TROPICAL CYCLONE ‘ISAAC’

CYCLONIC IMPACT IN THE CONTEXT OF THE SOCIETY AND ECONOMY OF THE KINGDOM OF TONGA

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DISASTER INVESTIGATION REPORT

No. 5

CENTRE FOR DISASTER STUDIES

James Cook University

of

North Queensland
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Cyclonic impact in the context of the society and economy of the Kingdom of Tonga

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September 1982
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1 INTRODUCTION

Tropical Cyclone Isaac threatened and devastated different parts of the Kingdom of Tonga, 2/3 March 1982. The impact of the cyclone was extensively reported in Australia by television, radio and the press.

The Centre for Disaster Studies at James Cook University has, as one of its several objectives, the provision of assistance in any appropriate manner to countries and communities in neighbouring areas of South-east Asia or the western South Pacific that are natural disaster-prone or affected. In pursuit of this objective the two authors of this investigation report visited Tonga arriving in the southern and largest island, Tongatapu, on 8 March. In the ensuing eleven days of the visit up to 18 March extensive field surveys were made of the capital city, Nuku'alofa and of the villages of Tongatapu in addition to discussions with a number of government representatives concerned with dealing with the emergency phase of the disaster and the early stages of rehabilitation. We had the opportunity to meet those manning the Emergency Operations Centre including the Hon Dr S. Langi Kavalia, Minister of Works and Education, who was in charge of the relief and rescue operations. We were also able to be observers at the overseas aid co-ordination meetings organised and chaired by the Australian High Commissioner, Miss Maris King. These particularly facilitated our appreciation of the problems that followed immediately after the cyclone. The range of observations was extended, through the courtesy of the Tongan Red Cross which permitted the two authors to join the relief voyage of the chartered ferry boat Eleanor May, to several of the islands of the Ha'apai group. This voyage ended for the authors at Pangai, the capital of the island of Lifuka.

The length of the impact survey was inevitably limited by the availability of funds and the time that two investigators could devote to the task. We also faced difficulties in arranging travel to the islands.

Although the time which could thus be utilised for the survey made it impossible to probe all aspects to the depths desired and limited the analysis to only the earliest stages of recovery, it is considered that the information collected and the direct impressions derived have made it possible to present findings which will illuminate the particular
characteristics of a tropical cyclone disaster in a society which in socio-economic terms is in a development stage. Whilst undoubtedly every area or country has its own special physical or human qualities which result in a particular hazard or a disaster event having unique features, a study such as is presented here has the potential to assist the better understanding of disaster events and to provide guidance which can improve preparedness and mitigation.

2 COMPARATIVE ANALYSES OF NATURAL HAZARDS AND DISASTERS

There are some general characteristics which can be recognised in the nature, behaviour and type of impact of specific categories of natural hazard. There are, additionally, local or unique physical features that must be recognised. Likewise the nature of human response and the adoption and application of appropriate strategies to deal with actual or potential hazards demonstrate many basic principles and common characteristics, yet there are circumstances which are specific to a given society or country. The fact that at least some of the conditions affecting the nature and response to a hazard or disaster relate to local as well as to general factors supports the claim that comparative disaster studies have an important contribution to make towards improved disaster management and planning.

A distinction has been made (White, 1974) between the types of response to natural hazards involving different levels of a community's technological resources and socio-economic sophistication. Tonga can be placed in the first of the types, a folk or pre-industrial category, though where the first stages of urbanisation are taking place at Nuku'alofa some elements of the next type, the modern technological or industrial category, may be increasingly identifiable.

The context in which the impact of tropical cyclone Isaac must be analysed is that of a developing society located in a relatively isolated situation with limited technological and economic resources and with particular forms of social and economic sensitivity to disruption due to natural environmental stress. The insular nature of the Kingdom is particularly relevant. It must also be noted that Tonga is subject to a range of natural hazards - tropical cyclones, earthquakes, volcanic eruptions, tsunamis, droughts and even, locally, small tornadoes.
3 THE GEOGRAPHICAL SETTING

3.1 Physical Geography

The Kingdom of Tonga comprises about 169 islands located in the South Pacific and spread over an area of 363,000 square kilometres between 15°S and 23.5°S and 173°W and 177°W. Thirty-six of the islands are inhabited. The total land area of the islands is only 668 square kilometres and the approximate population is 96,400 of which 65,000 are located on the island of Tongatapu which comprises about half the total land area of the Kingdom. Tongatapu extends about 34 kilometres in its longest east to west axis and 15 kilometres north to south.

The islands of Tonga are mainly in three groups, Tongatapu in the south, Ha'apai in the centre and Vava'u in the north. Further to the north (300 kilometres or more), north-east and north-west of Vava'u, are the Niulas, notably Niutoputapu and Niuafo'ou. The distance from Nuku'alofa to Lifuka (the regional town for the Ha'apai group) is about 175 kilometres and to Neiafu (the main town and port of Vava'u) about 340 kilometres. The Tongan islands are approximately 650 kilometres south-east of Fiji.

Broadly three types of islands make up the Kingdom:

(a) Volcanic islands are characterised by upstanding relief with a few low coastal areas but more commonly cliffed coastlines. These islands are predominantly located north and west of the other Tongan islands.

(b) Raised volcanic islands primarily of volcanic tuff or breccia with incorporated coral rocks and based on submarine plateaux less than 90 metres below sea level.

Several of the islands making up the south-east of the Ha'apai group plus 'Eua (east of Tongatapu) are of this type.
(c) Coral islands many of which are raised atolls or barrier reefs.

Many of the islands of the Tongatapu and Vava'u groups, the northern islands in the Ha'apai group and also Nomuka come into this category. They are often surrounded by barrier or fringing reefs which afford some protection against storm surges and high waves or tsunamis.

Both types (b) and (c) are comparatively flat with substantial coastal margins below 5 metres and mostly with altitudes not exceeding 50 metres. Some of the island coasts are cliffed (especially the coasts oriented outwards from the centre of Tonga) though elsewhere the low-lying coasts are potentially at risk from raised sea-levels. For example, much of the north coast of Tongatapu is not far above high-tide level. The south-west and central coast is low and rocky, but further east from the centre, limestone cliffs about 11 metres above high water occur with a wave-cut platform of finely cemented limestone 30 - 60 metres wide at their base.

Except on 'Eua there are no permanent streams. In many cases there is no fresh surface water, though underground flows or springs on the beaches indicate the presence of subterranean fresh water in some of the coral islands. More often shallow wells reach brackish water or fresh water lenses, if they occur, are too thin even to support wells. In such circumstances water must be collected from the roofs of buildings and stored in cisterns and is directly dependent on the rainfall.

The natural vegetation of most of the islands has been replaced by coconut plantations or crops. This change continues with increasing population and growing land pressure. Forests, of limited commercial value cover about 15 per cent of the land especially in 'Eua, Vava'u, Tofua and Late islands. Whether cultivated or natural, trees dominate most vegetation covered areas and contribute some shelter to what otherwise are very exposed areas. This point will be examined again in a later section.
3.2 Socio-economic Features

3.2.1 General

Since man is a necessary component in any hazard or disaster situation, response to environmental stresses will reflect the social and political institutions and organisations of the affected society, many of its demographic characteristics and the economic infrastructure. Many of the considerations involved under this heading have features that are unique to the particular political and socio-economic systems involved. It is they that make it necessary often to consider disaster management strategies within a specific context. This is not to say that general principles and understanding derived from world-wide experience are irrelevant but it does mean that modifications are required to suit local institutions.

3.2.2 Food

Tonga has a basically subsistence agricultural economy. Copra and to a minor extent bananas, vanilla and some vegetables and watermelon provide the main exports and with tourism earn foreign currency. Although internal cash exchange is growing considerably at the village level the basic objective is to provide the daily food supply which depends upon root crops (yams, taro, sweet potato and cassava), tree fruits (breadfruit, custard apple, orange, pawpaw, mango) and plantain and banana. Coconuts, which cover about half the land area of Tonga, are important both for domestic use and to provide the copra and some desiccated coconut for export. Maize is the cereal most suited to the area but is not grown on any significant scale. Other economic plants include pandanus, paper mulberry, sugarcane and a widely distributed cultivation of tobacco and kava (Piper methysticum).
Although droughts are not unknown and are sometimes serious, the climate (both temperature and a reasonably well-distributed rainfall) favours all-the-year-round growth with little need for storage since supplies are usually always forthcoming. Indeed many of the traditional foodstuffs do not store well. It is only in times of interruption of supply, such as wind damage from tropical cyclones, that the customary pattern of food production becomes vulnerable.

Severe wind damage, especially to wind sensitive products such as breadfruit, pawpaw and bananas, can cause supply difficulties which persist for several months or longer. Coconut palms can stand high winds though the nuts may be shed and the foliage bruised so that yield takes two or more years to recover. Even severe winds probably uproot or irrecoverably damage the growing shoot of only a small percentage (5-10 per cent) of the palms, though in small and badly devastated localities this loss may be exceeded.

In the case of root crops, which are often intercropped under the coconut palms, wind damage can severely affect the foliage. However, since the plants grow near the ground and are often sheltered by taller plants around them, such effects tend to be more localised and in very exposed locations. If the leaf damage is considerable the underground tubers can rot, especially when they have not grown to maturity. Six or seven months have then to pass before a new crop can be planted and is ready to yield, and shortage of replanting material may delay the establishment of a new crop. If local sources of planting material are unavailable it is difficult to import it from elsewhere for several reasons, one of which is the quarantine situation essential to avoid bringing in plant disease.
Cassava is more vulnerable than yams or taro and, with its taller but brittle stems, can be broken down or even blown out of the ground. A partial solution to reduce wind effects is to cut the stems down before the cyclone arrives. This presupposes not only sufficient time to carry it out but also a considerable degree of belief in the inevitability of severe winds affecting the area.

Food shortages of varying degrees of severity inevitably occur after a severe cyclone. The normal dietary pattern is such that shortages in local food supplies are not readily substituted for by imports or relief supplies. Many local needs are for items that rarely enter into international trade and of which local surpluses (even if other areas close by escape severe damage) are usually very limited.

In the meantime local exchange and trade are upset. Such economic disruption can be compounded if food relief is distributed on a free basis since this can undermine the normal commercial pattern. On the other hand when villagers lose their capacity to earn cash they are unable to find money to purchase foods to replace their normal production.

Fishing is an important part of the domestic economy. Fish and shell fish provide an additional basis for exchange or trade and an important source of protein in a high carbohydrate diet. Rough seas, storm surges and high winds cause losses of boats and of outboard motors or damage coastal fish traps on the fringing reefs. Replacement of these facilities requires finance and other resources which may not be available at village level.

In economic terms material or financial reserves are limited or non-existent at village level. If a tropical cyclone causes severe losses it is difficult or impossible without government help to recover the
situation. It may be equally difficult unless overseas relief is forthcoming for the government to provide relief on a large scale.

3.2.3 Social system

The social system of any country plays a significant role in the way the individual, the community and government at different levels deal with the consequences of disaster. Tongan society tends to be conservative, conscious of rank and influenced by tradition. But no society is static and changing circumstances and adjustments make generalisation of this sort somewhat dangerous. Marcus (1977) suggests that in cultivation and other ways families have become more individualistic, for instance working their own 8 1/4 acre (3 1/3 ha) tax allotments independently. Social changes of this sort mean that the nature of the response and the capacity to respond to a disaster are also changing.

Where co-operative effort and reciprocal help between villagers still remain a strong characteristic in the present day social system, emphasis on self-help to rehabilitate food production, or house building or generally to tidy up after the cyclone can be a successful policy. Maximum progress and flexibility of recovery activities are likely to be possible when the community is willing to get together as a whole to restore normal conditions. Even at the family level the extended family structure has more potential to cope with the stress of disaster than does the nuclear family. The opinion has been expressed that 'the culture (Polynesian) was equipped to handle the numerous hazards it had to face in the beautiful but actually quite hostile Pacific environment' and that the way of life showed 'a thoroughly realistic and practical exploitation of its environment' (Encyclopaedia Britannica 15th edition, 1974, volume
14, p. 728). A sociological and anthropological study in depth is needed to confirm or discount the suggestions made here. A brief visit such as was made by the authors could do no more than provide general impressions. The observation made in the Fijian islands, that present trends are towards greater dependence of outlying islands and villages upon the decisions and actions of the central government (Brookfield 1977, p. 143) is also applicable in Tonga and must be set against some of the points raised above.

The village is the prevailing settlement pattern. On the smaller islands a single village (usually with between 100 and 400 people) is a characteristic pattern. The village is located close to the sea, usually parallel to the beach, since fishing is an important activity, and the only access to the village is from the sea. Sites are often on a raised coral platforms between 2 and 5 metres above high water and consequently in danger from a major storm surge combined with high seas or even more from a tsunami. Local factors are significant in assessing the risk and individual sites therefore require separate consideration. Through complacency or ignorance unsuitable sites may be developed, the low-lying marshy Sopu area is an example. As yet no effective legislation provides a framework within which land use planning can be promoted.

Often a coral fringing or barrier reef encircles the islands. The shallow and difficult waters over the reefs make navigation and access to the islands difficult especially when the sea is rough, but, except where the reef is very narrow, it also has a valuable protective effect reducing the force of waves and the height of a surge or tsunami. Distances between islands vary greatly but intercommunication between villages usually involves boat journeys of several
kilometres or more. Although the Tongan is a skilful and hardy seafarer the problem of transport and communication links between many small communities on different islands complicates disaster relief considerably. In some cases there are fewer but larger boats plying between the different islands than there were in the past.

3.2.4 Urbanisation

The population distribution reveals the potential problem that in disaster both decisions and action tend to be focussed on the capital and on the island of Tongatapu. In the last census (1966) the population was distributed 62 per cent in Tongatapu, 14 per cent in the Ha'apai group, 18 per cent in the Vava'u group and 7 per cent in the Niua, 'Eua and the islands near Tongatapu. There has been continuing urban migration to Nuku'alofa and by now Tongatapu's share of the total population has climbed to an estimated 67 per cent. The demographic situation, therefore, has a direct bearing on the pattern of future disaster management.

Although it may seem at first sight strange to refer to problems of urbanisation, even Tonga is experiencing, albeit on a very small scale, some of the difficulties that town growth has brought to many Third World countries. In the more individualistic and less integrated social structure of the town self-sufficiency, family help, traditional customs and standards are vulnerable. An urban dweller is more dependent on others for many essential services and food supplies. A money economy becomes more dominant. Recent migrants to the town or its periphery, for example those who have recently established themselves in the Sopu area, are more vulnerable in disaster.

The Tongan in the past has been resilient in the face of adversity. Disasters had to be resolved with the
resources to hand and government agencies were not there on the spot to organise and provide aid. Although but a small town (18,000 people) Nuku'alofa has the physical presence of the central government and a concentration, admittedly very limited, of skilled technical personnel and of more technically sophisticated equipment. Electric power and telephones, services not available to the isolated island communities develop a dependence and a resultant incapacity to cope easily with disaster conditions which lead to their disconnection. Whilst the villages are less subject to this 'crisis of dependency' (Bayliss-Smith 1977, p. 5), it is none the less commencing in villages on Tongatapu which are readily accessible to Nuku'alofa, so that these villages have different problems and needs when it comes to the organisation of both relief and reconstruction after a disaster.

3.2.5 Technology

Movement into the technological age is not entirely beneficial. The servicing and repair of more complex equipment and facilities require special tools and skilled tradesmen. Both these requirements are not easily met for financial and other reasons. Without the opportunity to call on quickly and relatively easily obtainable skilled mechanics, electricians or plumbers, a nascent technological infrastructure is highly vulnerable to the disruption from natural hazards. The 50 Australian Army engineers and communication technicians, who were flown to Tonga soon after Isaac, were able to fill many gaps in the technological capacity to deal with the emergency. Such aid played a vital part in the assembly of information, the passing of instructions and the return of vital services to operation in a short time. Without such help many of these tasks would have taken a long time, during which great inconvenience would
have been caused. It was even possible to incorporate in their aid activities some help in mechanical repair that brought back into operation some heavy equipment that had become unserviceable long before Isaac's arrival and could not be repaired.

3.2.6 Organisational infrastructure

Counter-disaster organisations operate within the institutional and governmental structure of a country. This infrastructure in Tonga still reflects to a degree a society with a strong feudal and hierarchical tradition. The establishment of the new systems required for emergency relief and post-disaster recovery is sometimes more difficult to fit into a rigid structure in which quick decisions and an ability, sometimes by cutting corners, to institute new policies or measures to cope speedily with unexpected or rapidly evolving situations are less customary. When decisions rest in a few hands extreme pressures such as those generated by a natural disaster can overload the few individuals who can make the necessary decision. Critical delays or omissions can then result.

The strength of Christianity in Tonga has sustained the almost universal observation of the Sabbath as a day for worship, rest and social intercourse. The prohibition of work on the Sunday is admirable, except at such times as a disaster emergency, when one can ill afford, whatever the reason, to delay emergency measures or urgent rehabilitation. Although the momentum of relief operations slowed down on the first Sunday after the cyclone, special dispensations avoided delays on the next Sunday. The church (or several churches) is a focus for the religious life of the village though it seems to play a less active role in the counter-disaster welfare.
At the village level the Town Officer, who is democratically chosen, is the focus for action, the making of decisions or the distribution of information. A District Officer provides on behalf of a group of four or five villages the intermediary between them and the central government or the governor of a group of islands. A highly formalised structure at village level does not exist. The organisation of village action depends upon the drive, initiative and ability of its Town Officer. This varies considerably. Some loose form of village council may exist but this does not necessarily provide a vehicle for co-ordinating relief and rehabilitation. Nevertheless disasters may require a high level of both concern and initiative to be shown at village level since it is there that many of the first steps for relief and rescue must start.

4 COUNTER DISASTER PLANNING POLICY IN A DEVELOPING COUNTRY

Governments of developing nations face a range of conflicting demands upon the limited resources of finance, materials and skilled manpower. Development status involves policy resolutions on the best strategies for the achievement of progress on the road towards improved quality of life and a stronger economic base. The fact that the social and economic infrastructure requires attention implies also that the existing situation is in need of maintenance as well as improvement. Resources are needed to maintain and continue what has been already achieved as well as to institute new developments.

Lewis (1978) in his report to the Government of Tonga on the requirements for the mitigation of and preparedness for natural disaster planning makes some significant points on the relationship between counter-disaster planning and the needs for both the maintenance of the existing infrastructure of the economy and society and also its development. He emphasizes the two-way association between disaster and development. 'Thus the intricate levels of relationships between normal and extreme conditions, between relief and improvement and between development and maintenance become apparent' (Lewis, 1978, p. 31).
Underdevelopment can lead to situations which accentuate the impact and consequential disruption that a natural hazard may produce. Conversely, actions required to mitigate or prepare for disasters are often difficult to distinguish from those required for development programmes. Expenditure and effort devoted to development can assist disaster planning. A greater capacity to meet and withstand the disruptions of disaster contributes in a positive way to development.

These observations apply more widely than to Tonga alone. Developing countries and economies, wherever they may be, if they are also disaster-prone, will display the same general type of problem. Policies must be established which reflect an appreciation of the complex interaction of development, maintenance and disaster planning and relief.

An assessment of the impact of tropical cyclone Isaac must be undertaken within the social and economic context of present day Tonga. What has been established, prior to the cyclone, to deal with the threats of natural hazards must be evaluated in the light of available resources and national, regional and local needs. The aims of this survey are to examine the types of problems that an event such as Isaac raises, to identify the capability of the present institutions and organisations to deal with such problems and, if or where appropriate, to indicate possible areas for more attention or for the adoption of modified strategies. It is not the intention to criticize or censure for what was done or not done after Isaac.

5 THE TROPICAL CYCLONE THREAT IN TONGA

5.1 Nature of the Cyclone Risk

A detailed and comprehensive inventory of tropical cyclones in the Tonga region does not exist. It is not possible to analyse statistically the available data so as to produce reliable statements of risk based upon the frequency or probability of cyclones for the whole Kingdom. It is still less possible to ascertain whether there are well defined regional variations in cyclone risk. There is little recorded data on earlier cyclonic events in the area and it becomes impossible to assemble precise details on maximum winds,
magnitude of storm, central pressure, associated rainfall and so on. For many but not all of the storms, reconstruction of tracks can be achieved, but not to the extent required to determine if preferred patterns of movement exist.

Lewis (1978) in his report provides a list of known disasters (cyclones, storms, earthquakes, tsunamis and droughts). Twenty-eight hurricanes (tropical cyclones) between 1875 and 1973 are listed (see Table 1). In a survey prepared for the Proceedings of the Regional Disaster Preparedness Seminar at Macedon, Victoria, in 1981, 40 cyclones are reported to have struck some part of the Kingdom between 1875 and up to 1980 (Natural Disasters Organisation, 1981).

In an earlier survey (Visher and Hodge, 1925) a record back to 1830 is presented. A comment is made that the islands experience on average two storms per annum though in some years three or even more may occur. Most of the storms are reported to travel to the east, or south-east or south but a few move to the west.

Suffice it to say that there is a full realisation amongst all village and urban dwellers on the different islands that tropical cyclones represent a severe threat to those on land or especially at sea. At the village level in different groups of islands and on various occasions major devastation has occurred. It seems that whilst material losses have been great, loss of life has been generally small. Relief to stricken areas has been needed and close traditional inter-island links by sea have facilitated this, though on a government organised scale this seems to be a phenomenon of more recent times. Village communities would appear to have a capacity in the past to "weather the storm" and organise on a local level their own rehabilitation and recovery. Some suggest that there is a declining capacity.

Commenting on the failure of the Tongans to have established a fund of popular memories of previous cyclonic disasters (prior to 1961) Lewis observes (1978, p. 20) "Clearly, before 1961 the effect of hurricanes was absorbed and regarded as normal
in the cycle of environmental change and in the cycle of life itself in small islands amidst a vast ocean'.

The tropical cyclone season is normally considered to cover the months November to April, though it is possible to find occurrences in October or even May. These latter situations are rare and the cyclone is less truly comparable in structure to that occurring at the height of the season. The limited total of cyclones available for analysis makes it difficult to generalise. Looking at the record 1830 up to 1923 the distribution over the months is as follows:

<table>
<thead>
<tr>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>No record</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>4</td>
<td>16</td>
<td>7</td>
<td>17</td>
<td>6</td>
<td>0</td>
<td>4</td>
<td>59</td>
</tr>
</tbody>
</table>

However the marked double maxima with a sharp falling off in February does not appear in the subsequent record after 1923 and up to and including cyclone Isaac. The storm frequency appears to have shifted to a somewhat earlier part of the season:

<table>
<thead>
<tr>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>No record</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>8</td>
<td>10</td>
<td>13</td>
<td>7</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>49</td>
</tr>
</tbody>
</table>

Kerr's and Revel's analyses of the years November 1939 to April 1979 show a total of 22 cyclones affecting the 5° square, within which most of the Tonga islands occur, over the months November to January and 23 cyclones in the months February to April (Kerr, 1976; Revel, 1981).

The number of tropical cyclones covers storms of varying intensity from tropical depressions through tropical storms to hurricanes. In most cases the observed data do not permit the categorisation with any reliability. Likewise it is not possible to identify whether one part of the Kingdom is more prone to impact than another. This question of vulnerability is a matter of considerable importance since subjective beliefs enter into policy making and distribution of resources for counter-disaster measures.

Published in 1945, volume 3 of the Naval Intelligence Geographic Handbook for the Pacific Islands comments (p. 32)
on the frequency of tropical cyclones in these words 'In the south of the group, as at Tongatapu, they (cyclones) are not often experienced but they are more frequent in the northern islands where they are very destructive to plantations and buildings and necessitate relief being sent to the people by the government'.

Lewis directed attention to this matter in his 1978 report (op. cit.). He examined the areas in the three main island groups affected in the period 1941-1969 and found Tongatapu to have been affected 11 times, Ha'apai 9 times and Vava'u 7 times. During the same years 16 tropical cyclones or hurricanes affected the northern islands of Niuaofo'ou, Tafaki and Niuatoputapu. Lewis, in addition, assessed the data from Crutcher and Quayle (1974) and commented that the most prone area amongst the main island groups shifted according to how the intensity of risk was considered. The details below demonstrate these patterns, rank 1 being the highest frequency.

<table>
<thead>
<tr>
<th>Frequency of depressions</th>
<th>Frequency of tropical storms</th>
<th>Frequency of hurricanes</th>
<th>Frequency of storms and hurricanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rank 1 Vava'u</td>
<td>Vava'u</td>
<td>Tongatapu</td>
<td>Vava'u</td>
</tr>
<tr>
<td>Rank 2 Ha'apai</td>
<td>Ha'apai</td>
<td>Ha'apai</td>
<td>Ha'apai</td>
</tr>
<tr>
<td>Rank 3 Tongatapu</td>
<td>Tongatapu</td>
<td>Vava'u</td>
<td>Tongatapu</td>
</tr>
</tbody>
</table>

Revell (1981, p. 11) made an analysis of the frequency of tropical cyclones of storm or hurricane intensity (i.e. 10 minute sustained winds of 117 km/hr or more) over the period November 1969 to April 1979. He identified a number of high frequency areas, one of which was over southern and eastern Fiji and central and southern Tonga.

The data in Table 1 (p. 93) have been categorised as accurately as the entries permit for the whole period covered according to areas affected:

<table>
<thead>
<tr>
<th>Northern Islands</th>
<th>Vava'u</th>
<th>Ha'apai</th>
<th>Tongatapu</th>
<th>E, S or All Tonga</th>
<th>No record of Tonga</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>21</td>
<td>20</td>
<td>24</td>
<td>30</td>
<td>18</td>
</tr>
<tr>
<td>Of which</td>
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The information given above must be treated with caution since it relies on very subjective statements about damage and impact. It is not irrelevant, however, since counter-disaster planning is coloured by the perception of the hazard probability, especially among decision-makers, that such imperfect data or personal recollections provide. The recency of the double impact of tropical cyclones Anne and Ernie (December 1977, February 1978) has left the impression that Ha'apai is the most prone part of the Kingdom. A frequently held belief prior to cyclone Isaac was that Tongatapu was less threatened since most tropical cyclones came from closer to the Equator and were believed to diverge west or east of the main island of Tongatapu thus sparing the island. Even cyclone Isaac diverged to the south-west but not far enough for Tongatapu to escape its maximum wind speeds. A lull of only a few years rapidly develops complacency in any community. The record of the 1970s was sufficient to suggest that the real problems were in the central and northern part of the Kingdom. Whilst the frequency of threat from tropical disturbances of a range of intensities is high enough to keep their memory actively alive, the effective memory tends to be determined by the most recent major or severe cyclone.

Revell (personal communication) states that tropical cyclones with winds of at least gale force can be expected over the area Vava'u to Tongatapu on average on three occasions per decade. He indicates the return periods for different intensity tropical cyclones - i.e. with gale force winds (over 61 km/hr) - 3 years; storm force (over 88 km/hr) - 7 years and hurricane force (over 117km/hr) - 14 years. The wind speeds quoted refer to sustained (10 minute) wind speeds over open sea. Gust speeds are likely 50 percent or more greater and average wind speeds over the land will be slightly reduced by its frictional effect. Return periods especially for the cyclones of hurricane intensity cannot be calculated with a high level of accuracy since the period of reliable record provides only a relatively short sample and few events.
5.2 Preferred Tracks

As the supporting maps in Kerr (1976) demonstrate, it is difficult to postulate commonly used or preferred cyclonic tracks. As a general rule the movement, so far as the Tongan region is concerned, is in some form of southerly direction with south-east tending to be the most common direction, but unusual or erratic tracks complicate the pattern from time to time. A track which is aligned north to south between the meridians 174°W and 175°W has a high probability of causing widespread damage throughout the Kingdom. A track that is more oblique, to the east or west, to the zone may lead to a cyclone slipping through most of the islands, and the possibility that damage even from quite a severe storm, especially of smaller diameter, may be nil or localised in a small number of islands. Figure 1 shows some of the cyclone tracks followed since 1973.

It has been claimed that the Tongan Development Plans show an inadequate awareness of the potential disruption of environmental extremes. Such Plans suggest a belief that tropical cyclones are relatively infrequent in the Tongan islands as a whole and mainly affect the northern islands when they occur.

An accurate reconstruction of all the possible details of past events would make a positive contribution to the form and balance of policy and planning decisions for disaster management. A better and more extensive monitoring network, though on the face of it perhaps seen as an expensive luxury when there are so many other demands on scarce funds, would be a great assistance to the formulation of disaster mitigation and preparedness strategies.
Figure 1: The main tropical cyclones affecting the Tongan region 1973-1980. (Courtesy of the Fiji Meteorological Service).
6 TROPICAL CYCLONE ISAAC

6.1 Genesis and Subsequent Movement

Isaac originated as a small depression within a broad low latitude convergence zone at 10°S, 175°W some 450 km north-west of Apia (Samoa) on 27 February 1982 (Tongan times are used in this account). Initially it moved south-east to about 14°S 170°W and then turned south-west. The track (Figure 2) that it followed subsequently was relatively straightforward and showed no major departures from expectations. The data available were primarily the satellite cloud imagery which included both the GOES WEST (USA) and the GMS (Japanese) satellite information. Some additional data from shipping or island based weather stations were available but, as can be anticipated in this sort of island situation, contributed little additional precise information. Satellite cloud pictures often do not permit exact pin pointing of a tropical cyclone centre especially in the early stages of development. No radar coverage was available.

The track plotted through the Tongan area (Figure 3) by the Meteorological Officer at Nuku'alofa (Mr L. Fiffita) was established with some additional information assembled on damage and weather experiences as the cyclone passed through the islands. It is now accepted by many meteorologists that a wave-like oscillation (trochoidal motion) either side of a direct track is often a real characteristic. While it is difficult, with the sparse nature of the evidence, to be sure that the reconstructed track (Figure 3) is a true reflection of the details of the movement it appears to be quite acceptable. The damage pattern accords with it.
Figure 2: Track of tropical cyclone Isaac and estimated width of wind bands of indicated force either side of the track. (Courtesy of the Fiji Meteorological Service).
Figure 3: Reconstructed track of tropical cyclone *Isaaca* (after L Fifita, Meteorological Officer, Nuku'alofa). Local times are indicated. Insert shows section of the barograph chart at Nuku'alofa.
The nature of the detailed track also contributes an interesting point to the controversy over the extent to which, in detail, cyclone tracks show small-scale deviations responsive to the effect of island or reef areas they approach. The debate cannot be resolved from cyclone Isaac's path, but nevertheless in practical terms, if such deviations from the direct track on a sub-synoptic scale do occur, they have relevance to the assessment of cyclone risk. The temporary curvature of the track to the west which took the cyclone just to the west rather than over Tongatapu may or may not have had a link with the size and location of the island. It certainly had the effect of reducing the area of the island most severely devastated. It is interesting that the track of the severe tropical cyclone of March 1961 was similar to that of Isaac except that it passed to the east of Tongatapu.

Isaac's south-east track was sustained at about 11 km/hr up to 0100 1 March. It then changed to a south-west track in the first few hours of 1 March and steadily deepened until by 1900 1 March it was confirmed as a tropical cyclone. By 2400 that day it had been named Isaac, at which time sustained winds close to the centre were estimated to be 65 km/hr and the movement was about 9 km/hr. Deepening continued rapidly as cloud organisation became greater. Storm intensity, with sustained winds up to 74 km/hr, was reached by 0700 2 March. By 1000 2 March, when the storm was about 385 km north-east of Vava'u, it had developed a large well-defined eye, apparent on the cloud pictures, and was progressing south-west at speeds between 9 and 18 km/hr. As the storm moved into the Tongan region its speed of movement increased quite measurably. By 1300 2 March sustained winds were estimated to be reaching 120 km/hr.

6.2 Weather Forecasts

The special weather bulletin from Nadi, Fiji, issued at 1728 2 March, indicated that the cyclone, then 192 km north-east of Vava'u, was travelling 15-19 km/hr to the south-west with
sustained winds up to 120 km/hr, gusts to 167 km/hr and gales extending to 96 km from the centre. Strong south-west winds were forecast for Niufo'ou and Keppel Island though these were expected to decrease the next day as the storm moved south. Vava'u was expected to be under the effect of gale force south-east winds by early on 3 March with associated very rough to high seas and heavy rain periods. At 2200 2 March Isaac was 80 km east-north-east of Vava'u and by 0100 3 March it was within 56 km east of Vava'u. By now the intensification expected earlier had occurred and sustained winds close to the centre were up to 148 km/hr and gusts to 222 km/hr. Hurricane force winds were expected to 40 kilometres of the centre and gales to 80 kilometres. The movement now at 18 km/hr was being sustained to the south-west.

Tropical cyclone Isaac was a relatively tightly organised system. It was not a very large diameter storm. No published estimates of the diameter of the eye are known to the authors and the satellite imagery on the periphery of the scanned disk does not permit any reliable value to be determined. There is a hint in the satellite image that as the cyclone moved across Tonga the diameter of the eye decreased.

The subsequent weather bulletins summarised, with other details, are as follows:

(a) Issued at 0523 3 March

Isaac at 0500 3 March was located 32 kilometres north-east of the Ha'apai group of islands. The details of wind conditions were the same as those at 0100 3 March. The speed of movement to the south-west was expected to be 22 km/hr and within an hour of so (0600 3 March) islands in the group were expected to be crossed by the centre while the forecast indicated it would cross Tongatapu by 1500 3 March. The Fiji Meteorological Service report (26 March 1982) states that Isaac passed over the Ha'apai group at 0700 3 March giving
maximum sustained winds of 148 km/hr. Ha'apai reported sustained winds up to 105 km/hr at 0800 3 March after which all communications were lost. Plate 1 shows a portion of the GOES WEST satellite image for 0645 3 March.

Local information for some of the islands visited by the investigation team suggest that at 'O'ua the strongest winds were experienced between 0600 and 1000 3 March, with winds initially from the east, but after 0900 from the north. Field evidence from Ha'afeva suggested a calm of about 20 minutes before day break (Plate 2). The wind changes indicated by the villagers backed from strong destructive winds from north-east, then north to a brief spell of strong north-west winds. At Matuku local information and damage patterns suggested a calm of some ten minutes with winds of similar force but opposite directions before and after this lull. This would imply that the island was on the periphery of the eye which would have been larger (from satellite information) than, at the rate of movement indicated, the period of the lull would permit. The most damaging winds on Matuku were obliquely towards the beach - i.e. from the south-east.

(b) Issued 0815 3 March

Isaac was located close to Ha'apai. The gust and sustained wind speeds and the extent of hurricane winds remained unchanged but the gales had been extended to 160 kilometres from the centre. Direction and speed of movement was also unchanged. The track was expected to bring Isaac close to Nomuka by 1100 3 March and close to Nuku'alofa by 1700 3 March. The track probably took the cyclone across the Kotu group of islands.
Plate 1: GOES-WEST satellite picture of tropical cyclone *Isaac* at 0645 hours (Local time) 3 March. Cyclone passing through the Ha'apai group (courtesy Satellite Data Services Division, NOAA).
(c) Issued 1145 3 March

By this time (1100 hours) the cyclone was located 64 kilometres north-east of Nuku'alofa close to which it was expected to pass by 1500 3 March. Nomuka was expected to have severe sustained winds and gusts for the next two to three hours. No changes from the earlier statements on the storm intensity or behaviour were reported.

In Nuku'alofa a temporary building in use as a dormitory at Queen Salote girls' school was being sufficiently shaken by 10 am for the girls to be moved to newer stronger buildings.

By 1100 the situation in Nuku'alofa had reached the position in which banks and schools were being closed.

(d) Issued at 1420 3 March

At 1300 3 March Isaac was placed 24 kilometres to the north-west of Nuku'alofa (Fiji Meteorological Service Tropical Cyclone Isaac Preliminary Report, 26 March 1982) and it was predicted that it would pass to the west of Tongatapu at 1500 3 March. Wind directions in eastern Tongatapu, from vegetation evidence showed directions from east to north-east (for example at Niutoua). At Kolonga about 3.5 kilometres west damaging winds were from east or just south of east.

It was at about 1300 hours that another old building at Queen Salote school, struck by flying debris, started to break up. The 40 girls in it were led by their teachers behind the shelter of other school buildings to the protection of new buildings which stood up to the storm well. The winds were then reported to be northerly. The conditions were very severe for about four hours (1100 to 1500 hours) and in many areas worst
between 1330 and 1500 hours. Winds declined quite rapidly in north-west Tongatapu after 1500 hours.

The weather records showed that at 1345 3 March Nuku'alofa recorded its highest wind gust from 060° of 170 km/hr and the lowest pressure of 976.4 mb. The strongest sustained winds in Tongatapu were estimated at 130 km/hr (i.e. above the lower hurricane wind threshold). The estimated maximum gust at the airport was 152 km/hr. The centre of the cyclone was probably 25-30 kilometres west of Nuku'alofa at 1500 hours. It is unlikely that a more precise reconstruction of the track will be possible.

(e) Issued at 1610 3 March

By 1600 3 March Isaac was centred 48 kilometres south-west of Nuku'alofa. The general intensity of the cyclone and its associated winds were the same as before. A ship located 24 kilometres to the north-west of Isaac at 1600 reported sustained winds of 167 km/hr. Over Tongatapu winds by now were dropping. About the time of the weather bulletin sustained winds were about 93 km/hr (gusts to 130 km/hr) and were soon expected to decline to 65 km/hr (gusts to 102 km/hr). At Fua'amotu Airport winds had been mainly east-south-east as the cyclone approached, but as the centre moved past Tongatapu backed fairly sharply so that by 1800 hours the winds were north-easterly, settling down to bearing 030° by 2200 hours.

Recorded wind directions at Nuku'alofa are only available for 1000 hours local time. 2 March the wind was from 120° (from N), on 3 March 90° and by 4 March 350°. The rainfalls for the 24 hours ending 1000 hours were 2 March 3.2 mm, 3 March 21.3 mm and 4 March 120.2 mm.
(f) Issued at 2000 3 March

At 1900 3 March Isaac was 128 kilometres south-west of Nuku'alofa. No further special weather bulletins were to be issued. For Tonga the threat was over.

The cyclone continued its steady movement south-west at 24 km/hr until 0100 4 March. Then about 180 kilometres south-west of Nuku'alofa it recurved to the south-east but without any significant change in its rate of movement. However after this time the satellite imagery provided indications of declining intensity under the effects of increasing upper wind shear.

7 THE WARNING SEQUENCE

7.1 Issue of Warnings

The first alert* for Tonga was issued at 0545 2 March when Isaac's south-west direction became apparent. This direction of movement was confirmed and in consequence a gale warning was issued (1728 2 March) for the Vava'u group, while the alert was maintained for the rest of Tonga.

At 2300 2 March a hurricane warning was issued for the Vava'u, Ha'apai, Kotu and Nomuka island groups. This was based on the 2200 hours location and movement pattern. The centre was expected to be close to Vava'u 0400 3 March and the Ha'apai at 1300 3 March. The latter forecast was brought forward six hours in the next bulletin issued 3 1/2 hours later. Tongatapu was still under a tropical cyclone alert but the bulletin issued 0230 3 March (related to the 0100 cyclone position) extended the hurricane warning to Tongatapu. Tongatapu had approximately 9 hours warning before the main effects of the cyclone were being felt and about 11 1/4 hours before the

* Note: The term cyclone watch is not used in Tonga.
severest gusts were recorded at Nuku'alofa. Many people in Nuku'alofa or elsewhere in Tongatapu first became aware of the storm at about 8.00 am. By 1100 hrs the winds were severe in Nuku'alofa.

Already by 1130 hours the Tongan Broadcasting Station had experienced a power failure and, being unable to start the emergency generator, could no longer transmit (Tonga lost international contact at 1325). However by 1200 hours Tonga had requested the Nadi Weather Forecasting Centre to provide warnings to the Fiji Broadcasting Commission. Radio Fiji commenced the broadcasting in Tongan (not understood of course by the few of the inhabitants who did not speak Tongan) by 1335 hours and appeared to have been tuned into by many of the people of Tonga. Warnings were all cancelled by 2000 3 March.

The warnings that were issued were clear and the timing of the passage of the storm centre was good (with the exception of the bulletin issued 0815 3 March which delayed the cyclone's predicted arrival over Nuku'alofa until 1700 hours. This was corrected in the next bulletin (issued at 1145 3 March). There was a clear indication of the intensity and a reliable estimate of sustained wind speeds and gust speeds, though in a number of cases comments were made by individuals that the severity of the storm exceeded their expectation. The predicted heavy rain was received, though except very locally it was not a significant cause of disruption, but inevitably added to the damage to household and other water-prone goods exposed by building damage. The risk of the storm surge and high seas in low-lying coastal areas was also included in the usual messages. The question of awareness and perception of this threat is a matter that will be considered later.

With respect to the content of the warnings there is not a great deal of adverse comment. The lead time for the Vava'u group was, however, minimal. The hurricane warning was issued at 2300 2 March, and by 0100 3 March Isaac was only 56 kilometres east of the group. In the warning issued at 2300 the cyclone was forecast to be close to Vava'u only by 0400 3
March. Had it followed a more direct track to the south-west it is probable that the cyclone would have passed across the group causing far severer devastation. For cyclones of limited diameter moving between 20 and 30 km/hr and the distances involved between the island groups, and indeed between the individual islands, the possibility of incorrect timing or location is considerable. While the interval between bulletins (and of cloud imagery) is, and for financial reasons may have to remain, three hours a fail-safe forecasting system cannot be guaranteed.

Transmission of warnings to the public, or those concerned with disaster related responsibilities at the time of the threat, worked reasonably well up to the time of power failure. There existed already a system by which key organisations and personnel were to be alerted, in the case of an impending disaster threat, to keep tuned to the radio for further news. Radio has an established daily function in the transmission of information and even instructions throughout the Kingdom. The habit of listening is well developed both in the town and perhaps even more so in the village. The Tonga Broadcasting Commission retails an inexpensive transistor radio and most people have one. News spreads quickly in the village and even those without radio are likely to hear the news.

Although the radio station in Nuku'alofa (the only station) does not normally broadcast throughout the day (there are three broadcast sessions 0650-1000, 1200-1400 and 1730-2300), on the advice of the Meteorological Section, it remained on the air throughout the night 2/3 March. The warnings, in Tongan and English, were repeated at hourly intervals and updated whenever new information became available. On the initiative of the Meteorological Officer on the morning of 3 March basic advice on steps to take (on the same lines as that printed at the start of the telephone directory) was broadcast. Advice from the Ministry of Health was also broadcast. In the earlier stages of the threat some belief was current that the cyclone would not arrive until 4 March and then would go past Tongatapu to the east or west.
7.2 Receipt of Warnings

The authors of this report did not have the opportunity to undertake a structured and comprehensive examination of the receipt of warnings and the understanding of their significance in the many villages they visited. However the question was consistently raised with individuals and in no case, including the seven islands of the Ha'apai group that were surveyed, did anyone indicate they were caught out and that the cyclone came on them unawares. This does not necessarily mean that those who heard of the impending cyclone appreciated fully the sort of threat it implied, even though they knew it was coming and about when. The matter would need to be investigated far more rigorously before firm statements could be made. The impression gained is that not only was warning effective at the village level, but that in general terms at least the villager had a better appreciation of what a cyclone meant to him than urban dwellers (especially newcomers) in developed parts of the world that are cyclone-prone. These comments should not be construed in a too complacent manner however. The question of improved education for disaster mitigation and preparedness will be taken up at another place in this report.

In a recent report on Isaac made by Air Vice-Marshall W. Carter for UNRDO (April 1982) the procedures for the receipt and dissemination of warnings are discussed (pp. 9-14). A system has been established. Beyond the remarks made previously the present authors did not have the opportunity to evaluate the system in depth. No doubt there is room for improvement but this is a generalisation that can apply to almost every disaster situation or disaster-prone community. Carter makes a valid point with respect to community action in response to the warnings and presumably its interpretation of them in drawing attention to the low casualty figures caused by Isaac. The other point he most appropriately draws attention to is the fact that in Tongatapu (and to a large extent in Ha'apai) the daylight occurrence of the cyclone made it possible to take evasive action more easily and with less
risk. The fact that the cyclone passed over Tonga without slowing down or falttering limited the period of the impact to a few hours. Had the storm slowed down and occurred at night and on a Sunday the results may well have highlighted more deficiencies in warning dissemination and response.

Warning systems usually depend on fairly sophisticated communication networks with good back-up alternatives. The fact that this cannot be said of Tonga (apart from the satellite connection with the international communication system, the telephone network is extremely local and in many parts of Tonga non-existent, and internal radio links other than the Tongan Broadcasting Commission are minimal) has much less significance than at first sight might be expected. The deficiencies mentioned became much more crucial when the message flow (for example after a disaster) must be from outlying islands to the capital and to government officials and organisations. The question of transport facilities throughout the Kingdom will be examined elsewhere in this survey.

8 THE AFTERMATH OF THE CYCLONE: THE IMPACT OF TROPICAL CYCLONE ISAAC

8.1 Damage to Buildings

8.1.1 General

Thousands were made homeless and the value of buildings destroyed or severely damaged was put at $T10m. The low standard of many domestic buildings was in part responsible for the severity of the damage. Figure 4 is based on a detailed district by district survey undertaken by the Department of Works immediately following the impact of Isaac. It is presented here to indicate how localised damage can be. In the northwest villages of Tongatapu wind damage was extensive and media reports of devastated villages were unfortunately very true representations of the situation. Towards the centre and in most eastern parts of Tongatapu the degree of major damage to
Figure 4: Variation over the island of Tongatapu of the percentage of dwelling houses destroyed or severely damaged. Based upon a Government survey covering 62 divisions of the island. In the map areas with similar class intervals have been consolidated into single areas.
buildings declined markedly so that in extensive areas less than 5 per cent of the buildings could be described as destroyed or severely damaged. These buildings were widely distributed in a patchy and random fashion and reflected as much buildings of low strength and of old or poor construction rather than the intensity of the cyclone.

In 1973 cyclone Juliette made homeless 1250 families (perhaps over 8000 people) in the seven northern islands of Ha'apai. This indicates the scale of building damage. After Isaac it is claimed (Carter, 1982, p. 18) that half of the 1800 or so homes in Ha'apai were destroyed. For Tonga as a whole an estimated 2000 and perhaps up to 2500 houses require major repair or rebuilding.

The authors were unable to make a comprehensive survey of the Ha'apai group and were only able to visit Nonu, Mango, Fonoifua, Matuku, 'O'ua, Ha'afeva and Lifuka. There were some villages which suffered major damage or a scale described by the media accounts given to the outside world (Plate 3). There were other villages which for a variety of reasons came through the ordeal far less badly scarred. The question of shelter for individual village sites played a significant part. It must be realised that shelter is a condition that may apply to one cyclone and not to another according to the considerable range of possibilities of storm size, track and movement characteristics. A site cannot necessarily have absolute qualities of good or bad shelter, though one cannot avoid the impression that, where conflicting demands permit, villages have, through experience, been well sited. This impression would need very careful field analysis to confirm beyond doubt. The authors are aware that divergent views are held on the extent to which communities are environmentally sensitive and adjust their actions and decisions to environmental experience and understanding.
Vegetation around dwellings serves a double function. The mechanical friction of the plants reduces wind speeds. Vegetation also may impede flying debris thereby reducing its destructive potential. It was apparent when considering different villages that those with open sites and few trees displayed more damage than those where the houses nestled within fruit and other trees. Field studies in the Ha'apai group illustrated this point, for example at Nomuka, 'O'ua or even Pangai (Plates 4, 5 and 6). Admittedly trees close to buildings may cause damage if blown over but in balance their protective effects are greater.

While the use of some form of window shutters is not common, it was observed that some householders in the villages had taken steps to board up their windows before cyclone Isaac. In these cases windows had been protected from breakage.

Major cyclone threats may require evacuation either before or after a cyclone. Reception centres suitable to house safely large numbers of people at the height of a storm may be required. One must have some confidence in the strength of such reception centres. It was observed that some of the worst building failures in the more severely hit villages were the churches which, though large structures, clearly lacked strength (Plate 7). To some extent government buildings such as schools showed similar weaknesses.

As Lewis (1978, p. 41) indicated, buildings providing essential equipment or services, or where many people congregate, fire stations, telecommunication and radio stations, hospitals, schools, churches or hotels particularly, need to be built to more demanding standards.
8.1.2 Building construction

The Tongan Ministry of Works started phasing-in building regulations in 1981. Therefore nearly all buildings would not have had the benefit of being constructed to those regulations. This would apply in particular in the villages especially on the islands outside Tongatapu. Also, because of the difficulty of enforcing such regulations in their early stages, it is quite probable that more attention was given to their application to industrial and commercial buildings in Nuku'alofa than to houses in the villages.

There are four or five building construction firms on Tongatapu. Because of the low cost of Tongan labour, overseas firms are unable to compete successfully with them. Therefore these firms would do all of the large (one to four storey) construction work. The supervisors would probably have received some formal training in New Zealand or Australia, but many of the other workers would be learning on the job and would never receive any formal training. This leads to a situation where the building worker may attain a high degree of practical skill in say bricklaying or carpentry, but lacks any knowledge of the theory as to why certain procedures are adopted and the ramifications of changing them.

The building construction firms also build houses, but most houses would be built by the owner and his family, possibly with the help of a 'supervisor'. Building techniques are adopted mainly by copying from previously constructed buildings so that many ideas and methods, good or bad, are spread 'by example'.

On Tongatapu most houses were European style, rather than the traditional fale. They were mainly either timber-framed or concrete block construction with galvanized iron roofing. On some of the other islands visited by the authors, fales were more popular, but
they never represented a majority of the total number of houses.

There were few commercial or industrial buildings outside the capital Nuku'alofa. The main non-residential buildings were churches, shops and schools. Quite often the shops were only three metre square buildings used to house the goods, and the customer stood outside during transactions.

8.1.3 Distribution of damage

As previously mentioned, cyclone Isaac passed to the east and south of the Vava'u group of islands, through the Ha'apai group and to the west of Tongatapu. The worst damage to buildings was therefore caused at Pangai, the largest settlement on Lifuka Island, Ha'apai group. Plate 6 shows some damage to commercial buildings at Pangai, but this is not considered representative of the overall damage there. Many houses as well as churches and school buildings were damaged far more seriously than the commercial buildings shown. However there are some destroyed houses in the background. The overall damage ranged from loss of roof sheeting to total destruction.

Other smaller islands in the Ha'apai group were also severely damaged. One of the worst would have been Nomuka where 160 of the 180 houses on the island were reported to be damaged. Similar proportions of damage were reported from 'O'ua 48 houses damaged out of 50, and Matuku where only one house was not damaged. The island of Fonoifua fared much better, where 12 houses out of 21 were undamaged.

On Tongatapu, the villages of Kanokupolu, Kolovai and Fo'ui and others on the north-western peninsula were severely hit. The Department of Works survey, Figure 4, shows that more than three quarters of the buildings in those villages were damaged, with more than half being severely so. An independent survey conducted by
the authors, using different categories of damage severity, showed about two thirds of the buildings as being damaged, but agreed that more than half of the buildings were severely damaged. The difference between surveys probably arose from the definitions of the lowest classification of damage. The Works Department categorized "no damage" whereas the authors used "negligible damage" as their lowest class.

The Works Department survey showed that only about 20% of buildings in the Kolofo'ou district, which includes Nuku'alofa, were damaged. Of these, less than half were seriously damaged. Although the authors did not conduct a survey in this area, their overall impressions would agree with the survey results. Viewed in an overall context, the damage in the Nuku'alofa area was relatively minor. However, because it was the "central business district" and contained a number of three and four storey buildings, the unit cost per building would be significantly greater than the unit cost in the villages. The cost of repair would also be significantly greater.

Most of the villages to the south and east of Tongatapu had relatively minor damage, though the north-east coast, being the most exposed part of that side of the island, showed local concentrations of more severe wind damage.

The village of Niutoua, near the north-east corner, appeared to be the only exception. A church and three houses were destroyed and about twelve other houses lost some roofing. The buildings were on a ridge about 16 m high.

The authors were unable to visit the Vava'u group of islands because of the difficulties of arranging transport. However, reports indicated that the extent of damage was similar to that at Nuku'alofa. That is, although some damage was serious, it was not very
widespread. This was anticipated because the storm travelled to the east of Vava'u, thus the islands experienced less severe wind speeds than those to the east of the track.

8.1.4 Exposure

The speed with which wind hits an object is dependent upon the degree of shielding provided by surrounding objects. The small flat islands of Tonga offer little protection to each other in such an event as a tropical cyclone. Thus each island would expect to receive the full brunt of wind forces, depending upon its distance from the eye of the storm.

It is obviously convenient to have villages located near to the sea, as this is their means of transport and trade. Even on the larger islands such as Tongatapu, most villages are around the perimeter. Further, the villages tend to be long and narrow, stretching along the beach front and being only a few rows of houses deep. Therefore, individual houses within a village do not gain much protection from each other. With the exception of Nuku'alofa and some adjacent villages, they do not benefit from the suburban sheltering effect of larger cities. Thus if cyclonic winds approach from the sea, the houses have almost no protection. If the winds approach from another direction, the vegetation may afford some protection.

8.1.5 Housing

There were three main types of housing, timber-framed, concrete block, and traditional fale. Approximately half of the houses would have been timber-framed with the rest being approximately equally divided between block and fale. There was also a small number of concrete-framed houses. Most of the timber-framed houses were on low stumps. There were very few of the Queensland style high-set houses.
Damage to houses was typical of that seen by the authors in other wind storm damage surveys. The predominant form of damage was to the roof, being either loss of roofing or loss of part of the roof structure. Plate 3 illustrates both of these forms of damage. Most roofing was corrugated galvanized steel, fastened to battens with spring head roofing nails. As electricity is not available to most building sites, power driven screws and cyclone washers have not been introduced to Tongan house construction.

Roof framing was always timber, often fabricated as trusses. In general the roof framing tended to remain on the walls, if the walls themselves remained intact. However, in the badly affected areas the walls were often blown down. It is quite probable that the wall failure occurred as a consequence of the building losing the stiffening effect of the roof structure when the roof blew off. Plate 3 also shows wall collapse of some houses.

It was very interesting to note the much better performance of roof structure on concrete block houses, even though the timber-framing would have been the same as for timber-framed wall construction. In fact the overall performance of block wall construction was superior to that of timber wall framing, according to the authors' survey. However because the Tongan islands are also in an earthquake zone this form of construction cannot be recommended as preferable.

Surprisingly there was little damage to windows, although they tended to be relatively small, not picture windows. Also, quite a number were boarded up prior to the onset of the cyclone. This lack of window damage complements the observation that there was little damage caused by flying objects, even though there was a significant amount of debris (Plates 3 and 6). Possibly the converse is true, that houses damaged
by flying missiles soon disintegrated. Extra wind pressure within the building could well have caused collapse.

As would be expected, most fales had either minor damage or collapsed totally. Their structure does not allow for partial collapse. On a few occasions, bare fale frames were observed, but it was not clear whether these had been stripped of their walls and thatched roofing, or were in the process of being rebuilt.

8.1.6 Industrial and commercial buildings

Industrial and commercial buildings appeared to resist cyclone Isaac reasonably well. The impression was gained that even though there were far fewer of this type of building, the percentage damage was less than for domestic buildings. This aspect will be investigated in more detail in a later report.

There are a number of reasons for the better performance of this group of buildings. Firstly, it includes the few three and four storey buildings, and the other prestigious buildings in Nuku'alofa that would have been designed by engineers to resist cyclone wind forces. Such buildings performed well structurally, but some had their furnishings and carpets affected by water entry.

Secondly, many of the factory type buildings would have had some engineering input into their construction. Whilst they may not have been fully engineered for their particular site and function, they may have been copied from similar engineered buildings. It is most probable that there would have been a higher degree of building skill used in their construction, than in house construction.

Thirdly and most importantly, most of this type of building was at Nuku'alofa and surrounding areas, where the intensity of cyclone winds was not as severe as at
other parts of Tonga. Thus any building type would be expected to perform better than similar ones at Pangai, in the Ha'apai group.

Most of the damage to shops and industrial buildings was roofing damage. Sheets of roofing or part of roof structures were blown off. A number of verandahs were damaged. Some older, wooden-framed industrial buildings collapsed.

8.1.7 Churches, halls, schools

There are many churches and schools in Tonga. It appears that each village has its own primary school and one or two denominational churches. This pattern was also evident on the small islands visited by the authors. Secondary schools are located at the capital city of each island group, and are relatively large complexes.

The performance of church structures varied considerably. At Kolovai, one of the badly hit districts on Tongatapu, one large church with many windows was completely undamaged, although it was in an exposed area and in the midst of badly damaged houses. In the same district some other church structures were completely flattened. At Nuku'alofa, the cathedral type structures were also virtually undamaged. On the islands visited, most of the churches were damaged.

Plate 8 shows a church at Pangai that was almost totally destroyed. Not only was the roof structure blown off, but a row of massive concrete pillars inside the church was blown over. A close inspection of the pillars revealed that they were un reinforced, possibly typical of construction of that age.

The probable sequence of failure of churches and halls started with the roofing and part-roof structure being blown off. This allowed the wind inside the building
with the result that other parts of the roof structure were lifted and destroyed. Then the walls of the building, lacking the lateral support of the roof structure, often failed under the wind pressure.

It appears obvious that there were two levels of building skill used in the construction of different church buildings. The larger churches which survived were possibly built by trained tradesmen, to standards similar to those of commercial buildings of Nuku'alofa. The smaller churches, possibly serving poorer communities, appeared to have been built to the standard of local domestic construction. This latter situation would almost certainly have applied on the islands. Halls would have also fitted into the latter classification.

Primary schools, especially on the islands other than Tongatapu, would have been built similar to houses. In fact they were often about the size of a house.

Secondary schools, although being of similar construction to churches, performed considerably better. The main type of damage to these buildings was loss of roofing and some roof structure. The damage at Nuku'alofa College, shown in Plate 9 is typical of the performance of such buildings. This is also shown in Plate 10, Atenisi University.

No wall failure of classroom buildings was observed. This was probably because the internal walls helped brace the external walls against lateral wind forces. Such bracing would not have been available in church buildings.

The exception to this was the total destruction of two wooden buildings at the Queen Salote girls secondary school, Nuku'alofa. The buildings were both dormitories, forty or fifty years old and were moved to the site some twenty years ago. The timber structure had deteriorated somewhat with age.
8.1.8 The rebuilding programme

Lewis (1978, p. 32) was critical of the "abysmally low standard of domestic construction and the structural inadequacies of some government buildings". He emphasized the importance of taking early steps to improve the strength and quality of buildings through better building techniques and, even more important, tighter supervision and inspection of buildings while being constructed. He further recognised that the first essential for this improvement was the provision of an administrative and technical infrastructure.

Some of the problems associated with rebuilding are outlined here. A complete analysis can only be made when the full recovery from the cyclone has been made. Moves are in hand by the central government, following advice from Dr K J Eaton of the Building Research Establishment UK, to set up two workshops one in Nuku'alofa and one at Pangai to prefabricate the timber frames for the replacement houses. How this scheme will proceed can only be judged after its completion. The comments made here, therefore, relate to past experience or to the observations of the authors.

In the first instance there is the shortage of building materials, timber, cladding and nails, and tools already referred to. In the two weeks after Isaac villagers were busy salvaging all the materials they could. Roofing iron was even being recovered from the shallow sea over the fringing reefs, nails being straightened and wall sections or detached roof assemblies were being made suitable for complete reuse. Two presses for the reforming of buckled corrugated iron were amongst the aid equipment from Australia. With the pressure to provide shelter as soon as possible from the frequent rain-showers damaged
buildings were being speedily patched. The other major shortage is money. If salvaged materials are insufficient, few families in the villages have cash reserves that will enable them to obtain additional building materials. The price of self-help in repair or rebuilding may well be low grade buildings.

Whilst there is an urgent need for shelter as soon as possible after the event, it must be considered to be temporary shelter only. At a later date, when building materials are readily available, such patched reconstruction should be dismantled and repaired properly. If this does not happen, the patched building represents a potential hazard for the next cyclone, and is likely to be the source of flying debris.

The authorities in Tonga have a tremendous problem in trying to introduce cyclone resistant construction into house building. Clearly the present form of construction should not be used in rebuilding, as it has proved to be under-strength. The authorities are fully aware of this need for upgrading, but are faced with the problem of educating the house builders. This really means educating the whole community because, as was previously mentioned, most houses are built by the owners and their family. And of course when the community is scattered around thirty-six different islands the problem is further compounded.

Lewis (1978, p. 42) directed attention to the basic needs for advice and training in building methods. Simple forms of help can be given through leaflets, newspaper articles and even perhaps radio talks. More formal training of tradesmen and builders by short practical courses can help though may not succeed in the case of villages distant from Nuku'alofa. A general sharpening of the awareness of environmental hazards would also contribute to an increased
appreciation of the need to build better and stronger. This would perhaps be a process too slow to deal adequately with the rebuilding problems.

Whilst concrete block or reinforced concrete houses, if well constructed, will undoubtedly give better protection against strong winds, a number of problems suggest caution in promoting such construction without a great deal of preparatory investigation. Such buildings unless of fairly sophisticated design may well be unsuitable because of the earthquake hazard. With current inexpert techniques of reinforcement and block laying they are often a poor solution even to the wind threats. For the present there seems therefore, to be a strong argument in favour of concentrating on timber-framed buildings, in the construction of which indigenous wood-working skills can be utilised to the maximum advantage.

8.2 Storm Surge

No published central pressure for Isaac is available. At best this will have to be based on an estimate determined from the cloud organisation (curvature of feeder bands and pattern of clouds around the estimated location of the eye of the cyclone). Bearing in mind the reading recorded on the barograph at Nuku'alofa and the straight line distance to the estimated location of the storm centre a central pressure of 950-960 mb is a reasonable estimate.

A number of factors must be considered in the generation of storm surges. In an island situation, if the island size is small, the height of the surge will be little more than the open ocean value i.e. related mainly to the effect of the low pressure. Most of the islands of the Tonga group are surrounded by fringing reefs and in some cases protected also by barrier reefs. The shallow waters of these reefs afford some protection against a surge and certainly reduce the wave length and energy on the beaches themselves.
The magnitude of the surge effect is not therefore likely to be as great as along a continental coastline. The Tongan islands, except some of those of volcanic origin, are generally low-lying but only limited areas are sufficiently close to the high water mark to be seriously at risk from a surge of the height that can be expected. To the west of Nuku'alofa a low-lying swampy area has been settled in recent years as the capital has grown. People have migrated to the city from the other islands or other parts of Tongatapu to take advantage of opportunities for employment and educational facilities that the city is believed to offer. Land pressure has resulted in relatively unfavourable locations being settled. This area of Sopu (Plate 11) [identified as a vulnerable area by Lewis (1978, p. 16)] suffered the worst surge damage though more localized cases of the combined effects of the surge and waves affected coastal areas to the west (e.g. Kolovai) and to the east (e.g. east of Manuka). In a coconut plantation beside the coast road east of Manuka sea water had flooded inland about 120 metres despite a coral fringing reef of 500 metres or more width. Low-lying coastal parts of Nuku'alofa were also inundated. The surge exceeded the height of the coastal road by about 50-75 cm and sea flooding extended inland several hundred metres.

The people of Sopu found the water rising in their houses and within fifteen minutes reaching their waists. Some climbed upon tables, others waded through the waters to dry land in some cases guided by ropes that had been strung across deeper stretches. Walls or fences of gardens fronting the Vuna road were broken down by the sea. The coastal road was eroded by the force of the waves (Plate 11).

The sea water crossed the beach road at a height of about 70 cm and swept five houses from their stumps. All houses fronted the beach road and were swept about ten metres by the sea. From external appearances, three of them still seemed sound. The other two had wall damage; one resulting from a collision with another house (Plate 12).
Apart from those five houses, there appeared to be little structural damage caused by the storm surge, even though it extended approximately one kilometre inland in some places. Certainly there were other houses damaged and destroyed in the area, but that seemed to have been caused by wind rather than the storm surge.

Water remained in some houses for up to 3 days and even by 9 March still surrounded a number of the houses making access difficult and contributing to unbearable conditions where dead vegetation and other debris had started to rot. The area depended upon soakage pit toilets and this represented another hazard in flooded areas. In those areas underground water sources are in danger of serious pollution. In the lowest lying areas there was concern that the land was so little above sea level that the water table would remain high and, especially if maintained by heavy rain, the areas would dry out very slowly. Steps to improve permanent drainage are locally required in the reconstruction phase. Whilst this is true of the most poorly drained situations a period of dry weather after the cyclone (until rain on the morning of 11 March) had enabled large areas to dry out considerably. There were still major problems, however, in trying to find sites for siting emergency tent accommodation.

Estimation of the surge depth is difficult. The surge would have occurred on a rising tide and close to high tide (predicted for 1327 local time, that is just before the lowest pressure and highest wind gust recording at Nuku'alofa). The Fisheries Officer at the Sopu headquarters observed the sea coming over the coast road and moving inland and into his house about 12.30 pm. The high tide for that time was 1.2 metres about datum (not the highest of high tides which attain 1.4 metres).

On 3 March the water level across Vuna road at its junction with the access road to Queen Salote wharf was about 2.10 metres above mean sea level (based on observed debris levels (about 0.60 metres) on fences, in vegetation, etc, and a road
height of 2.26 metres). Taking predicted high tide level as 0.44 metres above mean sea level this suggests that the surge was of the order of 1.66 metres above the high tide. Along the Vuna road further west and east of Manuka field observations suggest that the surge was about 1.5 metres. It is not possible to determine the effect of waves (up to 2 metres on the inland edge of fringing reefs) on debris levels although these appeared to be consistent over considerable distances.

Behind the coast road, especially where low-lying marshy depressions bordered the coast, e.g., Sopu, water depths were up to 1.5 metres (though more normally about 1 metre). Where houses were poorly located it was reported that water levels inside reached about 1 metre; and in some areas were still at knee height at 9 am the next day. In other situations for example along the Vuna road in Nuku'alofa the water level in buildings about road height seemed to have been of the order of 40-50 cm though wave action may have made this appear more. It was still sufficient to drift a boat inland to near the meteorological office (Plate 13). Mostly the inland encroachment of the sea was about 300 metres but in some of the low areas to the west of Nuku'alofa salt water had reached just over 1 kilometre inland. Salt scorched vegetation at ground level provided a clear indication of the extent of flooding. Building damage in these inland areas, however, appeared to be due to wind and not wave or surge action. The water level inland was probably only 30 cm or so.

In the Ha'apai islands the surge would have occurred close to the time of low tide. This, together with a lower surge height and the fact that most of the villages were at a height of 2 to 3 metres or more above high water mark, meant that surge damage was not significant in the islands visited. Locally wave action removed sand from beaches and cut a notch at the upper level of the beach. In some instances the sea had flooded inland a short distance (a few metres) in lower lying situations. A comprehensive survey was not possible and subsequent information may reveal some more serious sea
flooding. East of the village of 'Uiha in the island of that name, south of Lifuka, sea encroachment was reported. On the eastern (exposed) side of Lifuka wave erosion was severe in places and coral rocks were cast up along the coast.

Wave erosion occurred on sections of the coast of Tongatapu, above surge height. In the Kolovai locality and notably at Niutoua wave action removed soil and vegetation on raised coral platforms (4.5 metres about high water) (Plate 14). On the south coast of Tongatapu a marine platform at the base of cliffs meant that the effects of the high seas were less apparent. However, in two places visited, the Stalactite Caves at Haveluliku (wave action reaching up to 4.5 metres above high water) and Ha'atapu Beach despite the protective reef, wave damage along the beach was marked.

In the Sopu area coral debris and sand were washed inland up to 70 metres from the sea edge. On the whole, however, the force of the water was not as severe as can occur in surge effected areas. In Nuku'alofa sand and rock deposits up to 20 cm thick occurred on parts of the Queen Salote wharf and along the coastal Vuna road (Plate 15). Debris was washed into the gardens of houses on the inland side of the road.

A future need, to be met when sources and opportunity permit, is the detailed mapping of coastal sections at risk from specified surge (or tsunami) heights.

8.3 Damage to Food and Services

8.3.1 Food crops

The high winds of Isaac defoliated vegetation over smaller islands but were limited mainly to the coastal fringes of large islands, especially of Tongatapu where inland wind damage was far less extensive. In terms of agricultural losses an initial government estimate put these at $T8.7m.

Because of the significance of the coconut both for domestic use and as an export product the wind damage to the crop caused by Isaac must be assessed. The
early reports tended to exaggerate the magnitude of such damage. The preliminary damage assessment made by the Ministry of Agriculture, Fisheries and Forests indicated that about five per cent of the coconut palms had been destroyed or damaged beyond recovery. A much greater number of the palms suffered considerable damage to their foliage (Plate 16). This not only is likely to affect future growth and nut production, but also produces a shortage of suitable quality leaves for the manufacture of thatch (wind damage to pandanus leaves, used for mats and baskets, is a similar problem).

The violent winds blew down large number of nuts, including those that were not fully mature. Other nuts remaining on the palms were bruised by the wind. The inevitable consequence of the cyclone was to produce an initial surplus of nuts for a few weeks followed by a shortage. Domestic demand takes priority so that with a smaller total crop a much reduced crop is available for export.

Past experience has shown that major wind damage reduces the crop of coconuts seriously for two years and full recovery may take five to eight years. After the March 1961 cyclone for example, it was not until September 1963 that the first copra export took place. The worst affected parts of Ha'apai and Tongatapu will experience a similar type of disruption of production though so close after the event a precise determination cannot be achieved. A long term objective, which potentially could spread the risks from disaster, would be crop diversification which would reduce somewhat the dependence on the coconut.

It is estimated that the blown down coconut palms would amount to about a quarter of a million stems. Whilst this would have been usable timber had it been properly processed, its availability all at one time exceeds the
sawmilling capacity. Unfortunately coconut wood deteriorates rapidly and most of these stems will probably be wasted. In the meantime whilst they remain on the ground in a rotting state they may harbour the harmful rhinoceros beetle.

The production of vanilla beans makes a very small contribution to the total export earnings but the effect of the cyclone cannot be ignored. In Tongatapu field surveys indicated that wind damage to the vines will result in a 35 per cent decline in the next harvest. It is also probable that adverse effects on the September/October flowering will also reduce the 1983 crop. Assuming similar effects in other parts of Tonga on overall crop loss of $T \frac{1}{4}$ m has been estimated.

Immediate food shortages after a cyclone are not a problem in the villages. For two weeks or so food that is blown down or root crops damaged by the wind are in over supply. It is after this time that the problems of food supply arise. It is doubtful whether starvation will occur but undoubtedly in some situations malnutrition is probable until existing or replanted crops start to yield. The situation is most likely to be difficult in urban areas where individual self-sufficiency in food is not possible. It is fortunate that most of Nuku'alofa escaped severe devastation.

Bananas and plantains are important elements in the daily diet. They are particularly wind sensitive. In the areas most severely affected by Isaac up to 90 per cent were blown down and up to nine months must elapse before a new crop matures (Plate 17). This is a serious interruption of an important food source.

Another reduction in normal food supplies resulted from the extensive damage to breadfruit trees which are easily uprooted because of their shallow rooting system.
in shallow soils. The damage assessment referred to above put the loss at 60 per cent. Even where the trees were not uprooted they suffered extensive damage to branches, foliage and fruit which were just coming up to harvest. Where the villagers showed more initiative, steps were quickly taken to right the trees in an attempt to prevent their death and to bring them back to bearing fruit. In several of the island villages in Ha'apai within a week or ten days of the cyclone many breadfruit trees had been restored to an upright position and damaged branches pruned.

Root crops suffered varying degrees of wind damage to their foliage. Once again the assessment of the effects of wind damage will only be finally possible some months in the future. It is quite easy to fall into the trap of believing the worst. Unless the wind damage is excessive the degree of yield reduction may well turn out to be less than anticipated, which soon after the cyclone was estimated to be between 30 and 60 per cent. Undoubtedly a short fall in supply will occur after the surplus in the first week or two following the cyclone. In less devastated eastern parts of Tongatapu however, it is highly probable that local supplies could be expanded.

Nevertheless the prevailing view in the days immediately following the cyclone was that one of the major problems for a number of months would be the food supply. Apart from the hardships caused by shortages of customary food supplies, reduced supplies will disturb local marketing and reduce the opportunities for cash earning. Disruptions of the local economy arising from the introduction of imported relief foodstuffs to fill the food supply gap are another problem on which further comment will be made when discussing disaster relief. Loss of capacity to purchase food rather than shortage of food is likely to be a problem for many. Cyclone Anna (December 1977) in
Ha'apai reduced cash crop production for 12 months. We must wait to see whether Isaac has a similar or worse impact.

8.3.2 Livestock

Livestock, other than pigs and poultry, do not represent a significant element in the Tongan village. In Tongatapu estimates of the losses of village poultry were put at 16 per cent and of pigs 8 per cent and it was assumed that losses of a similar magnitude would have been experienced in other devastated parts of Tonga. Commercial egg and broiler industries, developed on a very small scale, suffered an estimated loss from damaged sheds, dead stock and damaged feed of the order of $T 1/4 m. Minor losses would have been incurred in the small beef and dairy industries.

8.3.3 Fisheries

By the very fact of being an island Kingdom, fishing plays a major part in the economy of the majority of villages which are on or near the coast. The violent winds and high seas caused damage to fish traps in the shallow waters on the fringing reefs. Where action had not been taken to draw fishing boats out of the way of the waves, or where the storm surge had driven them inland from the sea edge boats were wrecked (Plate 18). From recent aid sources many fishermen have received outboard motors for their boats. Where foresight had not been shown to remove these from boats and to protect them under some form of cover the motors were lost or damaged by waves or salt water spray.

Interruption of the traditional fishing activities both reduces the important contribution of protein from sea food to the carbohydrate diet and also removes an element in the village exchange economy. Fishing direct from the shore cannot make good the loss of the catch from fishing boats. The Tongan has long been a
skilled navigator. Boats provide a vital element in inter-island communication and co-operative assistance. Loss of craft makes such contacts less easy and alternatives do not exist.

8.3.4 Communications

As indicated above, between many parts of the Kingdom the sea provides the only means of transport and communication. Air transport links Tongatapu, Lifuka and Vava'u but for most people, and most goods, the ferry transports such as the MV Kao and MV Olovahi provide the major facility. These vessels require wharves. Even for smaller vessels there is a lack of good anchorages. Damage to wharves has been an outcome of several past cyclones. Isaac was no exception. Vuna wharf and Queen Salote wharf at Nuku'alofa both suffered from the storm surge and the high waves. On the latter wharf observations at the height of Isaac indicate that the waves were breaking on the Custom's shed up to 5.2 metres. The surge covered the wharf access to a metre or more leaving sand and debris, damaging walls, breaking up moored small boats and scattering stacked containers on the wharf. Until the wharves could be cleared and made operational again, which was achieved with the help of Australian Army engineers within five days of Isaac (Monday 8 March) the ferries could not assist in the necessary relief transport. Even when operating normally one can expect it to take 2 weeks to ensure that bulky or large amounts of goods will reach Ha'apai, and 3 weeks to Vava'u, from Nuku'alofa.

8.3.5 Water supplies

Isaac caused serious interruption to water supply in several ways. In the coastal lowlands affected by storm surge, sea water inundated wells. The water in concrete cisterns that did not have covers, or that lost these covers in the high wind, was polluted by
leaves, small branches and other debris and, in villages near the coast, by salt-spray from the high seas. Other problems were caused by the high winds. Roofs, gutters and connecting pipes to the cisterns were extensively damaged. High level tanks were blown off their supports and even some of the tanks at ground level had their foundations disturbed. These experiences repeat problems that previous severe tropical cyclones have also caused.

8.3.6 Power supplies

In any high wind situation overhead power cables are vulnerable. Many villages especially on individual islands do not have electricity supplies, but in Nuku'alofa and nearby villages in Tongatapu, electricity networks have been established. These experienced wind disruption on a considerable scale. Power engineers were rapidly on the job so that much of Nuku'alofa had electricity restored by Monday 8 March. Perhaps some parts of the distribution network were made alive almost prematurely. Temporary rehabilitation of the supply was rapidly being extended further and further afield.

9 EMERGENCY RELIEF

9.1 Medical Aid

In a society that is struck by disaster the most testing time for a community is in the first few days that follow directly after the event. It is then that gaps in any pre-arranged counter-disaster plan show up and when deficiencies in the capacity of organisations or individuals to match up to the challenges can be recognised. At this time rescue or relief is beyond the scope of the individual and some form of co-operative assistance becomes essential.

Fortunately loss of life was not a major problem (6 deaths were reported). Equally fortunately, and remarkably, serious injuries were not numerous (150 injuries were reported) so
that the hospitals were not overwhelmed by casualties. Many of the injured could be attended to in their own villages. Vatuola hospital in Nuku'alofa, which suffered relatively minor window and guttering damage, had empty beds and the extent of its problems were lack of electricity and an inability to establish an emergency supply. Fifteen major injuries from the cyclone were treated there. The clinic at Kolovai was badly damaged, and in the Ha'apai group dispensaries at Nomuka and Ha'afeva had their operation adversely affected by wind damage. One potential problem, getting medical aid to the scattered islands of Ha'apai, was overcome by the availability of the four New Zealand and Australian helicopters stationed on Lifuka island. The medical teams of New Zealand, and Tongan personnel, were able to provide medical help (beyond the medical needs which were the direct outcome of the cyclone) and transport to hospital (Plate 19). The Tongan medical services did not experience a shortage of doctors or nurses to meet the cyclone impact.

There were medically related problems which arose in the early post-impact days. The priorities recognised by the government were water, shelter, food and sanitation - in that order.

As has been indicated in the introductory comments, most of the water supply (especially on the Ha'apai islands) depends upon roof collection and cement cistern storage. Many cisterns were either damaged or the water polluted. Medical inspection (especially in the Ha'apai islands) classified the remaining water storages into those suitable only for washing and those for drinking. Cisterns were repaired and cleaned and, where necessary, the water was treatedchemically to purify it. Where roofs and gutters still remained attention was given to the restoration of the connecting pipes from the gutters to the cistern. Advice was given on the radio (even before the storm struck Tongatapu) to be careful about polluted water. Emergency water supplies were provided by the helicopter lifts, from HMNZS Taranaki (which had a water distillation plant), the MV Kao and the Red Cross relief boat.
In situations where water was still deficient it was recommended that schools should remain closed.

It is customary, after a disaster, to be concerned about the prospect of disease epidemics as an almost immediate and inevitable consequence. This is especially true in tropical climates where the risks from polluted water, tainted food (especially if refrigerators are relied upon for meat and fish) and from flies are greater. Fears of typhoid, dysentery or other epidemics are often exaggerated in a disaster situation and sometimes lead to distorted relief priorities. Relief aid may then include unnecessary and unrealistic medical supplies, for example smallpox vaccines. Provision of large quantities of vitamin tablets is often unnecessary since very often only limited sections of the community need such supplies because of disaster.

Among the aid sought and offered from New Zealand and Australia were health inspectors with spray back-packs. Areas such as Sopu required spraying. In the western parts of Sopu a normal high mosquito nuisance increased significantly because of the lingering flood or surge water.

Major requests were made for medical supplies and drugs to overseas donors and to the World Health Organisation. Such requests tended to be inflated and to go beyond the immediate needs of the emergency. It is not suggested that exaggerated request lists were assembled irresponsibly. Rather they demonstrated clearly the difficulty that a developing country finds in distinguishing between the needs of disaster relief and those related to maintenance or improved development of services.

9.2 Shelter

Even in a tropical environment shelter is an important consideration. Finding alternative emergency accommodation is complicated when, as in the case of Sopu, suitable sites do not exist because of flooded land. Tents may be the only solution for the initial deficiency of shelter though they are not usually liked in tropical conditions (Plate 20). If the
shelter problem is to be resolved with adequate speed tents must be organised and transported rapidly. They are bulky items and very unlikely to be held in adequate numbers in a developing country. Their supply depends upon overseas relief. In the days following *Isaac* it was difficult to ascertain rapidly the number of tents required and where the needs were greatest. It was difficult also to determine the actual offers and the potential sources of tents and when and how they would arrive. Within a week of the cyclone considerable numbers of tents had been received (not without some having the incorrect tent poles or lacking them altogether) and distributed but some families were still experiencing problems of shelter. In a rural society there is little likelihood of large reception centres being available to house the homeless. In the villages there were few large buildings. It was fortunate that building damage at Nuku'alofa was not on such a large scale that there were large numbers of homeless. Emergency accommodation in the capital was not the very high priority need that it could have been had the scale of damage been extensive.

The tents received were, however, quickly put into use. In the western parts of the Sopu area two main tent groups were sited near the shore on well-drained sandy areas and by 17 March had even received some temporary electrical lighting. These amenities could not be made available to individual tents in other areas, nor to those housed in tents in the Ha'apai islands where electricity was not available at all. Tents did not remove the need to restore more permanent dwelling facilities at the earliest possible opportunity.

Many families lost more than their shelter. In the days after the cyclone several households had no cooking utensils (or kitchen buildings). Locally the provision of such utensils became an important relief requirement. Large numbers of that conventional aid item, blankets, were also flown in and distributed. Kerosene for lighting and cooking was another relief item.
9.3 Food

Emergency food supplies were not generally a vital need. In the Tongan society, outside the urban environment, a family does not normally have much food in store. Food is generally readily to hand or in the ground ready to be collected as and when required. Out of the town immediately after the cyclone food was plentiful, or even surplus, though not all the means of meeting normal needs were equally available. There were some exceptions such as the surge inundated Sopu area. At the emergency stage food shortages, if they occur, are likely to relate to special needs such as those of pregnant or nursing mothers or sick children or for weaning foods.

Three phases in the post-cyclone food situation can be recognised. Up to three weeks after the disaster, blown down but edible supplies of food can serve; in the next three or four months shortages are probable where root crops are not sufficient to fill the gap and then a final phase represents a long term recovery. In this third phase the guidance of FAO experts may be needed. Development and recovery merge at this time.

The supply and distribution of relief food needs careful planning. Such food aid is often of types or in a form to which a family is unaccustomed. This may require advice on the best ways to prepare the food as well as on the maintenance of a proper dietary balance. From a welfare viewpoint those whose earning capacity has been impaired through the effects of the cyclone may require a free distribution of relief food. Otherwise it is usually desirable to design distributional schemes which require the purchase of supplied food. One such policy that has been promoted, elsewhere, for example in parts of India, is "food for work". Government organised and provided work enables the people to find opportunities for earning cash which can then be employed to pay for the food. Dependence on charity and the loss of inclination to make efforts to help themselves, it is argued, is thus avoided.
Fish provides an important element of the normal diet. For this reason it was important that damage surveys should be speedily initiated after the cyclone. By 9 March the Fisheries Division had assembled an inventory of the losses of boats, outboard motors, nets, fish traps and of the property of the fishing community. In Ha'apai 40 to 50 per cent of the 160 boats were lost or severely damaged, while 80 per cent of the 160 outboard motors had been lost or made unserviceable by immersion in sea water. The loss level for fishing gear was put at 80 per cent and that for the destruction or severe damage to fishermen's houses at 95 per cent. In Tongatapu the toll was made up from 10 boats lost, a further 9 badly damaged, 1 outboard motor lost and 16 damaged by sea water. In addition 20 fish fence traps and considerable lengths of nets and many lines and hooks were lost.

One problem faced those fishermen who lost or suffered damage to their fish traps. Many of them were indebted to the Tongan Development Bank for loans to enable them to construct the traps. Now they had no traps and had lost their earning capacity.

Eleven fishermen's houses were destroyed and 6 severely damaged on Tongatapu. At the Fisheries Headquarters at Sopo'ovalu valuable electrical and other equipment including spares were lost because of the storm surge. Most of Tongatapu's fishing activity is located in the central and eastern districts and even these appeared to have suffered less devastation than in the Ha'apai islands.

9.4 Communications and Transport

The organisation of rescue and relief relies heavily upon the internal communication network. In Nuku'alofa and in those areas of Tongatapu where there was a telephone system communications started to fail about the middle of the morning as Isaac approached. In the ensuing days it was brought back into operation progressively and was then an important aid in the organisation of local relief. The radio station in
Nuku'alofa, 3AZ, was back on the air by 1100 hours on the day after the cyclone. International links were also re-established quickly.

In Tongatapu buses and truck transport was not interrupted for long and car hire, within the availability of vehicles, was possible. Generally the communication and transport facilities were not seriously affected though the post-cyclone requirements placed considerable pressure upon them and infrastructural limitations imposed some constraints on relief operations. One particular need that had to be given early attention in the Nuku'alofa area was the removal of garbage and debris.

9.5 Disaster Shock

Disaster shock still remains a controversial matter. In developed countries, after a major disaster has occurred, it is customary to consider that the community, or certain more susceptible sections of it, will display various psychological disturbances. A visit of a few days, particularly from persons who do not have an intimate understanding of the impacted society, does not permit the required depth of analysis. However, despite the undoubted personal hardships widely experienced, a few days after the cyclone our visits to different parts of Tonga, even to the severely disrupted Sopu area, did not reveal any readily apparent disorientation or psychological disturbance. No obvious breakdown of the social structure showed itself. The one possible very localised exception, the looting of the sea-damaged Custom's Shed at Nuku'alofa, may be viewed more as the outcome of the changing of a traditional society in an urban context than a consequence of the cyclone's effect.

It is possible that the society had a significant degree of in-built resilience. The local culture and economy appear to have a capacity to absorb the disruption due to extreme environmental stress. It would not be justified to assume that this is necessarily the case. It may be, alternatively, that the village society is extremely complacent and happy-go-
lucky. There still remains the possibility that externally derived assessments are inadequate and arise from insufficient depth of understanding of the particular society involved. This matter merits an intensive research enquiry directly related to the particular question of response to stress. Such an investigation must, however, give precedence to the more immediate demands on resources and more urgent needs of the community.

10 RELIEF ORGANISATION

10.1 Disaster Organisation before Isaac

The Lewis Report (1978, chapter 2) draws attention to the fact that, despite Tonga's proneness to several forms of natural hazard, it was only following the 1961 cyclone that organised disaster relief on any significant scale was introduced. Following the impact of cyclone Juliette (April, 1973) a Hurricane Relief Committee was set up under the chairmanship of the Hon. Dr S.L. Kavaliku. This Committee was re-activated following cyclones Anne (December, 1977) and Ernie (February, 1978). Through the activities of the Committee central government effort and resources were mobilised in the case of each of these cyclones. Reports on their impact were prepared and provided the basis for the organisation of relief.

We may note the statement by Lewis that "The significant contribution of the Hurricane Relief Committee has been first, in its very conception and establishment, in its orderly processing of reconnaissance and relief supply and in its clarification of some of the issues which relate the problems of hurricane relief to development itself". However Lewis went on further to suggest that the problem of disaster was a complex one requiring policy decisions and action in several different, though interrelated, aspects. He developed these ideas into the proposals for a disaster management structure which appeared as the conclusion of his report.

Out of the Lewis proposals came the recommendations from the Central Planning Department to Cabinet which in turn resulted
in the establishment of a National Disaster Committee in May 1979. This Committee was chaired by the Prime Minister and was virtually an augmented Cabinet. Following further discussions three sub-committees were formed:

(i) Preparedness;
(ii) Action Planning; and
(iii) Relief
(A continuation in effect of the earlier Hurricane Relief Committee).

The definition of the precise functions and procedures for these sub-committees was still being discussed and they could not be said to be fully operational at the time of Isaac's impact.

10.2 Organisational Changes as a Result of Isaac

It has been observed (Carter 1982) that at the time of Isaac a formal disaster plan did not exist, although the basic concepts of counter-disaster operations were appreciated in appropriate official circles. However the structure required to meet the counter-disaster needs had to be set up and some of the details ironed out in those early critical days of the emergency when it would have been most desirable to have had a tested and already well defined plan in existence.

Tonga's Fourth Five Year Development Plan (1980-85) did not consider the potential disturbance that disaster could cause and consequently from the welfare viewpoint did not make disaster preparedness an integral part of development planning. This is a pointer, at the level of concern involved, to the limited perception of the significance of the disaster threat in development terms.

Action was taken rapidly by the central government and by government departments and officials over all Tonga as their areas of responsibility came under threat from the cyclone. At Nuku'alofa the Disaster Relief Sub-committee met on the morning of 3 March. Immediately after this the office and department of the Minister for Works and Education, the Hon.
Dr S.L. Kavaliku was proclaimed as the headquarters for disaster organisation. Dr Kavaliku has a long direct experience with counter-disaster operations.

The Cabinet declared a national emergency and determined national disaster areas. It also indicated general priorities for action. Normal government work was suspended and relevant departmental resources were earmarked for disaster needs. The National Disaster Committee and its Relief Sub-committee together formed a disaster organisation. It was evident there was an urgent need to collect and evaluate the vital information about the cyclone impact over the Kingdom so as to enable decisions on emergency actions to be taken. To permit the implementation of these steps an Emergency Operations Centre was set up at the headquarters of the Tonga Defence Service at Nuku'alofa on 8 March.

In his report to UNDRO Carter (1982) indicated that the Cabinet on 8 March re-organised the disaster organisation set up in 1979. The Cabinet itself became the National Council for Disaster Relief, Rehabilitation and Reconstruction and was responsible for policy determination, while the Central Operations Centre replaced the Disaster Relief Sub-committee and executed these policy decisions. At the Central Operations Centre, 8 'action' desks were set up covering the concerns of construction, transport, services, health, administration, maintenance, agriculture and fisheries and commerce. This arrangement facilitated quick and easy intercommunication between the responsible officials. The Minister-in-Charge of the Centre was the Hon. Dr Kavaliku. A Communication Centre was also established adjacent to the Central Operations Centre.

The Central Operations group had a membership of six under Dr Kavaliku's chairmanship. There were five specified areas of responsibility as well as one member without a specified function. These areas covered National Assessment, Foreign Liaison, Regional Allocation, Priority Control (under HRH the Crown Prince) and Priority Designation.
He also had a direct contact with the Governors of Vava'u and Ha'apai. He was given considerable freedom of decision making so as to speed up disaster response. Disaster relief committees in Vava'u and Ha'apai were linked to Central Operations.

Even in a small community with the National Council set over the Central Operations Centre there is nevertheless the possibility that the sort of quick and incisive decision, for example the policy to be adopted on the receipt of world food aid in the early days of an emergency, cannot be sufficiently rapidly reached. Delegation of responsibility and the opportunity to call emergency meetings with minimal notice are essential parts of an effective counter-disaster operation. Extreme, abnormal and unexpected conditions converge when a disaster occurs. They must be met by specially designed strategies of which speed is the essence. Had there been an existing disaster plan it is probable that some of the urgent relief could have been undertaken more quickly. By Saturday 6 March many of the initial damage assessments, at least in Tongatapu, had been assembled and the more immediate rehabilitation proposals made. The next day was Sunday and emergency action lost momentum indicating the strength of the social system even in the face of disaster.

However when the authors of this report arrived the next day in Nuku'alofa a great deal of clearing and emergency action had been achieved. Although the greatest activity had occurred in the capital, and in the rural areas less progress was apparent, nevertheless the extent of the recovery in so limited time demonstrates considerable resourcefulness and resilience. Yet more could have been undertaken if, in those early days after the cyclone, it had not also been found necessary to set up the relief organisation first before co-ordinated efforts could be properly undertaken.

By 15 March it was possible for an official termination of the emergency phase to be announced. The rehabilitation and recovery phases then began. The Government estimate was that
these would last for two years and would be under the guidance of the Hon. Dr S.L. Kavaliku who was appointed to chair a new small Office for Disaster Relief and Reconstruction. The Government still retained the Central Operations structure in an advisory capacity. The authors of this survey left Tonga too early to assess whether this new organisational system, conceived in the aftermath of the cyclone, was likely to be an improvement on the ways in which recovery after the cyclone disasters of the 1970s was tackled.

11 PROBLEMS IN THE PROVISION OF EMERGENCY RELIEF

11.1 General
This section examines the actions taken and the problems that surfaced in the provisions of the different categories of relief in the priority order water, shelter, food and sanitation.

11.2 Water
For reasons already indicated many village communities were experiencing a shortage of potable water. The Australian and New Zealand helicopters and service personnel made significant contributions to this problem in the Ha'apai islands. Jerry cans of water were transported to the island villages but perhaps more valuable activities were those which were directed to the testing and chemical treatment of contaminated water in the cisterns that still held water and to the emergency repair of gutters and connecting pipes to the cisterns. Where possible cisterns were repaired and debris polluting the water in other cisterns was cleaned out. This rapid post-cyclone aid minimised the acute problems of supply and of health risk. As Lewis pointed out (1978, p. 14) in Tonga there is always a source of water in the coconut so that severe hardship from thirst will not occur. Nevertheless, if the estimate that the use of coconuts for drinking would amount to three to four nuts per person is reasonable, the loss of such a large number of nuts, which would otherwise provide copra for export, is important.
A concerted programme to advise on rural water supply and storage is needed in both the short and long term. Many cisterns are fed from quite inadequate roof areas. Other roof areas remain untapped. Until recently church roofs, by far the largest catchment areas in most villages, have not been fully utilized. A wide dissemination of advice on the best methods for constructing and maintaining cisterns, together with aid supplies of cement and reinforcement would make an effective contribution towards ensuring a reliable water supply. A different water supply problem occurred in some of the Tongatapu villages where water was pumped by electrically driven pumps. When the power was cut by the cyclone eighteen villages lost their water supply.

11.3 Shelter

Rapid action is called for to assist those who have lost their homes but this is in conflict with the need to see that repaired or rebuilt buildings are constructed better than before. If the time and funds permit, storm destruction provides the opportunities to incorporate new techniques and new materials and the prospect of a housing stock which will stand up much better to subsequent cyclones.

One cannot avoid sympathising with the villagers who set about rebuilding as quickly as possible. They could not afford to be without shelter until an unknown possibility of outside help and building materials might materialise. This, however, was resulting in the rebuilding of houses with salvaged timber and roofing iron and old nails from the wrecked buildings. Simple strengthening techniques such as metal straps or cross bracing were not known or their value appreciated by the village builders. Where roofs were replaced or walls re-erected on the original foundations they were no better, and often worse, tied down than before. Depending upon the amount of this emergency rebuilding there will be a considerable stock of low-grade buildings which will withstand future cyclones, perhaps of less intensity, very poorly.
The traditional Tongan fale with coconut trunk main supports and coconut palm thatched walls and roof can be built co-operatively in a week or two. Such buildings present a possible solution to the need for urgent restoration of shelter. They can meet the initial needs quickly and with a limited use of materials. When time permits government steps to provide building materials and to regulate improved building methods can be implemented. The traditional buildings serve just to tide the community over until the permanent housing has been completed and then can revert to their normal function for kitchens or storage.

One problem that was clearly evident in the early days of rebuilding in the villages was the deficiency of basic tools, saws, hammers and most critically of tin snips for cutting roofing iron. The latter deficiency not only made it difficult to recut roofing iron that had been salvaged, but prevented those who knew the technique for cutting strengthening straps from available scraps of corrugated iron.

The problems of replacing buildings are exacerbated by the fact that all building material except that for the traditional fale have to be imported - timber from New Zealand or Fiji for the frames, corrugated iron from Australia or Europe and cement. Few of those who lost their houses had insurance and even if they did they were under-insured. The very few who had a bank loan may also by the conditions of the loan have had their houses insured but when the loan is redeemed the normal practice has been to terminate the insurance. Those with a mortgage and a ruined house had still to pay the interest and repayments since no general moratorium on such payment has been made. All these circumstances emphasize the tendency to salvage whatever materials can be collected together and to build some form of shelter. Government plans to set up workshops for prefabricating the frame for timber houses in Nuku'alofa and in Pangai and assisting villagers, through example, to construct these dwellings correctly will take time. How far villagers can be persuaded to adopt these houses unless the financial terms are
generous is very uncertain. One possibility could be for the emphasis in the Government Small Project Rural Development Fund to be shifted towards reconstruction needs.

The Government was not without experience in the rebuilding of homes after a disaster. After Juliette the Hurricane Relief Committee initiated a rebuilding programme for 1250 families. These families were involved financially in the scheme. The Government was also actively involved in assisting rebuilding after the 1977 and 1978 cyclones.

11.4 Food

The problem of relief food supply revolves around:

(i) the maintenance of a proper diet if unaccustomed foods are made available from aid sources and perhaps wrongly prepared; and

(ii) the difficulties of distributing relief food without causing a major disturbance of the normal food marketing and distribution system.

It is quite possible for large distributions of free food to cause as much hardship to the producers and retailers who lose their outlets as it helps the recipients. One can appreciate the strong Government inclination to encourage self-help and self-reliance.

The distribution of food aid places large demands on any administration. In Tonga an infrastructure which could cope with a period of several weeks distribution of food on an individual or family basis does not exist and it is difficult to envisage who could fill the gap. It would put an unbearable burden on Town and District Officers if they were charged with the responsibility. One suggestion was advanced that Peace Corp volunteers could undertake the task but if the operation is to be sustained for some months it becomes a demanding one and requires experience as well as good will. The post-disaster government relief organisation properly wanted to
ensure that any relief food distribution was completely
planned before being instituted. One objective it had was to
ensure that before any food was distributed the maximum
possible utilisation of all the food supplies blown down by
the cyclone should occur.

Looked at from the viewpoint of national planning one can
appreciate that the Government should show some reluctance to
seek all the food aid offered from outside. What
international donors consider, with all sincerity, the best
and most appropriate aid is not that which governments of
disaster affected countries always feel will be most
beneficial. It is not entirely a bad situation for a country
to desire to stand on its own feet, unless this causes
unnecessary hardship to its people. In this sort of situation
one can see in a different light the apparent disinclination
of the Government to appeal to the United Nations World Food
Program for aid. The representative of the WFP complained on
16 March that he was still waiting to be approached after five
days in Nuku'alofa.

Rehabilitation both of the fisheries and of domestic food crop
production as speedily as possible is a vital and positive
step to an early termination of external food aid. A number
of food plants such as maize, sweet potato (kumala) pumpkin,
capsicum and tomatoes can be cropped after a shorter time than
the normal root crops. To provide seeds or planting
materials, on the scale required, demands supplies from
outside. Where the taro or yams had been badly wind damaged
there is also a need for planting material in excess of
locally available supplies. Aid offers have included such
materials in some cases in amounts exceeding the needs. A
critical problem, however, is the importance of avoiding the
import of plant disease or pests. Quarantine requirements
conflict with the need to get replacement crops into the soil
as soon as possible. Undue haste can, however, store up
troubles that may last for years.
11.5 Sanitation

Sanitation and hygiene problems in the villages relate mainly to deficiencies in water supply. Except in a few critical situations such as the flooded Sopu area health problems are not likely to be severe. The predominantly rural pattern of settlement helps to minimise the potential scale of epidemic diseases or widespread disaster-caused illness. The problem is less severe than in a densely populated rural area or in towns.

11.6 Welfare Services

A village society provides a form of welfare service by its very nature, being a more cohesive and integrated group. In Tonga there is no strongly developed formal government, centralised, welfare infrastructure. This lack tends to be more apparent at times of disaster stress since there is no organisation on which to rely for the administering to some of the needs arising, though it must be observed that voluntary organisations, notably the Red Cross, do an admirable job in filling the gap.

11.7 Damage Assessment and Inventories

Relief planning depends upon the availability of detailed and precise information about the impact of a disaster and its effects in the community. An early requirement, as soon as possible after the disaster, is the undertaking of a survey of the losses suffered and the resources available to meet the emergency. Considerable resources of personnel and good communications are needed to make such a survey and inventory at a time when personnel are under other pressures and communications are interrupted. It is also important that a simple but standardised format should exist, ready to be used as soon as it is needed.

The Tongan government was greatly assisted by the provision by the New Zealand Government of an Orion aircraft equipped for aerial photography. A low-level (160 metres) photographic damage survey of Ha'apai and Tongatapu was carried out on 5
March. This gave a graphic visual impression of the nature of the devastation, but, so far as is known, was not analysed to yield comprehensive statistical summaries.

On the ground the architect of the Department of Works organised a detailed damage survey of all of Tongaatapu which differentiated residential and commercial buildings and categorised the degrees of damage. Agricultural, fisheries and health surveys were also carried out. The governors of Ha'apai and Vava'u were required to determine the various losses and damages of their respective island groups. The Ha'apai survey was completed and ready for transmission to the central government by 15 March. In view of the difficulties presented by the scatter of islands making up the Kingdom and the considerable difficulties of communicating with the smaller and more distant islands, the achievements in information collection were very considerable. Perhaps like many such surveys that have followed disasters in other parts of the world they placed a heavy emphasis on what had been lost or destroyed. In several respects it is equally important to discover what has been left or remains operational so that it can be determined what are the remaining capabilities for recovery activities and what are the critical deficiencies that should be made good if possible.

12 INTERNATIONAL RELIEF AID

12.1 Reliability of Disaster Information

Whilst charitably one may assume that international aid following disaster is truly philanthropically offered and solely humanitarian in purpose, in practice its manner of provision and its particular character is frequently a cause of concern, confusion and sometimes direct embarrassment to recipient countries.

The starting point of the problem is often to be found in the sources of information and intelligence upon which aid is based. It is appropriate to comment that relief is as much a
matter of information flow as food flow. In some areas a
United Nations Development Programme representative has an
official responsibility to provide information to UNDRO and
other UN bodies concerned with disaster-relief. In other
areas the first impressions gained by the outside world come
from the media, newspapers, radio or TV. Media personnel
converge as best they can upon the stricken area. Up against
time, thwarted by the very disruption they are attempting to
assess and in some aspects, though unintentionally, getting in
the way of those who have urgent relief tasks to attend to,
they attempt to provide a picture of the disaster impact.
News items demand some positive statements and it is extremely
difficult to provide a balanced statement of the magnitude of
the disruption when it is the extremes that are being sought
and when the circumstances permitting the collection and
checking of information are so unfavourable.

One may quote the New Zealand Herald 8 March "On Lifuka
virtually everything except the hospital - built by New
Zealand Army engineers - has been pushed over, stripped or
badly damaged by the heavy hand of Isaac". This was certainly
not the impression gained by the authors of this report when
they visited the island on 15 March though the damage was
undoubtedly severe (Plate 6).

Especially in the developing countries governments under the
stress of disaster cannot organise quickly their own
information collection.

The probable result of all these circumstances is that if the
media consider, from the first sketchy reports, that a
disaster has occurred, the pattern of subsequent reporting
tends to support and possibly amplifies the details of loss
and need. Who can blame overseas governments, voluntary
organisations, even individuals responding in the light of the
impressions they have thus gained? Time is a vital factor in
emergency relief so careful and cautious analysis of the
information, let alone its checking, is unrealistic. Foreign
governments which have their own representatives on the spot
may be somewhat better served unless international communication links break down, but even these local representatives are not set up to provide comprehensive and accurate statistics about the disaster. Like everyone else they suffer the problems caused by the breakdown of local communications and find it difficult to collect precise information quickly in the early days of the emergency. Impressions and subjectivity are dominant.

Assumed aid requirements are assembled. Speedy transport facilities, i.e. aircraft are organised. The relief items are bundled aboard. There is no time to decide on the priorities for using limited transport resources. Australian Hercules aircraft made 5 relief aid lifts on 5 March and another 8 on 6 March. It is easy to appreciate the pressure put on those responsible for getting this volume of aid moving in so short a time.

In the hurry to get relief aid to the needy, it is often impractical to make careful lists or adequate descriptions of the cargo of the aid transporting aircraft. It is similarly difficult to provide loading plans for the aircraft that can help unloading at the other end and it is all too easy for items to be sent in an incomplete state (such as tents without tent poles).

12.2 Problems for the Aid Recipient

At the reception end a sudden and overwhelming problem presents itself. Items come 'out of the blue'. Personnel have to be found from somewhere to unload the relief planes. Some means of transport must be spirited from elsewhere to transport the aid to storage areas, so that it is not ruined by exposure nor pilfered. It is difficult to provide secure storage space since it may either already be in use or may not even exist.

Just what is received is not correctly known to those who have the task of allocating it. It may be quite inappropriate to the pressing needs of the disaster. Especially if the items are perishable or liable to deteriorate in heat or wet, almost
insuperable distribution problems can arise when the whole distribution infrastructure has been disrupted by the disaster or never existed for the scale of demands now being made upon it. Personnel attempting to assist with disaster problems are already stressed by excessive demands. The aid avalanche may be the last straw.

So far in this discussion reference is being made to relief that is sent with little or nothing in the way of request. Other aid is offered by telex, cable or telephone. It is hard to establish and maintain a clear picture of these offers. There was great uncertainty in Tonga about the need for tents (an estimate reaching 2,500 by 16 March but believed to exceed the actual needs). This uncertainty was matched by an equal degree of difficulty in balancing the promises against the delivery of tents. Offers are vague often because what is needed is not clear or what is available has not been confirmed. 'Minor' details such as how aid is to be transported can come as an afterthought. Amounts, types and suitability are uncertain. It is hard to refuse items, so that excessive duplication of materials (perhaps in response to an exaggerated assessment of the emergency) can be hard to avoid in the stress and urgency of the time. Are large amounts of medical supplies and drugs such as typhoid, smallpox, cholera vaccines relevant, or field dressings or vitamin tablets of assistance? Are the bales of clothing of sizes and types appropriate to the reception area? How well will clothing suitable for the average American or Australian fit, or be acceptable for a Tongan? Are non-traditional foodstuffs in large quantities anything other than an embarrassment or destined to be wasted? How can large amounts of perishable foods - e.g. grain or flour be stored? Storage except at Nuku'alofa presents a major problem in Tonga. The convergence of large quantities of aid goods overpowers the capacity of docks, wharves, storage sheds and personnel to cope with them. Too often scarcity follows quickly on the
heels of the glut as the memories of the donors fade in the first few weeks after the disaster and supplies dwindle. If an ordered pattern of steady relief delivery, what has been described as "trickle flow", can be organised it will do much to reduce convergence and waste.

The situations described so far, unfortunately tend to be repeated after almost every disaster whether one is dealing with a developed or a developing country. Local circumstances may vary and individual difficulties take on different levels of significance but the frequency with which similar problems plague aid provision indicates a need for improvement in this aspect of disaster management.

Despite energetic attempts by the Australian High Commissioner to organise and chair an aid co-ordination committee, and the equally well intentioned efforts of the local representatives of other overseas governments in Nuku'alofa and of United Nations or international agencies, it proved difficult to resolve many of the aid problems. It remained unclear what aid was being offered, how and when it was coming and how to deal with it on arrival. Experts from the United Nations and other organisations tended to feel that what they had to offer was not being fully taken advantage of. Local officials on occasion see some of the aid activities, well meant though the initiatives may have been, as a nuisance or even an impediment to their own disaster relief operations. As time passes after the initial stresses the inclination to stand on one's own feet and to promote self-help understandably grows.

A desire to do without too much dependence on aid can be translated as obstructive bureaucracy. This interpretation may then encourage donors to feel that it is almost their duty to impose aid for the good of the sufferers from a disaster. However, in support of the Tongan government, any emphasis that is put on self-help at local and indeed at government level is in harmony with current views on the best policy for achieving disaster recovery. If external aid is felt to be essential, it is often the case that bilateral arrangements
with friendly overseas governments, entered into freely and not under the duress of disaster, are preferred to ad hoc international disaster relief operations.

In some international relief situations aid may become available only under specified conditions or to achieve ulterior political or economic objectives that are concealed by the donor. Equally there are occasions when recipient countries see an opportunity to extract from donors all they can. This leads to exaggerated 'shopping lists'.

Some relief items can be readily identifiable as urgently needed. In the Tongan case many household necessities were lost in the cyclone such as cooking utensils or sewing machines while there was an obvious deficiency of tools for building purposes. On the other hand many other relief requirements are not so readily apparent. In such circumstances cash aid is often a more valuable form of help. Local people can make flexible and maximum use of money. Families who have lost their immediate means of earning find it difficult or impossible to raise school fees or expenses. While in the case of government schools it may be possible to waive fees for a time, church schools may not be able to forego this part of their income. Emergency sources of money can help tide over the difficult situation that follows a disaster until the economy returns to its normal condition. At the time of writing US$2.5m of international aid had been given or pledged (UNDRO News, July 1982). A considerable proportion of the large amounts of church rebuilding is likely to come from outside sources.

13 REHABILITATION AND RECOVERY

13.1 General

The authors were unable to stay beyond the point in time when the emergency was officially considered to be over (15 March). The New Zealand and Australian helicopter crews and other army personnel were pulling out of Ha'apai on 15 March, emergency needs being considered satisfied by then.
Comments that relate to the plans and actions for recovery cannot be followed in detail nor can all the eventualities, achievements or failures be forecast. The best that can be achieved without the opportunity of conducting a continuing study of the recovery, desirable though this is after each major disaster, is to make some general observations.

The most desirable form of reconstruction is one that proceeds without the work being hurried because of the inevitable pressures to get back to the pre-disaster state at the soonest possible opportunity. Moreover, in addition to proceeding at a measured and carefully controlled pace, it is clearly important not to re-instate inefficient systems, perpetuate weaknesses or deficiencies in previous organisations or prolong inequities or hardships that unarguably needed to be removed. All these very desirable objectives add up to both a slow and expensive return towards a normal lifestyle. Those who have been disadvantaged by the disaster can hardly be expected to welcome the slowness of recovery. The economy of a developing country is already under pressure before a disaster. Ambitious recovery plans become intricately tied in with development planning. International donors of relief aid come to the fore remarkably readily for a short time. Donors of development aid are less forthcoming and more likely to impose conditions on the use of such aid. Often they do not see relief and development aid as inseparable. The foundation for future development is shaken by a disaster. Building on this foundation without its effective repair can lead to an expensive and unsatisfactory use of development aid funds.

13.2 Improving Response to Disaster

Response to disaster can be improved in several ways:

(a) It is desirable to establish an operationally effective and tested counter-disaster organisation which can be activated at short notice. This organisation should preferably be derived from skills and resources in existing government organisations. Its formation in an emergency
should, as far as possible, not weaken the capacity of existing organisations to continue their normal routines. It is equally important that this special organisation can be readily reduced in size and activity to that of an operational nucleus when the disaster is over thus enabling most of its members to return to pre-disaster 'normal duties'.

The appropriate size of the counter-disaster organisation, whose prime aim is the maintenance of a capacity for readiness to deal with disaster, must of course be related to the population, resources and to the range of possible hazards of the Kingdom of Tonga.

(b) Associated with the organisation referred to in (a) above there must be a nucleus of trained personnel who have a skilled understanding of the sorts of challenges and needs a disaster can generate. In larger communities perhaps it is both desirable and possible to have separately defined bodies whose sole responsibility is disaster management (at least at the emergency stage). In a smaller community, such as Tonga, it may be that existing bodies, for example police, fire, medical, Tonga Defence Services should have separately recognised areas of responsibility for emergencies which are activated in the case of disaster and assume, through the direction of the counter-disaster organisation referred to, roles that take precedence over some or all of their normal tasks. At the time of Isaac it was possible to call on the Tonga Defence Service for relief assistance. The police played a rather passive role in the emergency; not having the resources for the planned role to undertake special disaster relief functions in addition to their normal duties.
Although a slowly increasing number of more senior officials have gained a better understanding of disaster management problems and skills in recent years, by participation in overseas seminars or training courses, their potential value has been reduced by their dispersal throughout the administrative structure or by transfer or promotion into areas with little or no connection with disasters.

The establishment and training of voluntary groups at individual village levels, with comparable units in the town, offers a potential contribution to the building-up of a counter-disaster organisation which has yet to be given much consideration in Tonga.

(c) The present administrative structure at the village level is a relatively loose one and villages enjoy a considerable amount of local autonomy. In future counter-disaster planning, as indeed in the many issues of development planning, there is an opportunity to use the energies and 'grass-root' activities of Town Officers and District Officers, as well as to capitalise on co-operative activities in the villages. At this level many of the priorities in disaster management can often be formulated best. Formalised village committees are not an institutional feature but some form of development of this sort exists in a number of cases. There is a tradition of co-operative effort at village level. The organisation of village resources at the pre-disaster stage, as well as after the occurrence of a disaster, could be encouraged so that action can be initiated before the receipt of outside instructions and not necessarily be dependent upon the central government. Obvious areas in which a useful contribution could be made
would be in damage surveys, identification of vital relief needs and the organisation of relief distribution.

In visits made to the Ha'apai islands it was apparent that differences in the amount and success of community action in the villages were associated, amongst other factors, with the amount of positive guidance or stimulus a Town Officer exerted.

(d) Lewis in his 1978 report suggested a framework which integrated disaster management requirements into the current governmental and legislative structure.

As has been shown elsewhere in this report (p.67), the central government found it desirable in the emergency phase after *Isaac* to re-examine the structure of the disaster organisation and to introduce a revised pattern. It is obviously important that, after the experience gained from *Isaac*, positive decisions are reached to enable Tonga to meet the next disaster with an effective and well understood organisation. There is indeed room also for different government ministries to refine their own internal counter-disaster plans for the future.

(e) For the reasons already discussed the infrastructure suggested under (c) must be closely associated with the Central Planning Department.

(f) International donors of development funds must revise the terms of reference of such aid to enable development to be based upon a foundation which is capable of withstanding disaster without the whole fabric of development progress being jeopardised or even revised each time a disaster occurs.
13.3 Disaster Mitigation

There are a number of obvious practical ways by which disasters can be mitigated. Their adoption must be considered in the light of the constraints which any society, however wealthy and technologically expert, must face.

(a) There is a need for improvements in the communication networks. In the case of Tonga this means radio links rather than telephone. One of the problems of radio links immediately following the storm was the destruction of radio aerials. When repairs or replacements are effected, more attention is needed to improving their strength and resistance to strong winds. Tonga's international link is efficient and adequate. The telephone system in the capital works well and any improvement would be to make it more able to withstand strong winds or to extend the area served.

(b) A pool of transport and mobile heavy lifting and earth moving equipment is needed. To fulfil this requirement finance is necessary. This is a scarce resource in a small developing economy. The size of the pool need not be large. Its maintenance at an efficient operating level is more critical. One of the incidental achievements of the Australian and New Zealand army engineers in Tonga immediately after Isaac was the repair and recommissioning of several pieces of heavy equipment which were out of action. A skilled cadre of personnel and a small but balanced holding of the appropriate types of equipment could be associated with the Tongan Defence Service. Both men and machines would have a development as well as a disaster relief role so that such resources would not lie idle waiting only for the next disaster. Alternative power
sources for vital areas such as hospitals, communications and radio, and water supply are essential. This requires at least a basic availability of mobile generators and their maintenance in working order.

The island make-up of the Kingdom places a particular stress on rapid communications and transport to the various islands. Such a system needs the capacity to deal not only with normal routine requirements but also with the special stresses arising after disasters. This need has been recognised in the past, and through aid funds MV Kao and MV Olovahi have been made available and have helped considerably improve the situation. More of this sort of development is needed. If possible, at the intermediate level of intercommunication, that is between the individual islands, a more regular system of sea links is needed, though it must be realised that there are problems because of navigational and landing difficulties (Plate 21) and the smallness of the population involved.

Better air links from Tongatapu to Ha'apai and Vava'u are of course desirable. The cost of such provisions could be excessive for the size of population and its needs. It may be, therefore, that this is an area where donors of disaster relief should recognised a special opportunity for helping, as in fact happened in the case of Isaac. The lifts of emergency supplies by the Australian Hercules, the US C130's, the New Zealand Andover and the use of Australian and New Zealand helicopters provided a good illustration of an aspect of relief aid which made a very significant and valuable contribution.
The problem of communication and transport are likely to persist even if considerably improved. Under such circumstances it is desirable to consider the decentralisation of some of the counter-disaster organisation and resources and to set up subsidiary disaster centres in the Ha'apai and Vava'u groups. There is a growing tendency for the resources essential for rapid disaster response to be concentrated in Tongatapu and in Nuku'alofa.

(c) Improved meteorological data within Tonga are desirable. Despite its minute land area and small population, the problem of monitoring the behaviour of threatening weather is an extensive one. Fiji, Western Samoa and New Zealand come to the aid of the Pacific Islands when it comes to the locating and tracking of tropical cyclones, and everyone is helped by the geo-stationary meteorological satellites. However the establishment or upgrading of the observational capacities at one of the northern islands Niuafou for example, at Neiafu (Vava'u) and at Pargai (Lifuka) could assist with the more immediate warning messages and advice. As an incidental spin-off such improvements could provide data for a better general understanding of weather phenomena in the low-latitude central South Pacific and could be justified as an aid programme in meteorological science, possibly through the World Meteorological Organisation.

(d) Attention should be given to improved control of building through the establishment of stricter building codes, advice and guidance, by means of example, on basic building skills and the implementation of a basic building inspection system. These forms of improvement must be part of a long-term project in which the general
community capacity to build better and stronger evolves within the constraints of the economy and the technology. A catalyst is required to start the process. It develops slowly but gathers momentum. The smallness of the Kingdom is an asset in achieving worthwhile results in a relatively short time scale. It is of interest to note that the houses constructed in Lifuka by the Housing Commission after Juliette in 1973 came through cyclone Anne very well. As the stock of improved structures grows, the emphasis in the relief after disaster can be shifted away from shelter to other needs. However, the more capital invested in improved housing the greater the financial problems of recovery if a future cyclone causes severe building destruction.

(e) Overall at all levels in the community from the decision-maker to the individual citizen (who may or may not be a different person) improved understanding of the nature of environmental stresses and of the ways of meeting them is a significant means for mitigating their disruptive effects. Prior to Isaac no organised regular educational and awareness programme had been mounted to achieve this better understanding. Looking ahead to the future an important development could be the establishment of a carefully formulated educational programme. Such a programme would be designed to inform everyone about the type of threat, its characteristics and behaviour, the dangers that result and the most appropriate responses and actions to adopt. It would be presented through Radio Tonga, the Tonga Chronicle and through the schools (see Lewis 1978, p. 42) and would be designed to present different aspects, e.g. refresher information on tropical cyclones at the beginning of the cyclone season
and then maintenance of interest and preparedness during the season. Knowledge and understanding are essential elements in preparedness programmes. The initiator of such a scheme could be the counter-disaster organisation mentioned above (a).

(f) Long term developments such as sea-walls to protect surge-prone coastal lowlands, or major water storage schemes (against drought or the disruption of local supplies), are more in the category of luxuries so long as more basic and urgent needs exist and the financial resources to meet them are under extreme pressure. On a smaller scale improvements in storage capacity to hold reserve supplies or equipment that can be employed in disaster relief, or in times of disaster, aid shipments from overseas would be desirable. In terms of a ranking of priorities, however, it is difficult to envisage these coming high up on a long list of developments required.

(g) Development in particularly hazardous locations is as yet on a small scale so that action in terms of land zoning is primarily a longer period issue. Exceptionally, Sopu provides an instance of the effects of urban migration and land pressure pushing development into a hazardous situation. Without too much interference with personal liberty to develop areas freely, land zoning regulations could be implemented successfully. In the Sopu case, unless extensive land fill and drainage are undertaken, an alternative site should be considered seriously. If the risks can be avoided so can many of the costs of meeting these risks. If tourism is to become a significant growth area in the future, both the location and construction of tourist facilities needs control. If this is not attended to the
government may find itself facing large costs at times of disaster (cyclone, tsunamis or earthquake).

(h) Insurance is not a solution for disasters. It does, however, spread the load and cushion the effects of a major disaster. The burden of the disaster remains and to it must be added the costs of administering the insurance scheme. Insurance is mainly a useful aid towards 'saving for a rainy day'. One of the aspects of disaster is its concentration of ill-effects all at one time and possibly on one group or area. If the price of the ill-effects is spread over time and over a wider population or area then it is more manageable. To this extent the existence of a well established insurance programme can influence disaster management policies.

If we review the long-term approaches to disaster management then it is probably in the phase of emergency relief and organisation that the earliest steps require direct and immediate attention. The other lines of action, which become more significant at the reconstruction stage, should not be neglected but will tend to move into the background as general growth and development planning proceeds. They will receive attention as and when resources can be devoted to them and when, in competitive terms, they rank high enough in priority.

14 CONCLUSION

It is felt that the main outcome of this impact survey is a demonstration of the nature of the emergency response of a cyclone impacted community in a developing country. From the first disaster trauma to the end of the emergency about 12 days elapsed. Life in Tonga has not yet, of course, returned to normal. Only the passage of time will indicate how long the process of returning to visual normality will require, and even then more time must elapse before final recovery is attained. Questions, to which answers cannot be expected until the
whole reconstruction has been completed, still remain. Will the recovery achieve more than the restoration of the status quo? Will the Kingdom be able to withstand the next cyclone with less upheaval and hardship?

The Tongan Government has not been ungrateful for the help and material aid that has converged on the Kingdom. It is not surprising, however, that it has displayed a desire to chart out and achieve for itself the country's return to normality. It is not unusual, once one has overcome the first shock of disaster and established an initial capacity for independent action, for an inclination to develop to rely on one's own efforts to complete the recovery. Attitudes justifiably arising from these tendencies can generate conflicts or tensions with a converging flood of experts and international aid teams who have varying levels of understanding of the developing society they have come to assist.

Baker (1977, p. 294) remarks upon the problems of achieving progress in development planning in Tonga. 'The stage has now been reached in Tonga where the absence of decision making and of subsequent legislative implementation of such decisions is likely to be far more of a brake on future development than shortage of finance for funding capital projects'. If this is a fair analysis, it has relevance to future disaster management.

Tonga and Tongans have had a long experience of disasters (not only of natural origin). Facing such circumstances they have displayed resilience and self-reliance in their response. These qualities can be taken advantage of and improvements in the effectiveness of disaster planning will then depend primarily upon policy decisions. Underlying structural changes of a political, economic or social nature may well provide some of the answers for better resistance to disaster. It cannot be ignored, however, that some of the socio-economic changes resulting from disaster may also increase vulnerability. An illuminating report The Hurricane Hazard: Natural Disaster and Small Populations (Brookfield 1977) provides grounds for careful thought. Discussion in this report, related to eastern Fiji, could apply in many respects to Tonga.
Population growth and the beginnings of urban migration are clearly features of present-day Tonga. As elsewhere in the world 'as development increases and proceeds unchecked so vulnerability to losses and damage from environmental extremes increases. With the introduction of new methods and 'alien' systems, indigenous skills and awareness to potential hazard become eroded, forgotten or ignored in favour of the more immediately apparent material advantages of rapid change' (Lewis 1978, p. 18).

Relief on a large scale and rapidly made available may well conceal trends towards increased vulnerability to disaster. Cyclone Isaac's impact on Tonga provides an illustration of disaster response and management in rather special circumstances - a developing economy based on a widely dispersed and predominantly rural island society in the early stages of technological sophistication. Carter (1982) observes that recovery from cyclone Isaac will put pressure on the use of Tonga's resources for at least the next two years since these resources must be employed for development, maintenance and disaster preparedness. As he concludes '... if in the near future Tonga should suffer yet another sizeable natural disaster the effect on the nation could be catastrophic' (ibid p. 25).

Postscript

30 May 1982 UNDRO NEWS September/October 1982. A severe wind storm with gusts up to 150 km/h devastated the Hahake district of Tongatapu island. 70 houses and eight schools, their water supply system and an estimated 90 per cent of the banana crop and 70 per cent of the cassava and other root crops were damaged. The emergency sweet potato (kumala) replanting scheme launched with help and contributions from UNDRO/UNDP/FAO and Switzerland, following the effects of tropical cyclone Isaac, was severely affected. The food deficit caused by that cyclone was exacerbated by this new disaster.

The estimated total damage was put at $US1.1m. A jointly organised aid programme by UNDP/FAO/WFP/UNICEF was initiated both to provide immediate relief and to establish new self-reliant agricultural schemes.
# APPENDIX A

## TABLE 1: TROPICAL CYCLONES IN THE KINGDOM OF TONGA AND SURROUNDING AREAS SINCE 1830

<table>
<thead>
<tr>
<th>Date and year</th>
<th>Area most affected</th>
<th>Direction of movement</th>
<th>Indication of intensity</th>
<th>Major Impacts if recorded</th>
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<td>March 1830</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>24 January 1833</td>
<td>Vava'u</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>9 March 1833</td>
<td>Ha'apai</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1834</td>
<td>Lifuia,</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>November 1835</td>
<td>Vava'u &amp; Ha'apai</td>
<td>-</td>
<td>Severe</td>
<td>-</td>
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<tr>
<td>1837</td>
<td>Vava'u</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7-10 February 1839</td>
<td>Ha'apai</td>
<td>S</td>
<td>Severe</td>
<td>-</td>
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<tr>
<td>1840</td>
<td>Vava'u</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>5-6 April 1848</td>
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<td>S</td>
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<td>-</td>
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<tr>
<td>12-15 April 1848</td>
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<td>SE</td>
<td>Severe</td>
<td>-</td>
</tr>
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<td>Tongatapu</td>
<td>SW</td>
<td>Severe</td>
<td>-</td>
</tr>
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<td>E</td>
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<td>-</td>
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<td>12-13 February 1874</td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10 April 1874</td>
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<td>SW</td>
<td>-</td>
<td>-</td>
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<tr>
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<td>Severe</td>
<td>-</td>
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<td>4-9 January 1875</td>
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<td>SW</td>
<td>Severe</td>
<td>-</td>
</tr>
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<td>12-13 March 1875</td>
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<td>S</td>
<td>Severe</td>
<td>-</td>
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<tr>
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<td>14-20 March 1877</td>
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<td>31 March 1877</td>
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<td>-</td>
<td>Severe</td>
<td>-</td>
</tr>
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<td>19 December 1877</td>
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<td>SW</td>
<td>-</td>
<td>-</td>
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<tr>
<td>3-8 March 1879</td>
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<td>W</td>
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<td>-</td>
<td>-</td>
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<td>Severe</td>
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<td>Indication of intensity</td>
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<td>------------------------</td>
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<td>-------------------------</td>
<td>---------------------------</td>
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<td>-</td>
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<td>- 1888 Tongatapu</td>
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<td>Minor?</td>
<td>Reported as coming from W and S of Nuku'alofa</td>
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<td>Minor?</td>
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<td>All Tonga</td>
<td>ESE</td>
<td>Severe</td>
<td></td>
</tr>
<tr>
<td></td>
<td>especially Vava'u and Ha'apai</td>
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<td></td>
<td></td>
</tr>
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<td>9 February 1913</td>
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<td>-</td>
<td>Severe</td>
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<td>Centre passed E to N of Nuku'alofa</td>
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<td>-</td>
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<td>-</td>
<td>-</td>
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<td>-</td>
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<td>-</td>
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<td>6-9 March 1923</td>
<td>-</td>
<td>SE</td>
<td>Minor?</td>
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TABLE 1: CONTINUED

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<tr>
<th>Date and year</th>
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<th>Direction of movement</th>
<th>Indication of Intensity</th>
<th>Major Impacts</th>
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<td>14 March 1923</td>
<td>East and south of Ha'apai</td>
<td>S</td>
<td>Minor?</td>
<td>Nuku'alofa 999 mb NE wind force 10 (?)</td>
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<td>28-29 November 1923</td>
<td>All Tonga</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>- 1928</td>
<td>Vava'u</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>30 November 1930</td>
<td>-</td>
<td>-</td>
<td>Severe</td>
<td>-</td>
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<tr>
<td>December 1930</td>
<td>Niuafou'ou, Niuatoputapu</td>
<td>-</td>
<td>Severe</td>
<td>Worst for some years</td>
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<td>February 1931</td>
<td>Niuafou'ou</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
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<td>March 1932</td>
<td>South Tonga</td>
<td>-</td>
<td>-</td>
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<td>-</td>
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<td>-</td>
<td>-</td>
<td>Kerr (1976)</td>
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<td>18 January 1936</td>
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<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>February 1936</td>
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<td>-</td>
<td>-</td>
<td>Kerr (1976)</td>
</tr>
<tr>
<td>24-25 February 1937</td>
<td>Nuku'alofa</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>18 February 1941</td>
<td>Keppel Island &amp; north Tonga Islands</td>
<td>WSW</td>
<td>Severe</td>
<td>Keppel Island 984 mb. Barely reached gale force</td>
</tr>
<tr>
<td>26-27 December 1941</td>
<td>100 km south of Tongatapu</td>
<td>SE</td>
<td>Minor</td>
<td>Gale force not exceeded</td>
</tr>
<tr>
<td>11-12 January 1944</td>
<td>100 km south of Tongatapu</td>
<td>SE</td>
<td>Minor</td>
<td>Gale force not exceeded. Track similar to December 1941</td>
</tr>
<tr>
<td>30 January 1944</td>
<td>Niuafou'ou</td>
<td>SE</td>
<td>-</td>
<td>Passed between Niuafou'ou and Keppel Island. Force 9 at Niuafou'ou</td>
</tr>
<tr>
<td>17-18 February 1945</td>
<td>Vava'u, Ha'apai</td>
<td>SE</td>
<td>-</td>
<td>Passed between the two island groups. No significant damage reported</td>
</tr>
<tr>
<td>16-17 January 1946</td>
<td>North of Niuafou'ou and Niuatoputapu</td>
<td>E</td>
<td>Minor</td>
<td>-</td>
</tr>
<tr>
<td>Date and year</td>
<td>Area most affected</td>
<td>Direction of movement</td>
<td>Indication of Intensity</td>
<td>Major impacts</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------------</td>
<td>-----------------------</td>
<td>-------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>24 February 1947</td>
<td>Just south of Tongatapu</td>
<td>E</td>
<td>Minor</td>
<td>No winds above gale force nor significant damage</td>
</tr>
<tr>
<td>11-12 December 1948</td>
<td>Vava'u &amp; Ha'apal</td>
<td>E</td>
<td>Minor</td>
<td>After 3 days stationary E of Lau Island then rapid movement between the two Island groups and declined</td>
</tr>
<tr>
<td>19-20 December 1949</td>
<td>Ha'apal &amp; Tongatapu</td>
<td>SSE</td>
<td>Rather weak</td>
<td>Nuku'alofa winds not above gale force, Heavy rain over all Tonga, 1/5 banana crop lost</td>
</tr>
<tr>
<td>1 February 1950</td>
<td>Niuato'ou</td>
<td>W</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>25 January 1952</td>
<td>Ha'apal &amp; Tongatapu</td>
<td>SE</td>
<td>Minor</td>
<td>Between two Island groups Nuku'alofa 985 mb. Wind not over force 8</td>
</tr>
<tr>
<td>12 January 1954</td>
<td>50 km north of Niuato'ou</td>
<td>W</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>25 April 1954</td>
<td>-</td>
<td>SE</td>
<td>Moderate</td>
<td>-</td>
</tr>
<tr>
<td>28-29 January 1955</td>
<td>Just north of Tongatapu</td>
<td>SE</td>
<td>Minor</td>
<td>-</td>
</tr>
<tr>
<td>17-18 February 1956</td>
<td>North of Vava'u</td>
<td>SE</td>
<td>Minor</td>
<td>-</td>
</tr>
<tr>
<td>7 December 1957</td>
<td>Vava'u</td>
<td>SE</td>
<td>-</td>
<td>Rapid movement. Brief spell of strong winds but no significant damage reported. No wind reports above force 8 but banana and breadfruit damaged Vava'u Track of south of Tongatapu</td>
</tr>
<tr>
<td>3 December 1958</td>
<td>Nuku'alofa</td>
<td>E</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>14 February 1959</td>
<td>East of Tonga</td>
<td>SSE</td>
<td>Minor</td>
<td>-</td>
</tr>
<tr>
<td>Date and year</td>
<td>Area most affected</td>
<td>Direction of movement</td>
<td>Indication of Intensity</td>
<td>Major Impacts If recorded</td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------------------</td>
<td>-----------------------</td>
<td>-------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>19 March 1960</td>
<td>West of Vava'u</td>
<td>SW</td>
<td></td>
<td>Moved S from Samoa. Force 11 wind at Vava'u. Cyclone Flora</td>
</tr>
<tr>
<td>16-17 March 1961</td>
<td>Vava'u, Ha'apal &amp; E of Tongatapu</td>
<td>SSW then S &amp; SE</td>
<td>Severe</td>
<td>0300 hrs 17 March centre 15-25 km E of Ha'apal. Wind hurricane force from 2300 hrs 16 March. Lowest pressure 950 mb. Major damage Ha'apal - small islands to S especially Nomuka suffered major damage to buildings, crops and vegetation</td>
</tr>
<tr>
<td>12-14 March 1963</td>
<td>100 km SE of Keppel recurved island</td>
<td>W SW SE at 11 March, 13 March W of Ha'apal, nearly stationary for 12 hrs then SE between Ha'apal &amp; Tongatapu</td>
<td>Moderate cyclone</td>
<td>24 November Nuku'alofa maximum wind force 10 Close to Niuafou'ou night of 13 Jan. Pressure at Vava'u 14 Jan 982 mb. Erratic track Rapid movement between Ha'apal and Tongatapu. Nuku'alofa 0700 hrs 27 Feb pressure 987 mb. Gales in southern Islands Cyclone Dolly</td>
</tr>
<tr>
<td>24-26 November 1964</td>
<td>Ha'apal, Nomuka, Tongatapu</td>
<td>SE</td>
<td>Moderate cyclone</td>
<td></td>
</tr>
<tr>
<td>February 1968</td>
<td>Vava'u</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>13-14 January 1969</td>
<td>Niuafou'ou, Vava'u</td>
<td>SSE then SE</td>
<td>Minor</td>
<td></td>
</tr>
<tr>
<td>26 February 1969</td>
<td>Ha'apal, Tongatapu</td>
<td>SSE</td>
<td>Minor</td>
<td></td>
</tr>
<tr>
<td>18-19 February 1970</td>
<td>E of Tonga</td>
<td>N</td>
<td>Minor Storm force</td>
<td></td>
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</table>
TABLE 1: CONTINUED

<table>
<thead>
<tr>
<th>Date and year</th>
<th>Area most affected</th>
<th>Direction of movement</th>
<th>Indication of Intensity</th>
<th>Major Impacts</th>
<th>If recorded</th>
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<tr>
<td>8-9 April 1970</td>
<td>Nomuka</td>
<td>SE</td>
<td>Gale</td>
<td>Cyclone Gillian</td>
<td></td>
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<tr>
<td>14-16 April 1970</td>
<td>N'Iuafo'ou</td>
<td>SW then SE</td>
<td>Gale</td>
<td>Cyclone Helen</td>
<td></td>
</tr>
<tr>
<td>25 October 1972</td>
<td>W of Tonga</td>
<td>SE</td>
<td>Minor force</td>
<td>Cyclone Bebe</td>
<td></td>
</tr>
<tr>
<td>1-2 January 1973</td>
<td>Keppel Island</td>
<td>S</td>
<td>Storm</td>
<td>Cyclone Elenore</td>
<td></td>
</tr>
<tr>
<td>4 April 1973</td>
<td>Ha'apai</td>
<td>SE</td>
<td>Storm</td>
<td>Cyclone Juliette</td>
<td></td>
</tr>
<tr>
<td>10 December 1973</td>
<td>North of Tongatapu</td>
<td>SE</td>
<td>Minor only</td>
<td>Cyclone Lottie</td>
<td></td>
</tr>
<tr>
<td>26 April 1974</td>
<td>North of Vava'u</td>
<td>ESE</td>
<td>Storm</td>
<td>Cyclone Tina</td>
<td></td>
</tr>
<tr>
<td>15 April 1977</td>
<td>North of Ha'apai</td>
<td>ESE</td>
<td>Gale force over Tonga</td>
<td>Cyclone Pat</td>
<td></td>
</tr>
<tr>
<td>26-27 December 1977</td>
<td>Ha'apai</td>
<td>SE</td>
<td>Severe storm</td>
<td>Cyclone Anne</td>
<td></td>
</tr>
<tr>
<td>19-20 February 1978</td>
<td>Ha'apai</td>
<td>ESE</td>
<td>Moderate storm</td>
<td>Cyclone Ernie</td>
<td></td>
</tr>
<tr>
<td>25 March 1980</td>
<td>North of Ha'apai</td>
<td>E</td>
<td>Minor</td>
<td>Cyclone Tia</td>
<td></td>
</tr>
<tr>
<td>2-3 March 1982</td>
<td>Ha'apai, Tongatapu</td>
<td>SSW</td>
<td>Severe</td>
<td>Cyclone Isaac</td>
<td></td>
</tr>
</tbody>
</table>

Note: Times and dates GMT; Total 153 years, 108 tropical cyclones

Prior to the date when satellite cloud imagery became generally available, the possibility of missing tropical depressions or cyclones over extensive sea areas was considerable. Where land fall took place, there was a greater probability that the event would be recorded, especially when of a severe intensity, but even in these situations the type of permanent record whether in a local newspaper (if it existed) or a government file was often incomplete or imperfect. Reconstructions of tracks, even of dates and times let alone precise meteorological information are usually elusive. Careful inventories of damage are rarely available.

The material in this table owes a great deal to Vilsher's assembled material up to 1923 (Visher & Hodge, 1925) and to the information in Kerr (1976) which covered 1939-1969 and Revell (1981) 1969-1979. Supporting information has also been derived from Lewis (1978). Some uncertainties remain in the tabulation. One or two entries may indeed relate to fictitious events which have arisen over earlier confusions of dates which have then been incorporated in the summaries referred to above. Gaps in the record may be filled from other sources unknown to the authors whilst in a number of instances the record will remain imperfect for all time.
<table>
<thead>
<tr>
<th>Date</th>
<th>Name</th>
<th>Track</th>
<th>Area of Tonga Affected</th>
<th>Other Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 April 1973</td>
<td>Juliette</td>
<td>ESE turning SE</td>
<td>7 northern Islands of Ha'apai at night</td>
<td>Declining by time reached Tonga. Gales to about 18°15' In north and 20°20' In south</td>
</tr>
<tr>
<td>10-11 December 1973</td>
<td>Lottie</td>
<td>ESE</td>
<td>Passed just north of Tongatapu morning 11 December</td>
<td>Narrow band of gale force winds 50 kilometres wide</td>
</tr>
<tr>
<td>27 December 1977</td>
<td>Anna</td>
<td>SE</td>
<td>Ha'apai</td>
<td>Storm force winds over all Ha'apai Group. Winds at Ha'apai 1 pm 56 km/hr; 2 pm 96 km/hr; 3 pm 115 km/hr; 4 pm 9 km/hr; 5 pm 4 km/hr; 7 pm 83 km/hr. By morning of 28 240 kilometres south of Niue.</td>
</tr>
<tr>
<td>19-20 February 1978</td>
<td>Ernie</td>
<td>S</td>
<td>Ha'apai late evening 20 February</td>
<td>Changed course to south and slowed down. It crossed Ha'apai, passed east of Nomuka, 45 kilometres east of Tongatapu then swung SW. Storm force winds over Ha'apai; gale force Vava'u and Tofua and Nomuka but not Tongatapu</td>
</tr>
<tr>
<td>24-25 March 1980</td>
<td>Tia</td>
<td>E</td>
<td>North of Ha'apai</td>
<td>Passed north of Kao Island and of Ha'apai Group. Slowed and weakened as it passed through Tonga midday 25 March with winds 56-74 km/hr</td>
</tr>
</tbody>
</table>
Plate 2  Wind felled trees blown in opposite directions Ha'afeva island, Ha'apai group. (Photograph J. Oliver)
Plate 3
Damage Lifuka Island. Roof cladding removed by wind from large building in centre. Debris strewn landscape. (By courtesy New Zealand Air Force)
Plate 4  House destruction and temporary shelter, 'O'ua island, Ha'apai group. (Photograph J. Oliver)

Plate 5  Debris, wind damaged trees, damaged houses, Nomuka Island. (Photograph J. Oliver)
Plate 6  Building damage Pangai, Lifuka island, western shore.  
(By courtesy New Zealand Air Force)
Plate 7 Destruction of church 'O'ua island. Problem of refugee reception buildings. (Photograph J. Oliver)

Plate 8 Damaged masonry church Pangai. (By courtesy Tonga Chronicle)
Plate 9  Roof cladding and part of roof structure stripped by hurricane winds. Nuku'alofa college, Tongatapu. *(By courtesy Tonga Chronicle)*

Plate 10  Surge waters Sopu. Roof cladding removed from Atenisi University. *(By courtesy Tonga Chronicle)*
Plate 11 Damaged sea wall and road, Vuna road east of Nuku'alofa.  
(Photograph J. Oliver)

Plate 12 House washed off supports and drifted inland. Remains of supports and steps in left foreground, wall damaged, Sopu.  
(Photograph J. Oliver)
Plate 14  Removal of soil cover from raised coral platform by waves. Niutoua, Tongatapu. (Photograph J. Oliver)

Plate 15  Coral rock debris Queen Salote Wharf. Containers scattered by surge and waves. (By courtesy Tonga Chronicle)
Plate 16  Wind damaged coconut palms. Water cisterns left without roof catchments. (By courtesy New Zealand Air Force)
Plate 17  Wind damaged banana plants below coconut palms western Tongatapu. *(Photograph J. Oliver)*

Plate 18  Boats washed up and damaged. Nuku'alofa *(Photograph J. Oliver)*
Plate 19  NZAF relief helicopter lands at Mango Island, Ha'apai group with medical team. (Photograph J. Oliver)

Plate 20  Tented accommodation, Sopu. (Photograph J. Oliver)
Plate 21
Landing relief items from the Red Cross relief boat. Use of dug-out canoes in shallow water over fringing reef, Mango Island.
(Photograph J. Olvera)
ACKNOWLEDGEMENTS

The carrying out of this survey required considerable financial support as well as the opportunity for the investigators to phase the demands it made on their time into their programme of other commitments.

It was only through the generous approval and financial support provided by Professor K.J.C. Back, Vice-Chancellor of James Cook University, that Professor J. Oliver was able to undertake the survey. In the case of Mr G.F. Reardon it was the support, financial and otherwise, of the James Cook Cyclone Structural Testing Station that made his participation possible. We also wish to acknowledge the active efforts Professor D.H. Trollope, Chairman of the Centre for Disaster Studies, made to try to facilitate our survey. Our thanks are also due to Mr John Ngai for the preparation of the illustrative material, Miss Cathy Robinson and the Word Processing Section for typing the report.

The assistance that subsequently made the survey possible materialised once we had managed to reach Tonga. Up to that point we were on our own, not knowing what we could achieve nor indeed whether we would be able to reach the devastated areas. We owe a great deal to the Australian High Commissioner in Nuku'alofa, Her Excellency Miss Maris King. In particular the opportunity to attend a series of aid co-ordination meetings organised by her gave us a valuable insight into many of the aspects of the problems of disaster relief on the spot.

We would like to express our gratitude for all the local assistance in Tonga that was so generously provided. In addition we have been helped by responses from many people or organisations from whom we have sought information.

We would first like to acknowledge, with sincere appreciation, the readiness with which we were received by His Royal Highness the Crown Prince Tupouoto'a and by the Hon. Dr S. Langi Kavaliku, Minister for Works and Education. We were given significant help by Mr David Keith, Director of Works and his colleagues, Mr B.M. Hodgkinson (Government Architect) and Mr Bob Garner (Clerk of Works). Mr C. Ratcliffe, Principal Fisheries Officer at Sopu, likewise assisted our enquiries significantly. At the Central Operations Centre we were given a most friendly reception from the Hon. Fusitua, who had the difficult task of dealing with all those who converged on Tonga because of the cyclone from overseas.
In the early days of our survey we received much valuable advice and information from Miss Nanasi Pau'u Vaea, Administrator of the Special Education Ofa Tui Amanaki Centre for Handicapped Persons and from Mrs Judith Finau, in charge of the Tongan Red Cross. Our survey was made much more complete by the opportunity we were given to visit several of the Ha'apai islands with the Red Cross relief boat. We owed much to the patience and friendship of the Red Cross staff and the boat's captain and crew. Mr Grenville Kirton, who supervised the relief voyage, facilitated our village surveys. To each of the villages we wish to extend thanks to the Town Officers and to those whom they arranged as guides for our village inspections. At Pangai we were privileged to meet the Governor of Ha'apai and to discuss with him the effects of the cyclone on the islands of the group.

In Nuku'alofa we received a great deal of valuable information from the Meteorological Officer, Mr L. Fifita. We were also helped by the manager of the Radio Station, 3AZ, Mr Bala Krishnan. We were grateful to the manager and staff of the International Date Line Hotel who helped us in several ways, not least in arranging accommodation in the difficult days following the cyclone.

Colonel Frank Thorogood from Melbourne, who was the International Red Cross representative for the cyclone operation, gave us invaluable assistance in meeting people who could contribute to our enquiries. His Excellency Mr John Brady, the New Zealand High Commissioner, enabled us to obtain copies of the aerial survey of damage carried out by the NZAF Orion. Requests for information to the Fiji and New Zealand Meteorological Services were most fully and usefully responded to.

We found the reports to the Tongan Government of Mr James Lewis on disaster preparedness and prevention and that of Air Vice-Marshall W. Carter, UNDRRO consultant, on the actions taken to deal with tropical cyclone Isaac both of significant value. We acknowledge with gratitude their willingness to make these sources available to us.

There were so many others who assisted us in a variety of ways that it is inevitable we cannot name all. We apologise for any omissions but hope that we can indicate our thanks to all we had the opportunity and pleasure to meet.
REFERENCES


The following Disaster Investigation Reports have been published previously:


These publications can be obtained from

The University Bookshop
James Cook University of North Queensland
Post Office
Townsville Qld 4811
Australia