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Implications of Climate Change and Sea Level Rise for the Kingdom of Tonga

Report of a Preparatory Mission

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and
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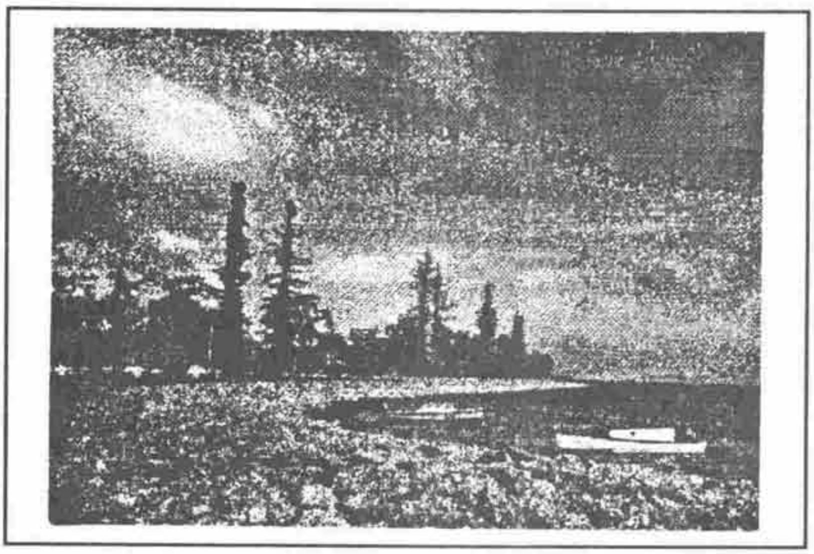

Nuku'alofa Seawall, Tongatapu

by
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Apia, Western Samoa
December 1992

Foreword

The report which follows constitutes one of nine Climate Change Preparatory Mission Studies of individual Pacific Island countries solicited by the South Pacific Regional Environment Programme.

Task team members were identified and the terms of reference for the studies were established in mid-October 1991 and the Letter of Understanding, constituting the formal agreement between both parties, was transmitted at the end of November.

Initial plans were made to undertake the mission to Tonga in early February 1992. However, the Tonga task team was advised by SPREP in late January that specific terms of reference applied to this mission. These terms of reference were to be obtained directly from Tonga. Prior commitments on the part of the concerned Tongan government representatives resulted in further delays. It was finally agreed to undertake the mission on March 4th-12th, an in-depth study being proposed for Nuku'alofa as a specific component of the terms of reference.

No further mandate was forthcoming and it was agreed, on arrival in Tonga and following discussion with the Tongan government representatives who received the task team, to follow the general terms of reference for preparatory missions while considering the possibility of conducting site-specific studies on three low-lying areas of Tongatapu: Kanokupolu-Kolovai, Sopu-Popua and the Fanga 'Uta lagoon area. In the absence of the government officials who had initially recommended to SPREP that some site-specific studies be conducted, following a visit to the three sites, and after further discussion with those officials receiving the task team, it was finally decided to restrict our enquiry to the general terms of reference of the mission.

This succession of unfortunate events resulted in the entire study being conducted during a period at which both task team members were engaged in fulltime teaching. This meant inevitable delays in the production of the final report. It is sincerely hoped that its quality and potential utility to both the Government of Tonga and the South Pacific Regional Environment Programme will more than compensate for the difficulties encountered.

Acknowledgements

This study could not have been carried out without the collaboration of the Government of Tonga and, indeed, of a very large number of individuals who made themselves available for interview at very short notice. Annex 1 comprises a list of all those people. May it serve as recognition of their generosity and of their interest in the mission.

One name must, however, be singled out; that of Mr. Taniela Tukia, Physical Planner with the Ministry of Lands, Survey and Natural Resources. To conduct an investigation of this scale in a period of eight days is something of a challenge under the best of circumstances. "Losing" a single day through transportation difficulties or cancelled interviews can have dramatic consequences. Mr. Tukia ensured that we worked with the maximum of effect, both in an intellectual and an operational sense. He arranged transport, interviews, accommodation, modified the programme at short notice, identified documentary sources and, above all, manifested a critical interest in our exercise. Our debt to him is considerable and we sincerely hope the results are worthy of his investment.

Insofar as SPREP is concerned we are debted to Dr. Chalapan Kaluwin, Climate Change Officer, for his appreciation of the challenging circumstances under which this study was conducted.

Contents

Introduction

Irrespective of which part of the world one lives in, the environment now figures highly on most national agendas, be they economic, political or social, and among the many environmental issues, one dominates. Global climate change hangs over all of us like the sword of Damocles, alarming because of the enormous scale of the phenomenon, our inability to delineate its exact configuration, and our apparent incapacity to check its course.

In the Pacific the prospects of climate change and attendant sea-level rise are particularly alarming. The sea is omnipresent. Several countries are composed exclusively of atolls whose maximum height nowhere exceeds five metres above sea level, while elsewhere populations and resources are concentrated almost exclusively in the coastal zone. In addition, tropical cyclones, tsunamis and storm surges already pose serious threats to many islands. And all these act on what are, from the outset, extremely fragile ecosystems. In other words, Pacific Island countries are, by definition, extremely vulnerable in the face of predicted changes.

This vulnerability is compounded by a sense of powerlessness in the face of the challenge. Which, if any, of the small - often micro - states have the means to meet the challenge of global climate change? Is it, indeed, humanly possible for any state to counter the process? And added to the powerlessness, there is a sentiment of confused frustration and anger at having to face up to environmental changes which have been generated by the actions of other (rich, industrialised) states located in distant parts of the world.

The importance of environmental issues for almost a decade has meant that many national and regional studies have already addressed, in part or in whole, the subject of climate change, thereby covering much of the ground identified in the terms of reference for this study. Tonga is no exception. The following studies are particularly relevant, as they address a number of the issues in much greater depth than the present report:

- *Tonga: A Country Profile*, Washington, D.C.: Office of Foreign Disaster Assistance, Agency for International Development. 1986. 52pp.

- *Environmental Management Plan of the Kingdom of Tonga*, Bangkok: Economic and Social Commission for Asia and the Pacific. 1990. 197pp.

- *National Report of the Kingdom of Tonga to the United Nations Conference on Environment and Development*, Nuku'alofa: Government of Tonga. 1991. 54pp.

- *Kingdom of Tonga, Sixth Development Plan, 1991-1995*, Nuku'alofa: Central Planning Department. 1991. 331pp.

It is recommended that these be essential reading to complement the present study.

One other introductory observation needs to be made. The above, and most other country reports on Tonga, provide a formal geographic, demographic and economic portrait of the country. The information varies little from one report to another. Cognizant of this fact, and to the extent that it has been found to be accurate, we have limited ourselves to a summary treatment of these topics in the following pages, updating them where appropriate, with new information. We have also endeavoured to summarise the relevant scientific material on climate change, information which is increasingly almost exponentially in volume and becoming more and more refined in terms of interpretation and prediction.

This leads us to the essence of this report. Rather than belabour the reader with what is already widely known and readily available in other documents, we have sought, wherever possible, to address novel and Tonga-specific dimensions and issues related to climate change as they were brought to our attention during the mission. We have added to these our own reflections on what we learned. In so doing, we hope to complement rather than duplicate the other national environmental studies and, indeed, the other country reports produced according to the same terms of reference. We feel such an approach is rendered all the more appropriate given the fact that Tonga differs in a number of important respects from several of the other countries:

1. The country comprises an unusually diverse mix of both high and low islands.

2. It is located towards the southern limits of the tropics, the capital Nuku'alofa being situated on latitude 21.09°S.

3. It is situated in a region of considerable cyclonic activity.

4. Although Tonga is legally a constitutional democracy, effective authority is wielded by the sovereign through a privy council, all of whose members are nobles appointed by the monarch.

5. The country's population in terms of size at least is, to all intents and purposes, stable.

Taken together, these characteristics result in a slightly different assessment of the likely effects of climate change on the Kingdom of Tonga compared to most other island nations in the Pacific. At the same time, they in no sense modify the primary purpose of the study, to provide a general review of the nature and long term implications of climate change and sea level rise for the country.

1. Geographical Context

1.1 Location and physical character

The Kingdom of Tonga in the South Pacific has a land area of 668 km^2 distributed among some 169 islands between latitudes 15°S and 23.5oS and longitudes 173°W and 177°W. Nearly half the land area is on Tongatapu island, where most of Tonga's people reside.

The islands of Tonga are either volcanic or of limestone composition. Limestone islands rise exclusively from the Tonga Ridge. Most volcanic islands rise from the Tofua Ridge. As shown in Figure 1, the distribution of these islands correlates well with their composition.

The volcanic islands from `Ata in the south to Tafahi in the north are mostly active and rise from the Tofua Ridge. Underwater volcanic activity along the Tofua Ridge is common and occasionally results in the appearance of islands, which seldom endure more than a few days above the sea surface: Fonuafo'ou (Falcon Island) and Late'iki (Metis Shoal) are two which have been studied (Charlton, 1941; Melson *et al.*, 1970). By analogy with active volcanic island arcs elsewhere, it would seem probable that the Tofua Ridge is growing through volcanic accretion at the present time and, while there may be local subsidence in time and space, the long-term tectonic trend is a rising one.

The fact that the volcanic islands are getting larger has few implications for the future of Tonga's population should sea level rise as predicted. The reason for this is that most of the volcanic islands in Tonga are uninhabited or sparsely inhabited. The important exception is Niuafo'ou.

The basalt volcano of Niuafo'ou is distinct in composition from the other (andesitic) volcanic islands in Tonga (Reay *et al.*, 1974). It is also distinguished by the fact that it is not a cone but the partly-drowned rim of a caldera (Jaggar, 1931). Recent eruptions have occurred along the caldera rim and have had a direct impact on human settlement. An account of the associated disruption, the resettlement on 'Eua of the inhabitants of Niuafo'ou, and their subsequent return was compiled by Rogers (1986).

The majority of people in Tonga live on the line of limestone islands, named the Tonga Ridge, from 'Eua in the south to Niuatoputapu in the north (Figure 1). Of these islands, most people live on the largest, Tongatapu. The limestone islands of Tonga exhibit considerably more variability in physiography, composition and origin than their volcanic counterparts. The higher limestone islands are all thought to be ancient volcanoes which became swathed in limestone following submergence only to emerge subsequently. On Niuatoputapu and on 'Eua the volcanic core has been exposed by subaerial erosion (Hoffmeister, 1932). On the other high limestone islands, Tongatapu and in the Vava'u group, a volcanic core is only inferred to be present (Cunningham and Anscombe, 1985).

Many of the high limestone islands in Tonga have uncommonly fertile soils, which are believed to be the consequence of eruptive material from the volcanoes of the Tofua Ridge drifting eastwards and becoming incorporated in the limestone cover of these islands as it was forming (Orbell *et al.*, 1985).

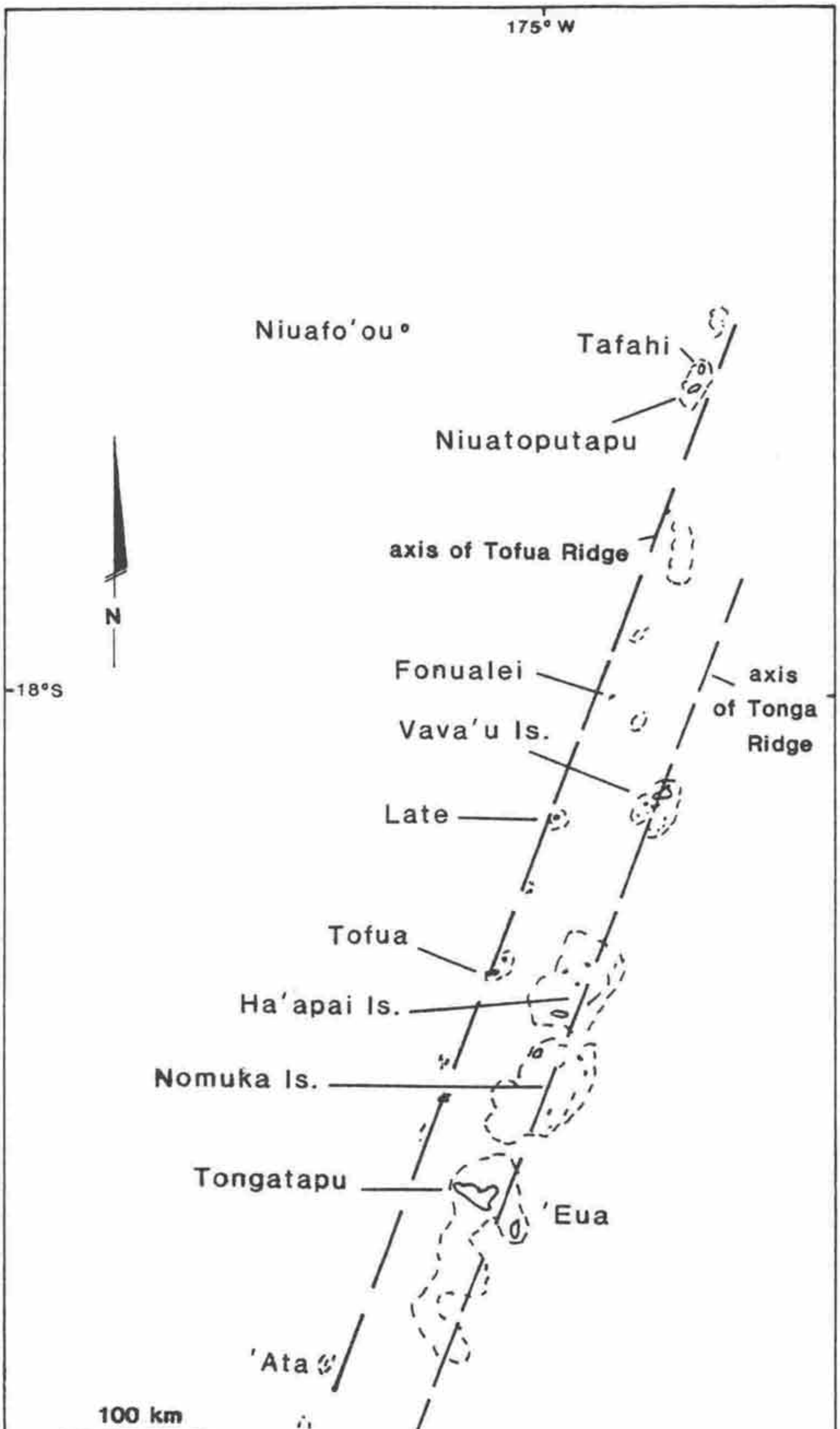

Figure 1. Islands of Tonga showing the relationship between island distribution and the lines of the Tonga and Tofua ridges

Volcanic tuff and breccia are common constituents of the low limestone islands of Tonga but these generally have a greater proportion of calcareous detritus than the higher ones. This reflects the recent age of these low islands and the importance of accumulation of reef detritus (in particular) during storms in their formation. Such islands are common in the Ha'apai and Tongatapu groups and are often founded on a base of recent reef with a living fringe.

1.2 Regional geological setting

The islands of Tonga lie on the western side of the Tonga (-Kermadec) trench, a major area of lithospheric plate convergence in the South Pacific. Along the Tonga Trench, the Pacific Plate in the east is being thrust beneath the Indo-Australian Plate in the west. Heat generated along the sub-surface contact between these plates assists the upwelling of magma along a line parallel to the trench axis. This upwelling has given rise to the line of active volcanoes along the Tofua Ridge (Dupont and Herzer, 1985).

The Tonga Ridge, from which the limestone islands rise, is closer to the trench axis and termed the forearc or frontal arc. This is the edge of the Indo-Australian Plate which has been thrust upwards as the result of overriding the Pacific Plate. The Tonga Ridge is thus a zone of uplift and fracturing. Much of the fracturing has been linked to irregularities on the downgoing Pacific plate (Dupont and Herzer, 1985).

The seismicity of the Tonga region has long attracted attention and it was here that the first empirically-derived model of plate convergence was produced (Barazangi and Isacks, 1971). Maps of earthquake focus distribution show that the shallowest earthquakes occur closest to the axis of the Tonga Trench. With increasing distance westwards, depths of earthquake foci increase. Deep-focus earthquakes related to plate convergence along the Tonga Trench have been recorded as far west as Viti Levu island in Fiji.

Many of the earthquakes along the Tonga Ridge produce island uplift. Testimony to such coseismic-uplift events are the sequences of emerged notches along Tongatapu's south coast where Sawkins (1856) described the effects of the last event thus.

> "Tongataboo, one of the Friendly Islands, was visited a few months previous to my sojourn there in 1854 by an earthquake, when the north-east portion of it was tilted down to an inclination sufficient to produce an encroachment of the sea for nearly two miles inland, gradually diminishing to the south-eastern shore as far as Nuku'alofa, where it now washes the roots of a tree that grew within a garden adjoining a house that has been entirely destroyed. The western coast has visibly risen some feet, and a spring of water has sunk below the surface" (1856: 383).

Coseismic uplift occurs in response to the release of stress which has been building up over a long period of time. Coseismic uplift of around 1 m has been calculated to have affected Tongatapu's south coast every 849 years on average (Nunn and Finau, unpublished data). By comparison, the Ryuykus forearc in Japan experiences coseismic- uplift events every 1200-1400 years (Sieh, 1981). The cumulative magnitude of coseismic uplift needs to be considered relative to the magnitude of the subsidence which occurs between coseismic-uplift events before a figure for net movement can be determined. Despite this, it seems clear that the overall recent tectonic trend within the limestone islands of Tonga is an upward one. Emergence has characterised the last few thousand years.

Another consequence of the convergence of plates along the Tonga Trench is that the Tonga Ridge has been broken up into a series of large blocks, each of which has apparently moved independently of the others during the last few hundred thousand years (Taylor and Bloom, 1977). This movement has apparently not been solely vertical but has also involved considerable amounts of tilting. Thus the Tongatapu block has tilted south to north causing the northern part of the island to experience submergence relative to the southern part. In Vava'u the situation is reversed with the main island's south coast having been drowned and the north coast uplifted. These differential movements have probably been operating far more slowly and over a much greater time span than the widespread uplift of the islands described above (Nunn, 1991a).

1.3 Climate

The climate of Tonga is characterised by the contrast between a wet season (December- April) and a dry season (May-November). At least some 60-70% of annual rainfall falls during the wet season. Owing to the seasonal proximity of the South Pacific Convergence Zone (SPCZ), the northern islands of Tonga receive more rainfall (~2600 mm/year) than the southern islands (~1700 mm/year).

Temperatures vary likewise. Mean annual temperature at Niuafo'ou (Keppel) is about 26^{o}C (79^{o}F) while on Tongatapu it is about 23^{o}C (73^{o}F). This variation manifests the distinction between the tropical climate and environment of northern Tonga and the subtropical character of its southern parts.

In all parts of Tonga, evapotranspiration usually exceeds rainfall only during June and July. Severe water shortages can occur in places during these latter months, particularly if precipitation during the preceding months has been lower than usual.

The two principal causes of rainfall variation in Tonga are the occurrence of tropical cyclones, which can result in unusually wet periods, and an El Niño event, which can cause prolonged droughts.

The most destructive aspects of cyclones are the associated high-speed winds and storm surges. The role of cyclones in recharge of island water lenses is also important. On average two cyclones affect Tonga annually (1830-1982 data) but this figure disguises the fact that there is more than a 50% probability that no cyclones will affect Tonga in any particular cyclone season (November-April) while in other years, three or more cyclones may pass through the group.

The Southern Oscillation Index (SOI) measures the pressure difference between Darwin and Tahiti and is used to predict long-term interannual climate variations. When the SOI is negative (pressures are relatively high at Darwin - an El Niño event), the SPCZ lies north and east of its usual position and dry conditions are likely in the tropical south and west Pacific. It has been shown that tropical cyclones are more likely to occur during El Niño events (Revell and Goulter, 1985), but the dry conditions are rarely significantly alleviated by the associated bursts of cyclonic rainfall. Meanwhile notable droughts in Tonga occurred in 1926, 1930, 1951-53 and 1977-78. At the time of our visit in March 1992, a drought, associated with a prolonged El Niño event, was in progress. An unusually high number of tropical cyclones had correspondingly developed in the region between November 1991 and March 1992.

1.4 Vegetation

Most of the limestone and inhabited volcanic islands of Tonga have a vegetation cover which is largely in response to human presence. Little is known of the vegetation of uninhabited volcanic islands in Tonga. Agriculture is the main livelihood of most of the inhabitants of Tonga. Most forest in Tonga is an agroforestry system comprising horticultural crops with an open overstory of tree species used for fruits, nuts, medicine, timber or ornament. The coconut palm is the dominant species on most islands. Indigenous forests are found on many volcanic islands and also on 'Eua. Mangrove forests are not extensive in Tonga, usually restricted to lagoon coastlines. Additional details of Tonga's vegetation are given in the National Report of the Kingdom of Tonga to the United Nations Conference on Environment and Development (UNCED).

1.5 Soils

The soils of the limestone islands of Tonga are unusually fertile since the limestone contains large amounts of volcanic detritus produced by the nearby volcanoes at the time the limestone was forming. Emergence and subaerial erosion of the limestone has led to the concentration of volcanic materials in the soil. Volcanic island soils are developed only on the older volcanic slopes and are generally highly fertile. Additional details are given to the Tonga report to UNCED.

1.6 Reefs

Most of Tonga's limestone islands are surrounded by extensive reef systems which are important elements of the marine ecosystem. Owing to freshwater runoff and recent volcanism, reef development is comparatively poor around most volcanic islands in Tonga. Reefs and associated lagoons cover an area of 5352 km^2 and are important to fisheries (National Report to UNCED).

Offshore reefs have an important protective function in reducing wave energy and hence island shoreline erosion. Tonga's reefs are likely to be healthier than many other island reefs in the Pacific which have been adversely affected by terrigenous sediment deposition because there are no rivers to transport such sediment on most islands. Yet sea-surface warming, overexploitation and the use of explosives and poison are probably putting a degree of stress on Tonga's reefs which may significantly affect their ability to respond to future climate and sea-level changes.

1.7 Water

Water is not abundant on the limestone islands of Tonga but neither is it in especially short supply on the largest of them. The most important water resources are the freshwater lenses which occur within the limestone: there is a six-year reserve on Tongatapu at present levels of demand. Some 85% of the population depends on this groundwater resource, 15% on rainwater, mostly collected by roof-catchment systems. The latter are especially common on the small low islands like many of those in Ha'apai where the freshwater lens is comparatively small in volume. Water is generally abundant on the larger volcanic islands where rivers and lakes are present (National Report to UNCED).

1.8 Population size and growth

While Tonga's population has grown substantially from the end of the 19th century - from less than 20,000 in 1891 to almost 100,000 today, it now shows signs of stabilising (Environmental Mangement Plan, 1990: 13).

The 1986 Census recorded a total population of 96,535, with an average annual rate of growth of 0.49% during the preceding decade. This low rate of growth is a product of both declining fertility and accelerating out-migration. The annual rate of natural increase for the period 1980-87 was 2.3% and the annual rate of net emigration of the order of 1.8%, resulting in an annual rate of growth of 0.5%. There are indications that the rate of out-migration is accelerating (Sixth Development Plan, 1991: 61-63.)

While such figures imply that there is likely to be a consequential levelling-off in terms of pressure on resources in the near future, they obscure the fact that out-migration is a selective process, involving both sexes in the productive age groups. Thus, in 1986, some 41% of the country's population was under 15 years of age and this percentage is declining only slowly. In addition, effective pressure on resources is also determined by population distribution and standards of living.

1.9 Population distribution

The four island groups that constitute the Kingdom of Tonga are divided into five administrative divisions organised from the north to the south as follows: Niua, Vava'u, Ha'apai and, finally, the Tongatapu group which is subdivided into Tongatapu itself and 'Eua.

According to the 1986 census, Tongatapu contained 67.2% of the country's population, almost half of whom were living in the capital Nuku'alofa. It being a high, limestone island, one might conclude that Tonga's population is not at great "risk" in an environmental sense. However effective vulnerability in the face of sea level rise is greatly augmented by the fact of its concentration on the low, northern shore of Tongatapu, where the capital is located.

This risk is increasing from year to year by virtue of the accelerating internal re- distribution of population. Tongatapu has long dominated demographically and already in 1921 the island contained 40% of the Kingdom's population. As Table 1 and Figure 2 indicate the rate of growth of Tongatapu's population is double the national average, Vava'u and Niua Divisions are stable, while Ha'apai and 'Eua are declining - the former quite rapidly:

Table 1. Population by divisions and rates of growth.

Division	Population 1976	1986	Annual Rate of Growth
Tongatapu	57 411	63 794	1.1
Vava'u	15 068	15 175	0.1
Ha'apai	10 792	8 919	-1.9
'Eua	4 484	4 393	-0.2
Niua	2 328	2 368	0.2
Total	**90 085**	**94 649**	**0.5**

(Source: Statistics Department, 1991: viii)

Population densities now approach 250 persons/km^2 on Tongatapu, almost double the country's average of 127 persons/km^2.

The maximum height of Tongatapu above sea level is only a little over 60m, whereas much of the settled area is below the 5 m mark. Virtually all migrants to Tongatapu settle there.

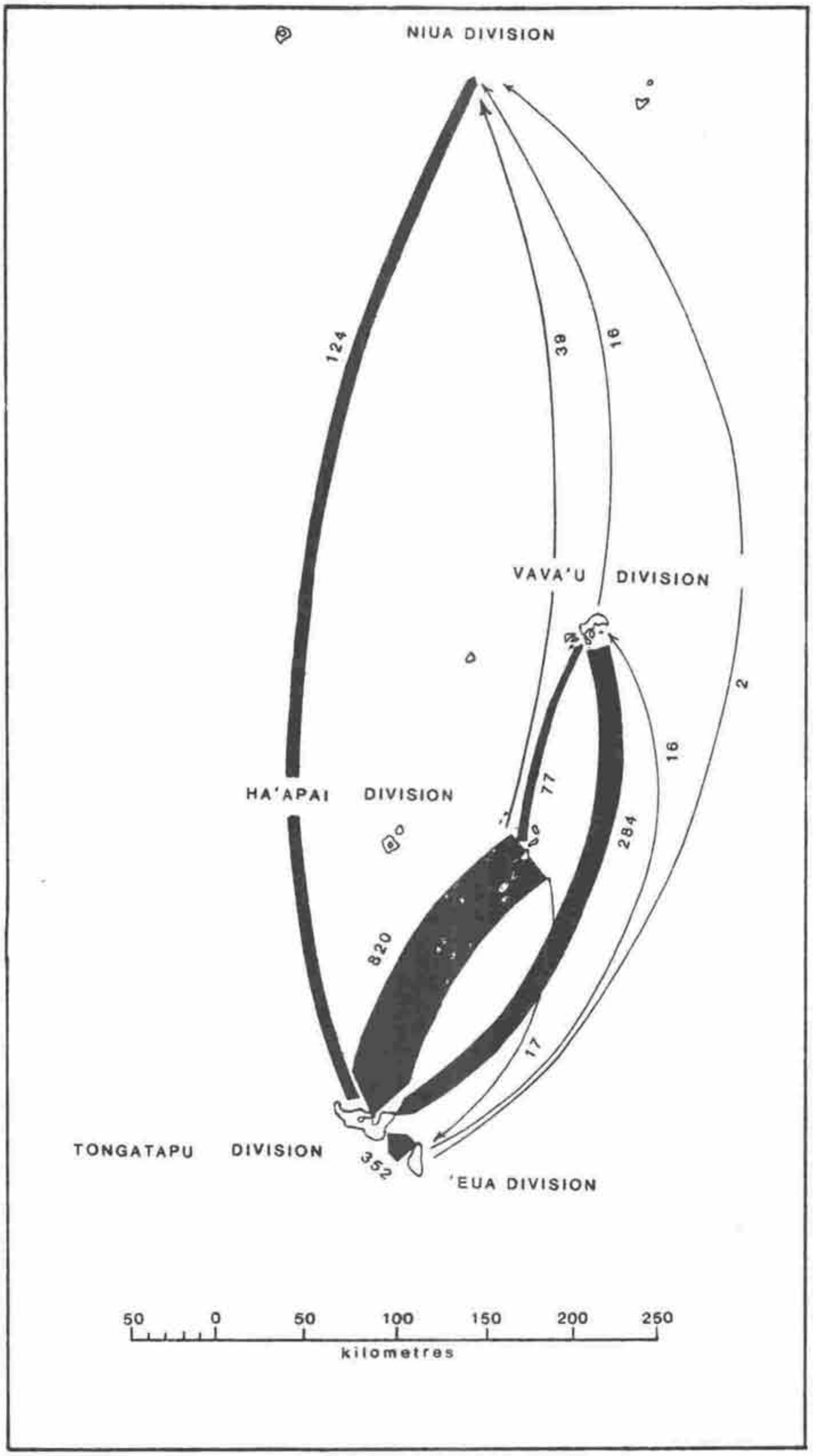

Figure 2. Net migration streams between divisions in Tonga, 1976- 1986 (Sixth Development Plan, 1991)

In other words, internal migration is leading to an increasing concentration of Tonga's population on one of the islands that is particularly vulnerable to inundation and shoreline erosion, and specifically the northern side of Tongatapu where the capital city is located.

1.10 Economy and standard of living

Tongatapu has an agriculture-based economy organised around semi-subsistence small- holdings. Subsistence production focuses on a range of customary root crops - yam, taro, sweet potato and the more recently introduced cassava. Commercial production has focused on copra and other coconut products which have been severely affected in recent years by drought, cyclones and falling world prices. As a result, considerable effort has been made over the past decade to diversify into higher-value export crops: notably vanilla, bananas and squash. However, they have proved hazardous ventures because of problems of quality control, disease, management and major fluctuations in supply and demand (Sixth Development Plan, 1991:118-127; Fonua, 1992:19-22). On the other hand, the export of root crops to overseas migrant communities has progressively grown.

Because of the high fertility and excellent physical properties of the soils of the main islands agriculture continues to be a viable option, in spite of the small size of holdings and demographic pressures It accounts for approximately one-third of the Gross Domestic Product.

Forest resources are minimal in Tonga and onshore metalliferous mineral resources are non-existent. On the other hand, the Exclusive Economic Zone contains very significant marine resources, notably tuna and, possibly, hydrocarbons, but the former remain largely untapped. The real extent and volume of the hydrocarbon reserves remain to be determined.

While there is some manufacturing, notably a textile industry, tourism represents the second most important sector of the economy, accounting for over 10% of GDP. It is expanding rapidly (National Report of the Kingdom of Tonga to UNCED, 1991: 13-14).

Aid constitutes an important source of funds for the national economy as do remittances from relatives overseas for individual household economies (op.cit. 74-16, 19). Tonga and Tongans are vulnerable to fluctuations in both.

In 1990 the total value of imports amounted to approximately US$62M and exports to a mere US$12M. This was coupled with minimal economic growth (L'Etat du Monde, 1992: 378-9).

1.11 Ethnicity, culture and society

Tongan society is ethnically and culturally extremely homogeneous and tightly organised. Tongans or part-Tongans accounted for over 96% of the population in 1986. Almost all Tongans are Christians, strict Sunday observance being a significant expression of this fact. The single most important Church is the Free Wesleyan, with 44.1% of the population being adherents in 1986. The other most important denominations are Roman Catholic (16.3%), Latter Day Saints (Mormon) (12.3%) and the Free Church of Tonga (11.4%). The Mormons are making significant in-roads on the other faiths, notably the Wesleyans and the Free Church.

All faiths except the Mormons are members of a single Council of Churches, this organisation serving both to increase the power of the established religions in the country and to be at the root of an important "chink in the facade" of a tightly organised feudal society.

The majority of Tongan children receive their education in Church-run schools, Tongan being the language of instruction in most cases at the Primary level. Educational levels are high, with universal literacy and, in 1986, over three-quarters of the 25-34 years group having achieved some level of secondary education and 4.5% some tertiary training (Population Census, 1986: xviii).

Marriage is near-universal in the country and all marriages are Christian celebrations. The nuclear family is inscribed within the broader web of the extended family, this latter serving as the basis for Tongan social organization.

Finally, Tongan society is highly stratified with, at the top, the monarch and the royal family. There follows, in succession, 33 hereditary nobles and their families, an intermediate group of *matapule* and, finally, the great mass of commoners. Nobles and commoners are bound to each other by a complex web of rights and obligations.

Perhaps the most significant expression of social organization is to be found in the system of land tenure whereby each Tongan male over 16 years of age is entitled to an urban allotment (or `api) not exceeding 0.16 ha and a rural or garden one not exceeding 3.3 ha. All land in the country is, ultimately, Crown Land, but is in fact divided into four tenure categories: a) Hereditary estates of the King, b) Hereditary estates of the Royal Family, c) Hereditary estates of the Nobles and *matapule*, and d) Government land. All allotments are drawn from the last two categories.

This tenurial regime is at the origin of very considerable problems in terms of access to land. One, land is very unequally distributed, between the Monarch and the Royal Family on the one hand and the commoners on the other. Two, virtually all available allotment land - in particular town allotments - has been allocated, leaving as many as 75% of eligible males without any legal title land.

In response to the demand, the tendency is increasingly for the Government to subdivide and allocate environmentally marginal land.

To conclude, Tongan society is a remarkably conservative one in which both the Monarch and the nobility on the one hand, and the established Churches on the other, exercise a great deal of influence over the population as a whole. While there are some important manifestations of "stress" in the system, with respect particularly to the growth of new Churches and the severe limitations in access to land, they cannot yet be perceived as severe destabilising forces. In this latter respect, the heavy and continued out-migration of Tongans is no doubt an important consideration.

1.12 Political and administrative arrangements

Although Tonga is, formally, a constitutional monarchy, effective power is wielded by the Monarch and a select group of nobles. Thus, according to the Constitution, the King (or Queen) is head of both state and of government. He (or she) acts through a Privy Council (or Cabinet) which is appointed by him from among the nobles with members serving until normal retirement age.

There is, in addition, a Legislative Assembly comprising 14 elected members (7 of them nobles, elected by the 33 nobles of the country, and the other 7 commoners, elected by universal suffrage), members of the Privy Council and the Speaker.

The Government of Tonga is organised into a broad set of Ministries/ Departments, the most important of which are the Ministries of Health; Agriculture and Forestry; Fisheries; Labour, Commerce and Industries; Lands; Survey and Natural Resources; Works; Foreign Affairs and Defence; together with the Tonga Visitors Bureau, and the Central Planning Department.

Most important, in the context of the present report, there is an Environmental Planning Section within the Ministry of Lands, Survey and Natural Resources. In addition, there is a standing Inter-Departmental Environment Committee created initially to prepare the *Environmental Management Plan for the Kingdom of Tonga* and subsequently transformed into a permanent committee with a view to supervising the implementation of the Plan. The Committee is formed of the heads of all the above Ministries and Departments and is chaired by the Secretary of MLSNR.

These political and administrative arrangements result in a certain incoherence by virtue of the fact that the Environmental Planning Unit is extremely small and subsumed within a large Ministry with which its interests are not always compatible. The Government departments are, in turn, tributary to a Legislative Assembly whose power and capacity to initiate action is relatively limited. By virtue of the authority of the King and the Nobility in Tonga, a great many initiatives are disseminated from the top down, thereby circumventing what are now the usual processes of reflection and evaluation in many Pacific Island countries.

2. Environmental Problems

2.1 Physical hazards

The principal physical hazards affecting the Kingdom of Tonga are attributable to its location close to the line of lithospheric plate covergence along the Tonga Trench.

Plate convergence produces earthquakes, the foci of which are located along the subsurface boundary between the plates, the Benioff Zone. The position of this and the form of the downgoing plate is well known from the study of earthquake foci and seismic- wave travel times in the Tonga region (Dupont and Herzer, 1985). The occurrence of occasional large-magnitude earthquakes in Tonga is testified to by the geomorphological evidence of abrupt vertical displacements such as that described in section 1.2 above. Specifically, the earthquake hazard in Tonga is that associated with high-magnitude, medium-frequency events of which the 1977 Tongatapu earthquake is a good example, and very high-magnitude low frequency events, such as those which caused abrupt uplift of (parts of) islands in Tonga. The latter events occur every 849 years or so on Tongatapu (Nunn and Finau, unpublished manuscript) and, for that reason, are not worth discussing in the context of changes over the next few decades. This is especially true since the last coseismic-uplift event may have occurred only in 1854 (Sawkins, 1856)..

The high-magnitude medium-frequency events are of more concern. Earthquakes of magnitude 8.3 or greater occurred in 1902, 1919 and 1948: others with magnitude 7.5-8.2 occurred in 1913, 1917, 1921, 1943, 1946 and 1949. The 1977 earthquake had a magnitude of 7.2 and caused damage to buildings in 'Eua, Ha'apai and Tongatapu.

Tsunami (seismic sea waves) result from rapid displacements of the ocean floor. For Tonga most of the risk comes from landslides along the steep flanks of the Tonga Trench and some eight events have been recorded since 1853.

Plate convergence is also responsible for the volcanic activity of Tonga, both above and below sea level. This is restricted to a line of islands at least 50 km from those where most people live. While there is some risk of ash falls on inhabited islands, the greatest threat is posed by the activity on the inhabited island of Niuafo'ou where ten eruptions have occurred since 1853.

There is no reason to suppose that earthquakes and volcanic activity will not continue at similar rates in future.

2.2 Climate hazards

The two most common climatic hazards in Tonga are tropical cyclones and droughts. The latter, and to a lesser extent the former, occur in association with prolonged negative Southern Oscillation Index values or El Niño events. Tropical cyclones form only over oceans where sea-surface temperature exceeds 27-28°C enabling their demand for abundant moisture to be satisfied. In the South Pacific, tropical cyclones commonly develop along the South Pacific Convergence Zone (SPCZ).

Tropical cyclones have the ability to cause serious damage to island landscapes and immense difficulties for their inhabitants. The destructive effects of tropical cyclones in Tonga have been amply documented (see, for instance, Oliver and Reardon, 1982). The worst effects have been on the lower islands, as illustrated by Woodroffe's (1983) study of morphological and vegetation change on islands in the Ha'apai and Tongatapu groups following Tropical Cyclone Isaac in March 1982. Hurricane-force winds commonly affect agriculture and buildings most severely while storm surges can produce morphological changes to island coastlines and result in widespread flooding, an effect exacerbated by accompanying torrential rainfall. It is clearly a matter of some concern to know whether or not tropical-cyclone frequency is likely to change under the influence of continued global warming.

Few predictions have been made regarding changed frequency of tropical cyclones in a warming world. A rudimentary argument is that since tropical-cyclone development is confined to the area where sea-surface temperatures exceed 27-28°C, any increase in the size of that area (as the result of sea-surface temperature increase) will result in an increase in the number of tropical cyclones which develop during a particular cyclone season. This view is supported by Holland et al. (1988) who stated that "cyclone activity is likely to increase in the central South Pacific" (p 438) as the result of continued warming in the region. These writers also deem it likely that "cyclone activity will spread [further] eastward into the central South Pacific" (p 453) placing Tonga more centrally within the cyclone-prone region.

A correlation between increasing sea-surface temperatures and tropical-cyclone frequencies over the past few decades is supported by data presented for all parts of the Pacific (except the northwest quadrant) by Nunn (1990, 1991). Such a correlation need not be proof of a casual link, although this is not wholly improbable.

It has been demonstrated by Revell and Goulter (1986) that most tropical cyclones develop when the SOI is negative, that is during El Niño events. It is therefore also critical to determine what will happen to El Niño periodicity in the next few decades as earth-surface temperatures rise. An increase in the incidence of El Niño events is likely to cause an increase in tropical-cyclone frequency yet it is by no means clear what will happen to El Niño periodicity with increasing earth-surface temperatures in future. It is reassuring to note that Nicholls (1989: 2-30) found that the frequency of El Niño has been robust with respect to past climate changes" although he also emphasises the lack of understanding surrounding the El Niño phenomenon.

2.3 Human-linked "hazards"

There is no doubt that future climate change, itself perhaps a largely human-linked "hazard", will pose problems for Tonga but the severity of these can be properly assessed only by regarding them as part of the range of environmental problems. Of those facing Tonga at present, some appear to be critical in the sense that, if they are not satisfactorily tackled soon, environmental quality will deteriorate to such an extent that future climate change could cause little further deterioration.

Perhaps the most important of Tonga's current environmental problems is deforestation, particularly the removal of native forests but also the clearing of coconut woodland. Many informants told us how the landscape of Tongan islands had been altered by deforestation over the years with the result now that firewood is scarce and most demands for timber and timber products are met by imports. For the Tongatapu group, substantial timber reserves remain only on 'Eua where they are being rapidly depleted. The effects of deforestation on Tonga have been recognised and reported elsewhere (National Report to UNCED).

Soil erosion is a serious environmental problem in parts of Tonga and one which is commonly associated with deforestation and/or agricultural development of steepland areas. The latter is a particularly severe problem in Vava'u (National Report to UNCED).

Throughout Tonga, informal beach-sand mining is a common practice yet one which has caused many problems. Prominent among these is the shoreline erosion which takes place or is exacerbated by removal of a protective beach cover. Similar problems may eventuate from other forms of interference with the coastal system, particularly those associated with clearance of mangroves (*sotia matatahi* or "guardians of coastlines") and reclamation schemes (National Report to UNCED).

Conservation of forests, of soils, and of beach resources is the obvious solution to the above-mentioned environmental problems. This is true not only because undesirable trends could be reversed but also because the future promises change at extraordinary rates compared to the recent past. Natural systems (forests, soils, beaches) will hence be placed under extraordinary stress. If these systems are already under stress, then the process of deterioration will be greatly accelerated compared to a situation where antecedent stress is absent or negligible.

3. Climate and Sea-Level Changes - Emerging Environmental Problems?

3.1 The global problem

Scientific consensus, as expressed by the Intergovernmental Panel on Climate Change (IPCC), is convinced that the climate of the earth is changing and will continue to do so into the future. The best models available predict that earth-surface temperatures will rise (relative to 1990 temperature) by 1°C by 2025 and 3°C by 2100.

The IPCC also concluded that **global** mean sea level will likely rise in the future with best estimate predictions of 18 cm by 2030 and 44 cm by 2070. They predicted that, even with substantial reductions in future emissions of the major greenhouse gases, such future increases in temperature and 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. For the South Pacific, much of the work on climate-change and sea-level rise undertaken in the late 1980s and subsequently was pursued as part of the South Pacific Regional Environmental Programme (SPREP) Action Plan. 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 countries. SPREP has 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).

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 one of these. Terms of reference are given in Annex 2.

The Second Regional Conference on Climate Change, held in Nouméa in April 1992, established clear guidelines for future work and confirmed SPREP's coordinating role in this domain. Priority was given on this occasion to Coastal Zone Management (CZM) studies and research with a view to formulating criteria to assess the vulnerability of island coastal areas to sea level rise.

3.2 Recent climate change in Tonga

In common with the rest of the Pacific, indeed the rest of the world, it is now clear that for most of the past 5000 years, the climate of Tonga has been changing (Nunn, 1990b). It is important to understand the details of past climate change in Tonga for several reasons. Firstly, it is important to examine how other variables, such as physical environment and human lifestyle, responded to particular climate changes and therefore, by analogy, to predict what is likely to happen in future. Secondly, it is especially important to know at what rate climatic variables (such as temperature and precipitation) changed in the past few decades so as to establish the antecedent conditions upon which future climate changes (resulting from the human-enhanced 'greenhouse effect') will be superimposed.

There is good reason to suppose that 200-300 years ago the climate of most of the central Pacific Basin including Tonga was significantly cooler (Nunn, 1991b). This was the time of the maximum of the Little Ice Age (approximately 1300-1850 AD) and since then temperatures have gradually risen. It may be that the temperature rise of the last few decades in the South Pacific is simply that marking of the end of the Little Ice Age, one of numerous natural oscillations of climate with ~500-year durations which have been superimposed on the much longer-term climatic oscillations marking the alternation between Quaternary glacial and interglacial periods.

Time series data from the Pacific islands suggest that temperature rise over the last 100 years has been of the order of 0.4-0.6°C. The longest series analysed (1887-1986) is from Government House in Suva, Fiji, where a rise of approximately 0.6°C is apparent (Nunn, 1990b). Data made available to us in Tonga suggest a comparable rise in mean temperature. The decadal average of annual mean temperature at Nuku'alofa was 23.6°C from 1950-1969 yet increased to 24°C in 1980-1989. It is equally instructive to look at the years in which annual mean temperature exceeded 24°C at Nuku'alofa: available records show these to have been 1950, 1952, 1970, 1981, 1984, 1988, 1989, 1990 and 1991. The last five of these years have been the hottest on record at Nuku'alofa. This suggests that the warming trend experienced in most other parts of the globe has also affected Tonga.

Owing to the influence of the Southern Oscillation, there is considerably more variability in rainfall records in Tonga (as elsewhere in the region) compared to temperature and no long-term trend can be isolated with confidence. It is believed that precipitation around the beginning of the Little Ice Age was less than today (Nunn, 1991b) but no trend is subsequently discernible. The recent increase in tropical cyclone frequency in the southwest Pacific (Nunn, 1991b) has presumably increased annual precipitation totals unless this has coincided with a recent increase in droughts. No data are known which allow such assertions to be tested satisfactorily.

3.3 Recent sea-level change in Tonga

Like temperature, there is good evidence in the central Pacific that sea level has also been changing over the past few thousand years. Nunn (1991a) showed that sea level in Tonga probably reached its present level around 6500 years ago, exceeding it by around 2 m subsequently falling to its present level. The conclusion now needs revision in the light of Ellison's (1989) analyses of pollen from mangrove sediments. This allowed her to fix the position of sea level on Tongatapu at -3.2 m and -1.7 m (relative to present mean sea level) respectively 6870 and 5650 years BP (Before Present). A sea level of around 1.5 m above present mean sea level is thought likely to have affected Tonga some 3000-4000 years BP. Since this time the overall trend of sea level in the Tonga region has been a falling one. Yet superimposed on this falling trend have been oscillations, most of which are believed to have been associated with minor climatic oscillations of the kind described in the preceding section.

For more recent times, data from New Zealand (Gibb, 1986) and American Samoa (Nunn, 1993) suggest that sea level fell at the start of the Little Ice Age, about 1300 AD, and since its maximum (the coolest time), some 200-300 years ago, has been rising. The long- term record (1906-1990) from Honolulu suggests sea level is rising at a rate of 1.5 mm/year, the Pacific mean is around +1 mm/year (Wyrtki, 1990).

No directly-measured data over a sufficently long time period to isolate a long-term sea- level trend are available for Tonga. It is crucial in areas like Tonga, where short-term fluctuations of sea level associated with the Southern Oscillation occur, that long-term trends are not identified prematurely. Probably the best information we have on sea level in Tonga over the past few decades is that presented by Nunn (1990c) using surrogate data. A sample was taken of long-established coastal settlements from the Solomon to the Cook Islands and interviews conducted by students from those settlements with their elderly inhabitants to find out how the shoreline had changed since the time they could remember. Only 7 sites were investigated in Tonga, including 3 on Niuatoputapu which is believed to be rising tectonically. The salient results are summarised in Table 2.

From Table 2 it can be concluded that in those comparatively stable parts of Tonga (i.e. excluding Niuatoputapu), shoreline inundation has been occurring at an average rate of around 10 cm/year for the past 77 years on average. The similarity of this figure to the regional mean suggests it is reasonably accurate. Although sea-level rise is not the only possible cause of this lateral shoreline inundation, the two are believed to linked in this case since the latter is a phenomenon observed throughout the region rather than just locally.

The other interesting conclusion from Table 2 is that Niuatoputapu is rising so fast that the effect of rising sea level is being reversed. The same is also true for many of the islands in Vanuatu, where uplift rates of 0.3-5.0 mm/year have been measured (Taylor et al., 1980). While rates for uplift of Niuatoputapu may also be within that range, most of the other Tonga islands are rising at slower rates. The island of 'Eua is rising at 0.033 mm/year (Taylor, 1978), the south coast of Tongatapu at a maximum of 1.6 mm/year (Nunn, 1993). It may thus be concluded, although no precise data are available for the islands named, that most of Tonga is not rising fast enough to offset the effects of current sea-level rise to any significant extent. Niuatoputapu appears the notable exception but this may change if the rate of sea-level rise increases in the future as predicted.

No data were found which would allow us to satisfactorily evaluate whether or not the wave climate of Tonga's coasts and reefs has changed recently. A similar statement can be made about the incidence of storm surges although, given the recent increase in tropical cyclone frequency in the region (Nunn, 1991b), it would be expected that storm surges have affected Tonga's coasts more frequently in recent than earlier decades of this century.

Table 2. Data referring to recent sea-level change in Tonga (from Nunn, 1990c)

Island	Settlement	Time Span of Data (years)	Direction of Sea-Level Change	Maximum Inundation or Emergence (m)	Rate of Inundation or Emmergence (cm/year)
Lifuka	Koulo	83	+	7.00	8.43
Lifuka	Pangai	68	+	8.00	11.76
Niuatoputap	Falehau	59	-	12.00	-20.34
Niuatoputap	Hihifo	58	-	10.00	-17.24
Niuatoputap	Vaipoa	60	-	14.00	-23.33
Vava'u	Ovaka	71	+	10.00	14.08
Vava'u	Pangaimotu	86	+	5.00	5.81

3.4 Current data acquisition in Tonga

The available data referring to the climatic and sea level of Tonga over the past few decades are few and generally inadequate to identify long-term trends. Yet in view of current concern about future climate and sea-level change, it is clearly desirable that better information becomes available on temporal changes in environmental variables in the future.

Meteorological data are collected at seven stations in Tonga. All but that in Nuku'alofa started in the 1980s. Analysis and archiving of these data are carried out by the New Zealand Meteorological Service in Wellington. Archival data are much less readily accessible now than in the past. Recommendations by Brook *et al.* (1991) include a strengthening of the meteorological network and more in-country data analysis. Identification and monitoring of long-term trends of meteorological variables is not in the mandate of most Pacific island meteorological services but will probably become increasingly so in the future. More data and in-country data analyses are clearly desirable. Initial analysis of the Nuku'alofa temperature data should be undertaken and results compared with those obtained from elsewhere in the region.

Sea-level monitoring is difficult in Tonga because of the islands' tectonic instability, particularly their proneness to abrupt vertical displacements during large earthquakes (coseismic-uplift events). It is probably for *this reason* that all the 1888 AD benchmarks on Tongatapu except one have disappeared. The latter has apparently been elevated by 0.1 m since 1888. The existing tide gauge at Nuku'alofa has been operating only since *June 1990* and is linked to the Tropical Oceans and Global Atmosphere (TOGA) global network. At present data from the TOGA gauge are analysed in Honolulu. A new "state- of-the-art" gauge supplied by the Australian government - capable of making much more precise measurements using the Greenhouse energy band - will also be installed in Nuku'alofa and linked to the Global Positioning System. Data from this gauge will be analysed in Adelaide. Other offers of sea-level monitoring have been made by Japan, Germany and New Zealand.

The question of whether improved and more sea-level monitoring facilities in Tonga will yield useful data appears to have been addressed only superficially although many of the people we spoke to are well aware of the problems. Specifically these are related to the likely ability of long-term trends of sea-level change being able to be identified from gauge data even after 30-40 years of monitoring. Much depends of course on how clear the future trend of sea-level change is but the limited information available from the recent past suggests that noise from El Niño events may also obscure a serial sea-level trend, particularly on Tongatapu.

The best illustration of El Niño noise is provided by the data from the currently-operating tide gauge at Nuku'alofa (Figure 3). Since August 1990, from which continuous data are available, mean monthly sea level has varied by 1.6 m. This is significant in Tonga where tidal range is generally 0.7-1.1 m.

Uplift rates of various parts of Tonga vary from 0.033 mm/year to at least 1.6 mm/year (see preceding section) and coseismic-uplift events with maximum magnitudes of probably around 1-1.2 m have occurred in parts of the group. The effects of coseismic uplift in the Nuku'alofa area and northern Tongatapu have been recognised by many investigators including Zann (1984) and Ellison (1989). Significant localised subsidence occurred in parts of northern Tongatapu during the 1977 earthquake, the magnitude of which was not among the highest on record for the island.

Assuming that tectonic effects such as those described can be filtered out of the gauge data, and allowance can be made for the effects of the Southern Oscillation, we estimate that at least a 40-year record will be required before a long-term trend of sea-level change can be isolated at Nuku'alofa. This assumes that sea level rises in the future at a rate approximating that predicted by the IPCC (see section 3.1).

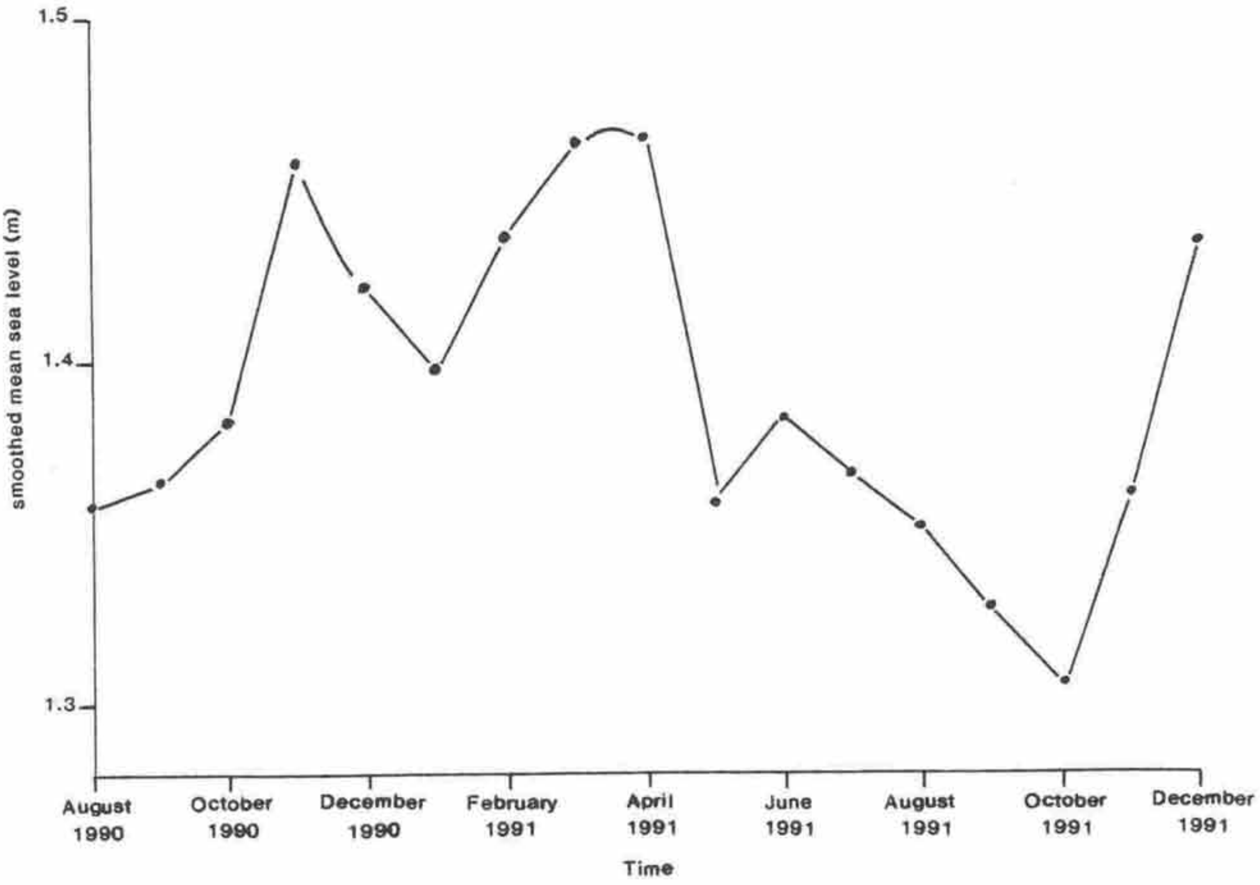

Figure 3. Mean monthly sea level at Nuku'alofa (data from Tonga Hydrographic Division)

4. Environmental Issues: Priorities, Awareness and Institutional Strategies[1]

> Economic development in Forum Island Countries and co-operation with donors has never been so paramount in the minds of Island Governments. For many, if no all, economic development is now the bread and butter of tomorrow's generations and those after them.-
>
> Alfred Sasako (Forum Secretariat)
> *Pacific Islands Monthly*, March 1992.

4.1 A question of priorities

Virtually all Pacific Island nations fall within the "relatively poor" or "very poor" categories using the parameter of GNP/capita (Atlaséco, 1989: 14-15). Further, their populations are in most cases predominantly rural and subsistence production constitutes a significant proportion of total economic activity. In the circumstances it is inevitable that economic development is, without exception, the primary preoccupation of national governments, donor countries and international agencies present in the region.

Tonga is no exception to this rule as the Pacific Islands Developing Countries' Report to UNCED indicates (Asian Devlopment Bank, 1992:104). Environmental issues rank low on the national agenda. In the final analysis they are important preoccupations for only a very small number of educated Tongans, some expatriates and one small Government administrative unit - the Environmental Planning Section of the Ministry of Lands, Survey and Natural Resources (MLSNR).

If the picture is beginning to change, it is purely because of external initiatives, where the environment is becoming an important issue on the global agenda,

For people and countries that are widely acknowledged to be located in "paradise" the idea of giving serious attention to environmental protection is, to say the least, perplexing. Environmental problems are considered to exist "elsewhere", in the industrialised countries and not on small Pacific islands.

Added to this is the fact that, compared with several other countries in the region, Tongans feel their country to be a "low risk" one. Tsunamis and earthquakes are extremely rare and few of the islands are true atolls.

These sentiments are voiced at all levels of Tongan society. Not surprisingly then, the present mission was received with some perplexity in both government offices and in more informal conversations with ordinary citizens. It was considered to be a "new,project" whose pertinence was far from evident and which required considerable explanation as a prelude to any discussion.

[1]. The observations made and the issues raised in this section are derived from the interviews conducted during the course of the mission to Tonga. The sentiments and opinions expressed do not always conform with statements made in official publications, nor are they necessarily empirically valid. However they appear to determine present priorities in the country.

4.2 The problem of understanding environmental issues

"Global change" is a concept which is extremely difficult to grasp and even harder to respond to. It is judged to be yet another phenomenon which originates and is defined from outside Tonga. Further, it is an entirely novel one, both in its configuration and in terms of the time scale associated with it. In other words, the notion that mankind is in the process of modifying the chemical composition of the atmosphere, which in turn is modifying the earth's heat balance, thereby modifying climate patterns, surface temperatures and so leading to an increase in sea level, defies comprehension for most human beings, Tongans included. In addition, given that such changes are occurring over decades, if not centuries, the ability to "feel" them is far from evident to say the least.

Compounded with this is the fact that, while scientists are able while to identify global trends, there is absolutely no consensus about the regional expressions of these trends. In the circumstances it is extremely difficult - if not impossible - for Tongans to understand the processes and to prepare for changes which are perceived as originating beyond the boundaries of their country. No one knows specifically what one can expect to happen in Tonga, beyond the fact that there will be "change". But, what kind, how much, when? The time scale is fundamentally different from that which modern planners are used to working with, The phenomenon is considered to be an entirely new one and past experience is of little help in addressing it. In the circumstances, how can Tonga and Tongans be expected to address it and prepare for it?!

It was even suggested on several occasions that the benefits may be positive, notably with regard to agriculture. Thus, Tonga's food crops are tropical and yet the climate is a sub-tropical one with a cool season which carries significant risks for subsistence production. If the temperature were to increase such risks might be reduced.... It was also suggested that sea level rise would "improve navigation" in the country!

4.3 " We don't know what is going to happen"

There is a widespread sentiment of powerlessness in the face of likely climate change and sea level rise. This is reinforced by the very limited amount of information available in the country and the extreme state of dependency it finds itself in. A certain amount of relevant data are generated within Tonga but research is often done in an uncoordinated manner and the results are invariably sent overseas for analysis.

The Meteorological Service is a good case in point. Rainfall and temperature records are kept assiduously but all the analyses are done by the New Zealand Meteorological Service in Wellington. Weather forecasting is provided by the Fiji Meteorological Service in Nadi, tsunami warnings come from Hawaii, etc.. In other words, relevant data are gathered but in no way controlled or interpreted. Hence there is no information generated in Tonga about climate trends or feeling about tendencies with regard to environmental issues.

Not only does the country not have the service of a climatologist, it has no seismograph ... and the Draughting Section of the Ministry of Lands, Survey and Natural Resources no longer has a complete set of topographic maps available for Tonga (because the printing of maps has now been transferred from the Directorate of Overseas Surveys in Great Britain to the private sector and demand is insufficient to justify new print runs...).

In other words, information is in some respects, getting increasingly scarce in Tonga in terms of both quantity and access. While the country is asked to make strategic decisions, it is becoming increasingly difficult to assemble and interpret the data in order to carry out the exercise in a responsible manner.

The present concern with sea level rise has resulted, within the last few years, in some five different overseas groups installing tide gauges in Tonga - including Russians, Germans, Japanese, Australians and Americans. Yet there are no coordination between the researchers, the data is analysed overseas and the Government of Tonga has limited access to the results. The concepts of dependency and marginality "apply to scientific endeavour and to the planning process with respect to global change as much as to the realm of economic development.

4.4 A certain fatalism

The fact that the present mission was frequently met with such remarks as "Well, do you think we will be sinking soon?!" and "God will help us" suggest that there are certain societal traits in Tonga which are of crucial significance to the Global Change issue. This sentiment was borne out by observations made by a number of people interviewed. Fatalism was suggested to be a marked Tongan character trait, and it is something which transcends a sentiment of powerlessness - of being citizens of a "poor", "small", "remote", "dependent" nation or, indeed, of being members of a well-structured, hierarchically organised society-. The country is steeped in a Methodist - Old Testament - tradition where God is to be feared and appeased. This leads to the sentiment of being protected by God and also punished by him, depending on whether one acts properly or improperly. Environmental issues are perceived by many people as fitting into this larger portrait of "God's will".

There are, of course, other religious traditions in the country which give much greater attention to the New Testament and which, by extension, are judged to be much less fatalistic. But the important point is that, as the Government must seek to more directly coordinate and influence the direction of environmental research, so the upper echelons of the Christian Churches need to become more aware of and involved in environmental issues such that they are infused into theological discussion. This is only just beginning in Tonga and it is not yet marked by any firm institutional commitment.

4.5 Tonga's environmental priorities

Although environmental awareness is relatively low in Tonga, this does not mean there is no environmental agenda. Rather, the major issues identified to the mission in the course of its visit are not related to Global Change. In this context, it was pointed out that the El Niño effect generates, on a short term basis, sea level changes comparable to those likely to characterise long-term sea level rise, and their consequences are not disastrous in Tonga.

As to be expected, the environmental issues of concern to the country are those directly related to population pressure and short term development strategies. These include:

- The over-exploitation of natural resources (forest and marine),
- The increasing use of pesticides, and their influence on groundwater quality,
- Coastal erosion, largely as a result of the exploitation of beach materials for construction purposes,
- The risk of oil seepages consequent on the eventual commercial exploitation of oil,

These are all tangible issues, the impact of which is already being felt or is likely to be experienced in the immediate future. In comparison, climate change and sea level rise are merely matters for speculation. In a context in which resources - human and financial - are in short supply it is scarcely surprising that scant attention be given to the latter.

4.6 Institutional arrangements and the environment

As one informed Tongan pointed out: "I have never been to a kava party where people talked about global warming" and as another civil servant dealing with environmental issues complained: "The environment has no teeth" (refering to the weakness of the environmental lobby in the country).

They are two dimensions of a single reality. Preoccupations are short-term, vested interests are in developmental issues, and global change is an abstract concept operating on a very long time-scale.

Tongan civil servants frequently attend international meetings dealing with global change issues, but they are basically there because the international community is concerned that Tonga be represented. In other words, their role tends to be a reactive rather than a proactive one. This only increases the difficulty of translating the information so acquired into policy decisions to be implemented by the Tongan administration.

The small Environmental Planning Section of the MLSNR is a very active (and technologically sophisticated) unit, but its agenda is determined mostly the priorities of external funding bodies, its efforts are directed largely to site-specific conservation issues, it does not have a coordinating role within the country, and it has little influence on overall Government policy and planning. Interestingly enough, it was initially conceived as a Parks and Reserves Office in the late 1970'a and this vocation continues to mark its activities.

Over and above these two simple observations, it is important to stress that, one, environmental issues are dealt with at a very low level in the Tongan administrative hierarchy and, two, Tonga is (as was often stressed) "a country of personalities, not a country of bureaucrats", Both have important consequences for decision-making. One, it tends to be highly individualistic and, two,it tends to move from the top down.

For global warming and sea level rise issues to figure more highly on the national agenda certain, specific, action needs to be taken. Firstly, awareness of the issues needs to be increased, particularly in the higher echelons of the religious and social hierarchies. Secondly, efforts need to be made to strengthen the Environmental Planning Section, notably by withdrawing it from the MLSNR structure. Thirdly, an independent environmental pressure group needs to be established in Tonga, perhaps along the lines of the South Pacific Action Committee for Human Ecology and the Environment (SPACHEE) - an NGO which can generate information and awareness and intervene outside the structures of contemporary Tongan society and polity. There are, of course, two important NGOs already in Tonga which do deal, tangentially, with environmental issues, the Tongan Red Cross and the Foundation for the Peoples of the South Pacific, but they tend to focus on disaster preparedness and response rather than address long term environmental issues.

Such observations involve "radical" changes which may well be slow in coming. Other changes, based on existing administrative structures, would greatly facilitate the adoption of a more creative approach to environmental, and particularly global change, issues. The most important would involve reviving and reorganising the Disaster Committee. This committee was designed as a purely reactive body - to respond to disasters - comprising representatives of the Police and Defence Departments and appropriate ministries. It is under the direction of a military office and, in the absence of disasters, is presently moribund. It could, appropriately, be revived and assume a pro-active role, addressing potential environmental problems, act as a clearing house for environmental issues and coordinate research and action. Tonga urgently needs such a body. The Environmental Planning Section could then become its administrative arm.

At the same time, the presently largely inactive Interdepartmental Environment Committee might be absorbed by it - or become tributary to it - and the revised body report directly to Cabinet in much the same way as the Development Coordinating Committee presently does.

The Interdepartmental Environment Committee was, of course, created for the purpose of preparing the *Environmental Management Plan for the Kingdom of Tonga* (1990) and, significantly, the principal recommendation of that report was that the committee be established on a permanent basis, enlarged and attributed the role of co-ordinating environmentally-oriented government action.

Finally, in response to member-country requests, SPREP has been promoting the formation of National Environment Management Strategy (NEMS) task forces. The purpose of such a task force, in Tonga, as in the other countries, is to assemble a team of interdisciplinary experts to address priority environmental areas and report directly on them to Cabinet.

At the time of writing, it is not clear whether the NEMS tasks force is operational, nor is it evident to what extent its mandate is significantly different from that of the Interdepartmental Environment Committee. Efficiency might be increased through integrating the latter into the NEMS task force.

Nevertheless, from a strategic point of view, the developments are important. Three committees are now juxtaposed at a high level in the Tongan hierarchy - the Interdepartmental Environmental Committee, the Development Coordinating Committee and the NEMS task force - which, together, address the whole span of environment/economic/developmental issues. Such a structure has the potential to reflect the aspirations of the recent UNCED meeting in Rio and ensure a healthy dialogue between environmental and developmental concerns with a view to achieving fully sustainable economic development that would be in the long-term interests of the Kingdom of Tonga.

5. Likely Impacts of Future Climate Change and Sea-Level Rise

The likely physical and human impacts of future climate change and sea-level rise on the Kingdom of Tonga cannot be assessed independently from the likely impacts of other contemporary environmental changes. In the discussion below some effort is made to integrate impacts of future climate change and sea-level rise with those of the other environmental problems noted in Chapter 3.

5.1. Inundation

While it is simplistic to think of inundation as the only important consequence of sea-level rise, even a rise of 44 cm, such as the IPCC predict by 2070, is not insignificant in the Pacific islands. It is, however, clearly less significant in a country like Tonga, which is comprised mostly of high islands and where uplift predominates, than it is in atoll nations like Tuvalu and Kiribati.

Within Tonga, the lowest islands occur in the Ha'apai group. Some rise no more than 5 m above mean sea level and are composed of superficial materials (sand and coral fragments) accumulated on a modern reef flat commonly around a core of emerged reef. The latter makes these islands much less vulnerable to destruction by storm waves or rising sea level than most true atoll motu (sand islands). The latter occur on many of the major barrier reef systems in Tonga but few are inhabited except in the Tongatapu lagoon. Owing to their low population densities and superficial composition, direct inundation of these islands is likely to be less of a problem over the next few decades than the increased amount of coastal erosion associated with sea-level rise.

Direct inundation will be a significant problem in those low parts of the larger, higher islands in Tonga. Principal among these areas will be the densely-populated parts of northern Tongatapu from Sopu through Nuku'alofa to Popua. Many of these areas are already swampy and may remain flooded for longer periods following storm surges or prolonged heavy rain. Seawall and similar shoreline protection structures are no barrier to inundation resulting from sea-level rise on limestone islands like Tongatapu and it seems certain that sea-level rise of the magnitude predicted by the IPCC for the next few decades will cause widespread inundation of the island's northern parts.

Some rudimentary calculations of the areas of land likely to be inundated in the Nuku'alofa region if the sea-level rose by 1.5m [2] were made by Nunn (1988). The relevant map is shown in Figure 4.

Area N1 is the city centre. Land loss through direct inundation by land use would be in the following proportions: commercial (75.6%), Royal Palace and Tombs (17.1%), open space (5.4%) and residential (2%).

Area N2 is the port area of Nuku'alofa and includes many hydrocarbon storage facilities and is the site of much light industrial manufacturing. Land loss would be in the following proportions: residential (40.6%), agricultural (15.9%), industrial (11.3%), commercial and port (7.7%), mangroves (1.1%), and others (23.4%). Wharf facilities will clearly need building up if they are to remain viable.

Area N3 is a representative area of suburbs bordering the Fanga 'Uta lagoon. The shoreline here is not seawall-protected but fringed by mangroves and the debris of human occupation. Nearly half the area would be directly inundated were sea level to rise 1.5 m. The effects of moating would amplify the effects on ocean-facing coasts by about +0.15 m in the lagoon. By land use, land loss would be roughly in the following categories; residential (96.2%), mangroves (2.5%), agricultural (0.5%), commercial (0.2%), and others (0.6%).

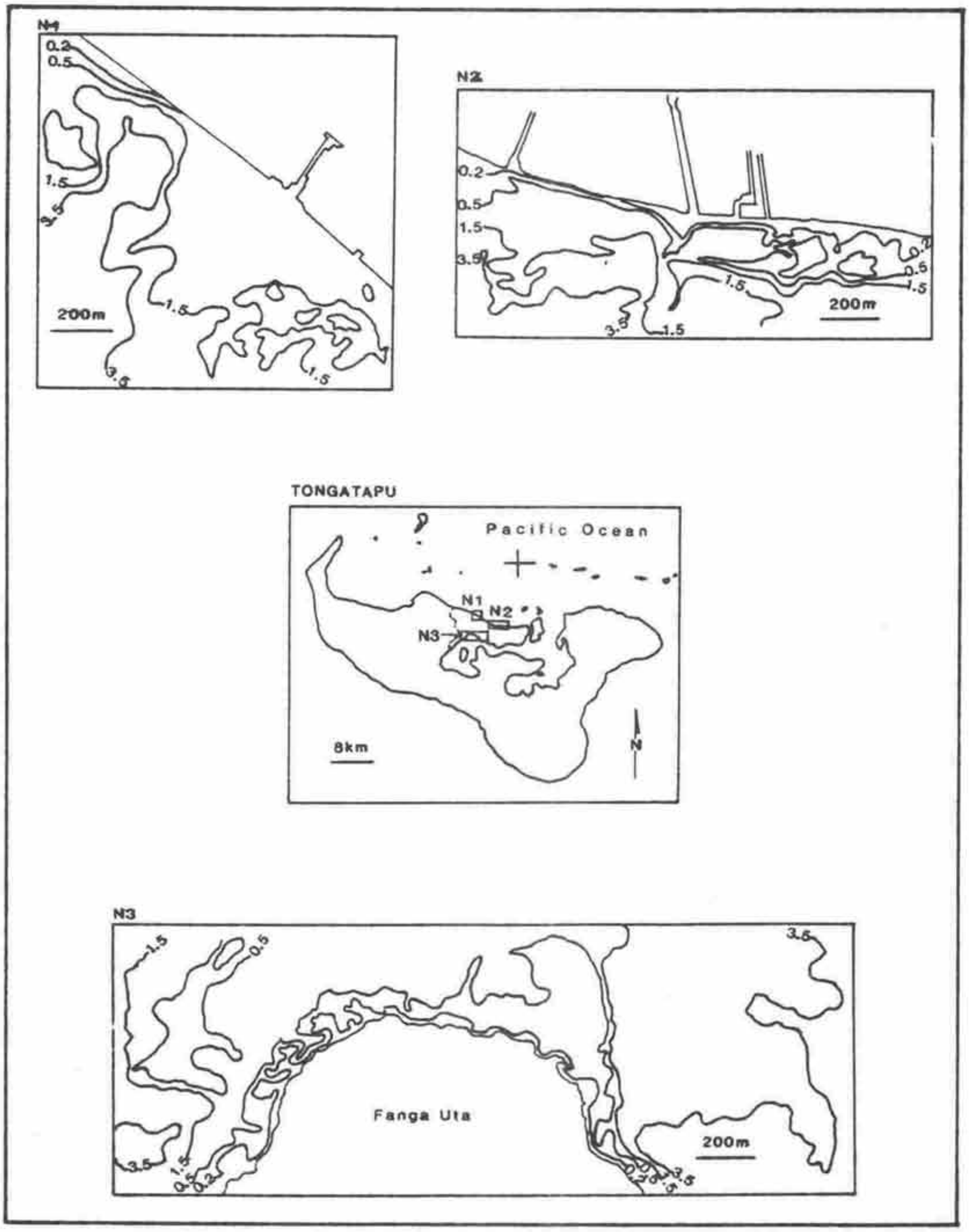

Figure 4. Nuku'alofa, Tongatapu. The location of Nuku'alofa is on the central diagram which shows Tongatapu; Nuku'alofa is bounded by the broken line, the cross represents the point 175°10'W 21°05'S. The three squares (N1, N2 and N3) represent case studies: N1 - central Nuku'alofa, N2 - port area, N3 - representative suburb

5.2 Groundwater resources

Most groundwater in Tonga exists beneath the surfaces of the limestone/permeable islands as freshwater lenses. The upper surface of the freshwater lens is the water table. Extraction from wells drilled into the freshwater lens results in its depletion, as does natural outflow around its periphery. Recharge in the form of rainfall is necessary to maintain freshwater lenses. Mean annual recharge under present demand conditions necessary to maintain the Tongatapu lens has been calculated as 528 mm or 30% of mean annual rainfall (Unpublished data, Ministry of Lands, Tonga).

If sea level rises as predicted, the water tables of island freshwater lenses will also rise. On a limestone island, the freshwater lens is widest at around mean sea level. Its domed surface (the water table) rises above mean sea level and may cause (freshwater) flooding on low islands in Tonga before sea level has reached the same height. Yet given the general character of Tongan islands, this is likely to be a problem in only a few places - in Ha'apai, in northern Tongatapu, and along the broad coastal (emerged reef) fringe of Niuatoputapu, for example.

In such places, greater mixing between fresh and saline water may result from increased tidal ranges associated with reef overtopping and this will reduce the volume of the potable freshwater resource. Yet, for the next two decades, fears expressed to us about pesticide pollution of groundwater resources seem much more legitimate causes for concern and action. Most of Tonga's high islands have large groundwater resources which could supply even higher demands than they do at present. *Assuming that recharge remains around present levels and the incidence and/or duration of droughts do not increase significantly*, there seems little need for immediate action. This assertion cannot be qualified since appropriate data are not available. If, as seems likely, precipitation throughout Tonga increases in the next few decades, the rates of recharge of island freshwater lenses are also likely to rise.

5.3 Impacts on coral reefs

Coral reefs are integral parts of the marine-littoral ecosystem and shoreline dynamics system in Tonga. Any change in their present function as the result of future climate change and sea-level rise will have consequences for the human and physical fabric of the islands.

If sea-surface temperatures increase above a certain point, corals may eject their symbiotic algae (zooxanthellae) resulting in 'bleaching' which may in turn result in widespread death of corals. It was long believed that bleaching was a simple response to temperature rise but it is now known that it is a response to the increase of stress on the ecosystem; stress which may be the result of high temperatures but also other factors relating to oceanographic variables such as salinity or to human-linked factors such as overexploitation, sedimentation or waste disposal. In other words, although widespread reef death may occur as the result of rising sea-surface temperatures in the future, the healthier a particular reef ecosystem is, the less likely it is to succumb to bleaching. It is difficult to predict what might happen in Tonga since "more data are required [on] the biological condition of the reefs" (National Report to UNCED, 1991: 30).

The ability of coral reefs to respond to sea-level rise by upward growth is another hotly- debated issue. We take what seems to us the most tenable view that since reefs reached close to present sea level, some 3000-4000 years ago in Tonga, they have been growing laterally rather than vertically. This change is not only one of form but also of species composition: Pacific reefs are dominated now by species involved in lateral reef extension rather than the species which dominated during the main postglacial sea-level rise when reefs were growing vertically. We regard it as unlikely that the species composition of Tongan reefs would change rapidly enough to offset the effects of sea-level rise on Tonga's coasts over the next 50-100 years (Nunn, 1991a).

Changes in species composition brought about by sea-level rise would also be hampered by increasing stress associated with rising sea-surface temperatures, increasing human impact and pollution. It seems probable that Tongan reefs will not respond to rising sea levels over the next 50-100 years so that their important function in protecting island shorelines will be significantly reduced if sea level rises as predicted.

5.4 Impacts on island lagoons and shorelines

Overtopping of coral reefs has two principal implications for islands in Tonga. Firstly, it means that larger waves than those which presently cross reefs will be able to do so, resulting in increased scour and sediment movement in lagoons and along island shorelines. This will increase the vulnerability of the latter to erosion. It will also cause more physical damage to the reefs themselves.

Secondly, it means there will be an increased exchange of water and sediment between the ocean and the lagoon-shoreline system. The effects of this are likely to vary considerably. Where present reefs form discontinuous barriers, as in Tongatapu and Vava'u, little change seems likely. On islands which are surrounded by more continuous reefs, the effects could be substantial. Net sediment loss from the island lagoon-shoreline system to the ocean, particularly during and after storm surges (when a lot of material is in suspension), seems the most likely outcome.

Island shorelines will also be rendered more vulnerable to erosion following sea-level rise as the result of the Bruun effect. This is the idea that many shorelines have developed an equilibrium profile (morphology) relative to present mean sea level and tidal character, and that any change in sea level (and/or tidal character) will cause adjustment of this profile. Sea-level fall results in a seaward shift of the profile, sea-level rise in a landward shift producing erosion. That 70% of the world's sandy coastlines have been eroding recently (Bird, 1985) seems credible proof of the Bruun effect given the recent sea-level rise in most parts of the world.

The magnitude and rate of shoreline erosion as the result of the above factors will depend largely on the vulnerability of a particular coastline. Many coastlines in northern Tongatapu, including the Fanga 'Uta lagoon, are fringed with mangroves: others have broad beaches developed along their fronts. Both mangroves and beaches provide a high degree of natural protection against rapid shoreline erosion. In the same way, well- designed artificial structures, such as the Nuku'alofa seawall, can protect shorelines, against significant erosion (although not sea-level rise). Badly-designed seawalls may, however, exacerbate the effects of shoreline erosion or simply cause it to shift it elsewhere.

The most vulnerable part of Tonga to future erosion associated with sea-level rise appears to be northern Tongatapu, specifically along the lagoon-facing shores of the Kolovai peninsula all the way east to Sopu (where the seawall begins), and then from Nuku'alofa (where the seawall ends) eastwards all the way across the entrance of the lagoon to the north-facing coastline around Kolonga. Many of the Ha'apai island shorelines are likewise built largely of superficial materials and are therefore also highly vulnerable to erosion associated with sea-level rise.

Clearance of mangroves or removal of beach sand from shorelines will render these more vulnerable to erosion. The extent of mangrove clearance around the shores of the Fanga 'Uta lagoon on Tongatapu is alarming. We visited several sites including that adjoining the Ambassador Bar where mangroves have been cleared and reclamation has taken place. Such sites are very vulnerable to erosion in their present condition and, unless some artificial protection is put in place, may not survive more than a few years. We also examined the H4 (Hihifo) reclamation works lagoonwards of Fo'ui village in western Tongatapu where the mangrove fringe, which lies between the reclamation and the lagoon, remains intact. Local residents fear that clearance of the scrubland between the mangroves and the village will exacerbate storm-wave damage in this area. The proposed extension of the H4 reclamation scheme into the lagoon should take likely changing conditions into account.

Sand mining from Tonga's beaches is a serious problem and one which needs to be effectively tackled if coastal erosion resulting from sea-level rise is not to be severe (National Report to UNCED).

6. Conclusion and Recommendations

We encountered considerable misunderstanding concerning the nature and likely impacts of future climate change in Tonga. This needs to be remedied if the government and people of Tonga are to successfully negotiate the undesirable effects of future climate change which are predicted for the islands of Tonga.

We **recommend** that

1. the Environmental Planning Section of the Ministry of Lands, Survey and Natural Resources be made an autonomous body, answerable directly to the Privy Council. The Environment Unit would also need to coordinate information about future climate change sufficiently effectively to remove the misunderstanding that exists.

   We feel that the Environmental Planning Section presently concentrates too much of its energy on engendering general environmental awareness and on strategies for the conservation of natural resources in specific localities. While we recognise the importance of these functions, we feel that it is duplicated by a number of non-governmental organisations, and that the more-important (in our view) role of the Environment Planning Section should be as a clearing-house for information about future climate change and its likely impacts. We recognise that this role cannot be adequately fulfilled given present staffing levels.

2. a professional funded via SPREP be attached to the Environmental Planning Section. The principal task of the appointee would be to assemble, evaluate and disseminate information relating to future climate change in Tonga. The assembly of information relates to reading of relevant documents and collection of available data. Evaluation relates to the culling of relevant information and basic analysis of key sets of data. The most important part is dissemination in Tongan and English of clear, non-alarmist information about the likely impacts of future climate change in Tonga.

   We recognise that some of this work is in progress and we recognise the good intention behind its dissemination but we saw little evidence of its effectiveness. We attribute this to the few staff which the Environmental Planning Section presently has at its disposal.

3. two additional staff, educated to *at least* University-entrance level, be employed by the Environment Planning Section. These people will have the responsibility of assisting the senior staff of the Environmental Planning Section and in seeing that information is widely disseminated and correctly interpreted. We envisage these staff as travelling throughout Tonga with mobile display boards and giving presentations in appropriate places. We envisage these staff as conducting 2-3 day (or longer) workshops in Nuku'alofa specifically on the nature and likely impacts of predicted future climate change.

   There are other activities and projects which we feel are highly desirable. We feel that these are best carried out by members of an autonomous Environment Unit or by another body which can report directly to the Privy Council.

4. population distribution and land use in the main islands of Tonga is accurately mapped, notably with respect to altitude. This will allow the precise delineation of the most vulnerable areas and accurate knowledge of the numbers of people and economic activities at risk from rising sea level and increasing coastline vulnerability.

   Such data are important for future planning irrespective of the precise nature and pace of future climate and sea-level change. Further, data need to be evaluated and acted upon.

5. the National Environment Management Strategy (NEMS) task force should meet regularly to assess and evaluate the results of the collection of such data. The Disaster Committee might also become involved in this process, thus taking on a pro-active rather than simply a re-active role.

   We feel that it is important that the NEMS task force be vested with sufficient authority to be able to make strong recommendations directly to the Privy Council.

6. the Interdepartmental Environment Committee be absorbed by NEMS task force to reduce the duplication of effort and to increase efficiency, .

In addition to the above general recommendations we have several more specific recommendations.

7. information about appropriate seawall design is collected and disseminated. We saw numerous examples of failed shoreline protection structures obviously constructed without guidance from appropriate professionals. The need for artificial shoreline construction is already pressing in parts of Tonga and will become more so in the future.

8. mangrove (and associated shoreline vegetation) clearance is curbed by legislation and that mangrove replanting schemes are undertaken in appropriate areas.

9. current legislation concerning coastal sand mining is enforced and that severely-depleted beaches are replaced, where possible, by sand and/or gravel from offshore sources.

10. assessment be made of the adequacy and resilience of current water supplies in the smaller, lower and remotest islands of Tonga, particularly in view of likely future changes in population and climate.

11. involvement in existing and new regional studies to enhance salt tolerance and increase yields of both traditional and exotic crops and in general make them more tolerant to probable future environmental conditions, particularly in low-lying areas.

12. a national strategy be developed with regard to future climate and sea-level change over and above existing strategies. Specifically we suggest that this strategy looks at methods of reducing migration into vulnerable areas, reducing the existing population concentration in these areas, and establishing new population growth poles in areas (such as exist on both Tongatapu and Vava'u) which are not significantly at risk from future sea-level rise and coastal erosion. A clear implication of this is reducing the metropolitan dominance of Nuku'alofa.

Projected costings to 1995 are given in Annex 3.

There are many functions, such as national involvement in regional and global organisations and meetings, which we feel are being adequately performed by Tonga and Tongan government personnel at present. Such functions do not therefore form part of our recommendations.

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Annexes

Annex 1: Persons spoken to during Tonga visit.

(All persons were seen on Tongatapu unless stated otherwise.)

Ministry of Lands, Survey and Natural Resources
Mr. Tevita Puniani, Deputy Secretary
Mr. Taniela Tukia, Physical Planner
Mr. Francis Latu, Government Surveyor
Mr. Lindsay Furness, Hydrologist
Mr. Saimone Helu, Geologist
Mr. Samisone Pone, Chief Draughtsman
Mr. Paula Tau'ofa, Environment Unit
Mr. Stephen Bobko, Environment Unit

Meteorological Office
Mr. Paea Havea, Meteorological Officer

Department of Statistics
Mr. Sione Mosa'ti, Government Statistician

Department of Agriculture
Mr. Haniteli Fa'nunu, Director

Department of Fisheries
Mr. Tualau Mangisi, Director

Ministry of Defence
Mr. Rod Davies, Hydrographic Division

Public Works Department
Mr. Les Mathews, Architect

Ministry of Education
Ms. 'laise Tongilava, Ministry of Education
Ms. Kasa Kilioni, Examinations
Mr. Felise Tonga Finau, Apifo'u College
Mrs. Telesia Tonga, Form 7 College
Brother Christopher, St Joseph's College, Ha'apai
Staff and Students of Apifo'ou College
Staff and Students of Tonga College
Staff and Students of Form 7 College
Staff and Students of Tonga High School
Staff and Students of St Joseph's College, Ha'apai

Others
Mr. Futa Helu, 'Atenisi University
Mr. Laitia Fifita, Tonga National Council of Churches
Mr. Akilisi Pohiva, Parliamentarian
Mr. Viliame Fukofuka, Parliamentarian
Mrs. Vika Lutui, USP Centre
Mr. Na'a Fiefia, USP Centre

Annex 2: Terms of reference for the mission to Tonga

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 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 Climate 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 (eg. 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 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, the experts will prepare a joint report containing:

   (a) a general overview of the climatological, oceanographic, 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 the 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 3 above, will be simultaneously submitted to the Chairman of ASPEI, the Director of OCA/PAC and the SPREP Director for 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 formulating and implementing suitable response options to the expected impacts of climatic change.

Annex 3. Projected costings for key recommendations, 1993-1995.

	$AUS
Professional for Environmental Planning Section	
• Salary, support costs, etc.	60,000
2 additional staff for Environmental Planning Section	
• Salaries, support costs, etc	60,000
• Vehicle for Environment Unit	30,000
In-country educational programmes	30,000
Population mapping project	20,000
Upgrading of in-country meteorological data analysis	
• Computer hardware	10,000
• Additional staff (salary, etc.)	30,000
Study of appropriate artificial shoreline structures	15,000
Water supply assessment in selected areas	35,000
Crop study (share of regional costs)	15,000
Evaluation of potential new growth poles	
• Consultants' fees and report	50,000
Total	**355,000**