones that may result from changing climatic conditions are difficult to predict but their possible effects on fisheries resources will need to be monitored.

3.4.6 Engineering Structures

Sea walls and wharves are threatened by rising sea level as are roads and

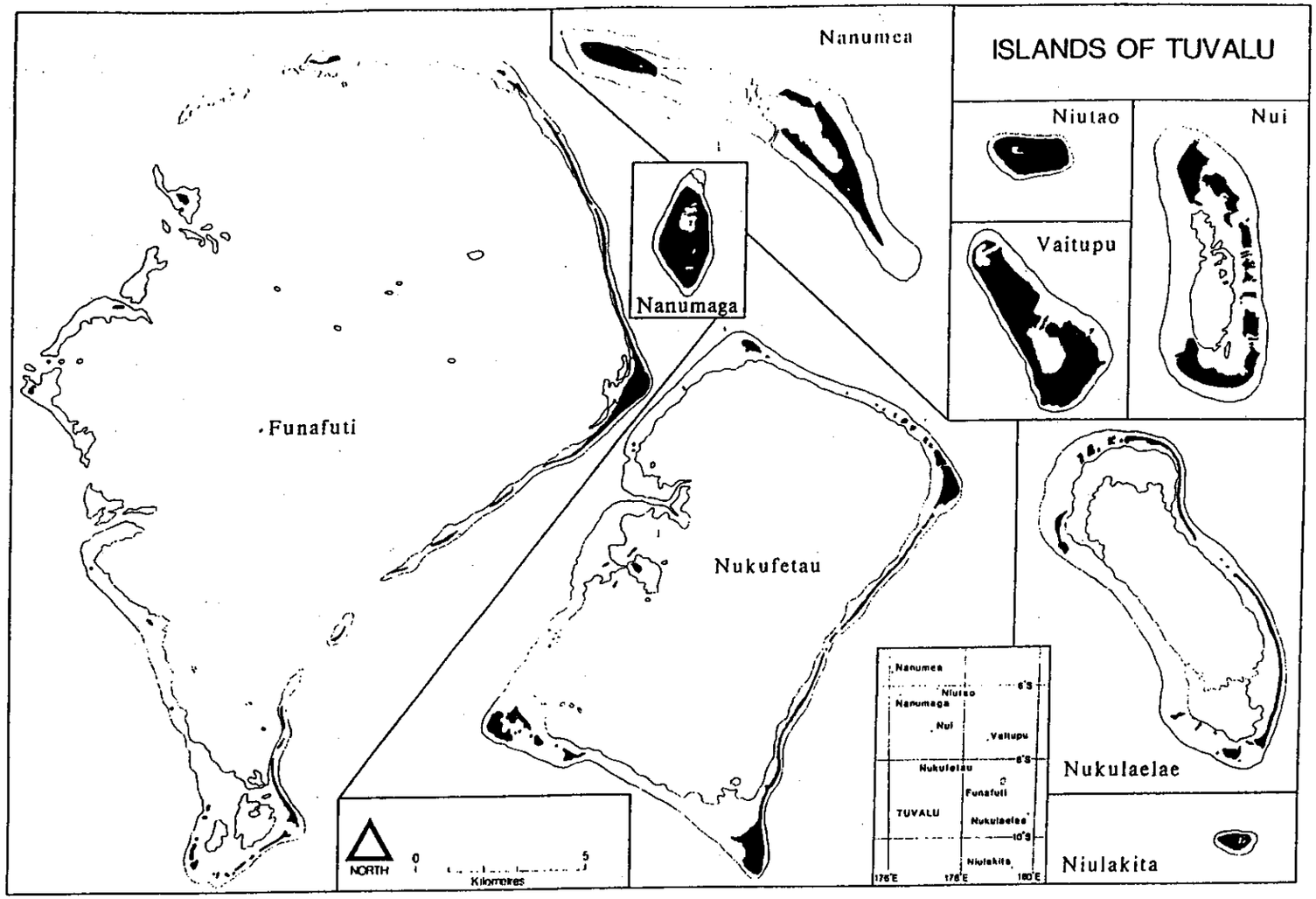

Fig. 2.3 Reef and island outlines of the nine islands of Tuvalu (from McLean and Hosking, 1991b).

1989). Reef growth depends on many factors besides coral growth. One useful analog is the rate of reef growth during rapid sea level rise after the last ice age. Average growth rates of 5 to 8 mm per year have been estimated for Kiribati during this period. Given the lowered estimates for sea level rise (Houghton et al., 1990), it is likely that coral growth can keep pace with sea level rise. But in fact most of the ocean reef surrounding atolls is exposed at low tide and growing will occur only at the reef edge. As the reef flat is covered due to higher water levels conditions for renewed and more extensive coral growth are likely to slowly develop.

A more serious threat to coral reefs is probably increased sea water temperatures. Elevated temperature has been implicated as a cause of coral bleaching, which can lead to decreased growth or even death of a coral reef (D'Elia et al., 1991). Sea water temperatures in Tuvalu average approximately 29°C which is considered to be within a degree of the upper level for coral growth. Most episodes of coral bleaching have been associated with relatively rapid elevation of sea water temperatures. Not enough is known about the process to determine whether a slow warming of the sea will have a similar effect. It is likely that coral growth will be adversely affected to some extent by elevated sea water temperatures.

An issue likely to be related to the disturbance of coral reef ecosystems is the incidence of ciguatera fish poisoning (Tebano, 1991); Kaly and Jones, 1991a). Careful consideration should be given to the possible ecosystem disturbances resulting from anticipated changes in climate and sea level and the associated influence on the incidence of ciguatera poisoning.

3.4.4 Water Supply

Relatively high rainfall spread throughout the year provides Tuvalu with water both for water storage tanks and to replenish the fresh water lens. The porous nature of atolls prevents surface water accumulation. However, a lens of fresh water roughly proportion to the size of the atoll "floats" on salt water in the soil beneath atolls where the width exceeds approximately 300 m. This can be accessed by wells or used for planting in pits dug to the water table.

Not all islands in Tuvalu have a significant fresh water lens. On Fongafale the compacting of land by road and airfield construction and increased land coverage by construction has limited rainfall infiltration into a freshwater lens already fragile due to the narrowness of the land mass. As a result there is no significant fresh groundwater on Fongafale.

As houses with corrugated iron roofs have replaced traditional houses more rain has been collected for household use. The UNDP is currently funding constructing of water tanks that will store 50 litres of water per person per day for 40 days in the three drier northern islands and for 30 days in the others.

TABLE 2.1

REEF AND ISLAND AREAS FOR TUVALU
(from McLean and Hosking, 1991b)

	Nanumea		Nanumaga		Niutao		Nui		Vaitupu		Nukufetau		Funafuti		Nukulaelae		Niulakita	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
1. Reef top																		
Reef platform	1710.32	83.31	412.75	100.00	305.53	100.00	1601.27	82.60	906.42	89.28	2558.72	21.96	3695.54	15.26	1403.68	37.13	74.12	100.00
Islets	365.87	17.82	300.76	72.87	235.06	76.94	351.46	18.13	528.96	52.10	331.01	2.84	270.48	1.12	182.95	4.84	42.07	56.76
Beaches	21.31	1.04	17.12	4.15	1.81	0.59	22.12	1.14	16.80	1.65	64.50	0.55	27.00	0.11	33.01	0.87	7.58	10.22
Reef flat	1323.14	64.45	97.87	22.98	68.65	22.47	1227.69	63.33	360.66	35.53	2163.21	18.57	3398.06	14.03	1187.72	31.42	24.47	33.02
Lagoon	324.63	16.69					337.39	17.40	108.88	10.72	9092.64	78.04	20521.62	84.74	2376.81	62.87		
Total Reef top	2052.95	100.00	412.75	100.00	305.53	100.00	1938.66	100.00	1015.30	100.00	11651.36	100.00	24217.16	100.00	3780.49	100.00	74.12	100.00
Reef Type	Atoll		Patch		Patch		Atoll		Atoll/Patch		Atoll		Atoll		Atoll		Patch	
Reef orientation (long axis)	NW-SE		N-S		E-W		N-S		NW-SE		NE-SW		NNE-SSW		NW-SE		E-W	
Reef top max. length x width	12.5 x 2.3 km		3.7 x 1.6 km		2.7 x 1.4 km		7.5 x 2.6 lm		5.4 x 2.7 km		14.4 x 8.3 km		24.0 x 18 km		11.0 x 4.1 km		1.3 x 0.8 km	
2. Island																		
Total island	365.87	100.00	300.76	100.00	235.06	100.00	351.46	100.00	528.96	100.00	331.01	100.00	270.48	100.00	182.95	100.00	42.07	100.00
Enclosed lagoon			29.20	9.71	9.93	4.23											1.92	4.56
Land area	365.87	100.00	271.56	90.29	225.13	95.77	351.46	100.00	528.96	100.00	331.01	100.00	270.48	100.00	182.95	100.00	40.15	95.44
Number of islets	6		1		1		18		9		37		33		20		1	
Large islet (s)	Nanumea (223 ha) Lakena (119 ha)		Nanumaga (301 ha)		Niutao (235 ha)		Fenau Tapu (138 ha) Meang (91 ha)		Vaitupu (524 ha)		Motulalo (95 ha) Lafanga (53 ha)		Fongafale (142 ha)		Nkuoku (72 ha) Tumiloto (47 ha)		Niulakita (42 ha)	
Distance from village to most distant land across lagoon or land	7 km	lagoon	1.7 km	land	2.1 km	land	6.1 km	lagoon	3.7 km	land	15 km	lagoon	19 km	lagoon	9.3 km	lagoon	0.75 km	land

Plate 3.3 A road on Fongafale, highlighting the vulnerability to wave action and coastal erosion.

was replenished offshore it is likely that large waves would be erosive (both since they would not deposit sediment and since the wave energy would not be dissipated by such sediment transport). Such an occurrence would be more likely under changed climatic conditions.

The dynamic nature of the coastal margins of coral atolls has been demonstrated by Howorth and Radke (1991). They point out that in parts of Funafuti, where the pressure on land is particularly intense, natural and human-induced coastline changes are causing serious social problems with possible additional effects on fishing and pollution of the lagoon environment. In their study Howorth and Radke identify several factors that may be contributing to retreat of the shoreline. These include the construction of reef channels which have modified sediment transport pathways, decreases in the reef-flat width and poorly designed coastal enginnering structures.

3.4.3 Coral Reefs

Both as a source of sediment and as a barrier to wave action, the rate of reef growth as sea level rises will be important. There is an extensive literature on this topic (e.g. Buddemeier and Smith, 1988 and McLean,

windward (eastern) reef. In the case of the large atoll of Funafuti the lagoon covers some 85% of the reef top and the 34 motu amount to only 8% of the reef platform. More than two-thirds of the 129 discrete atoll motu and reef islands that make up Tuvalu are less than 5 ha in area. Only seven have an area greater than 100 hectares and the twelve largest islands account for some 70% of the total land area (24 km^2) of Tuvalu. Island elevations rarely exceed three metres above mean sea level, with most land at or close to sea level. Hence Tuvalu is exceptionally vulnerable to high spring tides, storm surges, tsunamis and the projected sea level rise resulting from global warming.

Soils are usually very weakly developed on calcareous reef rubble and coral, foraminiferal or algal sands, with occasional additions of guano and pumice (Hosking and McLean, 1991b; Rogers, 1991). Consequently they are characterized by their alkalinity, immaturity of profile development, low water retaining capacity and by a deficiency of clay and natural fertility. Stoniness and a hard-pan at shallow depth limit the workability of many soils. Nevertheless, there are some relatively high quality, dark and phosphatic soils. Their distribution is highly variable ranging from less than 7% of the land area of Nukufetau to 77% on the small reef island of Niulakita (McLean and Hosking, 1991b). In moist hollows, including human-made pulaka (taro) pits, soils are augmented with humus to support subsistence gardening (McLean and Hosking, 1991b; Rogers, 1991).

The islands of Tuvalu have only a limited flora consisting largely of pantropical and easily dispersed species, principally as a result of the probable recolonisation of the islands by terrestrial biota during the Holocene (Woodroffe, 1991). Of the estimated 200 plant species, a maximum of 60 may be indigenous. None is endemic and up to 50% are endangered or severely restricted in distribution (Government of Tuvalu, 1992). The vegetation is dominated by coconut palms, pandanus, casuarina and salt tolerant ferns, creepers and grasses. Mangrove swamp is very limited in its occurrence. According to Rogers (1991), pisonia woodland probably occupied the bulk of the islands in the distant past, but only scattered pockets remain today. On all islands the natural vegetation has been severely modified by human activities including the introduction, cultivation, manipulation and utilization of plants. All vegetation types including scrub, bushes, creepers, mangroves and broadleaf trees are used for a great variety of purposes in the subsistence economy that characterises Tuvalu. Three-quarters of the land area of Tuvalu is occupied by coconut woodland and while copra production is its main commercial use the coconut palm has many additional uses (McLean and Hosking, 1991b).

Tuvalu's indigenous terrestrial fauna is equally poorly developed as its flora. There are no indigenous land mammals. Land vertebrates are not abundant and are restricted in species numbers, the main indigenous terrestrial fauna being birds, land crabs and insects. The bird life is made

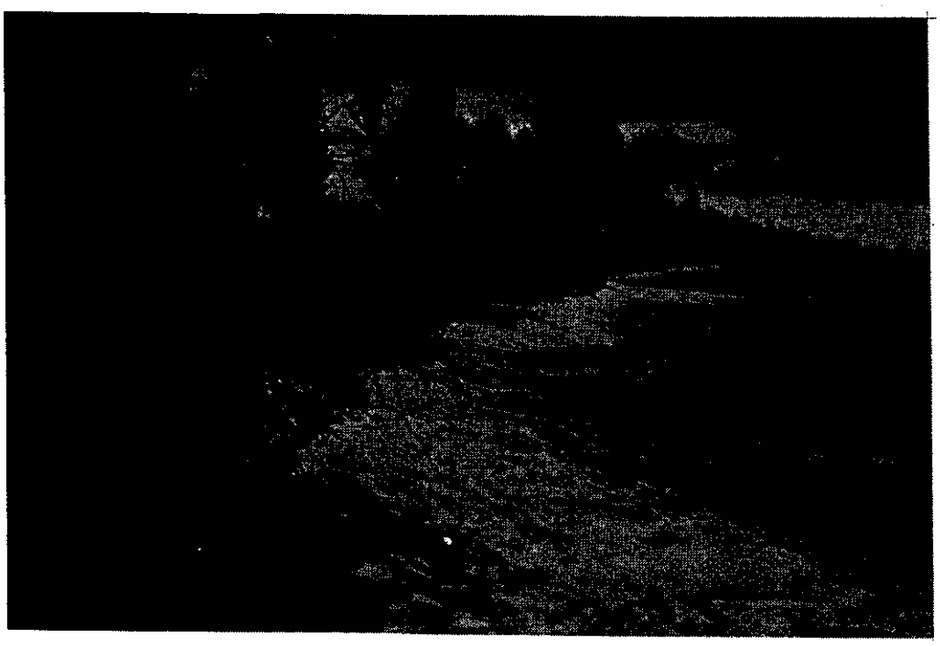

Plate 3.1 Wave action on the lagoon foreshore associated with high tides and moderate westerly winds at Fongafale.

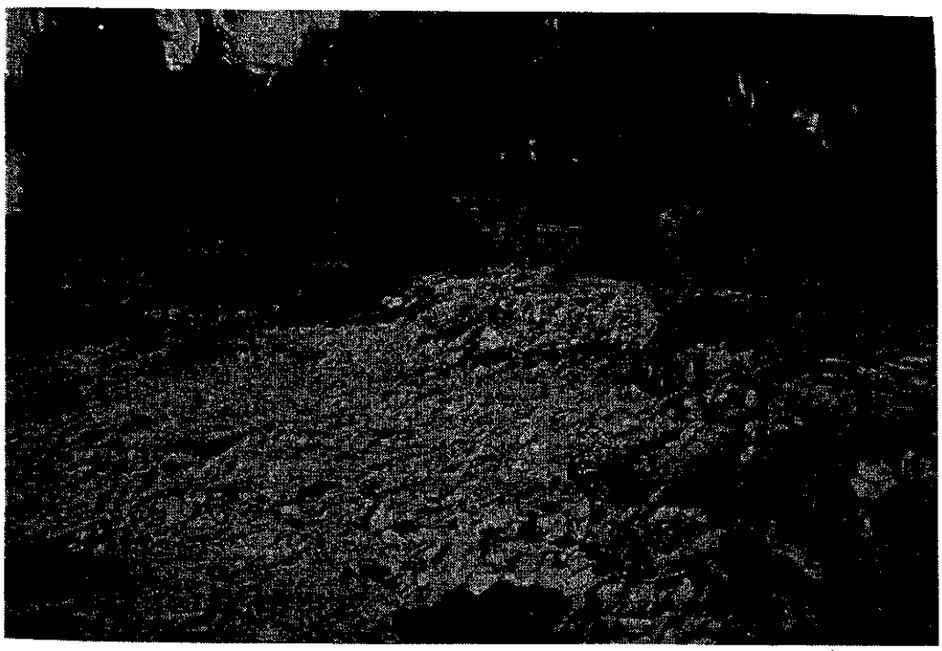

Plate 3.2 The effect of wave action associated with recent strong westerly winds and high tides - the undermining of coastal vegetation and the road on Fongafale.

up almost entirely of sea birds or migratory species - the 28 indigenous species reportedly present in Tuvalu belong to only 10 families. Insects dominate the terrestrial fauna but the diversity is still poor with only 22 species of butterflies, for example, compared with 12,000 in Australia. Tuvalu is relatively free of insect pests (Government of Tuvalu, 1992). Aphids attack pulaka on Funafuti, Vaitupu and Nui. Biological methods are being used for control.

2.2 Climatic and Oceanographic Setting

Tuvalu lies within the trade wind belt and its climate is characterized as tropical and marine. Descriptions of the climate processes and features of the Pacific region which affect Tuvalu's weather and climate have been provided by Mullan (1991), McGregor (1990), Zillman et al. (1989) and by Basher et al. (1990), among others, while Thompson (1987) has presented a detailed characterization of the nation's weather and climate.

The dominant atmospheric circulation features which influence Tuvalu's weather and climate are shown in Fig. 2.4. They are:

i) the semi-permanent anticyclone which is typically centred near 90 to 100°W on the eastern side of the Pacific Ocean. This feature results in the equatorial dry zone and its western extremity is associated with strong gradients in the annual average precipitation amounts within and adjacent to Tuvalu (Fig. 2.5).

ii) the easterly trade winds which are located on the northern side of the South Pacific anticyclone belt and whose strengths are influenced by its intensity. They tend to be strongest from about May to October when pressures in the anticyclone are highest. Flow within the trade wind belt is generally divergent and the associated subsidence creates a strong temperature inversion between around 1.2 and 2.5 km (Mullan, 1991) inhibiting convective cloud development and related heavy precipitation. However, in the Tuvalu region, and the western extremity of the trade wind belt in general, subsidence rates and hence the intensity of the trade wind inversion are much reduced and heavy showers are more frequent.

iii) the Monsoon Trough and Inter-Tropical Convergence Zone (ITCZ) influence Tuvalu in the southern hemisphere summer when these and other circulation features are best developed or in their southernmost positions. The ITCZ is the area of convergence and associated cloud and heavy precipitation which lies between the North Pacific northeast and South Pacific southeast trade winds. In summer the western Pacific arm of the ITCZ is enhanced by and coincident with the Monsoon Trough, an area of low pressure from northern Australia towards the Solomon Islands. On the northern side of this trough the northeast trade winds acquire a large westerly component once they cross the equator and the Southern Hemisphere Coriolis effect dominates. These monsoon westerlies can be squally

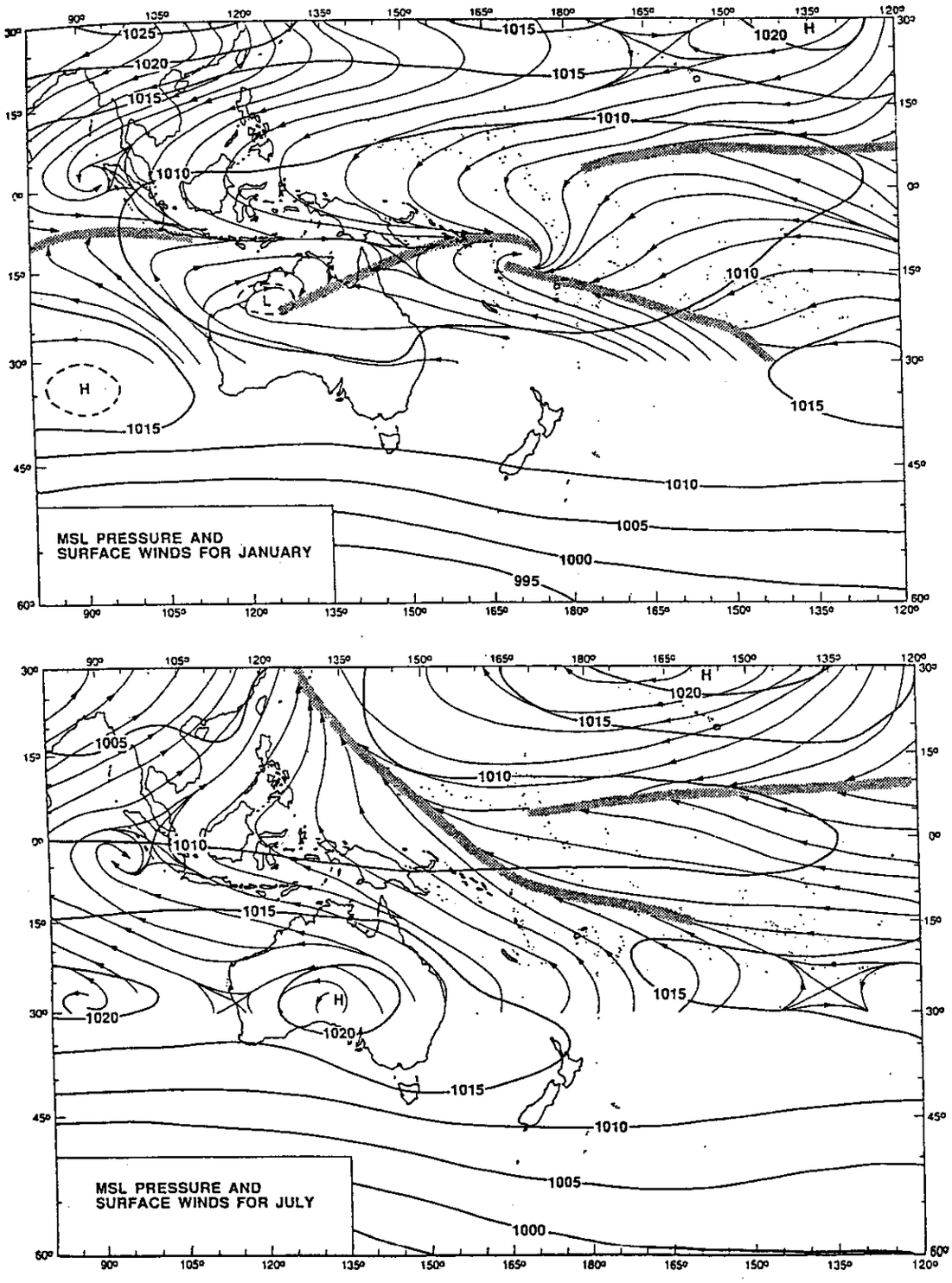

Fig. 2.4 Average patterns of mean sea level pressure (hpa) and surface winds for January (top) and July (bottom) (from Zillman et al., 1989)

to increased pschological stress resulting from anxiety and other factors. The reported appearance of melanoma in the indigenous population of Tuvalu raises the question whether this is related to improved diagnostic and reporting procedures, to environmental factors such as ozone depletion or to other as yet unrecognised causes. Issues related to food and water availability will be discussed in subsequent sections.

3.4.2 Island Land Mass

It is generally believed that the two most significant physical affects of sea level rise and climate change on low coral islands will be erosion of the coastline and inundation of low-lying areas, by either seawater from wave action or by fresh (brackish) water from a rising water lens.

The exact impact on a coral island will depend on other factors besides just island size and elevation. These include island shape, wind exposure, length of shoreline, composition and vegetation cover as well as the nature (size, depth and sediment content) of the adjacent reef and lagoon. The wide variation in these features for the islands of Tuvalu will mean that different islands will be affected differently by sea level rise. Although exact predictions cannot be made at this point some general points can be presented. Further study should be undertaken using the methodology described in IPCC (1991c).

The main physical characteristics of the nine islands of Tuvalu have been described in detail in Section 2.1. Reef top area tends to be much smaller for table reefs islands. This will tend to make them more vulnerable to land loss as sea level rises. The wider the reef area the greater the potential for sediment production. In addition wider ocean side reef flats can dissipate more wave energy before it reaches the island. Sand flats on the lagoon can serve the same purpose. A shallow lagoon will also generate smaller waves. Islands with more coastline per area will be more susceptible to erosion. Coastlines of hardened beachrock will be less susceptible.

Loss of land is a clear problem to a country whose total land area is 24 square kilometres. Increased sea levels and increased storminess which lead to increased wave heights are likely to cause increased erosion. Our visit coincided with an unusually high tide and stormy westerlies. Lagoon waves breaking over the road in the north part of Funafuti and undermining coconut palms illustrated this threat (Plates 3.1 and 3.2). Roads and other structures are highly vulnerable on the low and narrow motu (Plate 3.3).

Hurricanes can either add to island size by depositing lagoon or ocean sediment onto the land or decrease it by washing land away. A 19 km long bank of boulders up to 4 m high was deposited on the ocean side of Funafuti by Hurricane Bebe in 1972, increasing the island size by about 20% (Baines and McLean, 1976). There is also evidence of an earlier bank deposited by a nineteenth century hurricane. Were a hurricane to occur before sediment

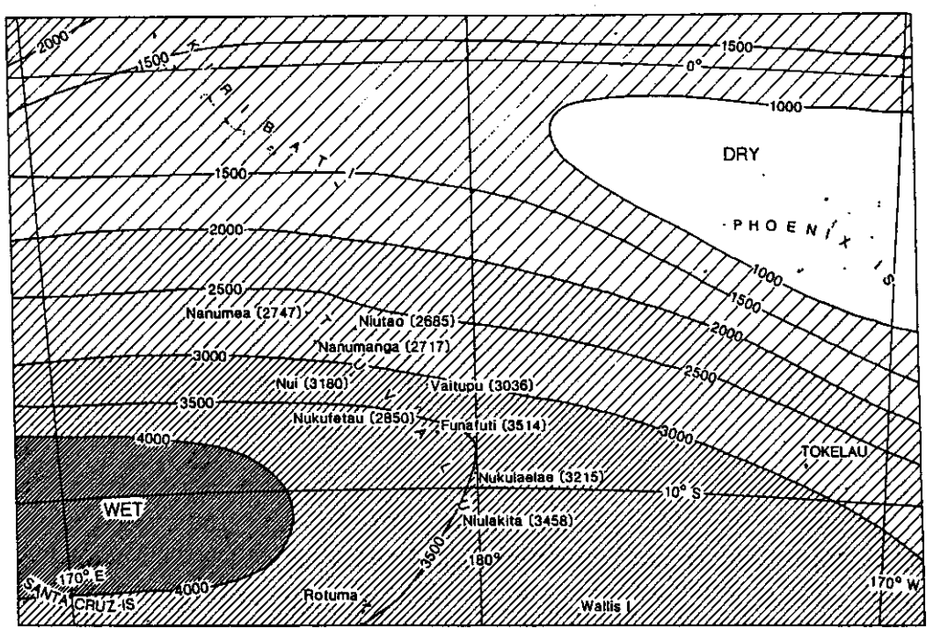

Fig. 2.5 Mean annual rainfall (mm) for Tuvalu and adjacent oceans, 1951-1980 (from Thompson, 1987).

with strong winds and heavy rain.

iv) the South Pacific Convergence Zone (SPCZ) is an important circulation feature of the region extending in mid-year from just north of Tuvalu to Samoa and thence to the Southern Cook Islands. The SPCZ is an area of convergence located between the lower latitude easterly trade winds and the higher latitude trades which in the western Pacific have a more southerly component. In summer it is more active with its western extremity between Fiji and Samoa linking to the eastern extension of the Monsoon Trough with its westerlies on the northern flank. Convective activity, winds and rain within the zone exhibit large day to day variability with the passage of synoptic disturbances.

v) tropical cyclones are low pressure synoptic systems with wind speeds of at least 34 kts (18 m s^{-1}). They form over warm oceans (temperatures above approximately 28°C) and at least 5 degrees from the equator. Divergent upper level flow is required and hence most southwest Pacific cyclones form in the Monsoon Trough, on the equatorial flank of the SPCZ or, more rarely, in the easterlies (Mullan, 1991). On average about nine tropical cyclones per year occur in the Southwest Pacific, developing in the wet season

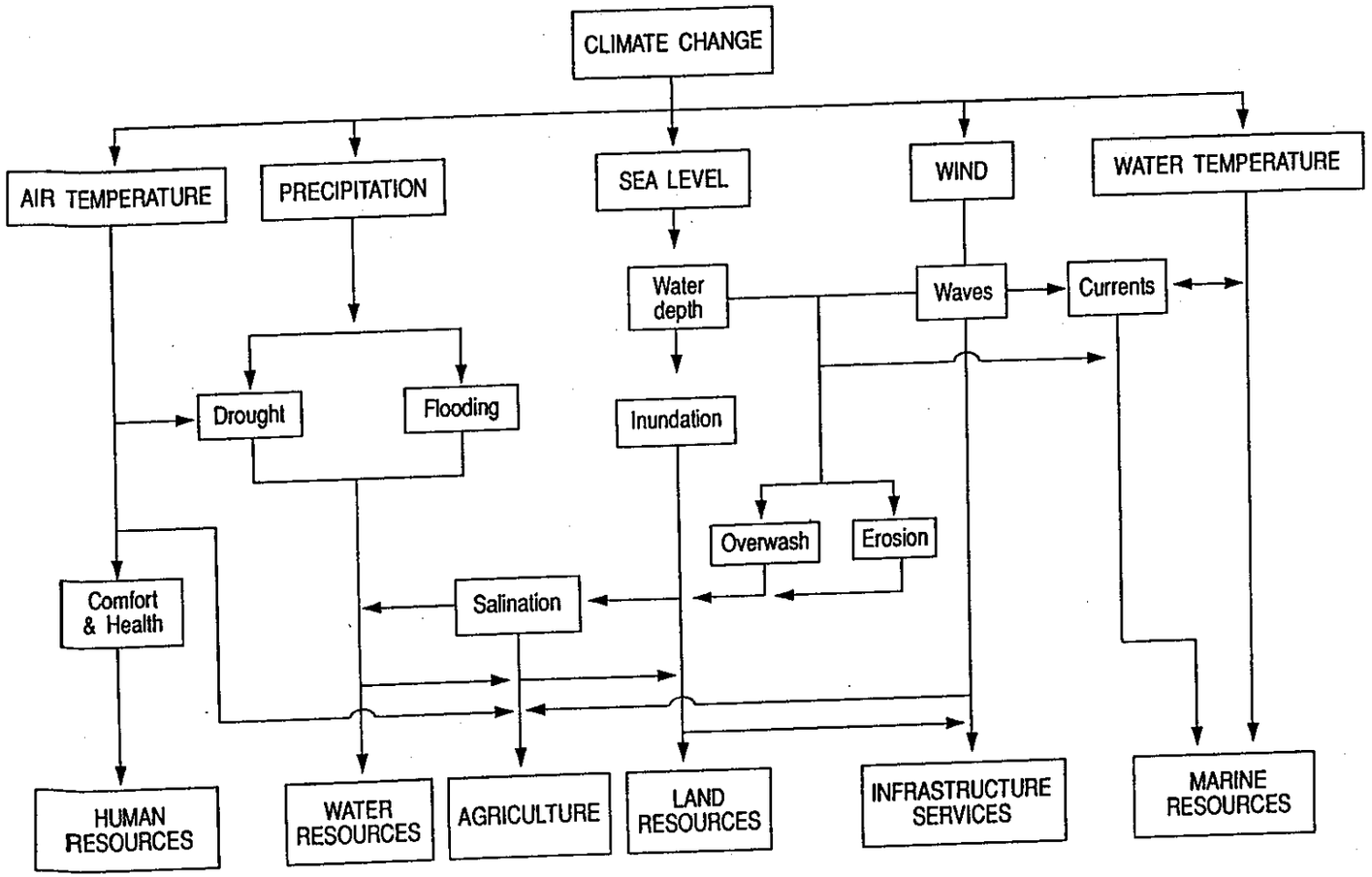

Fig. 3.6 Generalised effects of selected changes in the climate system on the environment and resources of Tuvalu.

Tuvalu and Fiji. Such disturbances may develop into hurricane force storms (wind speeds over 63 kts). From January through March this is especially aided by the warmer ocean surface temperatures. In association with the migration of the SPCZ there is a tendency for cyclones to form furtherest north in the early part of the cyclone season and further south in the latter half (Revell, 1981).

In addition to the seasonal migrations and intensifications indicated above the atmospheric circulation of the South Pacific also exhibits large month to month and interannual variability. The consequences are most clearly evident in the rainfall records (Seelye, 1950), but all climatological time series for the region exhibit this characteristic. As Mullan (1991) notes, two distinct modes of variability have been recognised: the El Nino/Southern Oscillation (ENSO) on interannual time scales and the 30 to 60 day oscillation on the monthly time scale.

The Southern Oscillation (SO) is a see-saw of atmospheric mass between the eastern tropical Pacific and the Indonesian region. The time scale of the oscillation varies between about two and seven years and extreme pressure swings may persist for up to a year. The centres of action are linked by the zonal (east-west) Walker circulation which intensifies when sea surface temperatures in the Indonesian (eastern equatorial Pacific) region are above (below) average and air pressures are below (above) the long-term mean. This represents the positive phase (as defined by the SO index: Tahiti minus Darwin air pressures) of the SO (Fig. 2.6). The name

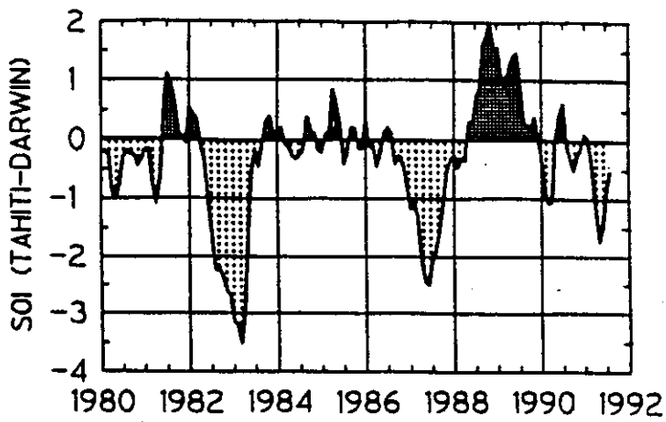

Fig. 2.6 Three-month running mean Southern Oscillation Index to August, 1991 (from Mullan, 1991)

3.4 LIKELY IMPACTS OF CLIMATE CHANGE ON TUVALU

The global framework for the changes in climate expected in the next century have been outlined in Section 3.2. For some parameters (temperature, sea level, storminess) the direction of change is accepted and only the magnitude is in doubt. For others (e.g. wind, rainfall) the overall directions of change, especially at a seasonal level, are uncertain at this point for any small region of the Pacific. This situation may improve as general circulation models become more refined. In this section the impacts of global warming and other associated climate changes and sea level rise will be discussed. A framework for reviewing possible impacts on the Tuvalu environment and resources (Figure 3.6) demonstrates the widespread effects of changes in air and water temperature, precipitation, wind and sea level.

3.4.1 Human Comfort, Productivity and Health

The Tuvalu climate is warm and humid with little seasonal variation. Increases in both of these parameters will heighten human discomfort and heat stress. This will presumably decrease worker productivity, especially for those working outdoors. A possible coping response would be to shift working hours away from the hottest midday hours. For the benefit of indoor workers, and in order to avoid, where possible, expensive and energy-consuming air conditioning it will be desirable to design buildings with maximum natural ventilation.

Human health is likely to be adversely affected by added heat stress. Higher water tables are also likely to cause a deterioration in health. For example, longer periods of standing water could lead to an increase in mosquitoes which in Tuvalu are vectors of dengue fever and elephantitis. The degree of contamination of surface, ground and lagoon water by human and domestic waste will also increase as the water table rises. Higher temperatures would also lead to more rapid deterioration of foods, medicines, chemicals etc.

Many of the dispensaries and related facilities on the outer islands are housed in buildings which are highly vulnerable to hurricane force winds. This and possible damage to other structures such as radio transmission equipment would greatly impair the ability to arrange for and provide emergency care during adverse weather events. There is also the possibility that underground reticulated systems (power, telephones) will be adversely affected by a rising and salt-contaminated ground water.

Environmental conditions and the availability of food, fresh water will obviously affect human health. Examples include the influence of higher temperatures on the ability to store food in remote tropical locations and the implications of climate change in general for the healing of injuries and skin and other infections. Mental health services may also be affected due

El Nino is commonly applied to the negative phase which typically occurs in association with abnormally warm ocean currents off the coast of South America and above average ocean surface temperatures in the central and eastern Pacific and/or lower water temperatures in the western Pacific (with consequently reduced convective activity) and an overall weakening of the Walker circulation. The term ENSO merely reflects the strong reinforcement of the atmospheric pressure contrasts and hence the strength of the Walker circulation by contrasting ocean temperature anomalies in the Pacific basin.

A large number of atmospheric and oceanic changes are associated with the ENSO events. For Tuvalu and the neighbouring ocean areas a negative SO index or El Nino event commonly means weaker trade winds at the surface and westerlies aloft, enhanced westerlies at the surface (Thompson, 1987), movement of the SPCZ northeastward of its climatological mean position to be closer to or over Tuvalu, increased seasonal and annual rainfall (Thompson, 1987), decreasing sea levels over a year or so (Fig. 2.7), a weakening of the easterly ocean current and an increase in the frequency of tropical cyclones (Fig. 2.8) (Revell and Goulter, 1986; Zillman et al., 1989; Mullan, 1991; Thompson, 1987; Nunn, 1990).

The 30 to 60 day oscillation (Mullan, 1991; Zillman et al., 1989) plays a major role in influencing the intensity of individual convective systems in the equatorial Pacific, and particularly its western half. The effect is associated with a series of eastward moving waves first appearing in the western Indian Ocean and propagating into the central Pacific. Zillman et al. (1989) note the links between this oscillation and ENSO - during El Nino years the waves are more clearly developed east of the Date Line but less so in the Indonesian region, but when the Walker Circulation is strong the opposite is the case.

Thompson (1987) and McLean and Hosking (1991a) have provided a comprehensive assessment of other characteristics of Tuvalu's atmospheric and ocean regimes. Some of the main features they highlight are:

i) while winds over 22 kts occur between 2 and 4 percent of the time, gale force winds (those over 33 kts) are relatively rare. Most of the gales occur with west or northwest winds during the cyclone season (November to April).

ii) Tuvalu's southern islands receive on average close to 3500 mm per year decreasing to around 2700 mm in the northern islands. While all locations have high rainfall all year round there is a distinct wet season from November to April when about 60% of the rainfall is received.

iii) interannual rainfall variability is moderate but it increases towards the north of the country. High or low amounts of rainfall persisting for more than two months are not very common, though a positive SO index is associated with increased incidence of prolonged low

A phenomenon which appears to show a major recent increase in the Tuvalu region is the occurrence of tropical cyclones. Tropical depressions develop into cyclones (wind speeds greater than 34 knots) in areas of appropriately warm sea temperatures and wind circulation patterns. In the Southwest Pacific such conditions generally occur from November to April with the median point of origin being 14°S 170°E. This, however, moves northeast during times when the Southern Oscillation Index is negative (Revell and Goulter, 1986). Thompson (1987) has recorded tropical cyclones originating in the Tuvalu region from 5-11°S and 177°W to 175°E for the period 1940-1985 . Whereas only eleven were recorded from 1940 to 1970, thirteen were recorded from 1972 to 1985. Two more occurred in 1985 and 1987. From 1990 through January 1992 there have been five more (Funafuti Meteorological Office records). Admittedly better record keeping, communication and satellite photographs will bias the data to show more cyclones in recent times (Figure 3.5), but the trend to more tropical cyclones originating in the Tuvalu region seems clear. Although only two of these storms developed into hurricanes while in the Tuvalu regions, others still caused considerable damage from wind and high waves. The only other hurricane generally agreed to have occurred in historic time was in 1891. However, a recent analysis of journals of European settlers in Tuvalu (McLean and Munro, 1991) suggests three more hurricanes occurred in the 1880s. This implies that there may have been other periods of high cyclone activity in the past that have not heretofore been acknowledged.

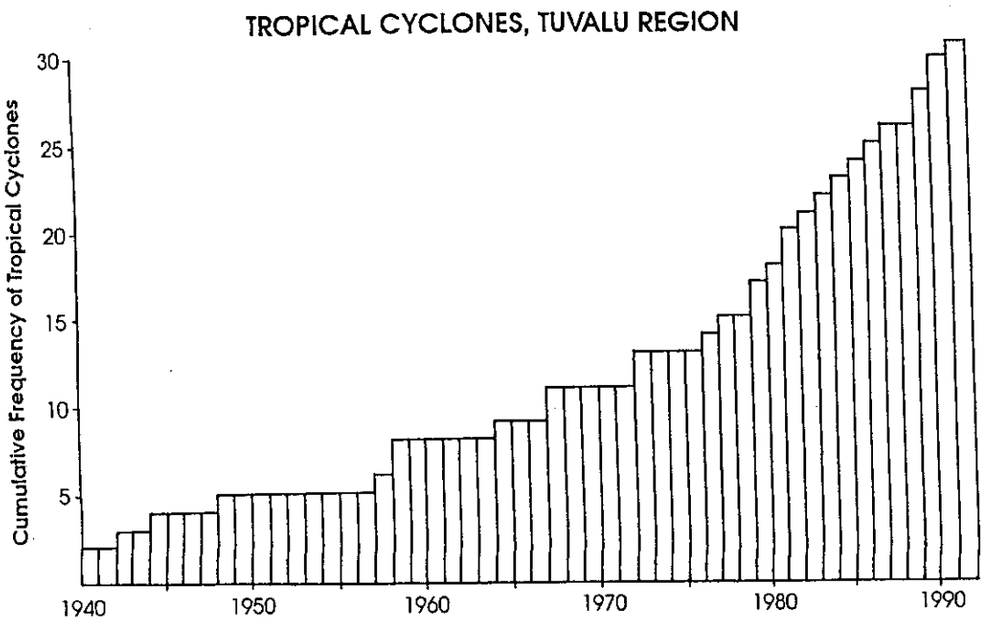

Fig. 3.5 Cumulative frequency of tropical cyclones in the Tuvalu region, January 1940 - January 1992 (data from Thompson, 1987 and files of the Tuvalu Meteorological Service).

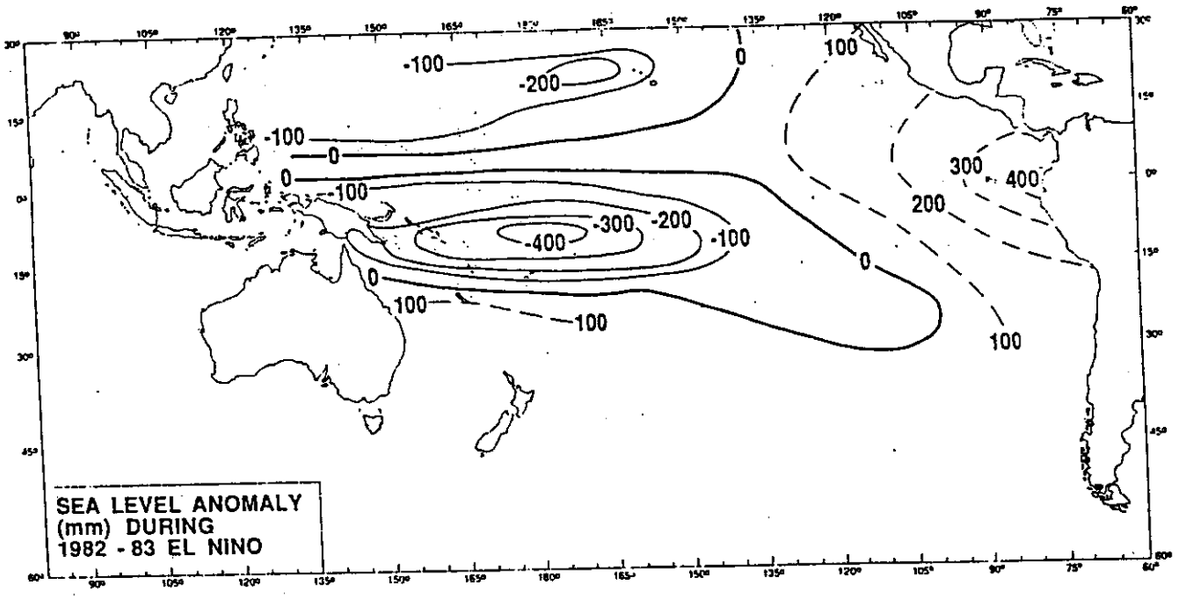

Fig. 2.7 The sea level anomaly pattern (mm) during the 1982-83 El Nino (from Zillman et al., 1989).

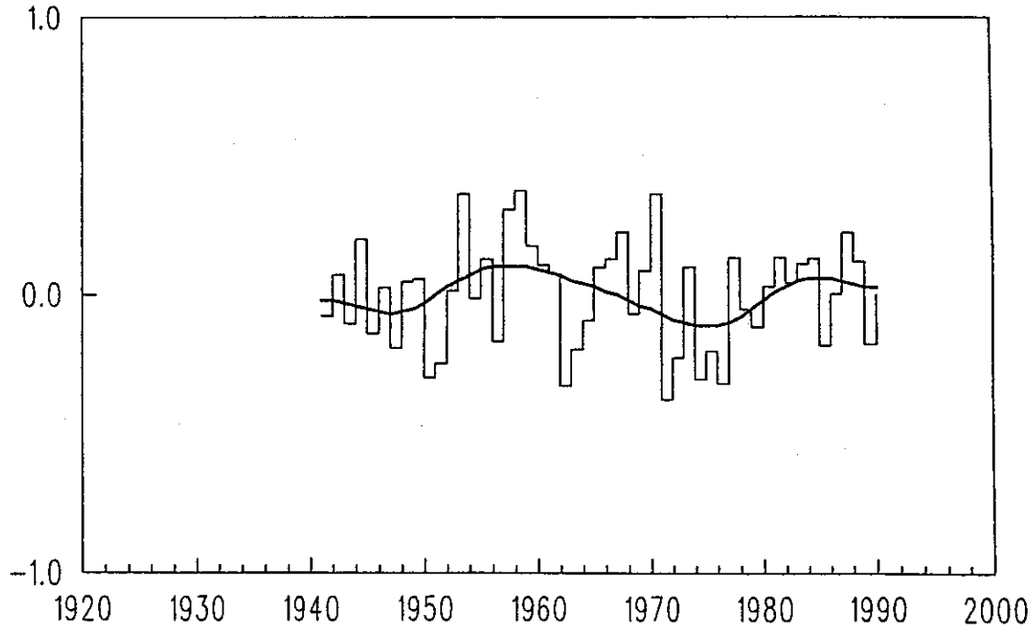

Fig. 3.3 Annual mean precipitation for Funafuti. Full scale represents 100% departure from normal. (diagram supplied by Dr. J. Salinger, N.Z. Meteorological Service).

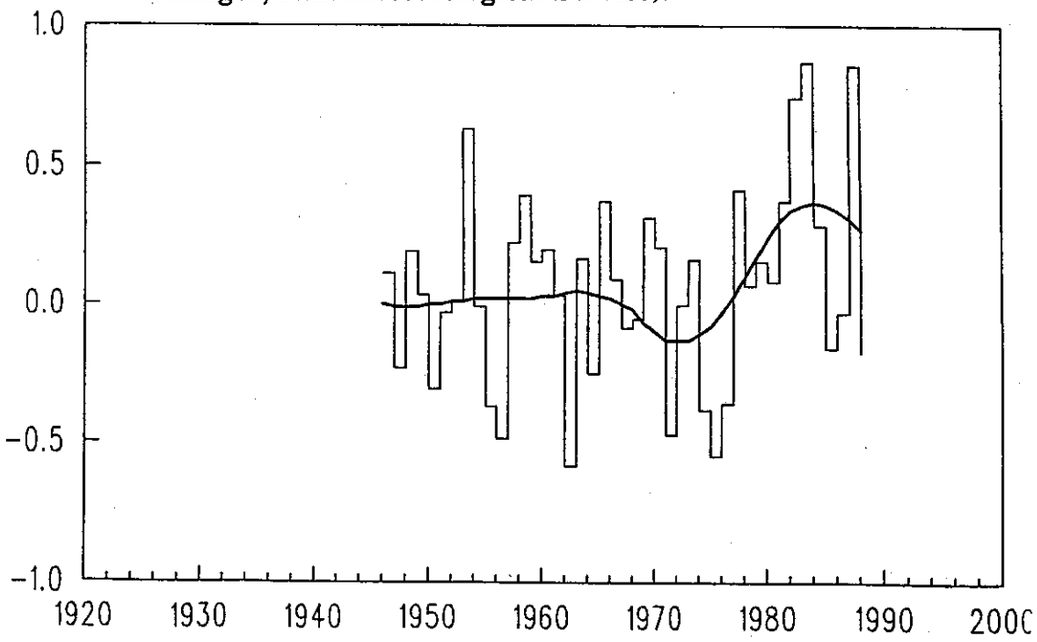

Fig. 3.4 Annual mean precipitation for Nanumea. Full scale represents 100% departure from normal. (diagram supplied by Dr. J. Salinger, N.Z. Meteorological Service).

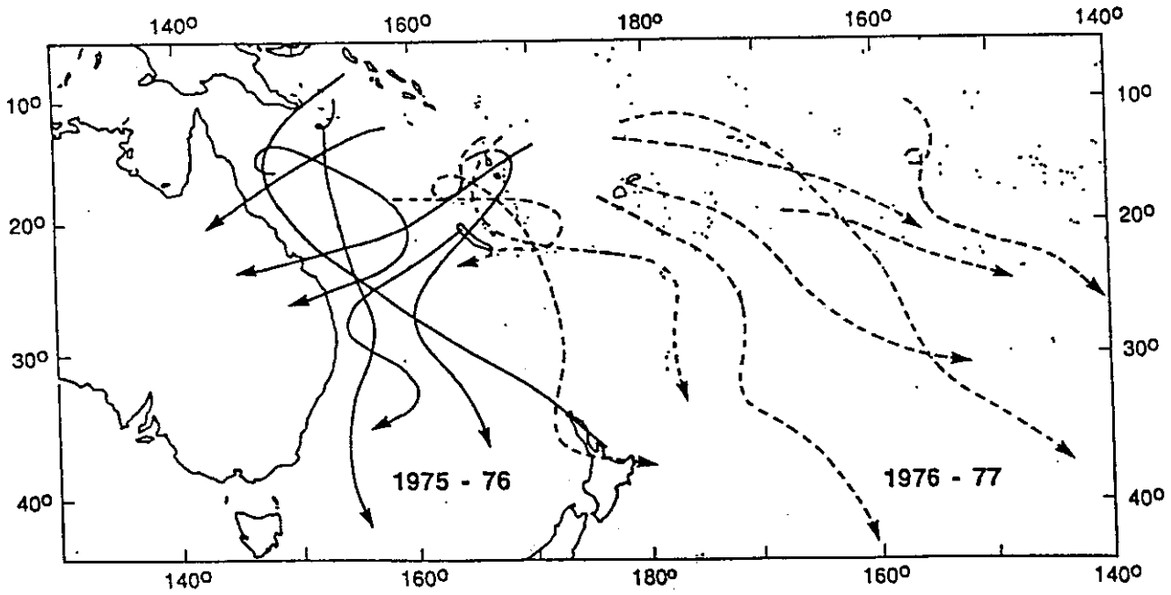

Fig. 2.8 Tropical cyclone tracks for 1975-76 (a non-El Nino year) and 1976-77 (an El Nino year) (from Zillman et al., 1989).

rainfall.

iv) short term high intensity rainfall is associated with thunderstorms while synoptic disturbances associated with tropical cyclones or the SPCZ bring heavy rainfall of longer durations. Once every 10 years at Funafuti a 24 h rainfall of 233 mm and a 72 h rainfall of 322 mm can be expected.

v) air temperatures are uniformly high all year round (mean 28°C)

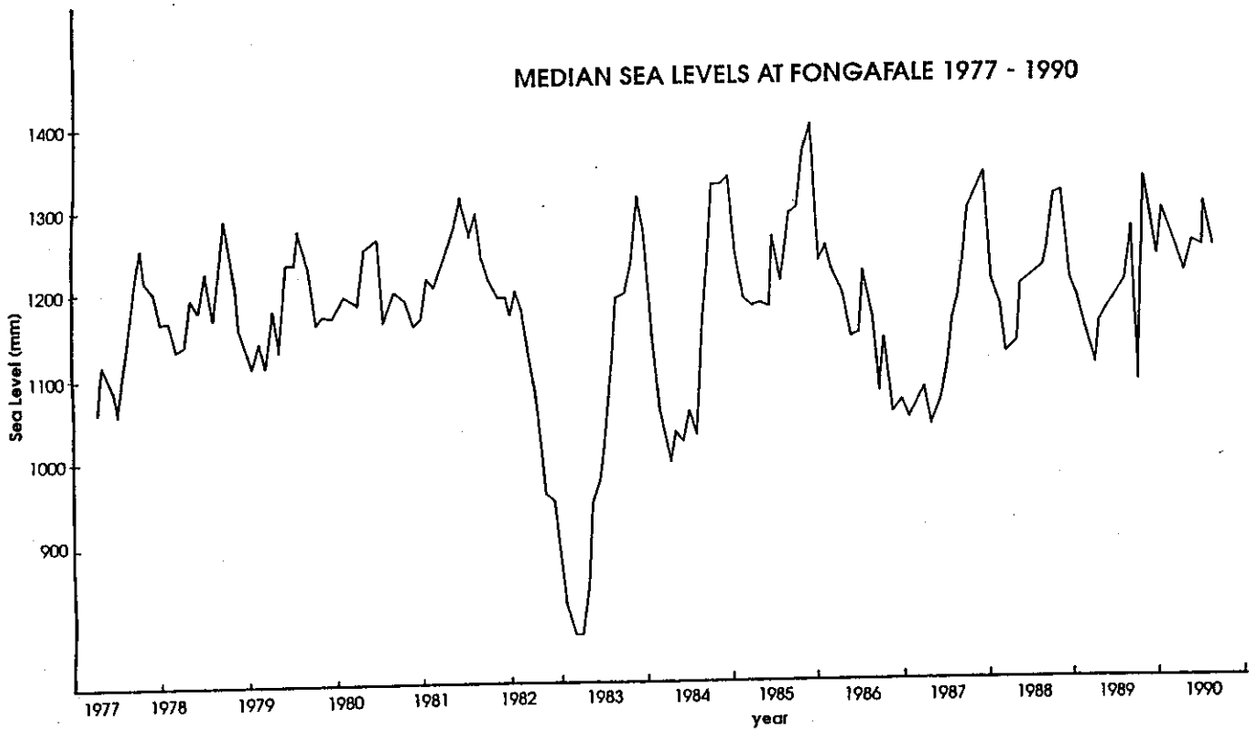

Fig. 3.2 Median sea levels at Fongafale, Funafuti between 1977 and 1990. Data supplied by TOGA Office, University of Hawaii.

though there is a comparatively large diurnal variation (mean maximum and minimum are 31°C and 25°C, respectively). Temperatures in excess of 34°C occur about once every two years (absolute maximum 36°C) while temperatures below 21°C occur once every three or four years in the south and once every 10 to 15 years in the north (absolute minimum 19°C).

vi) mean annual sea surface temperature is 29°C with a seasonal range of less than 0.5°C and little interannual variability. Nearly all reported waves and swells are under 3 m, with most having an easterly direction.

vii) according to Folland et al. (1984) sea surface temperatures in the South Pacific have risen by 0.5 to 1.0°C since 1912.

2.3 Land Use and Tenure

McLean and Hosking (1991b) report the results of an extensive land resource survey of Tuvalu. The main uses of land are for settlement (villages, buildings, facilities), for agricultural production including food crops for people and livestock, for copra production and for the provision of materials for construction, firewood, gardening and other activities. On the outer islands an average of 67% of the land area is occupied by coconut woodland. Many of the scrub, broadleaf tree and sub-canopy species within the coconut woodland are used for canoe construction and handicrafts, amongst other things. Together with ground creepers and ferns these plants have an important place in the production of food crops, particularly the use of leaves for compost and mulches for root crops, garden crops and coconuts. Given the previously described characteristics of the soil, the effects of high salt concentrations (in the ground water and at times aerially) and occurrences of drought partly brought on by high evaporation rates (averaging over 1700 mm per year), the suitability of land for relevant agricultural uses is limited to a few tree crops and field crops, most of which are already well established on the islands. A notable feature of the land use pattern on most islands is the spatial contrast in land use intensity and management which generally declines with increasing distance away from the villages and from the most frequently used roads and paths.

Pulaka (giant swamp taro, *Cyrtosperma chamissonis*) and taro (*Colocasia esculenta*) are the main food crops, these being cultivated along with several other crops and especially banana in pits excavated down to the "fresh" water table or in shallow basins. Fruits from trees such as breadfruit and pandanus are also important. Exotic vegetables are grown in house gardens on all islands. Sweet potato cultivation for home use and sale has recently expanded.

As McLean and Hosking (1991b) note, one of the most important influences on potential land use and agricultural development in Tuvalu is the system

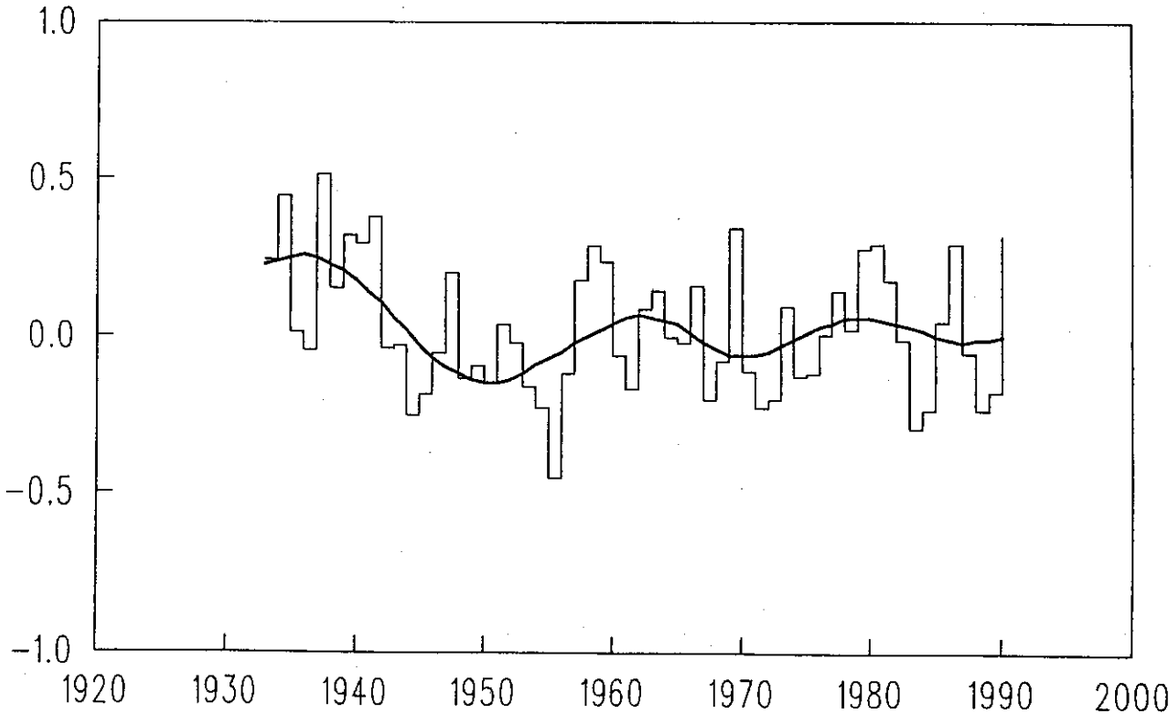

Fig. 3.1 Annual mean temperatures for Funafuti (°C) (diagram supplied by Dr. J. Salinger, N.Z. Meteorological Service).

eventuates, these large deviations in sea level would diminish. The magnitude of the peaks is approximately equivalent to the expected sea level rise in the next half-century. This would mean that the conditions which prevailed for a few months in 1982 would be similar to those that would occur regularly by the year 2040. The greatest potential danger would be the El Nino associated peaks superimposed on the consistently higher sea levels.

It is difficult to generalise about rainfall statistics for Tuvalu. Annual precipitation for the islands varies between 2700 and 3500 mm (Thompson, 1987) (Fig. 2.5). Average rainfall in Funafuti has not changed significantly in the last 50 years whereas the island of Nanumea to the North has experienced rainfall increases, especially in the last decade or so (Figures 3.3 and 3.4). Again a major feature of rainfall in Tuvalu is its large interannual variability. In Nanumea the monthly coefficient of variation for rainfall from 1951-1980 is about 60% (Thompson, 1987).

of land ownership. According to their analysis the key features are that most of the land is privately owned and it is subdivided on the basis of inheritance through which both males and females are entitled to benefit. Although this customary subdivision results in a large number of registered owners (over 2000) and land plots (over 13,000) for the 24.37 km^2 of land area (giving an average number of plots per owner of 8.5 and average area of plots of 0.22 ha), land use is generally undertaken on a shared or family group basis. Originally the subdivisions ran laterally across the islands from ocean to lagoon, thus giving each plot a cross section of the conditions on an atoll. However, as these lateral plots become increasingly narrow there is a tendency to divide the land longitudinally down an atoll motu (Fig 2.9). The result is that now some plots are composed entirely of poor soils and others of better quality land.

2.4 Settlement History and Cultural and Traditional Sites

No archaeological record of the first permanent settlement of any of Tuvalu's islands exists. Oral tradition from the northernmost island of Nanumea, generally accepted to be the first island settled, goes back 26 generations from 1974. At 25 years per generation this would place initial settlement from Samoa 650 years ago (Chambers, 1975). Known earliest settlement data for Fiji, Tonga and Samoa are about 3000 years B.P. and for the final major waves of migration that settled the Cook and Society Islands and New Zealand about 1000 B.P. (Nunn, 1990). Hence it is possible that settlement of Tuvalu occurred earlier than the oral record suggests.

Later history of Nanumea recalls the visit of a Tongan giant whose knees have left marked impressions on the shoreline. Such traditional sites as well as sacred sites exist on most islands of Tuvalu. More recent important sites are the landing place of missionaries on Nanumea atoll and the sites of the Royal Society coral drilling expeditions to Funafuti in 1896 and 1897. These were the first efforts to try and confirm Darwin's theory on the genesis of atoll islands (Rogers and Cantrell, 1991). The original drilling site is marked but the site is now substantially modified as it occurs in a borrow pit.

2.5 Socio-economic Information

2.5.1 Demography

Ethnically Tuvaluans are Polynesians, but there is some Micronesian influence due to the long and relatively close contact with Kiribati to the north. An estimated population of 2497 in 1876 has nearly quadrupled in just over 100 years since the provisional figures from the 1991 census indicate a population of 9069 for that year. Population expanded from 1876

a basis of our discussions in Tuvalu.

It is acknowledged by the IPCC that significant uncertainties exist in their predictions (± 0.15°C for their temperature predictions and ± 3 cm for sea level rise). Reasons for these uncertainties are noted in Section 1.1. In addition, it must be emphasised that these data are average global figures and may differ substantially in any given area. It is generally agreed that temperature change will be less near the equator.

This differential global warming is likely to cause changes in the general atmospheric circulation patterns as well as ocean current patterns. Some probable outcomes of relevance to Pacific countries are the weakening of trade winds, less pronounced El Nino episodes as well as a meridional shift in the position of wind belts. At present these interactions are not well enough understood to make specific predictions about change in rainfall or wind patterns in any particular area of the Pacific. Global rainfall is expected to increase as a warmer atmosphere will contain more moisture. It is also expected that storminess will increase, in particular the occurrence and intensity of hurricanes.

3.3 TUVALU DATA OF RELEVANCE TO CLIMATE CHANGE

A study of past events can often provide some indication of what to expect in the future. As the concentrations of greenhouse gases have been increasing for nearly two centuries, one would expect to see some evidence of climate change. Indeed the judgement of the IPCC (Houghton et al., 1990) is that in the last 100 years global mean surface air temperature has increased by 0.3 - 0.6°C and global sea level has increased by 10 - 20 cm. These increases are in the range of natural variability and cannot be taken as "proof" of global warming and sea level rise.

In Tuvalu climate records date back only to World War II. There is no discernible pattern in the annual mean temperature in Funafuti. The five-year average declined during approximately 1940-1950, 1960 -1970 and 1980-1990 and increased in the intervening periods. It now stands 0.2°C lower than it did in 1940 (Figure 3.1). Sea level data has only been collected systematically since 1975. Data from six mid-western Pacific monitoring stations show no significant increase in sea level since 1910 despite the global increase described above (McLean, 1989). A marked feature of these records is the large year to year variation. This is especially so in conjunction with El Nino events. As the higher sea level built up in the West Pacific by the easterly trade winds moved east across the Pacific in the 1982-83 El Nino, sea level in Tuvalu peaked around 10 cm above the datum level and then fell to 40 cm below datum (Fig. 3.2). In Tuvalu and other equatorial islands monthly averages may be 20 to 30 cm above normal (McLean, 1989). This large natural variability will delay detection of sea level rise for decades. In addition if the prediction of weaker El Nino events

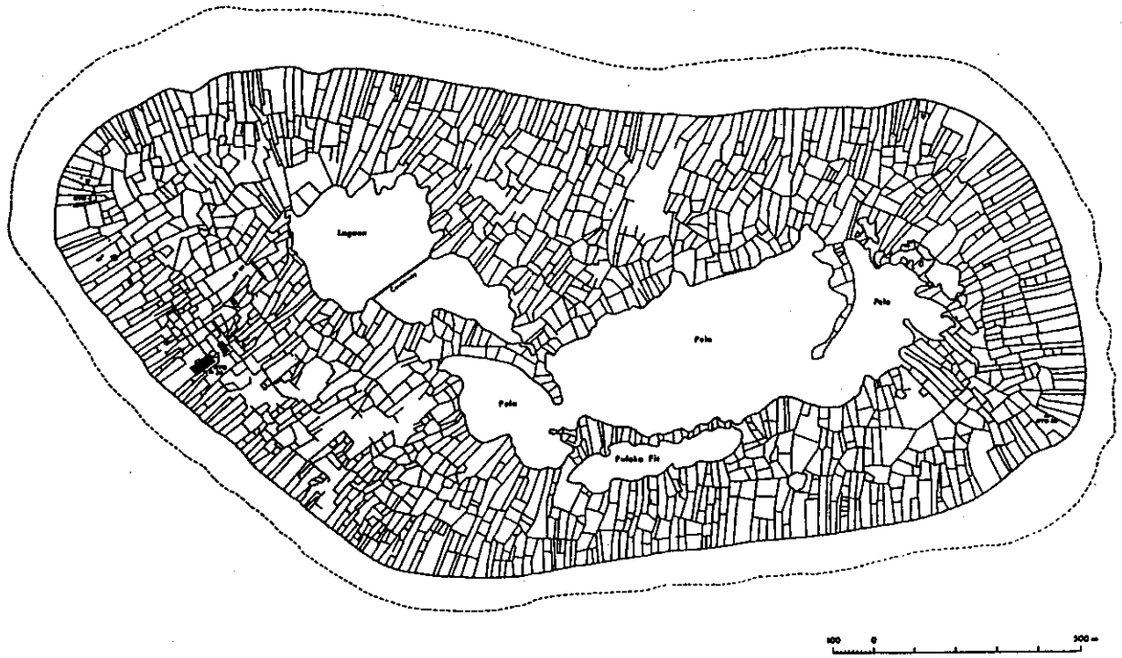

Fig. 2.9 Niutao land tenure boundaries, 1984 (from McLean and Hosking, 1991b).

3. GLOBAL CLIMATE CHANGE AND ITS SIGNIFICANCE FOR TUVALU

3.1 PREVIOUS WORK

There are hundreds and probably thousands of works that deal with some aspect of climate change, whether it be reasons for, results from or possible responses to climate change. Amongst the definitive global works are those of the International Panel of Climate Change (Houghton et al., 1990; IPCC, 1991a; IPCC, 1991b and IPCC, 1992). Other pertinent reports are Schiffer and Unninayar (1991) and Hengeveld (1991). At a regional level the Association of South Pacific Environmental Institutions (ASPEI) climate change working group has produced to date three major publications (Hulm, 1989; Pernetta and Hughes, 1990; Hughes and McGregor, 1990) that deal mainly with the expected effects of climate change in the South Pacific region. The New Zealand Meteorological Service (Basher, et al, 1990) and the Australian Bureau of Meteorology (Zillman et al., 1989) have recently reviewed the dynamic atmospheric circulation patterns for the South Pacific region. New Zealand's Ministry for External Relations and Trade (MERT, 1990) has prepared a statement on the implications of climate change for the South Pacific while Salinger (1991) has examined the instrumental record of temperature and precipitation for the South Pacific. Numerous papers relating to regional research on climate change are presented in a recent conference proceedings (Hay, 1991). Nation-specific reports for atoll countries have been commissioned by the Commonwealth Secretariat (Lewis, 1988 and McLean, 1989) for Tuvalu and Kiribati, respectively. A report on the Maldives was prepared by Pernetta and Sestini (1989). The first of the national ASPEI reports funded by the South Pacific Regional Environmental Programme was published in 1991 (Sullivan and Gibson, 1991). It dealt with Kiribati. Beside the present report, additional reports are being prepared for six other Pacific island nations.

3.2 PREDICTIONS FOR GLOBAL CLIMATE CHANGE

The Villach Conference on the Greenhouse Effect in 1985 predicted a rise of global temperature between 1.5° and 4.5°C and a sea level rise of between 20 and 140 cm in the following 50 years (UNEP, 1986). The uncertainty reflected in these ranges depended mainly on differing levels of reduction of greenhouse gas output. Based on these predictions the ASPEI team, in publications in the late 1980s, used a 1 m rise in sea level by the year 2050 as the basis for their studies (Pernetta and Hughes, 1989). Intensified research and international collaboration have led to a re-evaluation of these estimates. The International Panel on Climate Change predictions (Houghton et al., 1990), which have not changed in the 1992 update (IPCC, 1992), predict a global temperature rise of 0.3°C per decade (≈ 2°C by 2050) and a sea level rise of about 6 cm per decade (≈ 36 cm by 2050) over the next century. These globally averaged figures were used as

until the beginning of the 20th century, declined over the next decade and then grew over the remaining decades with dramatic increases following separation in 1975 and independence in 1978 when numerous Tuvaluan families returned from Kiribati where many been working in colonial administration or the Banaba phosphate mines. In the 1980s population growth rates have been below the natural growth rate indicating an emigration of Tuvaluans, to live, work (especially in the Nauru phosphate industry or as seamen) or study overseas. Due to the absence of a significant number of males as workers on foreign ships and in Nauru the male to female ratio in Tuvalu is estimated to be 46:54 (Government of Tuvalu, 1991b).

These national figures obscure several important demographic features. Considerable variation exists in total population numbers, growth rates and densities between islands. Table 2.2, based on provisional data for 1991, shows a very large and rapidly increasing population for Funafuti while many other islands have experienced population declines. For the nation as a whole population densities are high at 378 people per km^2, but in Funafuti it is now 1,454 per km^2. Historically Funafuti was one of the least populated islands and in 1973 it had less people than Nanumea, Niutao and Vaitupu. But with independence and the establishment of the seat of government on Funafuti the atoll experienced an explosive rate of population increase.

TABLE 2.2

POPULATION DISTRIBUTION, DENSITY AND GROWTH RATES BY ISLAND (1991)*

Island	Population		Density	Increase
	Number	% Total	per km^2	% from 1987
Funafuti	3837	42	1626	41
Vaitupu	1205	13	246	-16
Nukufetau	756	8	247	5
Nui	608	7	185	-2
Niutao	749	8	353	-14
Nanumaga	644	7	225	-10
Nanumea	825	9	231	-15
Niulakita	75	1	183	0
Nukulaelae	370	4	218	10
TOTAL	9069	100	372	7

* Based on provisional figures for 1991 cencus. The data do not include Tuvaluans working in overseas countries and also students studying overseas. To account for these it is estimated that approximately 1000 should be added to the population.

2.5.4 Employment

An estimated 50% of the total population of Tuvalu is between the ages of 15 and 54 years yielding a potential labour force of around 4500 people. In reality some 750 are employed in the public sector and another 600 in private business. Much of the remainding labour force are occupied in the subsistence sectors of fishing and agriculture or in homemaking. However, there are substantial numbers either unemployed or under-employed. Despite there being in recent years an expansion in public sector employment and opportunities in the private sector (e.g. work in domestic construction and fishing and in foreign fishing, an increasing number of school leavers has meant proportionately fewer have been unable to find paid work. However, there is a severe shortage of professional, managerial and technical skills in the work force. The requirement is frequently met by expatriate expertise.

2.5.2 The Economy

The economy of Tuvalu is characterized by its small size, limited and dispersed nature of land areas, small population, narrow and skewed economic base, extreme openness, limited or as yet unexplored natural resources and isolation from markets. The economy is at the subsistence stage of development with very limited land-based natural resources and most of the sea- based resources yet to be explored (Government of Tuvalu, 1991b). Capital investment activities of the Government have largely been funded using external aid. Cash activities are undertaken almost exclusively on the island of Funafuti, with small but developing activity on the largest island of Vaitupu.

Table 2.3 provides a breakdown of the national accounts of Tuvalu for 1990 (Government of Tuvalu, 1991b). The Gross Domestic Product at current market prices was $9.290 m. Some 10% of this was contributed by compensation to expatriate employees. When this is deducted the average per capita income of Tuvaluans was $917, with the majority of those living in the outer islands having an income substantially lower than this average would suggest. Table 2.3 also shows that the bulk of this income is related to government expenditures, agriculture being the major private sector economic activity, involving some 80% of the rural population (Government of Tuvalu, 1991b).

TABLE 2.3

NATIONAL ACCOUNTS FOR TUVALU*
(Source: Government of Tuvalu, 1991b)

Total Gross Domestic Product (GDP) of Tuvalu

	$Aus	%
Agriculture	1,096,100	12.4
Fisheries	556,900	6.3
Construction	1,529,300	17.3
Trade, Hotels and Restaurants	1,105,000	12.5
Real Estate and Housing	618,000	7.0
Government Services	3,067,480	34.7
Other	866,320	9.8
Total	8,840,000	100.0
GDP at Market Prices	9 290,000	
GDP - Expatriates' Comp.	8,290,000	
GDP Per Capita	917	

* GDP data based on preliminary estimates for 1990. Sector data for 1989.

is used to supplement this service, but during periods of adverse weather, maintenance or other adverse circumstances the outer islands are effectively cut off from each other, from the national capital and from the outer world. Due to poor load factors Funafuti receives infrequent international ocean cargo service, with only a Pacific Forum Line ship calling approximately monthly.

At present Funafuti is served three times weekly by Air Marshall Islands, flying from Majuro in the north to Nadi, Fiji in the south with a transit stop in Tarawa, Kiribati. Only day landing facilities exist at Funafuti, the airport being ungraded by international standards due to its unpaved nature and the lack of lighting and a perimeter fence. There is a proposal to upgrade the airport by paving and provision of new terminal facilities (see Section 4.2).

A satellite earth station installed in mid 1990 has greatly improved Tuvalu's links internationally. Within the outer islands communication is still by high frequency radio to each other and to Funafuti (see Section 3.4.7).

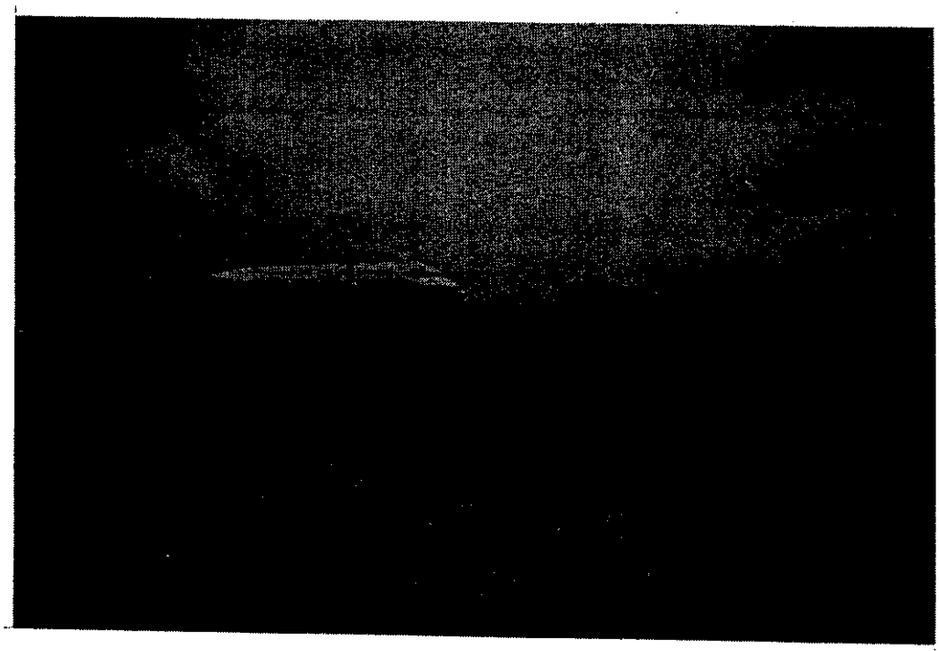

Plate 2.1 Air Marshall Islands turboprop aircraft, the only scheduled air service to Tuvalu, arriving on the grass and coral strip at Fongafale.

In addition to agriculture (see Section 2.3), fisheries form an important part of the economy of Tuvalu. In 1989 the seven boats in the Government fishing fleet based in Funafuti caught approximately 20,500 kg of fish, about half of which were captured by handline fishing on the shallow coral reefs. The remainder were caught by trolling (tuna and Wahoo) and handlining (snapper and grouper) in deep water beyond the reef slope (Patiale and Dalzell, 1990). Given the lack of agricultural land, Tuvaluans are reliant on locally caight fish for a major portion of their animal proptein needs. In addition to the Government fleet, private fishermen operate in the lagoon and beyond the reef. Patiale and Dalzell (1990) report that the private fishermen suppy about five times the fish to Funafuti as the Government vessels.

Tourism and commercial activities are growing contributors to the economy of Tuvalu (Table 2.3). However, they are heavily import based (affecting the balance of trade) and very dependent on rugular international air transport schedules. In 1990 there were 567 recorded visitor arrivals with a 95% occupancy rate for the sole hotel in Funafuti. This is currently being expanded and several privately owned guest houses and lodges have also been opened in recent years. Estimated visitor expenditure was $169,700 in 1989.

A number of small shops now operate in Funafuti,e specialising in the sale of local handicrafts. Many of the outer islands have small shops in Funafuti. A co-operative wholesale society imports bulk goods and sells to small businesses and to its bracnhes on each of the islands.

The economy of Tuvalu is strongly dependent on official development assistance. Principal donors to the development (capital) budget are the United Kingdom, Australia and New Zealand, together contributing over 75% to the expenditure which in 1990 was $5.2 m. Approximately two thirds of this sum was spent on the physical infrastructure, with social infrastructure and services receiving substantially less. Official development assistance for the recurrent budget take the form of contributions to the Tuvalu Trust Fund. This was established in 1987 with a capital base of $27.674 m. Earnings from the fund were expected to replace recurrent grant aid. In 1990 the fund earned $1.2 m (providing some 23% of total recurrent revenue) and had an estimated value of $34 m. The major domestic revenue sources are fisheries licences (annual average revenue of 17%), import duties and sales tax (17%), marine activities (13%) and income and company taxes (11%), but all these fluctuate from year to year.

The Government has attempted to limit expenditure in order balance income and expenditures. The result has been that between 1986 and 1990 revenue grew by 38% to $5.3 m while expenditure increased by 38% to $5.6 m. Despite these efforts the current account has been in persistent deficit.

Tuvalu does not have a minimum wage policy. The absence of unions has kept wage increases low and existing wage levels are running some 60% behind inflation. Prices are almost entirely import driven, with the consumer price index for 1990 at 147 (1983 base = 100) with an annual average rate of change of 3.8% in 1990 (Government of Tuvalu, 1991b). While there are no current estimates of the full balance of payments, trade statistics show a large gap between imports and exports, representing some 60% of GDP. In 1989 exports were valued at $11,600 while imports were $5.2 m. The discrepancy is a result of the poor performance of copra and philatelic sales and a strong demand for imported consumer items, raw materials and capital goods.

2.5.3 Health, Services and Infrastructure

Three tiers of education are available in Tuvalu - primary, secondary and limited tertiary, via the Tuvalu Maritime School and the Tuvalu Extension Centre of the University of the South Pacific. Primary schools exist on each island and education is compulsory at that level. There is an estimated literacy rate of 85% (Government of Tuvalu, 1991b). Approximate 300 students receive secondary schooling at Motufoua on Vaitupu Atoll while a further 100 students, approximately, receive secondary education overseas through either private or aid assisted funding.

The population of Tuvalu is generally fairly healthy by developing country standards (Government of Tuvalu, 1991b), but recurring public health problems include acute respiratory infections, diarrhoeal diseases, filariasis, conjuctivitis, fish poisoning, diabetes, rheumatism and hypertension. Many of these are related to the increased dependence on imported tinned meats, white rice and wheat-based starches. Nevertheless, there is no evidence of malnutrition due to normally good supplies of local starches which are high in fibre and of fish. There is a shortage of fresh fruits and vegetables despite many householders producing limited quantities from domestic gardens.

There is no access to potable water - all water must be boiled prior to drinking. Something less than 60% of the households have general access to water but this is increasing as a result of UNDP programmes. A serious outbreak of cholera occurred in 1990 associated with poor hygiene and solid and liquid waste managment practices.

Tuvalu has only one 30 bed general hospital. This is equipped with basic laboratory, xray, dental and surgical facilities. Each atoll has a clinic, with each served by one or two registered nurses, a maternal and child health aide and a sanitation aide. There is also a school dental programme.

After cessation of a domestic seaplane service in 1983, for economic reasons, Tuvalu is reliant on its own vessel (the Nivaga II) for domestic transportation between the islands. The fisheries research vessel (Manaui)

developments and for proposed changes to ongoing activities, but such assessments should be undertaken so as to not delay unduly appropriate development.

G. Tuvalu should decrease its reliance on expertise and advice from overseas consultants. There is an urgent need to develop and retain environmental knowledge and related practical experience within the country, on a continuing basis. Experience and familiarity are as essential to effective environmental management as is detailed scientific expertise. It is acknowledged that, in order to implement the recommendations presented in Section 5.2, it may be necessary to obtain short-term assistance beyond that available from regional organizations. However, the use of such additional assistance should be minimized and every effort made to develop and use local expertise. The need for and timing of such short-term expert missions should be determined by the Tuvalu government, in association with SPREP.

H. SPREP should ensure that it has the necessary expertise for providing independent advice on environmental management issues and impact assessment rather than continuing to rely on professional consultants who often have vested interests related to targeted aid and other considerations.

I. The monitoring of impacts subsequent to project implementation is just as important as monitoring prior to a project (i.e. baseline monitoring) in the context of a pre-project environmental impact assessment.

5.1.2 GENERAL RECOMMENDATIONS RELATED TO ENVIRONMENTAL ISSUES

The following recommendations should, wherever possible, be implemented by the existing and proposed government personnel. In many cases implementation will also require specific regional cooperation involving such agencies as SOPAC, USP, SPREP, FFA and SPC. It is essential that the Government of Tuvalu ensures that, where appropriate, its environmental projects are included in relevant regional work programmes.

1. As a priority approach, emphasis should be placed on development of indigenous knowledge and skills through appropriate training and education, in collaboration with regional organizations. In particular, and with regard to climate change and sea level rise, we recommend that the people of Tuvalu
   - be kept well informed about the issue and its implications for them
   - be advised as to actions they can take and the options they have

- be informed as to the plans the Government has to address the issue (e.g. contingency planning)

2. Assessment of the current environmental monitoring programmes being undertaken in Tuvalu and relevant programmes in adjacent areas.

3. Mapping of heights of islands above mean sea level and determination of vulnerability of given locations and the islands as a whole to sea level rise. An appropriate methodology for the task is described in IPCC (1991c).

4. Assessment of positive and negative effects of methods of shoreline protection, of artificial structures on or near the shoreline, of land reclamation and of other activities such as reef channel blasting. Obtain state of the art advice from SPREP including assessment of the benefits from planting vegetation to reduce coastal erosion rates.

5. Assessment of the environmental impacts arising from the acquisition and use of various forms of construction materials from different sources and locations, especially insofar as such activities affect vulnerability to climate change and sea level rise.

6. Assessment of the adequacy of domestic, community and commercial water supplies in view of climate change and anticipated socio-economic changes (e.g. increased population density, increased size of households, increased use of domestic appliances, increased tourism).

7. Collaborate in existing and new regional studies to enhance salt tolerance and increase yields of traditional and common exotic crops and in general make them more tolerant to the present and probable future environmental conditions (e.g. higher salt concentrations, higher groundwater table).

8. Strengthen current efforts to compile fish stock and catch records to assess and help achieve sustainable management of fish resources under changing environmental and resource use conditions. Development of methods to ensure reliable sources of sea food for local consumption(e.g. mariculture).

9. Undertake a comprehensive waste management study with due regard being given to the implications of CC/SLR (e.g. rising groundwater table and its effect on sanitation systems). The study should also include options for land reclamation (e.g. tidal land, borrow pits) using solid waste.

10. Ensure that the current and any future assessments of

transportation and communication systems give due regard to the increased requirements and standards due to CC/SLR (e.g. increased potential for damaging tropical cyclones). The sectors to be involved include:

i) interisland shipping and aircraft operations
ii) international shipping operations
iii) interisland radio and telecommunications
iv) international radio and telecommunications

11. Ensure that Tuvalu builds on the success of its current renewable energy projects and hence enhance its existing international image as a nation deeply concerned about global environmental issues. This could be achieved, in part, by further development of solar energy systems and by increased energy conservation.

12. Recognise that the majority of environmental problems ultimately arise from growth and migration of population, from efforts to achieve an improved quality of life and from a failure to achieve the sustainable use of resources. These considerations imply the need for improved population management, including:

i) additional efforts regarding family planning programmes
ii) matching island populations with island resources

Any developments that have the potential to bring about significant increases in population should, if possible, be established outside Funafuti.

13. Investigate in a formal manner, through questionnaires and other means, the attitudes of the people of Tuvalu towards relocation both within Tuvalu and to other countries, as a consequence of climate change and sea level rise.

14. Develop a national strategy related to climate change and sea level rise.

5.1.3 RECOMMENDATIONS RELATED TO SPECIFIC NEEDS OR ISSUES

We recommend the following:

1. That the previously identified need to increase the ability of the Tuvalu Meteorological Service to process, archive and interpret climate data (Brook et al., 1992) be addressed as a matter of urgency. This will require appropriate training and the provision of equipment.

2. That the Climate Change Officer be responsible for implementing a project leading to the collection and interpretation of anecdotal (e.g. recollections of elderly residents) data from the outer islands and for

encouraged in the Marine Training School curriculum and in the community based adult education programmes.

7. Increase access to information on climate change and sea level rise through the use of such media as posters, illustrated booklets and, most effectively, video cassettes.

8. Additional effort be placed on the boat and canoe survey to ensure that it provides useful data related to fishing effort and catch.

9. An information management system should be established to ensure that the results of environmental monitoring, technical studies and impact assessments are made available to relevant individuals and groups both within and outside government.

5.2 IMPLEMENTATION

5.2.1 PERSONNEL REQUIREMENTS

Consistent with our belief that emphasis should be placed on the development of indigenous expertise we have stressed the need to minimise the use of external experts and focus on the education, training and development of local expertise. The existing positions of Environment Officer and Climate Change Officer provide a foundation on top of which can be added the proposed Environmental Monitoring Officer and the Ministry representatives on TEAG (see Section 5.1.1).

SPREP should be requested to advise on and fund the position of Environmental Monitoring Officer and ensure that appropriate training of the new appointee is provided.

Where external technical expertise is required this should be acquired through collaboration with such regional agencies such as SPREP and SOPAC. These organisations should help ensure that the terms of reference, personnel and the outputs (e.g findings and recommendations) have been developed in light of the long-term interests of Tuvalu rather than of third parties such as aid donors and service providers.

5.2.2 TRAINING REQUIREMENTS

Both existing and newly appointed personnel will require immediate and ongoing training in order to develop and maintain relevant indigenous expertise and reduce the reliance on external consultants.

Environmental Officer

The Officer will require expertise in many areas including environmental

monitoring, impact assessment, management strategies and education. Provision must be made for such training, both locally and overseas.

Climate Change Officer

The Officer will require expertise in many areas but notably in the acquisition, processing, archiving and interpretation of climatic and related data and in environmental impact assessment. A knowledge of environmental education curricula and methods would also be advantageous. Appropriate training will be required, both locally and overseas.

Environmental Monitoring Officer

The officer will require technical expertise in many areas including physical, chemical and biological monitoring, the analysis and interpretation of such data and its role in environmental impact assessment. Such training can be undertaken locally, often as part of international scientific programmes operating in Tuvalu, but some overseas training will be essential.

Members of TEAG

Members of this group should receive early and general training in environmental impact assessment procedures - a workshop for Tuvalu is in the final planning stage and is opportune. Further training in environmental planning and management will be needed at an early date.

The Ministry representatives on TEAG would be expected to in turn influence the methods and environmental values/standards of their ministerial colleagues through discussion and other informal procedures.

Members of NDSC

Members of this group should receive early and targeted training in environmental impact assessment procedures - a workshop for Tuvalu is in the final planning stage and is opportune. Further training in environmental policy development, planning and management will be needed at an early date. This training should emphasise the integration of environmental criteria with economic, cultural and wider social considerations.

Members of NGOs

Where necessary and appropriate, members of NGOs should be given to access to relevant training programmes. The intent would be to develop a broadly based body of local environmental expertise and awareness.

5.2.3 WORKPLAN AND TIMETABLE

1992

- confirm appointment of Environmental Officer; arrange training as necessary
- revise job description of Climate Change Officer, as necessary; arrange training as necessary
- initiate and confirm appointment of Environmental Monitoring Officer; arrange training as necessary; identify required environmental monitoring programmes
- establish TEAG
- conduct EIA workshops in Tuvalu for relevant individuals
- modify functions of NDSC to include more emphasis on environmental factors and links with TEAG
- invoke regulations/legislation to make EIAs mandatory for all new developments and for proposed changes to ongoing activities
- commence work on the development of a National Environmental Management Strategy (NEMS); identify specific projects for implementation in 1993 (see below)
- improve methods for acquiring data on fishing effort and catch
- undertake a formal survey of the attitudes of Tuvaluans toward relocation brought about by sea level rise and climate change

1993

- continue with training of environmental personnel and officials
- implement selected environmental monitoring programmes
- implement the climate information processing system and upgrade and increase the acquisition of relevant weather and climatic information
- begin development and implementation of a national strategy for climate chnage and sea level rise
- begin implementation, under NEMS, of the following projects:
  - > assess vulnerability of land areas to sea level rise
  - > assessment of methods of shoreline protection, including their performance in Tuvalu
  - > assess impact of shoreline structures, land reclamation and reef channel blasting
  - > assess immediate and longer-term environmental impacts of using various sources and forms of construction material
  - > assess adequacy of water supplies in light of anticipated changes in climate and socio-economic conditions
  - > develop crops which are tolerant to salt and other adverse conditions and higher yielding
  - > undertake a comprehensive waste management study
  - > assess the transportation and communication systems to ensure their robustness under adverse environmental

conditions
  > implement a programme to achieve increased energy efficiency and reduced reliance on imported fossil fuel sources
  > increase efforts related to population planning, including family planning and interisland migration
- develop formal and informal educational programmes related to climate change and sea level rise and prepare educational resources including posters and video programmes
- implement improvements in the weather observing programme, communications facilities and services and in health care facilities and delivery of health services to reflect the increased significance of weather events in general and in particular the likely consequences of increased frequency and severity of tropical cyclones and of such changes as higher average temperatures and increased surface water

1994

- continue with training of environmental personnel and officials
- prepare a draft NEMS on the basis of the studies undertaken in 1993 and other relevant information
- implement the urgent recommendations contained in the NEMS

1995

- continue with training of environmental personnel and officials
- prepare the final version of the NEMS and commence implementation of all remaining recommendations
- assess the initial results of the environmental monitoring programmes and develop recommendations for enhancing environmental quality

5.2.4 FINANCIAL REQUIREMENTS

The following costs, calculated in $AUS, are general estimates for the period through 1995. The costs of activities already approved (e.g. Environmental Officer) are not included. In some cases only partial costs are shown. These are estimated to be the incremental costs where a larger project/activity is modified to include consideration of the ramifications of climate change and/or sea level rise.

		$AUS
Environmental Monitoring Officer - salary, training, support costs etc		30,000
In Country Training Programmes - EIA, NEMS, monitoring, education etc		25,000
Overseas Training Programmes - EIA, NEMS, monitoring, education etc		45,000
Climate Information System - hardware, training, data entry etc		60,000
Weather Observing Activities		60,000
Vulnerability Assessment		32,000
Shoreline Protection Assessment		15,000
Construction Material Study		15,000
Water Supply Study		10,000
Crop Study (share of regional costs)		15,000
Waste Management Study		35,000
Transport/Communications Study		35,000
Energy Initiatives (shared costs)		15,000
Population Planning Study (shared costs)		10,000
Education Programmes/Resource Materials		20,000
Health Programmes (shared costs)		10,000
	TOTAL	432,000

6. SUMMARY AND CONCLUSIONS

The diverse environmental and related problems facing Tuvalu are already very real and most evidence points to the fact that they will be exacerbated by climate change and sea level rise. Tuvalu has already taken some preemptive measures to address the various threats and the nation is to be congratulated on its foresight. However, much still needs to be done. While every effort should be made to ensure that, wherever appropriate and possible, indigenous expertise and experience is used to address the challenges, the reality is that currently Tuvalu is reliant on international agencies, regional organisations and other nations for much of the required financial resources and technical expertise.

Every effort should be made to reduce the dependency on external sources of funding and technical assistance and the programme developed in this study is designed with such an objective in mind. Hence the establishment of a variety of internal institutional arrangements is recommended as are training programmes for the personnel working within these structures.

The comprehensive list of recommendations related to general environmental concerns and the added consequences of climate change and sea level rise lead to a series of investigations, many of which will take place within the context of a National Environmental Management Strategy. Key concerns are that land areas which are already vulnerable to such environmental changes as the increased frequency and severity of tropical cyclones and higher sea levels will suffer still further as a result of activities such as the removal of material for construction projects, interisland migration and the disposal of domestic waste. The interrelated nature of these issues and actions mean that integrated rather than piecemeal studies are required. Both short- and long-term views must be considered.

While the desirable approach would be to address the original causes of such global environmental changes as climate modification and sea level rise, the reality is that we are being forced to deal with the effects. Often these are manifest far from the source of change. For this reason the international community has an obligation to small island nations such as Tuvalu and must assist them with the development of plans and activities which will, to the extent possible, alleviate adverse environmental impacts associated with climate change and sea level rise.

Hopefully this responsibility will be accepted and international agencies, regional organisations and individual nations will help meet the serious environmental and human challenges identified as a result of this study.

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APPENDIX I

ACRONYMS

ASPEI	Association of South Pacific Environmental Institutions
CC/SLR	Climate Change/Sea Level Rise
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
ENSO	El Nino - Southern Oscillation
FFA	Forum Fisheries Agency
ICSU	International Council of Scientific Unions
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Intertropical Convergence Zone
SO	Southern Oscillation
SOPAC	South Pacific Applied Geoscience Commission
SPACHEE	South Pacific Action Committee on Human Ecology and the Environment
SPCZ	South Pacific Convergence Zone
SPREP	South Pacific Regional Environment Programme
TEAG	Tuvalu Environmental Assessment Group
TOGA	Tropical Ocean Global Atmosphere
UNCED	United Nations Conference on the Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USP	University of the South Pacific
WMO	World Meteorological Organisation

APPENDIX II

PROGRAMME OF THE VISIT TO TUVALU

Friday 17.1.92 John Hay arrived in Funafuti from Tarawa (Kiribati) at 1.30pm. Met by Ms Misalaima Nelesone (Asst. Secretary, Office of the Prime Minister) and taken to the Filamona Lodge, Vaiaku, Fongafale. JEH spent the remainder of the day on local field reconnaissance and reviewing reference material on Tuvalu.

Saturday 18.1.92 Bill Aalbersberg arrived in Funafuti from Nadi at 10.30am. He was met by Ms Nelesone, Mr Fakavae Taomia (Scientific Officer, Tuvalu Meteorological Service) and by John Hay. The day was spent reviewing reference material and on local reconnaissances.

Sunday 19.1.92 Review and reconnaissance activities continued. A programme of consultations and items for discussion was compiled.

Monday 20.1.92 Meetings and other activities were arranged as follows:

0900 Discussions and planning meeting with Mr Amasone Kilei (Deputy Secretary to Government, Office of the Prime Minister), Ms Nelesone and Mr Taomia.

1100 Discussions with Ms Hilia Vavae (Chief Meteorological Officer, Tuvalu Meteorlogical Service) and Mr Taomia.

1400 Discussions with Hon. Mr Ionatana Ionatana, Minister of Labour, Works and Communications.

1530 Discussions with Mr Veta Palakua Sakaio, Director of Works.

1700 Field reconnaissance with Mr Taomia.

Tuesday 21.1.92 Meetings and other activities were arranged as follows:

0900 Discussions with Hon. Mr Tomu Sione, Minister for Natural Resources Development, Home Affairs and Rural Development.

1030 Interview at Radio Station and discussions regarding proposed live interview.

1100 Discussions with Mr Ado Valens Nnembuka, United Nations Volunteer, Statistics Division.

1130 Discussions with Mr James Conway, Energy Planner, Ministry of Foreign Affairs and U.S. Peace Corps.

1330 Discussions with Seluka Seluka, Director of Agriculture, Ministry of Natural Resources and Development.

1500 Discussions with Mr Colin Reynolds, Water and Sewerage Engineer, Public Works Division.

1600 Discussions with Hon. Mr Alesana Kleis Seluka, Minister of Finance.

1630 Continuing discussions with Mr Reynolds and with Mr Filipo Taulima, Water and Sewerage Section, Public Works Division.

Wednesday 22.1.92 Meetings and other activities were arranged as follows:

0845 Discussions with Mrs Siuila Toloa, Tuvalu Red Cross.

0930 Continued discussions with Ms Nelesone and Mr Kilei.

1100 Continued discussions and data gathering at Meteorological Office.

1230 Information survey at Library.

1400 Discussion with Mr Lopati Tefoto, Communications Officer, Telecoms.

1500 Discussions with Ms Hellani Kaitu, Census Commissioner, Department of Statistics.

1530 Discussions with Mr Siniala Auenga, Lands Officer.

1630 Discussions on report format and recommendations

Thursday 23.1.92 Meetings and other activities were arranged as follows:

0900 Discussions with Mr Sootaga Paape, Senior Education Officer and Mr Kasi Lelemia, Education Officer.

0945 Discussions with Mr Aunese Simati, Rural and Physical Planner, , Planning Section, Ministry of Foreign Affairs and Economic Planning.

1100 Discussions with Ms Annie Homaii, Medical Division, Hospital.

1230 Discussions and report writing.

1400 Discussions with Mr Sautia Maluofenua, Director of Fisheries and Mr Ian Keay, Principal Fisheries Officer.

1500 Discussion with Tuvalu Association of Non-Governmental Organizations (TANGO) - Mr Mavaega Kaua, President; Mrs Siuila

Toloa, Secretary; Rev. John Peleti, Tuvalu Christian Church.

1630 Further field reconnaissance

Friday 24.1.92

0900 Presentation and discussion of Interim Report and Preliminary Recommendations. Present:

Mr. Stephen Boland, Planner, Ministry of Foreign Affairs and Economic Planning
Mr. Itaia Lausaveve, Senior Agricultural Assistant, Department of Agriculture
Mr. Thomas Tafia, Tuvalu Energy Corporation
Mr. Kelese Kolone, Permanent Secretary for Natural Resources Development
Ms. Lina Petaia, Assistant Secretary for Foreign Affairs
Ms. Helina Schmidt, Acting Secretary, Ministry of Labour, Works and Communications
Mr. James Conway, Energy Planner, Ministry of Foreign Affairs and Economic Planning
Ms. Hilia Vavae, Chief Meteorological Officer, Ministry of Labour Works and Communications
Mr. Sautia Maluofenua, Director of Fisheries
Mr. Fakavae Taomia, Scientific Officer
Mr. Amasone Kilei, Deputy Secretary to the Government
Ms. Misalaima Nelesone, Assistant Secretary, Office of the Prime Minister

1415 Depart Funafuti for Nadi, Fiji.

APPENDIX III

COASTAL PROTECTION OPTIONS

Options for coastal protection are influenced by the availability of local materials, plant and labour (Fawcett and Partners, 1982). In Tuvalu materials are generally limited to stone, shingle, sand and some local timber. The stone comes from reefs or from the storm beach, or by the use of a compressor on or blasting of the reef. Coarse aggregate is obtained from the beach. Funafuti has a crusher for preparing sand from beach rock.

Existing practices

- A traditional method is near vertical dry stone walling. This is generally short-lived except in sheltered locations.

- mortared stone walling and concrete-filled drums, facilitated during the war by the more plentiful supply of cement and oil drums.

- stone filled gabion baskets; since 1976 walls have been started and in some cases completed on Funafuti, Nanumea, Nui, Vaitupu, Nukufetau and Nukulaelae. These have a life of about three years due to abrasion and flexing breaking the plastic covering thereby allowing subsequent corrosion of the mesh; repairs are difficult and only partially effective meaning that the overall life is very short.

- 0.3 m cubes of concrete randomly placed in a double layer at a slope of 1 in 2 to protect a short length of coastline adjacent to the deepwater wharf at Funafuti; such protection withstood the wave action associated with the 1981 westerlies while an adjacent gabion basket seawall was extensively damaged. To keep initial costs down the protection was designed for a storm with a return period of one year. Subsequent wave action has made the concrete cubes ineffective in places since their low mass makes them insufficiently resistent to movement - the blocks have been displaced by waves as small as one metre. A shortage of local materials, the need to use imported cement and other materials and the lack of equipment to transport and place larger and hence more effective blocks have hampered the success of this protection project. The small blocks call for careful attention to ongoing maintenance since under storm conditions the outer layer of rubble may be dislodged and moved down the slope. Repairs can be undertaken between tides.

Protection options

- use of stabilising vegetation, but in Tuvalu the natural ocean shore vegetation, primarily Scaevola and Messerschmidia, forms dense thickets, has been cleared in the vicinity of the villages.

- by beach replenishment, involving transport of material either from inland or from offshore sources. This option is expensive and demanding in terms of heavy plant requirements and in Tuvalu the only source of material is offshore, with high costs for dredgers.

- use of groynes. These are a common form of beach protection through the accumumation of beach material by the trapping of littoral drift. For the majority of sites in Tuvalu the wave attack is normal to the beach and there is little or no littoral drift. Groynes would be only partially effective and would present considerable challenges and impacts during construction.

- walls and reventments, ranging between a vertical face sea-wall and the surface protection of an existing beach slope. The surfaces may be flexible or rigid, permeable or solid. Their purpose is to directly resist and absorb wave energy and to retain beach material. Vertical walls are generally unstable and should only be used where space is limited and a massive form of construction is feasible. The former requires care with filling and drainage behind the wall as waves striking a vertical wall throw water upwards and over the wall and downwards into the beach material scouring this away. The latter may be arrested by using a stone apron at the toe of the wall to return the water. Numerous forms are possible:

i) vertical stonewalls generally require less stone than reventments, but dislodgement of a single stone leads to local collapse of the entire wall. The risk of collapse is reduced through the use of very large individual units of stone or imported cement. An alternative is to encage the stones in gabions.

ii) free-standing fabric bolsters filled with sand and placed close to the beach crest allowing construction of a stone wall with less material than if built free-standing. But the saving in stone does not offset the cost of the bolster; requires mortered stone protection.

iii) bagwork walling consisting of concrete bagwork laid by hand on fill material with the face grouted on completion; the bagwork is carried forward at a flattening slope to meet the natural beach profile; main advantages are the ease of installation in underwater conditions and ability to achieve essentially mass concrete without the use of barriers. The advantages are insignificant in Tuvalu as all protective works can be installed above low water

iv) gabion mattresses are an improvement over their vertical counterparts in that they suffer the same disadvantages but to a lesser degree; ease of underwater placement not pertinent to Tuvalu.

v) interlocking slabbed reventment can be placed at the natural beach profile or, to economise, at a steeper slope on built up core material. This option is expensive and involves imported materials.

vi) rubble mound protection consists of successive layers of durable material loosely laid on core material at a slope determined by the unit weight of the rubble and the degree of wave attack using emprical formulae. For Tuvalu a unit weight of 25 kg for local

materials is regarded as the maximum practical weight available on a consistently basis. This requires a slope of 1 in 4 or flatter. An alternative is 0.3 m concrete cubes which require a slope of 1 in 1 or flatter. Rubble mound protection has much to commend it being flexible, durable, of a permeable nature and capable of being produced and installed using local labour and materials.

Reynolds (1988) has also provided a comprehensive review of coastal protection experiences and options for Tuvalu. He concluded that the practice of laying large coral rock or modified concrete blocks is in general satisfactory and is expected to be suitable for any new revetments.